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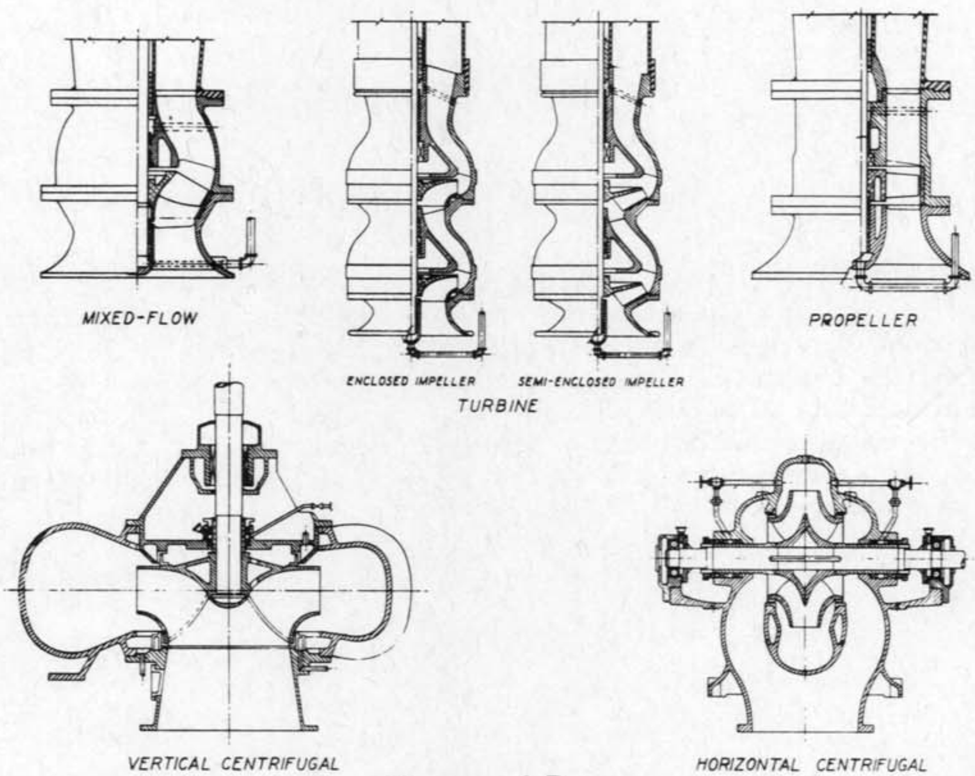
Department of the Interior
Bureau of Reclamation

OPERATION AND MAINTENANCE EQUIPMENT AND PROCEDURES

RELEASE NO. 39

January, February and March 1962



Types of Pumps

CONTENTS

Cover Sheet. Irrigation pumps used by the Bureau of Reclamation on projects in the 17 western states vary from giants such as those used on the Columbia Basin Project at Grand Coulee Dam which have a capacity of 1,600 cubic feet per second with a lift of 280 feet, to those required at the end of a small lateral to lift 1 cubic foot of water per second a height of a few feet. The five general types of pumps employed for this work are shown. 328-701-7609

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INTRODUCTION

Several of the articles appearing in this issue of the bulletin describe procedures used in the operation and maintenance of irrigation equipment and systems by project operators in attendance at the Irrigation Operators' Workshop in December 1961. In some instances, there was a request for additional information not then available in published form. Information requested on other operation and maintenance practices and procedures will be included in future releases of the bulletin, as they can be prepared.

This bulletin, published quarterly, is circulated for the benefit of irrigation project operation and maintenance people. Its principal purpose is to serve as a medium of exchanging operation and maintenance information. It is hoped that the labor saving devices or less costly equipment developed by the resourceful water users will be a step toward commercial development of equipment for use on irrigation projects in a continued effort to reduce costs and increase operating efficiency.

To assure proper recognition of those individuals whose suggestions are published in the bulletins, the suggestion number as well as the person's name is given. All Bureau Offices are reminded to notify their Suggestions Awards Committee when a suggestion is adopted.

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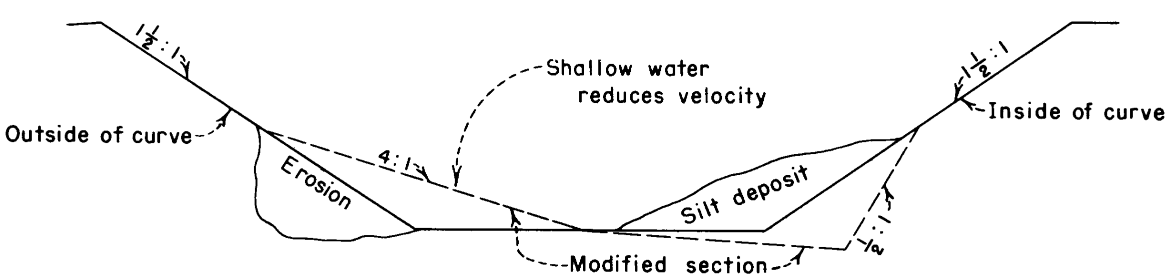
Division of Irrigation Operations
Office of Assistant Commissioner and Chief Engineer
Denver, Colorado

PREVENTING EROSION AND BERMING OF CANAL CURVES

The erosion of the outside of canal curves in earth sections combined with the formation of berms or silt bars on the inside of the curves constitutes one of our more troublesome O&M problems in the maintenance of canals and laterals. This erosion and deposition process is, also, one which aggravates itself rather than reaching a balanced condition. That is, increased erosion tends to throw more water towards the outside of the curve, where the water is deeper, and this aggravates the erosion. As more material is eroded, there is more to deposit on the inside of the curve thus throwing more of the water towards the outside. This process is not likely to develop a dangerous condition overnight; but over a period of time, the outer bank is weakened and the canal section assumes such shapes that it must be corrected.

Mr. Fred C. Krauss, Chief, Nebraska Irrigation Maintenance Branch in the Bureau Office at McCook, Nebraska, has tried what appears to be a good solution to this problem and his solution is being passed on to those who may wish to try his corrective measures.

In cleaning a canal that is badly eroded on the outside of the curve with a silt deposit on the inside, Mr. Krauss moves the silt directly across the canal into the eroded area and even overexcavates the inside of the curve, so that the slope of the inside bank is 1/2:1, or flatter if that appears to be too steep. However, Mr. Krauss believes the slope should not be flatter than 3/4:1. The material is used to build up the outside slope to a 4:1 slope, so that the final section is modified similar to that shown in the sketch below.



Because the amount of silt in canal water varies and because of differences in the ability of soils to resist erosion and differences in canal velocities, the suggested slopes may not be exactly the right ones to use in all instances, but this can be determined by trial. The degree of curvature will also have some influence on the slopes that should be used. This procedure should not be attempted in a canal lined with a buried membrane as the overexcavation would very likely result in removal of or damage to the membrane.

Figure 1

Mr. Krauss reports that in the 1920's, he reshaped the curves of a canal on the North Platte Project in Nebraska in accordance with the method outlined; and during the years he remained on the project, these curves required no further attention. He reports similar good results on the Mirage Flats Project in Nebraska during the late-1940's. From 1950 to 1957 he treated some of the curves on the Cambridge Canal, Frenchman-Cambridge Division, Missouri River Basin Project, Nebraska. Figure 1 shows a curve at about Station 1245 on the Cambridge Canal. The inside of the curve (right side of photograph) was cut to a 1/2:1 slope with the excess material being placed on the outside of the curve to form a 4:1 slope. At the time the photo was taken, the canal had been in service for four seasons after the bottom was reshaped and there has been no maintenance work or cleaning in the meantime. It is obvious that there has been no noticeable amount of either cutting on the outer bank or silt deposition on the inner bank.

Figure 2

By contrast, Figure 2 is a

photograph of a nearby curve on the Cambridge Canal about 200 feet above the one shown in Figure 1, which was originally a normal section with 1-1/2:1 slopes on both banks. This curve received no attention during the 4 years preceding the time the photograph was taken. By comparison with the "superelevated" section in Figure 1, there has been erosion of the outer (right) bank and there is a heavy silt deposit on the opposite bank.

From the performance of the curves shown and the performance of a number of other curves on the Cambridge Canal which Mr. Krauss has given the "superelevation" treatment, we must conclude that the procedure followed by Mr. Krauss has been effective in reducing the erosion and silting of canal curves.

