Department of the Interior
Bureau of Reclamation

OPERATION AND MAINTENANCE EQUIPMENT AND PROCEDURES

RELEASE NO. 35

January, February and March 1961

CONTENTS

Front Cover.--The photograph on the cover of this issue of the bulletin could lead one to the conclusion that we are now fishing in our canals from motorized equipment. In a way, we are. We are fishing experimentally with electrical logging equipment in an attempt to determine the source of seepage from canals and laterals. The article "Electrical logging to Locate Seepage," beginning on page 1, reports on results. P371-D-23231.

OPERATION AND MAINTENANCE

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INTRODUCTION

Release No. 29 of the bulletin included a brief article on preliminary laboratory studies of epoxy-polysulfide resins as a bonding agent in making concrete repairs. Numerous requests for additional information on the use of these materials in concrete construction and repair have been received from field offices over the past several months. To supply a demand for this information, the Division of Engineering Laboratories of the Office of the Assistant Commissioner and Chief Engineer, Denver, has prepared a brief report of further studies made in the laboratory and field and suggest recommended procedures. The article appears beginning on page 15 and is a condensation of a more extensive report now being prepared.

Beginning on page 8, is an article describing "Bubbler" type pressure gages and their use in the Kansas River Projects area of the Missouri River Basin Project to measure water levels in rivers, creeks, and reservoirs in lieu of other types of equipment used for this purpose. The article was prepared by Ray Aldrich of the Projects Office staff, who as Chief, Water Control Branch, Division of Irrigation Operations, Bureau of Reclamation, is closely associated with the operation of the gages.

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 laborsaving 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 this and subsequent 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

ELECTRICAL LOGGING TO LOCATE SEEPAGE

At the eighth annual meeting of the Four States Irrigation Council, held in January 1959 at the Denver Federal Center, Dart Wantland, Geophysicist, Engineering Geology Branch, Office of the Assistant Commissioner and Chief Engineer, Denver, Colorado, reported that the Bureau of Reclamation had made field trials of the electrical logging method to detect possible seepage from operating canals. These trials were carried out in the Central Valley Project, California, in October 1958 under the Lower-cost Canal Lining Program. A total of 7.3 miles of canals were logged, along selected reaches of the canals. The first test of the electrical canal logging method was performed for the Bureau by a firm of consulting geologists and geophysicists.

As a result of the first canal logging test it was concluded that the electrical logging would assist in locating and tracing seepage, if combined with a knowledge of soils and geologic formations along the canals studied. It was felt that further field trials were warranted to define the conditions under which the procedure would or would not "work." Further, field work and an evaluation of the results were the subject of a report presented by Mr. Wantland in Denver, Colorado, on January 12, 1961, at a joint meeting of the Four States Irrigation Council and the Upper Missouri River Water Users' Association.

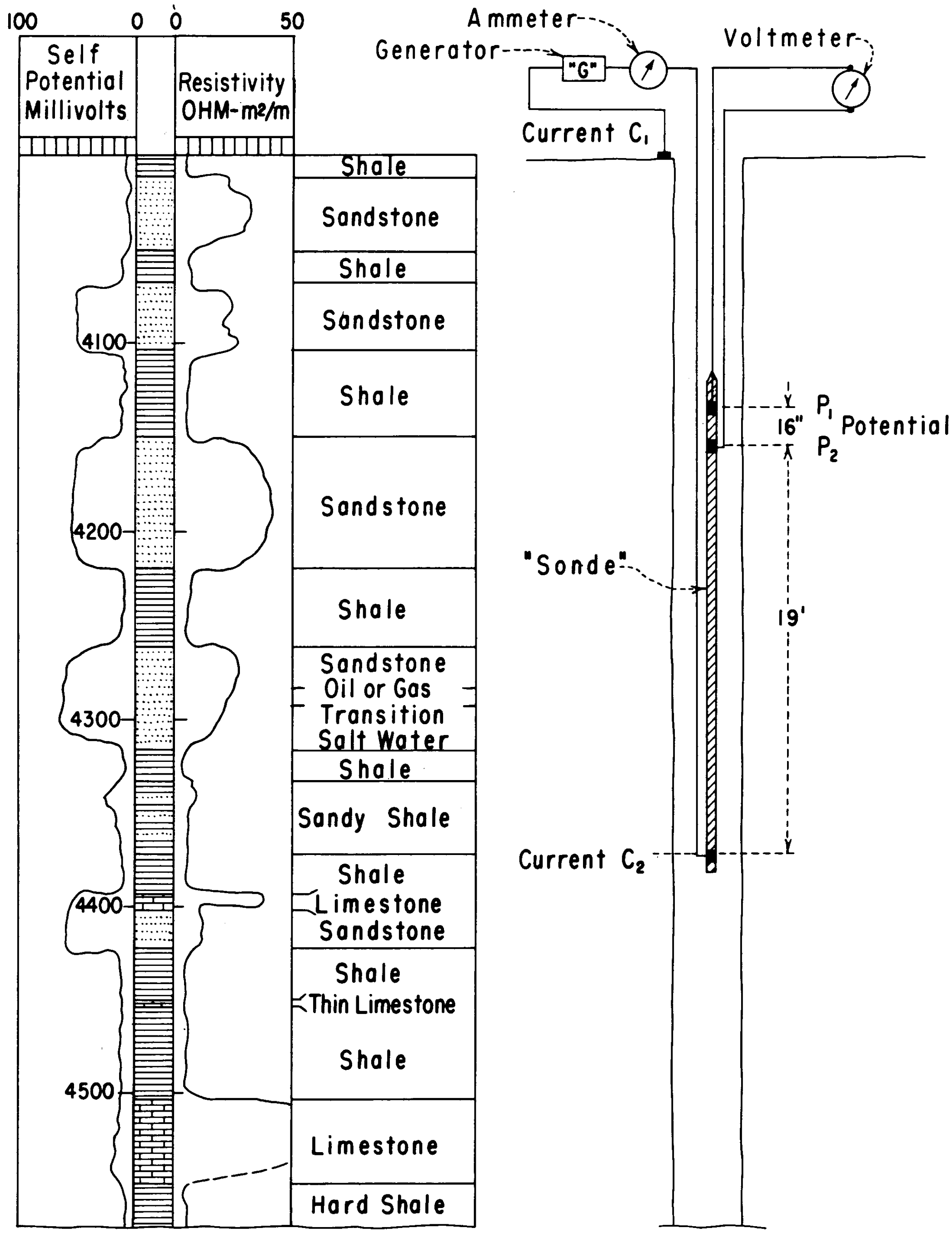
The electrical logging technique was originally developed for use in (uncased) drill holes and was first applied in France in about 1927 by Messrs. C. and M. Schlumberger. The electrical logging of drill holes is now routine for all oil exploration and oil field development, and drill hole logging services are available throughout the world.

