Maintenance
and Operation
of Water
Supply Systems

MO 210

MAINTENANCE AND OPERATION OF WATER SUPPLY SYSTEMS

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FOREWORD

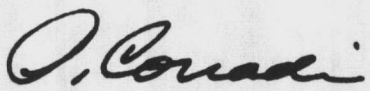
This publication provides technical guidance for the operation and maintenance of water supply systems at naval shore activities.

A safe, adequate and reliable supply of water is vital for the sustenance and health of personnel; for industrial and fire protection requirements; and, for special needs of the activity. Such a supply of water is indispensable for the successful accomplishment of the mission of the activity. Proper operation and maintenance of water supply systems are essential to the provision of a water supply that is safe in quality, adequate in quantity and reliable in service.

In this publication are presented the responsibilities of personnel engaged in the operation and maintenance of water supply systems, procedures for the proper operation and maintenance of the systems and the safety measures and precautions that are involved.

Recommendations or suggestions for modification, or additional information and instructions that will improve the publication and motivate its use, are invited and should be submitted through appropriate channels to the Chief, Bureau of Yards and Docks, Washington, D.C., 20390.

This publication is certified as an official publication of the Bureau and, in accordance with Secretary of the Navy Instruction 5600.16, has been reviewed and approved.



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Rear Admiral (CEC) *U.S.N.*
Chief, Bureau of Yards and Docks

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176 *Recarbonation Unit for Water Softening Plant*, Infilco, Inc., Tucson, Ariz.
178 *Pitot Tubes with Velocity Pressure Gage for Hydrant Flow Tests*, Joseph G. Pollard Co., New Hyde Park, L.I., N.Y.
179 *Gage Assembly for Measuring Fire Hydrant Pressure*, Joseph G. Pollard Co., New Hyde Park, L.I., N.Y.

180 *Two Views of Split Sleeves for Repairing Leaks*, Smith-Blair, Inc., South San Francisco, Calif.
181 *Mechanical Joint Fitting*, Smith-Blair, Inc., South San Francisco, Calif.
182 *Wet-Barrel Type, or California, Fire Hydrant*, A. P. Smith Manufacturing Co., East Orange, N.J.
183 *Pit-Type Fire Hydrant*, A. P. Smith Manufacturing Co., East Orange, N.J.
184 *Dall Flow Tube*, B I F Division of the New York Air Brake Co., Providence, R.I.
185 *Gentile Tube*, ITT General Controls Inc., Warwick, R.I.
186 *Magnetic Flow Meter*, Taylor Instrument Companies, Rochester, N.Y.
187 *Kennison-Type, Open-Flow Nozzles*, B I F Division of the New York Air Brake Co., Providence, R.I.
188 *Two Methods of Mounting a Ball Bearing on a Shaft*, Worthington Corp., Harrison, N.J.
192 *Injector Pump*, Fairbanks, Morse & Co., Kansas City, Kansas

CHAPTER 1. INTRODUCTION

Section 1. PURPOSE AND SCOPE

1.1.1 PURPOSE. This manual provides technical guidance for the maintenance and operation of shore-based water supply systems. Such systems are the responsibility of the Water and Sewage Branch, Utilities Division, Public Works Department. While this manual is prepared primarily for use by operating personnel in the Water and Sewage Branch, the inclusion of sections on maintenance policies, operation policies and on organization and relationships of the divisions of the Public Works Department, makes it a helpful tool for all public works personnel.

1.1.1.1 Water Supply Systems. Water supply systems include sources, pumping, treatment, storage and distribution of potable and nonpotable water used at shore-based naval activities, and consist of water supply facilities and water distribution systems.

1.1.1.1.1 Water supply facilities. Water supply facilities are divided roughly into these three categories.

(1) Sources. Purchased, surface, underground and saline.

(2) Pumping. Pumps and pumping plants.

(3) Treatment. Treatment plants and appurtenant equipment.

1.1.1.1.2 Water distribution systems. By definition, these systems include all water conduits and supply mains with necessary appurtenances through which water is conducted between the source and the service entrances at the building served, or other point of utilization. The basic components of water distribution systems are:

(1) Conduits.

(2) Supply mains and service lines.

(3) Distribution reservoirs, elevated storage tanks, and standpipes.

(4) Valves, valve boxes, and manholes.

(5) Hydrants.

(6) Meters and equipment for measurement and control.

(7) All appurtenant equipment such as automatic controls and cathodic protection devices.

(8) Exterior drinking fountains.

1.1.2 SCOPE. This manual is divided into five chapters:

(1) Chapter 1 reviews the maintenance and operational responsibility for water supply systems, and the organization and relationships of the divisions of the Public Works Department, and their relationships with other components of the activity.

(2) Chapter 2 presents a general description of the component parts of a water supply system.

(3) Chapter 3 describes operational procedures to be followed.

(4) Chapter 4 deals with specific details of maintenance procedures for equipment and systems which are used in the sources, pumping, treatment, distribution and storage of water.

(5) Chapter 5 describes the precautions and safety measures which apply to the maintenance and operation of water supply systems.

1.1.2.1 Revisions of Manual

1.1.2.1.1 New information. The assistance of all public works personnel engaged in water supply system activities is solicited to keep this manual current and adequate. New information will generally originate at the Water and Sewage Branch level, where the maintenance and operation of water supply systems are performed. The information in this manual will be revised as improvements are accepted.

1.1.2.1.2 Improvements. When new materials, new equipment and/or new methods are developed and found more satisfactory than those in use, it is requested that complete information on such improvements be forwarded to the Chief of the Bureau of Yards and Docks through the cognizant field activity.

Section 2. RESPONSIBILITIES AND RELATIONSHIPS

1.2.1 MAINTENANCE RESPONSIBILITIES. The Utilities Division of the Public Works Department is responsible for the maintenance of water supply systems, as described below. It should be noted, however, that the Maintenance Control Division and the Maintenance Division participate in these maintenance activities, as described in "Organization and Functions for Public Works Departments", NAVDOCKS P–318 (Reference 1). In addition, other divisions, such as Transportation, may be requested for the Utilities Division, through the prescribed channels, to perform certain specific maintenance duties. This responsibility for maintenance includes:

(1) Operator inspection, preventive maintenance inspection, continuous inspection, inspecting work in progress, final acceptance and testing of work when completed.

(2) Service work in accordance with procedures and schedules established and maintained by the Utilities Division.

(3) Determination of the need for maintenance. Maintenance work considered necessary beyond the responsibilities in (1) and (2), above, shall be recommended by the Utilities Division and processed through the Maintenance Control Division for accomplishment either by contract or by station forces in accordance with "Maintenance Management of Public Works and Public Utilities", NAVDOCKS P–321 (Reference 2).

(4) Scheduling shutdown time for the availability of equipment and systems for accomplishment of maintenance and overhaul. Long time recorded experience of the equipment should be considered in order to arrive at a schedule that will reduce nonscheduled interruptions of service to a minimum. Arrange to automatically bring the due date of scheduled maintenance and overhaul to attention in time to assure alternate arrangements for provision of service during maintenance and overhaul.

(5) Providing for the necessary assistance requested for maintenance control inspections in specialized areas.

(6) Providing technical and journeymen assistance as necessary and available when maintenance and overhaul work is accomplished by station forces.

(7) Maintaining equipment records of inspections and corrective actions taken on all equipment and systems for which the Utilities Division is responsible.

(8) Staffing with the minimum number of personnel to perform the above functions.

(9) Carrying out the following functions:

(a) Training of operator personnel in maintenance procedures.

(b) Rendering assistance in maintenance budget planning.

(c) Recommending methods for performing maintenance work.

(d) Recommending new materials and/or equipment for replacement.

(e) Protection of the water supply system against freeze-ups.

(f) Utilizing the assistance of the Maintenance Control Division in setting up inspection procedures.

1.2.2 OPERATION RESPONSIBILITIES. The Water and Sewage Branch of the Public Works Department is responsible for the operation of the water supply facilities and distribution systems. This responsibility includes:

(1) Training of operating personnel in operating procedures.

(2) Proper scheduling of the start-up of certain sections of the water supply system, which may be in standby status, as needed.

(3) Shut down of certain sections and return to standby status, as water requirements diminish.

(4) Safe and efficient operation of all equipment and facilities of the water supply system.

(5) Constant vigilance concerning water supply, with particular attention to possible depletion of supply.

(6) Notification to the Engineering Division of possible future increased water requirements.

(7) Rendering of assistance for operation budget planning.

1.2.3 COMMAND RESPONSIBILITIES

1.2.3.1 Commanding Officer. The Commanding Officer of a particular shore establishment is responsible for the organization and operation of the various components of his command, according to established directives and procedures, and for the liaison between these various components.

1.2.3.2 Public Works Officer. The Public Works Officer, under the authority delegated to him by the Commanding Officer, is responsible for the operation and administration of the Public

Works Department, and for the liaison between components of the Department, and with other departments and components of the establishment.

1.2.4 ENGINEERING DIVISION. The Engineering Division is responsible for all matters pertaining to engineering studies, reports, surveys and tests; preliminary designs and estimates for special repair and improvement projects; engineering design, including development of plans and specifications, with due recognition of the support available from the Field Engineering Officer; field engineering, including hydrographic and subsurface surveys; photographic services; and, the maintenance of technical plan files and records.

1.2.4.1 Adequacy of Water Supply. When directed by the Public Works Officer, the Engineering Division will determine the current adequacy of the water supply system of the activity.

1.2.4.2 Surveys and Tests. Upon the request of the Utilities Division, and at the direction of the Public Works Officer, the Engineering Division will conduct specific surveys and tests of the water supply system of the activity.

Section 3. WATER REQUIREMENTS

1.3.1 QUANTITY. Sufficient water must be supplied by each naval shore activity's water supply system to fulfill domestic, industrial and fire protection needs. Requirements for domestic uses are set forth in "Design Manual, Civil Engineering", NAVDOCKS DM–5 (Reference 3).

1.3.2 SPECIAL USES. Water supplies for special uses, such as cooling, processing, flushing, issues to ship, lawn sprinkling and air-conditioning, are known as industrial water. Water supply requirements will be influenced by the extent of industrial water use, and some guidance may be obtained by a study of other activities having similar industrial use requirements (see Reference 3).

1.3.3 FIRE PROTECTION. Water for firefighting is of paramount importance at any naval activity. Fresh or salt, it must be delivered in adequate quantity and at adequate pressure to be a dependable weapon against fire. Fresh water should be used if supply permits, but often, for waterfront activities, salt water will prove more dependable or economical. Requirements for firefighting are presented in "Design Manual, Fire Protection Engineering," NAVDOCKS DM–8 (Reference 4).

1.3.4 WATER PURCHASE AND SALES

1.3.4.1 Purchase. When the water supply for a naval activity is procured from a nearby municipal or commercial source, the Navy cannot direct the operation and maintenance procedures used by the supplier. The fact that the Navy has accepted the water supply indicates that investigations have been made that have proven the acceptability of the supply. Under such circumstances, however, it is highly important that check controls be set up to detect any sanitary shortcomings in the outside supply as it is delivered to the shore-based activity. The Water and Sewage Branch of the Utilities Division is responsible for the operation of the water supply system under these circumstances of procurement. The Branch Head and other branch personnel should acquaint themselves with the operating procedures of the supplier to uncover any weak points and set up safeguards for the activity in the event of emergencies. Qualified personnel of the Engineering Division should be consulted in these matters.

1.3.4.2 Sales. At certain naval shore establishments, the activity may find it necessary to supply water for civilian and military housing. Such supply is provided according to accepted commercial procedures, and must be properly metered and billed to the user.

Section 4. PROCUREMENT OF SUPPLIES

1.4.1 GENERAL PROCEDURE. Usually, all requests for procurement of operating and maintenance supplies will be made to the Supply Officer of the activity.

(1) When local conditions warrant material purchases by the Public Works Department, such requests shall be made to the Administrative Division which will then perform this procurement function.

(2) Whenever possible, use will be made of standard stock items in lieu of nonstandard.

(3) Requisitions for material are prepared by the maintenance or work center supervisor from the material list furnished with the document authorizing the work.

1.4.2 SHOP STORES. The administration and operation of shop stores are the responsibility of the activity Supply Officer. The shop store supervisor is responsible for the replenishment of stock and for maintaining stock at the proper levels. The return of material to store for credit follows the principle that each job shall bear neither more nor less than the actual cost of materials used on the job. All materials drawn from shop stores for use on a job, but not used, will be returned to shop stores for credit, provided it is in quantities of issue and fit for reissue.

1.4.3 DETAILED PROCEDURES. For further information on the procurement of operating and maintenance supplies, see Chapter 5 of "Cost Accounting for Controlled Maintenance of Public Works and Public Utilities", NAVEXOS P–1604 (Reference 5).

Section 5. PERSONNEL

1.5.1 CIVILIAN PERSONNEL

1.5.1.1 Responsibility for Assignment. The assignment and training of civilian personnel is the responsibility of the Shops Division Director under the authority delegated to him by the Shops Engineer or the Assistant Public Works Officer.

1.5.1.2 Number and Assignment. Water supply systems vary so greatly in design, arrangement and complexity, that modification of established yardsticks for determining the number and assignment of personnel is frequently necessary. A study is needed for each activity. Determining factors include the design and operating characteristics of the installation, the number of shifts needed, the output required, and the emergency fire-flow needs. Manpower requirements can be reduced by installing automatic controls and warning systems to replace manual controls, which require constant attention. By overlapping shifts, additional personnel needed to care for morning and evening peak flows can sometimes be provided without hiring more men.

1.5.1.3 Experience. If possible, all men hired to operate and maintain water supply systems should have previous experience in municipal waterworks or allied fields. Supervisory and operating personnel must be able to make sound, independent decisions in unusual situations. Mechanical aptitude is an important asset.

1.5.1.4 Training. Continued training is required to maintain high standards of service, ensure efficient operation and to keep personnel informed of current technical developments.

1.5.1.4.1 On-site training. All personnel must be shown that the health and safety of the activity depend on the conscientious performance of their duties. All operating personnel should be familiar with technical publications and instructions pertinent to their operating and maintenance duties. Personnel should attend all courses and meetings initiated by the activity command, and should study all available home study courses.

1.5.1.4.2 Short schools. All personnel should be urged to take the training courses offered by local trade associations, labor groups, trade schools, colleges and universities on water supply and related subjects.

Section 6. DEFINITIONS

1.6.1 SPECIFIC TERMS. Terms which apply to division and branch organization, responsibility, assignments, relationships, etc., may be found in appropriate Navy manuals. Definitions of technical terms, which are not defined or explained in the text, will be found in the Glossary.

CHAPTER 2. WATER SUPPLY SYSTEMS

Section 1. ELEMENTS OF SYSTEM

2.1.1 SAFE AND ADEQUATE SUPPLY OF WATER. The water supply system of a naval shore-based activity must provide a safe and adequate supply of water for the sustenance and health of personnel; industrial needs; fire protection requirements; and, special needs (e.g., for piers and drydocks) of the activity.

2.1.2 DESCRIPTION OF ELEMENTS. A complete water supply system consists of a source of supply, pumping facilities, treatment equipment and plant, storage facilities and a distribution system. The specific facilities of a system vary considerably at different shore-based activities because of the difference in sources, and in quantity and treatment requirements.

2.1.2.1 Source of Supply. The water supply for a naval shore-based activity may be obtained by purchase from a nearby source, by Navy development of ground water or surface sources, or by conversion of saline water to potable water.

2.1.2.1.1 Purchased supplies. Whenever feasible, treated water under pressure should be purchased from a nearby municipality or private water company. Additional pumping and treatment by the Water and Sewage Branch of the Utilities Division is sometimes required. In a few cases, raw water may be purchased and fully treated by the Branch. A purchased supply (see fig. 1) may be augmented by ground or surface supplies, or used only as a standby for emergencies.

2.1.2.1.2 Ground water supplies. This type of water supply includes wells, springs and infiltration galleries.

2.1.2.1.3 Surface supplies. This type of supply consists of water taken from lakes, ponds, streams, impounding reservoirs and catchment areas. Water from these sources almost always requires extensive treatment, and is, therefore, used only if satisfactory ground or purchased water supplies are not available.

2.1.2.1.4 Saline water. Many coastal areas, islands and even some inland regions, have little or no fresh water, although adequate supplies of sea or brackish water are available. When it is necessary to operate and maintain naval installations in such areas, the water supply may be derived by converting the saline water into fresh water, as discussed in paragraph 3.2.10.

2.1.2.1.5 Water supplied in tanks or containers. It is sometimes necessary to supply personnel with potable water transported in tanks or containers. Special provisions for handling such water is covered in paragraph 2.3.4.

2.1.2.2 Pumping Facilities. Water pumping facilities are classified according to use, as outlined in the following paragraphs.

2.1.2.2.1 Well pumps. This classification includes all types of pumps used to obtain water from wells.

2.1.2.2.2 Low-lift stations. These stations pump water from a surface supply to the treatment plant.

2.1.2.2.3 High-lift stations. These stations pump from gravity storage or other nonpressured source directly into the distribution system, or through a pressurized treatment plant.

2.1.2.2.4 Booster stations. These stations pump from a relatively low-pressure feeder main to the distribution system. They may be installed in a long supply line to boost the pressure of the whole system, or may serve a portion of the system that is at a higher elevation.

2.1.2.2.5 Fire pumping stations. These stations are high-lift or booster stations that are installed and operated to provide larger amounts of water on demand for fire-flow requirements.

2.1.2.3 Treatment Facilities. Facilities for treating water supplies vary from simple chemical feeders to complete plants for more complex water treatment. Principal treatment functions are:

(1) Disinfection.
(2) Fluoride adjustment of water.
(3) Scale control.
(4) Iron and manganese removal.
(5) Corrosion control.
(6) Clarification.
(7) Taste, odor and color control.
(8) Conversion of saline to potable water.
(9) Swimming pool treatment.

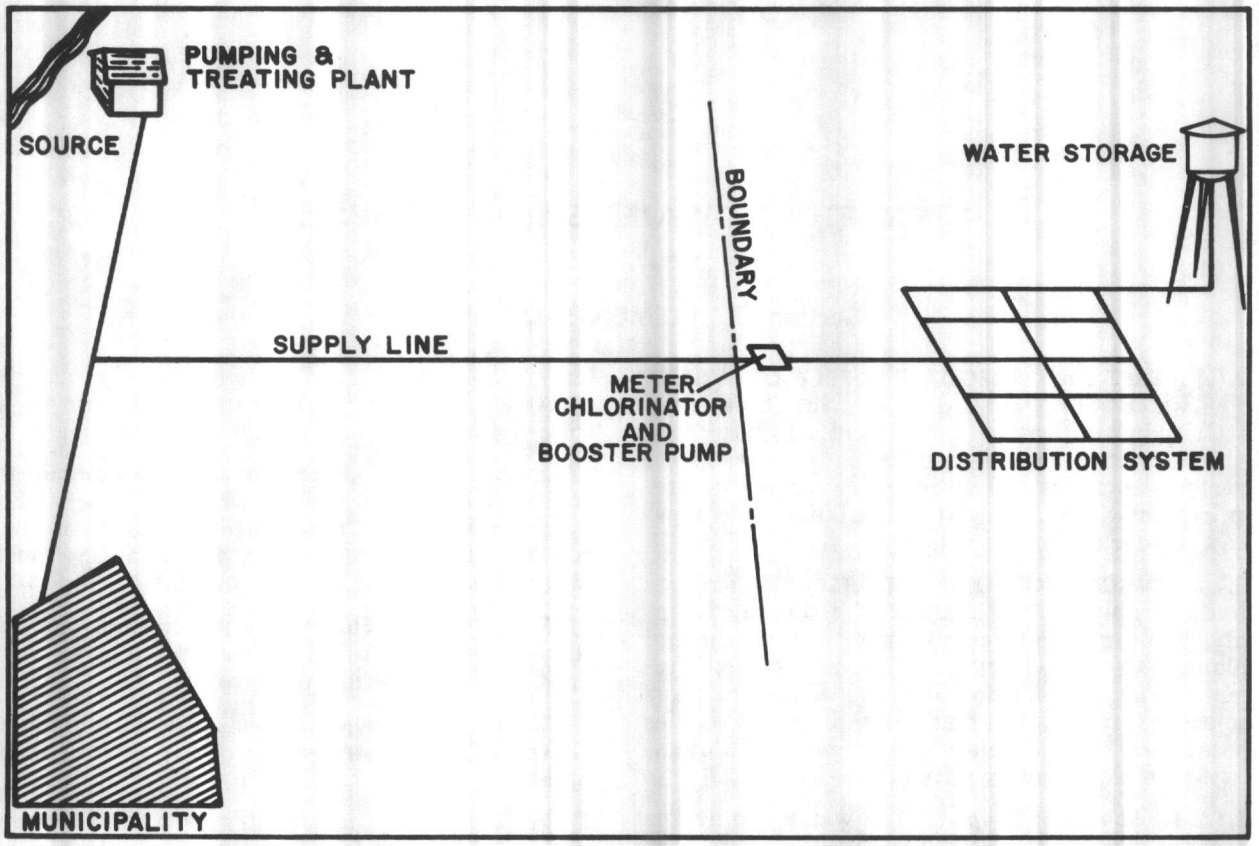


FIGURE 1

Water Supply Purchased from an Outside Source

Additional water treatment functions required for industrial and other uses are not included in this manual (see Reference 3).

2.1.2.4 Distribution System. The distribution system includes the network of mains, service lines, valves, hydrants, reservoirs and elevated tanks required for constant service or pressure equalization. A balanced-pressure distribution system is supplied, in part, from elevated tanks, pressure tanks or high-level reservoirs, at strategic points in the system. A direct-pressure distribution system has no elevated storage or pneumatic tank, therefore pressure is maintained by constant pump operations.

2.1.2.4.1 Mains and piping. Mains and piping are divided into the following groups:

(1) Feeder mains, supply distribution mains and storage tanks.

(2) Distribution mains which are the pipe lines that make up the distribution system, including any feeder mains from which service lines take their supply.

(3) Service lines which connect individual building plumbing to distribution mains.

(4) Supply lines which connect the source of supply to the treatment plant. In a strict sense, these are not part of the water distribution system, as untreated water is never allowed to enter the distribution system itself. Such lines are often termed transmission lines.

2.1.2.4.2 Storage tanks. The following types of tanks are included in this classification:

(1) Elevated storage tanks which store water at an elevation approximating that of the normal hydraulic gradeline. They may be on towers or high ground.

(2) Ground storage tanks which store water at or near ground level. A pumping station is necessary to pump water from these tanks directly into the distribution system or to elevated storage tanks.

(3) Pneumatic storage tanks are pressure tanks, at or near ground level, which are partially filled with compressed air to keep pressure at the distribution system level. They may be used at very small installations instead of elevated storage tanks, or at locations where elevated tanks would be hazardous.

(4) Emergency reservoirs are small ground storage tanks which are filled from the distribution system, although they are not permanently connected to it. They are located in strategic areas for use in fire fighting if the water supply or distribution system should fail.

2.1.2.4.3 Valves and hydrants. The following types of equipment are included in this classification:

(1) Gate valves in feeders and distribution grid for isolating sections of the system for repair.

(2) Pressure-reducing valves on service connections to prevent excessive pressure in installation areas of relatively low elevation.

(3) Check and backflow-prevention valves to prevent reversal of flow.

(4) Corporation cocks for main-to-service connections.

(5) Curb-cocks on service connections.

(6) Fire hydrants of both standard type for normal street use and flush type (pit-mounted) for airfield-apron use.

2.1.3 CONSERVATION. Water wastage is an indication of inefficient operation. It is also an economic burden and a dangerous drain on the water source. Controlled water consumption and reduction of waste to a minimum are vital to continuous, efficient and economical operation of a water supply system. The importance of conservation is apparent to all personnel during critical water shortages resulting from reduced rainfall, lowered ground water levels or temporary increases in activity personnel. At such times, rigid controls are necessary to provide water for basic personnel needs, essential operations and fire protection. Conservation, however, is not merely an emergency measure, but a full-time necessity for the effective accomplishment of the activity mission, the protection of health and welfare and economy. It is mandatory that all wastage be eliminated.

Section 2. REQUIREMENTS

2.2.1 QUANTITY. Water quantity requirements for a naval shore-based activity are discussed in Chapter 9 of Reference 3.

2.2.2 QUALITY. The quality requirements for the water supply system of a naval shore-based activity are determined by the factors of health and palatability; protection of the distribution system and other components of the water supply system; and, certain industrial needs (see Reference 3). The standards of potable water as approved by the Bureau of Medicine and Surgery are shown in Appendix IV.

(1) Paramount of these factors is the health of personnel. Water must be kept free of harmful toxic materials and disease-causing bacteria; chemical additives, such as fluorides, must be carefully controlled. Additionally, the water must be acceptable to the user in terms of taste, odor, color and temperature.

(2) The distribution system itself, as well as other parts of the water supply system through which the water moves, must be protected against the very water it carries. Water, therefore, may have to be treated to minimize corrosion and scale formation, and to control organic growths, before entering the distribution system.

(3) Within the capabilities of the water supply system treatment facilities, water should be delivered for industrial use as near to quality requirements as possible. Special treatment for the prevention of corrosion and reduction of hardness may be necessary. However, it is usually more economical to delegate the responsibility for the treatment of industrial water to the user. This is a matter of command decision, and the purpose is to lessen the treatment load on the station water supply system.

Section 3. PREVENTION OF CONTAMINATION

2.3.1 PROTECTION OF WATER-SUPPLY-SOURCE QUALITY

2.3.1.1 U.S. Public Health Standards. The standards of the United States Public Health Service, as modified by the Bureau of Medicine and Surgery, on water supply sources and their protection are accepted and approved for Navy use. These standards require that the water supply shall be obtained from a source free from pollution or, if once polluted, adequately purified by natural agencies, or from a source adequately protected by treatment. With the increasing commercial, scientific and industrial development of the country, water sources remaining free from pollution are, and will diminish considerably. For the same reason, natural agencies are in most cases inadequate for purification of a water supply that receives pollution either intermittently or continuously. Therefore, treatment is the principal protection of water supplies from pollution and contamination, particularly in more populous areas.

2.3.1.2 Protective Measures. There are two main regulatory control measures that are helpful in reducing the amount of treatment necessary: Control of pollution and control of watersheds.

2.3.1.2.1 Control of pollution. Water pollution control as exercised through legally constituted state and Federal commissions or boards will help to regulate the quantity and condition of sewage and industrial wastes that a body of water may receive, consistent with its ability to assimilate such wastes.

2.3.1.2.2 Control of watersheds. Natural water quality may be safeguarded and improved by regulation and control of individual watersheds. Among the means by which water quality may be preserved are the reforestation of denuded areas in order to prevent soil erosion and to aid their ability to hold water and conduct it to ground storage; the promotion of contour plowing in order to prevent excessive runoff and subsequent soil erosion; the control and regulation of recreational activities, such as swimming, boating, fishing, camping and picknicking; the drainage of swamp areas; the maximum possible drainage of acid mine wastes away from water sources; and, close control of sanitation practices by patrolling the watershed.

2.3.1.3 Natural Purification Agencies. Assisting the above regulatory control measures in reducing the pollution load of a water source, are the natural agencies of self-purification. These include such natural agencies as dilution by increased rainfall or runoff; aeration by flow over rugged terrain or waterfalls; filtration through the ground; and, sedimentation or settling in lakes and reservoirs.

2.3.2 PROTECTION OF SURFACE SUPPLIES. In addition to the natural protection offered surface water supplies, certain protective measures can be taken to help keep them pure.

2.3.2.1 Natural Protection. Small upland streams and larger surface watercourses serving uninhabited, forested drainage basins rarely are subjected to a pollution load that the agencies of self-purification cannot handle. Occasional human and animal pollution is usually the only source of contamination. Bacterial loads are low, and turbidities even on high runoff will not be excessive because of the protection of the natural ground cover. Such sources can be readily used, with storage and chlorination the only treatment required, if control of all human activities is established over the watershed, and the natural state of forestation is maintained.

2.3.2.2 Protective Measures. Very few sources of water supply remain that afford such conditions of natural purity. Streams in their passage through drainage basins are subjected to silt and mud from plowed fields at periods of heavy rainfall; to insecticides and fertilizers from lands on which they are used; and, to domestic sewage and industrial wastes from cities and towns in the watershed. It is, therefore, necessary that these sources of supply be artificially purified. Even where such purification is necessary, it is better to reduce or prevent pollution of water, than to rely entirely on treatment for producing safe water. The following measures can be taken to protect surface supplies from the effects of waste loading.

2.3.2.2.1 Sewage treatment. Because of the excessive demands of untreated sewage and industrial waste on the resources of a water course, treatment of these wastes is a primary step in protecting a source of water supply. The object of such treatment is to prevent damage to the receiving waters, and the extent to which wastes are treated should be determined with this objective in mind. When a specific water supply is being protected, current practice is to chlo-

rinate sewage plant effluents in order to oxidize the organic material that serves as a food supply for many micro-organisms, and to reduce bacterial loading.

2.3.2.2.2 Promotion of conservation activities. Reforestation and planting of ground cover minimize erosion, conserve water and reduce floods by retaining surface water for slower release to streams. Soil, insecticides, and fertilizers may be retained on the fields and kept out of streams, if contour plowing is promoted.

2.3.2.2.3 Drainage of swamps. Water in swampy areas is a source of color, tastes and odors primarily because of decaying vegetation. The growth of algae and other micro-organisms is also promoted in such waters because of the abundance of food and the penetration of light in the shallow depths. Where such conditions exist in a catchment area, economical drainage can usually be effected by clearing the natural stream channels and constructing drainage ditches.

2.3.2.2.4 Watershed inspection. Watershed operations should follow state and federal laws dealing with sanitation or sanitary codes. It should be made certain that such preferred methods of sanitation as the burning or burying of dead animals, disposal of manure from barnyards and proper sewage disposal are followed. Direct discharge of sewage and other putrescible matter to a lake or stream should be prevented. Pit privies should not be allowed within 100 feet of the water's edge, and should preferably be 200 feet away. If recreational use of the catchment area is to be allowed, increased vigilance on the part of those responsible for the safety of the supply is required. Control of these activities is important even if complete water treatment is given. A sufficient number of toilets must be provided at convenient points, and their use enforced. Boating activities must be curtailed as gasoline and oil from these activities, even in small quantities, can cause serious treatment difficulties as well as taste and odor problems. Use signs and other means of instruction to warn the public against violations of sanitary regulations that would endanger the safety of the water supply.

2.3.3 PROTECTION OF GROUND WATER SUPPLIES. The quality of ground water is influenced by the character of the soil and the underground layers of rock, sand and gravel through which it flows. As water flows downward, carbon dioxide, which is a product of bacterial activity in the soil, is dissolved and the water becomes more acid. Water is also filtered as it passes through the soil thus becoming clear. Acid water has the capability of readily dissolving many minerals that it contacts on its passage through the ground. Limestone (calcium carbonate) is easily carried into solution by an acid water, and in the dissolving process makes the water "hard." Sources of surface or underground pollution may affect the quality of ground water. In limestone regions where there are many cracks, crevices and caverns, pollution from surface streams or drainage is particularly hazardous to underground supplies. Such pollution may be carried many miles to contaminate wells and springs. Lagooning of industrial and municipal wastes should be prohibited in such regions. Underground discharge of wastes from cesspools or septic tanks may also endanger a ground supply.

2.3.3.1 Protective Measures Against Surface Contamination. Operation and maintenance personnel must operate and maintain existing equipment and facilities under existing conditions. Whenever equipment, facilities or operating conditions do not meet design standards (see Chapter 9 of Reference 3), operating and/or maintenance personnel should either make corrections as indicated in paragraph 4.2.2.2, or seek engineering advice on measures to be taken. The following paragraphs describe conditions which should be corrected.

(1) Improper location. If a well or spring is located on low ground or is near a pond, lagoon, privy or barnyard, it should be suspect, and corrective measures taken unless regular analysis of the water continually indicates its acceptability (see fig. 2).

(2) Improper drainage. Where natural drainage does not exist, the surface should be graded to meet standards described in Reference 3. In the case of a spring, a diversion ditch and curbing may be required to prevent surface contamination and to protect against flooding (see par. 4.2.2.2(1)). Well-pump house drainage from a floor drain should never be connected to a sanitary or stormsewer, but should be conducted to a gravel pocket. If improper conditions exist, corrective measures should be taken.

(3) Livestock on grounds. Where livestock in the area may wander over a water source, a protective fence is required (see paragraph 4.2.2.2 (2)(a)).

(4) Lack of watertightness. Where there is no concrete slab providing a watertight cover at least 18 inches beyond the casing, or where the well casing is not sealed, or does not meet the design standards for casings indicated in Reference 3, corrective and/or maintenance measures should be taken (see par. 4.2.2.4).

(5) Unsealed abandoned wells. Figure 3 shows how a ground water supply may be contaminated from an abandoned well by surface pollution through a fissured limestone formation. See paragraph 4.2.2.6.2 for methods of sealing abandoned wells and test borings.

(6) Defective well linings. See paragraph 4.2.2.6.3 for maintenance procedures.

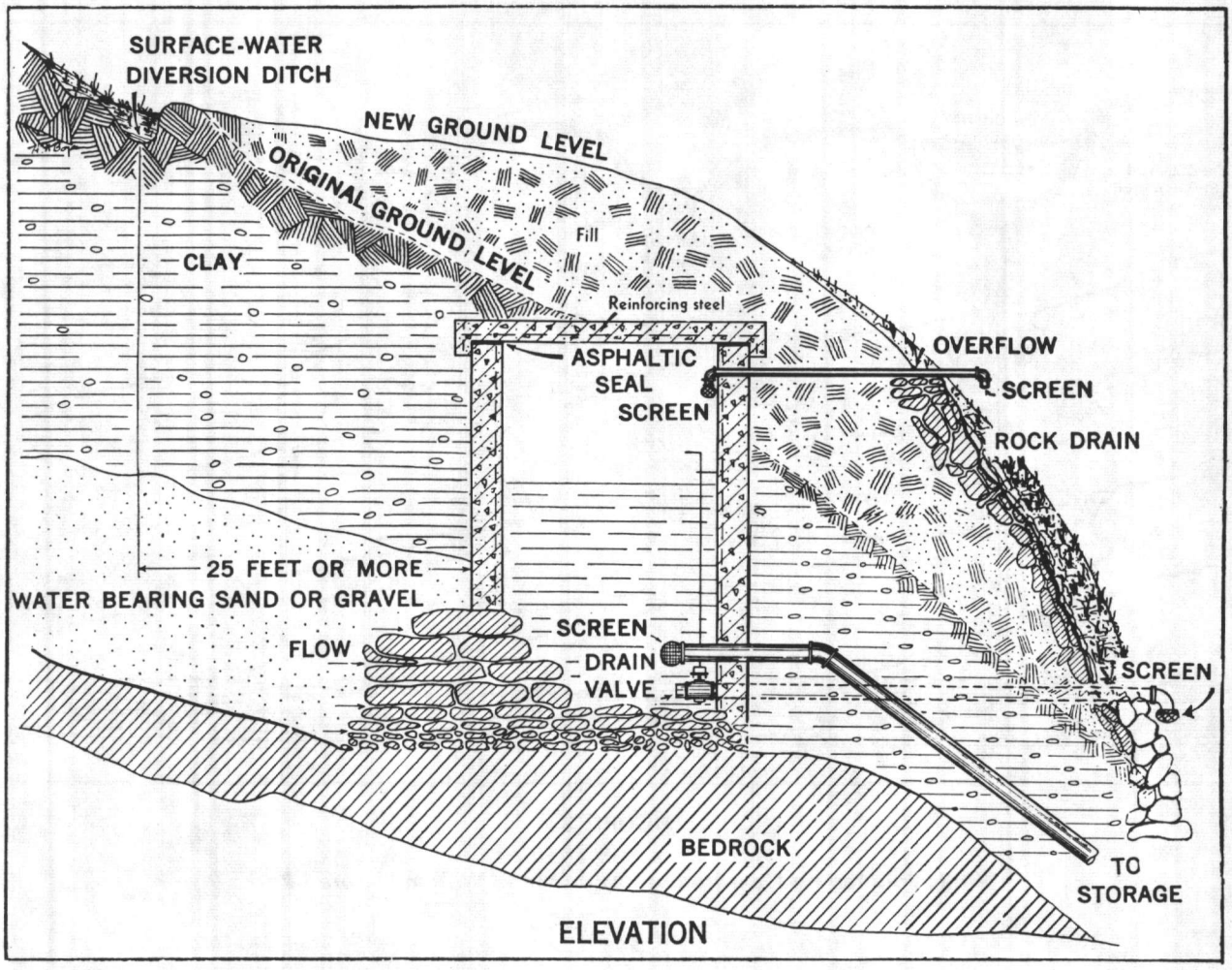


FIGURE 2

Protection of Spring from Surface Contamination

2.3.3.2 Protective Measures Against Underground Contamination. Where underground contamination is suspected, operation and maintenance personnel should seek engineering advice or take corrective actions as suggested in the following paragraphs or in Chapter 4. The situation should be suspect if wells are located near latrines, septic tanks, subsurface drainage fields and polluted bodies of water. Design standards appear in Reference 3.

(1) Chlorination of all supplies from springs and infiltration galleries is required to ensure that the water is safe for human consumption. Control of the pollution that may enter the catchment areas of such waters is so uncertain and difficult that chlorination becomes a necessity. Practice of watershed inspection and sanitation is required, but will not eliminate the need for chlorination.

(2) Although full protective measures may be taken to prevent contamination of wells, pollution detection is difficult, and pollution from undetected sources may enter the supply. Therefore, all well water supplies must be chlorinated. Grossly contamined wells should be abandoned. If bacteriological and chemical tests consistently reveal contamination in the untreated well water, a special study should be made to determine the source of pollution.

2.3.3.3 Protection Against Contamination Through Improper Operation. To guard against pollution through improper operation of well supplies, observe the following rules:

(1) Always prime a pump with potable water.

(2) Disinfect a pump after installation and after any repair (see par. 4.2.2.5).

(3) Particular attention should be given to the disinfection of pump packing. Difficulty is

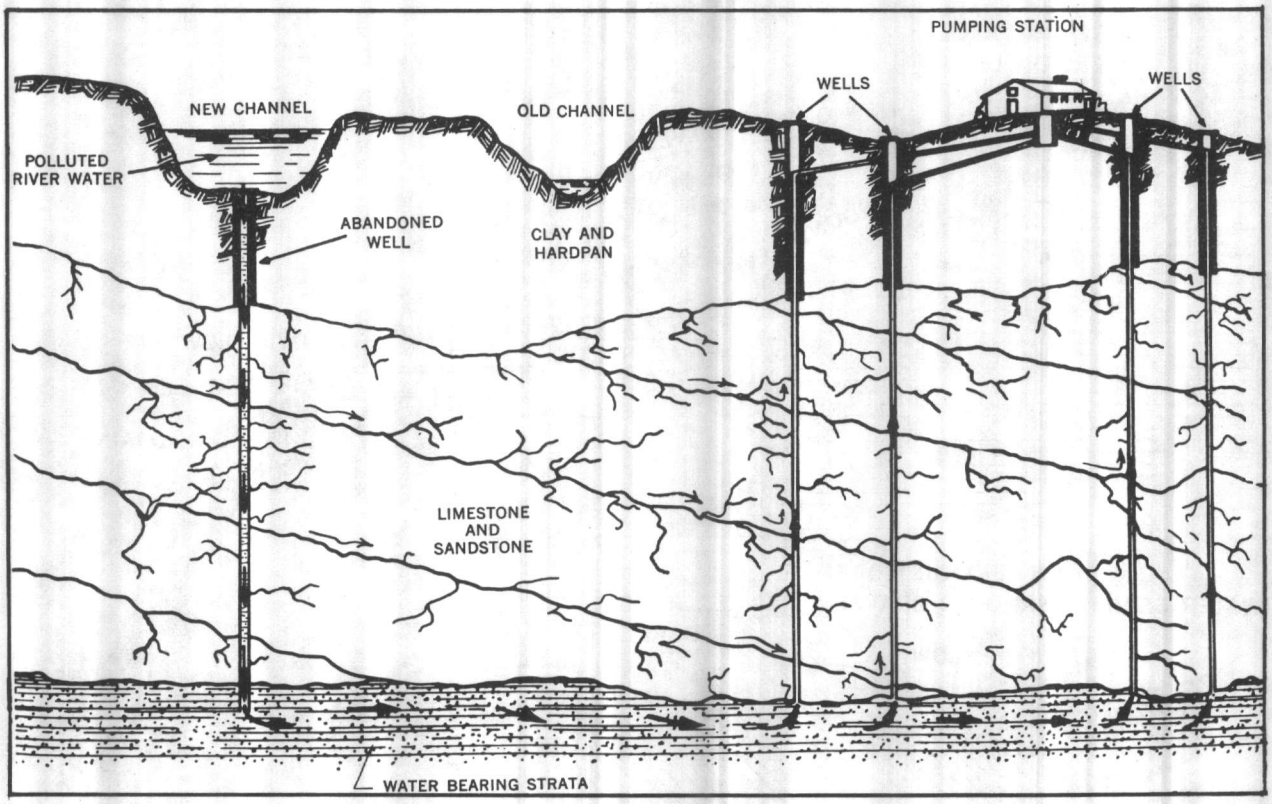


FIGURE 3

Wells Polluted by Flow from an Abandoned Well in Fissured Rock

sometimes experienced in eliminating bacteria from this particular element.

(4) Keep the drain from a pump base open and free so that any leakage will be carried away from the source.

2.3.4 PROTECTION OF WATER SUPPLIED BY MOBILE TANKS AND/OR CONTAINERS. The instructions for handling potable water by mobile tanks and/or containers are contained in BUDOCKS instructions which are included as Appendix I of this manual. There can be no deviations from these instructions. It must be emphasized that the procurement and use of bottle-type drinking-water coolers is prohibited by BUDOCKS instructions in response to specific recommendations of the Bureau of Medicine and Surgery. Only those methods of storing and transporting water as outlined in Appendix A are permissible.

2.3.5 PROTECTION OF WATER DISTRIBUTION SYSTEMS. Public health standards require that all elements of a water supply system be free from sanitary defects and health hazards; that all known sanitary defects and health hazards be systematically removed at a satisfactory rate; that there be effectively enforced rules and regulations in existence which prohibit connections or arrangements by which liquids or chemicals of unsafe, unknown or questionable quality may be discharged or drawn into the system; and, that there be in existence a continuing program to detect health hazards and sanitary defects within the water supply system. Any physical connection between a water supply of good quality and an unsafe supply may not be permitted, nor may any connection be permitted between a potable supply and a sanitary or storm sewage system, including manholes, pumps, valve pits or any other location that may allow unsafe or contaminated waters to enter the potable supply.

2.3.5.1 Cross-Connections. A cross-connection is the physical connection of a safe supply and a nonpotable or polluted supply. It may allow liquids or chemicals of unsafe, unknown or questionable quality to flow directly into or be discharged into a potable supply. If an activity supply is to be interconnected with a municipal supply, approval of the activity command, acting on the recommendation of the activity medical officer, and of the municipal health authorities must be obtained.

2.3.5.2 Backflow. Backflow is the backing up of contaminated or polluted water into the potable water system. Backflow conditions frequently occur because of improper construction, subsequent changes in piping or carelessness of users. The hazard created depends on the degree of pollution in the unsafe water; the volume of backflow that could occur; and, the likely frequent occurrence of conditions that could cause backflow, such as negative pressure in the potable system and improper design and installation of plumbing fixtures. Negative pressures can result from line shutoffs because of repairs to main breaks or plumbing; high fire flow, especially with pumpers; inadequately sized or tuberculated pipe; pressure surge and water hammer; and, excessive water consumption.

2.3.5.2.1 Backflow at different locations. The following are examples of backflow conditions in different locations.

(1) Water Treatment Plants. Flow between raw- and treated-water tanks may occur through cracked dividing walls or leaking bypass valves.

(2) Valve Pits and Hydrants. Where drained to sanitary sewers, valve pits and hydrants are subject to flooding through sewer stoppage. Backflow can occur through leaking valve stems and drain ports of automatic valves and hydrants.

(3) Dual Water Systems. Dual water systems may be cross-connected unintentionally during alteration of the systems.

(4) Swimming Pools. Direct connection of the fresh-water inlet to the swimming pool or the recirculating piping creates possible backflow conditions. Valved cross-connections between a potable supply and the swimming pool system for makeup water or filter backwash can cause backflow or siphonage by leaking valves or lower pressures.

(5) Plumbing Fixtures. If pipes supplying toilet tanks, lavatories, sinks or other similar fixtures, terminate below the highest level of liquids that the fixture may hold, a danger of backflow exists. The most effective means of preventing this condition is to provide an air gap of at least three times the diameter of the supply pipe between the highest possible water level in the fixture, and the overhead supply faucet or fitting. If an air gap is not practical, an approved vacuum breaker or backflow preventer may be used.

(6) Shops, Laboratories and Utility Plants. Whenever water is used in process operations or for equipment operation, backflow conditions can occur through improper connection. Examples are submerged connections to photographic chemical tanks; direct connections to condenser and cooling water systems in power, refrigeration and air-conditioning plants; and, direct water and sewer connections to water-cooled compressors.

(7) Sewers. Old automatic sewer flushing devices mounted in manholes create serious hazards. New installations of this type are not permitted. Manual sewer flushing with a hose is generally not hazardous, provided the hose is not left unattended in the sewer.

(8) Sewage Pumping and Treatment Plants. In sewage pumping and treatment plants, backflow may occur through a potable water connection to pumps for priming and gland sealing; to venturi meters and chlorinators; and, to sewage and sludge lines for flushing. Hoses used for washing walkways, flushing tanks and channels should never be carlessly permitted to hang into sewage.

(9) Ship-to-Shore Connections. Connection of the shore potable water system to a ship's nonpotable water systems in violation of existing OPNAV directives may permit contamination of the shore systems if the ship's pumps are inadvertently started.

2.3.5.2.2 Prevention of backflow. The numerous conditions under which backflow can occur require water supply personnel to be constantly vigilant. Periodic surveys of the system must be made by competent personnel. Occurrence of positive bacteriological tests on samples from one section of the system suggests possible backflow in that area. Listed below are the more important methods of backflow prevention. These methods are discussed in detail in paragraph 3.4.2.3.

(1) Elimination of cross-connections.
(2) Separation by air gap.
(3) Backflow preventer.
(4) Backflow protection units (see fig. 4).

2.3.5.3 Ship-to-Shore Connections. The instructions relating to ship-to-shore connections between potable water systems ashore and any water system aboard ships are contained in OPNAV instructions which are included in Appendix B of this manual. Among other things, the directive requires that only authorized shore personnel make water connections between shore and ships. The instructions for the care and disinfection of facilities used and the procedures to be followed in making such ship-to-shore connections are contained in BUDOCKS instructions which are included in Appendix C of this manual.

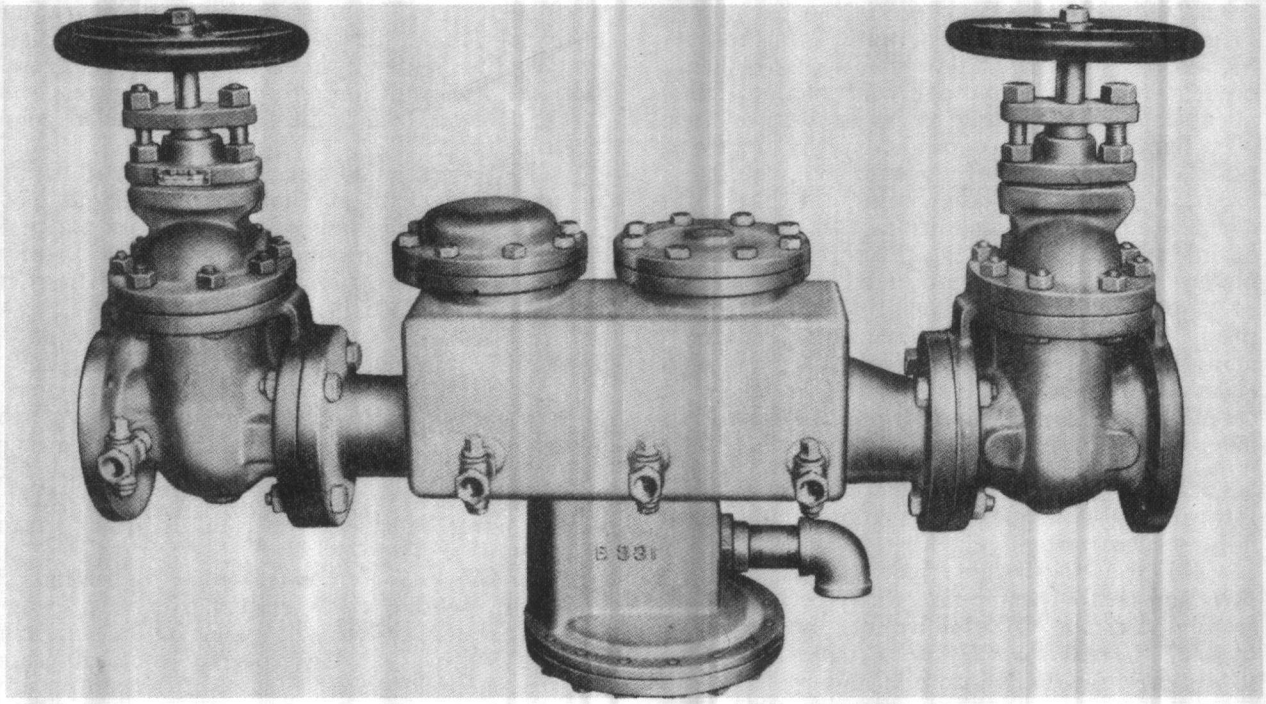


FIGURE 4

Typical Backflow Protection Units

Section 4. EMERGENCIES

2.4.1 RESPONSIBILITY. Health and fire protection are so dependent on a safe and adequate water supply that measures for protection of the system and plans for emergency operation are a basic responsibility of the Water and Sewage Branch. Operating personnel must be fully trained in these protective and emergency measures. One important aspect of emergency measures—the disinfection of tanks, treatment units and mains—is covered in detail in paragraphs 3.2.2.6 and 4.4.4. A general outline of emergency water supply operations is contained in the following paragraphs.

2.4.2 EMERGENCY WATER SUPPLY OPERATIONS. Emergency water supply operations must be planned well in advance and be immediately ready for placing in effect. The plan should be kept current and should establish standard operating procedure for alerting water supply and firefighting personnel, and should clearly define the duties of each individual.

2.4.2.1 General Plan. The plan must provide for the earliest possible restoration of water service to essential activities in a prescribed order, and at the same time provide sufficient water to meet minimum health and sanitation requirements. Some of the essential features of the plan are discussed below.

(1) Personnel should be trained in specific functions and duties; they must know where to report and what to do. Repair and emergency crews should be organized and trained to work as a complete unit. While volunteers may be of some assistance in emergencies, they should not be relied on to perform principal waterworks duties. Personnel responsible for the operation of water supply systems will have adequate knowledge of:

(a) The physical plant, including characteristics, size, capacity, location, operation and maintenance.

(b) The current inspection status of pumps, motors, engines, chlorinators, chemical feeders, indicating devices, controls, valves, water sources, storage and distribution facilities, fire hydrants and connections.

(c) The availability of water and the effect of fire-flow drain upon the supply system; alternate and emergency methods of obtaining supply; and the effects of failure of each unit of equipment on other components of the system.

(2) The plant should be coordinated with other interested activity components, such as medicine, fire prevention, transportation and supply. The probability of water contamination must be anticipated, and emergency procedures dealing with contamination and disinfection must be developed in conjunction with medical personnel.

(3) It should be assured that current, accurate and complete distribution system, sectional and valve-location maps are prepared, kept current and readily available to operating personnel. A schematic diagram of all pumping station layouts, piping and equipment should be conspicuously posted for future reference.

(4) Arrangements should be made to provide additional transportation service for hauling personnel, equipment and materials during emergencies.

2.4.2.2 Supply Sources. Particular protective actions which pertain to supply sources include the following.

(1) The stationing of guards at all key points to prevent accidental or intentional contamination of the source of supply.

(2) The selection of possible auxiliary supply sources and their clearance with the medical officer; establishment of a procedure for connecting them into the system in an emergency and for disconnecting them as soon as the emergency is over.

(3) The provision of protection against flood damage either by sandbagging or the construction of temporary earth levees.

(4) The investigation of the possibility of excessive contamination or pollution caused by domestic or industrial wastes entering the source of supply, and steps either to eliminate such hazards or to provide for adequate treatment.

(5) Inspection for improper well construction, e.g., pumps and motors in a subsurface pit, or inadequate sealing against pollution and the correction of unsafe conditions.

(6) The testing of purchased water supplies periodically to assure that they are adequately chlorinated.

2.4.2.3 Pumping Plants. Standby power should be arranged for the pumping plant, using internal combustion engines that can be put into immediate service when needed. As an expedient, a salvaged vehicle engine or the power takeoff pulley of a tractor can be belt-connected to a pump.

2.4.2.4 Treatment Plants. Particular actions which pertain to treatment plants include the following.

(1) Study of the treatment plant and operating procedures to determine points that would be critical in an emergency. Thus, if plant capacity may be limited by a single unit, the provision of a standby unit of that type might facilitate emergency operation. Inadequacy of treatment due to damage of certain units usually can be offset by increasing the chemical dosage to produce safe water at the cost of lowered efficiency.

(2) Provision, and maintenance in working condition, of standby and portable chlorinators for emergency chlorination. Hypochlorinators or gas-feed chlorinators may be used where suitable.

(3) Maintenance of an emergency supply of hypochlorite.

(4) Protection of intake and suction lines in the plant against the entrance of foreign objects which might plug the lines or injure equipment.

(5) Establishment of a procedure for chlorinating auxiliary water sources.

(6) Inspection of chlorine residuals in the distribution system frequently and adjustment of plant dosage as needed. Residuals above the normal requirements may be justified in an emergency. Such increases, however, should be checked with the Field Engineering Officer, and, through him, the District Medical Officer.

(7) Chlorination of all pumping or filtering equipment when it is first installed, and following repairs.

2.4.2.5 Distribution Systems. Particular actions which apply to distribution systems include the following.

(1) Inspection of the distribution system and supply lines to see whether or not they can supply critical areas with enough water to fight fires despite power or main failures at any point. Plans for providing temporary duplicate supply facilities at critical points should be formulated. If construction changes are needed, approval should be requested through normal channels.

(2) Study of the advisability of adding valves in the system to localize areas that would be affected by failure of a single main and to minimize loss of water due to such failure.

(3) Maintenance of adequate stocks of essential repair parts. To keep repair stocks at a minimum, carry standard size valves and sleeves, and stock reducers to adapt standard size fittings to all piping in the system.

(4) Investigate the availability of manpower, materials and equipment which may be borrowed for use in emergencies from nearby municipal and civil defense officials.

(5) Inspection of all valves, hydrants, pressure regulators and other equipment, in accordance with Chapter 4, and consideration of the need for increased inspection frequency for critical points. Immediate repairs should be made where needed. Valves and hydrants are essential parts of the system and must be tested periodically and kept in good working order at all times.

(6) Maintenance of complete and accurate maps and records. Assure that copies of maps and records used by operating and maintenance personnel are not available to unauthorized persons.

(7) Careful inspection for improper connections which may be health hazards, including cross-connections between the water system and any unsafe or unapproved systems; direct connections with the sewage system; and, direct connection with dish-washing equipment, hospital sterilizers, flush-valve-operated toilets and siphon-jet urinals. For further information on improper connections, see paragraph 2.3.5.

(8) Leak and flow surveys at periodic intervals in order to determine system efficiency should be made. Data should be sufficiently complete to determine changes, additions and improvements required for emergency conditions.

2.4.2.6 Repair Tools and Equipment. Adequate supplies of repair tools, shoring braces and emergency equipment such as floodlights and small air compressors are essential. If the necessary tools and equipment are not on hand, or available from the supply sources in the activity, investigate the possibility of procuring them from neighboring communities or contractors during emergencies (see Chapter 4, Section 1).

Section 5. COLD WEATHER OPERATION AND MAINTENANCE

2.5.1 PROBLEMS OF COLD WEATHER. In cold weather, freezing presents a major problem to a water supply system. Wells may freeze, frost heave may damage well pump installations, pump bearings may freeze, water intakes may clog due to ice, filtration rates may become slower due to increased viscosity of the water, chemical reactions in the treatment process may slow down, and many other problems may arise. None, however, is more difficult to cope with than the problem of distribution and storage of water under such conditions. Where seasonal freezing is the only problem, as opposed to conditions which keep the ground permanently frozen, pipes must be buried below the depth to which the frost penetrates. It is also necessary to heat stored water when extremely cold temperature prevail.

2.5.2 THAWING FROZEN SYSTEMS. Because of the lack of protection against freezing, and sometimes regardless of it, pipes frequently may freeze in temperate zones. When this happens, the pipes must be thawed.

2.5.2.1 Electrical Thawing. Electrical thawing is quick and relatively inexpensive. The electrical current for the thawing operation consists of a source of current (a direct-current generator, such as a welding outfit, or a transformer connected to an a.c. outlet), and two insulated wires connecting the current source and the pipe (see fig. 5). Only qualified personnel should be assigned the responsibility for the use of power lines as a source of current. As current flows through the pipe, heat is generated and the ice within the pipe begins to melt. As the water starts to flow, the rest of the ice is progressively

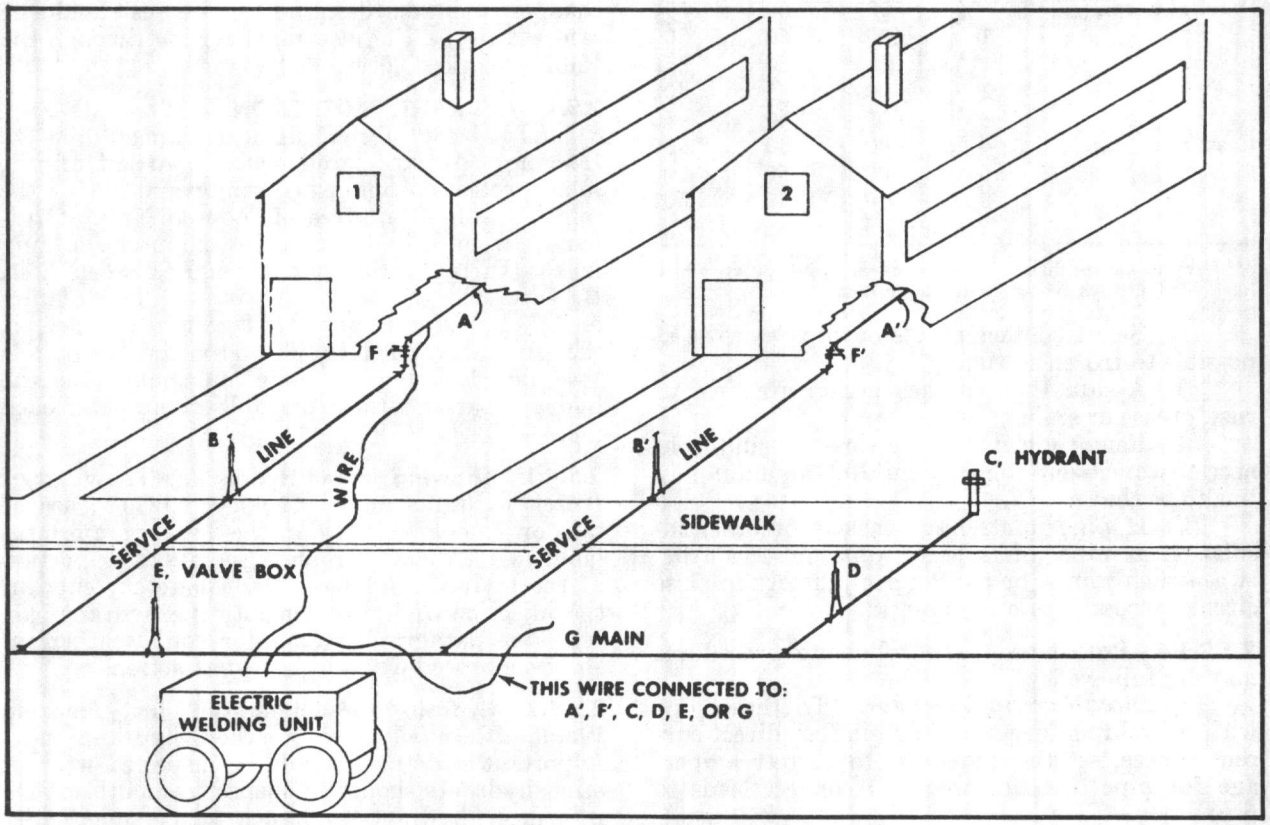


FIGURE 5

Connection Points for Thawing Frozen Service Lines

melted by contact with the flowing water. The wires from the current source may be connected to nearby hydrants, valves or exposed points at the ends of the frozen sections.

2.5.2.1.1 Current and voltage. Some data concerning current and voltage required for thawing various sizes of wrought iron and cast iron pipes are in table 1.

2.5.2.1.2 Time. Time required for thawing varies from five minutes to over two hours, depending on pipe size and length, intensity of freezing, and several other factors. Best practice is to apply current until water flows freely.

2.5.2.1.3 Precautions. The following precautions should be given careful attention.

(1) The use of higher current than listed in Table 1 should be avoided. When in doubt, use low current for longer period.

TABLE 1
Relation of Current and Voltage Required to Thawing

Type of pipe	Pipe size (in.)	Pipe length (ft.)	Approximate (volts)	Approximate (amps.)[1]
Wrought Iron---	¾	600	60	250
	1	600	60	300
	1½	600	60	350
	2	500	55	400
	3	400	40	450
Cast Iron-------	4	400	50	500
	6	400	50	600
	8	300	40	600

[1] Use no more than 100 amperes on lead pipes which have lead fittings or any soldered joints.

(2) Select contact points on pipe as close as possible to frozen section.

(3) Assure that contact points are free of rust, grease or scale.

(4) Remove meters, electrical ground connections and couplings to building plumbing in line to be thawed.

(5) If pipe joints have gaskets or other insulation at pipe joints, thaw pipe in section between such joints, or use copper jumpers to close circuit across insulated points.

2.5.2.1.4 Procedures. The following procedures may be followed.

(1) Direct-Current Generator. To thaw pipe with a welding generator or similar direct-current source, set the generator to correct amperage for pipe to be thawed and connect leads to pipe.

(2) Alternating-Current Circuit. Transformers are required to adjust amperage of an alternating-current circuit to the pipe being thawed. To minimize hazards, a competent electrician or lineman should set and connect transformers, make the connections and assist in the thawing procedure. Where frequent thawing is necessary at different points, the transformers may be mounted on a trailer for ready use.

2.5.2.2 Steam Thawing. Steam thawing is slower and is used only when insulating material in pipe joints or couplings makes the use of electricity impracticable. In steam thawing, a hose connected to a boiler is inserted through a disconnected fitting and gradually advanced as the steam melts the ice.

2.5.3 PROTECTION OF INTAKES. Damage to intakes by surface ice can be prevented by location of the intake below the ice level, and by placement of lake intakes beyond the ice line of the lake. More serious, however, is a special icing problem caused by frazil or needle ice which forms as free submerged ice crystals. The crystals gradually collect in the intake and eventually block the opening. If frazil ice cannot be removed by scraping or other manual means, it may be removed by reverse flushing by pumping water out of the intake. If necessary, steam can be piped into the water to raise the temperature sufficiently to prevent ice formation. Repeated formation of frazil ice may be corrected by changes in intake design. Such cases should be referred to the Engineering Division through the Public Works Officer.

2.5.4 HYDRANT PROTECTION. Hydrants (fig. 6) must be protected against damage due to freezing. A box placed over a hydrant affords some protection against freezing and leaves the top of the hydrant free of snow and ice. Ordinarily, when a hydrant is closed, water standing in the barrel drains out through a weep hole. Be sure that the weep hole is kept free of dirt or other obstructions. In freezing weather, if the ground-water level is above the weep hole (see fig. 6), plug the hole and pump out the hydrant barrel with a portable pump after each use.

2.5.4.1 Thawing Frozen Hydrants. Thawing of frozen hydrants may be achieved by the use of salt or calcium chloride; the heat of an insulated wire wound around the exposed portion of the hydrant and fed an adequate current; or, the injection of live steam into the hydrant barrel. See paragraph 4.6.2.2 for cold weather inspection procedures and remedial action.

2.5.4.2 Hydrant Maintenance in Freezing Weather. In sub-zero weather, hydrants near important structures should be inspected weekly; other hydrants should be inspected monthly. Do not flush hydrants on such inspections. See Chapter 4, Section 6 for details of maintenance of hydrants in both freezing and temperate weather.

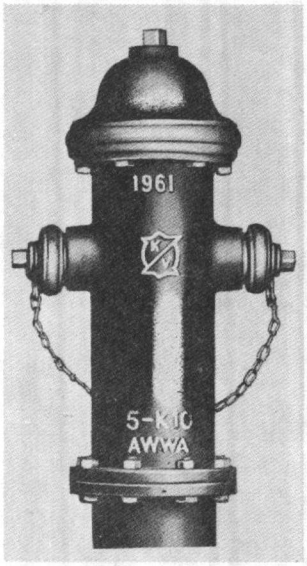
Standard Model

Compression Type

Test Pressure:
Water 300 lbs.

Working Pressure:
Water 150 lbs.

Sizes:
Main Valve 4¼", 4½", 5¼"
Standpipe ID 7"



Exterior view showing marking cast on standpipe. Direction to open cast on cap.

PART	MATERIAL
CAP BOLT NUTS	BRONZE
OPERATING STEM NUT	BRONZE
ALEMITE FITTING	STEEL
"O" RING WEATHER SEAL	BUNA N SYNTHETIC RUBBER
CAP	CAST IRON
ALLEN HEAD SETSCREW	STEEL
LOCK NUT	BRONZE
COVER PLATE	CAST IRON
COVER PLATE BOLTS AND NUTS	RUST-PROOFED STEEL
"O" RING PRESSURE SEAL	BUNA N SYNTHETIC RUBBER
COVER PLATE GASKET	CORK FIBRE
NOZZLE CAP HOOK	STEEL
NOZZLE CAP GASKET	RUBBER
NOZZLE	BRONZE
NOZZLE CAP	CAST IRON
NOZZLE SCREW	BRONZE
NOZZLE CAP CHAIN	STEEL
UPPER STANDPIPE SECTION	CAST IRON
STANDPIPE BOLTS AND NUTS	RUST-PROOFED STEEL
STANDPIPE GASKET	SPECIAL COMPOSITION
STEM	C.R. STEEL
SEAT REMOVING WRENCH GUIDE	BRONZE
WRENCH GUIDE SETSCREW	BRONZE
LOWER STANDPIPE SECTION	CAST IRON
DRAIN VALVE FACING	TREATED LEATHER
DRAIN VALVE	BRONZE
ELBOW BOLTS AND NUTS	RUST-PROOFED STEEL
ELBOW GASKET	CORK FIBRE
SEAT RING	BRONZE
SEAT RING GASKET	ASBESTOS FILLED COPPER
DRAIN VALVE KEY	STEEL
TOP PLATE	CAST IRON
MAIN VALVE	BALATA
FULL COVER BOTTOM PLATE	CAST IRON
ELBOW	CAST IRON
DRAIN TUBING	BRONZE

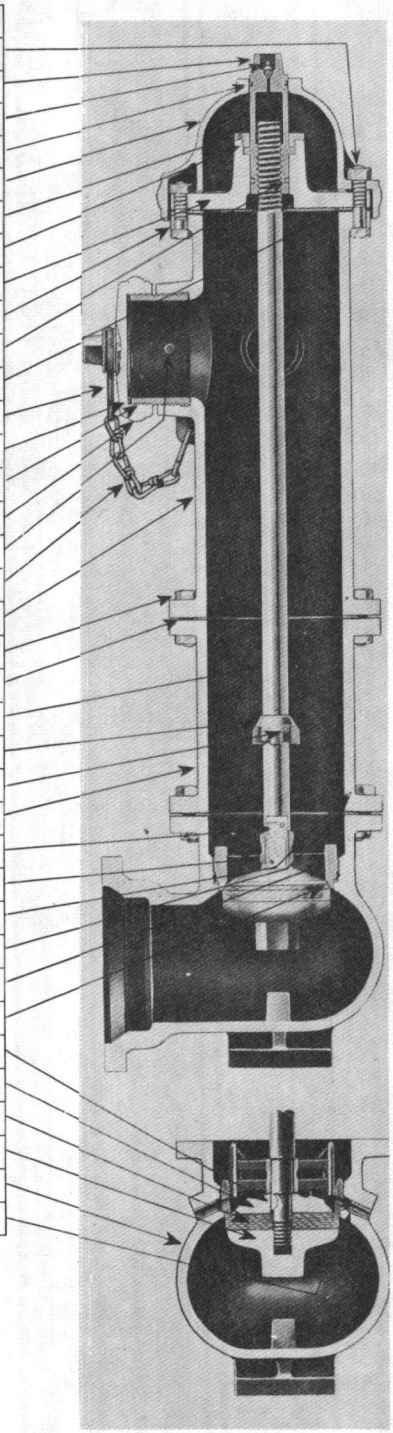


FIGURE 6

Typical Fire Hydrant

2.5.5 OPERATING AND STANDBY EQUIPMENT. Protecting operating and standby equipment against damage is especially important if freezing weather is probable. Make sure lubricants are changed to winter grades. Drain equipment temporarily out of use or on standby service, or provide proper antifreeze coolant to prevent freezing and bursting of such units as the housings of pumps, radiators, piping and similar items. For full details on maintenance of various types of equipment in freezing weather see Chapter 4.

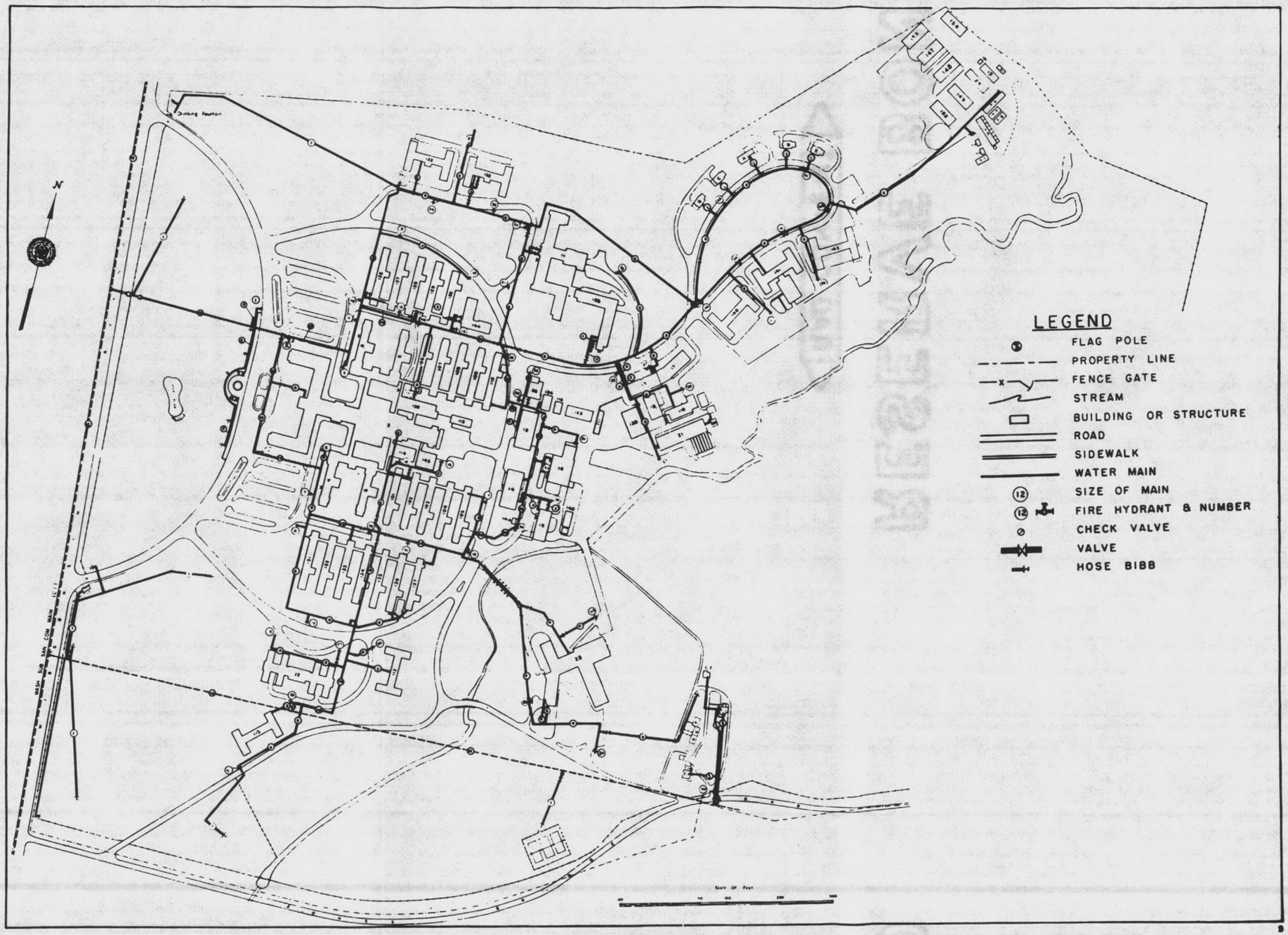


FIGURE 7

General Utility Map

POTABLE WATER SUPPLY AND DISTRIBUTION OPERATING RECORD *(See Instructions on Reverse Side)*

NAVDOCKS 2568 (4-59)

ACTIVITY | MONTH AND YEAR | SOURCE OF SUPPLY

DATE	WATER SUPPLIED 1000 Gallons: PURCHASED (1)	WELLS (2)	SURFACE (3)	TEMPERATURE °F (4)	pH (5)	CHLORINE RESIDUAL: CHLORINE RESIDUAL (6)	SAMPLE POINT (7)	CHLORINE RESIDUAL (8)	SAMPLE POINT (9)	CHLORINE RESIDUAL (10)	SAMPLE POINT (11)	CHLORINE RESIDUAL (12)	SAMPLE POINT (13)	CHLORINE RESIDUAL (14)	SAMPLE POINT (15)	CHLORINE Pounds: CHLORINE GAS (16)	HYPO-CHLORITE (17)	CHEMICAL INHIBITORS - Pounds (18) (19) (20) (21) (22)	FLUORIDATION: FLUORIDE POUNDS (23)	CONCENTRATION (24)	BACTERIOLOGICAL EXAMINATION: WATER SUPPLIED: AGAR COUNT (25)	10 ml / 100 ml (26)	WATER DISTRIBUTED: AGAR COUNT (27)	10 ml / 100 ml (28)	SAMPLE POINT (29)	WELL PUMPING RECORD: WELL NO. (30)	STATIC LEVEL (31)	DRAW-DOWN (32)	HOURS PUMPED (33)	WATER PUMPED (34)	REMARKS (35)
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31																															
TOT.						MAX.																						TOTAL			
MAX.						MIN.																									
MIN.						TOTAL CHEMICALS USED																									
AVE.						TOTAL CHEMICALS ON HAND																									

Signatures: PREPARED BY | REVIEWED BY

Fold → Fold →

FIGURE 8

Potable Water Supply and Distribution Operating Record

GENERAL INSTRUCTIONS

A. NavDocks Form 2568 "Potable Water Supply and Distribution Operating Record" is designed for use as a management tool for analysis of operating data and evaluation of potable water supply and distribution performance. All Naval Shore activities should prepare and maintain this form. The portions of this form which will be filled in by the operator will depend upon the facilities provided in the system.

B. This record should be supplemented by NavDocks Form 2567 "Potable Water Treatment Plant Operating Record" at those activities where treatment additional to that covered by this form is accomplished.

C. *DISTRIBUTION:* This record should be prepared in duplicate and data recorded daily by the person in charge of the plant. At the end of each month it should be summarized. The original should be retained on file with one carbon copy forwarded to the District Public Works Officer, Attention D-110 not later than the tenth of the following month. Forwarding letter is not required. Activity files should include records of the current and two preceding years.

D. *TESTS:* The kind, number and frequency of analyses and tests should be based on recommendations of the District Public Works Officer. All tests performed should be in accordance with procedures as outlined in NavDocks TP-Pw-12, "Water Supply Systems" as revised and modified by BuDocks Instructions, and as outlined in the current edition of the American Public Health Association Manual "Standard Methods for the Examination of Water and Sewage."

E. The services of the District Public Works Office Special Assistant for Sanitary Engineering (D-110) should be requested in connection with problems concerning the preparation of this record.

SPECIFIC INSTRUCTIONS

Cols.

0 Date. Day of Month.

WATER SUPPLIED

1 Purchased. Enter the quantity of water purchased in 1000 gal. units.

2 Wells. Enter the quantity of water produced by Navy wells in 1000 gallon units.

3 Surface. Enter the quantity of water produced by Navy from surface source in 1000 gallon units.

4 Temperature. Enter temperature of water at or near beginning of distribution in degrees Fahrenheit.

5 pH. Enter pH of water at or near beginning of distribution.

CHLORINE RESIDUAL

6 Chlorine Residual. Enter free available chlorine residual of water at or near beginning of distribution in ppm. If chloramines are used so indicate in Col. 35 "Remarks".

7 Sample Point. Enter station number of building nearest point of sampling.

8 Chlorine Residual. Enter free available chlorine residual of water at sample point in ppm. If chloramines are used, so indicate in Col. 35 "Remarks".

9 Sample Point)
10 Chlorine Residual)
11 Sample Point)
12 Chlorine Residual)
13 Sample Point)
14 Chlorine Residual)
15 Sample Point)

Enter sample point identification and free available chlorine residual as for Columns 7 and 8. If chloramines are used, so indicate in Col. 35.

CHLORINE (Pounds)

16 Chlorine Gas. Enter amount of chlorine gas in pounds used during the 24 hour period.

17 Hypochlorite. Enter the amount of hypochlorite in pounds used during the 24 hour period. (Actual weight of compound.) Indicate compound in Col. 35.

CHEMICAL INHIBITORS (Pounds)

18)
19) Blank columns for use as needed to record amounts in pounds of meta-
20) phosphates, silicates, lime or other chemicals used to inhibit scale
21) or corrosion. Indicate compound in Col. 35.
22)

Cols.

FLUORIDATION

23 Fluoride. Enter the amount of fluoride in pounds used in the 24 hour period. (Actual weight of compound.) Indicate compound in Col. 35.

24 Concentration. Enter the fluoride concentration in ppm in the water after fluoridation.

BACTERIOLOGICAL EXAMINATION - WATER SUPPLIED

25 Agar Count. Enter from DD Form 686 if shown thereon, the Colonies per cc after 24 hours at 37°C on Agar.

26 10 ml/100 ml — Enter from DD Form 686 the number of positive portions over the number of portions of the sample examined. For example, 3 positive 10 ml portions out of 5 - 10 ml portions examined would be entered as 3/5. Indicate size tube used.

BACTERIOLOGICAL EXAMINATION - WATER DISTRIBUTED

27 Agar Count. Enter from DD Form 686 the Colonies per cc after 24 hours at 37°C on Agar.

28 10 ml/) 100 ml) — Same as for Column 26 above.

29 Sample Point. Enter the station number of the building nearest the point of sampling.

WELL PUMPING RECORD

30 Well No. List all the station wells by well number.

31 Static Level. Enter the distance in feet from a fixed datum at the surface to the level to which the water in the well rises when there has been no pumping for 24 hours.

32 Drawdown. Enter the difference in feet between the distance from datum to which water in the well drops during pumping and the static level.

33 Hours Pumped. Enter the total number of hours pumped in the month for each well.

34 Water Pumped. Enter the total quantity of water pumped in the month for each well.

Note: Static Level and Drawdown are usually measured monthly except when conditions are critical during which weekly or even daily measurements may be necessary. For this record, weekly or monthly average for each well are satisfactory.

35 Remarks. Enter in this column unusual operating conditions and/or matters requiring attention, such as:

a. Shutdowns.
b. Equipment out of service.
c. Equipment mal-functioning.
d. Critical items, such as chemicals, laboratory equipment, and reagents in short supply.

POTABLE WATER TREATMENT PLANT OPERATING RECORD

(See Instructions on Reverse Side)

RAYDEX CKS 2567 (4-59)

ACTIVITY | MONTH AND YEAR | SOURCE OF SUPPLY | TYPE OF TREATMENT

DATE (0)	RAW WATER: RAW WATER (1)	TEMPERATURE °F (2)	pH (3)	TURBIDITY (4)	COLOR (5)	CO_2 (6)	ALKALINITY P (7)	ALKALINITY M (8)	HARDNESS (9)	TDS (10)	(11)	(12)	CHLORINE RESIDUAL (13)
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
24													
25													
26													
27													
28													
29													
30													
31													
TOTAL													
MIN.													
MAX.													
AVG.													

DATE (0)	SOFTENING: WATER BY-PASSED (14)	WATER SOFTENED (15)	WASTE SLUDGE (16)	TURBIDITY (INFLUENT) (17)	(18)	FILTRATION: HRS. FILTERS OPERATED (19)	NO. FILTERS BACKWASHED (20)	AVE. LOSS OF HEAD (21)	BACKWASH WATER (22)	(23)	(24)	FILTERED WATER (25)
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
TOTAL												
MIN.												
MAX.												
AVG.												

Fold →

DATE (0)	FINISHED WATER: COLOR (26)	ODOR (27)	TASTE (28)	pH (29)	TURBIDITY (30)	CO_2 (31)	ALKALINITY P (32)	ALKALINITY M (33)	HARDNESS (34)	TDS (35)	TEMPERATURE °F (36)	(37)	(38)	CHLORINATION: CHLORINE RESIDUAL (39)	CHLORINATION: FEEDER SETTING (40)	FLUORIDATION: FLUORIDE CONCENTRATION (41)	FLUORIDATION: FEEDER SETTING (42)
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17																	
18																	
19																	
20																	
21																	
22																	
23																	
24																	
25																	
26																	
27																	
28																	
29																	
30																	
31																	
TOTAL																	
MIN.																	
MAX.																	
AVG.																	

TOTAL CHEMICALS USED

TOTAL CHEMICALS ON HAND

Fold →

DATE (0)	CHEMICALS USED IN POUNDS: ALUM (43)	(44)	PRE-LIME (45)	POST-LIME (46)	(47)	(48)	(49)	(50)	(51)	(52)	(53)	(54)	CHLORINE (55)	FLUORIDE (56)
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
13														
14														
15														
16														
17														
18														
19														
20														
21														
22														
23														
24														
25														
26														
27														
28														
29														
30														
31														
TOTAL														
MIN.														
MAX.														
AVG.														

Fold →

DATE (0)	BACTERIOLOGICAL EXAMINATION: RAW WATER AGAR COUNT (57)	10/100 ml (58)	1 ml (59)	0.1 ml (60)	FINISHED WATER AGAR COUNT (61)	10/100 ml (62)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
TOTAL						
MIN.						
MAX.						
AVG.						

REMARKS (63)

SIGNATURES

PREPARED BY

REVIEWED BY

FIGURE 9

Potable Water Treatment Plant Operating Record

GENERAL INSTRUCTIONS

A. NavDocks Form 2567 "Potable Water Treatment Plant Operating Record" is designed for use as a management tool for analysis of operating data and evaluation of potable water treatment plant performance. A separate form should be prepared for each potable water treatment plant at the activity. The portions of this form which will be filled in by the operator will depend upon the complexity of the treatment process.

B. This record is supplementary to NavDocks Form 2568 "Potable Water Supply and Distribution Operating Record" and should be used only when the treatment is additional to disinfection, fluoridation and/or treatment for scale and corrosion control.

C. *DISTRIBUTION:* This record should be prepared in duplicate and data recorded daily by the person in charge of the plant. At the end of each month it should be summarized. The original should be retained on file with one carbon copy forwarded to the District Public Works Officer, Attention D-110 not later than the tenth of the following month. Forwarding letter is not required. Activity files should include records of the current and two preceding years.

D. *TESTS:* The kind, number and frequency of analyses and tests should be based on recommendations of the District Public Works Officer. All tests performed should be in accordance with procedures as outlined in NavDocks TP-Pw-12, "Water Supply Systems" as revised and modified by BuDocks Instructions, and as outlined in the current edition of the American Public Health Association Manual "Standard Methods for the Examination of Water and Sewage."

E. The services of the District Public Works Office Special Assistant for Sanitary Engineering (D-110) should be requested in connection with problems concerning the preparation of this record.

SPECIFIC INSTRUCTIONS

Cols.

0 Date. Day of Month.

RAW WATER

1 Raw Water. Enter quantity of raw water entering plant daily in 1000 gallon units.

2 Temperature. Enter temperature of raw water at 0800 daily in degrees Fahrenheit.

3 pH. Enter pH of raw water.

4 Turbidity. Enter turbidity of raw water in units.

5 Color. Enter color of raw water in units.

6 CO_2. Enter free CO_2 of raw water in ppm.

7 Alkalinity *P*. Enter phenolphthalein alkalinity of raw water in ppm as $CaCO_3$.

8 Alkalinity *M*. Enter methyl orange alkalinity of raw water in ppm as $CaCO_3$.

9 Hardness. Enter total hardness of raw water in ppm as $CaCO_3$.

10 TDS. Enter total dissolved solids of raw water in ppm.

11)
12) Blank columns for use as needed.

13 Chlorine Residual. Enter free available chlorine residual of raw water in ppm. If chloramines are used indicate in Column 63 "Remarks".

SOFTENING

14 Water By-Passed. Enter amount of water by-passing softening in 1000 gallon units.

15 Water Softened. Enter amount of water softened in 1000 gallon units.

16 Waste Sludge. Enter amount of sludge wasted in 1000 gallon units.

17 Turbidity (Influent). Enter turbidity of water entering softening process in units.

18 Blank column for use as needed.

FILTRATION

19 Hours Filters Operated. Enter the sum of the hours operated by each filter in the 24 hour period.

20 No. Filters Backwashed. Enter the number of filters backwashed in the 24 hour period.

21 Average loss of Head. Enter the average of the loss of head at the time of backwashing of all filters backwashed in the 24 hour period.

22 Backwash Water. Enter the total amount of water used in backwashing filters in the 24 hour period in 1000 gallon units.

23)
24) Blank columns for use as needed.

25 Filtered Water. Enter the amount of water filtered in 1000 gallon units.

FINISHED WATER

26 Color. Enter color of finished water in units.

27 Odor. When the finished water has a definite odor the Plant Operator will indicate this fact by entering the letter "O" for further investigation.

28 Taste. When the finished water has a definite taste the Plant Operator will indicate by entering "SW" sweet, "SE" salty, "SO" sour or "BI" bitter for further investigation.

29 pH. Enter pH of finished water.

30 Turbidity. Enter turbidity of finished water in units.

Cols.

31 CO_2. Enter free CO_2 of finished water in ppm as $CaCO_3$.

32 Alkalinity *P*. Enter phenolphthalein alkalinity of finished water in ppm as $CaCO_3$.

33. Alkalinity *M*. Enter methyl orange alkalinity of finished water in ppm as $CaCO_3$.

34 Hardness. Enter total hardness of finished water in ppm as $CaCO_3$.

35 T.D.S. Enter total dissolved solids of finished water in ppm.

36 Temperature. Enter temperature of finished water in degrees Fahrenheit.

37)
38) Blank columns for use as needed.

39 Chlorine Residual. Enter free available chlorine residual of finished water in ppm. If chloramines are used indicate in Column 63, "Remarks".

40 Chlorine Feeder Setting. Enter feeder dial setting.

41 Fluoride Concentration. Enter average of all daily tests.

42 Fluoride Feeder Setting. Enter feeder dial setting.

CHEMICALS USED (In Pounds)

43 Alum. Enter total quantity used in 24 hour period in pounds.

44 Blank column for use as needed.

45 Pre-Lime. Enter total quantity in pounds used in 24 hour period for coagulation aid or softening.

46 Post-Lime. Enter total quantity in pounds used in 24 hour period for stabilization.

47)
48)
49)
50)
51) Blank columns for use as needed.
52)
53)
54)

55 Chlorine. Enter total quantity in pounds used in 24 hour period for all uses.

56 Fluoride. Enter total quantity in pounds used in 24 hour period.

BACTERIOLOGICAL EXAMINATION OF RAW WATER.

57 Agar Count. Enter from DD Form 686 the colonies per cc after 24 hours at 37°C on Agar.

58 10*ml*/100*ml*. Enter from DD Form 686 the number of positive portions over
59 1*ml*. the number of portions of the sample examined. For example:
60 0.1*ml*. 3 positive 10*ml* portions out of 5-10*ml* portions examined would be entered as 3/5. Enter 1*ml* and 0.1*ml* portions as reported on DD Form 686.

BACTERIOLOGICAL EXAMINATION OF FINISHED WATER

61 Agar Count. Enter from DD Form 686 the colonies per cc after 24 hours at 37°C on Agar.

62 10*ml*/100*ml*. Enter from DD Form 686 the number of positive portions over the number of portions of that concentration examined as in Col. 58 above.

63 Remarks. Enter in this column unusual operating conditions and/or matters requiring attention, such as:

a. Shut downs.
b. Equipment out of service.
c. Equipment mal-functioning.
d. Critical items, such as chemicals, laboratory testing equipment and reagents in short supply.

Section 6. REPORTS AND RECORDS

2.6.1 GENERAL PLANNING GUIDE. The need for a workable record and reports system, as a guide to well-planned operation and maintenance, has been proven. It is not simple. It is, rather, a procedure that requires careful planning, close supervision and persistent effort if maximum benefits are to be gained. All personnel responsible for the operation of a water supply system must have an adequate knowledge of the system and all its parts. They must know the location, purpose, capacity, operation, maintenance and current inspection status of all water sources, pumps, motors, engines, indicating devices, controls, valves, elevated tanks, ground storage, distribution layout, treatment facilities, fire hydrants and connections. They must know what to expect in the way of fire-flow demands in various areas, and how to meet those demands. They should know why the failure of any part of a system or its equipment affects other parts of the system. The required reports and records provide the basis for such knowledge of the system. In addition to reports and records as a basis of such knowledge, operating personnel must also be familiar with manufacturer's catalogs, brochures and instruction manuals for all installed equipment (see par. 2.6.2.7), and they must also be familiar with all local command directives (see par. 2.6.2.8).

2.6.2 BASIC RECORDS. The following records are required for efficient operations.

2.6.2.1 General Water Utility Map. The general water utility map is a diagram of the entire water supply system. It can be prepared by tracing the outlines and essential information from an installation map. The scale normally used is 1 inch equals 400 feet; for small installations, the scale may be 1 inch equals 300 or 200 feet.

2.6.2.1.1 Content. The map includes the following data.

(1) Street names.

(2) Number or names of major industrial buildings and piers.

(3) Sizes of mains.

(4) Fire hydrants.

(5) Valves.

(6) Sectional plat limit lines.

(7) Orientation arrow.

(8) Scale.

(9) Date last corrected.

2.6.2.1.2 Preparation. Mains are drawn in different types of lines and line widths to indicate relative sizes and to make relative carrying capacity readily discernible. The map should clearly indicate areas that are adequately piped; areas which do not have the proper size mains; and, areas where improvements are needed, e.g., short extensions to eliminate dead ends. Detailed street, road and building lines are not included on the map; however, where such lines will help identify locations, they may be drawn in lightly (see fig. 7).

2.6.2.2 Detailed Utility Map. A detailed utility map is a consolidated map of all utilities systems on the installation. Because it clearly indicates the relative locations of all systems, it helps maintenance personnel to avoid damaging one underground system when working on another. The best scale for the map is 1 inch equals 50 feet, but the scale of 1 inch equals 100 feet may be used. At a congested intersection, inserts of a larger scale may be needed to show all data clearly.

2.6.2.2.1 Content. The following information on the water supply system is needed to make the map complete.

(1) Plat designation or number.

(2) Adjacent plat numbers.

(3) Street names.

(4) Mains and main sizes.

(5) Materials of mains.

(6) Year each main was installed.

(7) Valves and valve numbers.

(8) Fire hydrants and fire hydrant numbers.

(9) Building numbers.

(10) Measurements to service lines.

(11) Distance from main to curb-cock.

(12) Date last corrected.

(13) Orientation arrow.

(14) Scale.

2.6.2.2.2 Preparation. Because of the large scale, these maps are usually drawn in several sections. However, the map for a small system can sometimes be drawn on one sheet and can also serve as a general water utility map. If the installation utilities systems are too complex to permit a clear consolidated drawing, an overlay map may be prepared for each utility, using a general installation map as a base. Relative locations of all systems can then be determined by placing one overlay directly over another.

2.6.2.3 Gate-Valve/Hydrant Record. Detailed information about each valve in the system should be kept on file so that the valves may be found and operated quickly at any time. An ozalid master is to be prepared for each valve and hydrant. Enough copies of each should be made to provide a full set of gate-valve/hydrant records for all distribution system personnel.

2.6.2.4 Hydrant Record. Manufacturer's data for each type of hydrant should be obtained, and filed referenced by hydrant number. The information should be maintained as for gate-valve records, with data on hose and steamer connections.

2.6.2.5 Pumping Station Diagram. A schematic diagram for each pumping station should be provided showing all major piping and control valves in bold lines, as well as indications of source of supply, direction of flow and point of discharge of piping, and the purpose and identifying number of each valve. Mount the diagram on the pumping station wall for guidance of operators and, in emergencies, of personnel not familiar with the layout.

2.6.2.6 Structural Plans and Well Records. Copies of structural plans of treatment plants, pumping stations, reservoirs, wells, elevated tanks and meter and valve vaults should be kept available for immediate use.

2.6.2.7 Equipment Records. Manufacturer's catalogs, operating instructions, parts lists, maintenance books and brochures on all installed equipment must be complete and readily available. Copies of record and as-built drawings should be kept at the treatment plant.

2.6.2.8 Local Command Directives. All local command operation and maintenance directives, such as directions for flushing of catchment areas, should be kept on file and made readily available to all authorized personnel. Water supply system personnel must be familiar with all of these command directives and adhere to their instructions in operations and maintenance.

2.6.3 OPERATING RECORDS. Records should be kept to assist in judging operational details and to show performance of the units in fulfilling the requirements for which the plant was designed.

(1) Daily operating records should list routine laboratory tests and flow variations, the quantity of pumped sludge, temperature, rainfall and other valuable data in connection with design. Records should be kept of expenditures for power, chemicals, replacements and labor.

(2) Operating records must be kept to facilitate the evaluation of the effectiveness of the treatment process. Improvements in equipment and the use of new chemicals can only prove increased operational efficiency if records are kept.

(3) Operating records should list routine laboratory tests, amount of chemicals and the like, as outlined in the operating reports (see Figures 8 and 9).

2.6.3.1 Potable Water Supply and Distribution Operating Record. This form is designed for use as a management tool for analysis of operating data and evaluation of potable water supply and distribution performance. Complete instructions on the method of daily entries on this form are found on its reverse side.

2.6.3.2 Potable Water Treatment Plant Operating Record. This form is designed for use as a management tool for the analysis of operating data and the evaluation of potable water treatment plant performance. A separate form should be prepared for each potable water treatment plant ~~at~~ the activity. The sections of the form which will be filled out by the operator will depend upon the complexity of the treatment process. Complete instructions on the method of daily entries on this form are found on its reverse side.

2.6.3.3 Physical and Chemical Analysis of Water. This form (Figure 10) is used for the annual analysis of potable water. It may also be used ~~for~~ specially requested analyses which may be required at any time.

2.6.3.4 Bacteriological Examination of Water. This form (fig. 11) is used for sanitary engineering laboratory reports of the examination of water samples to determine the bacteriological safety of the water supply system. Information on this form is transferred to the Potable Water Treatment Plant Operating Record (see fig. 9) and/or the Potable Water Supply and Distribution Operating Record (see fig. 8).

2.6.3.5 Other Records and Reports. In addition to the forms shown here, the efficient and economical operation of a water supply system requires that additional reports be made by higher echelons to command, to FEO's and to the Bureau of Yards and Docks. The operator may be ordered to assist in gathering data for such reports, if necessary. The quantity of reports should insure that sufficient information on which to base decisions is available for command and higher echelons without unnecessary and time-consuming paper work. The requirements for reports and records are determined by command, on the recommendation of the Utilities Division. Since these additional records and reports will vary from activity to activity according to particular needs, they are not described here. Local conditions will determine the forms and records that should be maintained.

PHYSICAL AND CHEMICAL ANALYSIS OF WATER

SAMPLE NO.

FROM: *(Station or unit)* | DATE

TO: *(Name and location of laboratory)*

SAMPLE FROM *(Location of sampling point)*

COLLECTED BY	DATE	HOUR	SOURCE *(Designate ground, surface, raw, treated)*

REASON FOR EXAMINATION	EXAMINATION REQUESTED BY

NOTE: All results reported in parts per million unless otherwise noted except for pH, temperature, and specific conductance. One liter of potable water is assumed to weigh one kilogram.

I. FIELD ANALYSIS

1. pH	TEMPERATURE	
	°F	°C

ITEM	PPM
2. CARBON DIOXIDE (CO_2)	
3. DISSOLVED OXYGEN (O_2)	
4. HYDROGEN SULFIDE (H_2S)	
5. CHLORINE DEMAND (Cl_2)	

FIELD ANALYSIS BY

DATE OF ANALYSIS

II. SPECIAL LABORATORY ANALYSES

Check (X) individual items to be included in the Special Analyses. Request determination only of those substances suspected of being present in significant amounts.

(X)	ITEM	PPM
	1. As	
	2. Se	
	3. Pb	
	4. B	
	5. Cu	
	6. Zn	
	7. Cr *(Hexavalent)*	
	8. PO	
	9. Cd	
	10. CN	
	11. Phenolic Compounds *(PPB)*	
	12. Others *(Specify)*	
	13.	
	14.	
	15.	
	16.	

III. ROUTINE LABORATORY ANALYSIS

(CHECK ONE)

	REQUESTED		NOT REQUESTED

1. COLOR	
2. TURBIDITY	
3. ALKALINITY ($CaCO_3$)	
P	MO
4. TOTAL HARDNESS ($CaCO_3$)	
5. NON-CARBONATE HARDNESS ($CaCO_3$) *(By Computation)*	
6. CARBONATE HARDNESS ($CaCO_3$) *(By Computation)*	
7. TOTAL DISSOLVED SOLIDS	
8. SPECIFIC CONDUCTANCE *(Micromhos)*	

ITEM	PPM
9. CALCIUM (Ca)	
10. MAGNESIUM (Mg)	
11. SODIUM (Na) AND POTASSIUM (K)	
12. HYDROXIDE (OH)*	
13. BICARBONATE (HCO_3)*	
14. CARBONATE (CO_3)*	
15. SULFATE (SO_4)	
16. CHLORIDE (Cl)	
17. NITRATE (NO_3)	
18. IRON (Fe) TOTAL	
19. MAGANESE (Mn)	
20. SILICA (SiO_2)	
21. FLUORIDE (F)	

*State whether determined or computed from P and MO alkalinity.

REMARKS *(Such as unusual appearance, taste, odor, etc.)*

LABORATORY ANALYSIS BY | DATE OF ANALYSIS

DD FORM 1 APR 53 710 REPLACES WD AGO FORM 8-125, 1 APR 45, WHICH MAY BE USED

GPO 83-56027

FIGURE 10

Physical and Chemical Analysis of Water

BACTERIOLOGICAL EXAMINATION OF WATER

RETURN COMPLETED REPORT TO	SAMPLE NUMBER
	COLLECTED BY

COLLECTION POINT

DATE AND TIME OF COLLECTION	DATE AND TIME OF EXAMINATION

CHLORINE RESIDUAL AT COLLECTION ⇩	FREE AVAILABLE *(mg/l)*	pH
	TOTAL AVAILABLE *(mg/l)*	

DIRECT MEMBRANE FILTER PROCEDURE
(Report results of verified test in 'Remarks')

VOLUME FILTERED *(ml)*	
COLIFORM PER FILTER	
COLIFORM COLONIES PER 100 *ml*	

PORTION	LACTOSE BROTH GAS FORMATION		BGB	EMB	LACTOSE BROTH GAS FORMATION		GRAM STAIN
	24 HRS	48 HRS			24 HRS	48 HRS	
10 ml							
10 ml							
10 ml							
10 ml							
10 ml							
ml							
ml							
ml							
ml							

MPN COLIFORM PER 100 ml

REMARKS

SIGNATURE OF LABORATORY OFFICER

LABORATORY

All procedures will be in accordance with the latest edition of 'Standard Methods for the Examination of Water, Sewage and Industrial Wastes' (American Public Health Association Inc.).

DD FORM 1 JUN 60 686 G-54992

FIGURE 11

Bacteriological Examination of Water

Section 7. SAFETY

2.7.1 IMPORTANCE. Efficient operation of any water supply system depends largely on safety in terms of both personnel and equipment. Accident prevention requires constant care and thorough training of all personnel. Personnel must be alert in recognizing hazards and must cooperate with the activity safety officer in the establishment and institution of a safety program. Detailed operating precautions and safety procedures are presented in Chapter 5. The procedures and cautions contained in the United States Navy Safety Precautions, OPNAV 34P1 (Reference 6), also apply and must be observed. Breaches of prescribed safety standards may be a matter for appropriate disciplinary action.

CHAPTER 3. OPERATION

Section 1. SOURCES

3.1.1 BASIC SOURCE OF WATER. Water is continuously circulating through the hydrologic cycle of precipitation as rain, snow, runoff, infiltration, storage, evaporation from lakes and oceans, and reprecipitation. The source of water supply is merely the point in the natural cycle where water is temporarily removed for use, and eventually returned to nature. Figure 12 illustrates this hydrologic cycle.

3.1.1.1 Types of Sources. Both surface and ground water sources are commonly used for water supply. The reasons for choosing one over the other are many and include such factors as the quantity available, the dependability of the supply, and the costs of construction, treatment and distribution.

3.1.1.2 Water Collectors. In addition to natural sources, such paved areas as the landing strips and aprons of naval air fields are used to collect water for storage where water is scarce. Vast areas of sea water, with bays and marshes of brackish water, provide a plentiful supply ready for conversion to potable water. However, saline water is the least desirable source because of the high cost of removing the salt.

3.1.2 GROUND WATER SUPPLY. Generally, ground water supplies are used by smaller in-

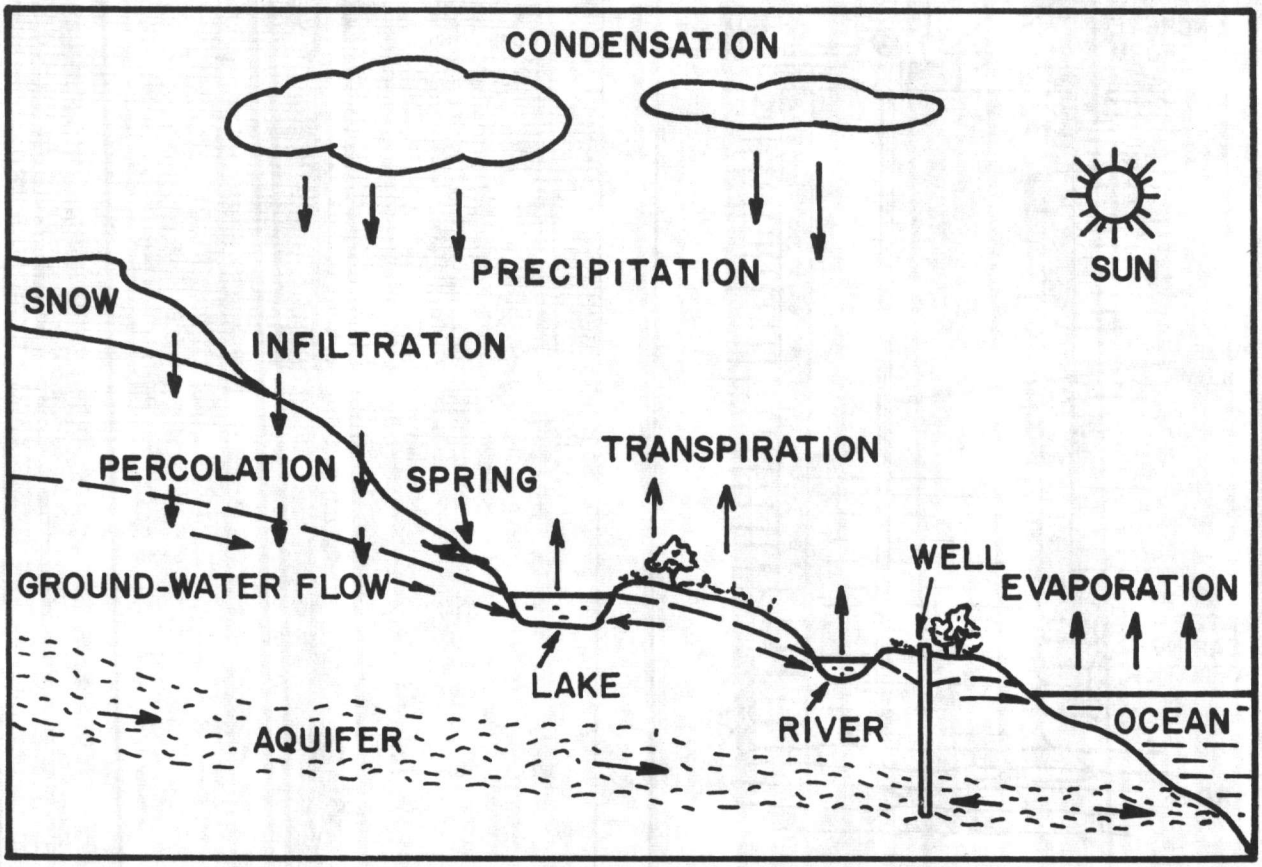


FIGURE 12

The Hydrologic Cycle

stallations because of the limited quantity that can be obtained from an aquifer (an aquifer is an underground formation which yields a usable amount of water to wells or springs). One possible objection to an underground supply is that the water may be excessively "hard." This condition may occur because of the percolation of the water through mineral deposits from which hardness-causing constituents are leached or extracted. On the other hand, an underground supply generally has the advantage of requiring less treatment because of the natural removal of impurities as the water passes through various underground soil formations. However, these conditions are general; some mineral deposits do not contribute to hardness, and some underground formations may not be of the type that effectively remove objectionable material.

3.1.2.1 Wells. Although there is no exact dividing line between the two, wells less than about 100 feet in depth usually are classified as shallow wells, and those more than 100 feet as deep wells.

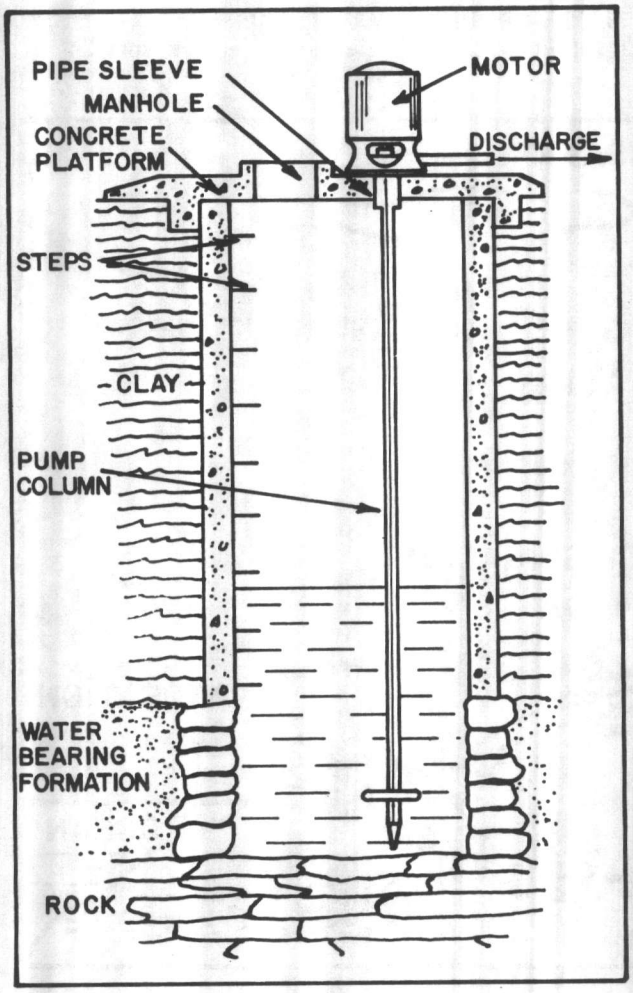


FIGURE 13

Large Dug Well

3.1.2.1.1 Shallow wells. These wells may be one of two types,—dug or driven.

(1) Dug Wells. This type of well consists of vertical holes, usually 4 to 6 feet in diameter, excavated through top soil until the water-bearing stratum is encountered (see fig. 13). Such wells may be lined with concrete, brick, rough stone or vitrified tile.

(2) Driven Wells. This type of well may be used where ground water is within about 25 feet or less of the ground surface, and where there are no boulders or intervening rock formations. These wells are easily constructed and can be protected against superficial pollution (see fig. 14). Like dug wells, they are more subject to

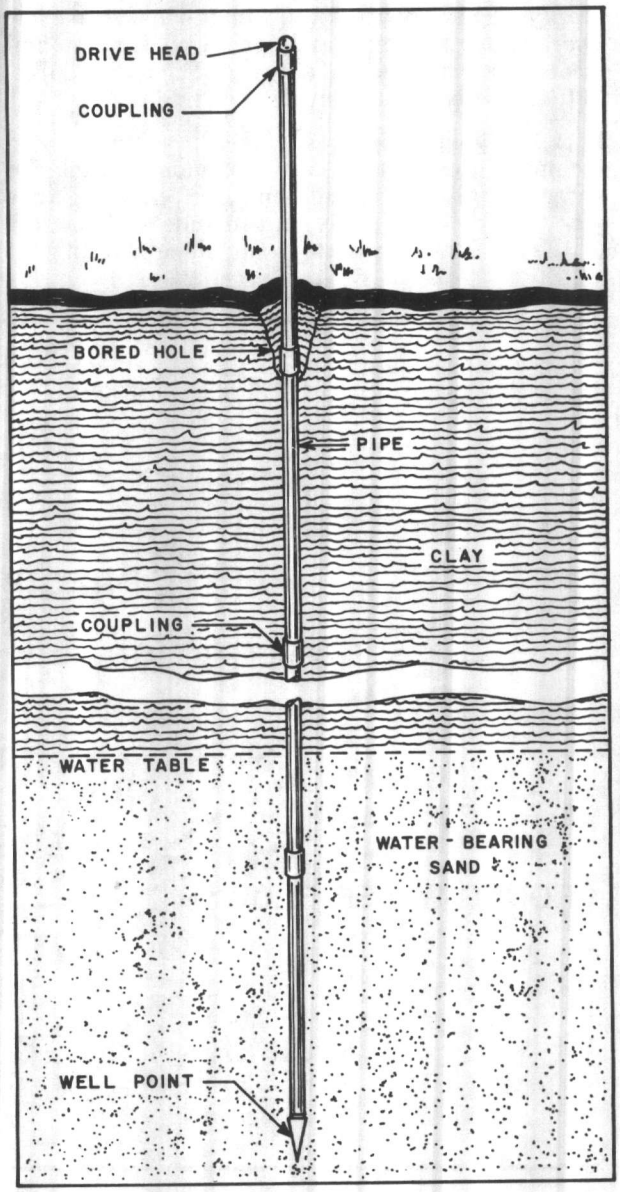


FIGURE 14

Driven Well

underground pollution than deep wells which penetrate impervious material. The simplest type of driven well consists of a perforated brass strainer, cone-shaped at one end, attached to the bottom of an iron pipe. The iron pipe is used to drive the strainer through the upper soil layers and into the water-bearing material.

3.1.2.1.2 Deep wells. When it is necessary to go deeper to reach ground water or to avoid pollution, wells must be drilled to deeper water-bearing strata or rock crevices. (See fig. 15 for the construction of a deep well.)

(1) Drilled Wells. This type of well is utilized under the following circumstances. Ordinarily, drilled wells are 6 to 12 inches in diameter, although in some instances they may be larger. Properly sealed, metal casings can provide effective protection against the entrance of surface water and polluted ground water. If the water bearing material is sand and gravel, a strainer of the proper dimensions is usually attached to the bottom of the casing.

(2) Gravel-Wall Wells. This type of well is often used when the sand in the water-bearing stratum is so fine that it prevents enough water from entering the well casing. Such a well is similar to a standard deep well, except that for several inches around the well screen, the sand is removed and replaced with gravel (see fig. 16). This type of construction increases the area of contact with the water-bearing stratum; therefore, the resistance to the flow of water into the well area is decreased, and in this way the capacity is increased. The gravel outside the screen also helps to prevent sand from being drawn into the well during periods of high pumpage. Screened and gravel-wall wells require special maintenance attention. Well maintenance is covered in Chapter 4.

3.1.2.2 Springs. Springs occur where a water-bearing stratum reaches the surface of the ground, or where ground water is forced through fissures in rock "outcrop" at the surface.

(1) The first type of spring is usually of local origin and care must be exercised in the elimination of nearby sources of pollution. Locating the origin of the rock spring requires detailed knowledge of the geological formations in the area. Although the elimination of nearby sources of pollution may be less important for the rock spring, it should be remembered that polluting material may pass through the fissured rock for great distances without any improvement in the quality of water.

(2) Many methods have been developed for the collection of spring water. In general, the source should be protected by concrete or another impervious type of permanent structure that will exclude all water, except that issuing from the spring formation. If the water does not emerge from the ground at a well defined point, it may be collected and carried to a collecting well or basin by means of tile lines with open joints. These lines are laid in ditches at right angles to the established direction of underground flow. The tile should be surrounded with crushed stone or gravel and the ditch filled with clay to keep out any surface drainage. (See fig. 3 for a properly constructed spring.)

(3) Regardless of the type of construction, all springs must be covered. The surplus water should be piped from the structure so that surface water cannot enter the spring during periods of flood. It is not necessary to ventilate spring structures; therefore, all openings should be avoided, except an inspection manhole fitted with a tight, locked cover.

3.1.2.3 Infiltration Galleries. An infiltration gallery is an open trench or tunnel cut into an aquifer to intercept ground water. It is similar in principle to a well, except that it is horizontal. The lining of the gallery provides the required structural strength without preventing the free flow of water into the gallery through crevices or openings in the lining. Water is taken from the gallery in the same manner as from shallow wells. According to sound design principles, galleries are generally located to take advantage of heavy flows of ground water in underground streams (see fig. 17).

3.1.2.4 Ranney Wells. This type of well (see fig. 18) is constructed by sinking a reinforced concrete caisson to the aquifer level and running horizontal screened lateral pipes from the side of the caisson into the surrounding water-bearing deposits. The pipes collect the water which is then emptied into the caisson. The caisson thus serves as a clear well from which water can be pumped. Installed alongside a river with the laterals extending below the river bed, the Ranney well allows collection of a naturally filtered water from the river.

3.1.2.5 Maui Wells. A Maui well is a particular type of infiltration gallery peculiar to such volcanic islands, as Oahu, Hawaii, where such wells supply water for the city of Honolulu and for the naval base at Pearl Harbor. These islands consist almost entirely of permeable volcanic rock. This permeable rock below sea level is saturated with sea water. However, infiltrating rain water passes down through the pervious rock until it rests on top of the salt water. Fresh water is lighter than salt water, and spreads on top of the latter as a "lens." When an almost unbroken coral reef surrounds the island as at Oahu, Hawaii, large quantities of fresh water may accumulate in the lens. The Maui well (see fig. 19) permits the fresh water to be skimmed off without contamination from the sea water beneath it. The installation usually consists of a 30-degree inclined shaft of the desired length, a pump room and sump at the bottom of this inclined shaft, and a further horizontal shaft

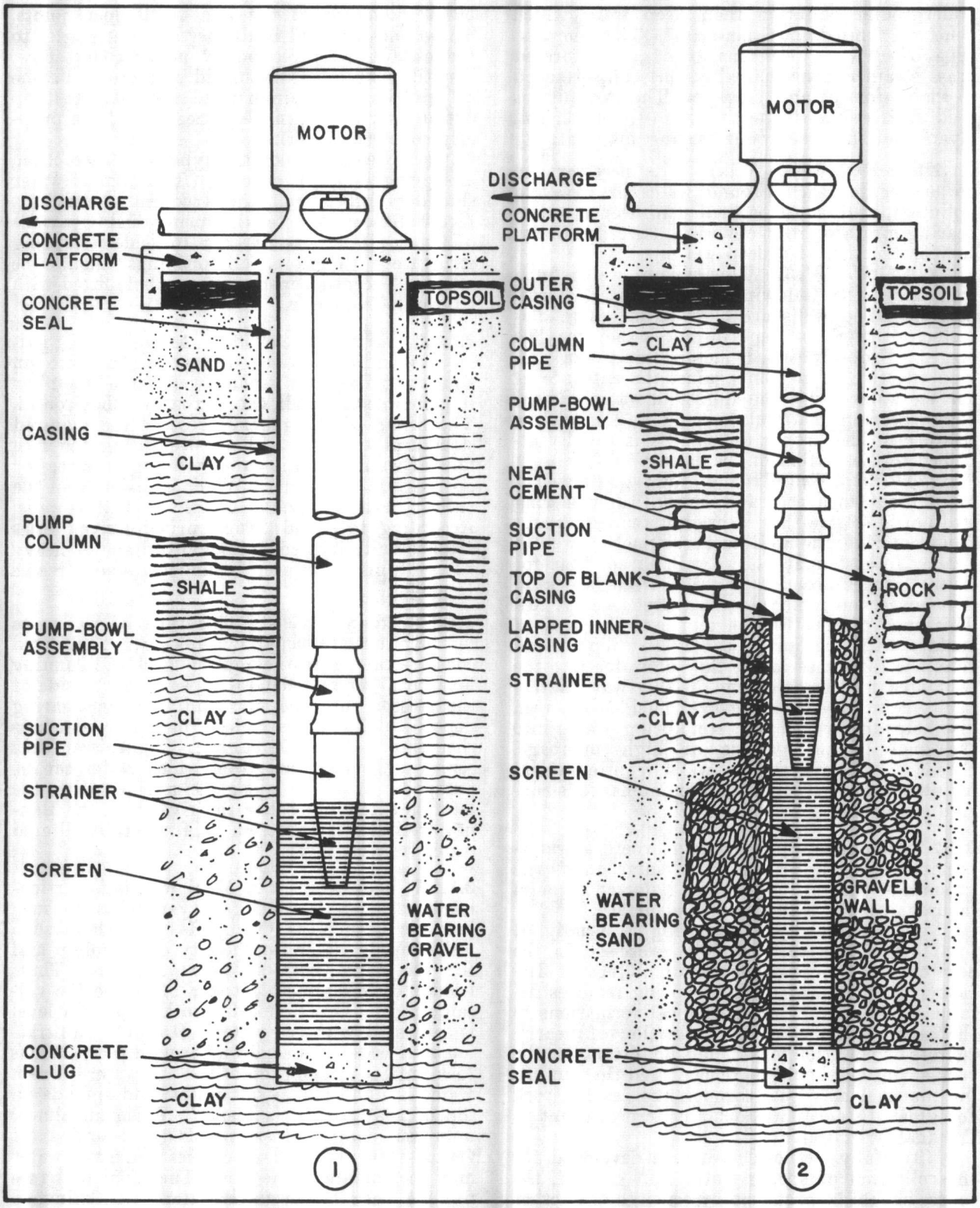


FIGURE 15

Deep Well

(1) Straight Drilled Well

(2) Underreamed Gravel-Packed Well

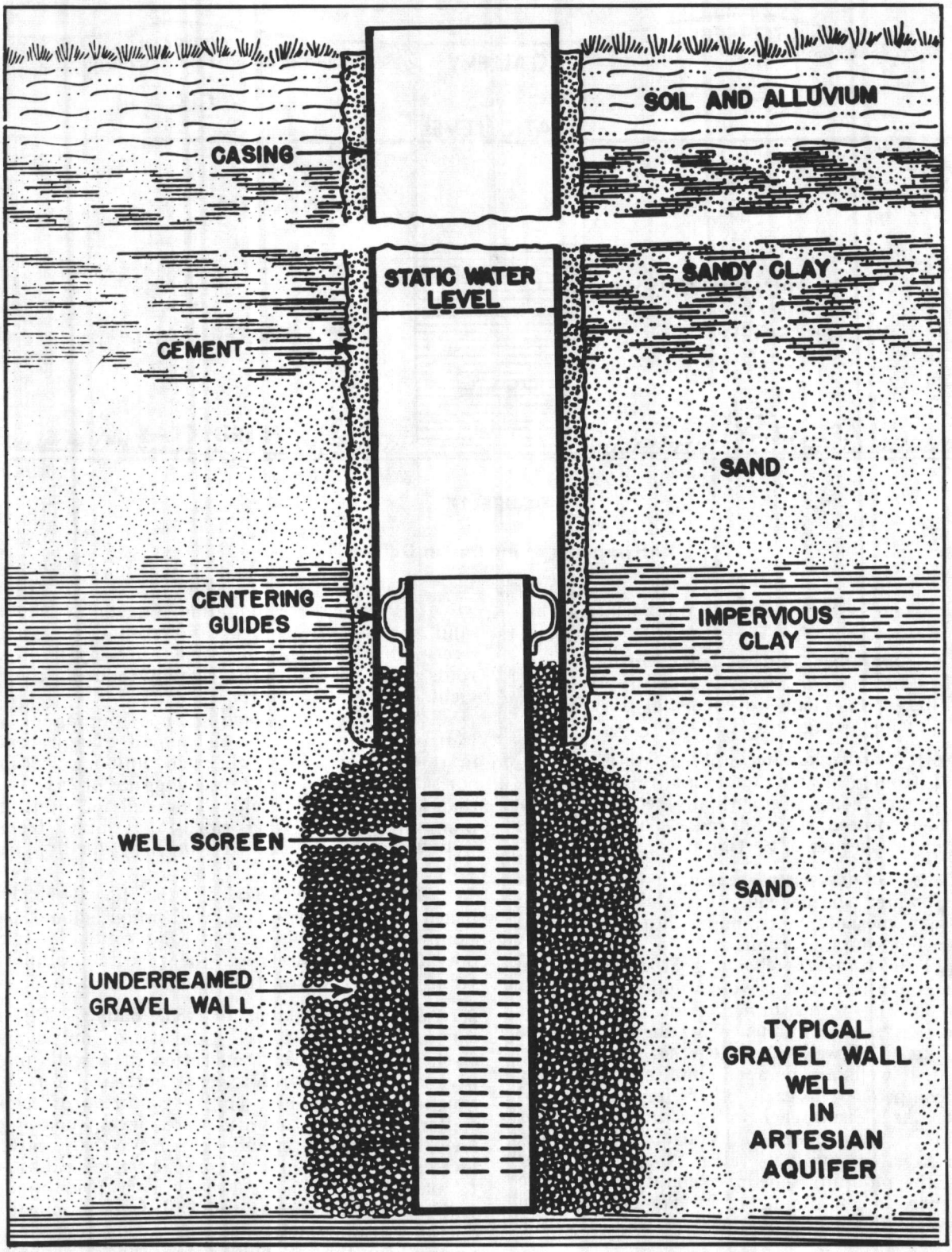


FIGURE 16

Gravel-Wall Well

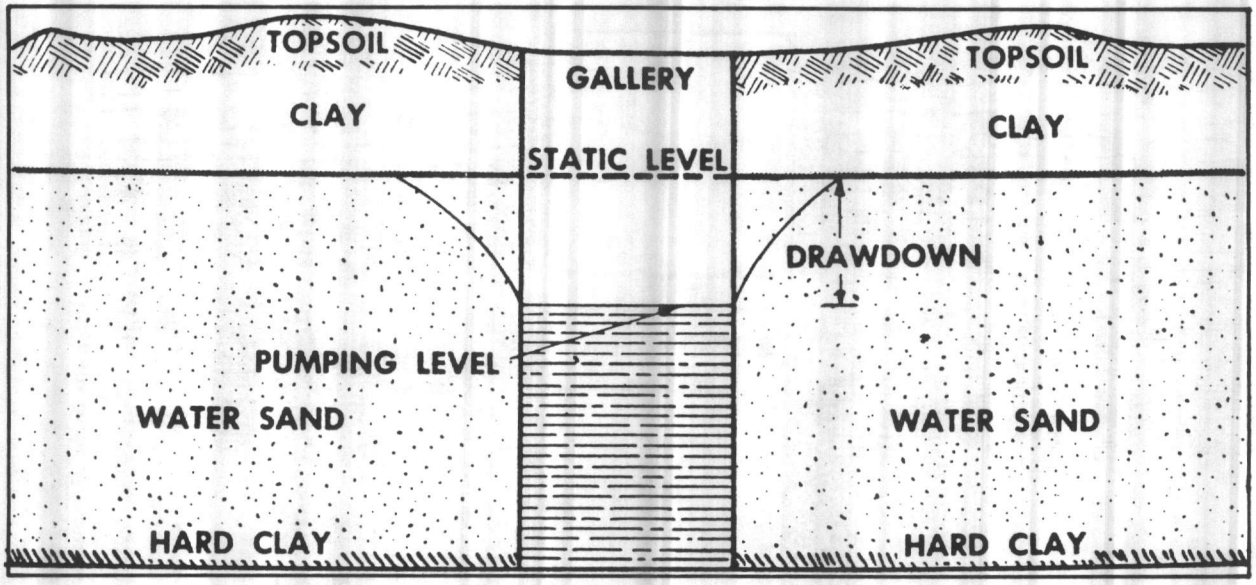


FIGURE 17

Hydraulics of Infiltration Gallery

which extends out into the volcanic rock to gather fresh water.

3.1.2.6 Operating Guides. Inland ground water supplies and coastal ground water supplies present different operating problems, as discussed in the following paragraphs.

3.1.2.6.1 Purchased water. When water is purchased from a nearby municipality, the operator's primary concern is with any necessary water treatment procedures required. This subject is covered in Chapter 3, Section 2.

3.1.2.6.2 Ground water—general. Operating a ground-water source consists mainly of taking necessary measurements, maintaining yield and preventing contamination.

(1) Balancing the Pumping Schedule. When water is pumped from a well, a depression is produced in the water table. This depression is called the "zone of influence" of the well. Zones of influence of wells close together may overlap so that, if wells are pumped simultaneously, they will compete with each other for the ground water. As a result, each well produces less water than if it were operated by itself. Therefore, when a water supply is taken from a group of wells, the pumping schedule should be set up so that there is a minimum of interference between zones of influence of neighboring wells (see fig. 20).

(2) Well Operation Wells should be pumped carefully and within specified pumping rates. Furthermore, wells in a well field should be operated in rotation to equalize wear on pumping equipment.

(a) Excessive pumping rates may cause sand and silt to pack in and around the well screen, thus clogging the screen, or may fill the voids in gravel-wall wells, thereby reducing their yield.

(b) Frequent starting and stopping of a well pump causes a certain amount of agitation in the aquifer around the well, and may wash out sand or gravel and cause clogging or cave-ins that will reduce the yield. The need for altering pump operation methods can be determined from well performance records and the quality of water produced.

(3) Well Water Samples. At intervals established by local command, well water should be examined for turbidity and sand content. The operator should draw off the required samples from special cocks installed in each well line.

3.1.2.6.3 Determination of well output. Since the maintenance of well capacity or output is essential to the proper operation of a well supply, it follows, therefore, that current information must be available on the condition of each well with respect to static water level, pumping level, drawdown, specific capacity, safe water level and safe yield. A comparison of this information with that collected at a prior time will tell whether or not the well is continuing to operate satisfactorily. The operation procedure presented in the following paragraphs is common to various types of wells.

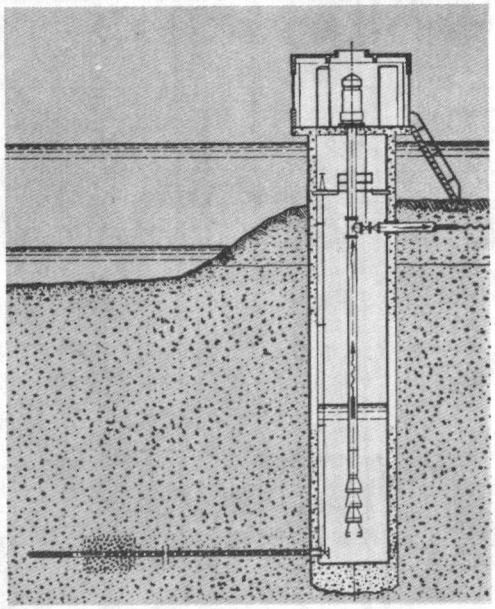
3.1.2.6.4 Determination of water levels and specific capacity. Usually a well contains an air pipeline placed in it at the time of pump installation,

Development of the Collector

YEARS AGO some alluvial aquifers were developed by infiltration galleries, constructed by digging long trenches of limited depth parallel to a river, then placing and covering perforated pipe. However, as the quantities of water required became greater and labor costs increased, the old-fashioned infiltration galleries became economically impractical.

In the early 1930's Leo Ranney, of Northwestern University, conceived a method of developing pure water from shallow alluvial deposits, utilizing the old gallery principle, but eliminating the construction difficulties encountered under the old method, and in addition providing better development of the aquifer.

The Ranney Method consists of sinking a reinforced concrete caisson from the bottom of which screens (sometimes called laterals) are projected horizontally like the spokes of a wheel (*fig. below*); as much as 3000 lineal feet from a single unit is practicable. The caisson is used as a clear well from which the water can be pumped. This complete unit is patented and is known as the "Ranney-Collector."



Ranney–Collector showing superstructure, caisson and laterals.

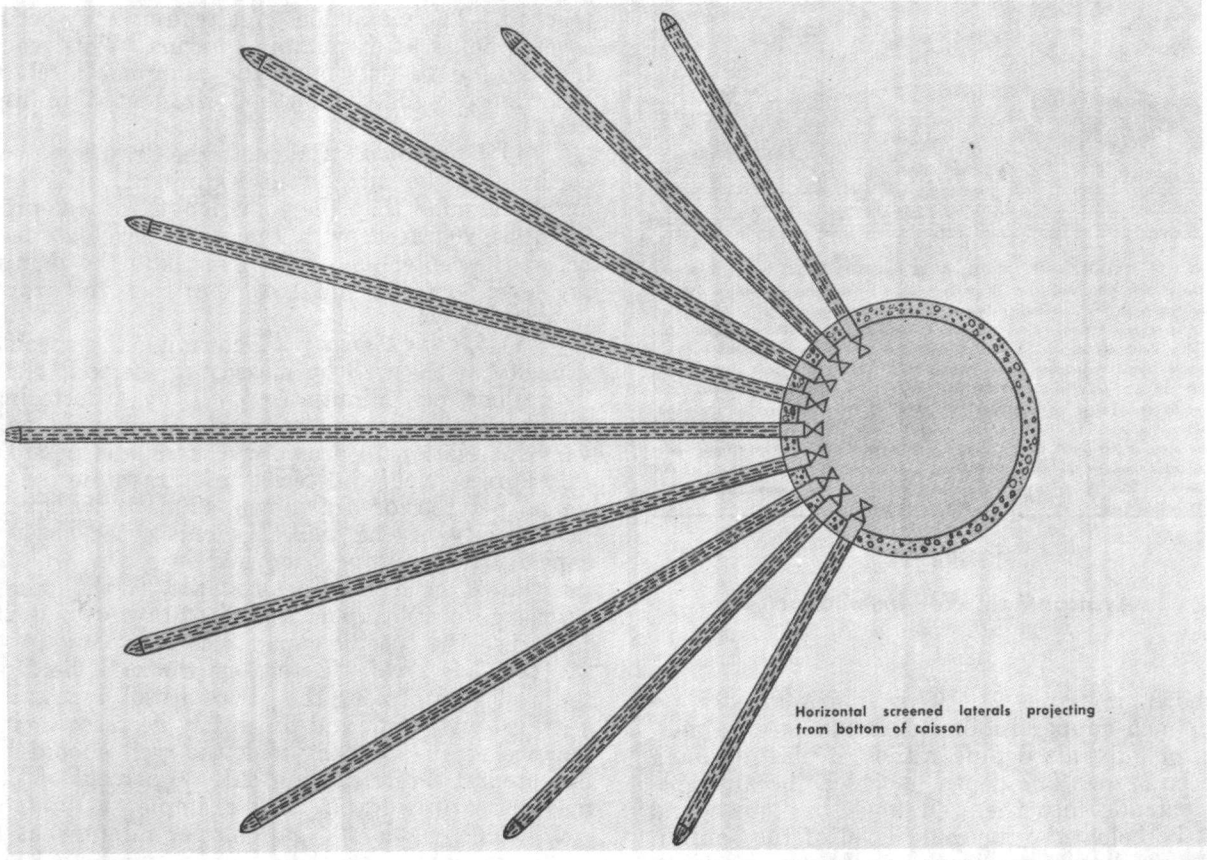
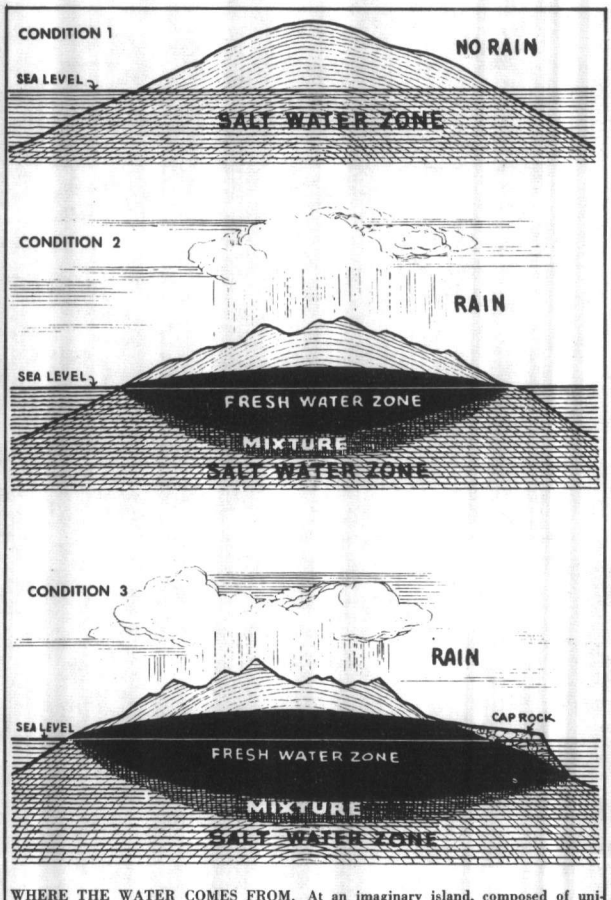


FIGURE 18

Ranney Collector Showing Superstructure, Caisson and Laterals



WHERE THE WATER COMES FROM. At an imaginary island, composed of uniformly permeable rock, and where it never rains, sea water would infiltrate and fill all open spaces in the lava rock below sea level, as in Condition 1. On the other hand, if considerable rain fell on the island regularly, part of the rain would infiltrate downward and displace part of the salt water so that a lens-shaped body of fresh water would accumulate as in Condition 2. The lighter fresh water would "float" on the salt water, and, since sea water is 1/40th heavier than fresh water, the depth of the lens below sea level would be about 40 times the height of the water table above sea level. In the Honolulu region there is a caprock of comparatively impermeable material which blocks seaward movement of water from the fresh water lens and thus thickens the edge of the lens as in Condition 3. This raising of the water level explains the artesian pressure in Honolulu and the many artesian wells of the Honolulu area.

FIGURE 19

Typical Maui Well Installation

as shown in figure 21. This line is usually ⅛- or ¼-inch copper tubing, or brass, steel, aluminum, or galvanized pipe, although plastic tubing may be used. The depth to which the air pipeline extends into the well must be known and must be below the pumping level of the aquifer. If no air line exists in the well, one should be installed. All seams or joints must be airtight. An air pump (bicycle pump) is connected to the upper end of the pipe and a pressure gage connected to the line in order to read the air pressure.

(1) Effect of Air. When air is forced into the line, water is expelled and the pressure in the line (gage reading) increases to a maximum until all the water is expelled. The gage reading (pressure) at this time becomes constant and is equivalent to the pressure necessary to support a column of water equal to that forced from the air line; that is, it is the same as the length of the submerged air pipeline. This pressure in feet, when deducted from the total length of air pipeline, is equivalent to the distance from the water level in the well to the center of the gage on the air pipeline (see fig. 21). If the gage reads in pounds per square inch, multiply the reading by 2.31 to obtain the equivalent feet of water. The use of a gage reading avoids the need for conversion.

(2) Static Level. Determine the gage reading after pumping has been discontinued for a period of four to eight hours. Calculate the static water level as described in Figure 21.

(3) Pumping Level. Start the well pump and note the air gage reading when it reaches a maximum.

NOTE: Additional air will have to be added from time to time until the maximum reading is reached. The maximum gage reading may occur several hours after pumping begins. This reading is used to determine the pumping level in accordance with the method illustrated in figure 21.

(4) Drawdown. Calculate the drawdown according to the method in Figure 21. For example, assume that the total length of air pipe is to be 200 feet, with the static level 25 feet below the centerline of the gage, and the pumping level 50 feet below the gage; then the drawdown is 25 feet.

(5) Specific Capacity. Determine the specific capacity of the well by measuring the well yield in gallons per minute (g.p.m.) by a metering device on the pump discharge. Well yield will vary in relation to drawdown, and it is possible to express yield in terms of drawdown, i.e., g.p.m. per foot of drawdown. This is the specific capacity of the well. Calculate the specific capacity by dividing the yield in g.p.m. by the drawdown in feet. For example, if the pump discharge is 250 g.p.m. and the drawdown is 25 feet, then the specific capacity is 10 g.p.m.

(6) Safe Yield. Determine the safe yield of the well. To prolong the life of a well, especially a gravel-wall well, and to greatly decrease maintenance at the proper yield, the well should be operated at a rate causing only 50 percent of the maximum drawdown. For example, a 125-foot well which yields 400 gallons per minute has a static water level of 25 feet and a pumping level of 75 feet, or a 50-foot drawdown. Satisfactory pumping level is 50 feet, or 50 percent of the maximum drawdown. Therefore, the safe well capacity is established and maintained for that condition regardless of the yield. As described, the safe pumping yield is the withdrawal rate which will not cause a lowering of the water table, and should cause no more than 50 percent

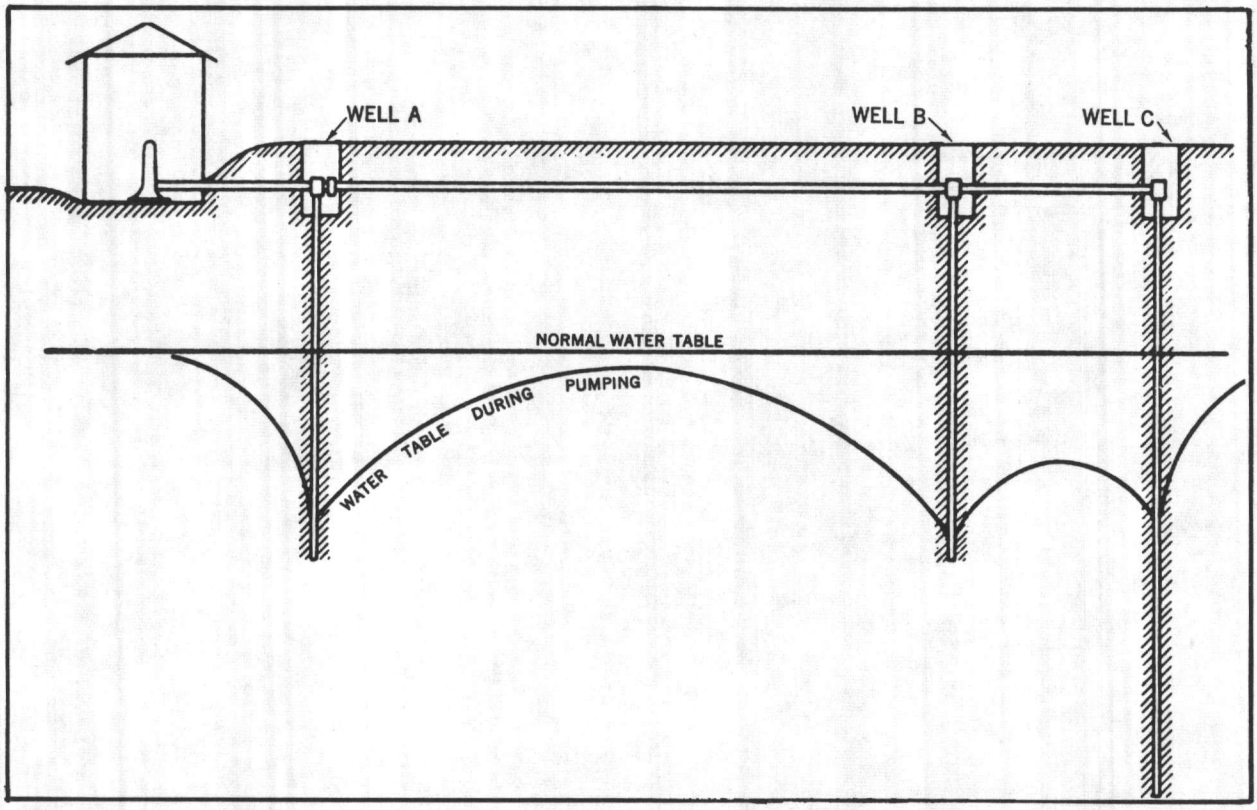


FIGURE 20

Zone of Influence of Well Pumping on Water Table

of maximum drawdown. This operation is especially applicable in gravel-packed wells (see fig. 16).

3.1.2.6.5 Periodic tests and records. Daily tests may be required in some instances, but day-to-day variations may not be significant. The number of wells may dictate the frequency of testing, but if possible each well should be tested at least twice a month. The data obtained is recorded on forms prepared for that purpose. By comparing the data from the previous test with the current test, or by plotting the data, it is possible to anticipate difficulties and to provide the proper maintenance. The recorded data may be interpreted to indicate one of the following conditions.

(1) Static Level Check. The operator should check the static level, drawdown and operation of each well, and record data in columns 30 through 34 of the Potable Water Supply and Distribution Operating Record (fig. 8), at the frequency required, to ensure that the well is not being overpumped.

(2) Water Table Lowering. Falling static level indicates a lowering of the water table. It is usually associated with a decrease in specific capacity and with a decrease in safe yield.

(3) Causes and Effects. The following interpretations may be placed on the observations of well behavior.

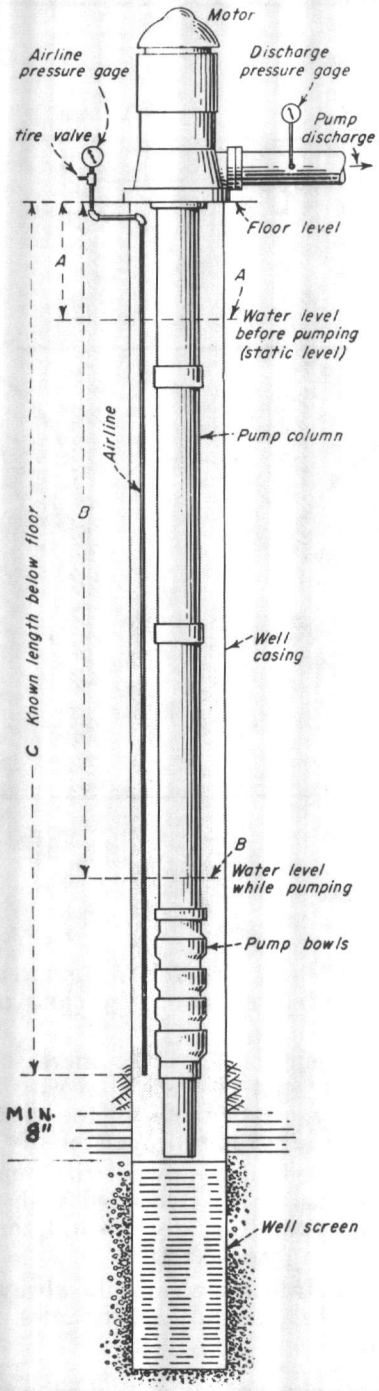
(a) A lower pumping level or increased drawdown may or may not be associated with a lower specific capacity, particularly if the yield in gallons per minute decreases proportionally.

(b) An increased drawdown with unchanged static level usually is associated with a lower specific capacity, and usually results from causes set forth in paragraph 3.1.2.6.6.

(c) A decrease in specific capacity always indicates well output loss and accompanies a decrease in safe yield.

3.1.2.6.6 Causes of undesirable well conditions. Several causes or factors contribute to adverse conditions, e.g., lower static levels, lower specific yield, greater drawdown, etc.

(1) Overpumping. Overpumping and pumping at high rates are often the immediate causes of loss of output of a well. Both result in lowering of water level, greater drawdown, incrustation and clogging of screens, and sand pumping. Lowering of the water table is the major cause of well output loss, and always results in a decrease in the specific capacity of a well.



A, water level before start of pumping = static level

B, water level while pumping = pumping level

B-A, amount water is lowered by pumping = drawdown

$$\text{Specific capacity} = \frac{\text{GPM}}{\text{Drawdown}}$$

This measures performance of well (not pump), gpm per ft.

C, air line of known length in ft, part of system for measuring water level. Air pumped into air line through a tire valve stem, with a hand pump, reaches its maximum stable pressure when all water is displaced through bottom, open end, of air line.

One psi of air pressure displaces 2.31 ft of water; then from known length of air line:

Distance from floor line to well-water level = $C - 2.31 \times$ air-line psig

FIGURE 21

Method of Making Well Water-Level Measurements

(2) Clogging. Clogging of screens may be due to bridging of sand grains over the opening, to corrosion, to incrustation or possibly to the growth of bacterial slimes. Screen clogging results in greater drawdown and decrease in specific yield. Clogging of gravel-packed wells by fines, incrustation or slimes has the same effect as clogging of screens. When the drawdown increases without a decrease in static level, clogging of some sort is indicated.

(3) Well Screen Collapse. Collapse of well screen or casing may be caused by overpumping, and decreasing specific capacity always accompanies this condition.

(4) Leaky Casings. Leaking casings may allow water to be lost to "thieving" strata. They may also allow the entrance of undesirable water from other strata, or they may allow the entrance of contaminating substances and harmful bacteria.

(5) Worn Equipment. Worn pump impellers or pump bowls also will contribute to a decrease in well output.

3.1.2.6.7 Remedies for well output loss. There are three methods of combating output loss, any one of which may be effective.

(1) Pumping Rate Reduction. Reducing the pumping rate will reduce output loss caused by overpumping, lowering of the water level, or decreasing the specific capacity. This remedy may dictate the construction of new wells or development of new well fields.

(2) Pump Bowl Lowering. Lowering the pump bowls will overcome output loss due to a drop in static water level in the well (see par. 4.2.2.6 (1)). This method is not usually a permanent remedy as the static water drops due to "mining" the aquifer, that is, pumping at a rate greater than the natural rate of aquifer recharge.

(3) Well Screen Cleaning. Cleaning the well screen may increase well output (see par. 4.2.2.6.1).

3.1.2.6.8 Coastal ground water. When ground water supplies are taken from coastal areas, salt water from the ocean may enter the same aquifer from which the supply is taken. Conditions may be such that salt water will be drawn into the well, making the water unfit to drink. Salt water intrusion has become an increasing problem as coastal areas have developed and water requirements have gone up. Neighboring communities drawing from the same fresh water lens affect each other's water supply to the extent that, in some cases, periods and rates of pumping are controlled by law.

(1) Physics. Because of its salt content, sea water is heavier than fresh water. The difference in weight is slight (a quart of sea water weighs only 2½ percent more than a quart of fresh water); however, it is enough to allow the fresh water to float on top of the salt water under calm conditions. This separation will occur in an aquifer when the water level is not disturbed too much by tidal effects or rapid changes in the amount of fresh water present (see fig. 22). As an example, a fresh-water head of five feet above sea level is enough to keep the salt water 200 feet below the sea level.

(2) Effects of Pumping. When coastal waters are pumped at rates which exceed the recharge of the acquifer with fresh water, the fresh water is lowered in the wells, the salt water level rises, and the wells produce salt water. Therefore, pumping rates must be accurately controlled and water level must be checked frequently. Increasing drawdown to obtain a higher yield is poor practice and results in mixing some sea water with the fresh water. Even slight mixing is bad because sea water has about 200 times as much dissolved solids as most fresh water.

(3) Special Operating Procedures

(a) When salt water intrusion is a possibility, check the chloride (salt) content at the frequency required to insure against intrusion. If it is increasing, the pumping rate must be reduced. If the salt content exceeds the allowable limit, the pump must be shut down and the well allowed to remain idle until the aquifer has recovered sufficient fresh water to permit pumping at the normal rate. This may take a long time.

(b) In some areas where salt water intrusion is serious, excess fresh water from other sources is pumped into the ground through an injection well located between the ocean and the fresh water wells. Thus a fresh water barrier (see fig. 23) is established and should be maintained to prevent salt water from reaching the wells. Adequately treated sewage plant effluent is sometimes used in lieu of fresh water for this purpose.

3.1.2.7 Well Records. In addition to the well data which is kept on the Potable Water Supply and Distribution Operating Record (fig. 8), local commands may require additional records for well operation. One such useful record is the well chart (see fig. 24). The well chart is a profile of the well and the surrounding ground. It is not necessarily drawn to scale, but should show the depths of water levels, pump settings, depth of pump intake, depth and length of well screen and various types of earth layers. Knowing the pumping level and referring to the well chart, the operator may quickly survey the operating conditions of the well.

3.1.3 SURFACE WATER SUPPLIES. Generally speaking, surface waters, whether from streams, lakes or impounding reservoirs, require treatment to make them safe for human consumption.

3.1.3.1 Upland Streams. Small spring-fed upland streams may yield practically clear, tasteless water, except during the height of rain storms when a moderate amount of suspended solids may be present. Although any objectionable bac-

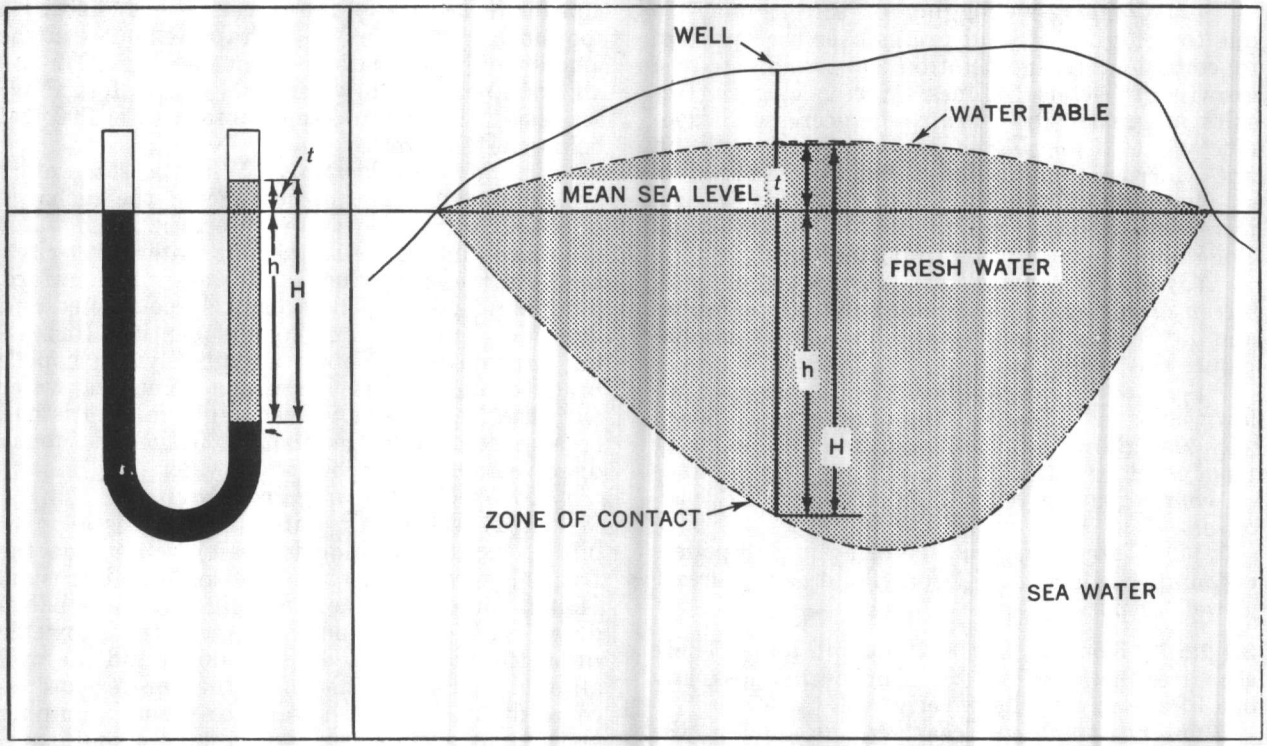


FIGURE 22

Relation Between Fresh and Salt Water

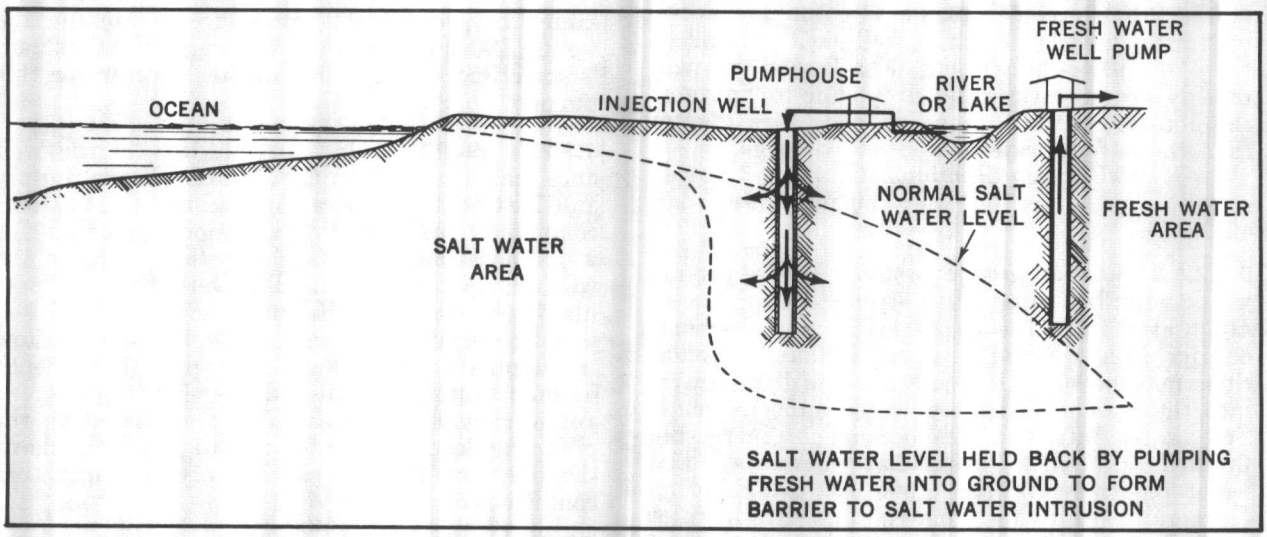


FIGURE 23

Fresh Water Barrier

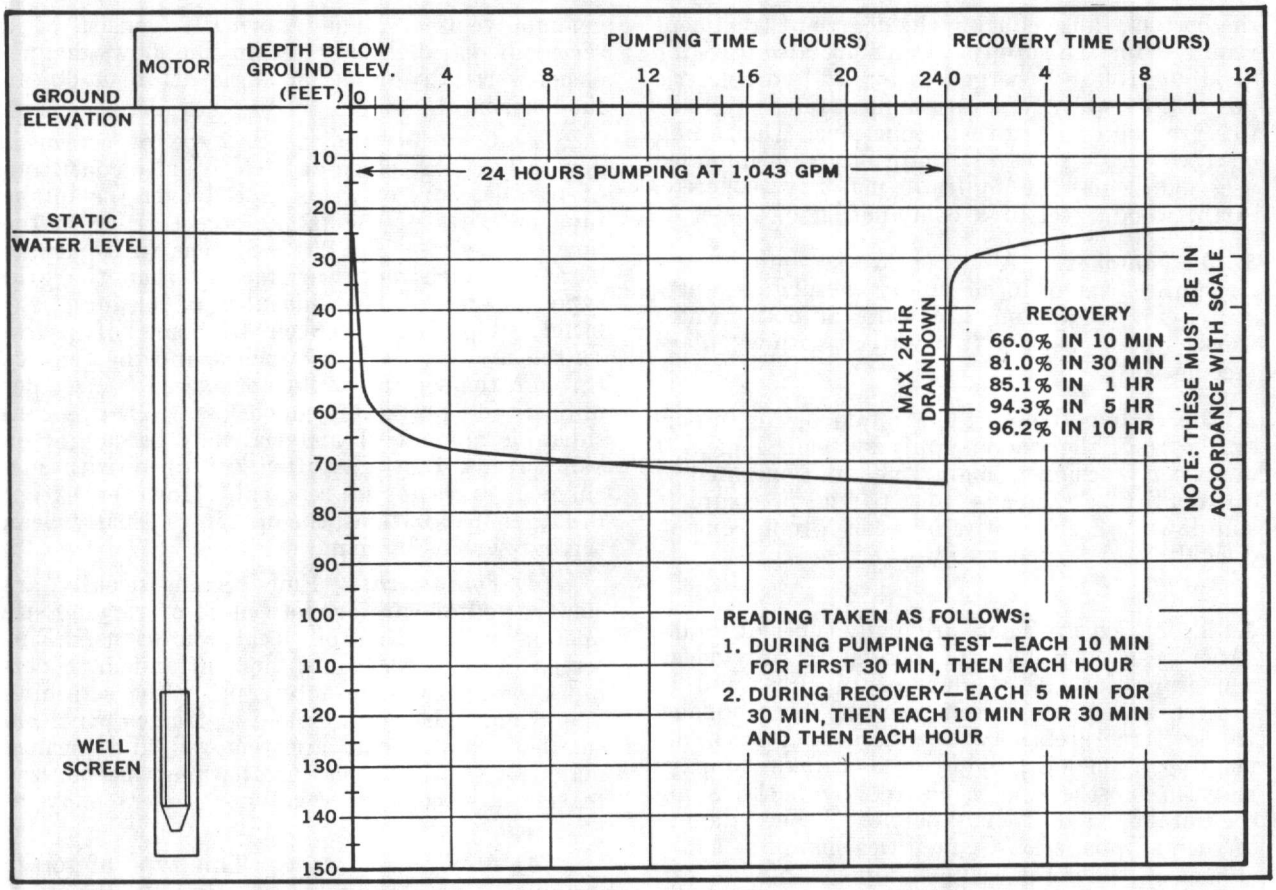


FIGURE 24

Well Chart

teria present may be of animal origin, such streams are always exposed to accidental or incidental pollution of human origin.

3.1.3.2 Large Streams. Large streams usually drain inhabited watersheds, and also receive more serious pollution by surface drainage from eroded or plowed fields so that the physical character of the water is usually inferior to that from large brooks. Furthermore, sewage and industrial wastes may be discharged directly into many streams without adequate treatment. Lakes, ponds, and impounding reservoirs yield water of better quality than most flowing streams because of the beneficial effect of self-purification by sedimentation and storage. The operator's concern with surface water supplies is largely that of maintenance. The maintenance of surface water sources and adjunctive equipment is discussed in Chapter 4.

3.1.3.3 Rivers. Water supplies from rivers will normally require the most treatment of water from any source. The turbidity, or muddiness; the mineral content; and the degree of pollution will vary considerably from day to day. (See Chapter 3, Section 2 for various treatment methods.) The variation in temperature of the water throughout the year may also make it undesirable, particularly during the warm summer months.

3.1.3.4 Natural Lakes. Except near the shoreline and in the vicinity of sewer outlets or outlets of large streams, lakes may yield water of fine quality. Besides requiring minimum treatment, the availability of large quantities of water is a decided advantage. Unfortunately, however, the most desirable method of disposal of sewage from a city is often the same lake from which an activity water supply must be taken. Sound design practice leads to care in locating a water intake to limit the pollution handled by the water treatment plant. In general, lake water is reasonably uniform in quality from day to day, and does not vary in temperature as much as a river or small impounding reservoir.

3.1.3.5 Dams and Reservoirs. By creating reservoirs, dams save water from periods of high river flow for later use. Such storage allows many of the impurities in a reservoir to settle on

the bottom, thus reducing the degree of treatment required for the supply. Dams are also used for flood control and the generation of hydroelectric power. Frequently, multipurpose dams are built to serve two or all of these functions. Depending on the size, structural conditions and intended use, dams may be built of masonry, concrete, earth, wood, steel or a combination of these.

3.1.3.6 Intakes. A water works intake is a structure located in or under a surface water source for conducting the water into the water works system, usually to a water treatment plant (see fig. 25).

3.1.3.6.1 Importance. The intake is an important part of the water supply system. Unless it is properly designed, maintained and operated, it can readily be the cause of a partial or complete shutdown of the entire system, often causing difficult and expensive work to return it to operation.

3.1.3.6.2 Types. There are many types of intake structures; their main purpose is to provide an anchorage for the conduit or pipeline, and to protect its opening from damage or stoppage. Intake structures may be screened or open depending upon local conditions. Intake stoppage may, in most cases, be cleared by backflushing the intake conduit or pipeline. Where danger of such stoppage exists, facilities should be available at all times for backflushing the intake. For the problem of ice and its removal, see paragraph 4.2.3.4.1.

3.1.3.6.3 Location of intakes. Intakes are fitted with gates at various depths, or have an adjustable suction pipe attached to a floating raft so that water can be taken from the reservoir or lake at different levels. Water may be drawn from or near the surface when the deeper water has a bad taste and odor because of decomposing organic matter. The intermediate depth is used when micro-organisms are prevalent near the surface. The lower depth can provide cooler water in the summer.

3.1.3.6.4 Screens. When necessary, intakes are equipped with removable screens to keep fish and debris out of the pipeline. A platform above the water provides access for servicing and cleaning of the screen. Intake screens should be cleaned at regular intervals determined by local experience.

(1) Classes. Intake screens are usually divided into two general classes—coarse and fine. Where the water treatment process includes filtration, fine screens are not usually used; it is more economical in most cases to remove fine material in the water treatment processes and to provide only coarse screens for the removal of large materials which may clog or injure pipelines, valves and equipment. Coarse bar screens are most commonly used. They normally consist of a series of parallel bars set in the flow channel either vertically or at an angle of about 60° to the horizontal.

(2) Coarse Screens. This type of screen is generally a bar screen or rack, usually consisting of parallel bars or grids placed over the intake pipe or ports of the intake structure or in the flow channel (see fig. 26). Screens with parallel bars are much more satisfactory than the grid type because of the difficulty of cleaning the latter. Openings between the bars of coarse screens are usually 1 to 3 inches, and the velocity through the screen should not exceed 30 feet per minute, and preferably much less. Where a considerable amount of material may be caught on bar screens, they are often equipped with mechanical rakes for its removal. However, except in larger installations, the operators usually clean the bar screens by hand.

(3) Fine Screens. Fine screens usually are constructed of wire or cloth mesh of varying size openings depending on local conditions. Fine screens are normally installed in tandem to permit cleaning without interrupting the screening operation. The mesh is held in frames which, in smaller installations, are removed and cleaned manually. For larger installations, mechanized traveling screens or revolving screens may be provided.

(4) Mechanized Screens. This type of screen usually is operated intermittently with the starting and stopping controlled by the loss of head which results from clogging of the screen. Fine screens are particularly applicable to water supplies where refuse is finely divided. Clogging material can be removed from screens by brushes or sprays, and from the spray water by a dewatering screw, flight conveyor or a liquid vibrating screen.

(5) Traveling Screens. This type of screen is an endless belt type in which the sections are linked together to form the belt. They are usually equipped with sprays for automatic cleaning.

(6) Rotating Screens. The two types of revolving fine screens are the drum and disk types.

(a) Revolving drum. This type of screen (see fig. 27) rotates on a horizontal axis with the flow entering the inside of the drum and passing through the mesh. The solids are retained on the mesh cloth inside the drum and flushed to a screenings trough inside the drum by water spray.

(b) Disk screen. A disk screen is a revolving spoked hoop with 6- to 60-mesh screen cloth covering the area within the hoop (see fig. 28). The screen rotates on a horizontal axis with the flow passing through the cloth parallel to the axis. The solids are retained on the cloth, elevated as the disk revolves, and flushed from the cloth by water sprays into a screening trough.

FIGURE 25

Intake for Water Works

3.1.3.7 Operation of Surface Water Supplies. Operations involved consist of taking the necessary measurements of water flow, keeping required records and making certain that screen and intakes are kept clear of debris. To determine the flow of water over dams or in streams see paragraph 3.4.4.4.

3.1.3.8 Records. Efficient and economical operation of surface water supplies require that adequate records be kept. In addition to the quantity of surface water supplied daily, as recorded on the Potable Water Supply and Distribution Operating Record (fig. 8); other pertinent information about surface supplies includes reservoir, lake or river levels, and intake used (where there is more than one). The form of such additional records is customarily established by the activity command on the recommendation of the Utilities Division.

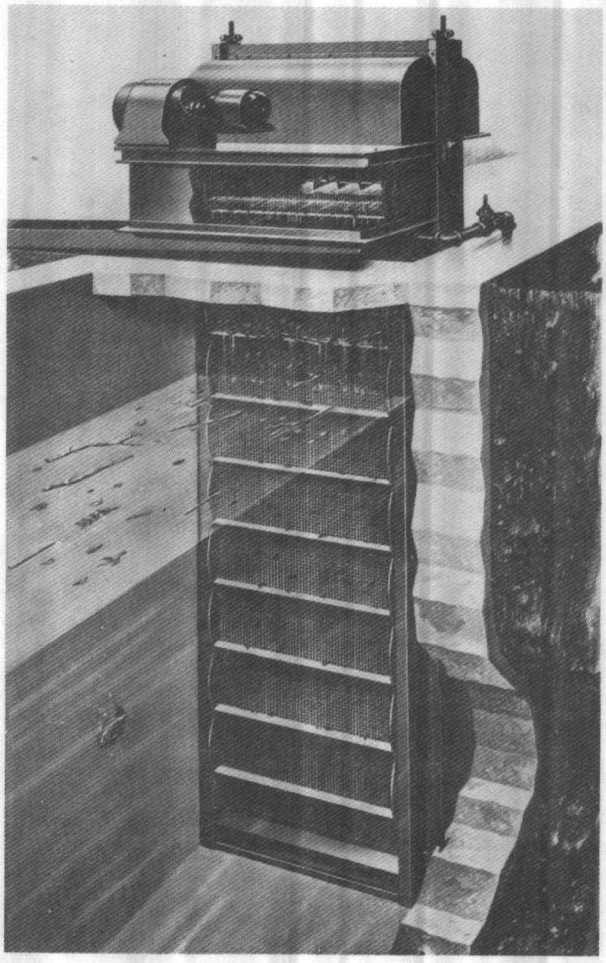


FIGURE 26

Coarse Screen

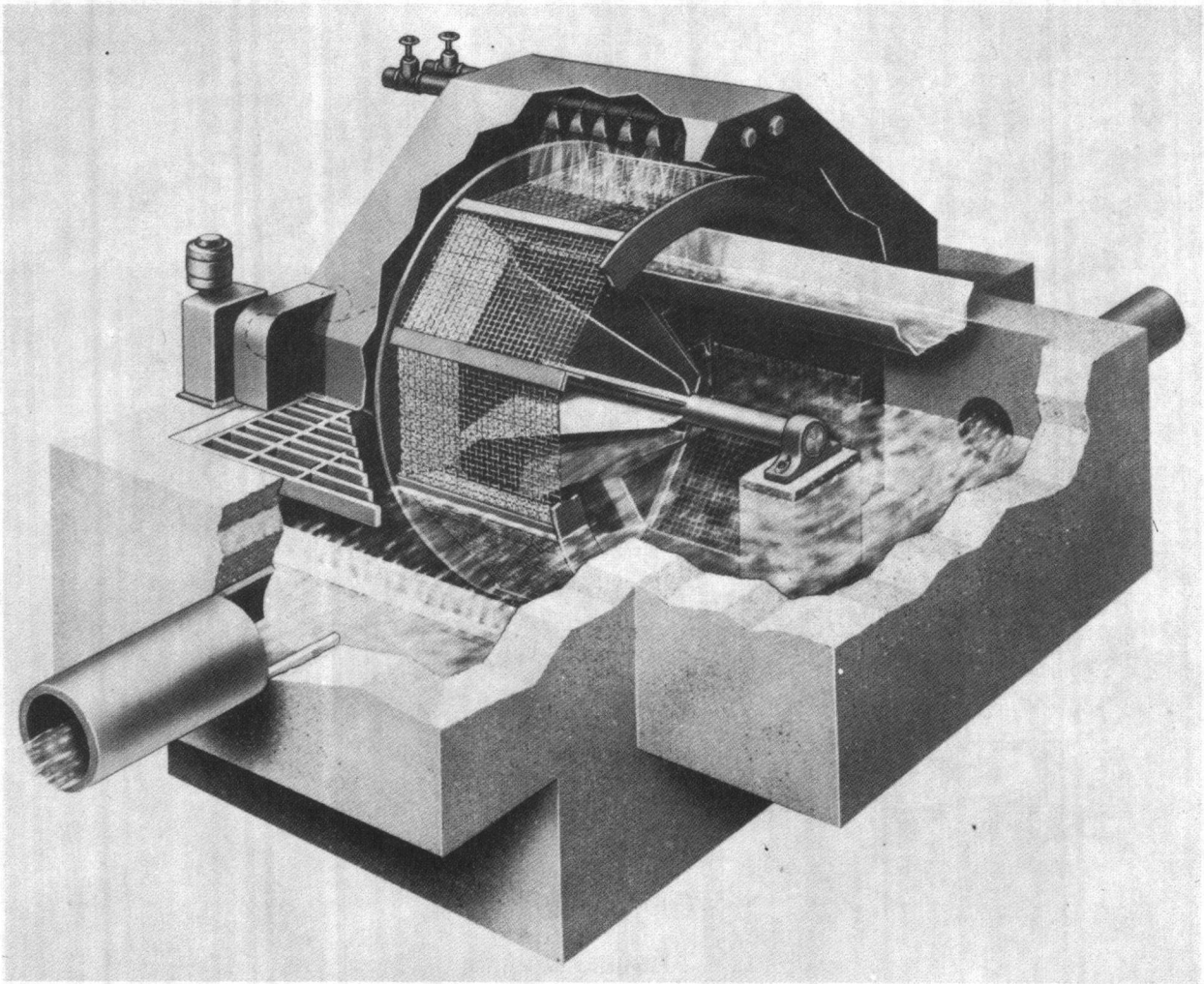


FIGURE 27

Revolving Drum Screen

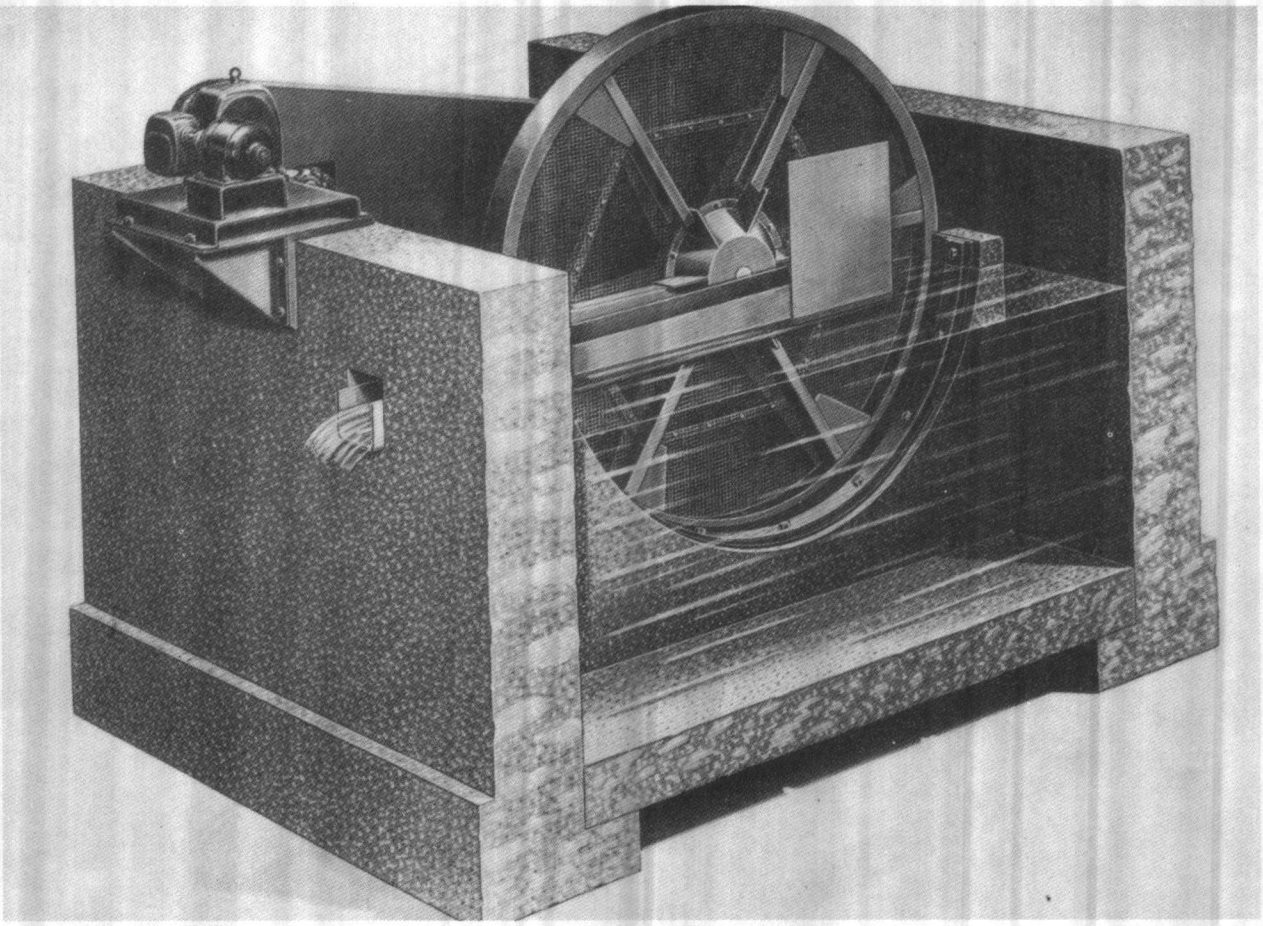


FIGURE 28

Revolving Disk Screen

Section 2. TREATMENT

3.2.1 UNAUTHORIZED METHODS. In the following paragraphs, the various standard water treatment methods are described. Under no circumstances may any other methods be employed for the treatment of water supplies at any naval shore-based activity without the specific permission of the Bureau of Yards and Docks.