* * * * *

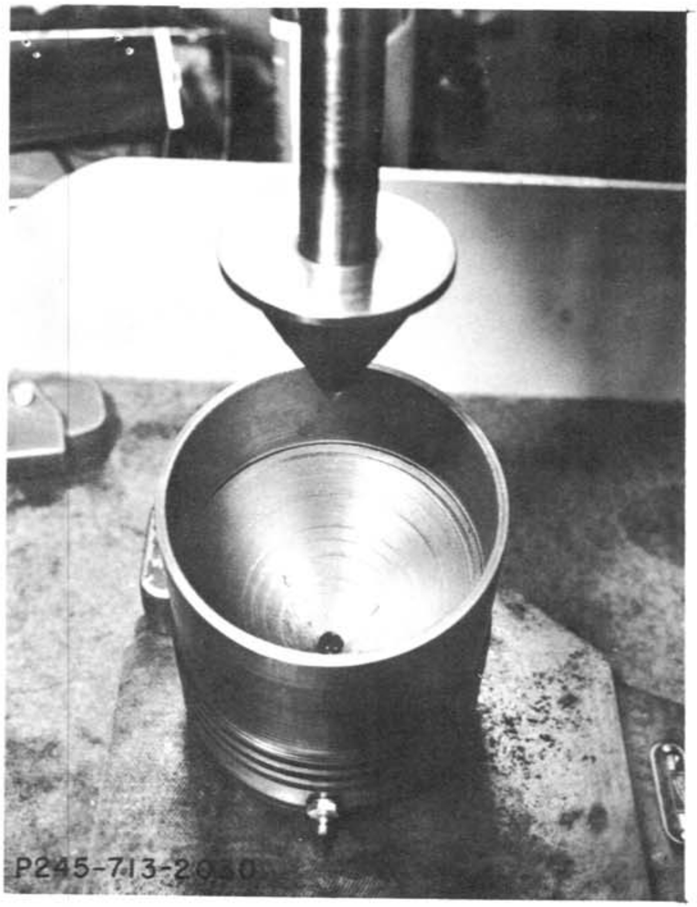
A PURGER FOR SEALED BALL BEARING

Mr. Lyle H. McIntosh, Equipment Specialist, South Platte River Projects, Loveland, Colorado, lectured on electrical pump maintenance at the Irrigation Operators' Workshop held in Denver, Colorado, in December 1961. One of the many items of interest to those in attendance at the meeting related to the care of sealed ball bearings.

A sealed ball bearing, according to Mr. McIntosh, requires no maintenance other than replacement. If a motor runs continuously, bearings of this type should be changed about once a year. If the bearings are rough when removed, the change should be made more often. Experience is the best guide as to when the bearings should be changed.

Mr. McIntosh reported that the South Platte Projects shop had made a device for use in servicing the sealed ball bearings, that is capable of handling bearings having diameters of from 7/8 inch up to 7 inches as shown in the photograph on the next page and on the drawing shown on page 5. The device consists of a 1/4-horsepower electric motor, to rotate the inner race of the bearing; a conical-shaped leather friction plug mounted on a shaft, to insert into the inner race to fill the inner race hole and provide for rotation of the inner race by the electric motor; a cone-shaped cup into which the outer race will fit and which is equipped with a grease fitting, so that grease can be forced through the bearing as the inner race is being rotated by the motor.

With the device, anyone around the shop can give the rotating bearing a "shot" of grease periodically until the old grease and accumulated dirt have been flushed out and replaced with new grease. After this treatment, the bearing is as good as new, provided there is no damage to bearing surfaces, and can be used almost indefinitely.



To set up and perform the operation described above, as illustrated in the photograph and drawing:

(1) Obtain a drill stand that will accommodate the electric motor to be used to drive the rotating shaft of the purger.

(2) Mount the motor in the drill vice provided in the stand and in a vertical position with the drive end down.

(3) Attach the purger rotor to the drill by means of a small shaft inserted into the drill jaws and into the small shaft recess drilled into the upper end of the purger rotor, tightening the rotor to the drill shaft by set screws provided for this purpose.

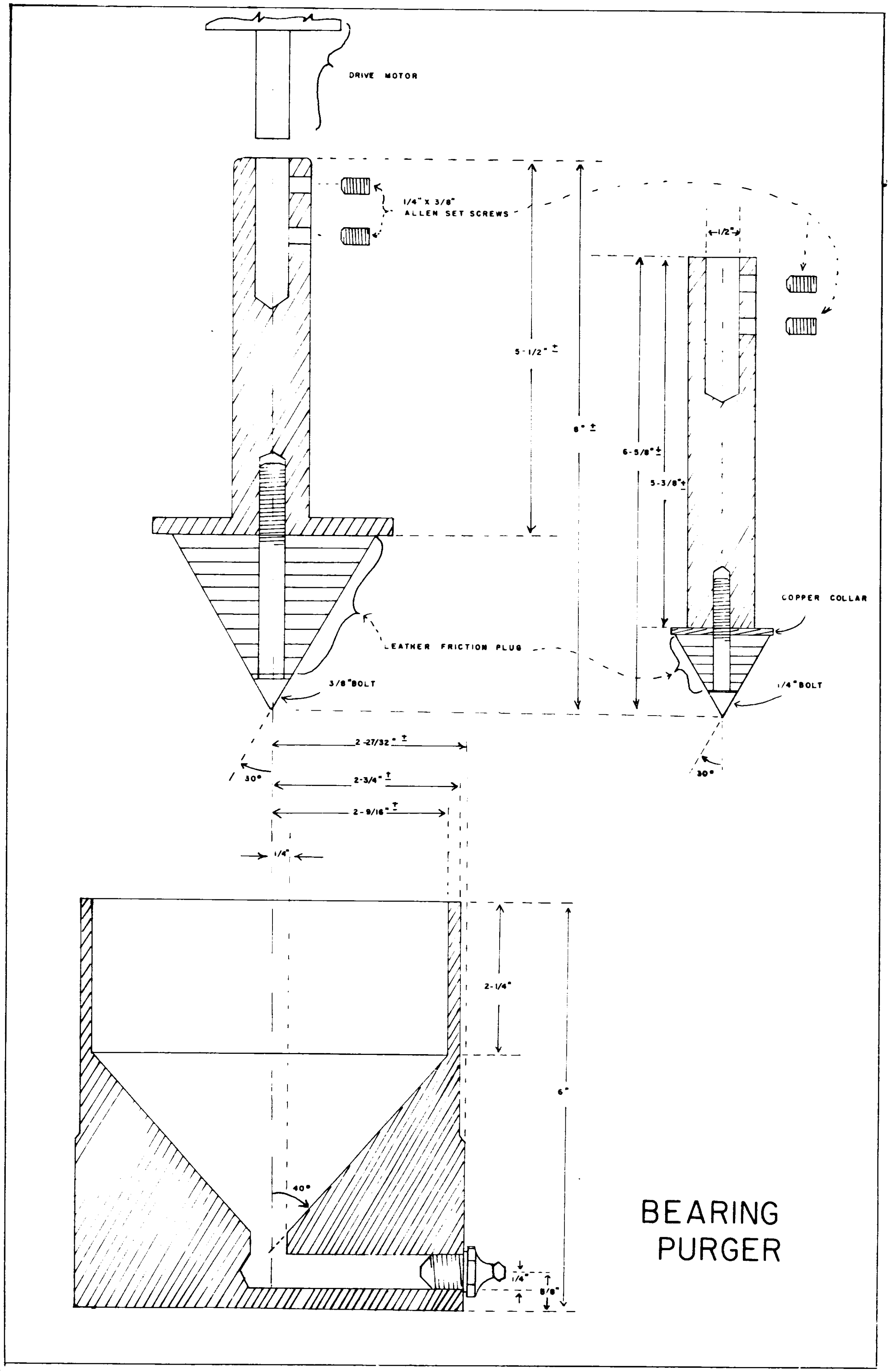
(4) Place the conical-shaped cup on the drill stand in line with the purger rotor.

(5) Place the bearing to be purged into the purger cup, making certain it is in a horizontal position.

(6) Start the electric motor and connect a grease gun, filled with a good grade of ball bearing grease, to the purger cup and pump grease until it starts to flow up through the sealed portion of the bearing.

(7) Continue rotating the bearing and at 15- to 20-minute intervals, pump additional grease into the bearing until the grease flowing from the bearing is clean, indicating that the cleaning operation has been satisfactorily accomplished and the bearing satisfactorily filled.

Two rotors for the purger are shown in the drawing. The smaller rotor is more convenient for servicing bearings of smaller diameter. Should further information be desired, write the Regional Director, Region 7, U. S. Bureau of Reclamation, Denver Federal Center, Denver, Colorado.


DRIVE MOTOR
1/4" X 3/8" ALLEN SET SCREWS
5-1/2" ±
8" ±
1/2"
6-5/8" ±
5-3/8" ±
COPPER COLLAR
LEATHER FRICTION PLUG
3/8" BOLT
1/4" BOLT
2-27/32" ±
30°
2-3/4" ±
2-9/16" ±
30°
1/4"
2-1/4"
6"
40°
1/4"
3/8"
BEARING
PURGER

OFFSETTING LOSSES IN PUMP CAPACITY DUE TO WATERBORNE SEDIMENT

The Office of Assistant Commissioner and Chief Engineer of the U.S. Bureau of Reclamation has concluded from a survey of pumping plants that 76 percent of all plants surveyed pump sediment in varying amounts all or a part of the time. It also was found that 84 percent of the surveyed plants reporting detectable loss of capacity were handling waterborne sediment at least a portion of the time. Only 3 percent of the plants showing a decrease in capacity were pumping relatively clear water.