Procedure

An electrical log of a drill hole is a continuous record of the electrical resistivity and of the self-potential or natural electrical voltage of the formations drilled through. Such logging requires that electrical contact with these formations be established by four electrodes, three of which are lowered into the drill hole and form a "Sonde" as shown in Figure 1. The generator, ammeter, and voltmeter designated in the figure are part of the measuring and recording equipment mounted in a logging truck located near the mouth of the well and by means of which a log is made as the "Sonde" goes down the hole. The idealized electric log in Figure 1 brings out that different kinds of rocks and formations have different resistivities and self-potential.

An electrical log of a canal is quite similar in many ways to an electrical log of a drill hole, and shows the variations from point to point in the resistivity and self-potential of the materials along the bottom of the canal. Contact is made on the canal bottom by

ELECTRICAL LOGGING OF DRILL HOLES



IDEALIZED ELECTRIC LOG

ELECTRODE AND CIRCUIT ARRANGEMENT

Fig. 1

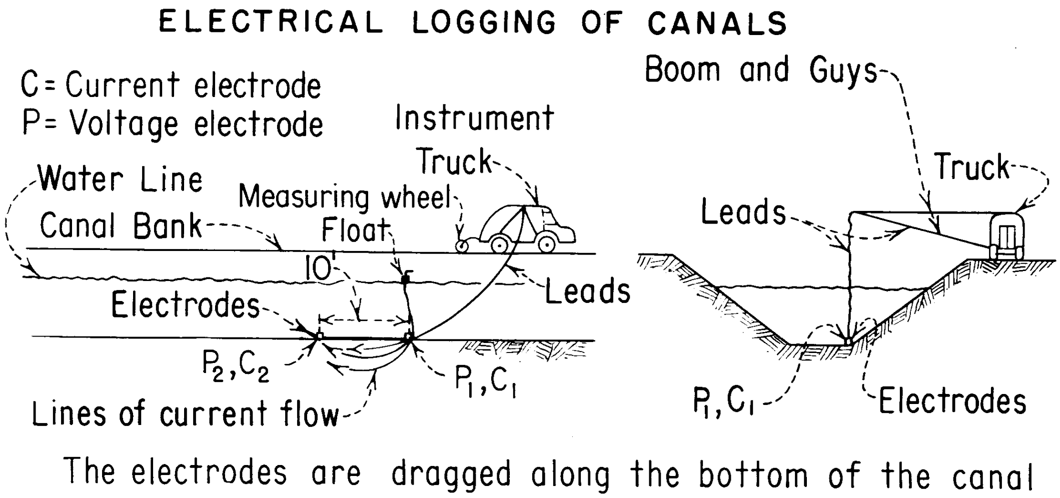


Fig. 2

two lead electrodes which are flat discs, about 2 inches in diameter and 1/2-inch thick. These electrodes are connected by individual waterproof wire lines to a source of electrical current and recording equipment in a field truck. As shown in Figure 2, current is sent through the ground between the two electrodes. The resistance and self-potential are measured and recorded, by the moving pens of a chart recorder, as the instrument truck moves along the canal bank dragging the string of electrodes in the canal. In effect we take a series of samples of earth materials at adjacent points along the canal bottom, measure their electrical properties and record the results graphically. Reaches of canals can be logged at a speed of about 2 miles per hour.

The spacing of the electrodes controls the depth to which the resistivity of formations is measured in electrical logging. In the Bureau's recent tests in Kansas logging was done mainly with a 10-foot spacing of electrodes which was found to be quite satisfactory after trying several different separations.

Second Field Trial

A bore hole logger was modified for canal logging by the Bureau and in April 1960 a second field logging trial was made; also in California. The equipment permitted us to test the possibility of measuring the self-potential in canal logging in addition to the resistivity, as in bore hole logging. We found that self-potential was present in a canal and could be measured.

The measurement of the self-potential was important because it is known that one cause of self-potential is water moving through porous media or, in other words, leakage. The photograph on the cover of this issue of the bulletin shows the Bureau logging truck at the Kirwin Canal during the second field test.

Because of the known direct relation between self-potential and water movement and the fact that the self-potential could be measured in the electrical logging of a canal, it was felt that additional field trials were warranted. It should be appreciated that in carrying out the logging testing and development we were following new paths and making a type of measurement in canals that had not been made heretofore. Before the second field tests, for example, we did not know if there was a self-potential from point to point along a water-filled canal, and, if so, whether it was strong enough to be measured with the equipment we had.

Third Field Trial

The third canal logging test, which was sponsored by the Soil and Moisture Conservation Program, was performed in September 1960 and covered some 4.5 miles of the Kirwin Main Canal, Solomon Division, Missouri River Basin Project, Kansas. The test was the most fruitful of our canal logging evaluation trials because there were considerable specific data on seepage and/or tightness of various reaches with which the interpretation of the electrical logs could be compared.

Following the electrical logging and partly guided by it, additional seep meter readings were obtained. In addition, inflow-outflow measurements and two ponding tests were completed by engineers from the Bureau Projects Office at McCook, Nebraska. There was also available a geologic profile, along the canal line, based on preconstruction field observation and drilling.

Local Conditions.

The Kirwin Main Canal flows in an easterly direction from the Kirwin Dam and lies on the north side of the valley of the North Fork of the Solomon River. The river valley in the area is from a mile to 2 miles wide and has been entrenched in limestone and shale formations. Silt and clay terrace deposits cover most of the valley floor. Unconsolidated sediments deposited by wind or by streams and also containing slope wash and talus lie near the base of the low hills north of the river.

Along some reaches the canal is excavated in limestone which is at or near the surface and is considerably weathered in certain locations. Along other sections the limestone is massive but may show extensive minor fracturing and faulting. Although the weathered limestone forms a relatively impervious claylike (marl) layer, tests indicated that the fractured limestone, although massive, would in certain places take a considerable amount of water. Earth lining had therefore been recommended and installed along certain reaches in the massive limestone.

Results of Logging

The electrical canal logs were studied and correlated with geological and topographic conditions along the different reaches and with seep meter measurements, ponding tests and inflow-outflow determinations. It was found that most of the reaches logged could be divided into two classes as follows:

> Class 1--Reaches where the electrical canal logs showed only small variations in resistance and in self-potential of about 20 ohms and 10 millivolts, respectively. It developed that such small variations in self-potential indicated reaches that were relatively tight. An example of such a tight reach is shown in Figure 3.
>
> Class 2--Reaches where the electrical logs showed very rapid and large changes in self-potential from point to point of from 25 to 50 millivolts. Evidence indicated that reaches or portions of reaches where the self-potential was large and variable indicated seepage. Figure 4 is an example of such a reach.

Variations in resistance along both types of reaches reflected the type of material in a given local area as low resistance silt and clay in comparison with relatively higher resistance chalk rock.