3.2.2 DISINFECTION. Except in rare instances, all mater supplies require disinfection. Disinfection is the chemical destruction of bacteria. Because of its economy, dependability, efficiency and ease of handling, chlorine is almost always used for this purpose. The term "chlorination" is generally used synonymously with "disinfection" in water works practice.

3.2.2.1 General Rules of Disinfection. Disinfection is a necessary step in the process of ensuring a safe water supply. All new, altered, or repaired water supply facilities must be disinfected before they are placed in service. Water from surface supplies may be disinfected before filtration, or before coagulation and sedimentation to prevent the growth of organisms. This procedure is known as prechlorination. It must also be disinfected after filtration to kill organisms that still remain, and to provide a safeguard against recontamination. This procedure is known as postchlorination.

3.2.2.1.1 Use of chlorine. Chlorine is the disinfectant specified for Navy use. In the form of chlorine gas, or of hypochlorites which yield chlorine in water, chlorine is presently the only widely accepted agent that destroys organisms in the water and leaves an easily detectable residual that serves as indicator of the completeness of treatment. The sudden disappearance of residual chlorine may signal contamination in the system. Under ordinary temperatures and pressures, chlorine is a greenish-yellow gas that is heavier than air. Its effectiveness as a disinfectant depends on the temperature and pH of the water to which it is added. Disinfecting action is faster at higher temperatures, but is retarded by high pH. If the pH is above 8.4, the rate of disinfection decreases sharply.

3.2.2.1.2 Other disinfectants. Ozone, potassium permanganate, bromine and iodine are also used to a limited extent as disinfectants. If excess lime is used for softening water, it makes the water alkaline and disinfects after about ten hours contact. However, the general applicability and economic advantage of chlorine has established it as the preferred disinfectant.

3.2.2.1.3 Safety precautions. General safety precautions for handling chemicals are given in Chapter 5. Because of the absolute necessity for careful handling of ammonia, chlorine and chlorine-yielding compounds, the following specific precautions must be observed.

(1) Chlorine Properties. Properties that make chlorine difficult to handle include the following.

(a) Chlorine gas is extremely irritating to the eyes, mouth, throat and nose. Repeated exposure to relatively low concentrations may have a cumulative effect on the lungs. Because chlorine is heavier than air, exhaust ducts for venting fumes are installed to draw air from the lowest point in the room. The exhaust system blowers or fans must have their switches readily accessible from the outside.

(b) Chlorine is noncorrosive when dry, but very corrosive when moist. Therefore, iron pipe can be used for dry gas, but parts coming into contact with chlorine solution must be made of silver, tantalum, glass, rubber or certain synthetic compounds.

(c) Chlorine reacts with greases, oils, alcohol and ether to produce solid compounds which clog fittings and chlorinator parts. Carbon tetrachloride is the best cleaning agent to remove these compounds; extreme care must be taken to provide adequate ventilation while using it (see par. 4.3.1.10(1)). Approval of the activity medical officer is required prior to use of carbon tetrachloride.

(d) High-test hypochlorites are relatively stable, but are extremely active oxidizing agents. If they come in contact with organic matter or other chemicals, they may cause an explosion.

(2) Withdrawing Chlorine from Cylinders. A cylinder received from the chlorine supplier may legally contain about 88 percent liquid chlorine by volume, and 12 percent dry chlorine gas at 79° F. Cylnider pressure keeps most of the chlorine in liquid form at ordinary pressures (see fig. 29). When the cylinder valve is opened and gas withdrawn, the pressure in the cylinder is relieved and more liquid passes into the gaseous form. The change from liquid to gas requires heat that is absorbed from the surrounding air through the cylinder walls.

(a) Safe withdrawal rates. If gas is drawn off too rapidly, so much heat is taken from surrounding air that frost forms on the cylinder

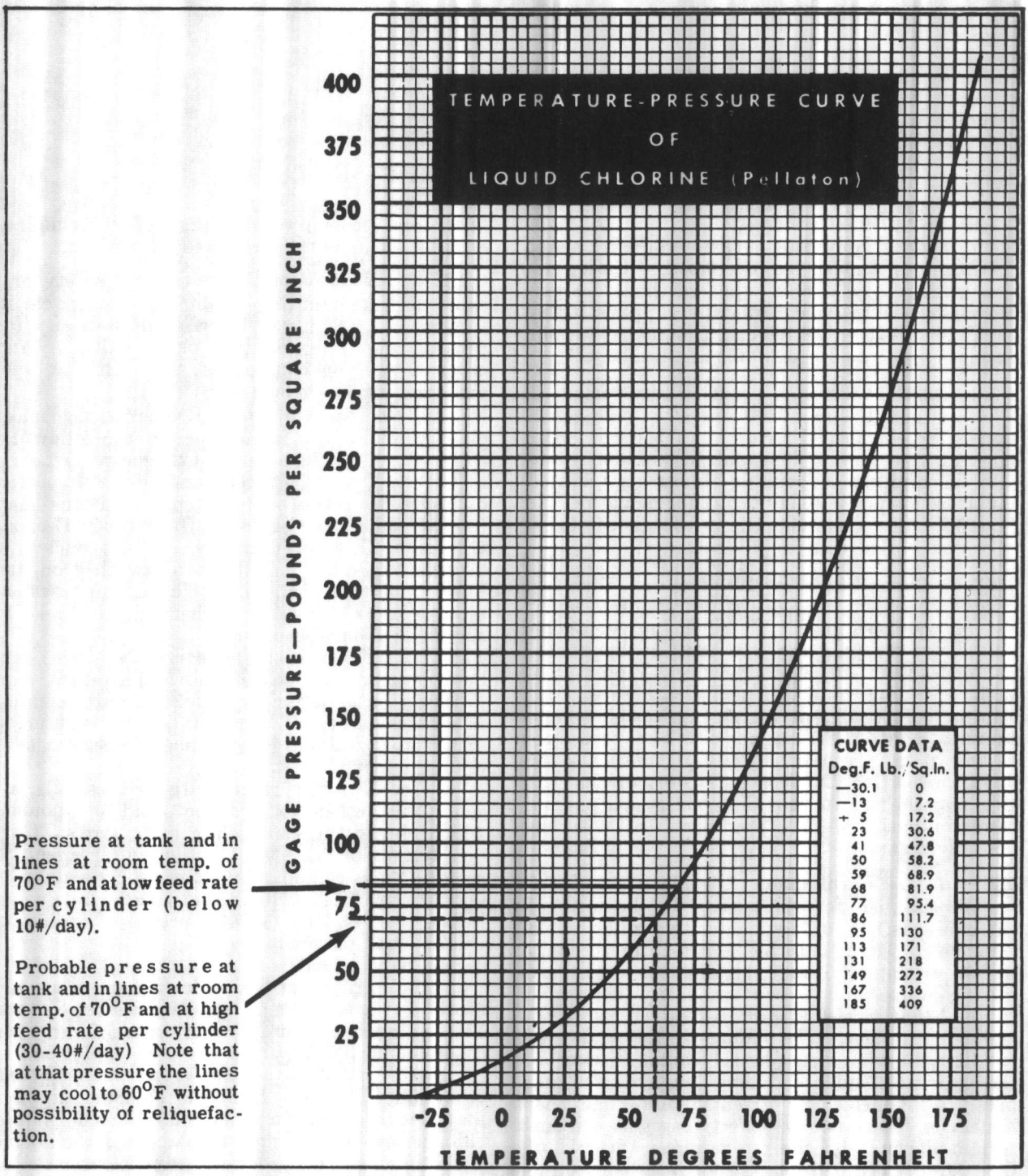


FIGURE 29

Temperature-Pressure Curve for Chlorine Gas

slowing gas formation. Maximum safe rates for drawing off chlorine are 400 lbs per day from 1-ton cylinders, and 40 to 50 lbs per day from 150-lb cylinders. Acceleration of chlorine gas withdrawal by heating the cylinders or placing them in a bath of hot water should not be attempted. This may melt the fusible plugs in the cylinder and allow the gas to escape. In addition, the hot iron of the cylinder can react with the dry chlorine.

(b) Reliquefaction. Chlorine gas will change back to liquid in the piping between the cylinder and the pressure-reducing valve in the chlorinator if its temperature is reduced below that of the cylinder contents. Such reliquefaction causes erratic chlorinator operation. To prevent reliquefaction of the gas, chlorine cylinders should be installed at points where their temperature will be the same or slightly lower than room temperature at the control unit. Avoid placing cylinders near heating units, in front of a window or in direct sunlight. Do not allow cold drafts on chlorine pipe. If room temperatures are low and artificial heat is required to keep chlorine gas from reliquefying in the piping, limit temperature in the artificial heating unit to 100° F.

(c) Chlorine hydrate. Chlorine hydrate, commonly termed chlorine ice, sometimes forms within the chlorinator and interferes with operation. It is caused by low tray temperatures. If not severe, its formation can be prevented by hanging a 100-watt light bulb against the glass bell of the chlorinator. Otherwise, temper the tray water by using a hot-water coil or small electrical heating element which is available from the chlorinator manufacturer.

(d) Metals to be used. Use wrought iron, steel, copper or any other serviceable pipe to conduct dry chlorine gas from cylinders to chlorinator. Pipe must be extra-heavy type for 250-lb service, and at least ¾-inch nominal size. Use a paste of freshly mixed litharge and glycerin to make up threaded joints; ordinary pipe dope cannot be used. Support piping securely. Slope it so that it drains back to cylinders without traps or snags, or provide drip legs at necessary sags to collect reliquefied chlorine gas. If room temperature des not vaporize condensate from a drip leg fast enough, shield the upper portion of leg with asbestos and warm the base with a permanently installed 100-watt light bulb.

(e) Opening valves. Open chlorine valves slowly and carefully, using a wrench of proper size (not longer than 6 inches); never use an extension persuader on the wrench. Open valves only part way; one full counterclockwise turn of the valve stem permits maximum discharge. Tap the wrench lightly to aid the operation of stuck valves.

(f) Closing valves. Close the valves as soon as the cylinder is empty and crayon mark the cylinder with a large "E" near the valve. Return the empty cylinders promptly to the supplier.

(3) Locating Leaks. (Also see par. 4.3.1.2). Even small leaks can be detected because of the characteristically sharp chlorine odor. When a chlorine odor is noted, authorized personnel should start the ventilating system, put on gas masks and locate the leak by holding an unstopped bottle of ammonia water close to pipes, fittings and valves. Ammonia vapor and chlorine gas form heavy white fumes, thus revealing the point from which chlorine is issuing. If the leak is in a line, shut off the flow of chlorine and repair the leak. If it is in the cylinder head and cannot be stopped by closing the valve, waste the gas from the cylinder outdoors in a good wind, or run it into a caustic soda solution. A solution of 25 lbs of caustic soda in 10 gallons of water will absorb 20 lbs of chlorine gas.

(4) Hypochlorites. To prevent accidents caused by the corrosive action of hypochlorites, use vitreous crocks or steel tanks lined with rubber or chlorine-resistant plastic as solution containers. Store calcium hypochlorite in a dry cool location, and keep the cans sealed. Rubber gloves and protective aprons should be worn when preparing and handling hypochlorite solutions.

(5) Ammonia. Ammonia fumes are poisonous, but even small concentrations are quickly noticeable by its characteristic odor. Because the gas is extremely soluble, ammonia which has escaped can be picked up by a water spray. The same precautions used with chlorine are used in handling ammonia, with the following exceptions and additions.

(a) Because ammonia is lighter than air, install vents at the top of room.

(b) Ammonia cylinders do not have fusible plugs because no fusible ammonia-resistant material is available. This presents an acute hazard because an ammonia cylinder filled to the legal limit becomes completely liquid at 145° F., and higher temperatures result in a build-up of hydrostatic pressure. Cylinders are tested at 700 psi under Interstate Commerce Commission regulations.

(c) Test for leaks in ammonia gas piping with a bottle of dilute muriatic acid. White fumes form as with chlorine.

(d) Ammonia solution or aqua ammonia can be stored indefinitely, but ammonia gas is evolved at about 80° F. if the container is open. Store it in a cool place and keep the container tightly plugged. Dilute with cool water to 15 percent ammonia content before feeding. Keep the room housing the feeder well ventilated.

(6) Sulfur Dioxide. Precautions in storing and handling chlorine also apply to sulfur dioxide. Leaks are located with a bottle of ammonia water.

(7) Gas Masks. Gas masks are provided for handling chlorine, ammonia or sulfur dioxide. Acid-vapor masks and canisters are used for

chlorine and sulfur dioxide. Ammonia masks and canisters are used for ammonia. Masks should be located near, but outside of, the chlorinator and chlorine storage areas. All personnel must be trained and drilled in the use of gas masks. Local drills should be conducted frequently. Masks are stored in a safe, available place, away from any possible gas leaks. Operating personnel must be thoroughly acquainted with the locations and the correct use of masks.

3.2.2.2 Chlorine Disinfectants. Chlorine disinfectants are available in a number of different forms as described in the following paragraphs.

3.2.2.2.1 Liquid chlorine.

(1) Containers. Liquid chlorine is liquefied gas under pressure and is shipped in seamless steel cylinders under Interstate Commerce Commission regulations. The standard sizes of shipping containers are the 150-lb cylinder, 1-ton container and 30-ton tank car.

(2) Container Characteristics. Each pound of liquid chlorine produces about 5 cubic feet of chlorine gas at atmospheric pressure and at a temperature of 68° F. A standard Chlorine Institute valve and a protective valve hood are screwed into the neck of each cylinder. The valve has a safety plug containing fusible metal that softens between 157° F. and 162° F. to protect the cylinder from bursting in case of fire. All cylinders must be factory tested every five years; 150-lb cylinders are tested at 500 lbs pressure and 1-ton containers at 800 lbs pressure.

3.2.2.2.2 High-test calcium hypochlorite. This chemical is a relatively stable, dry granular solid or powder which is readily soluble forming a chlorine solution. It is prepared under a number of trade names, including HTH, Perchloron, and Pittchlor. It is furnished in 3- to 100-lb containers and has 65 to 70 percent available chlorine by weight. Because of its concentrated form and ease of handling, calcium hypochlorite is preferred over other hypochlorites.

3.2.2.2.3 Sodium hypochlorite. This chemical is generally furnished as a solution that is highly alkaline, and therefore reasonably stable.

(1) Commercial Products. Federal specifications call for solutions having 5 and 10 percent available chlorine by weight. Shipping costs limit its use to areas where it is available locally. It is also furnished as powder under various trade names such as Lobax and HTH–15. The powder generally consists of calcium hypochlorite and soda ash which react in water to form sodium hypochlorite.

(2) Household Bleach. Ordinary household bleach is a sodium hypochlorite solution containing 2.5 percent available chlorine and is sometimes used at small installations.

3.2.2.2.4 Chlorinated lime. This chemical, also known as chloride of lime or bleaching powder, is seldom used in water disinfection. It is a mixture of calcium chloride and calcium oxychloride which will yield about 35 percent available chlorine when fresh. It deteriorates rapidly in hot moist atmospheres and should, therefore, be purchased in small packages that can be kept effectively sealed. Chlorinated lime contains an excess of insoluble lime; hence, solutions should be prepared in a separate container, the lime permitted to settle, and the liquid decanted into a separate tank for use.

3.2.2.3 Chlorination Principles. When chlorine gas is introduced into pure water, some of it reacts to form hypochlorous acid, and the rest remains as dissolved chlorine. These forms of chlorine are termed *free available chlorine*, because their oxidizing and disinfecting ability is fully available. Because most natural waters contain small amounts of ammonia and nitrogenous organic substances, free available chlorine will react with these substances to form chloramines and other complex chlorine-nitrogen compounds. These forms of chlorine compounds are termed *combined available chlorine;* part of the chlorine oxidizing and disinfecting ability is lost. Both free available chlorine and combined chlorine will react with oxidizable substances in water until their oxidizing and disinfecting ability is depleted. The amount of chlorine consumed in reacting with organic substances in a water in a given time (usually 10 minutes), is called the *chlorine demand.* Chlorine remaining in excess of the chlorine demand is the *total chlorine residual*, or *residual chlorine.* Residual chlorine is composed of both free available chlorine and combined available chlorine. The time elapsing between the introduction of chlorine and use of the water is termed the contact period.

3.2.2.3.1 Bactericidal effectiveness. The bactericidal effectiveness of chlorine depends on the following factors.

(1) Chlorine Residual. Chlorine effectiveness increases rapidly with increase in the residual. However, free available chlorine is 20 to 30 times as effective as combined chlorine under the most favorable conditions of pH (7.0) and water temperature (68° to 77° F.). Therefore, the relative amounts of free and combined available chlorine in the total residual is important.

(2) Contact Period. Within normal limits, the higher the chlorine residual, the lower the required contact period. If the residual is halved, the required contact period is doubled.

(3) Temperature. The effectiveness of free available chlorine at 35° to 40° F. is approximately half of what it is at 70° to 75° F.

(4) pH. The effectiveness of free chlorine is highest at pH 7 and below. At pH 8.5, it is one-sixth as effective as at pH 7, and at pH 9.8, it may require 10 to 100 times as long for a 99 percent bacteria kill as at pH 7.

3.2.2.3.2 Points of application. Plain or simple chlorination is the single application of chlorine as the only treatment before discharge to the distribution system, as in the chlorination of ground water supplies and previously unchlorinated purchased supplies. Prechlorination is the application of chlorine to raw water before coagulation, sedimentation or filtration. Postchlorination is the application of chlorine after filtration, but before the water leaves the treatment plant. Rechlorination is the application of chlorine into the distribution system or into a previously chlorinated purchased supply to maintain the chlorine residual. The above applications are normally continuous. Very heavy chlorination for a limited period is sometimes applied at specific points in the distribution system to destroy localized contamination.

3.2.2.3.3 Types of treatment. The usual types of treatment employed in chlorination are as follows.

(1) Marginal Chlorination. This process consists of the application of chlorine to produce the desired total chlorine residual without reference to the relative amounts of free available and combined chlorine present. It is so termed because the initial chlorine demand has been satisfied although some oxidizable substances remain. It is the usual type of chlorination. Marginal chlorination does not always destroy algae organisms and tastes, and its bactericidal effectiveness is not predictable within close limits.

(2) Chlorine-Ammonia Treatment. This process consists of adding both ammonia and chlorine to form chloramines. These compounds provide a persistent chlorine residual and in some instances reduce unpleasant chlorine tastes. Theoretically, a ratio of four parts of chlorine to one part ammonia is required. In practice, about a 3:1 ratio is used to provide an excess of ammonia. Too great an excess must be avoided because free ammonia in the water retards disinfection. Monochloramine is formed when the pH of water is above 8.5. Both dichloramine and monochloramine are formed when the pH value is 4.4 to 8.5. Adding ammonia before the chlorine prevents objectionable tastes in waters containing phenolic impurities. Chloramines react so slowly that a very long contact period is needed for complete destruction of micro-organisms. To eliminate this long contact period, chlorine may be applied first, and after the shorter contact period necessary for bacterial kill, the ammonia is introduced. Chloramine residuals are generally two to four times greater than those normally carried in marginal chlorination.

(3) Superchlorination. This process consists of adding more chlorine than is needed for the chlorine residual essential to marginal chlorination. This treatment is used to control tastes and odors. The method is particularly valuable in surface waters with variable ammonia and organic content. The surplus chlorine is later removed by aeration or by a dechlorinating agent such as sulfur dioxide or activated carbon. Aeration removes excess chlorine by dissipation into the atmosphere. Sulfur dioxide reacts with chlorine to form acids which are neutralized by the natural alkalinity of the water. It is fed by equipment similar to that used for chlorine (see par. 3.2.2.4). Activated carbon adsorbs excess chlorine and is removed by settling or filtration.

(4) Break-Point Chlorination. This process consists of the application of chlorine to produce a residual of free available chlorine, with no combined chlorine present. As chlorine is added, the total residual increases gradually after the initial demand of the water has been satisfied. At some residual concentration, depending on the water treated, free available chlorine reacts with the remaining oxidizable substances, including combined chlorine, and the residual drops sharply. When all oxidizable matter combined with the chlorine has been oxidized by reaction with free available chlorine, the residual consists only of free available chlorine; the residual then rises again and increases in direct proportion to increased dosage. The point at which the residual begins to increase is called the break-point.

(a) Break-point curves. Figure 30 shows typical break-point chlorination curves. Note that the curve rises at almost a 45-degree angle after the break-point is reached. Reactions are most rapid at a pH from 7 to 8 and at higher temperatures. Curve 1 shows a typical break-point for water containing a considerable amount of ammonia. Chloramines are first formed during the initial upward rise. The curve rises until sufficient free available chlorine is developed to react with chloramines; then it falls to a point where all ammonia compounds have been oxidized. With less organic matter in the water, as in curves 2 and 3, free available chlorine is formed sooner, destroying chloramines formed at the early stage. This action results in lower combined chlorine residuals and flatter curves before break-point. With practically no organic matter, curve 4 results. Chloramines are neutralized at an early stage as shown by the upswing of the curve. For some waters containing complex organic compounds, several intermediate break-points occur.

(b) Advantages. Advantages of break-point chlorination are high bactericidal efficiency, long-lasting residuals, and low taste and odor characteristics. It can be used only if detention periods are long enough to develop free available chlorine residuals. This varies with the organic content of the water. In some cases the treated water must be exposed to the air to permit the escape of the chloro-organic gases which are formed. Tests for ammonia nitrogen will assist in determining the break-point. In practice, 10 to 25 times as much chlorine as ammonia nitrogen content may be needed to reach the break-point.

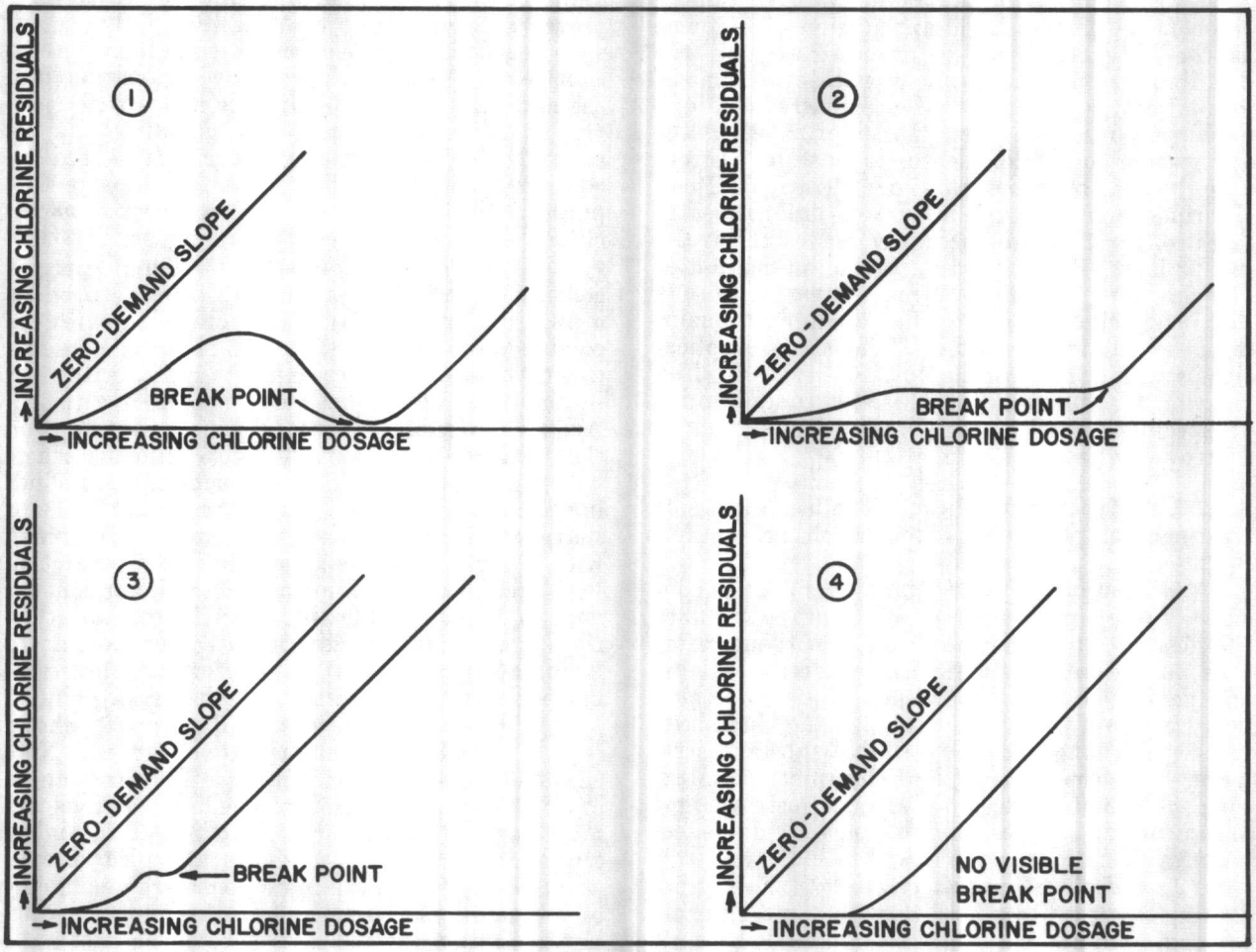


FIGURE 30

Break-Point Chlorination Curves

Break-point chlorination before, instead of after, filtration has been found desirable.

(c) Caution. Break-point chlorination should not be used for surface supplies with widely varying ammonia nitrogen content, unless trained assistance is available to make frequent tests for the break-point. With such waters, the break-point curve can change radically in a short time.

3.2.2.3.4 Other uses. Chlorine is also used to control tastes and odors in water. It reacts with the substances causing taste and odor, such as hydrogen sulfide, minute organisms, algae and organic compounds. If the reaction is incomplete, the taste and odor of some substances may be intensified or become more objectionable. Chlorine is also used to a limited extent to oxidize iron and manganese, and to remove color.

3.2.2.4 Chlorination Equipment. It is essential that chlorination equipment be properly located with proper ventilation according to the information contained in paragraph 3.2.2.4.1.

3.2.2.4.1 Safety and location. The design standards in Reference 3 require that all gas chlorinating equipment and chlorine gas cylinders, filled or empty, should be located in a separate room opening only from the outside, and shall not be located in the same room or enclosure with operating equipment, other than equipment required for chlorination. If these conditions do not exist, operating and/or maintenance personnel should seek engineering advice. A typical chlorinator installation is shown in Figure 31.

(1) Chlorinator Room. If the chlorination room is not located at such an elevation that the floor is level with or above the surrounding ground area, an exhaust fan (positive pressure blower type) should be installed to remove gas or air at the floor level, and mechanical exhaust ventilation at floor level provided in any case. Doors should open outward, and two-way light-

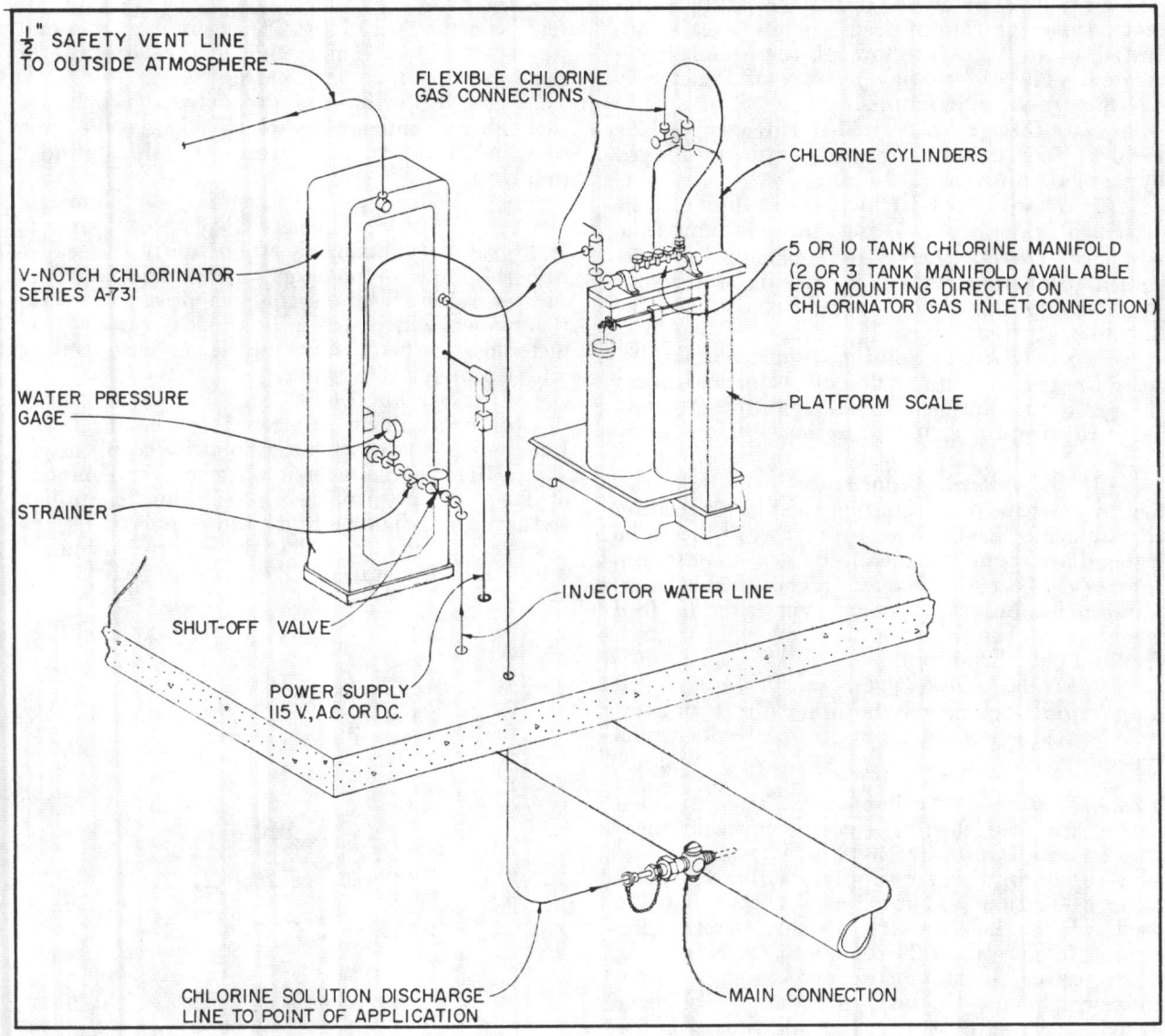


FIGURE 31

Typical Chlorinator Installation

ing switches should be provided both outside and inside the room. Where standard design conditions have not been met, personnel should seek engineering advice.

(2) Hypochlorinators. It is normal practice to locate hypochlorinators in the same room with other equipment such as pumps, switchboards, meters and the like. However, due to the corrosiveness of the solutions, it is better practice to locate them in a separate room. If adequate floor drains have not been provided for waste water, spillage, sludge and washdown water, a 6-inch curbing should be provided around the entire area used for this purpose, whether in a separate room or in the same room with other equipment.

3.2.2.4.2 Types of equipment. Chlorination equipment to feed chlorine gas or hypochlorite solution is classified by type, depending on methods of control; by type of feed; and, by the type of diaphragm.

(1) Methods of Control.

(a) Manual. In the manually controlled type, equipment must be started and stopped manually, and the rate of feed must be manually adjusted to the rate of water flow.

(b) Semiautomatic. In the semiautomatic type, equipment starts and stops automatically as water flow starts and stops, but must be manually adjusted to the rate of water flow. This type is normally used with water pumped at a fairly uniform rate.

(c) Fully automatic. In the fully automatic type, the rate of feed is automatically adjusted to the rate of flow of the water being treated. The differential pressure of a metering device is used to accomplish this.

(d) Dosage rate. In all three types, the ratio of feed to water treated, or dosage, is set by manual adjustment.

(2) Type of Feed. Chlorinators may also be classified generally as direct or solution feed.

(a) Direct. Direct-feed machines are designed to operate without a pressure water supply, feeding the chlorine gas directly into the flow to be treated.

(b) Solution. Solution-feed machines dissolve the gas in a minor flow of water and inject the resultant solution into the flow to be treated. They require a pressure water supply for operation.

(3) Diaphragm. Chlorinators are also classified by the type of diaphragm used in controlling the chlorine feed. There are two types—the water diaphragm and the mechanical diaphragm.

(a) Water diaphragm. The water diaphragm is always a vacuum type, solution-feed machine and has the advantages of being friction free and puncture-proof.

(b) Mechanical diaphragm. The mechanical diaphragm machine may be either direct- or solution-feed pressure type, or solution-feed vacuum type only.

3.2.2.4.3 Direct-feed chlorinators. These chlorinators are used chiefly as emergency equipment and on small installations where it is not possible to obtain a water supply suitable for operating a solution-feed machine. They cannot be used where the pressure of the water being treated is more than 20 p.s.i., and are limited in the types of semiautomatic and automatic controls which may be used. Because the chlorine is under pressure as a gas at all times, direct-feed machines are highly susceptible to the leakage of gas into the atmosphere with the resultant corrosive action on adjacent equipment and structures. The manufacturer's recommendations and instructions should be followed by the operator of the equipment. The operator must be thoroughly familiar with the equipment in order to ensure its proper operation, adjustment and minor repair.

3.2.2.4.4 Solution-feed chlorinators. This type of chlorinator introduces chlorine gas into the water supply by means of a chlorine solution usually formed by drawing chlorine gas into the jet stream of water at the low pressure point of an injector mechanism of the chlorinator. Two general types are used—the bubbling or pulsating, reduced-pressure type; and, the vacuum type. Because the chlorine is kept under a partial vacuum, there are fewer chlorine leaks than with pressure gas chlorinators and direct diffusers.

(1) Pulsating Type. This type of solution-feed chlorinator (see fig. 32) is suitable for small water supplies. These chlorinators operate in the following manner (see fig. 33).

(a) Chlorine gas flows from a cylinder through a compensator which adjusts the flow to a uniform rate, regardless of the cylinder pressure.

(b) The gas then enters a volumetric meter, which is a submerged displacement siphon, and gradually displaces water until it escapes into the outer cylinder as a large bubble. The sudden release reduces the gas pressure within the meter, which again fills with water. The metered gas then passes into a suction chamber where it mixes with water.

(c) Suction produced by an injection throat draws the chlorine solution into the discharge line, which carries it to the points of application.

(d) The volumetric meter fills and empties at frequent intervals as the solution is applied to the water. The more rapid the pulsations, the greater the rate at which the chlorine is introduced into the water. The rate of feed can be

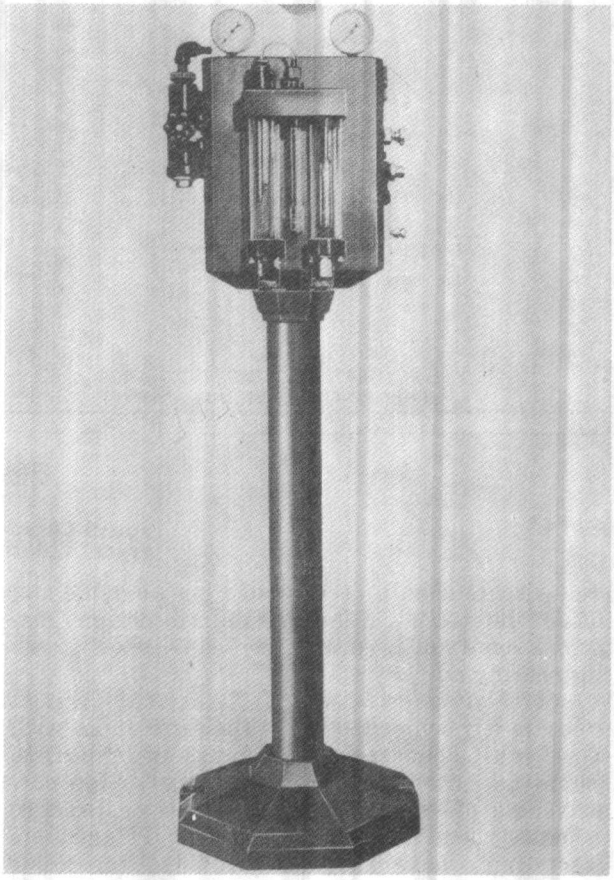


FIGURE 32

Pulsating Type Chlorinator

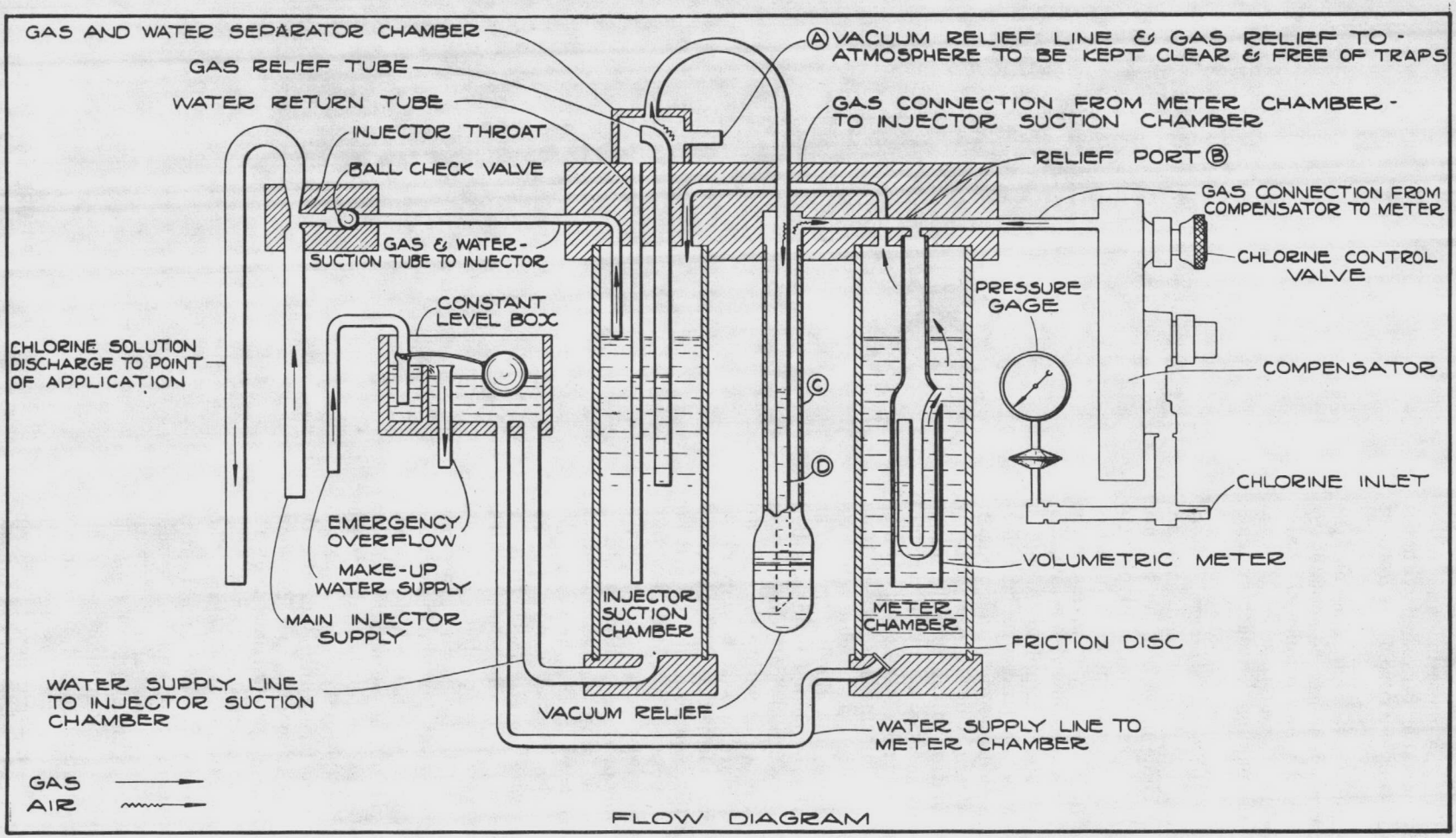


FIGURE 33

Flow Diagram of Pulsating Type Chlorinator

determined by timing the pulsation and referring to the calibration table furnished with the machine. A needle valve controls the rate of pulsation.

(e) A solenoid valve that controls the water supply to the machine can be actuated by the electric current of a pump to open the valve when the pump operates, and to close it when the pump stops, thus making the machine semiautomatic.

(2) Vacuum-Type Water-Diaphragm Chlorinator. Manufactured by Wallace and Tiernan, Inc., this type of machine has a bell jar set in a tray of water which acts as the water diaphragm (see figs. 34 and 35). A small quantity of water is constantly supplied to the tray to maintain the bell seal, and the excess overflows to waste. In some machines, this water is supplied through a constant-level box with a float-controlled make-up valve. The main elements of this chlorinator are the injectors through which a water supply flows; the chlorine control valve; and, the orifice meter. The injector creates a partial vacuum within the bell jar, thereby causing the water level to rise inside. Chlorine gas passes from the chlorine cylinder through the chlorine pressure-reducing valve and into the bell jar. The pressure-reducing valve is located inside the bell jar and is controlled by a ball-float which moves with the surface of the water within the bell jar. This inside water surface acts as a diaphragm. When it lowers, it causes the float-controlled valve to reduce the chlorine flow into the bell jar and, conversely, it increases the chlorine flow when the water level rises. The bell jar is also provided with a vacuum-relief valve to admit air when the chlorine supply is exhausted, or fails, and the water level in the jar rises. The metering orifice is also located inside the bell jar and above the water level. It controls the flow of the chlorine gas to the injector, where it is mixed with the water to be treated. The rate of feed is proportional to the negative pressure difference between the bell jar and the meter. The amount of vacuum within the meter is controlled by the height of the adjustable suction tube, and is indicated by the rise of water in the annular space within the glass meter tube. A scale mounted on the metering tube indicates the rate of chlorine feed in pounds per 24 hours. This machine can be equipped for manual, semiautomatic or automatic operation.

(3) Vacuum-Type Mechanical-Diaphragm Chlorinator. Manufactured by Wallace and Tiernan, Inc., the chlorine-control valve and compensator in this unit are of the needle and differential diaphragm type (see figs. 36 and 37). Gas pressure is reduced by this combination valve and compensator before metering, and it maintains a constant pressure of chlorine gas against the measuring orifice. The metered flow of chlorine gas is passed through the meter to the injector, where it is mixed with water; the resulting chlo-

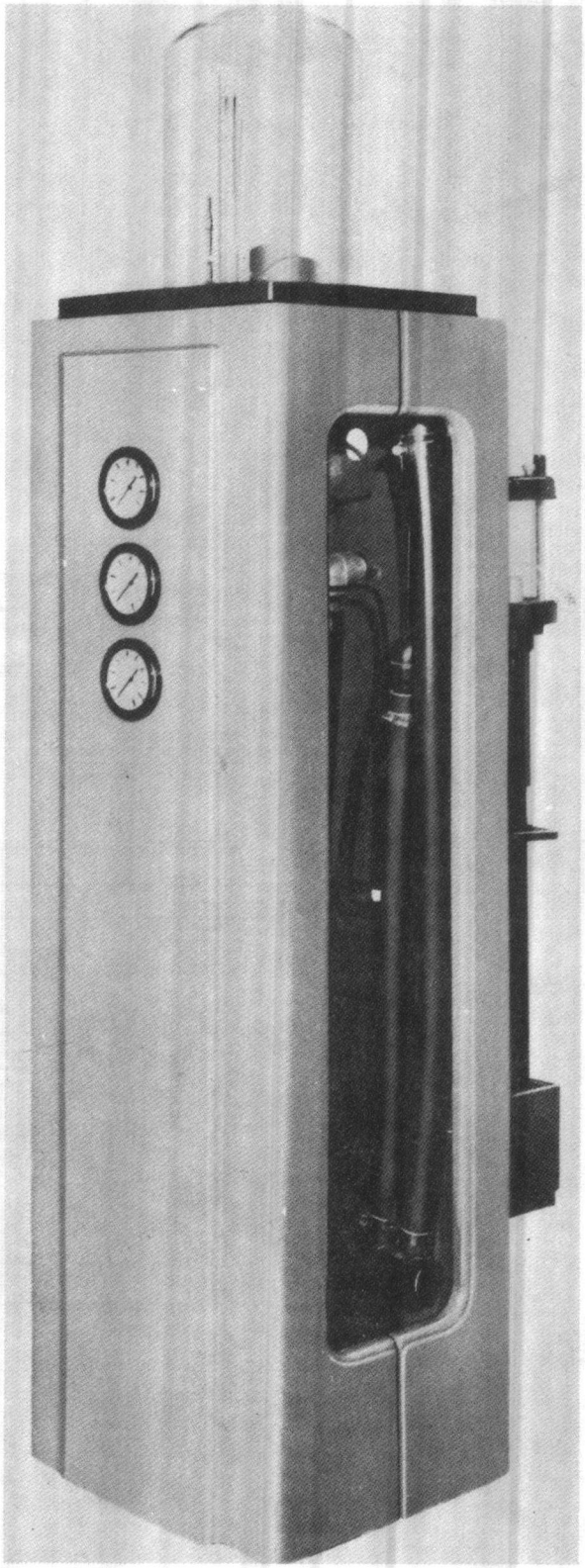


FIGURE 34

Vacuum-Type Water-Diaphragm Chlorinator

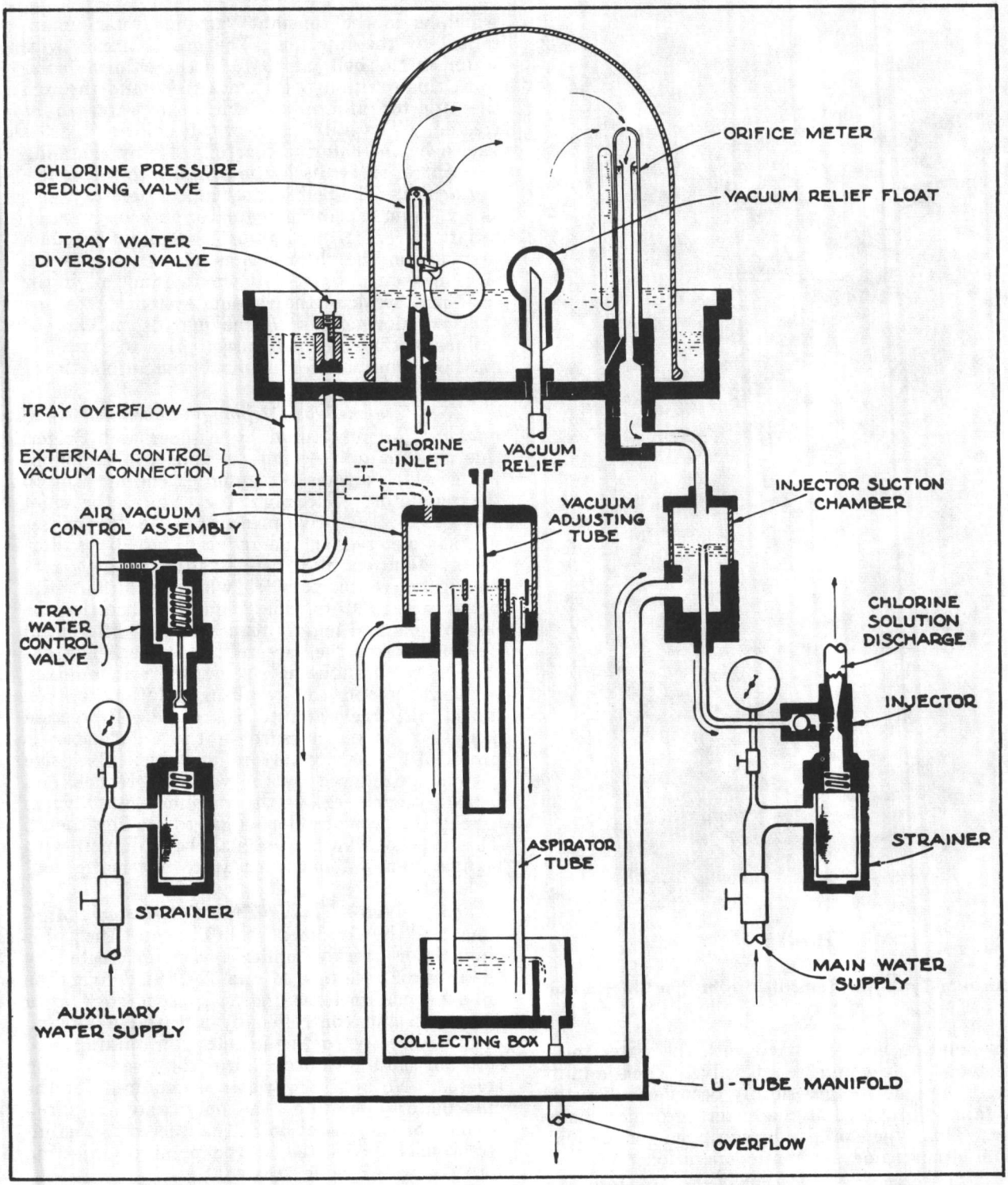


FIGURE 35

Flow Diagram of Vacuum-Type Water-Diaphragm Chlorinator

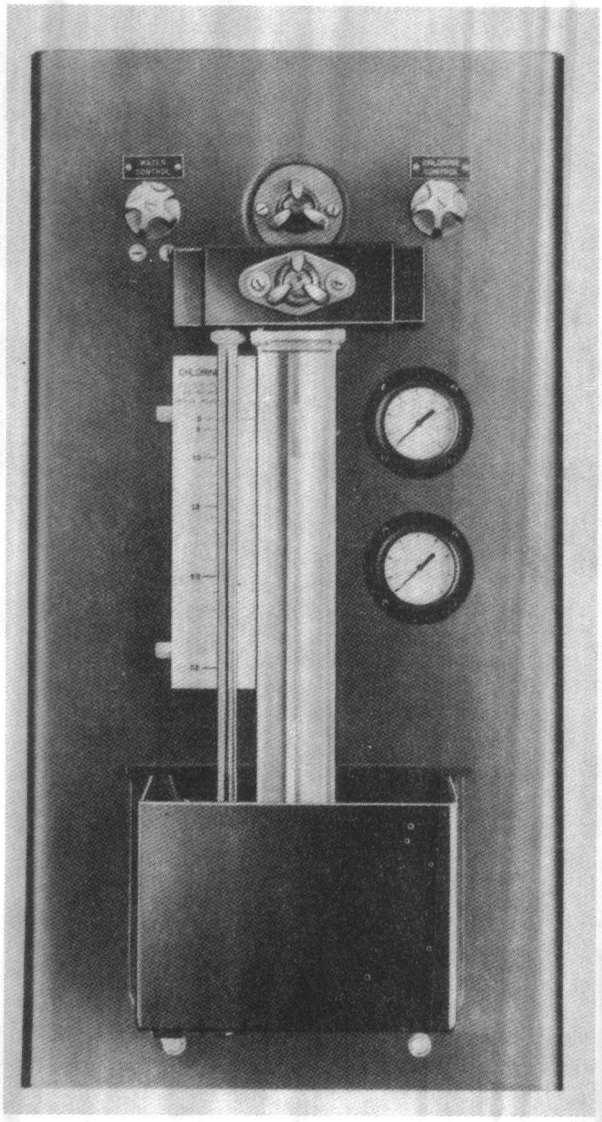


FIGURE 36

Vacuum-Type Mechanical-Diaphragm Chlorinator

rine solution is then mixed with the water to be treated. A vacuum relief valve which admits air if the chlorine gas supply becomes exhausted or fails is provided at the metering orifice chamber. This type can also be equipped for manual, semiautomatic or automatic operation.

(4) Volumetric Vacuum-Type Chlorinator. Manufactured by Builders-Providence, Inc., this machine (see fig. 38) requires water at 25 psi or above to inject chlorine solution against atmospheric pressure. Higher supply water pressures are required for greater injection pressures. Chlorine gas pressure is reduced and controlled by the chlorine control valve and the gas is then metered through a constant orifice to the bell jar, which is in the constant vacuum system maintained by the injector. The gas is mixed with water in the bell jar to form the chlorine solution; this solution is then drawn to and through the injector and mixed with the water to be treated. The rate of flow of chlorine gas is varied by the chlorine control valve by changing the control valve discharge pressure to the metering orifice. The bell jar, set in a water tray, acts as a vacuum control or regulator and as a vacuum relief valve. It maintains a constant vacuum pressure on the chlorine gas after it leaves the chlorine control valve and acts to admit air in the case of a break in the vacuum system, or to discharge chlorine gas to the outside in case of failure of the chlorine control valve to close. It may be equipped for manual, semiautomatic or automatic control.

(5) Vacuum-Type Diaphragm-Controlled Chlorinator. Manufactured by Fischer and Porter, this chlorinator (see figs. 39 and 40) has an injector which creates a vacuum extending back to the regulator. The regulator reduces the chlorine gas to a negative pressure. The flow of gas is then metered at the reduced rate by a flow meter. The gas flow rate is adjusted by a rate setting valve in parallel with the differential pressure regulator. The regulator throttles the flow of gas and maintains a constant differential pressure across the rate setting valve. The gas then flows through the ejector where it is mixed with water and the resulting solution is then mixed with the water to be treated. Protection against positive pressure in the chlorinator is provided by the pressure relief valve. Excessive vacuum is relieved by the vacuum breaker, and loss of vacuum causes the vacuum shutoff valve to stop the flow of chlorine gas to the flow meter. This type of chlorinator may be equipped with manual, semiautomatic or fully automatic controls.

(6) V-Notch Vacuum-Type Chlorinator. Manufactured by Wallace and Tiernan, Inc., this chlorinator operates under a vacuum created by the injector (see figs. 41 and 42). It delivers the chlorine gas, metered in the gaseous state by a rotometer and controlled by a variable V-notch orifice, directly to the injector for mixing into solution and injection into the water being treated. No auxiliary water is required for the chlorinator operation; the only water required is that for the operation of the injector. The injector may be located at the point of injection into the water being treated.

3.2.2.4.5 Hypochlorinators. Hypochlorinators are solution chemical feeders which introduce chlorine into the water supply in the form of hypochlorite solution. They are usually modified positive-displacement piston or diaphragm pumps. However, hydraulic displacement hypochlorinators are also used. Selection of a feeder depends on local conditions, space requirements,

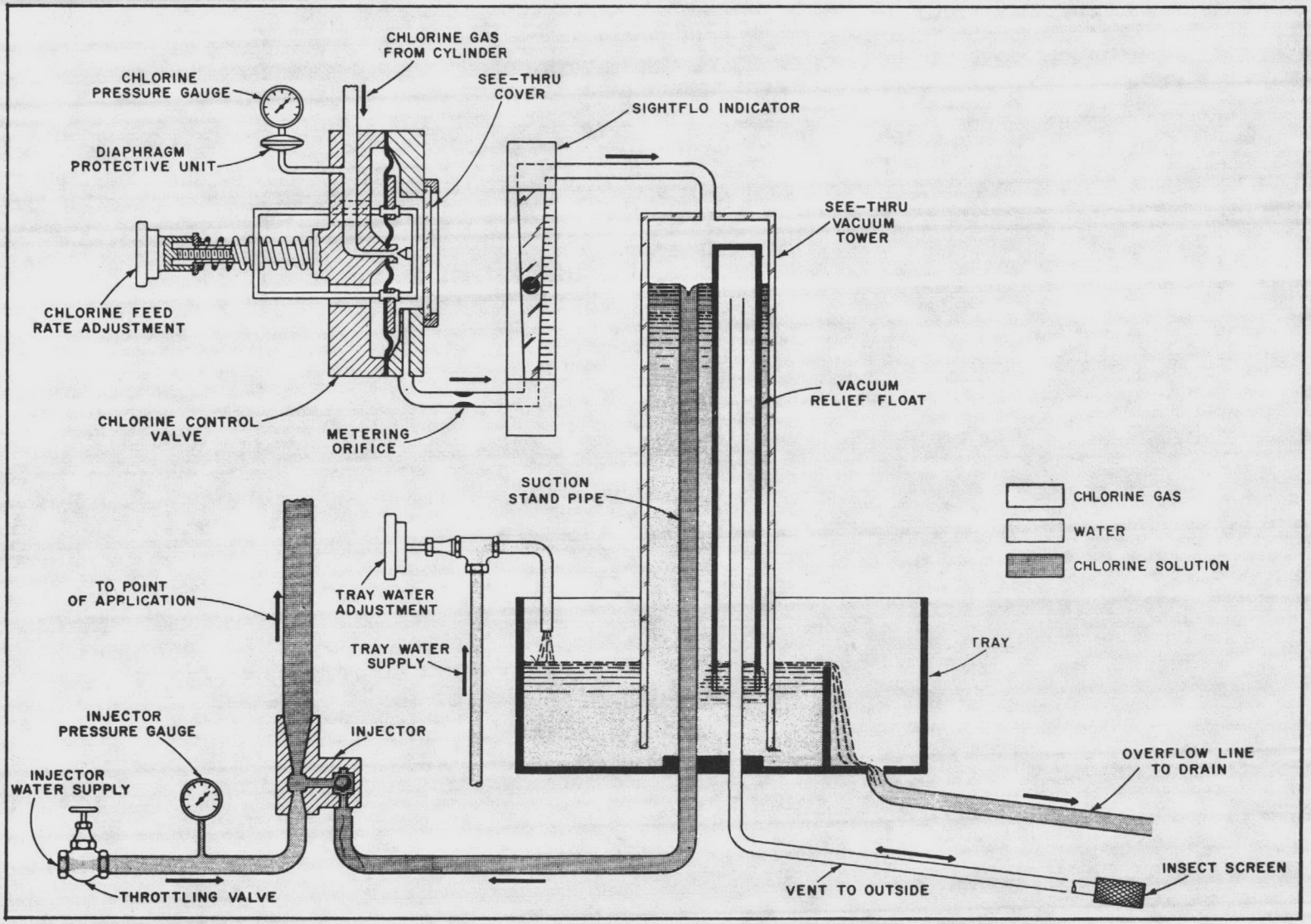


FIGURE 37

Flow Diagram of Vacuum-Type Mechanical-Diaphragm Chlorinator

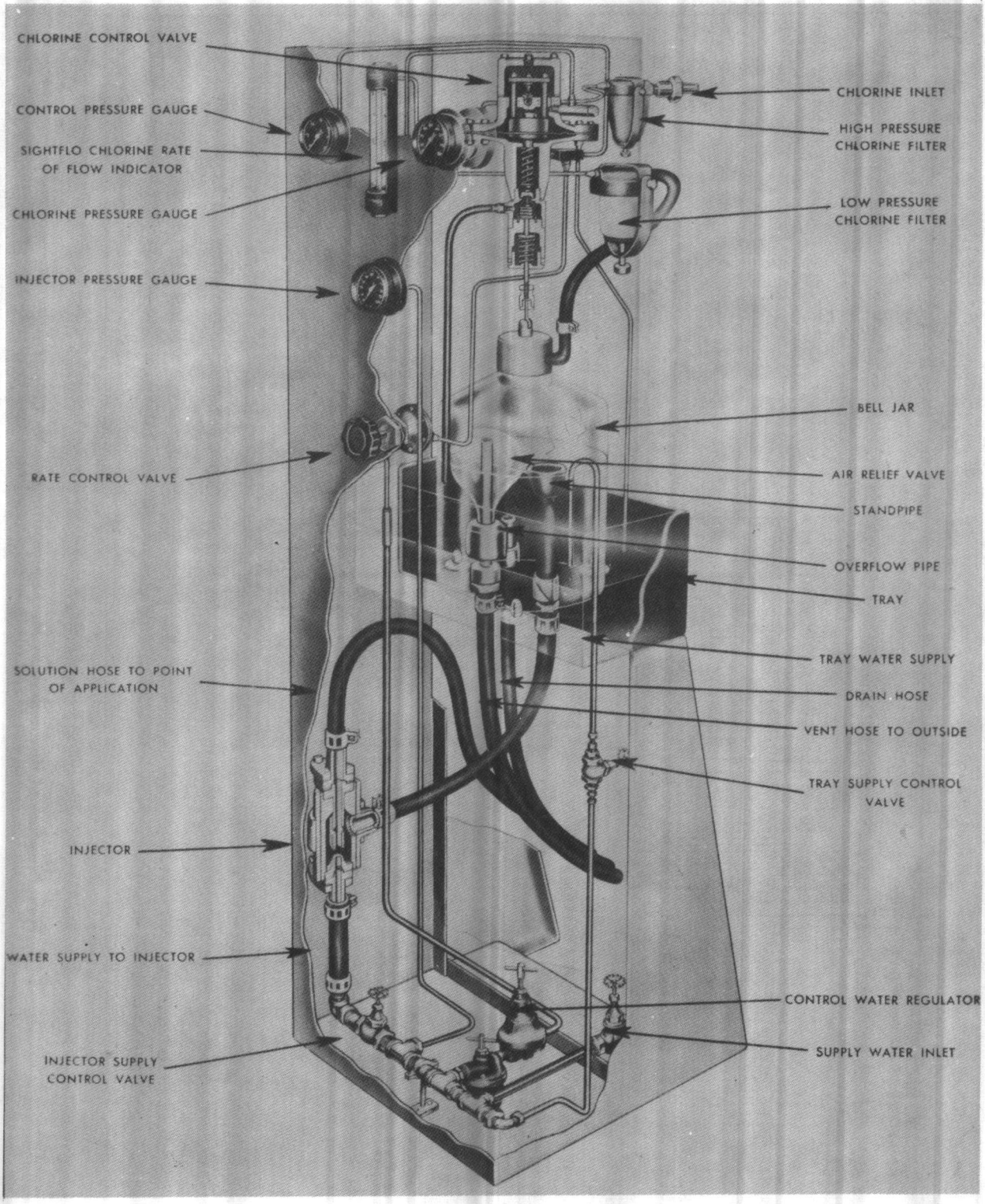


FIGURE 38

Volumetric Vacuum-Type Chlorinator

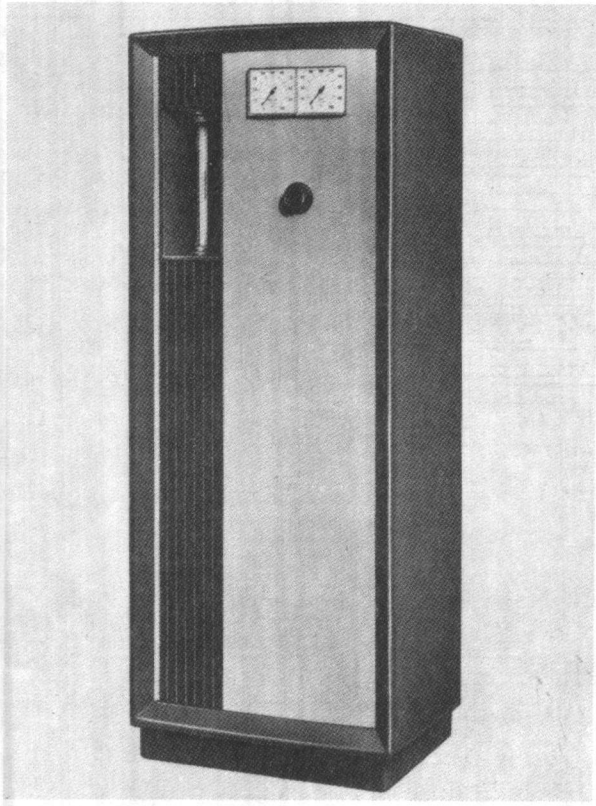


FIGURE 39

Vacuum-Type Diaphragm-Controlled Chlorinator

water pressure conditions and supervision available. Fully automatic types are actuated by pressure differentials produced by orifices, venturis, valves, meters or similar devices. Hypochlorinators are sometimes used as standby equipment for gas chlorinators. Portable equipment is also available which may be used for main disinfection or during emergencies. They can also be used to feed chemicals for scale and corrosion control. Common types of hypochlorinators are described in the following paragraphs.

(1) Proportioneers Chlor-O-Feeder. The Proportioneers Chlor-O-Feeder is a positive-displacement diaphragm-type pump with electric drive (figure 43) or hydraulic operating head (fig. 44). Maximum capacity of the most popular type, the heavy duty Midget Chlor-O-Feeder, is 95 gallons of solution in 24 hours.

(a) Semiautomatic control. The motor-driven type may be cross-connected with a pump motor for semiautomatic control (see fig. 45). The hydraulic type can be synchronized with pump operation by means of a solenoid valve.

(b) Fully automatic control. Motor-driven types are made fully automatic by use of a secondary electrical control circuit actuated by a switch inserted in a disk or compound-meter gear box (see fig. 46). This switch closes momentarily each time a definite volume of water passes through the meter, thus starting the feeder. A timing element in the secondary circuit shuts off the feeder after a predetermined, adjustable number of feeder strokes. In the hydraulic type, the meter actuates gears in a gear box which in turn controls operation of a pilot valve in the water or air supply operating the feeder. The dosage rate is controlled by water flow through the meter, thus automatically proportioning the treatment chemical. Opening and closing frequency of the valve determines the frequency of operation of the Chlor-O-Feeder.

(2) Wallace and Tiernan Hypochlorinator. This hypochlorinator is a positive-displacement diaphragm-type pump. A balancing valve allows water under full main pressure to flow into a chamber on the side of the diaphragm opposite the delivery side, thus balancing the diaphragm under equal pressures. The unit has a maximum capacity of 60 gallons of solution per 24 hours. Basic types and installation are the same as the Chlor-O-Feeder. Figure 47 shows a gasoline-driven unit; figure 48 shows an electric-motor-driven unit; and figure 49 shows a fully automatic hydraulically operated unit.

(3) Wilson-Type DES Hypochlorinator. This type of hypochlorinator is a constant-rate, manually adjusted, electric-motor drive, positive-displacement reciprocating pump for corrosive liquids. Maximum capacity is 120 gallons of solution per day. This unit is a piston pump with a diaphragm and oil chamber separating the pumped solution from the piston to prevent corrosion of working parts.

(4) Model S Hypochlorinator. Manufactured by Precision Chemical Pump Corp., the Model S hypochlorinator is a positive-displacement diaphragm pump with a manually adjustable feeding capacity of 3 to 60 gallons per day (see fig. 50). A motor-driven eccentric cam reciprocates the diaphragm, injecting the solution into the main supply. The use of chemically resistant plastic and synthetic rubber in critical parts contributes to long operating life.

3.2.2.5 Chlorination Control. It is generally accepted that waterborne diseases caused by bacteria are susceptible to control by chlorination of the water supply. On the other hand, the cysts of Endamoeba histolytic are most resistant. Chlorine dosage to produce a minimum adequate chlorine residual should be used routinely for all water supplies where only waterborne bacteria are present. Higher chlorine dosages with higher chlorine residuals should be instituted as the prevailing chlorination practice wherever epidemiological evidence indicates endemicity of nonbacterial waterborne diseases such as amebiasis and infectious hepatitis. The only true guide to proper chlorination is the bacteriological quality of the finished product. The adop-

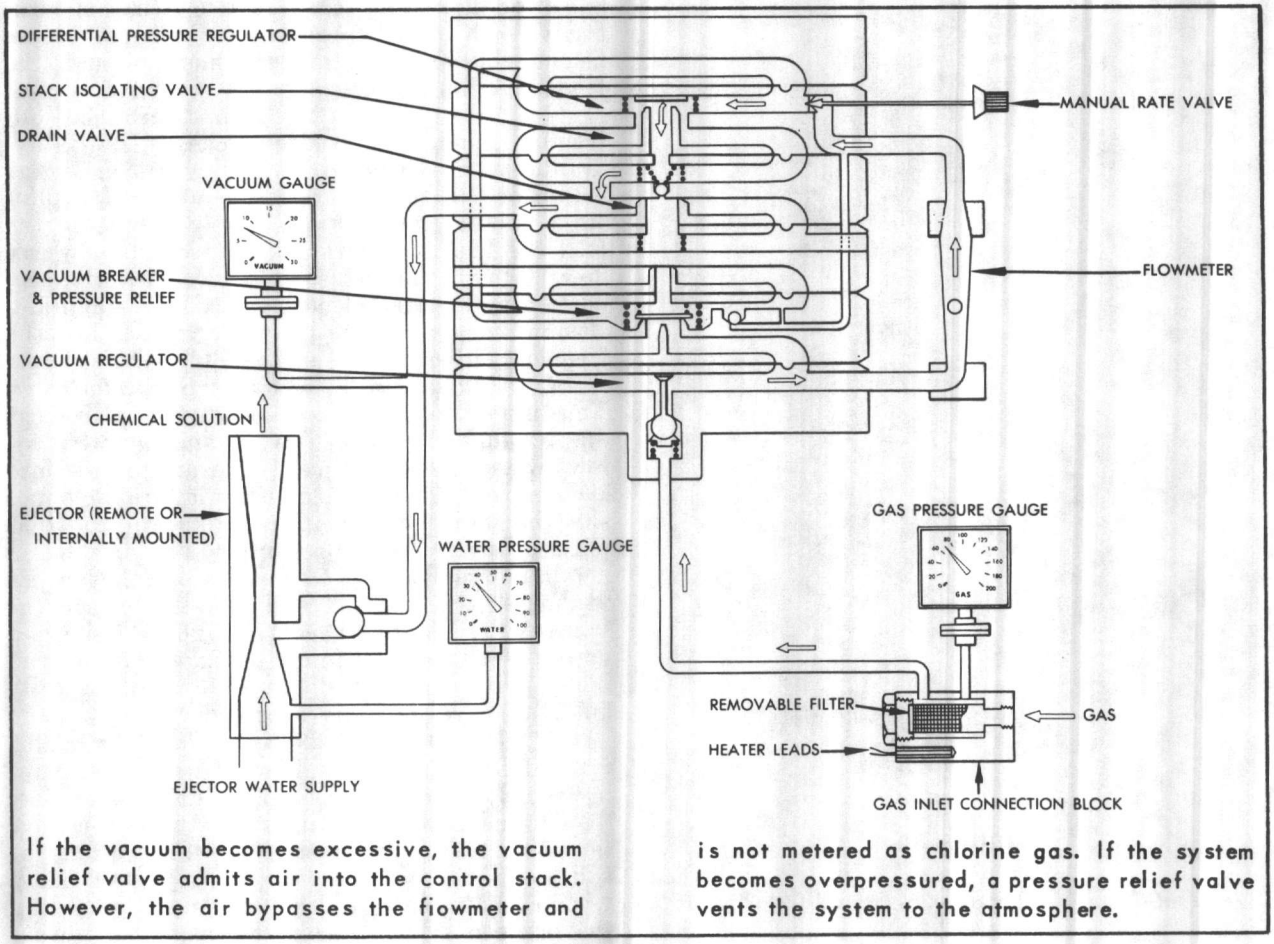


FIGURE 40

Flow Diagram of Vacuum-Type Diaphragm-Controlled Chlorinator

tion and maintenance of minimum chlorine residuals should not minimize, and should never replace, bacteriological analysis as the true measure of potability. Only during actual or potential outbreaks of waterborne diseases is the application of a chlorine residual throughout the entire water distribution system fully justified. During such periods, the residual chlorine concentration should be maintained at levels higher than those maintained in routine practice. (NOTE: In municipal operations, it is common practice to attempt to maintain a minimum residual throughout the distribution system to minimize aftergrowth, since it has been found that the residual is reduced by aeration in storage tanks, by reaction with biological life and organic growth in the system, and by reaction with slowly oxidizable substances in the water.)

3.2.2.5.1 Estimating dosage. To estimate dosage where no prior record of chlorination exists, or where chlorine demand changes frequently, use the following procedures.

(1) Determine the chlorine demand in accordance with the procedure given in the latest edition of "Standard Methods for the Examination of Water and Wastewater" (Reference 7), or start chlorine feed at a low rate and raise feed by small steps; at the same time make repeated residual tests (see par. 3.3.4.1) until a trace is found. Observe the rate of flow treated and the rate of chlorine feed at this point. Chlorine demand is then determined from the following equation.

$$\text{Demand in p.p.m.} = \frac{\text{Rate of feed (lbs per day)}}{8.34 \times \text{flow (m.g.d.)}}.$$

(2) Add the minimum p.p.m. of required residual to the chlorine demand (in p.p.m.) to estimate the p.p.m. dosage required for a satisfactory residual. Then set the chlorinator rate of feed in accordance with the dosage estimated. Further upward adjustments after making residual tests are usually required because the demand increases as the residual increases.

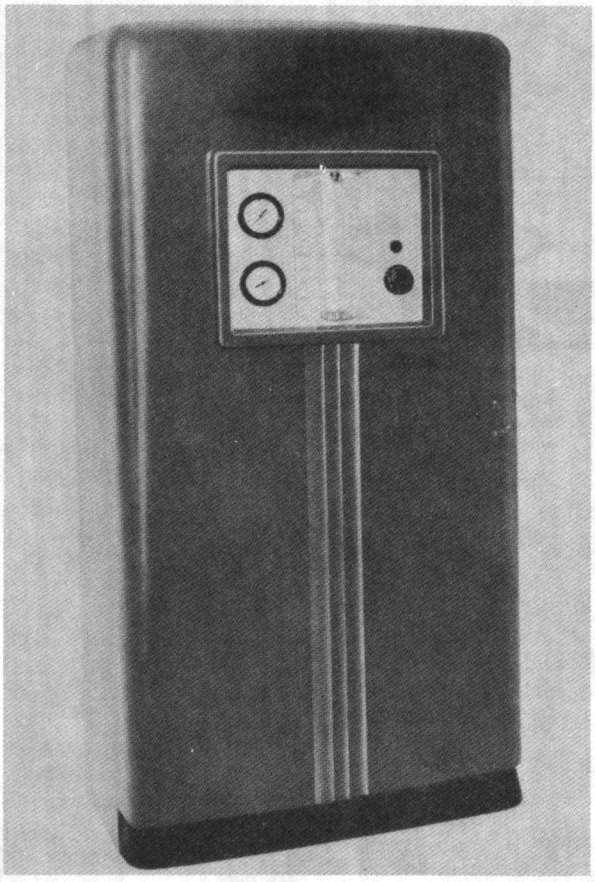


FIGURE 41

V-Notch Chlorinator

3.2.2.5.2 Checking rate of feed. To ensure that the chlorinator is feeding the indicated amount, the cylinders are usually mounted on a platform scale. Loss in weight during the check period is observed and the following equation employed.

$$\text{Feed rate (lbs per day)} = \frac{\text{Loss in weight (lbs)} \times 24}{\text{Check period (hr.)}}.$$

The rate of feed of hypochlorinators is found from the loss in volume of gallons of solution by determining the change in the depth of the solution in its container. Knowing the solution strength, the chlorine used can be calculated in pounds. Substituting this value in the above equation for the loss in weight, the pounds per day may be determined.

3.2.2.5.3 Residual tests. The application of chlorine or its compounds must be effectively controlled within definite limits to ensure economical and effective chlorination. The chlorine residual test is the practical basis for control. It is described in paragraph 3.3.4.1.

(1) Distribution-System Tests. Where distribution-system residual losses are relatively high and therefore govern feed, the residual required at the point of application is determined from local experience, and is used for immediate control purposes. However, this relationship changes with water temperature, quality and rate of consumption, and with the amount of organic matter and slimes in the distribution system. Daily tests of residuals in the distribution system are therefore necessary.

(2) Example. For example, to maintain a measurable chlorine residual in the far parts of a given distribution system, it may be found that 0.8 p.p.m. residual is required at the point of application in the summer, and 0.6 p.p.m. in the winter. Residual tests are made hourly at the point of chlorination, and the manual chlorinator is adjusted upwards or downwards as necessary. Less frequent tests are needed with semiautomatic or fully automatic chlorinators, but the residual must be determined in any case at least three times daily—at times of low, average, and maximum flows.

3.2.2.5.4 Preparing hypochlorite solutions. The available chlorine content of the chlorine compound used must be known in order to calculate the rate of hypochlorite solution feed. The available chlorine is usually marked on the container as a percentage of weight. Values generally are as follows.

Chemical	*Available chlorine (percent)*
Calcium hypochlorite	70
Sodium hypochlorite (liquid)	15
Chlorinated lime	35

(1) Weight of Chemical Required. To find the actual weight of the chlorine compound to be added, use the equation.

$$\text{Chemical required (lbs)} = \frac{\text{lbs of chlorine required} \times 100}{\% \text{ available chlorine}}.$$

(2) Dosing Solution Required. To find the amount of one percent dosing solution needed to treat a given quantity of water with the desired dosage, use the equation.

$$\text{Dosing solution required (gal.)} = \frac{\text{Volume treated (gal.)} \times \text{desired chlorine dosage (p.p.m.)}}{10{,}000}$$

(3) Solution Preparation. To prepare various quantities of 1 percent dosing solution, use the amounts in Table 2.

(4) Feed Rate. To find the rate of feed of chlorine in gallons per day, use the equation.

$$\frac{\text{Chlorine rate of feed (g.p.d.)} = \text{flow (m.g.d.)} \times \text{dosage (p.p.m.)}}{\text{dosing solution strength (\%)} \times 10{,}000}.$$

(5) Solution Strength. To find the number of pounds of chlorine compound needed to prepare a dosing solution of the desired strength, use the equation.

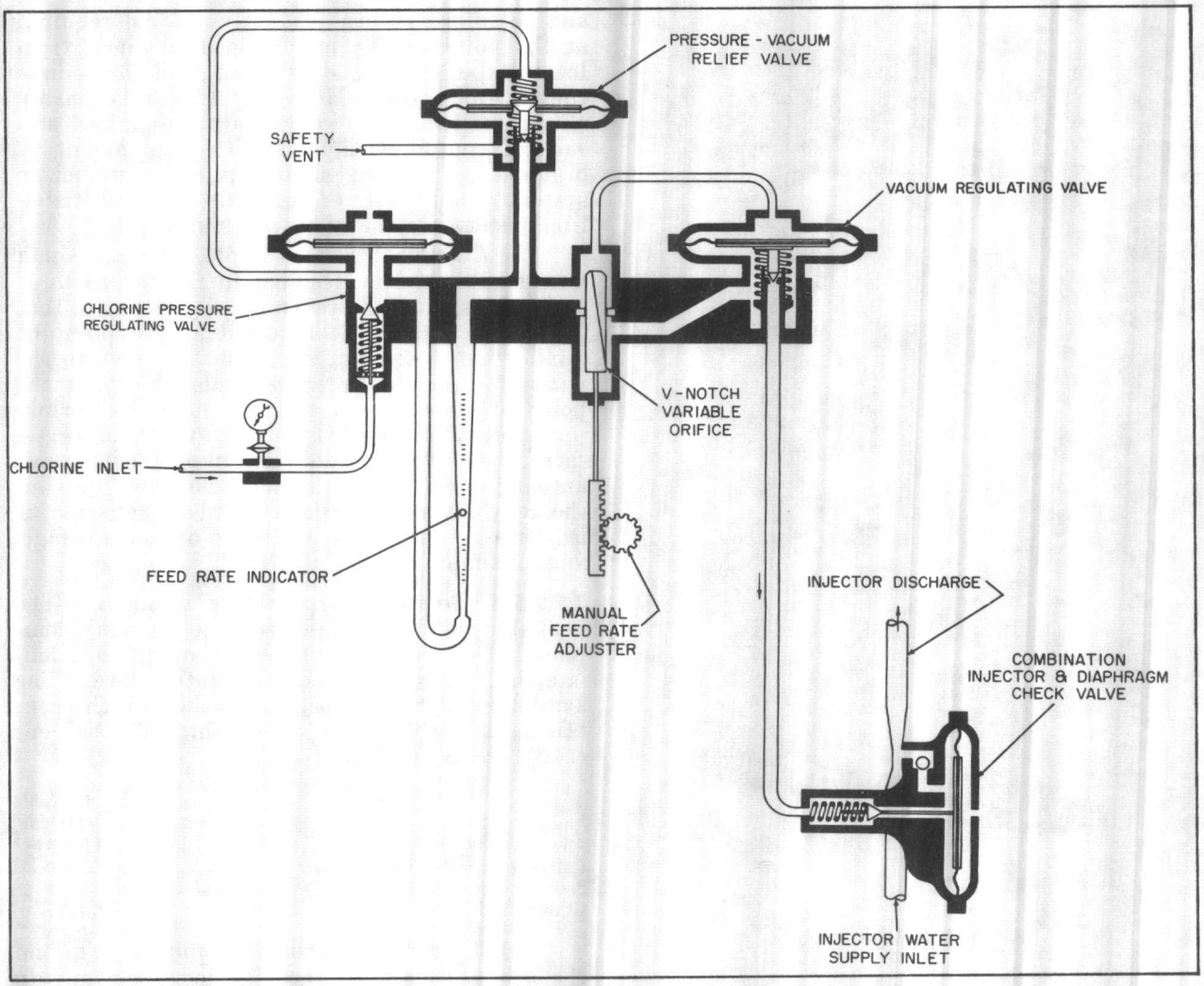


FIGURE 42

Flow Diagram of V-Notch Chlorinator

TABLE 2

Chlorine Compounds Used to Prepare 1 Percent Dosing Solution

Dosing solution (gal.)	Dry chemicals				Hypochlorite stock solution			
	Calcium Hypochlorite 70% avail. Cl_2		Chlorinated lime 35% avail. Cl_2		(gal.) Available chlorine			
	(lbs)	(oz.)	(lbs)	(oz.)	15%	10%	6%	5%
5	0	9½	1	3	⅓	½	⅚	1
10	1	3	2	6	⅔	1	1⅔	2
15	1	12½	3	9	1	1½	2½	3
20	2	6	4	12½	1⅓	2	3⅓	4
25	2	15½	5	15½	1⅔	2⅓	4⅙	5
30	3	9	7	2½	2	3	5	6

$$\text{Weight of compound required (lbs)} = \frac{\text{strength of solution (\%)} \times \text{volume required (gal.)} \times 8.34}{\text{\% available chlorine in compound}}$$

(6) Stock Solution Required. To find the gallons of hypochlorite stock solution needed to prepare a dosing solution of the required strength, use the equation.

$$\text{Volume stock solution required (gal.)} = \frac{\text{strength of dosing solution (\%)} \times \text{volume of dosing solution required (gal.)}}{\text{strength of stock solution (\%)}}.$$

3.2.2.6 Disinfection of Water Supply System Components. Water mains, wells, filters, storage tanks and other components of a water supply system become contaminated during construction and repair. Flushing the system to remove dirt, waste and surface water is the first step, but it is not a sufficient safeguard. To ensure a safe water supply, each unit of the system must be thoroughly disinfected before it is placed in operation. Disinfection procedures are set forth in "A Standard Procedure for Disinfecting Water Mains", AWWA Standard C–6 1–54 (Reference 8).

3.2.2.6.1 Disinfecting agents. The chemicals used in disinfecting a water supply system are the same as those used in disinfecting water, e.g., a hypochlorite solution or chlorine gas.

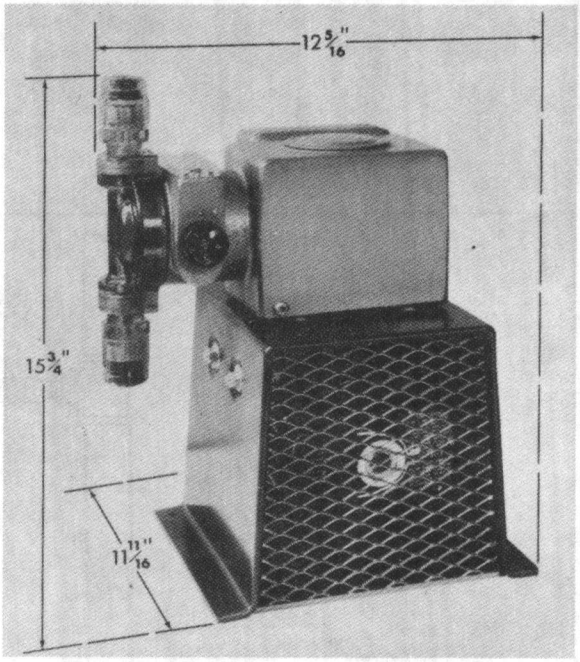


FIGURE 43

Electrically-Driven Proportioneers Chlor-O-Feeder

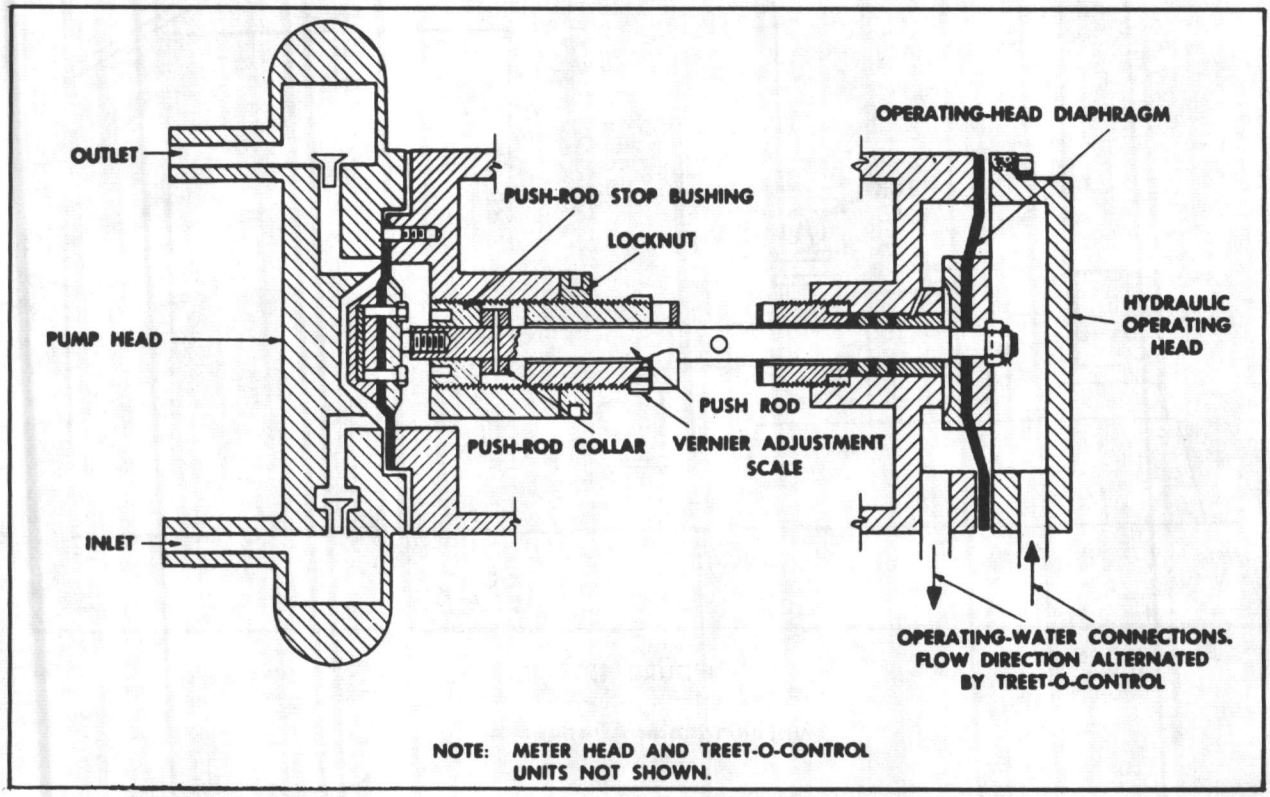


FIGURE 44

Diagram of Manually-Controlled Hydraulically-Driven Hypochlorinator

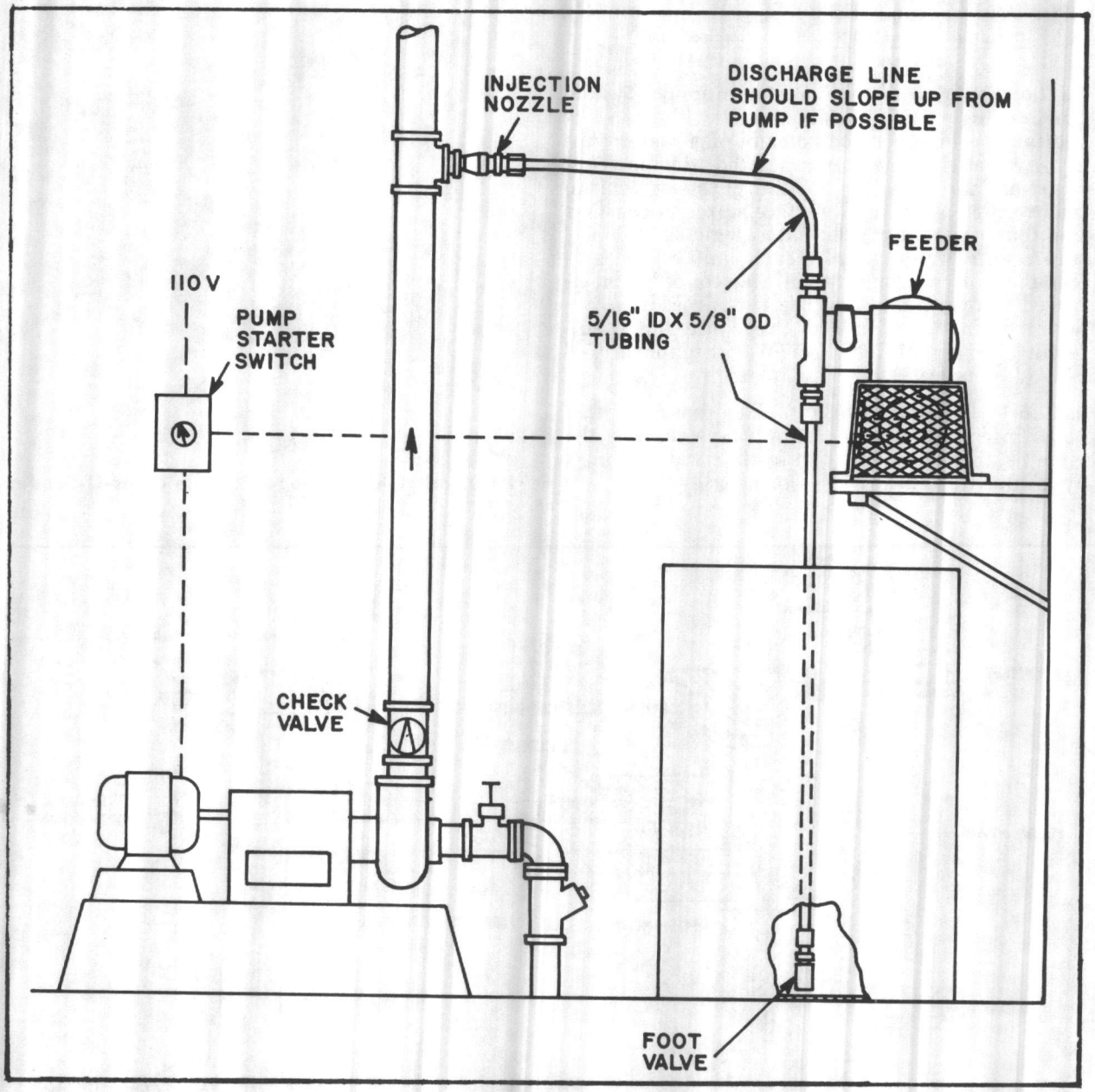


FIGURE 45

Hypochlorinator Arrangement

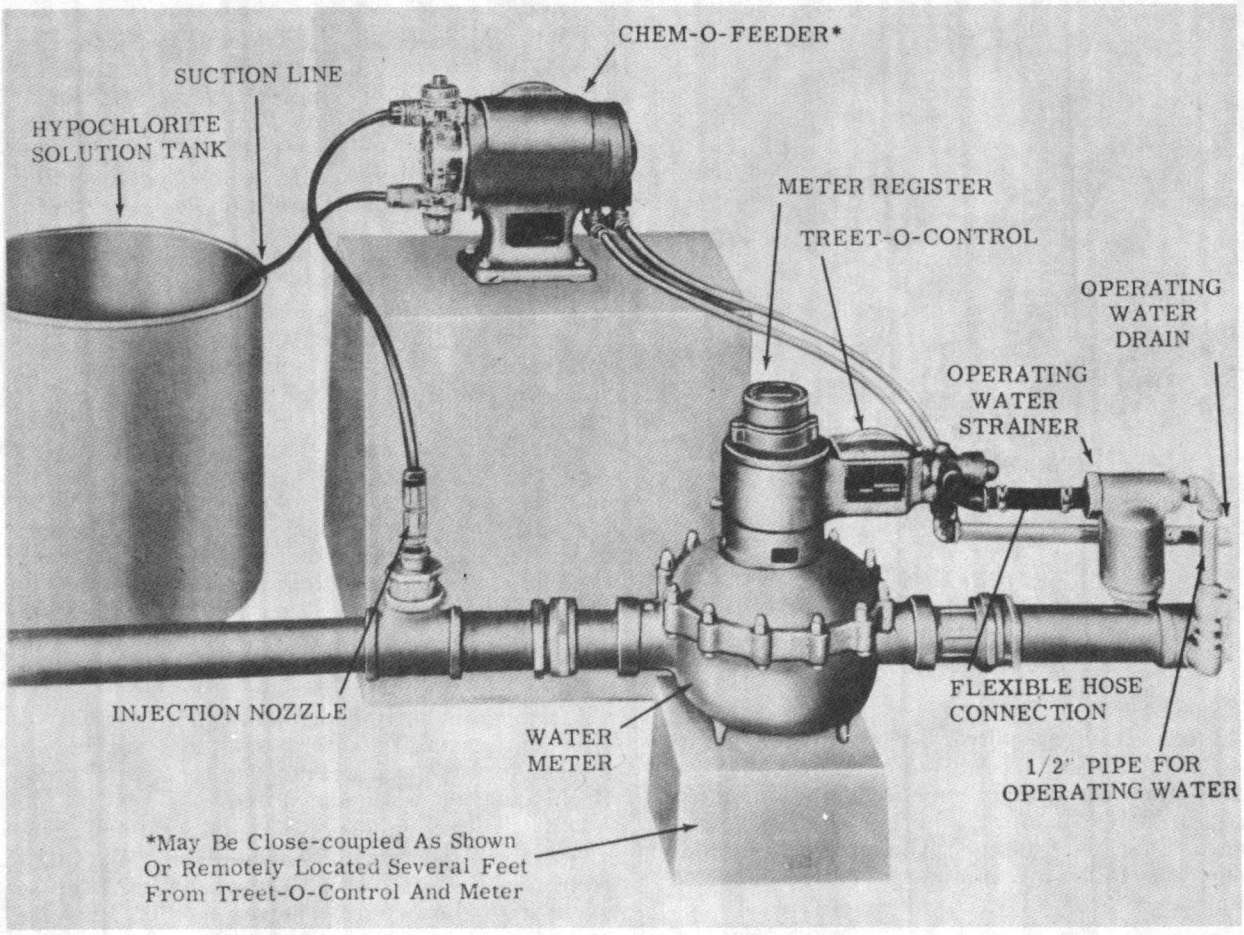


FIGURE 46

Motor-Driven Hypochlorinator with Fully Automatic Control

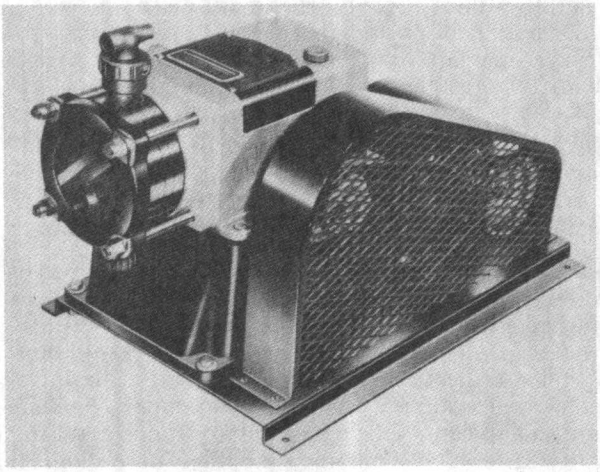


FIGURE 47

Manually-Controlled Gasoline-Motor-Driven Hypochlorinator

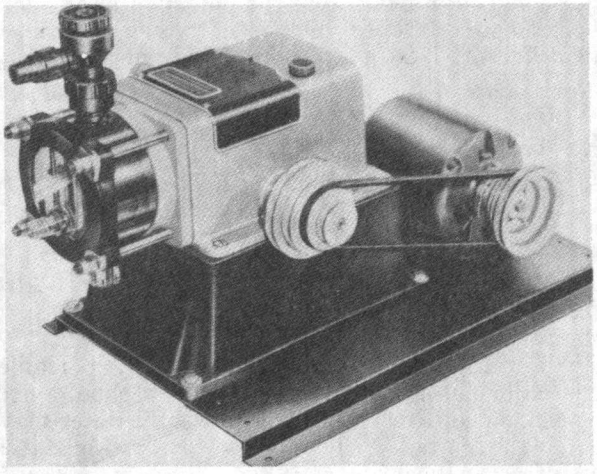


FIGURE 48

Manually-Controlled Electric-Motor-Driven Hypochlorinator

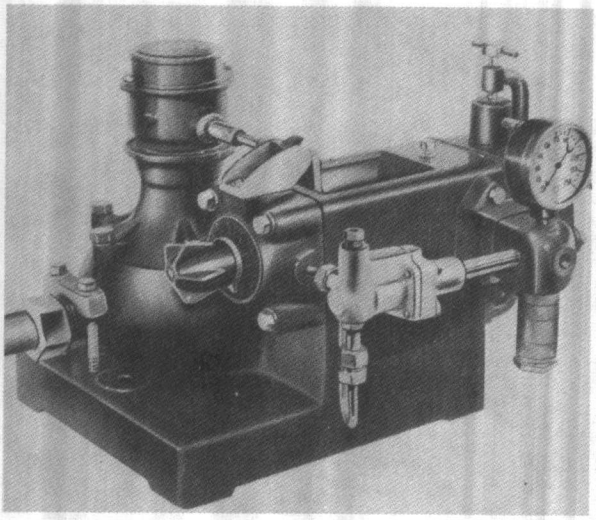


FIGURE 49

Fully Automatic Hydraulically-Operated Hypochlorinator

3.2.2.6.2 Dosage required. The chlorine dosage required to disinfect any unit thoroughly depends upon the contact time, and the amount of jute, untarred hemp and organic chlorine-consuming material present. Under average conditions, the following minimum dosages are recommended.

Unit	*Minimum dosage (p.p.m.)*
Pipe	50
Storage tank	50
Filter	100
Well	150

The volume of water in the unit to be disinfected must be computed before the chlorine dosage can be estimated. The volumes of water contained in different sizes of pipe are listed below.

Pipe diameter (in.)	*Volume per ft. of pipe (gal.)*
6	1.47
8	2.61
10	4.08
12	5.88
16	10.45
20	16.32

3.2.2.6.3 Methods of applying disinfectant. The following methods of applying disinfectants should be observed.

(1) Liquid chlorine is applied by portable gas chlorinators. Chlorine cylinders should not be connected directly to mains because water may enter the cylinder causing severe corrosion and resulting in hazardous leakage.

(2) Hypochlorite solution is usually applied by measuring pumps, gravity-feed mechanism or portable pipe disinfecting units.

3.2.2.6.4 Procedures. Personnel applying disinfectants should follow these procedures.

(1) Before adding disinfectant, the section should be flushed thoroughly with water until all dirt and mud is removed. A velocity of at least 3 feet per second is required for adequate scouring.

(2) Stop all branches and other openings with plugs or heads properly braced to prevent blowouts.

(3) Disinfect the water mains in sections introducing the disinfecting agent through taps or hydrants at the ends of each section.

(a) If a portable gas chlorinator or hypochlorinator is available, introduce the discharge from the chlorinator into an auxiliary water line leading to one of the hydrants or taps. Bleed the air from the line at high points and crowns. Add the predetermined chlorine dosage as the main is slowly filled with water. Continue feeding until the water discharging at the other end of the section contains the desired residual chlorine. Let the chlorinated water remain in the contaminated unit or section for 24 to 48 hours. Then flush until the chlorine residual is only that amount normally in the supply. Make daily bacteriological analyses of water samples until the analyses show no further disinfection is required. Frequently, unsatisfactory samples will be obtained for a week or more after disinfection. Rechlorination is then required.

(b) If a chlorinator is not available, feed a strong hypochlorite solution into the main from a pail through the highest hydrant top or valve with the bonnet removed. Add the hypochlorite and water until the main is full and the chlorine residual is about 50 p.p.m. Test the residual at the far end of the main. Bleed out any air trapped in the line.

(c) If the mains are to be disinfected under pressure using supply or booster pumps, feed the chlorine into the main with gas chlorinators or hypochlorite feeders. Take care to ensure adequate and accurate distribution of the disinfecting agent when using pumps.

(d) The use of dry calcium hypochlorite directly in mains is not uniformly effective because of unequal mixing with the water. Therefore, if calcium hypochlorite is to be used, a solution of this chemical should first be prepared.

3.2.2.6.5 Emergencies. Natural contamination of water supplies may increase markedly because of emergency conditions. Standby or portable chlorinators must be maintained in working condition to meet emergency disinfection requirements in water supply components. This equipment cannot be expected to make drinking water safe after bombing, sabotage or biological warfare have rendered it unsusceptible to disinfection by chlorination.

(1) Wartime Emergencies. Information on the treatment and protection of water supplies subjected to contamination by atomic, biological or chemical warfare is covered in "ABC War-

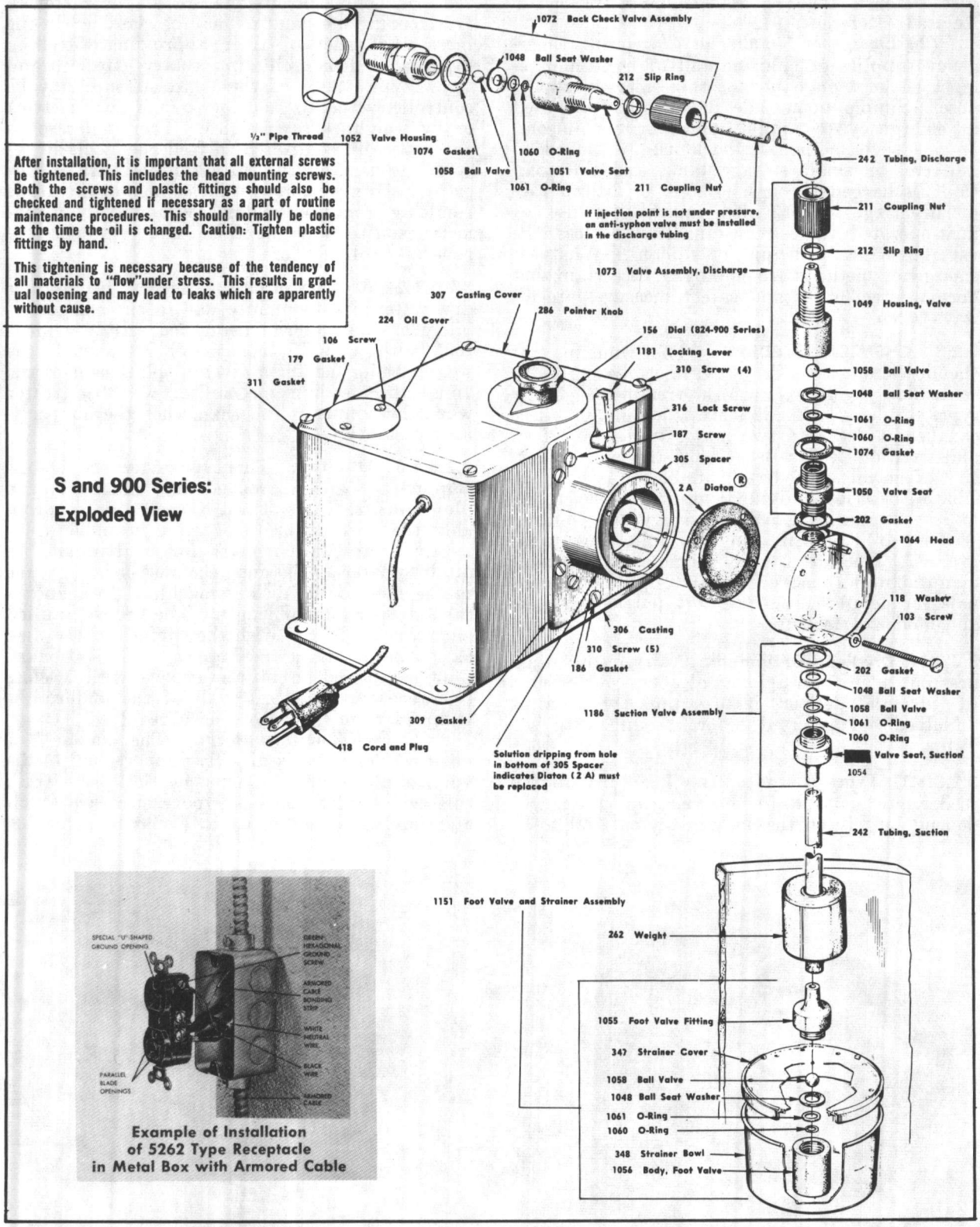


FIGURE 50

Model S Hypochlorinator

fare Defense Ashore", NAVDOCKS TP–PL–2, Revised (Reference 9).

(2) Emergency Supplies of Chemicals. Emergency supplies of chlorine and of hypochlorites must be kept on hand for this emergency purpose. Simple homemade devices may be used in emergency to apply hypochlorite solutions. In one such method, hypochlorite is mixed in a barrel or small storage tank, and the solution discharged through a hose. Uniform rate of discharge is provided by making use of float-operated valves, constant-head devices, the variable-orifice principle, or siphons. Whatever emergency methods are employed, be certain that normal precautions and safety measures are always taken.

3.2.3 CHEMICAL FEEDERS. The amounts of chemicals added to the water must be carefully controlled to ensure uniform treatment. Many types of chemical feeders are available, but they can be divided into two major types—dry feed and solution feed. Because of the wide diversity of chemical feeders available, it is not feasible to describe individual units. However, the more common designs of both dry and solution feeders are discussed in the following paragraphs. Operators are instructed to consult manufacturer's instruction and operating manuals for details concerning any particular make and model of feeders.

3.2.3.1 Dry Feed Equipment. A dry feeder measures out a uniform amount of chemical per unit of time and delivers it to a tank, where it is dissolved or dispersed before mixing with the water.

3.2.3.1.1 Types of dry feeders. The type of dry feeder most suitable for a given application will depend largely on the amount of material to be fed per hour, and the nature of the material. Dry feeding mechanisms may be classified in the increasing order of their approximate feeding capacity as disk, oscillating, rotary gate, belt and screw type. Any of these mechanisms may be controlled so as to feed by volume (volumetric) or by weight (gravimetric). They can also be automatically controlled to feed chemicals in response to demand, such as variation in water flow or pH. However, unless the savings in chemicals resulting from the greater accuracy of the gravimetric control warrant it, the smaller feeders are generally volumetric.

3.2.3.1.2 Accuracy of feed. Errors in feeding dry materials are mainly due to the compressibility of the material being fed. It is evident that with a fluffy, compressible material, the weight being fed for a given displacement of the volumetric feeding mechanism will be greater when the hopper is full than when the hopper is nearly empty.

3.2.3.1.3 Disk type. This type of feeder (fig. 51) employs a rotating grooved disk and stationary plow for feeding. The grooved disk is probably the most accurate of all continuous volumetric feeding mechanisms for small quantities of dry materials because the measuring groove in the face of the disk is machined to a known capacity per unit of length. The groove is filled and struck off level with the surface of the disk as it emerges from the hopper. The stationary plow is shaped to fit the groove with a close tolerance and practically all of the material is removed from the groove as it revolves.

(1) Feed Rate Adjustment. The amount of material delivered is directly proportional to the number of revolutions made by the disk. With this type feeder, various groove sizes are available having capacities up to a maximum of 400

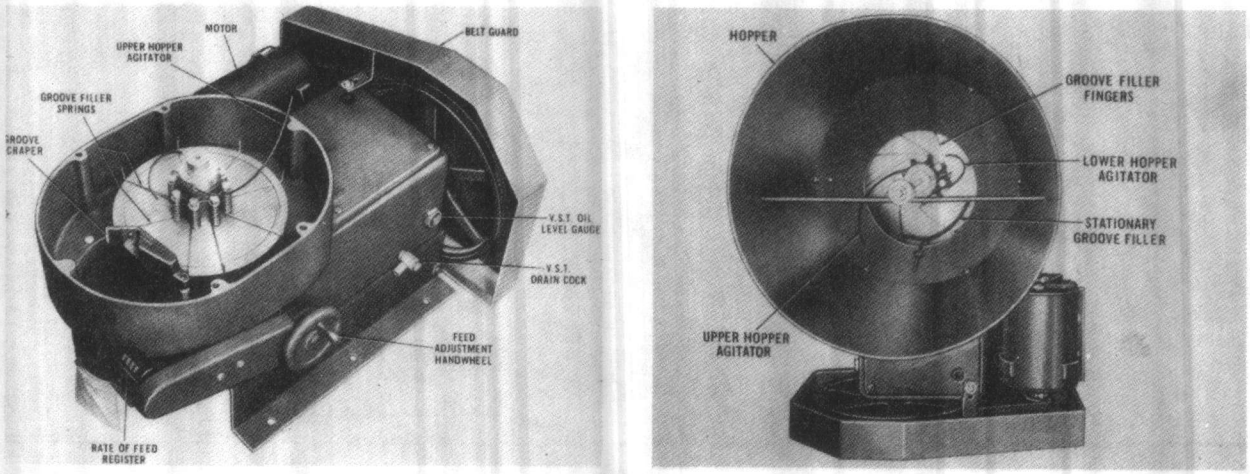


FIGURE 51

Disk-Type Chemical Feeder

ounces (25 lbs) per hour. A downward adjustment range of approximately 100 to 1 is obtainable through a variable speed drive. The maximum feed rate given above is based on 150 r.p.m. of the disk and material weighing 65 lbs per cubic foot.

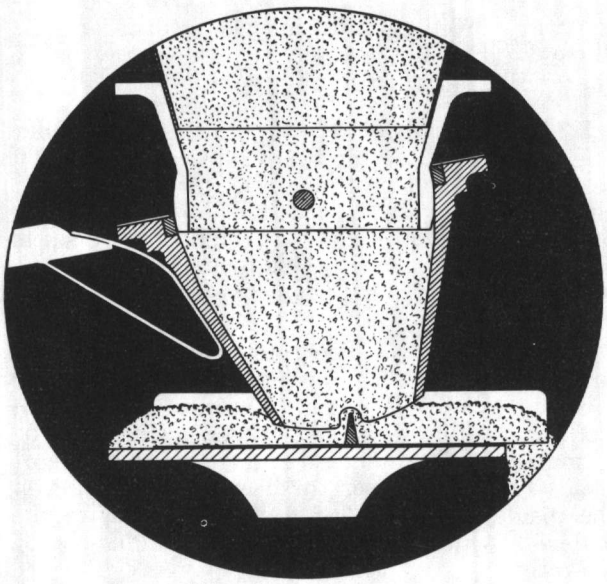
(2) Accuracy of Feed Rate. With a shallow hopper and a noncompressible material, accuracy will be well within plus or minus 1 percent by volume, or plus or minus 3 percent by weight. The disk feeder is suitable for such water treating chemicals as hydrated lime, soda ash and activated carbon; and for average feeding rates of 10 lbs per hour. Where higher rates of feed are desired, the groove is omitted and various widths of plows or spiral openings are inserted between the plate and the underside of the hopper to pull more or less material off the edge of the disk. Either of two methods is generally used; the first is to adjust the orifice by positioning a knife, and the second is to use a fixed plow and to vary the speed of the disk. The accuracy of this latter type feeder is within ±5 percent by volume.

3.2.3.1.4 Oscillating feeder. This type of feeder (fig. 52) has an average range of from 10 to 200 lbs per hour with an accuracy of within ±3 percent by volume under fair conditions. With compressible materials, such as hydrated lime, this range of variation may increase to between 5 and 6 percent.

(1) Method of Operation. In the oscillating- or reciprocating-type feeder, the motor drives a connecting rod to oscillate the hopper in either direction. This motion pushes a measured portion of the material on to the receiving tray, from which the material is scraped to fall into the mixing chamber or other suitable receptacle, e.g., a lime slaker. The length of stroke or degree of oscillation is controlled by a micrometer screw on the connecting rod. This screw also provides the means to adjust the distance between the bottom of the feed tray and the end of the oscillating nozzle.

(2) Agitators in Hopper. Agitators consisting of a pair of plates on opposite sides of the hopper are used when feeding hydrated lime or materials weighing no more than 40 lbs per cubic foot. These plates are given a slight vertical movement through a bell crank on the oscillating hopper. The material fills the oscillating throat and tray beneath. As the oscillating throat moves back and forth, a scraper is moved first to the right and then to the left; as it moves it pushes a measured amount of material off the tray.

(3) Feed Rate Adjustment. The width of the tray is fixed, but the depth of material on it may be changed to suit various conditions and materials by raising or lowering the tray. Ordinary changes in the rate of feed are made by changing the stroke length or the backward and forward travel of the oscillating throat, not by moving



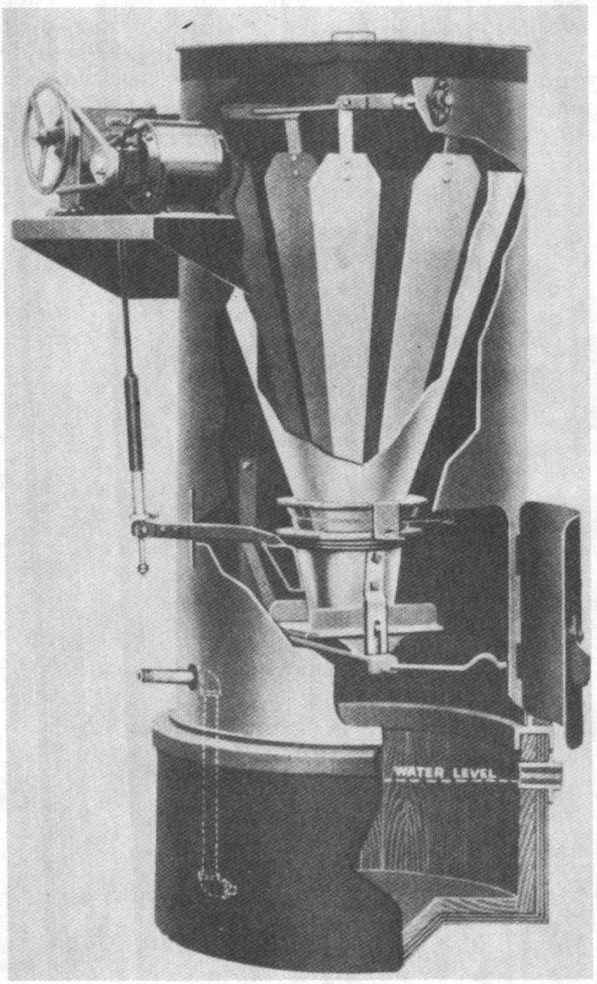


FIGURE 52

Oscillating-Type Chemical Feeder

the tray. Feeding rates may be adjusted over a 40 to 1 range for any setting of the tray below the oscillating throat.

3.2.3.1.5 Rotary gate feeder. This type of feeder (fig. 53) is suitable for feeding rates of from 200 to 500 lbs per hour of material with free flowing characteristics. It consists of a horizontal drum or rotor with a series of equal-sized pockets around the outer face. This drum is mounted at the lower end of a hopper between spring-loaded pressure plates.

(1) Feed Rate. The rate of feed is directly proportional to the number of revolutions per minute made by the drum. Rotors are made with shallow, medium or deep pockets to suit the type of material being handled and the desired rate of feed. Outside scrapers or heavy balls riding on the inside of the rotors are used to remove the material which may cling to the underside of the rotors.

(2) Accuracy of Feed Rate. The rotary gate feeder is in many ways similar to the disk feeder described previously, as it will deliver an equal volume of material for each revolution. The uniformity of delivery by weight, however, depends upon the characteristics of the material being fed. Light compressible material will weight more per cubic foot, when it is compacted by the weight of material in a full hopper. Granular material that is not uniformly graded may become classified in handling so that part of the time the machine will feed all fine or all coarse material, and part of the time a composite mixture. Aside from these variations which may be as much as 10 to 15 percent by weight, the usual specification calls for an error not to exceed ±5 percent by volume.

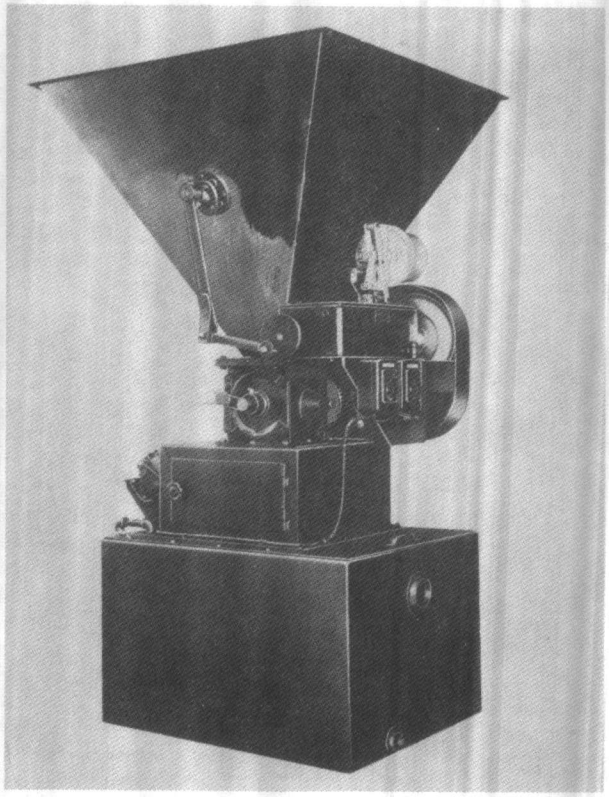


FIGURE 53

Rotary or Star Chemical Feeder

3.2.3.1.6 Belt-type feeder. This type of feeder (Figure 54) is usually employed with gravimetric controls. The belt-type gravimetric feeder is suitable for average feeding rates of from 500 to 20,000 lbs per hour, although for water treatment applications, requirements only occasionally reach 5,000 lbs per hour. The feeder may consist of a vibratory mechanism having a small material-supply hopper with a built-in shutoff gate, a short conveyor belt suspended from a scale mechanism and a variable speed transmission drive for the belt. One type of machine uses an electronic vibratory feeder instead of a mechanical vibrator. Large sizes of this machine may use a control gate positioned by the weight of material on the belt.

(1) Feeding Mechanism. Material flows from the hopper through the adjustable gate to the vibrating feeder tray from which it is discharged onto the weigh belt. The vibrating movement is imparted to the tray by a cam-operated oscillator through a wedge-shaped rubber bumper hanging freely from the scale beam between the oscillator jaws and the opposing jaw, which is attached to the feeding tray.

(2) Control Mechanism. Thus, when the beam and control wedge are lowered because of insufficient weight of the material on the belt, the amplitude of the feeding tray is increased, causing a greater feed. Vice versa, too much weight on the belt tilts the scale beam up and retracts the wedge, thereby decreasing the feed. Since a ⅛-inch vibrating movement of the tray will produce maximum feed, the feeder will respond to the most minute fluctuations of the scale beam. The momentary contact of the oscillator jaws with the wedge does not affect the sensitivity of the beam. A regulating knob at the oscillator mechanism adjusts the jaw opening at the proper distance, so that the scale beam will be level or "neutral" when the wedge has engaged sufficiently to effect the proper feed for the particular kind of material being handled.

(3) Feed Rate Adjustment. Changes in feed rate are obtained by adjusting the variable speed transmission to drive the belt at the desired speed when carrying a predetermined load per foot of belt. For example, with a belt travel of 1 foot per hour, the feeder will deliver 20 lbs per hour. On the other hand, 20 lbs per foot and a travel of 100 feet per hour will deliver 2,000 lbs per hour.

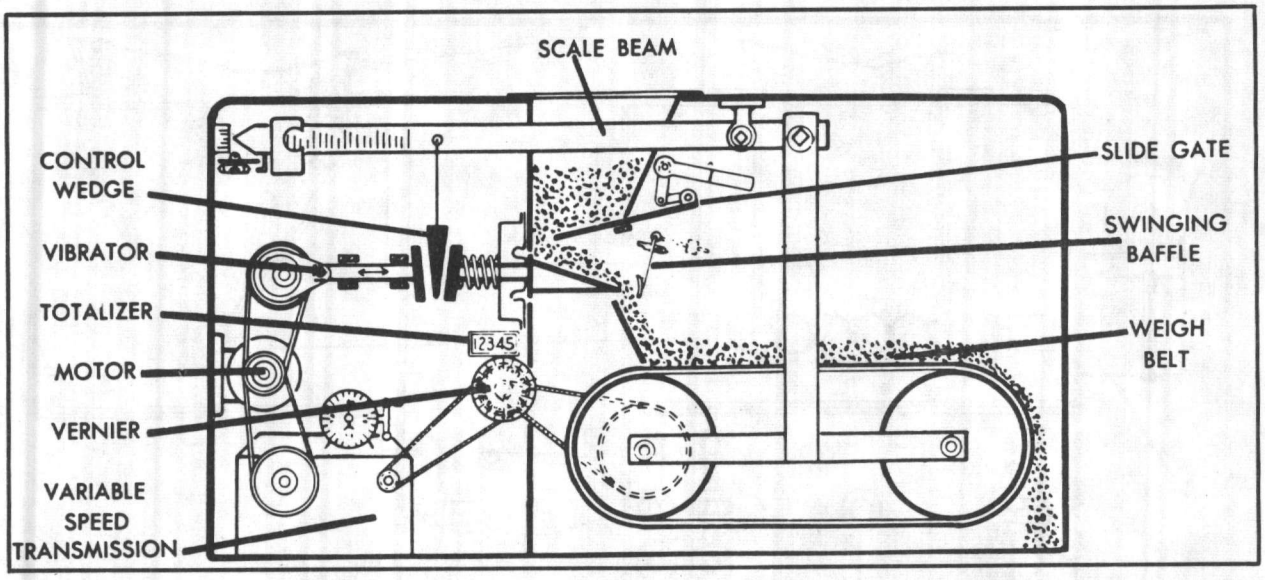


FIGURE 54

Belt-Type Gravimetric Feeder

(4) Flooding Control. To prevent flooding by finely ground materials such as hydrated lime, light soda ash or activated carbon, an automatic solenoid-valve-controlled air cylinder is attached to the adjustable gate located just above the vibrating tray. The solenoid is energized through either of two mercury switches. One of these is tipped by a swinging baffle placed directly in front of the feeding tray so that it will operate immediately if the material starts to fall off the tray at too great a rate. The other is operated by the scale beam when a serious overload on the belt causes it to tip sharply. When the excess material has been delivered off the belt so that the balance is restored, the solenoid circuit through the switch is opened, and the air cylinder automatically returns the gate to its open position.

(5) Flooding Control at High Feed Rates. Where extremely high rates of feed are required with materials which have a tendency to flood continually, the rotary feeding mechanism described above is incorporated ahead of the vibrating tray. A counter or totalizer is driven from the belt mechanism, and since a constant weight is carried on the belt, a multiplier taken from the scale reading will give the direct feed in pounds.

(6) Accuracy of Feed Rate. Accuracy is identical at the maximum and minimum rates previously mentioned because the same load is being weighed at all rates of feed. For any given material, the rate of feed is adjusted by changing the belt speed and not by altering the weight on the belt. The scales and control mechanisms are sensitive to 1/100 of a pound. Thus, if 20 lbs is being carried on the belt, the gravimetric error would be 20 lbs divided by 100, or 0.2 lb, which represents an error of 1 percent. The average accuracy of a belt-type gravimetric feeder is ± 2 percent, although spot checks may show a wider variation if flooding occurs.

3.2.3.1.7 Screw-type feeder. The familiar screw conveyor is the basis of a much used type of feeder (see fig. 55). Generally, a screw is run only partially full. With most materials, the flow will not be strictly continuous, but rather in a series of surges which is sometimes evened out by equipping a few inches of the discharge end with paddle arms instead of a helical flight. Some screw feeders use a double-helix screw to increase capacity and even out delivery. Variable-speed drives of either continuous or ratchet type are common.

(1) Hopper Agitator. The feeder shown in figure 55 is equipped with a ratchet drive and a hopper agitator on the higher speed drive shaft. This particular drive has two ratchets driven alternately by an oscillating arm with a variable throw that can be adjusted from zero to maximum during operation. Motion of the screw is thus discontinuous, consisting of two advances for each revolution of the drive shaft. In another type of ratchet drive having a single ratchet, the amount of ratchet stroke which is effective in turning the screw depends on the setting of a movable trip which can be set to advance the ratchet wheel from a single tooth to about 90 degrees for each revolution of the drive shaft.

(2) Feed Range. Feeder screws range from about 2 inches to as high as 12 inches in diameter. This wide variation in size makes it pos-

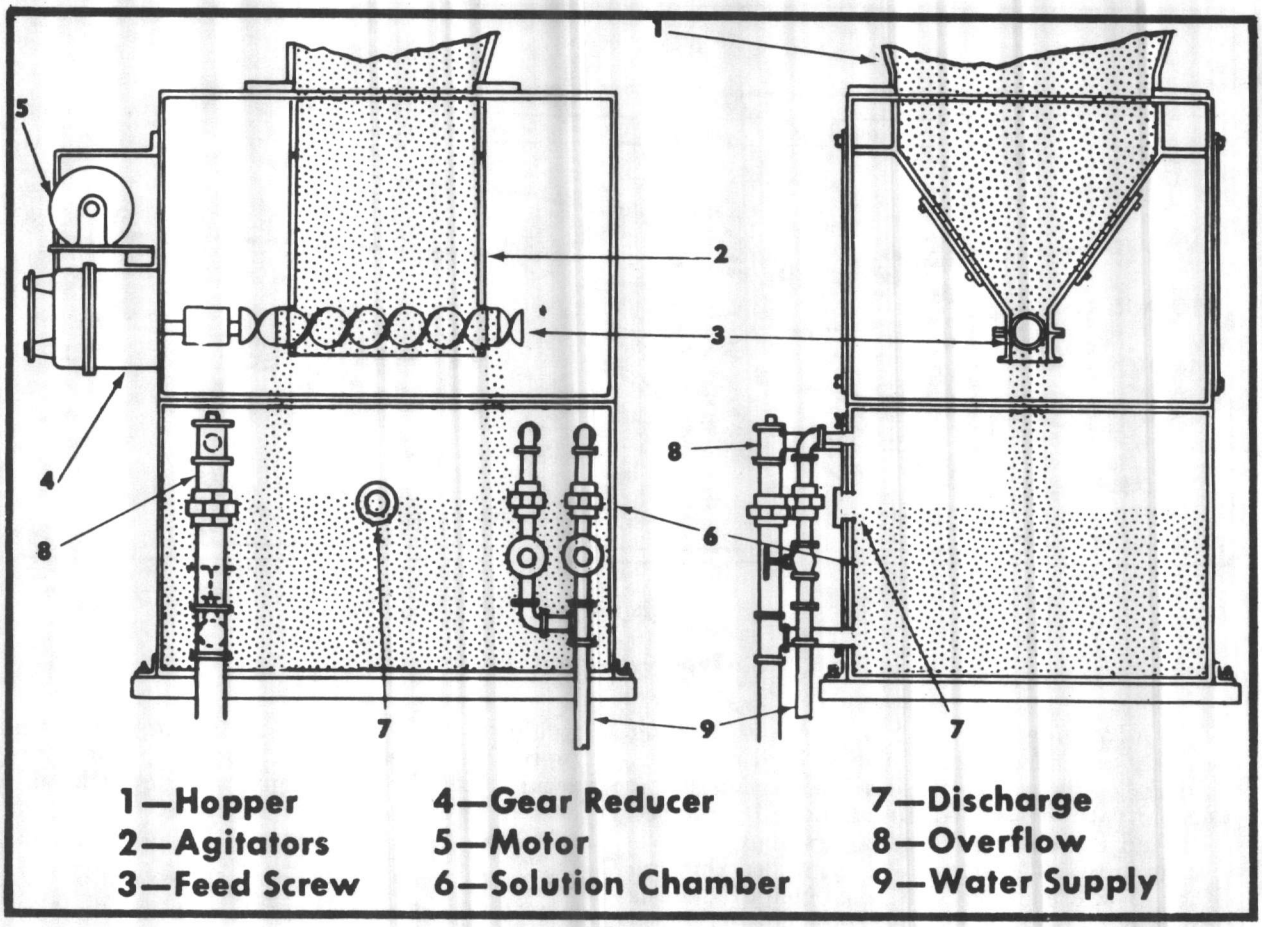


FIGURE 55

Screw-Type Feeder

sible to deliver very small or very large amounts of material for mixing, depending on the size of the screw conveyor.

3.2.3.1.8 Operating precautions. Dry feeder hoppers should be provided with screens at the upper end to catch lumps of chemical or pieces of bag which can plug the feed mechanism if they get into the hopper. The mesh of the screen should be such that lumps larger than can be handled by the feeding mechanism are held back. Dust removal units of the sock type are also recommended at the upper end of the hopper, and mist or dust removal equipment of either the mechanical or jet type, above the mixing chamber.

3.2.3.1.9 Loss-in-weight gravimetric feeder. This type of feeder is used in water treatment plants where highly accurate feeding rates are desired over ranges of 1 to 4,000 lbs per hour. The feed rate accuracy is ±1 percent by weight.

(1) Design and Construction. The loss-in-weight gravimetric feeder consists of a streamlined steel cabinet enclosing a material hopper and feeding mechanism mounted on scales. Doors at front and back give easy access to the scale beam, controls and feeding mechanism. A window in the front door permits observation of the illuminated scale beam compartment.

(2) Accuracy. The loss-in-weight system of feeding ensures scale-weighed feeding accuracy with no chance for cumulative errors. The feeder is usually mounted directly on a corrosion-resistant dissolver which forms a base. There is a dust-tight flexible connection between the feeder and dissolver.

(3) Setting Feed Rate. The hopper is filled and the scale beam balanced by manually adjusting the poise. The control dial on the rate setter is set to the desired rate of feed in pounds per hour.

(4) Rate-Setter Mechanism. The rate setter, operated by a synchronous motor, retracts the poise by a lead screw at the exact feed rate desired. As long as the feeder delivers material from the hopper, causing it to lose weight at the exact rate the poise is being retracted, the scale

beam will stay in balance. If the feeder delivers too much or too little, causing loss in weight faster or slower than the poise is retracted, the beam will tip, thereby operating controls which cause the feeder to correct its rate. Only a very small beam movement is required for control, and the scales are so sensitive that the beam is essentially in balance at all times. The position of the poise indicates the weight of material in the hopper at all times. A counter geared to the lead screw totalizes the weight fed.

(5) Start-Stop Operation. This type of operation of the feeding mechanism is the simplest type of control and is preferred where detention-type dissolvers even out the feed.

(6) Feed Rate Calibration. The vibratory feeding mechanism has a built-in shutoff gate that can be tightly closed while the hopper is being filled. Accurate, permanent calibration of the feed rate is assured by a synchronous motor which drives the lead screw. A mechanical or electrical rate setter, having a percentage adjustment, sets the speed at which the lead screw is driven and thus sets the feed rate. Remote control is possible, as is automotive proportional pacing.

3.2.3.2 Solution Feed Equipment. The most commonly used solution feeders can be classified as pot type, differential, decanter or swing pipe, proportioning pumps and rotating dipper.

3.2.3.2.1 Pot type. The principle of operation of this type of solution feeder (see fig. 56) limits it to chemicals that can be obtained in lump, briquet or ball form, and which are slow to dissolve when in continuous contact with water. As an example, when alum is used, it must be either potash or ammonium alum in lump form, and when alkali is used it must be sal soda in similar form. Soda ash, filter alum and similar chemicals should not be used in this type of feeder because they dissolve too fast.

(1) Description of System. The installation has an orifice plate in the raw waterline to be treated. An inlet line equipped with a sediment trap and a needle valve runs from the high or upstream side of the orifice to the underside of the dissolving pot. An outlet line runs from the top of the pot to the low or down stream side of the orifice. Shutoff valves are provided in both lines to permit recharging the pot.

(2) Operation. The pressure differential across the orifice plate in the main line causes a small stream of water to flow from the high pressure side of the orifice through the chemical pot to the low pressure side. This flow should force an equivalent stream of saturated chemical solution from the pot into the line. In theory, since the same differential pressure acts across the regulating valve as across the orifice, the discharge through the regulating valve at all settings will be a definite fraction of the flow through the orifice and will remain so in spite of variations in flow.

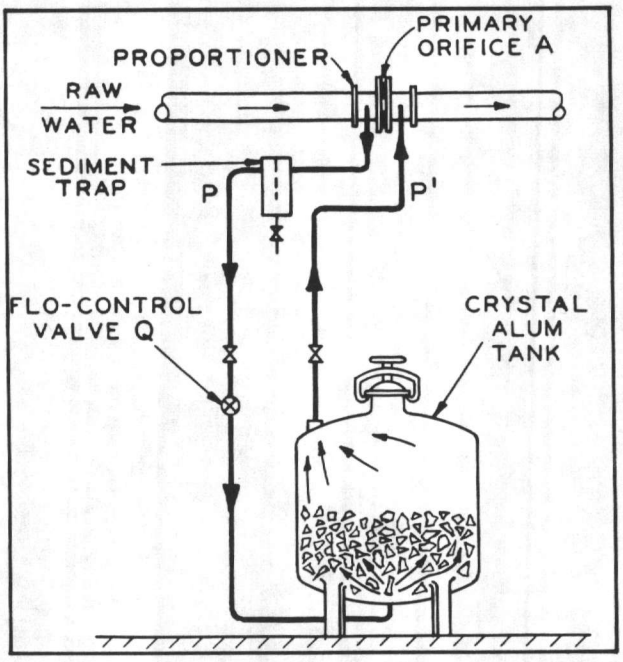


FIGURE 56

Pot-Type Solution Feeder

(3) Size. Pot feeders are made for charges of from a pound of chemical, or less, up to several hundred pounds. They are low in initial cost, but have the following limitations, especially for continuous service.

(a) They are suited mainly to chemicals of limited solubility so that a saturated solution will be maintained for reasonable periods.

(b) Where the solubility is low and the demand is high, a large throughput leads to excessive size, which is costly for positive pressure systems over 50 to 100 psi.

(c) There is no assurance that the solution being fed is of constant, uniform concentration. The chemical bed may channel, temperature changes may affect solubility and at high rates there may not be sufficient time for an equilibrium to be established.

(d) The feeding of saturated solutions is always difficult in practice, however reasonable it sounds in theory. For example, crystallization frequently takes place in the regulating valve and outlet line so that an accurate calibration cannot be maintained.

(4) Modification. To overcome these difficulties, the basic pot feeder has been modified to ensure feeding a solution of known concentration by using an immiscible liquid as a fluid piston or a bag as a separating membrane between the solution and the incoming water which displaces it.

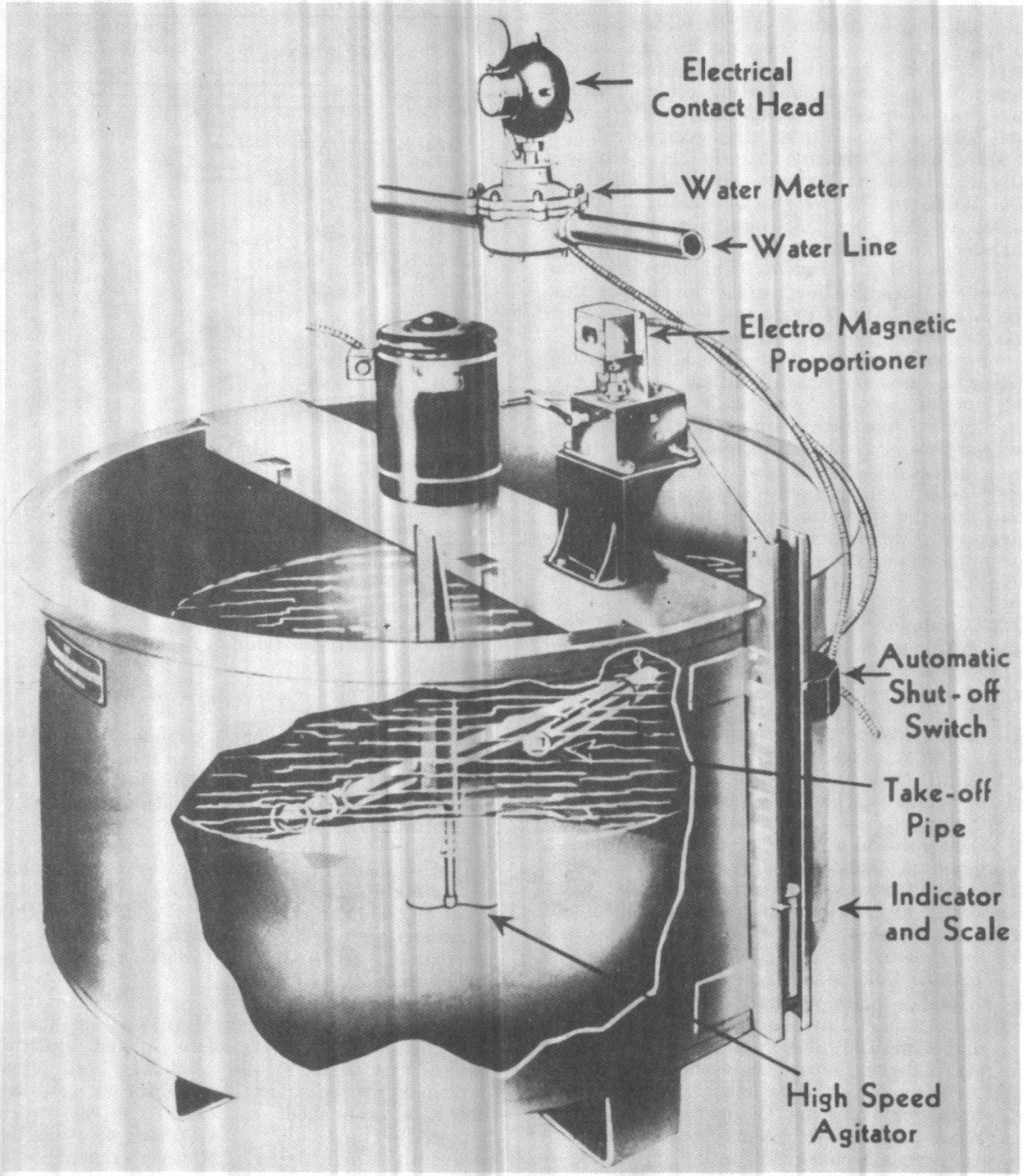


FIGURE 57

Decanter or Swing Pipe Solution Feeder

3.2.3.2.2 Differential solution feeders. This type of feeder uses a pair of pitot tubes, one looking upstream and the other looking downstream. One tank (on the downstream side) is filled with the chemical feed solution of known concentration.

(1) Operating Principle. In operation, the flow of water creates a pressure differential between the two pitot tubes which causes some water to enter on the upstream side from the upstream pitot tube. This flow displaces an equal amount of oil upward from the upstream tank across a needle valve into the downstream tank. The oil in turn displaces an equal volume of chemical solution from the downstream tank into the water through the downstream pitot tube.

(2) Recharging. When the oil-water interface comes close to the top of the gage glass on the upstream tank, the unit is recharged by introducing more chemical solution into the downstream tank and opening the drain valve below the upstream tank. The oil is then forced back into the upstream tank through the needle valve, which is opened wide during this process.

(3) Accuracy of Feed Rate. In practice, for any one setting of the needle valve, flow conditions cannot vary too widely without overfeeding at one end of the flow range and underfeeding at the other. This is because the static heads in the two compartments are not in balance and change during the complete feeding cycle, and because the pressure differential across the two pitot tubes increases with increased flow rates.

3.2.3.2.3 Decanter or swing pipe feeder. This type of feeder (fig. 57) uses a tank in which a chemical solution of suitable strength is prepared. Within the tank a drawoff head on a swing-pipe is lowered by a feed control unit. The feed control unit is driven by a fractional horsepower motor which, acting through reducing gears and a pawl and ratchet wheel drive, slowly rotates a cable drum. This unwinds the cable, lowering the drawoff head in the chemical tank thereby feeding the chemicals from the solution surface at a constant pressure and amount. The chemical may be picked up by a chemical pump supplying it to the water to be treated, or it may be discharged by gravity to the point of application.

3.2.3.2.4 Proportioning pumps. There are two major types of proportioning pumps used as solution feeders—the piston-type proportioning pump and the diaphragm-type proportioning pump.

(1) Piston-Type Proportioning Pump. This pump (fig. 58) is more economical because of its simplicity, compactness and ability to perform the double function of both metering and injection. Changes in concentration, viscosity and density over the range used with water treatment chemicals do not materially affect volumetric measurements.

(a) Accuracy of feed rate. Because of the incompressibility of water solutions, the proportioning pump will give sustained accuracies well within ± 1 percent by volume of maximum feed when used with solutions which do not carry suspended solids or abrasive materials.

(b) Operation principles. Pumps are available in a wide range of materials and in sizes feeding from a fraction of 1 gallon per hour to 50 gallons per minute. Proportioning pumps are of the positive displacement type with a neglible

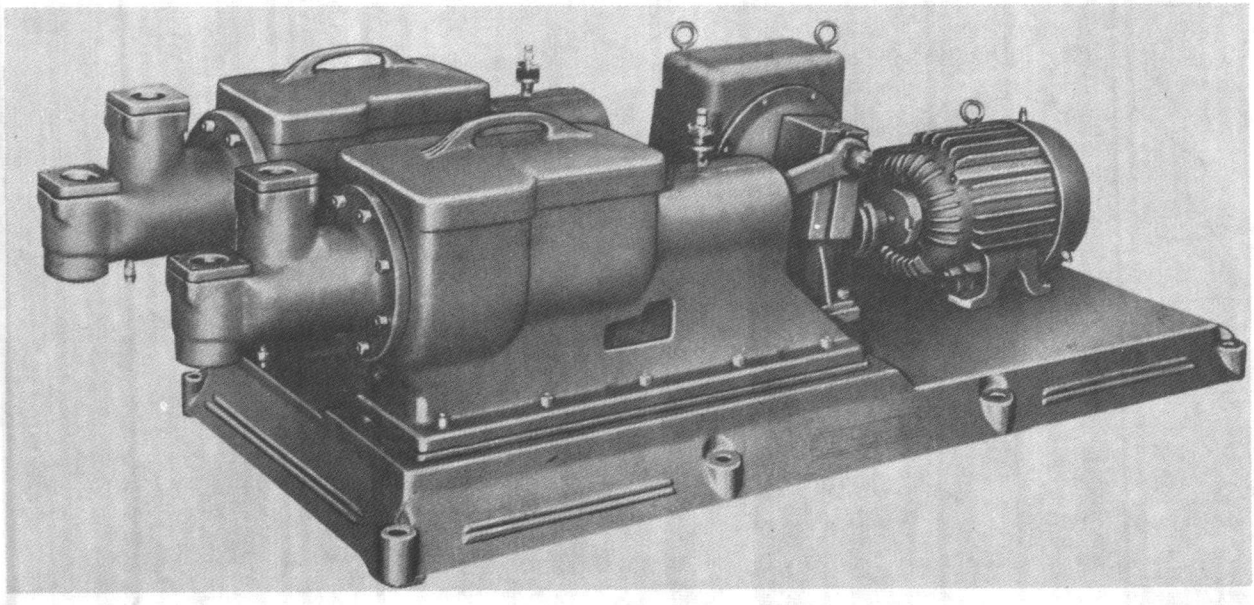


FIGURE 58

Piston-Type Proportioning Pump

"slip" characteristic so that when the plunger is withdrawn a given distance through the stuffing box, a metered volume of solution is drawn in through the suction line. When the plunger motion is reversed, the suction check valve closes and this volume is forced through the discharge check valve, through the delivery line and then to the point of application.

(c) Feed rate adjustment. The amounts of chemical fed per minute or hour are adjusted by changing the stroke length; the setting is usually shown by a calibrated scale on the pump frame. For certain applications, change of speed is also employed, although this adds to initial cost. There is also a limitation in the allowable range before check valve efficiency is impaired.

(2) Diaphragm-Type Proportioning Pump. This type of pump (Figure 59) differs from the plunger type in that the end of the plunger acts to move a flexible diaphragm back and forth. This diaphragm keeps the feed solution from contact with the plunger thereby eliminating the necessity for a chemical-resistant packing gland. The direct-acting type of diaphragm pump is suitable only for pressure up to 125 psi, whereas a hydraulically-backed diaphragm may be used for injection pressures well over 1,000 psi.

(3) Proportioning Pump Drives. Proportioning pumps are usually of the constant speed motor-driven type, although some designs include variable speed drives to provide for changes in feed rates.

3.2.3.2.5 Rotating dipper. The rotating-dipper liquid feeder consists of a tank in which the liquid level is maintained by a float valve or an overflow weir, and a dipper wheel for feeding the liquid (Figure 60). The dipper wheel consists of an arrangement of eight dippers, each with a capacity of approximately 1 pint. As the dippers revolve, each dipper in succession dips into the liquid, emerges filled to capacity and then, as it passes the horizontal, discharges the liquid into the feeder outlet. Each dipper is shaped so that excess liquid, due to the dipper velocity, spills out of the dipper and does not reach the feeder outlet. The rate of feed is proportional to the

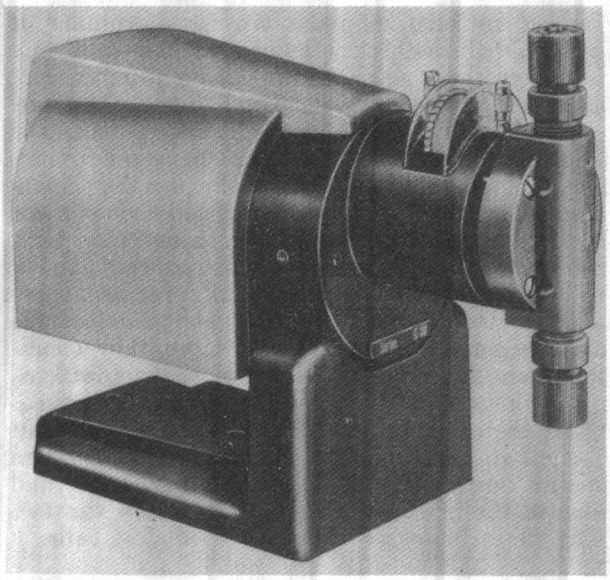
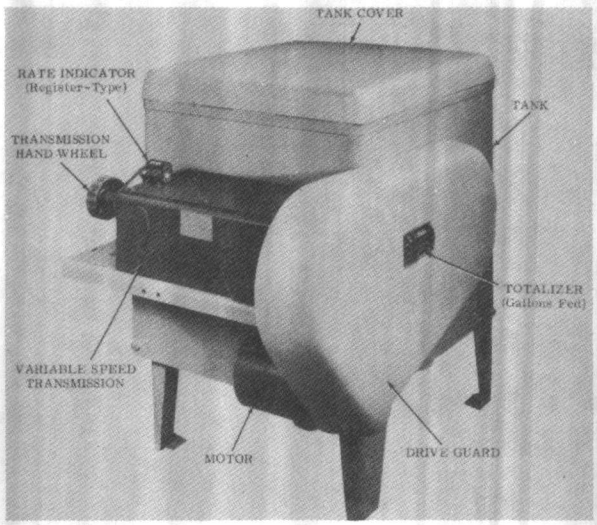


FIGURE 59

Diaphragm-Type Proportioning Pump



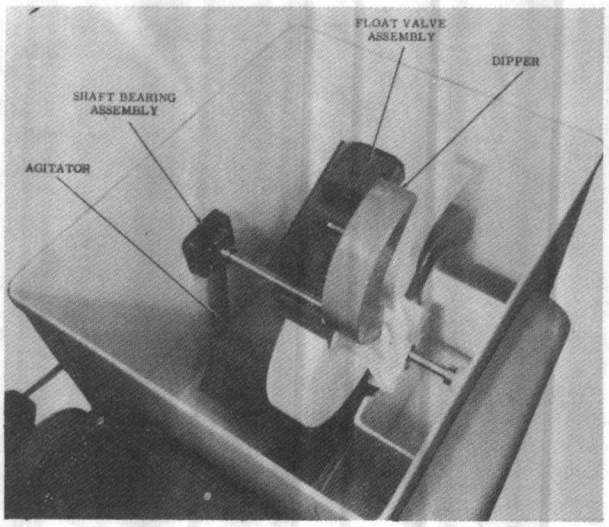


FIGURE 60

Rotating Dipper Feeder

rate of the dipper wheel. The dipper wheel is driven by chain from the variable speed transmission which has an adjustment for manual rate setting. When adapted for pneumatic proportional pacing, the transmission is equipped with a pneumatic positioner and the rate is set in response to a controlled air pressure received by the positioner. Usually in this case, ratio or dosage adjustment is obtained by an auxilliary transmission adjacent to, and driven by, the pneumatic transmission. Electrical proportional pacing is attained by start-stop of feeder motor in response to proportional electric signals. Dosage or ratio adjustment in this case is obtained by the standard adjustment knob of the transmission.

(1) Float Valve. A float valve is installed within the feeder tank to maintain constant liquid level. It regulates inflow of liquid to replenish that which is fed by the rotating dipper wheel. Such a float valve in the feeder tank is usually present when the feeder is *not* part of a recirculating system.

(2) Recirculating System Without Float Valve. When a float valve is *not* included, the reason is usually that the feeder is intended for use in a recirculating system whereby the liquid level in the feeder is maintained by the presence of an overflow connection. In a recirculating system, the source of liquid is a main supply tank connected to the inlet pipe of the feeder; the feeder overflow connection is made to the suction side of a circulating pump; the pump returns the liquid to the main supply tank to complete the flow cycle. Only the liquid fed by the rotating dipper wheel is removed from the recirculating system; when the liquid level in the main supply tank becomes low, it should be refilled in order that the level within the feeder may remain within the limits.

3.2.4 FLUORIDE ADJUSTMENT OF WATER. The Navy Department subscribes to the principle of minimizing dental cavities among children (16 years old and younger) at Navy shore activities by adjustment of the fluoride content of the station water supply to recommended levels. Current instructions issued by joint instruction from the Bureau of Medicine and Surgery and the Bureau of Yards and Docks shall be followed.

3.2.4.1 Fluoride Limits. The desired concentration of fluoride in water used for drinking and culinary purposes depends upon water intake by personnel, which in turn depends upon the average temperature of a specific locality. Table 3, taken from the 1962 Drinking Water Standards, U.S. Public Health Service, gives the recommended control limits of fluoride concentrations. The range of concentrations is determined by the annual average of the maximum daily air temperatures obtained for a minimum of five years at a specific location. The various ranges of concentrations of fluoride for different average temperatures present the margins of concentrations allowed. If the fluoride content drops below the lower control limit, then the fluoridation is considered ineffective. If it goes over the upper control limit, then fluoridation must be reduced at once until adjustment to the proper concentration is made. Further information regarding the proper fluoride concentration levels for specific localities can be obtained from the regional Public Health medical directors.

3.2.4.2 Fluoride Chemicals. Fluoride compounds most commonly used in fluoridation are sodium fluoride, sodium silicofluoride and hydrofluorosilicic acid. The first two are dry, white crystal-

TABLE 3

Recommended Fluoride Concentrations at Different Temperatures

Annual avg. of max. daily air temperatures (° F.)	Control limits		
	Lower	Optimum	Upper
50.0–53.7	0.9	1.2	1.7
53.8–58.3	.8	1.1	1.5
58.4–63.8	.8	1.0	1.3
63.9–70.6	.7	.9	1.2
70.7–79.2	.7	.8	1.0
79.3–90.5	.6	.7	.8

line powders, and the last is a corrosive liquid. *All are toxic chemicals and should be handled with extreme care, from the standpoint of both bodily contact and inhalation of dust or spray.*

3.2.4.2.1 Sodium fluoride. This compound has the advantage of being water soluble at almost exactly four percent over a wide temperature range. This property facilitates accurate feeding.

3.2.4.2.2 Sodium silicofluoride. This chemical is usually less expensive, but requires better control than sodium fluoride for accurate feeding, as the solubility varies from about 0.44 percent to 32° F. to about 98 percent at 100° F.

3.2.4.2.3 Hydrofluorosilicic acid. This chemical is the least expensive for fluoridation, but has the great disadvantage of being the most dangerous to personnel if not handled properly and with extreme care.

3.2.4.2.4 Sodium fluoride specifications. Wherever practicable, sodium fluoride of the following specifications should be used: sodium fluoride, commercial grade, 95 to 98 percent pure, crystalline, 100 percent through 20 mesh and not more than 2 percent through 60 mesh, packed in 100 lb bags. Where there is a definite possibility that

the fluoride may be mistakenly used for another water treatment chemical, sodium fluoride with a blue tint should be procured.

3.2.4.2.5 Fluoride chemical storage. Store all chemicals in a dry room convenient to the feed equipment. To protect chemicals from damage, place package on boards or grids to permit air circulation which prevents moisture from forming on the container bottom. Hopper-filling openings should be at a suitable height to avoid the use of ladders or platforms.

3.2.4.3 Points of Application. In feeding fluorides, it is not necessary to allow for a contact period as in chlorination. Water has no "fluoride demand", hence the entire quantity can be accounted for in the distribution system, unless it is lost through the treatment process. Some loss of fluoride occurs by adsorption on floc particles in flocculation. Ordinary filtration occasions a loss of 0.1 to 0.3 p.p.m. of the fluoride added. About 25 percent of the fluoride ion is lost by feeding fluoride solutions ahead of the lime softening processes. Therefore, the most desirable point of application is in the filter effluent or at the entrance to the clear well. Fluoride chemicals are added after all other chemicals have had an opportunity to react, but prior to final chlorination.

3.2.4.3.1 Well supplies. At installations having wells which do not deliver to a common point, it will be necessary to have an individual fluoride feeder for each well. For these installations, the most accurate and economical method of fluoridation is the application of unsaturated sodium fluoride solutions (less than 4 percent). For the preparation of such solutions, a weighed amount of the chemical is added to a definite weight or volume of water, and the mixture is mechanically or manually stirred until all the fluoride is dissolved. The operator should check these individual wells at regular intervals to ensure proper operation of the feeding equipment.

3.2.4.3.2 Wells pumped to central point before distributing. Where wells pump to a central point, such as a reservoir or ground storage tank, and before the water goes into the distribution system, fluorides should be applied by either dry or solution feeder equipment, whichever is more feasible.

3.2.4.3.3 Filtration and softening plants. Dry feeders, either volumetric or gravimetric, are usually provided to feed fluorides at filtration and softening plants.

3.2.4.3.4 Purchased water supplies. Whenever water is purchased and fluoridation is desired, the contractor should be asked to install the necessary fluoridation equipment at his plant. Only if this is not done should fluoridation be carried out on the installation.

3.2.4.4 Equipment. Previously described types of feeders are used for fluoridation, with some modifications or auxiliary equipment, depending upon the fluoride chemical used and the type of installation. Dust control equipment and provision for the safe disposal of emptied fluoride bags are particularly important.

3.2.4.5 Dosage. In fluoridation practice, the target residual in the distribution system is prescribed for each installation by the Bureau of Medicine and Surgery, based on the recommendations of the U.S. Public Health Service (see table 3). In general, the spread is from 0.7 to 1.2 p.p.m. of fluoride in the finished water supply, the average being about 1 p.p.m.

3.2.4.5.1 Effect of natural fluoride content of water. To determine the dosage that will give the required total fluoride residual, the natural fluoride content of the raw water must be considered. This content, however, is generally so small (usually 0.1 to 0.25 p.p.m.) in those areas where fluoridation is practiced, that little adjustment has to be made in the added fluoride dosage, if application is made after coagulation and sedimentation, which tend to remove part of the natural fluoride.

3.2.4.5.2 Chemical dosage. The amount of chemical fed to obtain the desired dosage of fluoride depends upon the fluoride content of the chemical compound used. As an illustration, with sodium silicofluoride containing 60 percent fluoride, about 14 lbs are required for each million gallons of water to add 1 p.p.m. of fluoride, while with sodium fluoride containing 44 percent fluoride, approximately 19 lbs are needed to achieve the same result. Similar adjustments have to be made for hydrofluorosilicic acid, which contains 22 to 30 percent fluoride.

3.2.4.5.3 Dosage chart. The chart shown in Figure 61 illustrates the method of determining the desired dosage for various fluoride-bearing chemicals. Chemical dosages must be set and supervised by properly authorized personnel. Overall dosage checks are made at least daily. Continuous observation of the equipment is a daily routine operation. Hourly checks reflect any dosage variations and provide a basis for regulation of overfeed and underfeed.

3.2.4.6 Sampling and Analysis. Methods of sampling and analysis pertinent to fluoridation are discussed in Paragraph 3.3.4.10.

3.2.4.7 Defluoridation. If the natural fluoride content of the water supply exceeds the maximum recommended by the U.S. Public Health Service or the Bureau of Medicine and Surgery, defluoridation is desirable to avoid dental fluorosis, a disfiguring mottling of the teeth. Fluorides can be removed from a water supply by the use of magnesia, calcium phosphates or calcined (acti-

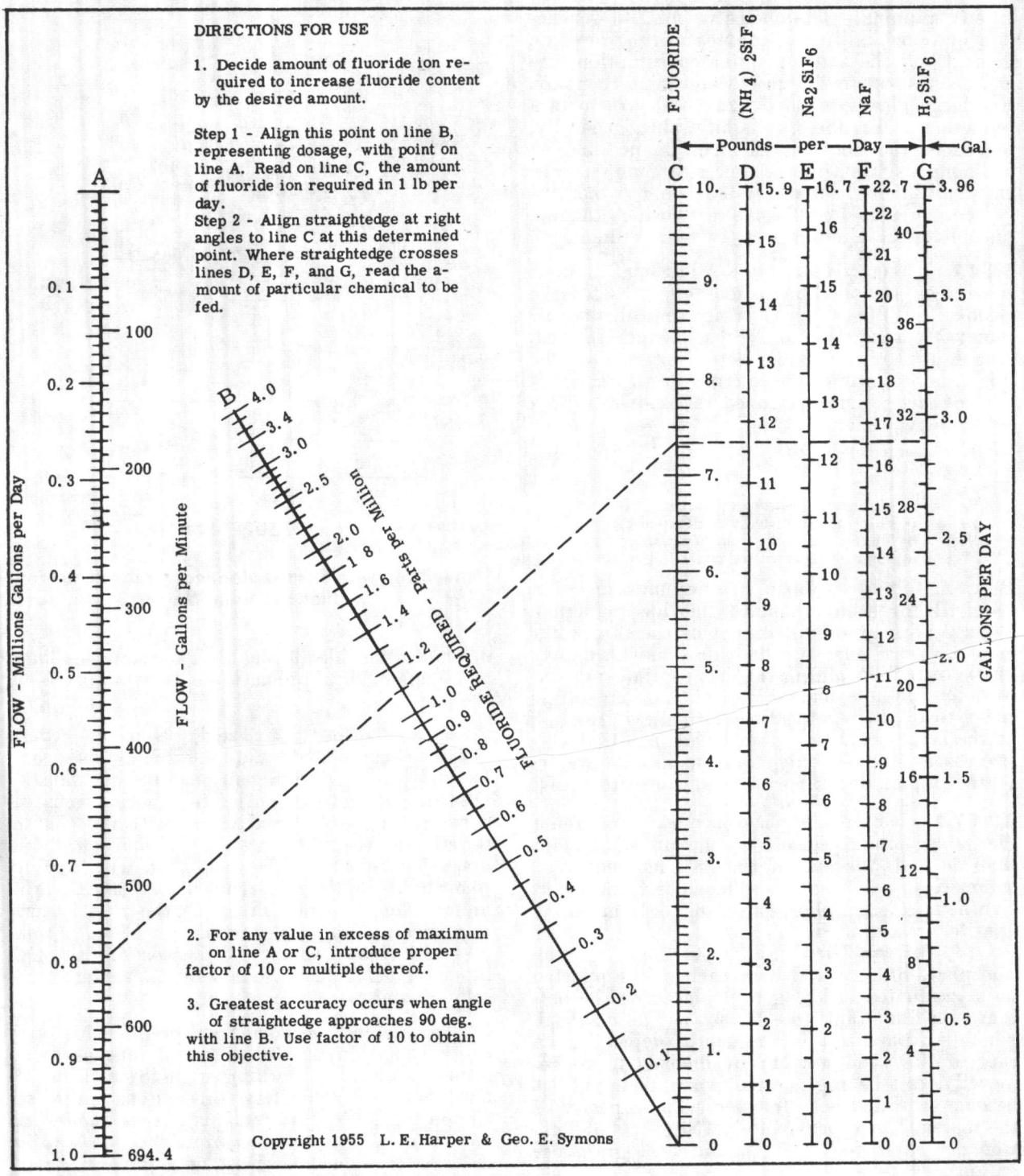


FIGURE 61

Nomogram for Determining Dosage of Fluoride-Bearing Chemicals

vated) alumina. The choice of method for defluoridation, as in other treatment processes, depends on the rate of water consumption, the characteristics of the raw water and economy. For large plants, when the raw water requires a reduction in hardness, it is advisable, generally, to reduce the fluorides as much as possible by utilizing magnesia in the lime softening process. In small plants, or where softening is not required, pressure contact filters using calcium phosphates or alumina may be more economical.

3.2.4.7.1 Magnesia method. Additional lime is sometimes used in lime-softening plants for the removal of fluorides. The amount of fluoride removal is a function of the magnesium removed, and is approximately equal to 7 percent of the initial fluoride times the square root of the quantity of magnesium removed, as shown in the following equation.

$$F_R - F_T = 0.07\, F_R \sqrt{\frac{Mg_R}{Mg_T}}.$$

Where,

F_R = Fluorides in raw water (p.p.m.).
F_T = Fluorides in treated water (p.p.m.).
Mg_R = Magnesium in raw water (p.p.m.).
Mg_T = Magnesium in treated water (p.p.m.).

Between 45 and 65 p.p.m. magnesium removal is required for each p.p.m. of fluoride reduction. Where the magnesium content of the raw water is too low for adequate fluoride removal, it may be increased by adding an appropriate amount of dolomitic lime, magnesia or magnesium sulfate prior to or during the lime softening. Because of the large quantities of chemicals required, this process is suitable only for low-fluoride waters (3 to 4 p.p.m. or less) which require softening.

3.2.4.7.2 Calcium phosphate method. Bone char (largely calcium phosphate) has an affinity for fluoride and was one of the first methods used commercially for removing fluorides from water. Synthetic calcium phosphates, such as a hydroxyapatite, are also used.

(1) Material Used. The granular calcium phosphate or activated bone carbon is supported on a graduated bed of gravel placed on the bottom of a filter tank (see fig. 62). The material, which is from 2 to 5 feet in depth (depending on rate of flow and amount of fluoride to be removed), can be regenerated when the unit has become saturated with fluoride. The capacity of the material is approximately 450 grams of fluoride per cubic foot (17.1 p.p.m. = 1 gram per gallon).

(2) Regeneration. After backwashing, regeneration is by successive passage through the fluoride removal unit of 1 percent caustic soda solution, raw water and weak phosphoric acid or carbon dioxide solution. The filter and regeneration tanks are specially constructed and lined with corrosion resisting material. The volume of water defluoridated between regenerations is dependent upon the initial fluoride content and the

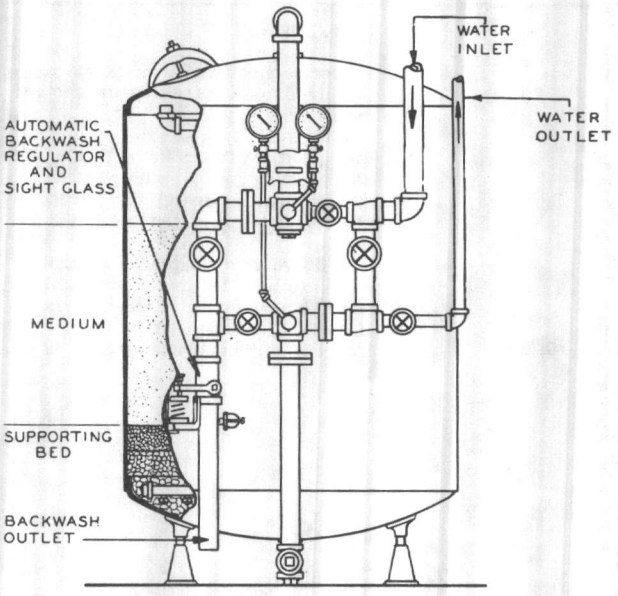


FIGURE 62

Filter Tank with Phosphate Medium for Removing Fluorides from Water

optimum fluoride residual. This volume should be regulated by automatic controls actuated by the meter.

3.2.4.7.3 Calcined (activated) alumina method. Calcined (activated) alumina, obtainable commercially as a drying agent, may be economically used for defluoridation. The fluoride removal capacity of the material varies with the characteristics of the raw water. The equipment and operation are much like those used with calcium phosphate for fluoride removal. When the alumina no longer removes fluoride, the material may be regenerated by backwashing for about 15 minutes with treated water, and then passing through it successively caustic soda solution, sulfuric acid solution and raw water.

3.2.4.8 Safety. Fluoride dusts or acids may cause irritation of the skin and mucous membrane. Personnel working with these chemicals must observe all safety precautions (also see Chapter 5). *Operators should wear rubberized gloves, plastic or rubber aprons and masks when exposed to fluorides.* Dust or acid must be removed immediately from the skin by bathing or washing. Remove spilled fluorides by wet mopping.

3.2.5 SCALE CONTROL. Scale refers to the white or light colored deposit formed on the inside of pipes and other surfaces in contact with water as a result of the crystallizing out of the hardness found in natural and lime-softened water supplies (see fig. 63). Scale consists most commonly of

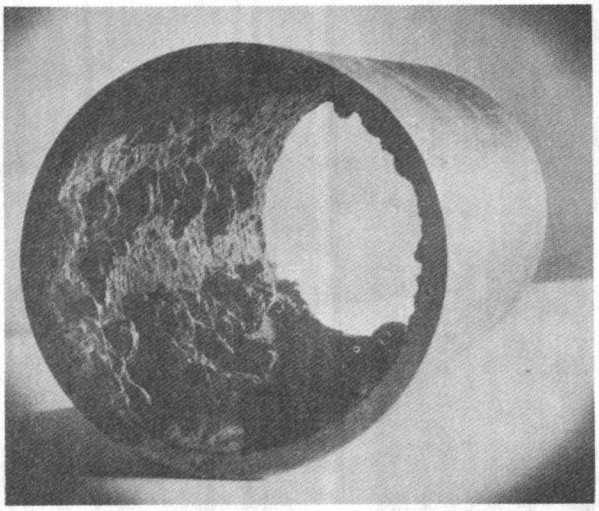


FIGURE 63

Water Line Containing Heavy Scale Deposit

calcium carbonate (limestone), although it may sometimes be calcium sulfate (gypsum) and may be mixed with corrosion products (rust), sand or other sediment present in the water. The tendency of a given water to form a scale may be calculated from its chemical analysis and the temperature or, for calcium carbonate scale, may be found by measuring the hardness before and after passage through a container of finely divided marble. Scale formation is undesirable because it has the following bad effects.

(1) Clogs pipes, thus reducing carrying capacity.

(2) Hinders operations by interfering with the functioning of valves and controls.

(3) Reduces operating efficiency of heating and cooling systems.

(4) Increases cost and reduces effectiveness of laundering and other soap-using processes. Scale formation can be controlled by threshold treatment or by softening of the water to remove scale-forming elements. Softening may be carried out by ion exchange or lime-soda treatment.

3.2.5.1 Threshold Treatment. Carbonate scales can be prevented by the addition to water of very low concentrations of polyphosphates (glassy phosphates; hexametaphosphate). There is no true chemical reaction. The added polyphosphate prevents any tiny crystals of scale which may form from growing, thereby preventing a buildup of scale (see fig. 64). The water is stabilized without actual removal of the scale-forming constituents. The maximum concentration of calcium bicarbonate that can be stabilized by threshold treatment varies with the temperature and the alkalinity of the water. For normal temperatures in the range of 50° to 70° F., a quite hard

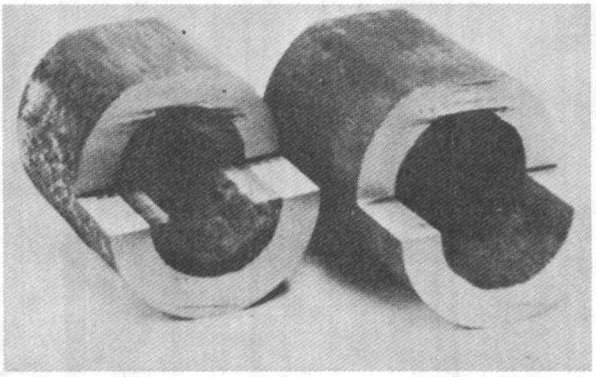


FIGURE 64

Effect of Threshold Treatment for Scale Prevention
Left—Without Treatment Right—With Treatment

water can be stabilized with 2 p.p.m. of glassy phosphates. When polyphosphates are used for scale control, dosage must be carefully controlled. Overdosing may result in a phosphate scale formation.

3.2.5.2 Softening by Ion-Exchange (Zeolite). Ion-exchange water softening is a chemical operation in which calcium and magnesium, the hardness-forming materials in water, are exchanged for other materials which will not form a scale. This action is accomplished by passing the water through a bed of a solid ion-exchange medium, such as an ion-exchange material, which will capture and hold the calcium and magnesium in the water, releasing to the water in exchange an equivalent amount of sodium. See figure 65 for an illustration of an ion-exchange softener. These ion-exchange materials used in the process are insoluble, granular, solid materials that possess this unique property of exchange. They may be natural mineral zeolites, such as glauconite (greensand); precipitated synthetic substances of chemical composition similar to natural zeolites; organic (carbonaceous) zeolites; or synthetic ion-exchange resins. Currently, the resins are used most commonly.

3.2.5.2.1 Operation. The manufacturer's instructions should be consulted for the details of operation of specific ion-exchange units. There are four steps in the ion-exchange softening process.