The amount of wear on moving parts of the pump coming in contact with silty water is proportional to the size of sediment. Sediment having a diameter greater than one-half the wearing ring clearance will cause appreciable wear. As a matter of comparison, previous studies of high head turbines having indicated this deleterious size to be 0.38 millimeter. However, the damaging size sediment for small pumps would be more nearly in the range of 0.10 millimeter. Since this approaches the lower limit of the sand size classification (0.0625 millimeter), it can be reasonably assumed that all water containing sand or larger size sediments is injurious to pumping plants. Water used to cool bearings or packing glands should contain no sediment.

The attached table lists and discusses four general flow conditions of the water sediment complex that are being handled by pumping plants. The conditions are classified primarily upon the size and amount of sediments. The recommended increase in pump capacities is also indicated. These values are based on an analysis of data collected for pumps having capacities up to 800 cubic feet per second.

Normal wear except that attributable to sediments is usually quite small in well designed pumps and should not exceed 3 percent between major overhaul periods. Thus, the larger recommended figure for increase in capacity can be considered to include normal wear whereas the small figure does not.

The table is prepared for conditions where the anticipated period between overhaul is 3 years for small pumps and 5 years or greater for large pumps. In cases where an annual major overhaul is anticipated, the recommended increase in capacity values is probably excessive.

* * * * *

CONDITIONS OF THE WATER-SEDIMENT COMPLEX
TO BE HANDLED BY PUMPING PLANTS

Description	Where found	Applicable to	Recommended increase in capacity (in %)	
			Small pumps <100 cfs	Large pumps >100 cfs
	a. Clear Water			
Contains no sand (.0625-2 mm) or silt (.004-.0625 mm); but may contain clay (<.004 mm) with a mean concentration of less than 100 ppm and organic material	Reservoirs (with capacity-annual inflow ratio greater than 0.03), large canals (capacity greater than 500 cfs) and drains and a few large snowmelt-fed streams	Reservoir, canal relift, drainage-type pumping plants, and branch from main canal	0-5	0-3
	b. Light Sediment Load			
Contains clay (<.004 mm) and silt (.004-.0625 mm) with a mean concentration of less than 500 ppm, and for short periods, fine sand (.0625-.125 mm)	Small reservoirs, drains canals, and snowmelt-fed streams	Reservoir, canal relift drainage well-sump and river-type plants, and branch from main canal	5-10	2-5
	c. Medium Sediment Load			
Contains clay (<.004 mm) and silt (.004-.0625 mm), and sand (.0625-2 mm) with a mean concentration of less than 2,000 ppm which can occur as fine sand (.0625-.125 mm) in small amount most of the year and coarse sand (.125-2 mm) during flood periods.	In few canals and drains that carry sediment-laden storm water frequently, and most rivers and streams where erosion is normal	A few canal relift and drainage plants, most well-sump types, at canal terminal, and some river-type plants	10-15	5-8

CONDITIONS OF THE WATER-SEDIMENT COMPLEX
TO BE HANDLED BY PUMPING PLANTS--Continued

Description	Where found	Applicable to	Recommended increase in capacity (in %)	
			Small pumps <100 cfs	Large pumps >100 cfs
	d. Heavy Sediment Load			
Contains clay (<.004 mm) and silt (.004-.0625 mm), and some fine sand (.0625-.125 mm) or frequently contains coarse sand (.125-2 mm) and occasional gravel (2-8 mm) with a mean concentration of greater than 1,000 ppm	In rivers where erosion is great and aggrading sand streams	Well-sump and river-type plants and main canal terminal	15-20	8-15

PUMP MAINTENANCE-MECHANICAL COMPONENTS

In nearly every major irrigation project, conditions occur where water must be lifted from its normal elevation to an elevation suitable for serving higher land of the project. An irrigation pumping plant is then required. The plant may vary from giants such as the Grand Coulee or Tracy Pumping Plants constructed by the Bureau of Reclamation in Washington and California, which lift water from major rivers to serve entire irrigation systems, to the small plant at the end of a lateral, lifting 1 cubic foot per second a height of a few feet.

The inspection and maintenance of mechanical components of the large and small pumps, recommended operating practices, operating characteristics of various types of pumps and some of their operational and common problems were discussed during an Irrigation Operators' Workshop held in Denver, Colorado, by Wesley W. Beck, Hydraulic Machinery Branch, Division of Design, Office of Assistant Commissioner and Chief Engineer, Bureau of Reclamation.

Regardless of size or amount of lift, the engineer's problem is the same, that of selecting the proper size, number and type of pumps and determining the most feasible plant layout. Hydraulic laws and principals must be observed, but the designing engineer must also make certain that the plant is economically sound and that costly features that add little to economy of operation are avoided.

Types of Pumps

Five general types of pumps are used in Bureau of Reclamation pumping plants. They are: propeller, mixed-flow, vertical-turbine, horizontal centrifugal and vertical centrifugal. Construction of the various types is shown in Figure 1.

Vertical-turbine pumps with semienclosed impellers are sometimes used where the pumping head is 30 feet or less. However, the Bureau requires that enclosed impellers be used in all vertical-turbine pumps with pumping heads of over 30 feet.

Propeller, mixed-flow and turbine-type pumps operate with the pump bowl submerged, suspended in an open sump by the column through which the water from the pump is discharged.

Horizontal centrifugal pumps are set on a pump floor above maximum water surface elevation to prevent possible flooding of the motors. Each pump is equipped with a flared suction tube extending down into the plant sump.

Vertical centrifugal pumps usually have intake tubes and elbows leading from the plant forebay to the pump. The pump casing may be set above or below normal water surface and may be set on a pump floor, or, in the case of large units, embedded in concrete.

Typical Characteristics

Typical characteristics of the various types of pumps are shown in Figure 2. The characteristics of the vertical-turbine-type pump are essentially the same as for the centrifugal. Characteristics of pumps in each type may vary considerably, however, the general shapes of the curves will be similar to those shown.

The brake horsepower input and head of mixed-flow and propeller pumps increase sharply as the flow from the pumps is decreased, and at zero flow the pumping head and brake horsepower input amount to several times the values at design flow. These characteristics make these types of pumps unsuitable for installations where throttling of the pumps is required. They are generally used for comparatively large capacities at low pumping heads and operate most satisfactorily with a short discharge line, preferably with no valves in the line other than a flap valve on the end. If regulation of the discharge is desired, it is accomplished by bypassing part of the discharge back to the sump rather than by throttling.

The brake horsepower input of centrifugal and turbine-type pumps, on the other hand, decreases as the flow from the pump is decreased, and at zero flow the head of the pump is not excessive. These characteristics make these types of pumps adaptable for many kinds of installations. They can be throttled to provide the desired flow, with a corresponding saving in horsepower input, and with little loss in pump efficiency. They are started against a closed discharge valve, thus simplifying starting procedure when two or more pumps are manifolded into one discharge line. Vertical turbine-type pumps are well adapted for small pumping plants where extensive regulation of flow is desired. They have been used by the Bureau in the smallest sizes at pumping heads as low as 10 feet, and in sizes up to 25 cubic feet per second at pumping heads as high as 275 feet.

In selecting the type of pump to be used, pumps normally available from manufacturers should be considered in order to avoid units that will involve special designs. Figure 3 shows a Pump Selection Diagram that has been developed by the Bureau based on the types of pumps used in existing installations. The diagram shows the range of capacity and head over which each type of pump would normally be selected. To illustrate, the diagram shows that for vertical turbine-type pumps the normal head range is between 10 and 275 feet and the capacity range can vary from 1.1 cubic feet per second to about 25 cubic feet per second. In those areas not covered by a specific pump type we are in the realm of special design and the type of pump selected will depend upon several factors other than head and capacity, such as, overall efficiency, plant layout, pump setting, operating restrictions or requirements, etc.

Shop Assembly and Shop Tests

Where the size of the units permits, generally in units with motors up to 1, 500 horsepower, pumps and motors are purchased as a unit by the Bureau of Reclamation. After manufacture and before shipment, each unit is completely assembled and tested in the manufacturer's shop. Test reports, showing actual test data and characteristic curves, are forwarded to the Bureau for approval before shipment of the units. This procedure assures correct fitting of parts and proper performance of the units, as any errors or deficiencies can be corrected before a unit is shipped. If the units are too large to be tested in the manufacturer's shop, they must be tested in the field after installation to determine whether all warranties have been fulfilled.

Installation

The performance of all pumping apparatus is warranted by the manufacturer. Whenever possible he supervises the installation and conducts usually under full operating conditions, such starting tests that are possible. After a pump has been properly installed, all necessary precautions have been taken in alinement, and it has been checked for proper direction of rotation; it is ready to service and start. Servicing usually consists of the installation of the kind and type of lubricants recommended by the manufacturer, checking packing and stuffing boxes, checking for free rotation, etc.