A summary of the comparison between the interpretation of the electrical canal logs, in terms of tightness or seepage, along different reaches and the seep meter readings and other data shows as follows:

Number of Seep Meter Comparisons	Interpretation of Electric Logs as Showing:		Confirmation of Interpretation as Showing:			
	Small SP Tightness	Large SP Leakage	Tightness		Seepage	
			Verified	Not Verified	Verified	Not Verified
36	25	11	24	1	9	2

The above table shows that there were 36 seep meter measurements at which points small self-potential variations were shown in 25 cases and the logs interpreted as indicating tight conditions. This interpretation was confirmed by the meter readings in 24 cases and not confirmed in 1 case. The prediction-confirmation ratio for tightness was 24/25, or 96 percent. Large and variable self-potential was shown in 11 cases and the logs were interpreted as showing leakage. This interpretation was confirmed in 9 cases and not confirmed in 2 cases. For leakage the ratio was 1/11, or 82 percent. Combining these ratios an overall prediction success of 33/36, or 91 percent, was shown.

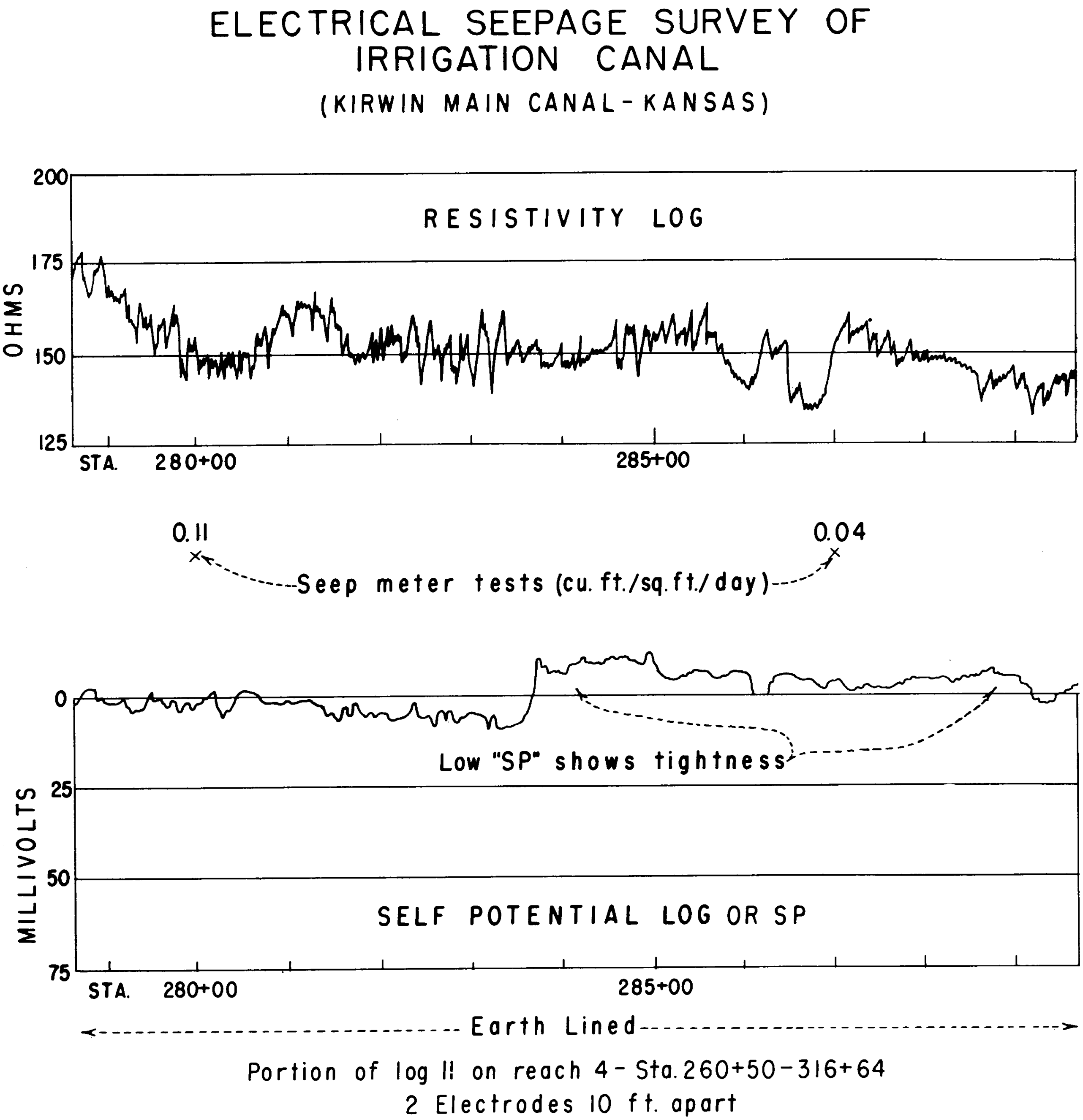

ELECTRICAL SEEPAGE SURVEY OF IRRIGATION CANAL
(KIRWIN MAIN CANAL-KANSAS)
RESISTIVITY LOG
OHMS
200
175
150
125
STA. 280+00
285+00
0.11
0.04
Seep meter tests (cu. ft./sq. ft./day)
0
25
50
75
MILLIVOLTS
Low "SP" shows tightness
SELF POTENTIAL LOG OR SP
STA. 280+00
285+00
Earth Lined
Portion of log 11 on reach 4 - Sta. 260+50-316+64
2 Electrodes 10 ft. apart