(1) Backwash. During the softening period, water flowing downward through the zeolite bed leaves suspended matter on the surface of the bed. As this accumulation grows, the pressure drop across the bed increases and the bed becomes more compact. Therefore, when the zeolite bed becomes exhausted, it is necessary not only to regenerate it, but also to backwash it to remove the surface deposit and to ensure efficient regeneration and later operation. Backwashing consists of flowing water upward through the bed at

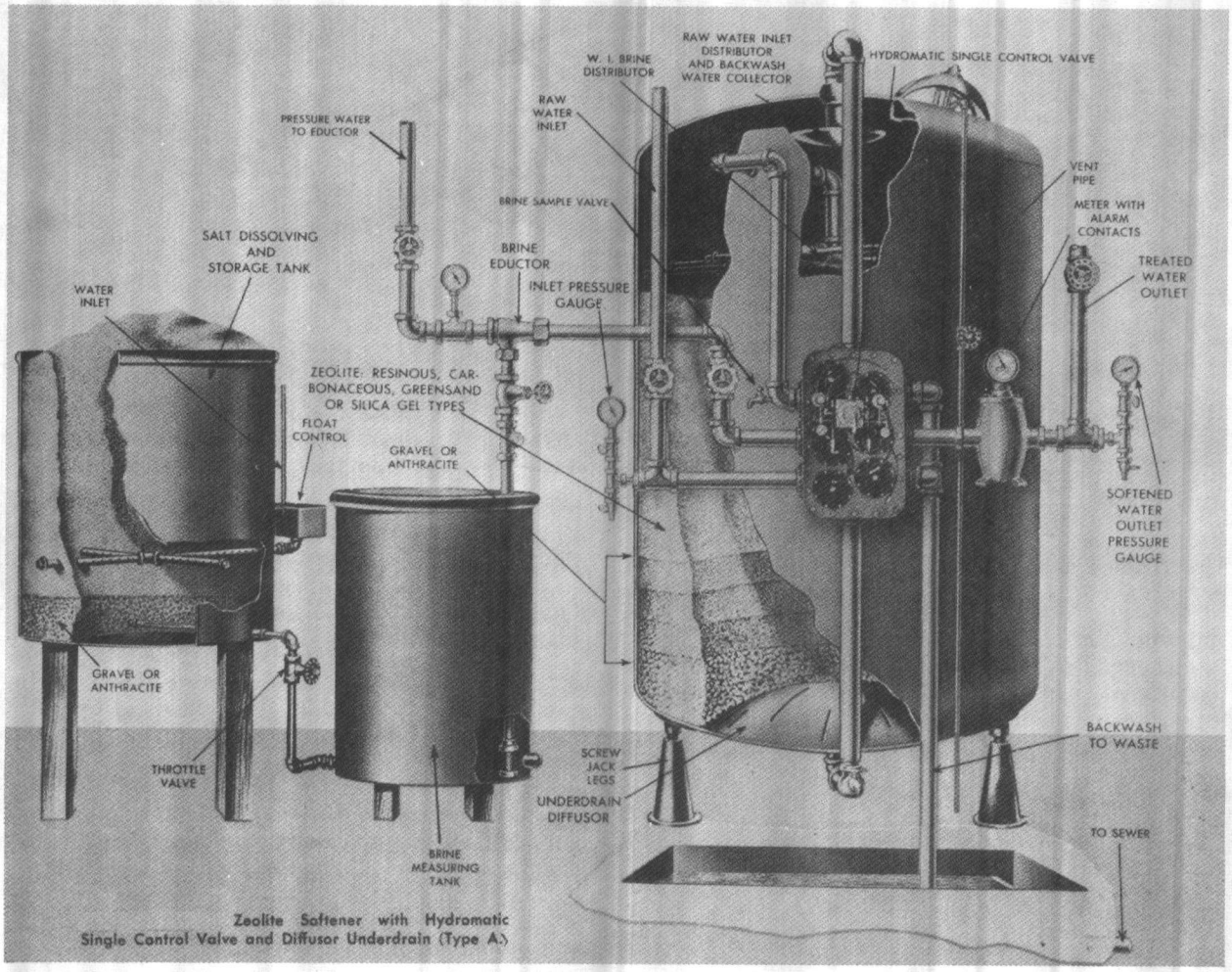


FIGURE 65

Ion-Exchange Unit for Water Softening

a rate which causes the bed to expand a specified minimum amount. This permits dirt to be separated from between zeolite grains and floated off at the top to the sewer. It also cleans and loosens the bed so that in the succeeding regeneration step the salt solution can properly contact all the zeolite.

(2) Regeneration. In the course of softening water, the sodium content of the ion-exchange bed is depleted and requires regeneration by passage through it of a common salt solution in order to restore its capacity to remove hardness from water. The sodium of the salt displaces the calcium and magnesium taken up by the bed during the softening step and restores the ion-exchange material to its original condition. The salt solution is fed into the softener above the resin bed and flows downward. The efficiency of this operation is determined by use of the proper amount and strength of salt solution, distribution and rate of flow and time of contact with the bed. The salt solution should be added slowly. For greensand, allow about 5 minutes. For other materials follow the manufacturer's instructions (usually 15 to 20 minutes).

(3) Rinse. After regeneration, the ion-exchange bed must be rinsed to flush out the excess salt solution. To accomplish this, water is passed downward through the bed until all traces of salt have been thoroughly washed out. Rinse at rates recommended in the manufacturer's instructions. Ordinarily the rate is about 2 g.p.m. per square foot of bed surface area with about a 20-minute rinse period. Synthetic resins require a longer rinse.

(4) Service. After the bed has been regenerated and rinsed, the softening process is resumed by passing raw water downward through the bed at the manufacturer's recommended flow rate, and into the effluent mains. This flow is

continued until the bed is again exhausted and regeneration is again required.

3.2.5.2.2 Supplementary treatment of ion-exchange softened water. An ion-exchange softener produces water of zero hardness. Since this water will not form a protective coating on distribution piping, oxygen in the water will cause rusting of exposed iron. It is therefore desirable to mix the softened water with unsoftened water to obtain the desired degree of hardness. If the unsoftened water contains so much iron that the final mixture would contain more than 0.3 p.p.m., the unsoftened water should be aerated and filtered before it is mixed with the softened water. The pH of ion-exchange softened water may be adjusted to make the water less corrosive by addition of a caustic-silicate solution.

3.2.5.2.3 Records. Records to help determine the efficiency of ion-exchange softeners and control operation will be reported on the form prescribed by local command. These records should include.

(1) Raw-water hardness.
(2) Soft-water hardness at beginning and end of run.
(3) Backwash rate.
(4) Length of time of backwash.
(5) Length of time of salt-solution injection.
(6) Strength of salt solution used during each regeneration.
(7) Rate of rinse.
(8) Length of time of rinse.
(9) Gallons softened in each run.

3.2.5.2.4 Tests. The necessary tests for ion-exchange softening, including the soap test for hardness, are covered in Paragraph 3.3.4.6.

3.2.5.3 Softening by Lime-Soda. Water may also be softened by adding lime, or lime and soda ash, to precipitate the hardness-causing compounds. After precipitation, the insoluble compounds are removed by sedimentation and filtration. Lime-soda softening plants are constructed essentially the same as water filtration plants. Lime (and soda ash) are added to the raw water, and the softening reaction occurs during mixing and flocculation. The precipitated calcium and magnesium compounds are removed during sedimentation. An additional step, called recarbonation, is frequently provided just prior to filtration in order to stabilize the water so as to prevent further precipitation in the filters and distribution mains. If raw water has a high turbidity, the turbidity is partially removed by plain sedimentation prior to the softening process. Sedimentation and filtration are discussed in Paragraph 3.2.8.3.

3.2.5.3.1 Lime-soda process. Ordinary lime (quicklime or calcium oxide) is added to water, forming calcium hydroxide (slaking the lime).

Calcium oxide (quicklime) + water = Calcium hydroxide. (slaked lime)

(1) Basic Reactions. When the slurry or solution of slaked lime is added to water containing carbonate (temporary) hardness, the calcium hydroxide reacts with the calcium and magnesium bicarbonates in the water to form the almost insoluble carbonate and magnesium hydroxide which precipitate, leaving the water quite low in carbonate hardness.

Calcium bicarbonate (Temporary calcium hardness) + Calcium hydroxide (Slaked lime) = Calcium carbonate (Precipitate) + Water.

Magnesium bicarbonate (Temporary magnesium hardness) + Calcium hydroxide (Slaked lime) = Magnesium hydroxide (Precipitate) + Calcium carbonate (Precipitate) + Water.

(2) Noncarbonate Hardness. In the lime-soda process, noncarbonate (permanent) hardness is removed from the water by use of soda ash (sodium carbonate) in addition to lime. The following typical chemical reaction takes place.

Calcium sulfate (Permanent calcium hardness) + Sodium carbonate (Soda ash) = Calcium carbonate (Precipitate) + Sodium. sulfate (Dissolved)

Soda ash also reacts with chlorides and nitrates of calcium in the same way. If the water contains both carbonate and noncarbonate hardness, as is usually the case, both lime and soda are used.

(3) Residual Hardness. The lime-soda process does not produce a "zero hardness" water as does ion-exchange softening, because there is still a small amount of calcium carbonate and magnesium hydroxide dissolved in the lime-softened water.

3.2.5.3.2 Additional softening methods. Lime-soda softening often results in the formation of soluble complex basic carbonates of magnesium and of a softened water of high alkalinity. Methods of overcoming these limitations are discussed below.

(1) Excess-Lime Treatment. In the excess-lime treatment, a softer final water is produced by adding 50 p.p.m. or more excess lime to precipitate the magnesium almost completely. The excess calcium is then precipitated with soda ash.

Soda ash is required in an amount to combine with the noncarbonate hardness of water and the excess lime.

(2) Split Treatment. Inadequate softening facilities can be overcome by split treatment. In this process, as large a portion of the raw water as possible is overtreated with lime to obtain maximum reduction of hardness. The excess is then neutralized by mixing with raw water. Split treatment produces a greater reduction in hardness of a given quantity of raw water than does the addition of the same quantity of chemicals to the total supply at one time.

(3) Excess Lime and Recarbonation. Treatment with excess lime and recarbonation consists of the excess-lime treatment followed by treatment with carbon dioxide (or scrubbed flue gas) to neutralize the excess lime. Carbonate hardness can be reduced by this method approximately to the solubility limit of 20 to 35 p.p.m. hardness (depending on the temperature), because calcium carbonate is less soluble at the higher pH of 9.3 to 9.7, resulting from the use of excess lime. The recarbonation is carried out to reduce the pH of the final water to about 8.0 so that it will be more palatable and will not produce calcium carbonate deposits on particles of sand in the filter nor in the distribution system.

(4) Addition of Alum. Alum coagulates finely divided precipitates of calcium carbonate and magnesium hydroxide, thereby facilitating their removal. Without alum treatment, longer time periods are required for precipitates to coagulate and settle. The addition of alum also converts soluble magnesium salts to insoluble magnesium aluminates which can be removed by settling and filtration.

(5) Excess Lime, Recarbonation and Secondary Flocculation. This treatment is carried out as follows.

(a) Excess lime and correct soda ash are added to combine with noncarbonate hardness, then mixed and allowed to settle.

(b) Excess lime is neutralized with carbon dioxide gas.

(c) Sludge produced by the water softening process or a coagulant are mixed in and allowed to settle.

(d) Carbon dioxide gas is added again and the mixture is filtered.

This process decreases the load on filters, lessens incrustations on filter sands, and produces a more nearly balanced, and therefore more stable, filtered water. It is especially adapated to treating and softening highly turbid waters.

3.2.5.3.3 Chemical feeding. Continuous softening requires application of chemicals in proportion to the rate of water flow through the treating units. If the flow is constant over definite periods of time, the chemicals can be fed through adjustable constant-feed machines. If the flow is variable, proportioning devices are used in which the chemicals are fed in solution or suspension. See paragraph 3.2.3 for a discussion of these feeders.

(1) Soda Ash. This chemical dissolves easily in water forming a clear, stable solution. After preparation, the solution needs no further agitation and can be added directly to the water through a feeding device.

(2) Choice of Lime. Either quicklime or hydrated lime may be used as the chemical. Hydrated lime is fed with volumetric or gravimetric chemical feeders (see par. 3.2.3). Quicklime is fed generally with a belt gravimetric feeder or universal type of volumetric feeder discharging into a lime slaker, from which milk of lime is discharged. The lime slaker may be of the detention type or pug mill (or paste) type. Water and lime are added in the proper proportions (usually approximately 4:1 ratio by weight) to form a creamy lime slurry, or milk of lime. Thermostatic control of water ratio is maintained. Because suspended matter tends to settle, continuous agitation is necessary to keep the mixture uniform. Therefore, devices for feeding lime usually have mechanical agitators. The flow through feed lines must be fast enough to prevent lime from settling and clogging lines. *If it is necessary to shut down the lime feeding process, immediately flush out all lines and equipment to prevent clogging.* All lines should be flushed out periodically to clear out any lime which may become caked or deposited in the lines.

3.2.5.3.4 Determination of dosage. A quantitive analysis of the water is necessary for determination of lime and soda ash requirements. Many types of formulas have been proposed and developed for calculating dosages of lime and soda ash. Among the simplest are these. To remove carbonate hardness.

Lb 100% CaO per 1000 gal. = 0.0106 (p.p.m. Co_2 + p.p.m. half-bound CO_2) + 0.019 × p.p.m. Mg.

To remove noncarbonate hardness.

Lb 100% Na_2CO_3 per 1000 gal. = 0.009 (p.p.m. noncarbonate hardness as CaCO).

Where x is the noncarbonate hardness to be left in the water.

These formulas are based on pure chemical compounds. The results from the first formula should be divided by the percentage CaO present in the lime used and multiplied by 100. If the exact analysis of the quicklime is unknown, the results may be divided by 0.88, and, for hydrated lime, by 0.68. It is well to check the calculations for lime and soda ash requirements by actually adding the calculated dosage to small measured quantities of the water to be treated and analyzing the treated water. The following procedures will be found convenient.

(1) Prepare a standard lime suspension by adding 10 grams of lime (Ca(OH)) to 1 liter of boiled and cooled distilled water. If quicklime is used, mix it thoroughly with just enough water to make a boiling solution, then dilute to 1 liter.

A standard solution of soda ash is prepared in the same manner. The addition of 1 ml. of the standard solution to 1 liter of water gives a dosage of 10 p.p.m.

(2) Place 1 liter of water to be treated in a beaker or jar and add the calculated quantities of lime suspension and soda ash solution needed to soften it. Stir gently for 30 minutes and allow to settle until the liquid becomes fairly clear (usually 10 to 15 minutes).

(3) Siphon off about one-half of the clear solution, warm to about 120° F. (49° C.) and filter through filter paper.

(4) Analyze the filtrate for alkalinity in accordance with standard laboratory test procedures.

(5) Use the differential alkalinity tables in Reference 7, or tests for hardness, to determine whether the extent of softening agrees with that expected from the chemical dosage used.

3.2.5.3.5 High-rate softening devices. Lime-soda softening may be carried out in high-rate softening equipment (solids-contact clarifiers) such as the Precipitator, Accelator, Hydro-Treator and Spiractor. The Precipitator, Accelator, and Hydro-Treator may also be used as combined flocculation and sedimentation units when no softening is required.

(1) Precipitator, Accelerator, and Hydro-Treator. These three units (see figs. 66, 67, and 68) operate on essentially the same principle.

(a) Principles of operation. Precipitates formed are kept in motion by a combination of mechanical agitation and hydraulic flow. The velocity of water gradually decreases as it rises through the unit. A point is reached at which the precipitate particles are too heavy to be supported by the water and remain behind, thus separating from the water. The accumulated precipitate is termed the sludge blanket.

(b) Proper operation. When operating properly, passage of the water upward through the sludge blanket speeds up the chemical reactions and causes precipitates to grow larger. They then remain in the sludge blanket so that the water rising above the top of the sludge blanket and flowing over the weirs is clear. Operation depends on balancing the settling tendency of the particles of precipitate by the velocity of the upward flowing water. Continued operation tends to build up the sludge blanket so that automatic desludging devices are provided to keep it at a constant level. Operation of the equipment is covered in detail in manufacturer's instruction manuals.

(2) Spiractor. The Spiractor (see fig. 69) consists of an inverted conical tank looking much like a giant ice cream cone. In it, the lime-soda softening reaction takes place in the presence of a suspended bed of added calcium carbonate granules which act as catalysts on which calcium carbonate from the water rapidly deposits.

(a) Operation principles. In operation, the tank is slightly more than half filled with 0.1 to 0.2 mm. (0.04–0.08 inch) granules. Hard water and the treatment chemicals are pumped in tangentially at the bottom of the cone close to each other so that they mix immediately. The stream of treated water rises through the granular bed with a swirling motion and the vertical velocity

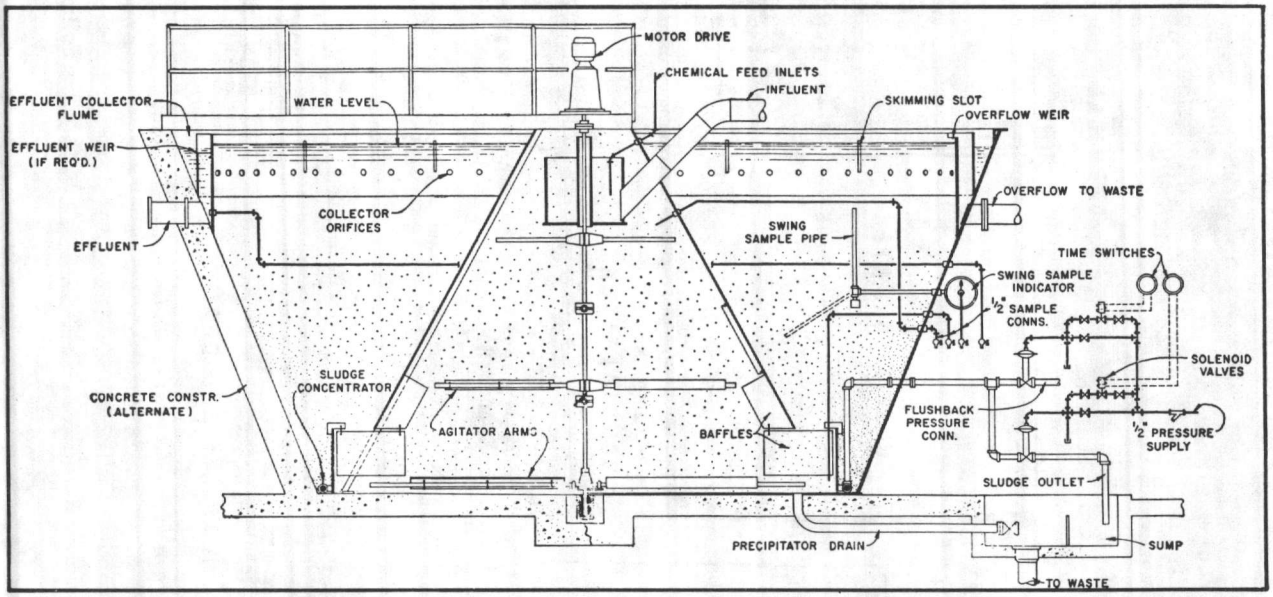


FIGURE 66

Solids—Contact Clarifier (Precipitator)

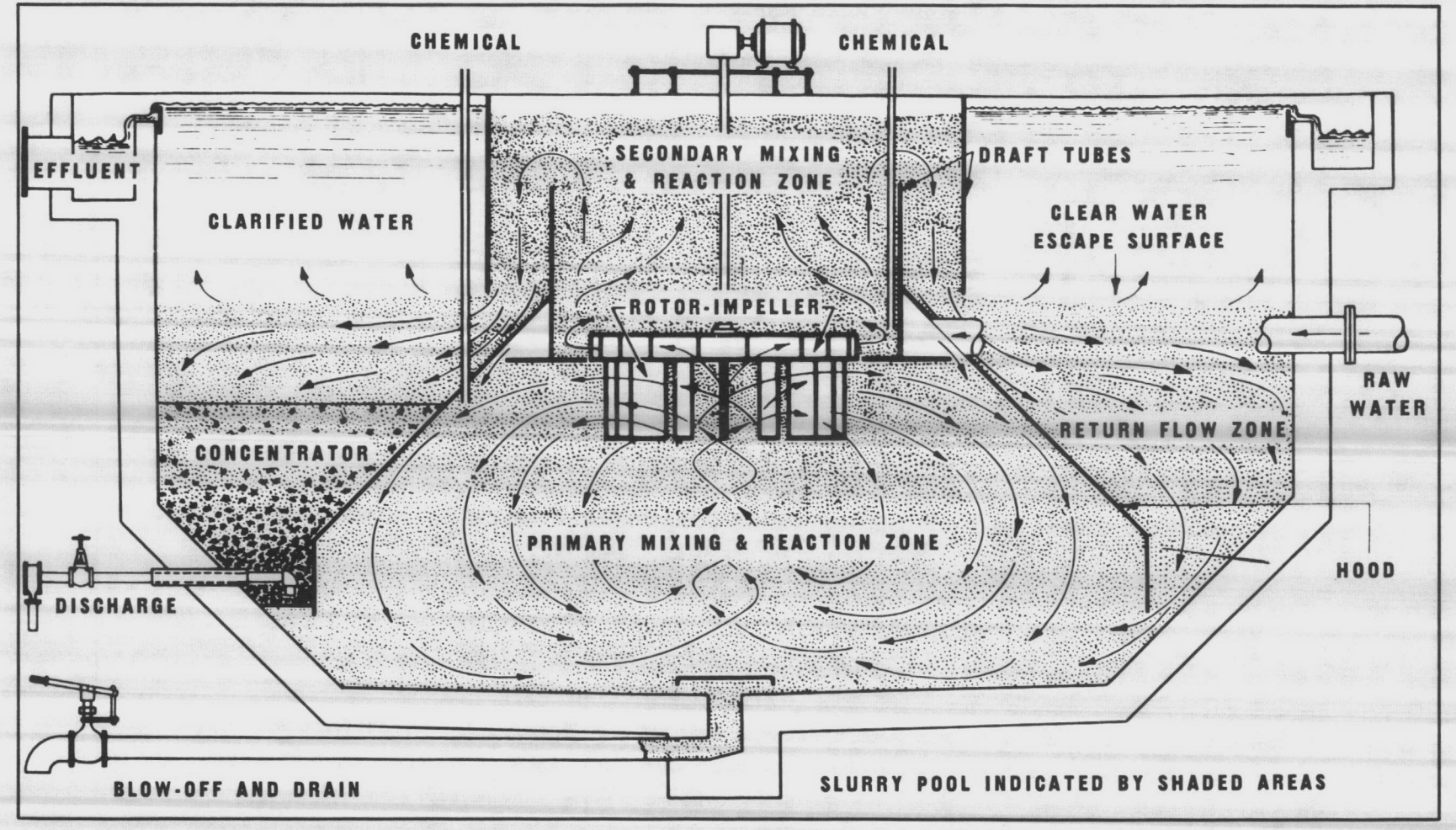


FIGURE 67

Solids—Contact Clarifier (Accelerator)

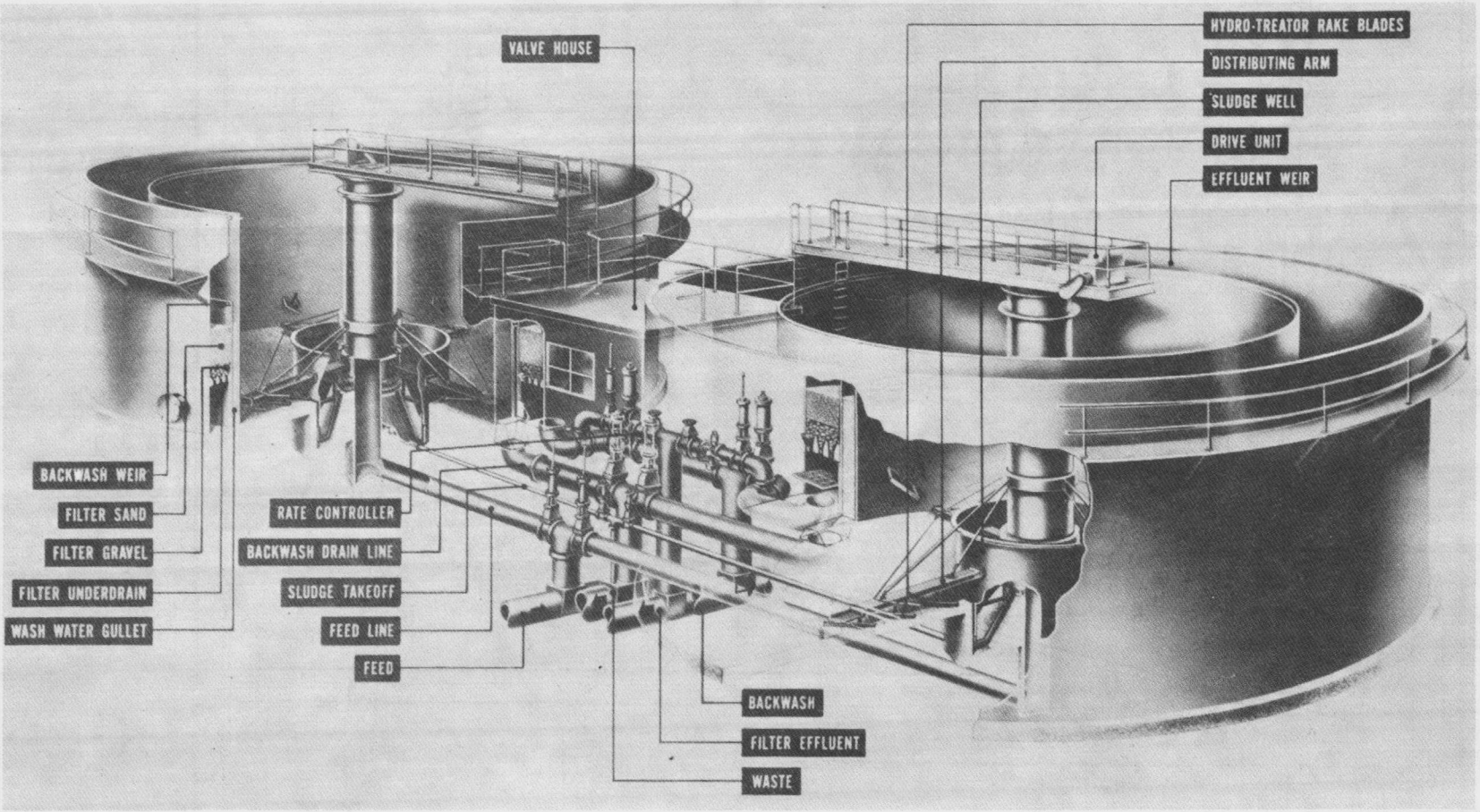


FIGURE 68

Solids—Contact Clarifier (Hydro-Treator)

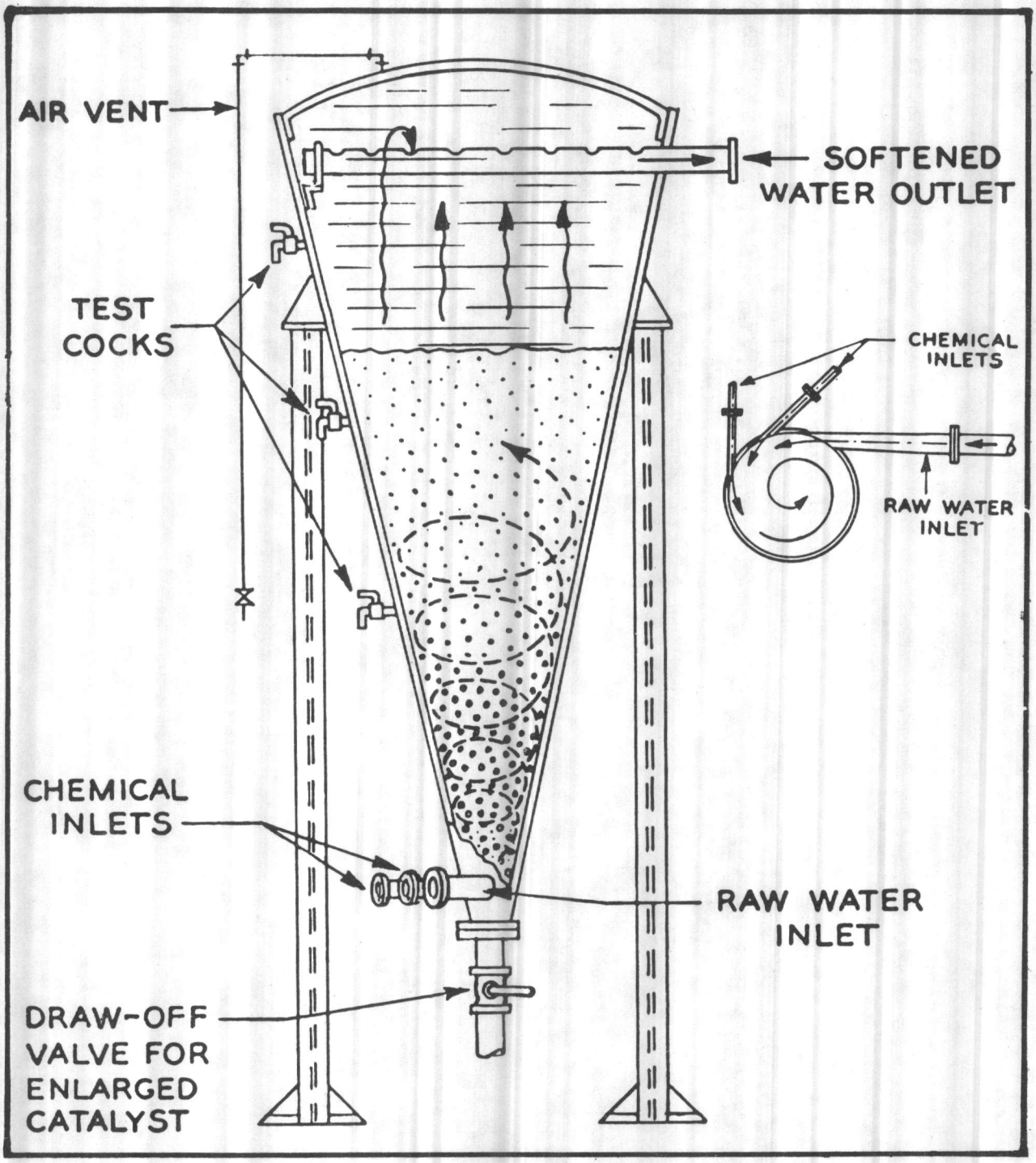


FIGURE 69

Solids—Contact Clarifier (Spiractor)

decreases to a point where solid material is no longer in suspension. The contact time, eight to ten minutes, is enough to complete the softening reactions. Softened water is drawn off the top of the cone.

(b) Precipitated hardness. The precipitated hardness adds to the calcium carbonate granules during the process, increasing their size. However, the level of granules in the unit is kept down to the desired point by continuously withdrawing the large particles from the bottom. New catalyst material must be added periodically. It can be produced by regrinding and screening the discharged material. The softened water is usually filtered through a sand filter to remove any remaining turbidity.

(c) Advantages of equipment. The advantages of the equipment are its small size for any given rate of flow, low installation cost, rapid treatment and lack of moving parts. In addition, the precipitated hardness is withdrawn as sand-like granules, which are much easier to dispose of than the watery slime from the usual lime-soda process. The unit is most effective when hardness is predominantly calcium; there is less than 17 p.p.m. magnesium hardness, the water temperature is above 50° F. and turbidity is less than 5 p.p.m.

3.2.5.3.6 Safety in handling lime. Operators must be particularly attentive to the common sense rules of good housekeeping in handling lime (see Chapter 5). This chemical should be carefully stored in a dry area away from any combustible materials. An efficient dust-collecting system should be used whenever dust is present at handling points. A dry-pickup vacuum cleaner should be employed for removing dust around unloading equipment and chemical feeders.

(1) Protective Clothing. Protective clothing should always be worn for personal safety in case bags break or the dust collection system fails. The proper dress is heavy denim clothing with long sleeves, heavy gloves, bandanas, and trousers tied around the shoe tops. Chemical goggles and suitable dust masks should be worn. Any exposed skin areas should be covered with protective creams.

(2) Cautions. Particular caution must be observed to avoid accidental contact of quicklime with water, and when working with freshly slaked lime because of the heat generated when the lime is mixed with water. Serious skin burns and eye damage can be caused by contact with hot lime solution. *Operators should always wear chemical goggles or face shields when operating lime-feeding equipment.*

3.2.6 IRON AND MANGANESE REMOVAL OR CONTROL. Iron is present in many ground waters, whereas manganese is present only occasionally, and then usually along with iron. The presence in a water supply of more than 0.3 p.p.m. of iron, or more than 0.5 p.p.m. of manganese, is considered objectionable. These compounds stain everything with which they come into contact. This is especially true of plumbing fixtures and clothes that are rinsed in water. Iron and manganese affect certain foods, such as causing tea to turn black and darkening vegetables cooked by boiling. Iron also favors the growth of various bacteria generally known as "crenothrix". These crenothrix growths are stringy and gelatinous, and may become so voluminous as to interfere with the flow of water through the pipes. Manganese stains, especially on clothes, are even more objectionable than iron rust because they are darker. Deposits of manganese oxide are almost black. Iron and maganese can be removed from water, or their undesirable effects eliminated, by the methods described in the following paragraphs.

3.2.6.1 Threshold Treatment. If the amount of ferrous iron does not exceed two to three p.p.m., color and staining can be prevented by the threshold treatment described in Paragraph 3.2.5.1. In this treatment, the addition of about 2 p.p.m. of polyphosphate is required to sequester 1 p.p.m. of iron. To be effective, it is important to add the polyphosphate to the water before the latter comes into contact with air, or is treated with chlorine. Polyphosphates will hold manganese in solution provided that the manganese does not exceed approximately 1 p.p.m. At weight ratio of 2 p.p.m. polyphosphate to 1 p.p.m. manganese is required. As in the case of iron, the polyphosphate must be added before contacting the water with air or chlorine.

3.2.6.2 Chemical Precipitation of Iron. Iron dissolved in water as iron bicarbonate is removed by oxidizing it to insoluble ferric hydrate, a gelatinous rust-colored material. Methods of removal are influenced by the presence of organic matter, carbon dioxide and carbonates. Organically combined iron can best be removed by coagulation and filtration.

3.2.6.2.1 Aeration. In waters high in carbon dioxide and containing no dissolved oxygen, iron exists as ferrous bicarbonate. When the water is aerated, carbon dioxide is released, iron changes to ferrous hydroxide and, on contact with oxygen, is oxidized to ferric hydrate. Ferric hydrate is not soluble. It looks like ordinary rust and is readily removable by sedimentation and filtration. Spray, wood and coke-tray type aerators are efficient and require little attention in operation. (See Figure 70 for an illustration of an aerator.) Aeration to oxygen saturation is not recommended with low alkalinity waters because it increases corrosiveness. With such water, if the pH is not too low, limited amounts of oxygen can be introduced by a "snifter" valve in the water line just before a pressure filter which then removes the ferric hydrate floc.

3.2.6.2.2 Contact oxidation. This method is used to remove iron that is present in small amounts (less than 0.1 p.p.m.) or remains in solution after other processes have removed the bulk of it. A greensand zeolite treated with manganous sulfate and potassium permanganate (called manganese zeolite) oxidizes the iron from soluble ferrous state to the insoluble ferric state and deposits the iron oxides formed on the zeolite grains. Regeneration is carried out with potassium permanganate solution which restores the oxidizing capacity of the bed.

3.2.6.2.3 Sand filters. Where iron is incompletely precipitated by aeration and sedimentation, sand filters (see Paragraph 3.2.8.3.3(1)) act as contact beds and remove most of the remaining iron. The oxidizing action is confined to the upper portion of the bed and results in coating the sand with iron oxide, which has been found to be more active than clean sand for iron removal.

3.2.6.3 Chemical Precipitation — Manganese. Manganese, when present, is almost invariably associated with iron. Due to its chemical similarity to iron, it is removed by the same processes. However, manganese is not oxidized as readily. This is shown, for instance, by the presence of black manganese stains below the iron stains in sand filters. The following differences in treatment should be noted.

(1) Simple aeration and filtration are seldom adequate for manganese removal. It is necessary to increase the pH of the water to about 9.4 before effective precipitation of manganese can be obtained by this means.

(2) Oxidation of the manganese with chlorine, followed by coagulation, sedimentation, and filtration usually gives satisfactory results.

(3) Filter sand with a manganese dioxide coating aids in removing manganese.

(4) Contact aerators are quite effective in removing manganese.

3.2.6.4 Ion-Exchange for Iron and Manganese Removal. In the process of softening, a sodium zeolite will also remove any dissolved iron and manganese. In some instances, the softening process becomes incidental to the principal objective of removing iron and manganese. All of the iron and manganese must be in solution in the ferrous or manganous state before passing through a zeolite bed of this type, otherwise a precipitate will form that will clog the bed. Therefore, air lift pumps, pneumatic tanks or other aerating devices cannot be used ahead of the zeolite beds in this process. Operating procedures are the same as described in paragraph 3.2.5.2.1.

3.2.7 CORROSION CONTROL. The control of corrosion is important for maintaining the delivery capacity of the mains, prolonging the life of equipment and protecting the quality of water delivered. Whenever corrosion is minimized, there is an appreciable reduction in maintenance and operation costs. Corrosion, especially when it attacks installation utility systems, can seriously interfere with accomplishment of the activity mission by causing plant shutdown for repairs and by wasting critical materials. Corrosion causes leaks in mains and domestic piping, resulting in the waste of water. Products of corrosion cause clogged pipelines and equipment, and reduction in pipeline flow capacity. Corrosion also causes water to become turbid and imparts color which will stain fixtures and clothing in laundering. Corrosion control is, however, a complex engineering problem because of the many combinations of causes, influencing factors and effects that are possible in any situation. Because the major controlling factor is one of design, the discussion in this manual is limited to a brief description of corrosion and some of the methods used for control.

3.2.7.1 Theory of Corrosion. Corrosion is commonly considered to be an electrochemical reaction in which metal deteriorates or is destroyed in contact with its environment or surroundings, such as air, water or soil. Corrosion is essentially the same in all metals. Such refined metals as steel are relatively unstable and tend to change back to the stable compounds, usually oxides of their natural ores.

3.2.7.1.1 Electrochemical reaction. The term electrochemical reaction means that chemical changes and an exchange of electrical energy take place at the same time. Thus, whenever corrosion occurs, there is a flow of electric current from the corroding portion of metal into the electrolyte or conductor of electricity, such as water or soil, and back into the same metal at another point or into another metal which forms an electrical contact with the corroding metal. The point at which current flows from the metal into the electrolyte is called the anode, and the point to which the current flows from the electrolyte back into a metal is called the cathode.

3.2.7.1.2 Flow of current. The electric current flowing from the metal carries charged particles, called ions. of the metal with it. As the metallic ions are dissolved in the electrolyte, they are exchanged for hydrogen ions, which flow to the cathode and tend to deposit a hydrogen film on the cathode. The metallic ions carried from the parent metal are usually changed to oxides by dissolved air in the electrolyte, and are deposited as corrision products, most often near or on the anode. In the case of steel, these oxides form the familiar rust.

3.2.7.2 General Methods of Corrision Control. In a given situation, corrosion may have one cause or many, hence control measures must be planned to meet the specific conditions. Since it would be impossible to give specific measures covering

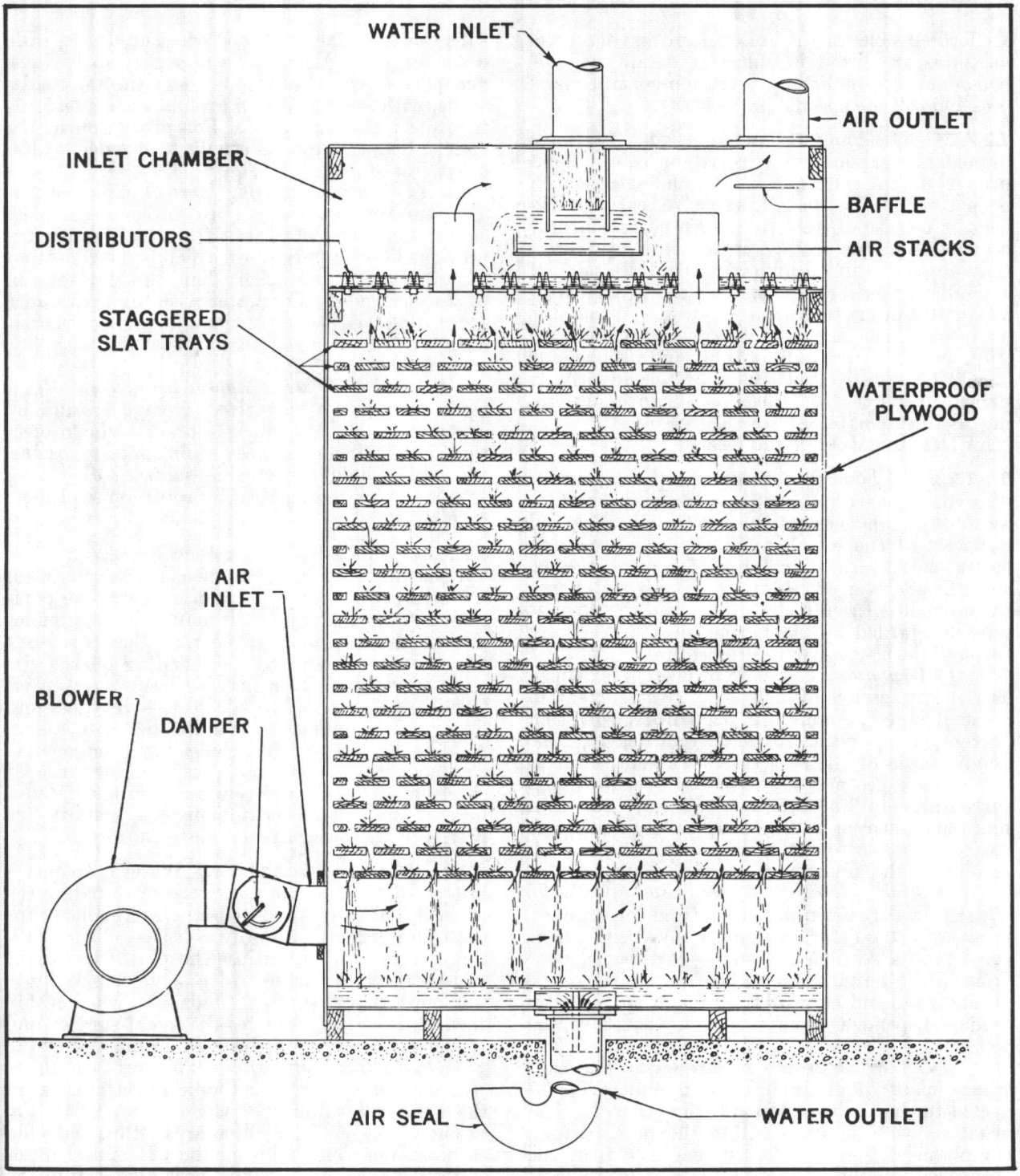


FIGURE 70

Aerator

all local problems, the following overall control measures are listed in sufficient detail to guide personnel in establishing corrosion control measures and solving specific problems.

3.2.7.2.1 Designing against corrosion. The most important weapon against corrosion is, of course, proper design. Design entails the selection of proper materials, the allowance of extra thickness of metals where it is known corrosion may occur, the proper protection of metals by protective coatings and linings, the installation of cathodic protection systems and the provision of adequate water treatment devices. While the operator is not immediately concerned with design, which is essentially a command problem, he should be familiar with some of the underlying principles. For a detailed discussion of designing against corrosion, see "Corrosion Control", NAVDOCKS MO–306 (Reference 10).

3.2.7.2.2 Cathodic protection. As previously indicated, whenever current leaves a metal surface located in an electrolyte, electrically charged particles of the metal go into solution, causing corrosion. If the flow of this current can be stopped or reversed, theoretically the metal will not corrode. In cathodic protection, the current flow is retarded by passing an auxiliary current through the electrolyte to the metal.

(1) Definition. Cathodic protection is defined as the application of sufficient direct current to a metal object, counter to the normal corrosion current, to prevent current from leaving the anodic areas of the structure. The entire metal object then becomes negative or cathodic to its surroundings. For each environment, a certain minimum current must be applied to mitigate corrosion. The source of current is immaterial, as long as the amount of current is adequate.

(2) Steel Elevated Water Storage Tanks. These tanks are often protected from corrosion by means of cathodic protection. Typical equipment consists of a rectifier to produce a direct current from the alternating supply, control rheostats, an ammeter and carefully sized and spaced electrodes suspended from the tank roof into the water.

(a) Current density requirement. The electrodes, made of platinum or aluminum, are connected to the positive wire of a d.c. circuit. The negative wire is connected to the tank bottom, completing the circuit for current flow from the electrodes to the tank surface. The induced electrical current flows continuously from the electrode to the tank. This current must be equal in all parts of the tank. Current density of about 5.0 milliamperes per square foot is necessary for bare metal; less is required if the tank is partially protected by paint.

(b) Current density distribution. For even distribution of current density, it is essential to place the electrodes at certain predetermined locations, otherwise full protection for the entire submerged surface will not be secured. In wide diameter water tanks, it is necessary to locate a group or circle of electrodes near the tank sidewalls, with another group around the center area to protect the tank floor. For protection of the riser, a long electrode is usually suspended within a few feet of ground level.

(c) Factors affecting current requirements. The current requirement to provide complete cathodic protection varies with a number of factors, the most important of which is the resistance of water and the number, diameter and spacing of the electrodes. For water with high resistance (low dissolved solids content), higher current densities are required than for water with low resistance.

(3) Other Water Supply Equipment. This equipment can be protected from corrosion by application of the principle of cathodic protection. This includes steel sedimentation basins, flocculators and the outside surfaces of piping systems. For details of such protection see Reference 10.

3.2.7.2.3 Protective coatings and linings. Protective coatings and linings serve as barriers between the metal to be protected and the corrosive environment. In many cases, it may be more economical to use a protective coating than to use a more resistant material. Depending on the circumstances, protection may be needed either internally or externally. Protective coatings and linings may be either nonmetallic or metallic. Nonmetallic protection includes paint and enamel coatings, cement masonry, plastic linings, rubber sheeting and glass and ceramic coatings. Metallic coatings include galvanizing and cladding or plating with more corrosion resistant metals.

3.2.7.2.4 Corrosion inhibitors. Water is frequently treated to eliminate the causes or to reduce the intensity of corrosion. Chemical treatment for corrosion control generally consists of the addition of chemicals to adjust the pH of the water and to effect the deposit of a solid or gelatinous film on the metal surface. This film, when evenly formed, effectively isolates the metal surface and prevents direct contact between water and metal.

(1) Calcium Carbonate. Calcium carbonate will deposit a film on cathodic areas because of the greater alkalinity of these areas. The film excludes oxygen from these areas, thus reducing cathodic reaction. Raising the pH of the water slightly above its calcium carbonate saturation value will sometimes cause a thin calcium carbonate film to be continuously deposited on the metal. Treatment varies with the composition of the water. Hard alkaline waters may require the addition of only slight quantities of soda ash. Soft waters of low alkalinity may need both lime and soda ash.

(2) Phosphates. Glassy phosphates such as Calgon, Nalco 918 and similar compounds, have wide application in treatment for minimizing the

effects of corrosion in water supply systems. Corrosion inhibition is caused by the adsorption of the phosphate, or one of its complexes, on the material surface forming a protective film. The rate of supplying the phosphate to the metal surface is the important factor rather than its concentration in the water.

(a) Initial dosage. For initial installations, it is desirable to have a high dosage (10 p.p.m.) to form a film as quickly as possible. A modified polyphosphate containing zinc is sometimes used initially for this purpose. As soon as the protective film has formed, the dosage can be reduced to from 2 to 4 p.p.m., depending on what is required to maintain a film on the metal.

(b) Useful range. Phosphates are useful in a pH range of 5 to about 8, with best results obtained in pH ranges from 6.5 to 7. When beginning polyphosphate treatment in corroded pipe systems, difficulty is often experienced with the sloughing off of existing corrosion products. Therefore, care is required to avoid complaints.

(c) Feeders. Chemical feed is usually by solution feeders similar to hypochlorinators. Since polyphosphate solutions support bacterial growth, use a small amount of hypochlorite (2 to 3 p.p.m. residual chlorine) in the feed solution to avoid contamination.

(3) Sodium Silicate. The addition of sufficient quantities of soluble silicates to water will produce a precipitation of a thin, gelatinous metal silicate film on the metal. To maintain this film, sodium silicate must be fed continuously at a rate of about 30 p.p.m. (8 p.p.m. silica addition). Silicates are best adapted to the treatment of very soft waters.

3.2.8 CLARIFICATION. The term clarification refers to the removal from water of floating or suspended mud, clay, living or dead aquatic organisms or growths and other material to produce a relatively clear, clean liquid.

3.2.8.1 Choice of Process. Plain sedimentation (settling) is seldom used alone for the clarification of water. Due to increasing pollution of water sources, the sedimentation process usually is not sufficient and it must be followed by filtration. Plain sedimentation is rapidly being replaced by mechanical and chemical treatment in order to reduce the size of units, to increase efficiency and to improve treated water quality. Coagulation and sedimentation are usually followed by filtration.

3.2.8.1.1 Type and degree of treatment. The type and degree of treatment will depend upon the nature of the raw water, which will vary widely depending on its source. In general, the process entails coagulation (including flash mixing and floc conditioning), settling or sedimentation and filtration (see fig. 71).

3.2.8.1.2 Microstraining. A recent development, particularly useful for the removal of the bulk of heavy algae suspensions prior to the conventional clarification or filtration processes, is microstraining. In this process, the raw water passes through a rotating, fine mesh screen which is continuously backwashed by a spray arrangement.

3.2.8.2 Coagulants and Coagulation. Coagulation includes the addition of chemicals which form a gelatinous precipitate (floc) to entrap suspended matter and color, and the enlargement of the particles so that they settle rapidly. Most water sources, and especially surface streams, contain enough finely divided material in suspension to require coagulation for removal before filtration, even though the water may have been previously subjected to plain sedimentation. In addition, certain forms of algae and micro-organisms act as a form of suspended matter and may be removed by coagulation, flocculation and settling in the sedimentation basin.

3.2.8.2.1 Principles of coagulation. Coagulation is accomplished through the addition of a chemical called a coagulant, which reacts with alkalinity in the water to produce a gelatinous precipitate or floc. The gradual growth of this floc by a slow mixing process is called flocculation. During the growth process, the floc increases in size, absorbs color, enmeshes bacteria particles causing turbidity, and with its increased weight settles to the bottom of a sedimentation basin provided for this purpose.

3.2.8.2.2 Equipment for coagulation. The equipment used to promote the growth of floc is called a flocculator, and the basin or chamber in which it is installed is called the flocculating basin. It is in the processes of coagulation, flocculation and sedimentation, that the greatest removal of suspended matter takes place.

3.2.8.2.3 Process mechanism. The process of coagulation involves complex chemical and physical reactions beyond the scope of this manual. However, in basic terms, the addition of a coagulant to water produces two actions, one electrical and one chemical. The suspended particles of mud and clay carry minute negative electrical charges. The coagulant floc is a colloidal, hydrous oxide, with a small positive charge. The positive charges attract and neutralize the negative charges, thus causing an agglomeration or joining together of the suspended particles and the floc. As this combined particle develops and increases in size, it becomes dense enough to settle out of the water.

3.2.8.2.4 Chemicals used as coagulants. Some of the more widely used coagulants, their chemical reactions and uses are listed below.

(1) Aluminum Sulfate. When aluminum sulfate (filter alum) is added to a water containing natural alkalinity in the form of calcium or magnesium bicarbonate, the theoretical reaction is as follows.

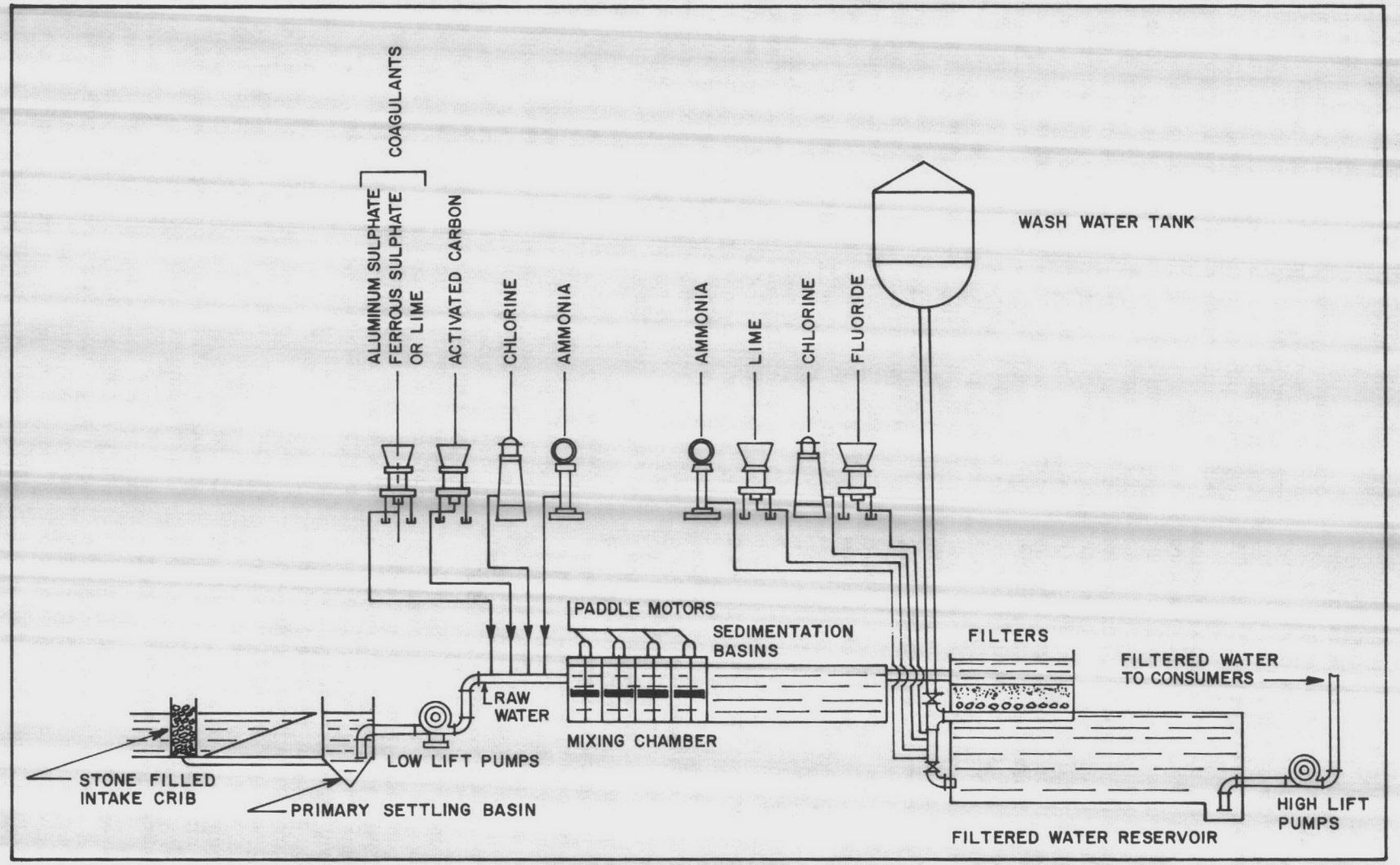


FIGURE 71

Schematic Diagram of Clarification Process

filter alum + natural alkalinity = desired floc; aluminum sulfate + calcium carbonate = aluminum hydroxide + calcium sulfate + carbon dioxide + water.

(a) Need for alkalinity. When water does not contain sufficient natural alkalinity to react with alum, an alkali such as calcium hydroxide (hydrated lime) is added. The theoretical reaction is.

filter alum + added alkali = desired floc; aluminum sulfate + calcium hydroxide = aluminum hydroxide + calcium sulfate + water.

Sodium carbonate (soda ash) may also be used with alum to supply the necessary alkalinity. The reaction is.

filter alum + added alkalinity = desired floc; aluminum sulfate + sodium carbonate = aluminum hydroxide + sodium sulfate + carbon dioxide + water.

(b) Alum use without added alkalinity. It is advantageous to use alum alone when possible, since it greatly simplifies control of the treatment process. It does not intensify color that may be present in the water and may actually reduce the color already present to some extent. Ordinarily, the resulting increase in hardness and corrosiveness is of little consequence. The minimum dose should never be less than 5 p.p.m. even with relatively clear water in that smaller doses will not produce the concentration of aluminum hydroxide necessary for floc formation. The usual pH range for use of alum is 5.5 to 6.8.

(2) Ferric Salts. Liquid, crystalline and anhydrous (without water) ferric chloride are available as coagulants. Ferric chloride is corrosive in the liquid state, or as the damp solid. Ferric sulfate is available as a commercial coagulant and has the advantage of being less corrosive than ferric chloride. The chemical reactions for ferric chloride and ferric sulfate are.

coagulant + natural alkalinity = desired floc; ferric chloride + calcium bicarbonate = ferric hydroxide + calcium chloride + carbon dioxide.
coagulant + added alkalinity = desired floc; ferric chloride + calcium hydroxide = ferric hydroxide + calcium chloride.
coagulant + natural alkalinity = desired floc; ferric sulfate + calcium bicarbonate = ferric hydroxide + calcium sulfate + carbon dioxide.
coagulant + added alkalinity = desired floc; ferric sulfate + calcium hydroxide = ferric hydroxide + calcium sulfate.

Ferric salts are used for the following reasons.

(a) Ferric floc is heavier than aluminum floc and settles more readily. It is also more completely precipitated over a wider pH range.

(b) Ferric floc does not redissolve at high pH when lime is used for corrosion control.

(c) Ferric floc forms more rapidly in cold water than does alum floc.

(d) Ferric coagulants are effective in color removal in alkaline waters with pH value over 9.0, and in iron and manganese bearing waters when used with lime to produce a pH value of 9 to 9.6.

(3) Coagulant Aids. A single coagulating chemical is often sufficient to produce good results. However, if the characteristics of the water create a difficult coagulation problem, there are available several materials which will improve the effectiveness of the coagulation process or speed the settling of the floc when used in addition to the coagulant chemical. The effect of a coagulant aid on flocculation is shown in figure 72.

(a) Activated silica. Chiefly used among these aids is activated silica, or sodium silicate treated with aluminum sulfate, chlorine, ammonium sulfate or carbon dioxide. The mixture must be aged 10 minutes or more. The use of this chemical results in the formation of a dense, heavy floc which is especially valuable in treating water low in suspended solids.

(b) Polyelectrolytes. A number of compounds, classified as polyelectrolytes, have lately become commercially available as coagulant aids. These are complex organic compounds and are usually synthetic. They may be anionic in character (negatively charged, or cationic (positively charged) or nonionic (neutral). Since all polyelectrolytes are not equally effective with all waters, a degree of experimentation is desirable. The question of toxicity arises when commercially prepared products are offered. This has led to the establishment of a technical advisory committee of the U.S. Public Health Service to review the matter of toxicity of compounds as they are submitted by manufacturers. Only those compounds which have received clearance by this agency shall be employed in the treatment of potable water.

(c) Clays. Several commercial clays have been found to aid in "weighting" floc so as to speed settling. Samples for testing their applicability for caogulation of a particular water may readily be obtained from manufacturers or local suppliers.

3.2.8.2.5 Determination of chemical dosage. Many factors influence the type and amount of chemicals required for effective coagulation of raw water. Dosages of chemicals required vary greatly, from as low as 1 p.p.m. to more than 100 p.p.m. Jar tests (see par. 3.3.4.16), laboratory scale coagulations, are usually carried out on the raw water to obtain information as to the kind and quantity of chemicals to use. It then remains to modify the jar test results by trial runs in the plant to find the exact dosage required to obtain the most economical results. It is usually more efficient to run jar tests than to experiment in the treatment plant. Every water treatment plant requiring coagulation should make at least one jar test daily to determine or to check the chemical dosages required. Control tests for coagulation processes are covered in paragraph 3.3.4.16.

3.2.8.2.6 Chemical feeding equipment. The amounts of chemicals added to the water must be carefully controlled to ensure uniform treat-

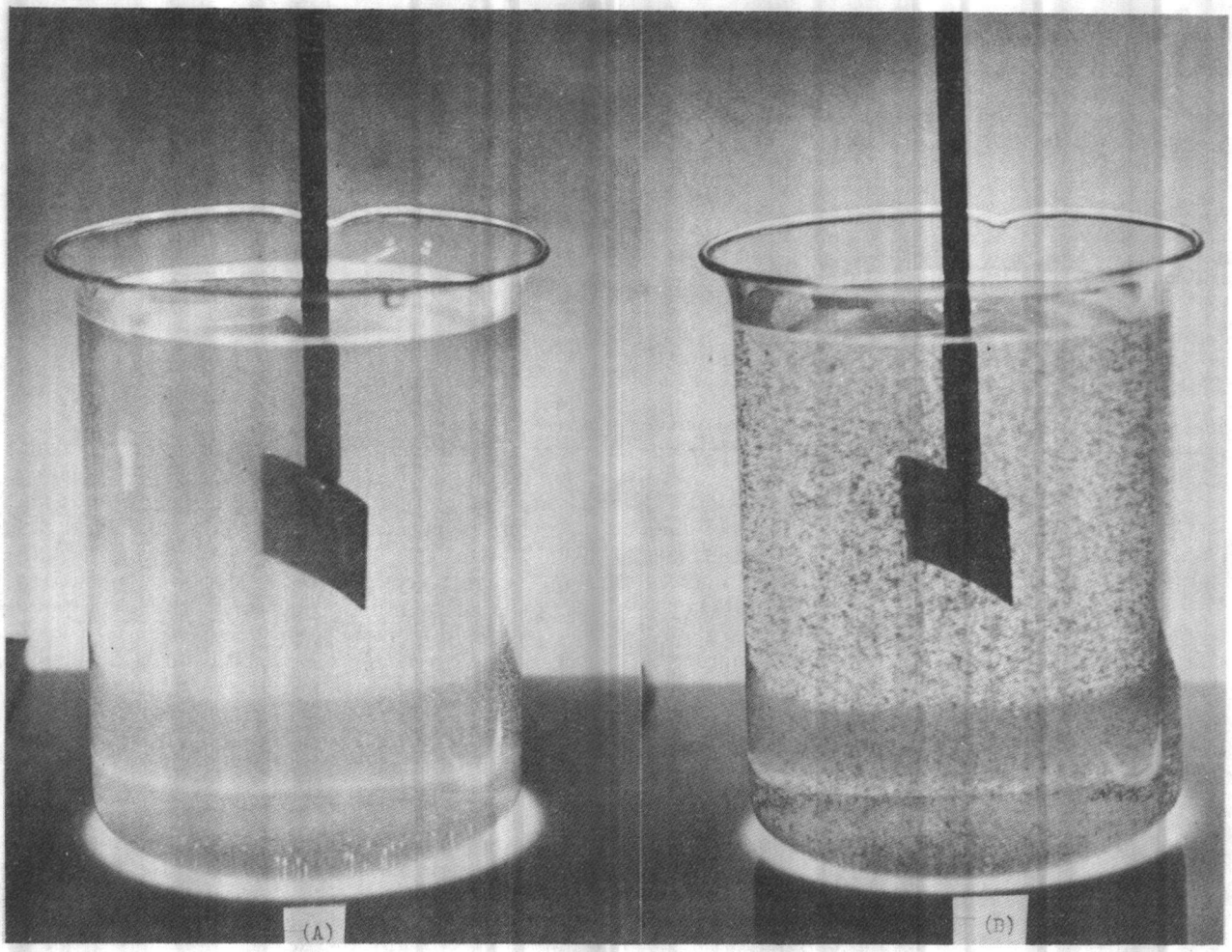


FIGURE 72

Effect of Coagulant Aid on Floc Formation

(A) Without Coagulant Aid
(B) With Coagulant Aid

ment. Many types of chemical feeders, manually or automatically controlled, are available, but dry feeders are most often used because of their greater accuracy and simpler operation. See paragraph 3.2.3.1 for a discussion of dry feeders.

3.2.8.2.7 Flash-mixing. The more quickly the coagulants can be uniformly mixed with water to be treated, the more rapidly and completely will the chemical reactions take place. In water treatment practice, this is called rapid or flash-mixing. The compartment in which this process takes place is known as the mixing chamber or basin. The devices by which rapid mixing is accomplished are known as rapid flash-mixers. These include pumps, aero-mixers, turbo-mixers, hydraulic jumps, air-agitated mixing chambers and mechanical stirrers (see fig. 73). Some mixing will also take place in the pipes and conduits through which water flows.

3.2.8.2.8 Flocculation or floc conditioning. The purpose of flocculation, which follows the addition and mixing of the coagulant, is to promote the growth of the floc particle and to provide opportunity for contact between the floc and the suspended particles causing turbidity. The increased weight of the floc results not only from the increased size of the floc but also from the adsorption of turbidity particles on the enlarged precipitate as it moves through the water. The more opportunity floc has to contact the suspended turbidity, the more efficient is the removal. Floc increases in size through the action of gentle stirring, and contact between the floc and turbidity is promoted by allowing low enough velocities through the flocculation chambers and furnishing a long path of travel. Too much agitation will break up the floc.

(1) Flocculating Equipment. While individual

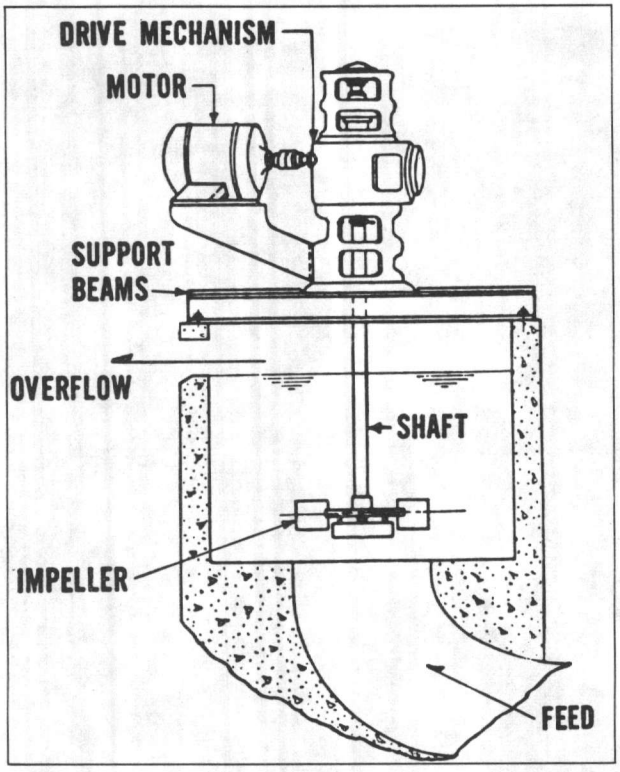


FIGURE 73

Flash Mixer

installations may vary, most flocculation equipment is of one of three types—baffle basins, power-driven paddles or agitators and spiral-flow flocculators.

(a) Baffle basins. Baffle basins are the older method, and as suggested by the name consist of a tank with baffle walls built in them to turn the water. The baffles may be of the "over and under" type, or the "end around" type. The passageways formed by the baffles constrict the flow so that increased velocity is set up, and in going around the baffles, the water is "turned over on itself".

(b) Mechanically stirred basins. The second type are mechanical tanks with a paddle-like stirrer which imparts a velocity to the water. The area of the paddles is usually from 10 to 25 percent of the cross-sectional area of the tank (see Figure 74). These mechanical devices are used to achieve slow or gentle stirring and to provide a long path of travel for the floc. The paddles, usually of steel or wood, are generally mounted on a steel frame revolving on a horizontal axis, the vertical dimension of the frame being slightly less than the depth of water. The rotating unit may be mounted so that the axis is either parallel or perpendicular to the direction of the flow of water. Normally there are three to four units in a row, and three to four rows in a series, as may be required.

(c) Walking-beam flocculators. The "walking-beam" type of flocculator provides the same primary functions as the rotary type, but by a different mechanism (see fig. 75). This flocculator applies the stirring action by means of an up-and-down motion of paddles mounted on triangular forms at the bottoms of long vertical arms.

(d) Spiral-flow flocculator. The spiral-flow flocculator consists of a circular or square basin of such a design that the water enters tangentially so as to cause spiral flow. Usually the effluent pipe leads from the center and upper portion of the basin so as to ensure this spiral flow and to prevent short-circuiting of the water being flocculated. Appreciable agitation in the basin can be assured by proportioning the inlet to secure a velocity of 2 to 3 feet per second for the entering water. These tangential flow basins are well adapted to small filtration plants, and also as additions to existing plants where only a limited head is available to provide needed agitation.

(2) Cleaning. Generally, flocculators are cleaned at 3- to 6-month intervals, or when development of an odor or a tendency for floc particles to rise to the surface indicates that septic sludge conditions are developing. For detailed cleaning and maintenance instructions, see Chapter 4. Copies of the manufacturer's instructions should be kept available for ready reference. Personnel must thoroughly familiarize themselves with the equipment so that repairs may be made quickly and properly.

3.2.8.2.9 Floc settling. This process is accomplished in basins designed to produce sufficiently low water velocities so that the floc can settle out quite completely in the time allowed for the water to pass through the basin. Correct basin design keeps the water from flowing directly from inlet to outlet, and distributes the flow uniformly throughout the cross-section of the basin. A uniform velocity of no more than 1 foot per minute is desirable.

3.2.8.2.10 Operation of sedimentation basins. The main items in the operation of sedimentation basins are the control of the quantity of water flowing through the basin; the removal of sludge from the basin; and the cleaning of the basins and the sludge collecting equipment. Figure 76 shows a sedimentation basin which utilizes longitudinal sludge collecting flights.

(1) Control of Flow. Control of the quantity of water flowing through the sedimentation basin is accomplished by the use of plant metering devices or by periodic checking of the discharge rate of the raw water pumps. In cases where the raw water enters the plant by gravity flow, an orifice plate, venturi tube or other type of meter, and a control valve are used so that the flow-

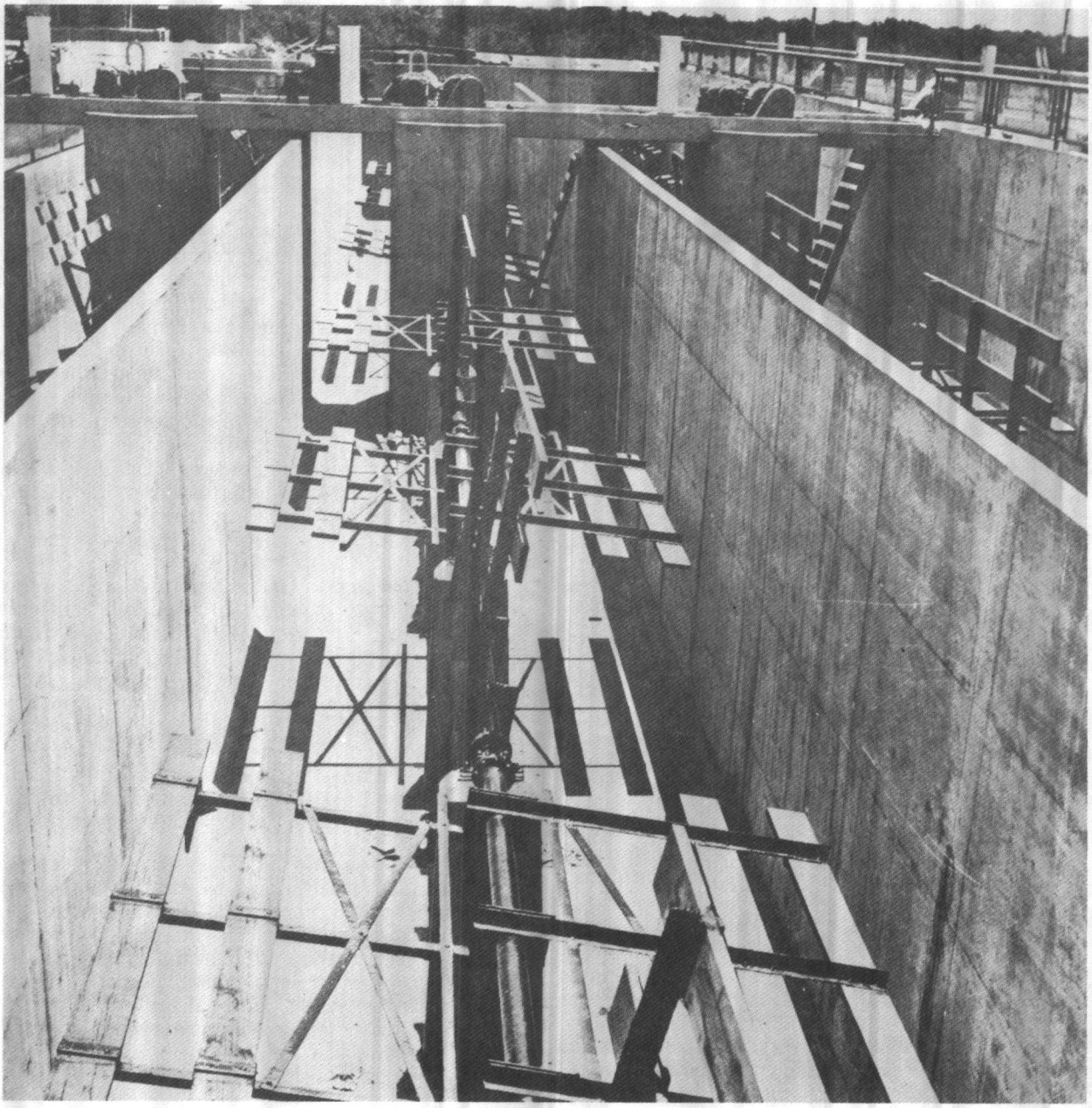


FIGURE 74

Rotating Paddle Flocculator

through quantity can be accurately determined and controlled.

(2) Detention Periods. Detention periods of four to six hours are commonly used in sedimentation basins. There are several practical methods of estimating this detention time, including the use of dyes, confetti, submerged floats and a salt solution.

(3) Short-Circuiting. Studies with the use of dyes have shown that a portion of the entering water may pass through the basins in less than 15 to 25 percent of the computed detention period, whereas other portions of the water may remain in the basin for periods well in excess of the computed period. While the use of dye is very helpful in indicating the existence of serious short-circuiting and just where water may be passing through the basin at a high rate, eventually dye diffuses throughout the water in a basin and further observations are not feasible. In the absence of other means, however, the use of dye is very helpful in disclosing where short-

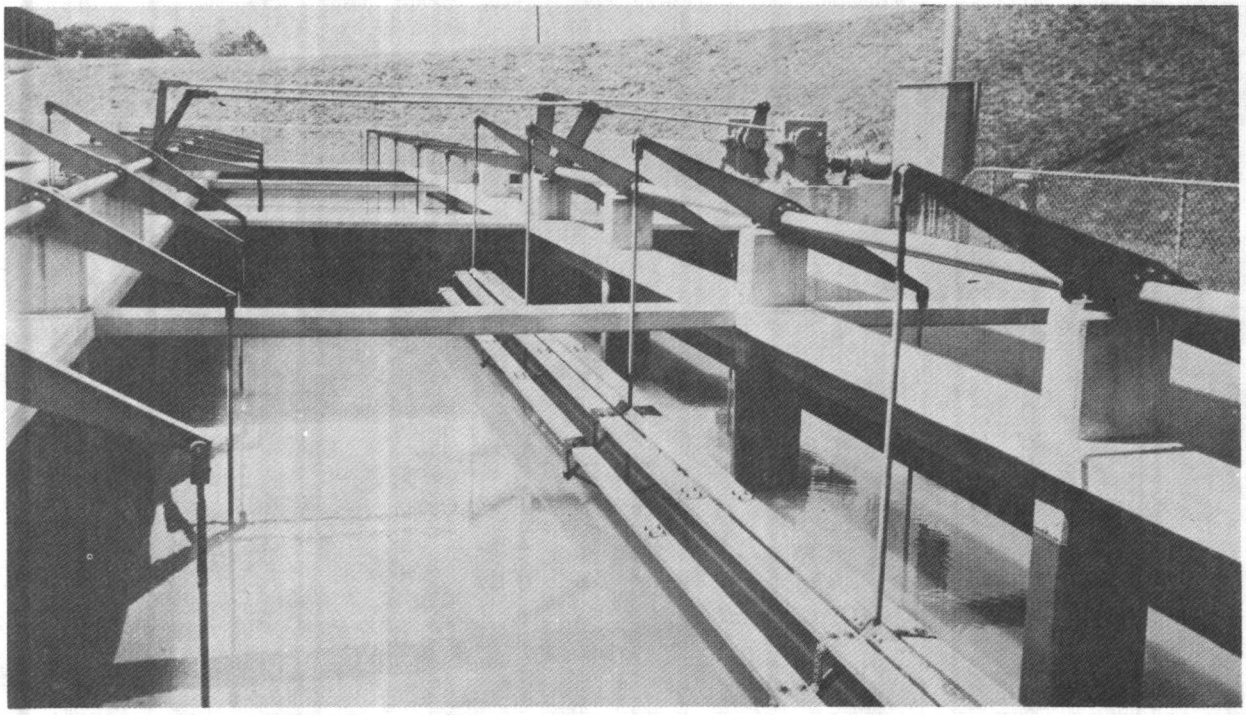


FIGURE 75

Reciprocating (Walking-Bear Type) Flocculator

circuiting is occurring. Observation of eddies that result in short-circuiting in sedimentation basins may also be made with confetti. A small handful of confetti is dropped into the stream of water entering a basin at intervals of 5 minutes so as to disclose the direction and the velocity of the currents. The three-dimensional appearance of the batches of confetti also makes observation of vertical eddies possible.

(4) Detection of Water Movement. Submerged floats with an above-the-water flag or target will indicate the direction and rate of movement of water through a basin. The floats should have a large area to make them respond to slow velocity currents, and their depth of submergence should be as representative as possible. Floats are particularly useful in the study of large open basins or reservoirs.

(5) Salt Method for Detention Time Determination. The most accurate procedure for measurement of detention time is with the use of salt solutions. This consists of the application of a strong solution of salt to the influent of the sedimentation basin in a quantity necessary to produce a dose of about 3 p.p.m. (in terms of chlorides) for a period of 5 minutes. Immediately upon the application of salt to the influent, samples of water should be collected from the effluent of the basin, and this should be repeated at intervals of 5 minutes so that subsequently the chloride content of the series of samples may be determined. These samples will reveal when a portion of the salt-treated water has reached the outlet end of the basin; when the maximum concentration of salt has reached the effluent end of the basin; and, when the last trace of salt has disappeared from the basin, as shown by the return of the chloride content to normal.

3.2.8.2.11 Sludge removal from sedimentation basins. Sludge removal may be either intermittent or continuous.

(1) Intermittent Removal. For sedimentation basins not equipped for continuous sludge removal it is necessary that an adequate number of drain valves be provided and properly spaced over the bottom of the tank. These valves are opened periodically and the sludge removed by gravity drainage.

(2) Continuous Sludge Removal. Continuous removal of sludge has been found to be more satisfactory and efficient, particularly where there is a considerable amount of sludge to be removed. It is considered essential in modern design practice. Square and round sedimentation basins are usually equipped, in the bottom of the tank, with a spiral rake that rotates and moves the sludge to the sludge drain in the center. The tank bottom is sloped toward the center to assist in moving the sludge toward the drain. For rectangular basins, scrapers are provided that are dragged along the floor of the basin, carrying

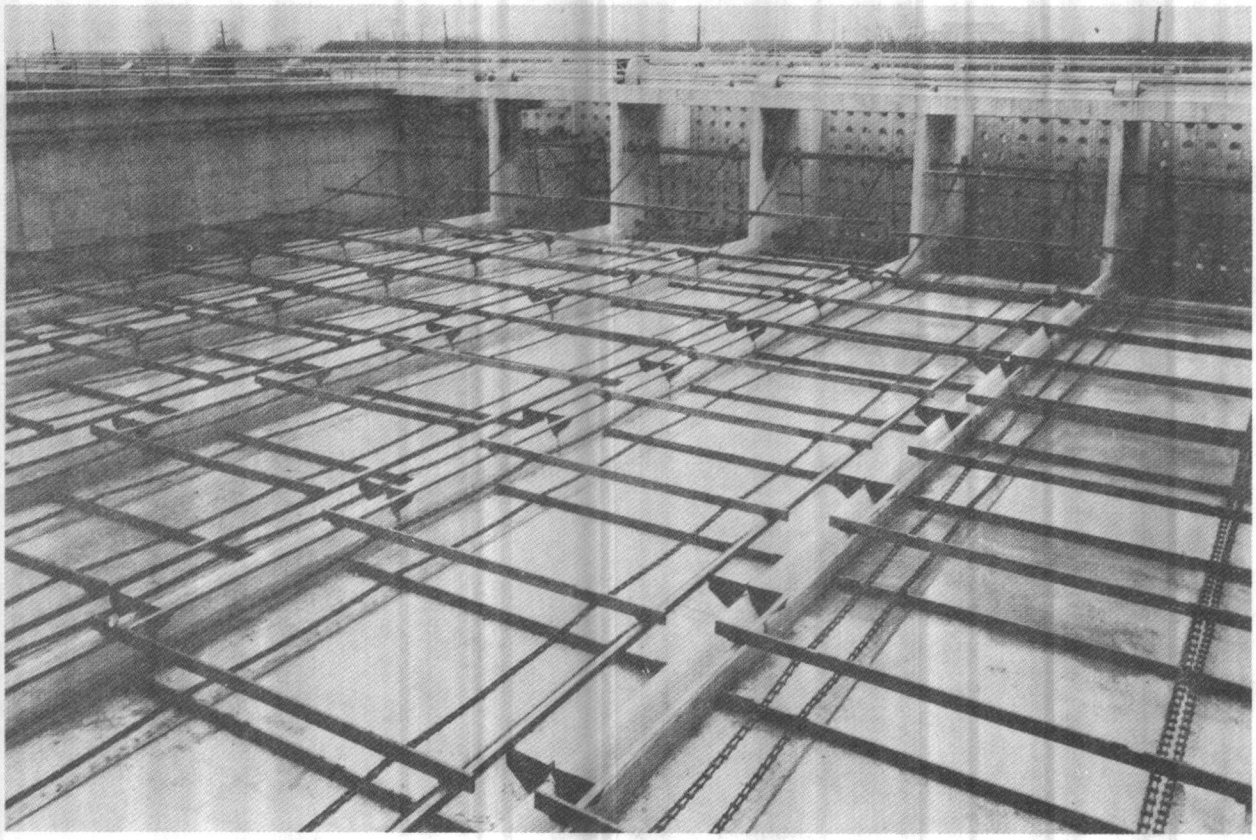


FIGURE 76

Sedimentation Basin Showing Longitudinal Sludge Collector System Utilizing Flights on Chains

the sludge to sludge hoppers located at the bottom of the inlet end of the tank (see fig. 77). From these hoppers, the sludge is removed either by gravity or by pumping to disposal areas.

(3) Sludge Return. In some cases where sludge is removed continuously, it has been found desirable to return a part of the sludge to the raw water as it enters the mixing basin. This returned sludge aids coagulation and increases the rate of settling, adding bulk to the new floc being formed and making it more effective and more rapidly settling.

(4) Protecting the Mechanism. Whenever any foreign objects are dropped into the tank which could injure the sludge collecting mechanism, the mechanism must be stopped immediately and the object removed.

3.2.8.2.12 Cleaning sedimentation basins. Sedimentation basins are cleaned at about 3-month intervals, or whenever development of an odor or rising floc particles indicate development of septic sludge conditions. Basins with mechanical equipment for removing settled sludge usually clean themselves satisfactorily during normal operations. However, it may be necessary at times to drain them, and to clean the tank and mechanism with a high-pressure water hose.

(1) Sludge Depth Determination. The depth of deposited sludge at various places in the basin should be observed from time-to-time to ascertain the points where sedimentation is most effective and also when the basins should be cleaned. These observations may be made by attaching a wooden rod at right angles to the center of a lightweight board structure about 2 feet square, so that this flat surface may be slowly lowered until resistance is offered by the sludge. Obviously, the upper portion of the sludge deposit has little consistency and therefore will not be felt with this device. Nevertheless, the upper level of the solidified sludge will be made quite apparent. Another method of sludge evaluation is with a hook light (described in par. 3.2.8.3.9(4)).

(2) Detailed Procedures. For detailed cleaning and maintenance instructions, see Chapter 4. If the plant has mechanical sludge collectors, keep a copy of the manufacturer's instructions at hand for ready reference. Operators must be

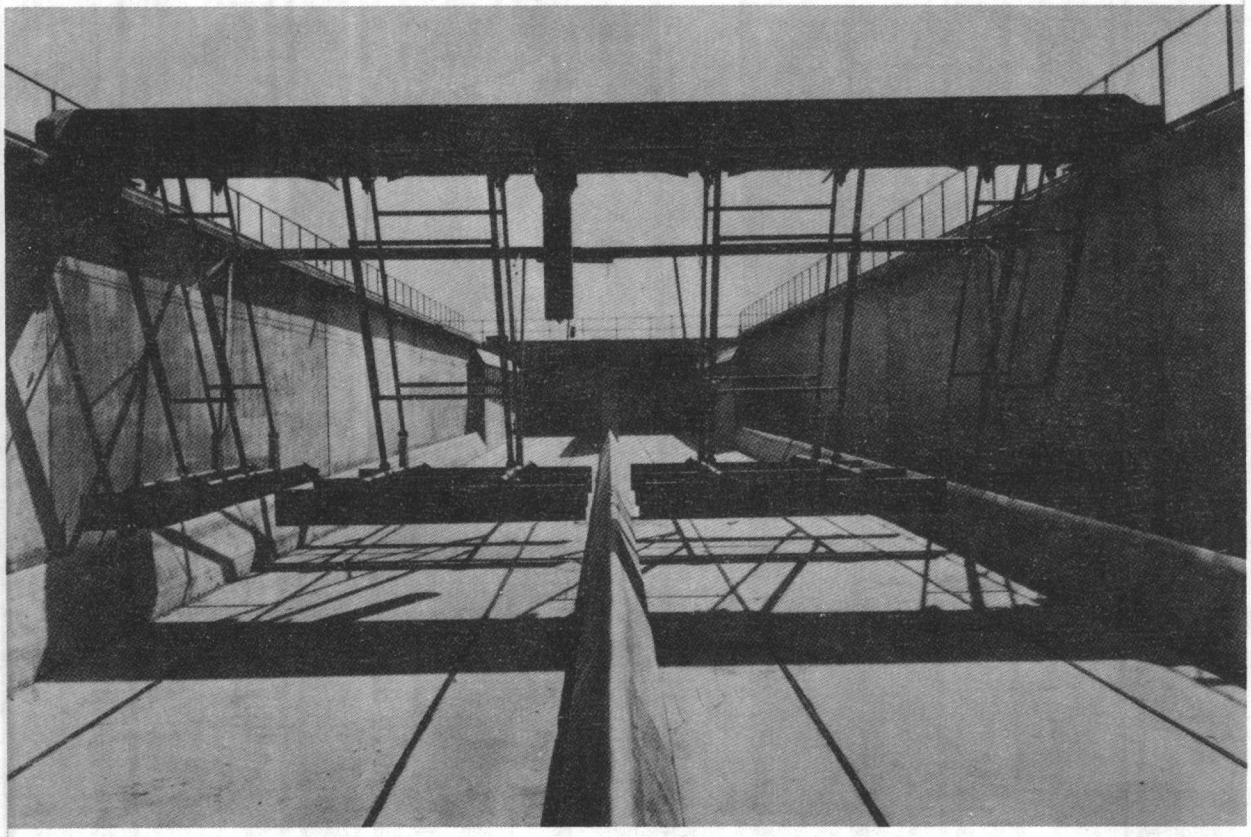


FIGURE 77

Sedimentation Basin with Longitudinal Sludge Collector System Using Sludge Rakes

completely familiar with mechanical appliances and instruction books so that emergency repairs can be made quickly and correctly.

3.2.8.3 Filtration. Water from the settling basins is brought to the filters as the next step in the purification process. This water contains very finely divided suspended matter such as minute particles of floc, clay and mud that has not coalesced, and bacteria and microscopic organisms that have not been removed by settling. The purpose of the filter is to remove this last portion of suspended matter so as to give the final treated water a clear, sparkling and attractive appearance.

3.2.8.3.1 Principles of filtration. The efficient operation of a filter depends upon effective pretreatment of the water; proper washing of the filter; special cleaning of the filter medium if that becomes necessary; and, maintenance of rate controllers, loss-of-head gages, underdrains and valves in a satisfactory operating condition. A filter consists of a bed of carefully sized and washed sand or other filter medium, such as screened and washed anthracite coal, supported by graded gravel. The gravel rests on an underdrain system or filter bottom (see fig. 78). The removal of suspended and colloidal matter is accomplished in several ways, discussed in the following paragraphs.

(1) Straining. When first placed in use, a clean filter will remove only that material larger than the opening of the pores. As this action progresses, a mat is formed on top of the sand; smaller particles are removed by this mat, and more efficient clarification is obtained. This straining action takes place on or near the surface of the filter sand. The thin surface mat of fine sand, floc particles and other fine solids which do most of the filtering job is often referred to as the "schmutzdecke" (German for dirt layer).

(2) Sedimentation. Particles smaller than the pore spaces tend to settle out within the pore space, because of the relatively large volume of these voids in a filter medium. They act as minute settling basins and therefore tend to remove suspended matter.

(3) Flocculation. Colloidal floc formulations may carry over from the sedimentation basin and continue to coalesce and grow in passageways between the medium grains and become large enough to be retained. This offers further oppor-

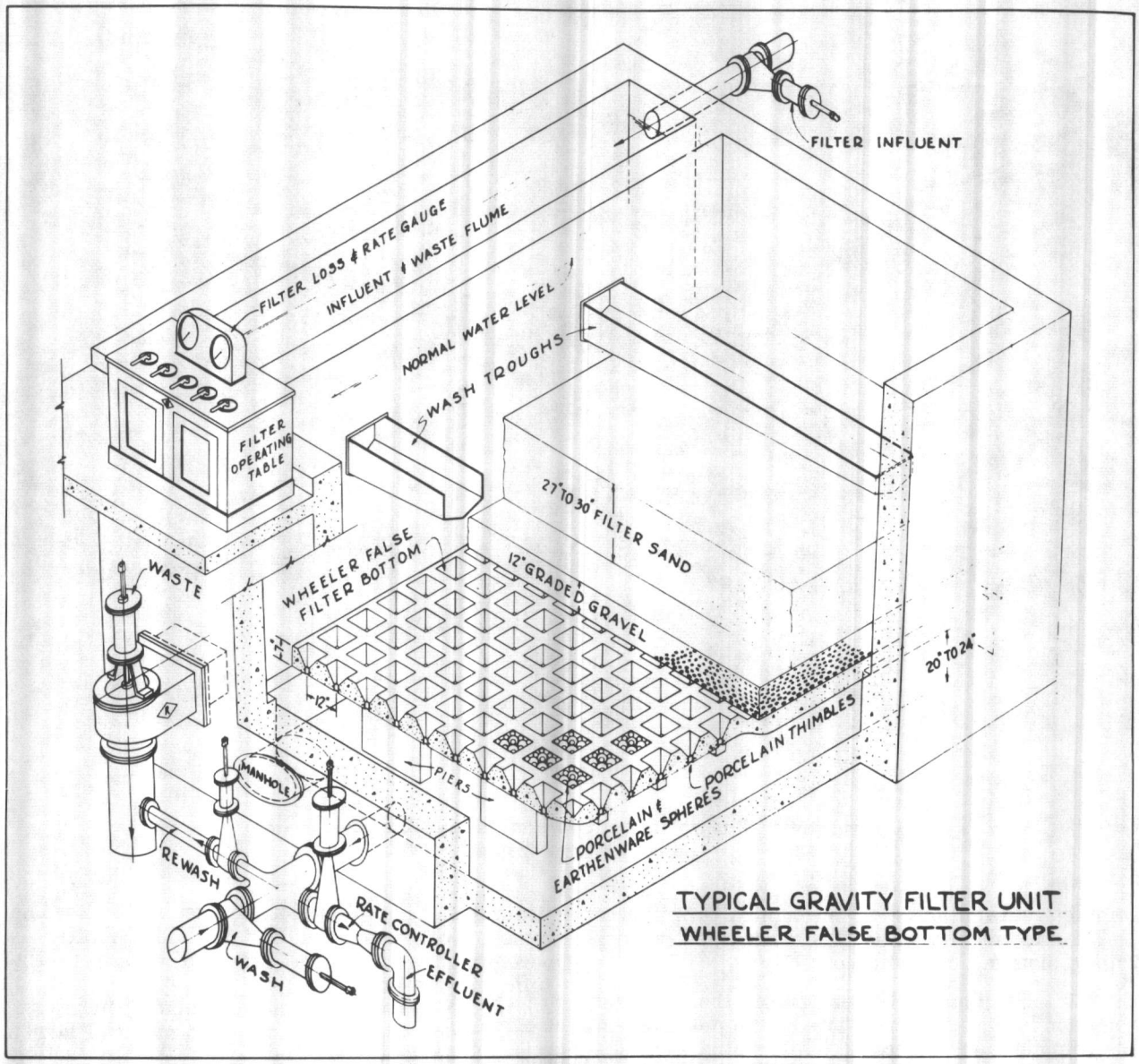


FIGURE 78

Diagram of Filter Installation with Wheeler Filter Bottom

tunity for other impurities to become entrapped. Also, this action will usually increase pore velocities, which in turn tends to carry floc particles further in to the bed helping to build up head loss in the filter. The filter will eventually have to be backwashed to restore it to full filtering capacity. Most foreign matter is removed in the top few inches of the sand bed. However, to prevent any material from passing through the filters, sufficient depth of filter media (24 to 30 inches) and restricted filter rates must be maintained.

3.2.8.3.2 Types of filters. In modern water works usage, two principal types of filter are used—rapid sand filters and diatomite filters. A third type, the slow sand filter, is seldom used in modern installations. Diatomite filters are primarily used in swimming installations and in advanced base water supply. Only in exceptional cases and when approved by the Bureau of Yards and Docks are diatomite filters used in the treatment of potable water at permanent naval shore activities.

(1) Rapid Sand Filters. There are two types of rapid sand filters—gravity and pressure.

(a) Gravity filters. This type of filter is essentially open-top, rectangular concrete or wooden boxes about 10 feet deep (see fig. 79). An

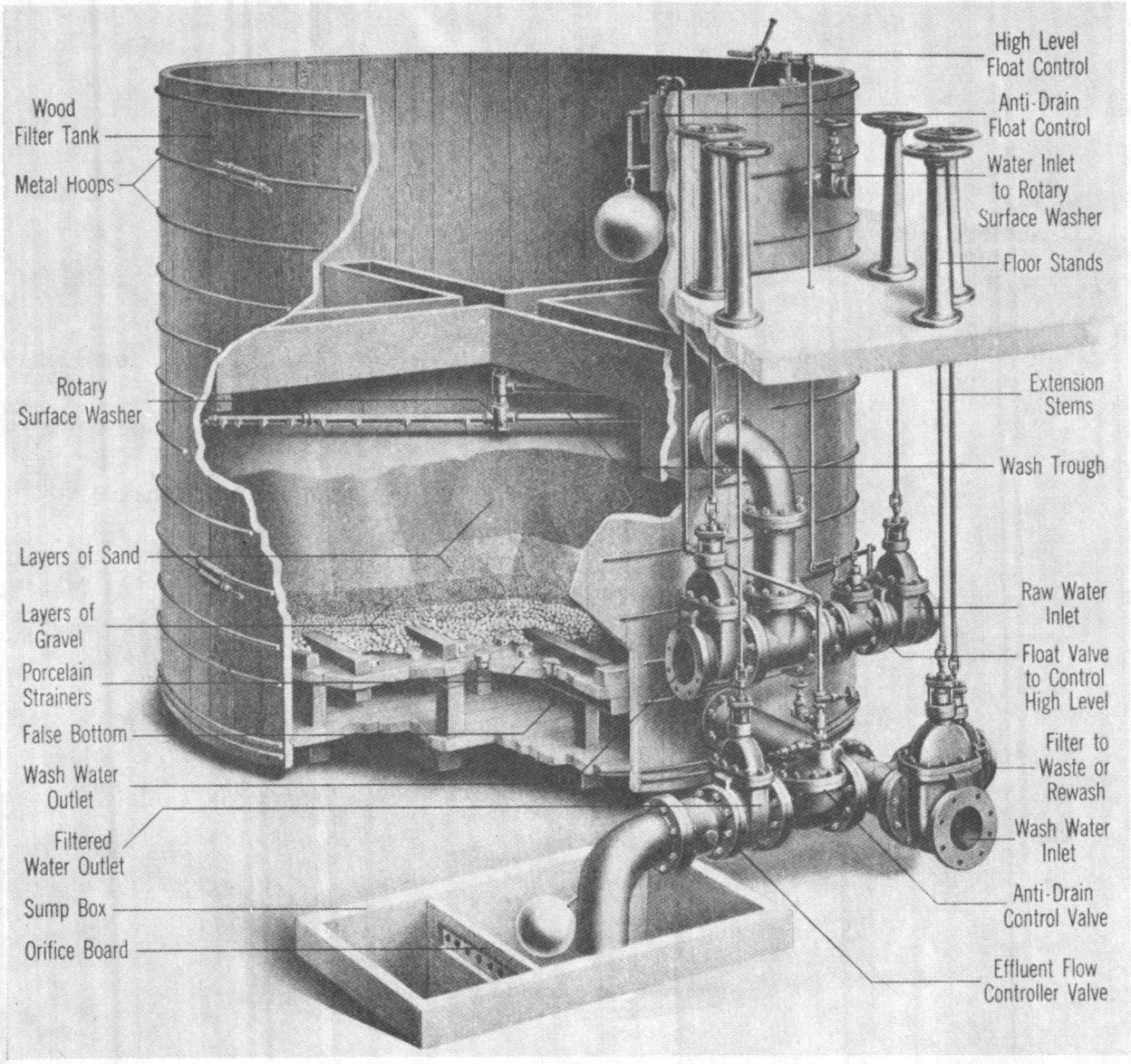


FIGURE 79

Cutaway Illustration of Gravity Sand Filter with Rotary Surface Wash

underdrain system at the bottom is covered with graded gravel, which in turn supports a 24 to 30 inch layer of filter sand. Gravity filters are usually designed to filter at about 2 g.p.m. per square feet of filter bed area. However, in an emergency, up to 4 g.p.m. per square feet can be obtained with a properly coagulated water.

(b) Pressure filters. This type of filter consists of a filter bed in a closed tank. Water is pumped through the filter under pressure. A pressure filter can be installed with the tanks set either vertically or horizontally and operates on the same principles and at the same rate as gravity filters (see fig. 80).

(2) Diatomite Filters. This type of filter is a special pressure (or vacuum) filter which uses a porous mineral powder, known as diatomaceous earth, as the filter medium for the removal of suspended materials from water. The pressure-type diatomite filter, used in swimming pool and advanced-base water supply systems, consists of a tank-like steel shell supporting a series of cylindrical filter elements on which a layer of diatomaceous earth is built up. (see fig. 81). These elements may be wire-bound plastic or steel cores, metal screen mesh, sintered brass, porous stone or Carborundum.

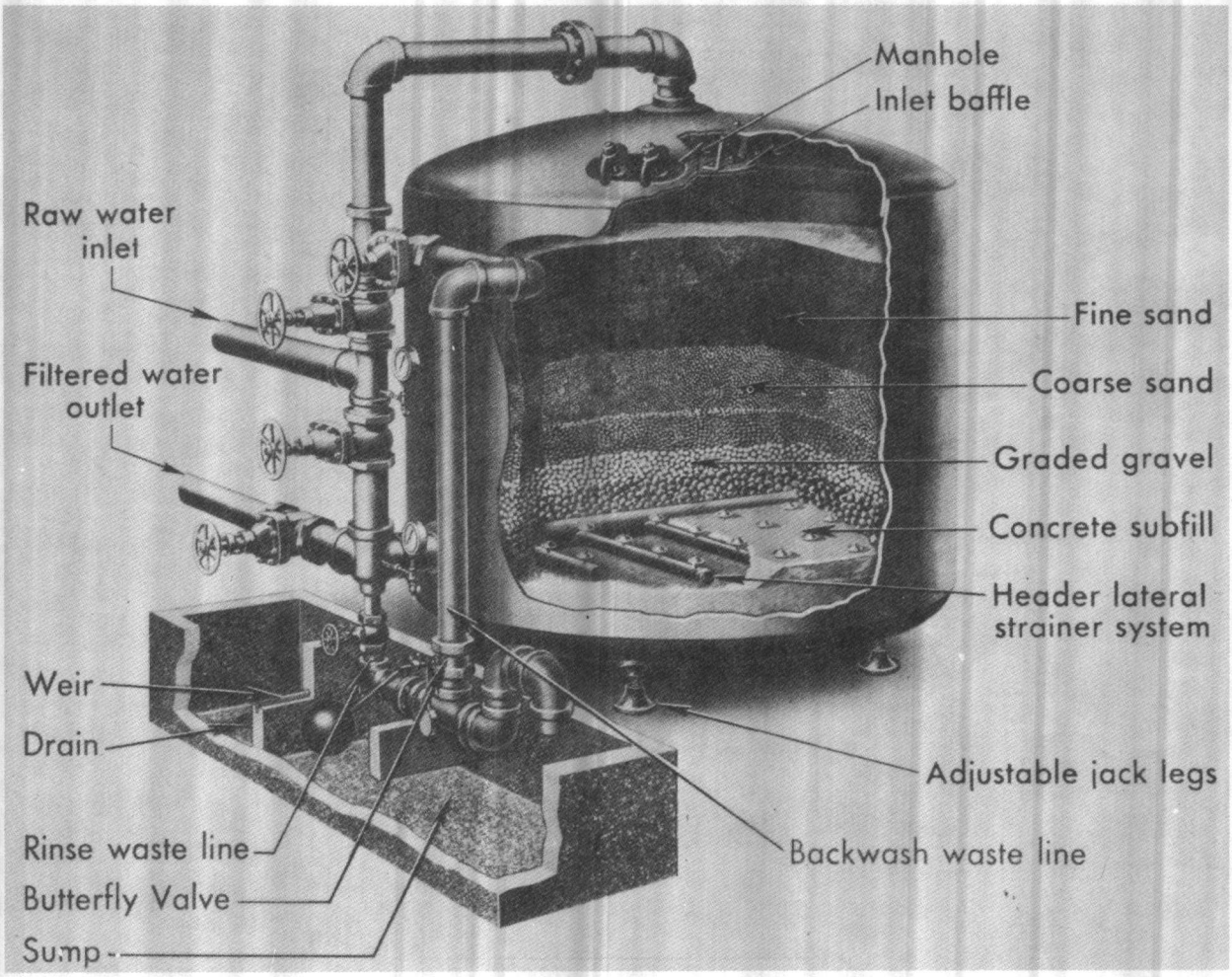


FIGURE 80

Pressure-Type Rapid Sand Filter

3.2.8.3.3 Filter media. Materials now employed as filter media include sand, anthrafilt and diatomite.

(1) Sand. Filter sand is composed of sharp or rounded durable grains of clean silica, such as quartz or quartzite. A filter sand is acceptable under the following conditions.

(a) When powdered and left for 24 hours in a warm bath of 20 percent hydrochloric acid, it may not lose more than 5 percent of its original weight.

(b) When heated to over 700° C., it may not lose more than 2 percent of its weight.

(c) Its effective size must be between 0.35 and 0.70 mm. and the sand must have a uniformity coefficient of 1.5 to 1.6. The effective size of a filter sand is that grain size which is smaller than 90 percent (by weight) of the grains in the stand and larger by 10 percent. This characteristic is used as an index of a sand's filtration rate. If a sand were regarded as being made up entirely of the effective size grains, the filtration rate would be the same as for the original sand. Effective size equals the rated size of opening (in mm.) of a sieve that passes 10 percent by weight of the filter sand.

(2) Anthrafilt. Anthrafilt is a filtering medium obtained from carefully selected, cleaned, and screened anthracite coal. It is acceptable under the following conditions.

(a) It must be dirt free.

(b) The effective size must be 0.65 to 0.73 mm.

(c) It must have a weight of about 53 lbs per cubic foot.

(d) The ash content may not be over 11 percent.

(3) Diatomaceous Earth. Diatomaceous earth has the physical appearance of white face powder or finely milled white flour. It is very

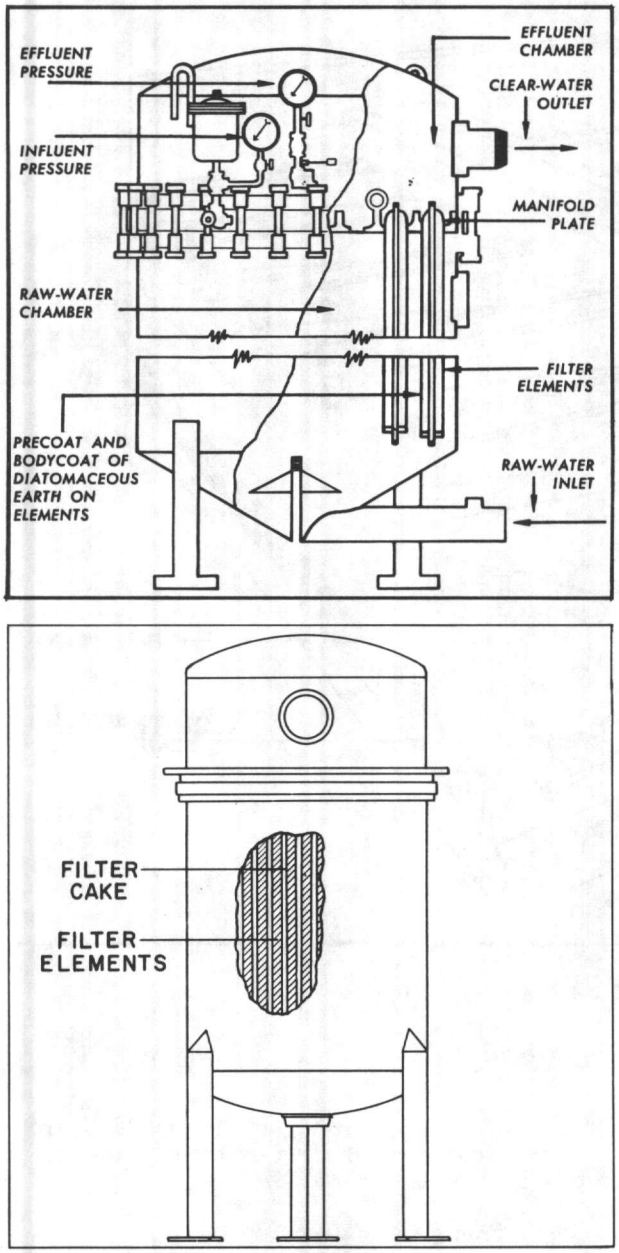


FIGURE 81

Pressure-Type Diatomite Filter (Two Views)

light and has great bulk per unit of weight. Diatomaceous earth is available from several manufacturers in various grades (particle size) for different uses.

3.2.8.3.4 Filter gravel. Gravel in a filter has three main functions. It supports the sand, permits water to flow freely to the underdrain and it aids in distributing wash water to all parts of the sand uniformly.

(1) Gravel Grading. Gravel is usually placed in the filter in graded layers, with the coarsest grade on the bottom and the finest on top. When the filter is in use, a 27-inch total depth of gravel may shrink to as low as 18 inches.

(2) Gravel Distribution. Unequal distribution of wash water sometimes results in a jet action that may cause the top layer of gravel to become uneven and mounded. Adding a 4-inch layer of coarse sand on top of the graded gravel helps stop the mounding.

3.2.8.3.5 Filter bottom and underdrain system. Underdrains (fig. 82) provide an outlet for water passing through the filter and are also the means of supplying wash water to the underside of the beds.

(1) Pipe-Type Underdrain System. This system consists of a cast-iron manifold or header with laterals usually on 6-inch centers. The laterals are closed at the outer ends, but have orifices drilled in the underside. Total area of all orifices is about 33 percent of the area of the filter surface.

(2) False Bottoms. Various types of false bottoms are also used as underdrains. Some of these are assembled from specially designed perforated clay tile sections, others from sections of porous Carborundum or similar materials, and still others may be largely cast in place of concrete.

3.2.8.3.6 Filter equipment. Filter equipment includes the following.

(1) Rate Controller. When a filter bed is first put into operation or has just been washed, water passes through it far too quickly for efficient filtration, unless the filtering rate is controlled. Therefore, the effluent line must be throttled to reduce the rate of flow. As the filter bed becomes clogged, the rate of filtration decreases and the amount of throttling must be reduced accordingly to keep the rate of filtration uniform. Manual control of the filter rate is impractical, so that the rate-of-flow controller must be used. See Figures 83, 84.

(2) Loss-of-Head Gage. The loss-of-head through a filter is the friction loss of the water through the sand bed and underdrains of the filter. It is measured as the difference between the surface elevation of the water on the filter, and the static operating level of the water in a vertical tube on the discharge pipe of the filter. The loss-of-head gage is operated by two floats, one at the surface of the water in the filter and the other at the static operating level of the water in the main underdrain pipe. The loss-of-head gage (fig. 85), which measures the difference between the two elevations, is the most important guide to filter operation.

(3) Wash-Water Controller. Wash-water controllers are considered an essential part of a modern filter plant. A rate-of-flow controller similar to the one controlling the filtering rate, a butterfly valve or a special type plug valve may be used to control the wash-water rate. The valve

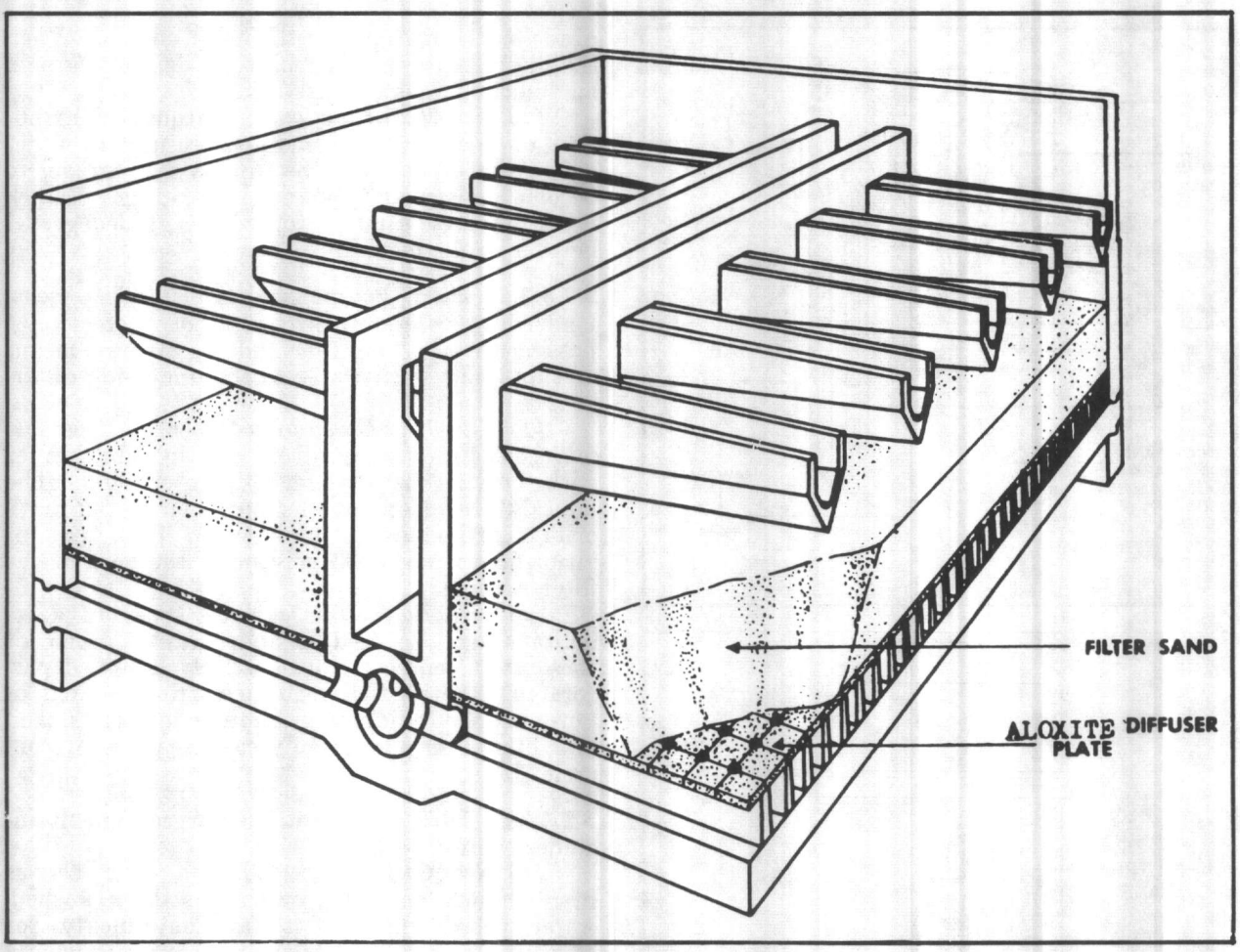


FIGURE 82

Filter Underdrain System

operation mechanism, or control, and a pressure gage showing the pressure in the wash-water pipeline on the discharge side of the control valve should be located on the operating floor.

(4) Rate-of-Flow Indicator. A rate-of-flow indicator measures the rate of water production by the filter. It usually consists of a venturi meter in the filter effluent line operating an indicating instrument located on the operating floor where it can be readily seen by the operator. In some types of plant equipment, it is combined with the loss-of-head gage and the rate-of-flow controller metering devices.

(5) Hook Gage. A hook gage is a series of vertical sharp pointed rods held in a frame which may be hung on the side of the filter (see fig. 86). The tips of the sharp pointed rods are set accurately at 2- to 3-inch spacings. It is used to check the rate of filtration and washing by observing and recording the time required for the water level to rise or fall between the points. The volume of water in the filter between the gage point levels is easily calculated, and from the recorded time, the rate is readily and accurately determined.

(6) Piping and Valves. Filter piping is usually located in a pipe gallery and carries the influent, effluent, wash water and waste water to and from the filters. Valves and piping are so arranged that some of the piping may be used for more than one purpose. The rate-of-flow controllers and metering units are installed in the pipelines to which they apply. Valves may be operated manually, electrically, hydraulically or pneumatically. Sampling taps and air cocks for release of trapped air are usually provided. Because of expansion and contraction, at least one sleeve joint should be provided in each pipeline at each filter. The pipe gallery should be well light, ed, well ventilated and provided with a floor drain or sump pump. All piping and valves should be kept painted at all times in order to minimize external corrosion.

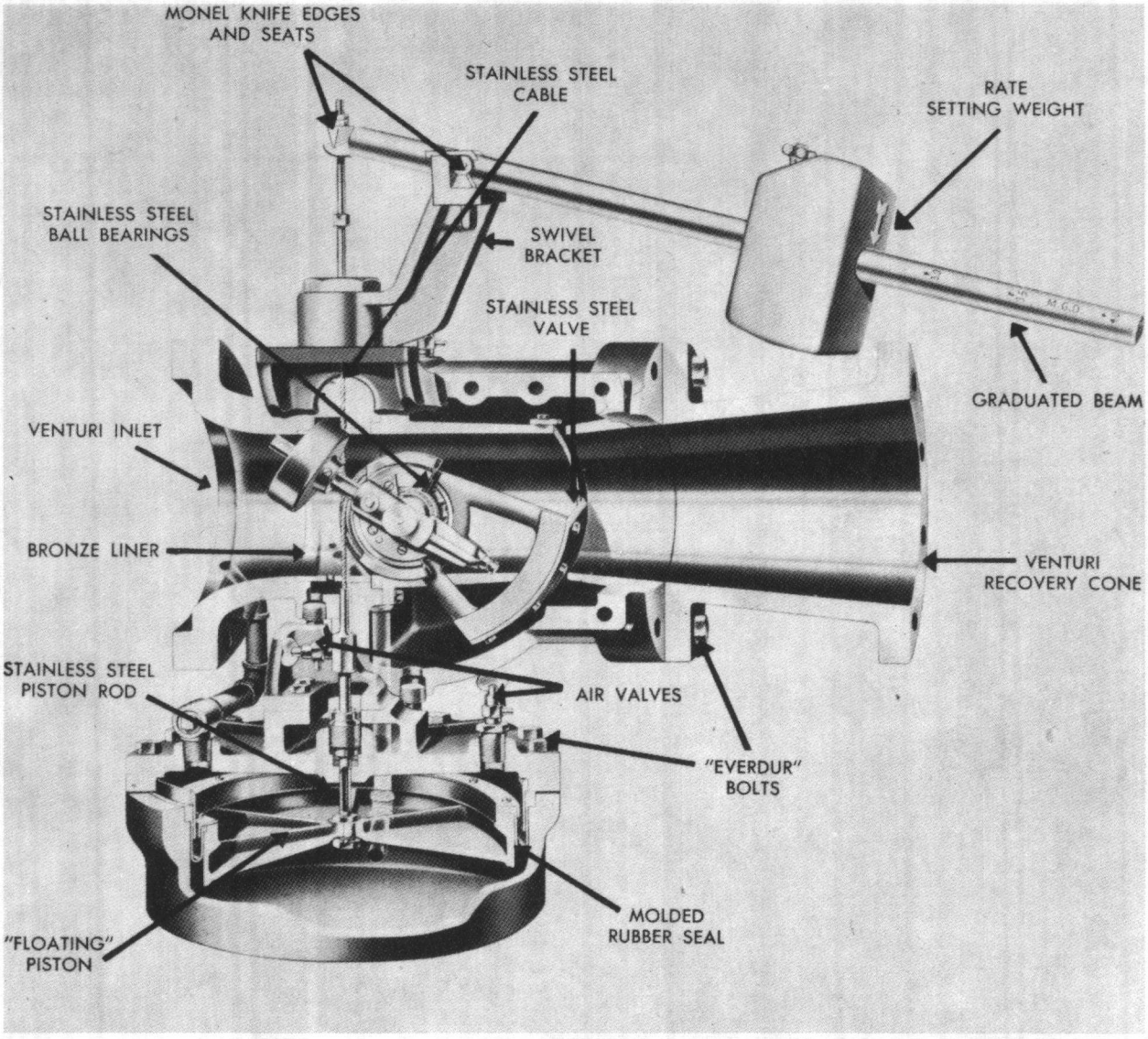


FIGURE 83

Cutaway View of Filter Rate Controller

3.2.8.3.7 Operation of sand filters. An influent pipe carries the partially clarified water from the sedimentation basin to the filter bed, discharging behind a baffle wall ahead of the filter bed or by overflowing distribution troughs so that water currents do not disturb the sand bed. The water filters downward through the sand and gravel into the underdrains, passes through a rate controller, and is collected in a filtered-water reservoir called a clearwell.

(1) Backwashing. When the loss-of-head gage shows that the filter is becoming dirty or clogged, the filter must be washed. This is done by reversing the flow through the filter in order to remove the accumulated material on the filter and to carry it to waste through the plant sewer.

(2) Operating Difficulties. The main operating difficulties in rapid sand filters are caused by an accumulation and formation of mud balls on the filter; sand incrustation by chemicals in the water; separation of the sand bed from the filter wall in pressure filters; air binding; sand clogging; micro-organisms not removed by coagulation and sedimentation; and, ice formation on outside filters.

3.2.8.3.8 Filter rate control. A constant and controlled rate of filtration is necessary because

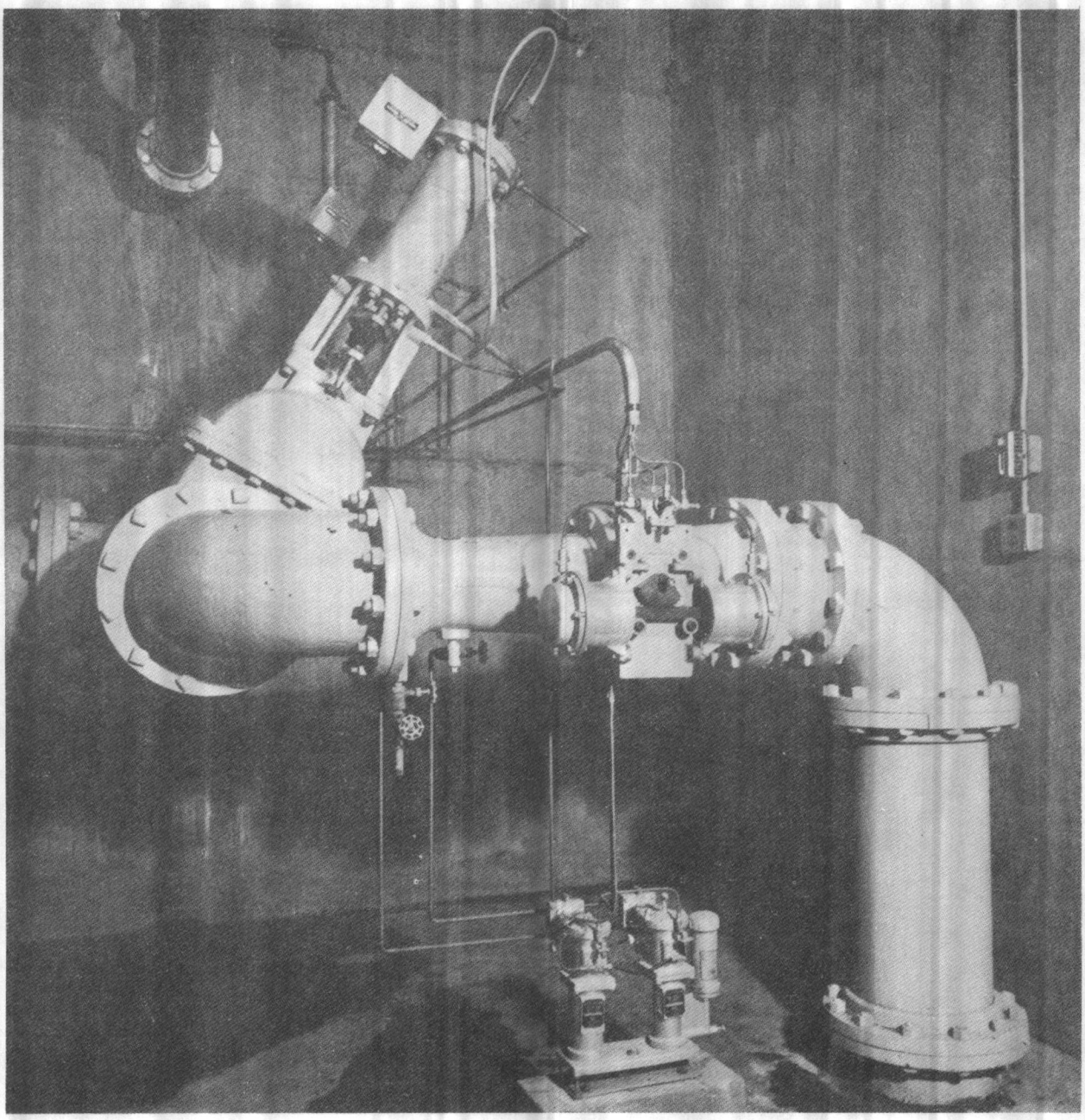


FIGURE 84

Installation View of Rate Controller

changes in the filtering rate may cause breaks in the *schmutzdecke*, allowing the water to pass through the bed without being filtered. Also, a decrease in the pressure under the filter surface may cause dissolved gases to be released from the water thereby causing the filter to air-bind.

(1) Essentials of Rate Control. There are two essentials in the control of the filtering rate. An adequate supply of influent water is required to meet the desired rate; and, the total filtering rate must be maintained at the maximum allowable for the size of the filter and the maximum permissible filtering rates.

(2) Influent and Effluent Control. The supply of influent water is usually fixed by the elevation of the outlet weir from the coagulating

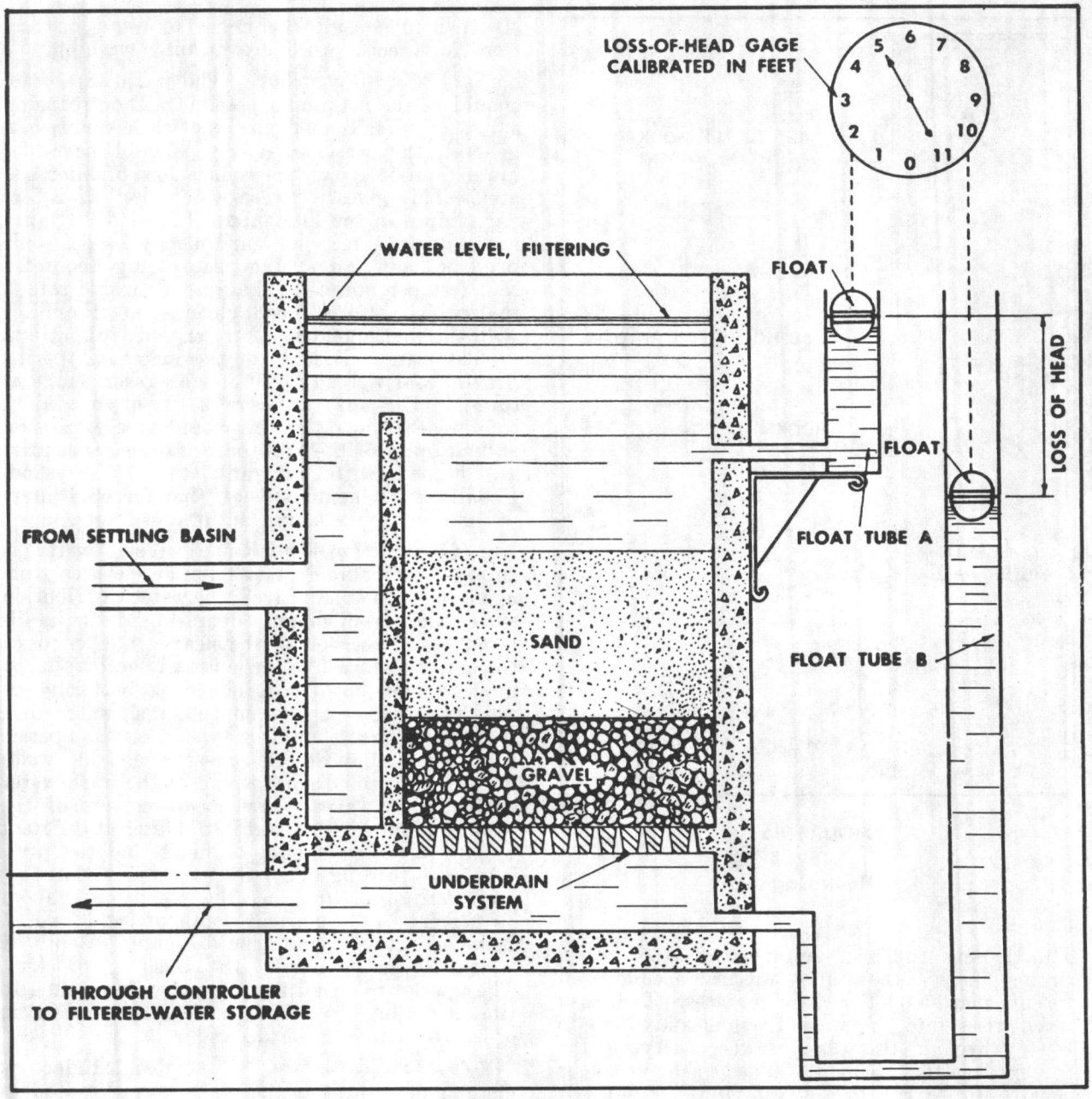


FIGURE 85

Loss-of-Head Gage

basin where the influent flow is by gravity. If pumping is required, the level may be controlled by a floating controlled inlet valve which opens when the water level drops and closes when it rises. The discharge rate of the filter may be controlled manually by use of a butterfly or plug-type valve, or it may be controlled by an automatic rate-of-flow controller.

3.2.8.3.9 Washing filters. After a filter has been in service for some time, foreign matter will have collected on the surface and in the top layers of sand to the extent that the loss of head becomes excessive. It is then necessary that the filter be backwashed to clean the sand bed. It is usual practice to wash a filter when the loss-of-head has reached 7 to 9 feet, or after about 50 hours of service, whichever occurs first. (The practice is the same for both sand and anthracite filters.) The bed is washed by reversing the flow to force the filtered water up through the gravel and sand.

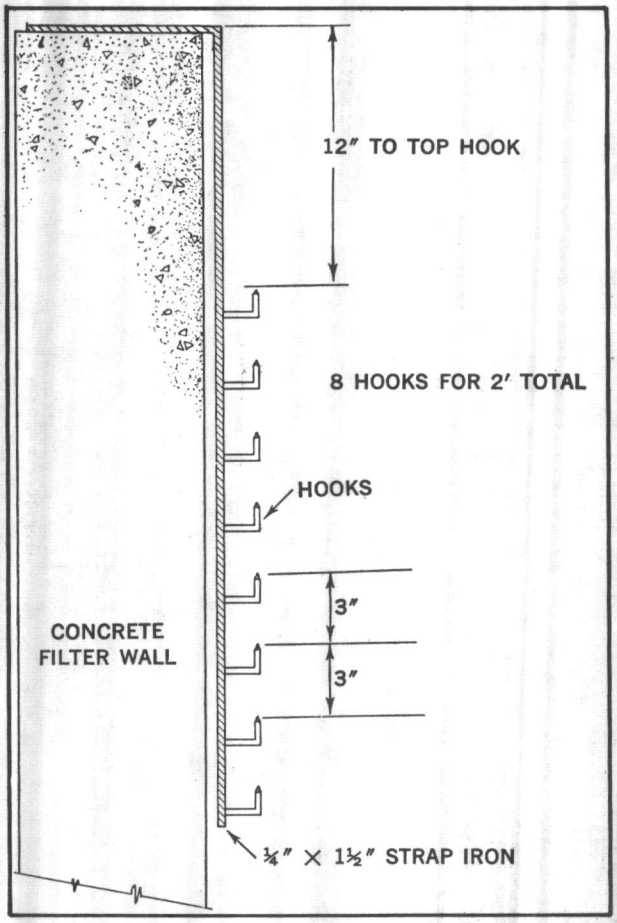


FIGURE 86

Hook Gage

This loosens the bed, agitates the sand grains against each other and washes accumulated foreign matter off the grain surfaces. The wash water rises into the wash troughs and flows to waste through the plant sewer, carrying the foreign matter with it. The wash water is usually discharged to a stream for disposal, but in some cases it is necessary to discharge it to a settling pond to avoid stream pollution.

(1) Methods of Washing. Although there are some differences in the details for different rapid sand filters, the basic method of operation and washing is the same. The main differences are in operating controls and instruments and gages. In small plants having manual operation, it is necessary to operate each valve by hand and only loss-of-head gages are provided. In larger and more elaborate plants, filter operating tables are provided where the valves are operated or controlled by push buttons or small levers, and a number of additional instruments and gages are provided. Because of the variations in control of different rapid sand filters, operators are instructed to consult the manufacturer's instructions for precise procedures in filter washing.

(2) Wash-Water Rate. The wash-water rate should be the maximum possible without causing a loss of filter media with the wash water. In general, the wash-water rate should never be lower than 15 g.p.m. per square foot of filter bed area. This gives a "wash-water rise" of 2 feet per minute in the filter above the sand. Higher rates, up to 4 feet per minute may be desirable in some cases, an average rate being about 2.5 to 3 feet per minute. The most desirable rate is that which affords good cleaning of the filter with the least quantity of water and without loss of filter sand. Because of the increased specific gravity and viscosity of water at lower temperatures, higher wash-water rates are often used in cold weather in order to get effective expansion and cleaning of the sand bed. Lower wash rates are needed with anthrafilt than with sand. Usually, a wash rate one-half that for sand filters is sufficient for washing anthracite filters.

(3) Control of Wash Rate. Wash water is supplied either by gravity from an elevated storage tank at the plant; from the water distribution system; or, from a pump operating from the filtered water reservoir or the clearwell. Control of the amount of wash water is usually accomplished by a rate-of-flow controller, or a butterfly- or plug-type valve located in the wash-water line. A pressure gage should be located on the operating floor to indicate the pressure in the wash-water line at the discharge end of the wash-water controller or valve. Test measurements of the expansion of the filter bed in the filter at different wash-water rates should be made and the pressure gage reading taken for each rate. Satisfactory washing occurs when the expansion is about 40 percent of the normal depth of sand (e.g., a 24-inch depth of sand should occupy a depth of 30 to 36 inches during the washing process). The operator can adjust the valve from time to time according to the pressure gage reading in order to maintain the desired rate.

(4) Sand Expansion. The most satisfactory method of adjusting the wash-water rate so as to avoid loss of sand is by measuring the expansion of the sand bed during washing. Sand expansion may be measured by two methods. Cups are attached at 1-inch intervals along a pole and the pole lowered into the filter during washing (the highest cup which collects sand indicates the height of sand expansion); or a hook light (see fig. 87) with a waterproof battery-operated lamp is lowered into the filter while washing until the light just disappears. This shows the height to which the sand has expanded. (*Never use a light connected to a power source.*)

(5) Measuring Wash Rate. The rate of washing can be found by drawing the water down so that it is level with the top of the wash-water trough, closing the wash-water drain valve, then

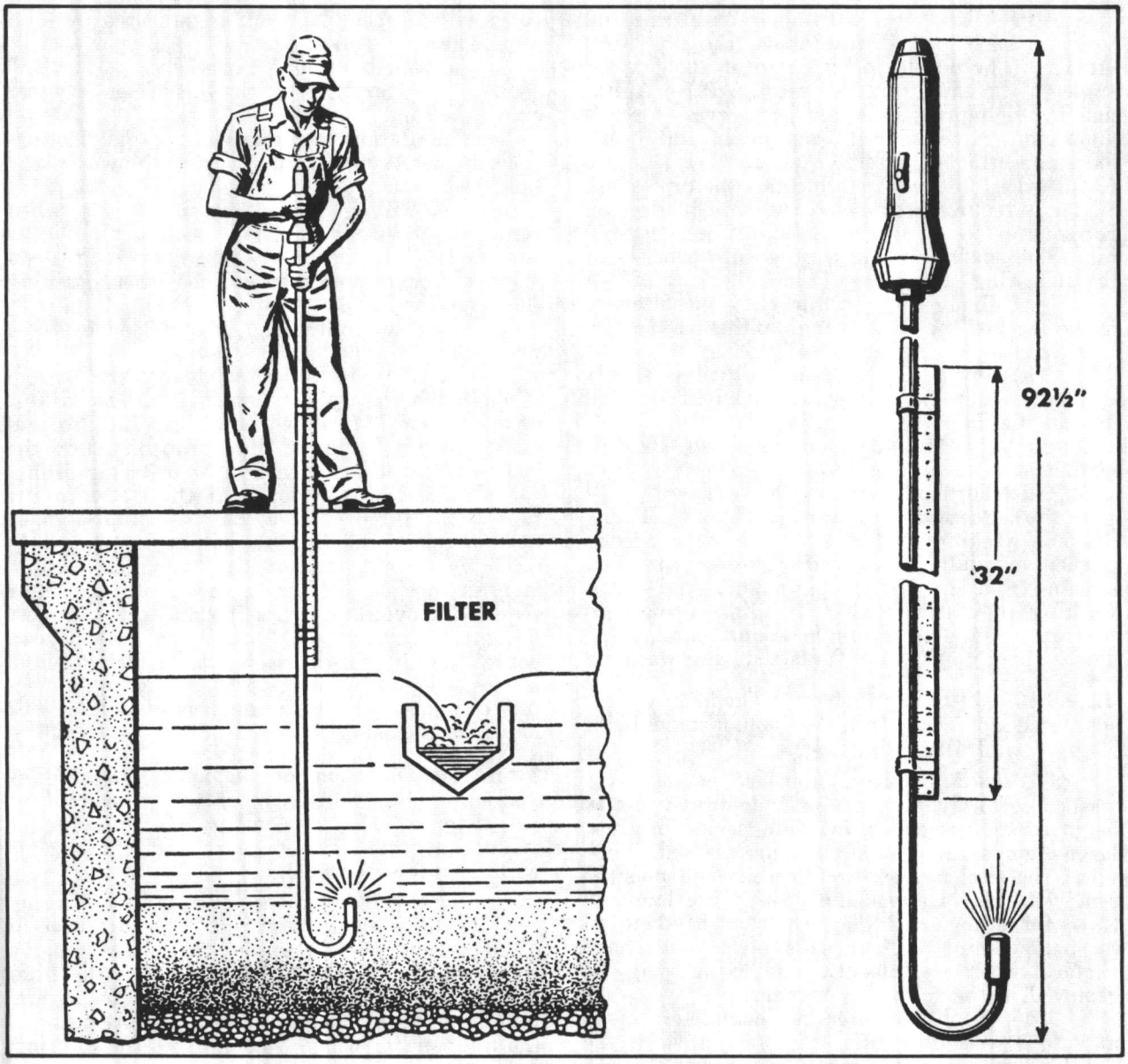


FIGURE 87

Hook Light for Measuring Sand Expansion

opening the wash-water valve to normal setting. Observe the time required (in decimal parts of a minute) for wash water to rise 12 inches in the filter. Divide 12 by this figure to find rise in inches per minute.

(6) Washing Time. The time needed to wash the filter bed varies with the type of filter media, sand grain size, condition of water and rate of wash. Generally, a bed can be cleaned adequately in three to five minutes. However, the best evidence that the bed is cleaned is the appearance of clear wash water above the bed. The filter operator must observe the wash water closely during backwashing in order to determine when the wash is completed and to conserve wash water. The more thoroughly the bed is washed, the longer it can be used before it becomes clogged. In addition, accumulations of mud balls and cracking of the bed will be prevented.

(7) Surface Wash. Surface washing is a method of cleaning sand to aid the conventional reverse-flow washing. Installed equipment for surface washing may be either fixed or rotating pipes. It has been successful in many cases in eliminating mud balls and some forms of sand incrustation. The equipment normally consists

of a rotary distributor with horizontal arms and spray nozzles located just above the filter bed surface. The nozzles point down at about a 45° angle to the sand surface (see fig. 79). Agitation by high pressure water jets serves to scrub the sand grains against each other and break loose any attached foreign matter. The jets also furnish the force required to rotate the pipe arms. Water is required for surface wash at 0.5 g.p.m. per square foot of filter area at not less than 50 psi. The surface washing procedure consists of the following steps.

(a) Bring the water level in the filter up to the level of the wash trough and start the surface wash.

(b) Open the wash-water valve slowly and only sufficiently to obtain a slight upward flow in the filter.

(c) Operate the surface wash in this manner for about a minute.

(d) Turn off the surface wash.

(e) Proceed with normal filter washing. Surface washing of filters may also be accomplished manually by directing a high pressure stream from a fire hose into the sand while washing the filter, or by attaching a piece of perforated pipe to a fire hose and moving the device about on the sand surface during washing.

3.2.8.3.10 Operating troubles. Commonly encountered operating troubles include mud balls, clogging and air-binding.

(1) Mud Balls. If a filter bed is not backwashed correctly, sand grains and foreign matter begin to stick together. Over a period of time, large clumps, called mud balls, are formed. They lower the efficiency of the filter bed and must be removed. Surface washing usually breaks down these formations and they can then be removed by backwashing. If the plant does not have surface wash equipment, mud balls may be removed in the following manner.

(a) Wash the filter bed completely clean at 2 to 3 week intervals, using about twice the usual amount of backwash to make sure the bed is cleaned thoroughly.

(b) When the wash water is clear, reduce the rate until the bed is expanded about 20 to 25 percent. This exposes mud balls on the sand surface.

(c) Remove the mud balls manually with a 10-mesh screen attached to a long handle.

(2) Clogging. Normally, filter sands become clogged only at the surface and are restored to use by ordinary washing methods. Sometimes, however, the entire sand bed becomes clogged and caked and cannot filter properly. It can then be restored to use only by removal of the sand and gravel from the filter and thoroughly washing or replacing it as may be needed. See Chapter 4 for complete maintenance instructions.

(3) Air-Binding. Air-binding occurs when pockets of air accumulate in the sand. It interferes with proper filtration, as indicated by high loss of head.

(a) Air-binding is caused by.

1. Operating with insufficient water above the sand.

2. Permitting relatively rapid fluctuations in head, causing holes to be blown in the sand bed.

3. Filling the filter too rapidly when returning it to service after washing.

4. Allowing the water level to drop below the surface of the sand bed when draining the filter for inspection.

(b) Air binding can be corrected by these procedures.

1. Fill the bed slowly from the bottom through the wash-water line to force the air out of the filter. This must be done carefully to prevent violent agitation of the sand bed. Allow the bed to stand idle for several hours after filling.

2. Keep the depth of the water in the top of the filter greater than the total loss of head through the filter before it is cleaned in order to prevent development of partial vacuum and air pockets. Usually the depth of water required above the sand is about 5 feet. In most designs, this permits a 7- to 9-foot loss of head before the filter begins to operate under vacuum.

3. During operations, avoid wide fluctuations in head which may cause holes to be blown in the sand.

3.2.8.3.11 Operation of diatomite filters. The diatomite filter is usually of the pressure type (see Figure 81). It consists of a number of cylindrical filter elements suspended from a plate within a pressure vessel.

(1) Filtering. At the start of the filtering run, the filter elements are given a thin coat of diatomaceous earth simply by introducing a slurry of the diatomaceous earth into the filter inlet and then recirculating the water for several minutes. This coating (called the pre-coat) is the filter media which accomplishes the filtering. As in sand filters, the dirt accumulates on the filter medium; likewise, the loss of head through the medium increases. This serves as the operator's guide to the proper time to backwash the filter. The length of the filtering run may be increased by feeding small amounts of diatomite slurry (called the body coat) during the run.

(2) Cleaning. Cleaning or backwashing is accomplished by surging liquid backward several times through the filter to the point of backwash discharge. A quick opening valve is used in this operation, and only a minute or two is required to completely clean the filter.

(a) Compressed air cleaning. Some types of elements, because they have a tendency to plug with the diatomite, require a backflow of compressed air for proper cleaning. Most manufacturers of wire-wound elements now recommend such an air pump to clean the elements.

(b) Flexible elements. Some elements made of a more flexible material, such as woven cloth, are more easily cleaned because of their ability to expand and contract with the flow of water. This is similar to the action of washing clothes in a washing machine.

3.2.9 TASTES, ODORS AND ODOR CONTROL. Water must be free from taste and odor as well as being safe. If the water supply has an unpleasant taste or odor, consumers will probably use any other available supply, whether or not it is safe. Taste and odor control involves treatment to prevent taste or odor formation or corrective treatment after formation. The principal causes of unpleasant tastes and odors in water are the following.

(1) Pollution by industrial wastes, such as those from canneries, chemical manufacturing plants and by-product coke plants.

(2) Excessive algae growths and slime deposits.

(3) Decomposition of organic matter.

(4) Dissolved gases, such as hydrogen sulfide (rotten egg odor).

Depending on the causes, tastes and odors can be reduced by aeration or by treatment with activated carbon, copper sulfate, chlorine or chlorine dioxide. Depending upon the type of problem, taste and odor control chemicals may be added to the raw water in the reservoir or in the treatment plant during rapid mix or flocculation after sedimentation or prior to filtration.

3.2.9.1 Aeration. Aeration is mainly effective for removal of dissolved gases; and, for most other odors, must be used in conjunction with other treatments. It is of little value for removal of algae or industrial waste odors. Aeration for removal of sulfide consists of exposing as much water surface as possible to the air. During aeration gases dissolved in the water supply are released to the atmosphere.

3.2.9.1.1 Types of aerators. Some types of aerators consist of overflowing trays or trays containing slats or coke over which the water is sprayed. Other methods include spraying water up over a shallow receiving basin and forcing air into the basin with diffusers or mechanical pump-type aerators. (For one type of aerator, see fig. 70.)

3.2.9.1.2 Operation. The operation of most aerators is practically automatic. Operators duties consist essentially of making sure that pipes, spray heads and surfaces are not clogged, and that air has free access to the water. If water is not to be filtered after aeration, aerators must be equipped with fine screening to keep out insects and other foreign matter. Daily, observe compressor or blower discharge pressure at normal rate of air flow. An increase usually indicates diffuser clogging. Also observe bubble pattern in aeration tanks.

3.2.9.2 Activated Carbon Treatment. Activated carbon is specially treated granular or powdered carbon which, because of its tremendously increased internal surface area, will adsorb larger quantities of dissolved gases, liquids and finely divided solids than ordinary carbon. It is highly effective in taste and odor control, provided that the type of activated carbon used meets required standards, the dosage is correct, the carbon is mixed intimately with the water and the carbon is in contact with the water for an adequate time.

3.2.9.2.1 Minimum standards. Acceptable commercial preparations of activated carbon are available under a number of trade names such as Aqua Nuchar, Cliffchar, Hydrodarco, and Norit. Any type may be used if it meets the following minimum standards.

(1) It may not contain soluble minerals injurious to health.

(2) The weight should be 10 to 11 lbs per cubic foot.

(3) The moisture content should not be over 8.0 percent.

(4) It should contain at least 90 percent pure carbon.

(5) It should be powdered form, which wets down and goes into suspension readily, does not settle too rapidly and does not float on the surface when applied.

(6) At least 99 percent of the carbon in water suspension must pass a 100-mesh sieve, and at least 94 percent must pass a 200-mesh sieve.

3.2.9.2.2 Dosage. Because of the wide range of odors in different waters, no general rule can be given for activated carbon dosage. The dose required at each plant must be determined by periodic laboratory tests.

(1) Test Technique. The test is made by preparing a number of samples of raw water, adding standard amounts of treating chemicals and varying amounts of carbon to each sample, allowing plant contact time, filtering and making odor tests. Numerical comparison can be made with the threshold odor test described in Reference 7. Generally, the amount of carbon required in the plant is less than that indicated by laboratory test.

(2) Probable Minimum Dose. A carbon dose of 3 p.p.m. removes most tastes and odors from water. However, if the tastes and odors are caused by pollution from industrial wastes, the dose may have to be increased to 8 to 10 p.p.m., or even 20 p.p.m. at times. When odors develop suddenly, feed an excess dose until they are under control.

3.2.9.2.3 Methods of application. Normally, activated carbon is fed into water by dry feeders somewhat similar to those used for coagulants (see par. 3.2.3). Because activated carbon is so finely powdered, it must be handled more carefully than coagulants to guard against spreading

carbon dust and causing fires or explosions. In addition, motors, lighting fixtures and switches must be explosion-proof. If dry carbon were dry-fed onto the water, it would float on the surface for a long time. Therefore, to ensure better mixing, the carbon is first wetted thoroughly, usually by agitating it with the feed water in a small box or tank. The agitating agent may be a paddle wheel, a strong spray, or a swirling action obtained by introducing the feed water at a tangent to the side of the tank. Most carbon dry feeders have a mixing chamber or hopper in which the carbon is wetted by the swirling action of the water.

3.2.9.2.4 Points of application. Activated carbon may be applied to the water at one or more of the following points, depending on the results desired.

(1) Raw Water. Application of the chemical should be as early as possible after entering the plant, but this point of application is not recommended for extremely turbid waters.

(2) Mixing Basins. When added before sedimentation, activated carbon not only removes foreign matter from the water, but the carbon which settles in the sedimentation basin continues to absorb products of sludge decomposition, thus preventing formation of secondary tastes and odors. It also permits the use of high dosages without adversely affecting the length of filter runs.

(3) Treatment Plants. Applying carbon just before filtration is recommended because it is not then removed during coagulation and flocculation, and its effect continues during the filtration process. The carbon that accumulates in the filter helps remove tastes and odors. When a filter is returned to service after backwashing, it is good practice to add a small batch of carbon to the filter influent.

(4) Split Feed. When part of the dosage is applied in the mixing basin and the balance just ahead of the filters, it is referred to as a split feed. Proportions of the dosage at these two points depend on the water being treated. This method combines the advantages of both feed methods and often gives better results than a larger total carbon dosage applied at a single point.

(5) Filters. Granular activated carbon can be used as the filter medium in gravity or pressure filters. Operation is identical to that of sand filters but backwash rates are lower to prevent loss of carbon.

3.2.9.3 Algae Control. The presence of algae does not make water unsafe. However, uncontrolled algae growth frequently causes unpleasant tastes and odors and may clog pipes and filter beds. Taste and odor problems are caused by a wide variety of algae, the type and intensity of the problem varying with the particular algae concerned. Algae growths occur mainly in large open reservoirs, in sluggish streams, and in surface supplies. Sunlight is necessary for their existence.

3.2.9.3.1 Types of treatment. Algae growth can be controlled by the use of algicidal chemicals and the alteration of environmental conditions such as the reduction of light intensity, the latter being applicable usually only in small storage basins and tanks. Control of algae with copper sulfate, chlorine or activated carbon are standard chemical methods.

(1) Copper Sulfate. In soft waters, 1 p.p.m. of copper sulfate (8.34 lbs per million gallons of water) destroys most algae. Larger dosages are needed in hard water because some of the copper is precipitated by the alkalinity in waters. Effective hard water dosage may be from 1 to 4.5 p.p.m., depending on the alkalinity of the water. Because copper sulfate kills fish, its use is limited. Concentrations that kill common varieties of fish and limiting safe dosages are listed below in pounds of copper sulfate per million gallons of soft water. Fatal concentrations are considerably higher in hard waters.

	Toxic concentrations p.p.m.	*Limiting safe dosage p.p.m.*
Trout	1.2	0.14
Catfish	2.5	.40
Suckers	2.5	.33
Carp	2.5	.33
Pickerel	3.5	.40
Black Bass	17.0	2.00
Perch	6.0	.67

(2) Chlorine. Chlorine dosage of 0.3 to 1 p.p.m. at the plant destroys most algae, but may intensify odors. The break-point method of chlorination (see par. 3.2.2.3.3(4)) requires higher dosages but eliminates taste and odor as well as killing algae. With this method, chlorination dosages vary from 0.8 to 10 p.p.m., or higher in exceptional cases. Chloramines have in some instances also been found to be an effective method of controlling algae growths.

(3) Activated Carbon. Because algae grows only in sunlight, they can be eliminated by preventing light from entering the water. This is the principle behind the activated carbon method of algae control. Usually carbon dosages of 6 to 20 lbs per million gallons of water place enough carbon in suspension to absorb all light. The carbon also removes tastes and odors in the water. This method is used only for relatively small basins or tanks. The use of activated carbon in large reservoirs is impractical.

3.2.9.3.2 Methods of application of copper sulfate. Before the chemical is applied, the volume of water in the reservoir to be treated is computed carefully to avoid underdosing or overdosing. Usually only that part of the reservoir showing algae growths should be treated. Algae growths are generally found in shallow areas and around

the shoreline. In computing water volume, the maximum depth is taken at 5 feet. Algae seldom grow below a 5-foot depth, because this is the maximum effective penetration of sunlight. Copper sulfate treatment is most effective if started early in the season before heavy algae concentrations have formed. The treatment is repeated whenever algae growths reappear.

(1) Solution Feed. If copper sulfate can be applied by solution feeders to the water entering the reservoir, continuous application of lower concentrations can be used instead of intermittent treatment. This usually results in the most efficient control of algae growths.

(2) Bag Feed. The simplest, though not the best, method of applying copper sulfate is to tie a bag of copper sulfate crystals to a boat and cover the reservoir in a definite zigzag pattern.

(3) Spray Feed. In reservoirs needing frequent treatment, the best method is to spray the copper sulfate solution or crystals on the water surface from a spray unit mounted in a boat. Apply the copper sulfate evenly to avoid overdosing shallow areas.

3.2.9.4 Color Removal. Color in natural waters is caused mainly by vegetable matter or by excessive amounts of iron and manganese. Minerals contained in industrial wastes may also cause color. The coloration is usually caused by colloidal matter and may be removed in the same manner as other colloids, by chemical precipitation, coagulation or adsorption, followed by filtration. No one method will remove all colors, and no single rule will apply to all waters. Color removal requires trial of the following methods to determine which is most efficient and economical in a particular situation.

3.2.9.4.1 Coagulation treatment. Coagulation with alum, followed by lime or soda ash if necessary, and filtration is the most common method. The alum must be added first and given some reaction time at a pH of 5.5 to 6 before adding the alkali. If the alkali is added first, it will "set" the colors and prevent removal.

3.2.9.4.2 Chlorinated copperas treatment. The addition of chlorinated copperas as a low pH with an alum dosage applied halfway through the coagulation basin has been very successful in some instances. Dosage has to be determined by trial.

3.2.9.4.3 Chlorination. Color removal by chlorination requires a dosage of 1 to 10 p.p.m., the correct amount being determined by trial. A detention or contact time of at least 15 minutes is necessary, and not less than 0.1 p.p.m. free or combined residual should be maintained.

3.2.9.4.4 Activated carbon treatment. Some color is susceptible to removal by activated carbon. The colloidal matter is adsorbed by the carbon and is then removed by sedimentation and filtration. Tests of carbon applied to a particular water is the only method of determining the effect of carbon for color removal.

3.2.10 CONVERSION OF SALINE WATER TO POTABLE WATER. Many coastal areas, islands and even some inland regions have little or no fresh water, but unlimited supplies of sea water or brackish water are available. When it is necessary to establish and maintain Navy installations in such areas, the water supply must be derived by converting saline water into fresh water. Present methods of salt water demineralization are quite expensive. These methods include distillation, chemical ion-exchange and electric membranes. Experimentation with other methods including osmotic processes, solvent extraction of water and separation by freezing, are currently being conducted by both governmental and private agencies.

3.2.10.1 Distillation. At this time, however, distillation is generally the most practical method for demineralizing saline water. Water produced by distillation is very soft, practically free of dissolved impurities, and contains no bacteria. (It should be chlorinated, however, to provide a measurable chlorine residual protection against entry of bacteria through incompletely covered tanks or other possible sources of contamination.) Saline water conversion by distillation consists of heating the water to produce steam, cooling to condense the water vapor, and collecting the distilled water in a separate container.

3.2.10.1.1 Heat of vaporization. Changing boiling water to steam requires a large amount of heat, known as the latent heat of vaporization. This latent heat must be removed by cooling to change the steam into water. The salt and other dissolved substances in the saline water do not vaporize and remain behind. Thus the distilled water is freed of salt.

3.2.10.1.2 Types of equipment. Many different types of distillation equipment have been developed in an attempt to make the process cheaper. Due to the energy that must be supplied to heat the water, water produced by this process costs considerably more than treated surface or ground water. At the present time, much attention is being paid to the development of distillation equipment in which the sun serves as the heat source. Shallow troughs of saline water covered with transparent plastic or glass are exposed to the sun. Water vapor rises from the trough and condenses on the sloping cover. The condensed water droplets converge and flow down the cover to a container. A large area is needed for each gallon of water produced. This solar distillation is not yet developed sufficiently for practical use in areas of plentiful sunshine. The most efficient distillation methods in use today require the consumption of fuel to produce heat. Various mechanical processes and heat exchange

units have been developed to reduce the amount of heat lost in distilling a given amount of water.

3.2.10.2 Multiple Effect Distillation. When distilling water in large quantities, the steam is condensed by the circulation of cooling water around the steam line in a condenser. The cooling water thus becomes heated. Multiple-effect evaporators may be of either submerged tube or of flash construction. Operation checks include daily observation of operating temperatures, blowdown and burner operation, if direct fired.

3.2.10.2.1 First and second effect. In simple or single effect distillation, the cooling water and the heat it contains are then discharged to waste. The multiple effect process was devised to save some of the heat given up by the condensed water. In this process, water is boiled in an evaporator to produce steam at ordinary atmospheric pressure. This steam is condensed and cooled. The cooling water from this step is used as feed water to a second evaporator (second effect), which is operated under somewhat lower pressure so that the boiling temperature of the water is lower.

3.2.10.2.2 Third effect. Steam produced in this manner may be condensed, and the cooling water used to produce additional steam in an evaporator (third effect) operated at still lower pressure. In this way the heat losses are reduced and the fuel is used more economically. The amount of fuel required per gallon of water produced is approximately one-third as much for triple effect distillation as for single effect distillation. Multiple effect systems with as many as twelve effects have been made.

3.2.10.2.3 Blowdown. To prevent concentrations reaching a point where scale would form on heating surfaces or salt would precipitate in large quantities, a portion of the feed water is discharged to waste in amounts equal to the distillate produced. This wastewater is known as blowdown.

3.2.10.3 Vapor Compression Distillation. Another distillation process used at Navy installations is the vapor compression or thermocompression method. Like the multiple effect process, the vapor compression process also conserves the heat given up by the condensing steam. However, it does this in a single stage, with the result that the unit is smaller and more compact.

3.2.10.3.1 Principles of operation. Figure 88 shows a typical vapor-compression distillation unit at a Navy installation. The flow diagram for this unit is shown in Figure 89.

(1) Heat Pump Principle. The unit operates on a heat pump principle. Heat is removed from the vapor (steam) produced and transferred back to the water being heated in the evaporator. The steam from the evaporator is compressed in the compressor. Compressing the steam causes its temperature to rise so that it is above the temperature of the steam in the evaporator. The compressed steam then passes to the heat exchange section of the evaporator where the increased heat is transferred to the evaporating water to produce more steam and the compressed steam is condensed to water at the same time. The newly-formed steam is compressed in turn, and the cycle is repeated.

(2) Closed Heat Cycle. In giving up its latent heat, the compressed steam is reduced in temperature to the point where it becomes distilled water, the final product. This use of a combination evaporator-condenser with a steam compressor creates a closed heat cycle which permits the continued reuse of the latent heat of vaporization. As shown in the flow diagram, the heat contained in the distillate, blowdown and engine gases is economized by transferring it to the feed water in heat exchangers. In this manner, as much heat as possible is conserved. The concentrated brine is continuously blown down through an overflow pipe to prevent the salt water in the evaporator from becoming too highly concentrated. A high rate of blowdown is desirable to keep the brine concentration down. The operator is then chiefly concerned with varying the rate of blowdown and rate of feed water to obtain the best results.

3.2.10.3.2 Equipment. The principal components of a vapor compression distillation plant are described in the following paragraphs.

(1) Evaporator. After preheating by flowing through the heat exchangers, the feed water enters the evaporator at a temperature near the boiling point. Heat given up by the condensing steam in the steam chest is transferred through the vertical tubes, causing the feed water to reach the boiling point and partially vaporize. The steam and water rise inside the tubes to the upper section of the evaporator, which is simply a steam generator. A baffle arrangement allows the steam to pass on into the suction pipe of the compressor, but prevents the liquid from so doing. The liquid spills into the overflow pipe and is pumped out of the system to waste.

(2) Engine. The engine supplies the power to operate the vapor compressor and the pumps. It also furnishes heat to start the system and make up for heat losses. When electric motors are used to power the compressor, boilers are used to supply the initial heat to start the operation and to provide operational makeup heat.

(3) Vapor Compressor. The vapor compressor draws the vapor from the steam separator section of the evaporator, then compresses it about 3 psi and discharges this vapor into the steam chest of the evaporator. The temperature of the steam discharged is increased to a point about 10° F. higher than that of the boiling water inside the tubes, hence the vapor condenses on the outside of the tubes and is drawn off as distillate.

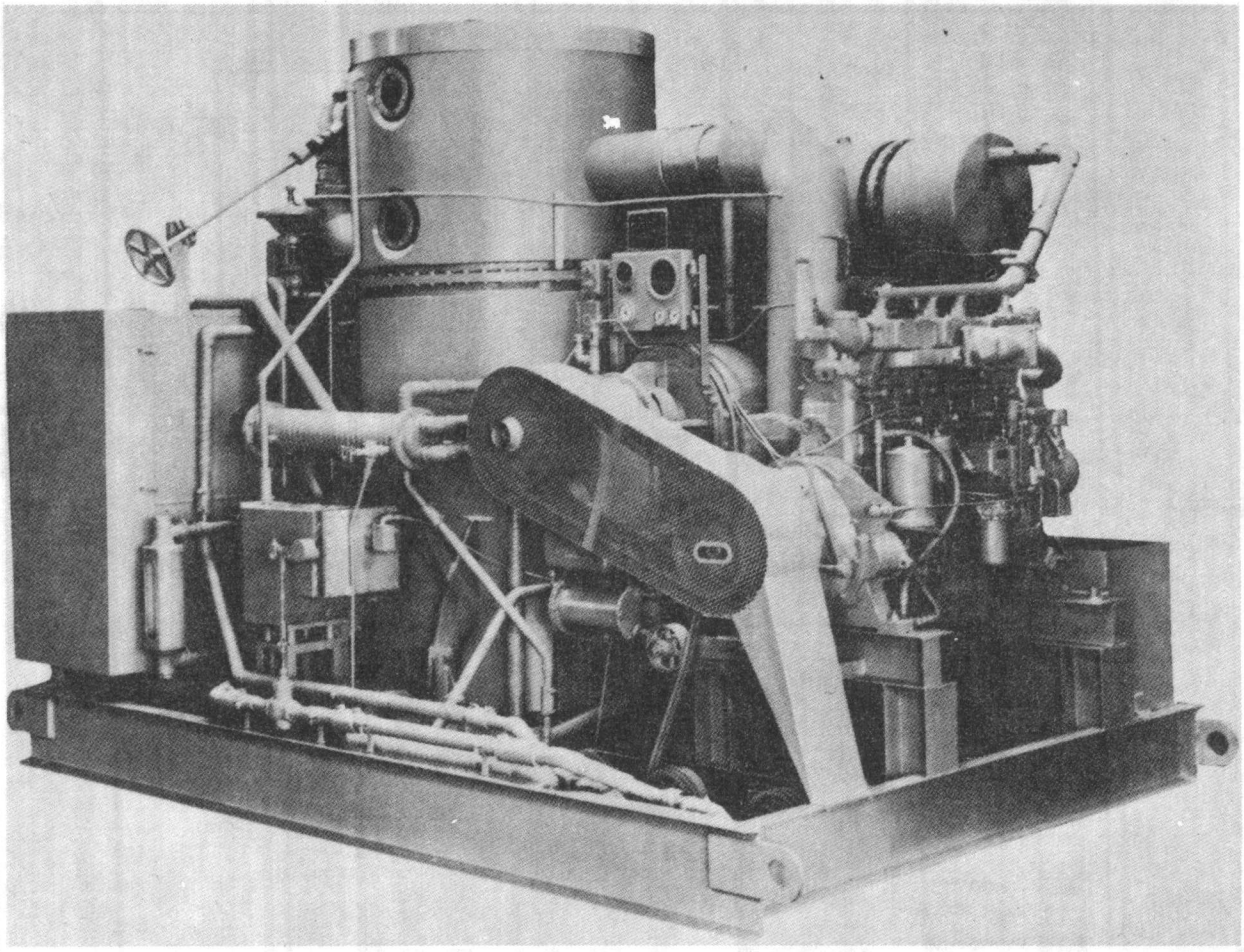


FIGURE 88

Typical Vapor-Compression Distillation Unit

(4) Vent Condenser. The vent condenser is used to condense steam vented with the noncondensable gases from the steam chest. Since the feed water is not deaerated, the initial air in the system plus the air constantly entering with the feed water must be vented. An air vent valve for this purpose is provided on the vent condenser. This valve must be opened sufficiently to completely vent the evaporator.

(5) Pumps. Centrifugal pumps are provided to draw the feed water from the raw water source and circulate it through the feed system into the evaporator, to force the distillate and blowdown through the cooler or through heat exchangers, and to pump the distillate from the cooler or heat exchangers to storage.

(6) Heat Exchange and Cooler System. Heat exchangers or coolers are used to cool the distillate and blowdown so as to recover heat for the feed water. A small part of the heat cannot be recovered and must be replaced by the heat from the compressor engine, or in the case of electric motor-driven compressors, from auxiliary boilers.

(7) Compressor Discharge Pressure Gage. Compressor discharge pressure increases as scaling progresses. When the evaporator becomes scaled to the point where the compressor requires the full rated horsepower, it becomes necessary to stop the unit and remove the scale (see Chapter 4). Indication of this necessity is obtained from the compressor discharge pressure gage.

3.2.10.3.3 Starting vapor compression units. Before starting or operating a vapor compression unit, operators should study the manufacturer's operating and instruction manual pertaining to the specific unit in question. The unit should not be started until the operator is familiar with the entire sequence of operations. All mechanical controls, equipment, fuel lines, electrical connections, lubricating points and utilities should be checked as indicated in the manufacturer's instructions. In the case of electric motor-driven compression units, boilers are used to supply heat to start the cycle and make up heat lost through radiation and other heat leaks. For

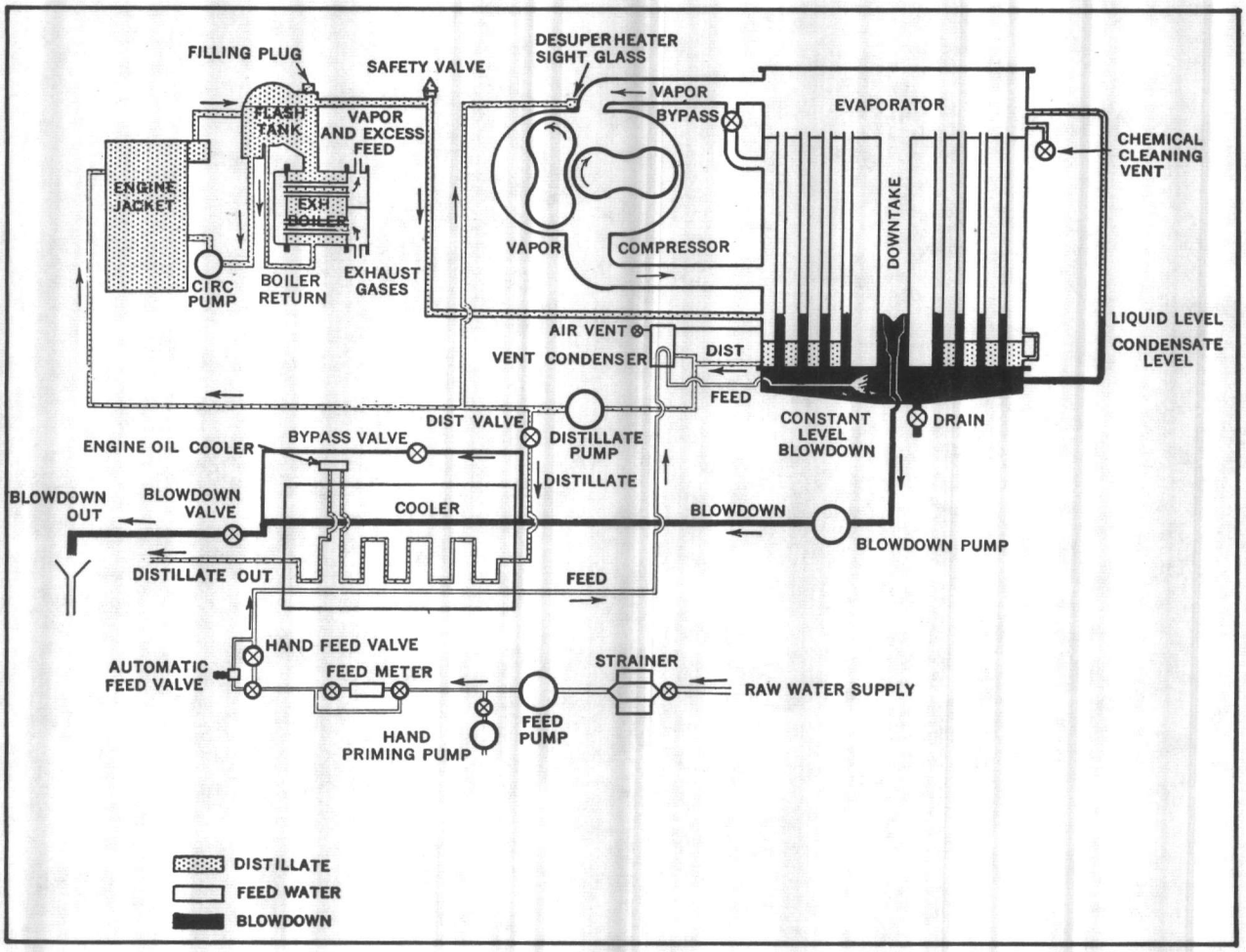


FIGURE 89

Flow Diagram of Vapor-Compression Distillation Unit

proper boiler operation, see "Central Heating and Steam-Electric Generating Plants", NAVDOCKS MO–205 (Reference 11). Where internal combustion (usually diesel) engines are used to drive the compressors, the heat from the engine cooling jacket is used to start and maintain the cycle. Distillation will begin when sufficient heat has been added to the system to vaporize the water in the evaporator.

3.2.10.3.4 Balancing vapor compression units. As distilled water is removed from the system, additional salt water must be supplied to it. The system is maintained in balance by an automatic feed valve or by proper adjustment of the hand valve. Adjustment of feed must be made very slowly to prevent sudden entry of large amounts of cold water into the evaporator. Time is required before a small change of the feed valve becomes effective. Therefore, at least two minutes should be allowed between adjustments. To obtain a proper balance, valve adjustments must be made on the feed flow, heat exchangers, oil coolers and vent control valves. Adjustments depend on such operating conditions as compressor speed, condition of evaporator tubes, temperature of feed water and the ambient (air) temperature. When the unit has been brought into balance, it will reach a stable operating condition and adjustments will be required considerably less frequently. Operation temperatures, blowdown and mechanical operating units (pumps, compressors, etc.) should be checked daily and lubricated as necessary.

3.2.10.4 Records. A daily log should be maintained to provide a record of hours of operation and the performance of the distillation unit. The daily log will indicate any unusual trends in the distillate flow, power requirements, pressures and other operating characteristics. Reviewing the log will call attention to existing and pending mechanical difficulties, and will facilitate good maintenance. The form and content of the daily log is established by local command upon the recommendations of the Utilities Division.

Section 3. QUALITY CONTROL

3.3.1 PURPOSE. Frequent chemical analyses and bacteriological examinations of raw and treated water are required to determine and control treatment to ensure a safe potable water. Chemical analyses will determine proper chemical treatment and the safety of the water in respect to chemical content. Bacteriological examinations will determine the necessity for disinfection as well as the safety of the water following treatment in terms of bacteria content. For the purposes of this manual, these tests and examinations can be considered in two categories.

3.3.1.1 Tests for Planning and Checking Quality. These tests are the most complex procedures which require a fully equipped laboratory and which are performed by skilled technicians. They are used in the planning of water treatment and in checking on the quality and safety of the produced water supply.

3.3.1.2. Operating Tests. These tests are necessary to ensure correct operation of the water supply system. They are conducted during treatment to ensure proper chemical feeding, physical conditions and water safety. This manual is concerned only with the details of this second category, since these are day-to-day operational procedures. For a complete discussion of all types of water tests for quality control and water safety, refer to Reference 7.

3.3.2 SAMPLING METHODS. The operator will usually be required to take the necessary samples for testing for quality control and safety. This is an important function, for unless the water sample is representative and uncontaminated, test results will not indicate the actual condition of the water supply. Sample containers should be of materials that will not contaminate the sample and, before use, shall be cleaned thoroughly with a detergent and fresh water rinse to remove all surface dirt. Chemically resistant glass is a suitable material for all sample containers, and polyethylene may be used for samples for chemical analyses. The size of the sample container used will depend upon the amount of water needed for a particular test.

3.3.2.1 Chemical Analysis. To make certain that representative, uncontaminated samples are obtained, the operator must observe normal precautions against accidental contamination. Sample containers and caps should always be rinsed well with the water to be tested. Direct hand contact with the mouth of the container, or with the cap, is to be avoided. Take samples with a minimum of splashing. The following precautions are necessary when taking samples for chemical analysis.

3.3.2.1.1 Wells. Pump the well until the normal drawdown is reached in order to obtain a representative sample. Rinse the chemically cleaned sample container and cap several times with the water to be tested and then fill with a minimum of splashing.

3.3.2.1.2 Surface supplies. Fill chemically cleaned raw-water sample containers with water from the pump discharge only after the pump has operated long enough to flush the discharge line. Take the sample from the pond, the lake, or the stream at intake depth and location with a submerged sampler. Submerged samplers may be obtained from laboratory equipment manufacturers. These devices are equipped with automatic or manual valve systems that permit the collection of water at the desired depth.

3.3.2.1.3 Plant. Take samples inside a treatment plant from channels, pipe taps or other points where good mixing is obtained. At some Navy installations, special sample taps are provided for this purpose.

3.3.2.1.4 Taps on distribution system. Let the tap run long enough to draw water from the main before taking samples.

3.3.2.2 Bacteriological Examination. In obtaining samples for bacteriological examination, contamination of the bottle, stopper or sample often causes a potable water supply to be reported as nonpotable. Full compliance with all precautions in the following paragraphs is necessary to assure valid results.

3.3.2.2.1 Bottles. Use only clean sterilized bottles furnished by the medical department of the installation, or an other qualified laboratory (see fig. 90). If bottles are not available from these sources, sterilization may be carried out in emergencies according to the methods described in Reference 7. The tops and necks of sample bottles with glass closures should be covered with metal foil, rubberized cloth or heavy impermeable paper or milk bottle cover caps before sterilization. Before sterilizing the sample bottle to be used for a chlorinated water sample, place 0.02 to 0.05 gram of thiosulfate, powdered or in solution, into each bottle to neutralize the chlorine

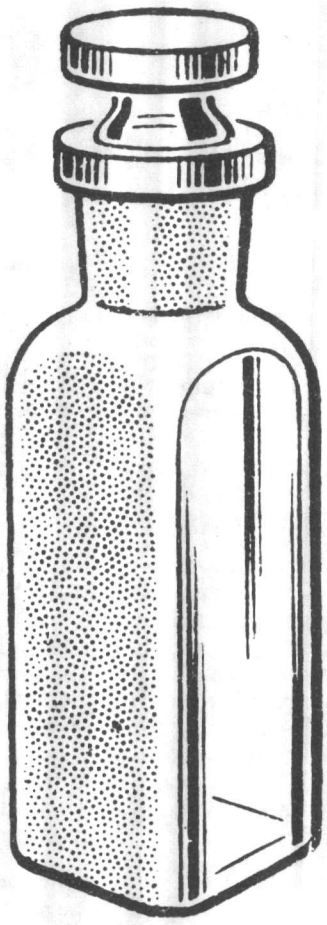


FIGURE 90

Bacteriological Sample Bottle

residual in the sample. Keep the sterilization temperature under 393° F. (200° C.) to avoid decomposition of the thiosulfate.