Starting

The steps necessary to start a given pump depend upon its type and use or installation. The steps required in starting many pumps are unnecessary in others. The methods used are also greatly influenced by the performance characteristics of the pump to be started, that is, by the shape of the power-capacity curve, and questions such as: Can the pump be started against a closed or open discharge valve, etc. ? For example, the starting procedure of a horizontal centrifugal, bottom suction pump would be as follows:

(1) Close discharge valve.

(2) Prime pump.

(3) Start the motor.

(4) Open valves in seal waterlines to stuffing boxes.

(5) Open discharge valve slowly.

(6) Observe leakage from stuffing boxes. Some leakage is necessary in order to insure proper packing lubrication.

(7) Check general mechanical operation of the pump and motor.

If the pump is to be started against a closed check valve with the discharge gate valve open, the steps would be the same, except the discharge gate valve would be opened some time before the motor is started. The pump manufacturer's instructions usually give a detailed procedure for starting a given pumping unit.

Stopping

The procedure for stopping a pump also depends on the type and use; for example, the procedure to stop the pump used in the previous illustration would be as follows:

(1) Close discharge gate valve.

(2) Stop the motor.

(3) Close valves in seal waterlines to stuffing boxes.

The manufacturer's operating instructions usually give a detailed procedure for stopping a given pumping unit.

Discharge Valves

In a single unit plant with short discharge lines the flap gate in the discharge structure is all that is needed or required for discharge regulation or control. However, with more than one unit or with long discharge lines other means must be used to prevent recirculation, etc.. One of the following three systems is most generally used in the discharge lines from centrifugal and vertical turbine-type pumps:

(1) Check valve with associated guard valve. --This is used in relatively small discharge lines and where simplicity of operation is desired.

(2) Electrically operated discharge valves. --These are suitable for any size and type of installation but become inoperable in the event of a power failure.

(3) Hydraulic cylinder valves. --These are suitable for any size and type of installation and when used in conjunction with an accumulator tank they "fail-safe" in the event of any malfunction of the pumping unit.

Valves in the discharge lines from mixed-flow or propeller-type pumps are usually avoided. The most satisfactory arrangement is to have a separate discharge line with flap valve on the end of each pump.

Throttling

Discharge capacity of centrifugal and vertical turbine pumps can be reduced simply and usually safely by throttling the discharge. In this manner, artificial friction losses are introduced by throttling, and a new head curve is obtained which intersects the head-capacity curve at the desired flow. By an examination of the brake horsepower curves in Figure 2 we can determine which type of pump may be safely throttled without exceeding the motor horsepower limitations of the prime movers. Normally, throttling of a centrifugal type of pump to 50 percent of rated discharge can be done for extended periods without harmful effect to the pump.

When throttling below the 50 percent limitation it is usually imperative to consult the manufacturer to find if the pump is suitable for operation at this reduced flow. Such operation usually means heavier shafts, possibly a double-volute in the case of centrifugal type pumps, to withstand the increased radial thrust, etc.

Another problem arises when a pump is operated for any length of time against a closed discharge, that is the thermodynamic problem caused by the heating of the liquid in the pump casing. The difference between the horsepower input to the pump and the water horsepower developed by the pump is lost in the unit. These power losses are converted into heat and transferred to the liquid in the pump. When operating at shutoff, power losses equal shutoff horsepower. Low-capacity, high-head pumps should be watched most closely for this occurrence.

Power Failures

If a check valve protects a pump from reverse flow after power failure, there is generally no reason why the pump should not be restarted immediately upon restoration of power. The electrical control used at the plant will determine if this will be automatic or if an operator must visit the plant to get it back on the line. With both the electrically operated and hydraulic-cylinder-operated discharge valves, limit switches are used which require that the valves must be in the closed position before the electrical circuit to the motor may be energized after a power interruption. Again, the electrical control used will determine if the restart will be automatic or manual. A pump that requires priming before starting generally cannot be restarted automatically after a power failure because of the possibility of loss of prime.

Dry Operation

Most pumps have close running clearances and cannot be run dry at all, or in some cases for longer than a few seconds without being seriously damaged. A centrifugal pump with excessive clearances between the stationary and rotating elements could be run dry for an indefinite period but even then the risk of galling and seizure is present.

Maintenance and Inspection

Because of the wide variation in types, sizes, parts, and design of irrigation pumps, comments regarding maintenance and inspection are necessarily rstricted to the most commonly used types and sizes. The manufacturer's instruction books should be very carefully read and studied before attempting to start, operate or service any given pumping unit. However, in all plants daily, semiannual and annual inspection and maintenance are required.

In large attended installations an hourly record is kept of the equipment. Card files are maintained and any change in unit characteristics readily found. However, most irrigation pumping plants do not fall in this class, therefore, the daily inspection usually consists of an operator, and in some instances the ditchrider or watermaster, visiting the plant twice daily. He checks the lubricant, bearing temperatures (usually by feel), and would probably note any change in sound of a running pump or vibration of the unit. A sudden rise in the temperature of a bearing or stuffing box is more indicative of trouble than one which constantly runs warmer than usual.

In irrigation pumping plants the semiannual inspection is somewhat of a misnomer in that we usually have a complete shutdown of the pumps anywhere from 3 to 5 months during the winter season. Roughly after about 1, 000 hours of operation or 6 weeks of continuous pumping a so-called semiannual inspection should be carried out. This inspection should consist of:

(1) Stuffing box:

  (a) Free movement

  (b) Clean and oil gland bolts and nuts

  (c) Inspect packing to see if it needs replacement

(2) Check pump and drive alinement and correct if necessary

(3) Drain and refill oil-lubricated bearings

(4) Check grease lubricated bearings for correct amount and kind of grease

A thorough inspection of each pumping unit should be made once a year by an experienced mechanic and crew. In addition to the semiannual inspection the following should be checked annually:

(1) Bearings should be removed, cleaned, and examined for wear.

(2) Bearing housings cleaned.

(3) Stuffing box packing removed and examined for wear.

(4) Coupling halves disconnected and alinement checked. (Vertical units checked for runout.)

(5) Drains, seal water piping, and any other piping should be checked and flushed.

(6) Any instruments and measuring devices checked and tested for accuracy.

Maintenance of Pump Parts

Again, because of the wide variation in types and parts, the comments regarding the maintenance of pump parts are being restricted to six basic parts.

Pump casing. --Irrigation pump casings are not normally subject to very extensive wear. However, the water passages should be thoroughly cleaned and painted during a complete overhaul. Special care and examination should be made of the cutwater or volute tongue and the metal-to-metal fits where the stationary wearing parts seat in the casing. New gaskets should always be available when reassembling a pump casing because very rarely can the old one be salvaged. Figure 4 shows a cut through a typical side-suction horizontal centrifugal-type pump. The names of the various main parts are indicated in the upper right-hand corner of the illustration.

Impellers. --An impeller removed from a pump should be very carefully inspected. All surfaces should be examined for any unusual wear or cavitation pitting. Abnormal wear or pitting may warrant a new impeller and possibly the use of a special metal or alloy should be investigated. This may involve considerable expense. For instance, an impeller made of 29-9 chrome-nickle or 18-8 stainless alloy will be about 5-1/2 times as expensive as a standard cast-bronze impeller. Most large impellers will give years of service regardless of pitting and wear by treating the affected areas with "metal build-up." Normally a cracked impeller cannot be successfully repaired and therefore should be replaced. The impeller balance should be checked each time it is out of the casing during an overhaul. The coating of impellers to protect the metal against abrasive materials in the pumped water has met with varying amounts of success in most instances. The use of neoprene paint applied in several coats has proven quite successful on one of our projects, however, the cost of this type of application can become quite expensive. Factory application of baked phenolic coatings is being used with a fair degree of success by a few pump manufacturers. Experiments now being conducted in the new field of epoxies may produce a good type of coating which can be field applied.

Wearing rings. --This applies to centrifugal and turbine-type pumps only, as a bowl liner is all that is installed in a vertical propeller or mixed-flow pump. The type and method of attaching the stationary ring to the casing varies considerably among manufacturers, and the impeller ring is usually either screwed or pressed on, therefore, before attempting to remove these parts the manufacturer's instructions must be followed. Also the clearance and tolerance standards vary so widely that no definite rule can be followed. The methods to measure clearances are also quite varied. Figure 5 illustrates the various types of wearing rings used. The methods of restoring worn clearances are as follows:

(1) No wearing rings provided:

(a) Buy new parts

(b) Build up the worn surfaces by welding, spraying, etc.

(c) Install rings if sufficient metal is present

(2) Single wearing rings:

(a) Obtain a new casing ring bored undersize. Then, true up the impeller hub to size by turning in a lathe.

(b) Build up worn casing ring by welding or spraying so it can be bored undersize. Then, true up the impeller hub to size by turning in a lathe.

(c) True up the casing ring by boring oversize, build up the impeller hub, and machine to give correct clearance.

