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87th Congress
2d Session

COMMITTEE PRINT NO. 1

STUDY AND INVESTIGATIONS OF USE OF MATERIALS AND NEW DESIGNS AND METHODS IN PUBLIC WORKS

FLOOD CONTROL, NAVIGATION, AND OTHER WATER RESOURCES DEVELOPMENT

PREPARED FOR

COMMITTEE ON PUBLIC WORKS
UNITED STATES SENATE

BY THE

CORPS OF ENGINEERS
UNITED STATES ARMY



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MEMORANDUM OF TRANSMITTAL BY THE CHAIRMAN

U.S. SENATE,
COMMITTEE ON PUBLIC WORKS,
June 21, 1962.

To the Members of the Committee:

In response to our committee resolution of January 22, 1962, the Corps of Engineers has completed and transmitted a report dealing with the use of new materials, new use of materials, and use of new designs and methods in water resources projects of the Corps of Engineers, U.S. Army.

I believe that you will find the report of the Corps of Engineers very informative. It reflects their understanding of the water resources problems and methods whereby a better job can be done in the development, protection, and utilization of the Nation's water resources.

The report discusses conventional methods utilized in site investigations, hydrology, hydraulics, construction, and operation and maintenance of water resources projects. It points out the numerous improved techniques and pieces of equipment utilized by them. Many of the techniques and pieces of equipment have either been developed by the Corps of Engineers, cooperatively with other Federal water resources development agencies, or cooperatively with industry. The report also enumerates the many new and improved materials being used, and also those on which research is being conducted.

DENNIS CHAVEZ, *Chairman.*

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COMMUNICATIONS

U.S. SENATE,
COMMITTEE ON PUBLIC WORKS,
January 29, 1962.

Maj. Gen. WILLIAM F. CASSIDY,
Director of Civil Works, Corps of Engineers,
Department of the Army, Washington, D.C.

DEAR GENERAL CASSIDY: The Committee on Public Works, in executive session on January 16, 1962, approved a committee resolution authorizing hearings, study, and a report on the use of materials in the construction of buildings, roads, water resource projects, and other public works.

To attain the objective of the committee it will be most helpful if we could obtain the cooperation of industry and the Government agencies in the collection of information called for by the resolution; therefore, it will be appreciated if you will supply us with such information as is related to your interest or activity.

A copy of the resolution is enclosed for your information. If you require further details please contact Mr. John L. Mutz of the committee staff who is in charge of handling this particular study.

I believe that with the new materials and new uses of known materials being developed and utilized, we should be able to gather considerable information on this subject, thereby making an extremely interesting and constructive contribution to the various producers, fabricators, and users of materials. Furthermore, it would be most useful and helpful if we were to obtain information with respect to new designs and new methods of installation of materials.

It is my hope that your organization will be in a position to appear before the Committee on Public Works to make a formal presentation during the early part of April 1962. After the hearings or presentations are completed, it is planned to have a committee report prepared thereon and submitted to the Senate.

I would appreciate it if you would advise me if you will be able to complete such a report for presentation to the committee at the suggested time, so that we may set tentative dates for the hearings.

Sincerely yours,

DENNIS CHAVEZ, *Chairman.*

[87th Cong., 2d sess., U.S. Senate, Committee on Public Works]

COMMITTEE RESOLUTION PROVIDING FOR A STUDY AND INVESTIGATION OF USE OF MATERIALS IN PUBLIC WORKS

Whereas the Senate Committee on Public Works has under its jurisdiction measures relating to flood control and rivers and harbors, roads and highways, public buildings, water pollution control, water power and other matters relating to developments within the Nation; and

Whereas the Senate Committee on Public Works has authority to make investigations into any matter within its jurisdiction; and

Whereas the Senate Committee on Public Works members have been vitally interested in the development, protection and utilization of our Nation's water resources as evidenced by their active participation in the hearing and deliberations of the Senate Select Committee on National Water Resources; and

Whereas there are now being produced and our scientists and technicians, both in industry and Government, are working on and perfecting many new materials and new uses of known materials and it is evident that such materials can be utilized efficiently and economically in the construction of public works, in the protection and operation of such works, in the preservation and proper utilization of our essential water resources and that such materials and their development and use enhance the opportunities for industrial and business growth and strengthening of our Nation's economy; and

Whereas representatives of industry and the Federal Government have shown a keen interest in discussing and disclosing their roles in the fields of research, development, and utilization of materials.

Therefore, be it resolved, by a unanimous vote of the Senate Committee on Public Works that the committee shall institute a study and investigation into the use of new materials, new use of materials and new designs and methods being used or which may be used in flood control and rivers and harbors, roads and highways, public buildings, water pollution control, water power, and other development, utilization, preservation, and protection projects, and that a committee report be prepared thereon and submitted to the Senate.

SEC. 2. Such study and investigation shall include but not be limited to metals, plastics, rubber, coal, petroleum, timber, concrete, asphalt, chemicals and their direct use, uses of their derivatives or use in combination with each other or other materials, and shall attempt to determine the following:

(a) Description of proposed use of application of the subject material;

(b) General description of the material in terms of physical and chemical characteristics and where possible, obtain a description of the physical or chemical phenomenon responsible for obtaining the desired effect;

(c) Results of laboratory and field tests to prove that the desired effect occurs and prove the durability or duration of the effect of the material;

(d) The limitations of the materials, i.e., problems of toxicity, limitation of effectiveness under certain climate, soil, or physical conditions;

(e) Cost of materials per standard units, i.e., square foot, lineal foot, cubic foot, etc., and cost projection in terms of future production capacity, improved manufacturing techniques, etc.; and

(f) Availability of material both on a current and future basis.

Adopted: January 22, 1962.

DENNIS CHAVEZ, *Chairman.*

HEADQUARTERS,
DEPARTMENT OF THE ARMY,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D.C., April 2, 1962.

Hon. DENNIS CHAVEZ,
Chairman, Committee on Public Works,
U.S. Senate.

DEAR MR. CHAIRMAN: In response to the request in your recent letter we have prepared and transmit herewith a report entitled "Use of New Materials, New Use of Materials and Use of New Designs and Methods in Water Resources Projects of the Corps of Engineers, U.S. Army."

We trust that the report provides the information which the committee desires; however, if there is additional information which the committee desires please let me know.

Sincerely yours,

WILLIAM F. CASSIDY,
Major General, U.S. Army,
Deputy Chief of Engineers for Construction.

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FLOOD CONTROL, NAVIGATION, AND OTHER WATER RESOURCES DEVELOPMENT

CIVIL WORKS MISSION OF CORPS OF ENGINEERS, U.S. ARMY

The civil works mission of the Corps of Engineers, U.S. Army, is to investigate, plan, construct, maintain and operate works for navigation, flood control and multipurpose water resource uses authorized by law. The civil works program of the Corps of Engineers constitutes a major portion of the Federal plan for development, protection and utilization of the Nation's water resources. The program is accomplished through a decentralized organization comprised of 11 divisions which are subdivided into 38 districts. The present program of the Corps of Engineers averages about $1 billion annually.

CORPS OF ENGINEERS ACTIVITIES IN RESEARCH AND DEVELOPMENT RELATED TO WATER RESOURCES

The Corps of Engineers conducts a continuing program of research and development for the purpose of solving problems relating to investigation, design, construction, and operation of civil works projects. The investigations are grouped into six broad engineering fields as follows:

Structural.
Hydrology.
Electrical and mechanical.
Soils and geology.
Concrete.
Hydraulics.

A considerable part of the program, particularly in the structural, hydrology, and hydraulics fields is devoted to development of improved engineering design techniques and criteria; however, investigation of materials, equipment and devices is also included. In the soils field a majority of the program relates to investigation of the engineering properties and behavior of earth and rock as construction materials. This activity is aimed primarily at establishing design criteria and improved methods of testing which will permit the economic use of a wide variety of earth and rock materials in the construction of dams, levees, and similar structures. In geology the program has included the development of a new tool for subsurface explorations (borehole camera) and investigation of foundation grouting techniques, equipment, and materials. In the electrical and mechanical field work is underway on the uses of cathodic protection as a means of mitigating corrosion of steel. In concrete the work involves investigation of cementing materials, admixtures, and characteristics of aggregates, and their effects on the durability and other properties of concrete. The program also includes investigation of construction equipment, and methods of evaluating performance of construction equipment; and development of new test procedures, improvements to existing testing procedures, and development and improvement of purchase specifications.

Most of the water resources research and development work of the corps is conducted at the U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss., and the Beach Erosion Board in Washington, D.C. Work on protective coatings and cathodic protection for mitigation of corrosion of metals is conducted by the Rock Island Paint Laboratory, Rock Island District, Rock Island, Ill. Some work is also performed by other district offices and by division laboratories. USAEWES performs work in soils, hydraulics, hydrology, and concrete. Beach Erosion Board performs field and laboratory work on problems relating to control of erosion of beaches and on littoral processes.

Many of the investigations are conducted in cooperation with technical societies such as the ASTM, ACI, and ASCE. Much of this work relates to development and improvement of purchase specifications and methods of tests, and in development and improvement in design techniques and criteria. Work is also conducted in cooperation with other Government agencies including the Bureau of Reclamation, Tennessee Valley Authority, and Bureau of Standards. Continuing liaison is maintained with Bureau of Reclamation and Tennessee Valley Authority, the other two Federal agencies engaged in water resources development. The corps, U.S. Bureau of Reclamation and TVA meet together periodically (annually or biennially) to review, discuss, and interchange information on research and development work being performed by each agency. Work is also performed in cooperation with industry associations such as Portland Cement Association and at times directly with manufacturers.

The Corps of Engineers keeps contact with industry activities through participation in professional societies activities by corps personnel, through direct contact with industry representatives, and through technical literature. New materials, new uses of materials, and new designs and methods developed by industry are studied for their possible application to corps work. When there is evidence that a new material, new use of a material, a new design or method may have application to corps work, investigations and tests are performed on the item to evaluate its usefulness, and develop criteria for its economical use on corps work.

HYDROLOGY

EQUIPMENT FOR RECORDING AND PROCESSING DATA

A commercial firm has developed an analog-to-digital recorder (ADR) which converts and records data from a stream stage gate or a rainfall gate into a punched tape record. Simultaneously, the ADR provides the digital value in electrical form for telemetering and other purposes. The digital value can be read directly from the punched tape and the tape record can be converted automatically into standard punched cards for computer analysis.

The ADR will facilitate the processing of basic hydrologic data. The Corps of Engineers is very much interested in the development of this instrument and its possible use in the $2 million stream gaging program operated by the U.S. Geological Survey and the $500,000 rain gage program operated by the Weather Bureau, both of which are conducted with funds transferred from appropriations provided to the corps.

ACOUSTICAL FLOWMETER

The Corps of Engineers is cooperating with the U.S. Geological Survey and the State of California in financing the development of an acoustic flowmeter for measuring stream velocities. The device utilizes the basic principle that the speed of transmission of high velocity sound waves through water is directly related to the velocity of the flowing water. Single transducers are mounted under water on each side of a stream so that a signal emitted by one transducer would be received by equipment on the opposite bank. The time intervals required for sound waves to traverse the water path, one upstream and one downstream, are an index to the stream velocity on a line between the two transducers and can be related to the channel velocity by means of current meter measurements.

The actual development of the acoustic flowmeter has been accomplished under contract with a commercial firm. Pilot instruments have been installed for field testing at several locations. It is believed that a satisfactory instrument can be developed for transmitting signals across a water path up to a length of 5,000 feet. The successful development of such an instrument would be of special importance in measuring velocities in unusually wide river sections, tidal areas where direction of flow is intermittently reversed, and in backwater reaches of reservoirs.