3.3.2.2.2 Sampling from a tap. Heat the outlet with an alcohol or gasoline torch for a few seconds to destroy any contaminating material that may be on the lip of the faucet. Occasional extra samples may be collected without flaming the faucet in order to determine whether certain faucet outlets are contaminated.

(1) First Step. Flush tap long enough to draw water from the main. Never use a rubber hose or another temporary attachment when drawing a sample for bacteriological examination from the tap.

(2) Second Step. Without removing the protective cover, remove the bottle stopper and hold both the cover and the stopper in one hand. Do not touch the bottle mouth or the sides of the stopper. Fill the bottle without rinsing (to avoid loss of thiosulfate). Replace the cap and fasten the protective covering carefully.

3.3.2.2.3 Sampling from tanks, lakes, streams, and pools. When collecting samples from standing water, remove the stopper as above, and plunge the bottle, mouth down and held at about a 45° angle at least 3 inches below the surface. Tilt bottle and allow air to escape and fill, moving it in a direction away from the hand holding it, so that water that has touched the hand does not enter the bottle. Discard a quarter of the water and replace the stopper.

(1) Lakes or Ponds. When collecting sample from *lakes or ponds*, take the water 25 feet or more from the shore (from boat or pier) and preferably in water at least 4 feet deep. Do not collect the sample at the shore.

(2) Streams. Collect *stream* sample at the point where the water is flowing, not from still areas. In a meandering stream, collect the sample at a point where flow velocity is normal. Use the procedure given above for standing water samples.

(3) Swimming Pools. When collecting water from a swimming pool, take the water from the side of the pool nearest the deepest part. Sample the pool while it is in use, preferably during the heaviest bathing load. Use the bottle containing thiosulfate. Fill according to the sampling procedure for standing water that is given above.

3.3.3 WATER SUPPLY SYSTEM TESTS. The following analyses and examinations are the minimum required in the operation of a water supply system.

(1) Complete chemical analysis of untreated water supply (annual).

(2) Complete chemical analysis of treated water supply (annual).

(3) Bacteriological examination of untreated water supply (monthly).

(4) Bacteriological examination of treated water supply (monthly).

(5) Treatment control tests during treatment (as directed by local command).

(6) Treatment control tests of treated water (as directed by local command).

The purpose of these procedures is to establish the effectiveness of water treatment and to measure the quality and safety of the potable water supply. More frequent analyses or examinations may be required as directed by local command.

3.3.3.1 Complete Chemical Analysis. A complete chemical analysis of untreated and treated water is to be made annually. If a competent chemist and adequate laboratory facilities are available, the analysis may be made locally. Otherwise, the analysis will be performed by qualified laboratories according to information

obtained from the Field Engineering Officer. Form DD 710, Physical and Chemical Analysis of Water (fig. 10), is used for reporting results. Normally, Part II, Special Laboratory Analysis, is made only if those substances are suspected of being present in significant amounts. Sample identification information indicated on this form should be included on the label attached to each sample.

3.3.3.2 Bacteriological Examinations. All bacteriological examinations are carried out according to the instructions contained in Chapter 5 (Water Supply Ashore) of "Manual of Naval Preventitive Medicine", NAVMED P–5010–5 (Reference 12). See this reference for precautions concerning bacteriological sample labeling, storage and transportation.

3.3.3.3 Treatment Control Tests. These tests are conducted routinely to ensure correct treatment operations and the output of water of the proper quality and safety. Listed below are the various tests for each of the major treatment processes. Since several different methods are available for some treatment operations, not all of the tests listed for a treatment may be required in all cases. Of necessity, there is some duplication since certain tests, such as that for pH, must be run for different types of treatment.

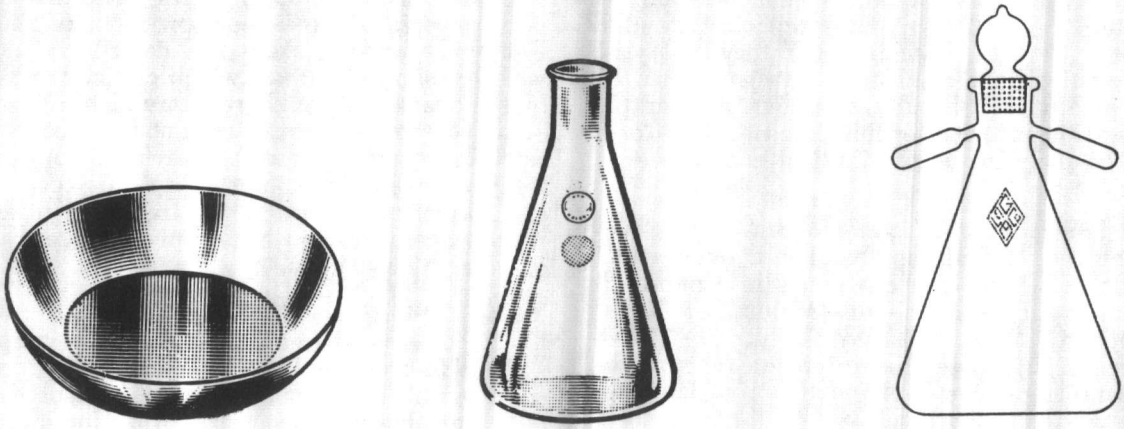
Process	*Tests*
Chlorination	Chlorine residual
	pH
	Temperature
Fluoridation	Fluoride
Scale control	Polyphosphates
	Total hardness
	Carbon dioxide
	Alkalinity
	Carbonate and noncarbonate hardness
	pH
Iron and manganese removal	Total iron
	Dissolved iron
	Total manganese
	Dissolved manganese
Corrosion control	pH
	Dissolved oxygen
	Polyphosphate
	Total iron
	Dissolved iron
Clarification	Jar test
	pH
	Alkalinity
	Turbidity
Taste, odor and color control	Threshold odor test
	Color
Distillation	Total dissolved solids
	Conductivity
	Chlorinity

3.3.4 TREATMENT CONTROL TEST PROCEDURES. As noted above, standard methods for water analysis are fully described in Reference 7. These require trained chemists or technicians and fully equipped laboratories. For evaluation of the treated water, these analyses can be made by installation laboratories, if available, or by outside laboratories according to the instructions of the Field Engineering Officer. During treatment itself, as part of the day-to-day operation of the water supply system, the tests listed above are performed for the treatment processes being used. For this purpose, there are described below a series of simplified tests which can be performed by the operator after short instruction. It should be noted that these tests are not to be considered as replacements for the regular laboratory analyses performed by laboratory technicians. They are control tests used during treatment to ensure proper operation and the output of a safe water of acceptable quality.

3.3.4.1 Principles of Tests. Certain of the following tests are based on the simple principle of adding to the sample a chemical that forms a color with the substance to be measured, and matching the treated sample with color standards containing known amounts of the substance. There are several colorimeter sets available commercially which vary slightly in use and operation. For that reason, the operator is cautioned to make a careful study of the manufacturer's instructions before using such equipment. Other tests are performed by titration (the careful addition of a standard solution from a burette) or by special instruments. Common laboratory equipment used in these tests is identified in figures 91 and 92.

3.3.4.2 Reagents. The various reagents required for the following tests are available from a number of manufacturers and laboratory supply houses. Some of these reagents require special preparation and handling prior to test use. This is customarily the responsibility of the laboratory technician, as in some cases the preparation of reagents requires a thorough knowledge of the chemical procedures involved. For complete information on the preparation of reagents, consult the manufacturer's instructions or Reference 7.

3.3.4.3 Chlorine Residuals. The orthotolodine-arsenite (OTA) test permits the measurement of relative amounts of total residual chlorine, free available chlorine and combined available chlorine (see par. 3.2.2.3 for definitions). This test has some limitations. In samples containing a high proportion of combined available chlorine, it may indicate more free available chlorine than is actually present, while in samples containing a low proportion of combined available chlorine, it may indicate less free available chlorine than is actually present. Precision of results depends on strict adherence to the conditions of the test. The conditions are the time intervals between addition of reagents; the relative concentration of free available chlorine, and of combined available chlorine in the sample; and, the temperature of the water. The temperature of the sample under examination should never be above 68° F. (20° C.). The precision of the test increases with decreasing temperature.



(A) (B) (C)

FIGURE 91

Common Laboratory Equipment

(A) Evaporating Dish (B) Erlenmeyer Flask (C) Titration Flask

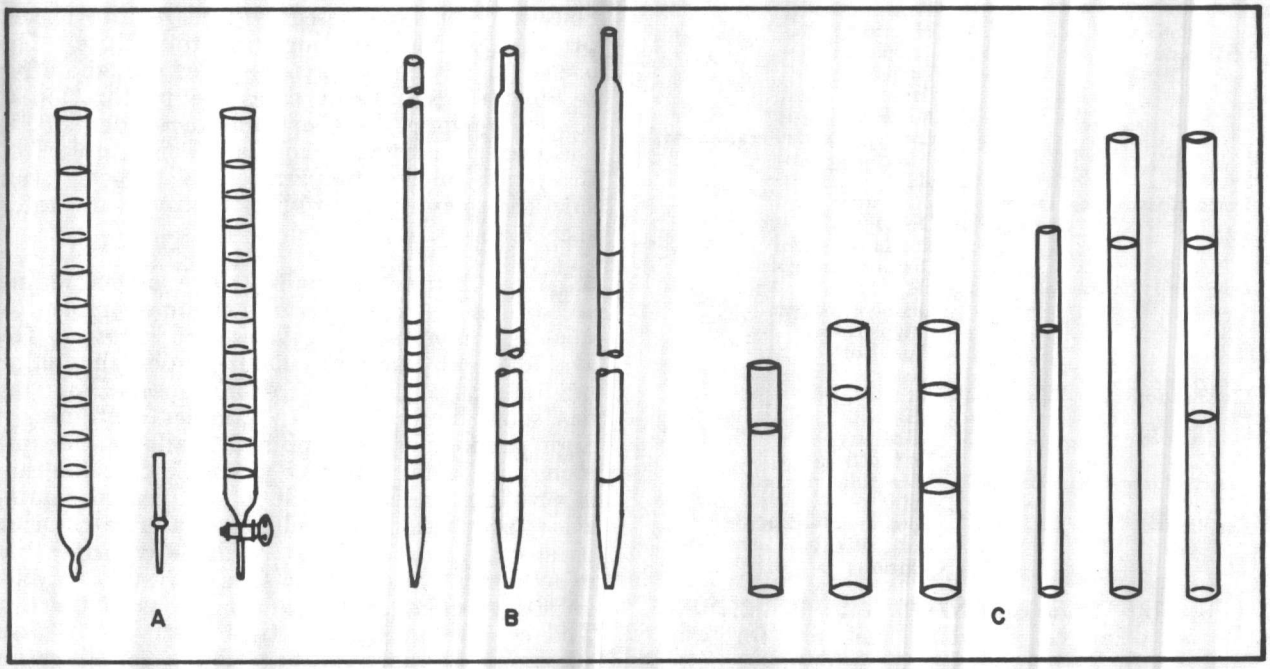


FIGURE 92

Common Laboratory Equipment

(A) Burettes (B) Pipettes (C) Nessler Tubes

3.3.4.3.1 Equipment and reagents. Color and turbidity compensating residual chlorine comparator with commercial permanent standards. The reagents used are orthotolodine (OT), and arsenite (A).

3.3.4.3.2 Procedure.

(1) Label three comparator cells A, B and OT.

(2) Use 0.05 ml. of OT reagent for each ml. of the sample taken. For example, use 0.5 ml. of OT reagent for a 10 ml. sample and 0.75 ml. for a 15 ml. sample. Use the same volume of A reagent as is specified above for OT reagent.

(3) To tube A, first add OT reagent, then add a measured volume of the water sample; mix quickly.

(4) Within five seconds, add arsenite reagent; mix quickly.

(5) Compare with color standards as rapidly as possible.

(6) Record the result; the value obtained represents *free available chlorine* and interfering colors.

(7) To tube B, first add arsenite reagent, then add a measured volume of water sample; mix quickly.

(8) Immediately add OT reagent; mix quickly.

(9) Compare with color standards as rapidly as possible.

(10) Record the results as the B–1 value.

(11) Compare with color standards again in exactly five minutes and record the result as the B–2 value; these values represent the *interfering colors* present in the immediate reading B–1 and in the five-minute reading B–2.

(12) To tube OT, containing orthotolodine reagent, add a measured volume of water sample.

(13) Mix quickly and compare with color standards in exactly five minutes.

(14) Record the result; the value obtained represents the *total residual chlorine* present and the total interfering colors.

3.3.4.3.3 Calculation of results.

(1) Total Residual Chlorine. From the value of OT subtract the value of B–2. The difference equals total residual chlorine.

(OT)−(B–2) = total residual chlorine

(2) Free Available Chlorine. From the value of A subtract the value of B–1. The difference equals free available chlorine.

(A)−(B–1) = free available chlorine

(3) Combined Available Chlorine. From the value of total residual chlorine, subtract the value of free available chlorine. The difference represents combined available chlorine.

(Total residual chlorine)−(free available chlorine) = combined available chlorine.

3.3.4.4 pH. pH is a measure of the strength of acid or alkali in a water. It is reported on a scale of 14 units on which pH 7 is neutral (in a technical sense), values below 7 are acid, and those above 7 are alkaline. Color comparators can be used to find pH by methods similar to those for determining chlorine residuals. The determination of pH in three simple operations is shown in Figure 93.

3.3.4.4.1 Indicators. Many pH indicators are available, each with a limited range. The following are usually used for treated water supplies.

pH range	*Indicator*
5.2 to 6.8	Chlorphenol red
6.0 to 7.6	Bromthymol blue
6.8 to 8.4	Phenol red
7.2 to 8.8	Cresol red
8.0 to 9.6	Thymol blue

The correct standards must be used with each indicator.

3.3.4.4.2 Procedure. As shown in Figure 93.

(1) Fill the tubes to the mark with the sample.

(2) Add the indicator to one tube in the amount specified by the manufacturer. (NOTE: Usually 0.5 ml. (10 drops) for a 10 ml. sample tube and proportionately more for larger tubes).

(3) Mix and place the tube in the comparator.

(4) Match for color and read the pH directly.

(5) If the color matches the standard at either the upper or the lower end of the range of the indicator, repeat the test with the next higher or lower indicator. For instance, if bromthymol blue is used and the sample matches the blue color of the 7.6 standard, the pH is 7.6 or higher. Therefore, use a phenol red indicator to check this value.

3.3.4.5 Alkalinity. Alkalinity of water results from the presence of bicarbonate, carbonate and hydroxides of calcium, magnesium, sodium and other metals. The term alkalinity has little or no relation to the pH of the water. It refers to the acid neutralizing capacity of the water. In other words, alkalinity of water refers to the amount of various alkalies in the water which are capable of neutralizing acids. One method of determining the alkalinity of a water sample is by titration with standard sulfuric acid first to the phenolphthalein (PT) end point, and then to the methyl purple or methyl orange end point. Although methyl orange is the "standard indicator", methyl purple is much easier for the average operator to use because its color change is easier to see, and the results obtained with it are good enough for almost all uses.

3.3.4.5.1 Reagents.

(1) Phenolphthalein (PT) Indicator Solution.

(2) Methyl Purple Indicator Solution.

(3) Methyl Orange Indicator Solution.

(4) Standard Sulfuric Acid (N/50).

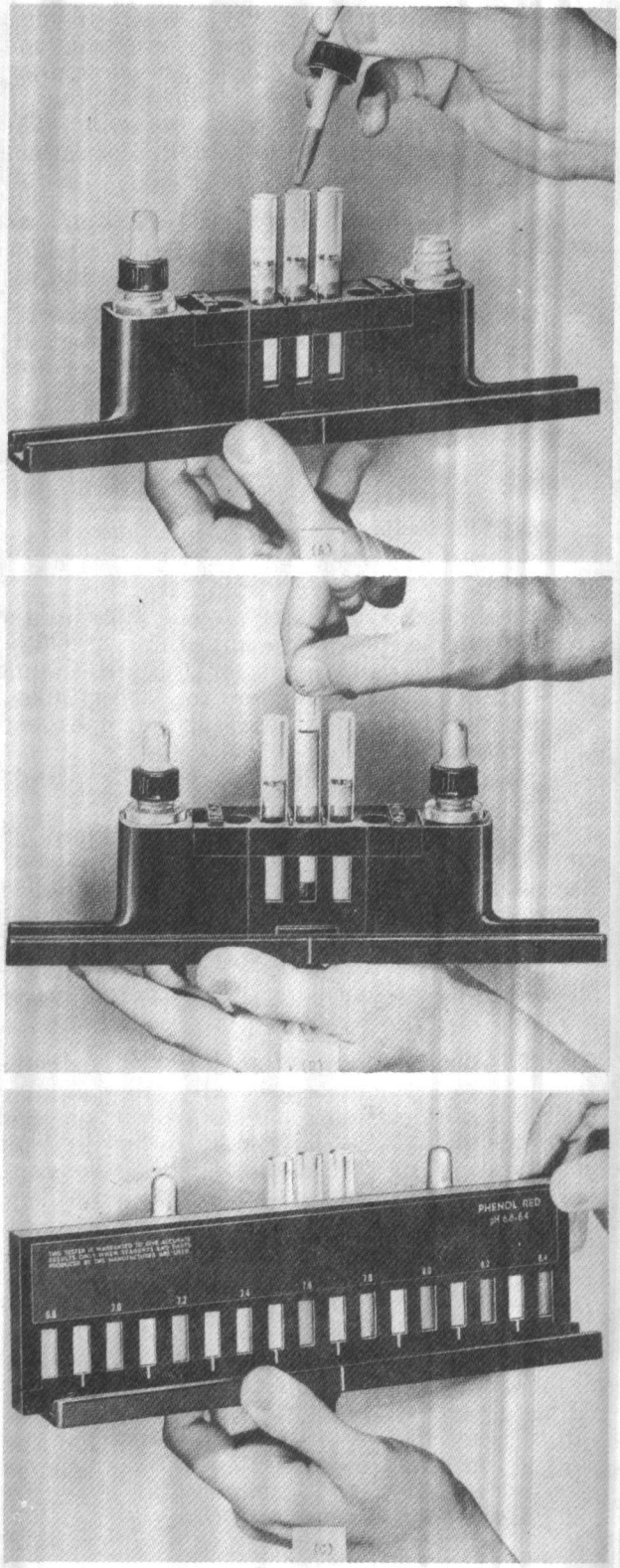


FIGURE 93

pH Determinations in Three Simple Operations

(A) Add Reagent (top)
(B) Remove Tube (center)
(C) Compare Colors (bottom)

3.3.4.5.2 Procedure with methyl purple.

(1) Measure 100 ml. of the clear sample (filtered if necessary) into an evaporating dish or Erlenmeyer flask.

(2) Add 4 drops of phenophthalein indicator solution. If a pink or red color develops, phenolphthalein alkalinity (alkalinity fraction contributed by hydroxide and half of carbonate) is present.

(3) Fill the burette with acid and add to the sample slowly just until the pink color disappears.

(4) Record the ml. of acid used.

(5) Now add two to four drops of methyl purple indicator.

(6) Continue titration, adding the acid in 0.5 ml. portions until a greenish tint appears where the acid hits the sample. Then continue the addition more slowly, about three drops at a time. The color will change from green to gray and then to purple. The appearance of the purple tint marks the end point.

(7) Record the total ml. of acid required to reach this end point. This includes the ml. of acid used in the phenolphthalein alkalinity titration and that used in the methyl purple titration.

3.3.4.5.3 Procedure with methyl orange.

(1) Measure 100 ml. of the clear sample (filtered if necessary) into an evaporating dish or Eryenmeyer flask. (NOTE: If an evaporating dish is used to get a white background for better color observation, the sample must be stirred with a stirring rod during addition of the standard acid.)

(2) Add four drops of phenolphthalein indicator solution. If a pink or red color develops, phenolphthalein alkalinity (alkalinity fraction contributed by hydroxide and half of carbonate) is present.

(3) Fill the burette with the acid and add to the sample slowly just until the pink color disappears.

(4) Record the ml. of acid used.

(5) Now add two to four drops of methyl orange indicator.

(6) Continue titration, adding the acid in 0.5 ml. portions, until the reddish color which appears where the acid hits the sample begins to persist. Then continue the addition more slowly, about three drops at a time, until the first pinkish tinge is seen throughout the sample. This is the end point.

(7) Record the total ml. of acid required to reach this end point. This includes the ml. consumed in the phenolphthalein alkalinity titration and that consumed in the methyl orange titration.

3.3.4.5.4 Calculations

(1) The phenolphthalein (PT) alkalinity is calculated, as p.p.m. of calcium carbonate, by multiplying the ml. of acid used in the phenolphthalein titration by 20.

P.p.m. PT alkalinity as calcium carbonate = ml. of acid used in step × 20.

(2) The total alkalinity, as p.p.m. of calcium carbonate, is found by multiplying the total number of ml. of acid used (step (6) above) by 20. This applies to both the methyl orange and the methyl purple procedures.

P.p.m. total alkalinity as calcium carbonate = total ml. acid used × 20.

3.3.4.6 Hardness. The titration method for determining water hardness is vastly superior to the old soap test which is slow, tedious, and often may give misleading results. The procedure is based on the fact that when a sample of water is titrated with a solution of EDTA (sodium ethylene diamine tetra-acetate), calcium and magnesium react with the EDTA to form soluble compounds in which calcium and magnesium are tied up so firmly that they cannot react with other materials. Standard EDTA solution is added to a water sample and the end point is detected by an indicator which is red in the presence of calcium and magnesium ions and blue in their absence. A total hardness test set (EDTA) is shown in figure 94.

3.3.4.6.1 Reagents

(1) EDTA solution.
(2) Hardness indicator powder.
(3) Hardness buffer.
(4) Hardness reagent.

3.3.4.6.2 Procedure

(1) Place a 50 ml. sample in a 250 ml. Erlenmeyer flask.

(2) Add one dipper of hardness indicator powder.

(3) Add 0.5 ml. of hardness buffer to hold the pH at around 10. The color of the mixture will be red if any hardness is present.

(4) Add the hardness reagent from a burette just until the red color disappears, giving way to a pure blue.

3.3.4.6.3 Calculations. The burette reading in ml. is multiplied by 20 to give the total hardness.

P.p.m. total hardness as calcium carbonate = ml. burette reading × 20.

3.3.4.7 Polyphosphate. Polyphosphate concentration can be measured by a color comparison test. The test is based on the fact that polyphosphates, which do not respond to the ordinary color tests for orthophosphate (also called normal phosphate), are converted to orthophosphate when boiled in acid solution. Thus, polyphosphate concentration is the difference between orthophosphate in the original water sample and orthophosphate found after the sample is boiled in acid solution. Because this test requires precise laboratory controls, it is customarily performed by a laboratory technician. Procedures to be followed are those given in Reference 7.

3.3.4.8 Color. Color in water is due to various materials in solution, although suspended turbidity occasionally adds an apparent color to water which may add to or disguise the true color. In water with low turbidity, the apparent color corresponds closely to the true color. However, if turbidity is high, the apparent color may be misleading. In such cases, in order to determine the true color, the water should first be filtered through clean white filter paper before comparing with the standards. Because the filter paper often removes some true color from the first portion of the sample, discard the first 100 ml. which pass through the filter and use the next portion for the color comparison. Make the color determination by matching the sample color with color standards in a color comparator.

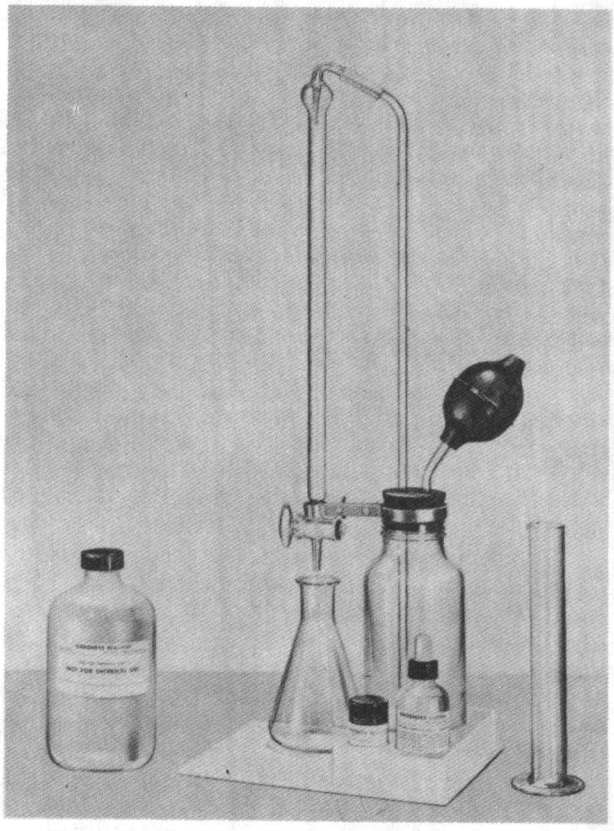


FIGURE 94

Total Hardness Test Set (EDTA)

3.3.4.9 Taste and Odor. Unless the water has a definite taste (sweet, sour, salty or bitter) the sensation produced upon the observer is generally due to the presence of odor rather than taste. These two senses work in unison. A sulfur water, for instance, apparently tastes "terrible" when it is really only its rotten egg odor which is registering on our senses. From the standpoint of measured observations, odor determinations are much to be preferred to taste determinations. There is no method for measuring tastes quantitatively.

3.3.4.9.1 Threshold odor test. The threshold odor test is the most widely used method of determining odor levels. It consists of comparing different dilutions of the sample (diluted with odor-free water) to an odor-free standard. The dilution at which the odor can just be detected is called the threshold point. The odor at the threshold point is expressed quantitatively by the threshold number. This is simply the number of times the odor-bearing sample is diluted with odor-free water. For example, if an odor-bearing water requires dilution to ten times its volume with odor-free water in order to make the odor just perceptible, its threshhold number will be 10. A more concentrated odor-bearing water will require dilution to 100 times its volume to make the odor just perceptible; its threshold number will be 100. Consistent measurement of odor values can be obtained only when fundamental principles are provided for.

(1) Some practice with the test is desirable to develop consistent threshold sensitivity. The consistency can be developed readily in most individuals. An acute sense of smell is by no means essential for this.

(2) An adequate supply of freshly prepared odor-free water must be available before starting the test.

(3) All glass must be clean and free of odor. Rinse all glassware several times with odor-free water prior to each test and between dilutions.

(4) Tests should be run in a room free from foreign odors. Odors caused by fresh paint, volatile solvents, tobacco smoke, food and the like will decrease the accuracy of the observations.

(5) Each dilution should be compared with the odorless standard to check judgment and minimize reliance on odor memory.

3.3.4.9.2 Equipment.

(1) Six 500 ml. Eryenmeyer flasks with ground glass stoppers.
(2) Two thermometers (O°–110° C.).
(3) One 250 ml. graduated cylinder.
(4) One 100 ml. graduated cylinder.
(5) One 50 ml. graduated cylinder.
(6) One 25 ml. graduated cylinder.
(7) One 10 ml. Mohr pipette.
(8) One large hot plate.
(9) One odor-free water generator (see Figure 95).
(10) Several large flasks for collecting and heating odor-free water.

3.3.4.9.3 Procedure. The first step is to determine the approximate range of the threshhold odor number.

(1) Add 250 ml., 63 ml., 16 ml., and 4 ml. portions of the odor-bearing water to separate 500 ml. glass-stoppered Erlenmeyer flasks.

(2) Dilute the last three of 250 ml. with odor-free water.

(3) Add 250 ml. of odor-free water to another flask which will be the reference for comparison.

(4) Heat the flasks to 140° F. (60° C.) on hot plate.

(5) Shake the odor-free flask, remove the stopper and sniff the vapors.

(6) Do the same with the flask containing the least amount of odor-bearing water and observe by comparison whether it contains an odor, and, if so, what type odor (see table 4).

(7) Repeat procedure in steps (5) and (6) using sample containing the next highest concentration of the water sample.

(8) Continue this process until all dilutions have been observed.

(9) Record which flasks contain an odor and which do not. Experience will enable an operator to estimate the approximate odor range by sniffing the undiluted sample, thereby eliminating the preliminary test.

(10) Based on the results obtained in the preliminary test, prepare a set of dilutions, using the amount of the sample diluted with odor-free water in the range corresponding to the lowest dilution in which the odor was detected. For example, if odor was detected in the 63 ml. dilution, but not in the 16 ml. dilution, use Series II in Table 5.

(11) Repeat the procedure in steps (5) through (9). The threshhold number is read from Table 6.

3.3.4.10 Fluoride. The Scott-Sanchis colorimetric test depends upon the formation of a stable zirconium fluoride that removes the zirconium

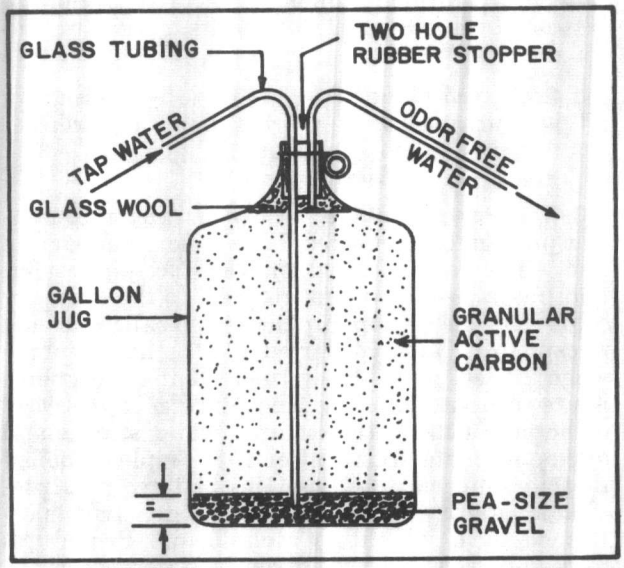


FIGURE 95

Odor-Free Water Generator

TABLE 4

Types of Odors Commonly Encountered in Water Supplies

Aromatic (spicy)	*Disagreeable*
cucumber	fishy
Balsamic (flowery)	pigpen
geranium	septic (sewage)
nasturtium	*Earthy*
sweetish	peaty
violet	*Grassy*
Chemical	*Musty*
chlorinous	moldy
hydrocarbon (gasoline)	*Vegetable*
medicinal	
sulfuretted (rotten egg)	

TABLE 5

Dilution Series for Determining the Threshold Odor Number

Series	I	II	III
Amount of sample diluted to 250 ml.	250	63	16
	177	44	11
	125	31	8
	88	22	5.5
	63	16	4

TABLE 6

Threshold Odor Numbers

Amount of sample diluted to 250 ml.	Threshold odor number
250	1
177	1.4
125	2
88	2.8
63	4
44	5.6
31	8
22	11
16	16
11	22
8	32
5.5	45
4	64

from a colored solution and thereby reduces its color. This method of analysis, therefore, is really a colorimetric method in reverse. The greatest strength of color occurs when no fluoride is present and the color fades as the fluoride content increases. This method has been found reliable for potable water containing chloride up to 200 p.p.m. and sulfate up to 200 p.p.m. Alkalinity or acidity does not interfere when present in amounts up to 200 p.p.m. as calcium carbonate. If these constituents exceed these amounts, or if iron, aluminum, phosphate, color or turbidity are present in even smaller amounts, a complicated distillation method must be employed before testing for fluoride (see Reference 7).

3.3.4.10.1 Reagents

(1) Acid zirconium alizarin reagent.

(2) Standard sodium fluoride solution made up so that 1 ml. is equivalent to 0.01 mg. of fluoride.

3.3.4.10.2 Procedure

(1) Add successively an increasing amount of the standard sodium fluoride solution to matched 100 ml. Nessler tubes to make up standards. The standards recommended (in ml. of standard sodium fluoride solution) are.

0	4	10
1	5	12
2	6	14
3	8	

(2) Make each of these standards up to 100 ml. with fluoride-free distilled water.

(3) Place 100 ml. of the sample in another matched Nessler tube.

(4) Bring the sample and the standards to near the same temperature by allowing them to stand at room temperature for 30 minutes.

(5) Using a 5 ml. volumetric pipette, add 5 ml. of the acid zirconium alizarin reagent to the sample and to each of the standards.

(6) Let mixtures stand for one hour. (NOTE: Do not allow the sample and the standards to stand much longer than one hour, as they tend to become cloudy and difficult to read.)

(7) After that time, compare the sample with the standards and record the amount of fluoride as that of the standard that most nearly matches the sample in color.

3.3.4.10.3 Calculations. To determine the fluoride in p.p.m. divide by 10, the amount of standard sodium fluoride in solution used in making up the standard matching the sample.

$$\text{p.p.m. fluoride} = \frac{\text{ml. standard fluoride solution in matching sample}}{10}.$$

3.3.4.11 Iron. In natural water, dissolved iron is mainly in the unoxidized (ferrous) state. When allowed to oxidize, the iron precipitates

as ferric hydroxide (rust). The following test for total iron measures both the ferrous and ferric iron content of a water sample. In the test, all the ferrous iron is oxidized to the ferric form in strongly acid solution. Potassium thiocynate solution is then added to form a characteristic red color which is matched with iron color standards.

3.3.4.11.1 Reagents

(1) Potassium thiocynate.
(2) Nitric acid, 6N.
(3) Potassium permanganate.

3.3.4.11.2 Procedure

(1) Measure out 50 ml. of the water sample into a 250 ml. Erlenmeyer flask.
(2) Add 5 ml. of nitric acid.
(3) Boil five minutes.
(4) Add three drops of potassium permanganate.
(5) If the color disappears, add one drop at a time until a permanent faint pink persists.
(6) Cool.
(7) Add 5 ml. of potassium thiocynate and mix.
(8) Place in a comparator and match with the iron color standards immediately. (NOTE: If the sample color is stronger than the highest iron standard in the comparator, use a smaller volume, dilute to 100 ml. and proceed as above. Multiply the result by the proper dilution factor, e.g., if 25 ml. were diluted to 100 ml., multiply p.p.m. read on comparator by $\frac{100}{25}$, or 4.)

3.3.4.12 Manganese

3.3.4.12.1 Reagents

(1) Nitric acid.
(2) Silver nitrate.
(3) Ammonium persulfate.

3.3.4.12.2 Procedure

(1) By means of a graduate, measure out 100 ml. of the sample.
(2) Pour this into a beaker or Erlenmeyer flask (250 to 500 ml. capacity) containing glass beads.
(3) Add 2 ml. of dilute nitric acid.
(4) Boil down to about 50 ml. (NOTE: Unless the sample is boiled sufficiently, certain oxides of the nitrogen may remain and lead to off colors and erroneous results.)
(5) Add two percent silver nitrate solution by drops until no further silver chloride precipitate forms, and then add 1 ml. in excess.
(6) Shake and heat to coagulate the precipitated silver chloride.
(7) Filter through a paper filter.
(8) Wash the precipitate with a small amount of distilled water which is added to the sample.
(9) Add about 0.5 gram of ammonium persulfate crystals to the filtrate.
(10) Warm (176° to 194° F., 80° to 90° C.) until the maximum permanganate color (purple) is developed (about 10 minutes).
(11) Cool and pour the colored solution into the 100 ml. flask or graduate used to measure the sample originally.
(12) Dilute to 100 ml. and mix well.
(13) Place in a comparator and match with manganese color standard. (NOTE: If the color is deeper than that of any of the standards (over 3 p.p.m.), it will be necessary to dilute the original sample with distilled water to bring the manganese content within the range of the standards. Measure out a smaller volume of sample, dilute to 100 ml., and proceed as above. Multiply p.p.m. read on comparator by $\frac{100}{\text{ml. sample}}$ to get actual p.p.m. manganese.)

3.3.4.13 Sulfide. A simple, reliable and sensitive color test for hydrogen sulfide works by aerating the sample so as to pass the sulfide through a test disk. A chemical on the test disk turns color in proportion to the amount of hydrogen sulfide present.

(1) Fill the special sample bottle to the mark with the water sample. (NOTE: Test papers and sample bottles are available from several manufacturers and laboratory supply houses.)
(2) A disk of hydrogen sulfide test paper is placed inside the sample bottle cap.
(3) An Alka-Seltzer tablet is dropped into the sample bottle and the cap placed on the bottle. (NOTE: The effervescence that takes place as the tablet dissolves aerates the hydrogen sulfide out of the sample and the gas passes through the disk of test paper. If hydrogen sulfide is present, the paper disk will turn yellow to dark brown to black, depending upon the amount present.)
(4) The color of the disk is then compared with the color chart furnished by the manufacturer to determine the p.p.m. of hydrogen sulfide in the sample water.

3.3.4.14 Carbon Dioxide. One method for determination of carbon dioxide in water is to titrate a water sample with standard sodium hydroxide. Phenolphthalein is used as the indicator. The main precaution concerning this test is preventing the loss of carbon dioxide from the water sample by aeration when the sample is taken and during the titration itself. For this reason, the use of a special 250 ml. conical titration flask with a 200 ml. graduation mark is recommended. With this the loss of carbon dioxide is minimized. While this method is adequate for plant checks, other tests can be conducted by laboratory technicians to check the outgoing water supply. For details of other methods see Reference 7.

3.3.4.14.1 Reagents

(1) Standard sodium hydroxide (N/50).
(2) Phenolphthalein indicator.

3.3.4.14.2 Procedure

(1) Use the 250 ml. titration flask that has a 200 ml. calibration mark. Preferably, allow the water sample to flow into the flask and overflow for a short time.

(2) Carefully pour off the excess water until the water level reaches the 200 ml. calibration mark.

(3) Add five drops of phenolphthalein indicator.

(4) Titrate rapidly with standard sodium hydroxide solution. Gently swirl the flask during titration and continue until the first permanent pink color is produced.

3.3.4.14.3 Calculation. The p.p.m. of free carbon dioxide is found by multiplying the number of ml. of sodium hydroxide added by 5.

p.p.m. free carbon dioxide = ml. of sodium hydroxide x 5.

3.3.4.15 Dissolved Oxygen. The test for dissolved oxygen, in order to be accurate, involves great care and considerable skill and practice. It must be performed under carefully controlled conditions. For detailed test methods see Reference 7.

3.3.4.16 Jar Test (Coagulation). The jar test is a reliable method for determining the proper chemical dosages and conditions for coagulation of water to remove color and turbidity.

3.3.4.16.1 Equipment. For best results, a multiple stirrer with variable speed adjustment is an essential piece of equipment. It provides good control of the method of agitation and ensures that all jars will be handled in exactly the same manner. Figure 96 illustrates a multiple stirring apparatus that may be used. These can be obtained from several manufacturers or laboratory supply houses. The jars are preferably illuminated from the bottom by fluorescent bulbs in a case covered with frosted glass. It has been found most convenient to run jar tests on 500 ml. samples in 600 ml. beakers. These work out well with the multiple stirrers. It provides sufficient depth of the sample to observe the results with ease and provides sufficient sample for analytical purposes.

3.3.4.16.2 Reagents. In the determination of proper coagulation, six different types of reagents may be required, depending upon what physical or chemical conditions are being tested.

(1) Coagulant (alum, ferric sulfate).
(2) Alkali (lime, sodium carbonate).
(3) Chlorination (chlorine, chlorine dioxide).
(4) Coagulant aid (activated silica, organic coagulant aids).
(5) Weighting agent (clay, calcite flour).
(6) Absorbent (powdered activated carbon).

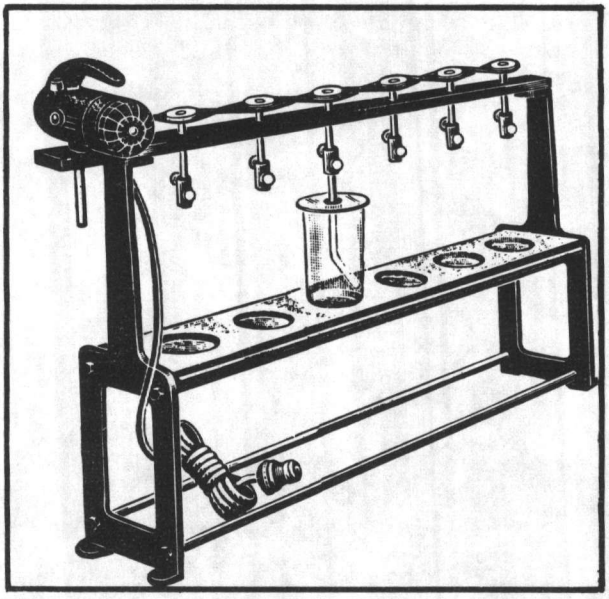


FIGURE 96

Variable-Speed Multiple Stirrer

A supply of each type of reagent should be available to run these tests. Jar-test reagent kits containing the needed reagents are available from several manufacturers. One such kit is shown in figure 97.

3.3.4.16.3 Procedure. Before starting a series of jar tests, determine the purpose of the tests, then plan conditions so that only the factor being studied is varied. For example, if it is desired to determine the effect of pH on the floc characteristics, a series of four or five samples should be run in which the coagulant dosage is constant, but the alkali dosage is varied, so that each sample has a different pH. The order of the addition of chemicals, flash mix and slow mix periods, temperature of the sample and all other variables should be the same in all samples. Only the alkali dosage would vary.

(1) First Series. When the primary object of the jar test is to determine the most suitable coagulant, when it is necessary to run at least one series, and usually several series, with each coagulant or combination of coagulants. The first series generally involves the addition of a fixed dosage of the coagulant (in most cases this would be alum) and a variable dosage of lime, soda ash, or sodium hydroxide in each of the jars.

(2) Second Series. Depending upon the results obtained in the first series, a second series will usually run over a narrower pH range using smaller differences among the jars for alkali dosages, but otherwise keeping the coagulant and its dosage the same as in the first series. Sometimes at the end of the second series, the

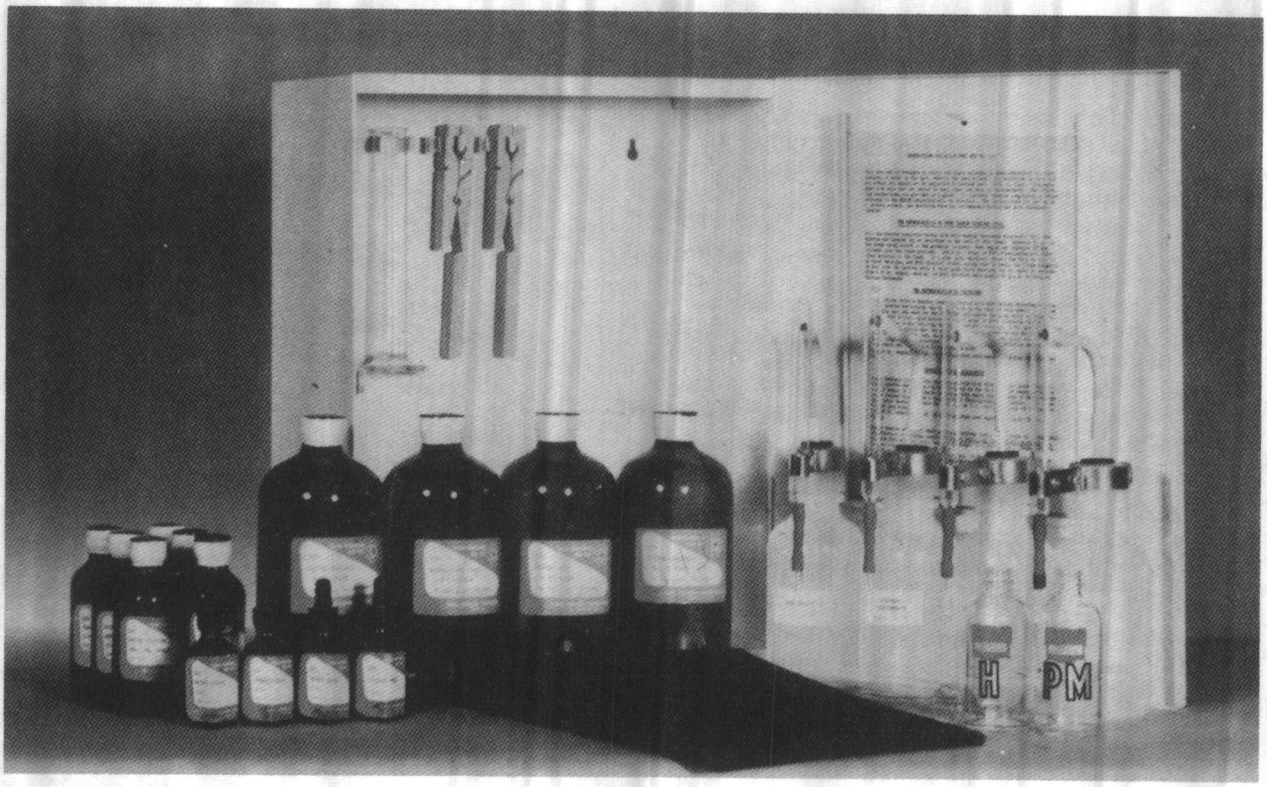


FIGURE 97
Jar Test Reagent Kit

optimum pH range is definitely established, but in other cases, it may be necessary to run additional series in order to clearly define the optimum pH band for that coagulant at the dosage level.

(3) Detailed Procedure. It is important to have the object of a particular series in mind at the start of the tests and to set down test conditions on data sheets (see fig. 98) so that the object of the test will be realized at the end of the series.

(a) Pour the required amount of reagent into a given volume of water. (NOTE: Usually 8.1 grams of the reagent to one quart of water.) Most jar test reagent kits are supplied in vials containing 8.1 grams of the reagent.

(b) During the addition of the chemicals, stir vigorously in order to affect quick and thorough mixing (60 to 80 r.p.m. on a mechanical stirrer). Too rapid addition of the chemicals should be avoided and approximately the same rate of addition should be used in all samples. NOTE A: This flash-mix period should not be less than 30 seconds, and may usually be as long as three to four minutes. NOTE B: If the water is warm and the floc forms quickly, there is some danger that a long flash-mix period will cause the floc which forms to break up. Under such conditions, it is better to run fewer samples or to get help in adding the treatment chemicals so that the flash-mix period can be shortened.

(c) Slow-mix the sample for 15 to 20 minutes to keep the floc particles in intimate contact with the water and circulating continuously. NOTE: If the stirring is too vigorous, the floc may break up and the results may be poor. If too little stirring is used, the clarification and color reduction may not be as complete as possible under the conditions of the test as the growing floc is not brought into contact with the impurities it is to remove.

(d) Throughout the slow mixing period, observe the samples carefully and record observations such as rate of formation of floc, floc size and appearance of the water between the floc particles (clear, hazy, clear but colored). NOTE: The size of the floc may be described according to the following table.

Approximate Average Particle Size

Description	*Approx. size (inches)*
Pinpoint	Extremely fine, but visible
Fine	1/64
Small	1/32
Fair	1/32 to 3/64
Good	3/64 to 3/32
Large	1/4 and larger

COAGULATION TEST RESULTS

Source _____ By _____ Date _____

Jar No.	Temp. °C	Turbidity (Parts per Million)	Color (Parts per Million)	Alkalinity (Parts per Million)	pH	Dosage ppm-gpg: Alkali	Dosage ppm-gpg: Coagulant	Test Duration Minutes: Mix	Test Duration Minutes: Stir	Test Duration Minutes: Settle	Floc: Time to Appear Min.	Floc: Index	Filtrate: Color (Parts per Million)	Filtrate: Turb. (Parts per Million)	Filtrate: Residual Alumina (Parts per Million)	pH
1																
2																
3																
4																
5																
6																

Source _____ By _____ Date _____

1																
2																
3																
4																
5																
6																

Source _____ By _____ Date _____

1																
2																
3																
4																
5																
6																

FLOC INDEX FOR TESTS

0 — No Floc 2 — Smoky 4 — Pin Point 6 — Fair 8 — Good 10 — Excellent 12 — Very Heavy

FIGURE 98

Typical Jar Test Data Sheet

TABLE 7

Floc Settling Scale

Minutes to settle 4 inches	Remarks
Less than 2	Excellent: Will give excellent results in upflow solids-contact equipment at relatively high rates.
2 to 4	Good: Will give good results in upflow solids-contact equipment at moderate rates.
4 to 7	Fair: Will give satisfactory results in upflow unit if rate of rise is low.
Greater than 7	Poor: Unless a low rate of rise is used, poor results will be obtained.

The dimensions given are only a very rough scale for evaluating a floc. The size of the floc is but one criterion of the effectiveness of a set of treatment conditions. The rate of floc settling is a more important criterion and quality of the supernatant water after settling is equally important.

(e) At the end of the slow-mix period, stop stirring and allow the floc to settle.

(f) Observe the settling carefully, reporting inches of clear water above the floc at two minute intervals, or more frequently, if the floc settles rapidly.

(g) Continue until all the floc is on the bottom of the jar, or for 15 minutes, whichever is shorter.

3.3.4.16.4 Results. The following scale may be used as a rough standard for evaluating the settling rates of floc for jar tests. It is based on the period required for the floc to settle 4 inches, which is the approximate depth of a 500 ml. sample in a 600 ml. beaker (see table 7).

3.3.4.17 Turbidity. Special instruments (see fig. 99) for measuring turbidity are available from several manufacturers. These instruments greatly simplify the work of the operator in this test. Results are reliable and accurate. Complete

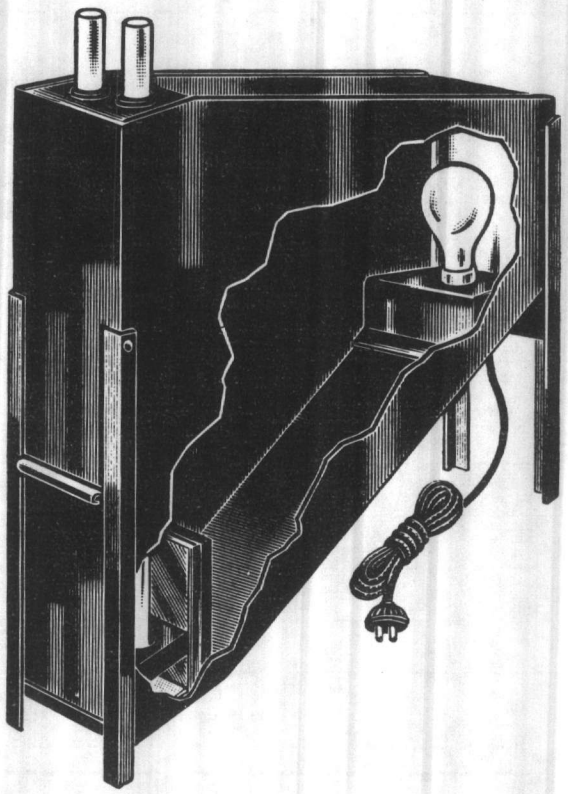


FIGURE 99

Turbidimeter

instructions are available from manufacturers, but in general, the principles of operation are the same. Usually an easy, five-step operating procedure is followed.

(1) The sample tube is filled with the water to be tested.

(2) The glass plunger is inserted in the tube.

(3) The tube is placed in the instrument.

(4) The dial at the side of the instrument is turned until the field seen in the eyepiece becomes uniform.

(5) The value indicated on the dial is read and the turbidity content of the sample being tested is determined directly from a chart furnished with the instrument.

Section 4. DISTRIBUTION, STORAGE, AND METERING

3.4.1 ELEMENTS OF DISTRIBUTION SYSTEM. The elements of a complete distribution system include distributing reservoirs, conduits or transmission mains, pipelines, booster stations, valves, hydrants, meters and service connections.

3.4.2 OPERATION OF DISTRIBUTION SYSTEM. The operation of a distribution system consists essentially of the proper setting and operation of valves, record keeping of water flows and levels and correct balancing of system flow to maintain desired pressure in all parts of the system. The properly designed and operated system will deliver sufficient water to meet the normal maximum demands at all points of use. For a typical distribution system piping layout, see Figure 100. The system must also deliver sufficient water to provide fire flows at all points. Where distribution systems have been carefully planned, the pipes are laid out in a grid or belt system. Whenever possible, the network has been designed so that the whole piping system consists of loops, and no pipes come to a dead end. In this way, water can flow to any point in the system from two or more directions. With this arrangement and adequate valves, the water supply need not normally be cut off for maintenance work or repairs in a pipe or main.

3.4.2.1 Detailed Utility Map. As noted in Paragraph 2.6.2.2, accurate record keeping of the location, type and size of all mains, pipes, valves, meters, hydrants and other appurtenances of the distribution system is essential. The operator must be thoroughly familiar with the water supply system and be able to locate any component on a moment's notice. This record must be kept up to date so that in an emergency the particular trouble spot can be readily located and prompt, proper action taken.

3.4.2.2 Piping. Piping layout and the selection of pipe material and size are a matter of design which is not the concern of the operator. Maintenance of the piping and mains in the distribution system is covered in Chapter 4.

3.4.2.3 Prevention of Backflow. As noted in paragraph 2.3.5.2.2, backflow is the backing up of contaminated or nonpotable water into the potable water system. In the following paragraphs, methods of prevention of this condition are described. Failure of backflow prevention, or improper connection causing backflow, require immediate action on the part of the operator. In many cases, this will be a simple matter of shutting off valves from nonpotable systems. The condition must be reported immediately to higher authority so that corrective action, which may require skilled technical help, may be taken promptly.

3.4.2.3.1 Elimination of cross-connections. Connections and water uses that create backflow conditions must be eliminated. Examples are bypass connections between raw and untreated water in a water treatment plant, and automatic sewer flushing devices. Particular attention must be given to the danger of cross-connections between potable systems and sea-water systems when making ship-to-shore connections. The instructions relating to these connections are contained in OPNAV instructions which are included in Appendix II. Among other things, the directive requires that only authorized shore personnel make water connections between shore and ships.

3.4.2.3.2 Separation by air gap. Provide an air gap between the water inlet and maximum overflow level of a particular device or system. If water under pressure is required, use air-gap inlet to either an elevated tank or a low-level tank with a pump. The latter method is commonly used at sewage treatment plants because of the many hazards. Similarly, provide air space between tanks holding or carrying potable water and those holding raw water or other nonpotable liquid. This eliminates the possibility of leakage through the tank walls.

3.4.2.3.3 Backflow preventers. These devices, frequently termed vacuum breakers, are used to prevent back siphonage, as from submerged inlet plumbing fixtures. Figure 101 illustrates schematically the arrangement of the component parts of a backflow prevention unit utilizing double-check valves.

3.4.2.3.4 Backflow protection units. These units are available from several manufacturers. Typical of these is the reduced pressure backflow preventer, shown in figure 4. This unit operates automatically by means of line pressure. The "reduced pressure" principle is applied in using an air-gap to break the atmosphere to create a zone within the unit where the pressure is always less than the supply pressure.

3.4.2.4 Water Surge and Hammer. Surge in a water pipe is a rise in pressure that is caused by sudden variations in water velocity due to

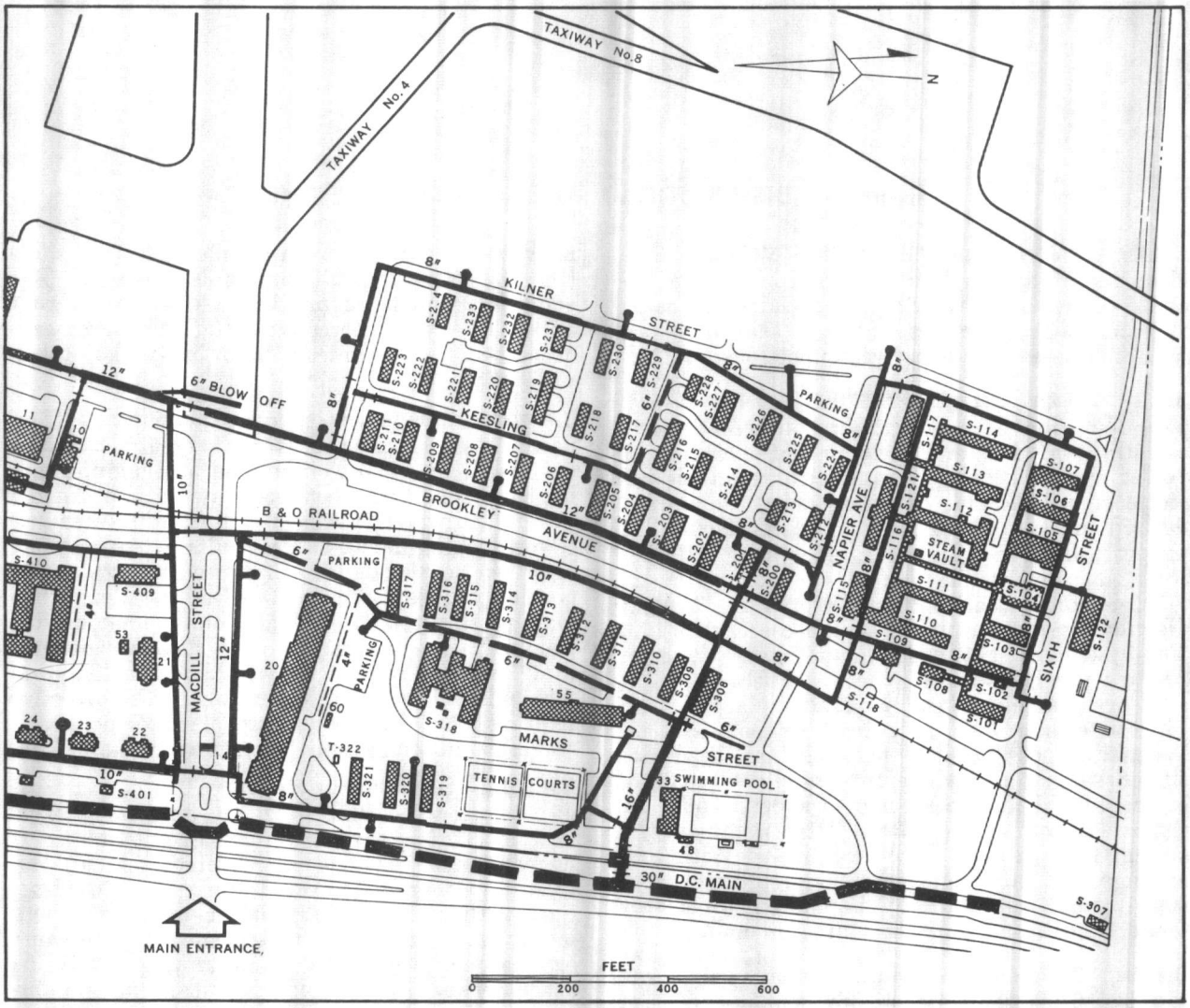


FIGURE 100

Typical Distribution System Layout

changes in water demand or pumping. A surge usually lasts for several minutes and, therefore, can be detected by pressure gages. It does not fluctuate above and below the line pressure rapidly, as does water hammer, nor does it deliver its force as damagingly. Sufficient pressure rise can cause pipe failure. Surge may sometimes be controlled by installing air chambers in the system to absorb the pressure rise and return it to the system evenly and at a slower rate. Water hammer is a rapid pressure fluctuation above and below the line pressure in a closed pipe system, caused by a sudden starting or stopping of flow, or by too rapid a change in the rate of flow. The force exerted may burst the pipe or force joints open. Operators are cautioned to close valves at a slower, more even rate if water hammer is heard. If water surge or hammer persists, the operator should notify higher authority immediately.

3.4.2.5 Valves and Appurtenances. Flexibility in the operation of a water supply system requires the use of the proper valves for the condition to be controlled. Aside from completely stopping flow, valves are used for throttling or controlling quantities of water flowing in a pipe channel. Other uses include pressure and level control, and proportioning flow. Appurtenances which aid in the control of valves include valve boxes, floor stands and post indicators.

3.4.2.5.1 Types of valves. There is a wide variety of valve designs available, but certain general types listed below and illustrated in figures 102 through 111, inclusive, characterize those used

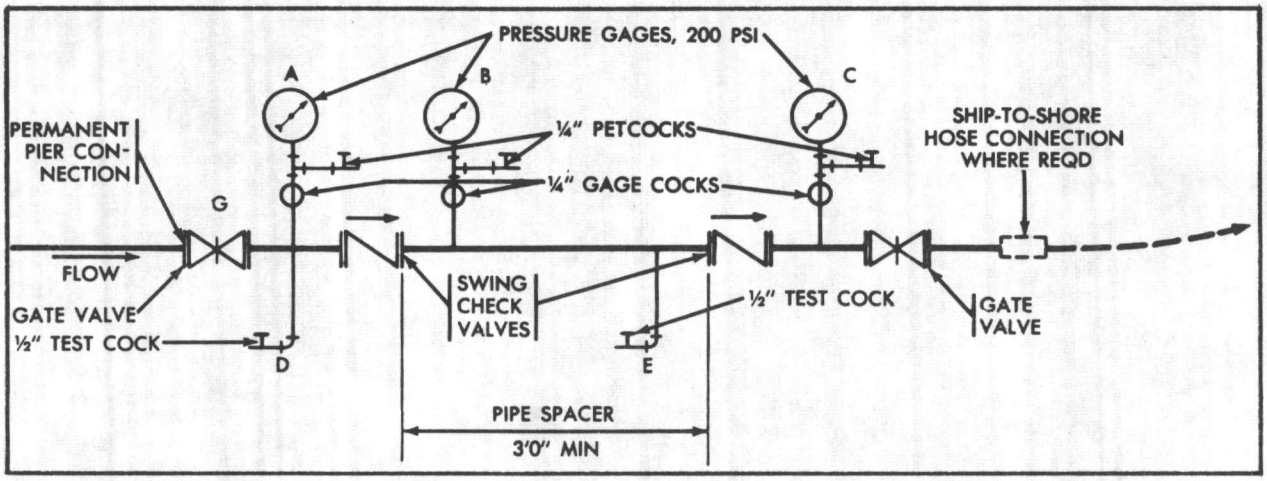


FIGURE 101

Backflow Prevention Unit Utilizing Double-Check Valves

most commonly in water supply systems operations.

(1) Gate.
(2) Check.
(3) Float.
(4) Altitude.
(5) Pressure Reducing.
(6) Corporation Cocks and Stops.
(7) Butterfly.
(8) Plug.
(9) Globe (not illustrated).

The construction, parts description and maintenance of these valves are discussed in Chapter 4.

3.4.2.5.2 Valve Operation. Many valves in a water supply system do not require an operator, but are controlled automatically. These include check, float, altitude and pressure reducing valves. Correction of any malfunction of this type valve is a maintenance matter (see Chapter 4).

(1) Manual Operation. When valves are operated manually, there are several sound rules to follow. In manually opening a valve, it should be opened all the way, then closed down one-quarter turn of the handwheel. This will prevent the valve from sticking in the open position. Valves should be opened slowly and at an even rate to reduce the hazard of water hammer. Unless otherwise indicated, valves are opened by turning the handwheel counterclockwise. Always consult the manufacturer's instructions for the operation of a specific type of valve.

(2) Power Operation. Power-operated valves require little operating attention, except in the case of power failure. When it then becomes necessary to close or open such a valve by manual operation, consult the manufacturer's instructions for such emergency measures. Most power-operated valves are equipped with safety devices to allow for such operation. (For operation of remote controls, see Chepater 3, Section 6.)

3.4.2.5.3 Appurtenances

(1) Valve Boxes. Street valves must be accessible for turning off and on; and, with large valves it is desirable that the entire valve be accessible for servicing. For the first purpose, valve boxes are used (see fig. 112), and for the second, vaults or manholes are used. Since valves are placed at various depths, valve boxes are made in two or more pieces which telescope so as to give adjustable lengths.

(2) Floor Stands. Valve controls may be mounted on floor stands for operating valves below a floor. They are operated manually by turning the handwheel, or by automatic controls. Some floor stands are equipped with indicators which show when valves are opened or closed. Floor stands (see fig. 113) are essentially an extension of the valve stem.

(3) Post Indicators. These indicators (see fig. 114) provide a convenient method of operating nonrising-stem gate valves placed below the ground or floor levels. They are used principally in fire-flow systems, and in this function must be fully approved by the Underwriters' Laboratories and the Associated Factory Mutual Fire Insurance Companies (indicated on the post by the letters UA and FM). The indicator post is operated by an attached operating wrench which acts as a locking device when not in use. The valve is opened by turning the wrench to the left, unless otherwise indicated. The open or closed position of the valve is clearly indicated by the target plates which show the words "Open" and "Shut" in glass protected openings on both sides of the post. Most post indicators are sealed open for safety's sake. If the seal was been broken,

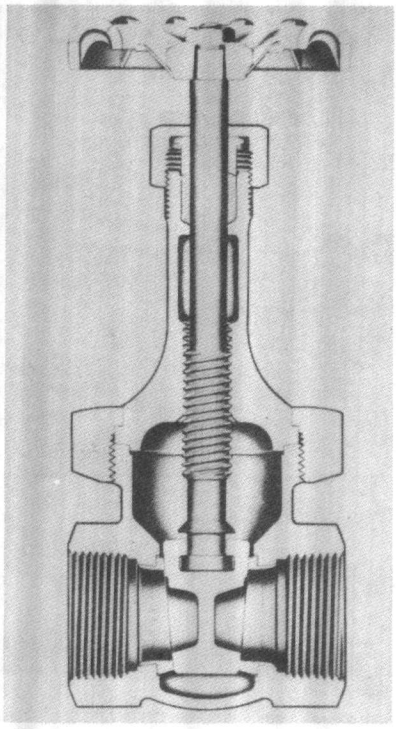


FIGURE 102

Gate Valve (Rising Stem)

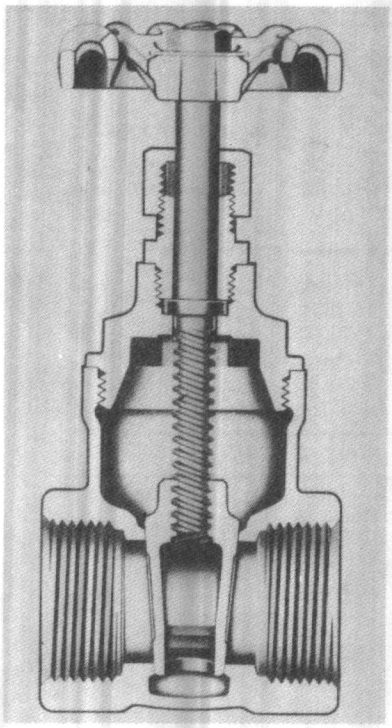


FIGURE 103

Gate Valve (Nonrising Stem)

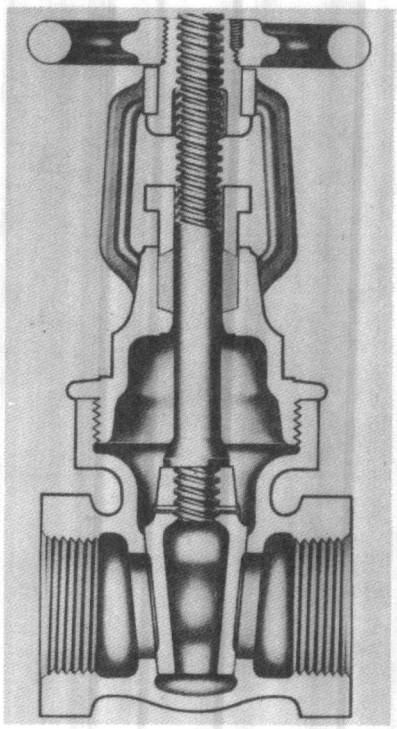


FIGURE 104

Gate Valve (Outside Screw and Yoke)

the operator should report the tampering to higher authority immediately.

3.4.2.6 Hydrants. The proper operation and use of hydrants are essential to the safety of the installation, as well as contributing to water supply economy. Damage through carelessness, ignorance or abuse can be minimized by allowing only authorized fire and utilities personnel to operate hydrants. Details of construction and maintenance appear in Chapter 4, Section 6.

3.4.2.6.1 Hydrant tools. No tools other than the hydrant wrench of the proper size shall be used on a hydrant. Ordinary wrenches and other tools ruin the operating nut. Unless otherwise designated, the nozzle and the operating nut are opened by turning to the left.

3.4.2.6.2 Outlets. Standard hydrants (see fig. 6) are equipped with two 2½-inch hose outlets, and a 4½-inch pumper outlet whose threads conform exactly to National Standard Fire Hose Threads.

3.4.2.6.3 Precautions. Hydrants exposed to traffic hazards must be protected by appropriate guards. Most damage is caused by accidents or improper or careless operation. Much of it can be prevented if operating personnel are made to realize that a properly functioning fire hydrant is important to the protection of life and property at the activity. Without much extra labor or effort, many precautions can be taken to keep the hydrant structure in good condition.

(1) The operation of fire hydrants should be restricted to responsible personnel who are trained in this and such allied work as firefighting or utility maintenance and operation.

(2) Hydrants should be opened and closed only with approved hydrant wrenches. If ordinary wrenches are used, damage to the operating nut is almost inevitable.

(3) Pipes should be connected only to draw off water for firefighting, except in emergency. Any such connection must be removed immediately after the emergency. Connections made to provide a temporary supply for vehicle washing, irrigation and so on should not be permitted.

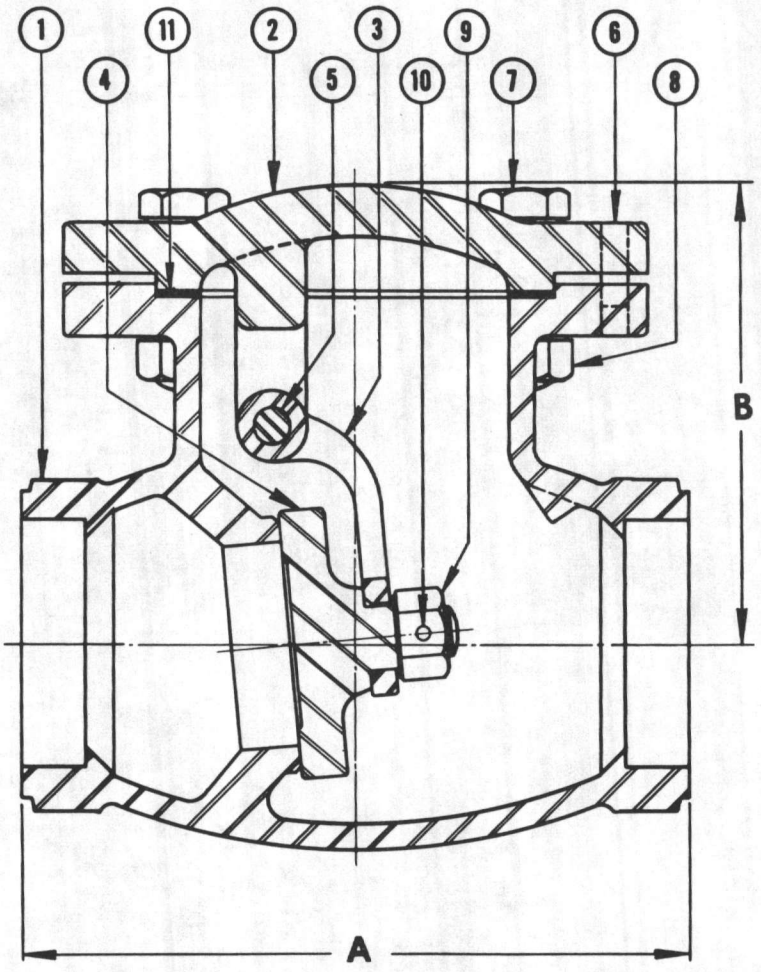
(4) The hydrant should be drained when not in use. This is particularly important in cold climates where ice in the hydrant may make it inoperative.

(5) The hydrant valve should be kept in either the wide open or fully closed position and never used to throttle the flow of water. If it is necessary to restrict the flow, separate gate valves should be attached to the hydrant discharge outlet.

(6) Reference 2 provides further details.

PARTS LIST	
1	BODY
2	COVER
3	CLAPPER ARM
4	DISC
5	CLAPPER ARM SHAFT
6	COVER PIN
7	COVER BOLT
8	COVER BOLT NUT
9	DISC NUT
10	DISC NUT PIN *
11	GASKET

* ½" TO 2" SIZE INCL.



DIMENSIONS IN INCHES

SIZE	¼	⅜	½	¾	1	1¼	1½	2
A	3⅛	3⅛	3¾	3¾	5	5½	6	6½
B	2 7/16	2 7/16	3	3	3⅝	3¾	4	4½

FIGURE 105

Check Valve

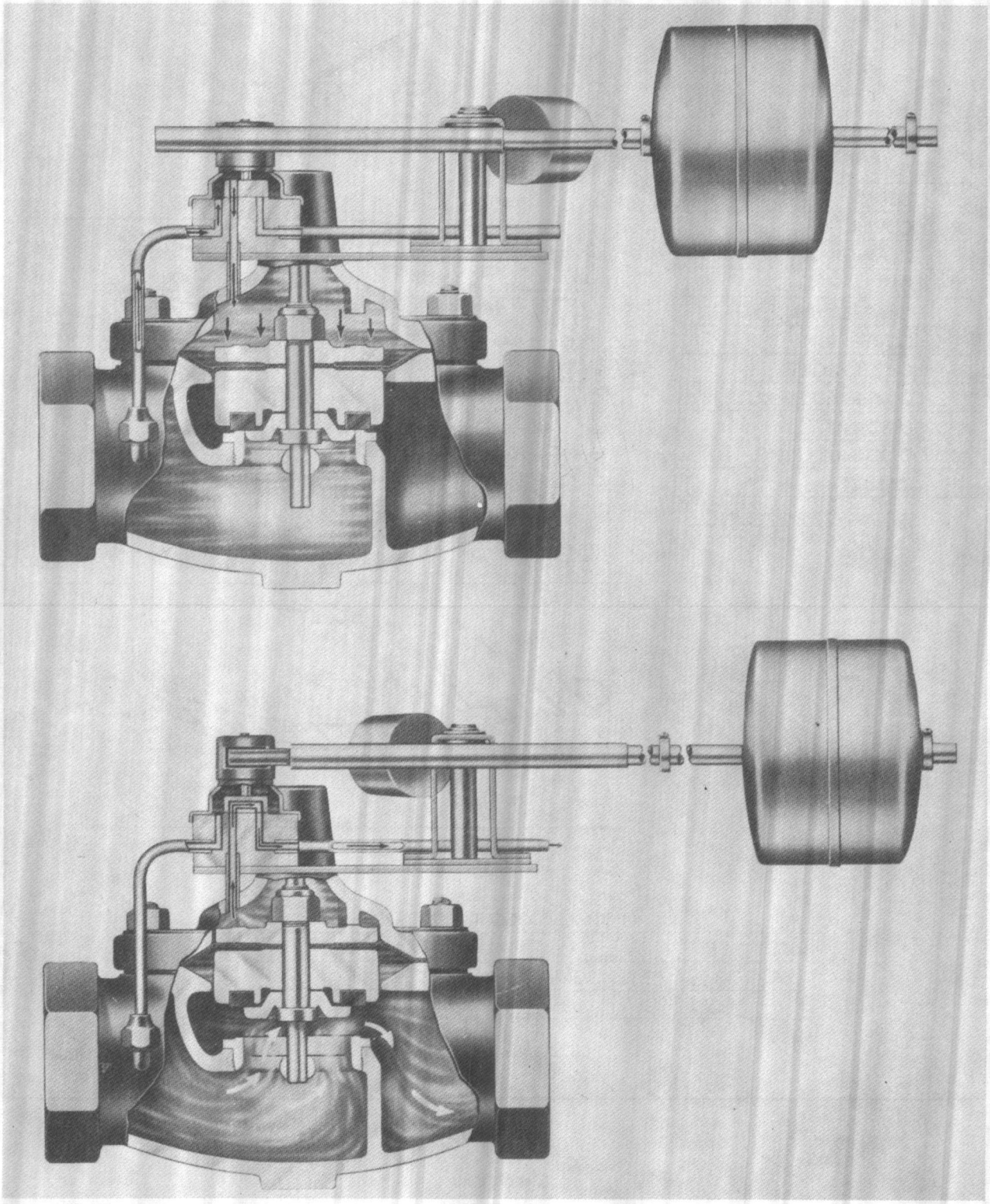


FIGURE 106

Float Valve

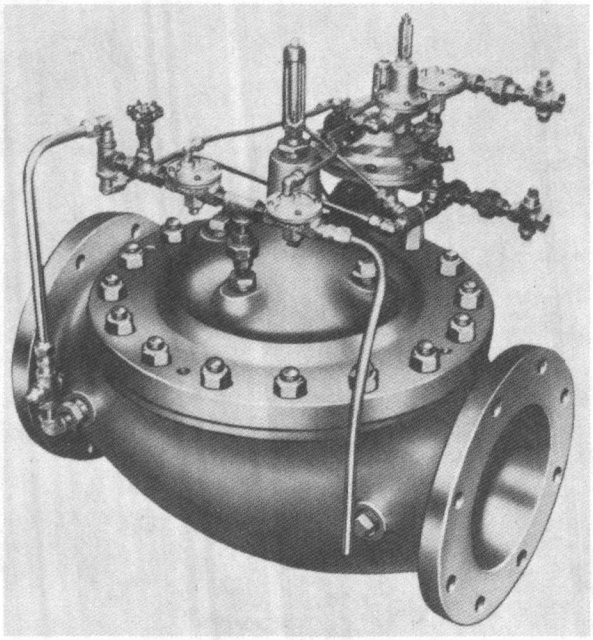


FIGURE 107

Altitude Valve

3.4.2.6.4 Improper use. The distribution system should always be protected against contamination through the improper use of hydrants. No pipes or hoses will be connected to hydrants for washing vehicles or for any other purpose than firefighting without specific authorization of the Utilities Division.

3.4.3 STORAGE. The operation of storage facilities in the distribution system is largely a matter of maintaining sufficient levels through adequate pumping, and controlling water flow through appropriate valves. The maintenance of storage facilities is essential to proper water system operation and is covered in Chapter 4.

3.4.3.1 Types and Amounts of Storage. Water may be stored in open reservoirs, underground reservoirs, elevated storage tanks and standpipes (see fig. 115, 116, and 117). Under no conditions should the amount of stored water be reduced to a point below that necessary for firefighting. Daily records, maintained by the operator, help insure against such a condition.

3.4.3.2 Live Storage. Live storage, where water is constantly circulating from the supply into the distribution system, is preferred to noncirculating storage because the latter depletes the chlorine in the water and allows tastes and odors to develop. If such dead storage is necessary, the operator must maintain a close watch on chlorine residuals and the development of odors and tastes, and report conditions regularly to higher authority.

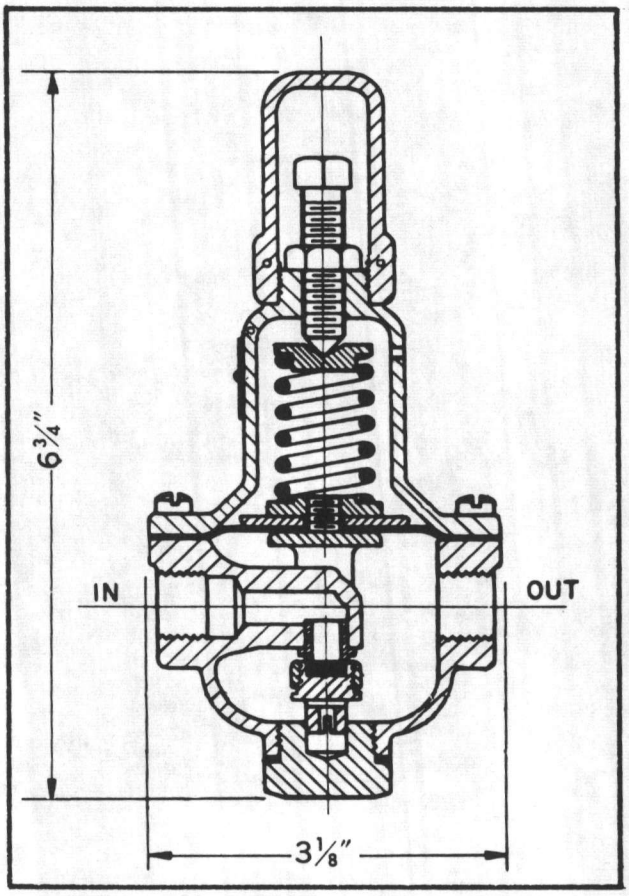
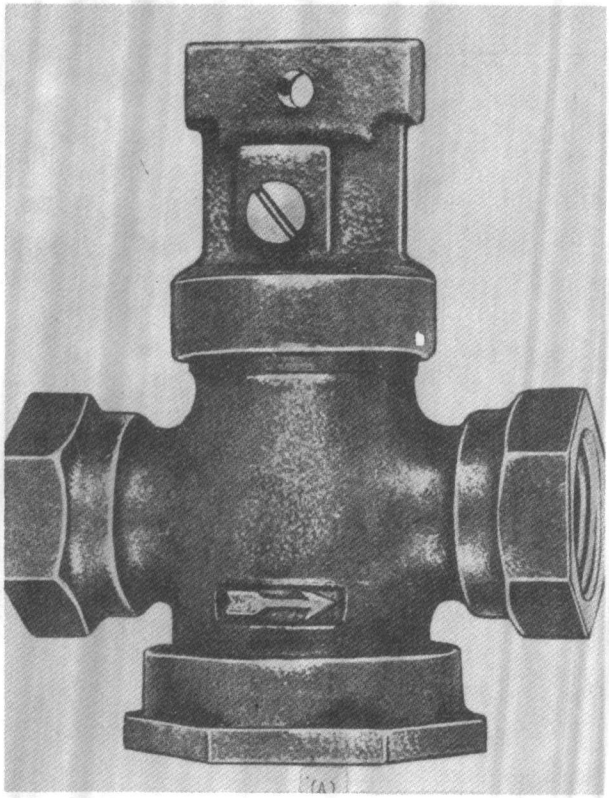


FIGURE 108

Pressure Reducing Valve

3.4.3.3 Pneumatic Tanks. Pneumatic tanks (see Figure 118) are usually found in use at smaller installations. They consist of a pressure vessel partly filled with water in order to leave an air cushion above to produce the desired water pressure. Pneumatic tanks may be located within buildings, on outside surface locations or underground. While the operation of these units is usually automatic, the operator is responsible for the effective operating of pressure equipment. It is important to see that the air cushion is maintained at all times. Air may be depleted by leaks and by dissolving in the water. The manufacturer's instructions should be consulted for methods of starting, stopping and operating this pressure equipment.

3.4.4 METERING. Generally, meters are required at naval shore activities at all points of supply and treatment. These points include purchased water connections, surface supply points, individual wells and treatment facilities. Meters are also desirable at many other points in a water supply system to provide records of



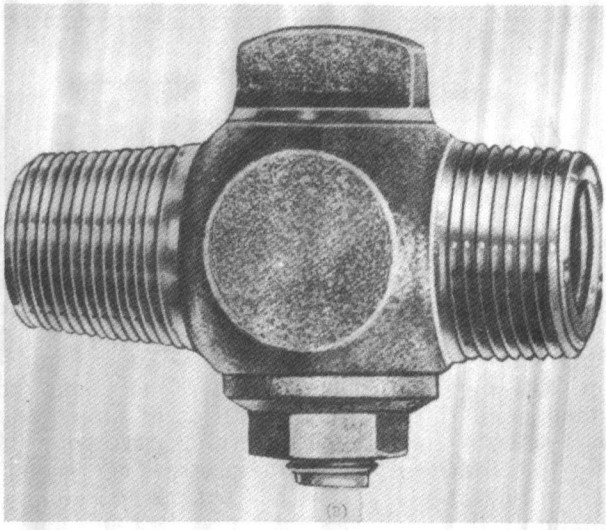
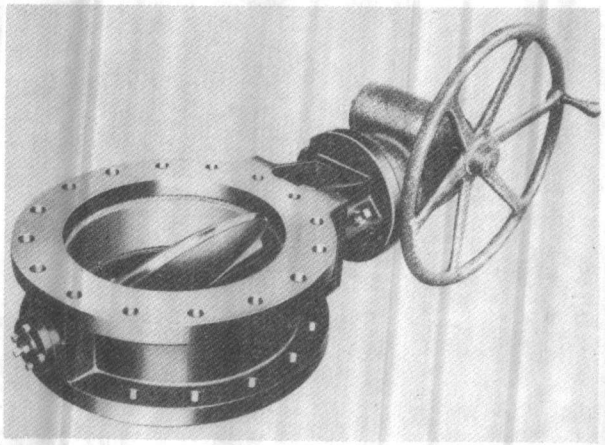
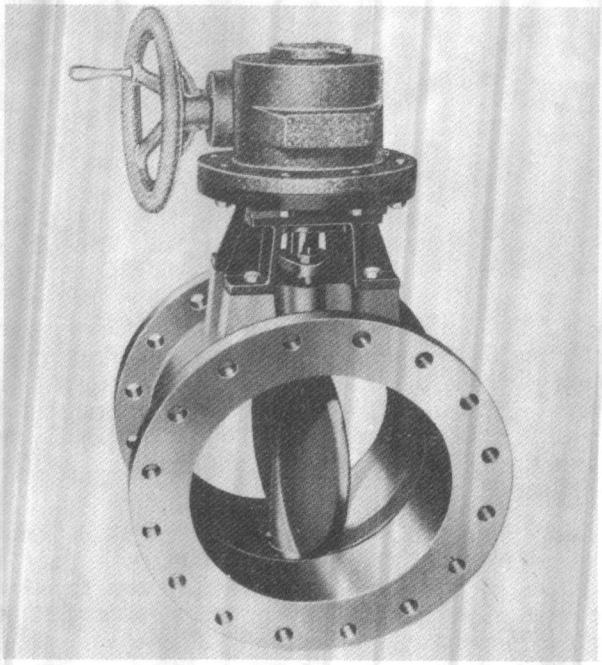


FIGURE 109

(A) Corporation Cock (Curb Stop)

(B) Corporation Stop





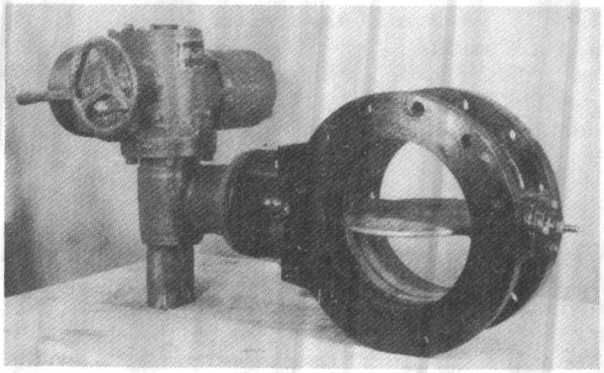


FIGURE 110

Manually-Operated Butterfly Valve

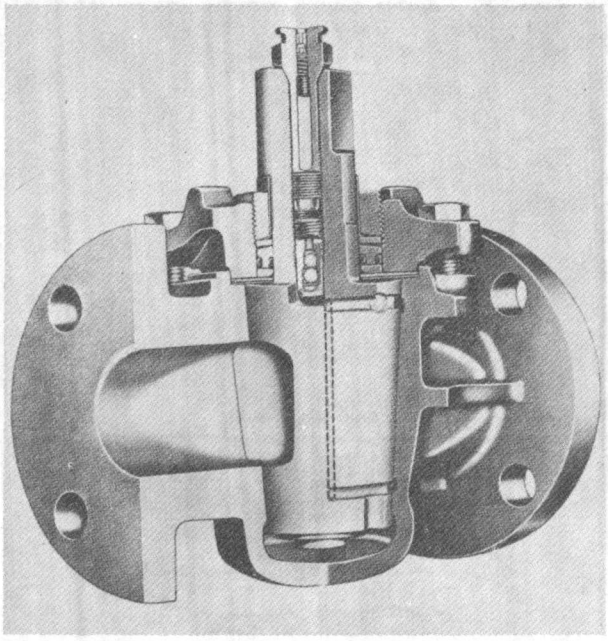


FIGURE 111

Plug Valve

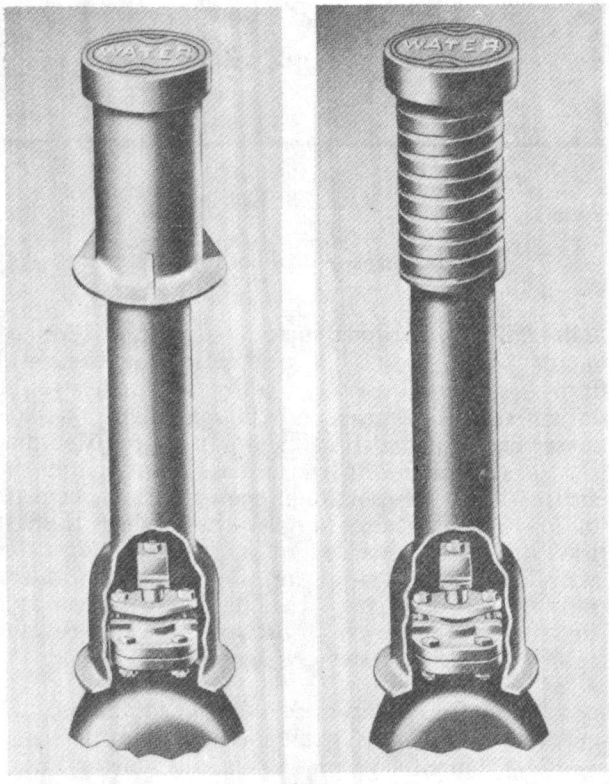


FIGURE 112

Valve Boxes

supply, production and consumption, and to furnish bases for determining cost and efficiencies of operation and the need for additions and extensions.

3.4.4.1 Meter Components. All meters have a primary element and a secondary element. The primary element is in contact with and is actuated by the water, while the secondary element translates the action of water flow on the primary element into terms of water quantity or rate of flow. The type of primary element determines the meter type.

3.4.4.1.1 Primary elements. Primary elements generally used in waterworks are of the head-area, velocity-head, velocity and volume classes.

(1) Head-Area Meters. This type includes weirs and flumes used in open channels, and orifices and nozzles with free discharge to the atmosphere.

(2) Velocity-Head Meters. This type includes the venturi tube, flow nozzle, orifice and pitot tube used in pipes carrying flow under pressure.

(3) Velocity Meters. This type includes propeller and turbine meters used principally in large-sized closed pipes. Portable propeller meters are also used to determine the velocity of flow in open streams and rivers.

(4) Volume Meters. The type principally used is the nutating or wobbling disk meter. Determination of water-level changes as water is discharged into or drawn from a tank of known size is also a form of volume metering.

3.4.4.1.2 Secondary elements. Secondary elements are actuated by movement or pressure changes of the primary element through either mechanical linkage, or by hydraulic, pneumatic or electrical impulses. They are classified below in accordance with the functions performed. Any combination of these functions may be provided in a single secondary device.

(1) Indicators. Indicating devices show only the momentary rate of flow. An example is a calibrated staff gage.

(2) Recorders. Recording devices show continuous rate-of-flow on a clock-driven chart.

(3) Totalizers and Integrators. Totalizing or integrating devices show total flow which has passed through the meter, as in a disk type house service meter.

(4) Control Meters. This type of meter controls the operation of other water system equipment, such as valves and chemical feeders.

3.4.4.2 Types of Meters

3.4.4.2.1 Disk meters. This type of meter (see fig. 119 is used chiefly for services supplied through pipes less than 1½ inches in diameter, although they are made in sizes up to 6 inches. This type contains a measuring chamber of definite content in which a disk is actuated by the

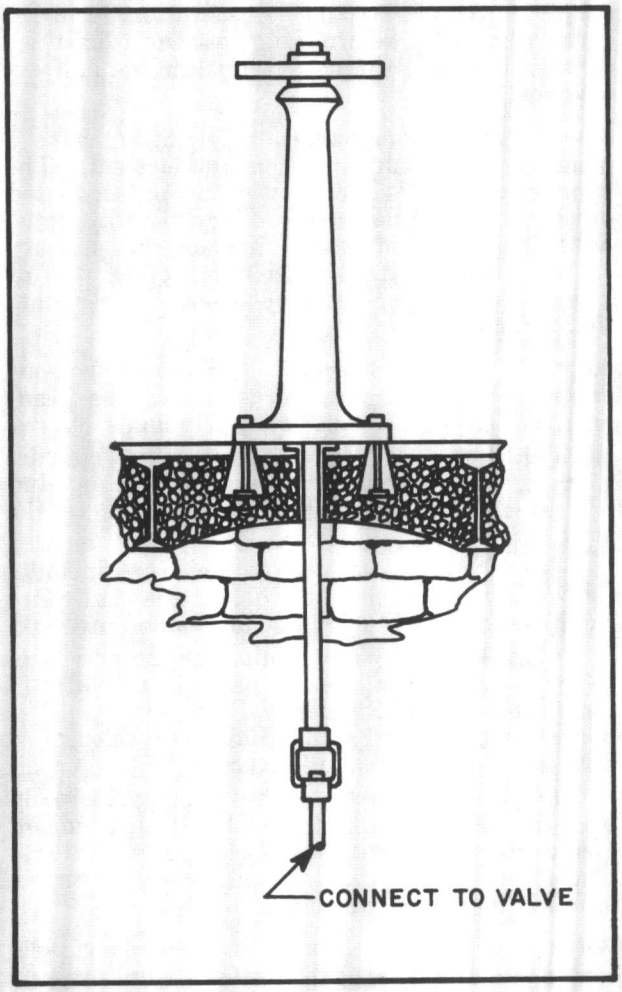


FIGURE 113

Floor Stand

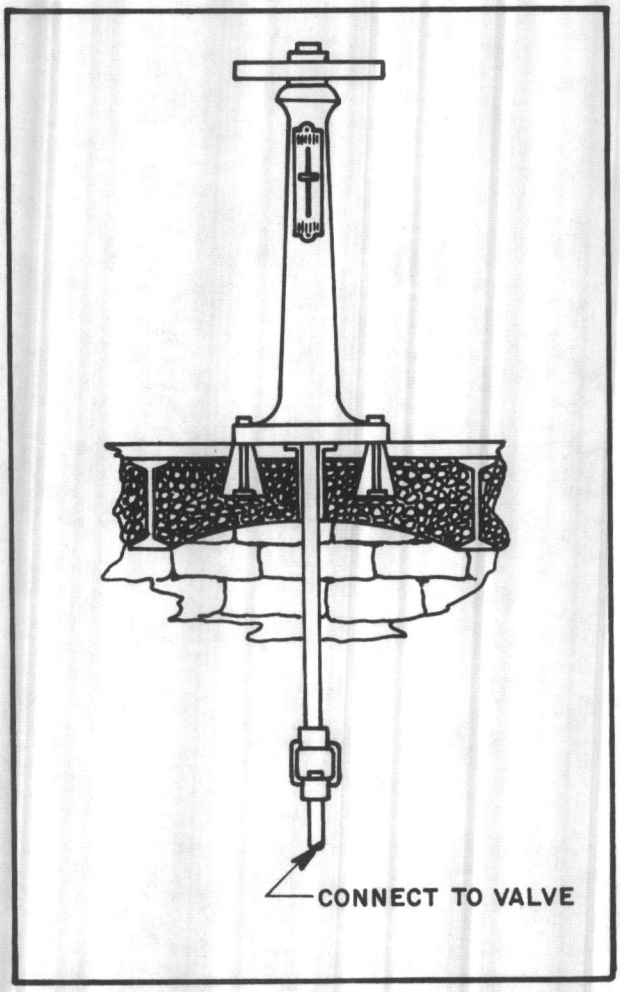


FIGURE 114

Floor Stand with Post Indicator

passage of water. Each cycle of motion of the disk marks the discharge of the contents of the measuring chamber. By means of gearing, the motion of the disk is translated into units of water volume on the register dial.

3.4.4.2.2 Turbine meters. This type of meter (see fig. 120) is used on large service lines and in metering supply sources. The turbine wheel revolves with a speed proportional to water velocity. These meters have a high flow capacity with low loss of head. They are not accurate in low velocity water flows.

3.4.4.2.3 Propeller meters. This type of meter (see fig. 121) is used for determining velocities of flow in a main or branch line. These meters use a propeller which is placed inside the pipe and is revolved by the water flowing past it. The rate of revolution of the propeller bears a definite relation to the velocity of flow.

3.4.4.2.4 Proportional meters. In this type of meter (see fig. 122) a proportion of the total flow is diverted through a bypass meter to be measured. The gears of the measuring bypass meter are adjusted to indicate on its register dial the total amount of water passing through the entire unit. Proportional meters are inaccurate on low flows and should not be used where there is likely to be low rate demand at times. It operates with a low loss of head and its capacity is limited only by the pipe size. It is principally used as a fire-line meter, or in other settings where sustained high rate flows are demanded.

3.4.4.2.5 Compound meters. The compound meter (see Figure 123), as its name implies, is a combination of two meters—a disk meter and a turbine meter. It is designed to make use of the features of each in situations where either one nor the other will make an accurate measurement of the full range of flows demanded. It is as-

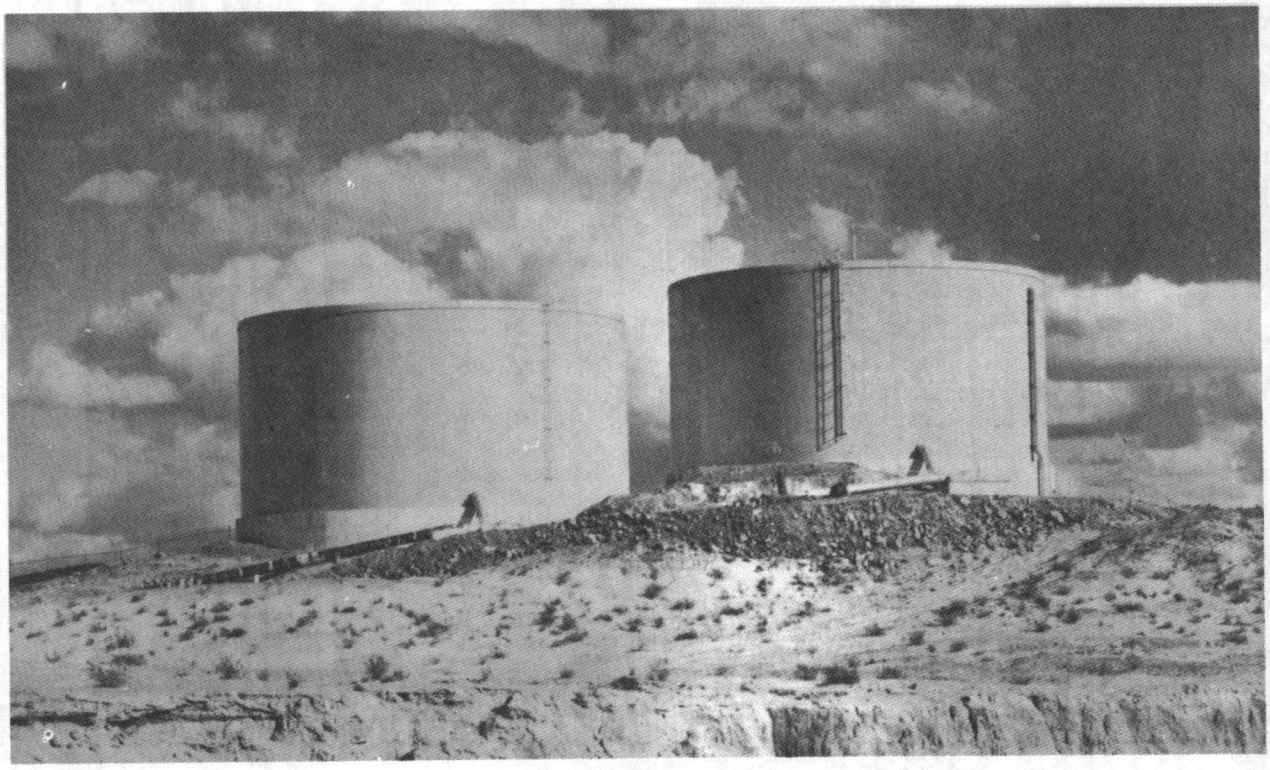
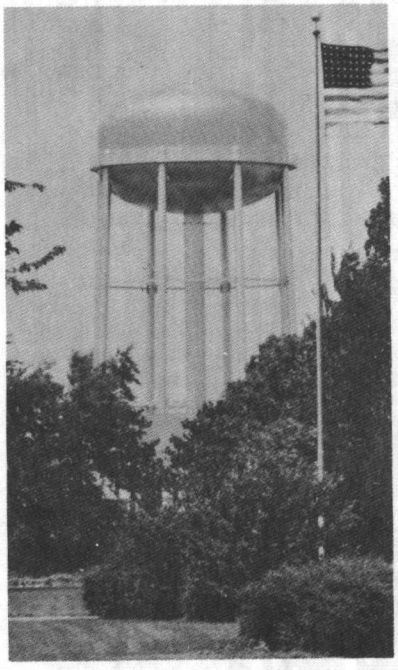
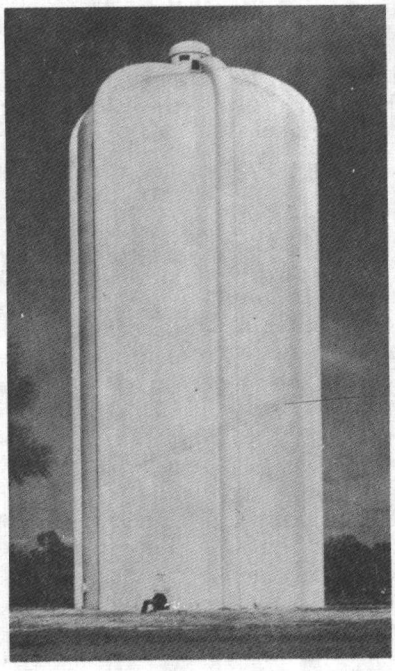


FIGURE 115

Ground Storage Reservoir





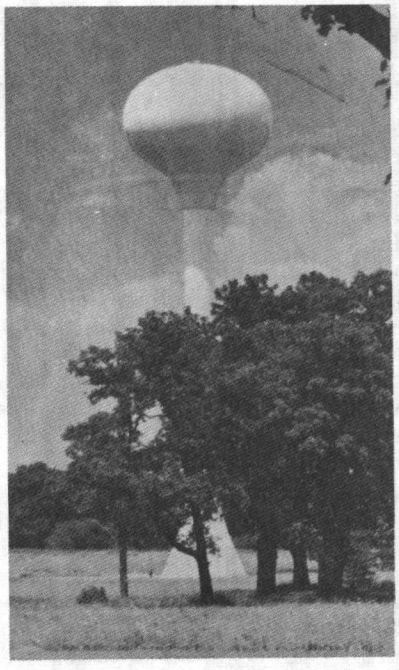


FIGURE 116

Three Types of Elevated Storage Tanks

sembled in such a fashion that small rates of flow are registered only by the small displacement (disk) meter. The small flows are prevented from passing through the turbine meter by a check valve which is weighted to keep its seat until a rate of flow is reached that is above the low rate at which the turbine meter is inaccurate, but below the maximum capacity of the bypass meter. When that rate of flow, predetermined by the manufacturer, is reached, the loss of head across the meter is sufficient to cause the check valve to open, admitting flow through the turbine meter.

3.4.4.2.6 Accessories. Remote indicating, recording and controlling accessory equipment is frequently installed for use with the above meters. This equipment is discussed in Chapter 3, Section 6. For operating instructions for specific equipment, consult the manufacturer's instructions.

3.4.4.2.7 How to read meters. Water is measured in terms of rate-of-flow (volume passing in a unit of time), or total volume. Units and equivalent usually used are.

Unit	*Equivalent*
Cubic feet per second (c.f.s.)	448.83 gallons per minute (g.p.m.)
c.f.s.	646,315 gallons per day (g.p.d.)
g.p.m.	0.00223 c.f.s.
g.p.m.	1440 g.p.d.
Million gallons per day (m.g.d.).	1.547 c.f.s.
m.g.d.	694.4 g.p.m.
cu. ft.	7.48 gal.

In reading a meter, the operator should first determine whether it is measuring the water flow in cubic feet or in gallons. There are two general types of meter dials—the straight-reading type and the circular-reading type.

(1) Straight-Reading Dial. The straight-reading dial (see Figure 124) may be read in the same way as mileage in an automobile. Thus, on the dials illustrated below, the totals of 41,873 cubic feet at the left and of 968,720 gallons on the right, are directly recorded. When the meter register has one or more fixed zeros, as on the dial at the right, always be sure to read these fixed zeros in addition to the other numerals.

(2) Circular-Reading Dial. In the circular-reading dial (see fig. 125), when a hand on any scale is between two numbers, the lower number is read. If the hand seems exactly on any figure, check the hand on the next lower scale. If that is on the "1" side of zero, read the figure on which the hand lies; otherwise read the next lower figure. On the circular-reading dials shown here, the totals are the same as those on the straight-reading register. To read the cubic feet register, at the left, begin with the "100,000" circle and read clockwise, the scales registering 4,1,8,7, and 3, respectively. To read the gallon register, at the right, begin with the "1,000,000" circle and read clockwise to the "100" circle, the scales registering 9,6,8,7, and 2, respectively. Then read the "10" gallon register as zero, regardless of its position, to make a total of 986,720 gallon.

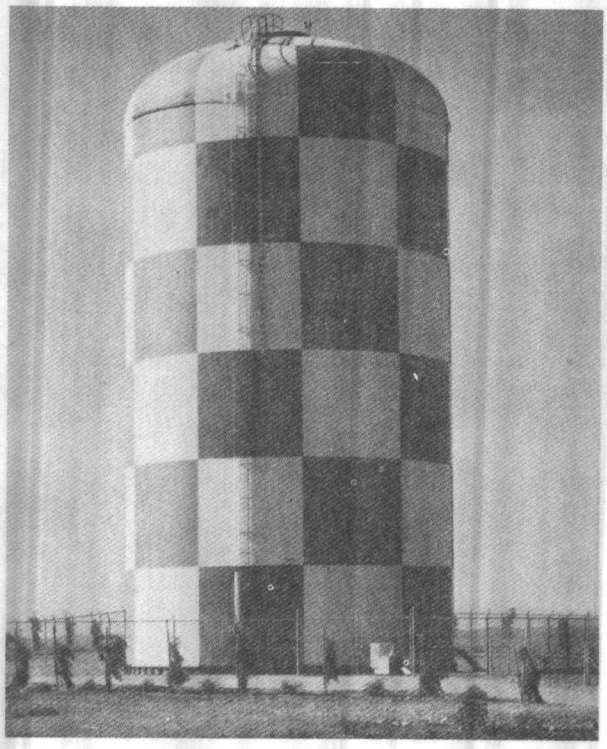


FIGURE 117

Standpipe

(3) Obtaining Current Reading. As the registers are never reset while the meters are in service, the amounts recorded for any given period must be determined by subtraction. To obtain a current reading, simply subtract the total dial reading from the last recorded reading. It must be remembered that the maximum amount that can be indicated on the usual line meter before it turns to all zeros and starts all over again, is 99,999 cubic feet, or 999,999 gallons. Thus, to obtain a current measurement when the reading is lower than the last previous one, add 100,000 to the present reading on a cubic feet meter, or 1,000,000 to the present reading on a gallon meter. The small denomination scale, giving fractions of one cubic foot or ten gallons, is disregarded in the regular reading. It is used for testing purposes only.

3.4.4.3 Venturis, Flow Nozzles and Orifices. Venturis, flow nozzles and orifice meters consist of a restricted area in a pipe, and taps upstream from the restriction and at the restriction to

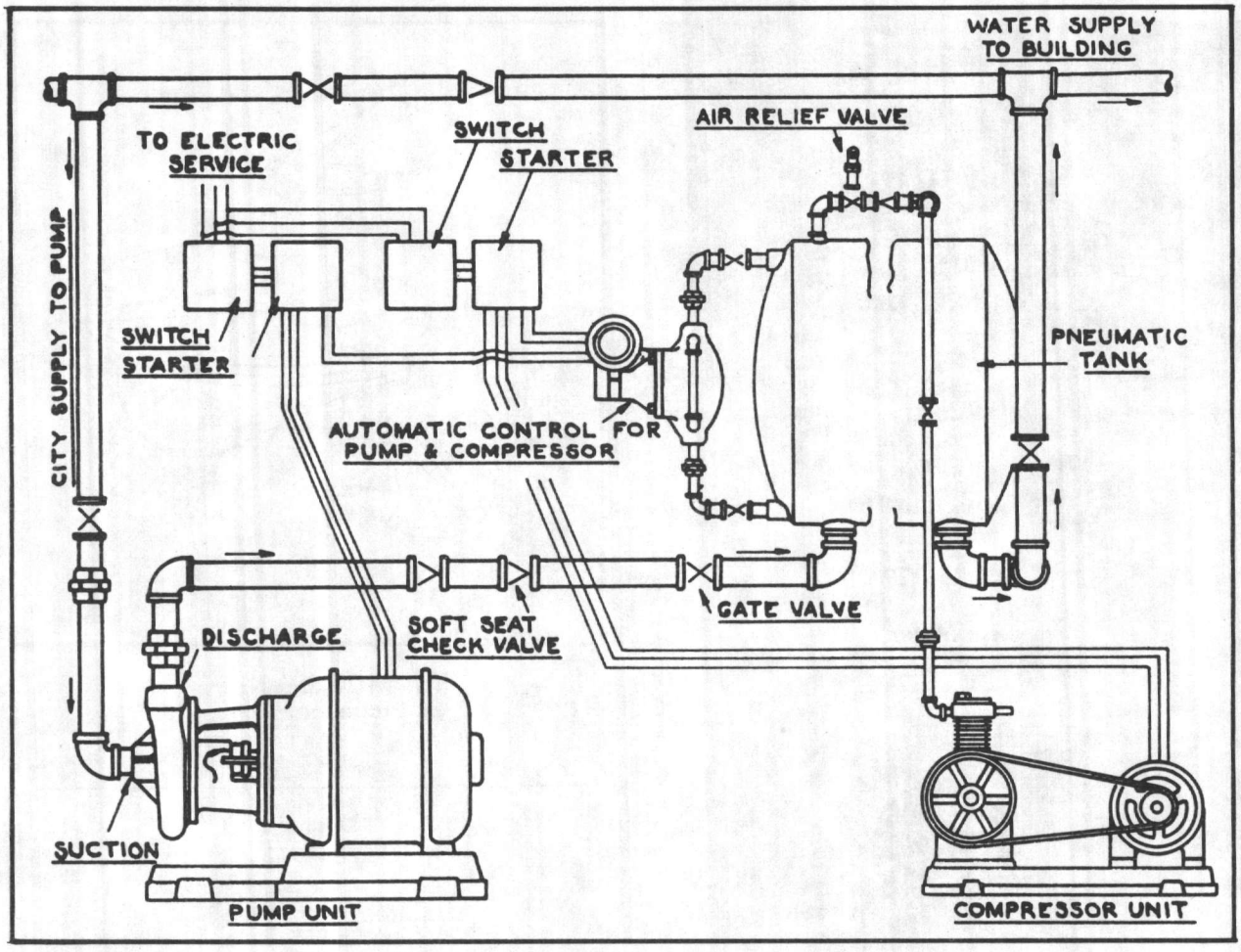


FIGURE 118

Pneumatic Storage Tank

determine the pressure at each point. As water flows through a restriction in a pipe, velocity increases in direct proportion to the relative decrease in cross-sectional area. The energy used in speeding up the flow causes a corresponding drop in pressure at the point of restriction. Thus, the differential pressure between the two taps is a measure of increase in velocity head. This increases as rate of flow increases. Changes in pressure head through these devices are shown in figures 126 and 127.

3.4.4.4 Weirs and Related Installations. Weirs are used to measure flow in channels or streams. A weir consists of a bulkhead or dam across the channel or stream, and a sharp level crest or specially shaped notch mounted on the crest. The volume or flow over the weir varies with the length of the crest or shape and size of the notch, and with the elevation of the water surface above the crest or the bottom of the notch. Since both the head and the cross-sectional area of flow over the weir vary with the flow, it is a head-area meter. Weirs are easily built and give fairly accurate measurement if properly installed. The more common types of weirs are the rectangular and V-Notch weir.

3.4.4.4.1 Rectangular weir. Rectangular weirs are suitable for flows over 150 to 200 g.p.m. The crest should be a sharply beveled metal plate. Figure 128 shows the minimum setting of the top of the crest above the channel, setting of the sides of the weir, and the location of the gage, in terms of maximum head (H), which should be at least 2.5 inches. Accuracy is greatly reduced if these dimensions are less than indicated, and if the length (L) is less than three times H.

(1) Francis Formula. The Francis formula for discharge of a rectangular weir is.
Where

$Q = 3.33\ LH^{3/2}$
Q = Discharge in c.f.s.
L = Length in feet.
H = Head in feet.

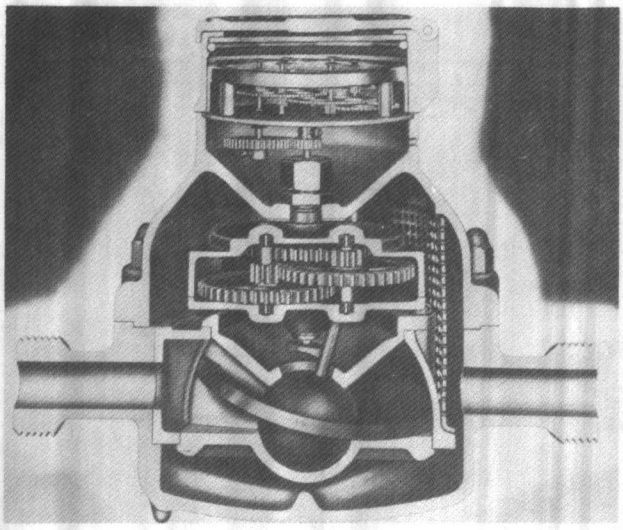


FIGURE 119

Disk Meter

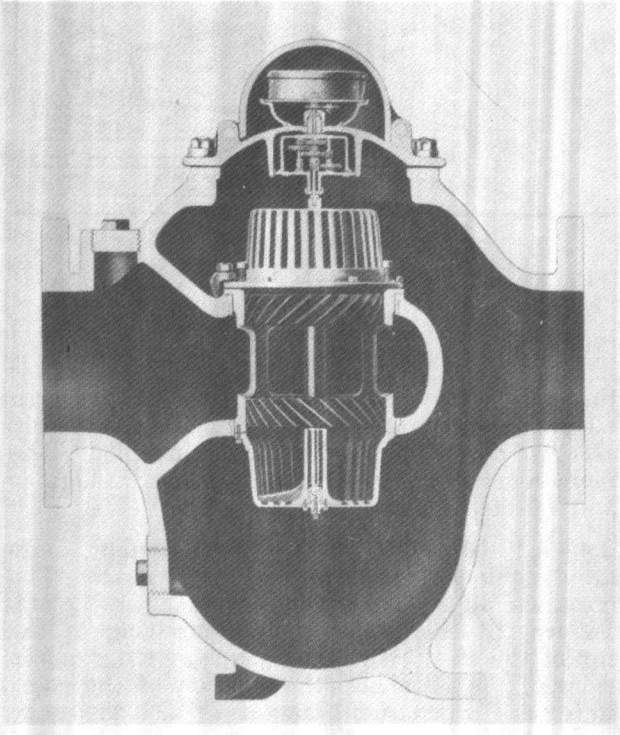


FIGURE 120

Turbine Meter

FIGURE 121
Propeller Meter

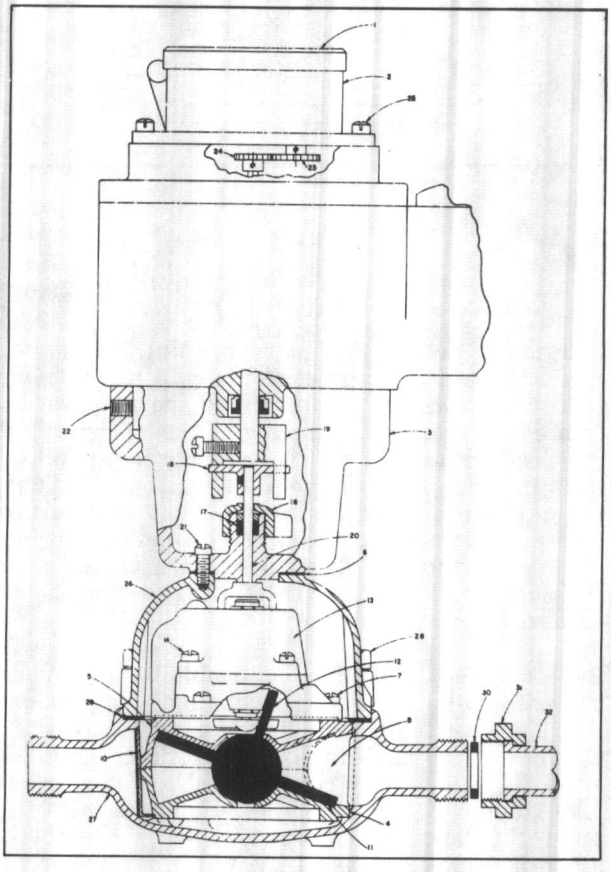


FIGURE 122
Proportional Meter

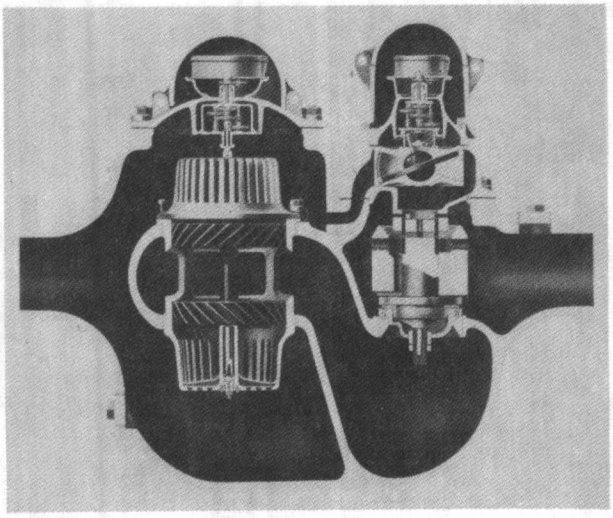


FIGURE 123

Compound Meter

(2) End Contractions. This basic formula does not provide for the velocity of approach nor for the end contraction caused by the sides of the weir. However, it may be used where the weir extends the full width of the channel (surpressed weir), or where L is greater than 10 H. Table 8 shows discharge in g.p.m. for varying heads and weir lengths, including the correction for end contractions, based on the following formula.

$$Q = H^{3/2}\,(L - 0.2H)$$

Actual flow, if the head is under 2½ inches, may vary considerably from the values shown in Table 8.

3.4.4.4.2 90° V-Notch weir. The 90° V-Notch weir (see Figure 129) is preferred for flow less than 1000 g.p.m. and is particularly suitable for very low flows. Table 9 shows discharge at various heads based on the King Formula.

$$Q = 2.52\ H^{2.47}$$

A large scale curve can be drawn from table 9, or the gage can be calibrated for direct reading of flow.

3.4.4.4.3 Parshall flume. A special type of measuring flume developed for determining the discharge in open channels is the Parshall flume (see fig. 130). This flume has an open and constricted channel in which the difference in liquid elevation above and below the contraction can be accurately translated into rate of flow. The surface rise is usually indicated and recorded by the same type of equipment as is used with weirs. The Parshall flume has several advantages over weirs. It is self cleaning; it can handle a wide variation of flow; it does not require as great a head loss; and, it is particularly useful where the available head is limited. The tabulations

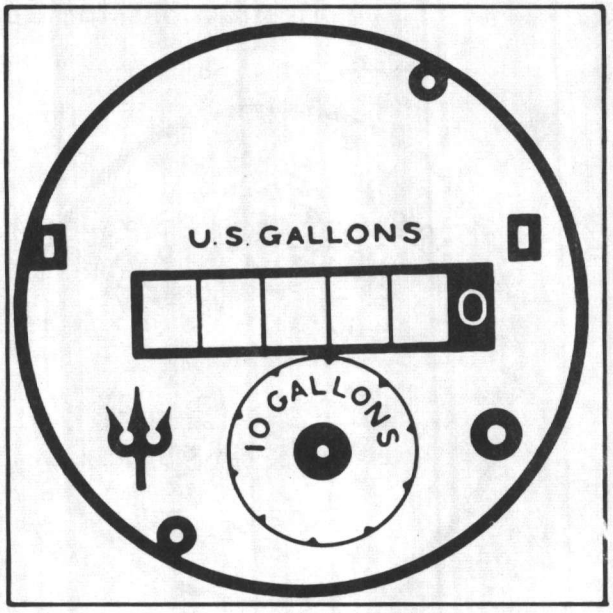


FIGURE 124

Straight-Reading Meter Dial

shown in figure 130 give the various dimensions required of Parshall flumes. The discharges for the various throat widths are given in Table 10.

3.4.4.5 Temporary Metering Methods. It is often necessary to determine the capacity of pumps which are not equipped with meters. In these cases, the expedients described below can be used. During metering by these methods, normal pressure must be maintained on the pump, by throttling if necessary.

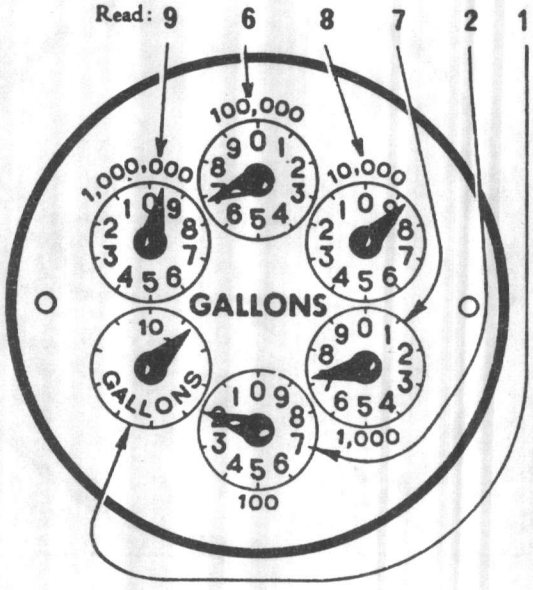
3.4.4.5.1 Displacement. If an elevated or ground storage tank (whose volume is known or can be determined) is available, and can be taken out of service, the simplest method is to pump to the storage tanks, measuring the rise in elevation for a given period of time. This rise can be converted into g.p.m. by the following simple calculation.

$$\text{g.p.m.} = \frac{\text{rise in inches} \times \text{gallons per inch}}{\text{minutes}}$$

3.4.4.5.2 Pitot tube. The pitot tube is a set of two tubes which measure directly the so called velocity head causing flow past a pipe of given section pipe. Two pressure readings are taken, as illustrated in figure 131, one from a tap flush with the wall, and the other from a connection pointing upstream to catch the impact of the current. The flush tap indicates static head, and the bent tube impact head. The differential between these two is the velocity head of the water flow. Thus, if D is the diameter of the pipe in inches, and h the differential or velocity head the formula is:

$$Q\ (\text{g.p.m.}) = 16.26D^2\sqrt{h\ \text{feet}}$$

Instructions for Reading Water Meters



6-Spindle Round-Reading Register

500 1054

Where a hand or a pointer is between two figures, the lesser of the two must always be taken.

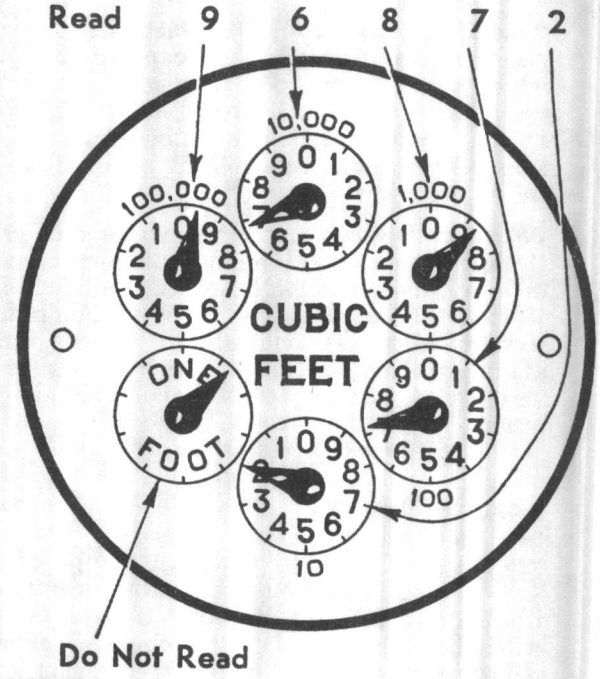
If there is any doubt as to the correct reading of any indice, refer back to the one next lower.

For example: In the illustrations, the hand in the 1,000,000 indice points between the 9 and the 0, hence the 1,000,000 indice must be read as indicating 9. In the 100,000 indice, the hand seems to indicate 7 exactly, while by referring back to the 10,000 indice next lower, we find its hand has not reached the 0; therefore, the 100,000 indice must be read as indicating 6 instead of 7. The entire reading of the registers, as shown, would be 968,721 gallons.

FORM 525G

(A)

Instructions for Reading Water Meters



500 554

Where a hand or a pointer is between two figures, the lesser of the two must always be taken.

If there is any doubt as to the correct reading of any indice, refer back to the one next lower.

For example: In the illustration, the hand in the 100,000 indice points between the 9 and the 0, hence the 100,000 indice must be read as indicating 9. In the 10,000 indice, the hand seems to indicate 7 exactly, while by referring back to the 1,000 indice next lower, we find its hand has not reached the 0; therefore, the 10,000 indice must be read as indicating 6 instead of 7. The entire reading of the registers, as shown, would be 96,872 cubic feet.

FORM 525CF

(B)

FIGURE 125

Circular-Reading Meter Dial

(A) Reading in Gallons
(B) Reading in Cubic Feet

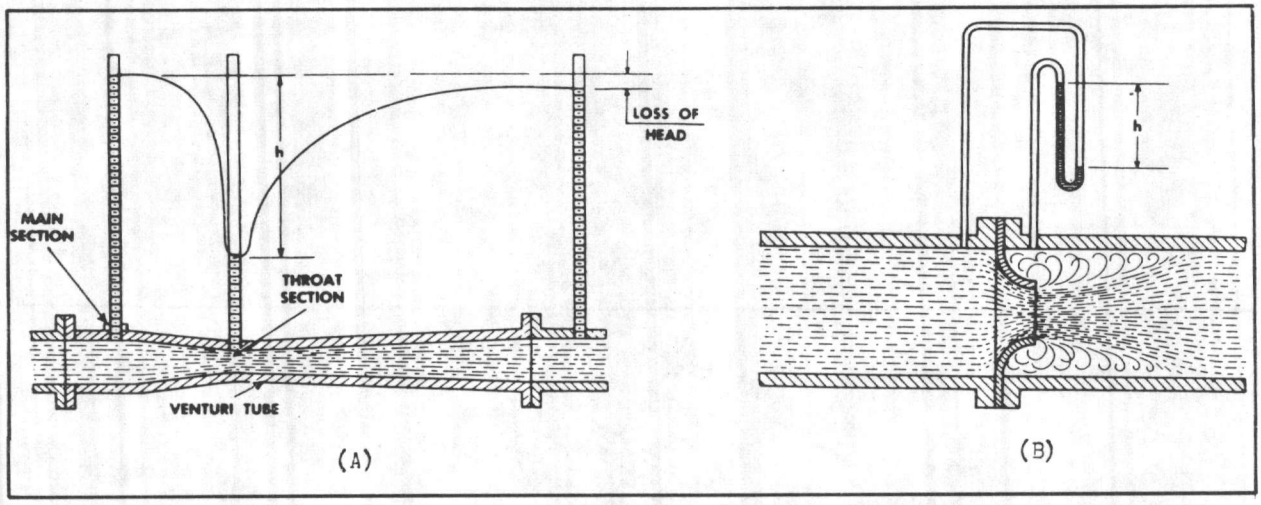


FIGURE 126

Diagrams Showing Changes in Pressure and Permanent Head Loss in

(A) Venturi Tube (B) Flow Nozzle

PIPE SIZE (INCHES)	O D STANDARD (INCHES)	O D EXTRA HEAVY (INCHES)	THICKNESS T (INCHES)
2	4	4¼	3 32
2½	4¾	5	3 32
3	5½	5¾	3 32
4	6¾	7	3 32
5	7⅝	8⅝	3 32
6	8⅝	9¾	3 32
8	10⅞	12	⅛
10	13¼	14½	⅛
12	16	16½	3 16
14	17⅜	19	3 16
16	20½	21½	3 16
18	21½	23¾	3 16
20	23¾	25⅝	¼
24	28½	30⅜	¼

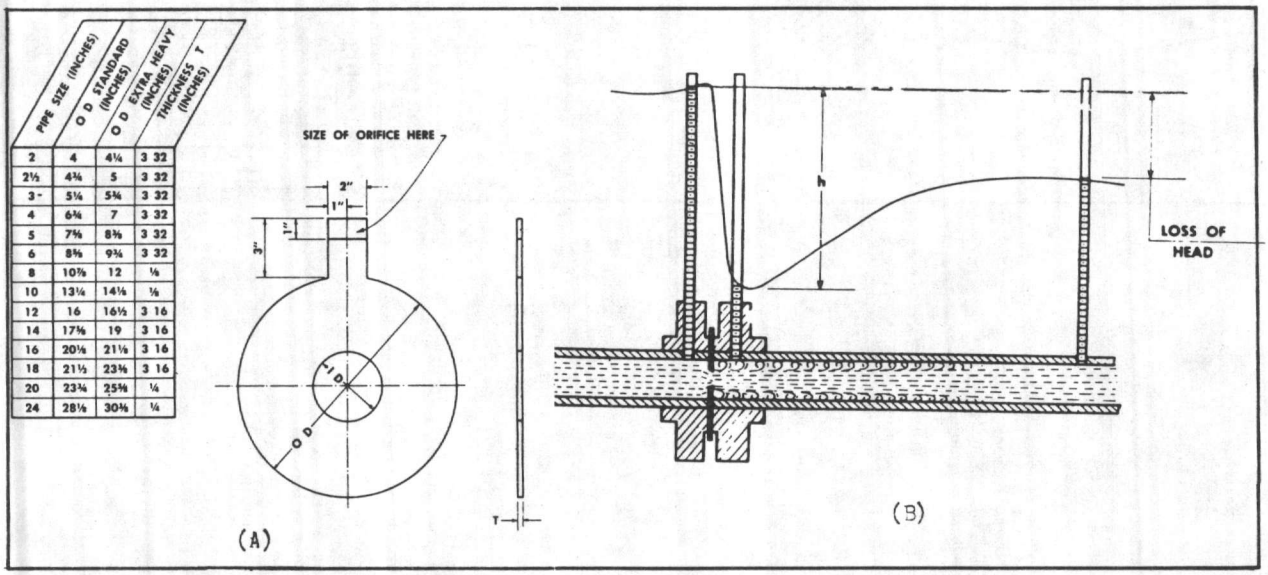


FIGURE 127

Orifice Plate Diagrams

(A) Dimensions

(B) Pressure Changes and Permanent Head Loss

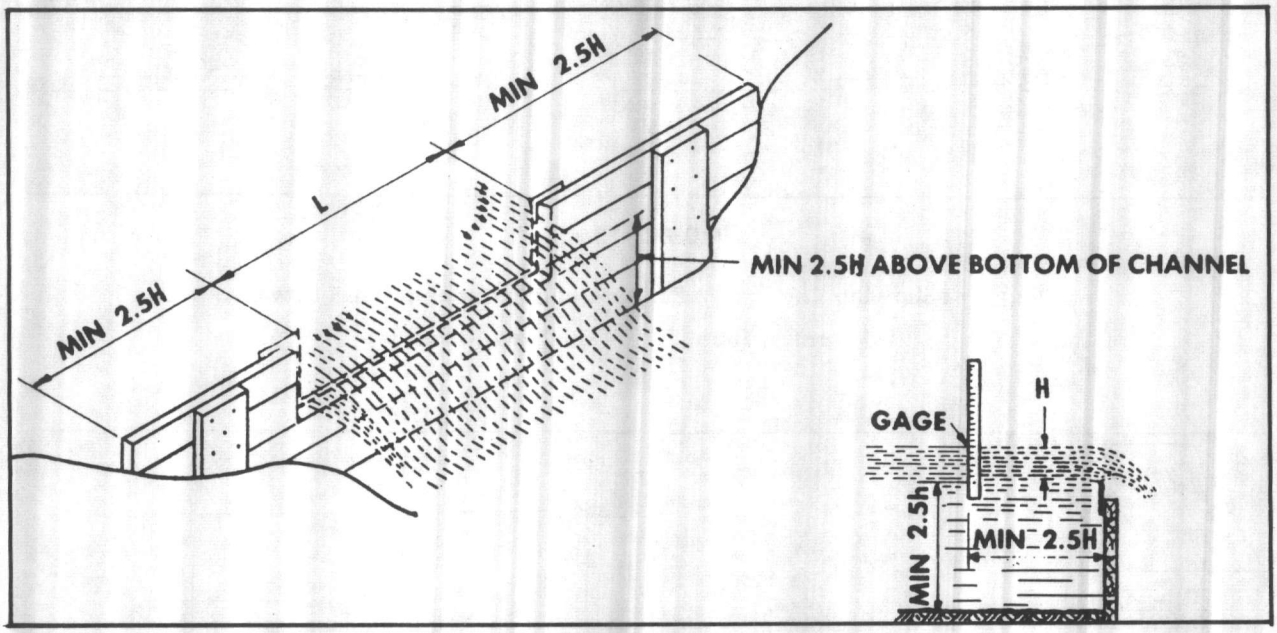


FIGURE 128

Rectangular Weir

TABLE 8 (Sheet 1 of 3)

Discharge in Gallons per Minute for Rectangular Weirs with Complete End Contraction

Head	Length of weir						
Inches	Feet	1 foot	2 feet	3 feet	4 feet	5 feet	Addition for 1 foot increase in length
1	0.083	35.40	71.5	107.5	143.50	179.8	36.04
1 1/16	.088	38.80	78.3	118.0	159.50	197.0	39.50
1 1/8	.094	42.67	85.0	128.2	171.22	214.5	43.02
1 3/16	.099	45.90	92.2	139.0	185.85	232.5	46.85
1 1/4	.104	49.50	99.8	150.4	200.85	250.4	50.45
1 5/16	.109	53.00	107.0	161.5	215.50	270.0	54.00
1 3/8	.115	56.75	114.7	173.0	231.00	289.5	58.00
1 7/16	.120	60.70	123.0	185.0	247.10	309.5	62.10
1 1/2	.125	64.90	131.0	197.0	262.15	329.5	65.15
1 9/16	.130	68.50	139.0	209.0	279.10	350.0	70.10
1 5/8	.135	72.50	147.0	222.0	297.00	371.5	74.70
1 11/16	.140	77.00	156.0	235.0	314.15	392.6	79.15
1 3/4	.146	81.00	164.0	248.0	331.20	415.0	83.20
1 13/16	.151	85.40	173.0	262.0	349.75	436.5	87.75
1 7/8	.156	89.50	182.0	275.0	367.70	460.0	92.70
1 15/16	.161	94.00	191.0	289.0	386.20	480.9	97.20
2	.167	98.90	200.5	302.0	404.00	506.0	102.00
2 1/16	.172	103.00	210.0	316.0	422.80	530.0	106.80
2 1/8	.177	107.80	219.9	332.0	443.70	555.0	111.70
2 3/16	.182	112.40	229.0	345.0	461.60	579.0	116.60
2 1/4	.187	117.00	239.0	361.0	482.30	605.0	121.30
2 5/16	.193	122.50	249.0	376.0	503.00	629.0	127.00
2 3/8	.198	127.00	259.0	390.5	523.00	655.0	132.00
2 7/16	.203	132.00	269.0	406.0	543.00	680.0	137.20
2 1/2	.208	137.00	279.0	422.0	564.90	706.0	142.90
2 9/16	.213	142.00	289.0	438.0	586.00	732.0	148.00
2 5/8	.219	147.10	300.0	453.0	607.00	760.0	153.50
2 11/16	.224	151.40	310.5	470.0	629.00	785.0	159.00
2 3/4	.229	157.00	321.5	485.0	649.20	815.0	164.20
2 13/16	.234	162.00	332.0	501.5	672.00	832.5	170.15
2 7/8	.240	168.00	343.0	520.0	695.30	870.0	175.30
2 15/16	.245	173.00	354.0	535.0	716.40	898.0	181.40
3	.250	178.00	366.0	552.0	739.30	926.0	187.30
3 1/16	.255	183.00	377.0	569.0	763.00	956.0	193.50
3 1/8	.260	189.10	388.0	588.0	787.20	986.0	199.20
3 3/16	.266	194.00	400.0	605.0	811.00	1,015.0	205.50
3 1/4	.271	199.00	410.5	624.0	835.00	1,047.0	211.00
3 5/16	.276	205.60	422.0	640.0	858.00	1,076.0	217.60
3 3/8	.281	210.80	435.0	659.0	883.00	1,105.0	224.00
3 7/16	.286	216.50	446.0	676.0	906.00	1,138.0	229.80
3 1/2	.292	222.80	458.0	695.0	931.15	1,167.0	236.15
3 9/16	.297	228.00	470.0	714.0	956.20	1,200.0	242.20
3 5/8	.302	234.00	483.0	731.0	980.40	1,230.0	249.40
3 11/16	.307	240.00	495.0	750.0	1,005.90	1,260.0	255.90
3 3/4	.312	245.00	506.0	769.0	1,031.20	1,292.0	262.20
3 13/16	.318	251.00	520.0	789.0	1,058.00	1,328.0	268.60
3 7/8	.323	256.50	533.0	808.0	1,089.00	1,355.0	274.50
3 15/16	.328	263.00	545.0	825.0	1,107.00	1,390.0	282.00
4	.333	269.00	556.0	846.0	1,134.00	1,424.0	288.00
4 1/16	.338	275.60	570.0	866.0	1,162.00	1,454.0	296.00
4 1/8	.344	281.60	584.0	885.0	1,186.90	1,490.0	301.90
4 3/16	.349	287.60	596.0	907.5	1,215.00	1,518.0	309.00

TABLE 8 (Sheet 2 of 3)

Discharge in Gallons per Minute for Rectangular Weirs with Complete End Contraction

Head	Length of weir						
Inches	Feet	1 foot	2 feet	3 feet	4 feet	5 feet	Addition for 1 foot increase in length
4¼	0.354	293.60	610.0	925.0	1,241.00	1,553.0	316.00
4⅜	.359	300.00	623.0	945.0	1,268.00	1,590.0	323.00
4⅜	.365	306.00	636.0	966.0	1,297.00	1,628.0	330.50
4⅜	.370	312.00	650.0	986.0	1,323.00	1,660.0	336.80
4½	.375	318.00	663.0	1,006.0	1,350.00	1,696.0	344.00
4⅝	.380	325.00	676.0	1,030.0	1,382.00	1,730.0	351.50
4⅝	.385	331.00	690.0	1,050.0	1,408.00	1,768.0	358.00
4⅝	.390	336.60	704.0	1,069.0	1,435.00	1,801.0	366.00
4¾	.396	344.00	717.5	1,091.0	1,465.00	1,835.0	374.00
4⅞	.401	350.00	731.0	1,111.0	1,492.00	1,875.0	380.90
4⅞	.406	356.60	744.5	1,131.0	1,519.00	1,908.0	388.20
4⅞	.411	363.70	759.0	1,156.0	1,551.90	1,948.0	395.90
5	.417	370.00	772.0	1,175.0	1,579.30	1,985.0	404.30
5⅛	.422	376.50	785.0	1,200.0	1,611.50	2,018.0	410.50
5⅛	.427	382.50	800.0	1,220.0	1,639.00	2,056.0	419.40
5⅜	.432	388.00	815.0	1,239.0	1,665.00	2,094.0	426.00
5¼	.437	395.50	830.0	1,262.0	1,696.40	2,130.0	434.40
5⅝	.443	401.00	844.0	1,285.0	1,726.00	2,168.0	441.00
5⅜	.448	409.00	857.0	1,310.0	1,760.00	2,208.0	450.00
5⅞	.453	415.00	871.0	1,330.0	1,787.50	2,243.0	457.50
5½	.458	421.60	887.0	1,352.0	1,817.50	2,282.0	465.50
5⅝	.463	428.50	903.0	1,376.0	1,846.90	2,321.0	470.90
5⅝	.469	435.50	915.0	1,395.0	1,875.00	2,358.0	480.00
5⅞	.474	442.50	932.5	1,419.0	1,907.00	2,400.0	487.60
5¾	.479	449.00	947.5	1,442.0	1,937.00	2,440.0	495.00
5⅞	.484	456.20	960.0	1,465.0	1,968.50	2,480.0	503.50
5⅞	.490	462.60	977.0	1,490.0	2,001.00	2,515.0	511.00
5⅞	.495	470.00	993.0	1,515.0	2,034.00	2,559.0	519.60
6	.500	476.50	1,005.0	1,535.0	2,063.00	2,600.0	528.00
6⅛	.505	----------	1,021.0	1,561.0	2,097.00	2,640.0	536.00
6⅛	.510	----------	1,039.0	1,582.0	2,125.00	2,675.0	543.00
6⅜	.515	----------	1,051.0	1,609.0	2,163.00	2,716.0	554.00
6¼	.521	----------	1,068.0	1,632.0	2,192.00	2,760.0	560.00
6⅝	.526	----------	1,083.0	1,655.0	2,225.00	2,801.0	570.00
6⅜	.531	----------	1,100.0	1,679.0	2,254.00	2,844.0	575.00
6⅞	.536	----------	1,112.0	1,704.0	2,290.00	2,881.0	586.00
6½	.542	----------	1,130.0	1,742.0	2,338.00	2,920.0	596.00
6⅝	.547	----------	1,147.0	1,760.0	2,362.00	2,962.0	602.30
6⅝	.552	----------	1,161.0	1,779.0	2,392.80	3,005.0	613.80
6⅞	.557	----------	1,178.0	1,803.0	2,422.00	3,047.0	617.80
6¾	.563	----------	1,193.0	1,826.0	2,455.90	3,094.0	629.90
6⅞	.568	----------	1,210.0	1,853.0	2,493.00	3,139.0	640.00
6⅞	.573	----------	1,226.0	1,878.0	2,523.50	3,180.0	645.50
6⅞	.578	----------	1,240.0	1,903.0	2,559.00	3,219.0	656.00
7	.583	----------	1,258.0	1,928.0	2,596.00	3,260.0	668.00
7⅛	.589	----------	1,272.0	1,949.0	2,621.50	3,300.0	672.50
7⅛	.594	----------	1,290.0	1,976.0	2,658.00	3,342.0	682.50
7⅜	.599	----------	1,309.0	2,000.0	2,695.00	3,384.0	695.00
7¼	.604	----------	1,322.0	2,029.0	2,730.50	3,436.0	701.05
7⅝	.609	----------	1,339.0	2,058.0	2,768.00	3,480.0	710.00
7⅜	.615	----------	1,356.0	2,080.0	2,799.60	3,522.0	719.60
7⅞	.620	----------	1,371.0	2,105.0	2,834.00	3,570.0	729.00

TABLE 8 (Sheet 3 of 3)

Discharge in Gallons per Minute for Rectangular Weirs with Complete End Contraction

Head	Length of weir						
Inches	Feet	1 foot	2 feet	3 feet	4 feet	5 feet	Addition for 1 foot increase in length
7½	0.625	----------	1,390.0	2,130.0	2,866.00	3,609.0	736.00
7 9/16	.630	----------	1,408.0	2,155.0	2,901.00	3,658.0	746.00
7 5/8	.635	----------	1,423.0	2,179.0	2,934.00	3,700.0	755.00
7 11/16	.641	----------	1,439.0	2,212.0	2,976.00	3,745.0	764.00
7¾	.646	----------	1,458.0	2,238.0	3,012.00	3,785.0	774.00
7 13/16	.651	----------	1,471.0	2,260.0	3,042.00	3,820.0	782.00
7 7/8	.656	----------	1,490.0	2,286.0	3,078.00	3,860.0	792.00
7 15/16	.661	----------	1,506.0	2,310.0	3,113.00	3,903.0	803.00
8	.667	----------	1,525.0	2,338.0	3,151.50	3,956.0	813.50
8 1/16	.672	----------	1,541.0	2,365.0	3,186.50	4,000.0	821.50
8 1/8	.677	----------	1,556.0	2,396.0	3,227.00	4,045.0	831.00
8 3/16	.682	----------	1,572.0	2,419.0	3,259.00	4,090.0	840.00
8¼	.688	----------	1,592.0	2,442.0	3,292.00	4,140.0	850.00
8 5/16	.693	----------	1,601.0	2,460.0	3,320.00	4,178.0	860.00
8 3/8	.698	----------	1,619.0	2,493.0	3,364.00	4,227.0	871.00
8 7/16	.703	----------	1,636.0	2,516.0	3,395.60	4,272.0	879.60
8½	.708	----------	1,652.0	2,540.0	3,430.00	4,312.0	889.70
8 9/16	.714	----------	1,670.0	2,570.0	3,469.00	4,362.0	899.00
8 5/8	.719	----------	1,689.0	2,595.0	3,504.00	4,415.0	909.00
8 11/16	.724	----------	1,706.0	2,626.0	3,545.00	4,460.0	919.00
8¾	.729	----------	1,723.0	2,656.0	3,585.00	4,511.0	929.00
8 13/16	.734	----------	1,741.0	2,680.0	3,620.00	4,552.0	940.00
8 7/8	.740	----------	1,760.0	2,705.0	3,654.00	4,600.0	949.00
8 15/16	.745	----------	1,777.0	2,739.0	3,698.00	4,648.0	959.00
9	.750	----------	1,791.0	2,765.0	3,734.50	4,699.0	969.50
9 1/16	.755	----------	1,810.0	2,792.0	3,771.00	4,749.0	979.00
9 1/8	.760	----------	1,830.0	2,816.0	3,811.00	4,799.0	995.00
9 3/16	.765	----------	1,848.0	2,844.0	3,843.00	4,849.0	999.00
9¼	.771	----------	1,866.0	2,876.0	3,887.00	4,899.0	1,011.00
9 5/16	.776	----------	1,880.0	2,901.0	3,921.00	4,949.0	1,020.00
9 3/8	.781	----------	1,898.0	2,927.0	3,958.00	4,999.0	1,031.00
9 7/16	.786	----------	1,918.0	2,960.0	4,001.00	5,049.0	1,041.00
9½	.792	----------	1,939.0	2,985.0	4,036.00	5,098.0	1,051.00
9 9/16	.797	----------	1,955.0	3,017.0	4,077.00	5,145.0	1,060.00
9 5/8	.802	----------	1,970.0	3,041.0	4,113.00	5,185.0	1,072.00
9 11/16	.807	----------	1,987.0	3,073.0	4,155.00	5,227.0	1,082.00
9¾	.812	----------	2,006.0	3,101.0	4,192.00	5,288.0	1,091.00
9 13/16	.818	----------	2,025.0	3,131.0	4,234.00	5,340.0	1,103.00
9 7/8	.823	----------	2,045.0	3,160.0	4,273.00	5,393.0	1,112.00
9 15/16	.828	----------	2,065.0	3,190.0	4,315.00	5,443.0	1,125.00
10	.833	----------	2,085.0	3,216.0	4,352.00	5,490.0	1,136.00

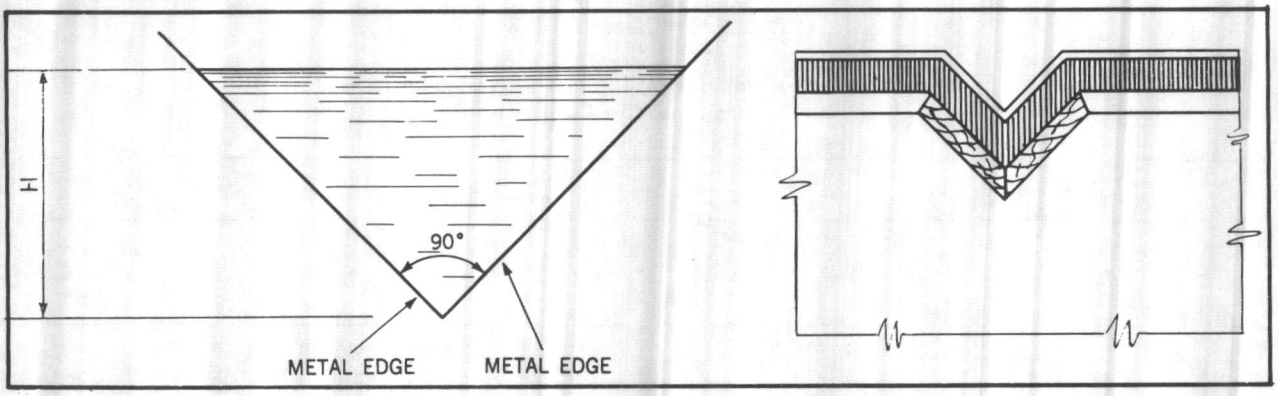


FIGURE 129

V-Notch Weir

For example, a pitot tube inserted in the center of a 6-inch main gives a differential head reading of 0.4 feet of water. To determine the flow.

$$Q = 16.26 \times 6^2 \times \sqrt{0.4}.$$
$$Q = 16.26 \times 36 \times 0.632.$$
$$Q = 370 \text{ g.p.m.}$$

3.4.4.5.3 Orifice discharge. A simple orifice meter for testing discharge from small well pumps and hydrants can be made with a piece of 2-inch pipe, three 2-inch pipe caps, a 2-inch gate valve and a pressure gage (see Figure 132).

(1) The 2-inch pipe between valve and cap is 24 inches long. The gage is 8 inches from the cap. The orifices are made by carefully drilling a 1-inch hole in one pipe cap, a 1½-inch hole in the second and a 1¾-inch hole in the third. For accurate metering, the holes should be machined to exact size. The downstream sides of the orifices are beveled at a 45° angle, making a perimeter ⅛-inch thick with a sharp 90° edge on the upstream side. This meter can be attached to a fire hydrant, the end of a pipe or the end of a 2½-inch fire hose.

(2) Rates of flow in g.p.m. through each of these orifices for various gage readings in pounds per square inch are given in figure 133.

TABLE 9

Discharge in Gallons per Minute for 90° Triangular Weir

h (in.)	h (ft.)	Q (g.p.m.)
1¼	0.10	4
1½	.12	6
1⅝	.14	9
1⅞	.16	12
2⅛	.18	16
2⅜	.20	21
2⅝	.22	27
2⅞	.24	33
3⅛	.26	40
3⅜	.28	49
3⅝	.30	58
3⅞	.32	68
4⅛	.34	79
4⅜	.36	91
4½	.38	104
4¾	.40	118
5	.42	133
5¼	.44	149
5½	.46	166
5¾	.48	184
6	.50	204
6⅝	.55	256
7¼	.60	320
7¾	.65	390
8⅜	.70	470
9	.75	555
9⅝	.80	653
10¼	.85	758
10¾	.90	872
11⅜	.95	997
12	1.00	1,130

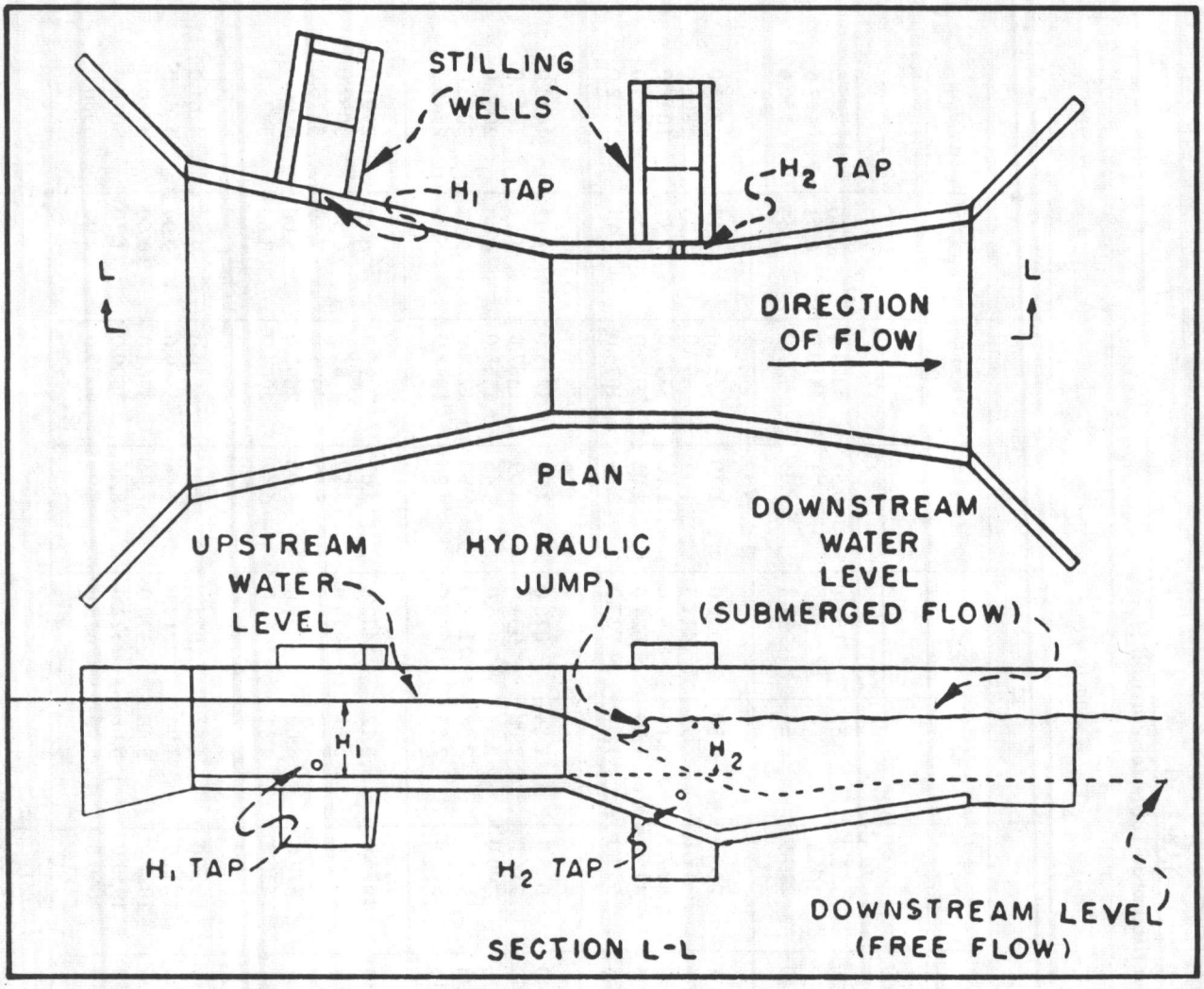


FIGURE 130

Plan and Section of Parshall Flume

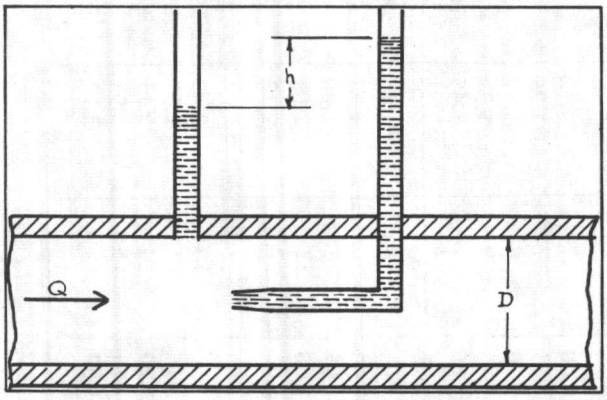


FIGURE 131

Pitot Tube Installation

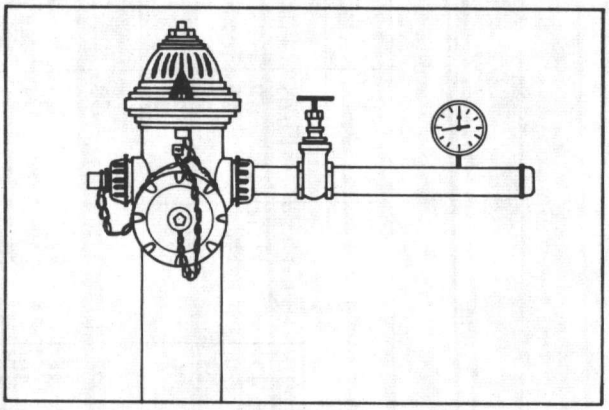


FIGURE 132

Simple Orifice Meter

TABLE 10
Free-Flow Discharge Table for Parshall Flume

Head		Throat width in inches									
		6		9		12		18		24	
ft.	in.	f.p.s.	g.p.m.	f.p.s.	g.p.m.	f.p.s.	g.p.m.	f.p.s.	g.p.m.	f.p.s.	g.p.m.
0.10	1 3/16	0.05	22.4	0.09	40.4						
.15	1 13/16	.10	44.9	.17	76.3						
.20	2 3/8	.16	71.6	.26	116.9	0.35	157.1	0.51	229.0	0.66	296.3
.25	3	.23	103.3	.37	166.1	.49	219.9	.71	318.7	0.93	417.5
.30	3 5/8	.31	139.2	.49	219.9	.64	287.3	.94	422.0	1.24	556.6
.35	4 3/16	.39	175.1	.62	278.0	.80	359.0	1.19	534.0	1.57	705.0
.40	4 13/16	.48	215.5	.76	341.1	.99	444.3	1.47	659.0	1.93	866.0
.45	5 3/8	.58	260.3	.90	404.0	1.19	534.0	1.76	790.0	2.32	1041.0
.50	6	.69	310.0	1.06	475.7	1.39	624.0	2.06	925.0	2.73	1225.0
.55	6 5/8	.80	359.0	1.23	552.0	1.62	727.0	2.39	1073.0	3.17	1422.0
.60	7 3/16	.92	412.9	1.40	628.0	1.84	826.0	2.73	1225.0	3.62	1625.0
.65	7 13/16	1.04	466.8	1.59	714.0	2.08	934.0	3.09	1387.0	4.11	1845.0
.70	8 3/8	1.17	525.1	1.78	799.0	2.33	1046.0	3.46	1553.0	4.60	2065.0
.75	9	1.31	588.0	1.98	889.0	2.58	1158.0	3.85	1728.0	5.12	2300.0
.80	9 5/8	1.45	651.0	2.18	978.0	2.85	1280.0	4.26	1912.0	5.66	2540.0
.85	10 3/16	1.59	714.0	2.39	1073.0	3.12	1400.0	4.67	2096.0	6.22	2791.0
.90	10 13/16	1.74	781.0	2.61	1171.0	3.41	1530.0	5.10	2289.0	6.80	3052.0
.95	11 3/8	1.90	853.0	2.84	1274.0	3.70	1661.0	5.55	2491.0	7.39	3316.0
1.00	12	2.06	925.0	3.07	1377.0	4.00	1795.0	6.00	2692.0	8.00	3590.0
1.05	12 5/8	2.22	996.0	3.31	1486.0	4.31	1934.0	6.47	2904.0	8.63	3873.0
1.10	13 3/16	2.40	1077.0	3.55	1594.0	4.62	2074.0	6.95	3119.0	9.27	4161.0
1.15	13 13/16	2.57	1153.0	3.80	1706.0	4.94	2217.0	7.44	3339.0	9.94	4461.0
1.20	14 3/8	2.75	1234.0	4.06	1822.0	5.28	2370.0	7.94	3564.0	10.60	4760.0
1.25	15	2.93	1315.0	4.32	1939.0	5.62	2522.0	8.46	3800.0	11.30	5072.0
1.30	15 5/8	3.12	1400.0	4.59	2060.0	5.96	2675.0	8.99	4035.0	12.00	5386.0

f.p.s. × .646317 = m.g.d.
m.g.d. × 1.54723 = f.p.s.

f.p.s. × 448.831 = g.p.m.
g.p.m. × .002228 = f.p.s.

Section 5. PUMPS AND PUMPING STATIONS

3.5.1. INTRODUCTION. Pumps of various types are required for the movement of liquids in the operation of a water supply system, as in the pumping of water from the supply source to the water treatment plant, feeding of various chemicals during the treatment process, moving the treated water into the mains and storage facilities, boosting pressure in the distribution system and fire-flow pumping. This section deals in general with the types of pumps and their uses. For detailed maintenance information, consult Chapter 4. Pumping stations can be defined as the pumps, piping, valves, gages, controls and the facilities to house them. However, a single well pump is considered a pumping station, despite the relative simplicity of the installation.

3.5.2 PUMPS. There are four general classes of pumps used in water supply systems and are differentiated by the methods they use to move the liquid. These are centrifugal, rotary, reciprocating and air-lift pumps. The last is a special type used only for well pumping. In actual practice, centrifugal pumps are most widely used for the movement of water, with the other types used for special applications. The chart in figure 134 gives some of the characteristics of different type pumps with which the operator should be familiar. Characteristic curves are furnished by manufacturers and show the interrelation of pump head, capacity, power and efficiency. Typical curves for volute and turbine pumps are shown in Figure 135.

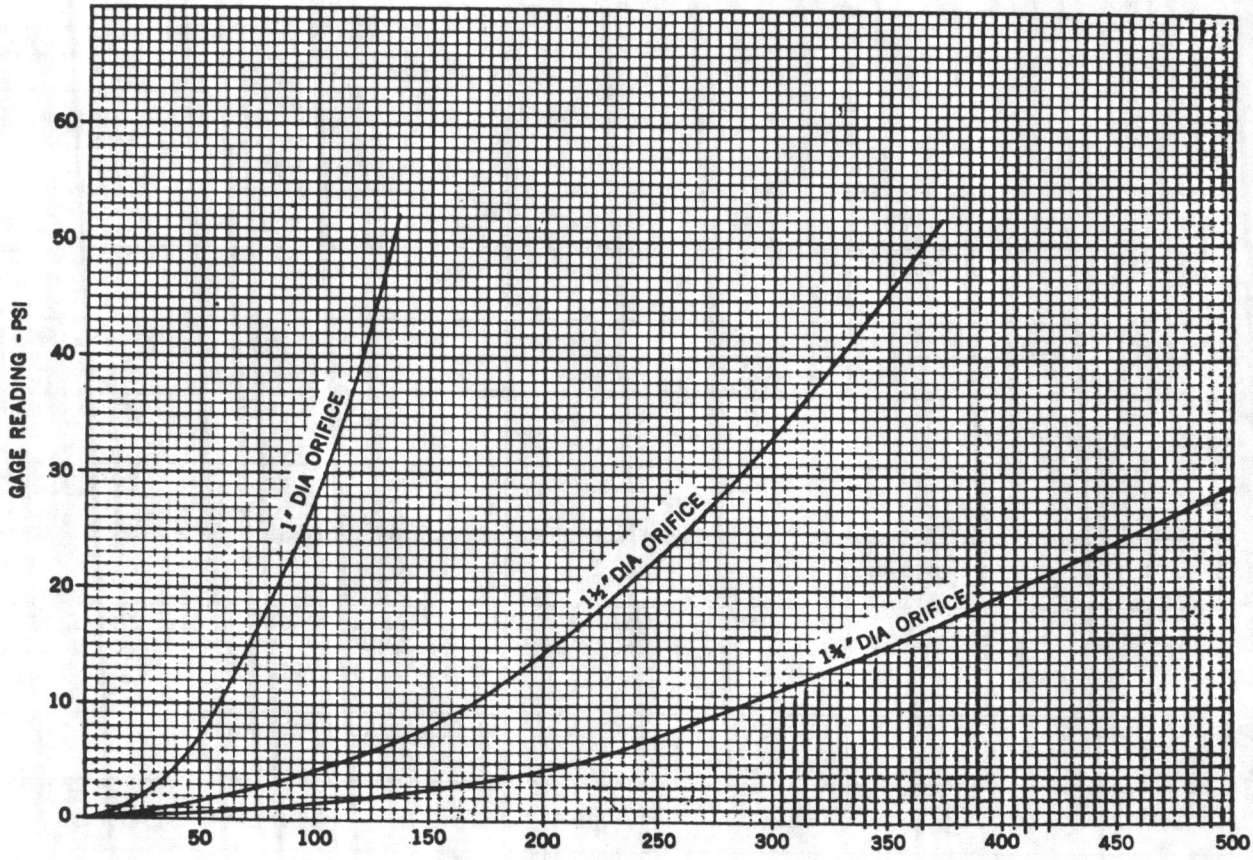


FIGURE 133

Calibration Curves for Orifice at End of a 2-inch Pipe

3.5.2.1 Centrifugal Pumps. A centrifugal pump consists of a casing or housing with an intake at the center, and a rotor or impeller so arranged that when rotated the impeller will discharge water or other liquids by centrifugal force into a discharge pipe on the outer rim of the casing. The head or pressure developed by the pump is entirely the result of the velocity imparted to the water by the impeller, and is not due to any impact or displacement. In most types of pumps, the impeller is a radial group of vanes curved backwards from the direction of rotation, and mounted either directly on the shaft, or on a single disk (open impeller, fig. 136), or between two disks (closed impeller, fig. 137).

3.5.2.1.1 Types of centrifugal pumps. The various types of centrifugal pumps used in water supply systems are volute, diffuser, regenerative-turbine, vertical turbine, mixed-flow and axial-flow (see fig. 138 through 143). These can be either single or multistage, single or double suction (see fig. 144). A single-stage pump is one which has only one impeller. A multistage pump is one which has two or more impellers in a single casing, one impeller discharging into the next. A single suction pump is one which admits water on only one side of the impeller. A double suction pump is one which admits water on both sides of the impeller.

3.5.2.1.2 Uses of centrifugal pumps. Centrifugal pumps are the type most commonly used in water supply systems as they are well adapted to all drives and to a wide variety of operating conditions. For reliable operation, suction lift should not exceed 15 feet. Multistage centrifugal pumps are used to develop high-discharge pressure.

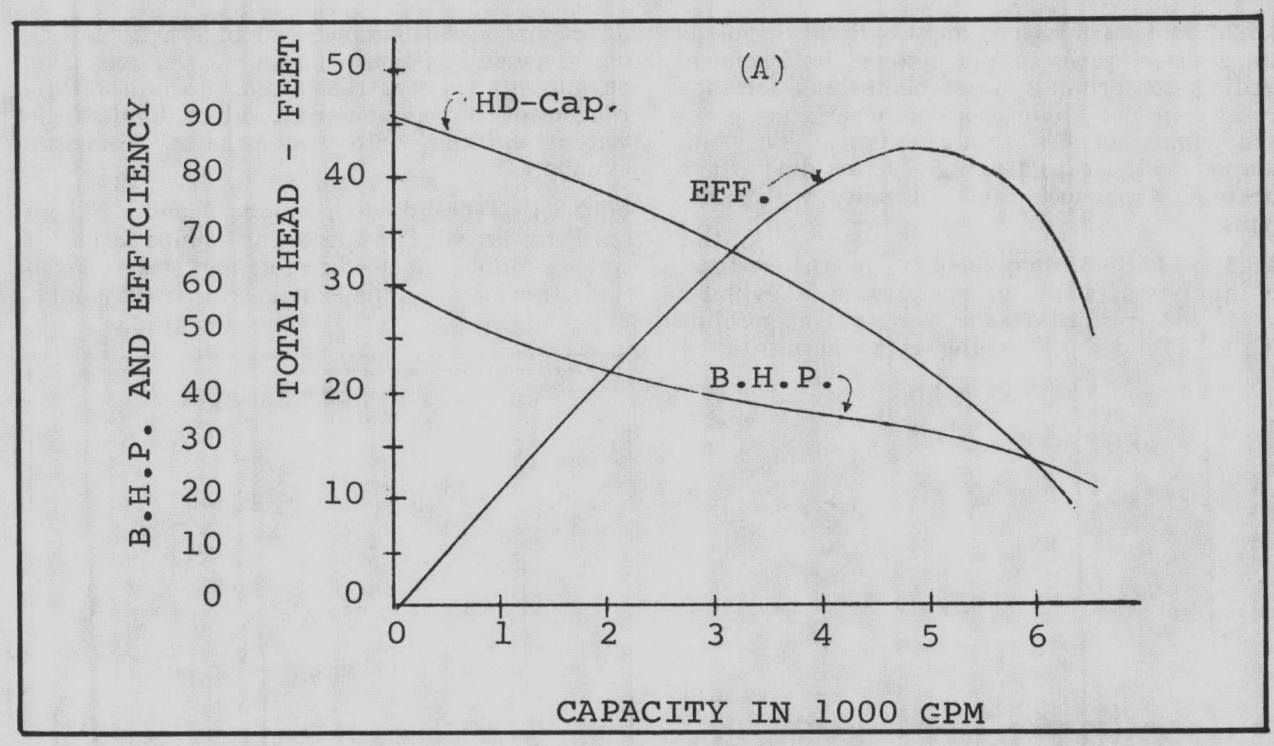
3.5.2.2 Rotary Pumps. Rotary pumps are positive-displacement pumps, and consist of a fixed casing containing gears, vanes, pistons, cams or screws operating with minimum clearance. Instead of "throwing" the water as in a centrifugal pump, a rotary pump traps it, pushes it around inside the closed casing and discharges it in a continuous flow.

3.5.2.2.1 Types of rotary pumps. The various types of rotary pumps in use in water supply systems include external gear, internal gear, vane, cam-and-piston, lobular, screw and shuttle-block. Several of these types are illustrated in figures 145 through 149.

	CENTRIFUGAL		ROTARY	RECIPROCATING	
	VOLUTE	AXIAL FLOW & TURBINE		DOUBLE ACTING POWER	DIRECT ACTING STEAM
FLOW	EVEN	EVEN	EVEN	PULSATING	PULSATING
EFFECT OF INCREASING HEAD					
CAPACITY	DECREASE	DECREASE	NONE	NONE	DECREASE
POWER	DECREASE	INCREASE	INCREASE	INCREASE	INCREASE
EFFECT OF DECREASING HEAD					
CAPACITY	INCREASE	INCREASE	NONE	NONE	SLIGHT INCREASE
POWER	INCREASE	DECREASE	DECREASE	DECREASE	DECREASE
EFFECT OF SHUTTING DISCHARGE VALVE					
PRESSURE	INCREASE 15 to 30 PERCENT	CONSIDERABLE INCREASE	PRESSURE INCREASES WITH DESTRUCTIVE EFFECT IF NO RELIEF VALVE USED		INCREASE
POWER	DECREASE 50 to 60 PERCENT	INCREASE	INCREASE TO DESTRUCTION		INCREASE
VALVES	NONE	NONE	NONE	INLET & DISCHARGE	

FIGURE 134

Chart of Pump Characteristics



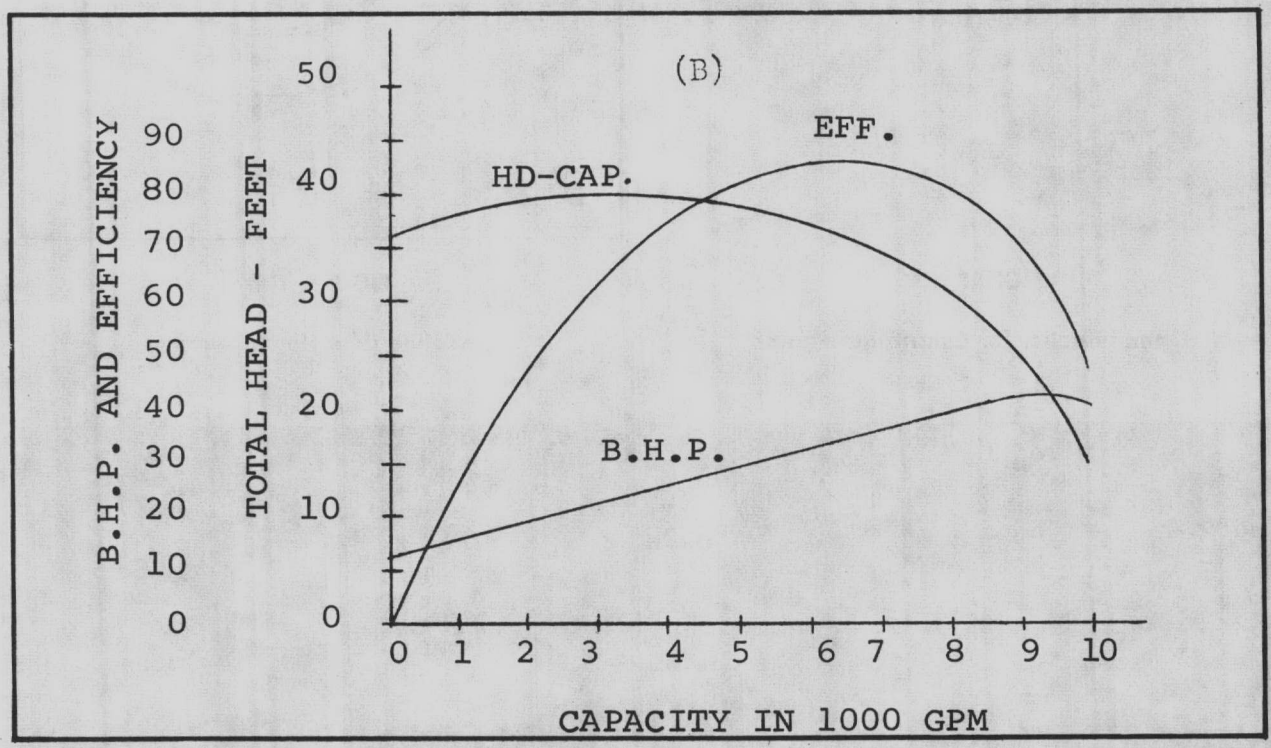


FIGURE 135

Typical Characteristic Curves for
(A) Turbine Pumps
(B) Volute Pumps

3.5.2.2.2 Uses of rotary pumps. Rotary pumps are used in water supply systems for chemical feeding, for priming larger pumps and for such limited special applications as emergency gasoline pumps for firefighting stations. They are adapted to low-capacity, high-suction duty where air- and vapor-lock cause difficulty with other types.