Fig. 3

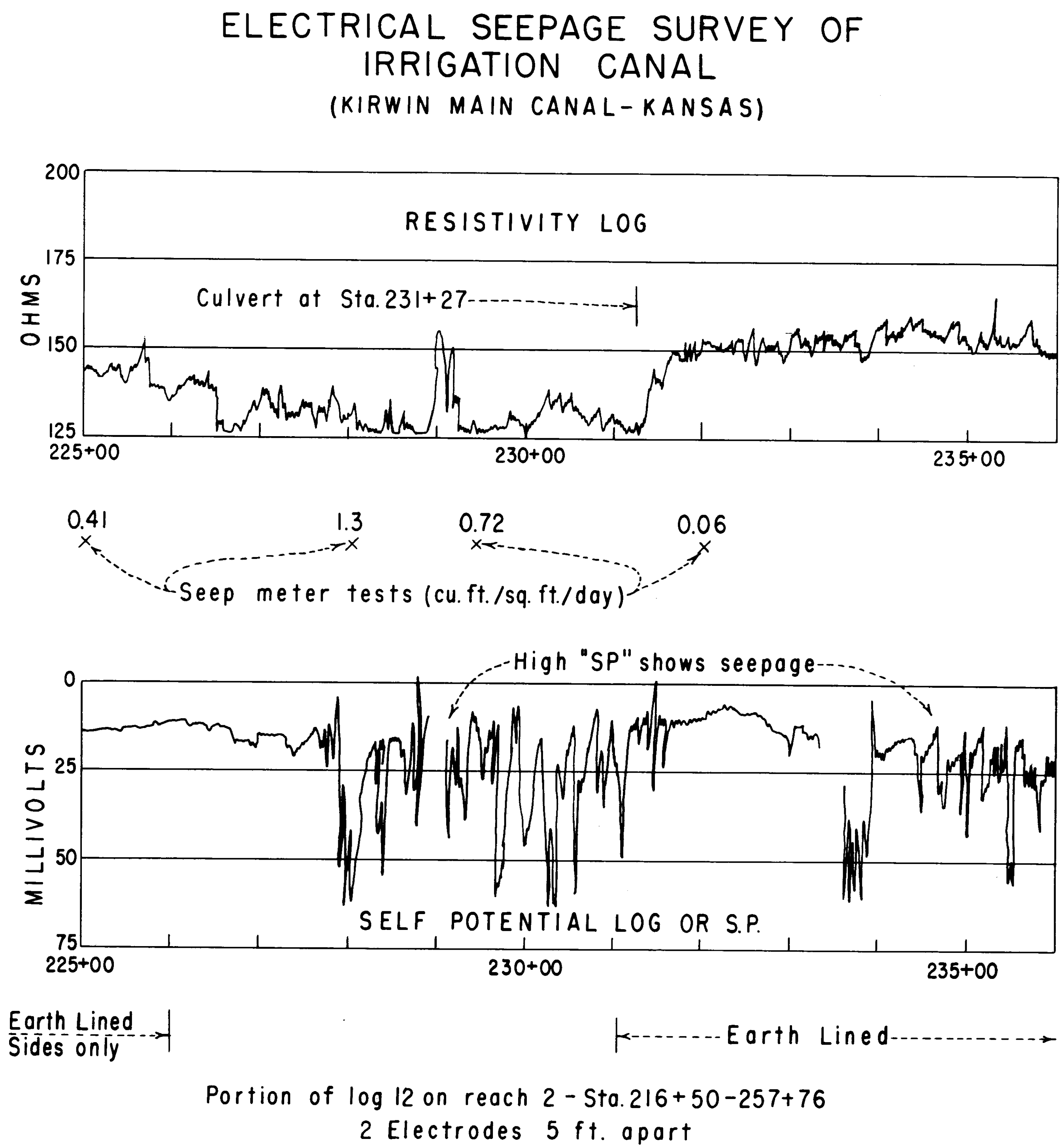

ELECTRICAL SEEPAGE SURVEY OF IRRIGATION CANAL
(KIRWIN MAIN CANAL-KANSAS)
RESISTIVITY LOG
OHMS
200
175
150
125
Culvert at Sta. 231+27
225+00
230+00
235+00
0.41
1.3
0.72
0.06
Seep meter tests (cu. ft./sq. ft./day)
High "SP" shows seepage
MILLIVOLTS
0
25
50
75
SELF POTENTIAL LOG OR S.P.
225+00
230+00
235+00
Earth Lined Sides only
Earth Lined
Portion of log 12 on reach 2 - Sta. 216+50-257+76
2 Electrodes 5 ft. apart

Fig. 4

For canals of the type of the Kirwin Canal and under conditions such as were present there, it can be said that the procedure appears to have merit as the confirmation secured is better than possible under the laws of chance.

There was certain additional confirmation from other measurements. On two reaches where tightness was indicated by the electrical logs for the entire lengths of the reaches and confirmed by 14 seep meter readings, inflow-outflow measurements in one case and ponding in another case also confirmed the log predictions. On another reach where leakage was indicated by the electrical log and confirmed by four seep meter readings, inflow-outflow measurements and ponding verified the interpretation of the log.

Conclusions

The conclusion reached after the first logging trial in California--in October of 1958--still holds. Those of us concerned were then and are now of the opinion that electrical logging will assist in locating and tracing seepage, if combined with a knowledge of soils and geological conditions along the reaches to be studied. It is felt that further field trials are warranted and they have been planned.

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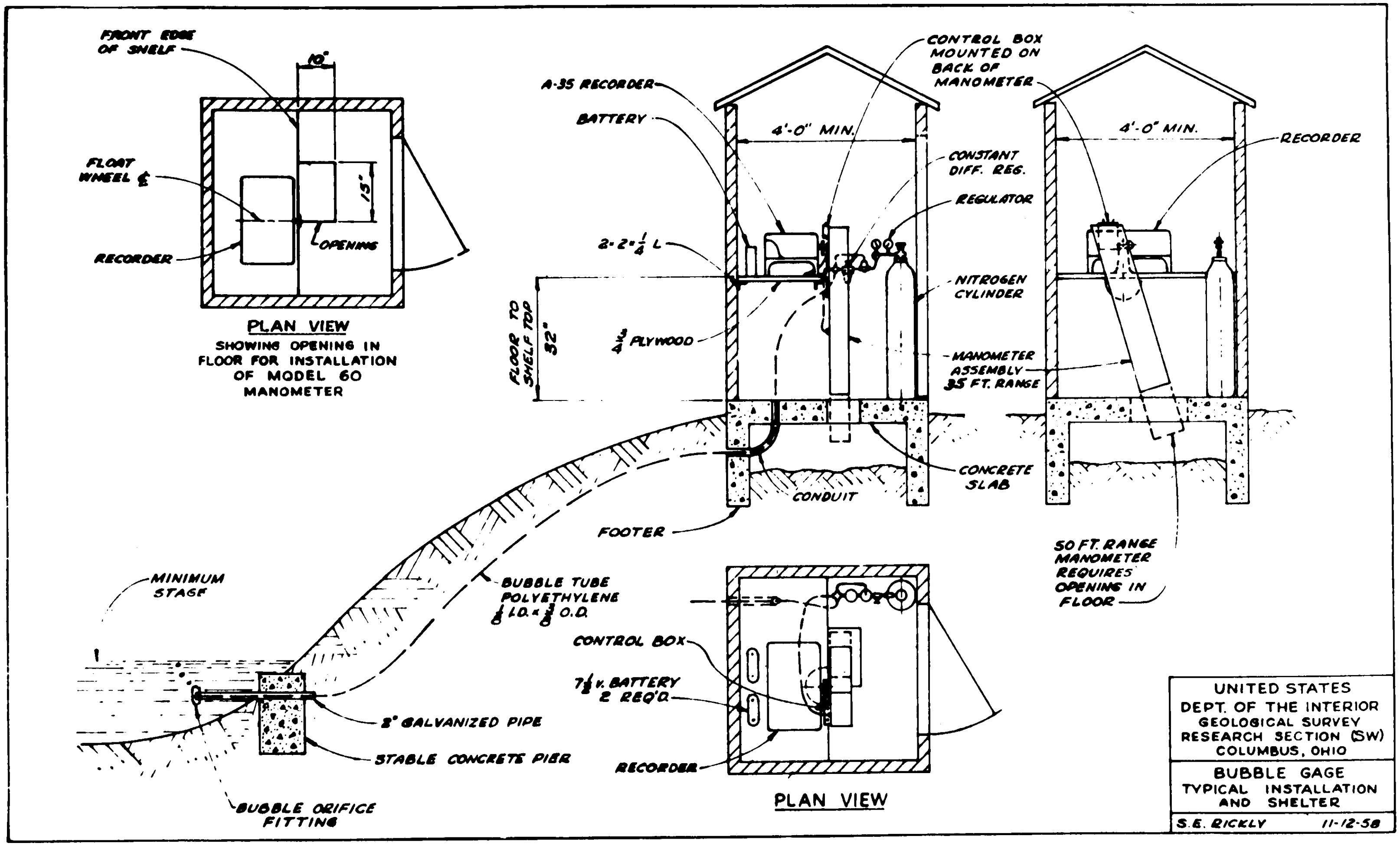
BUBBLER TYPE PRESSURE GAGES AND THEIR APPLICATION IN KANSAS RIVER PROJECTS