BUBBLER GAGE FOR WATER LEVEL MEASUREMENT

The conventional installation of a water stage recorder involves a stilling well located near the stream and a system of intakes connecting the well and the stream. In many cases, particularly where it is necessary to construct the stilling well and tunnel through a high dam, installation may be complicated and expensive. To avoid costly excavation, an improved pressure-type bubbler gage has been developed by the U.S. Geological Survey for measuring the water level in a stream (fig. 1). The Corps of Engineers adopted this equipment

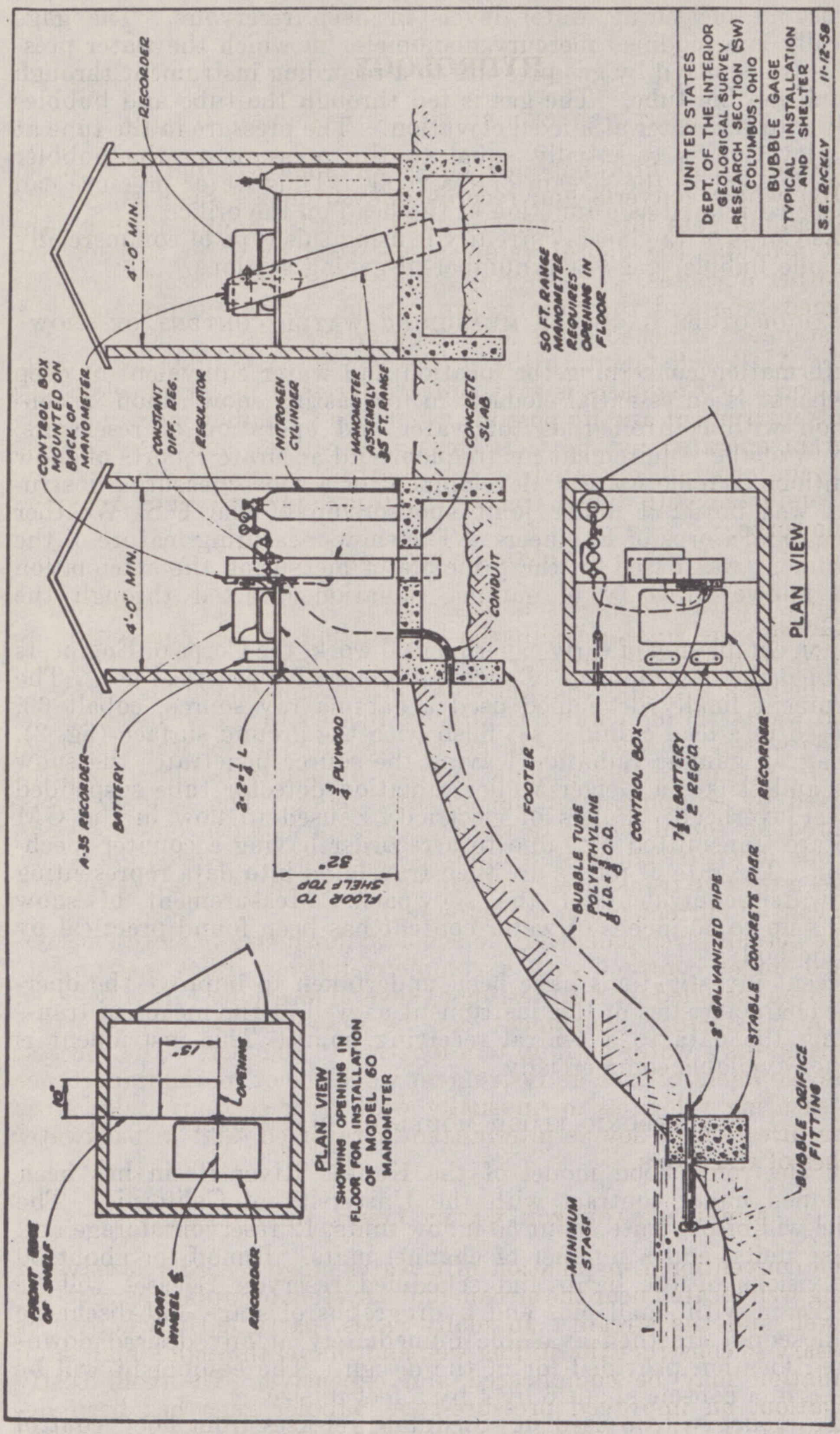

FIGURE 1.—Layout for typical bubble gage installation.

for use in measuring water levels in deep reservoirs. The gage basically is a modified mercury manometer in which the water pressure is transmitted by gas pressure to a recording instrument through a small flexible tube. The gas is fed through the tube and bubbles freely into the water at a fixed elevation. The pressure in the tube at any elevation is essentially equal to the pressure on the bubbler orifice located in the stream or reservoir. Thus water pressure can then be correlated as a function of the head on the orifice.

The Corps of Engineers currently is using this type of commercially available bubbler gage at a number of gaging stations.

RADIOISOTOPE GAGE FOR MEASURING WATER CONTENT OF SNOW

Information concerning the location and water equivalent of deep snowpacks is an essential element in forecasting snow runoff in connection with controlled use of water and operation of reservoirs. In view of the requirement for frequent and accurate reports of snow conditions in remote areas, development of a snow-measuring instrument was initiated under joint sponsorship of the U.S. Weather Bureau and Corps of Engineers. The snow-measuring feature of the instrument was based on the principle of measuring the attenuation of a known intensity of gamma radiation directed through the snowpack.

Upon completion of early experimental work, the Corps of Engineers extended the development of such equipment for practical use. The instrument finally developed used a gamma ray source, cobalt 60, enclosed in a lead cylinder set flush with the ground surface (fig. 2). A beam of gamma radiation leaving the source penetrates the snow pack and strikes a Geiger-Muller radiation detector tube suspended 15 feet overhead. Pulses of electricity caused to flow in the GM tube are transmitted by radio to a recorder having a counter mechanism. The rate of pulses are then translated into data representing the water equivalent of the snowpack. Measurement of snow depths up to 50 inches of water content has been found practical by this method.

Recent investigations have been undertaken to improve the operating characteristics of this instrument as well as the means of transmitting the data to a central receiving point. This instrument is not yet available commercially.

ELECTRONIC FLOOD MODEL OF RIVER BASIN

An electronic flood model of the Kansas River Basin has been developed under contract with the University of California. The model will incorporate about 50 inflow units, 12 reservoir storage and release units, and a number of channel units. Runoff for about 50 subdivisions of the basin and scheduled reservoir releases will be plugged in with small pins and hydrographs of stage and discharge (oscilloscope) are then available immediately at any desired downstream location provided for in the design. The equipment will be housed in a console about 6 by 4 by 5 feet in size.

The model will be used in scheduling releases from flood control reservoirs and associated flood forecasting in the Kansas River Basin. As data becomes available during a flood, the model will show

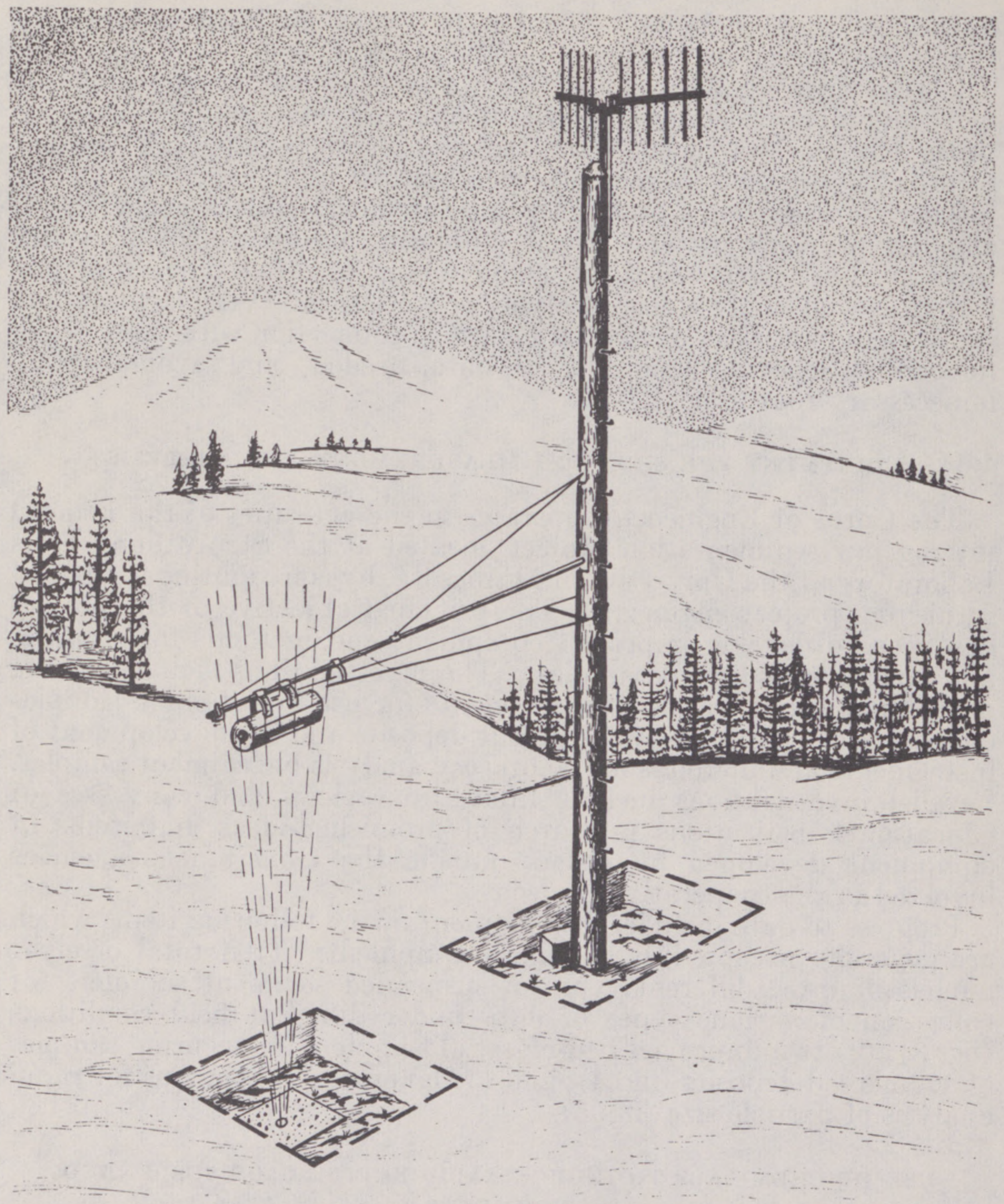

FIGURE 2.—Typical field installation radioisotope-radiotelemetering snow gage.

promptly the effects of reservoir storage on downstream conditions. Results of possible alternative reservoir operations are available immediately for downstream locations as an aid in determining what adjustment, if any, should be made in the reservoir regulation schedules.

INSTRUMENT FOR MEASURING WAVE HEIGHTS

In connection with a program of investigating winds and waves in inland waters to improve procedures for estimating freeboard allowances for dams and levees, a new type of instrument for measuring the height of relatively short waves was developed. This gage, developed by the Beach Erosion Board, is a step-resistance staff gage, consisting of four 5-foot lengths of standard aluminum channels. The channels are coated with neoprene rubber to insulate the internal

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resistances and contacts. The resistors and modified automotive type spark plugs are mounted on the channel at 0.2-foot intervals. The resistance changes caused by waves successively shorting out more and more resistance elements in the wave staff result in changes in the electrical current transmitted to a Brush oscillograph and are recorded by means of a magnetic pen motor.

This step-resistance staff gage is economical, easily constructed, and has proven very effective in providing information concerning wave heights. Gages of this type have been used in studies of inland waters as well as in studies involving ocean waves. Various programming devices have been developed for use in connection with these gages to permit selective recording of data needed, and avoidance of unnecessary recordings.

EQUIPMENT FOR SEDIMENT MEASUREMENT AND ANALYSIS

The Corps of Engineers cooperates in the activities of the Federal interagency sedimentation project, located at the St. Anthony Falls Laboratory at the University of Minnesota, by contributing funds and furnishing project engineers. The principal objective of the project has been to develop improved equipment and methods for securing and analyzing sediment samples. The investigations include (1) the development and testing of instruments for use in obtaining samples of suspended sediment and sediment deposits and (2) development of instruments and methods for laboratory analysis of sediment samples. Parallel investigations include literature reviews and canvasses of educational institutions in search of promising ideas and items of equipment developed by others outside the Government agencies involved in the cooperative project.

Progress to date includes development of the following items which are generally accepted as standard equipment: (1) A total of eight models of three different types of suspended sediment samplers for collection of various types of data under different field conditions (fig. 3); (2) two improved bed-material samplers for securing samples of submerged deposits (fig. 4); and (3) laboratory apparatus for rapid analysis of particle size (fig. 5).