3.5.2.3. Reciprocating Pumps. In the reciprocating pump, a piston operates in a cylinder much like pistons do in a steam or gasoline engine cylinder. Pumping is accomplished by direct piston displacement; double action, with discharge and suction occurring at the same time on opposite sides of the piston, is the usual arrangement. Spring retained valves regulate the water's entrance into and exhaust from the cylinder.

3.5.2.3.1 Types of reciprocating pumps. There are three types of reciprocating pumps in use in water supply system—direct-acting, steam-driven units (see fig. 150), diaphragm and power pumps.

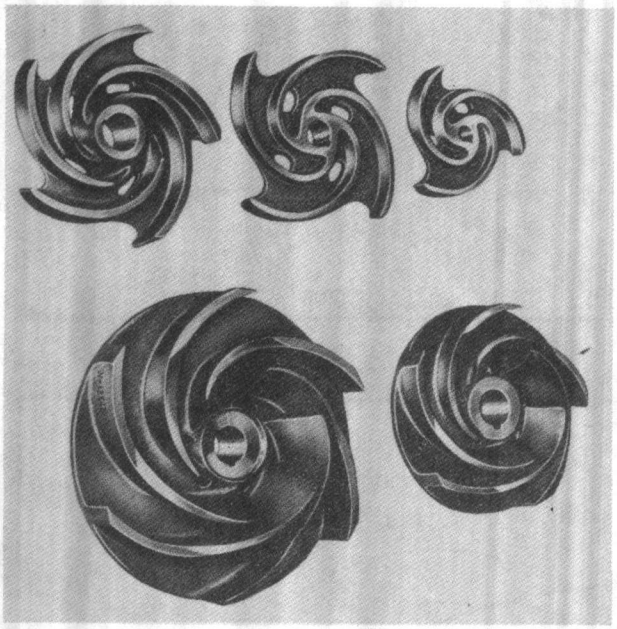


FIGURE 136

Open Impeller for Centrifugal Pumps

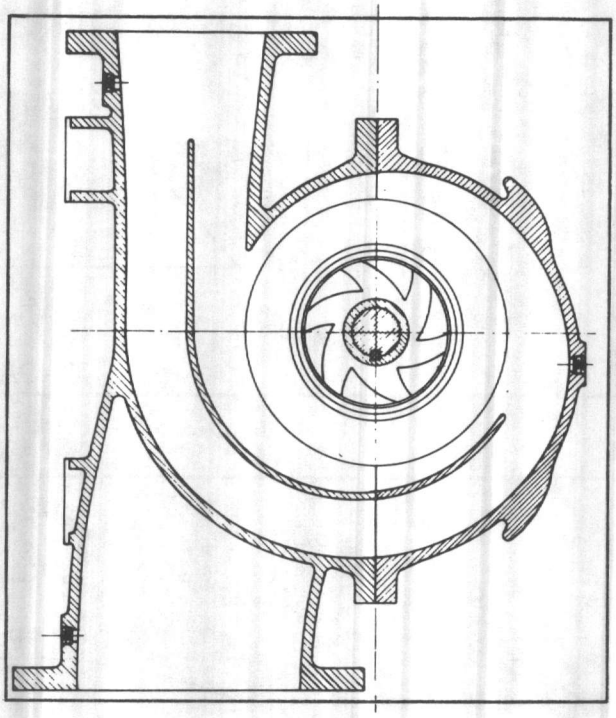


FIGURE 138

Volute Centrifugal Pump

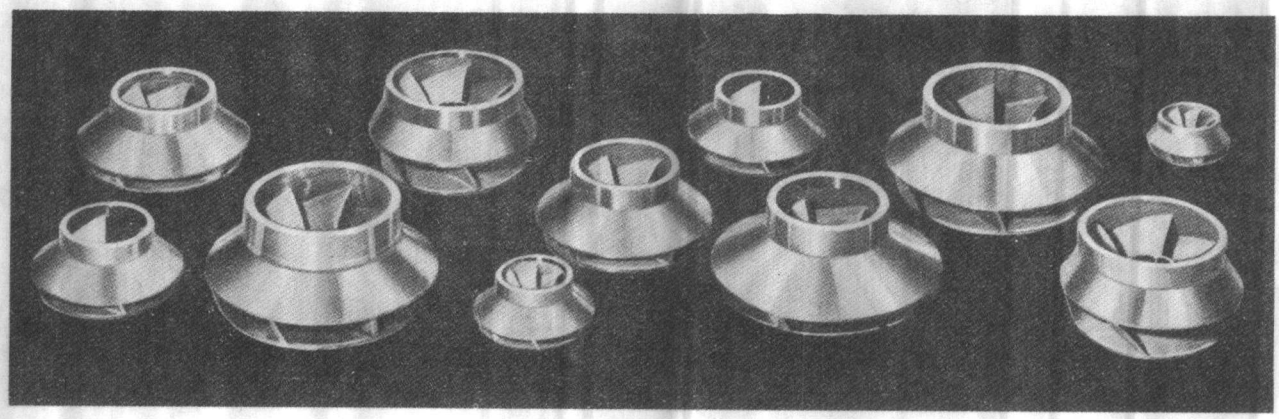
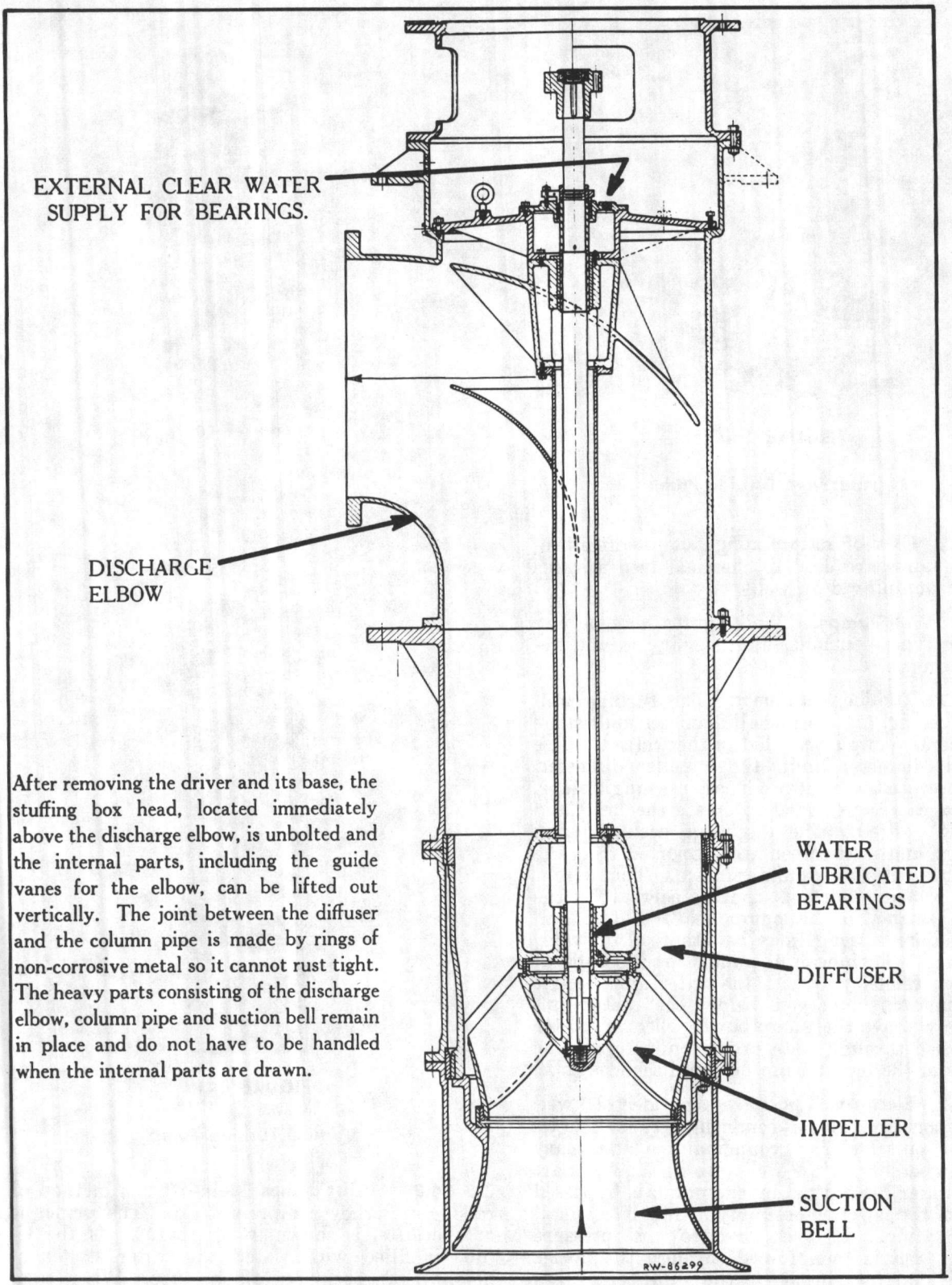


FIGURE 137

Closed Impellers for Centrifugal Pumps



After removing the driver and its base, the stuffing box head, located immediately above the discharge elbow, is unbolted and the internal parts, including the guide vanes for the elbow, can be lifted out vertically. The joint between the diffuser and the column pipe is made by rings of non-corrosive metal so it cannot rust tight. The heavy parts consisting of the discharge elbow, column pipe and suction bell remain in place and do not have to be handled when the internal parts are drawn.

FIGURE 139

Diffuser Centrifugal Pump

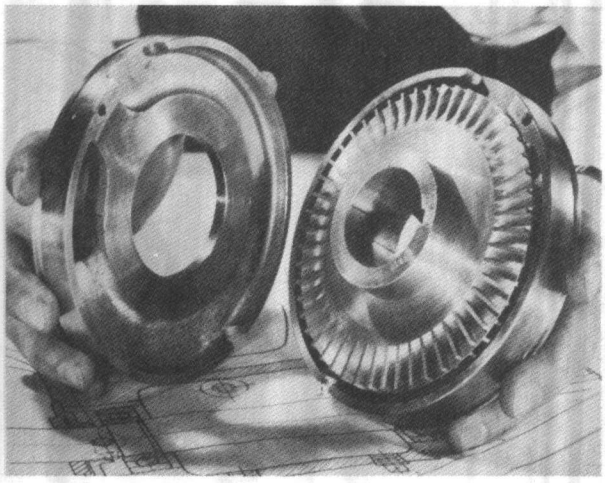


FIGURE 140

Regenerative Turbine Pump

3.5.2.3.2 Uses of reciprocating pumps. Reciprocating pumps are used in chemical feed systems and for pumping deep wells.

3.5.2.4 Well Pumps. Well pumps may be any of four types—turbine, ejector, air-lift and reciprocating.

3.5.2.4.1 Turbine well pumps. The turbine well pump (see fig. 151) is a small diameter multistage centrifugal pump suspended in the well. Because the well diameter limits the impeller diameter, and therefore the head produced in a single stage, multistages are provided to create the head and capacity desired. The discharge casing, pump housings, and inlet screen are supported from the pump base at the ground surface. The weight of the rotating parts is usually carried by the thrust bearing in the pump head. Pump and intermediate bearings may be either oil or water lubricated. Turbine well pumps may also be of the submersible type, with the watertight electric drive motor submerged below the water immediately above the pump bowl. Electric power is supplied through waterproof conductors. The pump and the motor hang on the discharge pipe.

3.5.2.4.2 Ejector well pumps. An ejector well pump consists of a centrifugal-type single-impeller pump above ground, and a stationary ejector assembly in the well (see fig. 152). Part of the water discharged by the pump is bypassed back to the ejector assembly through a small pressure line. It goes first to the pressure chamber and is then forced through the nozzle into the narrow throat of the tube. Its high velocity as it leaves the tube creates a reduced pressure which causes the water to enter from the well and rise in the pump suction pipe. The pump suction then lifts the water from this point, completing the pumping cycle.

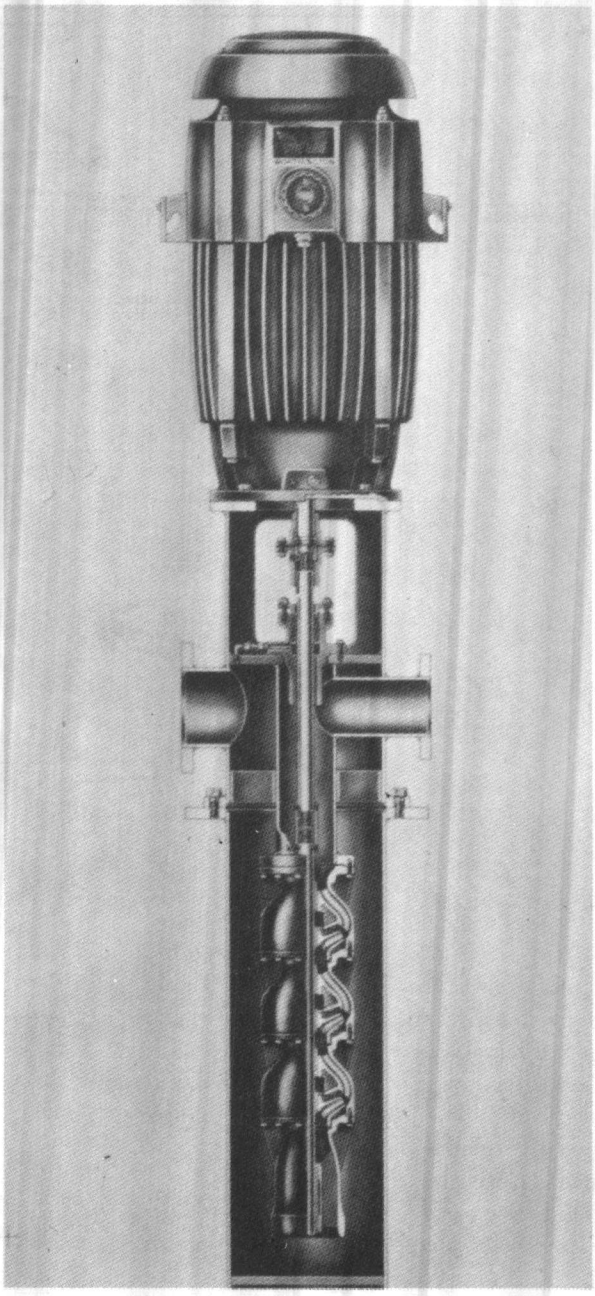


FIGURE 141

Vertical Turbine Pump

3.5.2.4.3 Air-lift pumps. Air-lift is a method of raising water by compressed air. The principle of operation is shown in figure 153. If the U-tube is filled with water, the water stands at height H in both legs of the tube. When compressed air is introduced, as shown in figure 153, a mixture of air and water is formed in one leg. The solid column of water, H, weighs more than the air-column, P, thereby forcing the air-water column over the top of the U-tube.

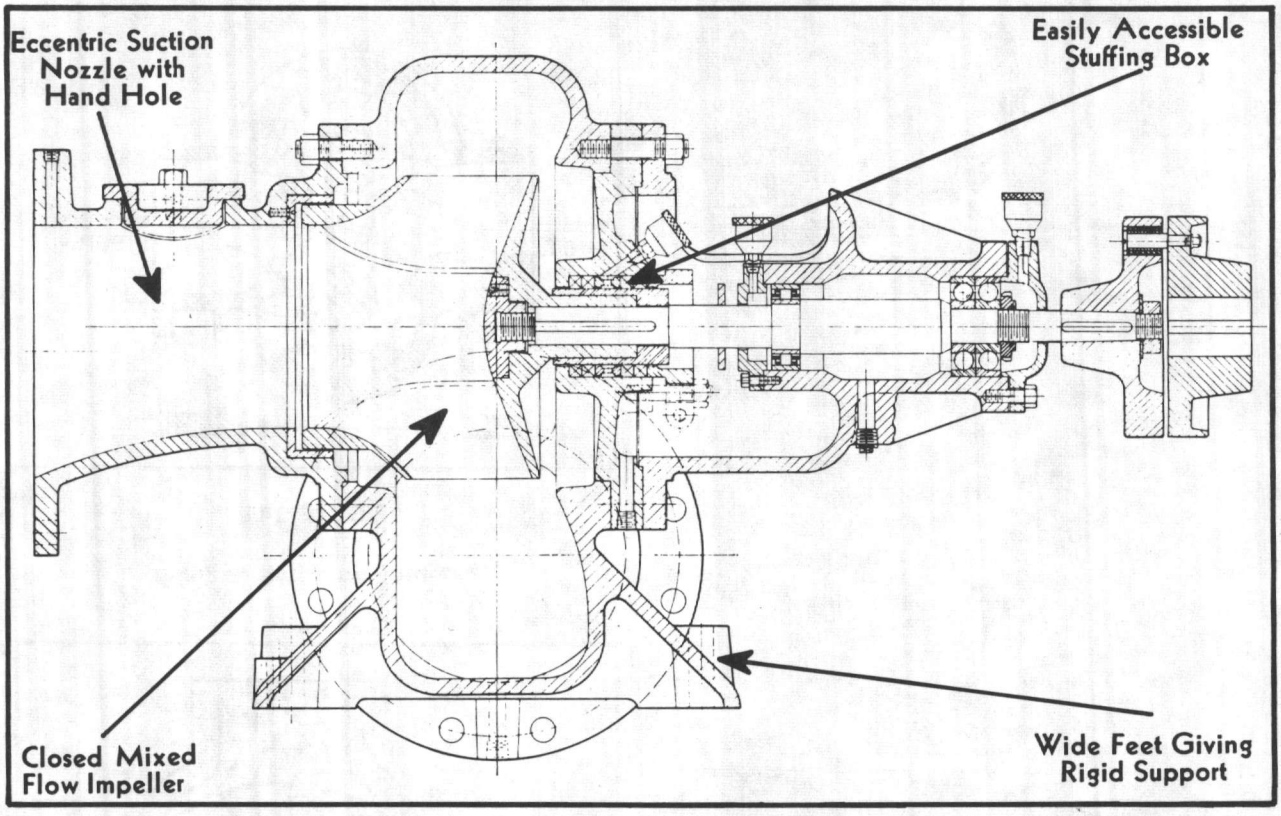


FIGURE 142

Mixed-Flow Centrifugal Pump

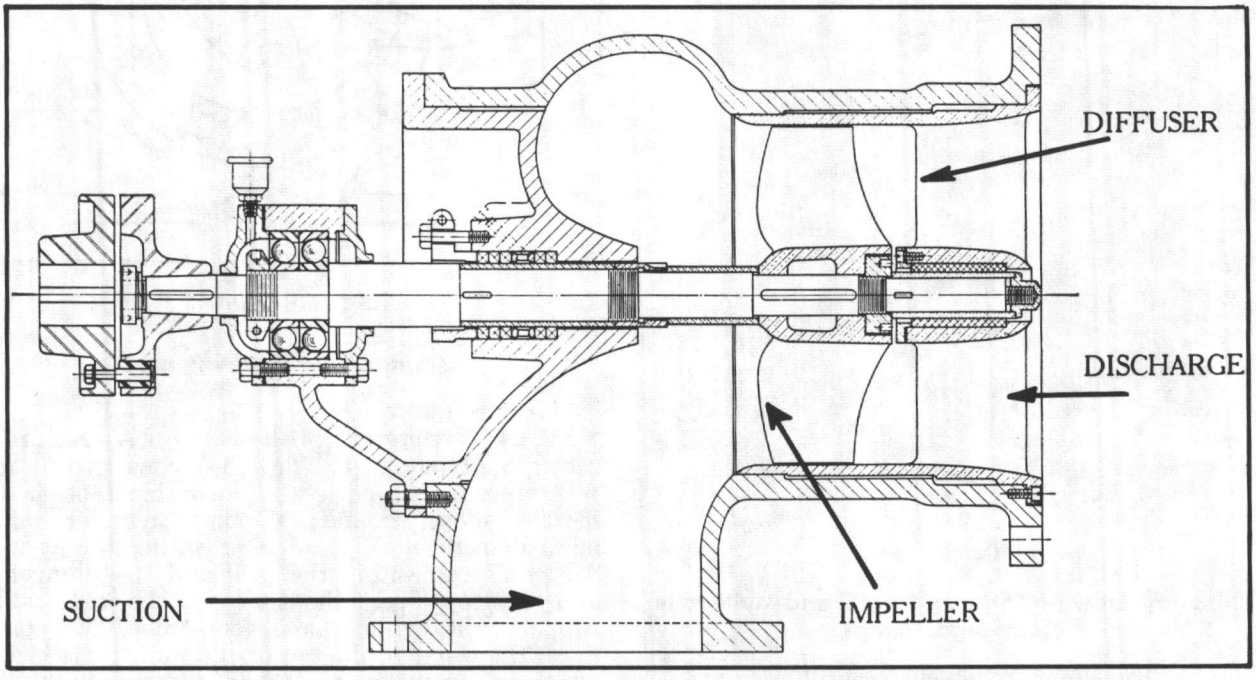


FIGURE 143

Axial-Flow Centrifugal Pump

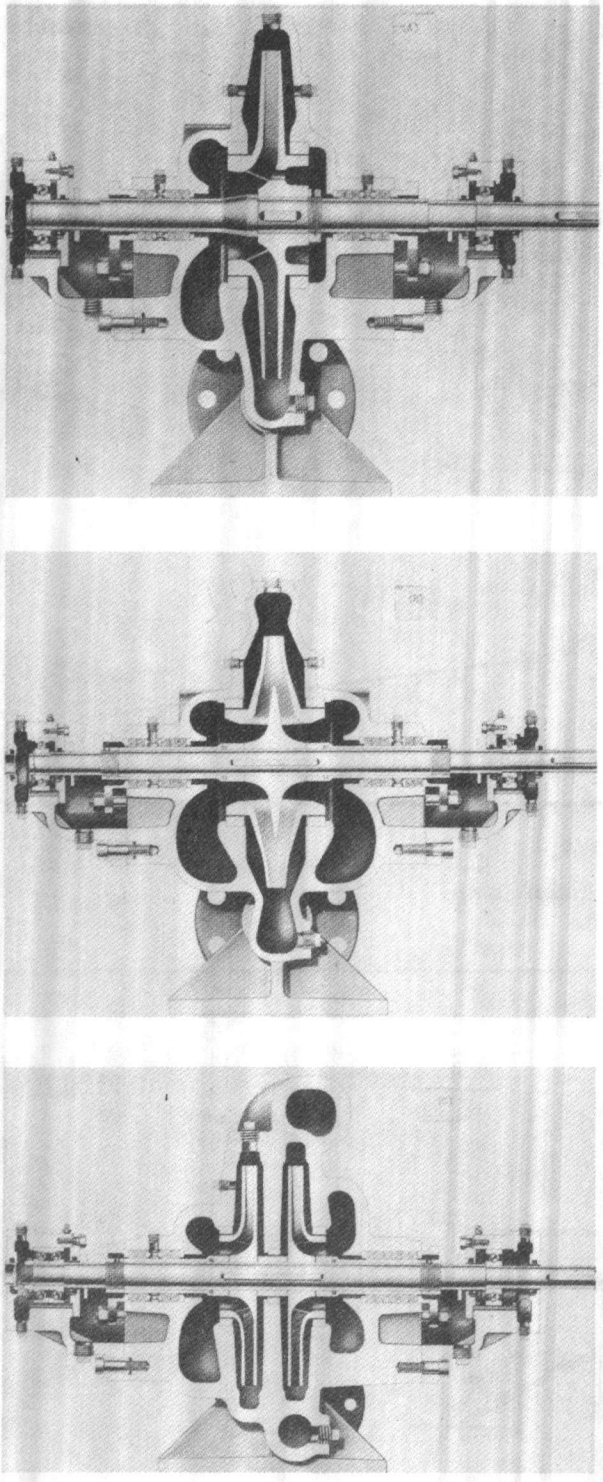


FIGURE 144

Cutaway Drawing Showing Single, and Multistage Centrifugal Pumps

(A) Single-Stage, Single-Suction
(B) Single-Stage, Double-Suction
(C) Double-Stage, Double-Suction

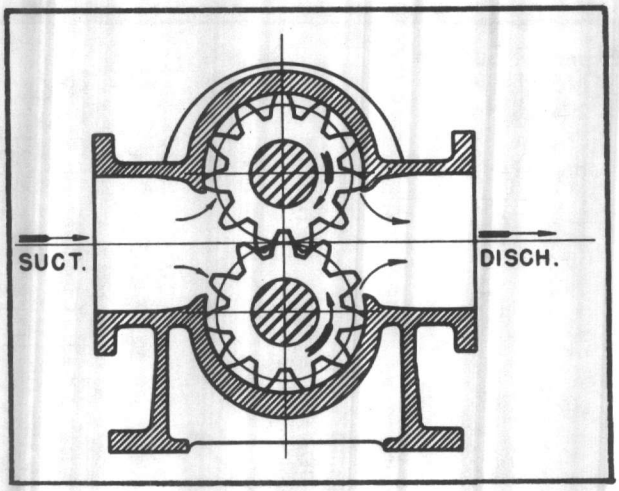


FIGURE 145

External-Gear Rotary Pump

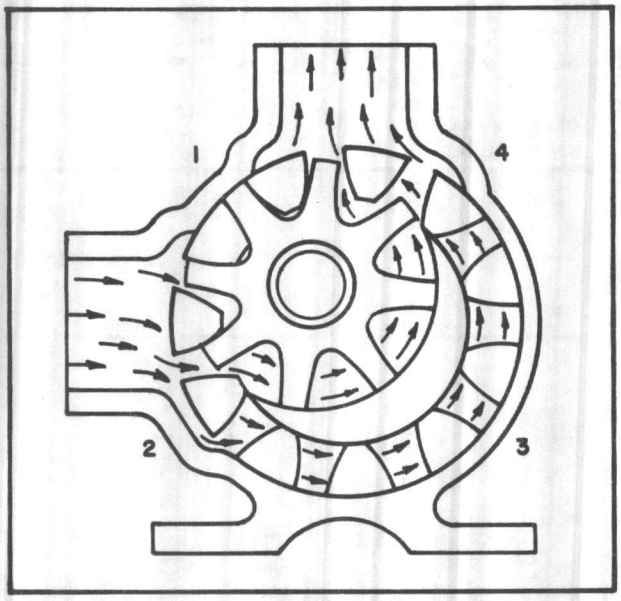


FIGURE 146

Internal-Gear Rotary Pump

3.5.2.4.4 Reciprocating well pumps. A reciprocating well pump (see fig. 154) consists of the following major parts—a power head or jack located above ground; a pump cylinder submerged in the well; a plunger within the cylinder; rods connecting the jack and the plunger; and, a drop pipe which houses the rods and supports the cylinder and foot valve, and conducts the water to the top of the well. The jack, which is driven by an electric motor or gasoline through gears or a belt, imparts reciprocating motion to the plunger.

3.5.3 PUMP OPERATION. Each operator, before starting a pump for the first time, should consult the manufacturer's instructions and local commands, and familiarize himself with the operating procedures for the specific installations. In the following paragraphs are outlined the general procedures to be followed for different types of pumps. For lubrication procedures, see paragraph 4.9.3.1.

3.5.3.1 Centrifugal Pumps. The following operating procedures apply to all types of centrifugal pumps. Figure 155 shows a schematic drawing of a centrifugal pump and its parts.

3.5.3.1.1 Priming. CAUTION: The pump must be primed before starting. Priming a centrifugal pump means removing the air, gas or vapor from the suction piping and pump casing. Unless primed, a centrifugal pump will not move water. Also, internal pump parts, depending upon liquid for lubrication, may seize if the casing is not completely filled prior to starting. Prime a pump by one of the following methods, depending on operation conditions.

(1) Positive Suction Head (Pressure). With a positive suction head, prime the pump in the following manner.

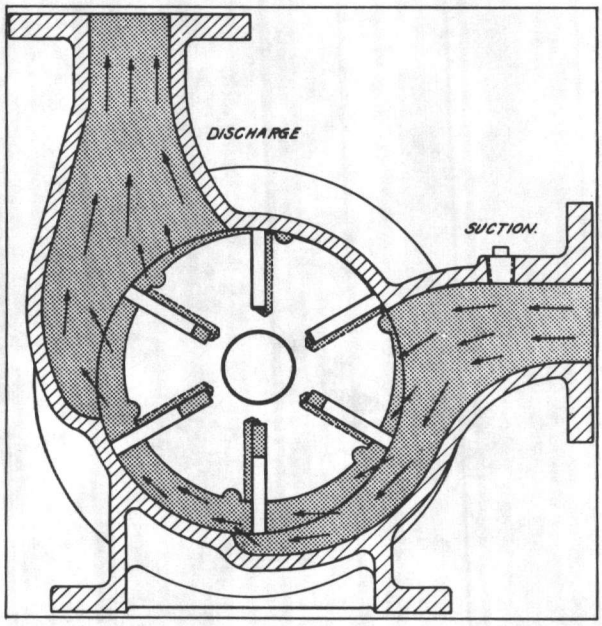


FIGURE 147

Vane Rotary Pump

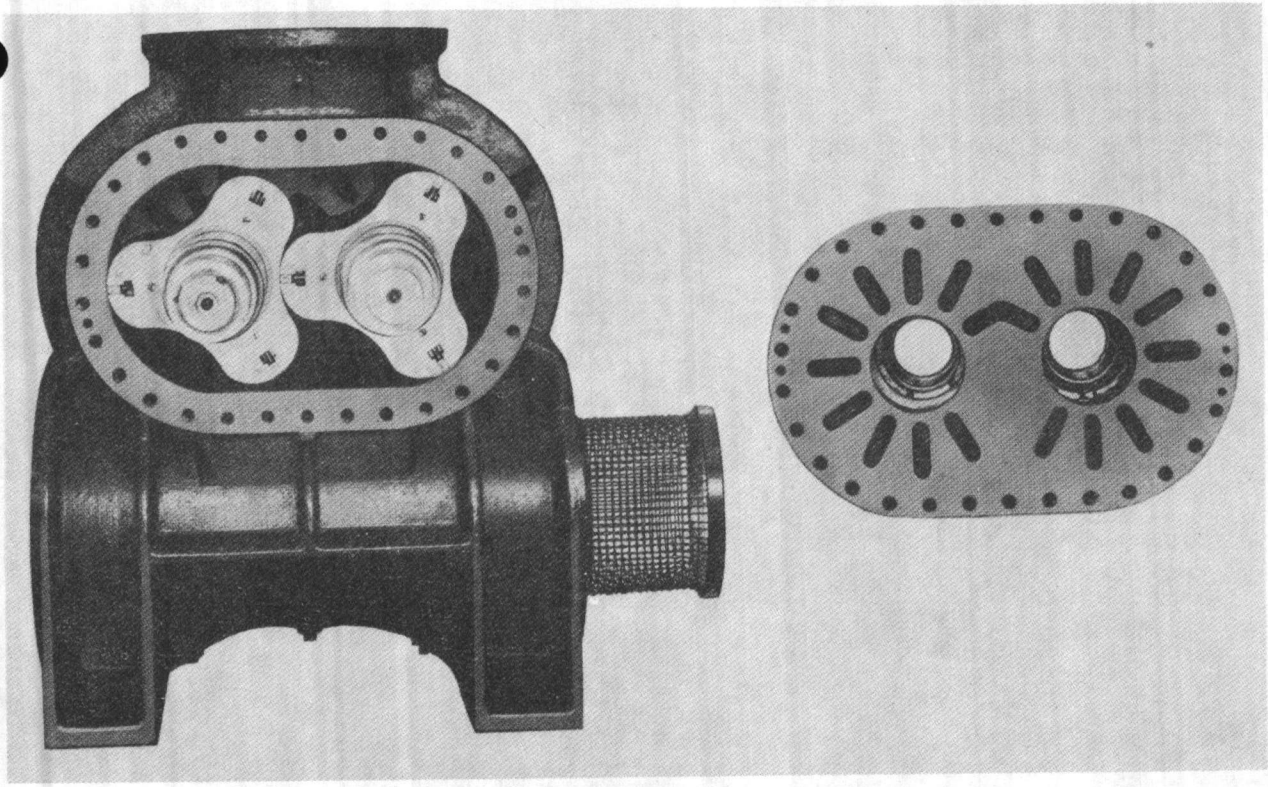


FIGURE 148

Lobular Rotary Pump

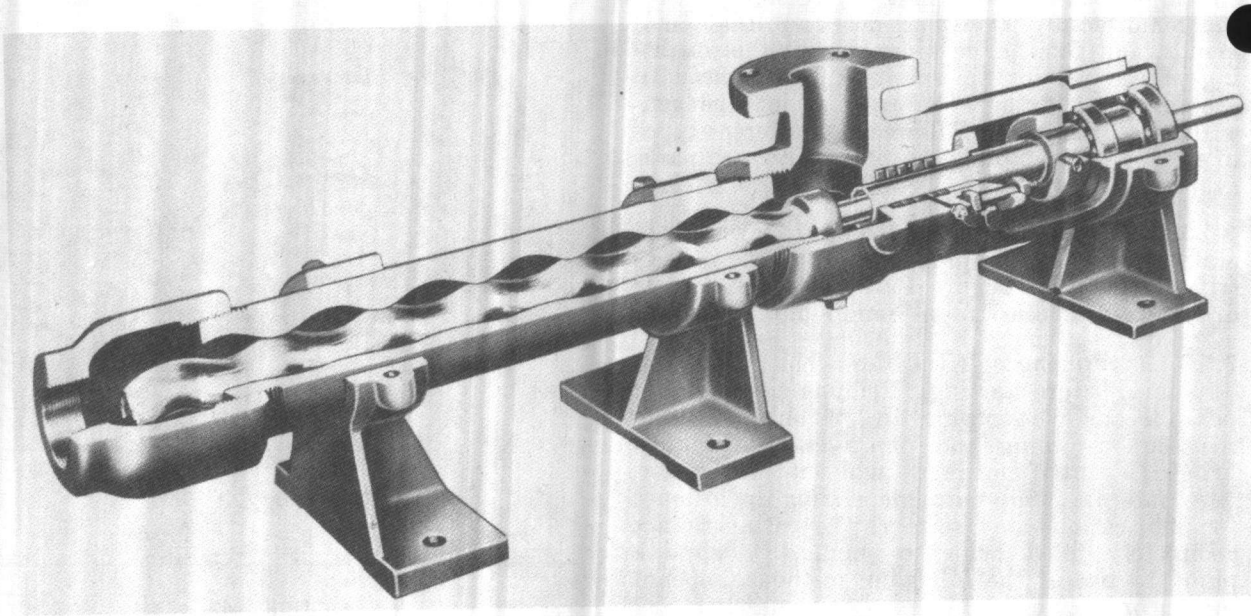


FIGURE 149

Screw Pump

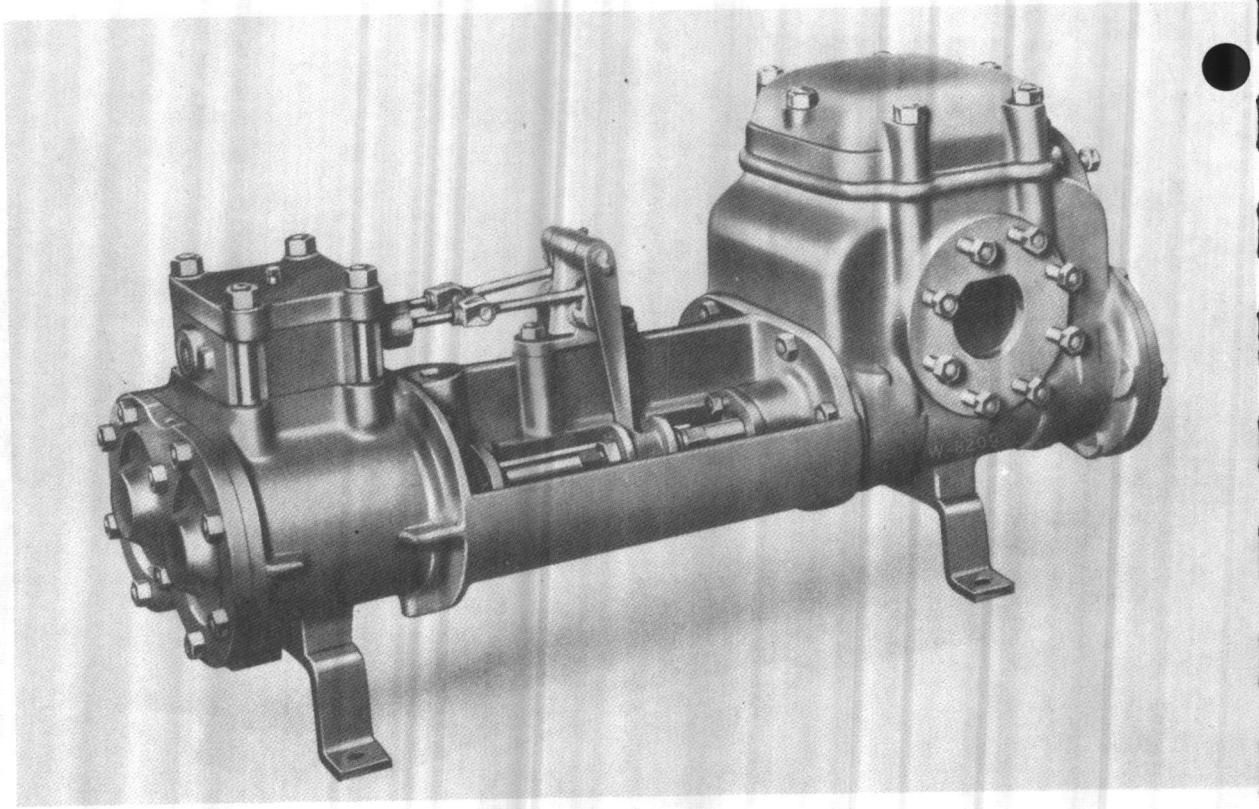


FIGURE 150

Reciprocating Pump

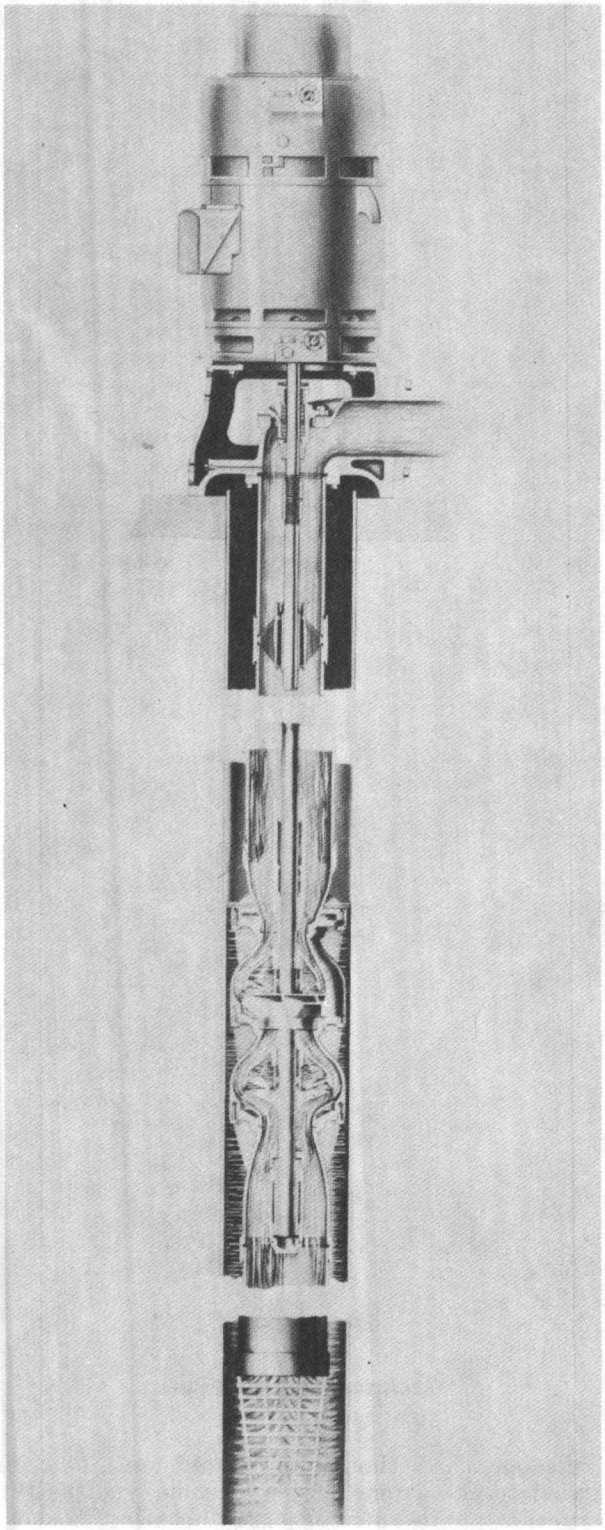


FIGURE 151

Turbine Well Pump

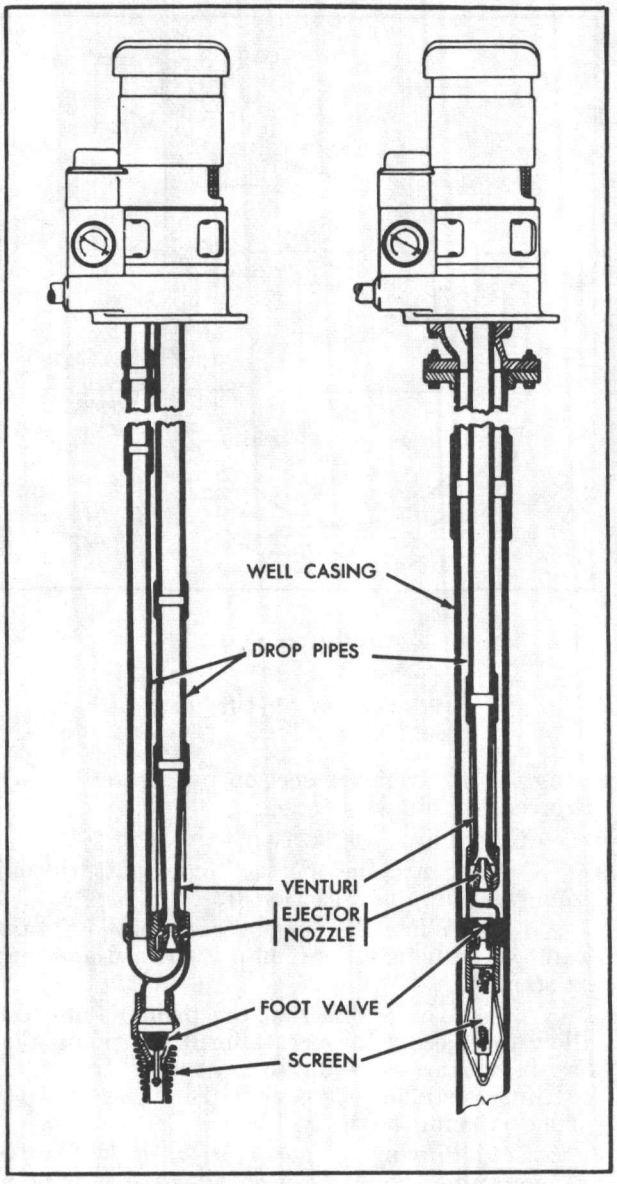


FIGURE 152

Ejector Pump Installed in Well

(a) Open all suction valves to allow water to enter the suction piping and pump casing.

(b) Open all vents located on the highest points of the pump casing to release all entrapped air.

(c) When the water appears as a steady stream (no air bubbles), the pump is primed and may be started.

(2) Negative Suction Head (Suction or Lift).

(a) Priming by ejector or exhauster. When steam, high-pressure water or compressed air is available, prime the pump by attaching an ejector to the highest point of the pump casing for evacu-

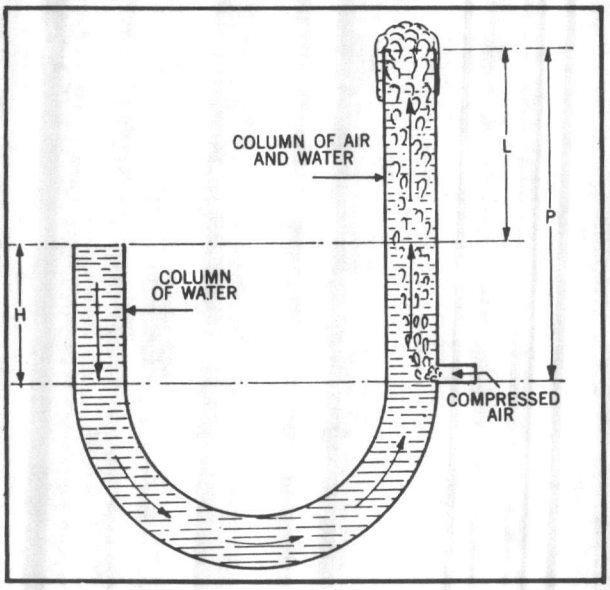


FIGURE 153

Principle of Air-Lift Pump

ating the air from the suction piping and casing. Proceed as follows.

1. Open the suction valve.

2. Start the ejector to exhaust the air from the pump and suction line.

3. When the ejector waste pipe exhausts water continuously, the pump is primed and may be started.

4. The ensure that the prime is not lost, allow the ejector to operate until the pump that has been started is up to operating speed. A continuous stream of water will indicate that the prime is being held.

(b) Priming a pump with a foot valve. A foot valve should be used at the lowest point on the suction line. The foot valve will retain water in the suction pipe and pump casing after the pump has been initially primed.

1. Open the suction valve, if one is installed.

2. Fill the suction pipe and casing with water from an independent source of supply.

3. Open the vent valves at the highest points on the casing to allow air to escape.

4. When the water appears as a steady stream (no air bubbles), the pump is primed and may be started.

(c) Priming by vacuum pump. Prime the pump by the use of a wet-type vacuum pump. The procedure is the same as priming by ejector.

3.5.3.1.2 Before starting.

(1) Open the valves on the cooling liquid supply to the bearing housings if the bearings are liquid cooled. Once the pump has been put into operation, the cooling liquid must be regulated to the extent that no visible condensation appears on the outside of the bearing housing. The appearance of condensation on the outside of the housing is an indication that condensation, which could cause corrosion of the bearings, is also forming on the inside of the housing.

(2) If valves are installed on the lines supplying water to the stuffing boxes, they should be opened.

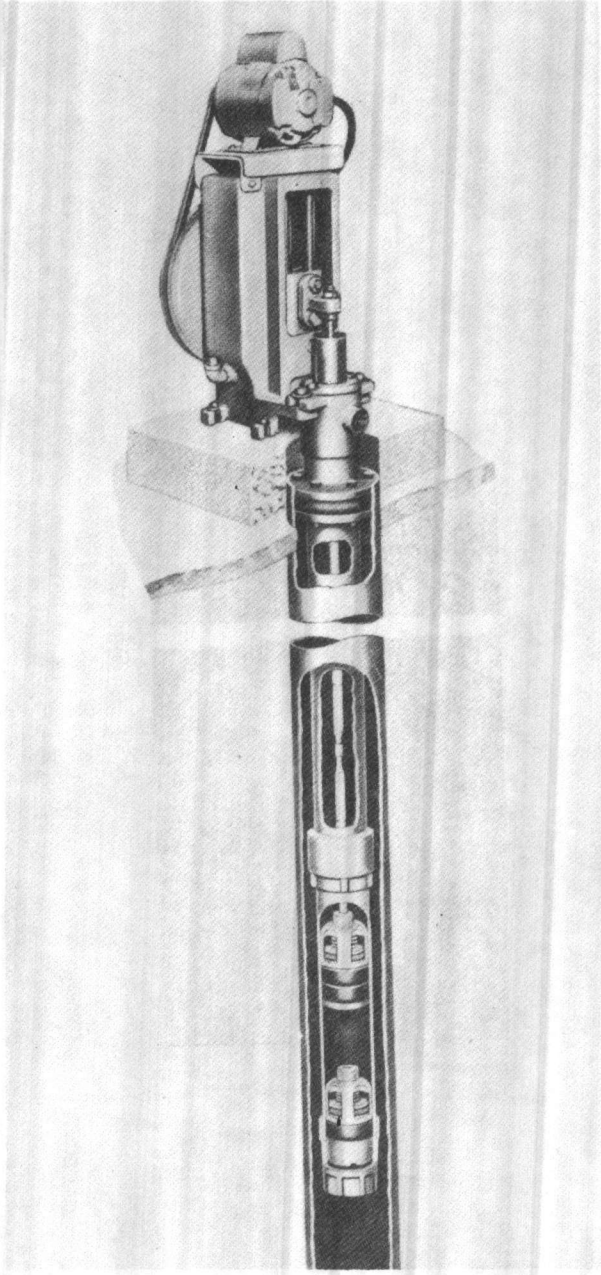
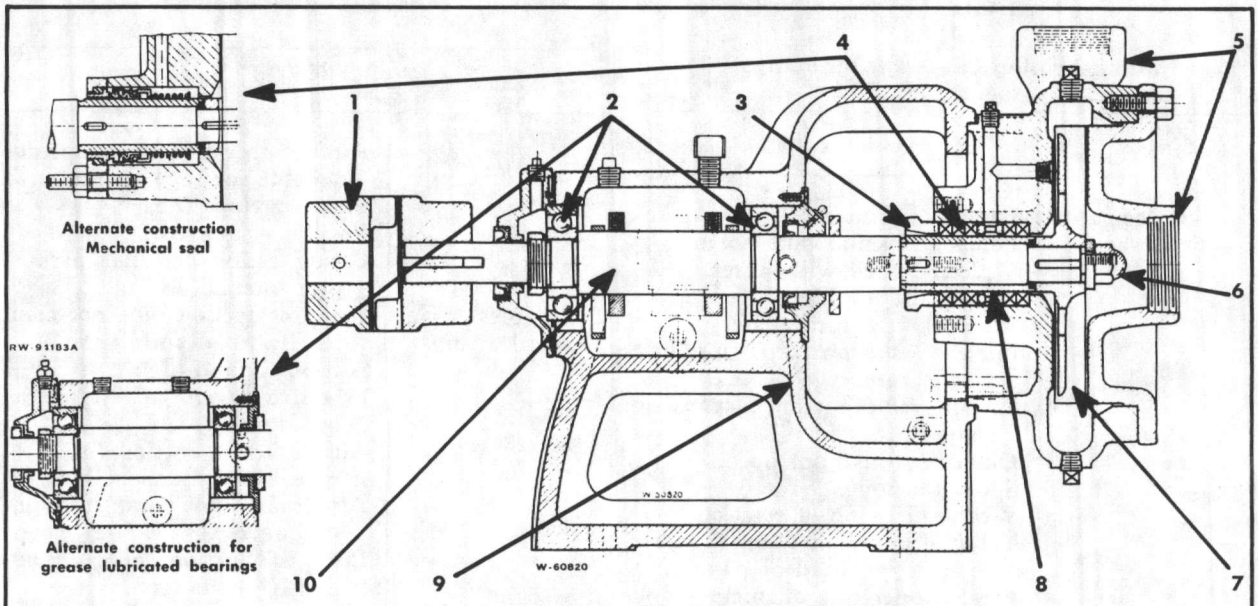


FIGURE 154

Reciprocating Well Pump



1 Flexible coupling

2 Modern ball bearings oil or grease lubricated

3 One-piece packing gland

4 Stuffing box arranged to accommodate either packing and independent seal or a mechanical seal

5 Pipe tapped suction and discharge connections

6 Self-locking impeller nut

7 Open impeller . . . hydraulically balanced . . . pump out vanes keep stuffing box clear of solids

8 Secured shaft sleeve . . . sealed against leakage

9 Box-type rigid cast iron frame

10 Large diameter shaft . . . eliminates vibration

FIGURE 155

Schematic Drawing of Centrifugal Pump Showing Location of Valve, Vents and Glands

3.5.3.1.3 Starting and operating.

(1) Turn the rotor several times by hand to lubricate the bearings. NOTE: It must be possible to turn the rotor by hand whether the pump is hot or cold. If the rotor is bound, do not operate the pump until the cause of the trouble is found and corrected.

(2) Start the driver according to the manufacturer's instructions.

(3) In the turbine-type centrifugal pump, open the discharge valve before starting. In other types, such as the volute pump, open the discharge valve slowly as soon as the pump a'tains full speed. Consult the manufacturer's instructions for each particular pump.

(4) During the routine operation of the pump, the bearings should be inspected occasionally for temperature and proper lubrication.

(5) The amount of valve opening on the liquid seal supply lines must be controlled, and the stuffing box glands so adjusted as to permit a slight seepage of liquid out of the stuffing box at all times during operation This seepage is required in order to prevent excessive wear of the shaft sleeves due to lack of lubrication, and to prevent overheating and damage to the shaft packing.

(6) The flow of water to the bearing housing cooling jackets should also be regulated to maintain proper bearing temperature.

3.5.3.1.4 Stopping.

(1) Normally, there is a check valve in the discharge line close to the pump. In such cases, the pump can be shut down by stopping the driver according to the manufacturer's instructions.

(2) The remaining valves should then be closed in the following order—discharge, suction, cooling water supply and other connections leading to the pump or system.

(3) In some installations, however, the use of a check valve is not feasible because of the creation of pressure surges or water hammer as the result of the sudden closing of the valve under high discharge pressure. *In such cases, the discharge valve should be closed slowly to eliminate the possibility of water hammer.*

3.5.3.1.5 Checklist for operating difficulties. See table 11 for a complete list of symptoms and possible causes of operating difficulties.

3.5.3.2 Rotary Pumps. Most rotary pumps do not require priming. If this step is necessary,

TABLE 11

Troubleshooting Check List for Pumps

Sympton	Possible cause
Pump does not deliver water.	Pump not primed.
	Pump or suction pipe not completely filled with water.
	Suction lift too high.
	Air pocket in suction line.
	Inlet of suction pipe insufficiently submerged.
	Suction valve not open or partially open.
	Discharge valve not open.
	Speed too low.
	Wrong direction of rotation.
	Total head of system higher than design head of pump.
	Parallel operation of pumps unsuitable for such operation.
	Foreign matter in impeller.
Insufficient capacity delivered.	Pump or suction pipe not completely filled with water.
	Suction lift too high.
	Excessive amount of air or gas in water.
	Air pocket in suction line.
	Air leaks into suction line.
	Air leaks into pump through stuffing boxes.
	Foot valve too small.
	Foot valve partially clogged.
	Inlet of suction pipe insufficiently submerged.
	Suction valve only partially open.
	Discharge valve only partially open.
	Speed too low.
	Total head of system higher than design head of pump.
	Parallel operation of pumps unsuitable for such operation.
	Foreign matter in impeller.
	Wearing rings worn.
	Impeller damaged.
	Casing gasket defective permitting internal leakage.
Insufficient pressure developed.	Excessive amount of air or gas in water.
	Speed too low.
	Wrong direction of rotation.
	Total head of system higher than design head of pump.

TABLE 11 (Continued)

Sympton	Possible cause
	Parallel operation of pumps unsuitable for such operation.
	Wearing rings worn.
	Impeller damaged.
	Casing gasket defective permitting internal leakage.
Pump loses prime after starting.	Pump or suction pipe not completely filled with water.
	Suction lift too high.
	Excessive amount of air or gas in water.
	Air pocket in suction line.
	Air Leaks into suction line.
	Air leaks into pump through stuffing boxes.
	Inlet of suction pipe insufficiently submerged.
	Water-seal pipe plugged.
	Seal cage improperly located in stuffing box, preventing sealing fluid from entering space to form the seal.
Pump requires excessive power.	Speed too high.
	Wrong direction of rotation.
	Total head of system higher than design head of pump.
	Total head of system lower than pump design head.
	Foreign matter in impeller.
	Misalinement.
	Shaft bent.
	Rotating part rubbing on stationary part.
	Wearing rings worn.
	Packing improperly installed.
	Incorrect type of packing for operating conditions.
	Gland too tight resulting in no flow of liquid to lubricate packing.
Stuffing box leaks excessively.	Seal cage improperly located in stuffing box, preventing sealing fluid entering space to form the seal.
	Misalinement.
	Shaft bent.
	Shaft or shaft sleeves worn or scored at the packing.
	Packing improperly installed.
	Incorrect type of packing for operating conditions.

TABLE 11 (Continued)

Sympton	Possible cause
	Shaft running off center because of worn bearings or misalinement.
	Rotor out of balance resulting in vibration.
	Gland too tight resulting in no flow of liquid to lubricate packing.
	Excessive clearance at bottom of stuffing box between shaft and casing, causing packing to be forced into pump interior.
	Dirt or grit in sealing liquid, leading to scoring of shaft or shaft sleeve.
Packing has short life.	Water-seal pipe plugged.
	Seal cage improperly located in stuffing box, preventing sealing fluid from entering space to form the seal.
	Misalinement.
	Shaft bent.
	Bearings worn.
	Shaft or shaft sleeves worn or scored at the packing.
	Packing improperly installed.
	Incorrect type of packing for operating conditions.
	Shaft running off center because of worn bearings or misalinement.
	Rotor out of balance resulting in vibration.
	Gland too tight resulting in no flow of liquid to lubricate packing.
	Failure to provide cooling liquid to watercooled stuffing boxes.
	Excessive clearance at bottom of stuffing box between shaft and casing, causing packing to be forced into pump interior.
	Dirt or grit in sealing liquid, leading to scoring of shaft or shaft sleeve.
Pump vibrates or is noisy.	Pump or suction pipe not completely filled with water.
	Suction lift too high.
	Foot valve too small.
	Foot valve partially clogged.

TABLE 11 (Continued)

Sympton	Possible cause
	Inlet of suction pipe insufficiently submerged.
	Operation at very low capacity.
	Foreign matter in impeller.
	Misalinement.
	Foundations not rigid.
	Shaft bent.
	Rotating part rubbing on stationary part.
	Bearings worn.
	Impeller damaged.
	Shaft running off center because of worn bearings or misalinement.
	Rotor out of balance resulting in vibration.
	Dirt or grit in sealing liquid, leading to scoring of shaft or shaft sleeve.
	Excessive grease or oil in antifriction-bearing housing, or lack of cooling, causing excessive bearing temperature.
	Lack of lubrication.
	Improper installation of antifriction bearings (damage during assembly, incorrect assembly of stacked bearings, use of unmatched bearings as a pair, etc.).
	Dirt getting into bearings.
	Rusting of bearings because of water getting into housing.
	Excessive cooling of watercooled bearing resulting in condensation in the bearing housing of moisture from the atmosphere.
Bearings have short life.	Misalinement.
	Shaft bent.
	Rotating part rubbing on stationary part.
	Bearings worn.
	Shaft running off center because of worn bearings or misalinement.
	Rotor out of balance resulting in vibration.
	Excessive thrust caused by a mechanical failure inside the pump or by the failure of the hydraulic balancing device, if any.

TABLE 11 (Continued)

Sympton	Possible cause
	Excessive grease or oil in anti-friction-bearing housing or lack of cooling, causing excessive bearing temperature.
	Lack of lubrication.
	Improper installation of anti-friction bearings (damage during assembly, incorrect assembly of stacked bearings, use of unmatched bearings as a pair, etc.).
	Dirt getting into bearings.
	Rusting of bearings because of water getting into housing.
	Excessive cooling of water-cooled bearing resulting in condensation in the bearing housing of moisture from the temperature.
Pump overheats and seizes.	Pump not primed.
	Operation at very low capacity.
	Parallel operation of pumps unsuitable for such operation.
	Misalinement.
	Rotating part rubbing on stationary part.
	Bearings worn.
	Shaft running off center because of worn bearings or misalinement.
	Rotor out of balance resulting in vibration.
	Excessive thrust caused by a mechanical failure inside the pump or by the failure of the hydraulic balancing device, if any.
	Lack of lubrication.

however, follow the procedures outlined in paragraph 3.5.3.1. Rotary pumps depend upon clearance for efficiency. Keep grit or other abrasive materials out of the water being pumped to prevent excessive wear and rapid loss of efficiency and self-priming ability. Always start the pump with suction and discharge valves open to prevent overload of the motor and damage to the pump. *If the discharge valve is closed, the pump mechanism may be seriously damaged.* A pressure relief valve which discharges back to the suction side of the pump is usually provided on the outlet piping. Adjust this valve for a relief pressure which will not overload the motor. Make sure the valve seats properly at normal pressure, otherwise loss of efficiency and priming ability will result. The relief valve should be checked weekly to determine that it is functioning properly. Consult Table 11 on operating difficulties for applicable items.

3.5.3.3 Reciprocating Pumps. The general procedures in paragraph 3.5.3.2 should be followed in starting and operating. *It must be emphasized that the discharge valve on the reciprocating pump must be open before starting or serious damage to the pump mechanism may result.*

3.5.3.4 Air-Lift Pumps. The principal precaution in the operation of an air-lift pump is to assure that the correct volume of air is being used. The volume of air should be the minimum required to produce a continuous flow. Lesser amounts cause discharge in spurts. Greater amounts cause more discharge at lower efficiency. If air is increased still further, discharge is reduced. The compressor output should be adjusted accordingly.

3.5.3.4.1 Uses. Air-lift pumps are useful for groups of wells discharging to ground storage and served by a single compressor installation. Lower efficiency is offset by lack of maintenance problems, especially in crooked wells and those producing sand. They are particularly adapted for emergency deep-well pumping using a portable air compressor for power. Air-lift pumps cannot be used for direct pumping to distribution systems or for horizontal transmission of water.

3.5.3.4.2 Operating difficulties. Common operating difficulties and their probable causes are as follows.

(1) The flow does not start. Compressor pressure may be inadequate or air line may have a leak.

(2) Air blows through the eduction pipe without water flow. Bottom of eduction line or foot piece is plugged with sand or clay. Close discharge valve and backblow. If this does not remove the obstruction, raise the eduction pipe and air line 20 to 30 feet and tape the eduction pipe with a hammer. The resulting vibration usually shakes the obstruction out of the pipe. If not, remove it completely and clean.

(3) The compressor builds up pressure, but the pump does not operate. The probable cause is an obstruction in the air line or foot piece, or a closed valve in the air line.

(4) The well pumps in spurts. The well may not be receiving enough air. Check for closed or clogged valves in the air line, or inadequate compressor delivery.

(5) The water level is lowered to a point where submergence is too low to pump at capacity with the air available. The probable cause is insufficient water entering the well. Check the capacity records to determine whether the well needs cleaning or backblowing.

3.5.3.5 Turbine Well Pumps. The general procedures for starting and operating centrifugal

pumps, described in paragraph 3.5.3.1 should be followed.

3.5.3.5.1 Uses. Turbine well pumps are used in deep wells 4 inches in diameter or larger.

3.5.3.5.2 Operating difficulties. In addition to the operating difficulties listed in table 11 which may be encountered, there are additional difficulties to watch for in a well installation.

(1) The pump will not start. The impellers are locked, most often caused by sand in the pump. Try raising and lowering the impellers by adjusting the nut. This may free them; if it does not, backwash with clear water.

(2) The pump does not deliver water. The probable cause it that the pumping head is too great. The water table has fallen and the suction lift may be too great. The discharge resistance may have increased to too high a value, also.

(3) The pump capacity is low. The operator should inspect for leaks. Openings in the pipe at flanged or threaded joints cause loss of water. The same is true for gaskets and packing. The operator should check for holes in the bowl, the column pipe or the pump head.

(4) There is too much vibration. The impeller and bowl passages may contain wood, rags, sand or other material that might throw the pump out of balance, or there may be too much wear in rotating parts, thereby causing excessive vibration.

CAUTION: *Before starting and operating a turbine well pump, be certain the discharge valve is open.*

3.5.4 DRIVERS. Modern pumps may be driven by steam turbines, internal combusion engines, or electric motors. The type of driver will depend upon the kind of power available, the size of the pumping unit, the type of pump, the speed control required and other considerations. For complete details and instructions on the operation of these drivers, consult reference 11, as well as manufacturer's instructions. The operation of these various drivers is relatively simple, and the operator should consult reference 11 and the manufacturer's instructions for starting, operating and stopping. In operating drivers, the operator must be on guard against unusual conditions which indicate malfunction. These would include.

(1) Unusual noises in operation.

(2) Motor failing to start or to come up to speed normally.

(3) Motor or bearings which feel or smell hot.

(4) Excessive hum.

(5) Regular clicking.

(6) Rapid knocking.

(7) Vibration.

If these or other conditions indicating operating difficulties are noticed, power should be shut off immediately, and the cause of the malfunction should be located and corrected.

3.5.5 DRIVES. Drives are the mechanisms used to transmit power from the driver to the pump. These include belt drives, chain drives, right-angle gear drives, variable-speed drives and such accessories as gear reducers, gear motors, speed changers, coupling, special shafting and bearings. For complete information on all of these drives and accessories, except chain and right-angle gear types, consult Reference 11. Operating difficulties are covered in detail in that reference. Chain drives may be one of three types—silent chain, single-roller or triple-roller. They may be designed for slow-speed, medium-speed and high-speed. Slow-speed drives are usually not enclosed; medium-speed drives may or may not be enclosed; high-speed drives should always be enclosed completely. Right-angle gear drives are frequently used for deep well pumps. Figure 156 shows the construction of a right-angle gear drive.

3.5.6 PUMPING STATIONS. As noted earlier, pumping stations can be defined as the pumps, piping, valves, gages, controls and the facilities to house them (fig. 157). The principal operating procedures involved include.

(1) Operation of pumps.

(2) Maintenance of the required flow of water.

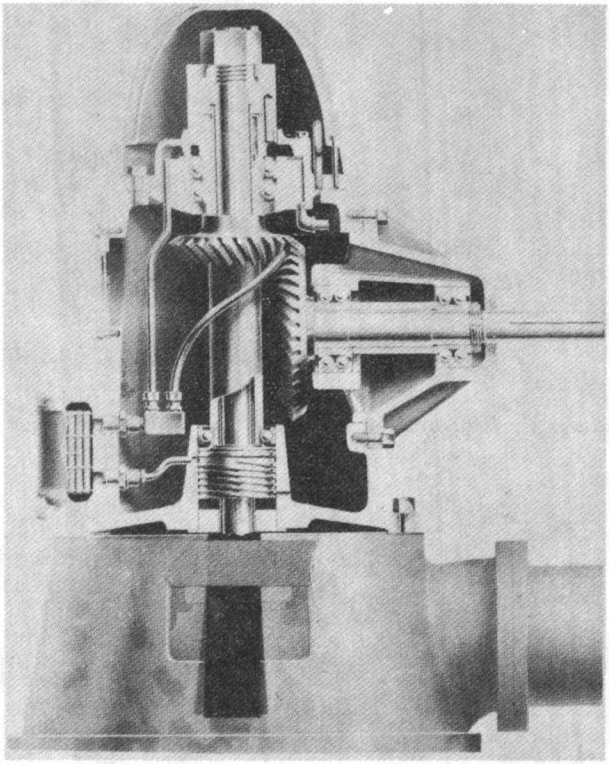


FIGURE 156

Right-Angle Gear Drive

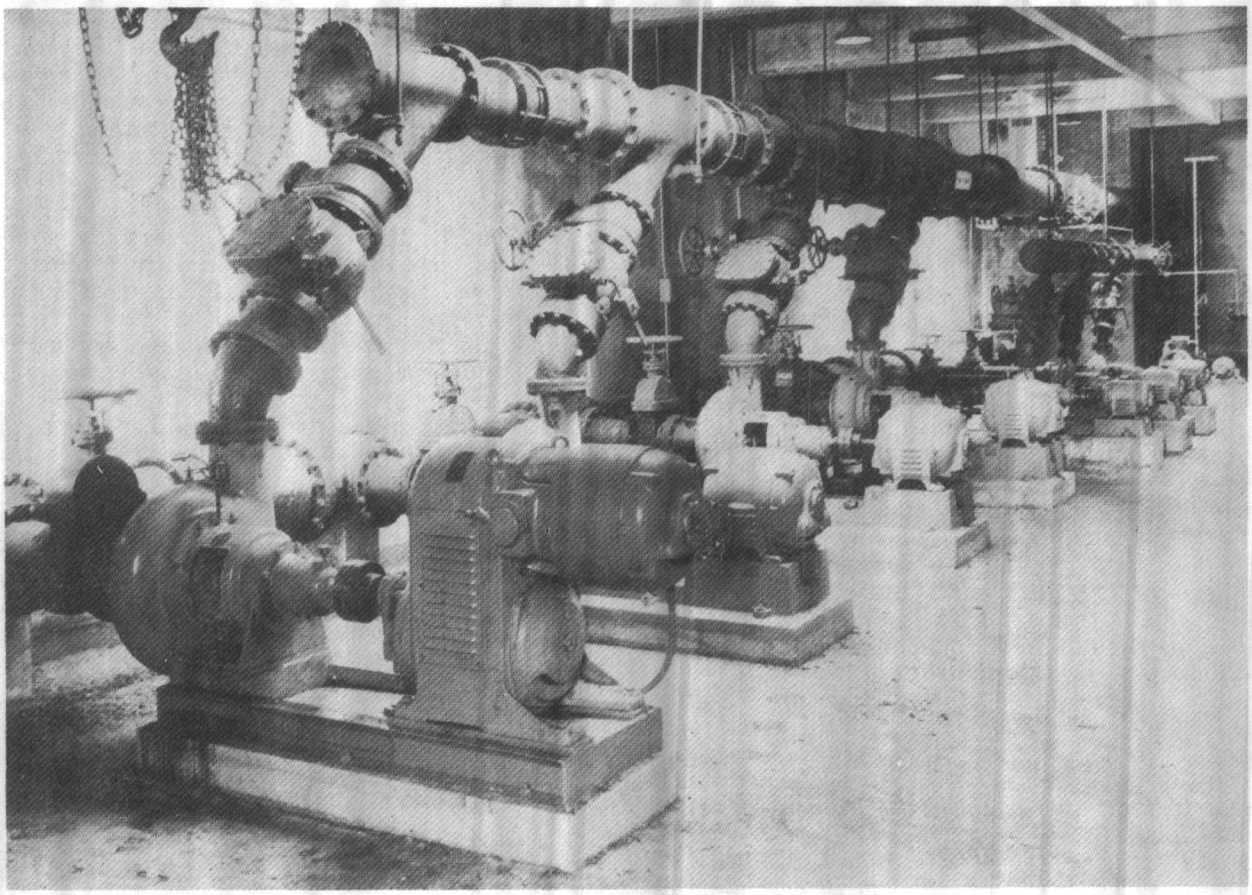


FIGURE 157

Typical Pumping Station

(3) Maintenance of the specified pressure ranges in each part of the distribution system.

(4) Periodic operation of standby equipment.

(5) Maintenance of the required fire-flow as needed.

3.5.6.1 Information Required for Operation. The operator must be familiar with all equipment and accessories, the piping layout, the location of valves and other items of station layout and the function of the particular pumping station. Efficient operation of pumps and pumping stations requires that information about equipment and the plant be readily available, and that information on normal and emergency operation and on maintenance be kept at or near the station.

3.5.6.1.1 Detailed utility map. Required information will include the detailed utility map (see Figure 7).

3.5.6.1.2 Pump information. Maintenance records, pump records and characteristic curves, station plans and design data, manufacturer's instructions, repair parts lists and guarantees are also required information. For each pumping station a chart should be furnished showing capacity at average discharge head of each pump when operating alone, or in combination with others. If operations reveal significant variations from expected performance, the operator should report these variations to higher authority immediately.

3.5.6.1.3 Distribution system information. The operator should know the direction of flow in the distribution system. He must keep the system balanced at all times, maintaining specified pressure ranges in each of its parts. It is particularly important that storage tanks be kept filled by adequate pumping. It is essential that the operator be familiar with the changes required to alter pressures or flows in any section of the distribution system.

3.5.6.2 Manual Controls. At stations with manual controls, operators start and stop pumps as the demand changes, open and close valves as required and maintain close observation of indi-

cating and recording devices, and the functioning of drives and drivers.

3.5.6.3 Automatic Controls. Automatic controls for the operation of pumping stations eliminate the need for constant attendance of an operator, and in some cases provide closer control of operations. For details of automatic controls, see chapter 3, section 6 of this manual.

3.5.6.4 Standby Pumps and Drivers. Standby pumps and drivers must be fully operative at all times to meet fire-flow demands and to replace out-of-service equipment when necessary. They should be run at least once a week, or at intervals established by local command. They should be inspected and serviced regularly, receiving the same attention as regularly operated equipment.

3.5.6.5 Housekeeping. Since plant efficiency depends on cleanliness, keep the machinery and surroundings clean and orderly.

3.5.6.6 Emergencies. Casualty plans to handle all emergencies are developed by local command. The operator must be familiar with these plans so that he can take the proper steps immediately in any emergency.

3.5.6.7 Fire Pumping. Providing maximum water flow to fight fires is one of the most important functions of the pumping station.

3.5.6.7.1 Fire notification. Unless the principal pumping station is manned at all times, arrangements are made for competent personnel to man the pumping station during fires. Telephone service is provided so that the fire chief can communicate readily with the pumping station. A fire station attendant shall notify the pumping station operator of all fires requiring increased water flow.

3.5.6.7.2 Operation of pumps. When an alarm is given, the necessary pump or pumps should be started as soon as possible and pumping maintained to keep storage tanks as nearly full as possible. Pumps and drivers should be run at full rated speed, even if the demand for water is small, until the operator is directed to shut down.

3.5.7 RECORDS. A daily pumping station activity record, showing what pumps were operated, the amount of water supplied, and other pertinent information will be maintained on a form prescribed by local command.

Section 6. INSTRUMENTS AND AUTOMATIC CONTROL

3.6.1 FUNCTION OF INSTRUMENTS. Various indicating and recording instruments are used in water supply systems to supply essential data on the system's performance. The information thus supplied alerts the operator to possible malfunctioning of equipment, leaks, and/or the need for adjustment in flow, pressure, chemical feed and the like. These indicating and recording instruments may have the second vital function of feeding the necessary information into control apparatus for the automatic operation of the water supply system equipment used in maintaining proper pressures, effective treatment processes and desired output, i.e., pumps, valves and chemical feeders.

3.6.2 INDICATING AND RECORDING INSTRUMENTS. Indicating and recording instruments range from direct-reading gages to the more complex instruments that receive more than one type of information from various sensing devices and integrate these data for control purposes.

3.6.2.1 Direct-Reading Gages. This type of gage (see fig. 158) is an indicating instrument used throughout the water supply system to give the operator an immediate reading of a particular variable (i.e., pressure, flow, water level, etc.). The scale is graduated in units according to the particular variable being measured, such as pounds per square inch for pressure, or gallons per minute for flow rate. Direct-reading gages supply information for immediate manual control of a particular condition by the operator. By reading the gage, he can determine whether or not he should increase or decrease flow, open or shut certain valves, or throttle or increase pump operation. Likewise, in the treatment plant, the operator can determine the need for chemical feed adjustment in the same manner. It is good practice to tap the gage gently before reading, to make sure the indicating hand is not sticking. Unauthorized personnel should not attempt to adjust a gage or recording instrument. The majority of trouble comes from tampering by inexperienced personnel. Only qualified technicians shall check and/or adjust these instruments.

3.6.2.2 Recording Instruments. The pointer of an indicating instrument may be supplied with a pen or stylus arranged to travel over a paper chart which is in continuous motion. There are three principal types of recorders; those using: (1) a round or circular chart; (2) a strip or roll chart which is continuously unwound from a roll; and, (3) a strip chart mounted on a drum. The first two are the more common . The speed of the chart may be governed by a clock, in which case the variable is plotted against time; or the speed may be controlled by the instantaneous rate of some other variable such as flow, in which case the variable being measured is plotted against the second variable controlling the chart speed. Recorders, then, consist of a sensing or detecting mechanism, an indicating pen or stylus, a chart, a means for advancing the chart and a case for enclosing the entire mechanism (see fig. 159).

3.6.2.2.1 Recorder mechanism. In most round-chart instruments the position of the pen is controlled by a mechanical linkage. Since the indicating mechanism in some roll-chart instruments has little power, special means must be taken to minimize friction of the pen or stylus on the chart. Hence, a frequent procedure is to impress the indicator on the chart at intervals by means of a clock-driven depressor or chopper bar.

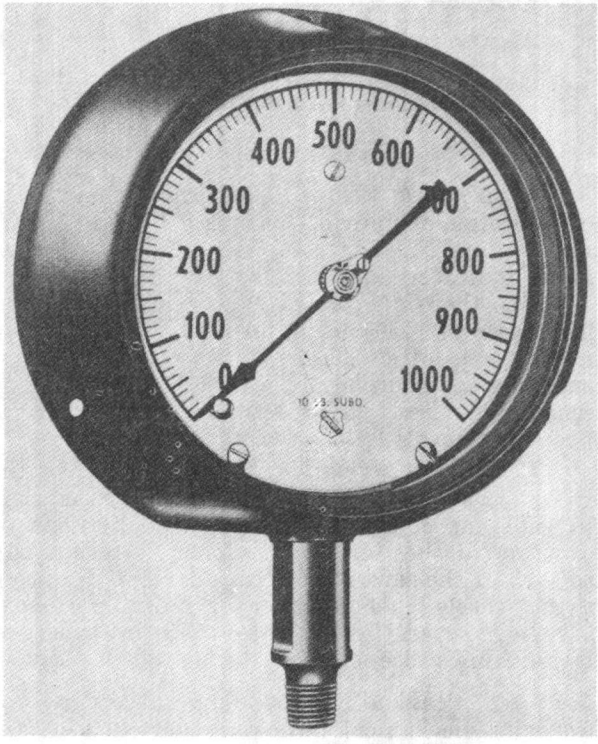


FIGURE 158

Typical Direct-Reading Pressure Gage

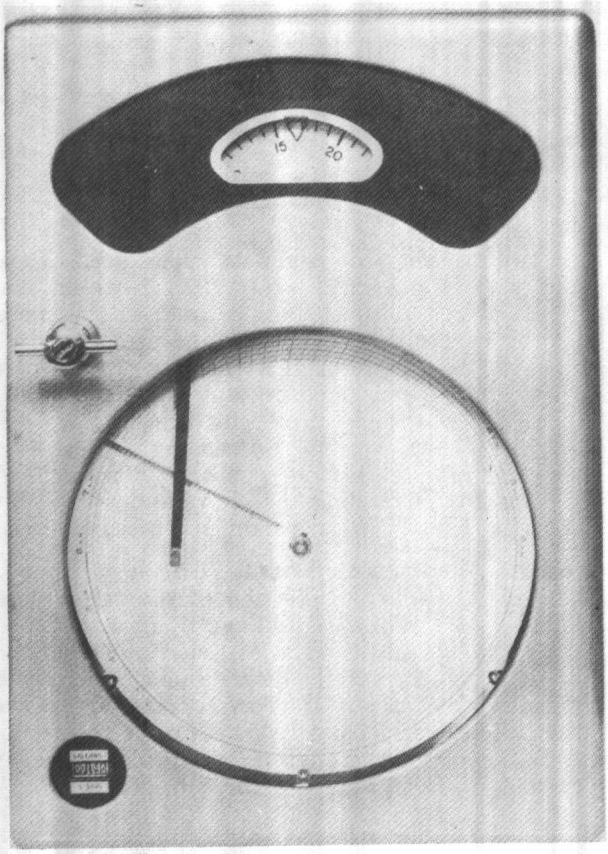


FIGURE 159

Round-Chart Recorder and Indicator

(1) Types of Records. Recorders may make either single or multiple records. In round-chart instruments, this is accomplished by the use of as many indicators and pens recording on the same chart as there are records. A roll-chart instrument (see fig. 160) using an electrical indicating mechanism, often has one indicator which is switched consecutively to a series of detecting or sensing devices. The switch is operated at proper intervals by the clock.

(2) Line Distinguishing. In order that the records may be distinguished, points are marked in different colors, by various combinations of dots and dashes, or by a number corresponding to each of the several detecting devices. Rotating print wheels, carbon paper or movable ribbons carrying several colors are used in this distinguishing process.

3.6.2.2.2 Pens and styluses. Single record recorders with mechanical indicating devices use capillary pens consisting of a reservoir for ink, and terminating in a point which is held against the chart. Pens are made of glass, monel metal or some other corrosion-resisting material. For recorder movements with little power, or for very rapid fluctuations, a stylus is more generally used. For continuous contact, the charts may be coated with wax or finely divided carbon. In intermittent contact (depressor bar) instruments, the stylus prints through a piece of carbon paper or a typewriter ribbon. Procedures for refilling pens, replacing carbon paper or typewriter ribbons are given in the manufacturer's instruction.

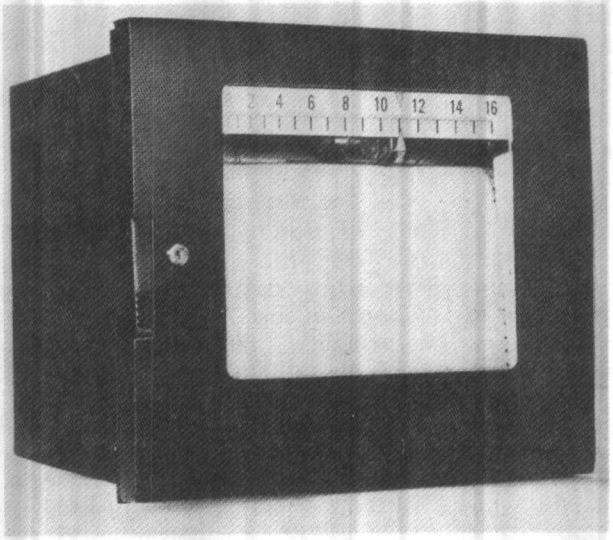


FIGURE 160

Roll or Strip Chart Recorder

3.6.2.2.3 Charts. Round charts are marked with concentric circles representing values of the variable, and radial arcs representing time. Round-chart records are for 24 hours or 7 days, and in diameters from 6 to 12 inches. Roll-charts are made in lengths up to 90 feet and widths to 12 inches. Lengthwise lines are provided for values of the variable, and crosslines for time. Chart speeds in standard strip-chart instruments vary from ½ to 6 inches per hour, with extremes of from 1 inch per day to 12 inches per minute. When charts are filled and replaced, the filled chart is filed for future reference for a period of time designated by local command.

3.6.2.2.4 Clocks. Clocks may be either spring-driven or the synchronous electric type, when alternating current is available. In round-chart instruments, the clock furnishes the power to rotate the chart, but in strip- and roll-chart records, the clock is used only to operate electric contacts which in turn cause a solenoid to move the chart and the depressor bar.

3.6.2.3 Operation. It is the operator's responsibility to make certain that.

(1) Each recorder has the proper chart and reserve supplies available.

(2) Marking mechanisms are functioning properly.

(3) Recorders using ink have an adequate ink supply in the reservoir, and a reserve supply available.

(4) Spring-driven recorders are wound according to the manufacturer's recommendations.

(5) Charts are changed at specified times.

(6) When a chart is removed from a recorder, it is clearly marked with the date, instrument number, and data measured.

(7) The chart is filed for future reference for a period of time designated by local command.

3.6.3 AUTOMATIC CONTROL. By automatic control, the opening and closing of valves, and starting and stopping of pumps can be carried out without action on the part of the operator. The operator, however, should be familiar with all automatic controls and should maintain observation of their operation at regular intervals established by local command. Because of the wide variety of automatic controls now in use, it is possible here to give only a general description of the methods involved. Operators should consult the manufacturer's instructions for complete details for each particular piece of equipment.

3.6.3.1 Controlling Agents. The controlling agent may be the rising and falling of water in a filter or water tank; the pressure in a water main; the rate of flow in a main; a clock or timing device; conductivity; pH; or, even turbidity.

3.6.3.1.1 Water level. Where water level fluctuation is the controlling agent, there are several devices that may be used.

(1) Float-Operated Switch. A float may be used as a sensing device which throws a switch when it rises to a given point, and another switch when it falls to another lower point. The switches make or break contacts closing or opening circuits in the control apparatus.

(2) Electrodes. In another type, two electrodes may be suspended at two elevations, so that when the water reaches the upper one, it causes a relay switch to be thrown in one direction, and when the water falls below the lower electrode, it causes the switch to be thrown in the other direction.

(3) Float-Operated Valve. A float may operate a valve (or its pilot valve) directly (see fig. 161), being connected to it by means of a lever or cord passing over a pulley.

(4) Pressure Sensor. Instead of a float, the pressure in a pipe connected to a tank or reservoir may be used as the sensing device.

(5) Bubble Pipe. A bubble control may be used for starting and stopping pumps. In operation, a compressor forces just enough air through a tube immersed in the suction tank to assure a continuous escape of bubbles. As the level of the measured liquid changes, a diaphragm reflects a corresponding change in back pressure in the tube, and actuates a switch.

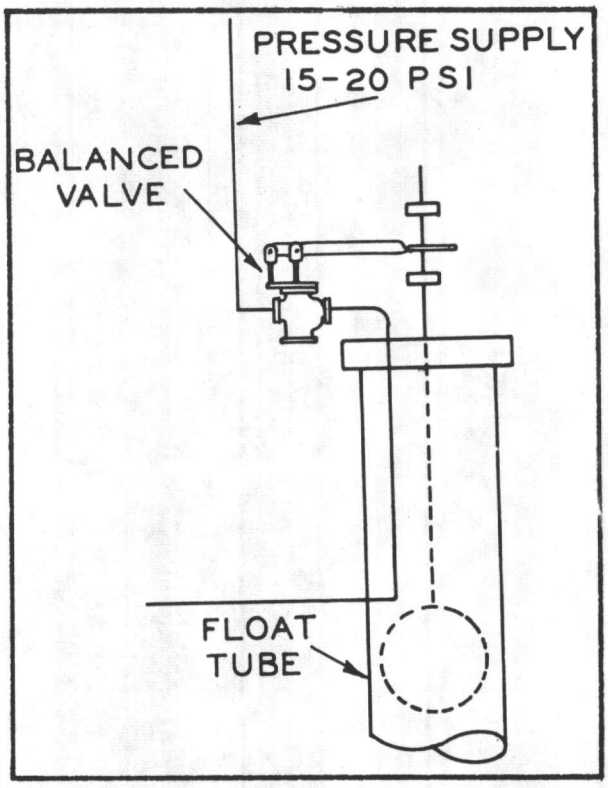


FIGURE 161

Float-Operated Control

3.6.3.1.2 Pressure. In pressure control, the sensing device is a diaphragm (in some cases a bellows or piston), acted upon by the pressure or a pressure differential exerted by the water (see fig. 162). The pressure is counteracted by a weight or spring so adjusted that when the pressure exceeds that for which it is set, the diaphragm moves and actuates a pump, valve or other device. This type of control may be used for normally closed valves which may be opened automatically when the pressure on one side falls below a certain level (as in valves separating high and low service districts).

3.6.3.1.3 Other controlling agents. A clock (see fig. 163) may be used to start a pump or open a valve at a given time, by setting a pin with which the clock hand makes contact. The pump can be stopped or the valve closed at another given time. At some installations, photoelectric relays have been installed which will sound an alarm or operate a pilot when the turbidity exceeds a certain limit, permitting automatic increase of the coagulant feed.

3.6.3.2 Control of Valves. Gate valves and butterfly valves used in automatic control are ordinarily operated by either air cylinders, hydraulic cylinders or electric motors (see fig. 164).

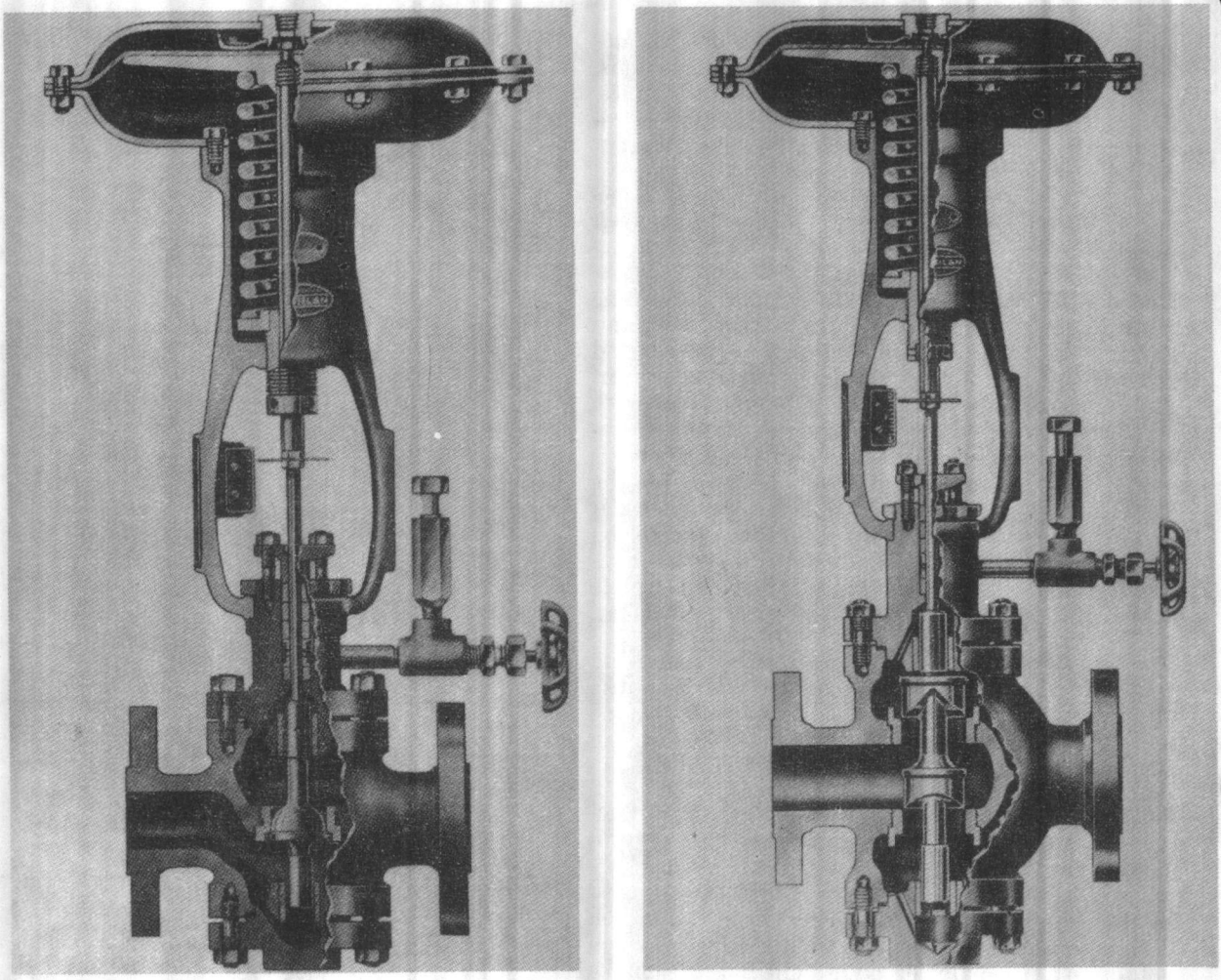


FIGURE 162

Cutaway Drawing of Two Pressure Control Devices

3.6.3.3 Control of Pumps. A pump may be started and stopped by any of the controlling agents previously listed, but pressure in the mains, and electric impulse from a remote control station are most common. The former commonly operates through electric current, a pressure gage, or similar device being provided with one contact point set at the pressure at which it is desired to start the pump, and another at the pressure at which the pump is to be stopped. Pumps which are controlled automatically, or by remote control, must be provided with self-priming devices.

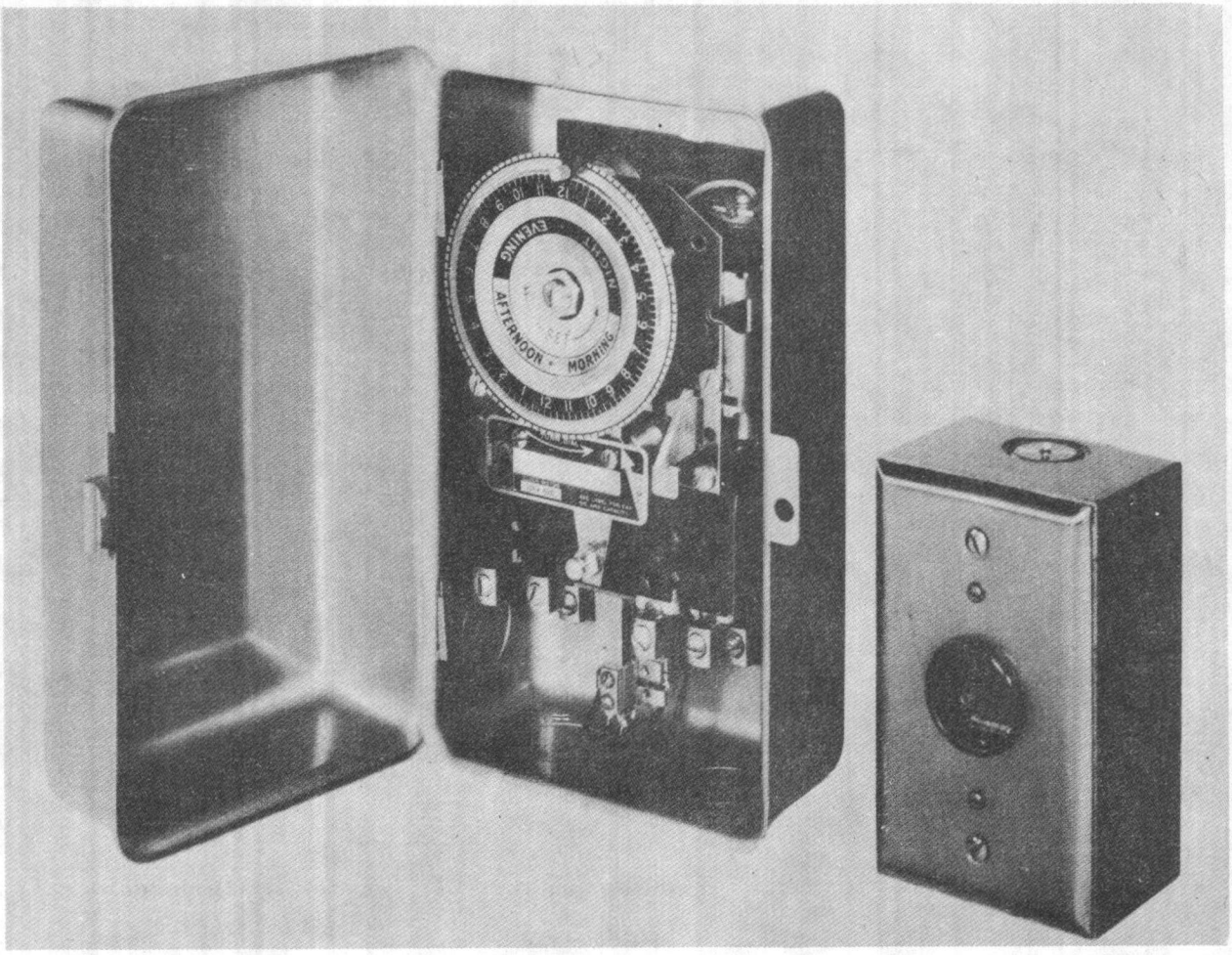
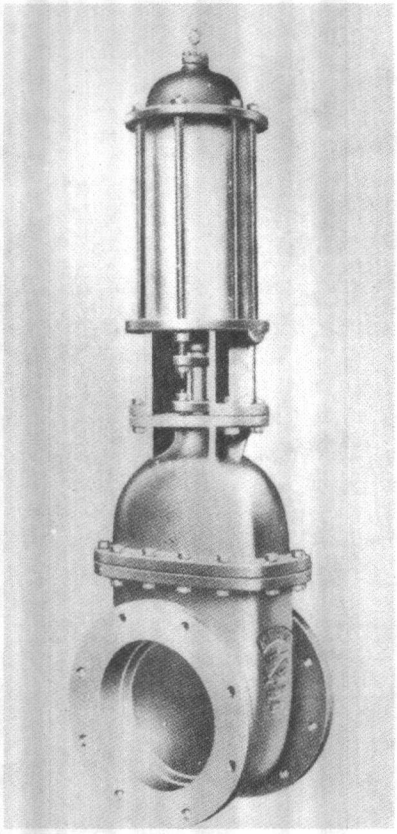
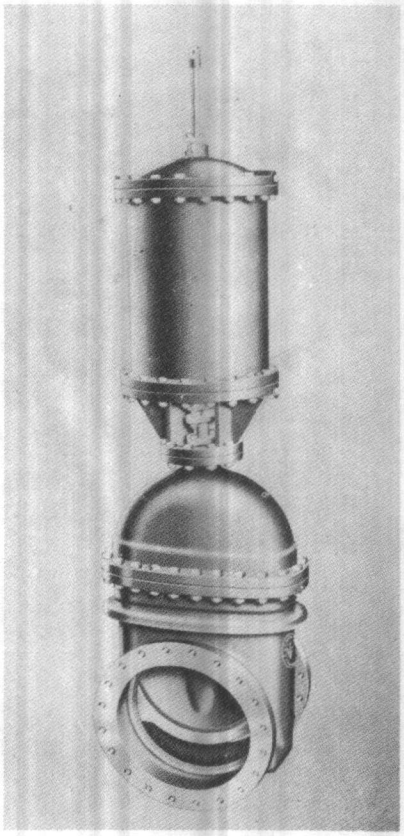


FIGURE 163

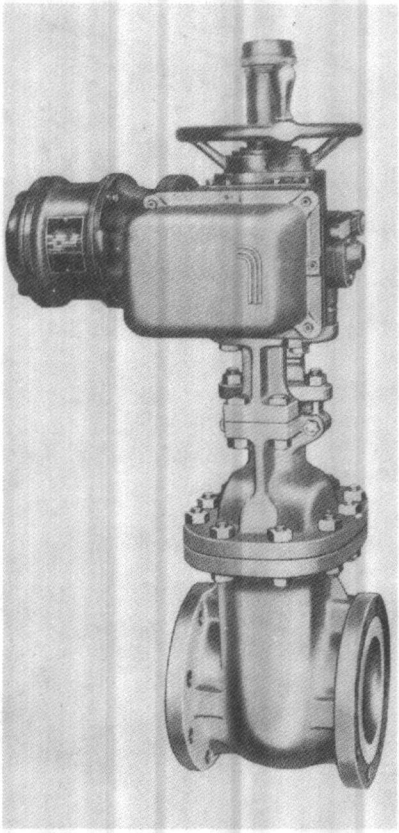
Time Control Clock



(A) Pneumatic



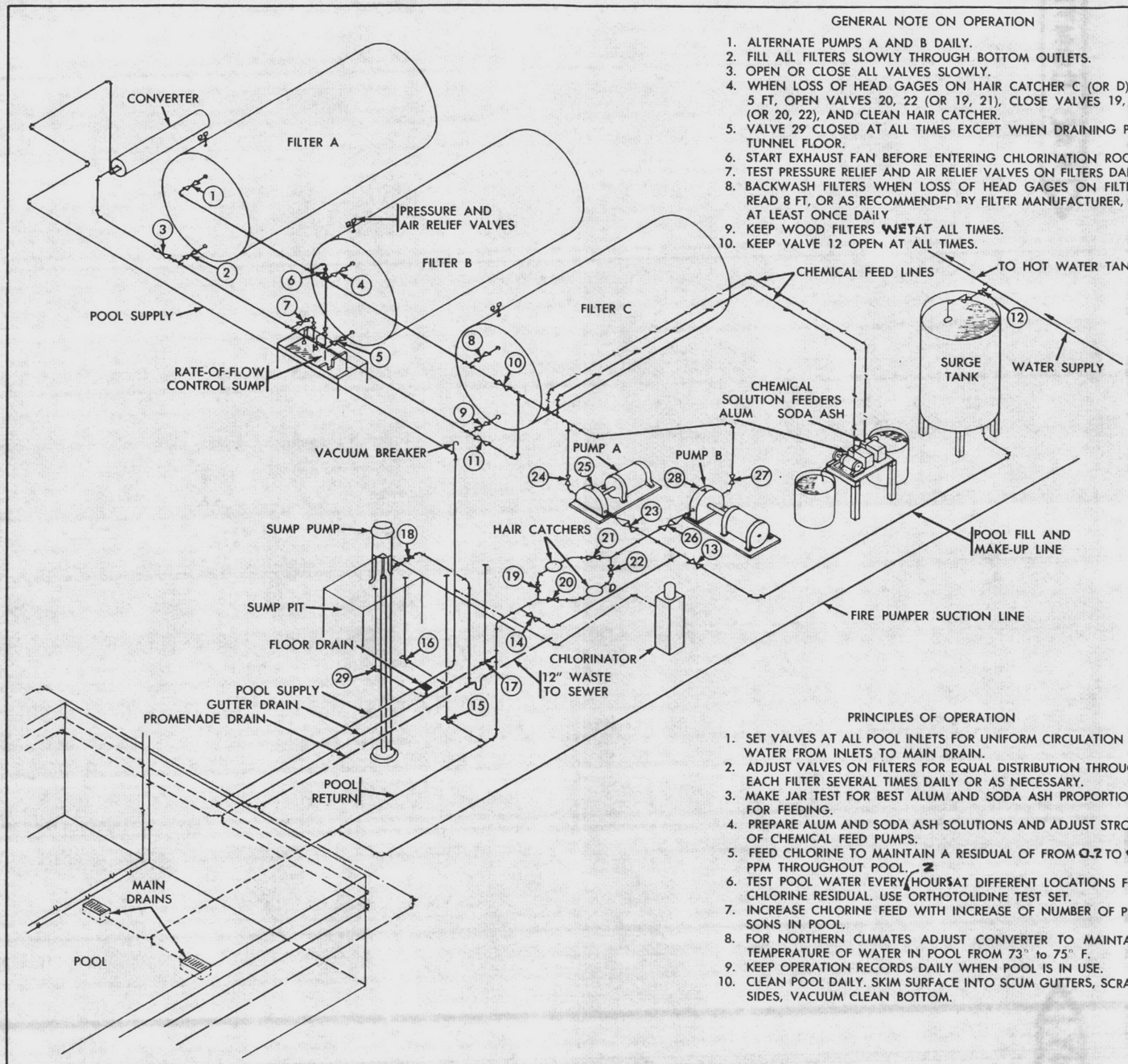
(B) Hydraulic



(C) Electric

FIGURE 164

Valve Control Cylinders



GENERAL NOTE ON OPERATION

1. ALTERNATE PUMPS A AND B DAILY.
2. FILL ALL FILTERS SLOWLY THROUGH BOTTOM OUTLETS.
3. OPEN OR CLOSE ALL VALVES SLOWLY.
4. WHEN LOSS OF HEAD GAGES ON HAIR CATCHER C (OR D) IS 5 FT, OPEN VALVES 20, 22 (OR 19, 21), CLOSE VALVES 19, 21 (OR 20, 22), AND CLEAN HAIR CATCHER.
5. VALVE 29 CLOSED AT ALL TIMES EXCEPT WHEN DRAINING PIPE TUNNEL FLOOR.
6. START EXHAUST FAN BEFORE ENTERING CHLORINATION ROOM.
7. TEST PRESSURE RELIEF AND AIR RELIEF VALVES ON FILTERS DAILY.
8. BACKWASH FILTERS WHEN LOSS OF HEAD GAGES ON FILTERS READ 8 FT, OR AS RECOMMENDED BY FILTER MANUFACTURER, OR AT LEAST ONCE DAILY
9. KEEP WOOD FILTERS WET AT ALL TIMES.
10. KEEP VALVE 12 OPEN AT ALL TIMES.

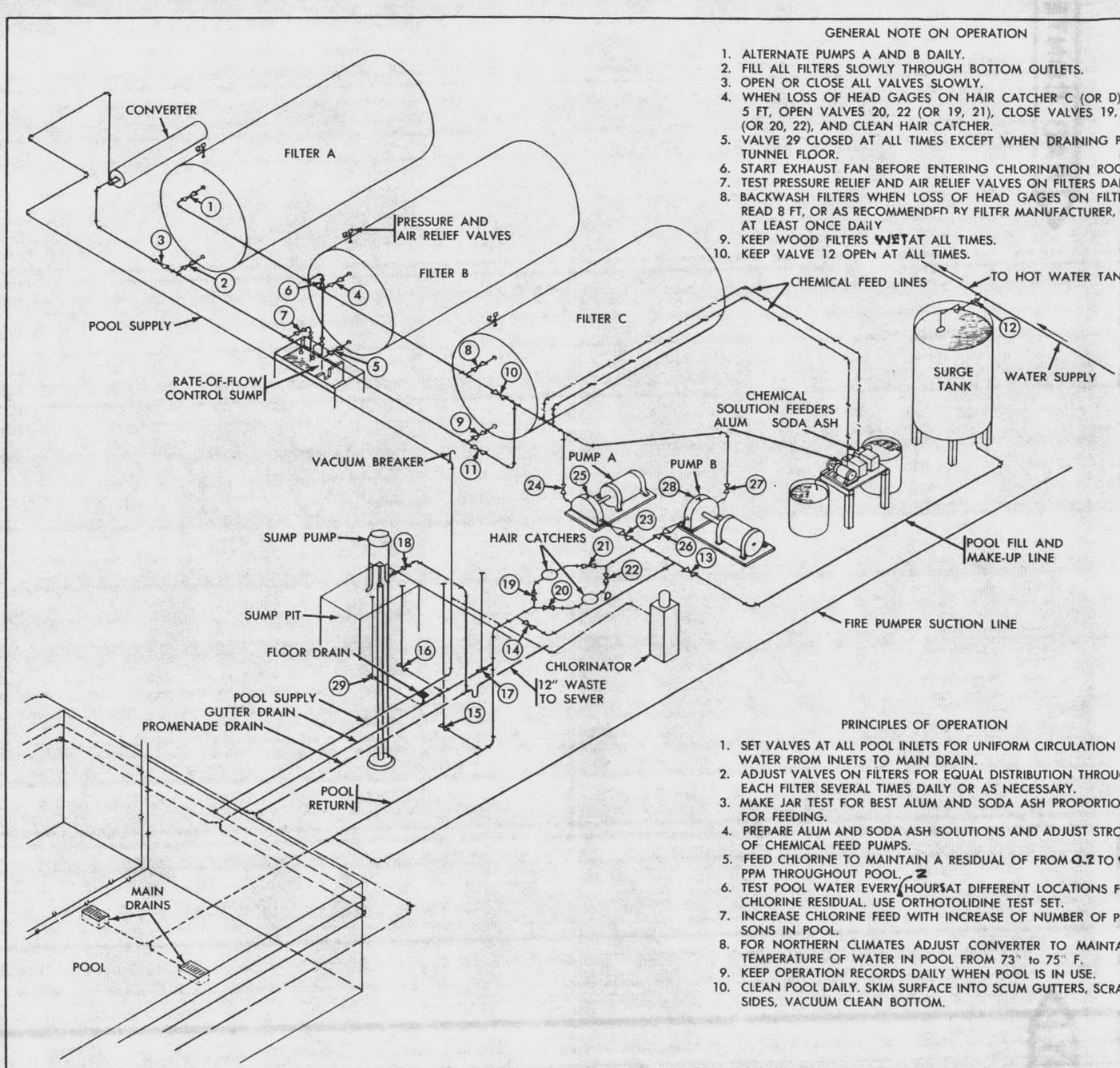
PRINCIPLES OF OPERATION

1. SET VALVES AT ALL POOL INLETS FOR UNIFORM CIRCULATION OF WATER FROM INLETS TO MAIN DRAIN.
2. ADJUST VALVES ON FILTERS FOR EQUAL DISTRIBUTION THROUGH EACH FILTER SEVERAL TIMES DAILY OR AS NECESSARY.
3. MAKE JAR TEST FOR BEST ALUM AND SODA ASH PROPORTIONS FOR FEEDING.
4. PREPARE ALUM AND SODA ASH SOLUTIONS AND ADJUST STROKE OF CHEMICAL FEED PUMPS.
5. FEED CHLORINE TO MAINTAIN A RESIDUAL OF FROM 0.2 TO 0.6 PPM THROUGHOUT POOL.
6. TEST POOL WATER EVERY 2 HOURS AT DIFFERENT LOCATIONS FOR CHLORINE RESIDUAL. USE ORTHOTOLIDINE TEST SET.
7. INCREASE CHLORINE FEED WITH INCREASE OF NUMBER OF PERSONS IN POOL.
8. FOR NORTHERN CLIMATES ADJUST CONVERTER TO MAINTAIN TEMPERATURE OF WATER IN POOL FROM 73° to 75° F.
9. KEEP OPERATION RECORDS DAILY WHEN POOL IS IN USE.
10. CLEAN POOL DAILY. SKIM SURFACE INTO SCUM GUTTERS, SCRAPE SIDES, VACUUM CLEAN BOTTOM.

INSTRUCTIONS FOR OPERATION	
TO FILL POOL (FROM EMPTY)	CHEMICAL SOLUTION FEEDERS AND CHLORINATOR OFF. CLOSE ALL VALVES EXCEPT 12, 13, 14, 16, 18. FILL POOL.
TO START FILTERS (FILTERS EMPTY WITH POOL FULL)	CLOSE VALVE 14; OPEN VALVES 1, 4, 6, 8, 11, 23 (OR 26), 24 (OR 27). CRACK VALVES: 2, 5, 9. START PUMP A (OR PUMP B). OPEN PETCOCK 25 (OR 28). WHEN PUMP IS PRIMED, CLOSE PETCOCK 25 (OR 28), OPEN VALVE 19 (OR 20), AND SLOWLY OPEN VALVE 21(OR 22). THEN CLOSE VALVE 13. WHEN WATER FLOWS THROUGH VALVE 6, OPEN VALVES 7, 10 AND CLOSE 11, 6. ADJUST VALVES 2, 5, 9 TO EQUALIZE FLOW THROUGH FILTERS A, B, C AT 3 GPM PER SQ FT AS SHOWN ON RATE-OF-FLOW INDICATOR OF EACH FILTER. TEST AIR RELIEF VALVE ON EACH FILTER. CHECK CONVERTER FOR STEAM. OPEN VALVE 3, CLOSE VALVE 7. EQUIPMENT IS NOW IN FILTER POSITION.
TO BACKWASH FILTERS (FROM FILTER POSITION)	SHUT OFF CHEMICAL SOLUTION FEEDERS AND CHLORINATOR. OPEN VALVES 6, 11 AND CLOSE VALVES 3, 10. TO BACKWASH FILTER A, CLOSE VALVES 5, 9. TO BACKWASH FILTER B, CLOSE VALVES 2, 9; OPEN VALVE 5. TO BACKWASH FILTER C, CLOSE VALVES 2, 5; OPEN VALVE 9. BACKWASH EACH FILTER AS DIRECTED BY FILTER MANUFACTURER. EQUIPMENT IS NOW IN BACKWASH POSITION.
TO RINSE TO WASTE (FROM BACKWASH POSITION)	OPEN VALVES 2, 5, 7, 10. CLOSE VALVES 6, 11. START CHEMICAL SOLUTION FEEDERS. RINSE TO WASTE AS DIRECTED BY FILTER MANUFACTURER. EQUIPMENT IS NOW IN RINSE TO WASTE POSITION.
TO FILTER (FROM RINSE TO WASTE POSITION)	OPEN VALVE 3; CLOSE VALVE 7. START CHLORINATOR. CHECK CONVERTER FOR STEAM. ADJUST VALVES 2, 5, 9 FOR EQUAL FLOW OF 3 GPM PER SQ FT AS SHOWN ON RATE-OF-FLOW INDICATOR OF EACH FILTER. EQUIPMENT IS NOW IN FILTER POSITION.
TO EMPTY POOL (FROM FILTER POSITION)	SHUT OFF CHEMICAL SOLUTION FEEDERS, CHLORINATOR, AND STEAM AT CONVERTER. OPEN VALVE 6. CLOSE VALVES 2, 5, 9, 1, 4, 8, 3. WHEN PUMP A (OR B) DRAWS AIR, STOP PUMP AND OPEN VALVE 15.
TO RECIRCULATE GUTTER DRAIN WATER USE ONLY WHEN ORDERED	CLOSE VALVE 16; OPEN VALVE 17.

FIGURE 165

50-Meter Swimming Pool Instructions for Operation of Sand Filters



GENERAL NOTE ON OPERATION

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2. FILL ALL FILTERS SLOWLY THROUGH BOTTOM OUTLETS.
3. OPEN OR CLOSE ALL VALVES SLOWLY.
4. WHEN LOSS OF HEAD GAGES ON HAIR CATCHER C (OR D) IS 5 FT, OPEN VALVES 20, 22 (OR 19, 21), CLOSE VALVES 19, 21 (OR 20, 22), AND CLEAN HAIR CATCHER.
5. VALVE 29 CLOSED AT ALL TIMES EXCEPT WHEN DRAINING PIPE TUNNEL FLOOR.
6. START EXHAUST FAN BEFORE ENTERING CHLORINATION ROOM.
7. TEST PRESSURE RELIEF AND AIR RELIEF VALVES ON FILTERS DAILY.
8. BACKWASH FILTERS WHEN LOSS OF HEAD GAGES ON FILTERS READ 8 FT, OR AS RECOMMENDED BY FILTER MANUFACTURER, OR AT LEAST ONCE DAILY
9. KEEP WOOD FILTERS WET AT ALL TIMES.
10. KEEP VALVE 12 OPEN AT ALL TIMES.

PRINCIPLES OF OPERATION

1. SET VALVES AT ALL POOL INLETS FOR UNIFORM CIRCULATION OF WATER FROM INLETS TO MAIN DRAIN.
2. ADJUST VALVES ON FILTERS FOR EQUAL DISTRIBUTION THROUGH EACH FILTER SEVERAL TIMES DAILY OR AS NECESSARY.
3. MAKE JAR TEST FOR BEST ALUM AND SODA ASH PROPORTIONS FOR FEEDING.
4. PREPARE ALUM AND SODA ASH SOLUTIONS AND ADJUST STROKE OF CHEMICAL FEED PUMPS.
5. FEED CHLORINE TO MAINTAIN A RESIDUAL OF FROM 0.2 TO 0.6 PPM THROUGHOUT POOL.
6. TEST POOL WATER EVERY 2 HOURS AT DIFFERENT LOCATIONS FOR CHLORINE RESIDUAL. USE ORTHOTOLIDINE TEST SET.
7. INCREASE CHLORINE FEED WITH INCREASE OF NUMBER OF PERSONS IN POOL.
8. FOR NORTHERN CLIMATES ADJUST CONVERTER TO MAINTAIN TEMPERATURE OF WATER IN POOL FROM 73° to 75° F.
9. KEEP OPERATION RECORDS DAILY WHEN POOL IS IN USE.
10. CLEAN POOL DAILY. SKIM SURFACE INTO SCUM GUTTERS, SCRAPE SIDES, VACUUM CLEAN BOTTOM.

INSTRUCTIONS FOR OPERATION	
TO FILL POOL (FROM EMPTY)	CHEMICAL SOLUTION FEEDERS AND CHLORINATOR OFF. CLOSE ALL VALVES EXCEPT 12, 13, 14, 16, 18. FILL POOL.
TO START FILTERS (FILTERS EMPTY WITH POOL FULL)	CLOSE VALVE 14; OPEN VALVES 1, 4, 6, 8, 11, 23 (OR 26), 24 (OR 27). CRACK VALVES: 2, 5, 9. START PUMP A (OR PUMP B). OPEN PETCOCK 25 (OR 28). WHEN PUMP IS PRIMED, CLOSE PETCOCK 25 (OR 28), OPEN VALVE 19 (OR 20), AND SLOWLY OPEN VALVE 21(OR 22). THEN CLOSE VALVE 13. WHEN WATER FLOWS THROUGH VALVE 6, OPEN VALVES 7, 10 AND CLOSE 11, 6. ADJUST VALVES 2, 5, 9 TO EQUALIZE FLOW THROUGH FILTERS A, B, C AT 3 GPM PER SQ FT AS SHOWN ON RATE-OF-FLOW INDICATOR OF EACH FILTER. TEST AIR RELIEF VALVE ON EACH FILTER. CHECK CONVERTER FOR STEAM. OPEN VALVE 3, CLOSE VALVE 7. EQUIPMENT IS NOW IN FILTER POSITION.
TO BACKWASH FILTERS (FROM FILTER POSITION)	SHUT OFF CHEMICAL SOLUTION FEEDERS AND CHLORINATOR. OPEN VALVES 6, 11 AND CLOSE VALVES 3, 10. TO BACKWASH FILTER A, CLOSE VALVES 5, 9. TO BACKWASH FILTER B, CLOSE VALVES 2, 9; OPEN VALVE 5. TO BACKWASH FILTER C, CLOSE VALVES 2, 5; OPEN VALVE 9. BACKWASH EACH FILTER AS DIRECTED BY FILTER MANUFACTURER. EQUIPMENT IS NOW IN BACKWASH POSITION.
TO RINSE TO WASTE (FROM BACKWASH POSITION)	OPEN VALVES 2, 5, 7, 10. CLOSE VALVES 6, 11. START CHEMICAL SOLUTION FEEDERS. RINSE TO WASTE AS DIRECTED BY FILTER MANUFACTURER. EQUIPMENT IS NOW IN RINSE TO WASTE POSITION.
TO FILTER (FROM RINSE TO WASTE POSITION)	OPEN VALVE 3; CLOSE VALVE 7. START CHLORINATOR. CHECK CONVERTER FOR STEAM. ADJUST VALVES 2, 5, 9 FOR EQUAL FLOW OF 3 GPM PER SQ FT AS SHOWN ON RATE-OF-FLOW INDICATOR OF EACH FILTER. EQUIPMENT IS NOW IN FILTER POSITION.
TO EMPTY POOL (FROM FILTER POSITION)	SHUT OFF CHEMICAL SOLUTION FEEDERS, CHLORINATOR, AND STEAM AT CONVERTER. OPEN VALVE 6. CLOSE VALVES 2, 5, 9, 1, 4, 8, 3. WHEN PUMP A (OR B) DRAWS AIR, STOP PUMP AND OPEN VALVE 15.
TO RECIRCULATE GUTTER DRAIN WATER USE ONLY WHEN ORDERED	CLOSE VALVE 16; OPEN VALVE 17.

FIGURE 165

50-Meter Swimming Pool Instructions for Operation of Sand Filters

SWIMMING POOL OPERATING RECORD
NAVDOCKS 2563 (4-59)

(See Reverse Side for Instructions)

ACTIVITY | MONTH AND YEAR | DESIGNATION OF POOL *(Building No. and/or Name)* | CAPACITY OF POOL *(Gals.)* | MAX. PERSONS PERMITTED IN POOL AT ONE TIME

CHEMICALS ON HAND AT END OF MONTH: ALUM _____ lbs.; SODA ASH _____ lbs.; CHLORINE *(Gas)* _____ lbs.; HYPOCHLORITE _____ lbs.; OTHER _____ _____ lbs.

DATE	MAKE UP WATER 1000 gal.	NO. HRS. HEAT. PLANT IN USE	TEMPERATURE AVERAGE W	TEMPERATURE AVERAGE AIR	TOT. NO. USING POOL	MAX. NO. IN AT ONE TIME	LBS OF CHEM. USED PER DAY ALUM	SODA ASH	CHL. HYPO.		FILTERS WASHED	TURBIDITY	POOL VACUUMED OR SCRUBBED	CHLORINATION ON	CHLORINATION OFF	FREE CHLORINE RESIDUAL TIME AND FREE CHLORINE RESIDUAL. AVERAGE RESIDUAL IN POOL.	pH	BACTERIOLOGICAL ANALYSES 10 ML./100 MLS POSITIVE	TOT. PLATE COUNT	TIME COLLECTED						
0	1	2	3	4	5	6	7				8	9	10	11		12	13	14			15	16	17	18	19	20
1																										
2																										
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28																										
29																										
30																										
31																										
TOTAL														MAX.												
MAX.														MIN.												
MIN.																										
AVG.																										

REMARKS

PREPARED BY

REVIEWED BY

FIGURE 166

Swimming Pool Operating Record—NAVDOCKS 2563

GENERAL INSTRUCTIONS

A. NavDocks Form 2563 "Swimming Pool Operating Record", is designed for use as a management tool in the analysis and evaluation of swimming pool operating procedures.

B. *DISTRIBUTION.* This record should be prepared in duplicate and data recorded daily by the responsible person in charge. At the end of the month it should be summarized. The original should be retained on file with one carbon copy forwarded to the District Public Works Officer. Activity files should include records of the current and preceding fiscal year.

C. *TESTS.* The kind, number and frequency of analyses should be based on recommendations of the District Public Works Officer. All tests performed should be in accordance with the procedures outlined in the current edition of the American Public Health Association Manual "Standard Methods for the Examination of Water and Sewage" in so far as these methods are applicable to swimming pool waters.

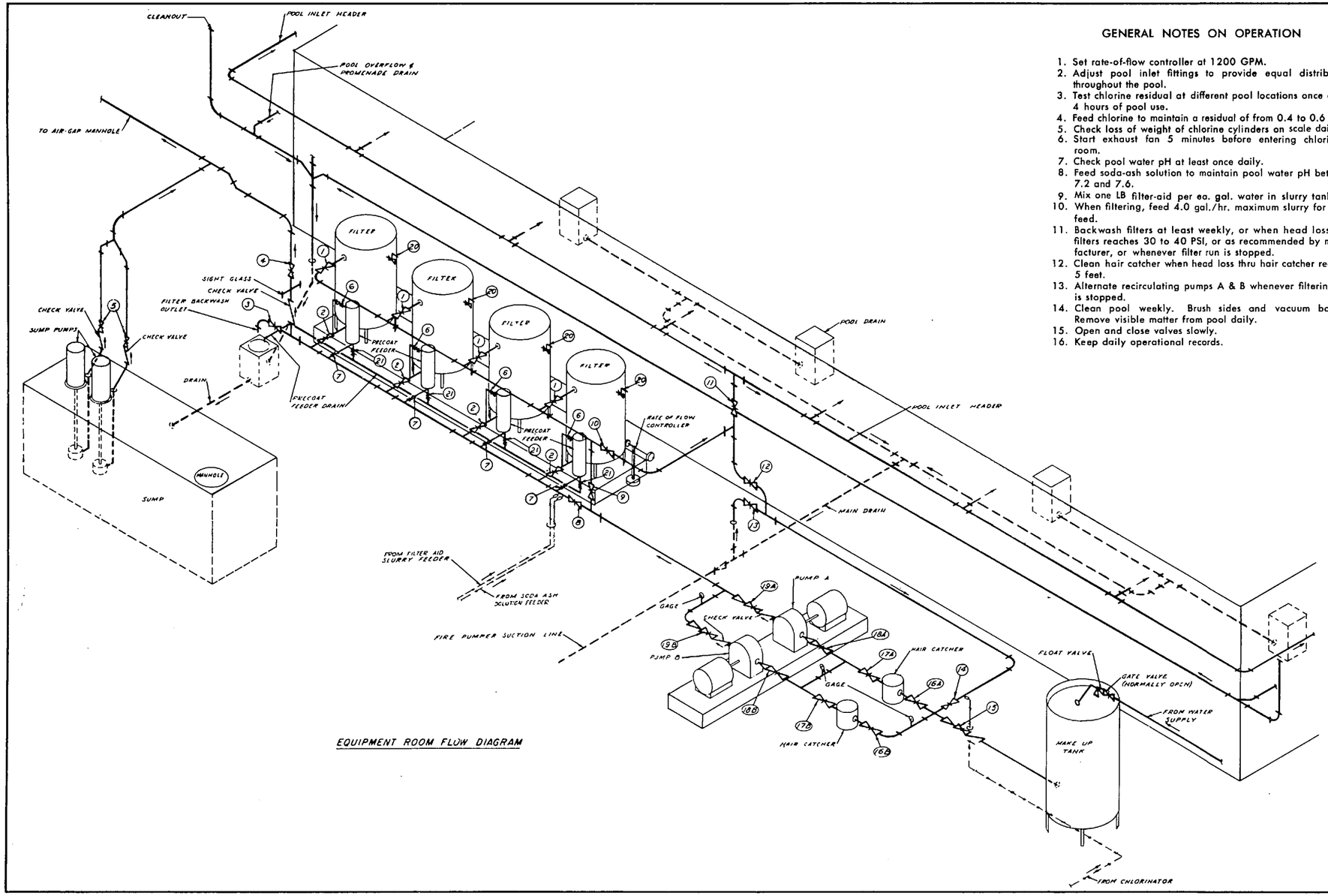
Columns

1. Record in 1000 gallon units the amount of water added to pool from domestic system.
2. Total number of hours the pool water treatment plant is operated each day.
3. Average water temperature while pool is in use.
4. Average air temperature while pool is in use.
5. Total number of persons using pool during one day.
6. Greatest number of persons in pool at any one time during the day.
7. Pounds of chemicals used each day, or each time a new batch is mixed. (Blank columns provided for addition of other chemicals; e.g. copper sulphate).
8. Check day filters are washed.
9. Greatest distance in yards from edge of pool to a point at which a 6" black disk is clearly visible when the disk is placed on bottom of pool at deepest point.

Columns

10. Record the letter V on day pool is vacuumed or letter S on day pool is scrubbed.
11. Record time chlorinator is started and/or stopped.
12. Record time of test for chlorine in spaces above column number and free residual in spaces below column number. Test to be made every 2 hours pool is in use.
13. Record pH of the pool water three times during the period the pool is in use.
14. This information to be taken from medical department or other laboratory report. Indicate size tube used. Enter Plate Count in colonies per cc after 24 hours at 37°C on Agar.

15 thru 20.
These columns may be used for recording special operating data as considered appropriate; e.g. diatomite filters operation.



EQUIPMENT ROOM FLOW DIAGRAM

GENERAL NOTES ON OPERATION

1. Set rate-of-flow controller at 1200 GPM.
2. Adjust pool inlet fittings to provide equal distribution throughout the pool.
3. Test chlorine residual at different pool locations once every 4 hours of pool use.
4. Feed chlorine to maintain a residual of from 0.4 to 0.6 PPM.
5. Check loss of weight of chlorine cylinders on scale daily.
6. Start exhaust fan 5 minutes before entering chlorinator room.
7. Check pool water pH at least once daily.
8. Feed soda-ash solution to maintain pool water pH between 7.2 and 7.6.
9. Mix one LB filter-aid per ea. gal. water in slurry tank.
10. When filtering, feed 4.0 gal./hr. maximum slurry for body feed.
11. Backwash filters at least weekly, or when head loss thru filters reaches 30 to 40 PSI, or as recommended by manufacturer, or whenever filter run is stopped.
12. Clean hair catcher when head loss thru hair catcher reaches 5 feet.
13. Alternate recirculating pumps A & B whenever filtering run is stopped.
14. Clean pool weekly. Brush sides and vacuum bottom. Remove visible matter from pool daily.
15. Open and close valves slowly.
16. Keep daily operational records.

INSTRUCTIONS FOR OPERATION

NOTE: Numbers in the following instructions refer to valves.

TO FILL POOL

1. Open 13, 14, and 15 (All others closed).
2. Fill pool to water level of make-up tank.
3. Close 14.
4. Open 16, 17, 18 (A or B according to pump), 9, 10 and 12.
5. Release air from pump by opening petcock on top of casing; close.
6. Start pump (A or B), open 19 (A or B to suit pump) and fill pool to 2" below overflow gutter.
7. Close 13.

TO FILL EQUIPMENT

1. Close 9.
2. Open 8, 2(all), 1(all), 20(all) and 14.
3. Close air release valves 20(all) when water flows from filters.
4. Close 15 and stop pump.

TO PRECOAT FILTERS AFTER FILLING POOL

1. Remove covers from precoat feeders.
2. Place 7 to 14 lbs. filter-aid in each precoat feeder add water and mix. Replace covers.
3. Open 6 and 7(all) and start pump.
4. Partially close 2(all) to provide flow thru precoat feeders.
5. Recirculate water until all filter-aid is deposited on elements and water runs clear.
6. Close 6 and 7(all).
7. Fully open 2(all).

NOTE: Continuous flow thru filter must be maintained between precoat and filter run operations or filter cake will drop off elements.

TO FILTER POOLWATER

1. Start chlorinator and soda-ash and filter-aid feeders.
2. Open 13 and 11.
3. Close 12.
4. Continue filtering until filter head loss reaches 30 to 40 PSI, or for a maximum of one week.

TO BACKWASH FILTERS

1. Stop chlorinator and soda-ash and filter-aid feeders.
2. Close 10.
3. Wait until maximum pressure is built up on the filter.
4. Close 1(all) and 2(all) and 8, and stop pump.
5. Open air release valves 20(all) to shock filter cake from elements.
6. Open 3 and 2(all) and drain all filters.
7. Close 3 and 20(all).

TO RINSE TO WASTE

1. Open 1(all), 4 and 9, start pump, and backwash until water is clear in sight glass. NEVER RINSE FILTERS TO SUMP AFTER DRAINING—THIS WOULD FLOOD EQUIPMENT ROOM.

TO PRECOAT FILTERS AFTER BACKWASHING

1. Close 4, 9, 11 and 13.
2. Open 8, 10, and 12.
3. Remove covers from precoat feeders.
4. Open 21(all) and drain precoat feeders.
5. Close 21(all). Place 7 to 14 lbs. of filter-aid in each precoat feeder, add water and mix. Replace covers.
6. Open 6 and 7(all).
7. Partially close 2(all) to provide flow thru precoat feeders.
8. Recirculate water until all filter-aid is deposited on elements and water runs clear. Proceed with filtering as above.

NOTE: Pump may continue running between operations. However, pump should never be operated against a closed valve for any extended period of time.

FIGURE 167

50-Meter Swimming Pool Instructions for Operation of Diatomite Filters

Section 7. WATER CONSERVATION

3.7.1 RESPONSIBILITY AND NEED. It is the responsibility of the operator to be vigilant at all times for water waste and leakage, and to take prompt corrective action when either is noticed. All water waste and leakage must be reported to higher authority immediately. Through carelessness, faucets and other fixtures may sometimes be left open, or not fully closed. Level controls for reservoirs and storage tanks may malfunction, causing overflow. These are typical conditions in which the operator may take prompt action by shutting off the flow of water to stop waste. Corrective measures for the adjustment or repair of malfunctioning equipment are covered in chapter 4, as is the repair of leaks in pipelines and mains.

3.7.2 CONSERVATION MEASURES. There are certain activities and locations which can contribute greatly to water waste. Consumption of water for various uses at an installation is established by local command directives. The operator should report violations of water consumption directives to higher authority.

3.7.3 FLUSHING MAINS AND DEAD ENDS. Periodic flushing of mains and dead ends is required to clean them and to reduce odors and tastes where circulation is poor. Schedules for such flushings will be established by local command so that unwarranted waste will not result.

3.7.4 WASTE AND LEAKAGE SURVEY. Waste and leakage surveys must be made annually to determine losses from waste, leaks and unmetered connections. While this is a command function, the operator should be familiar with the procedures involved, in order to carry out assignments which may be given him for such a survey. The prescribed method of making a waste and leakage survey is applicable to usual Naval activity conditions, but may be varied if the accuracy of the survey is not affected.

3.7.4.1 Source of Loss. Underground losses may be caused by leaks resulting from corrosion, breaks, pulled joints, stuffing-box leakage or imperfectly closed hydrants. In addition, there may be further wastage through leaky faucets and other fixtures, or from the unnecessary use of automatic flushing equipment. Systematic investigation is required to detect and minimize water system losses of all kinds.

3.7.4.2 Survey Procedures.

(1) The first step in a general wastewater survey is to make a check of all supply main meters. The accuracy of this check is of extreme importance. The test may be performed by comparison with a calibrated meter, by pitometer measurements or by other convenient and reliable methods. Tests must always be run at enough rates of flow so that the entire range of demand is covered.

(2) The second step is a careful inspection made to locate any unauthorized or unmetered main connections, bypasses around meters and broken or defective meters. All services and outlets within an activity should be metered if possible. All buildings, ships or other facilities for which unmetered connections are discovered should be equipped with suitable meters. Arrangements should be made to measure or meter the water consumption of such movable consumers as locomotives, cranes and concrete mixers, during the survey.

3.7.4.2.1 Elimination of surface leaks and waste. After the survey, the next step is a thorough inspection of the piping and fixtures in all buildings that use fresh water, and the elimination of leaks, drips and unnecessary automatic or continuous flushing. These inspections are made preferably at night and should be supplemented with meter readings and such listening devices as an aquaphone or an electronic listening apparatus. Wasteful water practices in latrines, wash houses, laundries, restaurants and lawn sprinklers should be looked for and eliminated.

3.7.4.2.2 Determination of daily consumption and minimum night rate. After completing the inspection of all visible lines and outlets, eliminating all unnecessary uses of water and metering all connections insofar as practicable, the next step is to determine the total daily consumption and minimum night rate.

(1) 24-Hour Test. The total daily consumption and minimum night rate is obtained by a 24-hour test, during which the main meters are read hourly, or at shorter intervals of about 15 minutes, during the hours of anticipated low consumption. With few exceptions, such as the central powerplant, latrines and barracks, there is no consumption during certain night hours. Consequently, periodic readings on service meters should be made along with those on the main meters during the night hours when consumption is lowest. If practicable, the night test should be made with only one main meter in operation, cutting out other meters temporarily.

(2) Determining Total Daily Consumption. The total daily consumption of all activities can be determined by two readings of each meter; one at the beginning and one at the end of the 24-hour test period. The difference between the summation of the main meter readings with those of all the service meters gives the leakage in mains, valves and hydrants, and losses through unmetered connections. The night readings of service meters, for locations which should have no night consumption, show the losses caused by correctable leakage, unauthorized use or waste.

3.7.4.2.3 Location and elimination of underground leaks. Locating and eliminating underground leaks in all mains and branches is the final step of the survey. To accomplish this, it is necessary to investigate the entire system between the main meters and the service meters. The following procedures should be used.

(1) The facility should be divided into a convenient number of sections chosen so that any section can be closed off by valves without affecting the remainder of the system.

(2) A metered bypass should be installed around each of these valves. This can be done conveniently by inserting ¾-inch corporation cocks on either side of the valve and connecting these to a ¾-inch disk meter with a heavy rubber steam hose that has pipe-union ends. The hose should be long enough to permit setting the meter on the ground if the valve is in a manhole.

(3) The section should be isolated by closing the selected valves and testing for tightness.

(4) The section should be fed through the metered bypass and the meter read at the end of each minute. The valves should be successively closed on all branch lines in the section, and in each case the time of closing noted. Several minutes should be allowed between successive closings so that the effect of each is shown independently by the meter readings. If, after closing all secondary valves, a flow through the metered bypass is still noted, the size of the section should be reduced step-by-step by closing the main valves in order, beginning with the valve farthest from the meter. These observations can best be made during night hours, from 11 p.m. to 7 a.m., because interference with the water supply to buildings, ships and quarters is avoided; and, during most of this period, the system is comparatively free from fluctuating demand.

(5) Using time and rate of flow as coordinates, a curve should be plotted showing the variations in flow throughout the test of any section. By noting the closing time of each valve on the curve, it can easily be seen which valves affected the rate of flow, and which leaks can be definitely identified with particular sections of pipe.

(6) When a leak is to be located in a long section of water main, an aquaphone or other listening device frequently helps locate the leak without the need for excessive excavation. Solution of harmless dyes or chemical tracers are sometimes useful for this purpose, too.

(7) After a leak has been located, action should be initiated to have repairs made. Procedures for temporary and permanent leak repairs are covered in Chapter 4.

3.7.5 PERMANENT SURVEY ARRANGEMENTS. Connections needed for making wastewater surveys should be permanent so that surveys can be repeated with slight cost. It is also necessary to prepare an itemized list of the materials needed and the complete stepwise procedure for each particular facility, together with the reasons therefor, so that succeeding wastewater surveys may be made on a routine basis without special study.

Section 8. SWIMMING POOLS

3.8.1 OPERATION SUPERVISION AND RESPONSIBILITY. Proper operation of swimming pools is important to safeguard tht health of personnel who use them. The operation of a swimming pool's water treatment plant may be supervised by Special Services, Recreation, the Medical Department, or the Public Works Department. The local command delegates authority for the operation and maintenance of swimming pools. The Public Works Officer, Medical Officer, and Special Service Officer shall clearly understand their respective responsibilities in this connection. Generally, the responsibilities of the Utilities Division in the operation of swimming pools include operation and maintenance of all water treatment equipment, pool cleaning and both chemical and bacteriological testing. Pool and water treatment equipment may be operated by either military or civilian personnel responsible for operations that maintain the sanitary quality of the water. Equipment maintenance is the responsibility of the Public Works Officer or the Special Services Maintenance Officer.

3.8.1.1 Responsibility. The Field Engineering Officer is responsible for providing the Commanding Officer of the activity with all required instructions and recording forms indicated in subsequent paragraphs. This shall be done only after consultation with the District Medical Officer, and final instructions shall be issued only upon the agreement of that office that the outlined procedures are satisfactory to the Bureau of Medicine and Surgery in all respects.

3.8.1.2 Operating Methods. No set of rules for operation can be set forth to apply to all types of pools at naval activities. There are similarities, however, in operative methods and in control measures, that apply generally to all types of pools. For information on specific equipment, refer to the manufacturer's operating instructions.

3.8.2 TYPES OF POOLS. This section is concerned with all types of pools used at Naval activities, including indoor and outdoor swimming pools; wading pools where the water is constantly recirculated; 50-meter pools; and, natural bathing waters. Of lesser interest are fill-and-draw pools, which are filled with water, used for some time, emptied, and refilled with clean water; and flow-through pools in which a continuous stream of fresh water flows into the pool and an equal amount of water drains from it.

3.8.3 REGULATIONS FOR POOL USE. Frequent personnel changes at Naval activities necessitate certain supervisory control measures, if the requirements of the Bureau of Medicine and of this Bureau are to be met in operating and managing swimming pools. To safeguard against improper practices, the following guides are recommended to persons primarily responsible for control and use of swimming pools.

3.8.3.1 Operators. No swimming pool should be placed in operation except under the care of a qualified operator, fully acquainted with all details of the pool installation. Trained personnel must be responsible for the continuous maintenance of operating control and bather supervision.

3.8.3.2 Bathing Load Limits. Pools of all types, in continuous use, should have three pool-water turnovers a day. That is, pools with filters and recirculation should recirculate the pool volume three times a day, and pools without recirculation should have three changes of water a day. Pools without recirculation and adequate disinfection should limit the number of bathers to one for each 500 gallons of water at every turnover. Disinfection should be maintained wherever possible, even in natural bathing waters, if in a confined area. Where adequate disinfection is practiced, the number of bathers may be governed according to formula, with safe bacteriological conditions as the ultimate guide.

3.8.3.2.1 Formulas. The following formulas may be used to determine the maximum allowable number of bathers in a Navy swimming pool at one time.

Let A = Diving area = area of pool defined by arcs of 10 foot radius swung from the ends of each diving board.
B = Swimming area = area in square feet of water more than 5 feet deep, minus A.
C = Nonswimming area = area in square feet of water less than 5 feet deep.
D = Number of diving boards × 12 = total number of divers (including those waiting to dive).

(1) Indoor or Outdoor Pools, Less Than 25 Meters. Consider the entire area of the pool, exclusive of the diving area, as in the swimming area and count one bather for every 27 square feet.

$$\text{Swimming capacity} = \frac{B+C}{27} + N.$$

(2) Indoor or Outdoor Pools, 25 Meters Up To (But Not Including) 50 Meters. Count one bather for every 27 square feet of swimming area and one bather for every 13.5 square feet of nonswimming area.

$$\text{Swimming capacity} = \frac{B}{27} + \frac{C}{13.5} + N.$$

(3) Indoor or Outdoor Pools, 50 Meters (or Larger). At large outdoor pools of this class, where a considerable proportion of the water is shallow, the 13.5 square foot allowance for nonswimmers may be safely reduced to 10 square feet, and the formula becomes:

$$\text{Swimming capacity} = \frac{B}{27} + \frac{C}{10} + N.$$

3.8.3.3 Signs. Signs shall be posted indicating the maximum permissible number of bathers, as computed according to the equation in paragraph 3.8.3.2.1.

3.8.4 OPERATION CONTROL AND SUPERVISION. Pool operation includes recirculation, addition of makeup water to replace leakage and splash, water treatment, water testing, and cleaning. Proper operation of swimming pool and related equipment is important primarily to safeguard the health of personnel who use Navy pools, and secondarily to protect the Navy's investment. (Some 50-meter pools represent an investment of $300,000 each.) Also, the difficulty and delay in procuring replacements necessitate continuous maintenance and care in operation. The instructions for operating standard 50-meter swimming pools are given in paragraph 3.8.4.2. Those instructions apply generally to all pools, except those employing diatomite filters (see par. 3.2.8.3.11).

3.8.4.1 Water Quality Control. Control of water quality will cover both physical and chemical characteristics of the water. Testing procedures appear in Chapter 3, Section 3.

3.8.4.1.1 Temperature control. Water temperature should not exceed 75° F. In indoor pools, the air should not be more than 8° F. warmer or 2° F. cooler than the water.

3.8.4.1.2 Clarity control. Water in the pool should be so clear at all times that a 4-inch black disk on the pool floor at its deepest point is clearly visible from the pool sides.

3.8.4.1.3 Dirt and scum. Dirt on the bottom, or scum on the surface of a pool, should not remain longer than 24 hours.

3.8.4.1.4 Chemical quality. Free available residual chlorine in the water should be maintained between 0.4 and 0.6 p.p.m. Free residual chlorine levels above 0.75 p.p.m. may irritate swimmers' eyes, skin, and mucous membranes. Combined chlorine residuals should be at least 2.0 p.p.m. when ammonia is used. Where the water is coagulated, the pH of the water should not drop below 7.0.

3.8.4.1.5 Bacteriological quality. Not over 15 percent of the samples taken over a considerable period should contain more than 200 bacteria per ml. on standard agar for 24 hours at 37° C., or should show a positive confirmed test in any of five 10 ml. portions when the pool is in use.

3.8.4.2 50-Meter Pools. The following instructions supersede the Bureau's 50-Meter Swimming Pool Manual of Operation. These instructions explain the basic principles of swimming pool operations and may be applied to all Navy pools if average potable water is used. If nonpotable water is contemplated, the supply may require pretreatment prior to its addition to the pool.

3.8.4.2.1 Sand filter pools. These instructions apply specifically to the standard 50-meter pool (with pressure sand filters) shown in figure 165 and generally to other types, even though the valve arrangement differs. The actual procedures for valve manipulation sequence, etc., are shown in figure 165. The basic instructions for proper operation of the swimming pool are set forth below.

(1) Set valves at all pool inlets for uniform circulation of water from inlets to main drain. The purpose is to assure that the recirculated water is mixed as thoroughly as possible to maintain the desired free chlorine residual.

(2) Adjust valves on filters for equal distribution through each filter several times daily, or as necessary. The purpose is to equalize the quantity of water passing through each filter. Wash all filters at about the same time, normally one after another. The pressure should be held to 18 p.s.i. maximum for wooden filters, or 60 p.s.i. for steel filters.

(3) Determine the necessary chemical dosage for all chemicals and set chemical feeders to maintain the desired chemical dosage of alum for coagulation and soda ash for pH adjustment. Test for pH, as necessary, to maintain pH between 7.2 and 7.6.

(4) Test pool water at least every two hours at different locations for chlorine residual. Increase the chlorine dosage as the bathing load increases to maintain the chlorine residual at the desired level.

(5) Adjust the converter to maintain the proper pool temperature.

(6) Keep operation records daily when the pool is in use. The record sheet (see Figure 166) is to be filed monthly with the Medical Department and Public Works Department.

(7) Clean the pool daily, skin the surface scum into the gutter, scrape the sides and vacuum the bottom. Each day, or at a satisfactory interval, the promenade floor is to be flushed down with a hypochlorite solution. For cleaning and maintenance procedures, see paragraph 3.8.5.7 and Chapter 4, Section 14.

3.8.4.2.2 Diatomite filter pools. The basic instructions for the proper operation of swimming pools utilizing diatomite filters parallel those mentioned in paragraph 3.8.4.2.1 for sand filters. The particular instructions for proper operation of diatomite filter pools are set forth below.

(1) Observe flow conditions at pool inlets to determine whether uniform circulation from inlets to the main drain will occur. The purpose is to assure complete mixture of recirculated water with the pool contents.

(2) Set the controls for equal distribution of flow through the filters.

(3) As in the case of sand filters, determine the necessity for pH adjustment. Use soda ash to adjust the pH upward. If high alkalinity persists requiring downward pH adjustment, specific instructions for the use of chemicals for this purpose shall be obtained from the Public Works Officer of the activity, or the Special Assistant for Sanitary Engineering, District Public Works Department, through the District Public Works Officers.

(4) Test for chlorine residual and pH, maintain proper chlorine residual and pH, adjust temperature and clean the pool, in accordance with the instructions given in paragraph 3.8.4.2.1.

3.8.4.3 Indoor and Outdoor Pools, Less Than 50-Meters. Once the operator is acquainted with the functions of the valves and procedures in figures 165 and 167, those procedures can be followed for nonstandard valves by disregarding the valve numbers on the figures. The basic instructions set forth in paragraph 3.8.4.2.1 or paragraph 3.8.4.2.2 also apply to nonstandard pools.

3.8.4.4 Natural Bathing Waters. Control of natural bathing waters entails different standards from those applying to artificial pools. For example, bacterial contamination of natural waters may be caused by drainage from agricultural lands as well as by sewage and bathers. If such drainage is the cause of pollution, it should be controlled wherever possible. In some cases, water disinfection by boat is practicable; in others, the water may be disinfected at its source of entry to bathing spot. Remoteness of pollution source and the dilution factor must be considered in this problem; for example, a relatively small amount of sewage pollution close to a bathing area may be more serious than heavy pollution at a distance.

3.8.4.4.1 Bacteriological classification. No absolute standard exists to justify treatment, but some guidance may be found in the following classifications, based on the number of coliform group organisms per 100 ml.

Class	*Average number coliform per 100 ml.*	*Evaluations*
A	0 to 50	Good.
B	51 to 500	Doubtful to poor.
C	501 to 1,000	Doubtful to poor.
D	1,000	Very poor.

Closer judgment of bathing suitability within these classes is based on the probable degree of active sewage pollution represented by the coliform concentrations.

3.8.5 WATER TREATMENT. The functions of a water treatment plant for a swimming pool are.

(1) Recirculation of pool water.
(2) Removal of hair, lint, and other debris.
(3) Chemical treatment of water for clarity and pH control.
(4) Filtration of water.
(5) Disinfection of water.
(6) Addition of makeup water.

3.8.5.1 Recirculation. Recirculation of pool water through the filter is accomplished by recirculating pumps. Only one pump is used for circulating, filtering, and backwashing the filters; the other is a standby unit for alternate days. Pumps should not be operated against a closed valve on the pool side of the filters because of pressure limitations of the filter shell (18 p.s.i. for wood and 60 p.s.i. for steel). Recirculation may be checked by looking for water movement at the pool inlets. If movement is small or absent, check the pumps; if the pumps are operating satisfactorily, the hair catcher may need cleaning.

3.8.5.2 Removal of Hair. Water being returned to the filter first passes through a hair catcher to remove hair, lint, and other large bits of foreign matter. Hair catchers, located in duplicate between the pool drains and the circulating pumps, usually consist of a removable cylindrical strainer of mesh or slotted metal within an outer metal chamber (see fig. 168).

3.8.5.2.1 Operation. Normally one hair catcher will be in service at a time. When the gages on each side of this hair catcher show a 5-foot loss-of-head, the valves on the second hair catcher are opened to place it in operation, and the first unit is valved off. The valved-off hair catcher is drained, the strainer basket removed, all parts cleaned immediately, and the unit reassembled ready for use.

3.8.5.3 Chemical Treatment. Chemicals (other than chlorine for disinfection) are used for coagulation and pH adjustment.

3.8.5.3.1 Coagulation. For swimming pools, coagulation is a simpler process than for potable water supplies. (Refer to par. 3.2.8.2 for the explanation of coagulation.) The coagulant is usually granulated plain alum (filter alum). Do not use ammonium alum because it will increase the ammonia content of the pool water and waste chlorine.

(1) Point of Application. The alum is applied at the circulation pump suction by means of an alum pot or at any location prior to the filter by means of other types of chemical feeders. The usual dosage is about 2 ounces of alum per square foot of filter surface.

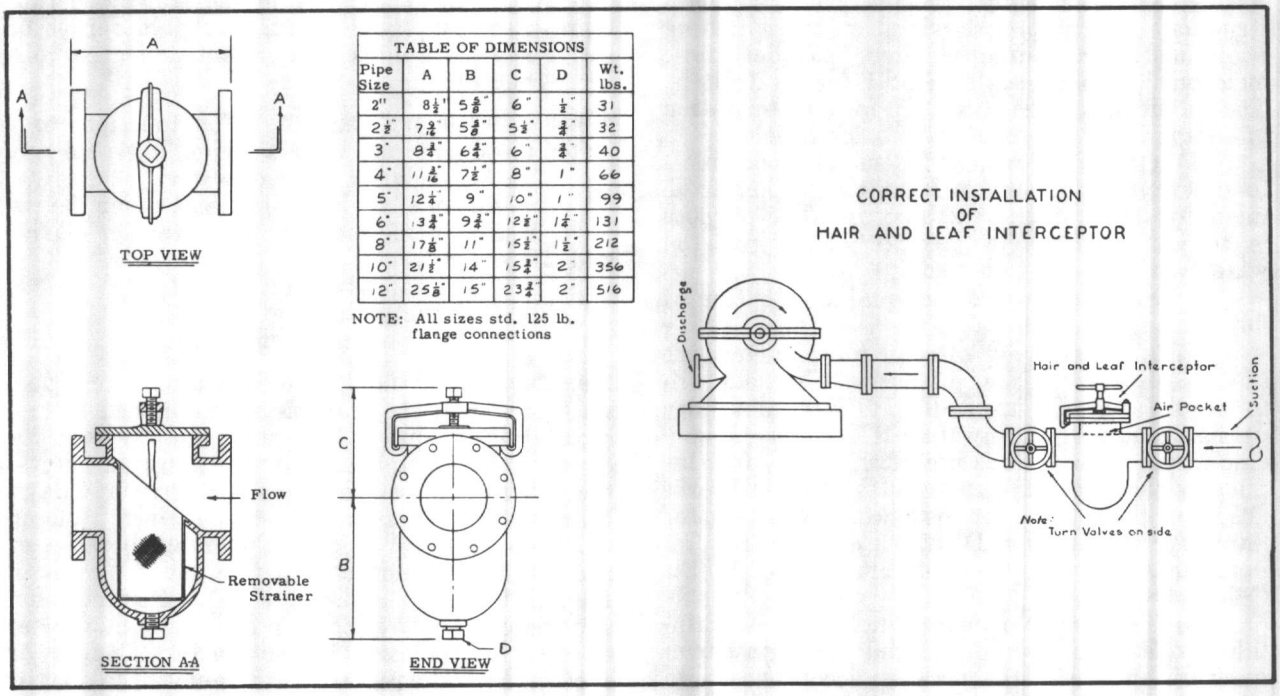


FIGURE 168

Hair Catcher

(2) Alum Pots. An alum pot with a screw clamp or cover (see fig. 56) operates satisfactorily, if care is taken to prevent clogging and corrosion. The first step in feeding the alum to the system is to check the connections. The line from the top of the pot should carry the chemical to the point of applications; the line to the bottom should carry the feed water from a source of pressure. To check on clogging of the lines, the top of the pot should be removed, the pot filled with water, and the valve on each line opened separately while the pump is in operation. The rise or fall of water level in the alum pots indicates that the pipes are clear.

(3) Floc Action. The alum floc builds up a mat on the surface of the filter medium. A properly formed mat will last until the filters are backwashed, when it will be broken up and carried to waste. The mat must be built up again after each backwash. An excessively high dosage of alum may result in a milky turbidity in the pool or too high a pressure drop across the filter. Turbidity in the pool may also be caused by too low a pH to form a satisfactory alum floc, so that if reduction in the alum dosage fails to clear up a milky turbidity, jar tests made according to paragraph 3.3.4.16 may be necessary in order to determine the proper dosage of soda ash for pH adjustment.

3.8.5.3.2 pH control. Proper pH must be maintained in pool waters in order to achieve good coagulation and effective disinfection, and to avoid irritation to swimmers' eyes and skin. (See par. 3.3.4.4 for a discussion of pH.) The optimum pH for pool water is from 7.2 to 7.6, or slightly above 7.0 on the alkaline side. Higher pH values may reduce the effective chlorine disinfection, cause irritation to swimmers, and increase pool turbidity when the water is very hard. pH values below 7.0 may cause rapid dissipation of chlorine with objectionable odors, irritation to swimmers, and discoloration of metal pool appurtenances as the result of corrosion.

(1) Upward Adjustment. Both alum and chlorine gas tend to lower the pH of the water so that an upward adjustment of pH is often required. This is done by introducing soda ash (Na_2CO_3) into the circulating waterline by means of a chemical feeder. Caustic soda should be used only on special authority (see par. 3.8.4.2.2 (3)). The amount of alkali to be injected must be determined by tests. A pound of soda ash per pound of alum is a good starting point for such tests. The alkali dosage may vary from time to time, particularly if alum or chlorine dosage has to be varied.

(2) Downward Adjustment. In some pools, it is difficult to maintain a low pH even though the use of caustic soda or soda ash is discontinued. Such pools usually receive makeup water high in alkalinity and pH, and may also be using hypochlorites or salt-electrolysis chlorinators, any of which contributes considerable alkalinity that cannot be offset by the normal alum dosage. The

alum dosage, however, should not be increased for the single purpose of lowering the pH. The operator must use acid or sodium bisulfate to maintain the pH as low as 7.6.

(a) Acid. Dilute acid (hydrochloric or sulfuric) may be added to pool water to lower the pH to the desired range of 7.2 to 7.6. The dosage is generally determined by experience, and only the amount required for the desired result is added each day. WARNING: Danger is attached to the use of acid, and it must never be used by inexperienced operators or without special authority (see par. 3.8.4.2.2(3)). The dangers are: 1. Operators may receive acid burns; 2. swimmers may receive acid burns, or eye and skin irritation; 3. equipment may corrode; and, 4. an overdose may be applied, thereby disturbing coagulation and increasing the turbidity.

(b) Sodium bisulfate. The procedure using sodium bisulfate ($NaHSO_4$), an acid-reaction compound, if safer than using acid to lower pH. CAUTION: Acid or sodium bisulfate treatment may be used only in special cases authorized as absolutely necessary by the Special Assistant for Sanitary Engineering, or by the Preventive Medicine Officer, and then only if the operator is experienced in its use.

3.8.5.4 Filtration. Filtration of recirculated swimming pool waters is usually carried out in pressure-type sand filters (see fig. 80), or diatomaceous earth filters (see fig. 81). Gravity-type sand filters may be used at some temporary installations.

3.8.5.4.1 Pressure-type filters. The general operating procedures for pressure-type filters are as follows.

(1) Air Release Measures. Air trapped in the filter interferes with filtration. The release valve on top of a pressure filter must be opened once each day, or more often, to remove air collected in the filter, especially if the pump is above the water surface, or the pump suction line is too small. If the pressure filter is higher than the pool surface, filter air-binding may be prevented by partial closing of the filter effluent valve. The valve should be closed only enough to maintain pressure in the filter; if closed too far it interferes with the recirculation flow rate.

(2) Continuous Operation. Once a pool is in operation, the filters and treatment equipment should be operated continuously 24 hours a day to keep the water clear and in satisfactory bacteriological condition. Proper operation results in a pool water so clear that the operator can read heads or tails clearly on a dime resting on the bottom at 7 or 8 foot depths. If filtration is stopped when the bathing load is low, algae growths are encouraged and water turbidity increases. Experienced operators keep filters and chlorinators in full operation, even on slack days, to obtain the greatest possible water clarity.

(3) Washing Filters. As in the case of gravity-type filters (see par. 3.2.8.3.7), a pressure-type filter must be cleaned and returned to proper and efficient operation when it contains an accumulation of dirt sufficient to offer resistance to the flow of water through the bed, or to make pump operation uneconomical. (Loss-of-head in filters is discussed in par. 3.2.8.3.6(2)). In a pressure-type filter, as head loss increases, the pressure in the influent line becomes increasingly greater than that in the effluent line. Filters are washed usually one at a time to obtain sufficient rate of wash-water flow. If the wash-water rate is not high enough, the sand bed will not be cleaned thoroughly and will cause filter troubles. It is possible to obtain cleaner filters and save wash water by agitating the top of the sand layer prior to washing, if the pressure filter is equipped with a surface wash or spray system built in for this purpose. Filters must be inspected frequently to ensure proper operation. The following steps are necessary to wash a pressure filter.

(a) Close valves on both influent and effluent lines to stop filtration and open the waste line from the filter.

(b) Slowly open the wash-water control valve until a flow rate of 15 g.p.m. per square foot of filter surface is reached.

(c) Continue washing for about five minutes after the full wash-water rate is obtained; or for at least two minutes after the wash water from the filter becomes clear, as observed in the watch glass, whichever is the longer.

(d) Close the wash-water control valve slowly, to obtain a hydraulic gradation of sand, that is, with the finest sand particles on the top of the bed.

(4) Filter Problems. Filters must be inspected frequently to ensure proper operation. The procedures for inspecting pressure filters are given in Paragraph 4.3.9.2. Problems of mud balls and cemented sand are discussed in Paragraph 3.2.8.3.10(1).

3.8.5.4.2 Diatomite filters. The description of diatomaceous earth filters, the basis of operation and filter-aid dosage are presented in paragraph 3.2.8.3.11. The length of filter run for swimming pool diatomite filters depends entirely on the pool-water quality, but the filter rate should not exceed 3 g.p.m. per square foot of filter surface. When the difference between the influent and effluent gage readings is from 30 to 40 p.s.i., the flow through the filter is reversed, to remove the filter-aid coating and accumulated dirt. Runs of 10 to 12 hours may be obtained when the turbidity is low. If, for any reason, the filter run is interrupted, the precoat will fall off the elements. Interruption or shutdown will make it necessary to backwash and to add a new precoat before starting up again.

3.8.5.4.3 Gravity filters. The description, operating principle, and operation procedures are pre

sented in paragraph 3.2.8.3.2; maintenance procedures are given in paragraph 4.3.9.1.

3.8.5.5 Disinfection. Filtration does not completely remove all bacteria present in swimming pool water. Therefore, the water must be disinfected to avoid any possible transmission of disease. Chlorination by chlorine gas or by chlorine-yielding compounds (hypochlorites) is the accepted method for disinfection of swimming pool water.

3.8.5.5.1 Operation and control. The chlorination operation for swimming pools is similar to that described in Paragraph 3.2.2.3. The free available residual chlorine in the pool water should be maintained between 0.4 and 0.6 p.p.m. Samples for testing chlorine content shall be taken from 12 to 18 inches below the water's surface (about elbow depth) in order to avoid the reduced chlorine content caused by sunlight, wind, and turbulence in the upper 6 inches or so of water.

(1) Slime Occurrence. Even if the free available chlorine residual appears to be in the correct range by test, the occurrence of slime on pool sides and bottom, or greenish water, is an indication that increased chlorine dosage or supplemental treatment with copper sulfate is necessary.

(2) Chlorine Odor. A stronger than usual chlorine odor in the air above the pool does not necessarily mean an excessively high chlorine content of the water. It may actually mean that there is not enough chlorine in the water. If the ammonia content of the water has increased, the chlorine may combine with the ammonia forming chloramines. Increasing the chlorine dosage burns up the excess ammonia so that the strong-smelling and eye-irritating chloramines can no longer form.

(3) Safety Practices. If chlorine gas is used for disinfection, all safety measures described in Chapter 5 shall be observed.

3.8.5.5.2 Bromination. The bromination method is not presently used to disinfect Navy pools, but about 10 percent of public pools in some states use bromine rather than chlorine. Although bacteriological studies indicate bromine to be about equal to chlorine in waters with a fairly low organic content, the Bureau of Medicine and Surgery has not approved its use for swimming pools.

3.8.5.6 Testing Procedures. Official testing procedures for water supplies and swimming pool waters are based on the procedures presented in reference 7. Details of tests for coagulation dosages, residual chlorine and bacteria are given in Section 3 of this Chapter.

3.8.5.6.1 Bacteriological. A minimum of one sample of pool water shall be collected weekly under the supervision of the officer responsible for operation, and analyzed for coliform organisms and total bacteria content. Samples shall be collected during periods of maximum bathing load in bottles treated with sodium thiosulfate, in accordance with the procedures in reference 7, or in sample bottles furnished by the Medical Department or sanitary engineering laboratory.

3.8.5.6.2 Physical. Turbidity of the pool water shall be checked at least once a day, and more often if indicated. Use the black disk test (par. 3.8.4.1.2), or the dime test (par. 3.8.5.4.1(2)) mentioned previously. Determine pool water temperature twice daily.

3.8.5.6.3 Chemical. Chemical tests are made for chlorine dosage, pH and coagulation control.

(1) Residual Chlorine. Determine residual chlorine as frequently during the day as experience proves necessary, but not less than once each two hours of pool use. Use the test procedures outlined in paragraph 3.3.4.3.

(2) pH. pH tests on the pool water shall be made daily, and more often, if necessary. Use the procedures outlined in paragraph 3.3.4.4.

(3) Coagulation Jar Tests. If there is difficulty in keeping the pool water clear, jar tests should be made at least daily to establish correct alum dosage. Use sampling and test procedures outlined in Paragraph 3.3.4.16.3.

3.8.5.7 Cleaning. Each day, or at intervals established by the local command, the promenade floor shall be flushed down with a hypochlorite solution, and the pool shall be cleaned. Procedures for cleaning are as follows.

(1) The pool sides are first brushed down with a stiff brush, disturbing the bottom dirt as little as possible. The pool bottom is cleaned by a vacuum cleaner. Place the vacuum cleaner on the promenade floor and attach to it a float-supported hose with a tow-type suction head on its free end. The head is lowered to one end of the pool floor and, by means of its attached ropes, is slowly and carefully pulled from side to side by an operator on each side of the pool. The vacuum cleaner discharges into the promenade-floor discharge. Excessive floating material can be overflowed into the gutter and valved to waste.

(2) At intervals of from 3 to 6 months, or as necessary, the pool is emptied and scrubbed thoroughly on the sides and bottom with strong soap solution. All soap traces must be flushed out of the system before the pool is ready for filling.

3.8.5.8 Records. The Swimming Pool Operating Record (NAVDOCKS Form 2563) is provided to maintain a daily account of pool operations. This form (fig. 166) carries complete instructions on its reverse side for its use.

3.8.5.9 Off-Season Protection. The following suggested steps, offered to protect outdoor pools from the winter elements, should be taken when the pool is closed in the fall.

(1) Wash each filter thoroughly several times so that it is in the cleanest possible condition during the off season. Impurities allowed to set in dirty filters during the winter may be difficult to remove later.

(2) Open the main drain so that melting snow or rain water will not collect in the pool. (The alternate practice, advocated by several authorities, is to allow the pool to remain full of water to a point about 6 inches below the overflow trough.)

(3) Disconnect the chlorinator completely and make sure that it is drained of all water. Unpainted metal parts should be covered with petrolatum to prevent corrosion.

(4) Drain the chemical and slurry feeders, precoat feeders, hair strainer and pump-impeller casing. Remove the fuses from the pump switch.

(5) Drain each of the filters through an opening at some point below the tanks.

(6) Plug or screen all drains and pool inlets to prevent the entrance of small animals or birds.

(7) Remove floodlight bulbs and reflectors; cover reflectors with a clear oil to protect against rusting.

(8) Pack suits and towels in rodent-tight containers and protect woolens from moths.

(9) Shut off the city water supply and drain all lines and toilets in the bathhouse.

(10) Cover any outside drinking fountain to prevent staining. (A barrel may be used.)

(11) Remove springboards and place them on a flat surface away from heat and moisture to prevent warping.

3.8.5.10 Troubleshooting. Table 12 is presented as a guide to troubleshooting for swimming pool operation.

TABLE 12
Trouble Guide for Swimming Pool Operation

Symptom	Poessible Causes	See Paragraph
Cloudy water	Poor coagulation	3.8.5.3.1
		3.8.5.6.3(3)
	Poor filtration	3.8.5.4
Cloudy water—Greenish	Algae—Chlorine too low	3.8.4.1.4
		3.8.5.5.1
	Copper corrosion—pH low	3.8.5.3.2
Cloudy water—Milky	pH low	3.8.5.3.2
	pH high in hard waters	3.8.5.3.2
	Too much alum	3.8.5.3.1
	Defective diatomaceous earth filter element	3.8.4.2.2
		3.8.5.4.2
Cloudy water—Rusty	Iron corrosion—pH low	3.8.5.3.2
	Iron in makeup—poor filtration	3.8.4.2.1
		3.8.4.2.2
		3.8.5.4.1(4)
Discolored side walls or bottom:		
Green	Algae—chlorine too low	3.8.4.1.4
		3.8.5.5.1
	Copper corrosion—pH low	3.8.5.3.2
Rusty	Iron corrosion—pH low	3.8.5.3.2
	Iron in makeup—poor filtration	3.8.5.4.1(4)
Eye irritation	pH low	3.8.5.3.2
	Chlorine high	3.8.4.1.4
	Chlorine low	3.8.5.5.1
Inlet flow low	Pumps not operating	3.8.5.1
	Hair catcher needs cleaning	3.8.5.2
Filter runs short	Too much alum	3.8.5.3.1
		3.8.5.6.3(3)
	Pool needs cleaning	3.8.5.7
Odor—Strong chlorine	Chlorine too high	3.8.4.1.4
		3.8.5.5.1
	Chlorine too low	3.8.4.1.4
		3.8.5.5.1
Skin irritation	pH high	3.8.5.3.2
Slime on sides or bottom	Chlorine too low	3.8.4.1.1
Water feels slippery	pH high	3.8.5.3.2

CHAPTER 4. MAINTENANCE

Section 1. GENERAL INFORMATION

4.1.1 PURPOSE. As defined in this manual, maintenance is the routine recurring work required to keep a facility in such condition that it may be continuously utilized, at its original or designated capacity and efficiency, for its intended prupose. This portion of the manual is designed to assist personnel concerned with water supply systems in maintaining equipment in good working condition, and to guide them in the systematic detection and correction of minor defects before major repairs are required.

4.1.2 SCOPE. This chapter deals with maintenance inspections and maintenance services of the equipment and components of a water supply system at Naval shore-based installations. The following sections present maintenance procedures primarily for operator inspection and preventive maintenance inspection, together with criteria for control inspection and major overhaul. In addition to specific directions for maintenance operations, this chapter contains tables specifying the frequency of maintenance operations. (Also see "Maintenance Responsibilities", par. 1.2.1.)

4.1.3 TYPES OF INSPECTION AND REPAIR. Water supply system personnel are concerned with three categories of inspection, and to some degree with overhaul and repair.

4.1.3.1 Operator Inspection. Regular inspection of equipment, or of a system, by an operator is part of his routine duties to ensure proper functioning of the system. Such inspection consists of lubrication, minor adjustments and renewal of parts which do not require major overhaul or repairs, plus detection and reporting (to the proper authority) of any observed abnormal conditions (appearance, leaks, unusual noises, etc.).

4.1.3.2 Preventive Maintenance Inspection. Cleaning, lubrication, minor adjustment and renewal of parts which do not require major overhaul and repairs, plus detection and reporting (to the proper authority) of any observed abnormal conditions (appearance, leaks, unusual noises, etc.) comprise preventive maintenance inspection. Such inspections are conducted by personnel not actually operating a particular piece of equipment or system, but who have been assigned specific areas of inspection responsibility.

4.1.3.3 Control Inspection. Scheduled examinations and/or tests of public works and public utilities are made to determine the physical conditions with respect to maintenance standards. These examinations are termed control inspections and are performed by personnel assigned to the Inspection Branch, or by others at the request of the Inspection Branch. Control inspection consists of electrical, mechanical and structural types of inspection.

4.1.3.4 Major Overhaul and Repairs. Normally, major overhaul and repairs are not made by operating personnel, but rather by the Maintenance Control Division and the Maintenance Division at the request of the Utilities Division, and according to schedules developed by the Utilities Division. In certain instances, outside contractors may be employed.

4.1.4 RECORDS AND REPORTS. The results of inspections and maintenance procedures shall be kept on record forms as established by, "Inspection for Maintenance of Public Works and Public Utilities", NAVDOCKS P–322 (ref. 13). These forms include the inventory record, the inspection checkoff card, the inspection record sheet, the inspection frequency file and other forms for specific uses (also see par. 2.6.2).

4.1.4.1 Historical Files. Historical files should be carefully prepared and maintained for each part and each piece of equipment in the water supply system. Such files should contain data and information by which the economy and reliability of the various parts of the system may be determined. For example, historical files which contain the data and conditions of the installation, types of material, record of time out-of-service, the causes of such out-of-service and the costs of operation and maintenance can be used in studies to determine proper replacements.

4.1.5 GENERAL INFORMATION ON MAINTENANCE. There are four types of information basic to fundamental maintenance of water supply systems: information on equipment and systems; corrosion prevention (including protective coatings, painting and cathodic protection); proper tools and test equipment; and, proper safety measures. Personnel charged with maintenance responsibility in water works should consult the following sources.

(1) For information on, and procedures for, maintenance management of public works and public utilities, see reference 2.

(2) For information on, and procedures for, inspection for maintenance of public works and public utilities and the reporting of maintenance deficiencies in naval property, see Reference 13.

4.1.5.1 Manufacturers' Information. The Public Works Officer or supervising personnel at each facility shall collect and maintain a file of manufacturers' instructions, parts lists and drawings on all equipment at that location (see par. 2.6.2.7). This information shall be available to operating personnel who should refer to it for any additional detailed information not contained in this chapter. Under some conditions, these manufacturers' instructions may indicate desirable modifications of the procedures in this manual to meet local conditions. Such modifications are permissible, but any modification of the instructions in this manual must be approved by the Public Works Officer of the facility.

4.1.5.2 Lubrication. Proper lubrication prevents damage to wearing surfaces, reduces the maintenance required and cuts power costs and equipment outages. The instructions which follow list the recommended lubricants for various uses. Directions for lubricating specific equipment are presented in tabular form and, where desirable, are repeated in the text applicable to the specific equipment items. These instructions are not inviolable; they may be modified as necessary by operator judgment to meet individual situations, but such modifications must have the approval of the Public Works Officer of the facility.

4.1.5.2.1 Lubricants. Oils, greases, and preservatives for water works are given in Table 13. This list does not contain all the lubricants available under Military Specifications, but the list has been developed in an effort to establish good lubrication practice for normal operating conditions with as small a number of good lubricants as is feasible. Use of Table 13 and Table 14 does not relieve the activity of the responsibility for using lubricants which meet the requirements of the equipment manufacturer's recommendations for lubricants for their equipment under the condition of operation (see par. 4.1.5.2.4). The information contained in Table 13 should be familiar to all maintenance and operating personnel. This list is subject to modification at the judgment of maintenance personnel, providing the modification is approved by the Public Works Officer.

CAUTION: In order to avoid plant failures due to improper lubrication, the following precautions should be observed.

(1) Do not overlubricate. Overlubrication will cause the antifriction bearings to heat and may damage the grease seals; it may also cause damage to the windings in electric motors.

(2) Totally enclosed or insufficiently guarded equipment should not be lubricated while it is in operation.

(3) Lubricant containers should be kept tightly closed, except when in use, to prevent contamination of the lubricant by the entrance of dust, grit and abrasives. Lubricants should be stored in dust-free areas, and containers kept closed. Before using lubricant containers, the spouts and lips should be wiped; before using grease guns, the gun and fitting should be wiped to insure the absence of foreign matter.

4.1.5.2.2 Provisions for greasing. The same grease gun fitting should be provided on all lubrication points requiring the same grease. This practice reduces the number of grease guns required, minimizes the use of improper lubricants and simplifies the operation.

4.1.5.2.3 Identification. The product symbol and identifying color should be marked on lubricant containers and grease guns, and at or near all oil cups and grease fittings to insure the choice of the proper lubricant for that location.

4.1.5.2.4 Lubricant uses. Table 14 contains a listing of uses for lubricants which generally are satisfactory when used on equipment operating under normal ranges of temperature, pressure and corrosion. However, in view of the wide variation in characteristics of equipment and conditions of operation, the manufacturers' instructions for lubrication should be checked to insure that listed lubricants meet the requirements of the manufacturers' recommended lubricants. When the manufacturers' recommended lubricants differ from those listed in Table 14, the recommended lubricants should be related to the specifications contained in the current edition of Reference 14.

4.1.5.3 Corrosion Prevention. The prevention of corrosion and surface deterioration is standard maintenance practice in water works. All exposed surfaces, whether external or internal, should be protected. Protective coatings and linings may be nonmetallic or metallic. The former includes paint, enamel, bitumin, cement, plastic and rubber. Metallic coatings include zinc, aluminum, and lead. Corrosion preventives are used on metal equipment surfaces that cannot be painted. Cathodic protection is used where electrolytic corrosion occurs.