"Bubbler" type gages are in use at many locations in the Kansas River Projects to measure the water levels in rivers, creeks, and reservoirs. They are used generally in new stream gaging stations; as replacements for the stilling-well type station where the streams tend to meander within the river bed; and as a means to provide a record of water-surface fluctuations on those dams with an existing reservoir level piping system. The U. S. Geological Survey in the State of Kansas has been using "bubblers" for 4 years, and is "well-pleased" with their performance. They are of the opinion that the records produced by this type of gage in a meandering, shifting sand stream are of much better quality than those from a stilling-well type station.

The "bubber" type gage is a recording pressure-type water level gage that records the depth of water above a fixed position gas orifice by measuring the inside gas pressure required to balance the outside water pressure, and to maintain a small "purge" flow of gas outward through the orifice. The inside gas pressure is usually measured at some remote location in a small shelter-house or control-house, as illustrated in the figure on the following page. Nitrogen is generally used as the gas supply. This gage is electronically operated by a servo-manometer assembly. The power to operate the servo-control unit and the 6-volt drive motor within the assembly is provided by dry cell batteries. The A-35 Leupold & Stevens recorders can be



Layout for typical bubble gage installation equipped with a negator constant torque spring, synchronous electric motor, or a battery electric driven clock. For the most part, the negator spring-driven clocks are used in the Kansas River Projects area, and will operate the recorder for approximately 130 days without rewinding. There are three types of installations in the Kansas River Projects: (1) For small streams, the control instruments and the fixed position orifices are connected by one tube; (2) For large streams or reservoirs with more than 350 feet separating the orifice and the control instruments, twin tubes are required to offset the friction of the gas movement. (Lovewell Reservoir Level Gage is of this type, requiring over 700 feet of twin tubing); (3) For reservoirs using a mercury manometer and reservoir level piping system in the outlet works or spillway, the servo-manometer assembly can be modified to provide a means of recording the reservoir water levels. The piping system is tapped, and the water pressure acts directly on the servo-manometer unit. (Kirwin and Cedar Bluff Reservoirs in Kansas, Enders Reservoir and Harry Strunk Lake in Nebraska, and Bonny Reservoir in Colorado, are of this type.)

The U. S. Geological Survey has 70 "bubblers" in operation in the State of Kansas and report that they are having only minor troubles at the present time. These are mostly within the servo-control unit. They have "ironed out" the difficulties as encountered during the 4 years of operating this type of gage.

The mobility of one of these gages is of great advantage. Nearly all of the material is salvageable and a "bubbler" type gaging-station can be moved from one location to another in a matter of hours or days, as compared to weeks or months to reconstruct a stilling-well type gaging station. The photograph at left, of the gaging station on the North Fork of the Solomon River at Glade, Kansas, shows both the stilling well and "bubbler" type stations. The stilling-well type gage has been replaced with the "bubbler" type pressure gage in the foreground. As the flow meanders from one part of the streambed to another, the "bubbler" orifice is easily moved to a new location.

The advantages of the "bubbler" as compared to the familiar stilling-well type gage are generally as follows:

(1) The mobility and salvageability have been discussed in a preceding paragraph. From this standpoint, a gage of this type might be considered for special studies on canals or streams.

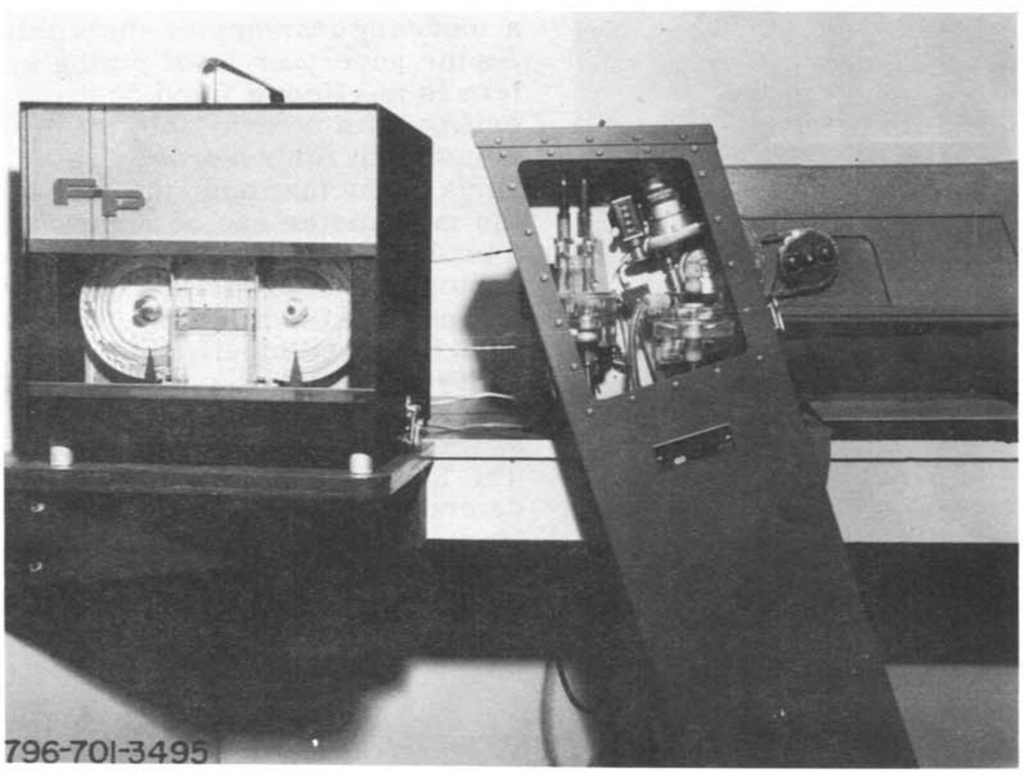
(2) The servo-manometer assembly costs approximately $700. The tubing costs about 30 cents per foot. These costs can be compared to construction expense for the installation of a well-type gage.