USE OF CHEMICALS TO INDUCE RAPID SETTLING OF SUSPENDED SEDIMENTS

Certain chemicals have been used effectively for inducing rapid settling of fine materials from water used in spreading operations. The chemicals cause fine sediment particles in suspension to gather into mass flocs whose settling rates are much more rapid than those of the individual sediment particles. The practicability of using this method to hasten sedimentation of fine materials behind dikes and in clearing up reservoirs and lakes is being field tested by the Corps of Engineers.

Investigations are also being made to study the feasibility of using this principle in dredging operations by concentrating the sediment prior to dumping operations.

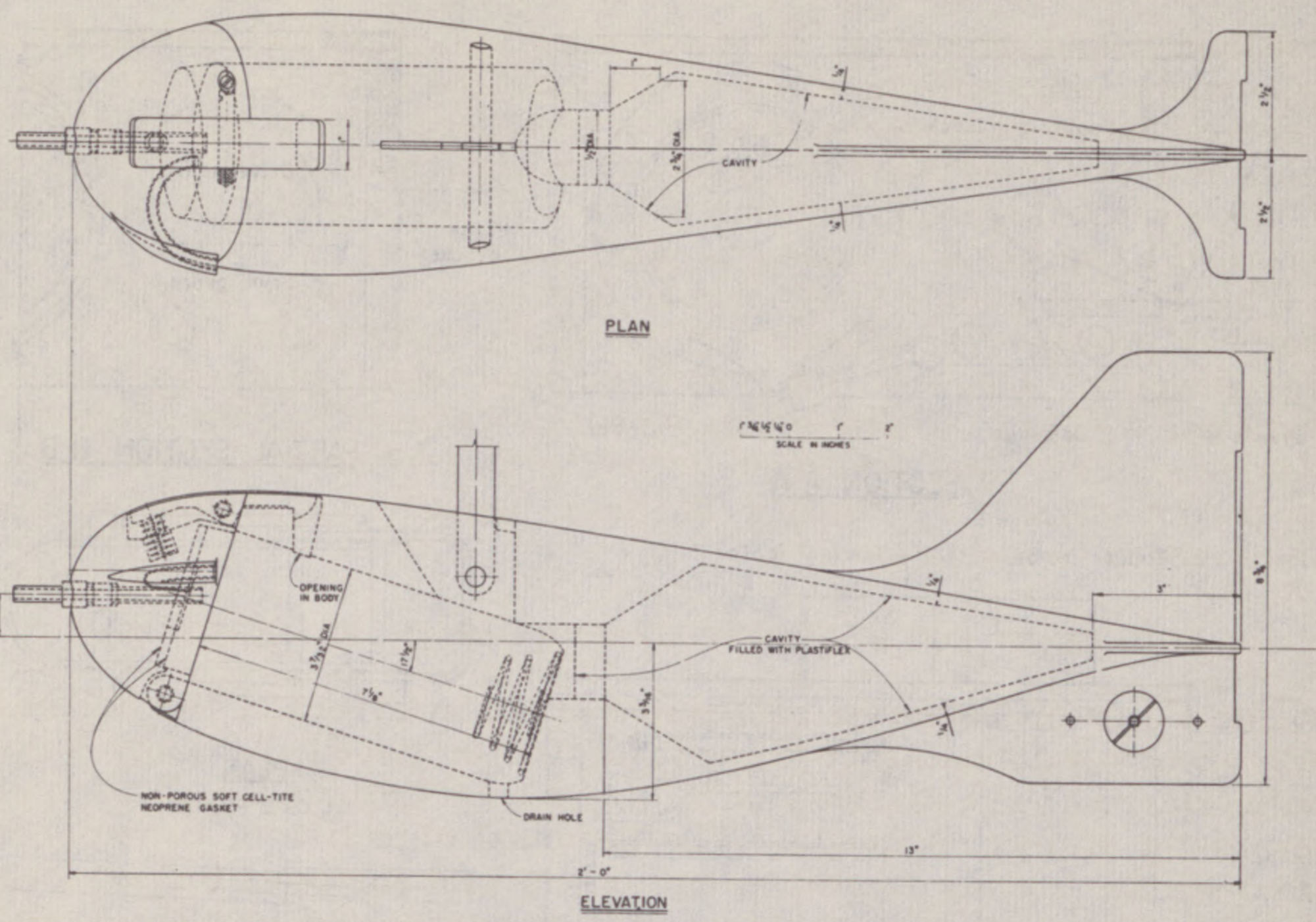
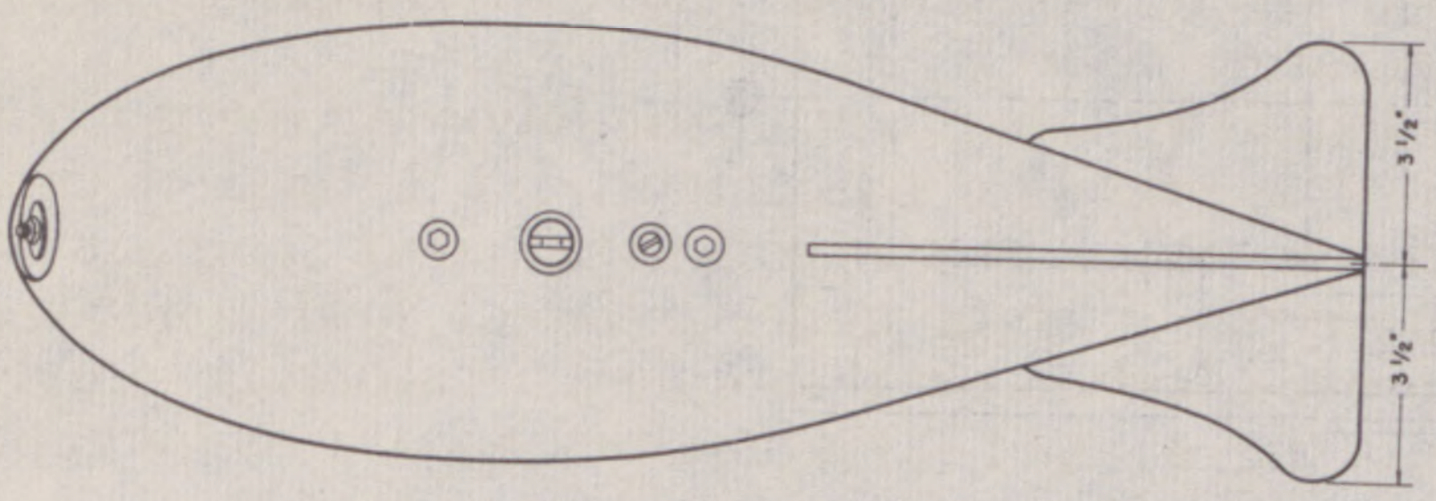


FIGURE 3.—Depth integrating, suspended sediment sampler, USD-49.



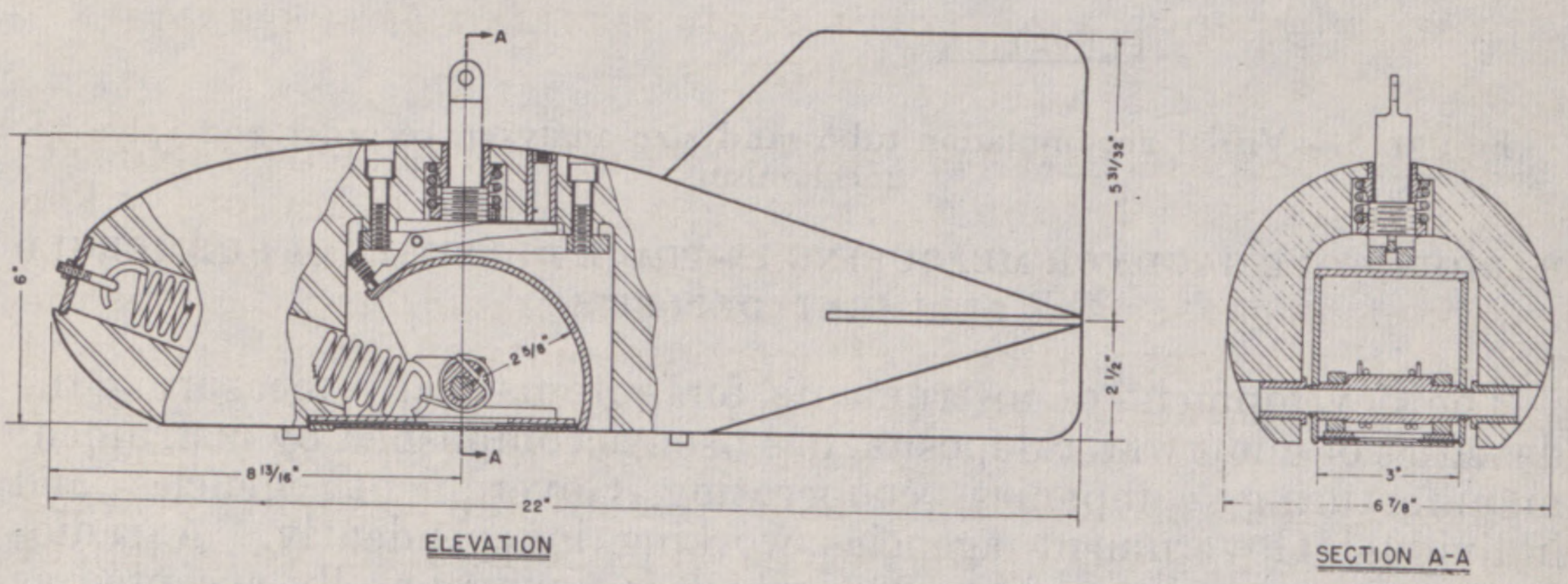


FIGURE 4.—Bed-material sampler USBM-54.

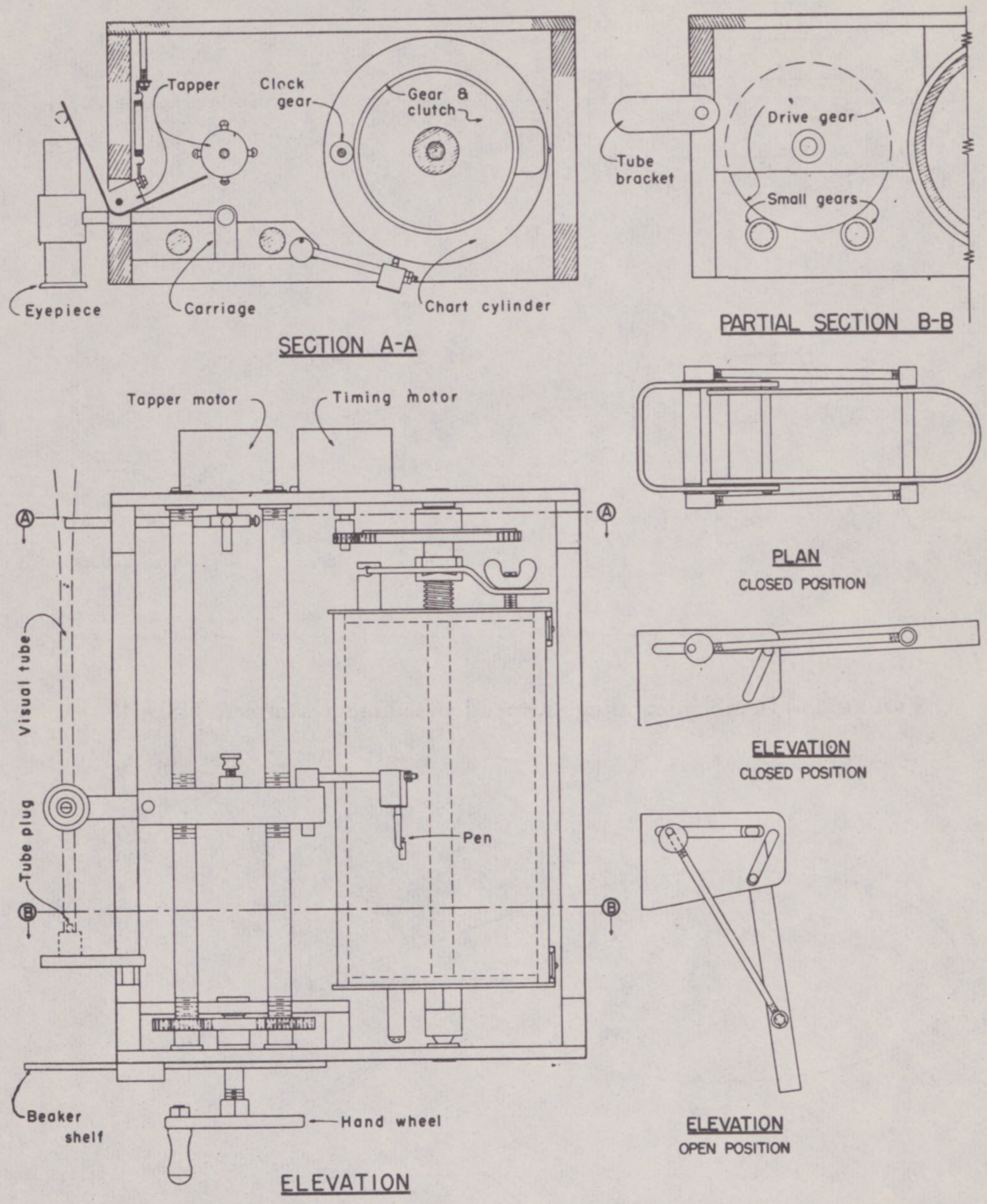


FIGURE 5.—Visual accumulation tube sand size analyzer, recorder and valve mechanism.