4.1.5.3.1 Paints. Surface coating by paint is the most general method of corrosion prevention. Paint should be selected to meet the existing conditions; the choice is dependent on whether or not the equipment or structure is indoors or outdoors. Selection may be made from pigment, bituminous, aluminum or rubber base paints, as the situation demands, but all paints shall be selected in accordance with the provisions of, "Building Maintenance Painting", NAVDOCKS MO–110 (Reference 15).

TABLE 13

Lubricating Oils, Greases and Preservatives

Product	Military Specification Number	Symbol	Approximate SAE Grade	Federal Stock Number [2]	Temperature Range
					Above
Lubricating oil, general purpose.	MIL–L–15016A	2075	20W	9150–235–5571	–10° F.
Do	do	[3] 2110	10 W–75	9150–223–4137	0° F.
Do	do	2135	20–75	9150–231–6664	0° F.
Do	do	2190	30	9150–231–6639	35° F.
Do	do	2250	40	9150–231–9057	35° F.
Do	do	[3] 3050	20 W	9150–223–4138	0° F.
Do	do	3065	30–80	9150–223–4131	5° F.
Do	do	3080	40–90	9150–223–8890	15° F.
Do	do	3150	140	9150–240–2258	25° F.
Lubricating oil, compounded.	MIL–L–15019B	4065	40	9150–243–3196	35° F.
Do	do	6135	140	9150–231–6645	60° F.
Do	do	8190	30	9150–231–9033	35° F.
Lubricating oil, mineral, Cylinder.	MIL–L–15018A	5190	140	9150–240–2260	Above 60° F.
Lubricating oil, steam turbine (noncorrosive).	MIL–L–17331B	2190TEP	30	9150–235–9061	Do.
Lubricating oil, internal-combustion engine, subzero.	MIL–L–10295A	OES	----------	9150–242–7603	–65° to 0° F.
Lubricating oil, instrument jewel-bearing, nonspreading, low temperature.	MIL–L–3918	OCW	----------	9150–270–0063	Above –40° F.
Lubricants; chain, exposed-gear and wire rope.	VV–L–751A	CW–11B	----------	9150–246–3276	All.
Lubricating oil, internal combustion, diesel.	MIL–L–9000E (ships)	9250	40–90	9150–231–6653	Normal.
Do	MIL–L–9000E (ships)	9500	90	9150–231–9041	Normal.
Grease, automotive and artillery	MIL–G–10924A	GAA	----------	9150–190–0907	–65° to 125° F.
Grease, ball and roller bearing	MIL–G–18709	BR	----------	9150–249–0908	125° to 200° F.
Grease, graphite	VV–G–671C	CG–1	----------	9150–272–7652	125° max.
Lubricating oil, internal combustion, preservative.	MIL–L–21260	PE–1	----------	9150–264–3941	
Lubricating oil, preservative, medium.	MIL–L–3150	PL–MED	----------	9150–231–2356	
Corrosion preventive, petroleum, hot application.	MIL–G–11796A	CL–3	----------	8030–231–2353	
Corrosion preventive, compound, solvent cutback, cold application.	MIL–C–16173B	CT–1	----------	8030–231–2362	

[1] SAE numbers 10 W through 50 are for crankcase lubrication.

SAE numbers 75 through 140 are for transmission lubrication.

[2] Federal stock numbers are for 5 gallon containers for lubricating oils and 35-lb. containers for grease, except one-half-ounce can for MIL–L–3918. For other size containers see Federal Supply Catalog 4.1 (ref. 14).

[3] Quenched.

TABLE 14

Lubricating Oil and Grease Uses

Equipment	Oil or Grease Symbol
Air compressors.	
Vertical with splash lubrication.	
Gage pressure less than 100 psi.	2110, 3050.
Gage pressure greater than 100 psi.	2135, 2190, 3050.
Horizontal	2135, 2190, 3050.
External lubrication, sight feed, wick feed, hand oiling.	2135, 2190, 3050.
External lubrication, circulating systems or splash type crankcase.	2110, 2135, 3050.
Cylinders: Wet conditions	8190.
Dry conditions	2190, 2250, 3065.
Bearings:	
Ball, all temperatures to 200° F.	BR.
Ball, low-pitch line speed.	
Operating temperature below 32° F.	2075.
Operating temperature 32° to 150° F.	2190, 2250, 3065.
Ball, medium-pitch line speed.	
Operating temperature below 32° F.	2075.
Operating temperature 32° to 150° F.	2135, 3050.
Ball, high-pitch line speed.	
Operating temperature below 32° F.	2075.
Operating temperature 32° to 150° F.	2110, 3050.
Ring-oiled, small, miscellaneous.	2110.
Kingsbury thrust bearing	2190TEP.
Thrust (other than Kingsbury, subject to water).	4065.
Thrust (other than Kingsbury, not subject to water).	2135, 2190.
Bronze guide	GAA.
Countershaft	CG 1.
Differential (enclosed)	3150, 5190, 6135.
Eccentric	3065.
Guide	GAA, CG 1.
Oilite bronze bushings	9250.
Pillow block	GAA.
Underwater-babbitted	GAA, CG 1.
Universal joint, slip splines	BR.
Chain Drives.	
Roller	3080, GAA, CG 1.
Roller (enclosed)	Winter, 2075; Summer, 3065.
Roller (semienclosed)	Winter, 3080; Summer, 6135.

TABLE 14 (Continued)

Equipment	Oil or Grease Symbol
Slow-speed	CW–IIB.
Medium-speed	5190.
Chemical feeders	See manufacturer's instructions.
Clarifier equipment	Do.
Couplings	6135.
Drive jaw clutch	9500.
Gear case or gear head	Low temperature, 3080, High temperature, 5190.
Gears.	
Herringbone	Winter, 2075; Summer, 3065.
Helical	Do.
Motor reducers	Winter, 3050; Summer, 2135.
Open	5190.
Planetary	Winter, 2075, 2110; Summer, 2135.
Worm and pump transmission	Winter, 3080; Summer, 6135.
Instruments	OCW.
Motors	See manufacturer's instructions.
Packing, Sludge Pumps	4065, 6135.
Pumps	See manufacturer's instructions.
Seal packings	GAA.
Shafting.	
Large	2190, 3065.
Small	2110, 2135, 3050.
Shear pins	WB.
Sheaves	CG 1, GAA.
Solenoid oilers	3050.
Valve stems	GAA.

4.1.5.3.2 Painting procedures. Application of paint shall be in accordance with procedures set forth in Reference 15.

(1) Surface Preparation. Surfaces to be painted shall be prepared properly before the paint is applied. Foreign substances on the surface interfere with the protective action of the coating. Therefore, loose scale, rust, dust, oil or grease should be removed completely. Only clean surfaces should be painted. Metal surfaces should be sandblasted where this preparatory treatment is applicable. Sandpaper or a wire brush should be used where applicable. Dust should be wiped off and greasy or oily surfaces should be cleaned with solvent cleaners.

(2) Preparation of Paint. Paint should be mixed properly and screened, if necessary, to remove grit and film. Paint containers should be covered when not in use. Brushes, rollers, and

spray applicators should be cleaned before and after use. For damp surfaces, where drying temperatures are less than 40° F., specially prepared paint should be used.

(3) Painting Schedules. Painting schedules should be set up on a periodic basis (1 to 10 years) depending on the paint used, the method of application and the conditions of wear.

4.1.5.3.3 Corrosion preventives. Corrosion-preventive compounds are used in pits, pump drywells and damp areas. Paint will not serve for this purpose. Table 13 shows two corrosion preventives commonly used in water works. More detailed listing and application of cleaners and corrosion-preventive coatings may be found in, "Design Manual—Drydock Inactivation and Reactivation", NAVDOCKS DM-29, Vol. 4 (Reference 16). This reference contains detailed information on the subject of protective coating materials and procedures as practiced in inactivation by the Bureau of Yards and Docks. Many of these materials and practices are applicable to inactivation of water supply equipment.

4.1.5.3.4 Cathodic protection. Cathodic protection consists of the application of sufficient direct current to a metal to prevent electrolytic corrosion which occurs where current leaves the anodic areas of the metal surface. The metal then becomes cathodic (negative) with respect to its surroundings, and corrosion is inhibited. The most common application in water works is in elevated steel storage tanks and mains. Criteria for the design of cathodic protection may be found in, "Design Manual—Electrical Engineering", NAVDOCKS DM-4 (Reference 17).

4.1.5.4 Preparation for Disasters. Protective measures for storms or earthquakes, which may result in power loss, must be made. If the facility has no standby power, provisions must be made for a standby source of potable water. These provisions should be made in design, but inspection of the standby source should be part of maintenance.

4.1.6 TOOLS AND EQUIPMENT. Effective maintenance requires tools to service the facility properly. Table 15 presents a list of suggested tools which should be available at the activity for general maintenance use. Specific tools may be required for specialized equipment. Special test equipment may also be needed. Consult the manufacturer's instructions for such equipment.

4.1.6.1 Tool Care. Tools have specific uses and shall not be used for other purposes. When the proper tool is not available, it should be obtained.

(1) Storage. Tools should be kept on a tool board or in a tool box, both of which should be painted at least once a year; both should also be kept clean. Tools not in their proper places should be in use; if not, they should be found and returned to their proper places.

TABLE 15

Suggested Tools for Water Treatment Plants

Axes, spare axe handles.
Awls.
Bars.
  Crow.
  Wrecking.
Bit brace and assortment of bits for wood and metal.
Blacksmith's anvil, tools, forge, and hand blower.
Bolt stock and dies.
Breast drill and assortment of drills.
Calipers.
  Inside and outside.
  Micrometer.
Caulking tools, water main type (assorted sizes and types).
Chisels.
  Assorted.
  Bull point.
  Cape.
  Cold.
  Diamond point.
  Round nose.
  Assorted, wood.
  Assorted, for air hammer.
"C" Clamps, assorted.
Cotter pin puller.
Countersink, assorted for wood or metal.
Cutters, wire.
Cutters, 1/2-inch bolt.
Dies, assorted for bolt and pipe threading stocks.
Drills.
  Assortment.
  Electric portable 5/8-inch for twist drills No. 60 to 5/8-inch with drill press stand mount.
  Electric portable 1/4-inch for twist drills No. 0 to No. 60.
  Hand.
  Press, bench type.
  Star drills of various sizes.
Extractors, screw, various sizes.
Files.
  Assorted sizes.
  Flat.
  Half round.
  Round.
  Taper (triangular).
  Wood rasp.
Fire pot, including metal foot and wrought steel ladle for use with B and S cast iron pipe.
Flanging tools, for use with copper pipe.
Flaring tools, for use with copper pipe.
Fuse puller.
Gages.
  Set of shims.
  Test for pressure and vacuum.
Glass cutter.
Grinder.
  Electric or hand, bench type.
  Wheels, coarse, fine and wire brush.
Hacksaw, adjustable frame with extra blades.

TABLE 15 (Continued)

Hammers.
  Ball peen, assorted sizes.
  Blacksmith's type.
  Caulking.
  Claw.
  Mason's.
  Rubber mallet.
  Sledge type, various sizes.
Hatchet.
Jacks, screw or hydraulic, various sizes.
Joint runner, asbestos, for use with lead joints.
Lathe.
  Metal, 12-inch swing, 24-inch centers.
  Tools and appurtenances.
Lead pot and ladles.
Levels.
  Line.
  Spirit, metal frame, 18 inch.
Line, Mason.
Manhole cover lifting hooks.
Mattock.
Nail sets, various sizes.
Oil cans, several types and sizes as required.
Packing hooks.
Packing tools, assorted.
Pipe Cutter.
Pipe Cutter, wheels (spare).
Pipe taps.
Pipe thread taps (combination), 1/4 to 2 inch.
Pipe threading stock with assorted dies.
Pipe tripod.
Plane, smooth, bench, 7 inch.
Pliers.
  Assorted sizes.
  Diagonal cutting.
  Gas.
  Combination slip joint.
  Needlenose.
  Wrench.
Plumb bob.
Puller, gear set.
Punches, assorted sizes, center, drift.
Putty knives.
Reamers, hand, taper, pipe expansion.
Rules, 6 foot folding.
Saws, rip, crosscut, compass and keyhole.
Saw set.
Saw vise.
Scale platform.
Screwdrivers, various sizes.
Screw pitch gage.
Scribers.
Sharpening stone.
Shears, tinsmith's, straight and curved blades, assorted sizes.
Shovels.
  Square point, long and short handle.
  Round point, long and short handle.
Snake, 25-foot spiral.
Soldering iron and appurtenances.
Specific tools for specialized equipment.

TABLE 15 (Continued)

Square, steel, large and small.
Stamping tools, steel, letters and numerals.
Straight edge, steel.
Tampers.
Tape, 50-foot steel.
Tar pot.
Torch, blow and gasoline.
Trowels.
  Floats, steel, and cork assorted.
  Pointing.
Valve resetting tool.
Vises, bench and pipe, portable chain vise and stand.
Voltage tester.
Wall scrapers.
Washer or gasket cutter for making own washers.
Welding outfit with appurtenances, goggles and gloves.
Wire stripper.
Wrenches.
  Adjustable, various sizes.
  Allen set screw.
  Box wrench set.
  Hydrant.
  Monkey.
  Open end, various sizes.
  Ratchet, socket set.
  Socket, set of various sizes.
  Spanner.
  Stillson, various sizes.
  Torque.
  Valve.

(2) Inspection. Tools must be inspected at monthly intervals. Damaged or worn tools shall be replaced, and edged tools (chisels, planes) shall be sharpened. Tools should be cleaned and lubricated before they are returned to storage.

(3) Caution. Do not use a screw driver as a chisel, pliers as a wrench or a wrench as a hammer; and do not use toothed-jaw (Stillson-type) wrenches on hard rubber pipe, or on bolts or nuts.

4.1.6.2 Equipment and Supplies. In addition to proper tools, a water treatment plant should be adequately supplied with equipment, implements and supplies that are essential to proper maintenance. Since good housekeeping is a part of the maintenance of both buildings and grounds, as well as of operating equipment, the equipment and materials needed must include housekeeping and gardening tools, equipment and material supplies. Table 16 presents a list of suggested implements, and Table 17 lists the suggested materials and supplies which should be available at the activity.

4.1.7 SAFETY EQUIPMENT. Safety equipment and safety practices for maintenance procedures are covered in Chapter 5 on Safety (also see Paragraph 2.7.1).

Section 2. SOURCES

4.2.1 NEED FOR MAINTENANCE. The maintenance of water supply sources is largely concerned with providing a continuous and adequate supply of water. Either failure or contamination of a supply may have serious consequences with respect to a shore-based facility, and may require water rationing, or even may result in a complete lack of water for potable use. If the potable water system also serves as a firefighting supply, failure of the source of supply may not be

TABLE 16

Suggested Equipment and Supplies for Water Treatment Plants

EQUIPMENT

Alemite or zerk grease guns for plant equipment.
Block and tackle for 1/2-inch and 3/4-inch rope.
Boots, rubber.
Brooms, street, ordinary, industrial.
Brushes, flue, paint and whitewash, scrubbing, wire.
Caulking gun for windows.
Chain hoist, 1-ton capacity.
Electric drop light, explosion-proof with 200-foot extension cord.
Electric torch light, 1 1/2 or 3 volt.
Flashlights, hand.
Gloves, rubber and canvas work.
Hydrometers, battery and alcohol.
Ladders, step, extension (20 foot).
Lanterns, red and white globe.
Leak detectors.
Manhole lifter.
Mop and handle.
Paint sprayer.
Pick.
Rope, 1/2-inch, 3/4-inch, 1-inch, and sash cord.
Safety equipment: Barricades.
Electric blankets.
First aid equipment.
Gas detector.
Gas mask (chlorine).
Harness (safety belt) with 25 feet of 3/4-inch rope.
Respirator for paint spraying, dust, etc.
Warning signals.
Squeegees, floor and window.
Torches, bomb-type.
Two-wheel hand trucks.
Vacuum cleaner.

TABLE 16 (Continued)

Valve key.
Waste cans.
Wheel barrow, rubber-tired.
Wringer buckets.

GARDEN IMPLEMENTS

Brush hooks.
Garden trowel.
Hedge clippers.
Hoe.
Hose: Garden type (300 feet).
Nozzle (Shut-off type).
Insect sprayer.
Lawn roller.
Mower, lawn (hand or motor).
Pruning shears.
Rakes, wood, steel.
Scythe.
Sickle.
Spade.
Sprinklers.

TABLE 17

Suggested Materials and Supplies for Water Treatment Plants

Alcohol or anti-freeze.
Assortment of bolts, nuts, washers, screws, cotterpins, rivets, lock washers, cap screws, stud bolt, etc., stored in jars or cans.
Bricks, common.
Calcium chloride (for icy pavements).
Calking compound.
Calking compounds, Durolite or equal, for glass house windows.
Calking yarn.
Cement.
Cement, asbestos.
Chain, assorted sizes and lengths.
Chamois skins.
Cleaning compound, broiler.
Cleaning powders, assorted.
Cleaning solvents (kerosene, dry-cleaning solvent, carbon tetrachloride).
Cups, drinking.
Cutter wheels, spare.
Disinfectants (CN and others).

TABLE 17 (Continued)

Emery cloth, assorted grades.
Fittings, brass or iron, assorted sizes.
Flashlight batteries.
Fuses, assorted.
Glass.
Graphite.
Grease, for lubrication.
Hose, nipples, and clamps for garden hose, extra.
Iron and boiler cement.
Kerosene.
Lead and lead wool.
Light bulbs.
Measures, oil, 1 quart and 1 pint.
Mops.
Nails, assorted sizes.
Oakum.
Oil for lubrication.
Oil, rust removing, penetrating.
Packing for pumps.
Paint remover.
Painter's drop cloths.
Paints, turpentine, linseed oil, thinners, etc.
Pipe joint compound.
Pipe stock, depending on system.
Plugs, rubber expansion.
Polish, brass.
Putty.
Rags, clean and sterilized.
Sand, stone or gravel.
Sandpaper, assorted grades.
Soap.
Solder.
Soldering paste.
Spare handles for hammers, hatchets and axes.
Spare parts for all machines and apparatus.
Sponges.
Steel wool.
Tape, friction and electrician's.
Thermometers, assorted.
Toilet paper.
Towels.
Valve grinding compound.
Waste, wiping.
Wicks, for torches and lanterns.
Wire, annealed. No. 10 and No. 16.

tolerated. Therefore, necessary steps must be taken to insure the continuous operation of water supplies at required capacity. The prevention of contamination and the disinfection of contaminated supplies is also an important phase of water source maintenance.

4.2.2 GROUND WATER SUPPLIES. Several maintenance procedures are applicable to all types of ground water sources. Examples are inspection for contamination, review of operating records, cleaning, structure repair and disinfection.

4.2.2.1 Review of Operating Records. Since maintenance of source-of-supply capacity is essential to proper operation of the supply, it follows that current information must be available on the conditions existing for that source. By comparing the data from previous tests with current data, or by plotting historical data, it is possible to anticipate difficulties and provide proper maintenance. Examples of the information required are static level and pumping level in wells, output, etc. (see Paragraph 3.1.2.6.2 for the descriptions of static level, pumping level and other such terms for which data are recorded.)

4.2.2.2 Sanitary Inspections. There are a number of inspections to be made at regular intervals with respect to sanitary conditions.

(1) Surface Drainage. Wells, springs and infiltration galleries are vulnerable to contamination from surface water. Surface drainage should be checked to make certain that soil grading provides drainage away from the source. If standing water is within 50 feet of a well, spring or infiltration gallery, ditches must be dug to carry it away.

(2) Pollution Sources. It should be assured that possible sources of pollution are nonexistent.

(a) Livestock. No livestock should be allowed within 50 feet of a well. Where there are grazing livestock, fence the well site.

(b) Cesspools, septic tanks, etc. No cesspools, privies, septic tanks and their tile fields, sewer lines or abandoned wells (if not properly sealed) should be located within 100 feet of a well. Where any such sources of pollution exist, they should be removed and the area covered with hypochlorite. Any open excavation resulting this removal should be filled with clean earth.

4.2.2.3 Cleaning. Inspect wells, springs and infiltration galleries to determine the presence of silt or other matter of a clogging nature. The presence of such material may be evidenced by a decrease in depth to the bottom of a spring, infiltration gallery or dug well, or in wells by a decrease in output or, more specifically, in deep wells by a decrease in specific yield.

(1) Springs, infiltration galleries and dug wells shall be cleaned when the accumulation of silt on the bottom reaches a depth of one foot.

(2) Deep wells and driven wells usually have screens on the lower end of the casing. Methods for the cleaning of screens are discussed in paragraph 4.2.2.6.1.

4.2.2.4 Structure Repair. Check all concrete housing or other watertight structure around a well, spring or infiltration gallery for possible cracks or leaks, and if found, repair them. If the housing contains a manhole, it must be watertight. In the case of dug wells, inspect the casing for cracks in joints and repair if external seepage or intrusion of silt is evident. Nonmetallic casings in bored wells are subject to cracking and should be repaired if cracks are found.

4.2.2.5 Disinfection. Major pollution of aquifers may take years to be overcome. Minor pollution may be overcome by the normal operating procedure described in Paragraph 3.2.2. Disinfection as a maintenance procedure may be applied to wells of all types, to springs, infiltration galleries and Ranney collectors. Deep wells of all kinds shall be disinfected after original development; each time the pump is removed; each time the screen is cleaned by surging methods (see Paragraph 4.2.2.6.1(5)); and, whenever regular bacteriological analyses indicate contamination is present. Disinfection procedures are described in the following paragraphs.

(1) Deep Wells. Prepare a solution of sodium or calcium hypochlorite containing 50 to 100 p.p.m. of free residual chlorine. Introduce the solution into the well through a hose which terminates at the level of the well screen. Allow the well to stand for 24 hours, and then pump to waste until the chlorine residual drops to 0.1 p.p.m. (Surging during chlorine treatment is helpful; see Paragraph 4.2.2.6.1(5).)

(2) Springs and Dug Wells. Add sufficient hypochlorite compound to insure a concentration of free residual chlorine of 50 to 100 p.p.m., or sufficient to maintain a residual chlorine concentration of 50 to 100 p.p.m. while the spring is flowing. When the discharge from the spring contains no residual chlorine, take a sample for bacteriological analysis. If the test is negative, the spring may be returned to use.

(3) Infiltration Galleries and Ranney Collectors. Add sufficient hypochlorite compound to insure a free residual chlorine concentration in the gallery of 50 to 100 p.p.m., allow to stand for 24 hours and then pump to waste until the residual chlorine content drops to 0.1 p.p.m.

4.2.2.6 Deep Wells. Periodic inspection of the operating records shall be made to determine if there have been any changes in the static level, pumping level, drawdown and specific yield. The most common causes of adverse conditions with respect to well output are overpumping or pumping at high rates, clogging of screens, collapse of well screen or casing, leaking casings and worn pump impellors and pump bowls. The first of these causes is a matter of operation, the others may be remedied by maintenance procedures. Remedies for adverse conditions include the following.

(1) The pump bowls may be lowered to overcome well output loss due to a drop in the static water level in the well. This practice usually does not result in a permanent remedy, particularly if the adverse condition is due to "mining" the acquifer.

(2) A leaking casing or collapsed screen may require replacing. This requires that the well casing be pulled and a new one installed. A collapsed or deteriorated screen sometimes may be pulled for replacement. These operations usually require the services of an outside contractor.

(3) The well capacity may have to be restored by cleaning the well screens or the area surrounding the well screen. This operation may be accomplished by the cleaning processes described in Paragraph 4.2.2.6.1.

4.2.2.6.1 Well screen cleaning. Well screens are used on deep wells, either drilled or bored, and on driven wells. However, the latter are not cleaned by all of the methods set forth below.

(1) Acidizing. Incrustation of screens is caused principally by the deposition of calcium carbonate, or sometimes by deposition of iron oxide or calcium sulfate. Incrustation may also be caused by corrosion. Acidizing with properly inhibited muriatic acid or sulfamic acid will clean encrusted screens. Do not use uninhibited acids. The following procedures are applicable.

(a) The severity of incrustation should be estimated from the records of changes in yield, specific capacity, drawdown, etc.

(b) Unless otherwise directed by the Public Works Officer, base personnel should not be used for acidizing operations. An experienced and qualified contractor should be employed. All persons working on an acidizing project should wear proper protective clothing. CAUTION: Before proceeding with the treatment disconnect the well from the distribution system.

(c) An inhibited acid should be used. Most frequently used for acidizing wells is muriatic acid (commercial hydrochloric acid, 27 percent concentration) purchased with, or to which has been added, an inhibitor. These inhibitors minimize the attack on the metal, but do not affect the reaction with calcium carbonate; they are proprietary compounds. Selection of the inhibitor or inhibited acid should be made so as to obtain the maximum protection of the particular metal in the screen.

(d) The acid should be added carefully through a hose placed in the casing with its discharge end at the level of the screen. This prevents dilution of the acid and gives a concentration of about 15 percent at the screen (see Figure 169).

(e) Usually, the acid should be left in the well for at least five hours. For quicker action, the acid may be heated, particularly if there is a flow of water past the well screen.

(f) After the acid treatment, the well should be pumped to waste until the pH of the water returns to normal. CAUTION: Provide for neutralization of this wastewater or other safe disposal until the water returns to normal.

(g) Sulfamic acid (do not confuse with sulfuric acid) should be used in place of muriatic acid when it is desirable to do so. Sulfamic acid is a granular solid that is safe and easy to store and handle. It may be dissolved in water at the jobsite to provide a strong acid solution that will do the same cleaning job as muriatic acid. Al-

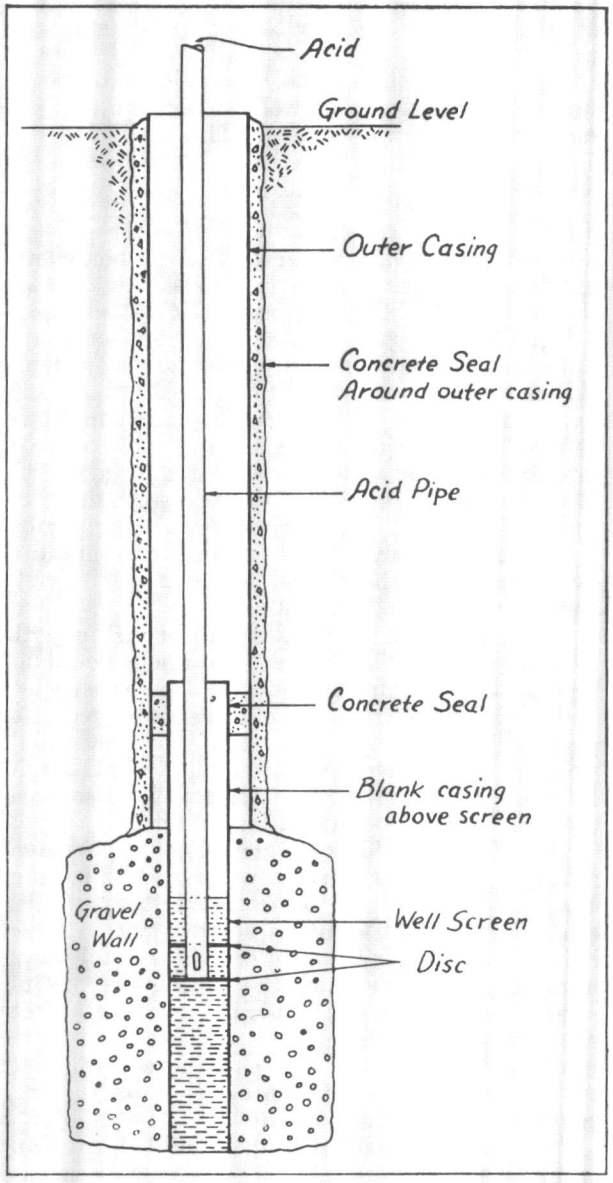


FIGURE 169

Method of Applying Acid to Individual Screen Sections of a Well

though it will not attack metals as rapidly as muriatic acid, inhibitors should still be used to protect the casing. To dissolve iron oxide deposits on the screens, add 50 lbs of salt for every 100 lbs of granular sulfamic acid.

(2) Chlorine Treatment. In addition to acid treatment, chlorine solutions may be used for cleaning well screens. Chlorine added to a clogged well may function in two ways. First, it destroys bacterial slime growths; and second, it forms weak hypochlorous acid which will attack the calcium carbonate. Follow these steps.

(a) Prepare solutions of chlorine containing 50 to 100 p.p.m. of chlorine and introduce the solution into the well in the same manner as acids are introduced (see Paragraph 4.2.2.6.1(1)(a) and (d)).

(b) Allow the well to stand for 24 hours, and then pump to waste until the chlorine residual reaches 0.1 p.p.m. Surging during chlorine treatment is helpful (see Paragraph 4.2.2.6.1(5)).

(3) Phosphate Treatment. The glassy phosphates (sodium hexametaphosphates) act as dispersing agents on such screen-plugging materials as amorphous silica, hydrated ferric oxide, iron carbonate and calcium carbonate. The treatment is as follows.

(a) Dissolve 15 to 30 lbs of glassy phosphate in a minimum amount of water and add 1 to 2 lbs of hypochlorite for each 100 gallons of water in the well casing under static conditions. To dissolve the phosphate, suspend the chemical in a wire basket or burlap bag—do not simply dump it in the dissolving tank or barrel. Add the solution to the well through a hose in the same manner as described for acids in Paragraph 4.2.2.6.1(1)(d).

(b) Allow the solution to remain for 24 to 48 hours and surge every two hours or so. If surging is not possible, allow the well to stand a week. CAUTION: Treatment with glassy phosphate for more than a week may cause the well yield to decrease.

(c) After treatment, pump the well to waste for some hours and test the output. Repeat the treatment until the output no longer improves.

(4) Dry Ice. Compressed carbon dioxide gas, or "dry ice" has been used for well cleaning with mixed results. It works best in deep wells with high static levels. The treatment procedure follows these steps.

(a) For wells 6 to 10 inches in diameter, use 10 to 15 lbs of dry ice for light surging and 25 to 50 lbs for heavy surging. Drop broken dry ice (pieces about 2 inches in diameter) into the well casing until enough has been added to blow the water out through the screen. There is no danger of freezing if there are 11 lbs (approximately 1.5 gallons) of water in the well casing for each pound of dry ice added.

(b) Provide a pressure gage on the well casing and seal the well to prevent loss of CO_2. When the gas is released, it expands and creates a surging action which produces backpressure and backwashing of the screens. The escape of gas through the water-bearing strata will be evident from irregular movement of the pressure gage needle. The particular conditions involved are different in practically all cases, and the exact procedure must depend largely on the judgment of the operator. CAUTION: Dry ice may cause "burns" if handled with bare hands. Therefore, use heavy gloves or tongs. Also, since high pressure may develop in dry ice treatment, provide for control and release of excessive pres-

sures (150 psi). The gas is suffocating, and ample ventilation must be provided.

(5) Surging. Surging is accomplished by a different method from that used for surging a new well being developed. This operation can be accomplished by utility personnel, without pulling the pump and without expert help. Follow these steps.

(a) Disconnect the discharge of the pump and alternately start and stop the pump. This operation raises the water in the pump casing and allows it to fall again. The greater the distance to the static water level, the more effective the operation. If the water level in the well stands at a high elevation, a surge pipe may be attached to the discharge of the pump.

(b) Repeat the process of starting and stopping the pump at short intervals until the discharge runs clear.

(6) Backwashing and Surging. Where surging alone is not sufficient in itself, backwashing may be used. This procedure consists of allowing a large volume of water to rush down the casing. Detailed steps are.

(a) Where bypass pump connections or wash-water lines are not included in the installation, remove the flap in the check valve.

(b) Open the pump discharge valve and allow a full head of water from the storage tank to rush down the well casing. If the casing fills rapidly, it is because the screen is badly clogged. CAUTION: Before starting the backwash operation, be sure the pump and motor turn freely; otherwise the downrush of water may rotate the pump in the wrong direction and unscrew the pump shafting.

(c) Allow the backwashing to continue for five minutes or so, then close the backwash valve, open the pump discharge valve and start pump, and run discharge to waste until the water is clear. Repeat the operation. Check the results by measuring water level and yield.

(7) Backwashing and backblowing. A combination of backwashing with water and backblowing with air may be used, if the well pump has been pulled. The compressed air increases the surging action and provides air-lift pumping which will remove dislodged sand. Use experienced labor for this operation, and follow this procedure.

(a) Remove the well pump and insert a 4-inch educator pipe to a depth consistent with the following table:

Depth of well (ft.)	*Submergence of eductor (%)*
10–50	70–66
50–100	66–55
100–200	55–50
200–300	50–43
300–400	43–40
400–500	40–33

The arrangement of eductor pipe and air line is shown in figure 170.

(b) Cap the 4-inch eduction line with a tapped pipe plug through which the air line runs. Connect the air pipe by means of an air hose (or nonrigid system) to an air compressor having a minimum capacity of 110 c.f.m.

(c) With the eduction valve open, build up the air pressure until the water is discharged and pressure reaches a constant value. Pump until water becomes clear.

(d) Release the air pressure, close the 4-inch discharge valve; apply air until static pressure is reached. At this point air escapes from the bottom of the 4-inch eduction pipe and causes both air and water to surge out through the screen and to create movement in the sand and gravel.

(e) Open the 4-inch discharge valve and allow the air-lift to pump out the loosened sand and silt.

(f) When the water is clear, repeat steps (d) and (e). Faster results are obtained if water can be pumped into the well casing at the same time as air is being added (step (d)).

(g) Check results after each series of operations. An increase in pumping pressure on the gage will indicate increasing inflow into the well and less drawdown. CAUTION: When starting backblowing operations, do not start at maximum rates. The gravel chamber should be full at all times to replace sand loss.

(h) For this operation, provide excess air. The desirable amounts of excess air, with 50 percent submergence, are shown in the following table:

Lift (ft.)	*Air required (c.f.m./gal. pumped)*
100	0.5
200	0.7
400	1.0
500	1.5

(8) Jet Cleaning. Horizontal jet cleaning of walls is done from inside the well screen. A relatively simple jetting tool with high pressure pump, necessary hose, a string of 2-inch pipe, and an adequate water supply are the only equipment needed. The jetting tool is shown in Figure 171. It consists of an attachment fitted with one to four horizontal nozzles (3/16, 1/4, or 3/8-inch orifices). The bottom of the tool is closed and the upper end is threaded so that it can be screwed to the lower end of the string of 2-inch pipe.

(a) Choose the correct nozzle. The choice depends on the high pressure pump. Table 18 gives the approximate discharge for various nozzles and pressures. The required pump pressure is the sum of the nozzle pressure plus the friction loss between the pump and the nozzle

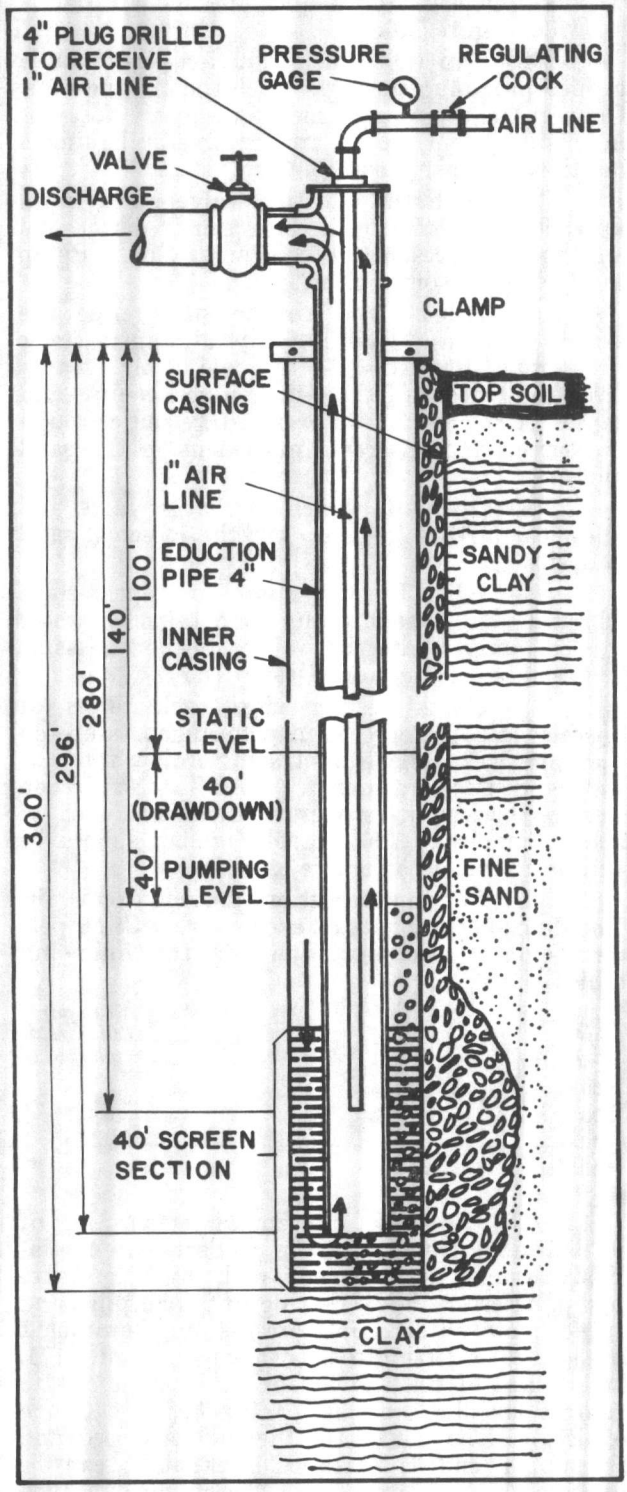


FIGURE 170

Piping Arrangement for Backwashing and Backblowing

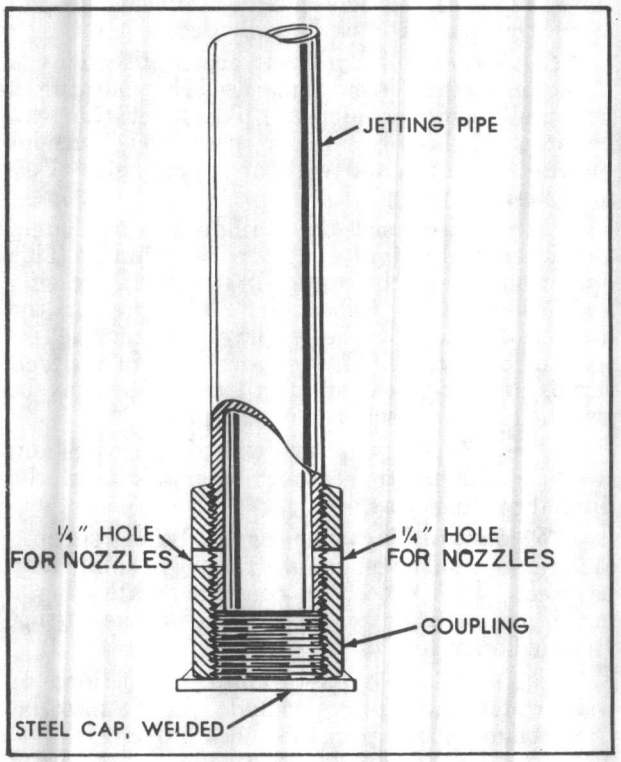


FIGURE 171

Jetting Tool for Well Screen Cleaning

For a 2-inch pipe, the friction loss is shown in the following table:

Discharge (g.p.m.)	*Pressure loss per 100 ft. (psi)*
50	4
100	10
150	17

Therefore, for a jetting tool with two ⅜-inch nozzles on a string of 2-inch pipe, 200 feet long at a pressure of 150 psi, the discharge will be 97 g.p.m., and the pressure loss will be 2 × 10, or 20 psi. The jetting pump will have to have a pressure of 170 psi to maintain a pressure of 150 psi at the nozzles.

(b) Attach the string of 2-inch pipe to a hose with a swivel connection at the top.

(c) Lower the jetting tool to the screen, turn on the high pressure pump, and slowly rotate the jetting tool while it is being slowly raised and lowered.

The forceful action of high-velocity jets, working out through the screen openings, breaks up the clogging material.

(d) Pump the well lightly at the same time the jetting is underway in order to remove the dislodged material; but the well pump should not be operated at full speed.

TABLE 18

Jetting Nozzle Discharge

Orifice (inches)	150 psi		200 psi		250 psi	
	1 Nozzle (g.p.m.)	2 Nozzles (g.p.m.)	1 Nozzle (g.p.m.)	2 Nozzles (g.p.m.)	1 Nozzle (g.p.m.)	2 Nozzles (g.p.m.)
3/16	13	25	15	29	17	33
1/4	23	45	26	52	52	37
3/8	49	97	56	110	61	120

(9) Sonic Process. This method shall be performed only by outside contractors. It consists of lowering a series of smaller, explosive charges on a wire into the well and detonating them by means of an electrical charge at the surface. The size of each charge depends on pipe size, thickness, grade, type and condition. The charges are placed on a connecting wire at calculated distances and are detonated in a special, delayed-time sequence. Each charge, lasting only a fraction of a second, creates an expanded gas bubble which produces a shock wave at its leading edge as it rushes down the well column. As the wave strikes the well casing, it causes strong vibrations which help loosen the clogging material. The expanding bubble also produces a surging action which helps clean the screen. This action is repeated with the detonation of each charge. CAUTION: Do not use any other method of explosive blasting for cleaning screens.

4.2.2.6.2 Well abandonment. Wells may be abandoned because of lowered water table; plugged screens; corroded casings which allow soil to enter the well; or, objectionable sand pumping. The following procedures apply.

(1) For deep wells and driven wells, the casing should be pulled and the hole filled with concrete, or should be securely capped to prevent any person or animal from falling into the well and to prevent contamination of the aquifer.

(2) Dug wells and springs, when abandoned, should be filled as a safety measure.

4.2.2.6.3 Well equipment inspection. In addition to the general sanitary inspection, deep well installations require additional inspection procedures, as follows.

(1) Check the well apron for watertightness. Be sure it will permit no seepage under it.

(2) Check the top of the casing for watertightness. Make certain the seal between the casing and the pump standard is intact.

(3) Check the well vent screens for clogging. Make certain they are not torn and that the vents have been installed properly.

(4) Check the well pits as a precaution against contamination.

4.2.2.6.4 Water for equipment operation. Water used for bearing lubrication and pump priming must be obtained from a safe and approved source. Make sure that cooling water for engines, air compressors or pumps is not returned to the water system.

4.2.2.6.5 Air compressors.

(1) Check the air intakes on compressors for screens as protection against the entrance of birds, insects, dust or contamination.

(2) Clean and replace the air filters.

(3) Blow down the air storage tanks to remove accumulated oil.

4.2.2.7 Bored Wells. Bored wells may fail because of casing collapse; lowering of water level by overpumping; and, screen clogging. Periodic inspections are required for exposed parts. Casings should be checked when the pump is pulled for any reason. Nonmetallic casings are subject to cracking or joint displacement. If the water is turbid, the screen is probably defective and should be removed, repaired and replaced. Any damage to the casings should be repaired.

4.2.2.8 Dug Wells. The nature of the construction makes dug wells difficult to maintain. Joints crack or fail, surface water may intrude and rapid silting or sanding may occur.

(1) Inspect casings periodically and repair as necessary.

(2) Dug well yields may be increased by driving horizontal collector pipes in the manner of the Ranney well collector system.

4.2.2.9 Driven Wells. Driving the well point may damage the screen or seal it off. If water yield decreases, suspect screen clogging and try backwashing. If this fails, pull the point and clean or replace it with a new one. CAUTION: Do not backwash driven-well screens at pressures greater than 150 psi.

4.2.2.10 Gravel-Packed Wells. This type of well may require more maintenance than other types because of silt clogging of both the screen and gravel space. Check gravel level; it should be above the top of the screen. Gravel should be

added as necessary. If the well is constructed with the gravel pack reaching the surface, the gravel level should be checked weekly and the gravel replenished as necessary.

4.2.2.11 Infiltration Galleries. In addition to the accumulation of silt, undermining of walls and failure of the wall structures may occur. Records on static level and drawdown of the infiltration gallery should be consulted at inspection time to determine if the gallery yield is being maintained. If the structure shows signs of deterioration, it should be shored up with proper attention to increasing the life of the structure. This repair may include cross bracing, adding sheet piles and adding gravel behind the walls if there has been a loss of material in that location.

4.2.2.12 Ranney Water Collectors. Ranney water collectors may be subject to contamination from overlying ground pollution if they are not deep. They may also be subject to silt or sand accumulation in some locations. Cleaning and disinfection are described in Paragraphs 4.2.2.3 and 4.2.2.5, respectively. Spalling of concrete walls, if severe, may require dewatering the collector well and guniting the surface.

4.2.2.13 Maui Wells. There is little maintenance to be done on a Maui well. Inspection of the tunnels can be made at the same time the pumps are inspected.

4.2.2.14 Maintenance Operation Frequency. The maintenance operation frequency and schedule of inspections are shown in Table 19.

4.2.3 SURFACE WATER SUPPLIES. As described in Chapter 3, surface water supplies may be taken from streams, rivers, impounding resorvoirs and lakes. Inspection and maintenance procedures depend on the type of source.

4.2.3.1 Watersheds. Every surface water supply has a watershed, the maintenance of which primarily involves sanitary precautions.

(1) Sanitation. The watershed area should be inspected at regular intervals. It should be made certain that facilities for the disposal of sewage, garbage and trash are available and in proper working order. Repairs should be made on these facilities when necessary. Where the watershed is not completely under the jurisdiction of the naval shore facility, liaison should be established with the local state health department.

(2) Cleaning. If recreational use of the watershed is allowed, it should be controlled to minimize possible pollution of the supply. If inspection reveals debris or unsanitary conditions, the situation should be corrected by proper means.

4.2.3.2 Reservoirs. As with watersheds, sanitary control must be maintained for the reservoir itself.

4.2.3.2.1 Recreational control. Where recreational use of a reservoir is allowed, it must be supervised and controlled in accordance with orders issued by the Public Works Officer or Field Engineering Officer, and the Bureau of Medicine. Regular inspection of conditions and analyses of the water supply reservoir are fundamental to good maintenance.

4.2.3.2.2 Mosquito control. In the summer months attention must be given to the control of mosquitoes. Since the larvae attach themselves to vegetation at the waterline in order to breathe, there are two means of control. All vegetation growing in shallow water and near the shore may be removed and the water level may be varied by a few inches at 10-day intervals. The larvae stage lasts 10 days, and the varying water level will either immerse the larvae or leave them exposed; either condition will destroy them.

4.2.3.2.3 Algae control. Control of algae growths to prevent tastes and odors is an operation function and, as such, is covered in paragraph 3.2.9.3. Inspection for maintenance operations shall report incipient algae blooms to the utility operating staff.

4.2.3.2.4 Capacity loss. Impounded reservoirs serve not only as sources of supply, but as sedimentation basins for silt. While this relieves the load on the treatment plant, it also gradually reduces the capacity of the reservoir. The extent of silting should be checked by plotting changes in bottom contour.

(1) Contour Lines to Locate Silt Deposits. The contour lines are determined by cross-sectional soundings at several locations between the dam and the upper end of the reservoir. Silting will be great where the reservoir first widens sufficiently to allow a decrease in entrance velocity to a point below the critical settling velocity.

(2) Period of Silting. Silting of reservoirs depends on the turbidity load of the entering stream, and appreciable loss of reservoir capacity usually requires a period of several years.

(3)Bottom Drawoff as a Preventive. Reservoirs with bottom drawoffs at the dam may be purged during flood flows by discharging excess water from the lower strata. Since the incoming water contains silt, it is heavier than the water in the reservoir, and bottom withdrawal will create a density current which sweeps underneath the major portion of the body of water, thus minimizing settling. The velocity of the density current is not sufficient, however, to create scour.

(4) Dredging as a Remedy. Dredging of silted reservoirs is the only maintenance remedy when capacity loss reaches an undesirable point. This work may be done by contract or by the activity's forces.

4.2.3.2.5 Sides and bottoms. When the sides of a reservoir become exposed because of lowered water level, they should be inspected. Extraneous debris and vegetation should be removed. The same operation applies to the bottom if it becomes

TABLE 19

Maintenance Procedures for Ground Water Supplies

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Operating record review	Ascertain changes in conditions since previous inspection and take necessary action.	SA	4.2.2.1.
Sanitary conditions	Dig ditches to carry away standing water within 50 ft. of well, spring or infiltration gallery.	SA	4.2.2.2.
Pollution sources	Fence area to keep livestock at least 50 ft. distant from well, spring, etc.	SA	4.2.2.2(1)(2).
	Remove cesspools, privies, septic tanks, etc.; cover area with hypochlorite; fill any open excavations resulting from removal.	SA	4.2.2.2(2)(b).
Wells, springs, infiltration galleries, silt, etc.	Remove accumulations if more than 1 ft. deep.	V	4.2.2.3.
Concrete; cracks in housing; Other watertight structures of wells, springs, infiltration galleries and Ranney wells.	Repair as necessary by making surface structure watertight.	Q	4.2.2.4.
	Shore up infiltration gallery wall structures.	Q	4.2.2.11.
Operating records and evidence of contamination.	Disinfect wells, springs, infiltration galleries, etc., when indicated.	V	4.2.2.5.
Well output loss and condition of well screen.	Clean well streen by approved method.	V	4.2.2.6 and 4.2.2.6.1.
Well equipment (well apron, top of casing, well pits); cracks and possible leakage.	Repair as necessary to make all items watertight.	SA	4.2.2.6.3.
Well vents	Clean, repair or replace if torn or clogged.	M	4.2.2.6.3(3).
Water use for equipment operation.	Make certain water for bearing lubrication and pump priming are from a safe supply, and that cooling water for engines and compressors is not returned to water system.	SA	4.2.2.6.4.
Air intakes on compressors	Screen air intake if necessary; clean and replace air filters; blow down air storage tanks to remove accumulated oil.	M	4.2.2.6.5.
Bored wells; casing failure	If water is turbid, the screen is defective; remove and replace.	V	4.2.2.7.
Dug wells; silt accumulation and wall failure.	Clean as necessary; repair cracked walls; increase capacity if necessary by driving horizontal collector pipes.	Q	4.2.2.8.
Driven well; decrease in water yield and screen clogging.	Try backwashing, or pull the point and clean or replace.	M	4.2.2.9.
Gravel-packed wells; silt clogging of screen and gravel pack; check gravel level.	Clean as necessary; add new gravel as required to keep the level at proper elevation.	M	4.2.2.10.

[1] M-Monthly; Q-Quarterly; SA-Semiannually; V-variable; as conditions may indicate.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

exposed. Sides should be graded to prevent erosion.

4.2.3.3 Dams. Impounding dams may be of concrete, masonry, earth or rockfill construction. Regular inspection shall include a check for leakage as well as for exposed surface conditions.

4.2.3.3.1 Concrete and masonry dams. Inspection shall be made at monthly intervals.

(1) Repairs. If leaks or seepage are evident, the necessary repairs should be made by plastering the upstream face of the dam with rich cement mortar. Visible cracks should be sealed with portland cement grout placed under pressure. CAUTION: Do not seal cracks on the downstream face of a dam until after the upstream face has been satisfactorily sealed. If surfaces are badly spalled, resurface by guniting.

TABLE 20

Maintenance Procedures for Surface Water Supplies

Inspection	Action	Frequency [1,2]	Reference Paragraph number
Watershed area	Make certain facilities are in working order for sewage disposal, and garbage and trash removal; repair facilities as necessary; remove debris.	Q	4.2.3.1
Recreational facilities on watershed.	Clean and repair facilities as necessary	M	4.2.3.2.1
Reservoir mosquito control	Remove vegetation in shallow water; vary water level a few inches.	Every 10-days (summer only)	4.2.3.2.2
Reservoir algae	Report algae blooms to operating staff	W (summer only)	4.2.3.2.3
Reservoir capacity loss	Dredge when necessary	A	4.2.3.2.4
Reservoir sides and bottom	Remove extraneous debris and vegetation from sides and bottom, if exposed; grade sides to prevent erosion.	W	4.2.3.2.5
Dams; leakage and exposed surface conditions.	Concrete and masonry dams: repair upstream face first, then downstream face.	M	4.2.3.3.1
	Earth and rockfill dams: sod or gravel slopes; keep riprap on upstream face even and in good condition; repair leaks by excavating and backfilling.	W	4.2.3.3.2
Ice conditions on concrete dam.	Where ice formations exist, break ice to a few feet upstream.	D (winter)	4.2.3.3.1(2)
Dam spillway conditions	If blocked, remove trash, debris or ice	D	4.2.3.3.1(3)
Dam gates	Lubricate gates and appurtenances	M	4.2.3.3.1(4)
Intake structures to ascertain cracks and determine silt deposits; ice conditions.	Repair cracks; remove silt deposits; take action to prevent ice clogging.	W	4.2.3.4.1
Intake screens	Remove any material not removable by regular operation procedures.	W	4.2.3.4.2

[1] D-Daily; W-Weekly; M-Monthly; Q-Quarterly; A-Annually; as conditions may indicate.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

(2) Ice-Thrust Protection. Where ice formations exist, break the ice along the dam to a distance of a few feet upstream to protect the dam against ice-thrust.

(3) Spillway Maintenance. If spillways are blocked by trash, debris or ice, they must be freed to prevent possible overtopping, and raising of the reservoir level to a point that might damage shorelines. One means of protecting spillways is to place a log boom 25 to 30 feet upstream of the spillway (see Figure 172).

(4) Gate Lubrication. At each inspection gates and appurtenance equipment should be lubricated as necessary.

4.2.3.3.2 Earthfill and rockfill dams. Properly constructed earth dikes provide a means for keeping water from entering the earth, and provide a means for any water that does enter the dike to travel to the downstream face of the dam without building up internal pressure.

(1) External Conditions. Embankments should be inspected and a proper appearance maintained with all slopes—sodded or graveled. Riprap on the upstream face should be kept even and in good condition.

(2) Leakage. If leaks or seepage are evident from inspection, the turbidity of the seeping water will indicate the importance of the condition.

(a) Clear water indicates no loss of soil and no increase in size of leak. Turbid water indicates a worsening of conditions, and the more turbid the water, the more urgent the need for repair.

(b) Seepage at or under the toe of the dam indicates a dangerous condition. Such seepage will result in failure. If seepage is observed, it should be reported to the Public Works Officer immediately.

(3) Repairs. Leaks of less-than-major proportions should be repaired immediately by excavating to a moderate depth on the upstream

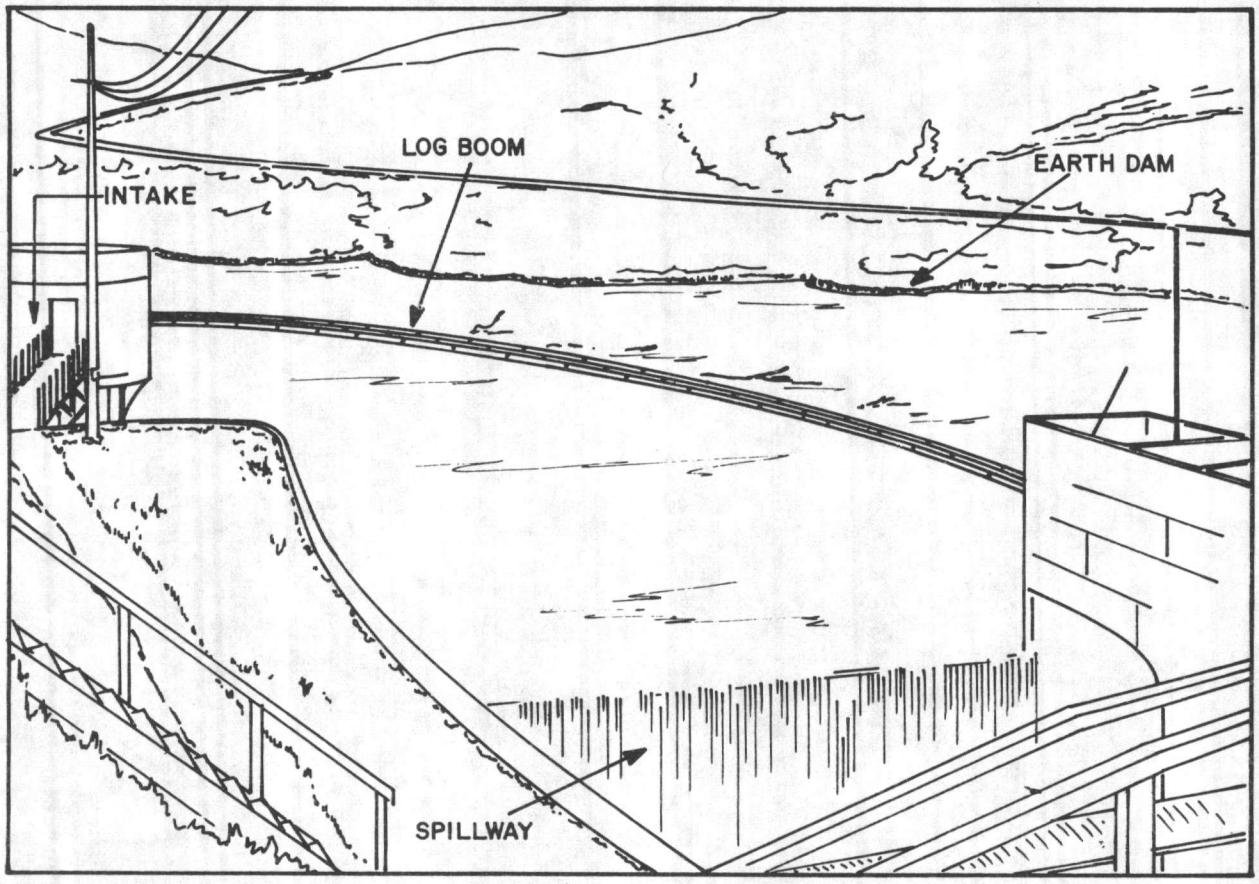


FIGURE 172

Log Boom for Protecting Dam Spillway

face and sealing with puddled clay rammed into place. Serious leaks require that the dike be cut down from the top and filled with good material. The new fill should be bonded into the original material and compacted as for a new embankment. When seepage is detected at the toe of the dam, new layers of earth should be added to the downstream face in the same manner as is done for new dikes.

(4) Spillways. Spillways for earthfill and rockfill dams require the same attention as concrete dams (see par. 4.2.3.3.1(3)), and gates, if any, require attention to lubrication.

4.2.3.4 Intakes. Maintenance operations on intakes in rivers, lakes and impounded reservoirs are concerned with the structure and its appurtenances.

4.2.3.4.1 Structures. Periodic inspections shall be made for cracks or structural defects. The depth of the suction well should be measured to determine the accumulation of silt and sand. These accumulations should be dredged as necessary. Where ice conditions endanger the structure or clog the intake opening, protective measures are necessary. Log booms should be installed or compressed introduced air at critical points to prevent freezing.

4.2.3.4.2 Screens. Remove any material on the screens that is not removable by ordinary operations. Lubricate and repair any accessory equipment to movable screens. Problems with ice may be reduced by the methods outlined in paragraph 4.2.3.4.1.

4.2.3.5 Maintenance Operation Frequency. The maintenance operation frequency and schedule of inspections for surface water supplies are shown in Table 20.

Section 3. TREATMENT PLANT MAINTENANCE

4.3.1 SOLUTION FEED CHLORINATORS. The maintenance operations described under this paragraph are applicable to all gaseous chlorinators, regardless of type. See paragraph 3.2.2.4.2 for a description of types and illustrations of chlorinator equipment.

4.3.1.1 Operator Inspection. As defined in paragraph 4.1.3.1, some preventive maintenance practices are fundamentally a part of normal equipment operations. Follow these precautions.

(1) When connecting chlorine valves or tubes to cylinders or equipment, use a new lead gasket each time, and use only one gasket in each connection.

(2) Guard against condensation on chlorine cylinder walls by maintaining proper ventilation around the equipment. Condensation may corrode scales or other equipment. An electric fan may be sufficient to keep the equipment dry. CAUTION: Do not use direct heat to dry cylinder surfaces.

4.3.1.2 Leak Detection. Chlorinators and all piping should be inspected daily for leaks. For chlorine leak detection, an unstoppered bottle of aqua ammonia (or an aspirator-type bottle) should be used near all joints, valves and piping. White fumes indicate chlorine leaks. Repair immediately, no matter how small, as they only increase in size and cause corrosion and damage which may become extensive. (Keep the ammonia bottle tightly stoppered when not in use.)

4.3.1.3 Gas System. In addition to leak inspection, all parts and piping in contact with chlorine gas should be inspected daily to be assured that operation is satisfactory. This includes metering devices, valves, tubing, etc., which should be disassembled and cleaned where necessary; the source of trouble should be determined; and faulty parts should be replaced at the first indication of weakening.

4.3.1.4 Chlorine Valves. All chlorine valves should be opened and closed daily during inspection in order to prevent freezing of the threads. Force should never be used to close chlorine valves. Stuffing boxes should be checked and faulty valves repaired or replaced immediately.

4.3.1.5 Chlorine Solution Tubes. Tubing should be inspected annually for locations of potential leaks (e.g., abrasions or cracks and kinks). Also, it should be determined if iron or manganese deposits are present. If so they should be removed by the addition of a 10-percent solution of hexametaphosphate to the makeup water at the rate of one drop per minute. This treatment should be continued until the deposit has disappeared. An inverted bottle, feeding out through a rubber hose, and a pinch-cock set for the desired rate should be used. (see fig. 173.)

4.3.1.6 Water System. Monthly, water strainers and pressure-reducing valves shall be checked for proper operation. Float valves should be adjusted, if necessary, to assure that the water is at the proper level and that leakage and splashing are at a minimum. Water flowing to wastes should not be excessive. The ejector capacity should be ample; if it is not, the ejector should be removed and cleaned with muriatic acid.

4.3.1.7 Hard-Rubber Parts. Hard-rubber threads or parts should be disassembled or operated quarterly to prevent "freezing" of joints and subsequent breakage during dismantling. Graphite grease should be used on threads before reassembly. CAUTION: Tools should not be used on hard-rubber parts (except a strap wrench, if necessary); screwed, hard-rubber parts should be hand tightened.

4.3.1.8 Vacuum Relief. Operation of the relief line should be checked daily; it should be open and contain no obstructions such as wasps' nests.

4.3.1.9 Cabinet and Critical Parts. Weekly, chlorinator cabinet and all parts should be cleaned, including the metering devices, where dirt may cause improper operation or produce an unsightly condition. Unpainted metal subject to corrosion should be painted, and covered with petrolatum or some other protective compound.

4.3.1.10 Overhaul. For complete annual overhaul, all chlorinator parts should be disassembled and cleaned thoroughly. The chlorinator cabinet should be painted inside and out with rust-resisting paint. All parts should be examined, and repaired or replaced as necessary. The chlorinator should be reassembled and checked for operation.

(1) Cleaning Liquids. Only wood alcohol or carbon tetrachloride should be used for cleaning chlorinator parts. After cleaning, the equipment should be allowed to dry. (Ethyl alcohol, ether or water should not be used to clean equipment; the first two react with chlorine to produce waxy substances, which are difficult to remove, and water combines with chlorine to form a corrosive

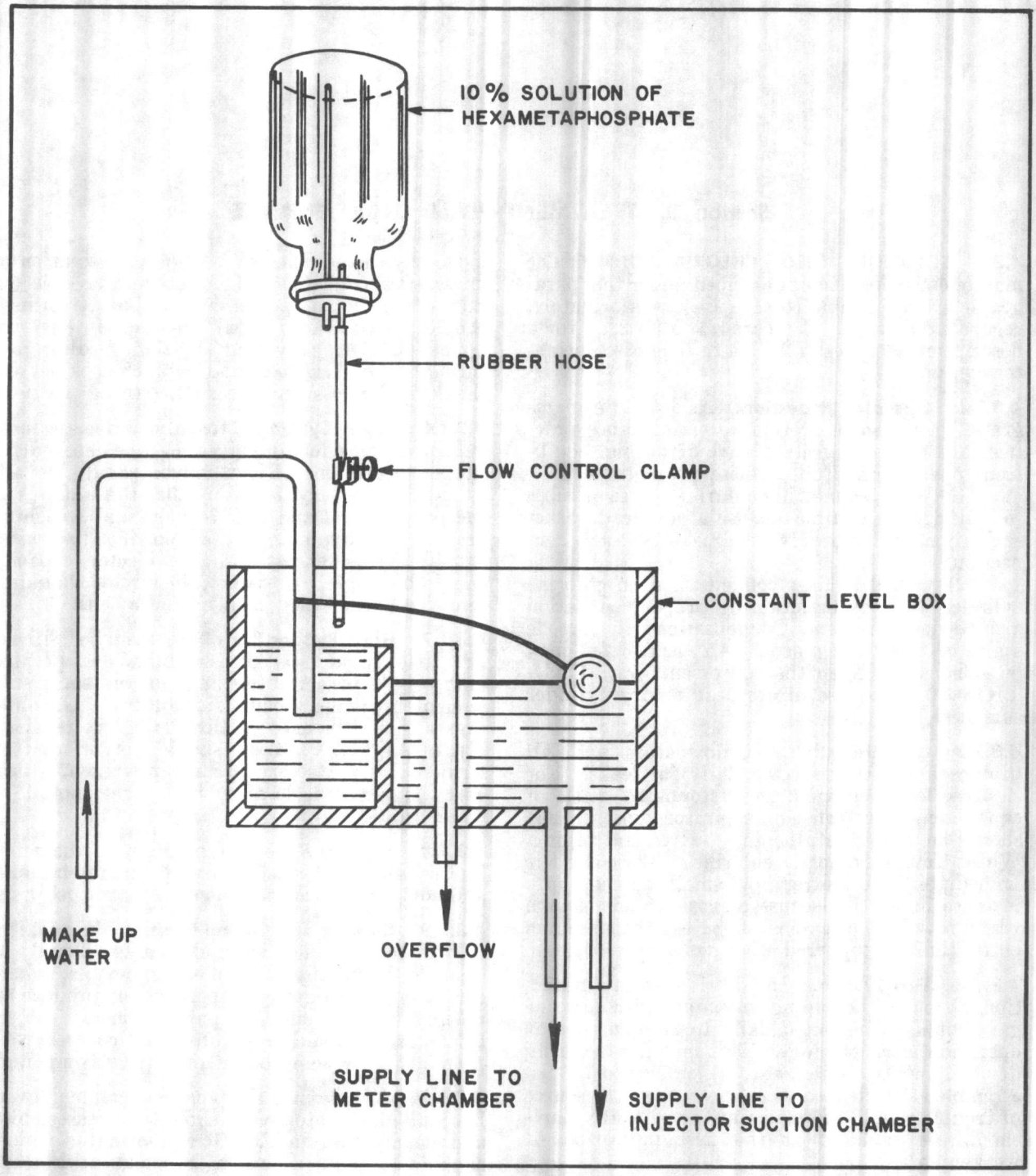


FIGURE 173

Arrangement for Adding Hexametaphosphate to Chlorine Solution Tubes

TABLE 21

Maintenance Procedures for Chlorination Equipment

Inspection	Action	Frequency [1,2]	Reference Paragraph number
Operation maintenance	Insert new lead gasket in chlorine valves or tubes to cylinders or equipment.	V	4.3.1.1(1)
Condensation on chlorine cylinders.	Ventilate	V	4.3.1.1(2)
Chlorine leak detection	Use unstoppered bottle of acqua-ammonia to detect leaks; repair immediately.	D	4.3.1.2
Gas system	Disassemble, clean and replace faulty parts in piping, meters, valves and tubing.	D	4.3.1.3
Chlorine valves	Open and close valves to assure that none are frozen in a set; check stuffing boxes, and repair or replace faulty valves or packing.	D	4.3.1.4
Chlorine solution tubes	Look for locations of potential leaks, and for iron and manganese deposits; if Fe or Mn are present, treat with a solution of hexametaphosphate in makeup water.	A	4.3.1.5
Chlorine feeder water supply	Clean water strainers and pressure reducing valves; adjust float valves and ejector capacity.	M	4.3.1.6
Hard-rubber threads, valves and parts.	Disassemble or operate; use graphite grease to prevent freezing; hand tighten only, do not use tools.	Q	4.3.1.7
Vacuum relief	Clean out any obstructions	D	4.3.1.8
Cabinet and working parts	Clean all parts where accumulation may interfere with proper operation.	W	4.3.1.9
Overhaul	Disassemble and clean all parts thoroughly; paint cabinet inside and out; examine parts and repair or replace as needed; use care in choice of cleaning agents and lubricants.	A	4.3.1.10
Direct-feed chlorinators	Use same procedures as for solution feed machines where they apply.	----------	4.3.2
Hypochlorinators	See Table 22	----------	4.3.3

[1] D-Daily; W-Weekly; M-Monthly; Q-Quarterly; A-Annually, V-Variable; as conditions may indicate.

[2] The frequencies shown are suggested and may be modified by local command, as individual installation conditions warrant.

acid.) CAUTION: Although carbon tetrachloride is nonflammable, it is toxic and unsafe for use in rooms where the concentration is greater than 100 p.p.m. NOTE: Carbon tetrachloride shall not be used without the expressed permission of the Public Works Officer.

(2)Lubricants. On metal screwed pipe fittings, only litharge and glycerine cement should be used. Oil or grease should not be used for lubrication at any points where they may come in contact with chlorine, as they react with chlorine to form a frothy substance.

4.3.1.11 Maintenance Procedure Schedule. The maintenance operation frequency and schedule of inspections are presented in table 21.

4.3.2 DIRECT-FEED CHLORINATORS. Direct-feed chlorinators, described in paragraph 3.2.2.4.3, require the same maintenance of gas piping and gas feeding mechanisms as do solution-type feeders (see par. 4.3.1), but do not require maintenance of equipment in contact with chlorine solutions, as there is no such contact.

4.3.3 HYPOCHLORINATORS. Feeders for hypochlorite solutions are described and illustrated in paragraph 3.2.2.4.5. All of these devices are solution feed, modified, positive-displacement or diaphragm proportioning pumps. See paragraph 4.3.6.5 for maintenance procedures for proportioning pumps.

4.3.4 DRY CHEMICAL FEEDERS. Dry chemical feeders are described and illustrated in paragraph 3.2.3. The following instructions apply to all types of volumetric and gravimetric dry feeders, including disk, oscillating, rotary gate, belt-type, screw and loss-in-weight. Specific instructions for specific types of feeders are given in paragraph 4.3.4.5.

4.3.4.1 Cleaning, Inspection, and Servicing. Daily, the following basic maintenance operations shall be applied to all dry chemical feeders.

(1) Clean the feeder, the feeder mechanism and the feeder surroundings. Use a vacuum cleaner or brush to remove spilled chemicals or chemical dust. Make certain that the orifice, knife edges, scrapers, shakers and openings are free of chemical accumulations in volumetric feeders, and that both belt rolls and belt, in belt-gravimetric feeders, are free of chemical accumulations.

(2) Check the feeder for general performance. Note and investigate unusual noises. Observe the condition of electrical wiring, fuses and connections. Check for oil drips and general deterioration. Make such repairs as are necessary to overcome deterioration and lack of good performance.

(3) Wipe all parts of the feeder and inspect for loose bolts, cracks, defective parts and leaks. Make the necessary repairs to eliminate undesirable conditions.

(4) Check the solution tank for sediment or undissolved chemical; remove accumulated material. If the dissolver is lined with asphalt, check the lining which should not be skinned away from the steel. Follow the manufacturer's instructions to repair such linings.

(5) Quarterly, service moving parts and lubricate, in accordance with manufacturer's instructions.

4.3.4.2 Test Calibration. Monthly, make test calibrations to check the accuracy of feed rate and of the mechanisms which control, indicate or record feed rates and amounts. The test procedures will vary somewhat with the type of feeder, but the following instructions apply generally.

4.3.4.2.1 Volumetric dry feeders. Make at least three tests within the normal operating range of the feeder.

(1) Feeders Not on Scales. Use a tared pan or other container to catch the discharge of the feeder for a definite period of time. Weigh the material discharged, calculate the rate of feed per hour and compare the result with the rate setting, rate indicator and recorder (if one is used). Repeat the test and average the results. Use particular care in timing and weighing operation. Make any adjustments necessary to bring the feed rate to within ±5 percent by weight of the rate setting.

(2) Feeders on Scales. Balance the scale while the feeder is stopped; start the feder and run for a definite period of time; rebalance the scale. From the two scale feedings, calculate the amount fed in the measured time period and then calculate the feeding rate in pounds per hour. Repeat the test. Average the data of the several tests and compare the result with the rate setting and the rate indicator (or indicator-recorder). Make such adjustments in the feeding device as are necessary to insure a feed rate error of less than ±5 percent by weight.

4.3.4.2.2 Gravimetric feeders. Make at least three tests within the normal operating range. Since there are different types of gravimetric feeders, the details of the tests differ. See paragraphs 4.3.4.5.4 and 4.3.4.5.5 for detailed test procedures, and consult the manufacturer's instructions.

4.3.4.3 Overhaul. Annual overhaul includes a thorough cleaning of the feeder, its feeding mechanism, housing and storage hopper; painting the exterior (and interior, where desirable); servicing and lubricating all drive mechanisms, bearings and other mechanical parts; and, cleaning, repairing and painting the solution and makeup tanks. Gravimetric feeders require additional attention to cleaning and servicing the feeder mechanism. For belt-gravimetric feeders, remove the feeder-belt assembly motors, belts and appurtenances, and overhaul completely as necessary. Loss-in-weight gravimetric feeders shall be disassembled, cleaned and inspected for wear, and repaired or damaged parts replaced as necessary.

4.3.4.4 Feeders Out-of-Service. For feeders out-of-service, it should be made certain that the feeder contains no chemical, and that condensation is not causing corrosion or deterioration. Belt feeders should have no chemical on the belt, while the feeder is out-of-service.

4.3.4.5 Specific Feeder Types. As pointed out in paragraph 4.3.4, specific types of feeders may have specific procedures applicable solely to that type. The following instructions cover the several specific feeders described in paragraph 3.2.3.

4.3.4.5.1 Disk-type feeder. It should be made certain monthly that the rotating disks are completely clean and free of caked chemicals, and that the stationary plow is free of chemical accumulations.

4.3.4.5.2 Oscillating-type feeder. The connecting rod to the oscillating hopper and the micrometer screw which sets the stroke should be inspected. The hopper agitators should be checked to make certain they move freely.

4.3.4.5.3 Rotary gate feeder. It should be made certain monthly that the pockets in the face of the star-rotor are clean and free of accumulations of chemicals, so that the rotor neither binds in the housing nor is loose enough to allow leakage. The rotor driving mechanism should be checked and it should be made certain that the scrapers, which clean the pockets, are doing an effective job.

4.3.4.5.4 Belt-type gravimetric feeder. The vibratory mechanism, the tare-weight balance, the feeding gate and the belt drive and belt should be inspected monthly. The feeder output should be tested by following these steps.

(1) After the belt and feeder have been cleaned, balance the scale and operate the feeder until scale beam is in close balance and indicates a proper load on the belt. If the feeder is proportionally paced, set the proportional equipment on "Manual Control"; set the instruments at maximum and proceed with the calibration test.

(2) Stop the feeder, make certain that the scale moves freely and is in exact balance. Adjust the amount of chemical on the belt by adding or removing chemical at the rear end of the belt, until an exact balance is obtained.

(3) Read the belt revolution counter or weight integrator, start the feeder and run it until a definite weight of chemical has been discharged (about two-thirds of a belt load). Stop the feeder.

(4) Balance the scale exactly by moving the poise. The difference between this scale reading and that at the start of the test is the weight of the material discharged. Check this amount against the number of pounds fed, as indicated by the revolution counter.

(5) If the weight of the chemical delivered differs from that indicated by more than ± 1 percent, adjust the poise on the scale beam and repeat the test. (NOTE: Moving the poise to a lower value reduces the loading on the belt, and vice versa.)

(6) Repeat testing and adjustment until a belt loading is found that agrees with the amount fed, as indicated by the totalizer counter.

(7) Whenever a feeder is used for a different chemical, the calibration must be repeated.

(8) Some belt-type feeders may be made to discharge into a tared container, in which case the feed rate may be checked by actually weighing the amount discharged in a definite period of time.

4.3.4.5.5 Loss-in-weight gravimetric feeders. The feeder scale should be inspected monthly to assure that it is sensitive to small weight changes; when the feeder is empty, the tare weight should be checked and it should be determined if the scale shows zero weight.

4.3.4.5.6 Screw feeder. It should be made certain monthly that the screw is clean and free of chemical accumulations or corrosion. The ratchet drive and variable-speed drive should be checked where used.

4.3.4.5.7 Lime slakers. Continuous lime slakers are part of the chemical feeder where quicklime is used for water softening. The following maintenance procedures shall be used on this equipment.

(1) Operator Inspection. Daily, clean dust-removal and vapor-removal equipment each shift, and make certain that dust and moisture do not reach the chemical feeding mechanism and cause caking or corrosion. Remove clinkers or grit not removed by regular operations.

(2) Cleaning Maintenance. Weekly, when the slaker is out of service, clean grit out of each compartment. Wipe off outside of slaker with an oily rag. (The thin film of oil prevents the adherence of moisture or lime solution and thus protects paint.) Clean the vapor-removal system and check mechanism for proper functioning. Clean all appurtenances.

(3) Inspection and Repair. Monthly, check agitators, stirrers and heat exchangers; replace any impellers on baffles in front of the heat exchanger which show appreciable wear. Inspect and repair, or replace as necessary, all wiring defects or metal deteriorations. Tighten bolts, eliminate vibration, tighten belts and paint where necessary. Every 1,000 to 1,500 hours, lubricate the support bearing-drive end, using a grease and not oil.

(4) Overhaul. Annual overhaul of lime-slakers involves the following procedures.

(a) Drain and clean slaker and dust-removal system.

(b) Check slaker bottom and sides for wear and repair as necessary.

(c) Paint slaker lids, exterior and inside top edges to reduce corrosion.

(d) Check for leaks in heat exchanger and for incrustation.

(e) Clean thermometers and check accuracy.

(f) Clean and lubricate bearings.

(g) Clean and repair controls, floats, piping, screens, valves and vapor removal equipment.

(h) Paint all equipment where necessary.

4.3.4.6 Maintenance Procedure Schedule. The maintenance operation frequency and schedule of inspections are presented in table 22.

4.3.5 DUST COLLECTORS. The need for dust-removal equipment with dry chemical feeders is mentioned in paragraph 3.2.3.1.8. Maintenance of dust-collector equipment involves these procedures.

(1) Lubricate the motor in accordance with conditions of usage and location. Consult the manufacturer's instructions.

(2) Inspect the filter bags for tears or other damage. Also, frequently check that the filter bags are properly and securely attached to the manifold plate at the bottom of the dust-collector cabinet. Install new filter bags whenever bag damage is evident.

4.3.5.1 Maintenance Procedure Schedule. Maintenance operations frequencies are presented in table 22.

4.3.6 SOLUTION FEEDERS. Solution feeders are described and illustrated in paragraph 3.2.3.2.

4.3.6.1 Pot Feeders. Maintenance consists of daily operation inspection, monthly cleaning and annual overhaul.

TABLE 22

Maintenance Procedures for Dry Chemical Feeders

Inspection	Action	Frequency [1,2]	Reference Paragraph number
Dry feeders	Remove chemical dust accumulations; check feeder performance; check for loose bolts; clean solution tank of accumulated sediment; lubricate moving parts.	D	4.3.4.1
Drive mechanisms and moving parts.	Service and lubricate	Q	4.3.4.1(5)
Calibration	Check feed-rate accuracy and adjust, as necessary	M	4.3.4.2
Overhaul feeders	Thoroughly clean feeder and feeding mechanism; paint; service and lubricate drive mechanisms, bearings; clean and paint solution tanks.	A	4.3.4.3
Feeders out-of-service	Clean, remove all chemicals from hopper and feeder mechanism.	V	4.3.4.4
Disk feeders	Clean rotating disk and plow	M	4.3.4.5.1
Oscillating feeders	Check and adjust mechanism and adjustable stroke rod.	M	4.3.4.5.2
Rotary gate feeders	Clean pockets of star feeder and scraper	M	4.3.4.5.3
Belt-type feeders	Check vibratory mechanism, tare-balance, feeding gate, belt drive and belt; calibrate delivery.	M	4.3.4.5.4
Loss-in-weight feeders	Check feeder scale sensitivity, tare-weight and null balance.	M	4.3.4.5.5
Screw feeders	Clean screw, check ratchet drive or variable speed drive.	M	4.3.4.5.6
Lime slakers	Clean dust-removal and vapor-removal equipment; remove clinker.	D	4.3.4.5.7(1)
	Clean equipment; wipe off feeder; check operation of vapor removal equipment; clean compartments.	W	4.3.4.5.7(2)
	Repair agitators, stirrers and heat exchanger baffles	M	4.3.4.5.7(3)
	Overhaul slakers; drain and clean; check sides and bottom for wear and repair; paint lids, exterior, inside top edges; check for leaks and incrustation in heat exchanger; check thermometer accuracy; clean and lubricate bearings; clean and repair controls, floats, piping, screens, valves and vapor removal equipment; paint where necessary.	A	4.3.4.5.7(4)
Dust collectors			4.3.5
Motors	Lubricate motors	V	4.3.5(1)
Filter bags	Check condition and attachment. Securely attach sound bags; replace damaged or torn bags.	V	4.3.5(2)

[1] D-Daily; M-Monthly; Q-Quarterly; A-Annually; V-Variable; as conditions may indicate.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

(1) Daily operator inspection includes observations of amount of chemical fed to determine whether flow through the pot is effective.

(2) Cleaning of the sediment trap and checking of the needle valve should be done at monthly intervals.

(3) Cleaning of the chemical pot and orifice should be done twice a year.

(4) Annual overhaul includes cleaning and painting of the pot feeder and appurtenances.

4.3.6.2 Differential Solution Feeder. The chemical storage tank should be inspected and cleaned and the volume of oil checked semiannually (replenished, if necessary). Annual inspection shall include a check of the pitot-tubes and needle valve. Paint the chemical storage tank and appurtenances as necessary.

4.3.6.3 Decanter or Swing-Pipe Feeder. Monthly, the swing-pipe should be checked; semiannu-

ally, the reducing gears, pawl, ratchet, and motor should be checked and overhauled annually, or as necessary, including cleaning, repairing and painting all parts that require attention.

4.3.6.4 Rotating Dipper Feeder. The manufacturer's instructions should be followed in maintenance of the motor. With respect to other parts of the feeder, these instructions should be followed.

(1) Change transmission oil after 100 hours of operation. Every six months, drain and flush transmission, clean interior to remove rancid and spent oil. Refill to gage level with oil specified by manufacturer.

(2) Lubricate dipper shaft bearings weekly.

(3) Clean drive chain and lubricate monthly; make certain that alinement is good; check and lubricate sprocket teeth.

(4) If an agitator is used, clean and lubricate at intervals recommended by manufacturer.

(5) Monthly, check the alinement, tension and inner cords of belt drives.

(6) Semiannually, check float valve seating, replace worn washers and worn valve seats. Check dipper clearance and adjust.

4.3.6.5 Proportioning Pumps. These liquid or solution feeders are described and illustrated in paragraph 3.2.3.2.4. Whether piston-type or diaphragm-type, these pumps are used for liquid chemicals and chemical solutions, including hypochlorite solutions.

4.3.6.5.1 Operator inspection. Regardless of the type of feeder, certain operation-maintenance procedures are applicable. Included in these procedures are these.

(1) Weekly, inspect sight-feed indicators to ensure that the solution is being delivered from the feeder, and check automatic controls and rates of feed under varying rates of flow of water being treated, if proportional feeding is being used.

(2) Weekly, check piping joints and packing glands to be assured that there are no leaks.

4.3.6.5.2 Cleaning. Monthly, follow these procedures.

(1) Remove and clean the sight-feed glass and plastic parts. Use a 5 percent solution of muriatic acid to clean off white deposits left by hard water.

(2) Clean and flush the solution storage tank. Clean suction hose and strainer, and screens on waterlines.

(3) Operate the shut-off and rate-control valves and mechanisms which control the output of the feeder.

(4) Disassemble, inspect and clean the feeding mechanism (diaphragm or plunger), and check the valves on the suction and discharge.

4.3.6.5.3 Overhaul. Annually, remove, inspect, clean and replace, as necessary, the feeding mechanism (diaphragm, plunger, orifice, needle valves, check valves, etc.). Replace all worn parts and packing. Check for corrosion; reline piston-pumps, if necessary; and, replace cracked diaphragms in diaphragm pumps. Paint or touch up all exposed metal parts, using enamel where required.

4.3.6.6 Maintenance Procedure Schedule. The maintenance operation frequency and schedules of inspection are presented in table 23.

4.3.7 SOFTENING EQUIPMENT. The theory and operation of water softening equipment are discussed in paragraphs 3.2.5.2 and 3.2.5.3.

4.3.7.1 Ion-Exchange Units. An ion-exchange unit is illustrated in figure 65. Maintenance procedures are set forth in the following paragraphs.

4.3.7.1.1 Softener Unit. The softener unit itself consists of a steel shell, containing a supporting grid in the bottom, a layer of gravel and a layer of ion-exchange resin. The shell is equipped with openings, valves and fittings.

(1) Shell. Annually, the exterior of the shell shall be cleaned and brushed with a wire brush, and then painted to protect it against corrosion.

(2) Valves and Fittings. Quarterly, fittings for the distribution of water and brine shall be checked for possible obstructions, corrosion and security fastness. Semiannually, each individual valve shall be inspected and tested for leaks, and repacked, if necessary.

(a) Semiannually, where multiport valves are used (see fig. 174 and 175), they shall be serviced and lubricated in strict conformance with the manufacturer's instructions. Lubricate this type of valve with grease as follows.

1. Add grease by pressure gun to each grease fitting, while the valve is set in "service" or "wash" position.

2. Turn valve half a turn and add more grease.

3. Give valve several full turns to spread the lubricant.

This lubrication operation does not require that the softener be removed from service, but if the water flow is stopped, no grease will get into the water.

(3) Ion-Exchange Medium. Quarterly, flush ion-exchange beds with chlorinated water containing at least 2 p.p.m. of chlorine. Do not use water with a hardness greater than 170 p.p.m., and be certain that the pH of the water is approximately neutral. Also, follow these directions.

(a) Check the bed surface for dirt, fines, organic growths and for smoothness. Scrape excess foreign matter off and replace with new resin. If the surface is uneven, the gravel bed underneath is not distributing the wash water evenly. The remedy consists of removal of resin and gravel, and replacing both in proper fashion.

TABLE 23

Maintenance Procedures for Liquid and Solution Chemical Feeders

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Pot feeders			4.3.6.1
Flow through pot	Determine amount of chemical fed to ascertain if flow through pot is effective.	D	4.3.6.1(1)
Sediment trap	Clean trap and check needle valve	M	4.3.6.1(2)
Chemical pot	Clean pot and orifice	SA	4.3.6.1(3)
Overhaul	Clean and paint pot feeder and appurtenances	A	4.3.6.1(4)
Differential solution feeders			4.3.6.2
Chemical storage tank	Inspect and clean	SA	4.3.6.2
Oil volume	Check and replenish	SA	4.3.6.2
Pitot tubes and needle valve	Check and replace as necessary	A	4.3.6.2
All equipment	Paint as necessary	V	4.3.6.2
Decanter or swing-pipe feeder			4.3.6.3
Swing-pipe	Check to make certain it does not bind	M	4.3.6.3
Motor ratchet, pawl, reducing gears.	Check and lubricate	SA	4.3.6.3
Overhaul	All parts to be inspected, cleaned, repaired and painted as necessary.	A or V	4.3.6.3
Rotating dipper feeder			4.3.6.4
Motor	Follow manufacturer's instructions	V	4.3.6.4
Transmission	Change oil after 100 hr. operation	100 hr	4.3.6.4(1)
	Drain and flush, clean interior and refill	SA	4.3.6.4(1)
Shaft bearings	Lubricate	W	4.3.6.4(2)
Drive chain	Clean, check alinement; check sprocket teeth; lubricate chain and sprockets.	M	4.3.6.4(3)
Agitator	If used, clean and lubricate according to manufacturer's instructions.	V	4.3.6.4(4)
Belt drives	Check alinement, tension and inner cords of belt drives.	M	4.3.6.4(5)
Dipper and float valve	Check dipper clearance and adjust float valve setting.	SA	4.3.6.4(6)
Proportioning pumps (hypochlorinators).			4.3.6.5
Operator inspection	Inspect sight feeders, rate of flow, piping, joints	D	4.3.6.5.1
Feeder	Clean feeder	W	4.3.6.5.1
Solution tank	Clean	M	4.3.6.5.2
Linings	If cracks occur, special linings should be repaired	A	4.3.6.5.3
Overhaul	Disassemble, clean and overhaul	A	4.3.6.5.3

[1] D-Daily; W-Weekly; M-Monthly; SA-Semiannually; A-Annually; V-Variable; as conditions may indicate.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

(b) Check height of ion-exchange bed surface, remove or add ion-exchange resin to maintain proper elevation. (A low elevation will allow excess fines and foreign matter to accumulate on the surface of the bed; a high elevation allows resin to be washed out during backwashing.) Extra ion-exchange resin may be added through a 2- to 3-inch half-coupling (with brass plug), provided for that purpose in the upper head of the shell, or through the manhole cover plate.

(c) Replace ion-exchange bed with new resin whenever the inspection indicates the need, or if the exchange capacity has decreased and cannot be restored by cleaning and special procedures recommended by the manufacturer (see par. 4.3.7.1.3(4)).

(4) Gravel. Quarterly, probe through resin bed to determine the surface of the supporting gravel. The surface should be relatively even with a maximum difference of 4 inches between high and low spots. Any indication of shifting gravel bed, caking or other difficulties, calls for repair efforts. Uneven gravel may be raked

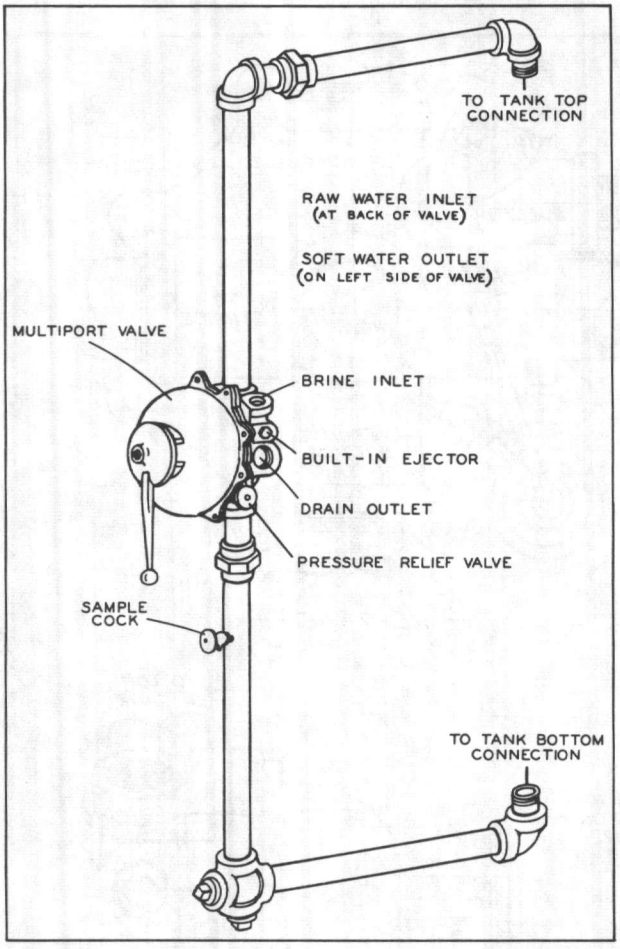


FIGURE 174

Arrangement for Multiport Valve for Ion-Exchange Water Softener

smooth, through the open manhole, during backwashing operations.

(a) Gravel removal. When gravel needs to be removed for one reason or another, new gravel may be cheaper to install than to remove, wash and regrade old gravel. New gravel should be lime-free (do not use ordinary river gravel). If old gravel is reused, screen out all resin particles. Spraying with water is the best method of removing the resin from the gravel on the screen.

(b) Gravel replacement. Replace or add new gravel in four layers. Fill the shell with water to the depth desired, then add the coarsest grade first; level the gravel layer to fill low spots; next, raise the water level to next depth required and add the next smaller grade. Repeat the process; then add the resin to the desired depth and classify by backwashing the bed.

(5) Underdrains. Annually, or as necessary, the condition of underdrains may be ascertained from the pressure drop across the underdrain system with a full backwash flow being discharged from the manhole. A greater pressure drop than existed at the time of installation indicates plugging underdrains; a lesser pressure drop indicates displaced or corroded nozzles. Underdrains shall be inspected, removed, cleaned, painted (where necessary) and replaced every three years.

(a) Manifold-type underdrains. Manifold-type underdrains shall be inspected when gravel is removed. Remove several laterals at random and check for clogging. Where clogging is evident, remove all laterals and clean mechanically, or by treatment with inhibited muriatic acid.

(b) Plate-type underdrains. Plate-type underdrains shall be removed, inspected, painted and replaced, every 3 years; make certain that the clearance space between plate and lower head is the same at all points.

4.3.7.1.2 Regeneration equipment. With regeneration equipment, the following procedures shall be used.

(1) Salt Storage Tank. The storage tank shall be cleaned at varying periods, depending on the amount of insolubles in the salt, tank size and the salt usage. Rock salt contains more insolubles than evaporated salt. The greater the salt usage, the more frequent the cleaning required.

(2) Brine Tank. The brine-measuring tank shall be cleaned every 6 months, and both exterior and interior surfaces painted.

(3) Brine Ejector. At annual intervals, the brine ejector shall be cleaned, disassembled and checked for erosion or corrosion; any clogging of piping shall be removed before the ejector is reassembled and replaced.

4.3.7.1.3 Operating conditions. At quarterly intervals, the operating condition of the softener shall be determined. Refer to operating records and make such tests and meter readings, as are necessary, to determine the following information.

(1) Flow Rate. Natural ion-exchangers can operate satisfactorily at a flow rate of 5 g.p.m. per square foot; synthetic resins at a rate of 6 to 7 g.p.m. per square foot. Rates higher than these will cause undesirable head loss through the bed and packing of the bed. Quarterly, adjust the controls of the flow rate.

(2) Backwash Rate. Rate of backwash should be 6 to 8 g.p.m. per square foot of bed surface. Rates below this value do not clean the bed properly; rates too high will wash some of the resin out of the softener and reduce its softening capacity. Quarterly, adjust the flow rate control to produce the optimum backwash rate.

(3) Pressure. Quarterly, check operating records for any change in the difference between inlet and outlet pressures. Any change in head loss through the softener indicates some difficulty. A decrease in pressure drop may indicate improper valve closure or a channelized bed. An

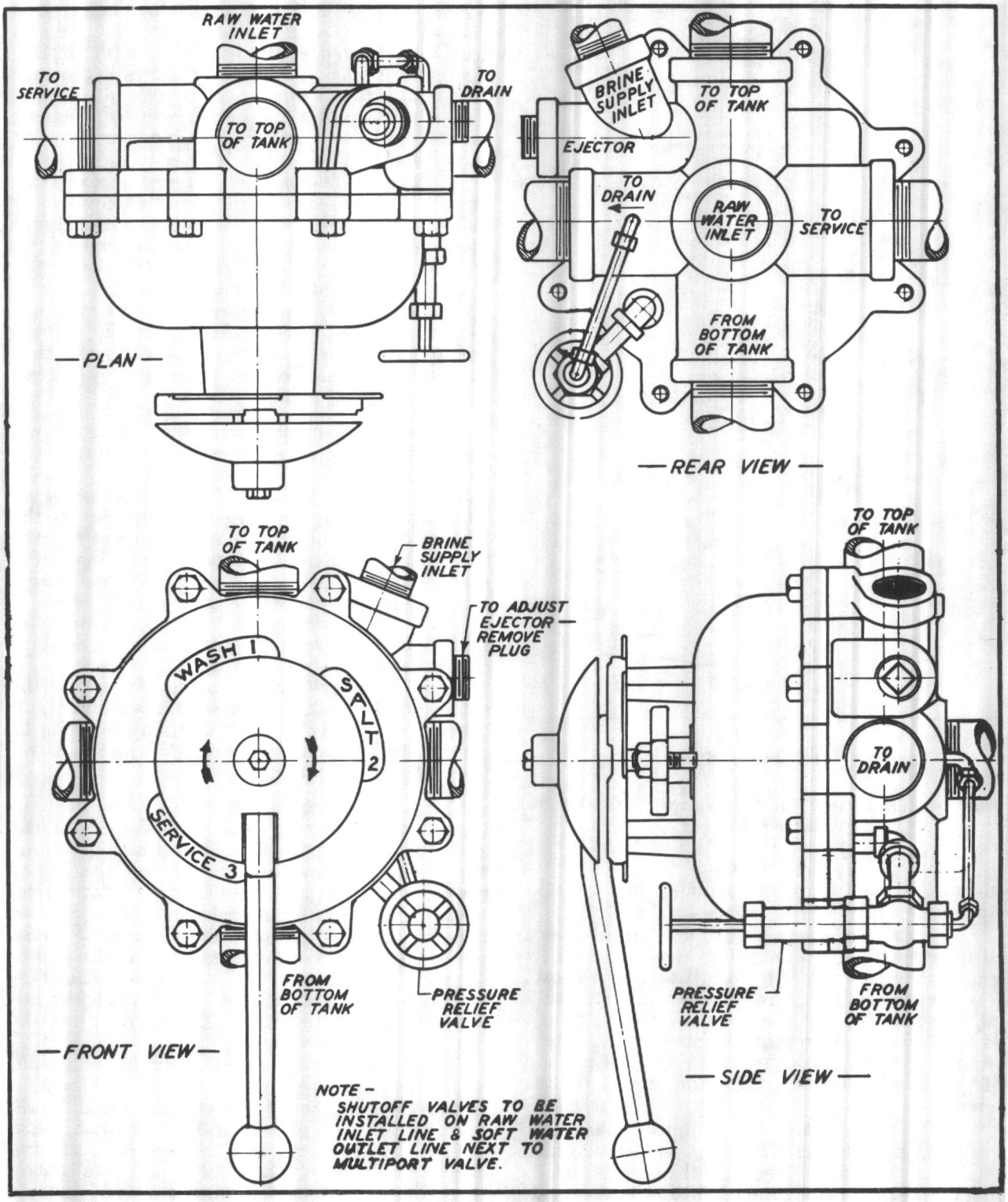


FIGURE 175

Multiport Valve for Ion-Exchange Water Softener

increase in pressure drop may indicate a valve not completely opened, a dirty bed or clogged gravel or underdrain system.

(4) Softening Efficiency. Quarterly, check the records to determine the softening capacity between the regeneration periods. Compare the amount of hardness removal now with that when the ion-exchange resin bed was new, and calculate the efficiency based on the original capacity as 100 percent. A decrease in efficiency may be caused by a dirty bed, coated resin grains, loss of ion-exchange bed or improper regeneration, either by weak brine solution or under-regeneration or over-regeneration. Replace resin bed if efficiency has decreased by 25 percent and cannot be restored almost completely by cleaning and special procedures recommended by the manufacturer.

4.3.7.1.4 Out-of-service softeners. Ion-exchange softeners, which are taken out of service, shall be emptied of water, if the out-of-service period is to be more than 10 hours; but synthetic resins should be kept damp (not submerged) during standby conditions. Also, do not regenerate resins before they are taken out of service.

4.3.7.1.5 Maintenance procedure schedule. The maintenance operation frequency and schedule of inspections for ion-exchange softening units are presented in table 24.

4.3.7.2 Lime-Soda Softening Equipment. Lime-soda softening of water is discussed in paragraph 3.2.5.3. The equipment involved consists principally of chemical feeders, mixing tanks and equipment, flocculation basins, sedimentation basins and recarbonation units. In some plants, the mixing, flocculation and sedimentation processes are carried on in one unit, termed a solids-contact basin, or a sludge blanket basin; they are also termed "high-rate" softening devices. These units are described and illustrated in paragraph 3.2.5.3.5. Chemical feeder maintenance is presented in paragraph 4.3.4. Maintenance of mixers, flocculators and sedimentation basins appears in paragraph 4.3.8. Maintenance of "high-rate" softening units is presented in paragraph 4 3.7.2.1, and that of recarbonation units in paragraph 4.3.7.2.2.

4.3.7.2.1 High-rate softening devices. Sludge-contact-type clarifiers are all proprietary items. Those devices which employ rotating parts have motors and gears which require maintenance; see paragraphus 4.11.2 and 4.12.6 for procedures for maintenance of such equipment.

(1) Operator Inspection. Monthly, check for leaks in valves and piping. Make certain that sludge valves function properly. Also check time clock and other accessories which control sludge valve operation.

(2) Cleaning Maintenance. Semiannually, drain unit, clean, and inspect wearing parts. Remove incrustation where it may interfere with operating parts; follow the manufacturer's instructions in this operation. Check chemical feed lines to make certain that they are not clogged and are in good condition.

4.3.7.2.2 Recarbonation units. Maintenance of these units depends on the equipment used, fuel burned, fuel impurities, effectiveness of scrubber and drier and materials of construction (see fig. 176). Consult the manufacturer's instructions for maintenance of compressor or blower.

(1) Operator Inspection. Daily, check burners, compressor, gages, and traps, and adjust equipment to assure optimum operation.

(2) Drier, Scrubber and Traps. At monthly intervals, check material in the drier and replace as necessary. Adjust spray and clean out connecting piping; clean gas traps.

(3) Corrosion Inspection. Every 6 months inspect all equipment for internal and external corrosion. Repair as necessary, and paint equipment or use protective coatings.

4.3.7.2.3 Maintenance procedure schedule. The maintenance operation frequency and schedule of inspections for lime-soda softening equipment are presented in table 25.

4.3.8 CLARIFICATION EQUIPMENT. See paragraph 3.2.8 for a discussion of processes and equipment, including mixers, flocculators and sedimentation (settling) basins.

4.3.8.1 Mixers. Mixing basins, whether baffled or mechanically stirred (rapid or flash), require attention and cleaning semiannually.

(1) After draining, wash down the walls with a hose and flush the sediment to the drain. Repair spalled spots on walls or bottom, as necessary.

(2) Check the valves or sluice gates for corrosion and ease of operation; clean and lubricate; paint valves as necessary.

4.3.8.1.1 Baffled mixing chambers. After cleaning the walls and bottom, brush the baffles and repair as necessary.

4.3.8.1.2 Flocculator basins. The following procedures apply.

(1) Monthly, during operation, check paddle rotation to assure that all flocculators are operating. Lower a light pole (bamboo fishing rod) into the water until the paddles strike the pole, giving evidence of paddle operation. Inoperative paddles may be caused by broken shafts or chains.

(2) Semiannually, drain and clean the basin, walls and floor; inspect the flocculator mechanism, the drive, bearings, gears and other mechanical parts; clean and lubricate. Especially check underwater bearings for silt penetration. Replace scored bearings. Paint mechanism parts, where necessary.

4.3.8.1.3 Rapid or flash mixers. Since rapid-mix devices revolve at great speed, *do not attempt to*

TABLE 24

Maintenance Procedures for Ion-Exchange Softening Units

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Softener unit			4.3.7
Shell	Clean and wire brush; paint	A	4.3.7.1.1(1)
Valves and fittings	Check for obstructions, corrosion and fastness	Q	4.3.7.1.1.(2)
	Check for leaks; repack if necessary	SA	4.3.7.1.1(2)
Multiport valves	Lubricate with grease; follow directions for lubrication procedure.	SA	4.3.7.1.1(2)(a)
Ion-exchange medium	Check bed surface for dirt, fines and organic growths; remove foreign matter and add resin to desired level.	Q	4.3.7.1.1(3)
Gravel	Probe through resin to determine gravel surface; level gravel surface with rake during backwash flow; replace gravel when caked, or if resin is being lost to effluent; wash and grade gravel and place in four separate layers; use new lime-free gravel at discretion of inspector.	Q	4.3.7.1.1(4)
Underdrains	Check pressure drop through underdrains; if necessary, remove manifold or plate underdrains; clean and replace.	A or V	4.3.7.1.1(5)
Regeneration Equipment			4.3.7.1.2
Salt storage unit	Clean tank as necessary to remove dirt	V	4.3.7.1.2(1)
Brine tank	Clean out dirt and insolubles; allow to dry; paint both exterior and interior surface.	SA	4.3.7.1.2(2)
Ejector	Clean, disassemble, check erosion and corrosion; clear clogged piping; assemble and replace.	A	4.3.7.1.2(3)
Operating conditions			4.3.7.1.3
Flow rates	Check rate of flow through bed; adjust controls to optimum rate, depending on type of resin.	Q	4.3.7.1.3(1)
Backwash rates	Check rate and adjust controls to optimum rate	Q	4.3.7.1.3(2)
Pressure	Check difference between inlet and outlet pressures; if undesirable changes in pressure drop have occurred, seek cause and remedy.	Q	4.3.7.1.3(3)
Efficiency	Compare total softening capacity with previous inspection; determine cause of decrease, if any, and remedy situation.	Q	4.3.7.1.3(4)
Out-of-service softeners	Drain; keep synthetic resins damp; do not regenerate before draining.	V	4.3.7.1.4

[1] D-Quarterly; SA-Semiannually; A-Annually; V-Variable; as conditions may indicate.

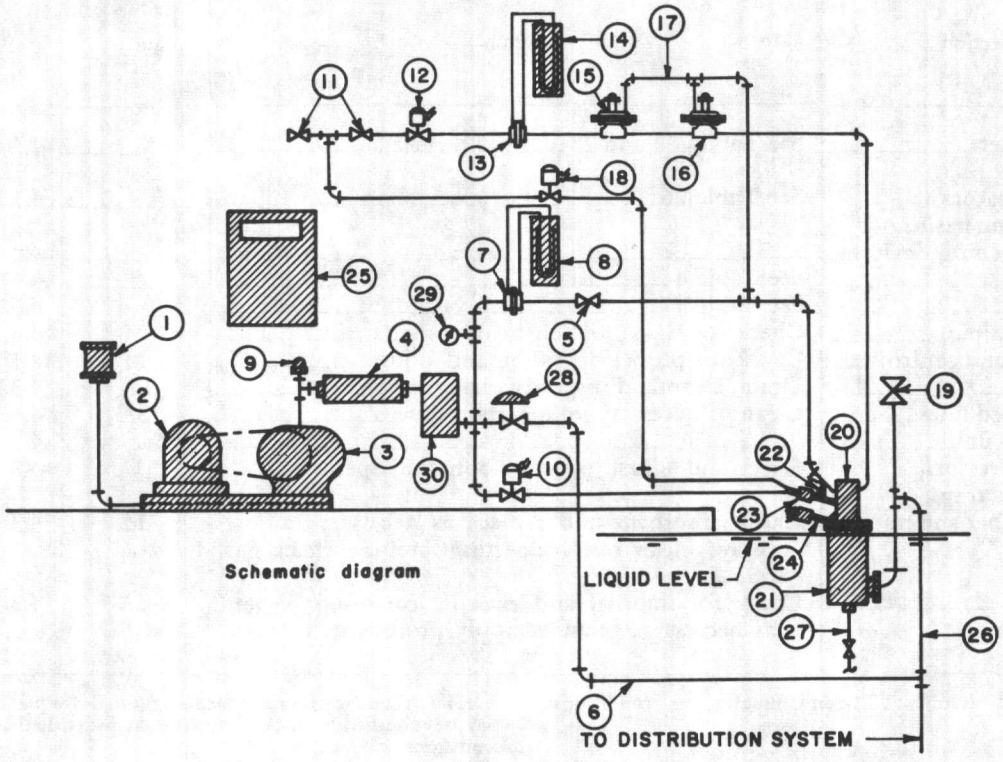
[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

check the rotation of the mixer paddles, except by visual observation. When the mixing basin is empty, the condition of the paddles, bearings, drive shaft and motor should be checked, and they should be cleaned, lubricated and painted as necessary.

4.3.8.2 Sedimentation Basins. All types of settling basin require the same basin maintenance, such as lubrication, cleaning, flushing and painting. Basins, which incorporate proprietary mechanisms or devices, shall be maintained in accordance with the manufacturer's instructions.

4.3.8.2.1 Revolving-sludge-collector basins. The specific maintenance procedures for these basins shall be in accordance with the manufacturer's instructions. The following procedures are the minimum required.

(1) Lubrication Schedule. Regular lubrication is required where the basin is in continuous operation. Intermittent operation affects the lubrication schedule, making it possible to increase the interval between lubrication periods. If operation periods are intermittent and infrequent, the mechanism shall be operated briefly between op-



1. AIR FILTER-SILENCER
2. BLOWER MOTOR
3. BLOWER
4. SNUBBER
5. CONTROL VALVE
6. SURPLUS AIR LINE
7. AIR ORIFICE
8. AIR MANOMETER
9. SAFETY VALVE
10. PILOT AIR SOLENOID
11. GAS SHUT-OFF VALVE
12. MAIN GAS SOLENOID
13. GAS ORIFICE
14. GAS MANOMETER
15. GAS REGULATOR
16. ZERO GOVERNOR
17. LOADING LINE
18. PILOT GAS SOLENOID
19. STACK VALVE
20. BURNER
21. DOWNCOMER
22. PILOT SPARK
23. PILOT
24. ULTRA VIOLET FLAME SUPERVISOR
25. CONTROL PANEL
26. CO_2 OUTPUT LINE
27. DRAIN LINE
28. RELIEF VALVE
29. PRESSURE GAUGE
30. SURGE TANK

FIGURE 176

Recarbonation Unit for Water Softening Plant

TABLE 25

Maintenance Procedures for Lime-Soda Softening Equipment

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Chemical feeders	See Tables 22 and 23		4.3.4; 4.3.5; 4.3.6
Mixers, flocculators and sedimentation basins.	See Table 26		4.3.8
High-rate softening devices			4.3.7.2.1
Motors	See Table 44		4.11.2.7
Gears	See Table 47		4.12.10
Valves and piping	Check for leaks; and check operation	M	4.3.7.2.1(1)
Time clock and controls	Check for proper operation and adjust	M	4.3.7.2.1(1)
Tank unit	Drain, clean and inspect wearing parts	SA	4.3.7.2.1(2)
Chemical feed lines	Clean, if necessary, to maintain flow	SA	4.3.7.2.1(2)
Recarbonation units			4.3.7.2.2
Burners, compressors, gages, and traps.	Check and adjust to ensure optimum operation	D	4.3.7.2.2(1)
Drier, scrubber and traps	Check absorbent and replace as necessary; adjust spray; clean out connecting piping; clean gas traps.	M	4.3.7.2.2(2)
Entire unit	Check for internal and external corrosion; repair as necessary; paint or apply protective coatings.	SA	4.3.7.2.2(3)

[1] D-Daily; M-Monthly; SA-Semiannually; as conditions may indicate.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

erating periods, and lubricated accordingly. Devices subject to wide seasonal temperature variations must have seasonal changes in lubricant grades, especially where summer grade oils thicken below freezing and reduce the flow capability. Daily or weekly lubrication of operating units is a part of operator inspection. The choice of lubricant and its frequency of application areestablished by the manufacturer or by local command. The following items, where they exist in the equipment, require attention on a regular basis, as set forth in the following paragraphs.

(a) The speed reducer should be inspected weekly to ensure that the oil is at the proper level, is free of water and grit and has the right body. If a reducer runs hot during its operation, the oil level may be too high or too low. Where the reducer is out of service for extending periods, make certain they are filled completely to prevent seals from drying out. Replace oil whenever necessary.

(b) The drive head should be lubricated daily, and care taken not to overlubricate.

(c) The worm gear oil level should be checked at least weekly, and water drained from the housing monthly.

(d) The turntable bearings should be lubricated at monthly intervals, and the oil changed twice yearly.

(e) Lubrication procedures for chains depend on the design of the chain and chain guard. Inspect monthly and add oil as necessary; drain off the accumulated oil as necessary; and, change the oil twice yearly.

(f) Annular ball bearings and thrust bearings are generally lubricated daily and inspected monthly for condition of lubrication.

(g) Center bearings, shaft bearings, bushings, etc., are lubricated according to the manufacturer's instructions.

(2) Tank Equipment Requires Annual Inspection.

(a) Check bolts and tighten nuts to maintain original alinements and adjustments.

(b) Check for excessive wear of moving parts, including gears.

(c) Flush and backblow sludge withdrawal line, using high pressure water or compressed air. NOTE: Do not allow waterline to be cross-connected to the drinking water supply system.

(d) Check the plows or rakes and straighten them if necessary.

(e) Check the motor condition (par. 4.11.2); couplings (par. 4.12.8); and, service shear pins (par. 4.12.9).

(f) Clean equipment and paint as necessary.

(3) Overload. If the equipment has an overload alarm, check it for operation. If the alarm sounds at any time, shut off the equipment, locate the source of trouble and rectify the situation. Under no conditions should the alarm switch be nullified in order to provide continuous operation under overload conditions. If the overload is caused by a sludge build-up leading to cut-out of the starter switch or pin shearing, the tank must then be drained and the sludge flushed out.

4.3.8.2.2 Conveyor-type collector basins. As with the revolving-sludge-collectors, specific maintenance procedures are set forth in the manufacturer's instructions. Maintenance procedures on the tanks and structures are the same for this type of sedimentation basin as they are for the circular-type basin. Generally, the maintenance procedures applicable to gears, chains, sprockets, reducers, etc., are also the same as those which apply to circular-type basins (see par. 4.3.8.2.1).

4.3.8.2.3 Upflow clarifiers. This is the same general type of equipment used for high-rate water softening or sludge-contact-type clarifiers. These are all proprietary items, and must be maintained in accordance with the manufacturer's instructions (also see par. 4.3.7.2.1).

4.3.8.2.4 Cathodic protection. Where aggressive water problems exist in water supplies, the sedimentation tank equipment may be protected by cathodic protection, either by impressed current or by galvanic protection with sacrificial anodes. Cathodic protection systems may be maintained by activity personnel or by service contract. The Field Engineering Office will provide guidance in developing maintenance procedures, or in contracting for such services. For more complete discussion of cathodic protection, refer to reference 10. The following paragraphs contain general maintenance procedures.

(1) Impressed Current Systems. Make inspections and necessary maintenance repairs at monthly intervals.

(a) Check exterior of enclosure for rust, corrosion or mechanical damage; check hinges and locks for inadequate lubrication, rust or other deficiencies; check wiring and fastenings, and rectifier for broken or damaged insulation, and for rust or corrosion on conduit; and, check exposed wires and cables and all electrical connections for insecurity, frayed or broken insulation and other deficiencies.

(b) Check interior of enclosure for rust, moisture condensation, loose wiring and signs of excessive heating. (Do not put hand or tools inside the enclosure.)

(c) Check anode suspensions for rust corrosions, bent or broken suspension members, frayed or broken suspension lines or cables, loose bolts, loose cable connections and frayed or broken wiring.

(d) Whenever necessary, replace or repair any item which will not pass inspection for continued service, and paint switch cans and exposed rectifier housing and other electrical gear as necessary.

(e) For information on steel water storage tanks, see paragraph 4.7.4.4.

(2) Sacrificial Anode Systems. The only maintenance required for a galvanic anode system is monthly inspection and potential tests to determine when replacement of anodes is necessary, and to ensure continuity of the electric circuit.

(a) When an abnormal decrease in current output (or potential of the protected structure) occurs, the anodes should be inspected for excessive disintegration.

(b) Check terminals and jumpers of test leads for rust, corrosion, broken or frayed wires, loose connections and similar deficiencies. Tighten all connections.

(c) Check the bushing supporting the anode for rust and corrosion. Where resistors are installed in the circuit, examine these units for corrosion, broken and frayed wires and loose connections. Tighten all connections.

(d) Check the anode suspensions as outlined in paragraph 4.3.8.2.4(1)(c), and install new anodes when necessary.

(3) Safety Precautions. Do not bridge insulated couplings or break electrical connections without engineering advice.

4.3.8.3 Maintenance Procedure Schedule. The maintenance operation frequency and schedule of inspections for clarification equipment are presented in table 26.

4.3.9 FILTRATION EQUIPMENT. Maintenance procedures on both gravity and pressure filters are essentially the same, differing only in detail. Some of the maintenance operations for diatomite filters are similar to those for sand filters; others are not.

4.3.9.1 Gravity Filters. Regardless of the type of filter medium used (sand or anthrafilt), the material which is filtered out of the water must be removed from the filter at regular intervals.

4.3.9.1.1 Filter media. During the course of daily backwashing (see par. 3.2.8.3.9), as an operating procedure, the operator should observe any conditions which may indicate a need for more complete inspection. The following procedures are minimal.

(1) At monthly intervals, drain the filter to the surface of the filter medium; inspect the surface for uneveness, sinkholes, cracks and evidence of algae, mud balls or slime.

(a) If depressions or craters on the surface are of appreciable size, dig out the sand and gravel, and locate and repair any break in the underdrain system.

(b) Mud balls are removed in the operating procedure outlined in paragraph 3.2.8.3.10(1).

(c) If sand shows evidence of algae, prechlorinate ahead of filters. Where severe algae

growths exist on sand or walls, remove the filter from service and treat the filter with a strong hypochlorite solution. Add enough hypochlorite to produce 2 to 4 p.p.m. of free residual chlorine in a volume of water 6 inches deep above the filter surface. Draw down the filter until the water level is just above the bed surface. Allow it to stand for six to eight hours, then backwash the surface, and follow this by a complete backwashing. Repeat, if necessary.

(2) Quarterly, during a backwashing period, probe the filter for hard spots and uneven gravel. Examine the sand below the surface by digging to gravel with the water drawn down to the gravel level. If clogged areas appear because of cementation of sand grains with mud balls, or because of carbonate deposits, or if the sand (or anthrafilt) grains have increased in size due to incrustation (e.g., in softening plants or where lime and ferrous sulfate are used for coagulation), clean the sand by treating the idle filter with an inhibited muriatic acid or sulfurous acid. The advice of the Public Works Officer should be obtained if the operator is unfamiliar with the use of these chemicals.

(a) Add the inhibited muriatic acid at the surface and allow it to pass downward through the bed and out the filter drain, or "rewash" the line; or add it to an empty filter through a small tap on the bed side of the wash-water line.

(b) Use sulfurous acid as follows. Allow the sulfur dioxide gas from a cylinder to discharge into the filter wash-water line while slowly filling the filter bed with wash water. Use one 150-lb cylinder to 6,000 gallons of water to produce a 0.3 percent solution. Allow it to stand for six hours.

(3) Semiannually, ascertain any change in the rate of wash-water rise, as determined during operating procedures (see par. 3.2.8.3.9.(2)) and check sand expansion (see par. 3.2.8.3.9(4)).

(4) Semiannually, inspect the sand and, if visual inspection does not reveal the condition of the medium, locate the elevation of the top of the bed to determine if the bed has "grown" in depth. Also, remove a sand sample and analyze it, as follows.

(a) Make a sampling tube 12-inches square by 36-inches deep. Force a tube to the gravel level and drain the bed. Remove the sand from within the tube. Collect several such samples from well-scattered locations on the filter bed, mix thoroughly, and reduce sample size by quartering until about 2 lbs remain. Dry this sample, mix, quarter and reduce to a usable sample size.

(b) Determine loss of weight of a 10 gram sample during acid treatment. Treat sample with 10 percent hydrochloric acid in a pyrex evaporating dish on a water bath for 24 hours. Replace acid loss during treatment period. Wash, dry and weigh the sand. Determine the weight loss and compare it to the previous analysis.

(c) From the remainder of the sand sample, remove 100 grams and run a sieve test. Compare the results to previous tests.

(d) If either inspection, weight loss or sieve analysis shows growth of sand grains to a point where filtration efficiency is impaired, treat the sand as outlined above in Paragraph 4.3.9.1.1(2)(a), and adjust the water treatment process as necessary. If treatment is not effective, remove the filter medium and replace with a new filter medium.

4.3.9.1.2 Gravel. Gravel inspection includes these procedures.

(1) At monthly intervals, check the gravel bed surface for uneveness, using a garden rake or pole as a probe during backwashing. If ridges or sink holes are indicated, the filter may need overhauling.

(2) Every six months, remove sand from an area about 3 feet square, taking care not to disturb the gravel. Examine the gravel by hand to determine if the gravel is cemented with incrustation or mud balls, or if it is not layered properly.

(3) If any undesirable conditions exist to a marked degree, the sand shall be removed and the filter gravel relaid. If uneveness or layer mixing is caused by faulty underdrain system, repair it; if it is caused by faulty backwashing, correct the backwashing procedure.

4.3.9.1.3 Filter underdrain system. Annually, or as observations indicate the need, the filter bottom should be inspected. Sand boils during backwashing, or sand craters on the surface, indicate trouble in the underdrain system, as does marked uneveness of the gravel layers. Inspection and treatment procedures are as follows.

(1) To inspect the bottom, remove the sand over an area of about 10 square feet. Select an area where sand boils or other indications of trouble have been noticed. Place planking over the gravel to stand on, and remove the gravel from areas about 2 feet square. Check underdrains for deterioration of any nature. If underdrains need repair, remove all sand and gravel, make repairs to underdrain, and replace gravel and sand in proper layers.

(2) Where underdrains are of the porous plate type, and are clogged with alum floc penetration, flood the underdrain system with a 2 percent sodium hydroxide solution for a period of 12 to 16 hours.

4.3.9.1.4 Wash-water troughs. At quarterly intervals, the level and elevation of troughs should be checked. Water should be drawn below the trough lips, the wash-water valve should be cracked and any low points observed where water spills over the lip, before the lip is covered completely.

(1) The troughs should be adjusted as necessary to produce an even flow throughout their lengths on both sides.

TABLE 26

Maintenance Procedures for Clarification Equipment

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Mixing basins	Drain, wash down walls, flush sediment to waste line; repair spalled spots on walls and bottom; Check valves on sluice gates; lubricate and paint valves as necessary.	SA	4.3.8.1
Baffled mixing chambers	Clean baffles and repair as necessary	SA	4.3.8.1.1
Flocculator basins	Check paddle rotation to ascertain if any flocculators are inoperative.	M	4.3.8.1.2
	Clean and lubricate drive, bearings, gears, and other mechanical parts; check underwater bearings for silt penetration; replace scored bearings.	SA	4.3.8.1.2(1)
Rapid (or flash) mixers	Check paddles; clean bearings and drive shaft; lubricate and paint as necessary.	SA	4.3.8.1.3
Revolving-sludge-collector basins.	Drain tank, check submerged parts	SA	4.3.8.2.1
Operating parts	Lubricate	D or W	4.3.8.2.1(1)
Speed reducers and oil baths.	Remove water and grit, replace oil, as necessary	W	4.3.8.2.1(1)(a)
Drive head	Lubricate—do not overlubricate	D	4.3.8.2.1(1)(b)
Worm-gear	Check oil level	W	4.3.8.2.1(1)(c)
	Drain water from housing	M	4.3.8.2.1(1)(c)
Turntable bearings	Lubricate	M	4.3.8.2.1(1)(d)
	Change oil	SA	4.3.8.2.1(1)(d)
Chains	Drain off water, add oil as necessary	M	4.3.8.2.1(1)(e)
	Change oil	SA	4.3.8.2.1(1)(e)
Annular ball bearings	Lubricate	D	4.3.8.2.1(1)(f)
Center bearings, shaft bearings, bushings, etc.	See manufacturer's instructions	V	4.3.8.2.1(1)(g)
Tank equipment	Tighten bolts and nuts; check for excessive wear, flush and backblow sludge line, check motors, couplings, and shear pins; check rakes, clean and paint equipment.	A	4.3.8.2.1(2)
Conveyor-type-collector basins.	See above, and consult manufacturer's instructions.	V	4.3.8.2.2
Upflow clarifier	See manufacturer's instructions	V	4.3.8.2.3
Cathodic protection			4.3.8.2.4
Rectifier-type	Check exterior and interior for condition; see manufacturer's instructions; repair, replace, or paint as necessary.	M	4.3.8.2.4(1)
Sacrificial anodes	Check anode condition and all connections, and replace as necessary.	M	4.3.8.2.4(2)

[1] D-Daily; W-Weekly; M-Monthly; SA-Semiannually; A-Annually; V-Variable; as conditions may indicate.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

(2) At semiannual intervals, metal troughs should be inspected for corrosion. If corrosion exists, the troughs should be allowed to dry, and then cleaned by wire brush and painted with a protective paint or coating.

4.3.9.1.5 Operating tables. Operating controls for filter valves may be mounted on a console, panel or table. The controls actuate the filter valves which may be powered either by hydraulic or pneumatic means. The controls may be connected to the valve mechanism either by cable or chains, electrical, hydraulic or pneumatic connections.

(1) These maintenance operations should be performed weekly.

(a) Clean the table, the console or the panel inside and out, using soap and water, if necessary.

(b) If cable-operated, check the tension on the cables, or the chains, used for connection to the valve operator, or for connection to the valve position indicators.

(c) If hydraulically-operated, inspect for leaks and stop any leakage; if pneumatically-operated, check tubing for possible leakage.

(2) Transfer valves (4-way) and handles should be adjusted monthly to make certain that all filter valves open at the same rate. Packing glands should be tightened, or new packing added as may be necessary.

(3) Transfer valves should be lubricated monthly with grease. They should not be over-lubricated; one-half turn of the grease screw should be sufficient.

(4) The valve-position indicator should be inspected monthly and adjusted to assure that it reads correctly in all positions.

(5) The 4-way transfer valves in the table should be disassembled annually and any worn parts, seats or washers should be cleaned or replaced with new ones.

(6) The inside of the table, console or panel should be painted annually to protect against corrosion.

4.3.9.1.6 Rate controllers. Rate-of-flow controllers (see figs. 83 and 84) may be either direct-acting or indirect-acting. Maintenance procedures for both types are set forth in subsequent paragraphs.

(1) Direct-Acting Controllers.

(a) Weekly, clean exterior, check for leakage through diaprhagm pot, and lubricate or tighten packing to stop any existing leakage. Also, assure that both the diaphragm and the control gate move freely between zero differential and the open and closed positions.

(b) At intervals of one or more years, remove and disassemble the diaphragm pot, including the rubber diaphragm. If the water does not cause tubercles, this operation may not have to be done more than once every three to five years.

(c) Every three years, disassemble and service the controller gate and mechanism. Inspect the venturi throat. Paint or apply protective coating, as necessary.

(2) Indirect-Acting Controllers.

(a) At weekly intervals, clean the outside of the controller; adjust the packing, lubricate or tighten the fittings as necessary to stop any leakage from the hydraulic cylinder, the controller valve, piping, or the pilot valve. Make sure that the knife edges seat correctly and are free of paint or other foreign matter. Also, be sure that the piston has free vertical travel and does not bind. Replace packing, if necessary.

(b) Annually, disassemble, clean and lubricate the pilot valve. Remove foreign matter from the piston with a cloth. Never use an abrasive to clean the piston. Make certain that the piston is free moving. Disconnect and clean the pilot valve piping and strainers; make certain that no foreign matter enters the pilot valve during the cleaning operation. Check for leaks or cracks in the diaphragm.

(c) Every third year, disassemble and service the controller gate and mechanism; inspect the venturi throat and apply protective coatings where necessary. Check the hydraulic cylinders, and maintain them in accordance with the manufacturer's instructions.

4.3.9.1.7 Gages. Indicating and recording instruments mounted on the operating table or control panel may include filter rate setters; a loss-of-head gage; a rate-of-flow gage; a water level; backwash rate-of-flow, wash-water rise and summation gages for total filter output, etc. Maintenance procedures for instruments are presented in paragraph 4.13.1.2.

(1) Mechanically-Operated Loss-of-Head Gage. The equipment which operates the indicator, or indicator-recorder, instrument requires the maintenance operations described in the following paragraphs. In addition to these instructions, the inspector shall consult the manufacturer's instructions for detailed adjustments.

(a) At monthly intervals, check the zero setting in the following manner. Open the equalizing valve on mercury float-type head gages and make certain that the indicator arm and the recording pen return to zero. Note the reason for any incorrect reading, and adjust the stop collar or wire cable, if necessary, to bring the indicator to the proper zero reading. On floats and float chambers, which are so equipped, release the air. (On some models, it is possible to release the air by jerking the wire cable lightly.)

(b) At monthly intervals, flush the mud out of the water pipeline running from above the sand to the loss-of-head gage. Drain the mud leg until the water runs free of sediment.

(c) Annually, remove the float from the float chamber; wash the float and remove incrustations; use care not to mar the float. Remove the mercury and clean it, avoiding any spillage of mercury (see par. 4.13.4.5 for directions). When replacing the mercury, be sure that the amount is correct. Also, paint the interior and exterior of the float chamber and other parts annually to prevent corrosion. In addition, check the pressure pipelines to the float chamber, and remove any incrustation.

(2) Diaphragm-Pendulum Unit Loss-of-Head Gage.

Where the actuating mechanism is of this type, the following general maintenance procedures apply. For a more detailed discussion of these procedures, consult the manufacturer's instructions.

(a) The following operations are to be performed monthly.

1. Purge the diaphragm cases of air, and check the cable to be sure that it leaves the segment at a tangent to the lower end when a zero reading exists on the unit.

2. Remove dirt from the knife edges; if it is necessary, tighten the cam hubs on their shafts.

3. Drain mud from the mud leg as described in paragraph 4.3.9.1.7(1)(b).

(b) Semiannually, check the pipelines to the diaphragm to make certain that they are open and free of incrustation.

(c) Annually, inspect the diaphragms for leakage, and replace if necessary. (NOTE: Spare diaphragms should be kept under water.) Also, disassemble the unit in order to clean and lubricate it when necessary. Check the working parts and the cables (they should be free of knots, splices or fraying). Repack the stuffing box if it is leaking. Make certain that the knife edges rest solely on their edges, where the pendulum is hung vertically, and be sure that all cable ends are knotted tightly.

(3) Mercury-Float-Type Rate of Flow Gages. For detailed procedures with respect to this type of equipment, consult the manufacturer's instructions.

(a) Once a month, check the unit by opening the equalizing valve to eliminate the differential pressure in the gage; adjust the indicator, the recording pens and the register to zero. Check the position of the stop collars on the cables; also, inspect and clean the stops on the indicator and recording pen.

(b) Every six months, check the accuracy of the rate-of-flow gages in the following manner. Determine the exact time for the water to drop one foot. Use hook gages (one above the other—1 foot apart). Also, determine the amount of water in this one foot depth (calculate, allowing for inlets, gullets, structural members, etc., or measure the input, if possible, from the wash-water rise or the drop in the level of the wash-water tank). During the period timed for the drop in the water level of 1 foot, note and record the reading of the rate-of-flow gage. Calculate the rate of flow and percent error, according to the following equations.

$$1.\ \text{g.p.m.} = \frac{V \times 60}{t}$$

Where,

V = volume in 1 foot depth of water (gal.)
t = drop time (sec.)

$$2.\ \% = \frac{F_1 - F_2}{F_2}$$

Where,

% = percent of error
F_1 = indicated flow rate (g.p.m.)
F_2 = measured flow rate (g.p.m.)

If the error is greater than ±3 percent, make the necessary adjustments.

(c) Semiannually, check the pressure pipelines to the float chamber, and clean and remove incrustation to allow for free flow.

(d) Once a year, clean the float and mercury (see par. 4.3.9.1.7(1)(c)). Also, paint the interior and the exterior of the float chamber and other parts if necessary in order to protect against corrosion.

4.3.9.1.8 Piping and valves. At monthly intervals, check for leaks at the joints; also, check the pipe hangers, and replace any that have deteriorated. Paint piping, valves and hangers if necessary in order to prevent corrosion. Maintenance procedures for valves appear in paragraph 4.5.1.

4.3.9.2 Pressure Filters. Except that the filter medium is housed in an enclosed pressure shell, pressure filters are constructed in the same way as are gravity filters with respect to the underdrain system, gravel and the filter medium (sand or anthrafilt). Pressure filters need the same care and attention as do gravity filters. Since their backwashing operations cannot be observed, the filter must be opened regularly and inspected carefully. The following maintenance procedures apply.

(1) Weekly, inspect piping and valves for leaks. Lubricate and repack valves if necessary.

(2) Quarterly, open the pressure shell and inspect the filter bed surface. Follow these procedures.

(a) Use a garden rake during backwashing while the manhole is open in order to test for mud balls in the lower part of the filter bed and for eveness of the gravel layer surface.

(b) Determine if the stand bed level has changed since the last inspection by comparing the bed surface elevation with some reference point.

(c) If the filter does not have a surface wash system, and shows evidence of mud balls, backwash it at the highest rate possible while jetting the surface with a stream of water from a high-pressure-hose nozzle.

(d) Annually, open the filter, remove the sand from an area sufficient in size to permit the inspection of the gravel. If the sand or gravel distribution indicates nonuniform distribution of backwash water, the filter media and gravel may need to be removed, and the underdrain system checked.

(e) Annually, clean and paint the exterior of the shell.

(f) Every third year (or more often if necessary), the filter medium and gravel should be removed, and the underdrain system checked for the distribution of wash water, and repaired if necessary. Clean the underdrain system, and paint it or apply a protective coating to all parts subject to corrosion, including the inside of the shell. Replace the gravel and the filter medium.

4.3.9.3 Diatomite Filters. Most diatomite filter installations in potable water supply plants are of the pressure-type, although there are vacuum-type filters that can be used in certain installa-

tions. In general, the maintenance procedures for cleaning the filter element are the same for both types. The following procedures apply.

(1) At monthly intervals, or as often as operating conditions indicate the need, check the filter elements. The need for cleaning is evident when the precoat has apparent bare spots on the elements. Causes of element clogging are iron oxide and manganese dioxide deposits and algae growths.

(a) For iron oxide removal, treat the elements with a 0.5 percent solution of oxalic acid. Information is available from manufacturers on the amount of oxalic acid to use on different size units. The following procedures are used.

1. Start with an empty filter after a regular washing.

2. Close the drain valve and the main outlet valve; open the recirculation valve.

3. Fill the tank to a level covering the top of the elements.

4. Add the proper quantity of oxalic acid, and recirculate for one hour.

5. Drain and hose down the elements and the tank interior.

6. Close the drain valve; refill, circulate a few minutes, and then drain again.

If the cleaning is not completely effective, repeat the procedure.

(b) The procedure for manganese dioxide removal it the same as for the removal of iron oxide, except that anhydrous sodium bisulfite must be added to the solution (see the manufacturer's instructions for the correct amount).

(c) To remove algae growths, add a 12½ percent hypochlorite solution to the tank volume after filling the tank to the proper level (see the manufacturer's instructions for the proper amounts to use for different sized units).

(2) Semiannually, check the piping and valves and appurtenant equipment, including the body feed equipment. Make whatever adjustments the manufacturer's instructions indicate to be necessary.

(3) Clean and paint all exterior surfaces annually, if necessary.

4.3.9.4 Maintenance Operation Schedule. The maintenance operation frequency and schedule of inspections for filtration equipment are presented in table 27.

4.3.10 AERATION EQUIPMENT. Aeration equipment operating procedures (waterfall, injection and spray nozzle design) appear in paragraph 3.2.9.1 (also see fig. 70).

4.3.10.1 Waterfall Aerators (Cascade or Step, and Tray or Splash Pan).

(1) Once a week, inspect the aerator surfaces for algae or other growths; precipitated iron oxide; and, for nonuniformity of water distribution and staining. Clean when necessary. Treat with coper sulfate or hypochlorite solution to destroy growths.

(2) Semiannually, clean and repair tray aerators, removing the trays as necessary. Inspect the coke tray aerators for biological growths and coke deterioration. Replace the coke if the cleaning is not effective. Repair the screens and enclosures if necessary.

(3) Repair or replace the surfaces on cascade or step aerators annually if necessary.

4.3.10.2 Injection or Diffuser Aerators. Injection or diffuser aerators may be either porous medium design or injection nozzles.

4.3.10.2.1 Porous ceramic diffusers—plate or tube. The maintenance of this type of equipment is carried out in the following manner.

(1) Upon evidence of the nonuniform distribution of air, or clogging that impairs operation, dewater the tank, inspect and clean diffusers if necessary.

(2) Every six months, drain the aeration tank and inspect the diffusers for joint leaks, broken diffusers and clogging. Porous ceramic diffusers may suffer clogging of either the water side or the air side (underside).

(a) Water side (porous plate diffusers). Use oxidizing acids to clean organic growths from plate surface. (NOTE: Chlorine gas introduced into the air line at intervals between inspections will help hold down organic growths.) Removable plates should be soaked in 50 percent nitric acid. Plates grouted in place cannot be treated with nitric acid; use chromic acid (made by adding 1 gram of sodium dichromate to 50 ml. of sulfuric acid). Pour approximately 2 fluid ounces on each plate on two succeeding days. CAUTION: These acids must be handled carefully. Particularly, do not pour water into sulfuric or chromic acid, as it will explode and splatter the acid over the person handling it. Such acid will cause severe burns to the skin and clothes. Acid treatment should be done only upon approval of the Public Works Officer and under the supervision of a chemist or other qualified personnel.

(b) Air side (porous plate diffusers). If clogging is caused by iron oxide particles from pipes, treat this condition with a 30 percent solution of hydrochloric acid. If clogging is by soot, oil or dust from improperly filtered air, remove the diffusers and burn off the extraneous material in a furnace.

(c) Porous ceramic tubes. Tubes may be removed and cleaned by soaking in acids or by burning, as described above for porous plate diffusers.

4.3.10.2.2 Porous saran-wound tube diffusers. These diffusers should be inspected and cleaned semiannually as necessary. This material cannot be subjected to strong acids or heat. It must be scrubbed with a brush and soap or detergent.

4.3.10.2.3 Injection nozzles. Injection nozzles should be inspected and cleaned semiannually as

TABLE 27

Maintenance procedures for filtration equipment

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Gravity filters			4.3.9.1
Filter media	Inspect surface for unevenness, sink holes, cracks, algae, mud balls or slime.	M	4.3.9.1.1(1)
	Dig out sand and gravel at craters of appreciable size; locate and repair underdrain system breaks.	V	4.3.9.1.1(1)(a)
	Chlorinate to kill algae growths	V	4.3.9.1.1(1)(c)
	Probe for hard spots and uneven gravel layers; if present, treat filter with acid.	Q	4.3.9.1.1(2)
	Check wash water rise rate and sand expansion during backwashing.	SA	4.3.9.1.1(3)
Filter media	Check sand condition for grain size growth; sample sand, determine weight loss on acid digestion, and run sieve test; acid-treat if necessary, or replace sand, if necessary.	SA	4.3.9.1.1(4)
Gravel	Check elevation of gravel surface	M	4.3.9.1.2(1)
	Examine gravel for incrustation, cementation, alum penetration, mud balls; if necessary, remove, clean and relay gravel.	SA	4.3.9.1.2(2)(3)
Underdrain system	Remove sand from area of 10 sq. ft., and inspect 2 sq. ft. area of gravel (or more); if underdrains are deteriorated, remove all sand and gravel, repair underdrains, replace gravel and sand.	A	4.3.9.1.3(1)
	If porous underdrain, clogged by alum floc, treat with 2% NaAH solution for 12 to 16 hrs.	V	4.3.9.1.3(2)
Wash water troughs	Check level and elevation, adjust	Q	4.3.9.1.4
	Check for corrosion; if present, dry troughs, wire brush, and paint.	SA	4.3.9.1.4(2)
Operating tables	Clean table (console or panel) inside and out	W	4.3.9.1.5(1)(a)
Cables	Adjust tension	V	4.3.9.1.5(1)(b)
Hydraulic lines (or pneumatic).	Check for leakage	V	4.3.9.1.5(2)
4-way valves	Adjust, tighten packing glands or add new packing.	M	4.3.9.1.5(2)
Transfer valves	Lubricate with grease	M	4.3.9.1.5(3)
Valve position indicator.	Adjust, if necessary	M	4.3.9.1.5(4)
4-way transfer valves	Disassemble, clean, lubricate and replace worn parts.	A	4.3.9.1.5(5)
Table	Paint inside	A	4.3.9.1.5(6)
Rate controllers			4.3.9.1.6
Direct-acting	Clean exterior, check diaphragm leakage, tighten packing, check freedom of movement and zero differential.	W	4.3.9.1.6(a)
Diaphragm pot	Disassemble, clean and replace	A or V	4.3.9.1.6(1)(b)
Controller mechanism	Disassemble, service;: clean venturi; paint surfaces needing protection.	Every 3 yrs.	4.3.9.1.6(1)(c)

[1] W-Weekly; M-Monthly; Q-Quarterly; SA-Semiannually; A-Annually; V-Variable; as conditions may indicate.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

TABLE 27 (Continued)

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Indirect-acting	Clean outside, adjust packing, lubricate and tighten fittings; check knife edges, check piston travel; repack as necessary.	W	4.3.9.1.6(2)(a)
Pilot valves	Disassemble, clean and lubricate; check piston travel; clean piping and strainers; check for leaks in diaphragm.	A	4.3.9.1.6(2)(b)
Controller mechanism	Disassemble, service; clean venturi; clean hydraulic cylinders; paint as necessary.	Every 3 yrs.	4.3.9.1.6(2)(c)
Mechanically-operated loss-of-head gages.	Check zero setting; adjust stop collars or cable; release air from float chamber.	M	4.3.9.17.(1)(a)
Mud leg	Flush out sediment	M	4.3.9.1.7(1)(b)
Float chamber	Remove float, clean; remove mercury, clean and replace; check pressure pipelines; paint interior and exterior.	A	4.3.9.1.7(1)(c)
Diaphragm-pendulum loss-of-head unit.	Check zero setting; purge diaphragm cases of air; check cable at segment; remove dirt from knife edges; tighten can hubs on shafts; drain mud from mud leg.	M	4.3.9.1.7(2)(a)
Pipelines to diaphragm.	Check for free flow and absence of incrustation.	SA	4.3.9.1.7(2)(b)
Diaphragm-pendulum unit.	Check for leakage; disassemble unit, clean and lubricate; check working parts, cables; repack stuffing box; check knife edges.	A	4.3.9.1.7(2)(c)
Mercury-float-type rate-of-flow gages.	Check at zero differential, adjust indicator arm and recording pens; check stop collars on cables.	M	4.3.9.1.7(3)(a)
	Check accuracy and percent error; if greater than ±3%, adjust.	SA	4.3.9.1.7(3)(b)
Pressure lines	Check and clean as necessary	SA	4.3.9.1.7(3)(c)
Float chamber	Clean float and mercury; paint all parts requiring protection.	A	4.3.9.1.7(3)(d)
Piping and valves	Check for joint leaks; check pipe hangars, replace, if necessary; paint, as necessary; also see Paragraph 4.5.1.1.	M	4.3.9.1.8
Pressure filters			4.3.9.2
Piping and valves	Check for leaks; lubricate and repack valves as necessary.	W	4.3.9.2(1)
Filter bed	Open pressure shell, check sand surface for mud balls, unevenness; check sand surface elevation; remove mud balls.	Q	4.3.9.2(2)
	Remove sand in sizeable area and check gravel.	A	4.3.9.2(2)(d)
Pressure shell	Clean and paint exterior	A	4.3.9.2(2)(e)
Underdrains	Remove sand, check gravel; remove gravel, check underdrains; clean, paint and repair; replace gravel and sand.	Every 3 yrs.	4.3.9.2(2)(f)
Diatomite filters			4.3.9.3
Filter elements	Check for clogging; clean as necessary (e.g., treat to remove iron oxide, manganese dioxide and algae).	M	4.3.9.3(1)(a)(b)(c)
Piping and appurtenant equipment.	Check for leaks, clean and repair auxiliaries	SA	4.3.9.3(2)
Exterior surfaces	Clean and paint	A	4.3.9.3(3)

necessary. Diffuser nozzles on header lines may become clogged from deposition inside, from iron oxide particles or on the outside from organic growths. Clogging from the inside may necessitate the removal of the individual nozzles for cleaning. Chlorine gas injection into the air-line header between inspections will hold down organic growths. At inspection periods, if growths are present scrub them off with a brush and detergent solution to which hypochloride has been added.

4.3.10.3 Spray Nozzle Aerators. The following procedures apply to this type of equipment.

(1) At weekly intervals, check the nozzles for clogging, and clean when necessary. Remove the nozzles only when necessary. Do not use a pipe wrench for this purpose. Check for inadequate spread.

(2) Quarterly, check air-line manifolds, remove caps and clean out sediment; check for joint leaks. Check pipe supports, replace or repair, and paint as necessary.

(3) If spray fences exist, repair and paint on an annual schedule.

4.3.10.4 Blowers and Accessory Equipment. Where injection aeration is used, adopt the following procedures.

(1) Daily, lubricate the blower or compressor according to the manufacturer's instructions. Check output pressures.

(2) Weekly, inspect the air filters; clean, repair or replace them as necessary.

(3) Annually, open the blower or compressor and inspect for internal erosion or deterioration; repair as necessary. Paint exterior surfaces.

4.3.10.5 Maintenance Procedure Schedule. Maintenance operation frequencies and the schedule of inspections for aeration equipment are presented in Table 28.

4.3.11 DISTILLATION EQUIPMENT. Multiple-effect evaporators are described in paragraph 3.2.10.2; vapor compression evaporators in paragraph 3.2.10.3.

4.3.11.1 Multiple-Effect Evaporators. As described in paragraph 3.2.10.2, these evaporators may be of two types.

4.3.11.1.1 Triple-effect submerged tube evaporator. Regardless of the model or manufacturer, scale shall be removed from the evaporator tubes as soon as the scale thickness reaches $\frac{1}{16}$-inch.

(1) Thermal Cracking of Scale. In the tube model, the scale may be cracked by suddenly flooding the shell with cold water after the tubes have been preheated with steam at the first effect coil steam pressure. This method of cracking is the most satisfactory when the scale thickness is less than $\frac{1}{16}$-inch.

(2) Mechanical Cracking of Scale. Where thermal cracking is not effective, mechanical cracking may be used.

(a) In the tube model, the scale may be cracked by inserting a bar between the lines of tubes.

(b) In the coil model, manual cracking may be done by bouncing the coils on a hard wood block in order to crack the heavier coating; this should be followed by wire brushing the coils. The manufacturer's instructions should be consulted. CAUTION: The use of a chipping hammer to remove the scale may seriously damage the coils.

(3) Acid Cleaning. In the coil model, scale generally may be dissolved quickly by immersing the coils in a 20 percent solution or muriatic acid (commercial hydrochloric acid). The coils shall be thoroughly washed in water before they are reinstalled in the evaporator.

(4) Zinc Plate Replacement. When the zinc plates have been reduced to about one-quarter of the original size they should be replaced.

(5) Condenser and Cooler Tube Cleaning. Where the design utilizes these tubes, they should be cleaned by flushing, wire brushing or scraping, and flushing again before they are reinstalled.

(6) Shutdown Protection. If the plant is to be shut down for an indefinite period and is subject to freezing conditions, all water should be removed from all parts of the evaporator.

4.3.11.1.2 Flash-type evaporators. Specific instructions for maintenance procedures will be found in the manufacturer's instructions, although the following procedures are the minimum required.

(1) Quarterly, check the evaporator stages for corrosion or incrustation; clean and repair as necessary.

(2) Semiannually, check the steam tube side of evaporator; and repair as necessary.

(3) Annually, inspect all parts of the unit, both interior and exterior, for signs of deterioration, and inspect the piping and valves. Repair or renew parts as necessary; paint exteriors.

4.3.11.2 Vapor Compression Distillation Units. Detailed instructions for maintenance procedures will be found in the manufacturer's instructions. The following procedures are the minimum required.

(1) After 200 to 400 hours of operation, check the evaporator for corrosion or incrustation. If the tubes are incrusted, use either chemical or mechanical means for scale removal. Mechanical cleaning is used for hard scale that is not removed by chemical treatment.

(a) For chemical treatment, apply an acid wash made by adding sodium bisulfate solution directly, or in solution, to the evaporator. Sulfamic acid, or inhibited muriatic acid, is better than sodium bisulfate, but inhibited acid should be used only if approved by the Public Works Officer. The amount of acid wash to be added will vary, depending on the size and type of unit. Consult the manufacturer's instructions. Generally, the acid wash is continued during a 2-hour

TABLE 28

Maintenance Procedures for Aeration Equipment

Inspection	Action	Frequency [1,2]	Reference Paragraph number
Waterfall type aerators (cascade).	Inspect aerator surfaces; remove algae; clean.	D	4.3.10.1(1)
Waterfall type aerators (tray).	Clean and repair trays; clean coke or replace.	SA	4.3.10.1(2)
Waterfall type aerators (cascade).	Repair or replace surfaces as necessary.	A	4.3.10.1(3)
Injection aerators			4.3.10.2
Porous ceramic plate or tube.	Check discharge pressure; if clogging is evident, dewater tank, clean diffusers.	V	4.3.10.2.1(1)
Porous ceramic plate or tube.	Drain aeration tank, check for joint leaks, broken diffusers, clogging.	SA	4.3.10.2.1(2)
Water side of ceramic diffusers.	Clean with acid, in place, or remove and soak in acid.	SA	4.3.10.2.1(2)(a)(c)
Air side of ceramic diffusers.	If plates are clogged by iron oxide, treat with HCl; if clogged by soot, oil, etc., remove diffusers and burn.	SA	4.3.10.2.1(2)(b)(c)
Saran wound diffusers	Clean by scrubbing with soap or detergent	SA	4.3.10.2.2
Nozzles	Clean nozzles inside and out	SA	4.3.10.2.3
Spray nozzle aerators			4.3.10.3
Nozzles	Check for clogging; clean, remove if necessary to clean.	W	4.3.10.3(1)
Manifolds	Remove caps and clean out sediment; check pipe supports, repair, as necessary; paint as necessary.	Q	4.3.10.3(2)
Spray fence	Paint	A	4.3.10.3(3)
Blowers and accessory equipment.			4.3.10.4
Compressor or blower	Lubricate, check output pressure for indications of clogging.	D	4.3.10.4(1)
Air filters	Clean, repair or replace	W	4.3.10.4(2)
Compressor or blower	Open, inspect, clean, repair and paint exterior surfaces.	A	4.3.10.4(3)

[1] D-Daily; W-Weekly; Q-Quarterly; SA-Semiannually; A-Annually; V-Variable; as conditions may indicate.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

recirculation period; methyl orange is used as the indicator to show when the acid is spent. After treatment, drain the unit, flush well, rinse with alkaline solution and return to service.

(b) For mechanical removal of scale formation, the equipment consists of an electric drill with bit and wire brush attachments that fit the evaporator tubes (see fig. 177). The tubes must be wet before the drilling is started. Water is fed through the drill bit during operation. Drill each tube and then wire brush. Remove scale from the evaporator shell or heads by scraping; remove all dislodged particles of scale from the evaporator. Reassemble the evaporator and return it to service.

(2) Quarterly, check all mechanical controls, fuel lines, electrical connections, lubrication points and valves.

(3) Semiannually, check the engine, vapor compressors, vent condensers, heat exchanger, cooler system and instrumentation. Clean, adjust and repair as necessary.

(4) Annually, check the entire system; clean, repair and paint as necessary.

4.3.11.3 Maintenance Procedure Schedule. Maintenance operation frequencies and the schedule of inspections for distillation equipment are presented in Table 29.

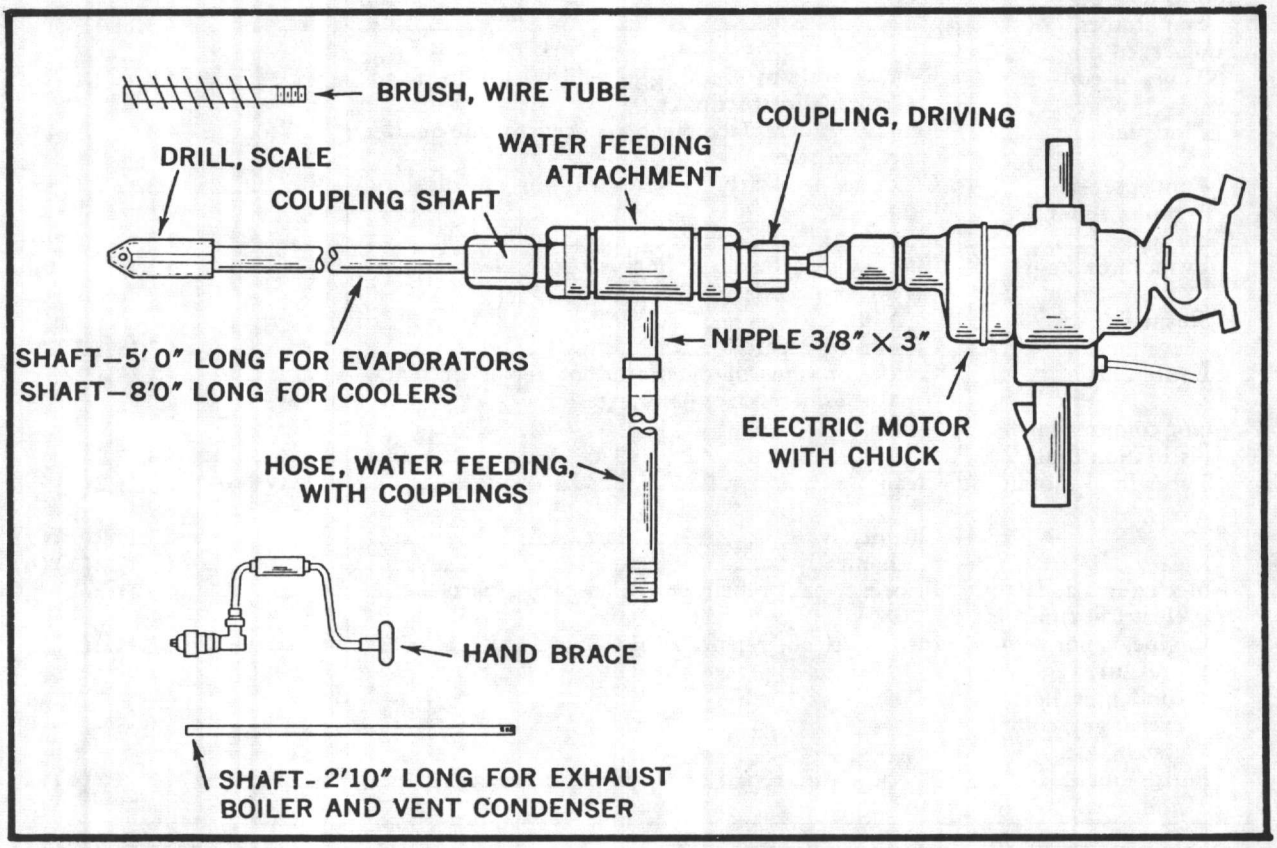


FIGURE 177

Mechanical Tube Cleaning Equipment

TABLE 29

Maintenance Procedures for Distillation Equipment

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Distillation equipment			4.3.11
Multiple-effect evaporators.			4.3.11.1
Submerged tube			
Tubes or coils	Remove scale by cracking or acid wash (see manufacturer's instructions).	V	4.3.11.1.1
Zinc plates	Remove and replace when reduced to one-quarter original size.	V	4.3.11.1.1(4)
Condenser or cooler tubes.	Clean, as necessary, by wire brushing and flushing	V	4.3.11.1.1(5)
Flash-type			4.3.11.1.2
Evaporator stages	Check for corrosion or incrustation; clean and repair as necessary.	Q	4.3.11.1.2(1)
Steam side of evaporator.	Clean and repair	SA	4.3.11.1.2(2)
Entire unit	Check for signs of deterioration; repair or renew parts, as necessary; paint exterior.	A	4.3.11.1.2(3)
Vapor compression distillation units.			4.3.11.2
Tubes in evaporator	Clean	Every 200–400 hrs.	4.3.11.2(1)
	Chemically	V	4.3.11.2(1)(a)
	Mechanically	V	4.3.11.2(1)(b)
Mechanical and electrical controls.	Inspect, clean, repair or replace worn parts	Q	4.3.11.2(2)
Engine, vapor compressors, vent condenser, heat exchanger, cooler system, etc.	Inspect, clean, repair, adjust	SA	4.3.11.2(3)
Entire unit	Check, clean, repair and paint as necessary	A	4.3.11.2(4)

[1] Q-Quarterly; SA-Semiannually; A-Annually; V-Variable; as conditions may indicate.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

Section 4. DISTRIBUTION SYSTEM—MAINS

4.4.1 COMPONENTS. The distribution system of a water utility includes the conduits or transmission mains, storage reservoirs, distributing mains and these accessories: booster stations, hydrants, main line meters, service connections and valves. For the purpose of simplicity of presentation in this manual, the maintenance aspects of these various components appear as follows.

	Sections
Booster stations	9 and 10
Hydrants	6
Mains	4
Meters	8
Storage	7
Valves	5

4.4.2 CARRYING CAPACITY LOSS. Decreases in the carrying capacity of pipelines result from increased friction in the system caused by an increase in the interior roughness of the pipe (decreased interior diameter). Causes of increased roughness, or decrease in line size, include corrosion and pitting, tuberculation, deposits of sediment, slime growths and air accumulation at high points in the line. Observations, which indicate these adverse conditions, consist of fire-flow tests (hydrant-flow tests), loss-of-head tests, pressure tests, simultaneous flow and pressure tests, and leak surveys.

4.4.2.1 Flow Tests. Flow measurement tests in mains are best made by pitometer surveys. These tests are best performed by an outside contractor. The tests may show closed or partly closed valves, obstructions, air pockets or loss of carrying capacity due to incrustation. These tests should be made whenever the operating conditions indicate that there is a need. In lieu of a pitometer survey, hydrant-flow tests may be used to check a limited part of the system.

4.4.2.1.1 Hydrant-flow tests. These tests, generally made for fire-flow checking, determine the residual pressure at one hydrant while the flows from a group of neighboring hydrants are measured. Tests should be made at times when consumption is normal in all parts of the system. The technique briefly is as follows.

(1) At the particular point where information is desired, place a gage on a fire hydrant (hydrant A).

(2) Place a hydrant pitot gage which reads in both psi and g.p.m. (see Figure 178), in the nozzle of another hydrant (hydrant B).

(3) Open the nozzle on hydrant B and read the pressure on the pitot gage and the residual pressure on hydrant A. (In order to obtain sufficient pressure drop, it may be necessary to open more than one hydrant [B, C, D, etc.] and make pitot gage readings on each.)

(4) Calculate the flow in the open hydrant by the following equation.
Where,

$$Q = 27\ D^2\sqrt{P}$$

Q = flow (g.p.m.)
D = diameter of nozzle (inch).
P = pitot-gage pressure (psi).

(5) The approximate amount of water available at 20 psi residual pressure (minimum desirable) is determined by the following equation.

$$Q_r = Q_t \times \frac{(P_e - 20)^{0.5}}{(P_e - P_o)}$$

Where,

Q_r = flow at residual pressure of 20 psi (g.p.m.)
Q_t = total discharge of the open hydrants (B, C, D, etc.).
P_e = pressure at A with B, C and D closed (psi).
P_o = residual pressure at A with B, C and D open (psi).

(6) Detailed instructions appear in AWWA Water Distribution, M–8, "A Training Course in Water Distribution" (Reference 18).

4.4.2.2 Pressure Tests. If pressure recorders do not exist on the system, particularly at high and low points, then annual checks should be made of pressures at various elevations and locations on the system (see Figure 179).

4.4.2.3 Loss-of-Head Tests. These tests should be made annually to determine changes in the internal conditions of the mains. Two pitometers, with attached manometers and an accurate recording gage, are used, one at each end of the section of the main under test. During the tests, all branch lines are shut off so that the flow will be through that section only, and in order that no water can be withdrawn from the test section by consumers.

(1) Observations should be made for a period of time on both manometers and gages. At the completion of one test period, the gages should be compared, then switched and another test made.

(2) The pressure readings should be converted to feet of head at each point; the pipe elevation at each point should be added to this pressure head. The difference between the two pressures is the loss of head.

(3) The loss of head divided by the length of test section (in feet) is the hydraulic slope which is reported in feet per 1,000 feet.

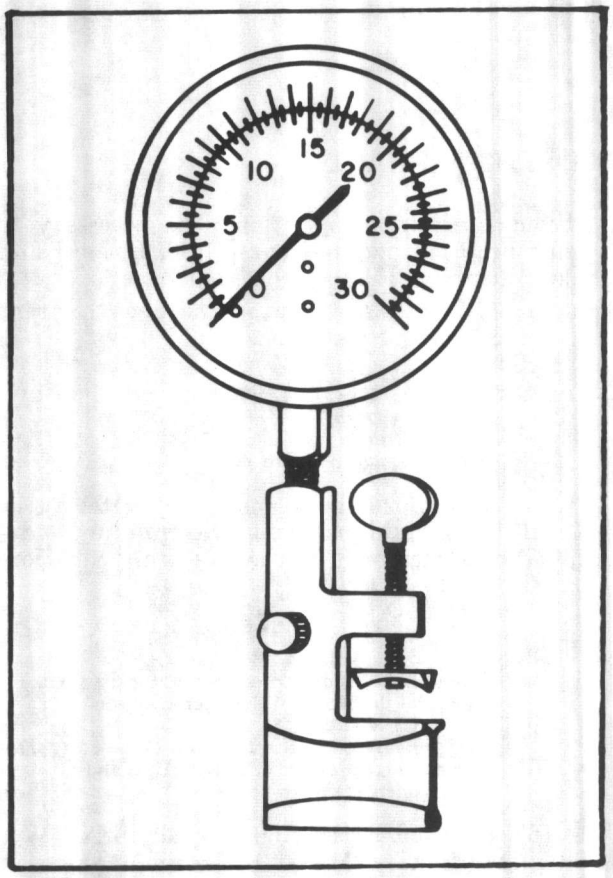


FIGURE 178

Pitot Tubes with Velocity Pressure Gage for Hydrant Flow Tests

4.4.2.4 Remedies for Carrying Capacity Loss. There are four methods of remedying carrying capacity loss, depending on the cause of the loss.

4.4.2.4.1 Cleaning. Cleaning should be done whenever flow tests or loss-of-head tests indicate that there is a need. Mains, which exhibit carrying capacity loss, may be cleaned in two ways.

(1) Small pipes containing calcium carbonate deposits or tubercles may be cleaned with inhibited muriatic acid; this treatment is not feasible for large pipes. See paragraphs 4.2.2.6.1 (1)(c) and 4.3.11.2(1)(a) for comments on the use of inhibited acid.

(2) Large mains are cleaned with scrapers. This operation is usually done by outside contractors, but may be done by the utility. The scraper is inserted through a cut in the main, and is moved forward by water pressure behind it until it exists at another cut in the line. Debris is flushed out of the line ahead of the scraper. Pipes so cleaned are subject to further tuberculation, if the character of the water causes tuberculation.

(3) Use a high initial concentration of a zinc-containing polyphosphate immediately after cleaning to minimize red water and tubercle formation.

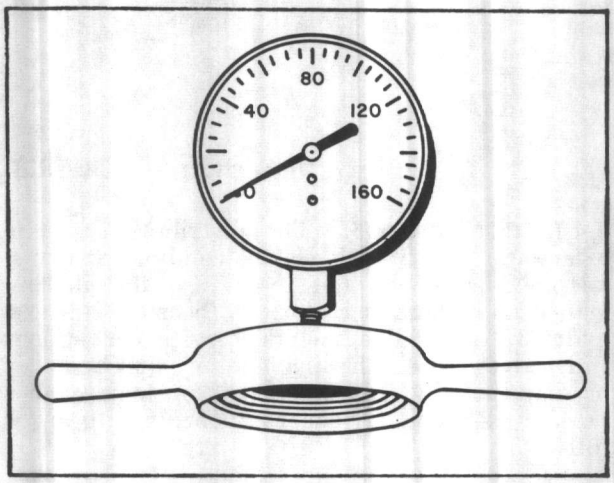


FIGURE 179

Gage Assembly for Measuring Fire Hydrant Pressure

4.4.2.4.2 Cleaning and lining. To avoid the necessity for repeated cleaning by scrapers, the pipe should be cement-lined *in place*, after it has been cleaned. This operation should be done by an outside contractor.

4.4.2.4.3 Operating procedure changes. Some of the conditions causing loss in carrying capacity may be remedied by changes in operating procedures.

(1) If the water supply is corrosive, or lacks buffering capacity, as it enters the distribution system, it will aggravate tuberculation. To offset this condition, a change in treatment may be instituted to stabilize the water and increase its pH.

(2) If carrying-capacity loss is caused by slime growth, special chlorination procedures may be adopted to remedy the condition.

(3) Where accumulation of sediment is the cause of carrying-capacity loss, periodic flushing of the entire system, through hydrants and blowoffs, is mandatory. The following procedure shall be used.

(a) Start the operation at the hydrants or blowoffs nearest the sources of supply, to avoid wasting water and to stir up the water in the distribution system to the least possible extent.

(b) Flush each point until the water discharged is reasonably clear. All valves must be in their normal operating positions before proceeding to the next point.

(c) Give special attention to flushing dead ends.

(d) If daytime flushing does not induce enough velocity to scour the mains, then night

flushing, with large discharges, shall be practiced. Nighttime flushing lessens service disruption caused by valve shutoffs and decreased pressures.

4.4.3 LEAK LOCATION. Leaks in pipelines reduce the capacity of the system, cause water to be wasted and reduce water pressures.

(1) To ascertain the location of leaks, surveys shall be made at the time of minimum water use.

(2) All valves should be shut off, except those which will direct all water flow through section under study. CAUTION: Notify the firefighting authorities prior to shutting off any section of the system. Insert a pitometer in the pipe, and determine if the flow is above normal for that time of day; if so divide the district into smaller areas until the area of the leak is pinpointed.

(3) Once the area has been located, finding the leak may be done in several ways; none of them is universal in its effectiveness.

(a) House-to-house inspection.
(b) Observation of the ground surface.
(c) Observation of sewer flows.
(d) Study of hydraulic gradelines.
(e) Listening for sound of leak with sonoscope or geophone.
(f) Blowing air in pipe, for submerged line.

4.4.3.1 Remedies. Rapid repair of breaks in the distribution system depends on trained men having the needed material immediately available. If the break or leak is large, several highly undesirable conditions exist. Fire protection service is impaired; escaping water may undermine and damage nearby structures; a health hazard may occur; and, normal service to consumers may be impaired.

4.4.3.1.1 Planning and preparation. Since water main breaks must be repaired as rapidly as possible, personnel must be trained and repair plans must be made in advance. The following procedures are essential.

(1) Post telephone numbers of key personnel and have alternate personnel available in case members of the regular repair crew cannot be reached at the time of a break. Notify firefighting authorities at the time the break is reported.

(2) Keep the following items available and ready for use at all times: valve keys, hand tools, digging tools, pavement breakers, trench shoring, portable centrifugal pump, flood lights, emergency chlorinator and hypochlorite tablets. Also, have advance arrangements with a municipal utility, public works department or outside contractor for the use of large construction equipment (e.g., power shovels, cranes, etc.), which may be needed, but are not normally stocked by the activity.

(3) Maintain an adequate stock of pipe repair materials and supplies.

4.4.3.1.2 Leak repair. The technique of repairing leaks depends on the type of leak. The following general procedures will apply.

(1) Use wood plugs to stop small holes temporarily. They can be replaced later with metal plugs, or repairs may be made by other means. Temporary wood plugs may be used to plug the ends of pipe up to 8 inches in diameter, but such plugs must be braced to withstand existing main pressure.

(2) Joint leaks shall be repaired by recalking the joint.

(3) Cracks in mains usually require that the valves be shut off in the affected area, especially in severe main breaks. Notify the firefighting authorities in case of main shutoff. These leaks may be repaired by one of these methods.

(a) Use a split sleeve (see fig. 180).

(b) Cut out a section of the cracked pipe and replace it with a piece of pipe and mechanical couplings (see fig. 181). These mechanical joints or couplings are manufactured by several companies for various types of repair jobs. For the methods of installation and most advantageous use of each, consult the manufacturer's instructions in order that the proper selection and installation may be made. If the break is too long for a short insertion piece, a whole length of pipe is to be inserted.

(4) Freezing of the main, to stop the flow of water for a short period during repairs, may avoid the necessity of closing valves. Apply a mixture of dry ice and gasoline around the main. The larger the pipe, the longer it takes to freeze. A 6-inch main has been frozen in two hours, with 150 pounds of dry ice and seven quarts of gasoline. CAUTION: Gasoline is highly flammable and toxic to breathe. Use caution in all cases.

4.4.4 MAIN DISINFECTION. When a water main is opened for repair, particularly by insertion of a new section or length of pipe, the line must be disinfected.

4.4.4.1 Procedure. The procedure to be followed for main disinfection is set forth in detail in Reference 8. These directions contain instructions for main disinfection procedures to follow when repairing or cutting into existing lines.

4.4.4.2 Disinfection Calculations. Where hypochlorite solution or chlorine is used for main disinfection, the uniform application of the disinfecting solution involves calculation of the volume of the pipeline to be disinfected. Also, it is necessary to calculate the chemical dosage, the available chlorine content of the solution and the bleed rate.

4.4.5 THAWING. Electrical thawing is the most common method thawing metal pipes and services. It cannot be used with nonmetallic pipe (see par. 2.5.2.1). Only qualified personnel should be assigned the responsibility for thawing pipes with electrical equipment.

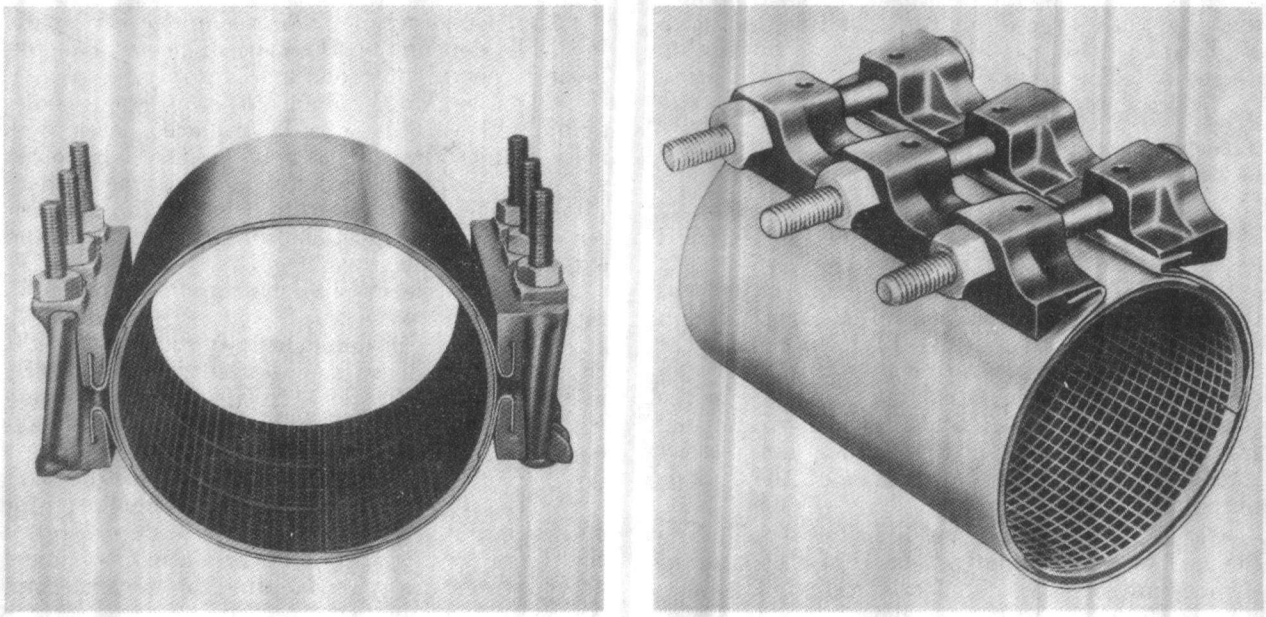


FIGURE 180

Two Views of Split Sleeves for Repairing Leaks

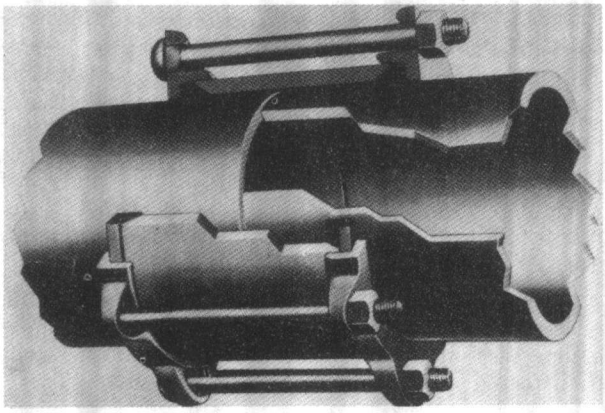


FIGURE 181

Mechanical Joint Fitting

4.4.6 BACKFLOW PREVENTERS. The frequency with which backflow preventers shall be inspected and tested depends largely on the make and model of the unit. This is true, also, of the test procedures to be followed. Therefore, consult the manufacturer's instructions for detailed procedures.

4.4.6.1 Double-Check Valve Type. In general, the following procedure is applicable to a unit which is essentially illustrated in the diagram of Figure 101. At monthly intervals, tests shall be made of the tightness of the unit, as follows (NOTE: Symbol designations apply to fig. 101).