(3) With double rings:

(a) New oversize impeller ring and use old casing ring bored out larger

(b) New casing ring bored under size and use old impeller ring turned down

(c) Replace both rings

(d) Build up either ring by welding or spraying and machining other part

Shafts and shaft sleeves. --It is unusual to replace a shaft on a centrifugal-type pump unless it has been damaged by the failure of other pump parts. On vertical pumps misalinement or improper lubricant can cause extensive shaft wear making replacement necessary. During a pump overhaul the shaft should always be examined very carefully for any sign of wear or surface irregularities, especially at all of the important points of fit. The more extensive use of stainless-steel shafting has helped considerably in the prevention of rusting and pitting of the shafts. Pump shafts are usually protected from erosion, corrosion and wear at the stuffing boxes, leakage joints, and in the waterways, by renewable sleeves. Shaft sleeves are usually the fastest wearing pump part and the one most frequently replaced. Once sleeves are worn appreciably, the packing cannot be adjusted properly. Excessively worn sleeves may tear and score new packing when installed. Thus, sleeves may require replacement when no other overhaul is necessary. Shaft sleeves can be rebuilt by welding or spraying and regrinding. However, unless a reliable machining and grinding shop is available the practice is not recommended. Normally spare shaft sleeves are furnished with the pump and when these have been used new replacements should be ordered from the manufacturer.

Stuffing boxes and packing. -- Stuffing box maintenance primarily consists of packing replacement. Although this sounds simple, it must be done correctly or the pump operation will not be satisfactory. An illustration of a conventional stuffing box is shown in Figure 6. The procedure for repacking a stuffing box should be as follows:

(1) Remove all old packing and clean the stuffing box.

(2) Make sure the packing is suitable for the service. The packing used should be the type and kind recommended by the pump manufacturer, or if this has proven unsuccessful for the service, then a packing produced and recommended for the service by a reliable manufacturer should be installed. There are many types of special packings that have proven to be very excellent for a given installation, however, each of these must be studied and used only on an individual basis.

(3) Insert each ring separately, pushing it as far into the stuffing box as possible and seating it firmly.

(4) Stagger successive rings so joints are 90° or 180° apart.

(5) Be sure seal cage, if used, is directly under sealing liquid connection.

(6) When proper number of rings have been inserted, install glands and tighten gland nuts firmly by hand or light wrench pressure then back off until gland is loose.

(7) New packing usually has to be run in.

(8) Allow stuffing box to have slight leakage.

Mechanical seals in lieu of conventional stuffing boxes are steadily gaining in popularity and acceptance by the pump industry. The principle of mechanical sealing, simply explained, is to change the method of using a series of conventional packing rings, compressed to the shaft or shaft sleeve by an adjustable gland, to a principle of two antifriction mating rings, one rotating, the other stationary, that are held together by compression. Mechanical seals are built in a wide range of sizes and pressures, using in their construction almost any suitable machinable material including, steel or its alloys, carbon, teflon, ceramics or fibre. The method of lubrication and the type of lubricant depends on service and design, therefore, the recommendations of the pump manufacturer should be followed very closely.

Bearings. --So many different variations of the two basic types of bearings are used in irrigation pumps that it would be next to impossible to cover them all. The most common question asked is the time interval between relubrication periods for antifriction or ball bearings. It is never advisable to set up a fixed time period for adding or renewing lubricant. Rather, let the operating conditions govern. Oil-lubricated bearings usually have an oil gage, and the proper level should be maintained. Yearly replacement of oil might be considered normal. On grease-lubricated ball bearings a lubrication check every 3 months is ample. Because too much grease causes more trouble than not enough, do not allow an inexperienced operator to add grease to ball bearings. Generally do not fill the bearing housing more than one-third full of grease.

Complete overhaul. --Most pump manufacturers think that a pump should not be opened or completely overhauled unless some factual or circumstantial evidence indicates that it should be done. That is:

(1) Factual evidence means facts, like a decline in performance, excessive noise, high bearing temperatures, motor overload, or similar indications.

(2) Circumstantial evidence means, past experience, similar pumps needed overhauling, etc.

An adequate store of spare parts should be maintained at all times for each size and type of pump used to insure a rapid restoration to service in the event of an unexpected overhaul. Rebuilding of worn parts or complete replacement was covered previously under the maintenance of pump parts.

Extended storage. --To prepare a pump for extended storage, first dry the pump thoroughly and coat castings with a light moisture-free protective coating. Remove all packing. Adequately protect all bearings and bearing housings from corrosion and dirt. Dismantle all readily accessible parts such as couplings, covers, etc.; dry and coat them with a rust-preventive compound. Wet-pit pumps should be removed from their settings, taken apart as necessary, properly coating each part and then stored. The winter storage problem, especially of wet-pit pumps, is usually a matter of individual project experience. Each project has very valid reasons for why they should either pull the pumps or let them freeeze in.

Operating Problems

Mechanically, an irrigation pump is a very simple machine but it would not seem so when reading or listening to reports from the field. From these reports it would appear that the first step when trouble develops is to panic, then step number two is to think real fast and quick of something someone else has done wrong to cause the trouble. Some great stories and theories of a fantastic nature develop from that point.

There are three basic areas in which pump troubles can occur. One is hydraulic, one is mechanical and the last is electrical. The hydraulic problems can be divided into two groups, the first being suction and intake problems before the liquid passes through the impeller and the second being system problems after the liquid has passed through the impeller. Figure 7 is a pump trouble-shooting check list to be used to try to locate trouble in a pump. A schedule or list of pump operating symptoms are shown along with a group of possible causes for each symptom. When isolated the cure for each trouble is usually self-evident. The basic idea for this check list was prepared by an engineer of one of the larger pump manufacturers in 1960. Starting from this idea it has been reworked to a single drawing size for inclusion in this discussion.

Common Pump Troubles

Pump noise. --Basically two types of noise in a pump are expressed by the words "crackling" and "rumbling." A "crackling" noise usually means suction troubles, which are causing the pump to cavitate. This condition exists in flowing liquids when the pressure at any point falls below the vapor pressure of the liquid at the prevailing temperature. To check this simply throttle the discharge from the pump; if the crackling stops, the diagnosis is correct. To correct this symptom one must find a way of increasing the pumps NPSH (Net Positive Suction Head). The other noise symptom "rumbling" means troubles in the discharge system usually caused by operation of the pump at part-load capacity or by operating the pump at capacities well in excess of those for which it was designed. The correction for this symptom is rather obvious.

Direction of rotation. --In a centrifugal-type pump the reverse direction of rotation, commonly produced by reverse mounting of the impeller on the shaft, causes a large drop in head and capacity, a great rise in power demand, and a large loss in efficiency.

Misalinement of parts. --Misalinement troubles should not be permitted to arise. The manufacturer's instructions are usually very explicit and normally not too difficult to follow. In addition to the effect on the pump bearings, misalinement will usually interfere with the proper functioning of stuffing boxes and cause undue stress on the shaft, which could cause failure due to fatigue.

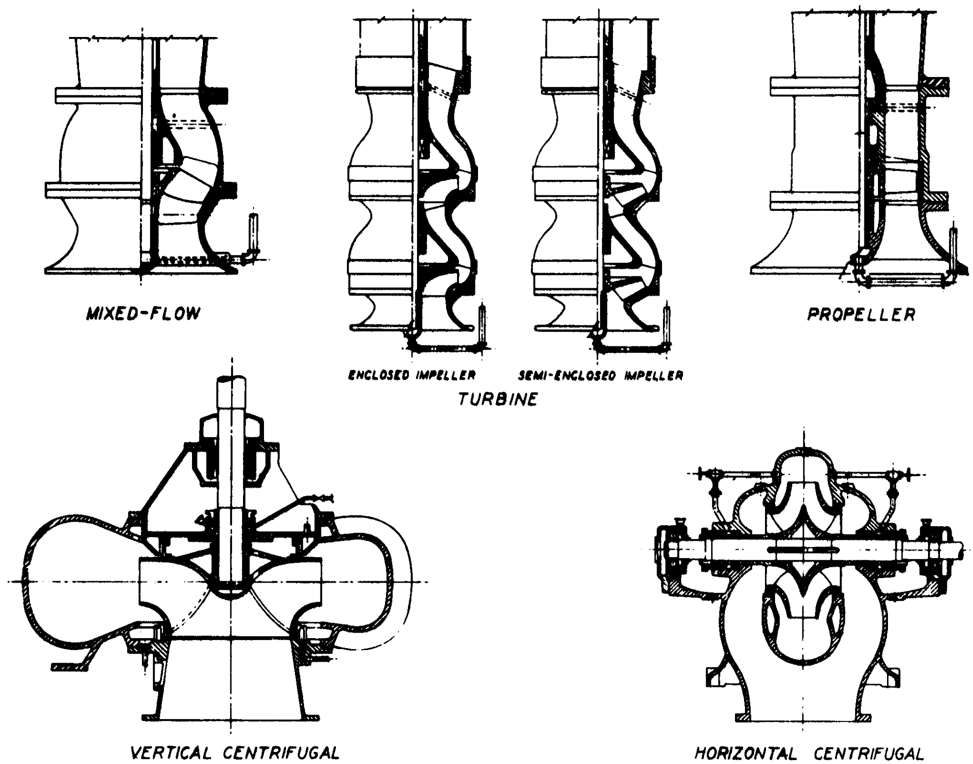
Foreign matter in the pump.--The presence of foreign matter in the pump impeller or casing can lead to serious trouble and should be carefully prevented. The use of the trashracks supplied and the keeping clean of the sumps during shutdown periods will usually prevent this occurrence.