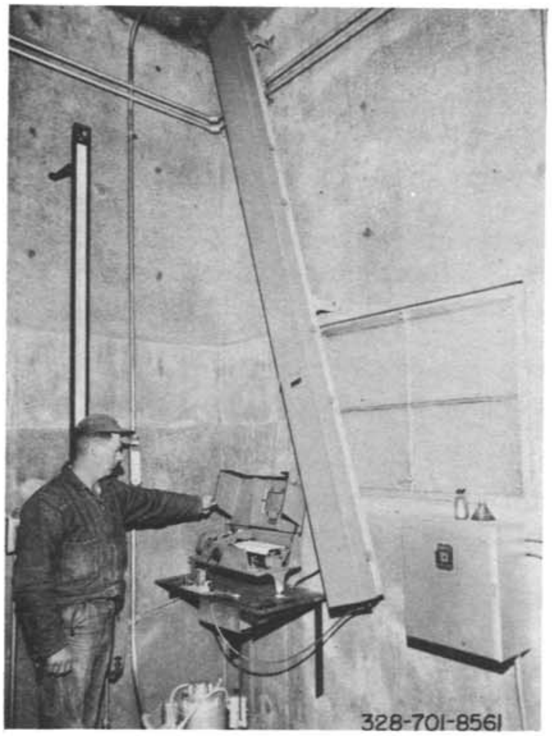
(3) Winter operation is simplified as the need of oil cylinders in the stream gages or heating the stilling wells on reservoir level gages is eliminated.

(4) Less maintenance is required on the tubing and fixed position orifice than on a stilling well and intake pipes.

(5) The problem of keeping the stream at the gage is greatly simplified.

(6) This instrument can readily be adapted to a digital punch recorder. This tape can be used directly to introduce the gage height data into an electronic computor, or converted to a special tape for other computors by a tape analyzer. The photograph below shows a digital punch recorder that the U. S. Geological Survey in Kansas is experimenting with as a replacement for the A-35 recorder.



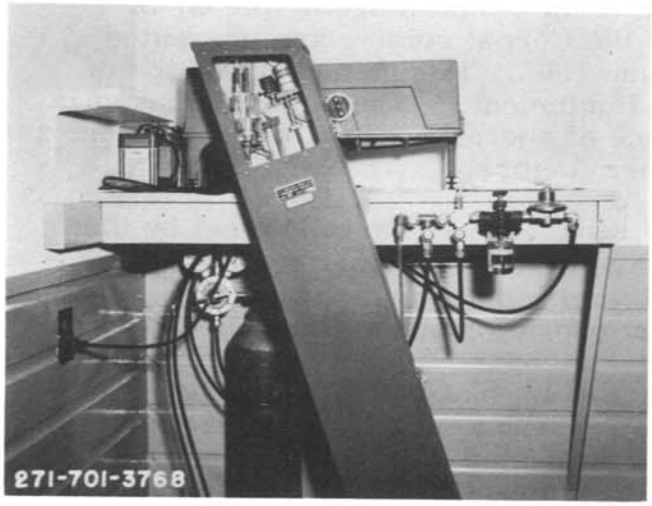


(7) The U. S. Geological Survey in Kansas feels that the records are more accurate.

(8) The bubbler dial on the servo-manometer assembly furnishes a means of reading the reservoir level to hundredths directly.

As the servo-manometer assembly is an electronically-operated instrument, the operation and maintenance is of a more technical nature, and may, therefore, be somewhat of a disadvantage. All of the "bubbler" type gages recording the water levels of reservoirs and streams in the Kansas River Projects are operated and serviced by U. S. Geological Survey personnel.

The "bubbler" type pressure gage in its modified form has provided a convenient means of recording the water surface levels for those reservoirs having an existing reservoir level piping system and a mercury manometer installation. As the reservoir level piping system is in effect a fixed position orifice with no available means of adjustment for reservoir water surface fluctuations, the size of the manometer can be somewhat of a problem as illustrated in the photograph at upper left of the Harry Strunk Lake installation. This "bubbler" gage has been modified to operate with the existing mercury manometer. The water pressure acts directly against the servo-manometer assembly. The length of the manometer is determined by the stage. Mr. R. C. Brandt, Reservoir Superintendent, is checking the pen line against the elevation reading taken from the mercury manometer installed on the wall beside him.



The manometer can be extended below the floor level or installed entirely below the floor level as in the outlet works of Kirwin Dam, see photograph at lower left on the preceding page. Because of the limited space in the outlet works control house, the manometer was installed on the wall below the control house floor. The "bubbler" type gages are not designed to record negative pressures, and the actual elevation of the float switch as installed must be at or below the minimum elevation to be recorded.

The 50-foot model of the "bubbler" type pressure gage can readily be adapted to record reservoir water levels by a series of fixed position orifices. The orifices should be installed with an overlap of approximately 10 feet to insure record continuity. The 50-foot model requires only 45 inches of wall space. This system is partially used on the "bubbler" gage at Lovewell Reservoir, photographabove, with the lowest orifice in use. The reservoir level gage for Lovewell Reservoir is installed in the garage at the caretaker's residence. The manometer is installed at a specific angle so that the angle can compensate for any error that is directly proportional to pressure.

The photograph below shows the location of the twin plastic tubes between the caretaker's garage and Lovewell Reservoir. The tubes are encased in a 3/4-inch thin wall conduit and were buried in a narrow trench 2 to 3 feet deep. The tubing is connected to a valve control system to facilitate the use of a second orifice to be installed at a higher level when the need arises. As a note of interest, the "bubbler" gage at Lovewell Reservoir was installed to replace a stilling-well type reservoir level gage that became inoperative when approximately 5 feet of silt and shale washed in over the top of the intake pipe.

The U. S. Army Engineer District, Corps of Engineers, Sacramento, California, also has been interested in the use of "bubbler" type pressure gages and have published results of study made of both a sheltered, stilling-well water level recording system and a "bubbler" type recording system at Pine Flat Dam on the Kings River, California. The "bubbler" gage is somewhat similar to that developed and in use by the U. S. Geological Survey. The results of the Corps' studies are presented in Project Bulletin No. 3, dated June 1960, "Design and Operation of Reservoir Water Level Measuring Equipment." The bulletin discusses accuracy; dependability; convenience of operation; cost of installation, operation and maintenance; and other factors.

The "bubbler" gages used in the Missouri River Basin Project by the Bureau of Reclamation can be considered as a reliable source of record for both flowing and ponded water, and can be adaptable to many locations for more efficient operation and maintenance.