RADIOISOTOPE GAGE FOR MEASURING IN-PLACE DENSITIES OF SUBMERGED SEDIMENT DEPOSITS

The development of instruments for automatically measuring the densities of underwater deposits, has been accomplished by instrument manufacturing companies, cooperating Government agencies and individual Government agencies working independently. A radioisotope probe, using radium 226, which is now generally accepted as being superior to conventional instruments for measuring densities of marine deposits, was developed through studies and contract arrange-

ments made by the Beach Erosion Board of the Corps of Engineers (fig. 6). Information relating to the development and performance of this instrument is presented in Technical Memorandum No. 121 by the Beach Erosion Board, September 1960.

UTILIZATION OF RADIOISOTOPES IN SEDIMENT TRANSPORT STUDIES

Considerable progress has been made recently in the development of techniques for tagging sediment samples with radioisotopes and tracing the movement of the sample particles in studies of sediment transportation associated with beach and estuary problems. Radioactive gold and scandium fused in glass particles have been used to determine the pattern of sand movement in harbors. The tracer material is placed on the harbor bottom, then detection instruments are moved over the bottom to determine both the direction and speed of movement of the radioactive particles. A study of this nature is described in a report by the Corps of Engineers, San Francisco district, dated April 1960, entitled, "Radioactive Tracer Techniques as an Aid in Resolving Sediment Problems." To date little use has been made of radioisotopes for investigation of sediment transportation problems associated with inland streams. Steps have been taken to initiate a joint study by the interagency sedimentation project and the Atomic Energy Commission to investigate the practicability of utilizing radioisotopes in development of a method for instantaneous measurement of suspended sediment concentrations in flowing water.

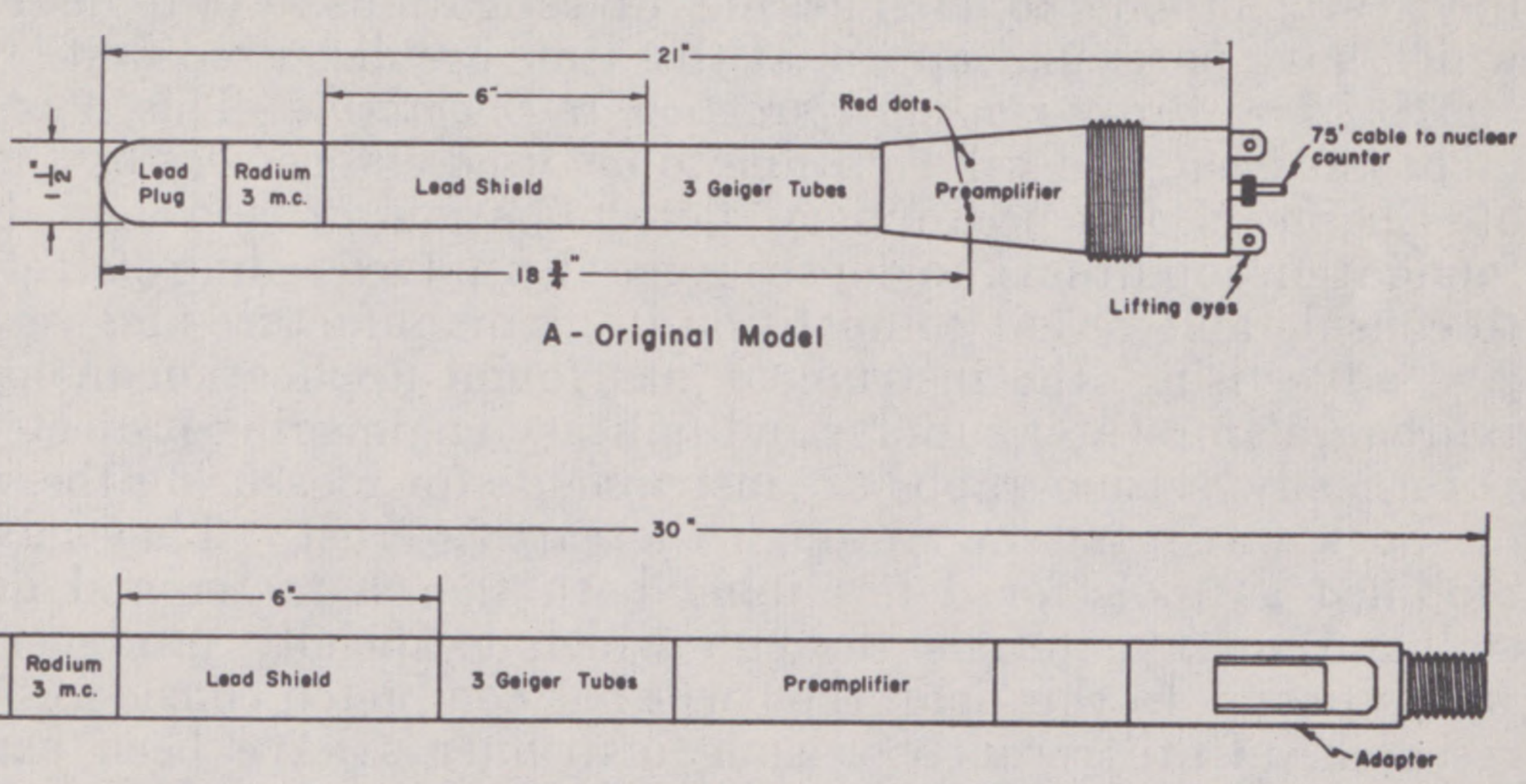


FIGURE 6.—Schematic layout of probe radioisotope gage for measuring in-place density of submerged sediment deposits.

SITE INVESTIGATIONS

Since the economics and design of engineering projects depend to a very considerable extent on subsurface geological conditions, the Corps of Engineers has utilized a variety of new exploration devices for investigation and sampling of subsurface soil and bedrock conditions. These methods and materials may be grouped conveniently into the following categories: (1) Those which combine geological interpretation with physical measurements, and which are therefore designated geophysical investigations; (2) those which permit interpretation and classification of subsurface conditions by means of soil and bedrock samples recovered by drilling and sampling devices, and frequently referred to as geomechanical methods. Some of the newcomers in these categories which have been used, or are considered for use, by the corps are described below.

GEOPHYSICAL EQUIPMENT

During the past 2 years several compact portable modifications of earlier bulky seismic and electrical resistivity instruments have been developed, which have greatly enhanced the application of geophysical methods to engineering investigations. Two instruments which have particular appeal at this time are discussed first.

Miniature direct-reading refraction seismograph.—This new instrument has been, and will continue to be, used extensively by the Corps of Engineers for preliminary determination of soil and bedrock foundation conditions, to depths generally not exceeding 50 feet. Due to considerable recent competition in its manufacture and very effective advertising, the instrument has found application in highway, railroad, dam, water supply, and military engineering projects.

Basically, seismographs are instruments for measuring the velocity of shock waves passing through the earth's crust. They have been modified as tools for determining both the character and depth of soil and rock materials through which artificially produced shock waves pass. In this field, the corps has conducted considerable basic research. Until recently seismic instruments have been extremely bulky and for the shallowest depth exploration required the use of explosives. With the development of the new miniature models equipped with transistorized velocity timers and sufficiently sensitive to record shock waves produced by pounding a steel plate with a common sledge hammer, the problems associated with the storage and use of dynamite have been eliminated. Also eliminated is the time-consuming operation of developing and interpreting photographic film records before depths of materials can be determined (fig. 7).

Tests to date indicate a fairly high degree of accuracy in determining thicknesses of soil and bedrock materials to depths not exceeding 50 feet. Where only one more or less uniform soil material covers the bedrock, the position of the latter has been measured to depths ranging between 60 and 80 feet. Therefore, in the experience of the corps,

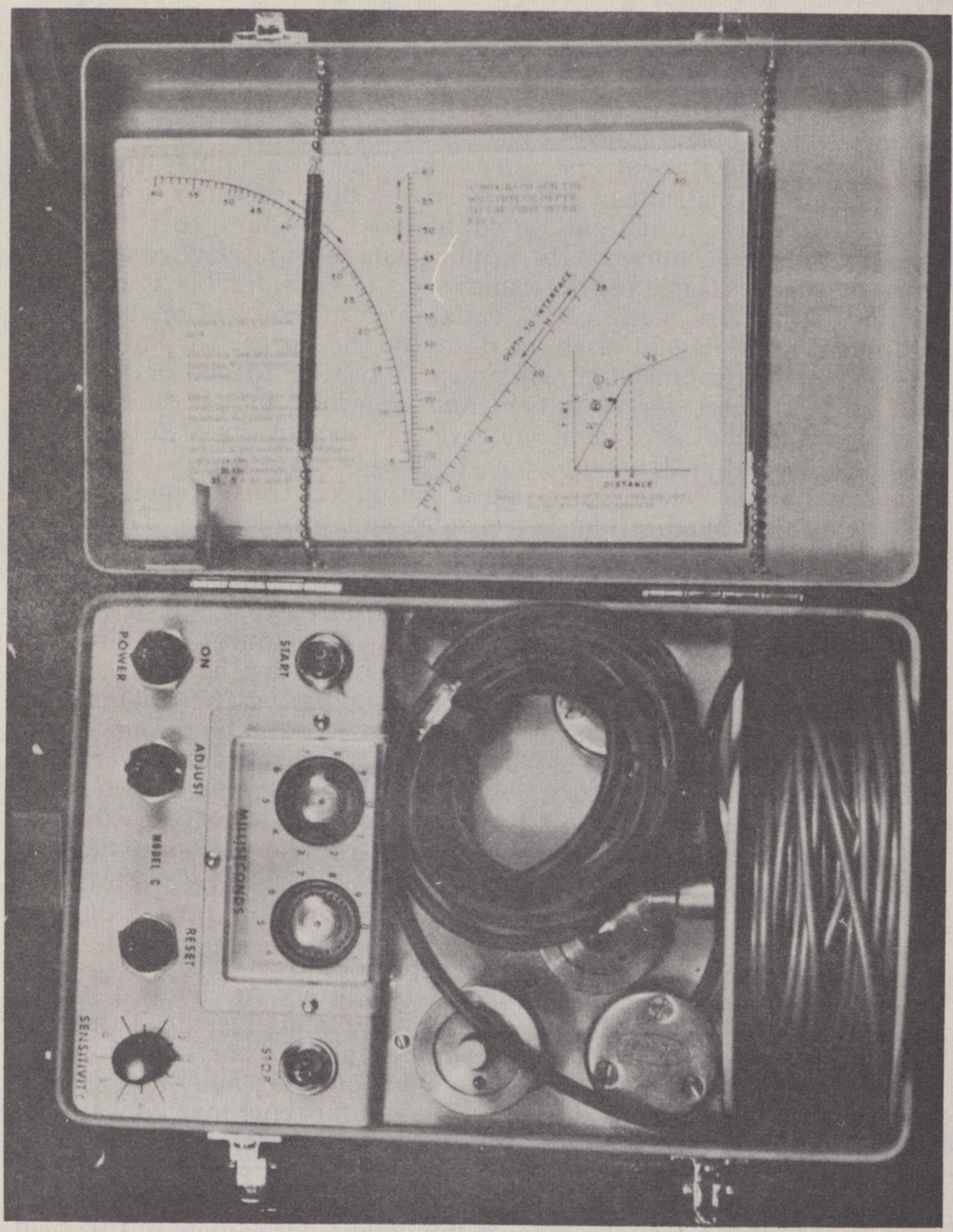


FIGURE 7.—View of typical light weight portable refraction seismograph showing control and millisecond signal timing panel with cable used to connect geophones or shock sensing devices with the control mechanism.