Water-hammer.--A sudden change in velocity of a liquid column causes this trouble or phenomenon. It is usually serious in long discharge lines or in discharge lines in which the velocity is relatively high. In long discharge lines with bad or abrupt changes in profile the problem of water column separation may occur. Dangerous water-hammer conditions are taken care of in the design stages. Usually water-hammer conditions can be taken care of by the installation of surge tanks, air chambers, slow-closing discharge valves, or other means. A complete discussion of water-hammer problems are much too long to be covered here.

Conclusions

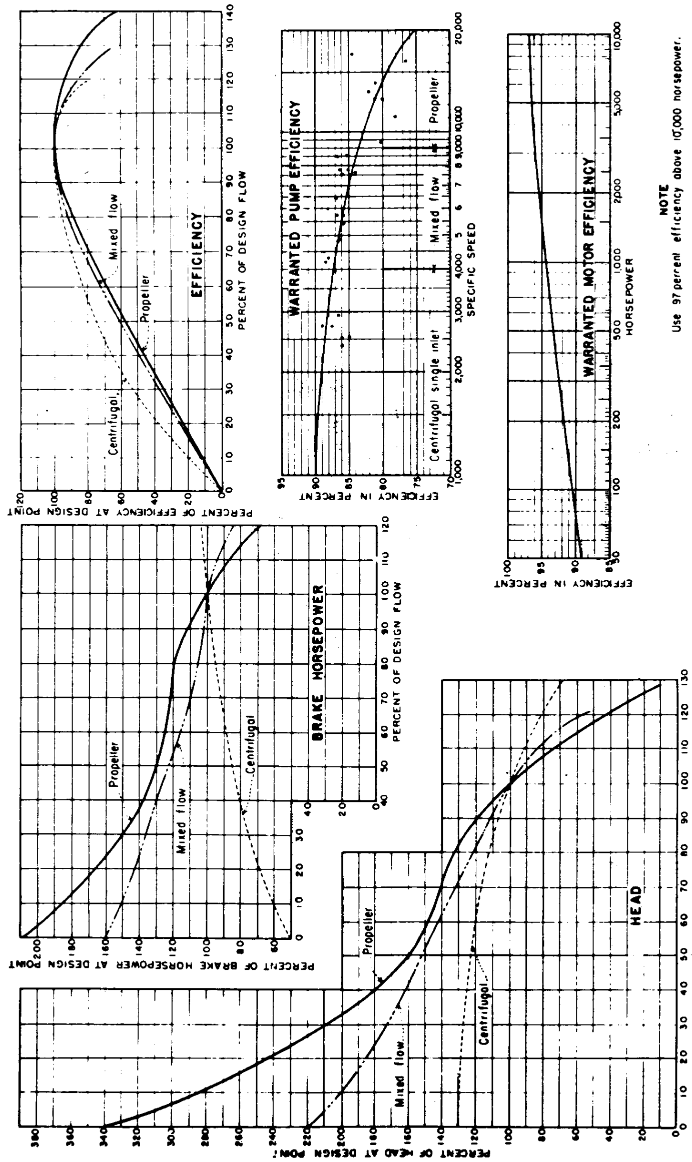
It is not possible in a discussion of this length to fully cover all of the many problems and considerations involved in pump maintenance. It is hoped that this discussion has acquainted you with the types and characteristics of irrigation pumping units and some of the many problems one must face in maintaining them in satisfactory operating condition.