Developed and adapted for use by the U. S. Geological Survey, the survey should be contacted for any technical advice regarding application for a specific job. It is suggested that inquiry be made to the Research Section, Surface Water Branch, U. S. Geological Survey, Columbus, Ohio.

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EPOXY RESINS FOR CONCRETE CONSTRUCTION AND REPAIR

An epoxy resin is a particular liquid or solid material which must be polymerized to attain useful properties. Exploration of these resins began in Germany in the thirties. Commercial quantities became available in 1949 and were of interest to the coatings and adhesives industries. In the late forties and early fifties, one of the major chemical companies began experimentation and these experimental resins have attained major importance in the epoxy field. These are the resins which are utilized primarily in epoxy resin compounds for concrete construction. Coincidental to the development of epoxy resins was the development of various processes to cure the resins into usable end products.

Early work in this country on the development of epoxy resins in concrete construction and repair was done by the California State Highway Department in 1953. Since then, such work has been done by manufacturers, Government agencies, and others in perfecting epoxy resin systems for application in concrete construction and repair.

Epoxy resins are chemical materials which, when properly applied in concrete construction and repair, can be used to bond fresh portland cement mortar or concrete to hardened concrete; to bond hardened concrete to hardened concrete; or when filled with an inert material, to patch, fill, or repair broken, eroded, or damaged concrete surfaces. Certain epoxy compounds are applicable as surface treatments, as crack and joint sealers or fillers, as grout, and for bonding dissimilar materials to concrete.

Bureau Investigations

Bureau investigations of epoxy resins for concrete construction and repair began about mid-1958, at which time several major evaluation programs were initiated. Prior to that time, several cursory studies were made on the possible merits of epoxy resins. These early studies revealed that much was to be learned about epoxy resins before general or widespread use could be recommended. The programs that followed were designed to provide what was judged to be the most essential information on epoxy resins as adapted to the particular and oftentimes unique circumstances in and around Bureau structures.

Many questions arose which could not be answered satisfactorily by various users or material suppliers, which led to additional laboratory investigations. It should be remembered that many different epoxy resin materials are available for concrete work, and each supplier furnishes directions for use (and surface preparation) which he believes best for his particular material. At the present time, there are no standards which are completely satisfactory for either materials or techniques in using them. Bureau studies are aimed at perfecting standards for use within the Bureau of Reclamation. .

Each Bureau test program is designed to include as many as practical of the variables which might affect performance. Different basic types of epoxy compounds are being compared under identical test conditions. These studies are being conducted because, at the present state of development, each potential application of epoxy resins requires special consideration. Indiscriminate use of epoxy resins in concrete construction or repair is not recommended.

MATERIALS

The Basic System

Epoxy resins are a class of true thermosetting plastics which require an external influence to convert to a stable solid mass. The systems which are of concern here are generally furnished in two components, one the resin, and the other the curing agent. The curing agent is added to the resin, a curing reaction commences, and the conversion occurs. Oftentimes, other materials are added to one component or the other to improve certain characteristics of the cured system.

Curing Agents

Conversion to the thermoset plastic can occur under the influence of heat, a catalyst, a reactive hardener, or a combination of these. Many desirable properties can be attained by proper use of reactive hardeners. The catalysts and hardeners, or mixtures of them, are classified under the general title of curing agents.

Many of the catalysts and reactive hardeners used in epoxy resin systems are strong chemicals which will damage human tissue and necessary safety precautions, which will be discussed later, must be employed when handling them.

To achieve an optimum cure, it is necessary to properly proportion the curing agent to the particular resin. The proper ratios are determined by the formulator and are given as "mixing proportions" in the directions for use of the material.

In order to achieve the correct chemical cure, it is necessary that the reactants be thoroughly dispersed one in the other. Thorough mixing must be accomplished to prevent isolated pockets of one component or the other. The materials will not intermingle by absorption, diffusion, etc. However, once the components are mixed, they must be used within a relatively short time as the curing reaction begins immediately. The time that a mixture remains in a usable or workable condition after mixing is called the "pot life."

Alloying Compounds

Cured epoxy resin systems, prepared by proper proportioning of resin and curing agent, are generally hard and brittle. For many applications, these properties are desired or are not detrimental and such systems are used. However, for most applications, tougher compounds are needed. These can be obtained by "alloying" or modifying the system.

Inert Fillers

Various types of inert fillers are sometimes incorporated into epoxy resin systems. Among these are mineral pigments and powders, sand and/or aggregate and fibrous types. Pigments are added to a system to achieve color, whereas other inorganic powders are added to control viscosity, heat dissipation, and other properties. Sand or aggregate is added to extend the volume of a particular resin. Fibrous types, sometimes called reinforcements, may be glass, asbestos, cotton, or synthetic fibers. These fillers may be incorporated into one component or the other, but more often are added to the system just after the resin and curing agent are blended.

Diluents and Thinners

Diluents and thinners are liquids added to an epoxy system to reduce the viscosity. The diluents generally are reactive; that is, contain a chemical group which will react with the epoxide groups in the resin. Thinners are generally nonreactive solvents such as xylene or toluene. The use of diluents or thinners should be held to a minimum as in all cases they degrade the physical properties of the cured system. Most Bureau applications will be made with systems which do not contain either diluents or thinners.

From this brief discussion, it can be seen that epoxy resin systems are complex products which require precise formulating and correct handling to attain proper cure and expected properties.

Safety Precautions

The epoxy resin compounds are chemical materials with which certain necessary safety precautions must be exercised when handled to avoid health problems, since some of the hardeners or catalysts are classed as primary skin irritants. Protective clothing and rubber or plastic gloves should be worn while handling these materials.

Goggles are often necessary to protect the eyes from splash, spray, etc. Special protective barrier creams should be applied to all exposed skin areas if the materials are to be sprayed or handled for any length of time. Spillage and tools should be cleaned immediately so accidental contamination does not occur. Finally, in close locations, adequate ventilation should be provided. The usual safety precautions should be exercised in handling the etching acid solution.

If an epoxy resin should contact the skin, either in component or mixed forms, it should be removed immediately to minimize the danger. The excess should be removed with a clean dry cloth or paper towel and the area washed thoroughly with soap and water. At least three good soapings are necessary. If water is not readily available, denatured alcohol may be used to remove the contamination, but the area should be washed with soap and water as soon afterwards as possible. Solvents should never be used to remove epoxy resins from the skin, as they transport the contaminent into the skin, thereby increasing the contamination rather than reducing it.

Cured epoxy resins are generally considered innocuous and present no potential danger. However, if grinding operations are necessary. a dust-type respirator should be worn to prevent inhalation of the epoxy dust.

Evaluation Tests in Progress

All testing of epoxy resin systems has been on proprietary materials. Wherever possible, materials of similar composition were tested together or in companion tests so that comparative data on particular types could be collected.