(1) Close gate valve G and open test cock D. NOTE: Pressure on gage A should drop to zero; pressure on gage B should drop slightly, and then hold.

(2) With test cock D still open, open test cock E. Note: Pressure on gage B should drop to zero; gage C should remain stationary.

(3) The check valves and other fittings are tight, if the previous gage reactions are obtained.

(4) Place the unit back in operation by closing test cocks D and E, and opening gate valve G.

4.4.6.2 Reduced Pressure Type. In general, the following procedure is applicable to the reduced pressure backflow preventers. At least once a month, tests shall be made of the effectiveness of the unit.

(1) Check the relief valve opening. A continuous discharge therefrom indicates a failure of some part vital to the prevention of backflow.

(2) If there is no discharge from the relief valve opening, check the pressure in the unit to make certain that it is less than the potable water system.

(3) Manipulate the two valves and check the operating conditions in accord with the manufacturer's instructions. If there is any evidence of failure to operate properly, close both valves and remove the flange heads; remove, repair and replace the moving parts.

4.4.7 MAINTENANCE PROCEDURE SCHEDULE. The maintenance operation frequency and schedule of inspections for the distribution system are presented in Table 30.

Section 5. VALVES AND ACCESSORIES

4.5.1 VALVES. Valves for water utility systems are descrbied and illustrated in paragraph 3.4.2.5. The maintenance of valves can be reduced to a minimum by periodic inspection, the inspection frequency depending on the specific service conditions and how often the valve is operated. In case of reactivation of a system, all main line valves shall be tested.

4.5.1.1 Manually-Operated Valves. Specific types of valves have specific maintenance procedures, as set forth in the following paragraphs.

4.5.1.1.1 Gate valves. Gate valves, whether in the distribution system (usually buried or in vaults), or in a water treatment plant, have several component parts that may require attention. These parts include a stem, a gate (either solid wedge or double disk), a body and a bonnet. Both the types of service and the design of the valve affect the maintenance operations.

(1) Distribution System Valves. These valves are, generally, nonrising stem, inside screw, equipped with a 2-inch square operating nut. Most distribution system valves will be buried, with a cast iron adjustable-height roadway box, resting on the bonnet and protecting the nut, as well as serving as the "port" through which the valve key is inserted. Common sources of trouble are "lost" valves, inoperable valves and valve boxes covered or obstructed by road grading or filled with foreign matter. Maintenance procedures are based on semiannual operation of each valve, and repairing as necessary. The maintenance steps involved are.

(a) Record all valve locations, as well as other data on the valve, in an indexed valve record book (see par. 2.6.2.3). Pertinent data referencing the location with respect to fixed markers should be recorded. A copy of the valve record, including maintenance operations performed and dates, should be in possession of the maintenance crew, as well as on file in the utility office. If a valve is "lost", use a dip needle or miner's compass to locate the valve, or a mine locator to locate the valve box, if it is buried. Record any errors in location in the record book, the note whether the valve was open or closed at the time of inspection.

(b) Check the operation of the valve; close completely and open completely, then back off

TABLE 30

Maintenance Procedures for Distribution System—Mains

Inspection	Action	Frequency [1,2]	Reference Paragraph number
Flow tests	Make tests as conditions indicate need	V	4.4.2.1
Pressure tests	Make tests as conditions indicate need	V	4.4.2.2
Loss-of-head tests	Determine, using pitometer	A	4.4.2.3
Cleaning	Employ outside contractor	V	4.4.2.4.1
Cleaning and lining	Employ outside contractor	V	4.4.2.4.2
Operating procedure	Change procedures as conditions dictate	V	4.4.2.4.3
Leak location	Use standard techniques	V	4.4.3
Leak remedies	Plan and prepare in advance	V	4.4.3.1.1
Leak repair	Apply standard techniques	V	4.4.3.1.2
Disinfection	See Reference 6	V	4.4.4.1
Thawing	Apply standard techniques	V	4.4.5
Backflow preventers			4.4.6
Double check valve	Test tightness of unit	M	4.4.6.1
Reduced pressure	Test tightness of unit	M	4.4.6.2

[1] M-Monthly; A-Annually; V-Variable; as conditions may indicate.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

on the valve about one turn. NOTE: If utility service operations will not permit the complete closing of a valve, close it completely and then open slightly.) If the valve does not seat properly in the closed position, open slightly to allow water to wash the foreign matter out of the valve seat. If necessary, open a hydrant to increase flow enough to flush foreign matter from the valve seat.

(c) Check and lubricate the valve stem packing. If the packing is dry, it will impede valve closure at all points of stem movement.

1. Lubricate dry packing by pouring a mixture of half kerosene and half lubricating oil down a ½-inch pipe, bent at the bottom so as to discharge the mixture onto the stem below the operating nut.

2. If the packing leaks, dig up the valve, tighten the packing gland, or replace the packing, as necessary.

3. To reduce leakage while the packing is being replaced, open the valve as wide as possible to pull stem shoulder tight against the bonnet.

(d) Check stem alinement. If valve operates easily near open or closed positions, but not when the valve is partially closed, the stem probably is bent. Replace a bent stem with a new one. (See the manufacturer's instructions for removing and inserting the stem.)

(e) Check for broken or stripped stem or stem nut. Either condition will permit unlimited turning of the stem without closing the valve. If this condition exists, isolate the valve, open it and replace the stem. If repair parts are not available, remove the stem and gate, and plug the bonnet from the inside with a wooden plug until permanent repairs can be made. If the valve stem nut is missing or damaged, replace it.

(f) If the valve has a bypass, check whether or not the bypass is open or closed, and see if the small valve is operating properly. (If this is a globe valve, see par. 4.5.1.1.4 for maintenance procedures.)

(g) If the valve is geared, check and lubricate gears, and correct any deficient condition.

(h) If the valve is installed in a manhole or vault, check the condition of the box or vault, and vault cover. Clean out any debris, and make any repairs necessary to the vault or cover. Raise or lower box or vault, if necessary.

(2) Treatment Plant Valves. At quarterly intervals, operate inactive valves to prevent sticking; clean and lubricate the threads on any stem-rising gate valve.

(a) At annual intervals, lubricate the valves according to the manufacturer's instructions. If the valve is geared, lubricate gears. If the valve gearing is open, wash gears with kerosene and lubricate them with a recommended lubricate (see table 14).

(b) Whenever a gate valve seat leaks, remove the valve and reface the valve seat. The procedure to be followed is detailed by the manufacturer; it includes these general steps.

1. Remove the bonnet; inspect and clean all working parts.

2. Check all working parts for signs of wear or deterioration.

3. Remove old packing.

4. Refinish the working parts by grinding, sanding or polishing, and lapping; replace any parts beyond reuse.

5. Replace the valve parts; repack and test the valve for proper operation.

(c) Chain wheels, used to operate valves out of reach, shall be lubricated quarterly.

4.5.1.1.2 Butterfly valves. This type of valve is used in both distribution systems and treatment plants. In distribution systems, the valves are placed in vaults, and all valves of any size are geared and/or powered. In treatment plants, butterfly valves are usually powered (pneumatic, hydraulic or motor-operated).

(1) Semiannually, the valve stem should be checked for watertightness and adjusted, if necessary, according to the manufacturer's instructions.

(2) On an annual basis, the valves should be checked for proper operation and for tight closure.

4.5.1.1.3 Rotary valves. This type of valve includes cone valves, solid plug (lubricated and corporation cock), rotating balls and multiport valves.

(1) Cone Valves. In this valve, the cone plug seats against the valve body in both open and closed positions. During opening or closing, the valve is lifted off its seat, revolved and reseated by a hydraulic cylinder, which may be either manually- or pilot-actuated. Rotating, ball valves are similar to cone valves. Maintenance operations include the following.

(a) Monthly all metal-to-metal contacts in the pilot mechanism; lubricate packing glands; and lubricate all parts of the seating and rotating mechanisms. (Comply with the manufacturer's instructions with respect to lubrication procedures.)

(b) Annually, dismantle the valve and remove corrosion products on the plug or valve body; wire brush both plug and valve body; paint valve inside and outside with two coats of corrosion-resistant paint in order to minimize tuberculation which prevents tight seating and causes wire drawing and seat erosion.

(2) Lubricated Plug Valves. Designs vary, depending on the particular manufacturer. Therefore, the manufacturer's instructions should be followed regarding lubrication and maintenance procedures. The following procedures are the minimum required and apply to all makes.

(a) Monthly or quarterly (depending on the design), lubricate the valve with a stick lubricant made specifically for this use. Be sure that there is enough lubricant in the valve so that

merely turning down the screw will supply the needed amount.

(b) Quarterly, operate all valves and check for possible corrosion or entrance of foreign matter between the plug and the seat. Lubricate gears where they exist.

(c) Annually, inspect for a possible need to dismantle the valves. If the valves are removed and dismantled, wire brush all surfaces and determine if the valve can be reconditioned by remachining the valve body and machining the plug. If these operations can be effective, lap the valve plug in the body to obtain a tight fit, and replace the valve in service. If reconditioning will not return the valve to usable service, replace the worn parts, or replace the whole valve. Consult the manufacturer's instructions for reconditioning techniques.

(3) Corporation Cocks (or Customer Service Valves). These valves are almost always buried with a valve box above to permit key access. It is seldom that these valves have to be dug up for servicing and repair. If so, they are usually replaced at the site and examined later at the maintenance shop for possible repair.

(4) Multiport Valves. These valves are used almost exclusively on ion-exchange water softeners (see par. 4.3.7.1.1(2)(a)).

4.5.1.1.4 Globe valves. These are compression-type valves employing a horizontal disk and a seat, the disk being lifted by a rising screw turned by a handwheel. The fluid through the opening may be straight-through or right-angle. Generally, these valves are used on small water or steam lines.

(1) Quarterly, operate the valves to prevent sticking. Check for leakage; adjust packing nut to eliminate stem leaks. If tightening the packing nut does not stop the leakage, open the valve wide, remove the packing nut and packing, and replace old packing with new.

(2) Semiannually, check the valve closure and possible leakage.

(a) If valve does not hold, remove valve stem and disk, and replace the valve disk with a new one.

(b) If valve seat and disk are both wire drawn, regrind or install a new disk and seat. Comply with the manufacturer's instructions for procedure to follow in repairing globe valves.

4.5.1.1.5 Diaphragm valves. These are also compression-type valves, of which there are several designs. They are used on chemical lines in water plants.

(1) Quarterly, operate valve, check the valve stem and lubricate as necessary; check for tight closing.

(2) Annually, check the diaphragm for cracks or signs or deterioration. Install a new diaphragm as necessary. Follow the manufacturer's instructions.

4.5.1.1.6 Sluice gates. Sluice gates are generally operated through gear drives by hand wheels or by motor drive. These are two types of sluice gates: (a) Those which seat with the pressure; and, (b) those which seat against pressure. Maintenance procedures are similar for both types.

(1) At monthly intervals, test for proper operation, especially operate inactive gates. Lubricate stem screws and gears.

(2) Once a year, clean the sluice gate with a wire brush and paint with a corrosion-resistant paint.

(3) Annually, for valves seating against pressure, check all wedges and adjust as necessary; provide uniform pressure at all wedges.

4.5.1.2 Power-Operated Valves. Valve operators may be electric, hydraulic or pneumatic. The valve itself is subject to the same maintenance procedures as outlined in Paragraph 4.5.1.1, but maintenance procedures for valve operators depend on the type of operator.

4.5.1.2.1 Motorized valve operators. Maintenance procedures for the motor appear in Paragraph 4.11.2, and for the gears in Paragraph 4.12.4. Limit switches should be checked quarterly.

4.5.1.2.2 Hydraulic valve operators

(1) At monthly intervals, the hydraulic cylinder should be checked while the valve goes through an operating cycle.

(a) Oil the packing around the piston rod and the tell-tale rod. Tighten the packing gland if leakage exists; replace the packing if normal tightening of the packing nut does not stop leakage.

(b) Check waste-line discharge. If this line continues to discharge water when the valve is in either open or closed position, disassemble the cylinder and check piston cup leathers for wear.

(2) At annual intervals, disassemble the cylinder and piston.

(a) Polish out scoring in cylinder liners with fine emery cloth; check cup leathers for wear, and replace, if necessary.

(b) Check the piston and the tell-tale rods where they contact the packing; polish out scored areas.

(c) Remove any corrosion products from the cylinder head and piston surfaces. Apply protective paint where required.

4.5.1.2.3 Pneumatic valve operators. Maintenance procedures for valves are similar to those for hydraulic-cylinder operated valves. Check the packing and air hose on a monthly basis; check the piston, cylinder, leathers, etc., annually.

4.5.1.2.4 Valve-pilot controls. Hydraulic-cylinder and pneumatic-cylinder valve operator, as well as automatic valves with internal cylinders, are usually actuated by manual, diaphragm or

motor-driven pilot valves. Maintenance procedures include the following.

(1) Monthly, check pilot control during one complete cycle of operation.

(a) Lubricate the pins and linkage, the packing glands and the threads on adjustment rods. Remove any corrosion products that might interfere with proper operation.

(b) Check for leakage at any point where it might exist (e.g., valve seat, cracked diaphragm).

(2) Annually, disassemble and check the pilot-valve unit. Clean strainers in piping lines; examine diaphragm for failure; and grind or replace valve seats which show evidences of pitting or leakage.

4.5.1.3 Automatic Valves. Generally speaking, maintenance operations on automatic valves depend on the particular design of valve and the use for which it was designed. (See Paragraph 3.4.2.5 for illustrations of various types of automatic valves.)

4.5.1.3.1 Air-release valves. This type of valve, when installed at the crest of a main or transmission line, allows air to escape automatically from the main. If it fails, the accumulation of air will reduce the flow capacity of the line, and may even stop the flow at low pressures. Lines which are subject to dewatering may have a combination air-release-vacuum-relief type of valve. Maintenance operations depend on the manufacturer's design, but the following procedures are the minimum required.

(1) Annually, remove the valve from service; check the float for leakage; check the pins and linkage for corrosion; remove corrosion products; and, clean the orifices.

(2) Annually, inspect the valve vault; check the masonry for frost damage; check the vault steps for deterioration; inspect manhole covers for proper seating and grade; repair the covers, and correct the grade, if necessary, in order to keep water from entering the vault.

4.5.1.3.2 Altitude valves. This type of valve is used on inlet lines to standpipes and elevated storage tanks in order to prevent overflows. These valves operate on one of three systems: (a) a diaphragm-operated pilot valve, which is a hydraulic-cylinder-operated valve that closes when the pressure on the diaphragm reaches a preset value; (b) a float-operated electric switch which actuates a solenoid pilot valve to a hydraulic cylinder which closes the inlet valve; and, (c) a float-operated pilot valve (by connecting cable or rods), with the pilot valve operating the hydraulic cylinder. These altitude valves can be adjusted to open only at a preset line pressure value, and to close in case of an unusual draft on the system. Maintenance operations depend on the design, but the following procedures are the minimum required.

(1) Monthly, check, as described in Paragraph 4.5.1.2.4, and lubricate the pilot control.

(2) Annually, disassemble and inspect the hydraulic cylinder, and repair as described in Paragraph 4.5.1.2.2. Also, inspect the main valve, and repair and paint it, as necessary.

4.5.1.3.3 Check valves. These valves serve to stop the reverse flow of water in a line. They may be used at pumping station discharge lines, at pump discharges or at booster pumping stations. The design varies from a simple swinging disk to one with closure controlled by a spring or a hydraulic cylinder that prevents check slam and water hammer. The disk seats on a metal, rubber or leather ring, generally at an angle. Another type, the ball check valve, is usually limited to small lines. Maintenance operations, which depend on the design of the valve, are described below.

(1) If the check valve has controlled closure, check the spring or hydraulic cylinder annually (see Paragraph 4.5.1.2.2). Check the pin wear on a balanced disk; make certain that the disk seats accurately in order to prevent leakage. For ball check valves, check the valve seat.

(2) When conditions indicate a need, disassemble the check valve and make whatever repairs are necessary.

4.5.1.3.4 Float valves. This type of valve is used principally as an altitude valve in distribution systems, and as a control valve in wash-water tanks and sedimentation basins. One design is a float-controlled, cable-operated butterfly valve used as a filter rate controller. Maintenance procedures depend on the design. Monthly inspection of the float, and annual inspection of the valve and the valve-operating mechanism are desirable.

4.5.1.3.5 Pressure-regulating valves. This type of valve, also called a pressure-reducing valve, is used to prevent the development of excessively high pressures at low–elevation sections of the distribution systems. The design and operating principles depend on the manufacturer, and maintenance procedures vary accordingly. Consult the manufacturer's instructions, but schedule valve inspection at least annually.

4.5.2 VALVE ACCESSORIES. Accessories for valves require maintenance according to the design, function and character of the accessory.

4.5.2.1 Gear Boxes. Most large manually-operated valves are operated through gears, as are motor-operated valves. These gears are housed in gear boxes.

(1) Monthly, or quarterly, lubricate the gearing according to the manufacturer's instructions.

(2) Semiannually, check the gear operation through a complete cycle of opening and closing. Listen for undue noise and observe smoothness of operation of the valve opening, and check for

lubricant leakage from flanges. Upon finding any evidence of improper operation, the operator should open the gear box, inspect the gears and make whatever repairs are necessary.

(3) Annually, inspect the housing for corrosion; clean and paint it as necessary.

4.5.2.2 Valve Boxes. All buried valves must have means for the valve key to reach the operating nut. This unit consists of a cast iron pipe about 6 inches in diameter, with a special yoke at the bottom to rest on the valve bonnet, and a cover at the street level (or ground level, if not in the street). These valve boxes are adjustable in height; some have covers with lock nuts to prevent unauthorized access.

(1) Maintenance of valve boxes should be on the same semiannual basis as the valve maintenance schedule for operation.

(2) Maintenance consists of cleaning out any debris in the box, checking for corrosion, checking the elevation of the top and alinement of the box so that the valve key can be inserted readily. If the valve box has corroded and is no longer serviceable, remove it and replace it with a new unit. If changes in street or ground level have left the valve box too high or too low, adjust the height so that the cover will be at the street or ground level.

4.5.2.3 Floor Stands. Floor stands, which are located on an operating floor and operate a valve at a lower level (as in a filter gallery), are described and illustrated in Paragraph 3.4.2.5.3(2). There are three designs—rising stem, nonrising stem and nonrising-stem-indicating. They may be plain or ball-bearing, or gear operated. Maintenance operations include the following procedures.

(1) Quarterly, lubricate the stem and, on indicator types, lubricate the rising-indicator collar.

(2) Annually, inspect the condition of the floor stand, clean off corrosion, and paint.

4.5.2.4 Valve Position Indicators. Different types of valves have different types of valve-position indicators. Nonrising-stem gate valves may have indicators on the floor stand. Filter plant valves may have indicators on the filter operating table, and butterfly valves, or other valves, used for flow control or throttling, may have electrically-controlled indicator units which look like an ammeter. The maintenance care required depends entirely on the design of the indicator unit. For example, post indicators require lubrication at quarterly intervals; and, electric position indicators should be checked for contacts, posts, wiring, etc., at annual intervals.

4.5.3 MAINTENANCE PROCEDURE SCHEDULE. The maintenance operation frequency and schedule of inspections for valves and accessories are presented in Table 31.

Section 6. FIRE HYDRANTS

4.6.1 DESIGN AND CONSTRUCTION. Fire hydrant maintenance, an important part of the facility fire protection system, consists mainly of inspection and testing. Special tools are required for replacement operations, and must be readily available for various types of hydrants installed. Consult the manufacturer's instructions. Most hydrants consist of a cast iron barrel with a bell or flange fitting at the bottom to connect to a branch from the main; a valve of the gate or compression type, with a long stem terminating in a nut above the barrel, and one or more outlets. There are many designs; a dry-barrel type is shown in Figure 6.

4.6.1.1 Dry-Barrel Hydrant. In cold climates, where freezing occurs, dry-barrel hydrants are used. Maintenance procedures include the following.

(1) The drain valve shall be kept open in all systems where the ground water level is below the hydrant foot in order that the barrel will drain and will not freeze in cold weather.

(2) Where ground water backs up into the barrel through the drain hole, the hole should be plugged and the barrel pumped out after each use of the hydrant.

4.6.1.2 Wet-Barrel Hydrant. Where freezing temperatures do not occur, wet-barrel (or California) hydrants may be used (see Figure 182). Maintenance requires that all packing glands be kept in condition to prevent leakage as well as to allow free operation of the stem controlling each outlet. Valve seats for wet-barrel hydrants afford easy access for inspection. Care must be taken to ensure that foreign matter does not interfere with proper seating of the valves.

4.6.1.3 Pit-Type Hydrant. Where this type of hydrant is used, as at airfields, care should be taken to remove water accumulations, especially in cold weather. Consult the manufacturer's instructions with respect to maintenance procedures (see Figure 183).

4.6.2 INSPECTION AND TESTING. Hydrants are inspected and tested by Public Works Department personnel accompanied by a Fire Department representative, in accordance with command and field engineering office directives. Hydrants can usually be maintained by replacing all worn parts and seats through the top of the hydrant. The operator must be sure that the proper tools are used.

4.6.2.1 Flushing and Testing. The schedule for flushing and testing of hydrants is prescribed in Reference 4. Local conditions may require more extensive flushing and testing. For example, in salt water systems, individual hydrant flows may appear adequate, but the system may be incapable of delivering fire demands due to the buildup of marine growths in the distribution systems.

(1) Hydrant flushing and testing should begin at the valve nearest the source of supply and proceed around a loop, or to the next hydrant, and then proceed to the next loop or hydrant.

(2) The hydrant should always be flushed with the valve fully open.

(3) The maximum water flow should be measured in the most important feeder and distribution mains at least annually (see par. 4.4.2.1).

(4) After a hydrant is flushed, inspect the barrel to make certain that the water was drained out of the barrel. When a hydrant does not drain properly, open the hydrant one or two turns with the hose outlet closed. If this operation is not successful in opening the drain hole, the hydrant must be dug up sufficiently to expose and clear the drain hole with a rod. There are a few hydrant designs that can be disassembled and the rod driven through the drain hole from the inside. (See the manufacturer's instructions.) Where the drain is plugged because of high ground water, the hydrant barrel must be pumped out after every use.

(5) If repairs require the shutting off of the water supply in any area, *the installation fire department must be notified immediately*, and the users on that part of the system should also be notified.

4.6.2.2 Cold Weather Inspections. In sub-zero weather, weekly inspections of hydrants near important structures should be made; and other hydrants inspected, monthly. See paragraph 2.5.4 for more information on hydrant protection in cold weather.

(1) Frozen hydrants are tested by placing an operating wrench on the nut and turning slightly. If it does not open with a normal force, the nut can be thawed with a blowtorch.

(2) If the valve will not open readily, the hydrant cap should be removed and inspected for ice by lowering a small weight on a string. If the barrel contains ice, it may be thawed by one of the following methods.

(a) Injection of live steam from a portable steam thawer.

TABLE 31

Maintenance Procedures for Valves and Accessories

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Manually-operated valves			4.5.1.1
Gate valves			4.5.1.1.1
Distribution system valves.	Locate, check operation, lubricate stem packing; if packing leaks, dig up valve and tighten packing gland or replace packing; check stem alinement; check for broken stem or stripped stem or chewed nut.	SA	4.5.1.1.1(1)
Valve bypass	Check for position, inspect and lubricate	SA	4.5.1.1.1(1)(f)
Gears	Check and lubricate; correct any deficiencies	SA	4.5.1.1.1(1)(g)
Vault	Check condition, clean, check masonry; make repairs, as necessary.	SA	4.5.1.1.1(1)(h)
Treatment plant valves	Operate inactive valves	Q	4.5.1.1.1(2)
	Lubricate as required (including gears)	A	4.5.1.1.1(2)(a)
	Replace or resurface leaking valve seats	V	4.5.1.1.1(2)(b)
	Lubricate chain wheels	Q	4.5.1.1.1(2)(c)
Butterfly valves	Check valve stem for watertightness, and adjust, if necessary.	SA	4.5.1.1.2
	Check operation and inspect for tight closure	A	4.5.1.1.2(2)
Rotary valves			4.5.1.1.3
Cone valves (and ball valves).	Operate; lubricate metal-to-metal contacts in pilot mechanism; lubricate packing glands; lubricate all parts of seating and rotating mechanisms.	M	4.5.1.1.3(1)(a)
	Dismantle, remove corrosion products, wire brush plug and valve body; paint valves with corrosion-resistant paints.	A	4.5.1.1.3(1)(b)
Plug valves	Lubricate with lubricant stick	M or Q	4.5.1.1.3(2)(a)
	Operate all valves; check for corrosion and foreign matter between plug and seat; lubricate gearing.	Q	4.5.1.1.3(2)(b)
	Inspect; dismantle if necessary; clean, wire brush, remachine plug and body or replace if condition is beyond remachining.	A	4.5.1.1.3(2)(c)
Corporation cocks	Remove and replace whenever necessary	V	4.5.1.1.3(3)
Multiport valves	See table 24		4.3.7.1.1(2)(a)
Globe valves	Operate valve to prevent sticking; check for leakage, adjust packing nut and replace packing if necessary.	Q	4.5.1.1.4(1)
	Check valve closure for tight shutoff; if valve does not hold, remove valve stem and disk and regrind seat and disk.	SA	4.5.1.1.4(2)
Diaphragm valves	Operate valve; check valve stem and lubricate as necessary; check for tight closing.	Q	4.5.1.1.5(1)
	Check diaphragm for cracks; renew as necessary	A	4.5.1.1.5(2)
Sluice gates	Operate inactive gates; lubricate stem screws and gears.	M	4.5.1.1.6(1)
	Clean valve with wire brush and paint with corrosion-protective paint.	A	4.5.1.1.6(2)
	Check seating wedges on valves seating against pressure.	A	4.5.1.1.6(3)
Power-operated valves			4.5.1.2
Motor-operators	See paragraph 4.11.2		4.5.1.2
Hydraulic-cylinder-operators.			4.5.1.2.2

TABLE 31 (Continued)

Inspection	Action	Frequency [1,2]	Reference Paragraph number
Hydraulic cylinder	Check through one valve operation cycle	M	4.5.1.2.2(1)
Piston rod and telltale rod.	Oil packing; tighten packing gland if leakage exists; replace packing if necessary.	M	4.5.1.2.2(1)(a)
Waste line discharge	Check for water flow when valve is wide open and shut; if leakage occurs, disassemble valve and piston, check leathers for wear and replace as necessary.	M	4.5.1.2.2(1)(b)
Cylinder and piston	Disassemble; inspect for scoring and corrosion; check cup leathers; polish any scored areas; remove corrosion products from piston surfaces and cylinder heads.	A	4.5.1.2.2(2)
Pneumatic valve operators.	Check packing and air hose; lubricate as necessary	M	4.5.1.2.3
	Check piston, cylinder and leathers; clean and maintain similar to hydraulic valve operators.	A	4.5.1.2.3
Valve operator pilot controls.	Check control through one full cycle of operation	M	4.5.1.2.4
	Lubricate pins, linkage, packing glands and adjustment rod threads as necessary; remove corrosion products; check for leakage and repair.	M	4.5.1.2.4(1)
	Disassemble; inspect unit and clean strainers; examine diaphragm for failure; regrind or replace worn valve seats.	A	4.5.1.2.4(2)
Automatic valves			4.5.1.3
Air-release valves, valve unit.	Remove valve from service; inspect float for leaks, and pins and linkage for corrosion; remove corrosion products; clean orifices.	A	4.5.1.3.1(1)
Vault	Inspect for condition of masonry, steps and manhole covers; repair as necessary.	A	4.5.1.3.1(2)
Altitude valves			4.5.1.3.2
Pilot controls	Inspect and lubricate (see Paragraph 4.5.1.2.4)	M	4.5.1.3.2(1)
Valve unit and operator.	Disassemble; inspect hydraulic cylinder and repair (see Paragraph 4.5.1.2.2); inspect valve, repair and paint, as necessary.	A	4.5.1.3.2(2)
Check valves	Inspect the closure control mechanism (if any); clean and adjust as necessary; check pin wear if balanced disk type; check seating on ball type.	A	4.5.1.3.3(1)
	Disassemble; clean, reseat and repair, as necessary	V	4.5.1.3.3(2)
Float valves	Inspect float; repair as necessary	M	4.5.1.3.4
	Inspect valve and valve operating mechanism	A	4.5.1.3.4
Pressure-regulating valves.	Inspect, clean, adjust, disassemble and repair as necessary (see manufacturer's instructions).	A	4.5.1.3.5
Valve accessories			4.5.2
Gear boxes	Lubricate gears (see manufacturer's instructions)	M or Q	4.5.2.1(1)
	Check gear operation through full operating cycle; listen for undue noise, etc.	SA	4.5.2.1(2)
	Check housing for corrosion; paint as necessary	A	4.5.2.1(3)
Valve boxes	Clean debris out of box; inspect for corrosion; check alinement and adjust as necessary.	SA	4.5.2.2(1)
Floor stands	Lubricate stem and indicator collars	Q	4.5.2.3(1)
	Inspect condition; clean and paint	A	4.5.2.3(2)
Valve position indicator.			4.5.2.4

TABLE 31

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Post indicators	Lubricate	Q	4.5.2.4(1)
Electric position indicators.	Check contact points, wiring, etc.	A	4.5.2.4(2)

[1] W-Weekly; M-Monthly; Q-Quarterly; SA-Semiannually; A-Annually; V-Variable; as conditions may indicate.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

(b) Pouring hot water into the barrel, using pails or a hose from a nearby hot potable water source.

(3) When the ice is thawed enough to permit the valve to open and water to flow, the valve should be opened and flushed slowly until all ice is removed. If the hydrant barrel does not drain, the water should be pumped out.

4.6.3 LEAKAGE TESTS. Annually, test the hydrant for tightness of joints and fittings in the following manner.

(1) Remove one hydrant cap and replace it with a cap fitted with a pressure gage. Open the valve slowly until it is wide open.

(2) Check for leakage at the following points.

(a) In the top of hydrant. If a leak is found, remove the cover and tighten or repack the packing gland.

(b) Where nozzles enter the barrel. For leaks here, calk the connection with lead.

(c) Nozzle caps. If the nozzle caps are leaking, replace any defective gaskets.

(d) Cracks in the barrel. For leaks emanating from cracks in the barrel, install a new barrel or a new hydrant.

(e) Drain valve. This valve should be closed when the hydrant is open. If water comes out of the drain or up around a hydrant, open the hydrant valve and replace the drain-valve facing or gasket.

(3) Close the valve, open the second nozzle, open the valve and flush the hydrant (note the residual pressure; see par. 4.4.2.1.1).

(4) Close the hydrant slowly and note the lowering of the water level in the hydrant after the valve is closed. If the water level does not drop, the operator should place his ear against the hydrant. If noise is heard, the main valve probably is leaking and must be replaced. If no noise is heard, the drain valve is plugged and must be opened.

4.6.4 VALVE PARTS. Annually, when the valve leakage tests are made, the following items shall be inspected.

4.6.4.1 Operating Nuts. If a nut is chewed or has rounded corners, remove it and replace it with a new nut. Lubricate the nut by removing the screw in the top of the nut and adding the lubricant recommended by the manufacturer. If necessary, lubricate the packing and the thrust collar by oiling the joint between the nut and the collar.

4.6.4.2 Nozzle Threads. The ease with which the nozzle can be screwed off and on should be checked. If the threads are damaged, the nozzle and/or the cap should be replaced.

4.6.4.3 Chains. If the chains are stuck to the caps by excess paint and do not move freely, the paint should be chipped out. Lost chains should be replaced, as required by fire prevention directives.

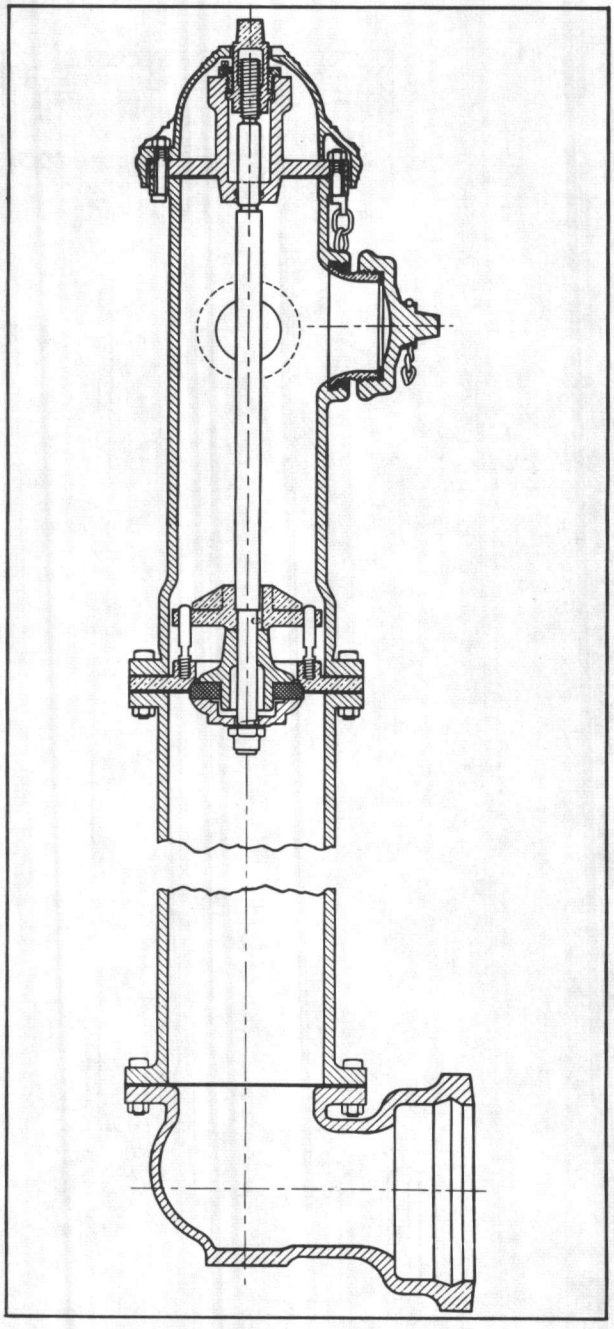
4.6.5 FLOW TESTS. Annually, during the leakage-test survey, the hydrant flow should be determined (see Par. 4.4.2.1.1). The residual pressure should be recorded when the valve is wide open.

(1) Compare the data with that in Table 32, and determine the approximate flow capacity of the hydrant. These are average data for an opening with rounded edges.

(2) Compare these approximate data with previous records. If the flow has dropped markedly from previous tests, or is unusually low, the valves may be closed, or partially closed, on the distribution system.

(3) If concurrent gate-valve inspection in the area does not reveal closed valves, a full study of the system flow may be needed (see par. 4.4.2.1). Check with the Public Works Officer before undertaking such a study.

4.6.6 MAINTENANCE PROCEDURE SCHEDULE. The maintenance operation frequency and schedule of inspections for fire hydrants are presented in Table 33.



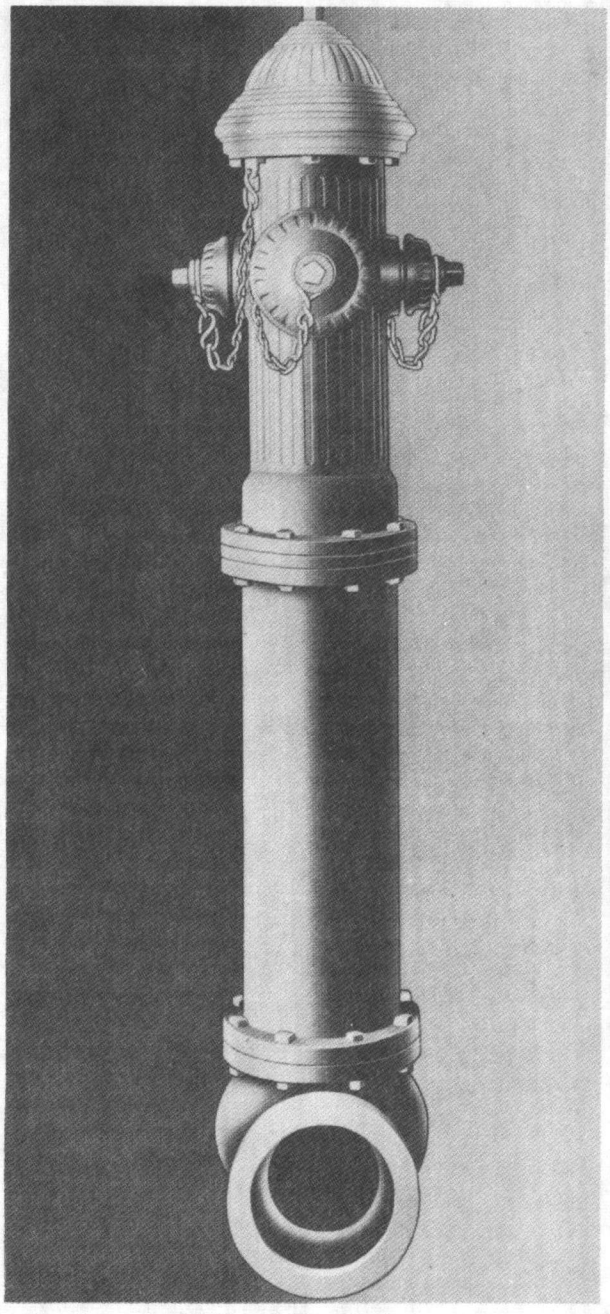


FIGURE 182

Wet-Barrel Type, or California, Fire Hydrant

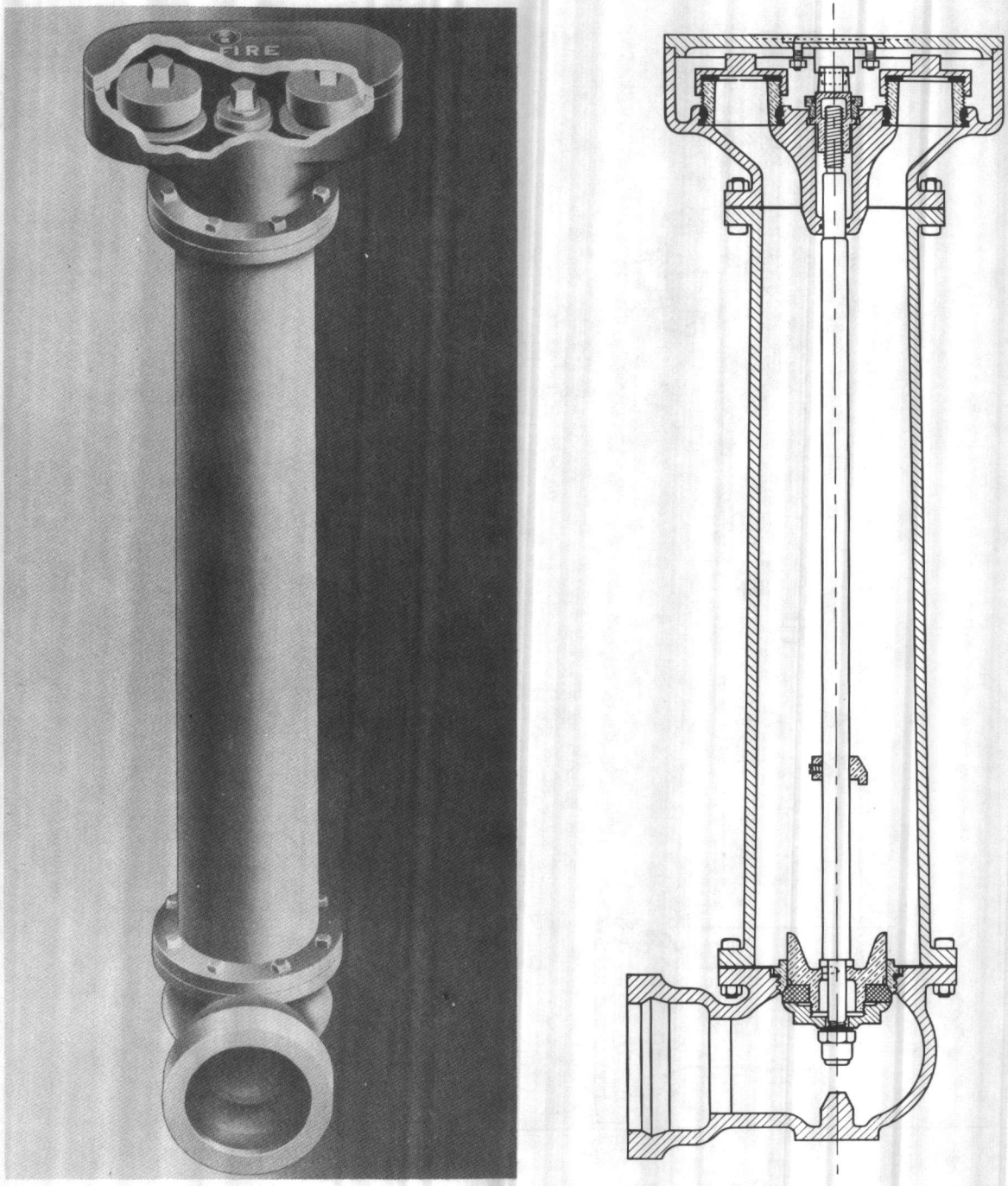


FIGURE 183

Pit-Type Fire Hydrant

TABLE 32
Hydrant Flow Capacity
One Nozzle

Residual Pressure (psi)	Discharge (Approximate) Nozzle Size	
	2½-inch (g.p.m.)	4½-inch (g.p.m.)
1	170	540
2	240	760
3	290	930
4	340	1080
5	380	1210
6	410	1320
7	440	1430
8	480	1530
9	500	1620
10	530	1720
12	580	1890
14	630	2030
16	670	2180
18	710	2310
20	750	2430
25	840	2730
30	920	3000

TABLE 33
Maintenance Procedures for Fire Hydrants

Inspection	Action	Frequency [1,2]	Reference Paragraph number
Dry-barrel hydrants	Check drain valve to be sure it opens	M	4.6.1.1(1)
	Where ground water level rises into barrel, plug drain valve and dewater barrel by a pump.	M	4.6.1.1(2)
Wet-barrel hydrants	Check packing glands and valve seats; repair as necessary.	Q	4.6.1.2
Pit-type hydrants	Check for water accumulation; dewater as necessary	M	4.6.1.3
All hydrants			4.6.2
On dead ends	Flush; check barrel after flushing	SA	4.6.2.1
Not on dead ends	Flush; check barrel after flushing	A	4.6.2.1
	Check water flow	A	4.6.2.1(1)
	Repair as necessary; if main shut down is required, notify fire department.	V	4.6.2.1(4)
In winter	Check for freezing; thaw, if necessary	W*	
		M**	4.6.2.2
Leakage tests	Inspect all places where leaks might occur; repair as necessary.	A	4.6.3
Valve parts			4.6.4
Operating nut	Check for rounded corners; replace as necessary; lubricate.	A	4.6.4.1
Nozzle threads	Check for damage; replace as necessary	A	4.6.4.2
Chains	Check for paint fouling; clean	A	4.6.4.3
Flow tests	Determine hydrant flow	A	4.6.5

[1] W-Weekly; M-Monthly; Q-Quarterly; SA-Semiannually. A-Annually; V-Variable; as conditions may indicate.
* Weekly near important structures.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.
** Monthly, elsewhere.

Section 7. STORAGE FACILITIES

4.7.1 BASIC FACTORS. Two basic factors affect the maintenance procedures to be followed with respect to storage facilities. These are the materials of construction (concrete, steel or wood), and the location of the tank (at ground level, below ground or elevated). Because all tanks have foundations, this subject is presented first in the following paragraphs. Thereafter, the procedures are organized according to the materials of construction. Maintenance procedures for appurtenances are grouped together following the procedures for tanks. The operation of storage facilities is presented in paragraph 3.4.3.

4.7.2 FOUNDATIONS. Foundations may be either concrete or wood. Each has its own maintenance procedures.

4.7.2.1 Concrete Foundations. Semiannually concrete foundations should be inspected for settlement, cracks, spalling and exposed reinforcing. If deterioration has set in, the foundation should be repaired with a mixture of one part cement to one part sand.

4.7.2.2 Wood Foundations and Pads. Wood foundations and pads should be inspected for split members, rot, termite infestation and for direct soil contact of untreated wood. Any repairs necessary to remove the undesirable condition should be made.

4.7.3 CONCRETE STORAGE TANKS. Concrete storage tanks may be either prestressed or nonstressed design. There is little difference in the maintenance procedures, which depend mainly on the location of the tank—above ground or below ground.

4.7.3.1 Ground Level Storage. At annual intervals, ground level storage facilities each spring should be inspected for watertightness and structural conditions and repairs made as necessary; at other intervals the maintenance procedures set forth in the following paragraphs should be performed.

4.7.3.1.1 Walls. Semiannually, exterior walls should be marked where leakage or seepage occurs. Annually, in the spring, they should be inspected for seepage or leakage from cracks, breaks or cracks in the interior seal membrane. Dewater the tank and check both the interior and exterior surfaces for spalling caused by frost action, as well as settlement, cracks and exposed reinforcing.

(1) All loose, scaly, or crumbly concrete should be removed and the wall patched with rich cement grout after wetting and painting with portland cement slurry. Hardened grout should be painted with iron waterproofing compound, or similar preparation.

(2) In repairing cracks, ¼-inch width and 1-inch depth should be chipped out. The cleaned crack should be moistened, and painted with portland cement slurry. The crack should be filled with a rich cement grout dry enough to stay in place in the crack, but not dry enough to allow it to slough off. When the grout has hardened, it should be painted with iron waterproofing compound, or a similar preparation.

(3) If cracks appear in prestressed concrete tanks, the problem should be referred to the erecting company for recommendations, even if the guarantee has expired or does not cover maintenance.

4.7.3.1.2 Expansion joints. Semiannually, joints should be checked for leakage at the juncture of the floor and the walls, and for loose or missing filler, debris or trash. They should be cleaned and repaired as necessary.

4.7.3.1.3 Roofs. Semiannually, the roof should be inspected for the condition of the covering. It should be made certain that roof hatches and other covers are locked, and that the screens on the overflow or at other locations are in place. They should be cleaned as necessary.

4.7.3.1.4 Earth embankments. Where the tank rests on an earth embankment, it should be checked for erosion resulting from the lack of full sod or vegetation coverage, and for damage from burrowing animals, improper drainage, ponding water along the base or leakage through the embankment or along the outlet piping. If leakage exists through the embankment, the tank should be drained and the bottom inspected for failure or cracks.

4.7.3.2 Underground Storage. If storage tanks are constructed below ground level, or are surrounded by an earth embankment, the semiannual inspection and repair include only the interior walls, roofs, appurtenances and embankment. The inspection procedures and maintenance operations are the same as given in paragraph 4.7.3.1. If the earth embankment, surrounding soil or interior of the tank shows evidence of tank leakage, the earth may need to be excavated and repairs made on the walls.

4.7.3.3 Elevated Storage. Concrete storage tanks, which are elevated above ground, require the same inspection procedures and repairs as are outlined in Paragraph 4.7.3.

4.7.4 STEEL STORAGE TANKS. In most cases, outside contractors should maintain and repair steel tanks. Several expert companies are available for this purpose. Care should be exercised not to employ inexperienced or unscrupulous contractors for this type of work. For elevated tank inspection and maintenance, follow explicitly the standards given in "AWWA Standard for Inspecting and Repairing Steel Tanks, Standpipes, Reservoirs, and Elevated Tanks for Water Storage, D101–53", (reference 19), and in "Tentative AWWA Standard for Painting and Repainting Steel Tanks, Standpipes, Reservoirs, and Elevated Tanks for Water Storage, D102–62T", (reference 20).

4.7.4.1 Ground Level Storage. Annually, after the winter season, steel storage tanks should be inspected for ice damage, watertightness and structural conditions. Twice each year, the maintenance procedures set forth in the following paragraphs should be effected.

4.7.4.1.1 Walls and bottom. Tank walls (exterior and interior) and bottom (interior) should be inspected semiannually for rust, corrosion, loose scale, leaky seams and rivets, and for the condition of the paint (both inside and out).

(1) Replace rivets, or patch leaking areas, and follow by cleaning and painting (see below).

(2) Check painted surfaces for rust, corrosion, cracking, peeling, alligatoring, chalking, fading or complete loss of paint. Empty the tank and examine the interior paint as corrosion is more likely on the inside. If the interior needs painting, arrange to take the tank out of service. Paint the tank interior as often as the exterior (more often if the stored water is corrosive), unless the tank is equipped with cathodic protection.

(a) Make certain that the paint used will protect the metal against corrosion. Consult the applicable guide specifications for paint selection and application methods.

(b) Use only one new coat, if the previously applied coat is in fair condition. Bare spots of steel shall be painted with a spot or patch coat before the finish coat is applied. If the condition of the old paint is bad, use a complete primer coat.

4.7.4.1.2 Roofs. Semiannually, the roof and its appurtenances—screens on overflows, hatches and manholes—as well as the condition of the paint, should be inspected.

(1) Make certain that the hatch covers and manholes are in place and locked, and that screens are in place to prevent the entrance of birds, insects, and other animals.

(2) If the spider rods under the roof have corroded, remove them as they are needed only during erection.

(3) Paint the roof, selecting the proper paint for the particular location.

4.7.4.1.3 Standpipes. Standpipes are, in effect, ground level storage tanks. The distinguishing characteristic is a relatively small diameter and extra height to provide head. Inspection and maintenance procedures are the same as for ground level steel storage tanks.

4.7.4.2 Underground Storage. If steel storage tanks are constructed below ground level, or are surrounded by earth embankment, the semiannual inspection and repair include only the interior of the tank, the roof and the appurtenances. The inspection and maintenance procedures are the same as given in paragraph 4.7.4.1.

4.7.4.3 Elevated Storage. In addition to the inspection and maintenance procedures set forth for ground storage steel tanks (see par. 4.7.4.1), the following specific procedures apply.

4.7.4.3.1 Tanks. See paragraph 4.7.4.1 for inspections and maintenance procedures.

4.7.4.3.2 Tower structures. Semiannually, tower structures should be checked for rust and corrosion; loose, missing, bowed, bent or broken members; loose sway bracing; misalinement of tower legs; and, evidence of unstableness.

(1) Inspect the back surface of the lattice bars and anchor bolts, the inside of boxed channel columns, and pockets where batten-plate connections and column bases form pockets for collecting trash and water. Clean and paint these enclosures, and fill with concrete, as necessary, to shed water.

(2) Check the bases and the base plates for evidence that water has collected at that point; if water is found, drill a 1½-inch hole through the channel-boxed section to allow complete drainage. Then grout the base plate with a mixture of sand and asphalt to prevent water from running under the plates. Taper the grout from the top edge of the plate to the pier.

(3) Check the sway bracing and tighten the turnbuckles, if necessary. Examine under clevis pins and rod loops where corrosion may be greatest. Drill holes in the balcony floor to eliminate standing water.

4.7.4.3.3 Roofs. In addition to general roof inspection and repair (see par. 4.7.4.1.2), obstruction and navigation lights should be inspected and relamped, if necessary.

(1) Also, check the operation of all other lights; check hoods, shields and receptacle fittings; look for missing or damaged parts. Repair or replace parts as necessary.

(2) Check lightning rods, terminals, cables and ground connections.

4.7.4.3.4 Risers and heating systems. In cold climates, potable water storage tanks, with small riser pipes, and elevated storage tanks, for fire protection only, usually have heating equipment to prevent freezeup in periods of severe low temperature.

(1) Annually, two months before the freezing season, inspect the riser for nonintegrity of the frost covering. Seal any openings to minimize heat loss. Also, check the heating system to ensure proper operation during the ensuing cold season.

(2) Annually, one month before the freezing season, operate the heating system for eight hours to check all elements under operating conditions.

4.7.4.4 Cathodic Protection Equipment. Only impressed-current cathodic protection systems are used for protecting steel water storage tanks against corrosion. This system of protection may be applied to all types of steel water tanks—ground level, standpipe, underground and elevated tanks. See paragraph 4.3.8.2.4 for a discussion of inspection and maintenance procedures for impressed-current systems. In addition, the following procedures apply annually.

(1) Note and record the current flow during the operation. If the current does not flow, check the fuses; electrodes which make contact with the tank; ground-wire connection to the tank; and, the immersion of electrodes. If the equipment is operating at voltages or amperages above those listed on the nameplate, the rectifier may be damaged. CAUTION: Make certain that the connections to the rectifier are not reversed in that reversed connections will result in tank damage.

(2) Check the operating record to determine if the electrodes are immersed at all times, or almost all the time. If the electrodes are not immersed, there will be no damage to the unit, but protection is not provided when the electrodes are not immersed.

(3) Check the anode condition and replace the anodes as necessary. Also, check the current flow; if it has diminished since the previous inspection, the anode probably needs to be renewed.

(4) In freezing climates, protect electrodes from ice which may tear them from their hangings or damage them. If ice formation is severe, turn off the current, remove the electrodes, store them until the freezing season is past and then reinstall them.

(5) Test the effectiveness of the cathodic protection system in one of two ways.

(a) Scrape and polish a spot on the tank wall at a point always immersed. At quarterly intervals, lower the water and inspect the spot; if protection is adequate, the spot will remain uncorroded.

(b) Suspend two polished mild-steel test plates in the tank at an elevation where they will alway be immersed (use No. 6 galvanized steel wire). Ground one plate to the tank wall, but have the other plate insulated from the tank. The extent of corrosion on the grounded plate will approximate the corrosion of the protected tank; the extent of corrosion on the other plate is a measure of the corrosion that would occur if the tank were not protected.

4.7.5 WOODEN STORAGE TANKS. Wooden storage tanks are never constructed under ground. They may be at ground level, but generally they are elevated structures. Maintenance procedures are relatively simple after the tank has been erected, if the tank is kept full of water. The following maintenance procedures apply.

(1) Semiannually, check the wood foundations and pads (see par. 4.7.2.2).

(2) Semiannually, check the wood towers for loose, missing, twisted, bowed, cracked or split pieces; for termite infestation; for misalinement of tower legs and evidence of instability. Also check the sway bracing. Repair or eliminate undesirable conditions.

(3) Semiannually, review operating data to make certain that the tank has been kept filled.

(4) Semiannually, check the structural condition of the tank, evidences of leaks and corrosion of steel bands (particularly at threaded ends). Also, make certain that the bands have the proper tension, and adjust as necessary. In addition, check appurtenances, e.g., ladders, screens, covers, roofs, etc. Make all repairs necessary.

(5) Annually, or as necessary, paint metal parts; but paint timber only if necessary for appearance.

4.7.6 PNEUMATIC TANKS. As pneumatic tanks are usually found in smaller installations (see par. 3.4.3), they may be too small for interior inspection, except for observations through a removable hand plate. The size, therefore, dictates the inspection procedures which follow.

(1) Quarterly, inspect the air pump and motor to make certain both are operating properly. Check the operating record to determine the time cycle of air pump operation. If the records show a decreasing time cycle, check for possible air line leaks.

(2) Quarterly, check valve operations; particularly, check the pressure relief valve. Repair or replace as necessary.

(3) Annually, check the tank for signs of corrosion both internally and externally. If corrosion products are apparent, take the following action.

(a) If the tank is large enough to permit the entry of personnel, paint the inside with corrosion-resistant paint, or cement-line. If the tank is too small to permit entry, consider the possibility of changes in operation or in chemical treatment to reduce corrosiveness of water. Corrosiveness of water. Corrosion effects are most likely in areas alternately exposed to air and water.

(b) Paint the exterior as needed.

4.7.7 APPURTENANCES. Semiannually, ladders, walkways, guardrails, handrails, stairways and risers should be inspected for rust, corrosion, poor anchorage, loose or missing pieces or other deterioration or damage.

(1) Be sure to check ladders inside as well as outside of the tank. Replace worn, corroded or missing parts; check for deteriorated lugs and rungs as necessary; and, make other repairs needed to ensure safety for the operators. Check revolving ladders on the roof for the condition of connection at the finial.

(2) Assure that bolts, screws, rivets and other connections are tight.

(3) Inspect the altitude valve vault's condition, and the valves for proper operation. Repair, clean and paint all equipment when necessary.

(4) Check the water level indicator for illegible or improper operating conditions, and repair when necessary.

(5) Inspect the cathodic protection equipment and repair when necessary. See paragraphs 4.3.8.2.4 and 4.7.4.4.

(6) At semiannual intervals, check the electrical connections to lights, cathodic protection, etc., for breaks in the conduit. Remove the conduit inspection plates and examine the internal connections for tightness and adequacy; also check relays for weak springs, worn or pitted contacts and defective operation. Repair and eliminate all undesirable conditions.

4.7.8 GROUNDS. At semiannual intervals, remove all accumulations of dirt, trash, debris and excess foliage on the area surrounding the storage tank.

4.7.9 MAINTENANCE PROCEDURE SCHEDULE. The maintenance operation frequency and schedule of inspections for storage facilities are presented in Table 34.

Section 8. FLOW MEASURING DEVICES

4.8.1 INTRODUCTION. Flow measuring or metering is discussed in paragraph 3.4.4, where, it is pointed out, that meters consist of a primary element (the flow measurement device) and a secondary element (the instrument). This section is devoted to the primary element (the flow measurement device). Maintenance of secondary elements (instruments) is presented in Section 13 of this chapter. This section on the maintenance of primary elements is divided into these categories—differential-head meters; velocity-type meters; head-area meters; and, volume meters. The first two types are used in main line meters on transmission and distribution mains; the third on open flow measurement; and the latter, generally, for house services.

4.8.2 DIFFERENTIAL HEAD DEVICES. Included in this category are the venturi tube, the insert flow nozzle, the pitot tube, the orifice plate, the Dall flow tube and the Gentile flow tube. Diagrams of these devices are shown in figures 126, 131, 132, 184, and 185.

4.8.2.1 Venturi-Type Devices. Generally, the following procedures apply to all types.

(1) At quarterly intervals (more often if necessary), flush and clean the annular chambers at the throat and inlet. Purge any air trapped in the annual chambers and connecting piping. Flush piezometer pressure taps.

(2) At annual intervals, inspect the exterior of the tube, and paint when necessary.

(3) At annual intervals, inspect the interior of the tube, if it has an inspection plate (or plates). Check the converging section, the throat and the diverging section for any signs of corrosion, tuberculation or other deterioration. If any such deterioration has occurred, dismantle the tube, clean and restore the smothness of the surface.

(4) Where the tube joint is a flange, make certain that the gasket does not protrude into the tube. If it does, remove and replace the gasket with a new one.

TABLE 34

Maintenance Procedures for Storage Facilities

Inspection	Action	Frequency [1,2]	Reference Paragraph number
Foundations, concrete	Check for settlement, cracks, spalling and exposed reinforcing; repair as necessary with 1 part cement to 1 part sand.	SA	4.7.2.1
Foundations, wood	Check wood foundations and pads for checked, split, rotted or termite infected members; also check for direct contact of untreated wood with soil; repair or eliminate undesirable conditions as necessary.	SA	4.7.2.2
Concrete tanks (ground level storage).			4.7.3
Walls	Check exterior for seepage; mark spots	SA	4.7.3.1.1
	Check exterior and interior for cracks, leaks, spalling, etc.	A (Spring)	4.7.3.1.1
	Remove loose, scaly, or crumbly concrete; patch with rich cement grout; paint grout with iron waterproofing compound.	A	4.7.3.1.1(1)
	Chip out cracks, repair with cement slurry	A	4.7.3.1.1(2)
	For cracks in prestressed tanks, consult designing and/or erecting company.	A	4.7.3.1.1(3)

TABLE 34 (Continued)

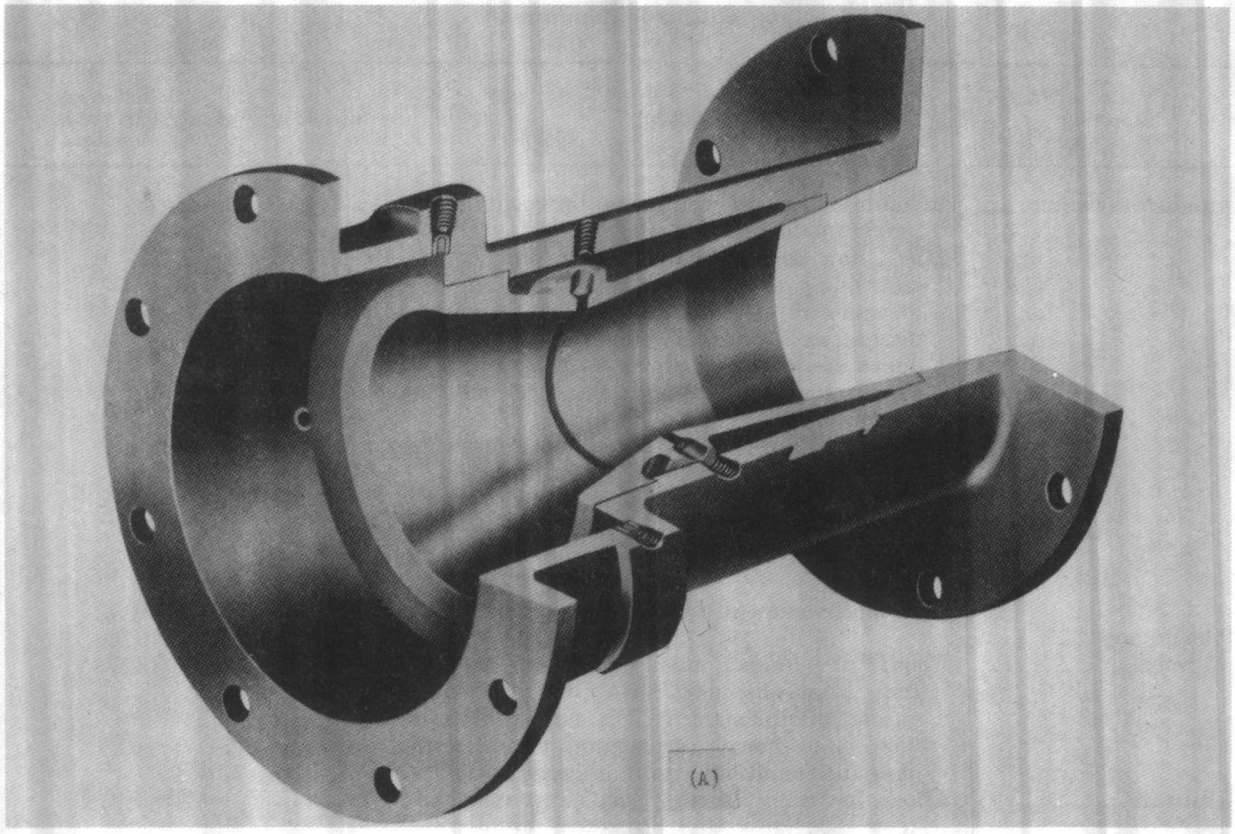
Inspection	Action	Frequency[1,2]	Reference Paragraph number
Expansion joints	Check for leakage; check for missing filter; clean and repair as necessary.	SA	4.7.3.1.2
Roofs	Check condition; check hatches; check screens on openings.	SA	4.7.3.1.3
Earth embankments	Check for erosion, burrowing animals, improper drainage and leakage through embankment; repair as necessary; if leakage through embankment exists, drain tank and look for cracks in tank walls or bottom.	SA	4.7.3.1.4
Concrete tanks (underground storage).	Check interior walls, roof, appurtenances and embankment; if leakage is evident, excavate and repair walls.	SA	4.7.3.2
Concrete tanks (elevated storage).	Check and repair	SA or A	4.7.3.3
Steel tanks (ground level storage).	Check for ice damage in spring; repair as necessary.	A	4.7.4.1
Walls and bottom	Examine exterior and interior for rust, corrosion products, loose scale, leaky seams and rivets and for condition of paint.	SA	4.7.4.1.1
	Replace rivets or patch leaking areas, as necessary (see Reference 18).	V	4.7.4.1.1(1)
	Check painted surfaces for deterioration; paint as necessary (see Reference 19).	SA	4.7.4.1.1(2)
Roofs	Check condition, hatches, screens, manholes and paint; lock hatches; remove spider rods if corroded; repair, replace or paint as necessary.	SA	4.7.4.1.2
Steel tanks (standpipes).	Follow instructions for ground level storage given in paragraph 4.7.4.1.	SA	4.7.4.1.3
Steel tanks (underground storage).	Check tank interior, roof and appurtenances; follow instructions given in paragraph 4.7.4.1.	SA	4.7.4.2
Steel tanks (elevated storage).	For general procedures follow instructions given in paragraph 4.7.4.1; for specific procedures see following paragraphs.	SA	4.7.4.3
Tanks	See paragraph 4.7.4.1	SA	4.7.4.3.1
Tower structures	Check for corrosion; loose, missing, bowed, bent or broken numbers; loose sway bracing; misalinement of tower legs; evidence of instability; repair as necessary.	SA	4.7.4.3.2
	Check surface of lattice bars, anchor bolts, boxed channel columns and pockets where water or trash collects; clean, repair, provide drainage or fill pockets; paints as necessary.	SA	4.7.4.3.2(1)(2)(3)
Roofs	For general instructions, see paragraph 4.7.4.1.2	SA	4.7.4.3.3
	Check obstruction and navigation lights, hoods, shields, receptable and fittings for missing or damaged parts, or inoperation; also check lightning rods, terminals, cables and ground connections; repair, replace or renew; paint as necessary.	SA	4.7.4.3.3
Risers and heating systems.	Two months before freezing weather, check riser pipe insulation and repair as necessary; also check heating system operation.	A	4.7.4.3.4(1)
	One month before freezing weather, operate heating system for eight hours; repair or adjust defective parts.	A	4.7.4.3.4(2)

TABLE 34 (Continued)

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Cathodic protection	In addition to the following instructions, see paragraph 4.3.8.2.4.	A or V	4.7.4.4
	Check flow of current; if absent, check fuses, electrodes, ground wire connections and immersion of electrodes; adjust or repair as necessary; if current flow or amperage is above desired level, adjust as necessary; make certain that connections to rectifier are not reversed.	V	4.7.4.4(1)
	Check operating records to make sure that electrodes are immersed at all times.	V	4.7.4.4(2)
	Check anode condition; replace as necessary	V	4.7.4.4(3)
	In freezing climates, protect electrodes against ice damage, or remove and store for winter season.	V	4.7.4.4(4)
	Test effectiveness of cathodic protection	V	4.7.4.4(5)
Wooden tanks			4.7.5
Towers	Check for loose, missing, twisted, blowed, cracked or split pieces; also for termite infestation, misalinement of legs and evidence of loose sway bracing; repair and eliminate undesirable conditions; paint as necessary.	SA	4.7.5(2)
Tank	Check operating records to make certain tank is kept filled; also check structural condition of tank for soundness, evidence of leakage and corrosion of steel bands; also check all appurtenances, ladders, roofs, screens, etc.; make any repairs or adjustments necessary.	SA	4.7.5(3)(4)
	Paint metal parts; paint timber only if necessary for appearance.	A	4.7.5(5)
Pneumatic tanks	Inspect air pump and motor; check operating record of time cycle; check for air leaks, if time cycle is too short; check valve operations, particularly pressure relief valves.	Q	4.7.6(1)
	Check tank for signs of corrosion; take steps necessary to eliminate corrosion or protect against it.	A	4.7.6(3)
Appurtenances	Check ladders, walkways, guardrails, handrails, stairways and risers for rust, corrosion, poor anchorage, missing pieces, general deterioration or damage; replace or repair parts as necessary.	SA	4.7.7
Miscellaneous appurtenances.	Check all electrical connections and conduits leading to tanks; make any repairs or adjustments necessary.	SA	4.7.7(6)
Grounds	Check for accumulations of debris, trash and foliage; clean the area.	SA	4.7.8

[1]Q-Quarterly; SA-Semiannually; A-Annually; V-Variable; as conditions may indicate.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.



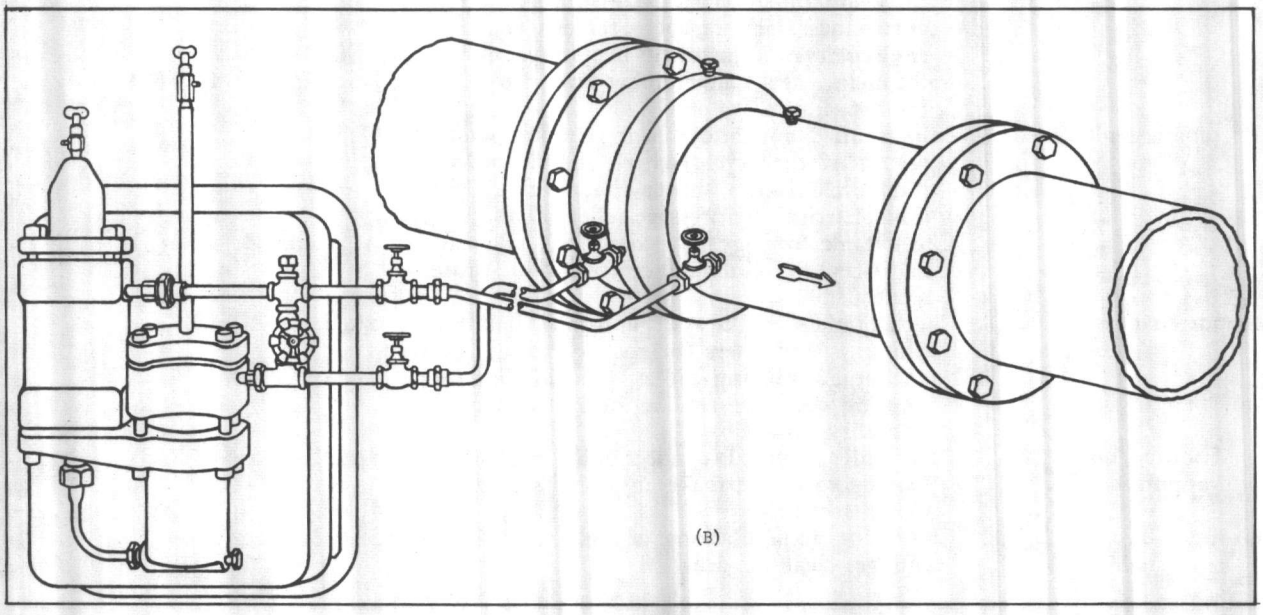


FIGURE 184

Dall Flow Tube

(A) Cutaway View

(B) Diagram of Installation

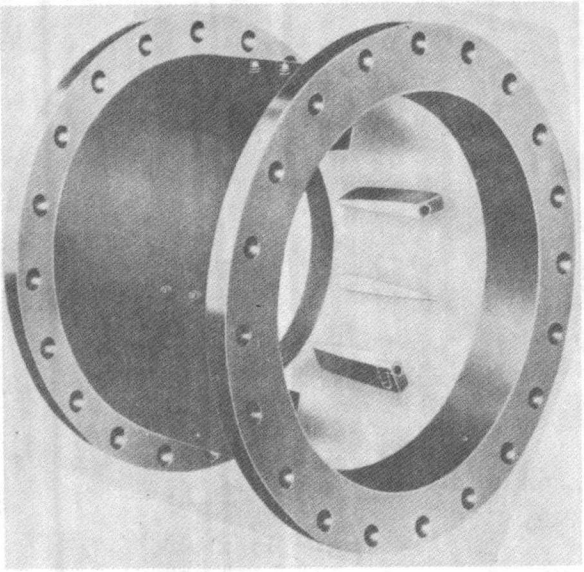


FIGURE 185

Gentile Tube

4.8.2.2 Orifice Plates. Orifice plates are seldom, if ever, used for main line metering. Where used, the plates shall be inspected annually. Remove the plate, clean and dress-off the roughness with a fine emery cloth. Flush out the sediment traps and the small piping.

4.8.2.3 Pitot Tube. Pitot tubes are generally used only in surveys of distribution systems. Permanently installed, they should be checked quarterly to make certain the tips are clean and sharp.

4.8.2.3.1 Gentile flow tube. This flow measuring device consists of a tube with a slight constriction in the wall, and with pressure nozzles or ports in the constriction. Half of the ports face upstream, and half downstream; and the differential head produced is based on the principle of the pitot tube. Maintenance consists of quarterly inspection to assure that the instrument taps are clear.

4.8.3 VELOCITY-TYPE METERS. Velocity-type meters (turbine and propeller types) are discussed and illustrated in paragraph 3.4.4.2.3. Maintenance procedures are set forth in the following paragraphs.

(1) Monthly, check the operation of the meter. If the operation is noisy, remove and examine the parts. Repair or replace when necessary. Clean the meter dial face and the glass cover when necessary.

(2) Semiannually, clean the meter pit. Remove any water in the pit before the freezing season.

(3) Annually, clean and paint the exterior of the meter if necessary.

(4) At variable intervals determined by previous experience, examine the interior of the meter, disassemble and inspect it for worn parts according to the manufacturer's instructions. Replace the parts and gears when necessary.

4.8.4 PROPORTIONAL METERS. This type of meter is described and illustrated in paragraph 3.4.4.2.4. Except for annual external painting, the only maintenance required is inspection of the bypass meter and its parts on a variable schedule, as is done for volume meters (see par. 4.8.8).

4.8.5 MAGNETIC METERS. Since this meter measures an electrical characteristic of flowing water, there are no protruding parts or constrictions in the throat (see fig. 186). The electrodes are flush. Maintenance consists of annual checking of the electrical connections and wiring, and painting, where necessary. Consult the manufacturer's instructions before attempting any disassembly for inspection purposes.

4.8.6 COMPOUND METERS. This type of meter is described and illustrated in paragraph 3.4.4.2.5. The component for measuring large flows is generally a velocity-type meter, and the component for measuring small flows is generally a disk, piston or nutating-disk type. Therefore, the maintenance procedures for the large-flow component will be found in paragraph 4.8.3, and the maintenance procedures for the small-flow component are the same as those for house service meters (volume meters), as given in paragraph 4.8.8.

4.8.7 HEAD-AREA MEASURING DEVICES. This type of flow-measuring device is described and illustrated in paragraph 3.4.4.4. All types of head-area meters are used for open-flow measurement, and their proper operation depends on the absence of interference of any kind at the discharge opening.

4.8.7.1 Weirs. Weirs, either rectangular or V-notch, require the following maintenance procedures.

(1) Daily, check the weir edge to make certain it is clean and free of algae growths and other interfering material.

(2) Where a weir is installed in a flume and is equipped with a breather pipe, make certain at monthly intervals that the breather pipe is open and, particularly in winter, that frost does not block the opening.

(3) Annually, on horizontal weirs, drain the weir and make certain that the water breaks evenly over the entire weir length. Check the weir edge for tuberculation or corrosion. Dress any rough spots, and make certain that the weir edge is level. On V-notch wiers, check the knife edge to be sure it is smooth and free from tuberculation or corrosion. Clean and dress as necessary.

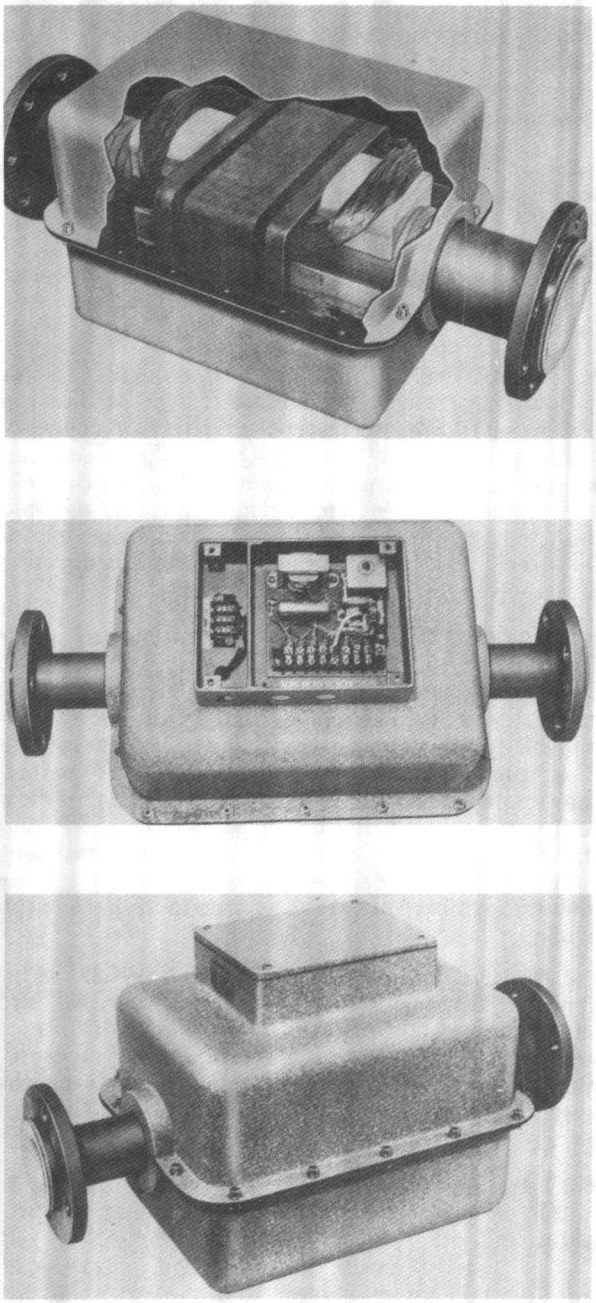


FIGURE 186

Magnetic Flow Meter (Three Views)

4.8.7.2 Parshall Flumes.

(1) Monthly, make certain that interfering substances do not appear in the throat section. Clean, as necessary, and remove algae growths. If algae growth is a problem, paint with an algacide coating.

(2) Quarterly, clean stilling well and float well. Clean the float, as necessary, and make certain that the connecting pipe is free of silt.

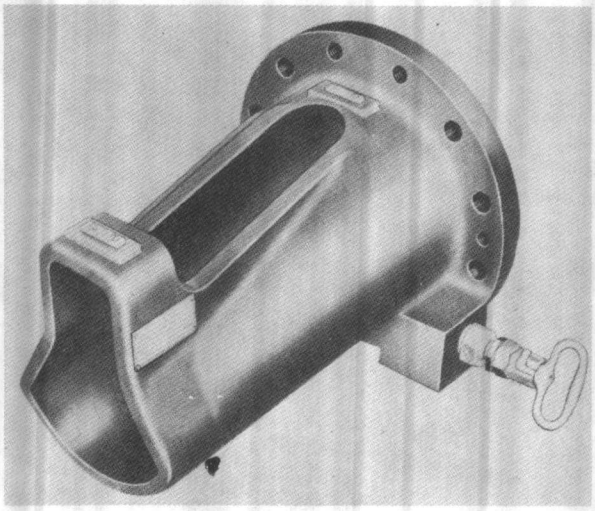


FIGURE 187

Kennison-Type, Open-Flow Nozzles

4.8.7.3 Open-Flow Nozzles. The Kennison-type, open-flow nozzles (see fig. 187) are factory calibrated, and are normally self-scouring. Since the top is open, they may be inspected easily. Check monthly for possible deposition, or organic growth. Purge connecting taps and lines of the instrumentation device. Paint whenever necessary.

4.8.8 VOLUME METERS. The following procedures apply to volume-type meters used as service meters, and for sizes up to 6 inches. They are described and illustrated in paragraph 3.4.4.2.1.

(1) Monthly, make certain that the meter is operating properly. If its operation is noisy, remove and examine the parts, and repair or renew when necessary. Check the dial face for cleanliness, and clean the glass dial cover when necessary.

(2) Annually, make certain that the meter has not been moved out of a horizontal position.

(3) Annually, one month before the freezing season begins, inspect and clean the meter housing or pit, and make certain the meter is protected against possible freezing.

(4) Annually, check the meter for damage by hot water backing up from an improperly operated water heater.

(5) At variable periods, clean and inspect the meter for worn parts; change gears and other parts when necessary.

(a) A schedule for the cleaning and repair of meters is necessary at each activity, and should be based on experience with the meters used in the system and the costs attributable to metering. A volume of water registered in a relatively short time may cause more deterioration of the meter than a small volume registered over a longer period. The schedule for cleaning

and repairs of meters should therefore have the following format.

Size (in.)	*Registration (cu. ft.)*	*Service (yr.)*
5/8		
3/4		
1		
1½		
2		
3		
4		
6		

(b) Disassemble the meter according to the manufacturer's instructions. Remove sediment; check the interior for corrosion or wear; replace the gears if they are worn; replace the disk or the piston when necessary; clean and brighten the exterior by wire brushing, sand or shot blast, or acid dip. CAUTION: Use acid dip only in accordance with the manufacturer's instructions and Bureau safety procedures.

4.8.9 MAINTENANCE PROCEDURE SCHEDULE. The maintenance operation frequency and schedule of inspections for flow measuring devices are presented in Table 35.

TABLE 35

Maintenance Procedures for Flow Measuring Devices

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Venturi-type devices			4.8.2.1
Annular chamber	Flush and clean annular chamber, throat and inlet; purge trapped air from chamber and connecting piping; flush piezometer pressure taps.	Q	4.8.2.1(1)
Exterior	Clean and paint as necessary	A	4.8.2.1(2)
Interior	Check interior for corrosion; dismantle, clean and restore; for flanged joints, check possible intrusion of gasket into interior; replace if necessary.	A	4.8.2.1(3)
Orifice plates	Remove plate, dress off roughness; flush sediment traps.	A	4.8.2.2
Pitot tube	On permanent installations, check tips and clean	Q	4.8.2.3
Gentile flow tube	Check instrument taps; flush if necessary	Q	4.8.2.3.1
Velocity-type meters	Check operation; check for noise	M	4.8.3(1)
Meter pit	Clean, remove water before freezing season	SA	4.8.3(2)
Exterior	Paint as necessary	A	4.8.3(3)
Interior	Check for worn parts; repair or replace as necessary.	V	4.8.3(4)
Proportional meters	Check on same program as velocity meters	V	4.8.4
Magnetic meters	Check electrical connections	A	4.8.5
Compound meters	Check large-flow component on same schedule as velocity-type meters (see paragraph 4.8.3).	M	4.8.6
	Check small-flow component on same schedule as volume meters (see paragraph 4.8.8).	V	4.8.6
Head–area meters			4.8.7
Weirs	Check weir edge to make certain it is clean	D	4.8.7.1(1)
	Check and open breather pipe, if any	M	4.8.7.1(2)
	Drain weir to check evenness of water break-over; check for tuberculation or corrosion; dress-off rough spots.	A	4.8.7.1(3)
Parshall flume	Check throat section to be sure it is clean and free of growths.	M	4.8.7.2(1)
	Clean stilling well and connecting pipe	Q	4.8.7.2(2)
Open-flow nozzles	Check and clean as necessary; purge connecting taps.	M	4.8.7.3
Volume meters	Check operation; check for noise	M	4.8.8(1)
	Check mounting and alinement	A	4.8.8(2)
Meter pit	Check, clean, remove water to protect against freezing.	A (Fall)	4.8.8(3)
Measuring unit	Check for possible hot water damage	A	4.8.8(4)
Unit parts	Check for worn parts, repair or replace as necessary; clean and brighten.	V	4.8.8(5)

[1] D-Daily; M-Monthly; Q-Quarterly; SA-Semiannually; V-Variable; as conditions may indicate.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

Section 9. PUMPS

4.9.1 MAINTENANCE TIMETABLE. Operating conditions vary widely, as does the design of individual pumps within a particular category. Therefore, it is not possible to develop a maintenance schedule that is applicable to all pumps and all conditions. The material presented in this section is minimum with respect to timing and action necessary, but maintenance personnel should compare these instructions with the manufacturer's instructions, and then prepare a specific maintenance timetable for each pump.

4.9.1.1 Inspection Records. Whatever the inspection or maintenance procedure, a log shall be kept of all inspection and maintenance actions. These records (see par. 4.1.4) shall be kept on file in the Utility Department office.

4.9.1.2 Operator Inspection. Operators shall make inspections on a routine basis during their regular tours of duty. The frequency of these operator inspections shall be determined by the Public Works Officer. Operator shall report immediately any irregularities in operation. The following procedures are a part of operator inspection.

(1) Check the bearing temperatures. An abrupt change in bearing temperature signifies difficulty more than does a continuous high temperature. Check lubrication; see instructions on lubrication under specific types of pumps in subsequent paragraphs in this section.

(2) Note any change in running sound. Any deviation from the normal sound of operation signifies trouble.

(3) Note suction and discharge pressure gage readings. Ascertain the cause if the gage reading is not normal for normal operating conditions.

(4) Make certain that the check valves and the pump suction screens are both open.

(5) Check the shaft packing.

(6) If the pump discharge is metered, check the discharge rate and ascertain the cause of any deviation from the normal operating flow rate.

(7) Check the motor instruments and meters for deviation from the normal.

(8) Note the direction of the pump rotation.

(9) Check the driving equipment (see par. 4.11.1).

(10) Refer to Table 11 and Table 37 for troubleshooting. Report any indication of trouble immediately.

4.9.2 PUMP PERFORMANCE. If the operator finds reason to believe that the pump performance has deteriorated at any time, he should refer the matter to the Public Works Officer who may order a field test of pump performance by personnel specializing in this work, or by contract. The Public Works Officer may order field tests, at annual intervals, for the purpose of aiding in the control of operating costs, in locating equipment defects and in determining whether or not the pump needs maintenance service or overhaul.

4.9.2.1 Data Required. The following information is required for a field test on a pump: (a) the rate of flow; (b) the head above elevation at discharge head base, plus the velocity head at the point of measurement, expressed in feet of liquid; and, (c) the velocity head, the suction head below the elevation of the discharge head base, the total pump head, the pump speed of rotation (not for reciprocating pumps), pump output and driver-power input, driver efficiency and overall efficiency. Testing is to be done as follows.

(1) Field testing of vertical turbine pumps shall be done in accordance with the methods and regulations set forth in, "AWWA Standard (App. B), American Standard for Vertical Turbine Pumps, E101–60 (ASA B58.1–1961)", (Reference 21).

(2) Field testing of other types of pumps shall be done in accordance with methods adapted by the Public Works Officer from Appendix A of Reference 21, or in accordance with the methods discussed in Chapter III of, "Training Course in Water and Sewage Plant Operation—Intermediate Course (Water)", NAVDOCKS P–334, March 1960, (Reference 22).

4.9.3 CENTRIFUGAL-TYPE PUMPS. Horizontal and vertical centrifugal pumps are described and illustrated in Paragraph 3.5.2.1. The following paragraphs describe the general maintenance procedures applicable to all types of horizontal and vertical centrifugal pumps. Details of procedures applicable specifically to volute, diffuser, regenerative-turbine, split case and multistage designs should be obtained by consulting the manufacturer's instructions. Also included under this general heading are these centrifugal-type pumps—mixed-flow pumps, axial-flow pumps and turbine-type pumps.

4.9.3.1 Lubrication. Operator inspection of centrifugal pumps includes attention to lubrication

on the following basis (see Table 14 for the proper lubricant for the various units).

4.9.3.1.1 Hand-oiler settings. Where hand oilers are used to lubricate the shaft bearings, the setting should be checked daily and adjusted according to the following table.

Pump Operation Schedule	Pump Running Time	Oiler Rate
Up to a maximum of 2 times a day.	Not over 5 min.	1 drop/15 min.
3 to 12 times a day.	Not over 5 min.	1 drop/4 min.
12 to 50 times a day.	Not over 5 min.	1 drop/2 min.
More than 50 times a day.	----------	2 to 4 drops/min.

4.9.3.1.2 Solenoid oiler. Where a solenoid oiler is used, daily inspection includes the following.

(1) Make certain that the solenoid leads are connected so that the solenoid is energized as soon as switch is closed, thereby raising the needle valve and allowing the oiler to operate.

(2) If oil does not flow after the current is turned on, inspect the needle valve for clogging.

(3) Set the lubricator for 2 to 4 drops per minute. See Table 14 for the lubricant to be used.

4.9.3.1.3 Ball-bearing. Daily, the oil level in the bearing-housing oil well should be checked, and maintained just below the overflow point of the filling cup or oil plug, when the pump is stopped.

(1) When adding oil, remove the oil vent plug in the top of the bearing housing.

(2) Do not add oil while the pump is running as the bearing race picks up oil which will drain down when the pump is stopped, and will overflow around the shaft, or out of the oil cup, if too much oil has been added.

4.9.3.1.4 Grease-sealed packing glands. Where grease is used as a water seal in a packing gland, constant grease pressure should be maintained on the packing during operation. Where a spring-loaded grease cup is used, it should be checked daily and kept loaded. It should be made certain that grease is being forced through the packing at the rate of about one ounce per day.

4.9.3.1.5 Enclosed-shaft-type bearings. Before operating the pump, the thrust bearing oil cup should be filled with the proper oil (see Table 14). The cup should be refilled weekly, or more often if necessary.

4.9.3.1.6 Ball-thrust bearings. The following procedures should be followed.

(1) At monthly intervals, add fresh grease to the grease cups, but do not attempt to keep the grease from coming out around the seal at the ball bearing collar, since the bearing housing is designed to relieve excess grease and thus prevent packing the ball bearing, which would cause overheating. CAUTION: Do not run the pump with dry bearings.

(2) Quarterly, change the grease in the grease cup, if the pump operates more than 50 times a day; otherwise, change the grease annually.

4.9.3.1.7 Guide bearings. At monthly intervals, on standard units, grease should be added through the grease fittings on the floor plate under the motor pedestal. On nonstandard units, the manufacturer's recommendations should be followed.

4.9.3.1.8 Ball bearings on open shaft type O. Monthly, the two ball bearings should be lubricated separately through grease fittings on the bearing housing, or through extension grease lines. Also, the pump bearing should be lubricated with grease.

4.9.3.1.9 Shaft bearings. Quarterly, the operator should drain the lubricant (unless otherwise specified for the particular pump model), and wash out the wells and bearings with kerosene. The wells should be refilled with the proper lubricant for sleeve, ball, roller or Kingsbury bearings.

4.9.3.1.10 Bearing housing. Quarterly, the operator should open the bearing housing, flush it clean with kerosene, and add clean, fresh grease. The housing should be kept clean, and only fresh grease used.

4.9.3.1.11 Universal joint couplings. Semiannually, the universal joint couplings and slip splines should be lubricated with fresh grease.

4.9.3.2 Bearings. Bearing maintenance procedures depend on the type of bearing.

4.9.3.2.1 Antifriction bearings. Monthly, the bearing temperature should be checked with a thermometer, not by hand. Antifriction bearings that are running hot probably have too much lubricant. The situation should be relieved.

(1) If a change in lubrication does not remedy the overheating, disassemble and inspect the bearing. If nothing is amiss, check the pump and motor alinement.

(2) Quarterly, drain the lubricant, wash out the wells and bearings with kerosene (see par. 4.9.3.1.9). Generally, the clearance allowance in bearings is 0.002 inch, plus 0.001 inch for each inch (or fraction of an inch) of shaft-journal diameter.

(3) Annually, when the pump is dismantled, check on the condition of the bearings and bearing race, and replace, as necessary.

(a) The preferred method in general use for mounting a bearing on a pump shaft is to heat the bearing to expand the inner race and shrink it on the shaft. The bearing is heated in

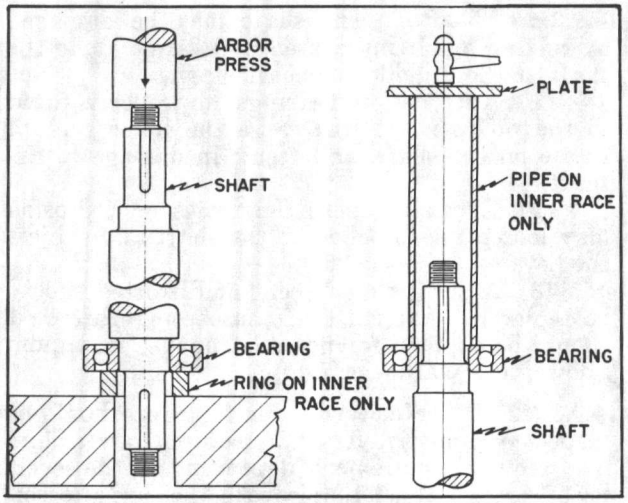


FIGURE 188

Two Methods of Mounting a Ball Bearing on a Shaft

an oil bath or electric oven to a uniform temperature of 200° to 250° F. When heated, it should be quickly mounted on the shaft.

(b) An alternate method employs force exerted by an arbor press or hammer blows, as illusrtated in figure 188.

(c) In forcing a bearing onto a shaft, care should be taken that the race is never cocked during the operation. The bearing position on the shaft should be pressed firmly against the shaft shoulder; It should be checked with a feeler gage.

4.9.3.2.2 Sleeve bearings. Monthly, the bearing temperature should be checked with a thermometer, not by hand. Sleeve bearings that are running hot probably need lubricant.

(1) If a change in lubrication does not remedy the temperature deviation from normal, disassemble and inspect the bearing. If the bearing is in good condition, check the pump and motor alinement.

(2) Quarterly, drain the lubricant, and wash out the wells and bearings with kerosene.

(a) Generally, the normal clearance allowance in these bearings is 0.002 inch, plus 0.001 inch for each inch (or fraction of an inch) of shaft-journal diameter. Refill the wells with proper lubricant (see table 14).

(b) Make certain that the oil rings are free to turn with the shaft. Repair or replace them when necessary.

(3) Annually, when the pump is dismantled for inspection, check on the condition of the bearings and replace them if necessary. Sleeve bearings are usually of the split type and are easily removed or installed. Rotation of the bearing is prevented by a pin in the top half of the bearing housing.

4.9.3.3 Packing. Selection of packing is usually done in accordance with the manufacturer's recommendations or assistance.

4.9.3.3.1 Types of packing. For pumping water, packing types include: (a) woven or braided cotton or asbestos, nonreinforced; (b) semimetallic plastic; or, (c) a combination of the two.

4.9.3.3.2 Packing selection. If the manufacturer's assistance is required for the selection of packing, detailed information must be supplied to the manufacturer on the following items.

(1) Liquid handled, its temperature and impurities, etc.

(2) Amount of abrasive matter present.

(3) Stuffing box dimensions (depth of box, outside diameter, and shaft or sleeve diameter); also, stuffing box pressure and temperature.

(4) Sealing cage (lantern gland) location and width.

(5) Shaft or sleeve material and hardness.

4.9.3.3.3 Packing the stuffing box. Semiannually, the stuffing box should be inspected for free movement of the stuffing box glands, and the gland bolts and nuts oiled. The operator should check for excessive leakage which cannot be reduced by gland adjustment, and follow these procedures.

(1) Remove the Old Packing. Before adding new packing to the stuffing box, be sure that all old packing has been removed and that the box is clean. Where a seal cage exists in the box, make certain that it is located opposite the sealing liquid inlet, in this manner. Measure the depth of box and sealing liquid inlet tap, then place enough rings of packing in the bottom of the box so that when the packing is compressed, the seal cage will be in its proper position. Make certain that the packing ring joints are staggered.

(2) Add New Packing. Use the packing recommended by the pump or packing manufacturer. CAUTION: Do not try to repack a pump by renewing only the last three or four rings. Cut the packing so that the joints are square after the packing is bent around the shaft. Packing should be cut about $\frac{1}{16}$-inch longer than measured to ensure that the O.D. of the ring hugs the stuffing box wall rather than the sleeve. Use care in cutting the first ring and use it as a pattern for succeeding rings. Except as detailed in the following paragraphs, use the follower gland and a few convenient equal-length spacers to compress each ring firmly into place before inserting the next ring. Stagger the joints, and be sure that the lantern ring is centered under the water supply connection. After the last piece of packing has been placed, tighten the follower gland nuts until fingertight.

(3) Woven and Braided Packing. For woven or braided packing, dip each ring of packing in oil before adding to the stuffing box. This type of packing does not have to be added one ring at a time. Fill the box half full, then draw rings up snug by taking up on the packing sleeves and

gland. Release the follower, add the remainder of the packing and draw up snug, then back off the gland until fingertight.

(4) Plastic and Metallic Packing. Plastic and metallic packing must be compressed individually. Dip each ring in oil, insert in stuffing box, and draw up tight by means of split packing rings and gland. Hand turn the shaft a few times to gloss the packing. Since nonjacketed plastic rings squeeze under the clearances, if placed next to the bottom of the box, bushings, seal cage, or glands (as the case may be), always use metallic or jacketed rings at these locations.

(5) Combustion-Type Packing. Where combination-type packing is used, follow the instructions supplied with the packing.

(6) Lantern Ring. If a lantern ring is used, be sure it is positioned correctly and, if grease sealing is used, be sure the lantern ring is filled with grease before the remaining rings are put in place.

(7) New Packing. New packing has to be run in. Start the pump with the stuffing box gland quite loose. Allow the pump to run 10 to 15 minutes.

(a) Gradually tighten the stuffing box gland until leakage is reduced to a constant drip.

(b) Packing that is too tight in the box will cause undue friction, create heat, and glaze the packing, and may score the shaft sleeves. Packing must remain soft and pliable.

(c) Drip leakage is needed to ensure proper lubrication throughout the packing box.

4.9.3.3.4 Packing gland assembly. At weekly intervals, the packing gland assembly should be inspected. If the stuffing box leaks too much, the gland should be tightened; if this action does not allegiate the condition, the packing should be removed and the shaft sleeve inspected (see pars. 4.9.3.2.2 and 4.9.3.6.2).

4.9.3.4 Sealing Water Systems. The operator should follow these procedures.

(1) Daily, check the water-seal packing glands for leakage. Make certain that there is a slow but constant drip of water to ensure that the packing is properly lubricated. If the leakage is excessive, tighten the gland. If this action does not relieve the condition, repack the stuffing box (see par. 4.9.3.3.3).

(2) Annually, disassemble the sealing-water lines and valves to make certain the water passages are open.

4.9.3.5 Rotary Seals. If a pump has seals which do not have the conventional follower and pliable, replaceable packing, the manufacturer's instructions should be consulted.

4.9.3.6 Shafts and Shaft Sleeves. Annually, when the pump is dismantled, the shaft should be examined carefully at the impeller hub fit, under the shaft sleeves and at the bearings.

4.9.3.6.1 Shafts. The shaft may be damaged by rusting or pitting caused by leakage along the shaft at the impeller or shaft sleeves.

(1) Antifriction bearings improperly fitted to the pump shaft will cause the inner race to rotate on the shaft, and result in damage to the shaft.

(2) Excessive thermal stresses or corrosion may loosen the impeller on the shaft and subject the keyway to shock.

(3) A shaft that is bent or distorted should be replaced. After a shaft has been repaired, it should be checked for possible runout (maximum allowable, 0.002 inches).

4.9.3.6.2 Shaft sleeves. Shaft sleeves should be inspected annually. They are subject to wear and may require replacement, depending on the severity of service. When the sleeve has become appreciably worn, it is impossible to adjust the packing to prevent leakage. Under these conditions, the sleeve should be replaced; otherwise, excessively grooved or scored sleeves will tear and score new packing as soon as it is inserted into the stuffing box.

4.9.3.7 Wearing or Sealing Rings. Annually, the operator should inspect the wearing or sealing rings which seal the discharge water from suction water in rotating pumps. They are not perfect seals and do allow some leakage, but this leakage should not be allowed to become excessive because of worn rings, or the pump efficiency will be impaired. Three types of wearing rings are shown in figure 189.

(1) Proper wearing-ring clearance is very important. In the most common type—the straight-type wearing ring (fig. 189)—the clearance need not be less than 0.025 inches, nor greater than 0.05 inches, on a diameter of the ring.

(2) For the L-shaped type, clearance in the space parallel to the shaft should be the same as for the straight type. The clearance of the space at right angles to the shaft is governed by end-play tolerances in the bearing.

(3) For specific information on the L-shaped and labyrinth-type rings, the pump manufacturer should be consulted.

4.9.3.8 Impeller. Annually, the rotating element and should be removed inspected thoroughly for wear (see par. 4.9.3.11.1 for dismantling procedure).

(1) Any deposits or scaling should be removed.

(2) The operator should check for erosion and cavitation effects. Cavitation causes severe pitting and a spongy appearance in the metal.

(3) Where cavitation effects are severe, some changes may be necessary in pump design or use. The matter should be reported to the Public Works Officer. Where cavitation effects are repaired by welding or metallizing and machining, the impeller should be balanced dynamically before it is replaced in the pump.

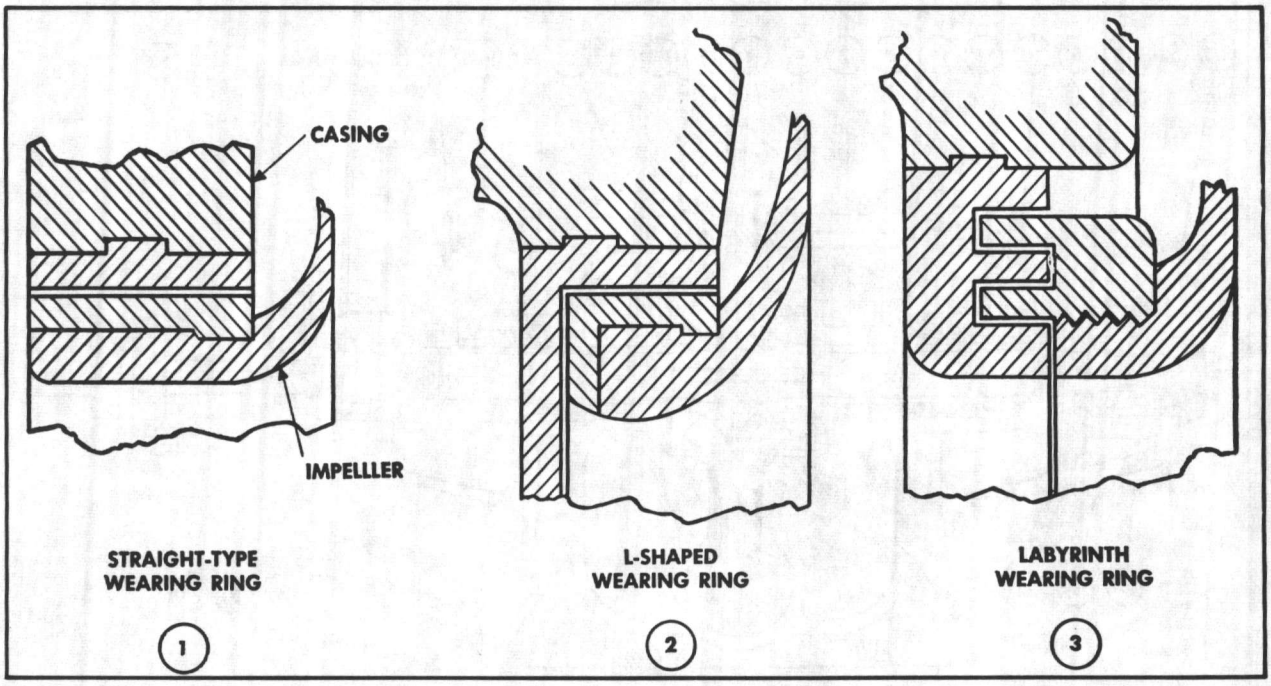


FIGURE 189

Types of Wearing or Sealing Rings

4.9.3.9 Casing. The waterways must be kept clean and clear of rust. Whenever the unit is dismantled, the waterways should cleaned and painted with a suitable paint that will adhere firmly to the metal. Best results are obtained if the paint has an enamel-like finish. A routine program of cleaning and repainting is desirable to prevent complete erosion of the protective coat before replacement.

4.9.3.10 Pump Shutdown. Whenever a pump is shutdown for an extended period, or for overhaul inspection and maintenance, the following procedures shall apply.

(1) Shut all valves on suction, discharge, water-seal and priming lines. Drain pump completely by removing the vent and the drain plugs until the water has run out. This operation protects the pump against corrosion, sedimentation and freezing.

(2) Open the motor disconnect switch, and remove the fuses.

(3) Drain the bearing housing, and refill it with fresh oil, or purge all the old grease, if the shutdown for an inactive period. If an overhaul is scheduled, do not refill the oil or grease receptacles until pump is reassembled.

4.9.3.11 Overhaul. The frequency of complete overhaul depends on the hours of operation of the pump, the severity of service conditions, the materials of construction in the pump and the care the pump receives during its operation. If the pump is not in continuous operation, it is not necessary to open a pump for inspection unless there is definite evidence that the capacity has fallen off excessively, or if there is an indication of trouble inside the pump or in the bearings. For pumps in relatively continuous operation, they should be dismantled on an annual basis.

4.9.3.11.1 Dismantling and reassembly. Since pump designs and construction vary from model to model, and from one manufacturer to another, there is no set of specific procedures for dismantling and reassembly. The following rules are basic, but for detailed procedures consult the manufacturer's instructions.

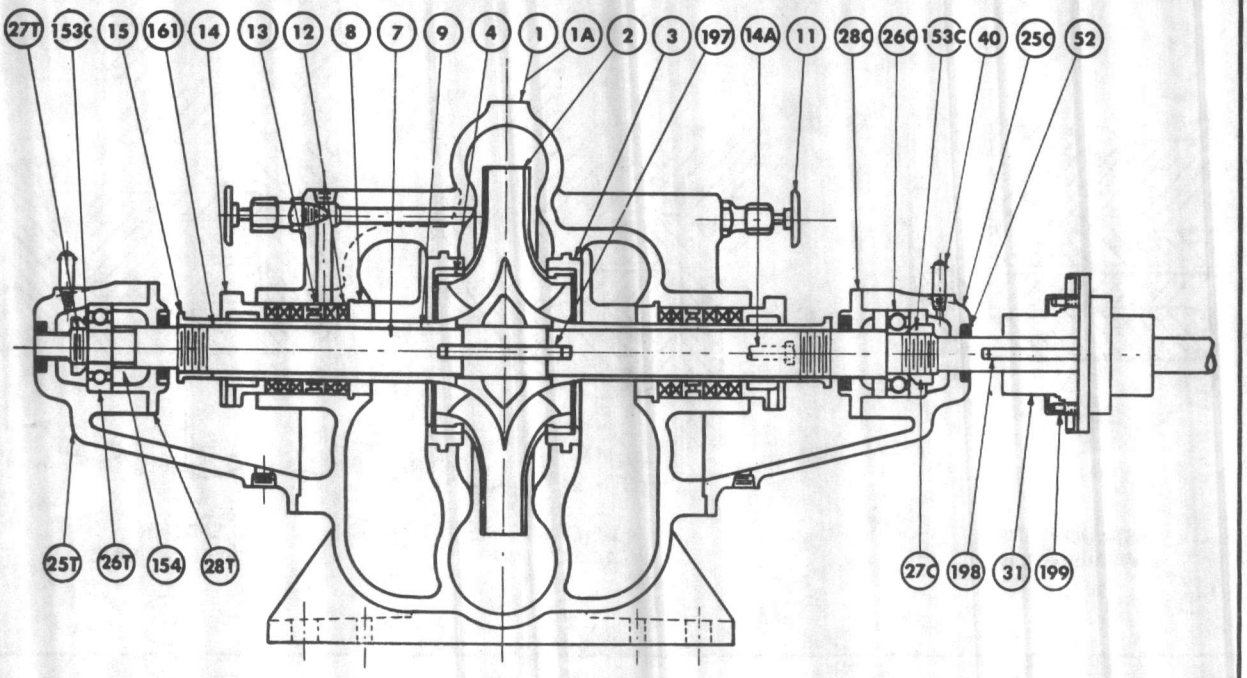
(1) Exercise extreme care in the dismantling operation to prevent damage to internal parts of the pump. For convenience in reassembly, lay out all parts in the order in which they are removed. Protect all machined faces against metal-to-metal contact and corrosion. Do not remove ball bearings unless absolutely necessary.

(2) While the pump is dismantled, also check the foot valves and examine the check valves to make certain they are seating and functioning properly.

(3) To assemble the pump, reverse the dismantling procedure. Follow the manufacturer's instructions explicitly.

(4) Check the pump and motor alinement after reassembly.

4.9.3.12 Mixed-Flow Pumps. Maintenance procedures for mixed-flow pumps follow the general procedures described in paragraph 4.9.3. For



1. Casing
1A. Casing gasket
2. Runner
3. Casing wearing ring
4. Runner wearing ring
7. Shaft
8. Stuffing-box bushing
9. Shaft sleeve
11. Water-seal valve
12. Packing
13. Water-seal ring (split)
14. Gland (split)
14A. Gland bolt and nut
15. Shaft-sleeve nut
26C. Ball Bearing
26T. Ball Bearing
27C. Retaining nut
27T. Retaining nut
31. Complete coupling
40. Grease fitting
25C. Ball-bearing housing
25T. Ball-bearing housing
28C. Ball-bearing end cover
28T. Ball-bearing end cover
52. Grease retainer
134. Bearing spacer sleeve
153C. Lock washer
161. Cord packing
197. Runner key
198. Coupling key
199. Coupling spring

FIGURE 190

Cutaway Diagram of Double-Suction Volute Centrifugal Pump

detailed procedures, consult the manufacturer's instructions.

4.9.3.13 Axial-Flow Pumps. Axial-flow pumps generally do not have wearing rings to maintain. Maintenance procedures for axial-flow pumps follow the general procedures described in paragraph 4.9.3. For detailed procedures, consult the manufacturer's instructions.

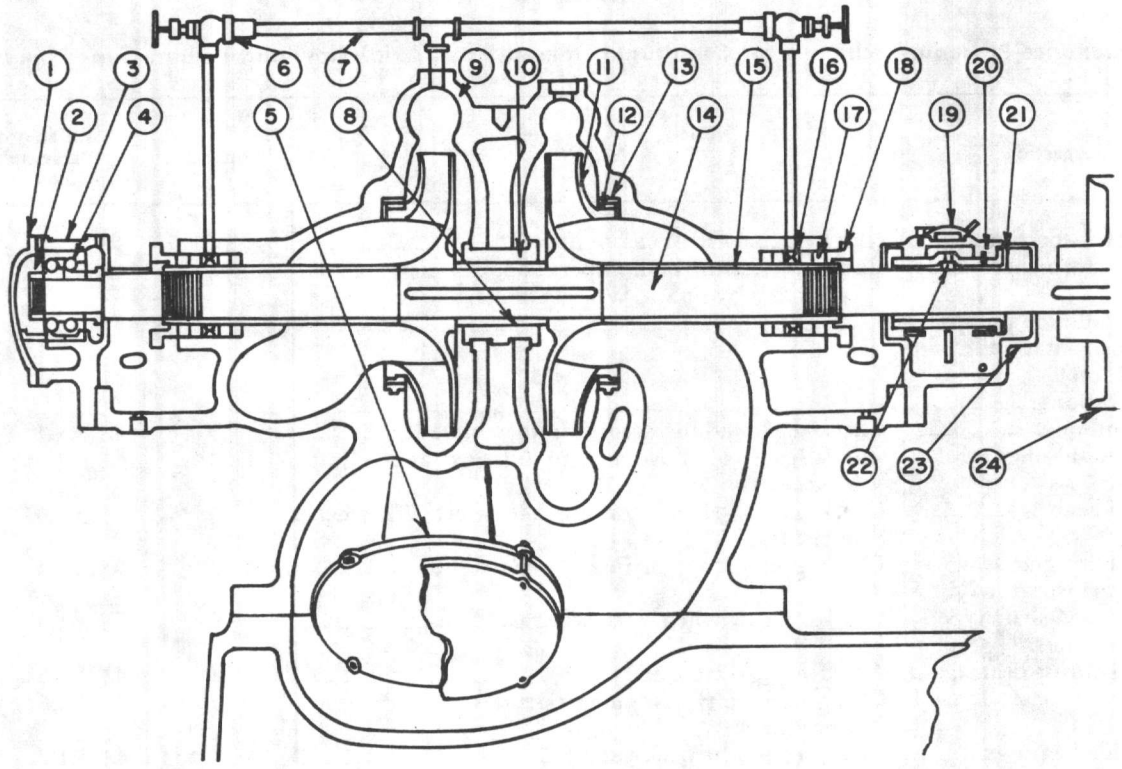
4.9.3.14 Turbine-Type Pumps. General inspection, maintenance and overhaul procedures are the same as those presented in paragraph 4.9.3. For detailed procedures, applicable solely to this type of pump, see the manufacturer's instructions. These procedures should be followed.

(1) Whenever the pump is dismantled and reassembled, be sure to check the clearance between the impeller and the liners, and check the endway movement of the shaft. Adjust the clearance equally on both sides of the impeller. It should be at least 0.01 to 0.012 inches; if not, replace the impeller and liner (see the manufatcurer's instructions).

(2) Annually, or whenever the pump is dismantled, paint the interior iron with a protective material suitable for underwater use.

4.9.3.15 Troubleshooting. Troubleshooting may be done by the operator or maintenance personnel. In either case, the recognition of symptoms and the causes are important. For a complete check list of troubleshooting symptoms, causes and remedies, see table 11. Cutaway views of two types of centrifugal pumps are shown in figures 190 and 191.

4.9.3.16 Maintenance Procedure Schedule for Centrifugal-Type Pumps. The maintenance operation frequency and schedule of inspections for centrifugal, mixed-flow, axial-flow and turbine-type pumps are presented in table 36.



1. SHAFT SLEEVE
2. RETURN GUIDE BUSHING
3. SUCTION COVER
4. BALL BEARING
5. THRUST PLATE
6. WATER-SEAL PIPING
7. SET COLLAR
8. SPACER SLEEVE
9. CASING
10. BALANCING DISK
11. RUNNER
12. RETURN GUIDE
13. WEARING RING
14. SHAFT
15. SHAFT SLEEVE
16. WATER-SEAL RING
17. PACKING
18. GLANDS
19. OIL-HOLE COVERS
20. BEARING HOUSING
21. BABBITTED SHELL
22. OILING RING
23. BEARING HOUSING
24. PUMP HALF COUPLING

FIGURE 191

Cutaway View of Two-Stage Centrifugal Pump

4.9.4 WELL PUMPS. Well pumps are described and illustrated in paragraph 3.5.2.4. Their function is to move water out of the ground, and they differ from other types of rotating pumps (centrifugal) only in details of design. They have impellers, bowls (casings), shafts, bearings, etc., and, therefore, in general, they are subject to the same maintenance procedures are are centrifugal pumps, particularly with respect to lubrication, bearings, packing, impellers, casing, and overhaul procedures. Paragraph 4.9.3 should be reviewed in connection with any maintenance on well pumps; the following paragraphs apply specifically.

4.9.4.1 Turbine Well Pumps. This type of pump may have either open or enclosed impellers and either water- or oil-lubricated shaft bearings.

4.9.4.1.1 Operator inspection. Refer to paragraph 4.9.1.2 for applicable operator inspection procedures.

4.9.4.1.2 Lubrication. See paragraph 4.9.3.1 for applicable procedures. In addition, observe the following instructions.

(1) Oil-Lubricated Pump and Bearings. Daily, make certain that oil tubing and lubricators are filled. Check solenoid oilers for proper operation and see that they are filled. Check oil level in

TABLE 36

Maintenance Procedure Schedule for Centrifugal, Mixed-Flow, Axial-Flow and Turbine-Type Pumps

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Operator inspection	Check various items as outlined	V	4.9.1.2
Pump performance	Run field tests of pump operation, capacity, etc., as scheduled by Public Works Officer.	V	4.9.2
Centrifugal-type pumps (horizontal and vertical).			4.9.3
Lubrication			4.9.3.1
Hand-oiler	Check daily; adjust according to table 14	D	4.9.3.1.1
Solenoid-oiler	Check leads, oil flow, rate of oil flow and adjust as necessary.	D	4.9.3.1.2
Ball-bearings	Check oil level in housing oil well; fill when necessary.	D	4.9.3.1.3
Packing glands (grease sealed).	Check grease cup; maintain proper pressure	D	4.9.3.1.4
Enclosed-shaft type bearings.	Refill oil cup when necessary	W	4.9.3.1.5
Ball-thrust bearings	Add fresh grease	M	4.9.3.1.6
	Change grease where pump operates more than 50 times daily.	Q	4.9.3.1.6(2)
Guide bearings	Add grease when necessary	M	4.9.3.1.7
Ball bearings on open shaft Type O.	Add grease when necessary	M	4.9.3.1.8
Shaft bearings	Drain lubricant, wash out wells with kerosene and add fresh lubricant.	Q	4.9.3.1.9
Bearing housing	Open housing, flush clean with kerosene and add fresh, clean grease.	Q	4.9.3.1.10
Universal joint couplings.	Lubricate when necessary	SA	4.9.3.1.11
Bearings			4.9.3.2
Antifriction bearings	Check bearing temperature with a thermometer; change, or adjust lubrication, if temperature so indicates.	M	4.9.3.2.1
	Drain lubricant; wash wells and bearings with kerosene.	Q	4.9.3.2.1(2)
	When pump is dismantled, check condition of bearings and bearing race; replace if necessary.	A	4.9.3.2.1(3)
Sleeve bearings	Check bearing temperature with thermometer; take necessary corrective step if bearing is too hot.	M	4.9.3.2.2
	Drain lubricant; wash out wells and bearings with kerosene; measure bearings with feel gage; take corrective action if necessarp; refill with oil.	Q	4.9.3.2.2(2)(a)
	Check oil rings; replace if necessary	Q	4.9.3.2.2(2)(b)
	When pump is dismantled, check condition of bearings; replace as necessary.	A	4.9.3.2.2(3)
Packing			4.9.3.3
Stuffing box	Check for free movement of gland; oil the gland and bolts; check for excessive leakage in order that gland adjustment will not reduce; repack, if necessary.	SA	4.9.3.3.3
Gland assembly	Check; if leakage is excessive, tighten gland; if tightening does not alleviate condition, remove packing and inspect sleeve.	W	4.9.3.3.4

TABLE 36 (Continued)

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Sealing water system			4.9.3.4
Packing glands	Check for leakage; adjust to produce slow, constant drip.	D	4.9.3.4(1)
	Disassemble sealing-water lines and valves to make certain that water passages are clear.	A	4.9.3.4(2)
Rotary seals	Consult manufacturer's instructions		4.9.3.5
Shafts	When pump is dismantled, check for alinement and distortion; examine for pitting, erosion and scoring; repair or replace when necessary.	A	4.9.3.6
Shaft sleeves	Inspect for wear; replace as necessary	A	4.9.3.6.2
Wearing or sealing rings	Check for wear and clearance; replace if clearance is greater than 0.05 inch on a diameter of the ring.	A	4.9.3.7
Impeller	Remove and inspect thoroughly; check for deposits or scaling and remove; check for erosion and cavitation effects; remedy cause of cavitation if possible; weld cavitation pits if severe; machine and balance.	A	4.9.3.8
Casing	Clean and paint with enamel-like finish coating; set up routine program.	A or V	4.9.3.9
Pump shutdown	For normal shutdowns, or for overhaul, shut all valves, drain pump; disconnect motor switch and remove fuses; before startup, drain oil and grease and refill; for dismantling, drain oil and remove grease.	V	4.9.3.10
Overhaul	Drain pump, etc. (see pump shutdown); dismantle with care, check all parts, repair or replace worn parts; check valves (foot and check); reassemble parts with care.	A or V	4.9.3.11
Mixed-flow pumps	Follow general procedures above (par. 4.9.3); for details, see manufacturer's instructions.	V	4.9.3.12
Axial-flow pumps	Follow general procedures above (par. 4.9.3); for details, see manufacturer's instructions.	V	4.9.3.13
Turbine-type pumps	Follow general procedures above (par. 4.9.3); for details, see manufacturer's instructions.	V	4.9.3.14
Troubleshooting	See table 11	V	4.9.3.15

[1] D-Daily; W-Weekly; M-Monthly; Q-Quarterly; SA-Semiannually; A-Annually; V-Variable; as conditions may indicate.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

sight lubricator for underwater bearings. Make certain that the oil feed is at an average rate of three to four drops per minute.

(2) Water-Lubricated Pump and Bearings. This type of design requires lubrication with clear water. Daily, make certain that the prelubricating tank is full when the pump is in use.

(a) When filling the tank by pump, be sure to close the tank-filling valve when the tank is full. Open lubrication valve to allow water to reach the bearings before the pump is started.

(b) If the bearings are lubricated from main pressure, close the valve after the pump is started.

(c) If the pumps operate automatically, with a prelubrication delayed-solenoid valve, allow one minute before checking lubricating valve for proper operation. Check solenoid valve and packing.

(d) Check the prelubrication control on pumps which have safety controls to prevent starting before prelubrication water is turned on. Make certain that this water flows to bearings when the equipment is supposed to function.

(e) Check the time-delay relay for proper functioning, and compare with the manufacturer's recommendation.

(f) Clean and lubricate the guides and linkages.

4.9.4.1.3 Packing assembly, shaft, and shaft sleeve. Refer to paragraphs 4.9.3.3 and 4.9.3.6 for maintenance procedures.

4.9.4.1.4 Impeller. Quarterly, check the impeller for maximum-efficiency setting, and adjust if necessary. On hollow-shaft motors, the adjusting nut is on the top of motor. Consult the manufacturer's instructions for the detailed procedure for adjustment. The following paragraphs give adjusting procedures for typical pumps.

(1) Closed Impeller With Sealing Rings.

(a) Raise the shaft by turning the adjusting nut until the shaft cannot be rotated freely by hand. Back off the nut and lower the shaft one-fourth to one-half of the total vertical clearance of the pump.

(b) For an extremely deep well, adjust the impellers a second time after a few hours of operation.

(2) Open or Semienclosed Impellers. To adjust, allow for stretch of the shaft when the pump is running with a thrust load on it, and proceed in accordance with the manufacturer's instructions.

(3) Pomona-Type Turbine Pump.

(a) Obtain a copy of the Pomona Pump Impeller Adjustment Chart as illustrated in reference 22.

(b) Ascertain the following information.

1. Total dynamic head at which pump will be operating.
2. Pump setting or drive-shaft length.
3. Pump capacity.
4. Full shaft diameter.
5. Full diameter of head shaft at adjusting nut threads.

(c) Consult the chart for directions. See reference 22 for example.

(4) Impeller Pitting. Whenever the pump is pulled for inspection, note signs of pitting or wear on the impellers. If pitting occurs in the lower stages, it may be due to cavitation. (See par. 4.9.3.8 for action in case of pitting due to cavitation.)

(a) Sand in the water will cause erosion of the impellers. If sand is the cause of the difficulty, change the operating procedures or subject the well to surging; surging and backwashing; or, backwashing and backblowing to reduce sand pumping (see par. 4.2.2.6.1). Where the effect is appreciable, repair or replace impellers not likely to last until the next inspection.

(b) Check the clearances. Repair or replace impellers, as necessary, to maintain the close clearance required for pump efficiency. See the manufacturer's intructions regarding pump clearances and efficiencies.

4.9.4.1.5 Bowls and waterways. When the pump is pulled for inspection, the bowls and water passage should be inspected for pitting, wear and corrosion. Pitting in the lower stages only is probably due to cavitation (see par. 4.9.3.8). Where sand causes troubles, see par. 4.9.4.1.4(4)(a) above.

4.9.4.1.6 Overhaul.

(1) Frequency. As with centrifugal pumps, the frequency of complete overhaul depends on the hours of operation, severity of operation, etc. Generally, however, a pump more or less in continuous operation should be pulled for inspection and overhaul on an annual basis. The work of overhaul should be done under experienced supervision and in strict accordance with the manufacturer's instructions. Inspection and overhaul certainly should be done if any of the following conditions exist, regardless of scheduled frequency of maintenance.

(a) The pump shaft does not turn freely because parts below the pump head are binding.

(b) The pump shows excessive vibration.

(c) A performance test (see par. 4.9.2) shows a decrease of 25 percent in capacity under normal head and speed conditions.

(2) Clearances. When the pump is pulled, check the diametrical clearance of each wearing ring to make sure that it is between 0.025 and 0.05 inches. See the following table for acceptable clearances for water-lubricated cutless rubber bearings. (Allow a maximum diametrical clearance of 0.025 inches on oil-lubricated bearings.)

Diametrical Clearance of Water-Lubricated Cutless-Rubber Bearings

Condition	Shaft Diameter (in.)	
	Up to 1½	1½ to 4
Clearance when new (in.)	0.020 to 0.032	0.040 to 0.050
Maximum clearance allowable (in.)	0.040	0.070

(3) Dismantling and Reassembly. This operation requires as much care as for centrifugal pumps (see par 4.9.3.11.1).

(4) Alinement. Annually, check the pump and motor alinement.

(5) Painting. Annually, or whenever the pump is pulled, paint all iron parts with a good grade of underwater paint or effective protective coating on the exterior of the pump and, if possible, on the interior parts subject to rust. Apply the paint only to surfaces that are clean and dry.

4.9.4.1.7 Troubleshooting. Troubleshooting may be done by the operator or maintenance personnel. In either case, recognition of symptoms and causes are important. For a check list of troubleshooting symptoms, causes and remedies, see table 37.

TABLE 37

Troubleshooting Chart for Turbine Well Pumps

Symptom	Cause of trouble	Remedy
Pump won't start	Impeller locked	Check for sand; try raising or lowering impellers; backwash; if unsuccessful, pull pump.
	Trash in casing	Check for such material; pull pump and clean.
	Corrosion or growths in pumps out of service for long periods.	Back flush with acid, chlorine and/or Calgon.
	Bearing friction	Change oil; check tube tension nut for tightness; check for bent shaft; replace if necessary; check anchoring of pump to make certain it hasn't caused bending or distortion of pump.
	Faulty motor or wiring	Check circuit breaker or fuses for open line; if starter, reset; disconnect motor from pump to see if it starts; check motor wiring against wiring diagram.
	Burned out fuses	Test voltage on phases of motor terminals.
	Tripped overload relay	Reset.
	Low voltage, defective motor, defective starting equipment.	Repair as necessary.
	Impellers not adjusted properly	Set high enough to allow room for shaft stretch due to hydraulic thrust; adjustment should allow shaft to turn freely.
	Well cave-in	Call outside contractor.
Pump doesn't deliver water.	Wrong rotation	Switch power leads.
	Speed too slow	Check voltage and frequency of power supply; check for excessive bearing friction, corrosion or obstruction of impeller; if belt driven, check for slippage or wrong pulley size.
	Pump not primed	Vent well to atmosphere to eliminate vacuum at pump suction; make certain there is a net positive suction head on the pump.
	Pump parts failure	Look for broken shaft, broken bowl assembly and loose column-pipe joints; tighten all impellers.
	Pumping head too great	Make sure discharge valves are open and that check valves don't stick; also, check water table level and other factors.
	Clogged suction	Clear clogged suction pipe, strainer or impeller by backwashing; if well screen is plugged, see par. 4.2.2.6.1.
	Well overpumped	See par. 4.2.2.6.
Pump uses too much power.	Wrong pump	Check model number, capacity rating, etc.
	Overspeeding	Check for high frequency, voltage, wrong gear ratios.
	Wrong lubricant	Check oil, motor bearings; check water-lubricated bearings.
	Tight packing	Adjust to allow enough leakage to lubricate shaft.
	Impeller rub	Adjust impeller height.
	Wrong rotation	Adjust two power leads.
	Misalinement, tight bearings, vibration in pump or casing.	Check and adjust.

TABLE 37 (Continued)

Symptom	Cause of trouble	Remedy
Low pump capacity	Low water level in well	Vent well, check pump inlet for excessive turbulence, vortexing or eddies; check bowls and well screen for sand, rust or bacterial blocking.
	Impeller wear	Check for metal loss at outer tips of impeller vanes; in fully enclosed impellers with wearing rings, check for wear and excessive clearance; semiopen impellers, without bottom shroud or wearing rings, need close-running clearance at bottom of vanes.
	Faulty instruments	Check for correct reading.
	Leaks	Check for openings in pipe at flanged or threaded joints and repair; also check for openings in bowls, column pipe and pump head.
	Speed low	Check as above.
	Bearing troubles	Check lubricating oil and grease for grade and quantity; check for sand in water.
	Rough operation	Make certain impeller and bowl passages are clear of sand and other obstructions; disconnect motor and check driver running alone; check for wear in rotating parts.
	Pump taking air	If physically possible, check on water velocity at pump inlet; check for leaks in well vent; determine if suction head on pump is sufficient; make certain that over-pumping is not causing water level to drop to point where pump grabs air.

4.9.4.2 Air-Lift Pumps. This type of pump is described and illustrated in Paragraph 3.5.2.4.3. Maintenance procedures are set forth in the following paragraphs.

(1) Daily, the following operations and inspections are to be performed.

(a) Lubricate the compressor in accordance with the manufacturer's instructions.

(b) Blow down the air-receiving tank.

(c) Check the relief valve on the receiving tank, or in the air line between the valve and the compressor. Repair, if not operating properly.

(d) Make certain that the cooling water is ample for cooling the cylinder jacket.

(e) Where several wells are pumped from a central compressor, balance the air supply to each well so that excessive pressure is not placed on the compressor.

(2) Weekly, the following operations and inspections are to be performed.

(a) Examine the compressor for oil pumping, if oil appears in the sample.

(b) Check the filters for air intake and replace, if necessary.

(c) Check for air contamination in the air lift. Since well water can become contaminated by air, make certain there are no cross-connections in the air system by which contaminated water may enter the well.

(d) Check the well water for presence of oil from compressed air by looking for oil film on surface of the water sample.

4.9.4.3 Ejector Pumps. This type of pump consists of a centrifugal-type, single-impeller pump aboveground, and a stationary ejector assembly in the well. The ejector assembly is made up of a nozzle within a tube, which tapers down to a narrow throat opening at the top of the nozzle (see fig. 192). For maintenance procedures for the centrifugal pump portion of the system, see paragraph 4.9.4.1 on turbine well pumps; otherwise the following procedures shall apply.

(1) Annually, or as directed by the Public Works Officer, disassemble the pump. Examine the casings, ring and impeller for wear or corrosion.

(a) Check diametrical ring clearance; make certain that it is not less than 0.005 inches, nor greater than 0.020 inches. If the wear is great enough to indicate failure before the next inspection, replace parts as necessary.

(b) Make certain that no water passages are clogged.

(2) Check lubrication, packing, bearings and pump-motor alinement, in accordance with the procedures described in paragraph 4.9.4.1.

(3) Annually, or as directed by the Public Works Officer, remove the ejector, the foot valve, and the screen from the well, and examine all parts for wear and corrosion.

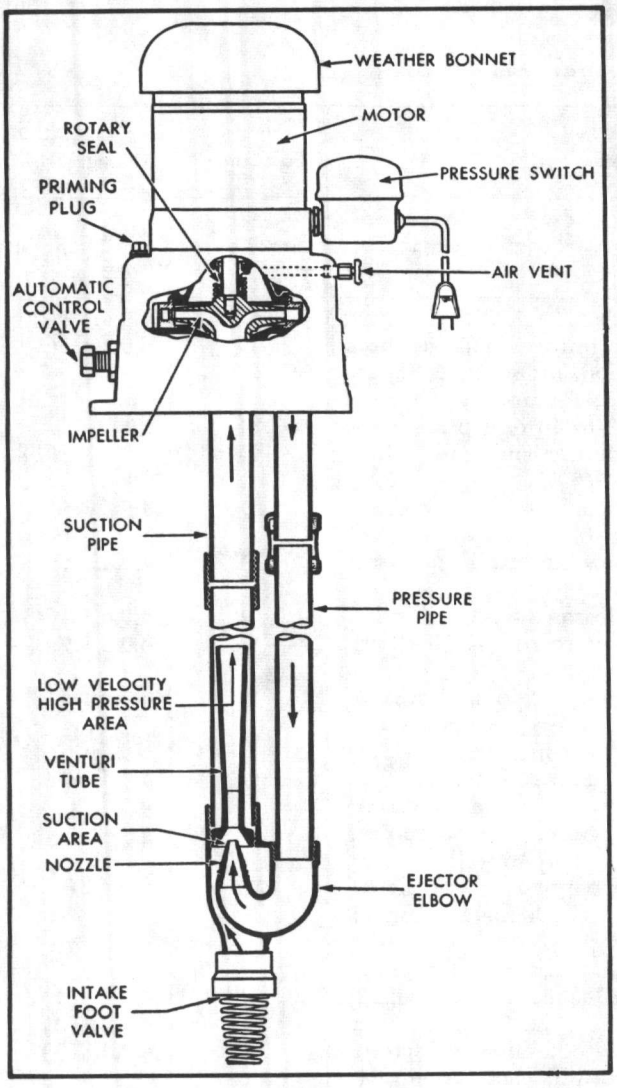


FIGURE 192

Injector Pump

(a) Check the size of the nozzle and the ejector throat to determine any loss in efficiency. If wear has occurred, consult the manufacturer.

(b) Check the foot valve for leakage. Reface, reseat or replace the valve if necessary. Install a new strainer if the old one is corroded.

(4) Annually, paint the exterior of the pump with a good grade of paint. Paint the interior whenever the pump is disassembled.

4.9.4.4 Reciprocating Well Pumps. This type of pump is described and illustrated in Paragraph 3.5.2.4.4.

4.9.4.4.1 Pump jack. For maintenance procedures for the pump jack, see Paragraph 4.9.4.4.3, and consult the manufacturer's instructions for detailed maintenance procedures.

4.9.4.4.2 Pump delivery. Semiannually, the pump output should be measured for a known number of strokes (see Paragraph 4.9.2). Delivery per stroke should be at least 90 percent of the volumetric displacement of the pump (i.e., plunger area times stroke length).

(1) Remove the pump from the well and check the valves and cup leathers, whenever either of the following two conditions exists.

(a) When the pump delivery drops to 50 percent or less.

(b) When the pump delivery is between 50 and 90 percent, but is less than the installation water requirements.

(2) Before revolving the pump, consult the manufacturer's instructions for the method of picking up the foot valve and for additional maintenance procedures.

4.9.4.4.3 Overhaul. Annually, the pump jack should be inspected for wear. Replace worn bearings and parts. Check packing assembly; repack, as necessary (see par. 4.9.3.3.3). If pump the delivery is satisfactory, do not overhaul the pump parts in the well. Paint the exterior of the pump as necessary.

4.9.4.5 Maintenance Procedure Schedule for Well Pumps. The maintenance operation frequency and schedule of inspections for well pumps are presented in table 38.

4.9.5 ROTARY PUMPS. This type of pump is described and illustrated in paragraph 3.5.2.2. There are many types of rotary pumps and, therefore, it is not possible to set up detailed maintenance procedures applicable to all types. Individual maintenance procedures must be in accordance with manufacturer's instructions. The following general procedures apply in all cases.

4.9.5.1 General Pump Maintenance. At variable intervals, carry on such maintenance procedures as are applicable from paragraphs 4.9.1 and 4.9.3.

4.9.5.2 Overhaul. At annual intervals, disassemble the pump and clean both exterior and interior.

(1) Check the clearance of the moving parts. Consult the manufacturer's instructions.

(2) Check the packing assembly, and repack, as needed.

(3) Check the bearings and the alinement of the pump and motor.

(4) Check all items applicable in paragraph 4.9.3.

(5) Paint exterior surfaces; paint interior surfaces (subject to rust) with a suitable underwater paint or effective protective coating.

4.9.6 RECIPROCATING PUMPS. This type of pump, including plunger, piston and diaphragm, is described and illustrated in paragraph 3.5.2.3. The following maintenance procedures are minimum.

TABLE 38

Maintenance Procedures for Well Pumps

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Well pumps	See par. 4.9.3		4.9.4
Turbine well pumps			4.9.4.1
Operator inspection	See par. 4.9.1.2		4.9.4.1.1
Lubrication	See par. 4.9.3.1		4.9.4.1.2
Oil-lubricated pump bearings.	Make certain tubing and lubricators are filled; check solenoid oilers for operation, and see that they are filled; check oil lubricator for underwater bearings; oil feed should be 3 to 4 drops per minute.	D	4.9.4.1.2(1)
Water-lubricated pump and bearings.	Check level of water in prelubricating tank; follow directions in text.	D	4.9.4.1.2(2)
Packing assembly, shaft and shaft sleeves.	See pars. 4.9.3.3 and 4.9.3.6		4.9.4.1.3
Impeller	Check impeller for efficiency; adjust if necessary (see text).	Q	4.9.4.1.4
	Check for pitting; check clearances	V	4.9.4.1.4(4)
Bowls and waterways	Check for pitting, wear and corrosion (see pars. 4.9.3.8 and 4.9.4.1.4(4)(a).	V	4.9.4.1.5
Overhaul	Check clearances, binding, vibration and loss of capacity; paint.	V	4.9.4.1.6
	Check pump and motor alinement	A	4.9.4.1.6(4)
Troubleshooting	See table 37	V	4.9.4.1.7
Air lift pumps	Lubricate compressor; blow down air receiver; check air-receiving tank valve; check cooling water supply; balance air supply to wells.	D	4.9.4.2(1)
	Check compressor for oil pumping; check air filters; replace as necessary; check for air contamination; check for oil in well.	W	4.9.4.2(2)
Ejector pumps			4.9.4.3
Centrifugal pump	See par. 4.9.4.1	A	4.9.4.3(1)
Packing	See par. 4.9.4.1	A	4.9.4.3(2)
Ejector assembly	As directed, remove ejector, foot valve and screen; check for wear and corrosion; check foot valve seating; check ejector throat; repair as necessary, or consult manufacturer.	A	4.9.4.3(3)
Body	Paint exterior and interior, as necessary	A	4.9.4.3(4)
Reciprocating well pumps	Check pump delivery; remove pump and repair, if delivery has decreased (see text); check valves and cup leathers.	SA	4.9.4.4
	Check pump jack	A	4.9.4.4.3

[1] D-Daily; W-Weekly; Q-Quarterly; SA-Semiannually; A-Annually; V-Variable; as conditions may indicate.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

4.9.6.1 Drives. See Section 12 of this chapter, and consult the manufacturers' instructions.

4.9.6.2 Piston Water Pumps. Annually, determine the slippage, that is, the decrease in percent delivery from the volumetric displacement per stroke of the pump.

(1) Compute the volumetric displacement from the piston or plunger area multiplied by the length of stroke; make proper allowance for double-action pumps.

(2) Calculate the percent delivery from a comparison of the measured delivery per stroke and the computed volumetric displacement per stroke. If the delivery is less than 90 percent of the volumetric displacement, check the valves, pistons and packing for leakage. Make any necessary replacements to maintain the desired efficiency.

(3) At annual intervals, dismantle the pump and inspect it thoroughly in the following manner.

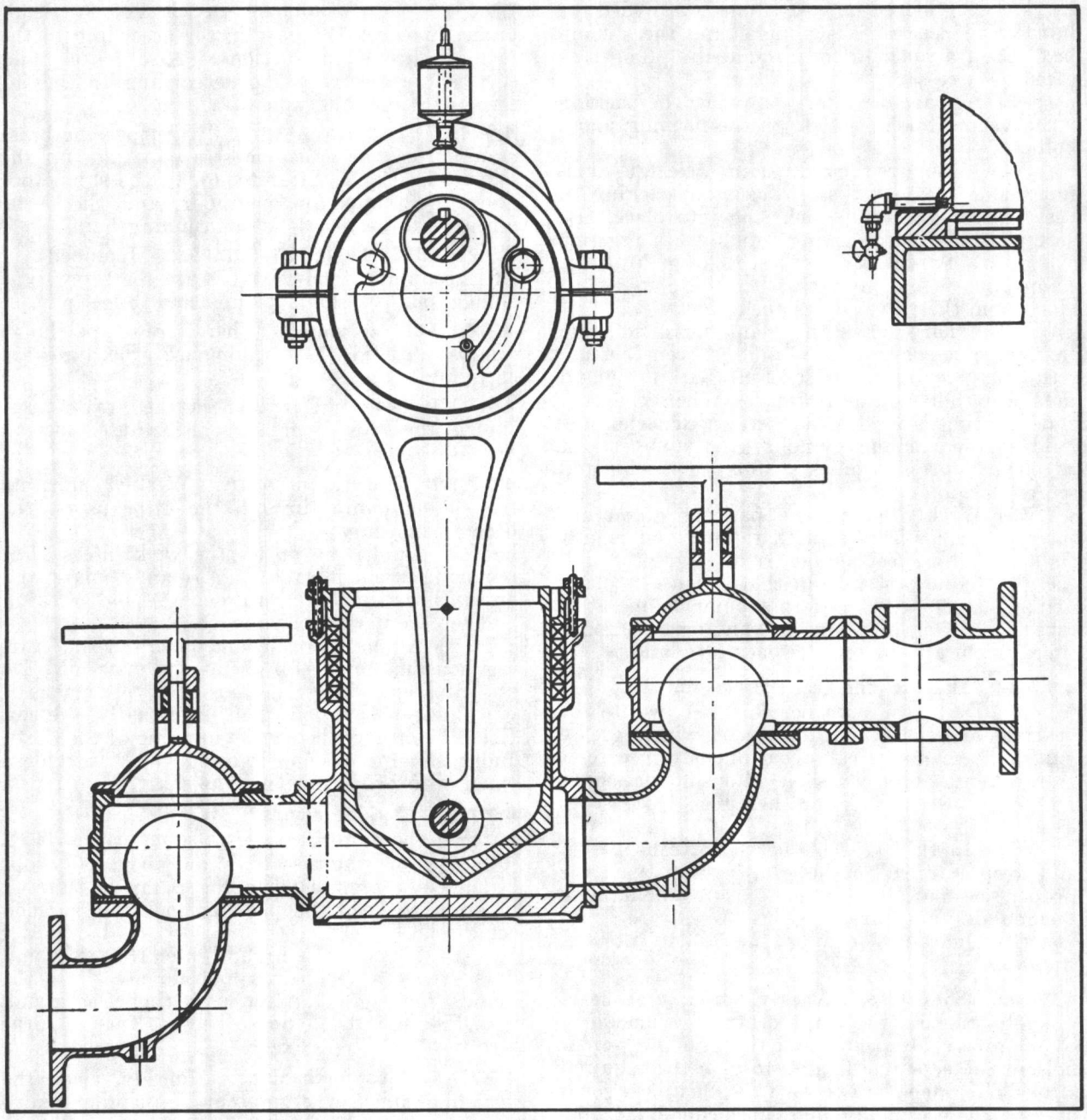


FIGURE 193

Diagram of Reciprocating Sludge Pump

(a) Remove and examine all valves, valve seats and springs. Reface valves and valve seats as necessary; replace worn or defective parts.

(b) Remove all old packing, and repack.

(c) Check the pump and the driver alinement.

(d) Check the plunger or rod for scoring or grooving.

(e) Clean the interior and exterior of pump. Paint the interior iron with suitable underwater paint or protective coating. Paint the exterior of the pump.

4.9.6.3 Diaphragm Pumps. Annually, dismantle the pump, clean the diaphragm, and examine for leaks or defects. Inspect the drive mechanism Consult the manufacturer's instructions for detailed maintenance procedures.

4.9.6.4 Sludge Pumps. The following minimum procedures apply to all types of reciprocating sludge pumps, a diagram of which is shown in Figure 193.

4.9.6.4.1 Packing.

(1) Daily (or more often, as necessary),

check the sight-feed oil cup, if one is provided for lubrication between the plunger and the stuffing box. Add a squirt of oil around the plunger as often as necessary.

(2) At variable intervals, renew the packing whenever no takeup is left on the packing gland bolts.

(a) Remove the old packing, clean the cylinder and piston walls. Place new packing in the cylinder and tamp each ring into place. Be sure that the packing ring joints are staggered.

(b) To break in the packing, run the pump for a few minutes with the sludge line closed and the valve covers open.

(c) Turn down the gland nuts, no more than is necessary, to keep sludge from getting past the packing. Be sure all packing gland nuts are tightened uniformly. When chevron-type packing is used, make certain that the nuts holding the packing gland are only fingertight as too much pressure quickly ruins the packing and scores the plunger.

(3) Weekly, check the packing gland adjustment to make certain that the gland is just tight enough to keep sludge from leaking through the gland, and not so tight that it causes scoring of the piston walls. Before a pump is operated, especially after it has been standing idle for a time, loosen all nuts on the packing gland.

4.9.6.4.2 Bearings and gear transmission

(1) Daily (or once per shift), lubricate the bearings and the gear transmission with a grease gun. If the pump runs continuously, grease it more often than once a shift. Consult the manufacturer's instructions for the type of grease to be used.

(2) Monthly, check the gear transmission and keep it filled to the proper level with the proper seasonal oil. Open the drain to eliminate accumulated moisture.

(3) Quarterly, change the oil to prevent sludging.

4.9.6.4.3 Shear pins. Weekly, check the shear-pin adjustment. Set the eccentric by placing a common 8- or 10-penny nail through the proper hole in the eccentric flanges to give the required stroke. Tighten the two $\frac{5}{8}$- to $\frac{7}{8}$-inch hexagonal nuts on the eccentric flanges just enough to take the spring out of the lockwashers.

(1) If shear-pin failures occur, check for a solid object lodged under the piston, a clogged discharge line or a stuck or wedged valve.

(2) When a shear pin fails, the eccentric will move to the neutral position and prevent damage to the pump. Remove the cause of failure and insert a new shear pin.

4.9.6.4.4 Ball valves. Quarterly, replace any valve balls that are worn small enough to jam into the guides in the valve chamber. A decrease in diameter of $\frac{1}{2}$-inch will be sufficient to cause this difficulty. Check the valve chamber gaskets; replace them when necessary.

4.9.6.4.5 Gear motors and electric motors. Semi-annually, check the gear motor according to the manufacturer's instructions. Also, check and service the electric motor according to the instructions in Paragraph 4.11.2.

4.9.6.4.6 Eccentric. Annually, remove the brass shims from the eccentric strap to take up the babbitt bearing. After removing the shims, operate the pump for one hour, and check the eccentric to be sure it is not running hot.

4.9.7 MISCELLANEOUS PUMPS. Included in this grouping of pump types are the screw-type sludge pumps, sump pumps and bilge pumps.

4.9.7.1 Screw Pumps. Where screw-type sludge pumps are used, the maintenance procedures are as follows.

4.9.7.1.1 Seals. Daily, check the grease pressure in the seals, if grease seals are used instead of water seals.

4.9.7.1.2 Bearings and filters. Weekly, lubricate the sludge pump through the oil cups on the bearing housing.

(1) Annually, replace the wick filters after removing the outer bearing retainer plate and outer thrust plate. Pull out the old wicking and replace it with new lengths.

(2) Annually, drain and flush out the bearing housings and refill them with new oil. Do not oil them while the shaft is revolving, as it will indicate less oil than is actually present. Keep the oil level below the low side of the shaft, and check for overlubrication, which is evident when oil overflows around the shaft.

4.9.7.1.3 Packing glands. Weekly, check the packing glands for leakage (also see par. 4.9.3.3).

(1) For water seals, allow about 60 drops leakage per minute when the pump is running in order to keep the packing cool and in good condition.

(2) If leakage is high, tighten the two gland nuts evenly a few turns, but do not draw the glands too tight. After adjusting the gland, turn the shaft by hand to be sure that it turns freely.

4.9.7.1.4 Float mechanism. Monthly, clean the float mechanism where automatic priming equipment is used on a sludge pumping installation.

4.9.7.1.5 Pump and motor. Follow the manufacturer's instructions for general pump maintenance (also see par. 4.9.1), and see paragraph 4.11.2 for procedures for motor maintenance.

4.9.7.2 Sump and Bilge Pumps

4.9.7.2.1 Sumps. Weekly, check for floating objects and accumulated deposits in the sump bottom. Clean as necessary.

4.9.7.2.2 Pump operation. Weekly, check the pump for failure to start when the switch makes contact. Check for failure to empty the sump at a normal rate. Also, check for inadequate suction, discharge and shutoff heads against

normal operating standards. Rotate the pump by hand to ascertain drag or misalinement. Service the pump.

4.9.7.2.3 Packing gland. Weekly, check the packing gland for evidence of leakage (see Paragraph 4.9.3.3 for procedures).

4.9.7.2.4 Wiring and controls. Monthly, check as follows.

(1) Check for loose connections, breaks and other damage to wiring and insulation.

(2) Check for short circuits, loose or weak contact springs, worn or pitted contacts and defective float switch.

(3) Tighten connections and parts; replace or adjust contact springs, clean contacts and make minor repairs.

4.9.7.2.5 Floats. Monthly, check for bent rod, binding or other damage. Straighten bent rod; relieve binding; apply light oil to moving parts; and, check operation of alarm system.

4.9.7.2.6 Bearings. Monthly, check the bearings. See paragraph 4.9.3.1.3 for bearing lubrication and paragraph 4.9.3.2 for bearing maintenance.

4.9.7.2.7 Supports. Monthly, check for unsound or ineffective supports, and for shaft misalinement. Make minor adjustment.

4.9.7.2.8 Motor. See paragraph 4.11.2 for maintenance procedures.

4.9.7.3 Porportioning Pumps. For maintenance procedures, see Paragraph 4.3.6.5.

4.9.8 PUMP PRIMING SYSTEMS. Most priming systems are described in paragraph 3.5.3.1.1. Maintenance procedures for particular systems will be found in the manufacturer's instructions, but the following procedures are basic.

4.9.8.1 Pressure Priming. Annually, make certain that the valves are in good operating condition.

4.9.8.2 Ejector Priming. Semiannually, check the ejector, electrodes, solenoids, relays and check the valves. Repair or replace defective or worn parts.

4.9.8.3 Vacuum Pump Priming. Semiannually, check air compressors, pressure controls, vacuum-relief valves and float valves. Inspect valve seats, diaphragms, contacts, floats and float mechanisms. Repair or replace worn parts when necessary.

4.9.8.4 Plunger-Pump-Type Systems. See paragraph 4.9.6.2 for maintenance procedures.

4.9.8.5 Automatic-Type Systems. Weekly, check the general performance and make adjustments; repair or replace parts when necessary.

4.9.9 MAINTENANCE PROCEDURE SCHEDULE FOR MISCELLANEOUS PUMPS. The maintenance operation frequency and schedule of inspections for rotary pumps, reciprocating pumps, screw pumps, sludge pumps, diaphragm pumps and priming systems are presented in Table 39.

TABLE 39

Maintenance Procedures for Rotary Pumps, Reciprocating Pumps, Sludge Pumps, Miscellaneous Type Pumps and Priming Systems

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Rotary pumps	General pump maintenance (see pars. 4.9.1 and 4.9.3).	V	4.9.5.1
Overhaul	Check clearances of moving parts, packing, bearings and alinement; paint exterior and interior surfaces (see par. 4.9.3).	A	4.9.5.2
Reciprocating pumps			4.9.6
Drives	See par. 4.12.1		4.9.6.1
Piston water pumps	Determine slippage, i.e., check for percent delivery below 90%.	A	4.9.6.2(1)(2)
	Dismantle and inspect; check valves, valve seats and springs; reface or replace worn parts; remove packing and repack; check alinement; check plunger or rod for scoring; clean and paint interior and exterior.	A	4.9.6.2(3)
Diaphragm pumps	Dismantle; clean diaphragm and check for cracks or leaks; check drive mechanism (see par. 4.12.1).	A	4.9.6.3
Sludge pumps			4.9.6.4
Packing	Lubricate	D	4.9.6.4.1(1)
	Renew packing (see par. 4.9.3.3.3); clean cylinder walls.	V	4.9.6.4.1(2)
	Check packing gland adjustment	W	4.9.6.4.1(3)

TABLE 39 (Continued)

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Bearings and gear transmission.	Lubricate	D	4.9.6.4.2(1)
	Check and fill gear transmission with oil; drain moisture.	M	4.9.6.4.2(2)
	Change oil	Q	4.9.6.4.2(3)
Shear pins	Check adjustment; set eccentric	W	4.9.6.4.3
	If pin fails, check and remove cause; replace pin	V	4.9.6.4.3(1)
Ball valves	Check balls for wear; replace, if necessary	Q	4.9.6.4.4
Gear motor and electric motor.	Check and service (see par. 4.11.2)	SA	4.9.6.4.5
Eccentric	Remove brass shims and take up babbitt bearing; run it for one hour.	A	4.9.6.4.6
Screw pump			4.9.7.1
Seals	Check lubrication	D	4.9.7.1.1
Bearings and filters	Lubricate	W	4.9.7.1.2
	Replace wick filters; drain and flush bearings, refill with oil.	A	4.9.7.1.2(1)(2)
Packing glands	Check for leakage (see par. 4.9.3.3) and adjust or repack as necessary.	W	4.9.7.1.3
Float mechanism	Clean and adjust	M	4.9.7.1.4
Pump and motor	See pars. 4.9.1 and 4.11.2	V	4.9.7.1.5
Sump and bilge pump			4.9.7.2
Sumps	Clean out floating objects and accumulated deposits	W	4.9.7.2.1
Pump operation	Check switch contacts, sump emptying rate, pumping heads, misalinement; service pump as necessary.	W	4.9.7.2.2
Packing gland	Check for leakage; adjust or repack as necessary (see par. 4.9.3.3).	W	4.9.7.2.3
Wiring and controls	Check connections for breaks or other damage to wiring and insulation; check for short circuits, worn contacts, defective float switch; tighten connections and parts; clean, repair or replace parts as necessary.	M	4.9.7.2.4
Floats	Check for bent rod, binding or other damage; correct undesirable conditions; apply light oil to moving parts; check alarm system.	M	4.9.7.2.5
Bearings	See pars. 4.9.3.1.3 and 4.9.3.2	M	4.9.7.2.6
Supports	Check and adjust as necessary; check alinement	M	4.9.7.2.7
Motor	See par. 4.11.2		4.9.7.2.8
Proportioning pumps	See par. 4.3.6.5		4.9.7.3
Priming systems			4.9.8
Pressure	Check valves	A	4.9.8.1
Ejector	Check ejector, electrodes, solenoids, relays, valves; repair or replace as necessary.	SA	4.9.8.2
Vacuum pump	Check air compressors, pressure controls, relief valves, float valves, diaphragm cutouts, floats, etc.; repair or replace worn parts as necessary.	SA	4.9.8.3
Plunger pump	See par. 4.9.6.2		4.9.8.4
Automatic	Check general performance and adjust; repair or replace parts as necessary.	W	4.9.8.5

[1] D-Daily; W-Weekly; M-Monthly; Q-Quarterly; SA-Semiannually; A-Annually; V-Variable; as conditions may indicate.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

Section 10. PUMPING STATIONS

4.10.1 REFFERENCES TO PUMPING STATION EQUIPMENT. Pumping stations are defined and described in paragraph 3.5.1 as the pumps, valves, piping, gages, controls and the facilities to house them. Maintenance procedures for pumps are covered in Chapter 4, Section 9; maintenance procedures for driving equipment and drives appear in Chapter 4, Sections 11 and 12, respectively; maintenance procedures for other facilities follow.

4.10.1.1 Records

(1) Whatever the inspection or maintenance procedure, a log shall be kept of all inspection and maintenance actions. These records (see par. 4.1.4) shall be kept on file in the Utility Department Office.

(2) In addition to maintenance logs, there shall be a file showing the location of all pieces of equipment in the pumping station. This file shall include the location of all pumps, motors, controls, valves, piping, etc.

4.10.1.2 Emergency Maintenance. Personnel charged with the maintenance of pumping stations and equipment must be familiar with all casualty plans, as developed by the local command, to handle all emergencies.

4.10.2 BUILDINGS. Procedures for the maintenance of building structures and appurtenances are presented in the MO Series of the Bureau of Yards and Docks publications. Procedures for the inspection of these facilities are presented in Reference 13.

4.10.3 VALVES. Maintenance procedures for all types of valves are presented in Chapter 4, Section 5, and in Table 31. In addition, the following procedures are pertinent to pumping station valves:

(1) At quarterly intervals, check the operation of all valves, particularly those that normally remain in either an opened or a closed position.

(2) Quarterly, check the packing glands for leaks. Take up the gland by turning down the nuts by one or two turns. If leaking continues, repack the valve stem.

(3) Annually, or as often as necessary, paint the cast iron valves, and make certain that all identification tags or plates are in place. Where such identification does not exist, it is recommended that tags or identification plates be installed.

(4) Whenever operation of the valve appears to indicate internal trouble, dismantle the valve and repair as necessary.

4.10.4 PIPING. Annually, or as often as necessary, paint all piping; use a gloss paint that resists moisture condensation. Repaint the pipes in the same color code as previously established, or if stencilled labels are used to identify the pipe, be sure the labels are restencilled. Where color coding or stencil identification has not been established previously, it is recommended that one or the other method of pipe identification be adopted. Color code the pipelines, or identify by painted stencil labels.

4.10.5 PUMP CONTROLS. As described in paragraph 3.5.6.2 and 3.5.6.3, pump controls may be either manual or automatic.

4.10.5.1 Manual Control. Since this type of control consists of manual starting and stopping, and opening and closing valves, the maintenance procedures are limited to the devices used.

(1) Valves. See paragraph 4.10.3 for maintenance procedures.

(2) Electrical Switches. Semiannually, check all switches to make certain that they do not bind or arc. Clean, repair or renew them as necessary.

(3) Instruments. See Chapter 4, Section 13.

4.10.5.2 Automatic Controls. Automatic controls are described in paragraph 3.6.3. Weekly, observe the control operation through one complete cycle. If the system includes an air-water pressure tank, check the water level in the tank to make certain it is not waterlogged. If it is waterlogged, drain it partially to restore the air cushion.

(1) Water Level Controls. Quarterly, check the float to make certain it moves freely, and adjust it as necessary. Check the cable (or rod); straighten or remove kinks and replace as necessary. Add light oil to pulleys or other moving parts if a rod connection is used.

(a) Semiannually, check the switches (see par. 4.10.5.1(2)) and all solenoids, contactors, relays and alarms.

(b) Annually, overhaul and test all parts. Test each unit for proper functioning. Disassemble and examine the interior parts of all valves, and control mechanisms. Check the packing and the stuffing boxes on valves and pivots. Reassemble the equipment, test and return it to service.

(c) Where tanks are involved in the system, annually apply a hydrostatic test at 150 percent of operating pressure.

(d) If a bubble pipe is used instead of a float, check the air dscharge pipe at quarterly intervals to assure that it is free, and check the air compressor system and the diaphragm switch. Clean, repair or renew worn parts when necessary.

(2) Pressure Controls

(a) At quarterly intervals, check the variout components of the control system, including the sensing device (a diaphragm, bellows or piston), all electrical controls, solenoids, contactors, relays and alarms.

(b) Annually, overhaul and test all parts, as described in paragraph 4.10.5.2(1)(b), and/or paragraph 4.10.5.2(1)(c).

(3) Instruments. See Chapter 4, Section 13.

4.10.6 STANDBY EQUIPMENT. Standby pumps and driving equipment must be inspected and serviced regularly. Maintenance schedules and procedures for standby equipment are the same as those for regular equipment, except that overhaul scheduling is variable, and not annually, as is often the case for many equipment items. Overhaul procedures should be followed about every third year, or oftener, if the equipment is used frequently. Maintenance of driving equipment is covered in Chatper 4, Section 11.

4.10.7 HOUSEKEEPING. Housekeeping is generally a part of operation (see par. 3.5.6.5), but whenever maintenance procedures are carried out, the maintenance personnel shall leave the equipment and surroundings in a clean condition.

4.10.8 MAINTENANCE PROCEDURE SCHEDULE. The maintenance operation frequency and schedule of inspections for pumping stations are presented in Table 40.

Section 11. DRIVING EQUIPMENT

4.11.1 TYPES OF EQUIPMENT. As pointed out in paragraph 3.5.4, driving equipment for pumps and other mechanical devices may be electric motors, gasoline engines, diesel engines or steam turbines. Maintenance procedures for these drivers are discussed in that order in this section.

4.11.2 ELECTRIC MOTORS. The material presented here on the maintenance procedures for motors is the minimum required with respect to timing and the action necessary. Maintenance personnel should compare these procedures with the manufacturer's instructions, and then prepare a specific maintenance timetable for each motor.

4.11.2.1 Inspection and Maintenance Records. Whatever the inspection or maintenance procedure, a log shall be kept of all inspection and maintenance actions. These records (see par. 4.1.4) shall be kept on file at the Utility Department.

4.11.2.2 Operator Inspection. Operators shall make inspections and necessary adjustments on a routine basis during their regular tours of duty. The frequency of these operator inspections shall be determined by the Public Works Officer. Operators shall report, immediately, any irregularities in operation. The following procedures are a part of operator inspection.

4.11.2.2.1 Operating conditions. At least once each shift, or more often if directed, the operator shall check for and report any unusual operating conditions to the Public Works Officer or other authority, unless he is authorized to take necessary corrective action. He should follow these procedures.

(1) Note any indications of excessive vibration that might be caused by unbalanced equipment or loose holding-down bolts.

(2) Check the bearing lubrication.

(3) Check for overheating as indicated by discoloration, bluing of the copper or other visual evidence, or by heat radiated to the hand, or registered by a thermometer.

(4) Check to make certain that the commutator and the collector rings run true, that all brushes ride freely in the brush holders, and that there is no chattering of brushes.

(5) Inspect for leakage of lubricant from the generator, exciter or motor bearings, as shown by oil or grease on the shaft extensions, or lubricant creeping toward the windings.

(6) Check for blackened commutator, and intermittent, continuous or excessive sparking at the commutator or brushes.

(7) Check for fine dust under the couplings with rubber buffers or pins.

(8) Check for smoke, charred insulation or solder whiskers extending from the armature.

(9) Listen for excessive hum, regular clicking, rapid knocking and chatter in the brushes.

(10) Check for loose electrical connections.

4.11.2.3 Motor Conditions. In addition to the above inspection procedures, also make weekly checks to assure that the motor is free from dirt and moisture, and that the operating space is free from dirt, dust, chips and any loose gear which may interfere with ventilation or may jam moving parts. Quarterly, clean and with compressed air.

4.11.2.3.1 Mountings. Quarterly, check coupling bolts and foundation bolts for tightness. Make certain that all covers and cover-holding bolts are in place and properly secured.

4.11.2.3.2 Electrical connections. Quarterly, check all connections, including the coil fastenings, for proper placement, and make certain that the connections of the field leads into the pole windings and the collectors, the connections between the poles, and the connections between stator leads and line cables are tight.

4.11.2.3.3 Windings and insulation. Annually, check the rotor and stator windings; clean and repair when necessary.

(1) Check the windings for moisture by using a megger to measure the insulation resistance. If moisture is found to be excessive by established standards, do not operate the motor until the windings have been dried by circulating small electric currents in the windings or by hot-air circulation.

(2) Defective windings may be caused by open circulating or shorting of adjacent windings.

(a) Shorted or burned-out windings should be replaced by new ones.

(b) Open circuits in windings should be resoldered.

(c) Reinsulate and paint with two or more coats of air-drying varnish.

4.11.2.3.4 Rotor. Quarterly, check the rotor (squirrel cage) for heating and broken or loose bars. Check the vent-fan blades for looseness or misalinement.

TABLE 40

Maintenance Procedures for Pumping Stations

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Buildings	See Reference 13		4.10.2
Valves	Also see Ch. 4, Sec. 5; and Table 31		4.10.3
	Check operation	Q	4.10.3(1)
	Check packing glands, tighten or replace packing as necessary.	Q	4.10.3(2)
	Paint	A	4.10.3(3)
	Dismantle and repair as necessary	V	4.10.3(4)
Piping	Paint; color code or otherwise identify	A	4.10.4
Pump controls			4.10.5
Manual			4.10.5.1
Valves	See table 31		4.10.5.1(1)
Switches	Check for binding and arcing; clean, repair or replace.	SA	4.10.5.1(2)
Instruments	See table 48		4.10.5.1(3)
Automatic	Observe operation through one complete cycle and adjust as necessary.	W	4.10.5.2
Water level	Check float, cable (or rod); adjust and oil, where necessary.	Q	4.10.5.2(1)
	Check switches, solenoids, contactors, relays and alarms; clean, adjust and repair or replace as necessary.	SA	4.10.5.2(1)(a)
	Overhaul and test all parts for proper functioning; disassemble and clean components; check packing of valves and pivots; repack as necessary; reassemble, test and return to service.	A	4.10.5.2(1)(b)
	Apply hydrostatic test to pressure tank if one is used; check water level.	A	4.10.5.2(1)(c)
	Check bubble pipe, compressor system, and diaphragm switch; clean, repair or replace worn parts.	Q	4.10.5.2(1)(d)
Pressure	Check all components for proper operation	Q	4.10.5.2(2)(a)
	Overhaul and test all parts (see par. 4.10.5.2(1)(b) and/or par. 4.10.5.2(1)(c)).	A	4.10.5.2(2)(b)
	Check instruments (see CH. 4, Sec. 13)		4.10.5.2(3)
Standby equipment	Check on same schedule as operating units; overhaul.	V	4.10.6
Housekeeping	Clean up after all maintenance operations on all equipment.	V	4.10.7

[1] W-Weekly; Q-Quarterly; SA-Semiannually; A-Annually; V-Variable; as conditions may indicate.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

(1) Semiannually, check the rotor surface for marks which may indicate foreign matter in the air gap, or worn bearings.

(2) Semiannually, turn over the rotor by hand to be sure there is sufficient clearance.

(a) Check the air gap with a feeler gage to prevent bearing wear which might permit the rotor to rub against the laminations. These measurements should be made on the shaft end of the rotor.

(b) Four measurements should be taken approximately 90 degrees apart, one of these points being on the load side, that is, the point on the rotor periphery which corresponds with the load side of the bearing.

(c) A comparison of the measurements with those previously recorded will permit the early detection of bearing wear.

(3) Semiannually, check the wound rotors for dirt and grime around the collector rings,

washers and connections. Check all connections and wedges for tightness.

4.11.2.3.5 Commutators and brushes. Semiannually, check, clean and repair as necessary.

(1) Check the commutator surfaces for high mica or high bars and for evidences of roughness or scratches. Clean out the slots and undercut mica where necessary. Rub down the commutator where necessary.

(2) Check the collector rings for cleanliness. Polish the surface when necessary.

(3) Check the brushes, and clean and adjust when necessary.

(a) Make certain the brushes have no tendency to stick in the brush holders.

(b) Assure that the brushes are properly located and that they seat squarely, with no part overhanging the edges of the rings.

(c) Make certain that the pigtails do not interfere with the brush rigging or with each other.

(4) Check the brush pressure, and adjust it as necsssary to agree with the value recommended in the manufacturer's instruction book; or use a brush pressure of approximately 2 psi of brush area.

4.11.2.4 Bearings. Procedures for both sleeve and antifriction bearings are covered in the following material.

4.11.2.4.1 Sleeve bearings. Weekly, check all bearing temperatures. Check the lubrication of oil ring lubricated bearings.

(1) Check the oil level and replenish it as necessary; remedy any lubricant leakage.

(2) Make certain that the rings turn freely, have no tendency to stick or bind and are carrying oil.

(3) In forced-feed lubricated bearings, observe through the sight-flow gage whether or not the oil is flowing freely to and from the bearings.

(4) If the oil rings become jammed and do not turn freely on the shaft, they must be cleaned and polished, and then checked for freedom of rotation.

(a) Flush the bearing oil reservoir and add new oil.

(b) Wipe the sight-glass tube clean and, if cracked, replace it with a new one.

4.11.2.4.2 Antifriction bearings. Weekly, check the bearing temperatures. At semiannual intervals, flush the antifriction bearings on the horizontal shafts. Use the following manner if the bearing housing is equipped with a drain plug.

(1) Clean the housing and both the grease and the relief fittings.

(2) Remove the grease from the relief plug hole in the bottom of the housing to allow for the easy removal of the old grease in the bearing when the solvent is added.

(3) While the motor is running, inject the grease solvent from a syringe into the bearing housing through the pressure-fitting hole. Continue the addition of solvent until all grease has drained out and clear solvent comes from the relief hole.

(a) Operate the motor intermittently during this procedure, but use care not to operate it long enough to damage the bearing without lubrication.

(b) Replace the grease and relief plug fittings.

(4) Refill the bearing housing in the following manner, after cleaning the pressure-gun fittings, bearing housing, and grease plug, to assure that no dirt gets into the bearing when grease is added:

(a) Before using a grease gun, remove the relief plug to prevent the rupture of the bearing seals because of excessive pressure in the housing. Be sure the relief plug opening is not stopped with hardened grease. (If so, remove it with a screw driver.)

(b) Start the motor; add grease with a hand-operated pressure gun, until the grease flows from the relief hole. In adding grease while the motor is running is dangerous, operate the motor intermittently while grease is being added. Do not overgrease.

(c) Stop the motor and replace the relief plug tightly with a wrench.

4.11.2.4.3 Bearing overhaul. For the most satisfactory service, it is desirable to open a bearing housing once a year, or after every 5,000 hours of operation, to inspect the condition of the bearings.

(1) If the bearings are worn, replace them with new ones. Use only bearings recommended by the manufacturer.

(2) Add new oil or grease, and aline and tighten the bearing caps carefully in order to insure proper rotor clearance.

4.11.2.5 Control Equipment. Control equipment includes switchboards, panel boards, control boards, pilot lights, circuit breakers and transformers.

4.11.2.5.1 General maintenance. Maintenance of de-energized equipment should not be limited to visual examinations, but should include weekly touching and shaking of electrical connections and mechanical parts to make sure that the former are tight and the latter are free to function. The following applicable procedures should also be performed weekly.

(1) Fasten bus supports which have become loosened, and clean the bus work if dust or other foreign material is present.

(2) Perform regular housekeeping chores.

(a) Do not leave loose tools or other objects in or around switchboard or control panels.

(b) Keep all safety appliances, such as grabrods, guard rails, safety signs and rubber matting in place and firmly fastened.

4.11.2.5.2 Pilot lights and alarms. It is essential that pilot lights be kept in good order so they will not fail in an emergency.

(1) Each shift, check all lights. Replace defective or burned out bulbs by new ones.

(2) Monthly, check mounting screws and connections for tightness. Tighten as necessary.

(3) Monthly, clean pilot light jewels, base assemblies, sockets and bulbs. Especially, check contact surfaces as most pilot lights operate on low voltage.

(4) Monthly, operate all control and safety alarm circuits. Repair as necessary.

4.11.2.5.3 Circuit breakers.

(1) Weekly, check the operation of the circuit breakers on the main switchboard. Make repairs when necessary.

(2) Monthly, check *all* circuit breakers.

(3) Semiannually, change the oil in the circuit breaker dashpots and recondition the contacts. Tighten electrical connections and mounting bolts. CAUTION: Before working on a circuit breaker, all of its connecting control circuits should be deenergized. Also, draw-out circuit breakers must be switched to the open position and removed before any work is done on them. Disconnecting switches ahead of fixed-mounted circuit breakers must be opened before any work is done on the breaker. When a disconnecting switch is not used, the supply bus to the circuit breaker must be deenergized before the circuit breaker is checked, adjusted or repaired.

4.11.2.5.4 Switchboards. The main switchboard should be cleaned semiannually, using the following procedures.

(1) Check the tightness of electrical connections.

(2) Measure and record the insulation resistance and temperature of all cables.

4.11.2.5.5 Controllers, relays, and panel boards

(1) Semiannually, recondition the contacts of all relays.

(2) Annually,clean all controllers, relays and panel boards. Tighten electrical connections and mounting bolts, and remedy defects when necessary.

4.11.2.5.6 Transformers. Annually, all transformers should be cleaned and hold-down bolts and electrical connections tightened.

4.11.2.5.7 Exposed equipment. Semiannually, the oeprator should check receptacles, junction boxes and fittings that are exposed to the weather for tightness of mounting bolts, defective gaskets, corrosion and cracked covers or parts. Unfavorable conditions should be corrected when necessary.

4.11.2.6 Troubleshooting. Troubleshooting may be done by the operator or maintenance personnel. In either case, the recognition of symptoms and the causes of the trouble are important. For a check list of troubleshooting symptoms, causes and remedies, see table 41, 42 and 43.

4.11.2.7 Maintenance Procedure Schedule for Electric Motors. The maintenance operation frequency and schedule of inspections for electric motors and auxiliary equipment are presented in Table 44.

4.11.3 GASOLINE ENGINES. Gasoline engines used as standby power must be operated weekly. The engine should be run for at least 15 minutes, under load if practicable. (See Reference 11 for information additional to that given in the following paragraphs.)

4.11.3.1 Inspection and Maintenance Records. Whatever the inspection or maintenance procedure, a log shall be kept of all inspection and maintenance actions. These records (see par. 4.1.4) shall be kept on file in the Utility Department office.

4.11.3.2 Operator Inspection and Service. Where these engines are in continuous operation, operators shall make inspections and service the equipment on a routine basis during their regular tours of duty. The frequency of these operator inspections shall be determined by the Public Works Officer. Operators shall report immediately any irregularities in operation. Where these engines are used as standby power, they must be inspected and serviced both before startup and after shutdown.

4.11.3.3 Standby and Startup Service. The following checks and service are to be performed before putting a gasoline engine into operation. Check for tampering or damage to the equipment, such as accessories loosened or removed, or loosened drive belts.

4.11.3.3.1 Before startup.

(1) Fire Extinguishers. Check fire extinguishers for ease of removal and tight mountings, full charge and closed valves. Make certain that valves and nozzles are not corroded or damaged.

(2) Fuel Tanks. Check fuel content in tanks and note indications of fuel leakage in fuel systems or tampering with the fuel system. Report any unusual change in fuel tank content to the proper authority. Add fuel as necessary. If the fuel pipe is frozen, melt the ice by wrapping pipe with cloth soaked in hot water. CAUTION: Do not thaw pipe with an open flame.

(3) Oil Reservoirs. Check the oil level in the reservoir and add oil if necessary. Check for oil leaks from engine crankcase, oil filter, oil tanks and oil cooler.