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it may be stated that the usefulness of this new and lightweight instrument, portable by two men, is limited principally to determining the thickness and depth of two soil or rock materials within a depth range of 50 feet. The device is readily available from at least five manufacturers at costs ranging between $700 and $2,000. At least five firms manufacture this instrument and our field installations are using seismographs produced by three of these firms.

Portable electrical resistivity instrument.—Like the miniature seismograph this new instrument has opened the door to wider use of geophysical exploration methods to supplement the more costly drilling investigation procedures. Its application is similarly confined to quick depth and thickness determinations of considerably lower magnitude than those within the capability of conventional heavier equipment. While not used to date by the corps, the instrument has been recommended for experimental testing to one or two field installations where its usefulness and accuracy in determining the thickness and depths of sand and gravel deposits are of interest.

The 20-pound instrument consists simply of a compact battery-potentiometer-galvanometer-range selection control cabinet, supplemented by four small ground electrodes and wire leads. The equipment is employed to measure various resistances of soils to electrical currents generated through them. Loss in potential of these currents between preselected input locations is translated to the resistivity of the soils through which the currents pass. Resistances and electrode spacings, in turn, are related to soil types and depths, respectively.

The Corps of Engineers was active in modifying the original four electrode resistivity apparatus for use in investigating foundations and construction materials. On the basis of this pioneer work, the limitations of this exploratory device to delineating one or two layers of soils, particularly sands and gravels, to depths not exceeding 50 feet is recognized. The cost of the instrument is approximately $500.

GEOMECHANICAL EQUIPMENT

By far, the greatest amount of subsurface investigation for design of engineering works is accomplished by purely mechanical means. These include earth and rock core-drilling machines (designed for both intermittent or continuous care sampling), borehole pumping and hydraulic pressure testing equipment, and borehole photography and television. Through their interest in improving mechanical techniques for obtaining accurate subsurface information, the corps in cooperation with industry has pioneered improvements in these devices which have resulted in mutual benefits to the Government and industry alike. A few of the more important newcomers in this field, which have been tested and used in varying degrees, are described below.

Processed diamonds.—The most advanced mechanism for obtaining continuous undisturbed drill core samples of bedrock is the rotary core drill, equipped with a diamond-studded coring bit. Diamonds used in this device are the rejects or byproduct of the diamond jewelry industry. They range in size from 10 to 20 stones per carat and vary in price from $4 to $12 per carat, the latter being controlled by stone quality and world market prices. Due to gradually increasing prices of these commercial diamonds (bortz), the diamond drill

bit industry has conducted research which indicates that larger worn diamonds may be reclaimed from used bits and, by factory processing, may be upgraded for reuse in new bits. The processing involves an abrasion and polishing operation which removes microfractures and angular projections, thereby restoring the original durable cutting properties of the stones. Processed stones are then combined with new stones in new bits, when top quality bits are not required.

While this development has been too recent for performance testing and rating by the corps, early reports of performance by one or two large diamond bit manufacturers are encouraging. The corps will conduct tests at its diamond bit testing laboratory in Dallas to determine the drilling efficiency of various combinations of processed and unused diamonds in bits designed for cutting different types of rock. Since the corps procures several hundred thousand dollars worth of diamond bits annually, the savings which might be realized by an effective partial substitution of lower cost processed diamonds may be substantial.

Rubber sleeve core barrel.—For many years the Corps of Engineers and the core drill manufacturing industry have directed their research toward improving devices for recovery and preservation of undisturbed soil samples. One of the principal deficiencies in the present state of this art has been the lack of a device which not only will preserve the newly recovered soil sample's natural undisturbed structure and moisture as it penetrates the sampling tube, but which in addition will provide an instantaneous elastic sleeve cover that will assure against damage to granular soils or fractured shales during transportation to the laboratory. Such a device has now been developed by one of the leading core drill manufacturers. It consists basically of a soil sampling barrel which, as it cuts and recovers the sample, covers it immediately with a rubber sleeve of a diameter less than that of the sample core, thus protecting the sample from grinding or blocking as it is brought to the surface.

The corps plans to utilize one of these new sample barrels in connection with our study of improved techniques for recovery of weak shales for triaxial shear tests.

Cylindrical color photography of boreholes—the borehole camera.—The Corps of Engineers has long recognized the need for supplementing conventional small-diameter core drilling investigations of bedrock foundations with economical photographic techniques, to assist in the interpretation of subsurface conditions which do not respond completely to the usual drilling and sampling procedures. Inaccurate appraisal of gaps in core recovery could result in overlooking serious foundation conditions. To remedy this problem, which until 1952 could be solved only by resorting to costly large-diameter shafts and borings, geologists in the Office, Chief of Engineers developed a camera capable of obtaining continuous 360-degree color photographs of the interior of 3-inch diameter boreholes.

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The camera with its lowering mechanism and power-supply are shown on figure 8. The camera proper is a stainless steel tube 2¾ inches in diameter and 31½ inches long, containing a compass which supports a hollow truncated conical mirror, and a camera unit equipped with a 15-mm. lens. Illumination is provided by a high-voltage flash tube directly above the conical mirror. The lowering mechanism actuates picture exposures. One exposure is made for each three-fourth inch of camera cable moving over the wheel *h*. The equipment is portable, and rapid color film developing services are available.

Since developing the very successful prototype, the corps has built two reproductions with minor modifications, and has procured two additional camera units from a private manufacturer licensed to construct these in accordance with the corps' drawings and specifications. Companion to the camera is an automatically driven picture projector which can be used for both plane and cylindrical image study of the interior surface of boreholes. The latter was constructed by the Eastman Kodak Co. in accordance with the corps' plans and specifications. Prices of the camera will depend on the number of complete units demanded and could range from $12,000 to $20,000 on that basis. Patent rights are held by the Corps of Engineers.

FOUNDATION EXPLORATIONS FOR EARTH DAMS

An investigation is now underway at the Waterways Experiment Station regarding the most reliable method of obtaining undisturbed samples of soft, weak clays suitable for producing reliable test data. Preliminary results indicate that the so-called Swedish Foil sampler has certain advantages in accomplishing this objective. This sampler contains movable steel ribbons which eliminate the friction between the sampler and the wall of the sampling tube. This equipment is supplied by Sprague and Henwood, U.S. distributors for the manufacturer.

Nuclear devices have been tested and are now in use to permit rapid determination of the density and water content of embankment samples for construction control and field research. Preliminary development and testing was carried out in cooperation with the Corps of Engineers.

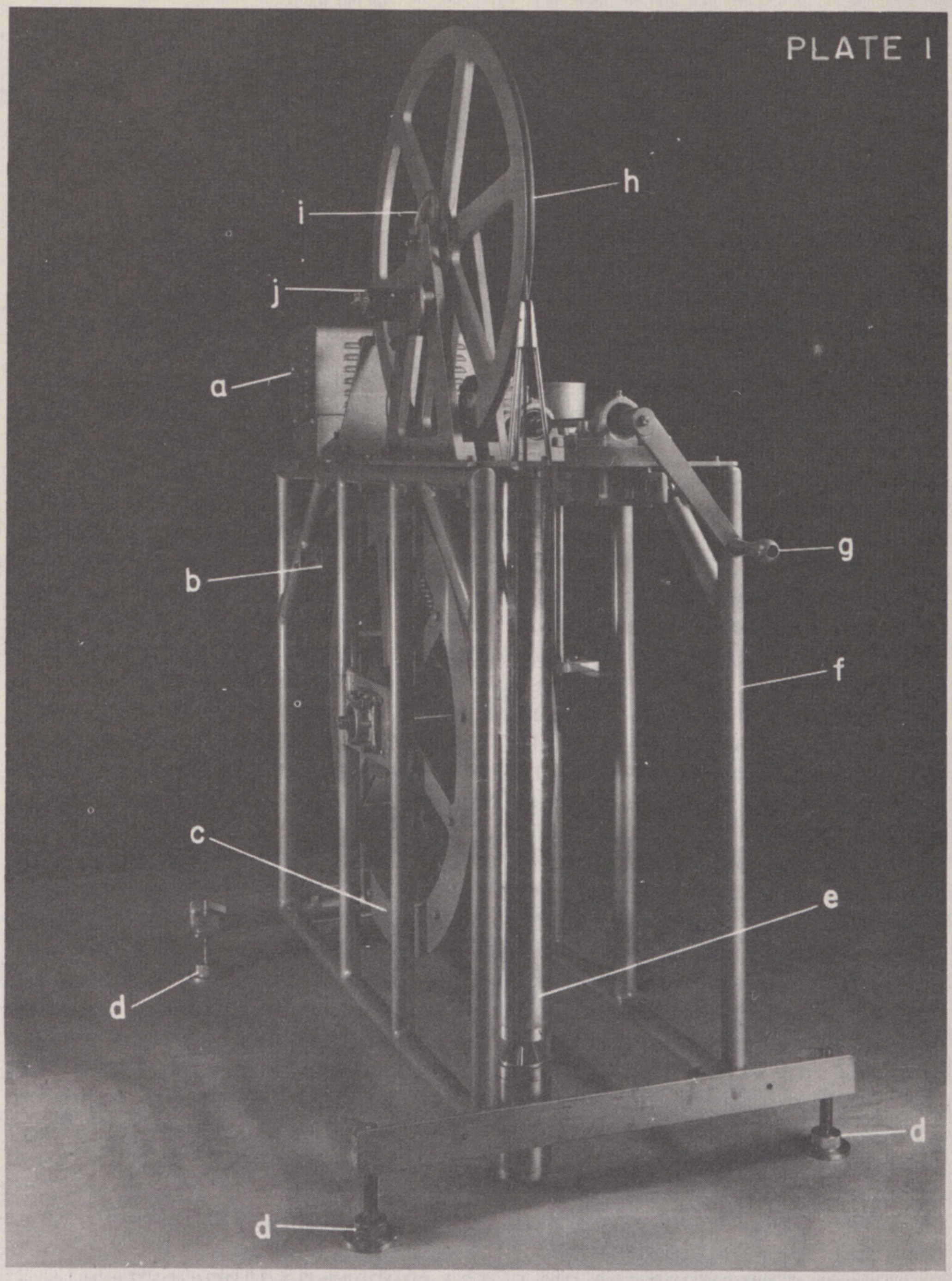


FIGURE 8.—Bore-hole camera developed by the Corps of Engineers, U.S. Army. e, camera proper, stainless steel tube 2¾ inches in diameter with quartz window inclosing conical mirror near lower end; a, power supply; b, level-wind control for cable; c, cable wheel; d, leveling screws; g, hand crank for raising and lowering camera, geared into wheel c (Corps of Engineers, U.S. Army).

HYDRAULIC DESIGN

DAMS

Epoxy resin protective coating.—Laboratory and field tests are being conducted to develop epoxy resin protective coatings for concrete surfaces subject to high-velocity flow. Further discussion of this material is presented under "Epoxy Resins for Repair and Protection of Concrete."

Harza high-head outlet gate.—Reservoir outlet gates have been designed and constructed to operate under heads up to 200 feet. The Harza gate, developed initially by the late Mr. L. F. Harza, eminent consulting engineer, and later improved by his sons, R. D. Harza and A. C. Hoffman, is a new type of gate which is claimed to be less costly and may operate satisfactorily for higher heads than other gates presently in use. The gate, which is shown in figure 9, is constructed economically by welding structural steel beams and plates. Laboratory and field tests made for the Harza Engineering Co. have established that the Harza gate will operate satisfactorily for heads up to 150 feet. Although the corps has not used this type of gate, it is planned to design and test one such gate at a future dam to verify its hydraulic performance and to determine whether or not appreciable savings can be made over the use of other types of gates. The Harza gate would be subject to royalty charges, except for the initial experimental gate.