Each individual test program has been designed to obtain information judged to be the most valuable for specific Bureau needs, in environments closely related to actual field exposures. Several hundred specimens are undergoing aging tests in a variety of exposure conditions so that the effects of the exposure on the properties of the resin can be determined. Of particular interest will be comparisons of initial test data with data obtained after exposure. Most of these tests are still in progress. To our knowledge, there is no comprehensive published report on the effects of aging on epoxy resins for concrete construction and repair. Specific laboratory reports will be published as Bureau exposure tests are completed.

Many test programs are under way in the laboratory. Included are impact tests, bonding tests, physical properties of epoxy resin mortars, resistance to cavitation erosion, and special application and performance studies, and others.

Many field trials are underway at various Bureau projects. Some were instigated by project personnel when they recognized that the use of epoxy resins might solve a particularly difficult concrete repair problem, and in such cases, materials from local suppliers were procured.

Field trials recommended by this office include applications of epoxy resins in almost all types of concrete repair work. Epoxy-bonded portland cement concrete repairs have been recommended, as have epoxy mortar repairs and old-to-old concrete repairs. All have not been completed as yet, as some are actually major repair programs to be accomplished as time and funds permit.

Some of the trials which have been completed include the repair of cavitated concrete of the outlet conduits at Grand Coulee Dam, Columbia Basin Project, Washington, and at Carter Lake Dam, Colorado-Big Thompson Project, Colorado; the repair of minor damage during the manufacture and handling of concrete pipe on one of the new irrigation systems now being constructed on the Central Valley Project, California; and the actual construction of fillets to later be bonded to the interior of a steel siphon to correct turbulence in the siphon. The materials for field repair were selected on trial basis from laboratory test results and on tested epoxy compounds listed by the Corps of Engineers.

Suppliers and Cost

For bonding new, fresh concrete or mortar to hardened concrete, and as the resinous binder in plastic mortar, the use of an epoxy-polysulfide compound is recommended. The material should be 100 percent non-volatile (100 percent solids), consisting of two components, mixed one to one by volume, and should meet Corps of Engineers purchase descriptions for "Grout (adhesive), epoxy resin base, flexible, filled."

A number of manufacturers supply compounds which meet the above requirements. Each of these manufacturers maintains a pool of tested material at their plant. Federal agencies may request release of materials from these pools by agreeing to pay the prorated share of the testing costs and the actual shipment inspection costs. Release should be obtained from the Corps of Engineers office monitoring the chosen pool as indicated on the list, pages 20 and 21. The actual purchase, however, is negotiated strictly between the manufacturer and the purchasing agency.

These suppliers can also furnish materials formulated to meet the purchase descriptions, but which are not maintained in a tested pool. These are their regular consumer products. We believe that, when small quantities are involved, that untested material will generally be satisfactory provided that the manufacturer certifies conformance to the requirements of the Corps purchase descriptions. The cost of the epoxy-polysulfide compound will be about $14.00 per gallon unit. If tested material is required, the prorated test costs will be in addition to the purchase price. The prorated costs will vary with the size of the pool and the amount ordered, but should be less than the costs of testing an individual batch for a specific use. We suggest that, for the present, if quantities in excess of 10 gallons are required, tested material be obtained.

As research and development on epoxies is moving forward at a very rapid rate, it is recommended that inquiries concerning the suitability of materials for a specific use and sources of supply be forwarded to the Chief Research Engineer, Division of Engineering Laboratories, Bureau of Reclamation, Building 56, Denver Federal Center, Denver 25, Colorado.

Recommended Construction and Repair Procedures

Wide general use of the epoxy resins in concrete construction or repair cannot be recommended at this time, as latent properties have not been fully evaluated. The techniques set forth below are not intended to replace standard concrete construction or repair procedures outlined in the Bureau's Concrete Manual, but are given to provide information on our current recommendations for limited use of the promising epoxy resin compounds.

The compound may be used either as a bonding agent for bonding fresh portland cement mortar to hardened concrete or as a patching mortar when filled with sand for making small patches. For the first application, the two components are mixed in equal parts by volume, applied to the cleaned surface, and the portland cement mortar or concrete applied while the bonding layer is tacky. On steep slopes and vertical surfaces, it is necessary to use forms to hold the new mortar or concrete in position while the initial cure takes place. When the forms are removed, or after initial set has occurred, the new mortar or concrete should be cured in the usual manner.

The blended resin, when mixed with three or more parts by weight of well-graded, clean, dry sand, produces a patching mortar for small repairs of concrete. The sand is blended into the mixed resin a bit at a time until thoroughly incorporated into the mixture. The epoxy mortar is then applied to the area to be patched and allowed to cure. In this case, the resin binder cures chemically and the curing membrane should not be applied. An epoxy mortar can be used to finish the edges of a portland cement mortar patch where the featheredges are difficult to attain behind a form.

The use of any thinners, solvents, or release agents, either on tools while working an epoxy mixture, or in the mix, should not be permitted.

Lubrication of tools while working epoxy mortar may be accomplished by dipping in a batch of catalyzed, but unfilled, resin as required, but should be held to a minimum. Solvents may be used only for the final cleanup.

Surface preparation for either application should be as follows: First, all loose concrete and dust should be removed; second, the surface to be patched should be etched with a one to four dilution of hydrochloric (muriatic) acid; and finally, when the etching action ceases, the surface should be thoroughly scrubbed with a stiff bristle brush under running water and rinsed clean. The scrubbing is essential to remove residual salts from the etching reaction. The cleaned surface should then be allowed to dry completely before application of the epoxy compound.

We would appreciate being advised of any proposed uses of these materials. We believe at this time that each application requires special consideration.

LOCATION OF CORPS OF ENGINEERS CONTROL CENTERS FOR POOLS OF TESTED EPOXY RESIN MATERIALS

Corps of Engineers
U. S. Department of the Army
180 New Montgomery Street
Post Office Box 3050,
Rincon Annex
San Francisco 19, California

Controls pools located at
San Carlos, California

Corps of Engineers
U. S. Department of the Army
Los Angeles District
Post Office Box 17277,
Foy Station
751 South Figueroa Street
Los Angeles 17, California

Controls pools located at
Los Angeles, California, and
Long Beach, California

Corps of Engineers
U. S. Department of the Army
Southwestern Division
Santa Fe Building
1114 Commerce Street
Dallas 2, Texas

Controls pools located at
Oklahoma City, Oklahoma

Corps of Engineers U. S. Department of the Army St. Louis District 420 Locust Street St. Louis 2, Missouri	Controls pools located at St. Louis, Missouri
Corps of Engineers U. S. Department of the Army Ohio River Division Laboratory 315-335 Main Street Cincinnati Gas and Electric Annex Cincinnati, Ohio	Controls pools located at Louisville, Kentucky; St. Paul, Minnesota; Woodside, New York; Whippany, New Jersey; Verona, New Jersey; Lansing, Michigan; and Chicago, Illinois

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