(4) Cooling system. Check the water in the cooling system and inspect for leaks. During the season when antifreeze is used, test coolant with hydrometer; add antifreeze and/or water, if necessary. Do not use alkali water.

(5) Accessories and Drives. Check for loose connections or mountings on carburetor, genera-

TABLE 41

Troubleshooting Chart for Electric Motors
AC and DC Motor Check Chart

Symptom	Cause of trouble	Remedy
Hot bearings, general	Bent or sprung shaft	Straighten or replace shaft.
	Excessive belt pull	Decrease belt tension.
	Pulley too far away	Move pulley closer to bearing.
	Pulley diameter too small	Use larger pulleys.
	Misalinement	Correct by realinement of drive.
Hot bearings, sleeve	Oil grooving in bearing obstructed by dirt.	Remove bracket or pedestal with bearing and clean oil grooves and bearing housing; renew oil.
	Bent or damaged oil rings	Repair or replace oil rings.
	Oil too heavy	Use a recommended lighter oil.
	Oil too light	Use a recommended heavier oil.
	Insufficient oil	Fill reservoir to proper level in overflow plug with motor at rest.
	Too much end thrust	Reduce thrust induced by driven machine or supply external means to carry thrust.
	Badly worn bearing	Replace bearing.
Hot bearings, ball	Insufficient grease	Maintain proper quantity of grease in bearing.
	Deterioration of grease or lubricant contaminated.	Remove old grease, wash bearings thoroughly in kerosene and replace with new grease.
	Excess lubricant	Reduce quantity of grease; bearing should not be more than half filled.
	Heat from hot motor or external source.	Protect bearing by reducing motor temperature.
	Overloaded bearing	Check alinement, side thrust and end thrust.
	Broken ball or rough races	Replace bearing; first clean housing thoroughly.
Oil leakage from overflow plugs.	Stem of overflow plug not too tight.	Remove, recement threads, replace and tighten.
	Cracked or broken overflow plug.	Replace the plug.
	Plug cover not tight	Requires cork gasket; or if screw type, it may be tightened.
Motor dirty	Ventilation blocked, end windings filled with fine dust or lint.	Clean motor will run 10° to 30° C. cooler; dismantle entire motor and clean all windings and parts.
	Rotor winding clogged	Clean, grind and undercut commutator; clean and treat windings with good insulating varnish.
	Bearing and brackets coated inside.	Dust and wash with cleaning solvent.
Motor wet	Subject to dripping	Wipe motor and dry by circulating heated air through motor; install drip- or canopy-type covers over motor for protection.
	Drenched condition	Motor should be covered to retain heat and the rotor position shifted frequently.
	Submerged in flood waters	Dismantle and clean parts; bake windings in oven at 105° C. for 24 hours or until resistance to ground is sufficient; first make sure commutator bushing is drained of water.

TABLE 42

Troubleshooting Chart for Electric Motors
AC Motor Check Chart

Symptom	Cause of trouble	Remedy
Motor stalls	Wrong application	Change type or size; consult manufacturer.
	Overloaded motor	Reduce load.
	Low motor voltage	See that nameplate voltage is maintained.
	Open circuit	Fuses blown; check overload relay, starter and pushbutton.
	Incorrect control resistance of wound rotor.	Check control sequence; replace broken resistors; repair open circuits.
Motor connected, but does not start.	One phase open; motor may be overloaded.	See that no phase is open; reduce load.
	Rotor defective	Look for broken bars or rings.
	Poor stator coil connection	Remove end bells; locate with test lamp.
Motor runs and then dies down.	Power failure	Check for loose connections to line, fuses and control.
Motor does not come up to speed.	Not applied properly	Consult supplier for proper type.
	Voltage too low at motor terminals because of line drop.	Use higher voltage on transformer terminals or reduce load.
	If wound rotor, improper control operation of secondary resistance.	Correct secondary control.
	Starting load too high	Check load that motor is supposed to carry at start.
	Low pull-in torque of synchronous motor.	Change rotor starting resistance or change rotor design.
	Assure that all brushes are riding on rings	Check secondary connections; leave no leads poorly connected.
	Broken rotor bars	Look for cracks near the rings; a new rotor may be required as repairs are usually temporary.
	Open primary circuit	Locate fault with testing device and repair.
Motor takes too long to accelerate.	Excess loading	Reduce load.
	Poor circuit	Check for high resistance.
	Defective squirrel-cage rotor	Replace with new rotor.
	Applied voltage too low	Increase voltage tap.
Wrong rotation	Wrong sequence of phases	Reverse connections of motor or at switchboard.
Motor overheats while running under load.	Check for overload	Reduce load.
	Wrong blowers, or air shields may be clogged with dirt and preventing proper ventilation of motor.	Good ventilation is manifest when a continuous stream of air leaves the motor; if not check manufacturer.
	Motor may have one phase open	Make sure that all leads are well connected.
	Grounded coil	Locate and repair.
	Unbalanced terminal voltage	Check for faulty leads, connections and transformers.
	Shorted stator coil	Repair and then check watt meter reading.
	Faulty connection	Indicate by high resistance.
	High voltage	Check terminals of motor with voltmeter.
	Low voltage	Check terminals of motor with voltmeter.
	Rotor rubs stator bore	If not poor machining, replace worn bearings.

TABLE 42 (Continued)

Symptom	Cause of trouble	Remedy
Motor vibrates after corrections have been made.	Motor misalined	Realine.
	Weak foundations	Strengthen base.
	Coupling out of balance	Balance coupling.
	Driven equipment unbalances	Rebalance driven equipment.
	Defective ball bearing	Replace bearing.
	Bearings not in line	Line up properly.
	Balancing weights shifted	Rebalance rotor.
	Wound rotor coils replaced	Rebalance rotor.
	Polyphase motor running single-phase.	Check for open circuit.
	Excessive end play	Adjust bearing or add washer.
Unbalanced line current on polyphase motors during normal operation.	Unequal terminal volts	Check leads and connections.
	Single phase operation	Check for open contacts.
	Poor rotor contacts in control wound rotor resistance.	Check control devices.
	Brushes not in proper position in wound rotor.	See that brushes are properly seated and shunts in good condition.
Scraping noise	Fan rubbing air shield	Remove interference.
	Fan striking insulation	Clear fan.
	Loose on bedplate	Tighten holding bolts.
Magnetic noise	Air gap not uniform	Check and correct bracket fits or bearing.
	Loose bearings	Correct or renew.
	Rotor unbalance	Rebalance.

TABLE 43

Troubleshooting Chart for Electric Motors
DC Motor Check Chart

Symptom	Cause of trouble	Remedy
Fails to start	Circuit not complete	Switch open, leads broken.
	Brushes not down on commutator.	Held up by brush springs, need replacement; brushes worn out.
	Brushs stuck in holders	Remove sand, clean up brush boxes.
	Armature locked by frozen bearings in motor or main drive.	Remove brackets and replace bearings or recondition old bearings, if inspection makes possible.
	Power may be off	Check line connections to starter with light; check contacts in starter.
Motor starts, then stops and reverses direction of rotation.	Reverse polarity of generator that supplies power.	Check generating unit for cause of changing polarity.
	Shunt and series fields are bucking each other.	Reconnect either the shunt or series field to correct the polarity; then connect armature leads for desired direction of rotation; the fields can be tried separately to determine the direction of rotation individually and connected so both give same rotation.
Motor does not come up to rated speed.	Overload	Check bearing to see if in first-class condition with correct lubrication; check driven load for excessive load or friction.
	Starting resistance not all out	Check starter to see if mechanically and electrically in correct condition.
	Voltage low	Measure voltage with meter and check with motor nameplate.
	Short circuit in armature windings or between bars.	For shorted armature, inspect commutator for blackened bars and burned adjacent bars. Inspect windings for burned coils or wedges.
	Starting heavy load with very weak field.	Check full field relay and possibilities of full field setting of the field rhetostat.
	Motor off neutral	Check for factory setting of brush rigging, or test motor for true neutral setting.
	Motor cold	Increase load on motor so as to increase its temperature, or add field rheostat to set speed.
Motor runs too fast	Voltage above rated	Correct voltage or get recommended change in air gap from manufacturer.
	Load too light	Increase load or install fixed resistance in armature circuit.
	Shunt field coil shorted	Install new coil.
	Shunt field coil reversed	Reconnect coil leads in reverse.
	Series coil reversed	Reconnect coil leads in reverse.
	Series field coil shorted	Install new or repaired coil.
	Neutral setting shifted off neutral.	Reset neutral by checking factory setting mark or testing for neutral.
	Part of shunt field rheostat or unnecessary resistance in field circuit.	Measure voltage across field and check with nameplate rating.
	Motor ventilation restricted causing hot shunt field.	Hot field is high in resistance, check causes for hot field; in order restore normal shunt field current.

TABLE 43 (Continued)

Symptom	Cause of trouble	Remedy
Motor gaining speed steadily; increasing load does not slow it down.	Unstable speed load regulation	Inspect motor to see if off neutral; check series field to determine shorted turns; check if series field has a shunt around the series circuit that can be removed.
	Reversed field coil shunt or series.	Test with compass and reconnect coil.
	Too strong a commutating pole, or commutating pole air gap too small.	Check with factory for recommended change in coils or air gap.
Motor continuously runs too slowly.	Voltage below rated	Measure voltage and try to correct to value on motor nameplate.
	Overload	Check bearings of motors and the drive to see if in first-class condition; check for excessive friction in drive.
	Motor operates cold	Motor may run 20% slow because of light load; install smaller motor, increase load or install partial covers to increase heating.
	Neutral setting shifted	Check for factory setting of brush rigging or test for true neutral setting.
	Armature has shorted coils or commutator bars.	Remove armature to repair shop, and put in first-class condition.
Motor overheats or runs hot.	Overloaded and draws 25% to 50% more current than rated.	Reduce load by reducing speed or gearing in the drive or loading in the drive.
	Voltage above rated	Motor runs drive above rated speed requiring excessive horsepower; reduce voltage to nameplate rating.
	Inadequately ventilated	Location of motor should be changed, or restricted surroundings removed; covers used for protection are too restricting of ventilating air and should be modified or removed; open motors cannot be totally enclosed for continuous operation.
	Draws excessive current because of shorted coil; grounds in armature, such as two grounds which constitute a short.	Repair armature coils or install new coil; locate grounds and repair or rewind with new set of coils.
	Armature rubs pole faces because of off-center rotor causing friction and excessive current.	Check brackets or pedestals to center rotor and determine condition of bearing wear for bearing replacement.
(a) Hot armature	Core hot in one spot indicating shorted punchings and high iron loss.	Sometimes full slot metal wedges have been used for balancing; these should be removed and other means of balancing investigated.
	Punchings uninsulated; punchings have been turned or band grooves machined in the core; machined slots.	No-load running of motor will indicate hot core and drawing high no-load armature current; Replace core and rewind armature; if necessary to add band grooves, grind into core; check temperature on core with thermometer not to exceed 90° C.
	Bush tension too high	Limit pressure to from 2 to 2½ psi; check brush density recommended by the brush manufacturer.

TABLE 43 (Continued)

Symptom	Cause of trouble	Remedy
(b) Hot commutator.	Brushes off neutral	Reset neutral.
	Brush grade too abrasive	Get recommendation from manufacturer.
	Shorted bars	Investigate commutator mica and undercutting, and repair.
	Hot core and coils that transmit heat to commutator.	Check temperature of commutator with thermometer to see that total temperature does not exceed ambient plus 55° C. rise, total not to exceed 105° C.
	Inadequate ventilation	Check as for hot motor.
(c) Hot fields	Voltage too high	Check with meter and thermometer and correct voltage to nameplate value.
	Shorted turns or grounded turns.	Repair or replace with new coil.
	Resistance of each coil not the same.	Check each individual coil for equal resistance within 10%, and if one coil is too low, replace coil.
	Inadequate ventilation	Check as for hot motor.
	Coil not large enough to radiate its loss wattage.	New coils should replace all coils if room is available in motor.
Motor vibrates and indicates unbalance.	Armature out of balance	Remove and statically balance or balance in dynamic balancing machine.
	Misalinement	Realine.
	Loose or eccentric pulley	Tighten pulley on shaft or correct eccentric pulley.
	Belt or chain whip	Adjust belt tension.
	Mismating of gear and pinion	Recut, realine or replace parts.
	Unbalance in coupling	Rebalance coupling.
	Bent shaft	Replace or straighten shaft.
	Foundation inadequate	Stiffen mounting place members.
	Motor loosely mounted	Tighten holding-down bolts.
	Motor feet uneven	Add shims under footpads to mount each foot tight.
Motor sparks at brushes or does not commutate.	Neutral setting not true neutral	Check and set on factory setting or test for true neutral.
	Commutator rough	Grind and roll edge of each bar.
	Commutator eccentric	Turn and grind commutator.
	Mica high—not undercut	Undercut mica.
	Commutating pole strength too great, causing overcompensation, or strength is too weak indicating undercompensation.	Check with manufacturer for correct change in air gap or new coils for the commutating coils.
	Shorted commutating pole turns.	Repair coils or install new coils.
	Shorted armature coils on commutator bars.	Repair armature by putting into first-class condition.
	Open-circuited coils	Same as above.
	Poor soldered connection to commutator bars.	Resolder with proper alloy of tin solder.
	High bar or loose bar in commutator at high speeds.	Inspect commutator nut or bolts and retighten and grind commutator face.

TABLE 43 (Continued)

Symptom	Cause of trouble	Remedy
	Brush grade wrong type; brush pressure too light, current density excessive or brushes stuck in holders; brush shunts loose.	See par. 4.11.2.3.5.
	Brushes chatter because of dirty film on commutator.	Resurface commutator face and check for change in brushes.
	Vibration	Eliminate cause of vibration by checking mounting and balance of rotor.
Brush wear excessive	Brushes too soft	Blow dust from motor and replace brushes with a changed grade as recommended by manufacturer.
	Commutator rough	Grind commutator face.
	Abrasive dust in ventilating air.	Reface brushes and correct condition by protecting motor.
	Off neutral setting	Recheck factory neutral or test for true neutral.
	Bad commutation	See corrections for commutation.
	High, low or loose bar	Retighten commutator motor bolts and resurface commutator.
	Brush tension excessive	Adjust spring pressure not to exceed 2 to 2½ psi.
	Electrical wear owing to loss of film on commutator face.	Resurface brush faces and commutator face.
	Threading and grooving	Same as above.
	Oil or grease from atmosphere or bearings.	Correct oil condition and surface brush faces and commutator.
	Weak acid and moisture laden atmosphere.	Protect motor by changing ventilating air, or change to enclosed motor.
Motor noisy	Brush singing	Check brush angle and commutator coating; resurface commutator.
	Brush chatter	Resurface commutator and brush face.
	Motor loosely mounted	Tighten foundation bolts.
	Foundation hollow and acts as sounding board.	Coat underside with soundproofing material.
	Strained frame	Shim motor feet for equal mounting.
	Armature punching loose	Replace core on armature.
	Armature rubs pole faces	Recenter by replacing bearings or relocating brackets or pedestals.
	Magnetic hum	Refer to manufacturer.
	Belt slap or pounding	Check condition of belt and change belt tension.
	Excessive current load	May not cause overheating, but check chart for correction of shorted or grounded coils.
	Mechanical vibration	Check chart for causes of vibration.
	Noisy bearings	Check alinement, loading of bearings and lubrication; and get recommendation of manufacturer.

TABLE 44

Maintenance Procedures for Electric Motors and Auxiliary Equipment

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Operating conditions	Check for excessive vibrations; remedy as necessary.		
	Check bearing lubrication; check for leakage		
	Check for overheating		
	Check commutator and brushholder	Every 8 hours.	4.11.2.2.1
	Check couplings with rubber buffers or pins		
	Check insulation for charring		
	Check sound for excessive hum, checking or chatter.		
Motor conditions	Check for dirt or moisture; make certain operating space is free from dirt, chips and loose gear, which may reduce ventilation.	W	4.11.2.3
	Clean motor with compressed air	Q	4.11.2.3
Mountings	Check coupling and foundation bolts, also covers and cover bolts; tighten as necessary.	Q	4.11.2.3.1
Electrical connections.	Check for proper placement and tightness; tighten as necessary.	Q	4.11.2.3.2
Winding and insulation.	Check rotor and stator windings for moisture and defects; dry out, clean, repair and varnish.	A	4.11.2.3.3
Rotor	Check for heating and broken or loose bars; check vent fan.	Q	4.11.2.3.4
	Check rotor surface for marks; clean or adjust as necessary.	SA	4.11.2.3.4(1)
	Check air gap; adjust or repair as necessary	SA	4.11.2.3.4(2)
	Check for dirt or grime around collector rings	SA	4.11.2.3.4(3)
Commutators and brushes.	Check, clean, and repair as necessary; check for high surfaces; rub down as necessary.	SA	4.11.2.3.5(1)
	Polish collector ring surface as necessary	SA	4.11.2.3.5(2)
	Check brushes; adjust to prevent sticking; check location and seating; adjust as necessary.	SA	4.11.2.3.5(3)
	Check pigtails; make certain they do not interfere with brush rigging.	SA	4.11.2.3.5(3)(c)
	Check brush pressure; adjust to proper value	SA	4.11.2.3.5(4)
Bearings:			4.11.2.4
Sleeve bearings	Check bearing temperatures; check lubrication	W	4.11.2.4.1
Antifriction bearings.	Check bearing temperature	W	4.11.2.4.2
	Flush bearings and add new grease	SA	4.11.2.4.2(1)(2)(3)(4)
Overhaul	Open bearing, clean, adjust or replace as necessary	A or V	4.11.2.4.3
Control equipment	Check electrical connections for tightness; check mechanical parts for freedom of movement; adjust as necessary; fasten any loose bus bars; clean up and remove any loose tools; check safety appliances; repair or replace as necessary.	W	4.11.2.5.1
Pilot lights and alarms.	Check all lights; replace any lights burned out	8 hours	4.11.2.5.2(1)
	Check mounting screws and connections for tightness; tighten as necessary.	M	4.11.2.5.2(2)
	Clean pilot light jewels, base assemblies, sockets, bulbs; particularly check contact points.	M	4.11.2.5.2(3)

TABLE 44 (Continued)

Inspection	Action	Frequency[1,2]	Reference Paragraph number
	Operate all control and safety alarm circuits	M	4.11.2.5.2(4)
Circuit breakers	Check operation of breakers on main switchboard	W	4.11.2.5.3(1)
	Check *all* circuit breakers	M	4.11.2.5.3(2)
	Change oil in circuit breakers dashpots and recondition contacts; tighten electrical connections. CAUTION: Deenergize circuit before any repair work.	SA	4.11.2.5.3(3)
Switchboards	Clean main switchboard; check tightness of electrical connections; check insulation resistance and temperature of cables.	SA	4.11.2.5.4
Controller, relays and panel boards.			4.11.2.5.5
	Recondition all contacts of all relays	SA	4.11.2.5.5(1)
	Clean; tighten electrical connections and bolts; remedy any condition below standard.	A	4.11.2.5.5(2)
Transformers	Clean; tighten hold-down bolts and electrical connections.	A	4.11.2.5.6
Exposed equipment	Check receptacles, junction boxes and fittings exposed to weather; check for tightness of mounting bolts, defective gaskets, corrosion, cracked covers and parts; remedy conditions below standard.	SA	4.11.2.5.7
Troubleshooting	See tables 41, 42 and 43		4.11.2.6

[1] W-Weekly; M-Monthly; Q-Quarterly; SA-Semiannually; A-Annually; V-Variable; as conditions may indicate.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

tor, regulator, starter, fan, fan shroud and water pump.

(6) Battery. Make certain that the battery is not leaking and that battery, cables and vent caps are clean and secure.

(7) Starter. Start the engine and observe the action of the starter mechanism. Make certain that the starter has adequate cranking speed, and engages and disengages properly without unusual noise.

4.11.3.3.2 After startup. Throttle the engine to normal (fast idle) warmup speed, then continue with the following procedures. CAUTION: Do not place the engine under load before it reaches the normal operating temperature as the engine may be damaged.

(1) Check the operation of the choker or primer. As the engine warms up, reset the choke to prevent overchoking and dilution of engine oil.

(2) Check all instruments in the following manner.

(a) Oil gage. Observe oil pressure gage or light indicator. If these instruments do not operate properly within 30 seconds, stop the engine immediately, investigate the cause and report the difficulty to the proper authority. Do not let the pressure drop below 10 psi at normal operating speed.

(b) Ammeter. The ammeter should show a higher charging rate immediately after engine startup, and then drop to zero, or show a slight positive charge with the accessories turned off at fast idle speed. Any extended high reading may indicate a dangerously low battery or faulty generator regulator. Any unusual drop or rise in ammeter reading may indicate a difficulty.

(c) Voltmeter. The voltmeter should register at least a nominal battery rating, usually indicated by a red line on the scale; if not, the battery needs recharging or replacement.

(d) Tachometer. Note if the tachometer indicates engine speed (in revolutions per minute) and varies with engine speed over the entire speed range.

(e) Fuel gage. Check the fuel gage for proper operation, and correct it if the operation is faulty.

(f) Temperature gage. If the temperature stays low after a reasonable warmup period, the engine cooling system or temperature control device needs a checkup. Do not operate the engine if the temperature range is above or below normal for any appreciable period of time.

(3) Check the engine operation using the following procedures.

(a) If the temperature is below normal, but the engine operates under load with the choke fully released and the oil pressure normal under acceleration, adjust coolant temperature controls to obtain proper temperature.

(b) Gradually, accelerate the engine several times, after it has reached normal operating temperature; investigate and correct any ususual noise or unsatisfactory operating characteristics. Check the operating temperature under load, and make any adjustments necessary.

4.11.3.4 Continuous Operation Service. This is an operating function, but should include checks on: (a) the clutch (for grabbing, chattering or squealing); (b) the transmission (for smooth, quiet operation without creep); (c) engine performance and controls (for lack of power, noise, stalling, overheating orexcessive exhaust smoke); and, (d) the instruments (for proper operation and readings).

4.11.3.5 Short-Stop Service. This type of service is also an operating function. It includes checks on fuel, oil and water; a check for leaks; a check on accessories and belts; and, checks on air cleaners. The necessary adjustments should be made.

4.11.3.6 Shutdown Service. When a gasoline engine is shut down, the following checks are required, with adjustment, repair or renewal as necessary. Also see paragraph 4.11.3.7, and consult the manufacturer's instructions.

(1) Fuel, Oil and Water. (See paragraph 4.11.3.3.1(2), (3) and (4)).

(2) Instruments (see par. 4.11.3.3.2(2)).

(3) Battery (see par. 4.11.3.3.1(6)).

(4) Accessories and Belts (see pars. 4.11.3.3.1 (5) and (7)).

(5) Electrical Wiring. Check insulation condition and connections.

(6) Air Cleaner and Breather Caps. Adjust oil level, or refill, when necessary.

(7) Fuel Filters. Turn and check for leaks; renew as necessary.

(8) Engine Controls. Check leakage for wear or damage.

(9) Gear-Oil Level. Check after cooling to hand touch.

4.11.3.7 Periodic Maintenance. The following maintenance procedures apply.

4.11.3.7.1 Accessories. Weekly, check and adjust loose connectoins, linkages, and the mountings of all accessories.

4.11.3.7.2 Air cleaners and breather caps

(1) Dry-Type Cleaners

(a) Weekly, remove and disassemble. Dip both body and element in kerosene; allow to drain dry. After cleaning, oil sparingly with crankcase oil; drain off excess oil and replace cleaner.

(b) Semiannually, remove all air-cleaner elements and make certain that all gaskets, seals, clamps and connecting hose or tubes are in good condition. Install new elements, baffles or body as necessary.

(2) Oil-Bath Cleaners

(a) Weekly, make certain that the oil is not excessively dirty and that the dirt does not occupy more than one-fourth of the capacity of the oil reservoir. Clean the oil cup and refill it to the proper level with crankcase oil. Wash the filter unit in kerosene; dry, reassemble and reinstall, with special attention given to mounting and alinement. Check the condition of the gaskets and replace them as necessary. If flexible steel tubing is used, wrap the connections securely. Make certain that all ducts from air cleaner to carburetor are secure and undamaged.

(b) Semiannually, check the level and cleanliness of the oil in the reservoir; drain, if necessary, and refill. Reinstall and check mounting. If the air cleaner has an external baffle, make certain that it is alined with the air stream from the fan. Clean the connecting hose and reinstall, properly clamped.

(3) Breather Caps and Ventilators

(a) Weekly, remove all breather caps and crankcase oil filter elements. Wash permanent-type filters thoroughly in kerosene, dip in crankcase oil, drain off and reinstall. Renew the filter elements where a throw-away type is used. Clean and service oil-bath breathers in the same manner as oil-bath air cleaners (see (2) above).

(b) Semiannually, see that the breather caps and ventilators are clean, in place, in good condition, correctly assembled and secure, and that the ventilator tubes are open.

4.11.3.7.3 Battery.

(1) Weekly, clean the top of the battery. If the terminal connections or posts are corroded, remove the connections and clean them thoroughly; apply a thin coating of grease. Tighten loose terminal bolts. Remove vent caps and check the electrolyte liquid level. Fill to the proper level when necessary. Add water as required. Check mounting and tighten to make it secure without damage to the battery case.

(2) Monthly, check the battery case for cracks or leaks. Clean the battery top; check the cables, terminals, bolts, posts, straps and hold-downs; adjust, repair or replace worn parts. Check the specific gravity of the electrolyte; if the reading is below 1.225, recharge or renew the battery. In addition, perform weekly maintenance procedures.

(3) Semiannually, if the specific gravity is above 1.225, perform a high-rate discharge test. Follow the instructions for a condition test which accompany the high-rate discharge instrument. Record the voltage; cell variation should be less than 30 percent.

4.11.3.7.4 Belts and pulleys

(1) Weekly, check the belts for fraying, wear, cracking or oil. Check belt deflection halfway between the pulleys, and adjust the tension if necessary.

(2) Monthly, in addition to the weekly check, make certain that the drive pulleys and hubs are in good condition and mounted securely.

4.11.3.7.5 Carburetor, choke, throttle, linkage and governor. Monthly, determine if these items are in good condition and securely installed. Make certain that the carburetor does not leak; that the control linkage is not worn; that the choke valve opens fully; that the idling speed adjustment is set properly; that the throttle valve opens fully when the accelerator is depressed; and, that the governor is secure and sealed. Clean and lubricate when necessary.

4.11.3.7.6 Coil and wiring.

(1) Weekly, check the wiring to make certain that it is securely connected; that the insulation is not cracked or chafed; and that the conduits and shielding are dry. Renew or report any unserviceable wiring.

(2) Monthly, check the coil for condition, cleanliness, mounting and terminals. Clean, repair or renew as necessary. Inspect all low-voltage wiring in the engine compartment. CAUTION: Do not tighten the wiring connections unless they are actually loose. Overtightening of terminals may cause damage.

4.11.3.7.7 Control rod. Weekly, clean and lubricate all control-rod points between the carburetor and the governor.

4.11.3.7.8 Crankcase.

(1) Weekly, check the crankcase oil level while the oil is warm, and add oil as necessary. If an oil change is necessary, drain the oil while it is hot, and refill. Be sure that the oil drain plug is replaced and tightened before oil is added. (On standby service, check oil after 64 hours of operation.)

(2) Monthly, while the engine is idling, check crankcase, valve covers, timing gear and clutch housing for oil leaks.

4.11.3.7.9 Clutch

(1) Monthly, check the clutch lever travel to make certain that the minimum free travel, before meeting resistance other than the pullback spring, is proper. Disengage the clutch completely; check for shifting without clash after a few seconds; if it clashes, the clutch is dragging.

(2) Operate the clutch at various speeds; listen for noises indicating dry or defective release bearing, clutch plate or pilot bearing. Jerky motion or sudden engagement indicates chatter or grabbing. Make repairs as soon as possible.

4.11.3.7.10 Distributor

(1) Monthly, carrying out the following procedures.

(a) Blow or wipe dust from distributor, body cap and external attachments. Remove cap; make certain that cap, rotor and breaker-plate assembly are in good condition, correctly assembled, secure and clean. Look for cracks, corrosion of terminals and connections, and for burning of outer ends of the conductor strap of the rotor. Correct any deficiencies.

(b) Make certain breaker points are well alined and adjusted to proper gap. If pitted, burned or worn, dress them with sandpaper or file them (but never with emery cloth); if badly pitted, install new points and replace condenser. Blow out sand or filings, if points are dressed.

(c) Check the breaker-plate assembly; if dirty, remove the distributor, dip it in kerosene or naptha; dry it with compressed air; lubricate the parts and reinstall them in the correct position, using care to keep any lubricant away from distributor points.

(d) Remove the wick and the lubrication cup; clean and dry them. Reinstall them after the distributor assembly is cleaned and blown dry with compressed air; then fill the cup with the proper lubricant.

(2) Semiannually, check the tightness of the distributor shaft by hand to determine if the camshaft is excessively worn in its bushing; renew it if necessary, and lubricate.

(3) Semiannually, make certain that the vacuum-advance mechanism and its vacuum lines are in good condition; that the mechanism can be moved by a finger through its normal range; that the diaphragm spring returns the mechanism to its original position when finger force is removed; and, that the mechanism does not bind or hang up. Adjust, repair or renew as necessary.

4.11.3.7.11 Engine

(1) Monthly, while the engine is operating, check for unusual noises (knocks, pings and rattles), acceleration, power and governed speed. Make any necessary adjustment, or report unusual conditions to higher authority.

(2) Monthly, check the cylinder head and gasket. Look for cracks or oil, water or compression leaks around studs, cap screws and gasket. Make the necessary corrections; renew the gasket head as necessary. Do not tighten the cylinder head unless there are signs of looseness or leaks. Follow the manufacturer's instructions in replacing the gasket or tightening the head.

(3) Monthly, make certain that the engine operates smoothly at idling speed. Connect the vacuum gage to the intake manifold and adjust the idling speed and idling mixture to give a steady maximum gage reading.

(4) Semiannually, make a vacuum test with the engine running at normal speed (see (3) above). The gage reading should be steady between 18 and 21 inches (at sea level). A fluctuating reading may mean a defective cylinder head gasket or valve. An extremely low reading may

indicate a leak in the intake manifold or the gasket. Follow the manufacturer's instructions for detailed procedures and remedies.

(5) Whenever the operating conditions indicate the need for attention, check the compression with all the spark plugs out. Insert a compression gage in the spark plug hole and rotate the engine at cranking speed, with wide open throttle, until the maximum compression is indicated. (The battery must be fully charged.) Check each cylinder, and follow the manufacturer's instructions with respect to remedies for low compression.

4.11.3.7.12 Fuel system

(1) Weekly, shut the valve to the fuel line, remove the drain plug of the fuel filter and drain water and sediment from the filter bowl. Replace the drain plug and tighten it; reopen the shutoff valve, and make certain there is no leakage.

(2) Monthly, check the fuel filter and sediment bowls, lines and connections. After closing shutoff valve, remove the filter bowl, gaskets and screens, and clean all parts in kerosene. Dry and reinstall with new gaskets. Flush the system, start the engine and check for leaks.

(3) Monthly, check the fuel pump and lines to make certain they do not vibrate or leak.

(4) Quarterly, remove gasoline in the tank, if it has been standing for some time, and fill the tank with fresh gasoline. If the tank or the fuel lines are gummed, remove the deposits with acetone or alcohol. If the gum has dried, scrape it out.

(5) Annually, check fuel pump pressure according to the manufacturer's instructions. Install a new pump if necessary. Run a pressure test on the new pump after installation.

4.11.3.7.13 Generator

(1) Weekly, check the generator and lubricate it according to the manufacturer's instructions.

(2) Monthly, check the condition of the generator and wiring. Remove the inspection cover and check the condition of commutators and brushes, and brush-connecting wires. Adjust as necessary.

(3) Semiannually, clean the commutator end of the generator with compressed air. If commutator is dirty, clean with fine (00) sandpaper, and blow out dust with compressed air.

4.11.3.7.14 Ignition

(1) Monthly, check the condition of the ignition switch, and clean as necessary.

(2) Whenever it appears necessary, check the ignition timing. Attach a neon timing light and make certain that the automatic spark controls advance the timing as the engine is accelerated gradually. Adjust the timing to conform with the manufacturer's instructions.

4.11.3.7.15 Instruments and gages.

(1) Weekly, inspect the ammeter, the voltmeter, the tachometer, and the temperature gage (see Paragraph 4.11.3.3.2(2)). Also check the oil gage while the engine is at full speed; make certain the pressure meets the manufacturer's specifications. If the oil pressure ever drops to zero, stop the engine immediately.

(2) Monthly, check the tachometer drive and adapter. Inspect the flexible drive shaft connections for oil leaks. Clean, adjust, repair or renew as necessary.

4.11.3.7.16 Manifold and heat control

(1) Monthly, check the intake and exhaust manifolds. Make certain that the gaskets are tight. If the heat control is manual, make certain that the heat control-adjusting pointer is set at the correct seasonal position. If the control is automatic, be sure that the bimetal control spring is in good condition and tightly connected to the heat control shaft and mounting. Also be sure that shaft operates freely, and that the spring controls the shaft and valve properly.

(2) Semiannually, check the entire manifold assembly—mounting, exhaust pipe and carburetor connecting flange nuts. Tighten all nuts evenly and securely.

4.11.3.7.17 Oil filters, coolers and lines

(1) Monthly, check the cartridge oil filter, cooler and external oil lines. Make certain there are no leaks. Change the oil cartridge as necessary, use new gaskets and tighten the cover securely.

(2) Monthly, on disk-type filters, turn the handle one complete turn, remove the drain plug and drain contents. Semiannually, clean and service disk-type oil filters. Remove the cover and the element and clean them in kerosene without disassembly. Replace if the element is in good condition, otherwise install a new element or an entire new filter assembly.

4.11.3.7.18 Power takeoff clutch. Quarterly (or after every eight hours of standby operation), lubricate the pilot bearings of the power takeoff clutch and the shaft-bearing throwout collar.

4.11.3.7.19 Radiator. Monthly, check the radiator core, shell, shutters, mountings, hose, cap, gasket, overflow tank and steam relief tube and valve.

(1) Clean the core air passages with compressed air, applied from the rear of the core (do not use steam). Straighten bent core fins, using care not to damage them.

(2) Check the coolant for rust, oil or other matter. If necessary, empty the cooling system, flush it and replace the coolant. If antifreeze is used, strain through a cloth if it is dirty, and return it to the system. Check the protective valve. Fill the system according to directions.

4.11.3.7.20 Spark plugs. Monthly, clean and check the spark-plug insulators and be sure there is no gas leakage around the insulator or gaskets. Whenever operating conditions appear to warrant

it, remove plugs and check for broken insulators, carbon deposits or electrodes burned thin. Clean deposits from electrodes and insulators; replace, if serviceable, or install new plugs if needed.

4.11.3.7.21 Starter

(1) Weekly, lubricate according to directions.

(2) Monthly, check condition and security of starter linkage and retracting spring. Lubricate where necessary. Remove starter inspection cover and check condition of commutator and brushes. Be sure the brushes operate properly, and adjust as necessary. Brush connecting wires should be tight and not chafing.

(3) Monthly, check the starter for action, noise and speed. Be sure the speed is adequate for cranking. If the starter is weak, repair or renew it as necessary.

(4) Semiannually, blow out the commutator end with compressed air. If the commutator is dirty, clean it with fine (00) sandpaper. Blow out sand dust with compressed air. Tighten the starter mounting bolts.

4.11.3.7.22 Universal joints

(1) Monthly (or after 256 hours of standby operation), inject grease into grease fittings at shaft points.

(2) Semiannually (or after 1024 hours of operation), disassemble, clean in solvent and lubricate all fittings.

4.11.3.7.23 Valve mechanisms

(1) Semiannually, adjust clearances to specifications. Make certain that all lock nuts are tight.

(2) Whenever the operating conditions appear to warrant, check the valve-tappet clearance on valve-in-head engines, while the engine is hot. Check valve tappets, rocker arms and spring. Adjust or renew as necessary. Be sure that oil is being delivered properly and that valve-cover gaskets are in good condition. On L-head engines, valve mechanism maintenance needs to be done only when valve noise or poor engine performance indicates a need.

4.11.3.7.24 Voltage and current regulator

(1) Monthly, check the condition of the regulator unit, adjust or repair as necessary.

(2) Semiannually, test voltage regulator, current regulator and cutout to make sure they are operating properly. Follow the directions accompanying the low-voltage circuit tester. Replace the voltage regulator if its operation is faulty.

4.11.3.7.25 Water pump, fan and shroud

(1) Monthly, check the water pump operation. Loosen drive belts and check the shaft for end play and loose bearings. Check the fan blades; make sure they are secured to the hub. Be sure the shroud is alined with the fan and is securely mounted. Tighten the drive belt to the proper tension.

(2) Monthly, tighten the gland nut with caution. Avoid overtightening which may cause scoring of the shaft and leakage.

4.11.3.8 Maintenance Procedure Schedule. The maintenance operation frequency and schedule of inspections for gasoline engines are presented in table 45.

4.11.4 DIESEL ENGINES. For the most part, the maintenance of diesel engines is similar to that of gasoline engines, except where details of design and operation differ. Consult the manufacturer's instructions and paragraph 4.11.3 to develop a maintenance procedure schedule.

4.11.5 STEAM POWER DRIVERS. Nearly all water works use electrified pumping equipment, unless the stations are old or there are other specific reasons for installing steam-powered units. For details on operation and maintenance procedures, see Reference 11.

4.11.5.1 Steam Turbines. Regular operator inspection is necessary with respect to lubrication. The sound of a turbine is the best indication of its proper operation. When any unusual noises develop, the turbine should be shut down and the matter reported to proper authority. Bearings require attention semiannually. Turbines in continuous operation should be dismantled annually, inspected, cleaned, adjusted and repaired as necessary, in accordance with the manufacturer's instructions.

4.11.5.2 Reciprocating Engines. Regular operator attention is necessary for proper lubrication. Where dashpot valves are used, monthly checks of operation are desirable. Packing glands should be tightened as often as necessary. Semiannually, the bearings should be checked, the piston rod examined for scoring and the packing renewed, if necessary. Annually, an efficiency test should be run on the engine, and all instruments and gages checked. A detailed maintenance procedure should be prepared from the manufacturer's instructions.

TABLE 45

Maintenance Procedures for Gasoline Engines

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Gasoline engines			4.11.3
Standby and start-up service.	Before startup, check the following items	V	4.11.3.3
	Fire extinguishers		4.11.3.3.1(1)
	Fuel tanks		4.11.3.3.1(2)
	Oil reservoirs		4.11.3.3.1(3)
	Cooling system		4.11.3.3.1(4)
	Accessories and drives		4.11.3.3.1(5)
	Battery		4.11.3.3.1(6)
	Starter		4.11.3.3.1(7)
	After startup, check following items	V	4.11.3.3.2
	Choke or primer		4.11.3.3.2(1)
	Instruments (oil gage, ammeter, voltmeter tachometer, fuel gage and temperature gage).		4.11.3.3.2(2)
	Engine operation		4.11.3.3.2(3)
Continuous operation service.	Operator service	V	4.11.3.4
Short-stop service	Operator service	V	4.11.3.5
Shut-down service	Check fuel, oil, water, instruments, battery, accessories, belts, wiring, air cleaner, fuel filters, engine controls and gear-oil level.	V	4.11.3.6
Periodic maintenance			4.11.3.7
Accessories	Check and adjust loose connections, linkages and mountings.	W	4.11.3.7.1
Air cleaners and breather caps.	Dry-type cleaners:	W	4.11.3.7.2(1)(a)
	Remove, disassemble; clean; dry and replace		
	Remove all elements; clean, check, replace or renew as necessary.	SA	4.11.3.7.2(1)(b)
	Oil-bath cleaners:	W	4.11.3.7.2(2)(a)
	Check for dirt, clean, dry, replace as necessary; check gaskets for leaks.		
	Remove, clean and check external baffle; clean hose and reinstall.	SA	4.11.3.7.2(2)(b)
	Breather caps and ventilation:	W	4.11.3.7.2(3)(a)
	Remove, clean as necessary; replace or renew		
	Check ventilators, tubes; perform weekly cleaning procedure.	SA	4.11.3.7.2(3)(b)
Battery	Clean top; check terminal posts, clean and apply thin coating of grease; tighten bolts, remove vent caps; check level; fill as necessary; check and tighten mounting.	W	4.11.3.7.3(1)
	Check case for cracks; check terminals, bolts, posts, straps; adjust and repair as necessary; check specific gravity; recharge or renew.	M	4.11.3.7.3(2)
	Perform high-rate discharge test	SA	4.11.3.7.3(3)
Belts and pulleys	Check belts for fraying, wear, cracking; check tension; adjust as necessary.	W	4.11.3.7.4(1)
	Check drive pulleys and hubs; adjust or repair as necessary.	M	4.11.3.7.4(2)

TABLE 45 (Continued)

Inspection	Action	Frequency [1,2]	Reference Paragraph number
Carburetor	Check for leaks, worn control linkage, proper idling speed, governor seal; clean, adjust, and lubricate as necessary.	M	4.11.3.7.5
Coil and wiring	Check wiring connections, insulation, conduits and shielding; clean, dry and adjust.	W	4.11.3.7.6(1)
	Check coil; clean, repair or renew; check low-voltage wiring.	M	4.11.3.7.6(2)
Control rod	Clean and lubricate	W	4.11.3.7.7
Crank case	Check oil level; add or renew oil as necessary	W	4.11.3.7.8(1)
	Check case, valve covers, timing gear, and clutch housing for leaks; remedy as necessary.	M	4.11.3.7.8(2)
Clutch	Check lever travel; check for clash on shifting; remedy as necessary.	W	4.11.3.7.9(1)
	Operate clutch at several speeds; check for noise, jerky action; make repairs as soon as possible.	M	4.11.3.7.9(2)
Distribution	Clean, remove cap, check for cracks, corrosion, etc.; remedy unusual conditions; check and aline breaker points and breaker plate assembly; clean, lubricate and reinstall or renew parts.	M	4.11.3.7.10(1)
	Check tightness of distributor shaft and adjust as necessary.	SA	4.11.3.7.10(2)
	Check vacuum-advance mechanism; adjust, repair or renew as necessary.	SA	4.11.3.7.10(3)
Engine	Check for engine noise; adjust or report to higher authority; check cylinder head gasket for leaks or cracks; renew as necessary.	M	4.11.3.7.11(1)(2)(3)
	Run vacuum test on engine; adjust or repair as necessary.	SA	4.11.3.7.11(4)
	Check compression in each cylinder	V	4.11.3.7.11(5)
Fuel system	Drain fuel filter to remove water and sediment	W	4.11.3.7.12(1)
	Remove elements of filter; clean, dry, reinstall with new gaskets; check fuel pump lines for leaks.	M	4.11.3.7.12(2)(3)
	Replace gasoline in tank, if it has stood for some time; remove gum in tank or fuel lines.	Q	4.11.3.7.12(4)
	Check pump discharge pressure; renew pump if necessary.	A	4.11.3.7.12(5)
Generator	Lubricate according to directions	W	4.11.3.7.13(1)
	Check wiring; check commutators, brushes, etc.; adjust as necessary.	M	4.11.3.7.13(2)
	Clean commutator	SA	4.11.3.7.13(3)
Ignition	Check and clean switch	M	4.11.3.7.14(1)
	Check timing and adjust	V	4.11.3.7.14(2)
Instruments and gages.	Check ammeter, voltmeter, tachometer, temperature gage (see Paragraph 4.11.3.3.2(2)); check oil pressure; remedy difficulties as necessary.	W	4.11.3.7.15(1)
	Check tachometer drive and adapter; clean, adjust, repair or renew as necessary.	M	4.11.3.7.15(2)

TABLE 45 (Continued)

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Manifold and heat control.	Make certain gaskets are tight; check operation of heat control; adjust as necessary.	M	4.11.3.7.16(1)
	Tighten all nuts on assembly, mounting, exhaust pipe and carburetor connecting flange.	SA	4.11.3.7.16(2)
Oil filters, coolers and lines.	Check cartridge oil filter; check for leaks; renew cartridge as necessary.	M	4.11.3.7.17(1)
	Check disk-type filters; drain	M	4.11.3.7.17(2)
	Dismantle disk-type filter; clean, replace or renew as necessary.	SA	4.11.3.7.17(2)
Power takeoff	Lubricate	Q	4.11.3.7.18
Radiator	Check, clean inside, clean core air passage; check coolant for rust; flush system and replace or renew coolant.	M	4.11.3.7.19
Spark plug	Clean insulators; check for gas leaks; renew any broken insulators.	M	4.11.3.7.20
	Clean electrodes and adjust gaps as necessary; install new plugs if needed.	V	4.11.3.7.20
Starter	Lubricate	W	4.11.3.7.21(1)
	Check linkage and retracting spring; adjust, lubricate and repair as necessary; check action, noise, speed; repair or renew as necessary.	M	4.11.3.7.21(2)(3)
	Clean commutator; tighten starter mounting bolts	SA	4.11.3.7.21(4)
Universal	Grease fittings	M	4.11.3.7.22(1)
	Disassemble, clean in solvent, dry, lubricate, reinstall or renew as necessary.	SA	4.11.3.7.22(2)
Valve mechanisms	Adjust valve clearance to specifications; tighten all lock nuts.	SA	4.11.7.3.23(1)
	Check tappet clearance, rocker arms, spring; adjust.	V	4.11.7.3.23(2)
Voltage and current regulator.	Check conditions, clean, adjust or repair	M	4.11.7.3.24(1)
	Test regulator; renew regulator if operating improperly.	SA	4.11.7.3.24(2)
Water pump, fan and shroud.	Check operation, end play in bearing and fan blades; clean, adjust or repair as necessary; tighten gland nut with caution.	M	4.11.7.3.25(1)(2)

[1] W-Weekly; M-Monthly; Q-Quarterly; SA-Semiannually; A-Annually; V-Variable; as conditions may indicate.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

Section 12. DRIVES

4.12.1 TYPES OF EQUIPMENT. The types of maintenance and procedures to be followed depend on the type of drive (belt, chain, right-angle gear, variable speed, etc.). Each of the several drive types is covered in this section. For more detailed information, see Reference 11. As a safety measure, whenever maintenance work is to be done, the main disconnect switch should be open and tagged, "Do Not Close!".

4.12.2 BELT DRIVE. Proper tension and alinement of belt drives are essential to long life of both the belt and the sheave or pulley, as well as to the efficient transfer of power. Spare belts should be stored in a cool dark place, and all belts should be tagged for identification as to sets and the equipment with which they are to be used.

4.12.2.1 Flat Belts. For either leather or rubber flat belts, the following procedures are applicable.

4.12.2.1.1 Operator inspection

(1) Tension. During each regular tour of duty, the operator should keep belt surroundings clean, and belt tension adjusted properly. (Slapping and whipping are evidences of improper tension.)

(a) To prevent leather belt slippage, an approved type of stick belt dressing should be used.

(b) To prevent rubber belt slippage, the pulley side of the belt should be moistened lightly with boiled linseed oil.

(2) Cleaning Belt and Sheave. The operator should keep the belt and sheave clean and free of oil. Oil should be removed with a rag moistened in carbon tetrachloride. CAUTION: Although carbon tetrachloride is nonflammable, it is toxic and unsafe for use in rooms where the concentration is greater than 100 p.p.m. NOTE: Carbon tetrachloride shall not be used without the specific permission of the Public Works Officer.

4.12.2.1.2 Periodic maintenance

(1) Renewal. Quarterly, the belt should be inspected for fraying, wear and cracks. A new belt should be installed whenever the existing condition indicates that the belt will not be servicebale for another three months. Before installing the belt, worn or damaged sheaves should be renewed. The operator should then slack off on adjustments, and never attempt to force a belt into position on a pulley. A screwdriver or similar lever should never be used to get belts onto sheaves. After the belt is installed, the operator should adjust the tension; it should be run for eight hours and tension readjusted, if necessary.

(2) Alinement. Whenever a belt does not appear to be tracking correctly, the operator should check pulley alinement with a straightedge or string, and correct as necessary.

4.12.2.2 V-Belts. A V-belt, which is adjusted properly, has a slight bow in the slack side when running, and when idle, it has a live springiness when thumped with the hand.

4.12.2.2.1 Operator inspection. As in the case of flat belts, the operator's duties include regular attention to the cleanliness of surroundings, belts and sheaves (see par. 4.12.2.1.1(2)).

4.12.2.2.2 Periodic maintenance

(1) Tension. Weekly, the operator should check the tension on the V-belts. If tightening belt to proper tension does not correct slippage, he should check for overload, oil on belts or other causes. Belt dressing should not be used to pervent slippage.

(a) An improperly tightened belt feels dead when thumped with the hand. If the slack side of the drive is less than 45 degrees from the horizontal, the vertical sag at the center of the span may be adjusted in accordance with the following table.

V-Belt Tension

Span (in.)	*Vertical sag (in.)*	
	From	*To*
10	0.01	0.03
20	.03	.09
50	.20	.58
100	.80	2.30
150	1.80	4.90
200	3.30	8.60

(b) Vertical drives, extremely short-center drives, and drives carrying pulsating loads need about 10 percent more tension than normal horizontal loads.

(2) Alinement. Whenever there appears to be excessive wear on the V-belt, a long straightedge should be laid across the outside faces of pulleys; allowance for difference in dimensions from centerlines of grooves to outside faces of the pulleys being alined should be made. Alinement should be corrected as necessary.

(3) Renewal. Quarterly, the belt should be inspected for fraying, wear or cracks. Rubber wearings near the drive are an indication of

improper tension, poor alinement or damaged sheaves. The cause should be investigated and remedied as necessary.

(a) Install a new belt whenever existing conditions indicate that the belt will not be serviceable for another three months.

(b) Never replace a single V-belt on a multiple drive. Always renew the complete set with a set of matched belts. (All belts in a matched set are machine-checked to insure equal size and tension.)

4.12.3 CHAIN DRIVES. Chain drives may be either single, double or triple roller, or silent type, and may be designed for slow, medium or high speeds. Slow speed drives usually are not enclosed. Medium speed chains are usually lubricated continuously with a drip or sight-feed oiler; and high speed chains are completely enclosed in an oiltight case, with the oil maintained at the proper level. Whenever maintenance work is to be done, be sure that the main disconnect-switch is open, and is tagged, "Do Not Close!".

4.12.3.1 Slack. At quarterly intervals, check the chain to make certain that it has the correct slack. Too much slack causes vibrations and chain whip, too little causes excess load and wear on the working parts. The chain should have a slight sag on the return run. If there is no tightener on the drive chain, notify the proper authority.

4.12.3.2 Alinement. Semiannually, the operator should make certain that sprockets are in line and shafts are parallel to insure absence of wear on inside of chain, sidewalls and sides of sprocket teeth. To check alinement, he should remove the chain and place a straightedge against the sides of the sprocket where no wear has occurred. A new sprocket and chain should be installed if the wear is appreciable on either.

4.12.3.3 Lubrication. Chains should be lubricated semiannually.

(1) Exposed Chains. Remove the chain, soak or wash it in kerosene, and clean the sprocket. Soak it in the proper lubricant (see table 14); remove excess lubricant by hanging the chain to drain. Reinstall the chain and adjust the tension.

(2) Enclosed Chains. Flush chain and enclosure with kerosene; drain and add fresh oil.

(3) Underwater Chains. Do not lubricate underwater chains in contact with grit; chains operating in clean water should be lubricated with grease applied by brush while the chain is running.

(4) Elevator and Conveyor Chains. Do not lubricate chains on bucket elevators or conveyors of feeders which handle gritty chemicals.

4.12.3.4 Equipment Renewal. Semiannually, the condition of all parts of the chain and spracket should be inspected.

(1) If either chain is worn, its life may be extended if the chains are turned over. If the sprockets are worn, reversing the sprockets on the drive shaft, also, will extend the life of the chain drive.

(2) If either the chain or the sprocket is badly worn, and if reversing one or the other is not helpful, a new chain and new sprocket should be installed as old, out-of-pitch sprockets cause excessive wear on a new chain.

4.12.3.5 Spare Parts. Semiannually, spare parts storage should be checked. It should be made certain that repair links for chain are available, oiled and in good condition.

4.12.3.6 Troubleshooting. Table 46 presents some common symptoms of imporper chain drive operation and their remedies.

4.12.4 RIGHT-ANGLE GEAR DRIVES. Whenever maintenance work is to be done, the operator should be sure that the main disconnect-switch is open, and is tagged, "Do Not Close!".

(1) Whenever a right-angle gear drive is started, remove the inspection plate and check the lubricant flow. If the lubricant does not flow, stop the drive and check for mechanical defect, or change the lubricant, as necessary.

(2) Quarterly, or after 500 hours of operation, drain and change lubricant. Follow the manufacturer's instructions in selecting oil for seasonal conditions.

4.12.5 VARIABLE-SPEED DRIVES. Whenever maintenance work is to be done, the operator should be sure that the main disconnect-switch is open, and is tagged, "Do Not Close!". Operator inspection includes the daily cleaning and drying of disks. Only clear solvents that leave no residue should be used. Also, the operator should check the drive throughout its entire range to make certain that shafts and bearings are lubricated and that disks move freely in shafts.

4.12.5.1 V-Belt

(1) Weekly, make certain that the V-belt runs level and true. Where the V-belt rides high on one side, stop the drive, remove the belt and wash the disk hub and shaft with kerosene. Relubricate the disk and shaft, and replace the V-belt in opposite direction.

(2) Before an extended period of shutdown (30 days or more), shift the drive to the minimum speed position to reduce tension on the spring and belt.

4.12.5.2 Drive Mechanisms

(1) Weekly, or twice monthly, lubricate through grease fittings at the ends of the shifting screw and the variable shaft. Move the shift drive from one end to the other to distribute lubricant over disk-hub bearings.

(2) Bimonthly, lubricate the thrust bearing on the constant speed shaft. Add two or three cupfuls or grease to the cup for that purpose. Also bimonthly, lubricate the motor-frame bear-

TABLE 46

Troubleshooting Chart for Chain Drives

Symptom	Cause of trouble	Remedy
Broken pins or rollers.	Shock leads or chain speed too high for pitch.	If speed-pitch relation is cause, use chain of shorter pitch.
Chain climbs sprockets.	Poor fit or severe overload	If sprockets fit poorly, renew; make sure tightener is installed in drive chain.
Chain clings to sprockets.	Possibly incorrect or worn sprockets or heavy tacky lubricants.	Renew or reverse sprockets, or change to proper lubricant.
Chain gets stiff	Poor alinement or excessive overload.	Correct alinement and eliminate overload.
Chain whips	Too long centers; or high pulsating loads.	Correct either condition.
Noise	Misalinement; improper slack, loose bolts.	Correct alinement; adjust slack; tighten bolts; reverse or renew worn chain.
Wear on chain side walls or sides of teeth.	Misalinement	Remove chain and correct alinement.

ings by two or three strokes of the grease gun through the force-feed fittings.

(3) Quarterly, lubricate frame bearings on variable speed shaft; add two or three shots of grease through forced-feed fittings.

4.12.5.3 Reducer. Monthly, the operator should check the oil level in the gear reducer, and refill or change the oil as necessary. The manufacturer's recommendations should be followed with respect to seasonal grades of oil to be used.

4.12.6 GEAR REDUCERS, GEAR MOTORS AND SPEED CHANGERS. The following procedures are minimum. Check the manufacturer's instructions for detailed maintenance procedures for specific units.

4.12.6.1 Flooded Lubrication Types. The following maintenance procedures apply.

(1) At least daily, the operator should check the general operation, including the oil level, the oil flow gages, the oil rings, the temperature, the operating sound and alinement.

(2) Weekly, check the oil level; add oil as necessary. Clean the unit and tighten any loose nuts and bolts.

(3) Semiannually, change the oil.

(4) Annually, check the entire unit for oil leaks, corrosion, other signs of deterioration and for mechanical defects. Remedy undesirable conditions and paint if necessary. Flush the unit with kerosene, then with light oil (if thorough draining is not possible). Refill the unit with proper oil.

4.12.6.2 Nonflooded Lubrication Types. These maintenance procedures apply.

(1) Daily, check operation and lubrication. Clean the unit. Remedy or report undesirable conditions.

(2) Annually, check the gear fit to make certain the gears are not loose, and check alinement by feeler gage. Aline the gear faces with a straightedge or string. Check for wear and wash with kerosene. Adjust, repair or renew worn parts as necessary, and relubricate.

(3) At variable intervals, as necessary, lubricate according to the manufacturer's instructions for frequency and the choice of lubricant.

4.12.7 DRIVE BEARINGS. Drive bearings may be of the following types: ball, roller, sleeve, thrust and underwater.

4.12.7.1 General Maintenance. The procedures mentioned in this particular paragraph apply to all types of bearings.

(1) Daily checks should be made for vibration and undesirable conditions.

(2) Annually, clean and inspect all bearings.

(a) Disassemble, clean and wash all parts of bearings with kerosene; include housing and oil lines. Check for defects in bearing surface. Rotate the bearing by hand to detect defects. Check races for nicks.

(b) Check bearing clearance, or measure total shaft movement. Clearances should not be greater than 0.002 inch plus 0.001 inch per inch of shaft diameter. If the bearing is faulty, renew the babbitted surface. For speeds below 200 r.p.m., lateral clearance greater than 0.01 inch and end-for-end clearance greater than 0.015 inch are dangerous. Remedy the situation, or report to proper authority.

(c) Reassemble the bearing; be sure that metal-to-metal surfaces are absolutely clean, that paint, particles or dirt are not present. Where gaskets or shims are used in split bearings, make certain that they are of proper thickness.

(3) For equipment not overhauled annually, make an annual check for bearing looseness. Correct or report any loose bearings.

4.12.7.1.1 Temperature checks. Daily or weekly, check of bearing temperature should be made by hand. Since many bearings operate at temperatures too hot to touch by hand, a temperature reading by thermometer should be made at least quarterly. If the temperature is too high, according to the manufacturer's instructions, the cause should be determined and any undesirable condition remedied or reported to the proper authority.

4.12.7.1.2 Lubrication. General lubrication practices are covered in this paragraph. For specific types of bearings, see paragraph 4.12.7.2.

(1) Bearings Without Reservoirs or Wicks. These bearings require daily lubrication attention, if operated 50 percent or more of the time.

(2) Oil-Lubricated Bearings. Monthly, add oil as necessary. Quarterly, drain and flush the housing of oil-lubricated bearings with kerosene. Drain kerosene completely and refill housing with proper oil to correct level.

(3) Wick-Oiled Bearings. On small motors, lubricated by wicks, check and oil wicks quarterly. Check for noisy operation or excessive bearing or shaft play. Avoid over-oiling.

(4) Grease-Lubricated Bearings. Inspect on a quarterly basis.

(a) For this type of bearing, on slightly inclined shafts equipped with drain plugs, flush thoroughly with hot (165° F.) light mineral oil, and fill with grease.

(b) For this type of bearing, on vertical or steeply inclined shafts, disassemble and clean, if possible. Add new grease under pressure with relief plug open (if there is one), until an excess appears while the unit is running. Replace relief plug, tighten and wipe off excess grease.

4.12.7.1.3 Water-cooled bearings. Annually, drain the cooling jacket or the water-cooled bearings and check for scale or corrosion of cooling surfaces. Flush out the system; clean with inhibited acid, acid phosphate compound or equal. Flush out cleaning solution, rinse with solution of washing soda or other alkali, flush out and refill with proper coolant. Use precautions in handling acid. Obtain the advice of the Public Works Officer, if unfamiliar with the use of inhibited acid.

4.12.7.2 Ball and Roller Bearings

(1) Monthly, check seals for leakage and renew leaking seals. Lubricate as needed with the lubricant recommended by the manufacturer. Do not use a pressure gun to grease an antifriction bearing which has no relief hole.

(2) Clean and repack the bearings annually, or more often if the seals leak grease. High-speed bearings require more frequent attention than slow-speed bearings.

4.12.7.3 Sleeve Bearings. Quarterly, inspect and lubricate sleeve bearings (reservoir-oiled or flooded, wick-oiled, and grease- and oil-lubricated plain bearings). Make certain that all metal surfaces are separated by a film of lubricant. Avoid excessive oiling which may damage rubber mounts and insulation.

4.12.7.4 Thrust Bearings

4.12.7.4.1 Ball and roller thrust bearings. Inspect and lubricate, as prescribed in paragraph 4.12.7.2.

4.12.7.4.2 Kingsbury thrust bearings. The Kingsbury thrust bearing is a pivoted-show type of bearing. In operation, the bearing shoes and thrust bearing disk are separated by an oil film approximately 0.002 inch thick.

(1) Lubricate monthly in accordance with the manufacturer's instructions.

(2) Semiannually, check clearance in Kingsbury thrust shoe. Use feeler gage inserted between shoes and thrust sleeve on opposite side. If a feeler gage cannot be used directly, move the shaft to determine end play. Clearance should be between 0.004 and 0.008 inch. Too little clearance will cause overheating, while too much clearance will cause the bearing to float and knock. If the clearance is more than 0.010 inch, adjust if possible, or renew worn shoes and babbitting. Consult the manufacturer's instructions for directions.

(3) Annually, drain oil, flush and refill with proper lubricant to proper level.

(4) As necessary, disassemble the thrust bearing without disturbing the rotating element. Follow the manufacturer's instructions in detail for this procedure. Where the bearing is scored, either overheating or dirt is indicated. Clean, repair or renew disks, and replace carefully with proper lubricant. If shoes or tilting segments are not properly coated with oil, the bearing will burn out. Make certain that all parts are properly coated with oil before they are replaced. NOTE: Merely filling the oil chamber is inadequate, particularly on the vertical Kingsbury bearing on deep well pumps.

4.12.7.5 Underwater Bearings. Semiannually, the operator should check the clearance and lubricate the bearings in accordance with the manufacturer's instructions. Bearings under water in basins are inspected on the same schedule as the basin is dewatered for inspection (see par. 4.3.8.2). Underwater bearings on well pumps are inspected only when the pump is removed (see par. 4.9.4).

4.12.8 COUPLINGS. Where couplings are used between the driver and the driven equipment, it is essential that the alinement be proper. Otherwise, not only the coupling, but the driver and driven equipment may be subjected to unnecessary wear.

4.12.8.1 Coupling Alinement. Semiannually, the operator should check the alinement with a straightedge, thickness gage or wedge; and realine by bringing the two units level up to 0.005 inch. Details for the realining procedure will be found in the manufacturer's instructions. While flexible couplings permit easy assembly of equipment, they must be alined as carefully as flanged couplings, if maintenance and repair are to be minimized. Rubber-bushed couplings must allow for the bolts to move in the bushing. In hydraulic-type couplings, the fluid should be changed annually. Old fluid should be drained and the proper fluid added to the desired level, according to the manufacturer's instructions.

4.12.9 SHEAR PINS. Where shear pins are used as protective devices to prevent damage due to overloads, it is necessary to check the cause of any failure. Consult the manufacturer's instructions for proper sizing of shear pin. Never use a pin having greater or less strength than that recommended by the manufacturer.

(1) Quarterly, remove the shear pin and check its condition. Operate the driver for a few minutes to wear off any corroded areas on the shearing surfaces. Lubricate and replace the pin.

(2) Annually, make certain that the supply of shear pins on hand is adequate and that the pins are properly identified as to the location to be used, the pin size, necked diameter, length and material type.

4.12.10 MAINTENANCE PROCEDURE SCHEDULE. The maintenance operations frequency and schedule of inspections for drives of all types are shown in table 47.

Section 13. INSTRUMENTATION AND AUTOMATIC CONTROL

4.13.1 BASIC FACTORS IN MAINTENANCE. Operational procedures for instruments and controls are presented in Chapter 3, section 6. The success of maintenance procedures is based on three factors: knowledge of the construction, operation, and adjustment of the equipment; the availability of the necessary special tools; stored spare parts and special instructions from manufacturers. For the special knowledge necessary, maintenance personnel should consult the manufacturer's instructions. Special tools and spare parts should be carefully labeled and kept in a specific case. Tools should be replaced after use. When spare parts are installed, replacements for them should be ordered immediately.

4.13.1.1 Components. Instrumentation systems consist of three component parts—the sensing element (or primary measuring device), transmission systems and receivers or terminal equipment. The latter, often termed secondary instruments, includes indicators (gages), recorders and totalizers, or combinations of all three. Automatic control systems consist of equipment which converts a sensed variable at the primary unit into a command or control of operating equipment (pumps, feeders, etc.) or process operation. Automatic controls are discussed in this section; other types of controls (manual, semiautomatic, etc.) are discussed where applicable in this publication.

4.13.1.2 Maintenance Schedules. The design and intricacy of instrumentation and automatic control systems depend on the function to be performed and the manufacturer's particular design. Because there are many manufacturers of instruments and automatic controls, it is not possible to list specific maintenance procedures applicable to all units. The following procedures are basic and the minimum required for the most common types of units, although, when developing maintenance schedules, maintenance personnel must relate the procedures given here to specific directions issued by manufacturers.

4.13.1.3 Records. Whatever the inspection or maintenance procedure, a log shall be kept of all inspection and maintenance actions. These records (see par. 4.1.4) shall be kept on file in the Utility Department Office. A particularly useful record system for instrumentation and controls is a card file for each piece of equipment. This card should show the type of equipment, the manufacturer's serial number, the date installed, the location and the frequency of scheduled maintenance. If these cards are arranged chronologically in a proper manner, each card will come to the attention of maintenance personnel at the proper time for the inspection to be made.

4.13.2 SENSING DEVICES. These devices, sometimes termed primary measurement devices, or primary instruments, are classified according to the variable sensed. Their design, operation and maintenance depend on the function of the device.

4.13.2.1 Flow Measurement. The following tabulation shows the devices included in this classification and the paragraph references where maintenance procedures for these units are presented.

Functional characteristic	Type of unit	Reference Paragraph number
Differential pressure producer--	Venturi type-----	4.8.2.1
	Orifice plate-----	4.8.2.2
	Pitot tube-------	4.8.2.3
Velocity meter----------	Propeller type----	4.8.3
	Turbine type-----	4.8.3
Proportional meter----------	----------	4.8.4
Magnetic meter----------	----------	4.8.5
Compound meter----------	----------	4.8.6
Head-area meter----------	Weirs----------	4.8.7.1
	Parshall flumes---	4.8.7.2
	Open-flow nozzles--------	4.8.7.3
Volume meter----------	Disk----------	4.8.8
	Piston----------	4.8.8

4.13.2.2 Level Measurement. Included in this classification are the float, bubble pipe, electrical probe and diaphragm.

(1) Floats. Maintenance procedures for floats appear in paragraphs 4.9.7.2.5 and 4.10.5.2 (1).

(2) Bubble Pipe. See paragraph 4.10.5.2(1) (d) for maintenance procedures.

(3) Electrical Probe.

(a) Quarterly, check the contacts, wiring and electrical connections, and repair as necessary.

(b) Semiannually, check the probe surfaces and the calibration. Clean, repair or renew as necessary.

(4) Diaphragm. The diaphragm is actually a pressure measuring device (see par. 4.13.2.3(1)).

4.13.2.3 Pressure Measurement. The most common devices in this classification are the diaphragm, the Bourdon tube and the manometer.

TABLE 47

Maintenance Procedures for Drives

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Flat belts			4.12.2.1
Operator inspection		V	4.12.2.1.1
Renewal	Check belt condition; renew as necessary	Q	4.12.2.1.2(1)
Alinement	Check pulley alinement; adjust as necessary	V	4.12.2.1.2(2)
V-belts			4.12.2.2
Operator inspection			4.12.2.2.1
Tension	Check and adjust as necessary	W	4.12.2.2.2(1)
Alinement	Check and adjust as necessary	V	4.12.2.2.2(2)
Renewal	Check belt condition and renew as necessary	Q	4.12.2.2.2(3)
Chain drives	Check slack and adjust	Q	4.12.3.1
	Check alinement and adjust	SA	4.12.3.2
	Lubricate exposed, enclosed, underwater chains, as directed; do not lubricate elevator or conveyor chains handling dusty chemicals.	SA	4.12.3.4
	Check condition of all parts; turn chain or sprocket or renew parts as necessary.	SA	4.12.3.4
	Check spare part storage	SA	4.12.3.5
	Troubleshooting; see Table 46	V	4.12.3.6
Right-angle drives	Check lubricant flow when starting drive	V	4.12.4(1)
	Drain and change lubricant	Q	4.12.4(2)
Variable-speed drives	Operator inspection, cleaning and drying as necessary.	D	4.12.5
V-belt	Check belt; be sure it runs level; adjust as necessary; adjust tension for shutdown if necessary.	W	4.12.5.1
Drive mechanism	Lubricate shifting screw and variable shaft	2W	4.12.5.2(1)
	Lubricate thrust bearing on constant speed shaft	2W	4.12.5.2(2)
	Lubricate frame bearings on variable-speed shaft	Q	4.12.5.2(3)
Reducer	Check oil level; refill or change oil as necessary	M	4.12.5.3
Gear reducers, gear motors and speed changers.			4.12.6
Flooded type	Check operation, oil level, etc.	D	4.12.6.1(1)
	Add oil as necessary	W	4.12.6.1(2)
	Change oil	SA	4.12.6.1(3)
	Check for oil leaks, corrosion and mechanical defects; remedy undesirable conditions.	A	4.12.6.1(4)
Nonflooded types	Check operation; clean unit	D	4.12.6.2(1)
	Check gear fit; aline gear; check for wear, wash with kerosene; adjust, repair or renew parts as necessary; relubricate.	A	4.12.6.2(2)
	Lubricate according to manufacturer's instructions	V	4.12.6.2(3)
Drive bearings			4.12.7
	Check for vibration; adjust or repair as necessary	D	4.12.7.1(1)
	Inspect; disassemble, wash with kerosene; check surface defects; check clearance; adjust, repair or renew as necessary.	A	4.12.7.1(2)
	Check for looseness in equipment not overhauled annually.	A	4.12.7.1(3)

TABLE 47 (Continued)

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Temperature checks	Check by hand	D or W	4.12.7.1.1
	Check with thermometer; correct undesirable condition.	Q	4.12.7.1.1
Lubrication	Lubricate bearings without reservoirs or wicks	D	4.12.7.1.2(1)
	Add oil to oil-lubricated bearings	M	4.12.7.1.2(2)
	Drain, flush and refill	Q	4.12.7.1.2(2)
	Lubricate oil wick bearings	Q	4.12.7.1.2(3)
	Check and lubricate grease-lubricated bearings	Q	4.12.7.1.2(4)
Water-cooled bearings	Drain, clean cooling jacket, refill	A	4.12.7.1.3
Ball and roller bearings	Check seals, renew leaking seals	M	4.12.7.2(1)
	Clean and repack bearings	A	4.12.7.2(2)
Sleeve bearings	Inspect and lubricate; avoid excessive oiling (also see par. 4.12.7.1.2).	Q	4.12.7.3
Thrust bearings			4.12.7.4
Ball and roller thrust	See paragraphs 4.12.7.1.2 and 4.12.7.2		4.12.7.4.1
Kingsbury	Lubricate	M	4.12.7.4.2(1)
	Check clearance between shoes and thrust sleeve; adjust or renew.	SA	4.12.7.4.2(2)
	Drain oil, flush, refill	A	4.12.7.4.2(3)
	Disassemble, clean, repair or renew disk	V	4.12.7.4.2(4)
Underwater bearings	Check clearance, lubricate, and adjust (also see pars. 4.3.8.2 and 4.9.4).	SA	4.12.7.5
Couplings	Aline, check, clean and adjust	SA	4.12.8.1
Shear pins	Renew any sheared pins after determining and eliminating the cause of failure.	V	4.12.9
	Remove pin; check condition; operate driver to wear off corrosion on shear surfaces.	Q	4.12.9(1)
	Check pin storage	A	4.12.9(2)

[1] D-Daily; W-Weekly; M-Monthly; Q-Quarterly; SA-Semiannually; A-Annually; V-Variable; as conditions may indicate.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

(1) Diaphragm Annually, disassemble and check the condition of the diaphragm for deterioration or potential leaks. Also check the calibration, and clean, adjust or renew the diaphragm as necessary.

(2) Bourdon Tube. Annually, check the calibration, and clean and adjust as necessary.

(3) Manometer. Semiannually, clean the tubes and the gage unit as necessary. Annually, or as often as required, add mercury to the tube. Whenever necessary, clean and replace the mercury (see par. 4.13.4.5).

4.13.2.4 Electrical Quantities Measurement. Included in this class of devices are the voltmeter, ammeter and watt meter used in connection with electrical power, and devices such as the glass electrode (for pH determination), dropping mercury electrode (for dissolved oxygen determination), amperometric chlorine meter and other voltage, current and resistance devices employed in process control.

4.13.2.4.1 Maintenance procedures

(1) All devices in this category should be kept clean and free of dust. Regular monthly or quarterly cleaning should be performed. It should be made certain that the glass parts are clean. The instrument setting should be at the zero reading and adjusted when necessary.

(2) For the most part, all of these devices are of rather intricate construction and should be subjected to maintenance procedures strictly in accord with the manufacturer's instructions, or returned to the factory when adjustments or repairs are required.

4.13.2.5 Position Determination. Indicators of the valve position (open or closed), the liquid level or of floating tank covers may employ rotary or vertical circuit contacts, floats, electrical probes and potentiometers. Floats have been discussed in paragraph 4.13.2.2(1) and electrical probes in paragraph 4.13.2.2(3). General procedures for maintenance include.

(1) Monthly, make certain that position indicators, employing either circular or vertical circuits, have clean contact points that do not arc.

(2) Semiannually, polish contacts. Renew any that have been deeply pitted by arcing.

4.13.2.6 Weight Measurement. Three devices included in this category are platform scales, balance beam (traveling poise), and weightometer (moving belt), as employed in some chemical feeders. These general maintenance procedures should be followed.

(1) In all types of weight measuring devices, keep the devices free of dust accumulations by regular inspection and cleaning on a weekly basis.

(2) Monthly, check knife edges for sharpness and freedom of deposits; also check poise screw, belt adjustment and lubricate according to the manufacturer's instructions.

(3) Annually, disassemble, thoroughly clean, reassemble, lubricate, adjust and calibrate as necessary. Follow the manufacturer's instructions for detailed procedures.

4.13.2.7 Temperature Measurement. Temperature may be measured by a mercury or an alcohol thermometer, or by thermocouples. The only maintenance required is the cleaning of the equipment at least quarterly.

4.13.3 TRANSMISSION SYSTEM. From the sensing device, which measures the variable, there must be a means for transmitting this discrete information to the instruments which indicate, record or totalize it. The transmission system may be mechanical, hydraulic, pneumatic or electrical; and each system consists of two components—the transmitter and the transmission link.

4.13.3.1 Mechanical Transmission System. Mechanical transmission is by direct mechanical linkage, cable, chain or rod. Such mechanisms require quarterly inspections to assure that pulleys and drums, or links, are lubricated, and that cables or rods are not corroded or dirty. Clean, lubricate and adjust the system when necessary.

4.13.3.2 Hydraulic Transmission System. This type of transmission includes both direct pressure transmission, and oil or other substance as the transmission fluid. In differential pressure transmission, pressure pipes are run directly from the differential head producer to the mercury wells of the secondary instrument. Semiannually, the pressure lines should be checked to assure that they are open and not restricted in any manner. Correct undesirable conditions. Where fluids other than water are used, maintenance procedures should be in accord with the manufacturer's instructions.

4.13.3.3 Pneumatic Transmission System. In this type of system, air pressure (between 3 and 15 psi) is the medium of transmission.

4.13.3.3.1 Transmitter. The transmitter contains a specially calibrated cam, positioned by a diaphragm or mercury float well, which responds to changes in the measured variable. This cam operates and controls a bleeder valve system and bellows unit to produce an output pressure directly proportional to the measured variable. Maintenance procedures include the following.

(1) Daily, flush the liquid side of the air-relay units, and drain the air sides. If the amount of water drained is large, remove the cover and examine the diaphragm for punctures or cracks. Use care not to bend the needle-valve stem when replacing the diaphragm. Check the air-input orifice, and clean and remove any foreign matter. Blow out the moisture traps. See the manufacturer's instructions for details of cleaning the metering orifice and nozzle.

(2) Whenever necessary, disassemble and repair or renew parts. Be sure to follow the manufacturer's instructions.

4.13.3.3.2 Transmission link. Transmission of the output signal is through a small pipe to the secondary unit. Semiannually, check connecting tubing to assure that there are no dents, crimps or other difficulties existing. Also check nozzle system for leaks.

4.13.3.4 Electrical Transmission System. One example of this type of transmission system is the time-duration-impulse system, for which maintenance procedures are described below. (For other systems, consult the manufacturer's instructions.)

4.13.3.4.1 Transmitter. In this system, the transmitter contains a cam, a synchronous motor and a magnetically operated mercury switch. The electrical output signal, which is proportional to the measured variable, is transmitted to the receiver converter, which is a counterpart of the transmission. Maintenance procedures include the following.

(1) Monthly, service the transmitter. Check the length of signal interval at various points throughout the instrument's range. Follow the manufacturer's instructions for methods of correcting errors.

(2) Quarterly, check the mercury switch and magnet. With the transmitter trip-arm riding on the cam, make certain that the magnet is far enough away from the mercury switch to ensure that there is no pull on switch. With the transmitter arm off the cam, make certain that the magnet pulls the movable electrode, that it is entirely clear of the mercury globule and that there is no electrical contact. Adjust as necessary according to the manufacturer's instructions.

(3) Every 6 months, remove the cam oil-trough, discard the oil, wipe the trough clean and refill it with special oil, as directed by the manufacturer's instructions. As the cam revolves, it will carry oil to the drive gears and cam bearing.

4.13.3.4.2 Transmission link. The signal may be transmitted over private wire (a.c. or d.c.), over telephone circuits or over multiservice wires. Check and repair wires whenever necessary.

4.13.4 TERMINAL EQUIPMENT. Receivers or secondary instruments are classified, according to the type of information desired, as indicators or gages (momentary indication of discrete information), recorders (chart record of information by time), and registers or totalizers (also termed integrators which express the total quantity of measured variable from start to current time). There are many styles and designs of each basic type, and there are various combinations of these types. Therefore, no detailed maintenance procedure can be given to cover all types, designs and combinations. Maintenance procedures depend, not only on the type of receiver (indicator, recorder or register), but also on the type of transmission system used. Maintenance personnel must study the manufacturer's instructions for detailed procedures, in addition to the following basic recommended procedures.

4.13.4.1 Indicators. Indicators have a calibrated dial, or band, and a pointer to show conditions of the moment to the observer.

4.13.4.1.1 All transmission types. For indicators utilizing any type of transmission system, the following procedures apply.

(1) Semiannually, clean the cover and the glass of indicator gages.

(2) Annually, check the instrument for zero setting and for calibration throughout its range. See the manufacturer's instructions. For level indicators, use base-line data for comparison; for the flow indicator, check against volumetric displacement; for pressure indicator, use a deadweight tester. In all cases, if the error is more than ± 3 percent, reset the hand or adjust the level motion as necessary.

4.13.4.1.2 Mechanical transmission system. For indicators utilizing a mechanical linkage transmission system, inspect and service the receiver on a quarterly schedule, in the same manner as is done for the transmitter (see par. 4.13.3.1).

4.13.4.1.3 Hydraulic transmission system

(1) Where direct water pressure transmission is used, the following procedures apply.

(a) Vent air from the mercury wells on a weekly basis, unless it is determined that less frequent venting is sufficient.

(b) Weekly, inspect the pulley shaft, chain, cam, stuffing box and other functional parts as prescribed by the manufacturer's instructions.

(c) Annually, inspect the pressure mercury wells. If the mercury has blown over, check the mercury level and replace lost mercury according to the manufacturer's instructions. Use virgin or triple distilled mercury (as directed by the manufacturer), or clean and replace the mercury when necessary (see par. 4.13.4.5).

(2) Where other hydraulic fluids are used, consult the manufacturer's instructions.

4.13.4.1.4 Pneumatic transmission system. In an indicator utilizing a pneumatic transmission system, the receiver mechanism is a counterpart of the transmitter mechanism and should be serviced on the same schedule and in the same manner as the transmitter mechanism (see par. 4.13.3.3).

4.13.4.1.5 Electrical transmission system. In an indicator utilizing an electrical transmission system of the time-impulse-duration type, the receiver instrument contains all of the fundamental elements of the transmitter unit and, in addition, a magnet and clutch mechanism and, of course, the indicator dial and pointer. Do not tamper with the internal mechanism. Where the mechanism has been permanently lubricated, do not add oil (see the manufacturer's instructions).

(1) Generally, the receiver should be serviced in the same manner and on the same schedule as the transmitter (see par. 4.13.3.3).

(2) Semiannually, the unit, including the white dials, should be cleaned.

(3) Annually, the operator should check the operation, and adjust, repair or renew parts as necessary. Disassemble only when necessary, and then only according to the manufacturer's instructions.

4.13.4.2 Recorders. Recording instruments contain all of the fundamental elements of an indicator unit and, in addition, contain a clock mechanism (spring or electrical), a chart and a marking pen. Charts may be either circular or strip, and are changed on schedule by operating personnel. Maintenance procedures depend on the type of transmission system employed, as well as on the design and other factors. Consult the manufacturer's instructions for detailed procedures. General maintenance procedures are as follows.

(1) Every 2 weeks, clean the chart-marking pen according to the manufacturer's instructions; and, after cleaning, check the ink flow. Also, inspect the cam cycle and the pulley freedom.

(2) Quarterly, check the pen and/or indicator zero positions, and adjust according to the manufacturer's instructions. Lubricate the unit in accord with manufacturer's instructions, but do not add oil to the parts that are permanently lubricated, or to electric clocks.

(3) Semiannually, or more often if necessary, examine the points of the contacts and clean or burnish them as necessary. Also, check the armature, clutch cups and other parts. Clean, adjust, repair or renew them when necessary, according to the manufacturer's instructions.

(4) Where receivers are of the design which utilizes a modular unit, or power supply modules, refer to the manufacturer's instructions for a troubleshooting guide, and service the mechanism, or remove and renew it in accordance with those instructions.

(5) Whenever necessary, replace the illumination lamp.

4.13.4.3 Totalizers or Registers. This type of receiver is quite similar in internal components to recorders but, in addition, contains an integrator mechanism which converts transmitted signals into a sum of the total quantity of material which has moved past the point of measurement from the beginning of the measuring period to the time of observation. This total appears on a numerical register similar to an automobile odometer. Clean, service and adjust registers on the same general schedule as recorders (see par. 4.13.4.2), and in accordance with the manufacturer's instructions.

4.13.4.4 Combination Totalizer-Indicator-Recorder. There are various combinations, designs and styles of instruments in this classification. There are also devices which summate totals from various individual totalizers, or show ratios of one flow to another. In general, the maintenance procedures and schedules are a combination of the procedures set forth for the individual units above (see pars. 4.13.4.1, 4.13.4.2 and 4.13.4.3). Be sure to develop a maintenance schedule in accordance with the manufacturer's instructions.

4.13.4.5 Cleaning Mercury. Since the mercury used in the instruments will pick up moisture, dirt and corrosion products, it needs to be cleaned. The frequency of cleaning will depend on conditions, and is subject to maintenance personnel judgment. An acceptable procedure is outlined below. The cleaning procedure described is essentially a laboratory-type operation. It is, therefore, preferable that the cleaning be performed by trained laboratory technicians in a properly equipped laboratory. If this is not practicable, the equipment provided and the procedure used by the Utility Division or by maintenance personnel should be inspected and approved by a Navy Industrial Hygienist, the Activity Medical Officer or the Field Engineering Office Sanitary Engineer.

4.13.4.5.1 Safety precautions

(1) Whenever possible, handle the mercury under water to avoid all possibility of mercury poisoning by absorption through the lungs and to keep cleaned mercury from becoming recontaminated by oxidation. Mercury is volatile to some extent, even at room temperature, and the fumes are poisonous. See the caution in paragraph 4.13.4.5.2(5).

(2) Where acid solutions are used in cleaning procedures, handle nitric acid solution and dichromate solutions carefully, as they are injurious to both skin and clothes. Suitable protective clothing should be worn.

(3) Spilled mercury creates a continuing health hazard and is difficult to clean up. Avoid spilling the mercury.

4.13.4.5.2 Cleaning procedure

(1) Equipment. Use a glass funnel and a glass or porcelain-enamel container. Prepare the funnel by heating the tip and drawing it out to an extremely small opening so that the mercury will run through in a fine stream. The container must be large enough to hold all the mercury to be cleaned at any one time, and must have a neck small enough to support the funnel. If possible, the container should have an outlet at or near the bottom to make it easier to remove the cleaned mercury from the container.

(2) Alkali Treatment. To clean mercury contaminated with oil or grease, use the following procedures.

(a) Fill a container with a 10 percent solution of potassium hydroxide. If the container has a bottom outlet, attach a rubber hose to the outlet and seal it with a pinch clamp, or by elevating the end of the hose.

(b) Pour mercury through the funnel into a potassium hydroxide solution. The mercury will sink to the bottom of the container, while the potassium hydroxide solution removes the oil and grease as the mercury passes through.

(c) After all of the mercury has passed through the solution, draw the mercury off through the hose into a clean glass or porcelain-enamel container. If the receptacle used for cleaning the mercury does not have a bottom outlet, remove the mercury by first pouring off the potassium hydroxide solution and then pouring the mercury into a clean container.

(3) Acid Treatment Nitric acid treatment is used to remove solids of corrosion products and water. After the mercury has been degreased by the procedure described above, or for the first cleaning (if degreasing is unnecessary), a clean container should be filled with a solution of one part concentrated nitric acid and three parts water. The mercury should be poured through a funnel into the nitric acid solution, and then removed as described in par. 4.13.4.5.2(2)(c).

(4) Washing. After treating the mercury with potassium hydroxide and nitric acid, it is necessary to wash it to remove traces of these reagents. A clean container is filled with distilled water, the mercury poured through a funnel into the distilled water, and collected as before. Repeat the washing process at least three times, then test the mercury with litmus paper to determine acidity or alkalinity. If acid reaction is obtained, continue washing and test with litmus paper until the mercury gives a neutral reaction.

(5) Drying. As the last step in the cleaning process, remove all water from the surface of the mercury by pouring it on absorbent blotting paper or cotton. Moisture can also be removed by placing the mercury in a glass or porcelain dish and heating it to slightly above 212° F., the boiling point of water. CAUTION: Fumes from hot mercury are extremely poisonous. Do not breathe any of the fumes when the mercury

is being heated. Be careful not to heat the mercury too near its boiling point, 674.5° F.

(6) Cleaning Containers. Cleaned mercury must not be put back into dirty glassware or into a manometer with dirty tubes. Prepare glassware for use with mercury by washing it with a solution of sulfuric acid and potassium dichromate or sodium dichromate. Prepare the solution by adding potassium dichromate crystals to concentrated sulfuric acid until no more crystals will dissolve. Then add a little extra dichromate so a few crystals remain undissolved in the bottom of the container, ensuring that the solution is definitely saturated.

4.13.5 AUTOMATIC CONTROLS. Automatic control systems are utilized to control the operation of equipment and processes. They employ an automatic feedback system which senses the condition or character of the final product and adjusts the processs operation and components to produce the desired product. In water works, there are few completely automatic control systems with feedback features. The most common are applied to the control of the water level (in elevated tanks); the flow in distribution systems or through filters; the pressure in the mains; and, treatment plant operation.

4.13.5.1 Level Control. The water level in standpipes is generally controlled through automatic altitude, float valves, or pressure valves, coupled with pump operation. Sometimes the control may be through a combination of pressure and flow. The maintenance servicing of control valves is covered in paragraph 4.5.1.3.2 through paragraph 4.5.1.3.5. Pump control maintenance is covered in paragraph 4.10.5.

4.13.5.2 Flow Control. Flow into or out of a system is usually controlled by pump operation or valving coupled with a flow measuring device, and much the same control equipment as for level control; see Paragraph 4.13.5.1 and the references therein for maintenance procedures.

4.13.5.3 Pressure Control. Pressure in systems is a function of pump operation related to flow or use of the water, and can be controlled by by the feedback of pressure to the control pump operation. Control systems for pumps are given in paragraph 4.10.5.

4.13.5.4 Treatment Plant Control. In water treatment plants, control systems are usually applied to chemical feeder operation, filter rate and filter backwash.

4.13.5.4.1 Chemical feeder control. Maintenance procedures for chemical feeder controls depend on the type of control exercised. Chlorination and neutralization may be controlled in a fully automatic system which involves a sensing device (glass electrode or potentiometer), transmission system (electrical) and motor controllers subject to the signal. Maintenance procedures are special for this type of equipment. Therefore, consult the manufacturer's instructions.

4.13.5.4.2 Filter rate control. Control of the filter rate may be automatic through rate controllers or, in some cases, by a turbidimeter connected with the valving system. Check the manufacturer's instructions.

4.13.5.4.3 Filter backwash control. Where an automatic control of backwash is installed, maintenance procedures are concerned with electrical switches and contacts, loss-of-head gages, turbidity controls, time-cycle control, pilot valves and other valves. Maintenance personnel should follow normal procedure for cleaning, repairing and adjusting these various components and, in addition, should consult the manufacturer's instructions for specific details with reference to the servicing and maintaining of the equipment.

4.13.5.5 Time-Cycle Control. Nearly all types of controlled units can be controlled, with respect to start-stop, on a time sequence or time-cycle basis. In this type of control, the control mechanism consists of a clock, usually electric; a cam with adjustable contacts; and, a contact-circuit unit. Maintenance procedures involve cleaning, lubrication and adjustment. Consult the manufacturer's instructions for details.

4.13.5.6 Supervisory Control. Control systems involving start-stop, rate control, valve opening and closing, and report-back are available in supervisory control systems, and are used particularly for control of the operation of scattered pumping stations and well fields. In addition to the normal components of control systems, supervisory control includes a scanning and reportback system. These units are usually mounted as module packs which can be removed and returned to the factory for servicing. Other than normal and regular cleaning, maintenance personnel should follow the procedures described in the manufacturer's instruction manual.

4.13.6 MAINTENANCE PROCEDURE SCHEDULE. The maintenance operation frequency and schedule of inspections for instruments and automatic controls are presented in Table 48.

Section 14. SWIMMING POOLS

4.14.1 REFERENCE TO OPERATION. Operation procedures for swimming pools are presented in Chapter 3, Section 8. Regular pool cleaning procedures are presented in paragraph 3.8.5.7. Troubleshooting procedures appear in table 12.

4.14.2 MAINTENANCE PROCEDURES. Procedures for maintaining specific equipment components of swimming pools appear elsewhere in this mannual. Table 49 shows the location in the manual where both operation and maintenance procedures will be found for specific equipment components.

TABLE 48

Maintenance Procedures for Instruments and Automatic Controls

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Sensing devices			4.13.2
Flow measurements	See paragraphs 4.8.2; 4.8.3; 4.8.5; 4.8.7; and 4.8.8.		4.13.2.1
Level measurement			4.13.2.2
Floats	See paragraphs 4.9.7.2.5; 4.10.5.2(1)		4.13.2.2(1)
Bubble pipe	See paragraph 4.10.5.2(1)(d)		4.13.2.2(2)
Electrical probe	Check contacts, wiring and electrical connections; repair as necessary.	Q	4.13.2.2(3)(a)
	Check probe surfaces and calibration; clean, repair or renew as necessary.	SA	4.13.2.2(3)(b)
Diaphragm	See paragraph 4.13.2.3(1)		4.13.2.2(4)
Pressure measurement			4.13.2.3
Diaphragm	Disassemble and check for condition and leaks; also, clean, adjust, repair or renew as necessary; check calibration.	A	4.13.2.3(1)
Bourdon tube	Check calibration, clean and adjust as necessary	A	4.13.2.3(2)
Manometer	Clean tubes and gage unit as necessary	SA	4.13.2.3(3)
	Check mercury level and add mercury if necessary; clean mercury if necessary (see paragraph 4.13.4.5).	A or V	4.13.2.3(3)
Electrical quantities measurement.	Clean as necessary; check zero setting and adjust as necessary; consult manufacturer's instructions.	M or Q	4.13.2.4.1
Position determination	Also see floats, paragraphs 4.9.7.2.5 and 4.10.5.2(1); check contact points for arcing; clean as necessary.	M	4.13.2.5(1)
	Polish contacts; renew if necessary	SA	4.13.2.5(2)
Weight measurement	Clean equipment	W	4.13.2.6(1)
	Check knife edges; also where applicable, check poise, belt adjustment and lubricate.	M	4.13.2.6(2)
	Disassemble, clean, reassemble, lubricate, adjust and calibrate.	A	4.13.2.6(3)
Temperature measurement.	Clean	Q	4.13.2.7
Transmission system			4.13.3

TABLE 48 (Continued)

Inspection	Action	Frequency[1,2]	Reference Paragraph number
Mechanical	Direct links—make certain pulleys, drums, cable, etc., work freely and are not corroded; clean, lubricate and adjust.	Q	4.13.3.1
Hydraulic	Pressure links—blow down pressure lines, make certain there are no restrictions; correct adverse conditions.	SA	4.13.3.2
Pneumatic			4.13.3.3
Transmitter	Flush liquid side of air-relay units; clean; if necessary check diaphragm; check air-input orifice, clean, blow out moisture traps.	D	4.13.3.3.1(1)
	Disassemble, repair or renew as necessary	V	4.13.3.3.1(2)
Link	Check connecting tubing for condition; check nozzle system for leaks.	SA	4.13.3.3.2
Electrical			4.13.3.4
Transmitter	Service transmitter; check signal interval length over instrument range.	M	4.13.3.4.1(1)
	Check mercury switch and magnet; adjust as necessary.	Q	4.13.3.4.1(2)
	Remove old lubricant, add new	SA	4.13.3.4.1(3)
Link	Check wires whenever necessary	V	4.13.3.4.2
Terminal equipment			4.13.4
Indicators	Clean cover and glass of gages	SA	4.13.4.1.1(1)
	Check zero setting and calibration	A	4.13.4.1.1(2)
Mechanical transmission.	Inspect and service as for transmitter (see paragraph 4.13.3.1).	Q	4.13.4.1.2
Hydraulic transmission	Vent air from mercury wells; check pulley shaft, chain, cam, stuffing box and other parts.	W	4.13.4.1.3(1)(a)(b)
	Check mercury wells; add new mercury if necessary; clean mercury if necessary (see paragraph 4.13.4.5).	A	4.13.4.1.3(1)(c)
Pneumatic transmission	Service on same schedule and in same manner as transmitter (see paragraph 4.13.3.3).		4.13.4.1.4
Electrical transmission	Service generally on same schedule as transmitter (see paragraph 4.13.3.3).		4.13.4.1.5
	Clean unit, especially dials	SA	4.13.4.1.5(2)
	Check operation, adjust and repair as necessary	A	4.13.4.1.5(3)
Recorders	Clean pen; check ink flow; check cam cycle and pulley freedom.	2W	4.13.4.2(1)
	Check zero position; adjust and lubricate	Q	4.13.4.2(2)
	Check contact points, armature, clutch, clutch cups, etc.; clean, adjust, repair, or renew parts.	SA	4.13.4.2(3)
	Renew modular unit if necessary	V	4.13.4.2(4)
	Renew illumination lamp as necessary	V	4.13.4.2(5)
Totalizers	Inspect, clean, adjust or repair on same schedule as recorders (see par. 4.13.4.2).		4.13.4.3
Combination T–I–R	Check, clean, adjust or repair on same schedule as individual components (see par. 4.13.4.1; 4.13.4.2; and 4.13.4.3).		4.13.4.4
Cleaning mercury	Clean as necessary; see text for procedure	V	4.13.4.5
Automatic controls			4.13.5
Level	See paragraphs 4.5.1.3.2; 4.5.1.3.3; 4.5.1.3.4; 4.5.1.3.5; and 4.10.5.		4.13.5.1
Flow	See same paragraphs for level and pump control.		4.13.5.2

TABLE 48 (Continued)

Inspection	Action	Frequency [1,2]	Reference Paragraph number
Pressure	See pump control (paragraph 4.10.5)		4.13.5.3
Treatment plant			4.13.5.4
Chemical feed	Consult manufacturer's instructions	V	4.13.5.4.1
Filter rate	Consult manufacturer's instructions	V	4.13.5.4.2
Filter backwash	For automatic controls, consult manufacturer's instructions.	V	4.13.5.4.3
Time cycle	Consult manufacturer's instructions	V	4.13.5.5
Supervisory	Consult manufacturer's instructions	V	4.13.5.6

[1] D-Daily; W-Weekly; M-Monthly; Q-Quarterly; SA-Semiannually; A-Annually; V-Variable; as conditions may indicate.

[2] The frequencies shown are suggested frequencies which may be modified by local command, as individual installation conditions warrant.

TABLE 49

Reference Table of Operation and Maintenance Procedures for Swimming Pool Equipment

Item	Operation Reference	Maintenance	Reference Table number
Alum pots	3.8.5.3.1(2)	4.3.6.1	23
Chlorinators	3.2.2.4	Ch. 4, Sec. 3	21
Filters.			
Diatomite	3.8.5.4.2	4.3.9.3	27
Gravity sand	3.2.8.3.6	4.3.9.1	27
Pressure sand	3.8.5.4.1	4.3.9.2	27
Filter controllers	3.2.8.3.6(1)(a)	4.3.9.1.6(2)	27
Hair catchers	3.8.5.2	3.8.5.2	
Off-season shutdown	3.8.5.9	3.8.5.9	
Pumps	Ch. 3, Sec. 5	Ch. 4, Sec. 9	36
Pump stations	Ch. 3, Sec. 5	Ch. 4, Sec. 10	40
Valves	3.4.2.5	Ch. 4, Sec. 5	31
Troubleshooting	Table 12		

CHAPTER 5. SAFETY PRACTICES

Section 1. BASIC CONCEPTS

5.1.1 GENERAL CONCEPT. Work hazards which have not been eliminated in the design of water supply systems and plants can be reduced by the provision of safety equipment and the adoption of proper precautionary measures.

5.1.2 REFERENCES. The objectives and administration of a safety program are described in Reference 6. That manual also contains details of the safety practices applicable to the maintenance and operation of water utilities. The procedures and precautions in this chapter are based on Reference 6, or abstracted from material published by the American Water Works Association in AWWA M3 Safety Manual, "Safety Practice for Water Utilities" (Reference 23).

5.1.3 BASIC SAFETY MEASURES. There are five key steps in the prevention of accidents.

(1) Injury records should be kept as a means of analyzing accident causes, spotlighting hazards and visualizing progress in a safety program.

(2) Safety hazards should be searched out.

(3) Equipment and work methods should be made safe.

(4) Personnel should be interested in safety by responsible authorities.

(5) Work habits should be controlled.

Measures which are basic to any safety program are described in the following paragraphs. More detailed discussions appear in other sections of this chapter, or in the references cited.

5.1.3.1 Fire Protection. Flammables must be stored with care, and fire extinguishers should be located outside all work rooms. The station fire department should be consulted for advice, and Reference 4 should be consulted.

5.1.3.2 Personnel Instruction. All personnel, particularly newcomers to a utility, should be thoroughly instructed as to plant safety requirements, personal safety protection and safe operating procedures, including procedures for obtaining needed items of personal safety or other safety equipment.

5.1.3.3 First Aid and Health Hazards. Personnel familiar with first aid are less susceptible to accidents than those not so prepared. Therefore, instructions should be given in first aid to all personnel. Preventive medicine personnel in the Bureau of Medicine and Surgery may be called on to provide consultation and direct assistance in dealing with health hazards in water utilities.

5.1.3.4 Personal Protective Equipment. Provision of personal protective equipment must include protection against hazards to eyes, face, head, respiratory organs, hands, feet and body. (See Reference 23 for detailed specifications of equipment.)

5.1.3.4.1 Face and eye protection. Suitable spectacles, cap goggles or face shields to be worn during any operation in which fragments of material or chemicals are likely to strike the operator's eyes or face should be provided.

5.1.3.4.2 Head protection. Provision should be made of protective hats of metal or plastic-impregnated fabric, or with fiber glass crowns suspended on an adjustable headband, wherever operations are in an area in which tools or materials may fall onto the worker. Metal hats should not be used where electrical hazards are likely to exist.

5.1.3.4.3 Respiratory protection. In dusty areas, or wherever toxic powders, fumes, vapors or gases, or where oxygen-deficient atmosphere exists, adequate ventilation must be provided. Ventilation should be supplemented by filter respirators, cartridge respirators or a breathing apparatus supplied with air or oxygen.

5.1.3.4.4 Hand and foot protection. These procedures are basic.

(1) Ordinary work gloves for ordinary hand protection against friction, minor scratches, or bumps are necessary. Specifically resistant gloves (leather, rubber, neoprene, plastic, etc.) for handling rough, sharp or hot materials, or chemically-active substances, should be provided.

(2) Ordinary work shoes may be worn for ordinary foot protection, but rough-soled shoes for slippery surfaces are preferable, as are rubber boots for work in wet areas. Safety-toe work shoes may be worn in all cases, but *must* be provided where tools or materials may fall.

5.1.3.4.5 Body protection. Overalls, or coveralls, may be sufficient for ordinary work. Where chemicals are being handled, rubber aprons, or laboratory coats may be needed. When working

on scaffolding or at dangerous heights, safety belts are necessary as safeguards against falls.

5.1.3.5 Proper Use of Tools. Accidents caused by improper use of tools can be reduced materially if the following basic rules are followed. (For details on the correct usage of specific tools, e.g., axes, hatchets, chisels and punches, files, hammers, picks, saws, screwdrivers, shovels and spades, wrenches and portable power tools, see Reference 23.) Follow these rules.

(1) Always select the appropriate tool for the job; never use a makeshift tool.

(2) Check the condition of a tool at frequent intervals; repair or replace it if it is defective.

(3) Do not use tools on moving machinery; stop the machine before making adjustments.

(4) Check the clearance at the work place to make sure there is sufficient space if the tool should slip.

(5) Have a steady footing so that there is no hazard of slipping, stumbling or falling.

(6) Protect hands by wearing gloves in confined spaces, except when using hammers; do not wear rings.

(7) Carry sharp or pointed tools in covers, or be sure they are pointed away from the body in case of a fall.

(8) Wear eye protection when using impact tools on hard, brittle material.

(9) After using tools, wipe them clean and place them in their proper places, where they will not be damaged or create a work hazard.

(10) Do not lay tools on the top of step ladders, or on other places where they can fall on someone below.

(11) Learn and utilize the proper manner of working with all hand tools.

(12) Use tools made of a nonsparking material where fire is a hazard.

5.1.3.6 Handling Equipment and Materials. Lifting, lowering and handling materials should be done safely; and proper procedures apply to such items as wheel-barrows, hand trucks, scaffolds and ladders. Chemical handling and storage require both common sense and safe practices (see par. 5.7.3 and Reference 23).

5.1.3.7 Pumping Stations and Power Drivers. Pumping stations with power equipment (motors, gasoline engines and diesel engines) not only need safety protection in the form of guard rails around dangerous or moving equipment, but also need safety practices with respect to oiling, repairs, solvents and storage of fuel, etc. (see Reference 6 and Reference 23).

Section 2. UNDERGROUND SAFETY PRACTICES

5.2.1 BASIC RULES. Underground structures, such as valve and meter manholes and vaults, may be subject to air contamination by gas leaking from a gas main or methane gas from decaying organic matter. Such contamination may cause loss of life. Pertinent precautions in Articles 11323 and 15103 of Reference 6 shall be applied before entering underground structures.

5.2.1.1 Specific Rules. The following rules are basic to safety practices with respect to underground structures.

(1) Protect the work area from traffic hazards by using barricades, signs and lights conforming to local and state regulations. At night the area must be marked appropriately with red lanterns, or other warning devices.

(2) Use proper tools to open the manhole or vault, and care in handling the cover to prevent foot and back injuries.

(3) Check the presence or absence of harmful gases or oxygen deficiency, using equipment recommended in "Mine Gases and Methods for Their Detection", Circular 33, published by the U.S. Bureau of Mines (Reference 24). Checking of the manhole atmosphere is especially necessary, if the manhole drains to a nearby sewer.

(4) Do not enter a manhole or vault until the structure is known to have sufficient oxygen to maintain life, or until fresh air is introduced mechanically.

(5) Provide a ladder for entering or leaving a manhole, vault or pit. Ladders must be in good repair. Also, provide personnel with hard hats.

(6) At least two men, trained in the application of artificial respiration, must be present at the manhole entrance at all times, while a third is inside a manhole or vault. One outside man is sufficient, if the space or enclosure is shallow.

(7) Do not permit smoking in or about a manhole or vault.

(8) Keep surface water and debris out of the vault or subsurface area while work is in progress.

(9) If maintenance construction is involved, proper shoring and bracing must be used to prevent cave-ins. Provide ladders of sound construction in sufficient numbers, located to provide quick egress of workers if emergencies occur.

(10) Do not leave tools where they may endanger personnel. Provide mechanical lifting aids to raise or lower heavy or bulky material to men working below ground. Ropes and cables should be discarded, if they show signs of serious deterioration.

(11) Proper containers, designed to prevent their overturning, should be used to melt jointing material. The carrying ladles should be large enough to hold melted material without spilling. A clear path between the melting pot and the joint being poured is necessary, and it should be sanded or otherwise treated to prevent slipping. Care is essential to avoid dropping hot metal on workers below. The joint must be properly prepared before pouring starts. Eyes should be protected by goggles, and hands by gloves.

Section 3. ABOVEGROUND STRUCTURES

5.3.1 BASIC RULES. Only trained and experienced personnel should be permitted to work on standpipes and elevated tanks, or other structures located above ground level. The following precautions are basic to safety practices with respect to work on elevated structures (e.g., water storage tanks).

5.3.1.1 Climbing Rules

(1) Use a safety belt wherever possible.

(2) Keep shoes in good repair. Before ascending or descending a ladder, check shoes and remove oil, grease, mud or other slippery material.

(3) Always face a ladder when ascending or descending; always use both hands. Do not allow more than one person at a time on a ladder.

(4) Before using a ladder, take the following precautions.

(a) Make certain the rungs are free from oil, grease, mud or other slippery material.

(b) Inspect the ladder for defective rungs, loose weldings or rivets, and any other dangerous condition.

(c) Test each rung before placing full weight on it.

(d) Carefully note the width and spacing of the rungs. Be especially careful if rungs are placed in a stagger pattern.

(5) Step on every rung; use a ladder with safety feet.

(6) Protect ladders set up in alleyways, walkways and roadways.

(7) Do not place ladders on slanting, oily or slippery surfaces. Where ladders must be placed on unsafe locations, either secure the ladder thoroughly or have it held by a workman stationed there for that purpose.

(8) Do not step on the top rungs of a ladder, unless the ladder is adequately secured and hand grips have been provided above the ladder.

(9) Never allow any personnel to remain on an elevated structure during an electrical storm.

5.3.1.2 Repair Safety. In repairing elevated tanks, adhere to the following precautions.

(1) Provide the proper personal safety equipment and be sure the workers not only use it, but also that they do not wear loose, bulky or torn clothing. Especially be sure that workers wear a hard safety hat when they are underneath work being performed overhead; an approved respirator or freshair mask when spray painting, or when exposed to dangerous vapors, fumes and dust; and, safety goggles, masks or face shields when wire brushing, shipping, dusting, sandblasting, welding, burning paint or washing structures down with disinfecting solutions.

(2) Properly use and maintain tools and equipment in the following manner.

(a) Keep tools clean and in good repair.

(b) Do not use matches or other open flames in tank interiors; secure illumination from vapor-proof flashlights or electric lights.

(c) Ground all electrical equipment; use three-pronged plugs having a third long ground lug, or use a ground wire if three-conductor cable is not available.

(d) Use only extension cord that is approved by the Underwriters Laboratories and labeled to show that all the requirements of the National Electric Code are met; inspect such cords regularly before using.

(e) Provide only rubber-sheathed cords for equipment in tanks and other grounded structures.

(f) Use low-voltage equipment (not over 32 volts) in damp locations and in tanks that are wet or that will cause excessive perspiration.

(g) Use bronze tools if there is any danger from flammable or explosive gases.

(3) Before entering a tank take the following precautions.

(a) Check for dangerous and explosive gases and vapors or the absence of oxygen, by approved equipment and methods.

(b) Inspect the ventilation; provide ventilating equipment if natural ventilation is not adequate.

(c) Install sufficient lighting for dark interiors.

(d) Place portable generators, compressors and other equipment where their engine exhaust gases will not enter the tank.

(e) Before starting work in a tank interior with no permanent grating, cover the riser opening with timbers, grating or other protection.

(4) Keep a firm grip with one hand if it is necessary to work for a brief period of time from a ladder; do not reach farther than an arm's length from the ladder; use a safety belt if work at one location will take a lot of time.

(5) Do not work from a ladder in a high wind.

(6) Do not inspect or work alone on or inside a tank. (A man entering a tank from the roof should always have a safety line securely fastened to him; a helper on the outside should

hold the line and be available at all times in case of an emergency.)

(7) Securely fasten all temporary plans and scaffolding.

(8) Carry tools in a tool box, a bag or a tool belt. Never carry tools in pockets or a pants belt, particularly sharp-edged or pointed tools. Keep the number of tools in a tool belt at a minimum.

(a) Haul tools, equipment and materials with a handline and tool bucket.

(b) When descending, bring the tools along; do not leave them lying around on elevated ledges, angle irons or the roof.

(c) Adopt all possible precautions against dropping tools.

(9) Inspect all rope and tackle and wire cable before using; do not load such tackle beyond rated capacity.

(10) Never look at the direct light of an arc welder without protective goggles. (Even reflected light from an arc welder is sufficient to injure eyes.)

(11) When using rope for slinging purposes, be careful it does not contact sharp edges, which may result in its being frayed or cut; apply blocking and padding where needed.

Section 4. DISTRIBUTION SYSTEM

5.4.1 LIMITATIONS OF MATERIAL COVERED. Maintenance operations on distribution systems may involve excavation, removal, repair or replacement of valves or pipe, but generally do not involve trenching and pipe-laying for any considerable distance. For this reason, this Section covers only general excavation practices and pipe and valve repairs. For information on safety practices in trenching machine operation, power shovel operation, blasting and trench construction, see Chapter 9, Section 4 of Reference 6, and Reference 23.

5.4.2 PROTECTION OF PUBLIC. The following safety practices are the minimum required.

(1) Provide substantial guardrails on all public walkways, sidewalks and thoroughfares bordering on or running through any construction site. In addition, temporary footwalks beyond the curb shall be substantially constructed and provided with protection on both sides.

(2) Place warning signs well ahead of the construction or repair area to warn traffic.

(3) Protect the work area by barricades, barriers or planks in order to provide a safe working space.

(4) If necessary, provide flagmen to direct or slow down traffic.

(5) During the hours of darkness, provide suitable and adequate lightings in addition to other protective measures.

5.4.3 EXCAVATIONS. Prior to making any excavation, determine whether or not utility installations (sewers, waterlines, electric lines, gaslines, etc.) will be encountered. Follow these general precautions.

(1) When the excavation approaches the level of such utilities, check blueprints and/or use careful probing or digging to locate the utility line. When it is uncovered, support and protect it carefully.

(2) Wear a protective hat when working in a trench, and wear adequate eye and foot protection when using a jackhammer, or when exposed to flying or falling objects.

(3) Keep a safe distance from other workers to avoid the danger of striking them with tools.

(4) Do not jump into a trench, but sit on the shoulder and slide in, if the trench is shallow. Use ladders where required (e.g., where trench is 5 feet or more in depth). Before climbing out of a trench, look all ways for traffic danger.

(5) Remove earth and other material in such a way that overhanging banks are avoided. Do not go under an overhanging bank and, when working near one, be very cautious. If it is necessary to remove an over-hanging bank, work from one side to the center, always facing the point of danger.

(6) Where necessary, shore trench walls. (See Reference 6 and Reference 23 for instructions for shoring and bracing.)

(7) If undercutting is necessary, provide adequate bracing, and restrict the public from all braced areas.

(8) Where practical, place excavated material at least 2 feet away from the edge of the excavation; otherwise provide bracing if necessary.

(9) Keep all tools, working material and loose objects away from the shoulder of the trench. Also keep tools and equipment out of open traffic lanes.

(10) Wherever possible, keep the spoil bank between the workmen and traffic. Keep excavated material out of traffic lanes. Remove pebbles and small stones continuously to prevent them from lodging on a hard-surface roadway where tires may pick them up and throw them, causing injury or damage.

(11) For detailed instructions on pipe handling, storing, laying, and calking, see Reference 23.

5.4.4 PIPE HANDLING. Pipe handling is no job for an amateur; only trained and skilled personnel, with suitable and adequate equipment should be given the assignment. For safety practices in pipe handling, consult Reference 23.

Section 5. SCAFFOLDS AND PLATFORMS

5.5.1 REFERENCE. For general safety requirements in the construction and use of scaffolding and platforms, see Chapter 10 of Reference 6.

Section 6. PUMPING STATIONS

5.6.1 SAFETY INSTRUCTIONS: Constant attention and alertness is the best way to avoid injury in any situation or location. This axiom is particularly applicable in pumping stations, where danger is always present because of pumps, motors, powerlines, etc. Personnel responsible for the supervision of either the operation or maintenance of equipment shall alert all personnel to the need for safety practices. Specific instructions shall be posted conspicuously, and these instructions shall include information on how to contact the nearest medical officer, fire station and other emergency activity. These instructions shall also show the location of the nearest inhalators, and shall explain the procedures for the latest approved methods of resuscitation. First aid instructions shall be posted, and there shall be periodic first aid courses and drills for appropriate personnel.

5.6.2 HOUSEKEEPING. All housekeeping methods and procedures shall be in accordance with good safety practice. The following procedures shall apply.

(1) Regularly clean all floors, windows, walls and equipment.

(2) Store all tools in the proper location when they are not in use.

(3) Make minor repairs of structures and appurtenances as soon as the need is evident.

5.6.3 MACHINERY AND ELECTRICAL EQUIPMENT. The following general rules shall apply at all times. For convenience, the listing of rules is classified under these categories: Safety Guards, General Repair Practices, Lubrication, Electrical Equipment and Use of Solvents.

5.6.3.1 Safety Guards. Guards (shields, fencing, rails or enclosures) are necessary to provide safety and to protect employees against exposure to or accidental contact with machinery or power-driven equipment. The following safety guards and measures should have been provided in design and installation. If these safety guards do not exist, or have been damaged, make certain that they are installed properly. If guards are removed during maintenance operations, make certain they are replaced properly. The following safety practices apply to guards.

(1) Guards should exist around prime movers, power transmission equipment and machines or moving machine parts.

(2) Guards should have hinged or removable sections, where it is necessary to change belts, make adjustments or admit lubricants.

(3) Guards or enclosures, within 4 inches of a moving part, should have a screen in which the opening is less than ½ inch. Where the guard or enclosure is between 4 and 15 inches from a moving part, the maximum screen opening should be 2 inches.

(4) Standard railing guards shall exist at distances of 15 to 20 inches from moving parts.

(5) Guards shall be strong enough to ensure real safety, and it should not be possible to bend them or push them against moving parts.

(6) Operating and maintenance personnel shall not remove guards, except for maintenance purposes only, and only when the machinery is not in operation.

5.6.3.2 General Repair Practices. In general maintenance practices, the following safety practices shall apply.

5.6.3.2.1 Pre-maintenance period

(1) Always stop machinery or drivers before cleaning, adjusting or making any repairs.

(2) Lock the switch gear in an open position so that no one can start the equipment while it is being worked on. Place a tag on the switch reading, "Do Not Close!".

(3) Remove guards only after the machinery is stopped.

(4) Where counterbalanced or weighted devices are used, make certain that the device is blocked to prevent accidental movement.

5.6.3.2.2 Tools. Examine tools before use to assure that they are sharp, clean and in safe working condition. Take sufficient time to handle tools properly, and never leave tools where someone may trip over them.

5.6.3.2.3 Repair period. In performing repair operations, these rules shall apply.

(1) Maintain sufficient labor and hoisting equipment on the job to handle heavy objects.

(2) Secure unbolted heavy objects if it is necessary for the maintenance personnel to leave the work area.

(3) Place substantial blocking under any equipment suspended or supported by jacks, or a chain hoist, before beginning actual work.

(4) Keep aisles and open spaces on the floor free of tools and other objects.

(5) Keep goggles within easy reach, and wear them when eye protection is needed.

5.6.3.3 Lubrication. For lubrication practices, the following rules shall apply.

(1) Where lubrication must be done while the equipment is in motion, the lubricant fittings should be at least 12 inches from dangerous moving parts, or a pipe should extend from the fitting to a point outside a guard. If these conditions do not exist, stop the machinery before oiling it.

(2) Apply only enough oil or grease to give good lubrication without overflow.

(3) If grease or oil is spilled, wipe it up immediately.

(4) Never point a grease gun at anyone, and never shoot grease into the hand.

(5) Take advantage of each lubrication to inspect the condition of all visible machine parts; report unsafe conditions at once.

(6) Replace all guards immediately after lubrication and before starting the equipment.

(7) Before starting a machine, be certain that personnel are clear of danger and that parts are free to move without damage.

5.6.3.4 Electrical Equipment. In addition to the following practices, consult Chapter 18 of Reference 6.

5.6.3.4.1 Switchboards and panels. The following safety rules apply to this type of equipment.

(1) Switchboards should be located and constructed in such a manner that fire hazards are reduced to a minimum and so that the switchboards are not exposed to moisture or corrosive gases. Where design and construction have not met these requirements, adopt such precautionary measures as will offset these deficiencies.

(2) If adequate illumination does not exist for the front of all switchboards and for the back of those which have parts or equipment which require adjustment, repair or renewal, provide auxiliary illumination.

(3) If clear operating space of adequate size and secure footing about all switchboards and motor control equipment do not exist, use extra care when performing maintenance operations.

(4) Make certain that special insulating mats on the floor at all switchboards are provided at all times.

(5) Open switchboards shall be accessible only to qualified and authorized personnel, and should be provided with proper guards and screens.

(6) Make certain that all electrical equipment, including switchboard frames, is well grounded at all times.

(7) If areas screened off because of high voltage are not provided with locks that open from the inside without keys, report the matter to proper authority.

(8) Permanent and conspicuous warning signs for panels carrying more than 600 volts must be displayed at all times.

(9) Use extreme caution where fully enclosed shock-proof panels do not exist and where such equipment is not provided with interlocks so that it cannot be opened when the power is on.

(10) Lock switches must be opened and tagged "Do Not Close!" when anyone is working on the equipment that the switch controls.

5.6.3.4.2 Motors. General safety practices with respect to motors are similar to those for other machinery (see Paragraphs 5.6.3.1, 5.6.3.2, and 5.6.3.3).

(1) Before working on a motor, be sure the power is shut off and the master switch is tagged "Do Not Close!".

(2) Before starting equipment, be sure that tools and other loose equipment are not left in the motor in any location where they may interfere with its operation.

5.6.3.4.3 Transformer stations. Water utility operating and maintenance personnel should be familiar with the layout and construction of transformer stations in order that they may safely perform routine inspection and minor maintenance, as well as recognize and report major damage, dangerous conditions and other troubles for correction by power system personnel. Plans of the electrical system shall be available at each station. For detailed safety practices see Chapter 18 of Reference 6.

5.6.3.5 Use of Solvents. The following general rules apply to the use of all types of solvents and cleaning fluids.

(1) Be sure that ventilation is adequate in the area where solvents are to be used. Do not use solvents in confined places (tanks, pump pits and vaults) without good mechanical ventilation.

(2) If possible, use only solvents having flash points above 100° F., or higher.

(3) Exercise caution in the use of solvents whose complete composition is not presented on the container.

(4) Do not use gasoline, carbon tetrachloride or other highly toxic or low flash-point cleaning agents without special authorization. Even when authorized, use extreme care in handling the solvent.

(5) Keep a suitable fire extinguisher near at hand and ready for use; (see Reference 4).

5.6.4 INTERNAL COMBUSTION ENGINES

5.6.4.1 Gasoline and Oil Storage. The storage of flammable liquids is controlled by agencies interested in fire prevention. For safety practices see Reference 4 and Chapter 17 of Reference 6.

5.6.4.2 Diesel and Gasoline Engines. Personnel should be thoroughly familiar with the manufacturer's instructions for operating and servicing these engines.

5.6.4.2.1 Starting

(1) Before starting an engine, personnel should be sure that the following conditions exist.

(a) Guards are in place around moving and rotating parts.

(b) No tools are near the engine.

(c) The floor in the vicinity of the engine

is clean, and free of all spillage of oil, grease, gasoline or water.

(d) All personnel are clear of danger.

(e) The gear shift is in neutral.

(f) Suction and discharge valves of pump lines are in proper position.

(g) Use the recommended safety grip (thumb not around the handle), when it is necessary to crank an engine by hand.

(3) Make certain that compressed-air equipment used for diesel starting has the proper pressure. Never, in any emergency, use other bottle gases to start a diesel.

5.6.4.2.2 Exhaust. When entering a building, immediately check for the presence of exhaust or other gases. Use only approved test instruments and methods (consult Reference 24). Maintain ventilating equipment in good condition, and make certain that exhaust outside does not short circuit back into the building through open windows or ventilators.

5.6.4.2.3 Operation and repair practices. Before starting repair work, be sure the engine is stopped and that the ignition key has been moved, so that no one else can start it. Safety practices given for machinery generally apply to work on diesel and gasoline engines (see par. 5.6.2). In addition, the following practices shall apply.

(1) Be properly clothed for the job.

(a) Never wear gloves, jewelry, neckties, long sleeves or loose or torn clothing near rotating parts.

(b) Keep hair clear of moving parts; wear a cap.

(c) Keep shoes in good repair. Avoid rubber heels; use a nonslip material such as neoprene.

(2) Set up and follow a regular, tested procedure for the maintenance and repair of engines.

(3) Do not oil, adjust or repair an engine while it is running or while the exhaust manifold is hot.

(4) Do not smoke while working on an engine.

(5) Keep the floor around engines clean, dry and free of slippery materials, and wipe up spillage immediately.

(6) When working on fuel tanks, fill with water before welding.

(7) Upon completion of repairs, thoroughly check the vicinity to ensure that all tools, portable lamps, plans, ropes and other objects have been removed, and that cleanup has been thorough.

5.7.1 GENERAL PRACTICES. The general safety practices which are applicable to pumping stations (par. 5.6.1) are also applicable to treatment plants. Where liquid lines are involved, valves should be chained, locked or tagged, as necessary, to indicate position. In addition, there are specific safety precautions which are applicable to laboratories and chemical handling.

5.7.2 LABORATORIES. In bacteriological and chemical laboratories, the following safety practices shall apply.

(1) Be familiar with the type of fire extinguisher to use for each kind of fire.

(2) Wear protective clothes, glasses or face shields, when operations require.

(3) Keep premises clean and neat.

(4) Do not use laboratory equipment for preparing and serving food.

(5) Provide a well-stocked first aid kit in an easily accessible location.

(6) Do not neglect any accident, no matter how insignificant. Apply first aid and notify person in charge.

(7) Consult Reference 23 for detailed safety practices in laboratories.

5.7.3 CHEMICAL HANDLING AND STORAGE. Detailed safety practices on all water works chemicals are presented in Reference 23.

(1) See this reference for detailed information on activated carbon, alum, ferrous sulfate, anhydrous ammonia, ammonium sulfate, carbon dioxide, chlorine, fluorides, lime, soda ash and sodium chlorite.

(2) For almost any chemical spillage on personnel, quick, thorough and continued flooding of the affected area with water is the best general first aid measure. Call a medical officer if chemical burns are involved, and always if the eyes have been affected by the accident.

(3) Since chlorine is the most dangerous of the chemicals mentioned above, some safety precautions on this chemical are given in paragraph 5.7.3.1.

5.7.3.1 Chlorination Safety Precautions. These precautions are abstracted from Reference 23, which should be consulted for additional details.

(1) Provide gas masks with full face piece and canisters designed to cope with chlorine.

(2) Maintain only the supply of chlorine in any chlorinator room that is sufficient for normal daily demands. Store the main supply in a detached noncombustible building or in a fireproof room which is vented only to the outside and which is separated from the main part of the building. Keep the chlorinator and chlorine storage buildings or rooms locked to prevent the entrance of unauthorized personnel and restrict these areas from any other use.

(3) Allow only reliable and trained personnel to handle chlorine.

(4) Handle containers carefully to avoid dropping or bumping them.

(5) Avoid hoisting containers as much as possible; if hoisting is necessary, use safe lifting clamps.

(6) Store cylinders in a cool place, away from dampness, steam lines and fire, and in an upright position secured from tilting and falling.

(7) Keep protective valve caps on containers when not in use; never tamper with safety devices on containers.

(8) Never connect a full cylinder to a manifold with another cylinder, unless temperatures of both are approximately the same.

(9) When not withdrawing chlorine or when cylinders are empty, keep the valves closed.

(10) Disconnect valves as soon as containers are empty, and check for chlorine leaks at the valve outlets. Test for leaks by passing an unstoppered bottle of strong ammonia solution around the valves. White fumes of ammonium chloride will appear if there is any leakage. Leaks around fittings, connections and lines can be detected in the same way. Do not apply ammonia solution to plated metal parts as it will remove the plating.

(11) When a chlorine leak occurs, only qualified personnel with suitable respiratory equipment will be assigned to investigate and correct the trouble. If chlorine is being discharged, close the container valve immediately. If chlorine is escaping in liquid form, turn the container so the chlorine escapes as gas, which will reduce leakage. Do not apply water to the leak; this practice is hazardous and results in corrosive action that may increase the leakage.

(12) Never apply flame, a blow torch or other direct heat to chlorine containers; discharge them in a room with a temperature of about 70° F.

(13) Never ship a defective or leaky cylinder unless it is completely empty. Paint "DEFECTIVE" plainly on all such cylinders.

(14) Follow all regulations on shipping, storing and using compressed-gas cylinders.

(15) Provide proper means of exit from areas where chlorine is stored or used.

(16) Never use a chlorine cylinder for any purpose other than holding chlorine gas. Do not refill cylinders.

(17) Administer first aid to exposed victims as soon as they are removed from the area of the leak. If the victim is unconscious and not breathing, use the back pressure arm lift or prone-pressure method of producing artificial respiration. Summon qualified medical assistance immediately.

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GLOSSARY

Absorption. The process of taking in or soaking up liquids; not to be confused with adsorption.

Acre-Foot. A measurement used for reservoirs or water storage that is equivalent to one acre (43,560 square feet) one foot deep, or 43,560 cubic feet or 325,830 gallons.

Adsorption. The adherence of dissolved, colloidal and finely divided matter on the surfaces of solid bodies with which they are brought in contact, not to be confused with absorption.

Air Binding. The condition whereby entrained air clogs or otherwise interferes with proper operation of a sand filter, pump or pipe.

Algae. Tiny plant life, usually microscopic, existing in water. They are mostly green, blue-green or yellow-green, and are the cause of most tastes and odors in water.

Algicide. Any substance which kills algae.

Appurtenances, Water System. Structures, devices and appliances, other than pipe and conduit, which are used in connection with a water distribution system, e.g., valves, hydrants, corporation cocks, services, etc.

Aqueduct. An artificial channel or large pipe (conduit) for bringing water from a distance.

Aquifer. A water-bearing formation or stratum beneath the earth's surface.

Artesian. An adjective applied to ground water, or items connected with ground water, e.g., a well, underground basin, etc., where water is under pressure and will rise to a higher elevation if afforded an opportunity to do so.

Backflow. The backing-up of water through a conduit or channel in the direction opposite to normal flow.

Backsiphonage. The flowing back of contaminated or polluted water from a plumbing fixture or cross-connection, into a water supply line, because of a lowering of the pressure in the line. (Also termed "backflow".)

Backwashing. The operation of cleaning a filter, or ion-exchange unit, by a reversed flow of water.

Bacteria. Microscopic vegetable organisms, usually single celled, with no chlorophyll, which multiply by dividing.

Coliform Group. Bacteria from the intestinal tracts of warm-blooded animals.

Basin. A natural or artificially created space or structure, surface or underground, which by reason of its shape and the character of its confining material, is capable of holding water. The term is sometimes used for a receptacle midway in size between a reservoir and a tank.

Black Alum. Water works alum containing a small percentage of activated carbon.

Blowoff. A controlled outlet on a pipeline, tank or conduit used to discharge water or accumulations of material carried by the water.

Boom. A floating structure, usually of timber or logs, used to protect the face of a dam, or other structure built in or on water, from damage by wave action, by floating material being dashed against it by the waves, or to deflect floating material away from such a structure.

Brackish Water. Water rendered unfit for drinking because of salty or unpleasant tastes caused by the presence of excessive amounts of dissolved chemicals, chlorides, sulfates and alkalies.

Cascade. A sudden drop installed in a waterway to produce agitation and aeration of the liquid flowing over it.

Casing, Well. Metal pipe used to line the borehole of a well.

Chloramines. Compounds of organic amines or ammonia with chlorine.

Chlorination. Treatment of water, sewage or industrial wastes by the addition of chlorine, either as a gas or liquid, or in the form of a hypochlorite, usually for the purpose of disinfection, odor control, oxidation, etc.

Chlorine-Ammonia Process. The application of chlorine and ammonia to water, or of ammonia to water containing chlorine, to provide combined residual chloramine for disinfection.

Clarification. See *Sedimentation.*

Coagulant. A chemical or material which when added to water or sewage will combine with added or naturally present chemicals to form a precipitate, called a floc, which will settle and aid in the removal of suspended matter in the liquid.

Coagulation. The process of producing a "floc" by the addition of a chemical to water or sewage; the floc assisting in the agglomeration or coalescence, or coming together of finely divided particles of suspended matter and bacteria to make them settle rapidly. Flocculation is that phase of coagulation where the floc is caused to form or grow by slow mechanical stirring with or without the addition of chemicals.

Coefficient. A numerical quantity or factor, determined by experimental methods, put into a formula, which expresses the relation between two or more variables, to correct the theoretical relation to that found in actual practice.

Discharge. The factor or number by which the theoretical discharge of fluids through orifices, nozzles, tubes, weirs, etc., must be multiplied to obtain the actual discharge.

Roughness. A factor, in the Kutter, Manning, Bazin and other formulas for computing the average velocity of the flow of water in a conduit. It represents the effect of roughness of the confining material of the channel or conduit upon the energy losses in the flowing water.

Uniformity. The degree of variation in the size of the grains that constitute a granular material. It is the ratio of: (1) the diameter of a grain of a size that is too large to pass through a sieve which allows 60 percent of the material (by weight) to pass through, to (2) the diameter of a grain of a size that is too large to pass through a sieve which allows 10 percent of the material (by weight) to pass through. The coefficient is unity for any material whose grains are all the same size, and it increases above unity with variation in the size of the grains.

Colloids. Finely divided solids which will not settle, but may be removed by coagulation or biochemical action.

Corrosion. Damage to metal (gradual eating away) due to chemical or electrochemical reactions, as rusting or pitting.

Crenothrix. A genus of bacteria characterized by unbranched, attached filaments having a gelatinous sheath in which iron is deposited. They precipitate metallic oxide deposits in pipes, etc., which sometimes color the water. They also, after their death, cause disagreeable taste and odor in the water.

Cross-Connection. In plumbing, a physical connection through which a supply of potable water could be contaminated, polluted or infected. A physical connection between water supplies from different systems.

Dam. A barrier constructed across a watercourse.

Degasification. The removal of dissolved gas from water.

Demineralization. The removal of dissolved mineral constituents from water.

Diatomaceous Earth. Extremely porous powder composed essentially of the siliceous skeletons of diatoms, which are extremely minute unicelled organisms.

Diffuser. Unit or device used to break up a fluid (liquid or gas) into minute particles and disperse them in another fluid, where they may be absorbed or dissolved, or whereby they may become more effective as chemical agents.

Discharge. (1) As applied to a stream, the rate of flow or volume of water flowing in a given stream at a given place and within a given period of time. (2) The process of water or other liquid passing through an opening or along a conduit or channel. (3) The water or other liquid which emerges from an opening or passes along a conduit or channel.

Disinfection. The process of killing most (but not necessarily all) of the harmful and objectionable micro-organisms in a fluid by various agents such as chemicals, heat, ultraviolet light, ultrasonic waves, radiation, etc. (Compare with *Sterilization.*)

Distillation. The process of converting a liquid to a gaseous, or vaporous state and condensing the resulting vapor to liquid under the influence of heat (and possibly reduced pressure or partial vacuum), followed by cooling. Used to remove impurities from a liquid in order to improve its purity.

Drawdown. (1) A change in surface elevation of a body of water as a result of the withdrawal of water. (2) The amount, in feet or inches, by which the water level in a well decreases while water is being withdrawn from a well by pumping.

Effluent. That which flows out, particularly a liquid which flows out of a containing space.

Electrolysis. A form of corrosion occurring in metallic pipe or metallic structures. It is caused by stray electric currents which pass through the earth on another conductor to the pipe, follow the pipe and later pass again into the ground, and reach another conductor. Such corrosive action occurs where the current leaves the pipe; and metallic ions in the pipe, induced by the flow of electrical current, enter the soil at that point. This definition also applies to galvanic action or self-electrolysis.

Evaporation. (1) The process by which a liquid (e.g., water) passes from liquid to a gaseous (vapor) state under the influence of heat. The term is generally applied to the functioning of the process below the boiling point of the liquid involved. (2) The quantity of water evaporated from a body (reservoir) of water, usually expressed in inches per month.

Filter. A device or structure for removing solid or colloidal matter (which usually cannot be removed by sedimentation) from water, sewage or other liquids or semiliquids, by a straining process whereby the solids are held on a medium of some kind (granular, woven, porous, etc.), while the liquid passes through.

Fire Demand. The quantity of water and rate of flow required for fire-fighting purposes, based on the types and sizes of structures burning and the duration of the fire.

Flashboard. A temporary barrier, of relatively low height and usually constructed of wood, placed along the crest of the spillway of a dam to allow the water surface in the reservoir to be raised above spillway level to increase the storage capacity.

Float Control. A float installed in a tank or body of liquid to control the pumps.

Floc. Small gelatinous masses which are accumulations of micro-particles, bacteria and other organisms, formed in a liquid by the addition of chemical coagulants, or by the gathering together of particles by mixing.

Flocculator. An apparatus for the formation of floc in water.

Flume. An open conduit which is constructed of wood, masonry or metal on a grade (sometimes elevated).

Control. A flume arranged for measuring the flow of water, sewage or other liquids, generally including a constricted section wherein a minimum energy exists at all states.

Parshall. A device for measuring the flow of liquid in an open conduit.

Friction, Hydraulic. The resistance to flow exerted on the perimeter or contact surface of a body of water moving in a stream or conduit, caused by the roughness that is characteristic of the confining surface and which induces turbulence and consequent loss of energy. Energy losses arising from excessive turbulence, impact at obstructions, curves, eddies and pronounced channel changes are not ordinarily ascribed to hydraulic friction.

Fungi. Small nonchlorophyll-bearing plants which lack roots, stems or leaves, and which occur (among other places) in water, sewage or sewage effluents, growing best in the absence of light. Their decomposition after death may cause disagreeable tastes and odors in water.

Gage. (1) A device for indicating the magnitude or position of a thing in specific units, when such magnitude undergoes change (e.g., liquid level, velocity of flowing water, quantity of flow, pressure of water, temperature,

etc.). (2) The act or operation of registering or measuring the magnitude or position of a thing undergoing change. (3) The operation, including both field and office work, of measuring the discharge of a stream.

Gaging, Stream. The measuring of the velocity of a stream of water in a channel, or an open conduit, and the area of cross section of the water for the purpose of determining the discharge.

Gate. A movable watertight barrier for the control of a liquid in a waterway or conduit.

Ground Water. Water occurring in a stratum (acquifer) below the surface of the ground. The term is not applied to water which is percolating or held in the top layers of the soil, but to that below the water table.

Head, Friction. That head lost by water flowing in a stream, conduit or pipe because of disturbances set up between the moving water and the wall of the conduit.

Hydraulic Grade. A line in any selected vertical plane connecting all points representing the head in any system. Frequently it is mistakenly called hydraulic gradient, but it is simply a curve representing line pressures at various points along a line or throughout a water system.

Hydrologic Cycle. The complete cycle of phenomena through which water passes, beginning as atmospheric water vapor, passing into liquid and solid form as precipitation, thence along or into the ground surface, and finally again returning to the form of atmospheric water vapor by means of evaporation and transpiration. Also called Water Cycle.

Hydrology. The applied science concerned with the waters of the earth, their occurrences, distribution and circulation through the unending hydrologic cycle of precipitation; consequent runoff, infiltration and storage; eventual evaporation or transpiration; and, reprecipitation. This science is concerned with the physical and chemical reaction of water with the rest of the earth, and its relation to the life of the earth.

Impeller. A rotating set of vanes designed to impel rotation of a mass of fluid.

Impermeability. The property of rock or earth which prevents perceptible movement of water through it under pressures ordinarily encountered in subsurface water. Even though the material allows capillary movement, it still may be impermeable.

Impervious. A term applied to a material through which water cannot pass. It is also applied to material through which water passes with great difficulty.

Infiltration. (1) The flow or movement of water through the interstices or pores of a soil or other porous medium. (2) The absorption of liquid water by the soil, either as it falls as precipitation, or from a stream flowing over the surface.

Langelier Index. An expression to indicate the hydrogen-ion concentration that a water should have to be in equilibrium with its content of calcium carbonate.

Level

Hydrostatic. The level or elevation to which the top of a column of water would rise, if afforded opportunity to do so, from an artesian aquifer, or basin, or from a conduit under pressure.

Pumping. The elevation at which water stands in a well when the well is being pumped at a given rate.

Static. The elevation of the water table or pressure surface when it is not influenced by pumping or other form of extraction from the groundwater body. It is the level of ground water in a well before pumping.

Main. A pipeline on the discharge side of a water pumping station.

Manometer. Single or double (U-tube) glass tube containing a liquid; an indicating instrument used for measuring flow, pressure or liquid level.

Meter. A device for measuring the flow of a fluid.

Micro-Organism. A minute plant or animal in water, sewage or earth that is visible only through a microscope.

Mixer, Flash. A device for quickly dispersing chemicals uniformly throughout a liquid.

Pathogenic. Disease producing.

Perched Water. Ground water occurring in a zone of saturation located above the general body of ground water, and separated from it by a zone of impermeable material.

Pitot Tube. A device for measuring the velocity of flowing water, using the velocity head of the stream as an index of velocity. It consists essentially of an orifice held to point upstream, connected with a tube in which the rise of water due to velocity head may be observed and measured. It may also consist of two orifices or openings, one facing upstream, one downstream, each connected to tubes (or water columns), in which case the difference in height, or the water differential, in the two columns is an index of velocity.

Pitting. The formation of small holes on metal surfaces due to corrosion.

Potable. Water which does not contain any objectionable substances or pollution, and is satisfactory for human consumption.

Prechlorination. Chlorination of water prior to filtration.

Recarbonation. In the lime treatment for water softening, a process to remove caustic alkalinity by changing calcium hydroxide to calcium carbonate by the introduction of carbon dioxide to water in a basin or "carbonation chamber." Used when excess caustic treatment of water is employed to obtain maximum removal of magnesium hardness.

Rechlorination. The application of chlorine to water at one or more points in the water distribution system following previous chlorination.

Riparian. An adjective pertaining to anything connected with an adjacent to the banks of a stream or other following body of water.

Riprap. Broken stone or boulders placed compactly or irregularly on dams, levees, dikes, etc., for protection of earth surfaces against the action of water.

Runoff. That part of the precipitation which reaches a stream, drain or sewer.

Scale. Accumulation of solid material precipitated out of waters containing mineral salts in solution, particularly calcium and magnesium salts, and formed or deposited on surfaces in contact with the water under certain conditions, usually under the influence of heat or evaporation.

Screen, Well. A special form of slotted or perforated well casing that admits water from an aquifer consisting of unconsolidated granular material, while preventing the granular material from entering the well.

Second Feet. Abbreviated expression for cubic feet per second.

Sedimentation. Process of subsidence and deposition by gravity of suspended matter carried by water, sewage or other liquids. Also called settling, it is usually accomplished by reducing the velocity of flow of the liquid below the point where it can transport the suspended material.

Service Connection. Any pipeline, with its appurtenances, which branches off or connects with a water main, and carries water from the main to a consumer.

Silting, Reservoir. The reduction of storage capacity in reservoirs due to the deposition of silt.

Size, Effective. The diameter of the particles, spherical in shape, all equal in size and arranged in a given manner, of a hypothetical sample of granular material which would have the same transmission constant as the actual material under consideration. There are a number of methods of determining "Effective Size", the most common being that developed by Allen Hazen. It consists of passing the granular material through sieves with varying dimensions of mesh, the effective size being determined from the dimensions of that mesh which will permit 10 percent of the sample to pass and will retain the remaining 90 percent. In other words, in this case, the effective size is that for which 10 percent of the grains are smaller and 90 percent larger.

Standpipe. (1) A pipe or tank connected to a closed conduit and extending above the hydraulic grade of the conduit, installed to afford relief from surges in pressure in pipelines. (2) A tank resting on ground, with its height greater than its diameter, used to store water in distribution systems. (3) A fixed vertical pipe for furnishing water to the upper part of buildings in case of fire.

Sterilization. Destruction of all living organisms, usually by a chemical compound or heat.

Stratum. A geological term used to designate a single bed or layer of rock which is more or less homogeneous in character.

Surge. A momentary increase in flow (in an open conduit) or pressure (in a closed conduit) which passes longitudinally along the conduit, due usually to sudden changes in velocty.

Tributary. A stream or other body of water, surface or underground, which contributes its water, even though intermittently and in small quantities, to another and larger stream or body of water.

Tuberculation. A condition which develops on the interior of ferrous pipelines caused by corrosive materials present in the water passing through the pipe. It results in the creation of small, more or less hemispherical lumps (tubercles) on the walls of the pipe, which increase the friction loss and, by reducing the velocity, also reduce the capacity of the pipe.

Turbidity. Finely divided, suspended and colloidal matter in water or sewage, which prevents the passage of light through the liquid, causing a "muddy" or "cloudy" appearance. In water, some turbidity-causing particles may be large enough to settle out while others require chemical treatment or filtration for their removal. Five p.p.m. of turbidity is the maximum allowable in drinking water; a maximum of 2 p.p.m. is desirable.

Vaporization. The process by which water changes from the liquid or sublimation to the gaseous state.

Water Hammer. The phenomenon of oscillations in the pressure of water in a closed conduit, flowing full, which results from a too rapid acceleration or retardation of flow. From this phenomenon, momentary pressures greatly in excess of the normal static pressure may be produced in a closed conduit.

Water Table. The upper surface of a zone of saturation (in ground water) where the aquifer is not confined by an overlying impermeable formation.

Water-Bearing Formation. A term, more or less relative, used to designate a geological formation that contains considerable ground water. It is usually applied to formations from which the ground water may be extracted by pumping, drainage, etc. See *Aquifer.*

Watershed. The area contained within a divide above a specified point on a stream.

Yield, Safe. The maximum dependable draft which can be made continuously upon a source of water supply (surface or ground water) during a period of years during which the probable driest period or period of greatest deficiency in water supply is likely to occur.

APPENDIX A

BUDOCKSINST 11330.8

"Potable Water Supply at Naval Shore Activities by Portable and Mobile Tanks and/or Containers"

BUDOCKS 11330.8
10 July 1959

DEPARTMENT OF THE NAVY
Bureau of Yards and Docks
Washngton 25, D.C.

BUDOCKS INSTRUCTION 11330.8

From: Chief, Bureau of Yards and Docks
To: Distribution List

Subj: Potable Water Supply at Naval Shore Activities by Portable and Mobile Tanks and/or Containers

Ref: (a) CNO ltr Op–443D/rc Ser:3395P44 of 15 Dec 1958 to BuDocks
(b) BuDocks Inst. 11330.1A of 19 May 1954
(c) NavDocks TP–PW–12, Water Supply Systems of 1 Feb 1954

Encl (1) Facilities to be Used and Operating Procedures to be Observed in Supplying Potable Water to Personnel at Naval Shore Activities by Portable and Mobile Tanks and/or Containers.

1. Purpose. To provide instructions for the care and disinfection of facilities used and operating procedures to be observed in supplying potable water to personnel at naval shore activities by portable and mobile tanks and/or containers.

2. Background. By reference (b), the Bureau established approved methods for supplying potable water to personnel at naval shore activities. Recent inspections by the Naval Inspector General have revealed that improper procedures are being followed in the transporting of potable water in tanks. The Chief of Naval Operations, by reference (a) requested the Chief, Bureau of Yards and Docks to prepare and issue instructions to shore activities outlining the methods to be used to preclude contamination when handling and issuing potable water from automotive trailer tanks and other mobile and/or interim containers.

3. Prohibited Method. The procurement and use of bottle type drinking water coolers was prohibited by reference (b), in response to specific recommendations of the Bureau of Medicine and Surgery. The mandate against dispensing drinking water by this method is reiterated.

4. Approved Facilities and Operating Procedures. Facilities to be provided and operating procedures to be observed in loading, transporting and transferring potable water by portable and mobile tanks and/or containers are described in enclosure (1).

5. Action. By authority delegated to the Bureau of Yards and Docks by reference (a), addressees are directed to comply with the requirements of this Instruction.

6. Coordination. This Instruction has been coordinated with the Bureau of Medicine and Surgery.

J. R. DAVIS
Assistant Chief for Maintenance and Material

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FACILITIES TO BE USED AND OPERATING PROCEDURES TO BE OBSERVED IN SUPPLYING POTABLE WATER TO PERSONNEL AT NAVAL SHORE ACTIVITIES BY PORTABLE OR MOBILE TANKS AND/OR CONTAINERS

1. General. Minimum facilities to be provided and operating procedures to be observed in providing potable water for drinking and culinary purposes to personnel working and/or living at tanks and/or containers shall be as prescribed below. All free chlorine residual concentrations shall be determined by the Orthotolidine-Arsenite (OTA) test.

2. Facilities.

a. Supply Facilities. The facilities listed and described below shall be provided at the naval shore activity selected to act as supplier of potable water. Where potable water is supplied from non-naval sources, these facilities shall be provided by the supplier under the services contract. Source facilities shall be only those specifically approved by the medical officer.

(1) Potable Water Supply Outlets.

(a) Potable water supply outlets (taps, faucets or hydrants) shall be designed, installed, located and maintained so as to insure the water against contamination.

(b) Such water supply outlets shall not be located in toilet rooms, wash rooms or other places where danger of contamination exists or may develop.

(c) Where hoses are used for loading potable water the supply outlet shall have a type of coupling which will permit quick attachment and removal of the hose.

(d) A threaded connection is permissible only when the hose remains connected to the supply outlet between uses and is adequately stowed with the open end covered with cap or closure with keeper chain.

(e) All taps, faucets and hydrant supply outlets shall terminate in a downward direction or gooseneck with the outlet not less than 18 inches above grade.

(f) Supply outlets used for filling tanks or containers shall be used for no purpose which could adversely affect the quality of the water.

b. Transportation and Handling Facilities. The facilities listed and described below shall be provided by the naval activity or non-naval agency transporting the potable water from source of supply to point of delivery.

(1) Hose.

(a) Hose for filling tanks or containers for transporting water shall have a smooth interior surface, be free from cracks or checking, and be sufficiently durable to withstand hard usage.

(b) All hose connections shall be of the quick coupling type except where hose remains connected between uses and is stowed properly.

(c) Hose shall be provided with caps or closures attached with keeper chains. Hose ends, caps or closures shall be prevented from touching the ground or other contaminating medium. When such contact occurs, the contaminated part shall be detached and replaced with a part disinfected as prescribed in paragraph 3c(1) below.

(d) Hose for filling tanks or containers shall be marked "POTABLE WATER ONLY", and shall be used for no other purpose.

(e) Hose shall be stowed on suitable racks or special reels in lockers or cabinets which are used for no other purpose.

(2) Portable and Mobile Tanks.

(a) Portable and mobile tanks for transport of potable water shall be constructed of smooth, heavy gauge, corrosion-resistant material and shall be completely enclosed from filling to outlet connections, except that vent openings are permitted when necessary if protected to prevent contamination of the water. A handhole with quick-opening cover shall be located on the top of the tank for the introduction of chlorine for disinfection. Tanks previously used for sewage, oil, gasoline or other contaminating matter shall not be rehabilitated for use in transporting potable water.

(b) Tanks shall be provided with drain that permits complete drainage of the tank.

(c) Tanks shall be labeled "POTABLE WATER ONLY" and shall be used for no other purpose.

(d) The inlet and outlet to the tank shall terminate in a downward direction or gooseneck and shall be provided with caps or closures with keeper chains for protection against contamination.

(e) Threaded fittings on tank inlets and outlets will be acceptable only if hoses remain attached between uses and are properly stowed with the open ends covered with caps or closures with keeper chains.

(f) When potable water is to be transferred from a tank by other than gravity, a suitable pump and drive should be housed on the tank.

(g) Where tanks are stationed at the point of delivery for direct dispensing of potable water, the tanks may be provided with one or more suitably located sanitary drinking spouts or dispensers for single service cups and used cup receptacles.

(h) Lockers or cabinets for stowing hose shall be provided on the tank at fill and outlet connections when hoses are to remain connected to the tank.

(3) Containers. Except for the tanks described above, only those containers approved by the Bureau of Medicine and Surgery for transporting potable water to personnel at naval shore activities shall be used.

c. Disinfection Facilities

(1) Suitable facilities shall be provided for the disinfection of hose, tanks and containers used in loading, transporting and transferring potable water. Minimum facilities shall consist of a surfaced sanitary area (such as gravel, asphalt, concrete, etc.) provided with potable water outlet and adequate drainage.

d. Stowage Facilities.

(1) Suitable facilities shall be provided for the stowage of hose, tanks and containers used in loading, transporting and transferring potable water. Minimum facilities shall consist of the following:

(a) Areas or buildings for stowing tanks or containers between uses in a sanitary manner.

(b) Suitable racks or reels in lockers or cabinets having tightfitting doors or covers for stowing hose. Lockers or cabinets shall be marked "POTABLE WATER HOSE" and shall be used for no other purpose.

3. Personnel Requirements and Procedures for Loading, Transporting and Transferring Potable Water and for Disinfecting Facilities used therefor:

a. Personnel Requirements.

(1) Personnel assigned to duties involving loading, transporting and transferring potable water shall be thoroughly indoctrinated in the principles of water sanitation applicable to their work, and shall observe the operating procedures described in this Instruction.

(2) When potable water is transferred into storage for distribution at a receiving activity, personnel at that activity shall be responsible for obtaining bacteriological analyses of the water in the system, as prescribed in reference (c) for station water supply systems.

b. Procedures for Loading, Transporting and Transferring Potable Water.

(1) Portable and Mobile Tanks. The following instructions for loading, transporting and transferring potable water apply to tanks having supply and discharge hoses which remain connected to the tank between uses and are properly stowed. These instructions should be modified for hoses that are not so connected and stowed. Procedures are:

(a) Open tank drain.

(b) Remove cap or closure from tank filling hose.

(c) Flush hose end with water from potable water supply outlet.

(d) Attach hose to potable water supply outlet.

(e) Flush tank thoroughly permitting this flushing water to drain through tank drain.

(f) Close tank drain.

(g) Place sufficient calcium hypochlorite (in solution) in tank to provide a free chlorine residual in the water being transported to 0.2 to 0.4 parts per million after 30 minutes of contact. The furnishing activity shall make this determination.

(h) Fill tank

(i) Disconnect fill hose, replace cap or closure and stow hose.

(j) Transport tank to point of use.

(k) Remove cap or closure from tank discharge hose and from receiving tank fill connection.

(l) Flush receiving tank inlet connection with water from mobile tank.

(m) Connect tank discharge hose.

(n) Transfer water.

(o) Disconnect tank discharge hose, replace cap or closure and stow hose.

(p) Replace receiving tank fill connection cap or closure.

(2) Containers.

(a) Containers shall be filled and transported in the manner prescribed by the activity medical officer.

c. Procedures for Disinfection of Hose, Portable and Mobile Tanks, and/or Containers.

(1) Hose. Hose shall be disinfected whenever the hose ends touch the ground or other contaminating medium or become contaminated in any other way. (Hoses stowed on tanks shall and whenever contamination is suspected.) Procedures are as follows:

(a) Remove caps or closures and place in a chlorine solution having a chlorine concentration of at least 100 parts per million.

(b) Connect hose to potable water supply outlet.

(c) Flush hose thoroughly by allowing potable water to flow through it about one minute.

(d) Drain hose.

(e) Elevate ends of hose to same level.

(f) Fill hose to overflowing with chlorine solution having a chlorine concentration of at least 100 parts per million and allow to stand for one hour.

(g) Drain chlorine solution from hose and flush.

(h) Remove caps or closures from chlorine solution, replace on hose and attach hose to tank and stow.

(2) Portable and Mobile Tanks. Portable and mobile tanks shall be disinfected once every two weeks and whenever contamination is suspected. Procedures are as follows:

(a) Remove caps or closures from fill and discharge hoses and place in a chlorine solution having a chlorine concentration of at least 100 parts per million.

(b) Connect tank fill hose to potable water supply outlet.

(c) Flush tank thoroughly with potable water through drain valve.

(d) Close drain valve.

(e) Elevate end of discharge hose above top of mobile tank.

(f) Place sufficient calcium hypochlorite (in solution) in tank to make a 100 parts per million chlorine solution when tank is filled with water.

(g) Fill tank with potable water until hose overflows.

(h) Disconnect fill hose from potable water supply outlet.

(i) Let chlorine solution from tank run back through fill hose until strong chlorine odor is noted.

(j) Elevate fill hose to same level as discharge hose.

(k) Refill tank to overflowing with potable water through hand-hole and allow to stand for one hour.

(l) Remove caps or closures from chlorine solution and replace on fill and discharge hoses.

(m) Lower fill and discharge hoses below tank outlet levels.

(n) Drain tank and fill and discharge hoses.

(o) Replace hose caps or closures, and stow hoses.

(p) Stow mobile tank in clean stowage area provided.

(3) Containers. The care and disinfection of containers for transporting potable water shall be as prescribed by the activity medical officer.

4. Assistance. The services of the cognizant Director, Overseas Division, Bureau of Yards and Docks, Area Public Works Officer or District Public Works Officer are available upon request for assistance in solving any problems regarding contamination in loading, transporting and transferring potable water at a naval shore activity or regarding the disinfection of facilities used in connection therewith.

APPENDIX B

OPNAVINST 9930.1B

"Ship-to-Shore Water Connections"

DEPARTMENT OF THE NAVY
Office of the Chief of Naval Operations
Washngton 25, D.C.

OPNAV INSTRUCTION 9930.1B

From: Chief of Naval Operations
To: All Ships and Stations (less Marine Corps field addressees not having naval personnel attached)

Subj: Ship-to-shore water connections

1. Purpose. This Instruction promulgates restrictive regulations and guidance regarding ship-to-shore water connections.

2. Cancellation. OPNAV Instruction 9930.1A of 14 December 1954 and CROSS-REFERENCE SHEET OPNAV 11320 of 14 December 1954 are superseded and canceled by this Instruction.

3. Discussion

a. Connection of a shipboard fire and flushing system to a potable-water system ashore without effective prevention of backflow may result, upon inadvertent operation of the ship's pumps with their relatively high pressures, in pumping polluted water into the drinking-water system ashore, causing contamination and endangering the health of personnel ashore and personnel of ships using the system. Where a municipal water supply system is involved, such connections may constitute violation of laws or local regulations.

b. As a general rule, ships are to operate their installed salt water pumping systems to provide fire and flushing water except when manifestly impracticable by reason of derangement, effecting of repairs, or drydocking.

4. Directive

a. Connecting Up. All water connections between shore and ships shall be made by authorized shore station personnel.

b. Restrictions on Shore Potable-Water Supply System Connections to Shipboard Nonpotable Systems

(1) Connections between potable-water supply systems ashore and nonpotable systems aboard ship are prohibited where the shore system is not protected at each individual potable-hose connection useable for this purpose, including each outlet of manifolds where employed, by an effective backflow prevention device as prescribed by the Chief, Bureau of Yards and Docks.

(2) Even where effective backflow prevention devices are so installed, such connections are authorized only when the necessary pressure and volume of fire and flushing water cannot be maintained by the ship's installed salt water pumps, or by alternate means such as connection to a nonpotable–water system ashore, to the fire and flushing system of an adjacent ship, or to portable pumps provided by the shore station taking suction from the harbor. Connections will not be made until positive steps have been taken to prevent inadvertent operation of the ship's installed salt water pumps.

5. Responsibility

a. Ship Commanding Officer. That no ship-to-shore water connections are made by ship's personnel; that positive steps are taken to prevent operation of the ship's installed salt water pumps before any ashore potable-water connections are made to ship's nonpotable system.

b. Shore Station Commanding Officer. That all ship-to-shore water connections are made in accordance with the provisions of this Instruction, and instructions in the premises promulgated by the Chief, Bureau of Yards and Docks.

6. Exception. Under conditions of extreme emergency where safety of a ship from fire or explosion may be at stake the provisions of paragraph 4 above may be suspended as circumstances dictate.

7. Additional Instructions

a. Shore stations which, pursuant to paragraph 4 above, are unable to provide fire and flushing water from mains to ships alongside must anticipate needs and provide alternate means for ships unable to maintain necessary pressure and volume with installed pumps.

b. Where separate potable and nonpotable systems exist, extreme caution must be exercised to avoid supplying ships' fresh water tanks from the nonpotable system. The separate systems should be conspicuously identified by such means as color, labels, warning signs, or tags.

c. It is permissible at any time to carry aboard fire-fighting hose lines attached to a potable-water system ashore provided these lines are used or equipped to be used as direct hose streams or for attachment to portable foam generators.

d. The practice of connecting ships' fire and flushing systems to a potable-water supply for flushing out to kill marine growth is no longer authorized.

RALPH E. WILSON
Deputy Chief of Naval Operations
(Logistics)

Additional copies may be obtained from:
NSC, Norfolk, Va.
GSD, NSC, Oakland, Calif.
Supply Dept., NGF, Washington, D.C.

APPENDIX C

BUDOCKSINST 11330.4

"Ship-to-Shore Potable-Water Connection Facilities

BUDOCKS INSTRUCTION 11330.4

From: Chief, Bureau of Yards and Docks
To: All Ships and Stations

Subj: Ship-to-shore potable-water connection facilities

Ref: (a) OPNAVINST 9930.1 Op–43B1 ser 1212P43 of 14 Jan 1954

1. Purpose. To provide instructions for the care and disinfection of facilities used and the procedures to be followed in making ship-to-shore connections with potable-water systems.

2. Discussion

a. The Bureau of Medicine and Surgery has recommended that the Bureau of Yards and Docks prescribe specific precautionary measures to protect ships' fresh-water tanks and systems from bacterial contamination when ship-to-shore connected.

b. Reference (a) promulgates restrictive regulations regarding ship-to-shore water connections which lessen the possibilities of contaminating the shore potable-water system from ships.

c. Facilities employed in ship-to-shore water connections are hoses, potable-water outlets, and sometimes portable meters. Hoses are subject to contamination by dragging along decks, dropping into the river or sea, or improper handling and stowage. Potable-water outlets may be contaminated by splash or spray, dust and dirt, or spillage from ships' scuppers.

3. Action

a. Shore station personnel should make all water connections between shore and ship as prescribed in reference (a).

b. The shore activity should:

(1) Label all hose used in ship-to-shore potable-water connections "POTABLE WATER ONLY" in such manner as to be legible at all times.

(2) Provide each length of hose with either screw caps or plugs or couple the ends when rolled for stowage.

(3) Provide each potable-water outlet along the waterfront with cap and chain.

(4) Provide suitable facilities for disinfecting, drying, and stowing potable-water hose.

c. Shore station personnel should employ the following procedures in making ship-to-shore potable-water connections:

(1) Remove cap and disinfect potable-water outlet just prior to use as follows:

(a) Flush outlet 15 to 30 seconds.

(b) If outlet drains, swab all interior surfaces back to control valve with solution containing not less than 100 p. p. m. chlorine.

(c) If outlet does not drain, calculate pipe volume back to control valve and fill with a solution containing not less than 50 p. p. m. chlorine.

(d) Let stand not less than 2 minutes and then flush 15 to 30 seconds.

(2) Deliver clean disinfected hose at dockside outlet just before connection is made.

(3) Remove hose caps or plugs, connect hose, and then flush 30 to 60 seconds.

(4) Make ship-to-shore connection.

(5) After use, thoroughly flush potable-water outlet cap and attach.

(6) Disinfect hose by filling with a solution containing not less than 50 p. p. m. chlorine, let stand not less than 2 minutes, and then flush 30 to 60 seconds.

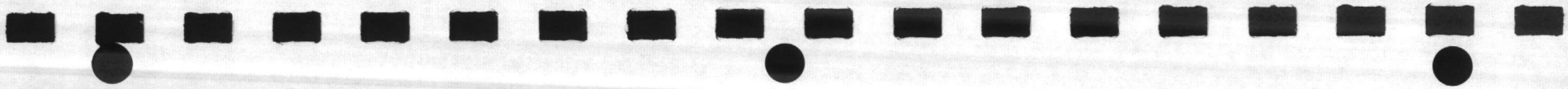
(7) Hang or rack in a clean place for draining and air drying.

(8) Cap and plug hoses and roll or hang indoors in a clean place.

(9) Keep portable meters in a sanitary condition at all times.

d. Ships' hoses should not be used for supplying the vessel with potable water except as may be necessary in those emergency conditions as outlined in reference (a).

J. A. McHENRY
Deputy Chief of Bureau



APPENDIX D

BUMEDINST 6240.3B

"Standards for Potable Water"

BUMED INSTRUCTION 6240.38

From: Chief, Bureau of Medicine and Surgery
To: All Ships and Stations

Subj: Standards for potable water

Ref: (a) ONMINST 5711.9 dated 16 May 1958 (NOTAL)
(b) BUMEDINST 5711.2 dated 30 January 1959 (NOTAL)

1. Purpose. To establish standards for water for drinking and culinary purposes throughout the Naval Establishment.

2. Cancellation. BUMED Instruction 6240.3A is canceled.

3. Background

a. Policy. The Department of Defense has established the policy of compliance by the Military Department with United States Public Health Service Drinking Water Standards, as may be modified by the Medical Services of the Departments, or as may be modified by competent authority for purposes of international agreement.

b. International agreement. Naval Tripartite Standardization Agreement ABC–NAVY–STD–23 was promulgated by references (a) and (b). The object of the agreement is to provide the United States Navy, the Royal Navy, and the Royal Canadian Navy assurance that drinking and culinary water delivered to each other's ships from installations under their cognizance meets certain minimum standards of quality.

4. Quality Standards. The standards for bacteriological quality, physical and chemical characteristics, and radioactivity shall be those in "Public Health Service Drinking Water Standards, 1962," Department of Health, Education, and Welfare. The Standards, as modified, may be found in NAVMED P–5010–5, "Water Supply Ashore," available through the Navy Supply System.

5. Definition of Terms. The following terms are defined for clarification in interpretation of standards:

a. Adequate protection by natural means involves one or more of the following processes of nature that produce water consistently meeting the requirements of these Standards: dilution, storage, sedimentation, sunlight, aeration, and the associated physical and biological processes which tend to accomplish natural purification in surface waters and, in the case of ground waters, the natural purification of water by infiltration through soil and percolation through underlying material and storage below the ground water table.

b. Adequate protection by treatment means any one or any combination of the controlled processes of coagulation, sedimentation, absorption, filtration, disinfection, or other processes which produce a water consistently meeting the requirements of these standards. This protection also includes processes which are appropriate to the source of supply; works which are of adequate capacity to meet maximum demands without creating health hazards, and which are located, designed, and constructed to eliminate or prevent pollution; and conscientious operation by well-trained and competent personnel whose qualifications are commensurate with the responsibilities of the position.

c. The coliform group includes all organisms considered in the coliform group as set forth in Standard Methods for the Examination of Water and Wastewater, current edition, prepared and published jointly by the American Public Health Association, American Water Works Association, and Water Pollution Control Federation.

d. Health hazards mean any conditions, devices, or practices in the water supply system and its operation which create, or may create, a danger to the health and well-being of the water consumer. An example of a health hazard is a structural defect in the water supply system,

whether of location, design, or construction, which may regularly or occasionally prevent satisfactory purification of the water supply or cause it to be polluted from extraneous sources.

e. Pollution, as used in these Standards, means the presence of any foreign substance (organic, inorganic, radiological, or biological) in water which tends to degrade its quality so as to constitute a hazard or impair the usefulness of the water.

f. The standard sample for the bacteriological test shall consist of:

(1) For the bacteriological fermentation tube test, five standard portions of either:

(a) 10 milliliters

(b) 100 milliliters

(2) For the membrane filter technique, not less than 50 milliliters.

g. Water supply system includes the works and auxiliaries for collection, treatment, storage, and distribution of the water from the sources of supply to the freeflowing outlet of the ultimate consumer.

6. Source and Protection

a. The water supply should be obtained from the most desirable source which is feasible, and effort should be made to prevent or control pollution of the source. If the source is not adequately protected by natural means, the supply shall be adequately protected by treatment.

b. Frequent sanitary surveys shall be made of the water supply system to locate and identify health hazards which might exist in the system.

c. Approval of water supplies shall be dependent in part upon:

(1) Enforcement of rules and regulations to prevent development of health hazards;

(2) Adequate protection of the water quality throughout all parts of the system, as demonstrated by frequent surveys;

(3) Proper operation of the water supply system under the responsible charge of personnel whose qualifications are acceptable to the Bureau of Yards and Docks or the Bureau of Ships, as appropriate;

(4) Adequate capacity to meet peak demands without development of low pressures or other health hazards; and

(5) Record of laboratory examinations showing consistent compliance with the water quality requirements of these Standards.

7. Standards. The limits listed below are generally those contained in "Public Health Service Drinking Water Standards, 1962." For sampling procedures and techniques, refer to NAVMED P–5010–5.

a. Bacteriological quality: limits. The presence of organisms of the coliform group as indicated by samples examined shall not exceed the following limits:

(1) When 10 ml. standard portions are examined, not more than 10 percent in any month shall show the presence of the coliform group. The presence of the coliform group in three or more 10 ml. portions of a standard sample shall not be allowable if this occurs:

(a) In two consecutive samples;

(b) In more than one sample per month when less than 20 are examined per month; or

(c) In more than five percent of the samples when 20 or more are examined per month.

When organisms of the coliform group occur in three or more of the 10 ml. portions of a single standard sample, daily samples from the same sampling point shall be collected promptly and examined until the results obtained from at least two consecutive samples show the water to be of satisfactory quality.

(2) When 100 ml. standard portions are examined, not more than 60 percent in any month shall show the presence of the coliform group. The presence of the coliform group in all five of the 100 ml. portions of a standard sample shall not be allowable if this occurs:

(a) In two consecutive samples;

(b) In more than one sample per month when less than five are examined per month; or

(c) In more than 20 percent of the samples when five or more are examined per month.

When organisms of the coliform group occur in all five of the 100 ml. portions of a single standard sample, daily samples from the same sampling point shall be collected promptly and examined until the results obtained from at least two consecutive samples show the water to be of satisfactory quality.

(3) When the membrane filter technique is used, the arithmetic mean coliform density of all standard samples examined per month shall not exceed one per 100 ml. Coliform colonies per standard sample shall not exceed 3/50 ml., 4/100 ml., 7/200 ml., or 13/500 ml. in:

(a) Two consecutive samples;

(b) More than one standard sample when less than 20 are examined per month; or

(c) More than five percent of the standard samples when 20 or more are examined per month.

When coliform colonies in a single standard sample exceed the above values, daily samples from the same sampling point shall be collected promptly and examined until the results obtained from at least two consecutive samples show the water to be of satisfactory quality.

b. Physical characteristics: limits. Drinking water should contain no impurity which would cause offense to the sense of sight, taste, or smell. Under general use, the following limits should not be exceeded:

Turbidity	5 units
Color	15 units
Threshold Odor Number	3

c. Chemical characteristics: limits. Drinking water shall not contain impurities in concentrations which may be hazardous to the health of the consumers. It should not be excessively corrosive to the water supply system. Substances used in its treatment shall not remain in the water in concentrations greater than required by good practice. Substances which may have deleterious physiological effect, or for which physiological effects are not known, shall not be introduced into the system in a manner which would permit them to reach the consumer.

(1) The following chemical substances should not be present in a water supply in excess of the listed concentrations where, in the judgment of the Bureau of Yards and Docks and the Bureau of Medicine and Surgery, other more suitable supplies are or can be made available.

Substance	Concentration in mg/1 (ppm)
Alkyl Benzene Sulfonate (ABS)	0.5
*Antimony (Sb)	0.01
Arsenic (As)	0.01
Chloride (Cl)	250.
Copper (Cu)	1.
Carbon Chloroform Extract (CCE)	0.2
Cyanide (CN)	0.01
Fluoride (F)	(See (3))
Iron (Fe)	0.3
Manganese (Mn)	0.05
Nitrate [1] (No_3)	45.
Phenols	0.001
Sulfate (SO_4)	250.
Total Dissolved Solids	500.
Zinc (Zn)	5.

[1] In areas in which the nitrate content of water is known to be in excess of the listed concentration, the public should be warned of the potential dangers of using the water for infant feeding.

* Not contained in Drinking Water Standards but this limit was determined by the Public Health Service and the Bureau of Medicine and Surgery.

(2) The presence of the following substances in excess of the concentrations listed shall constitute grounds for rejection of the supply:

Substance	Concentration in mg/1 (ppm)
*Antimony (Sb)	0.05
Arsenic (As)	0.05
Barium (Ba)	1.0
Cadmium (Cd)	0.01
Chromium (Hexavalent) (Cr^{+6})	0.05
Cyanide (CN)	0.2
Fluoride (F)	(See (3))
Lead (Pb)	0.05
Selenium (Se)	0.01
Silver (Ag)	0.05

* Not contained in Drinking Water Standards but this limit was determined by the Public Health Service and the Bureau of Medicine and Surgery.

(3) Fluoride. When fluoride is naturally present in drinking water, the concentration should not average more than the appropriate upper limit in the following Table I. Presence of fluoride in average concentrations greater than two times the optimum values in Table I shall constitute grounds for rejection of the supply. When fluoridation (supplementation of fluoride in drinking water) is practiced, the average fluoride concentration shall be kept within the upper and lower control limits in Table I.

TABLE I

Annual average of maximum daily air temperatures [2]	Recommended control limits—Fluoride concentrations in mg/1 (ppm)		
	Lower	Optimum	Upper
50.0–53.7	0.9	1.2	1.7
53.8–58.3	0.8	1.1	1.5
58.4–63.8	0.8	1.0	1.3
63.9–70.6	0.7	0.9	1.2
70.7–79.2	0.7	0.8	1.0
79.3–90.5	0.6	0.7	0.8

[2] Based on temperature data obtained for a minimum of five years.

d. Radioactivity: limits.

(1) The effects of human radiation exposure are viewed as harmful and any unnecessary exposure to ionizing radiation should be avoided. Approval of water supplies containing radio-

active materials shall be based upon the judgment that the radioactivity intake from such water supplies when added to that from all other sources is not likely to result in an intake greater than the radiation protection guidance [3] recommended by the Federal Radiation Council and approved by the President. Water supplies shall be approved without further consideration of other sources of radioactivity intake of Radium-226 and Strontium-90 when the water contains these substances in amounts not exceeding 3 and 10 $\mu\mu$c/liter, respectively. When these concentrations are exceeded, a water supply shall be approved by the certifying authority if surveillance of total intakes of radioactivity from all sources indicates that such intakes are within the limits recommended by the Federal Radiation Council for control action.

(2) In the known absence [4] of Strontium-90 and alpha emitters, the water supply is acceptable when the gross beta concentrations do not exceed 1,000 $\mu\mu$c/liter. Gross beta concentrations in excess of 1,000 $\mu\mu$c/liter shall be grounds for rejection of supply except when more complete analyses indicate that concentrations of nuclides are not likely to cause exposures greater than the Radiation Protection Guides as approved by the President on recommendation of the Federal Radiation Council.

8. Technical Assistance. Assistance with potable water problems may be requested from the following:

a. Preventive Medicine Units, in accordance with BUMED 6200.3A of 2 July 1957, Subj: U.S. Navy Preventive Medicine Units.

b. Bureau of Yards and Docks' Field Engineering Offices, in accordance with BUDOCKS Instruction 5450.19A of 21 September 1962, Subj: Sanitary Engineering Responsibilities of the Bureau of Yards and Docks Field Engineering Offices.

A. S. CHRISMAN
Deputy and Assistant Chief

Distribution:
SNDL Parts 1 and 2
Marine Corps List E less: 1050/1070/1080/2000/6200/7150/7200/7352/7503/7505/7506/8120/8121/8122/8180

[3] The Federal Radiation Council, in its Memorandum for the President, Sept. 13, 1961, recommended that "Routine control of useful applications of radiation and atomic energy should be such that expected average exposures of suitable samples of an exposed population group will not exceed the upper value of Range II (20 $\mu\mu$c/day of Radium-226 and 200 $\mu\mu$c/day of Strontium-

[4] Absence is taken here to mean a negligibly small fraction of the above specific limits, where the limit for unidentified alpha emitters is taken as the listed limit for Radium-226.

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