Fabridam.—The Fabridam is an inflatable rubberized fabric dam capable of installation on any stream, river, artificial channel, or waterway for varied purposes, such as flood control, water conservation, tidal control, lock systems, recreational facilities, etc. It might also be used in lieu of crest gates or flash boards on spillways of some dams. The fabric material is about one-eighth inch thick, consisting of four layers of extra strong fabric embedded in rubber. A system of pipes and valves are employed to inflate the dam with water, and the dam is deflated automatically by a siphon. A dam 6 feet high and 120 feet long has been installed by the Los Angeles City Water Department in the Los Angeles River. Operation of this installation has been completely satisfactory for about 5 years. It is understood that the cost of the installation was approximately $10,000. The material is available from the Firestone Rubber Co. There is some uncertainty regarding the life of the rubber and fabric material. If its life proves to exceed 25 years this product will be very valuable and its use should be widespread. Although the corps has not yet used the Fabridam, consideration is currently being given to making one installation in the near future to verify its hydraulic operation.

NAVIGATION LOCKS

Interlocking controls for miter gates.—An interlocking control system has been developed by the Corps of Engineers to prevent an operator from opening lock miter gates until the water levels on either side of

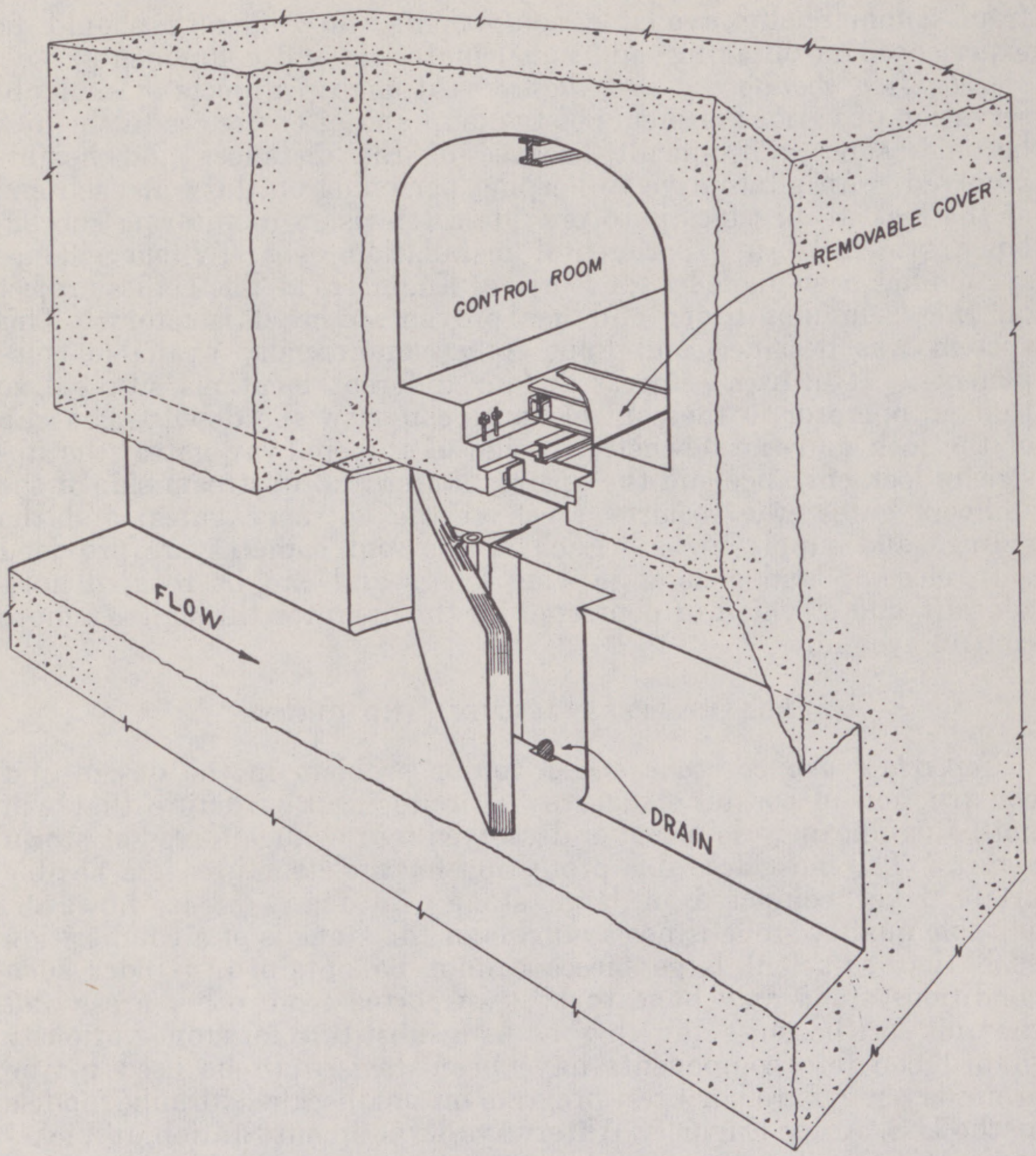


FIGURE 9.—Harza gate isometric view of gate and removable cover (partly open condition).

the gates become essentially coincident, thereby assuring that the strut arm will not be overloaded, which would result in damage and delays to navigation. The system operates from an air-purging differential pressure gage that controls a pneumatic booster-operated relay in the main control circuit. The system was installed in the control console in the upper control house of Eisenhower lock in April 1960 and was tested under actual operating conditions. The system was consistently accurate and would prevent operation of the gates until the water levels on either side of the gates were within 2 to 3 inches of being equalized. The system, as designed for the seaway locks, was limited to a maximum differential head of about 80 feet. However, this limitation can be overcome if necessary so that the sytem could be used on higher head locks. The cost of the components for the installation described above was about $500. Installation cost would probably be about $400. Since the system was fabricated

from commercially available components, no difficulty should be experienced in obtaining additional materials and components.

Television monitoring surveillance.—At many projects, visual observation of various elements of the dam and of entrances to the lock becomes slow and difficult because of the distances and heights involved. An alternative to keeping personnel on duty at each end of the lock at all times is to provide a television monitoring surveillance system. An experimental installation of a TV surveillance system has been made by the Corps of Engineers at The Dalles project on the Columbia River and has proven to be satisfactory. This system was designed and built from commercially available components. It utilizes cameras at four different locations situated so that an operator in the control house can view the downstream end of the lock and the downstream side of the spillway gates; the upstream lock entrance and the upstream area and upstream side of the spillway gates; the security àreas at the entrance gates; and the storage and supply areas. Each of the four cameras are provided with close-up and general viewing lenses and can be rotated horizontally and elevated or depressed by the operator through a remote control system.

BREAKWATERS, JETTIES, AND GROINS

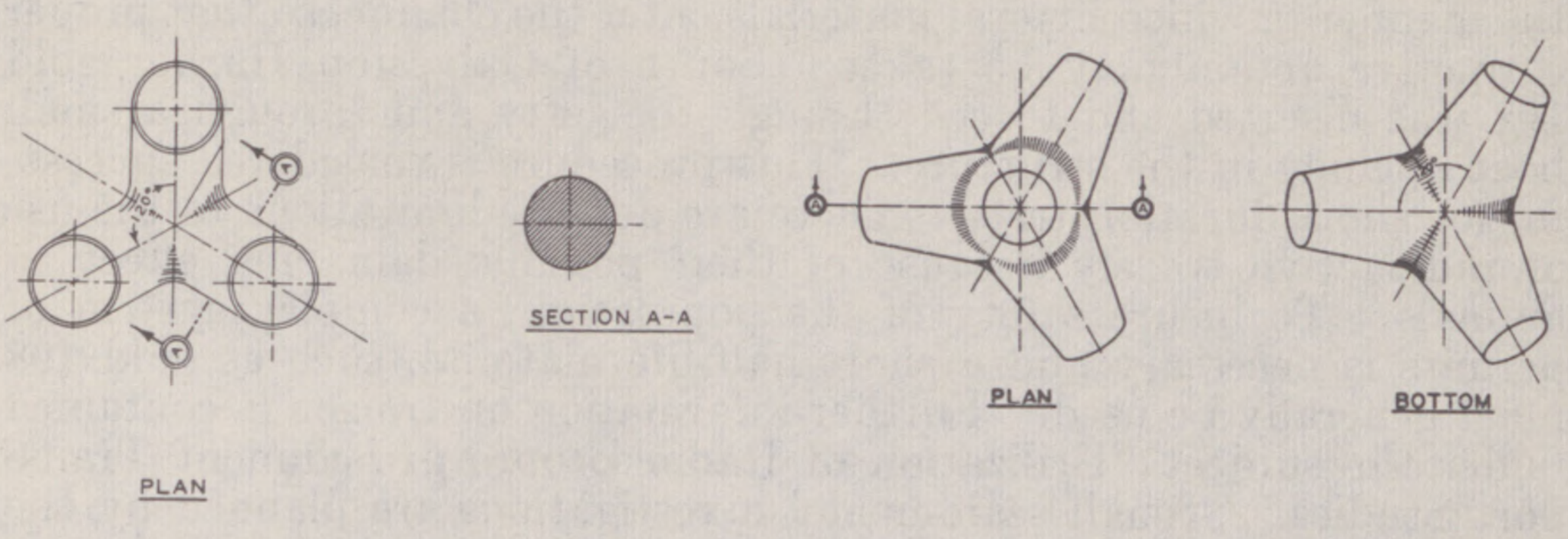
Concrete armor components.—A major problem in the design and construction of coastal structures is producing a structure that will not be significantly damaged or destroyed by the huge forces of storm waves. The most desirable protection for the structures is a flexible armor layer composed of large stone. In many areas, however, suitable quality stone is not available or the stone is of a composition such that sufficient large pieces cannot be obtained. Under such conditions stone may have to be transported from other areas and the unit cost becomes quite high. As a substitute for stone variously shaped concrete components have been devised to be used in the armor layer. Through a test program on small-scale hydraulic models at the U.S. Army Engineer Waterways Experiment Station at Vicksburg, Miss., it was determined that three of these shapes, the tribar, tetrapod, and quadripod, indicated the greatest potential for use. These are shown in figures 10, 11, and 12.

The tribar is composed of three vertical bars connected by a trunk section. From the center point of the trunk the bars are spaced 120° apart, and the horizontal distance between bars is equal to the length of the bar. This unit was developed and patented by Tribars, Inc., of Honolulu, Hawaii. The tetrapod is composed of four legs or pods projecting from a common point with each pod spaced 120° from that adjacent. This unit was developed and patented by Neyrpic Laboratories in Grenoble, France. The quadripod is composed of four pods, projecting from a common point with three pods in the same plane and the fourth extending vertically, making an angle of 90° with the plane of the other pods. This unit was developed by the Corps of Engineers.

In the United States, tetrapods have been used by the Corps of Engineers at Crescent City Harbor, Calif., Kahalui Harbor, Hawaii, and by Richfield Oil Corp. at Rincon Island, Calif.; tribars were used by the Corps of Engineers at Nawiliwili Harbor, Hawaii; and quadripods will be used at Santa Cruz Harbor, Calif., construction of

which will be begun about May 1962. Sufficient experience has not been obtained to form definite conclusions regarding the advisability of their general use, but limited experience indicates that concrete components may be superior to stone in some hydraulic aspects but inferior in durability and strength. As the units are constructed on site, the cost of the components will vary widely in various regions of the country depending on the cost and availability of concrete aggregate at that location. In addition, a royalty fee of $3 per cubic yard of concrete used is charged by Neyrpic, Inc., for the privilege of using the tetrapods design. Tribars and quadripods are royalty free to the U.S. Government.

Sealing of permeable jetties and groins.—Some stone structures designed for wave breaking purposes would furnish additional benefits if they were more impermeable and would interrupt sand or silt moving



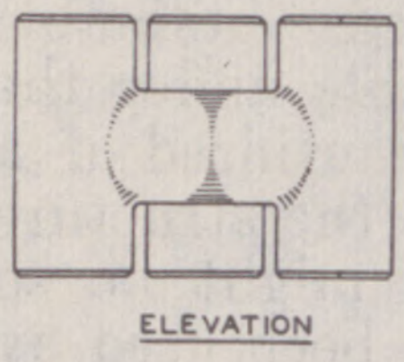


FIGURE 10.—Tribars.