* * * *



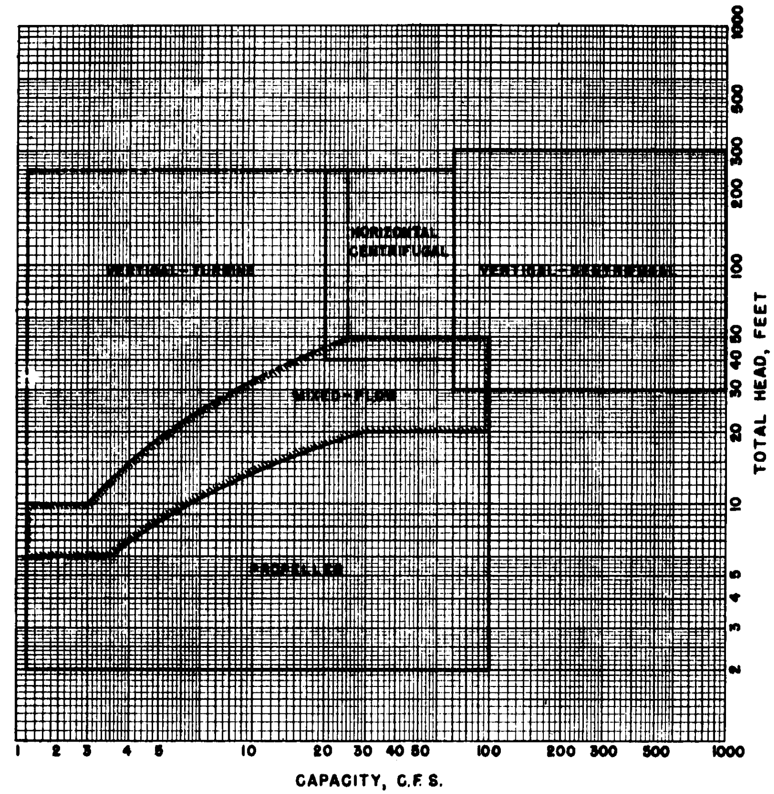
TYPES OF PUMPS

Figure No. 1



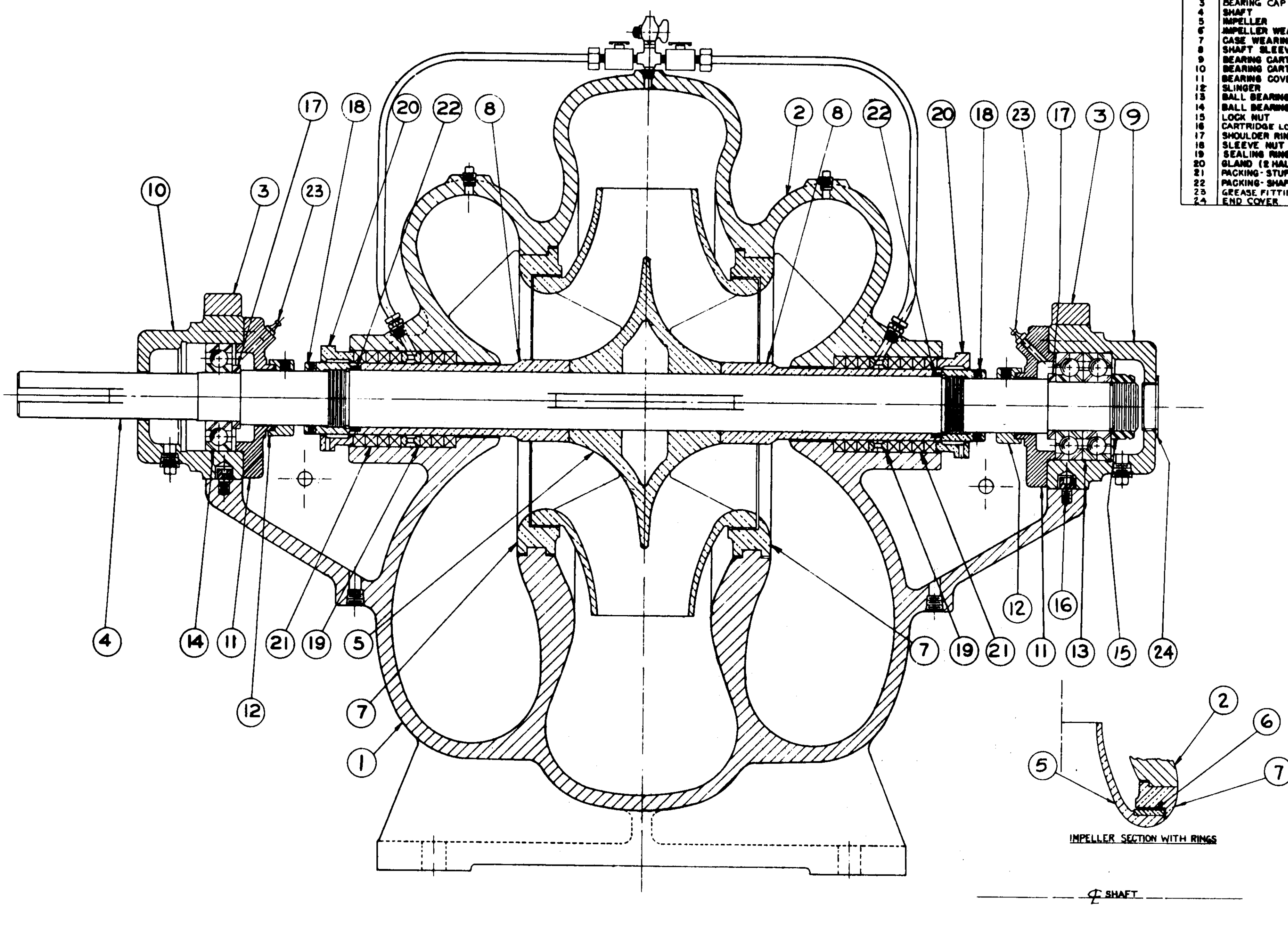
TYPICAL CHARACTERISTICS AND WARRANTED EFFICIENCIES OF VARIOUS PUMPS

Figure No. 2



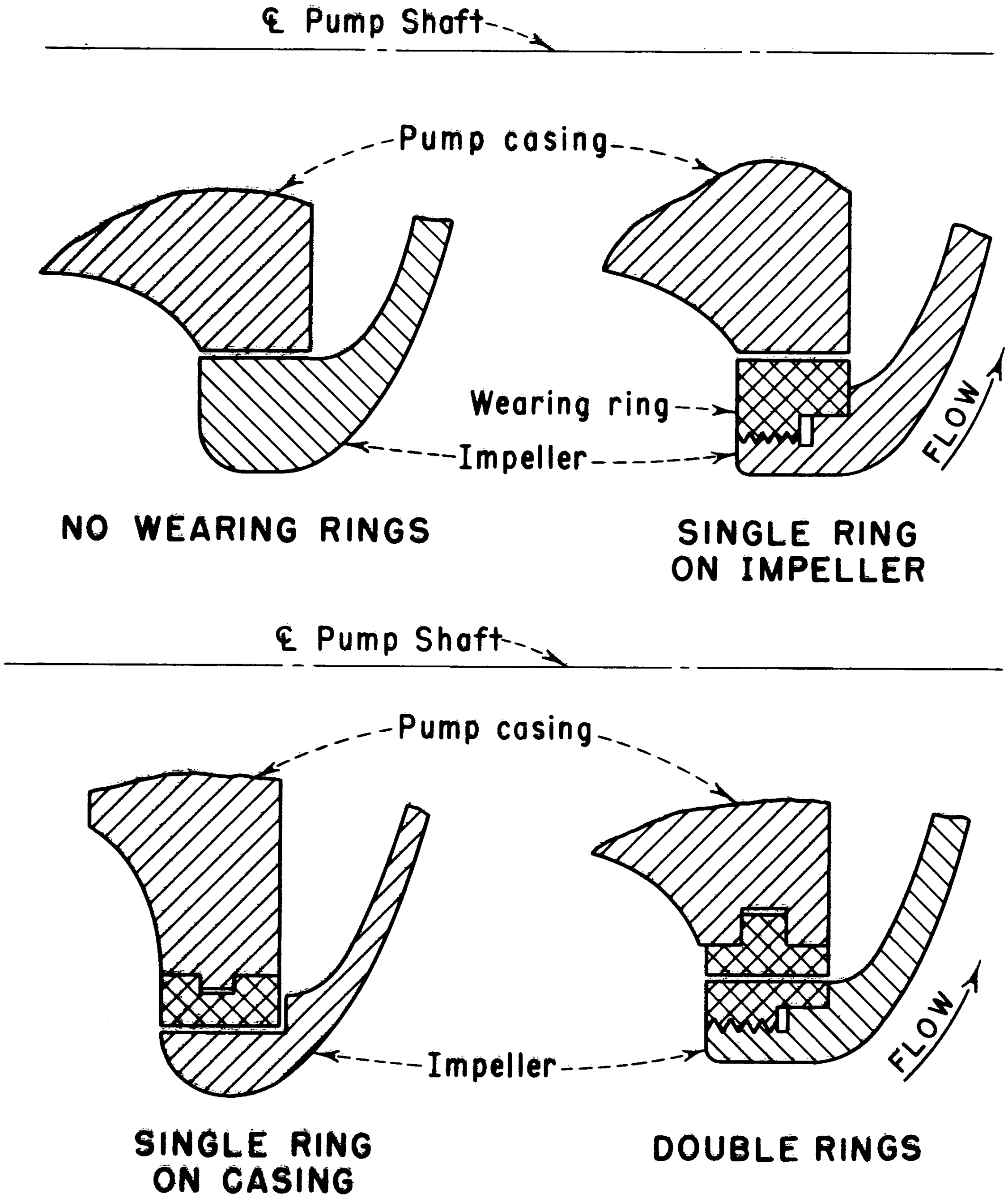
PUMP SELECTION DIAGRAM

Figure No. 3



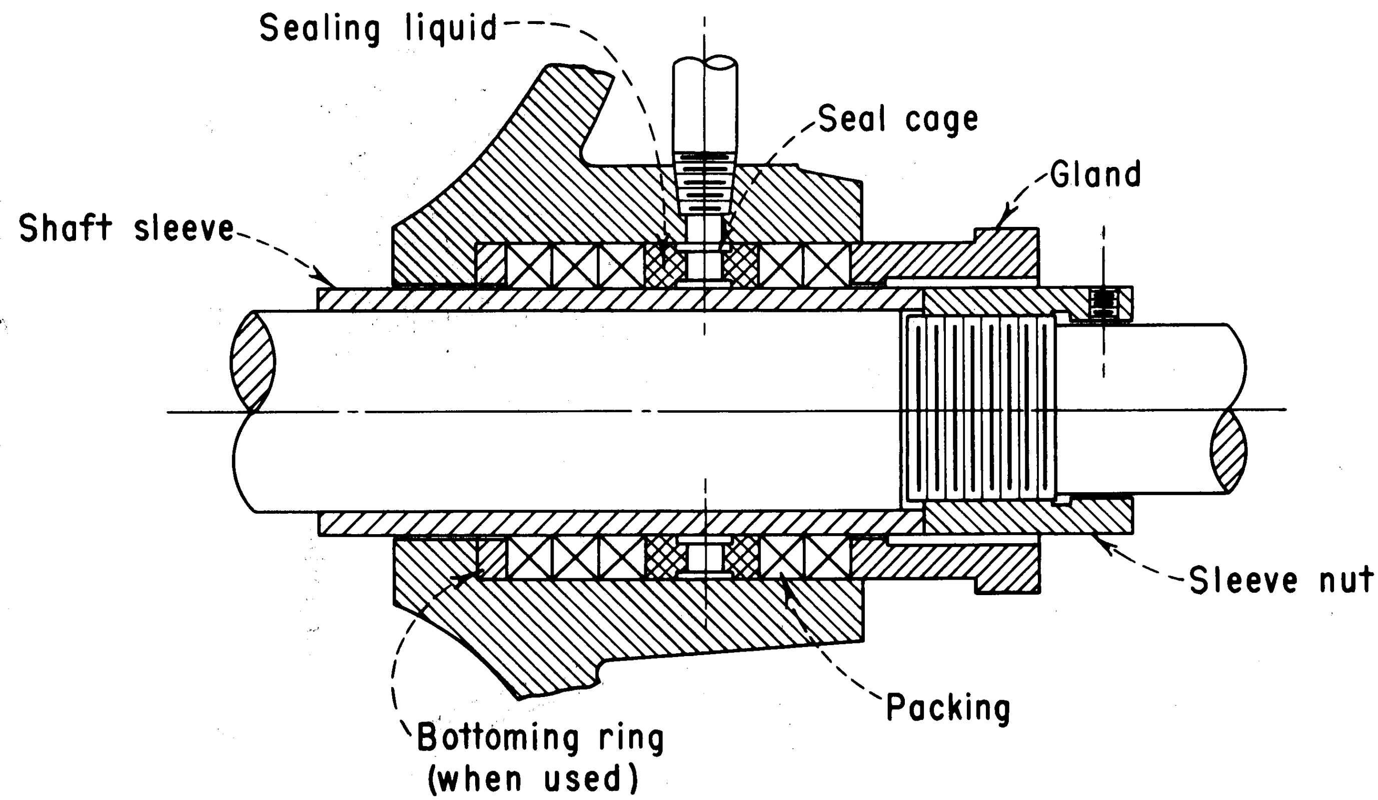
PART NO.	NAME OF PART
1	CASING (LOWER)
2	CASING (UPPER)
3	BEARING CAP
4	SHAFT
5	IMPELLER
6	IMPELLER WEARING RING
7	CASE WEARING RING
8	SHAFT SLEEVE
9	BEARING CARTRIDGE (OUTBOARD)
10	BEARING CARTRIDGE (INBOARD)
11	BEARING COVER
12	SLINGER
13	BALL BEARING (THRUST)
14	BALL BEARING (RADIAL)
15	LOCK NUT
16	CARTRIDGE LOCKING PIN
17	SHOULDER RING - WHEN FURNISHED
18	SLEEVE NUT
19	SEALING RING
20	GLAND (2 HALVES)
21	PACKING - STUFFING BOX
22	PACKING - SHAFT SLEEVE
23	GREASE FITTING
24	END COVER