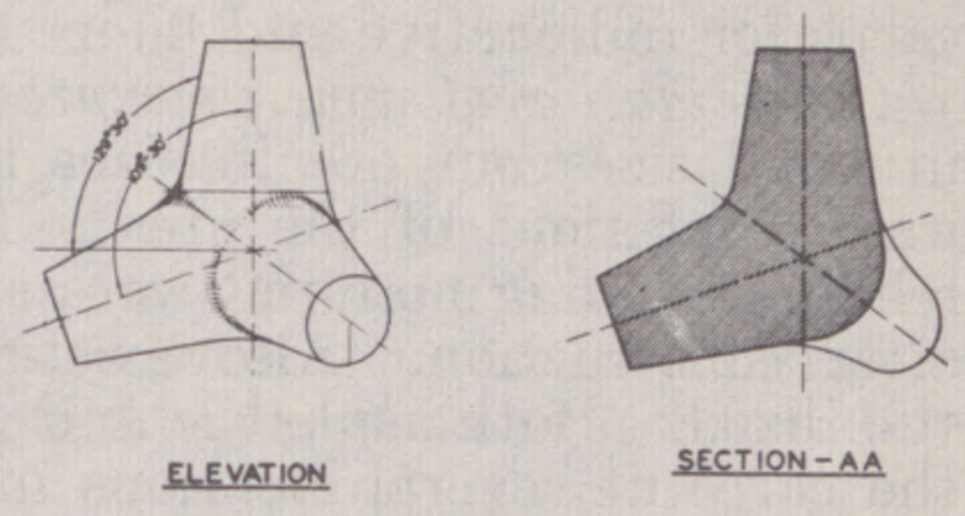
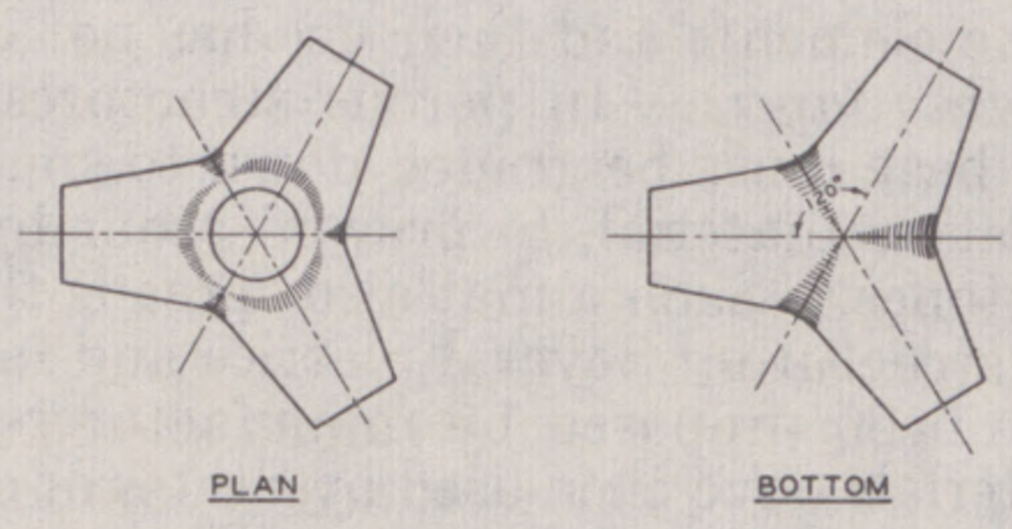


FIGURE 11.—Tetrapods.



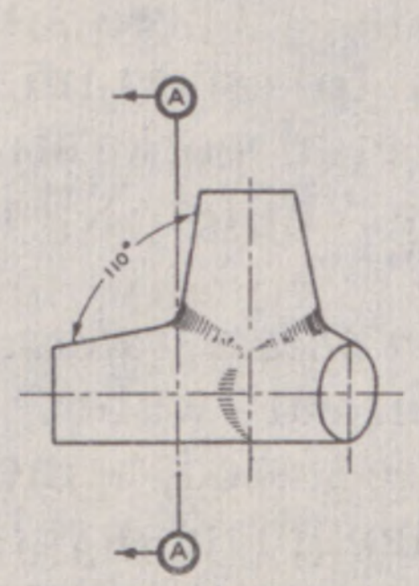


FIGURE 12.—Quadripods.

along the shore. Other stone structures have lost their impermeability. Various methods of grouting and forcing of asphaltic concrete or asphalt compounds into the interstices have been attempted by the Corps of Engineers at several locations, including jetties at Mission Bay, Calif. and Galveston Harbor, Tex. This has, at least temporarily, sealed the jetties above the waterline but is generally unsuccessful beneath the water surface. The cost of grouting the jetty at Galveston Harbor was about $41 per linear foot. This cost would vary according to access, sea conditions, and other factors at other locations. In general, it is considered that the use of either concrete or asphaltic mixes have not been fully satisfactory. The material separates, solidifies, or changes in characteristics upon being forced into water. Radioactive tracers have been used by the corps in studies to determine the permeability of structures or to determine the manner in which littoral materials enter the channel so that proper corrective action may be taken. South of Galveston Harbor gold 198 was inserted and traced through the jetty and through a small boat opening in the structure. This procedure is considered successful for short duration tests. There are definite limitations to the use of radioactive tracers because of their possible damaging effect to animals. To insure safety of the population, a complex system of permits is necessary and a short half-life material, such as gold 198 must generally be used. Further information on tracers is contained under the subject "Utilization of Radioisotopes in Sediment Transport Studies." Small scale-model investigations are planned by the corps for radioactive and fluorescent (nonradioactive) tracers.

Consolidation of stone structures.—In many areas stone is obtainable in small sizes but not in sizes large enough to be stable under the wave conditions of the area. This material could be utilized if a reliable bonding material were available to consolidate the structure after construction. Also existing unstable structures might be so stabilized. Both asphaltic and concrete mixtures have been used by the corps at several locations including the mouth of the Columbia River, Oreg., Galveston Harbor, Tex., and Panama City, Fla. The materials studied to date have lacked the bonding capability, strength, or resistance to the elements and their use has not been effective.

Filters and bedding layers.—In porous structures the construction material near the base must be graded down to smaller sizes, nearing that of the foundation material, to prevent scour by currents around and beneath the stones. Such a mat also spreads the load and deters settlement of the structure. Several plastics and fabrics or combinations thereof have been proposed by manufacturers for this purpose. Some of these materials have been used by States or other local governmental agencies in the State of Florida. These structures are being observed by the Corps of Engineers to ascertain durability of the material and its possible application in civil works structures. Further discussion of these materials including "Filter X" is given under the subject "Fiber and Plastic Materials."

Protection of timber and steel piling in ocean waters.—The life of both timber and steel are relatively short in salt water. Most paints and coatings to prevent corrosion of steel are tested, principally at the paint laboratory at Rock Island, Ill. Although many have been used in structures by the Corps of Engineers, improved coatings are needed.

Timber deterioration is due to decay in wet and dry portions, to marine borers and abrasion when placed in sandy or gravelly shores. Creosote, salts, and gunite have been used as aids in reducing decay and borer damage. The preventive measures may be defeated by bruising of the surface of the timber. Metal jackets have been proposed for borer and abrasion control, but in general are expensive methods. A plastic wrapping for timber piles as protection against borer damage is under observation at an installation in California.

CHANNEL STABILIZATION

Asphalt paving.—This material has been used extensively for bank protection on Mississippi River levees. It has been used to a very limited extent for revetment in flood channels of moderate velocity. The paving material consists of a mixture of hot asphalt, sand and gravel, which is placed in a layer 3 to 6 inches thick on the bank to be protected. Field experience by the corps has proven that this type of paving is effective on the Mississippi River, but that in rapidly rising and falling streams of moderate velocities the paving has a very short life. In the latter case, the porosity of the asphalt paving is not sufficient to relieve uplift pressure which results in cracking and rapid deterioration of the paving. The cost of asphalt paving for bank protection ranges from about 20 to 40 cents per square foot, depending upon the thickness and placing conditions. The material is abundantly available in most parts of the United States.

Articulated concrete bank protection.—This type of bank protection has been used extensively by the corps to prevent erosion of banks and levees on the Mississippi River. The revetment consists of large mattresses of small concrete units, held together by light steel reinforcing bars or wire mesh. In general, this type of bank protection has been effective, but when the articulated concrete slab is subjected to pressure pulsations due to stream turbulence, foundation materials pass through the spaces between the individual concrete units, causing settlement and damage to the bank protection. The cost of this bank protection is about $1 per square foot.

Kelner jetties.—This type of channel protection is used in some sandy streams where velocities are moderate and other types of protection would be too costly. Kelner jetties (fig. 13) consist of a number of steel jacks that are tied together with cables and located along banks to reduce velocities, thereby preventing bank erosion. Each jack is made of steel angle bars that are bolted together at their midpoints and tied together by wire at their ends. Field tests by the Corps of Engineers on the Rio Grande and Arkansas Rivers have shown the jetties to be at least partially effective in reducing stream bank erosion. The life of Kelner jetties is limited because it is impractical to do maintenance painting. The cost of bank protection by Kelner jetties is in the order of one-fourth of the cost of protection by riprap.

Fiber and plastic materials.—Several types of fiber and plastic materials have been proposed by manufacturers for use as bank protection. Nylon sheets have been used to replace the filter layer under rock bank protection. "Filter X," a cloth woven from polyvinylidene chloride resin monofilament yarns, has been used as the filter

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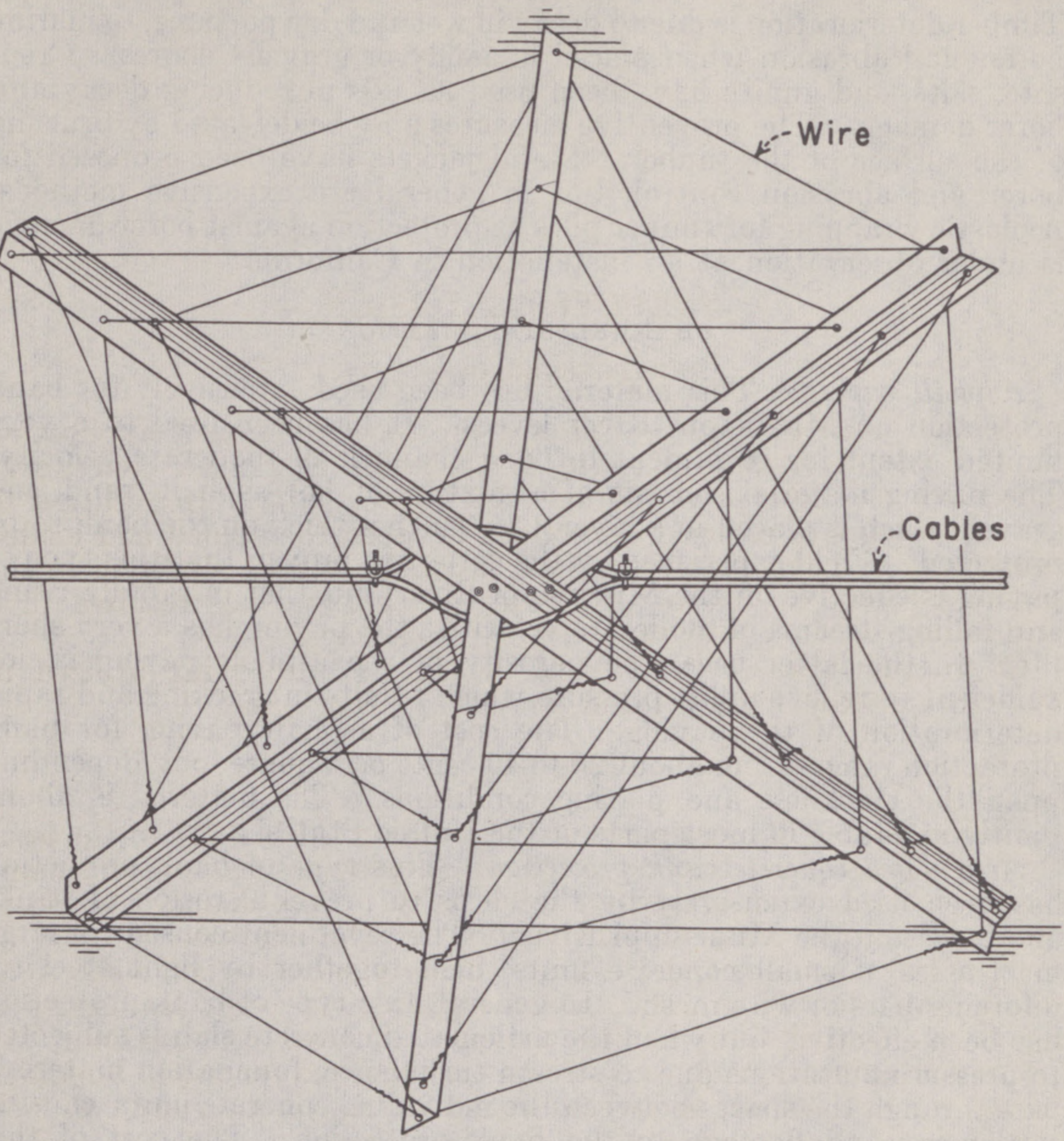

NOTES.—(1) Unit is usually 16′x4″x4″x¼″ angle iron laced with No. 6 wire. (2) Cables are usually ¾ ϕ. (3) Above unit is placed 12½′ on centers.