Figure No. 4



TYPES OF WEARING RINGS

Figure No. 5



CONVENTIONAL STUFFING BOX

Figure No. 6

PUMP TROUBLE CHECK LIST

A. SUCTION OR INTAKE TROUBLES

1. Pump not primed.
2. Pump or suction pipe not completely filled with liquid.
3. Suction lift too high.
4. Insufficient margin between NPSH available and NPSH required by pump.
5. Excessive amount of air or gas in liquid.
6. Air pocket in suction line.
7. Air leakage into suction line.
8. Air leakage into pump through stuffing boxes.
9. Foot valve too small.
10. Foot valve partially clogged or stuck.
11. Suction inlet insufficiently submerged.
12. Water seal pipe plugged.
13. Seal cage improperly located in stuffing box, preventing sealing fluid from entering space to form seal.
14. Water level below bottom impeller.
15. Suction pipe too small or clogged.
16. Inadequate sump design.
17. Strainer clogged.

B. SYSTEM TROUBLES

1. Speed too low.
2. Speed too high.
3. Wrong direction of rotation.
4. Total head of system higher than design head of pump.
5. Total head of system lower than design head of pump.
6. Specific gravity of liquid different from design.
7. Viscosity of liquid different from that for which designed.
8. Operation at very low capacity.
9. Parallel operation of pumps unsuitable for such operation.
10. System air locked.
11. Inadequate air relief control.
12. Inadequate surge suppression.
13. Improper positioning of pumps in relation to each other, or to obstructions.
14. Flap valve partially blocked.
15. Improper discharge piping.
16. Lack of vibration dampening or absorbing fittings in discharge piping system.
17. Discharge piping not properly anchored.
18. Siphonic discharge failed to prime.
19. Excessive abrasive matter in liquid.

C. MECHANICAL TROUBLES

1. Foreign matter in impeller.
2. Misalignment.
3. Foundations not rigid.
4. Shaft bent.
5. Rotating parts rubbing on stationary.
6. Bearings worn.
7. Wearing rings worn, or running clearances too great.
8. Impeller damaged.
9. Casing gasket defective, permitting internal leakage.
10. Shaft or shaft sleeves worn or scored at packing.
11. Packing improperly installed.
12. Incorrect type of packing for operating conditions.
13. Shaft running off center due to worn bearings or misalignment.
14. Rotating parts out of balance.
15. Gland too tight resulting in no flow of liquid to lubricate packing.
16. Failure to provide cooling liquid to water cooled stuffing boxes.
17. Excessive clearance at bottom of stuffing box between shaft and casing, causing packing to be forced into pump interior.
18. Dirt or grit in sealing liquid, causing scoring of shaft or shaft sleeve.
19. Excessive thrust caused by a mechanical failure inside the pump or by the failure of the hydraulic balancing device, if any.
20. Excessive amount of grease or oil in the housing of an anti-friction bearing or lack of cooling, causing excessive bearing temperature.
21. Lack of lubrication.
22. Improper installation of anti-friction bearings (damage during assembly, incorrect assembly of stacked bearings, use of unmatched bearings as a pair, etc.).
23. Dirt getting into bearings.
24. Rusting of bearings due to water getting into housing, or condensation.
25. Excessive cooling of water-cooled bearing resulting in condensation in the bearing housing of moisture from the atmosphere.
26. Improper impeller assembly in multi-stage pump.
27. Packing box under negative pressure.
28. Pump operating at or near critical speed.

D. ELECTRICAL TROUBLES

1. Line voltage does not match voltage for which motor is connected.
2. Low line voltage resulting in high amps and low speed.
3. Blown fuse or breaker.
4. Too small lead wires from power source to motor.
5. Too long leads from power source to motor, resulting in excessive voltage drop.
6. Damaged leads resulting in shorting or grounding.
7. Unbalanced line voltage.
8. Too small heaters resulting in unnecessary interruption of operation.
9. Too large heaters resulting in inadequate protection to motor and pump.
10. Motor coils shorted.
11. Inadequate lightning protection.
12. Open circuit in control system, or broken connection.

POSSIBLE CAUSES OF TROUBLES

SYMPTOM	HORIZONTAL CENTRIFUGAL	DEEPWELL TURBINE	PROPELLER AND MIXED FLOW
1. Pump does not deliver water though running	A1-A2-A3-A4 A6-A11-B1-B3 B4-B9-B10-D2 D4-D5	A3-A4-A11 A14-B1-B3 B4-B9-B10-D2 D4-D5	A4-A10-A11-A14 A16-A17-B1-B3 B4-B9-B10-D2 D4-D5
2. Insufficient capacity delivered	A2-A3-A4-A5 A6-A7-A8-A9 A10-A11-A15-B1 B3-B4-B7-B9 C1-C7-C8-C9 D2-D4-D5	A3-A4-A5-A9 A10-A11-A15-A17 B1-B3-B4-B7 B9-C1-C7-C8 C26-D2-D4-D5	A3-A4-A5-A11 A16-A17-B1-B4-B13 B18-C1-D2 D4-D5
3. Insufficient pressure developed	A5-B1-B3-B4 B7-B9-C7-C8 C9-D2-D4-D5	A5-B1-B3-B4 B7-B9-C7-C8 D2-D4-D5	A5-B1-B4-C8 D2-D4-D5
4. Flow stops after starting	A2-A3-A5-A6 A7-A8-A11-A12 A13-C1-D3	A3-A5-A11 A17-C1-D3	A3-A5-A11 A17-C1-D3
5. Pump requires excessive power	B2-B5-B6-B7 C1-C2-C4-C5 C11-C12-C15	B2-B6-B7 C2-C4-C5 C11-C12-C15 C21	B2-B4-B18 C2-C4-C5 C11-C12-C15 C21
6. Stuffing box leaks excessively	A13-C2-C4-C10 C11-C12-C13-C14 C16-C17-C18	A13-C2-C4-C10 C11-C12-C13-C14 C16-C17-C18	A13-C2-C4-C10 C11-C12-C13-C14 C16-C17-C18
7. Packing has short life	A12-A13-C2-C4 C6-C10-C11-C12 C13-C14-C15-C16 C17-C18	A12-A13-B11-C2 C4-C10-C11-C12 C13-C14-C15-C16 C17-C18-C21-C27	A12-A13-B11-C2 C4-C10-C11-C12 C13-C14-C15-C16 C17-C18-C21-C27
8. Pump vibrates or is noisy	A2-A3-A4-A9-A10 A11-B8-C1-C2 C3-C4-C5-C6 C8-C13-C14-C19 C20-C21-C22-C23-C24 C25-C28	A2-A3-A4-A9-A10 A11-A16-A17-B10-B11 B13-B15-B16-B17-B19 C1-C2-C3-C4-C5-C6 C8-C13-C14-C19-C20 C21-C22-C23-C24-C25 C28	A3-A4-A5-A16-A17-B1 B2-B8-B10-B13 B15-B16-B17-B18-C1 C2-C3-C4-C5-C6-C8 C13-C14-C20-C21-C22 C23-C24-C28
9. Bearings have short life	C2-C4-C5-C6-C13 C14-C19-C20-C21 C22-C23-C24-C25	B19-C2-C4-C5-C6 C13-C14-C19-C20-C21 C22-C23-C24-C25	B19-C2-C4-C5-C6 C13-C14-C19-C20-C21 C22-C23-C24-C25
10. Pump overheats or seizes	A1-A4-B8-B9-C2 C5-C6-C13-C14 C19-C21	B11-C2-C5-C11 C15-C21-C27	B11-C2-C5-C11 C15-C21-C27
11. Overheating of motor or motor burn-out	C1-C2-C4-C5 C8-C14-C15-C19 D2-D4-D5-D7 D9-D11	C1-C2-C4-C5 C8-C14-C15-C19 D2-D4-D5-D7 D9-D11	A16-A17-B4-B8-B9 B18-C1-C2-C4 C5-C8-D2-D4-D5-D7 D9-D11
12. Excessively low megohm reading between motor leads and ground	D6-D10	D6-D10	D6
13. Pump fails to start rotating	C1-C5-D1-D3 D6-D10-D12	C1-C5-D1-D3 D6-D10-D12	C1-C5-D1-D3 D6-D10-D12

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

PUMP TROUBLE SHOOTING

DENVER, COLORADO, OCTOBER 12, 1961 W. W. B.

Figure No. 7