FIGURE 13.—Standard unit Kelner jetties.

layer for offshore breakwaters and beach protection seawalls and revetments by the State of Florida. Tests by the manufacturer have proven the material to be resistant to all sorts of chemical and biological substances. Heavy loads, such as rock in a breakwater, may damage the thin sheets of material and thus limit its life. "Filter X" is manufactured by Carthage Mills, Inc., located in Cincinnati, Ohio. Its cost ranges from about 20 to 30 cents per square foot, depending on the size of installation. Although the Corps of Engineers has not yet used these materials, it appears that they may have application to some corps projects, and a test program to establish their suitability to corps needs is planned.

STRUCTURAL DESIGN

PRESTRESSED CONCRETE

Tainter gate anchorages.—Perhaps the most important application to date of prestressed concrete in Corps of Engineers civil works structures has been in anchorages for tainter gates. In addition to the advantages of reduced deflections between the noload and loaded conditions and the resulting more favorable stress condition in the concrete piers, the use of prestressed anchorages has resulted in a significant economy over conventional anchorages.

Other applications.—Prestressed concrete is also being utilized in the construction of bridges and powerhouse roof slabs.

NEW STEELS

Carbon steel.—The increased use of welding led in 1954 to the issuance of ASTM Specification A373 which provides carbon and manganese controls to insure better weldability. This change was incorporated into Government construction by the adoption in 1955 of Federal Specifications QQ–5–741a. A more recent carbon steel, A36, which was adopted in 1960, has a higher yield point leading to a significant contribution to the economy of steel construction. At Corps of Engineers projects, A36 steel is approved for use in buildings (using welded, bolted, or riveted construction), crane runways, lock and dam gates, stoplogs, and bulkheads.

High strength steels.—In recent years high strength steels have been introduced to civil works construction and have led to greater economy. The ASTM designated A242 and the more recent A441 have been used in the fabrication of control gates. Savings are achieved not only by a reduction in steel cost but also through the resulting need for lower hoist capacities.

Penstock steel.—The steel presently specified for power penstocks and surge tanks is the ASTM designated A–201, grade B, firebox quality. It is a carbon silicon steel for pressure vessels and has a slightly higher yield strength than the principal steel, A285, previously used for this type construction. It is also a better quality steel having improved notch toughness and better weldability.

ALUMINUM

Where savings are indicated, aluminum is being used for bulkheads and stoplogs at the corps water resources projects. Economy is achieved principally from the reduction in the required hoisting capacity. Other uses of aluminum include spiral stairs, handrails and grating where service conditions are corrosive and lightweight is desired.

FOUNDATION DESIGN

Recent years have seen the development of unusual features at civil works projects in the design of foundations for major hydraulic structures. Principal among these were the use of anchors to reinforce the foundation, the design of major drainage facilities, and the initiation of an extensive program for evaluating the shear strength of relatively weak foundation rock.

Foundation anchors.—Relatively short steel bars have been used extensively in the past to anchor spillway chute and stilling basin slabs to foundation rock to resist hydrostatic uplift forces. However, the recent use of long bars for reinforcing structural foundations was an important innovation at civil works projects. At one project such anchors were used in controlling differential rebound in a faulted, jointed soft rock. The differential rebound became evident upon completion of rock excavation. If this phenomenon had continued after construction of the structures, severe structural damage would have occurred. The design utilized long anchor bars grouted into holes drilled deep into the foundation and bonded at their tops to the concrete structure. The anchors retarded expansion of the top foundation layers and have effectively prevented differential movements along fault planes. This solution to the foundation problem was much more economical then the alternative of providing sufficient concrete weight (which would also require additional excavation) to restrict the foundation movements. In the future more frequent use of anchors can be expected to solve structural stability problems where otherwise costly excavation and concrete quantities would be needed.

Drainage.—A recent change in design criteria for hydraulic structures will provide greater construction savings. The change is the result of measurements made at existing structures and provides for increased reliance on foundation drainage to reduce hydrostatic uplift pressures against the structures, which results in lighter, more inexpensive structures. Foundation drainage has also been used to reduce hydrostatic buckling pressures around steel liners in tunnels and to improve the stability of earth dam abutments.

Foundation shear evaluation.—A program is presently being prosecuted to develop more reliable criteria for determining the true in situ shear strength of relatively weak rock foundations.

CONCRETE EMBEDDED PENSTOCKS

Design methods for penstocks embedded in concrete have not been well established. Designs have varied for different projects with art progressing as experience is accumulated. To obtain the economical advantage of this type of composite construction, the corps developed applicable design methods which involve consideration of both internal pressures (distributed to the steel and reinforced concrete backing) and external buckling pressures. It was estimated that this composite construction in lieu of penstocks standing free in the concrete tunnel saved over $10 million at one project.

DEVELOPMENT OF IMPROVED DESIGN CONCEPTS

Flood control channels.—An extensive study, which was initiated in 1959 and scheduled for completion during 1963, is being conducted to determine optimum reinforcement and concrete slab joint arrangements for the control of cracking and reduction in deterioration of reinforced concrete in high-velocity flood control channels. Some of the results to date have been used to make improved economical designs, and at the conclusion of this study, new criteria will be distributed for application at all pertinent projects.

Lock design.—In the design of large U-shaped drydock-type locks certain assumptions must be made concerning the distribution of foundation pressure beneath the structure, or otherwise the design is based upon a theoretical analysis of support from an elastic foundation. An instrumentation program on two lock structures is currently being conducted to provide engineering data for the future design of similar structures. Pressure cells, stress meters, and other devices were incorporated into the construction to measure foundation pressures, compressive stresses, settlements, and deflections.

Reinforcing steel working stresses.—Another investigation, which concerns the possibility of increasing working stresses for concrete reinforcing steel, is being conducted at the Treat Island, Maine, Exposure Station. It consists of concrete beam exposure tests which were initiated in 1951. The purpose of the test is to determine the effect of tensile cracking upon the durability of the concrete beams. Steel stresses were varied over a wide range so as to obtain a comparison between beams with different amounts of tensile cracking. Durability results to date have led to an increase in allowable working stresses for hydraulic structures from 18,000 to 20,000 pounds per square inch. Upon completion of the tests, it is hoped that results will be conclusive with respect to the advisability of increasing working stresses for rail or high-strength reinforcing steel.

Reinforced concrete.—The Reinforced Concrete Research Council maintains a program of sponsorship and financial support to research projects which promise to develop answers to reinforced concrete problems leading to improved practice. The Corps of Engineers maintains an active participation in the program through membership on the council. The results of sponsored projects are used to improve design criteria and concepts in our civil works construction.

Revised AISC specification.—The new revised AISC specification will be applied to the design of structural steel for permanent buildings. Applicable parts such as the more exact column formulas and formulas for combined stresses will be used in designing other steel structures such as gates and bulkheads. Published corps design manuals will be revised to incorporate the applicable new design rules of the AISC specification.

ELECTRONIC DATA PROCESSING

Where available, use is being made of electrical data processing devices to speed up routine computations relative to the stability computations of embankments and foundations of dams and levees, and foundation stability of floodwalls. Electronic data processing is also being used in solving a variety of other design problems.

CONSTRUCTION MATERIALS FOR CONCRETE

CEMENTING MATERIALS

General.—Prior to 1930, with a few exceptions, portland cement was the only cementing material used in portland cement concrete in the United States. Also it was not until after 1930 that specifications were developed for different types of portland cement and the different types became generally available. Slag cement was first used in dam construction in a public utility dam in the early 1920's. Natural cement was first used in dam construction by the corps about 1946. Pozzuolanas were used as early as about 1927 or 1928 in Big Dalton Dam built by the Los Angeles Flood Control District.

Portland blast-furnace slag cement.—This material is the product obtained by intimately intergrinding a mixture of portland-cement clinker and granulated blast-furnace slag. It is not a new material having been used in Europe for sometime past, however, until about 1954 or 1955 there was only one producer in the United States. About 1954 when portland cement was in short supply several (five or six) other manufacturers started production of PBFS cement. The main purpose was to provide a greater amount of cement from the available portland-cement clinker. There was little precedent for use of PBFS in this country and no substantial basis for judging the quality or performance even though there was available a Federal specification promulgated in 1952. The corps undertook a comprehensive investigation of PBFS in 1955 which was completed in 1956. Tests were made on samples of PBFS from all known producers. The producers cooperated by furnishing samples of PBFS, portland-cement clinker and slag. Largely as a result of these investigations the Federal specification for PBFS was subsequently revised to provide the PBFS cement equivalent in behavior and properties to types I, IA, II, and IIA portland cement.

During the period 1954–58 when portland cement was in short supply the price of PBFS was the same as portland cement. After 1959 at least one producer was offering PBFS at 20 cents per barrel less than portland cement. Since 1959 when portland cement supply began to exceed demand several of the producers have discontinued regular production of PBFS but are presumably in position to produce PBFS when ordered. During the period 1954–58 there were six to eight mills regularly producing PBFS. At present there seems to be only one mill regularly producing PBFS. PBFS has been used in only one corps project in the last 5 or 6 years.

Pozzolan.—Pozzolan is a silicious or silicious and aluminous material which alone possesses little or no cementitious value but which will, in finely divided form and in the presence of moisture, react with calcium hydroxide at ordinary temperatures to form compounds having cementitious properties. Pozzolan is one of the oldest, if not the oldest of cementing materials, having been used by the Romans as early as 12 A.D. and by the Greeks at even earlier dates. Pozzolan

has been in use in Europe in modern times and was used in the United States as early as 1927. Pozzolan was first used in corps work in the construction of Bonneville Dam (1937–42). At Bonneville a portland-pozzolan cement was used. It was not until 1957 however that the Corps of Engineers developed a satisfactory basis for widespread use of pozzolan. Specifications and criteria were developed from a comprehensive investigation of pozzolanic materials available in the United States which was started in 1951 and completed about 1957. Pozzolan has been used in more than 20 major corps structures started since 1957. Generally, pozzolan is used in mass concrete as a volume replacement for portland cement at a rate of as much as 30 percent.

Currently, investigations are underway to determine the maximum amount of pozzolan which can be technically and economically used. The investigation is being conducted using concrete made with 94 pounds (one bag) of portland cement and enough pozzolan to give required plasticity and strength. The investigation is not yet complete but some of the early results are encouraging. Usually concrete made with gravel coarse aggregate, natural sand and a 30-percent volume replacement of fly ash (an artificial pozzolan) requires about 135 to 145 pounds of mixing water per cubic yard for lean interior (2.00 to 2.25 bags of cementing material per cubic yard) concrete. In the investigation underway with this combination of materials, using 94 pounds of portland cement and as little as 100 pounds of fly ash workable concrete of ample strength for concrete dams and moderate height has been made with less than 85 pounds of water per cubic yard.

The most abundantly available pozzolan in the eastern half of the United States is fly ash, an artificial pozzolan. Fly ash is the finely divided residue that results from the combustion of powdered coal which is transported from the combustion chamber by exhaust gases. Each thermal power station using pulverized coal fuel and electrostatic precipitation of the fly ash is a potential source. Essentially all of the fly ash used up to now on corps projects has been supplied from four plants.

Natural pozzolans are available from at least five commercial sources west of the Mississippi River. The five known sources are located in Oklahoma, Texas, Wyoming, Oregon, and California.

Price of fly ash has ranged from $3.75 to about $17 per ton in the concrete. The f.o.b. source price is understood to be about $2 per ton. Freight, unloading, storage, and reclaiming make up the major portion of the cost. Most of the fly ash used has cost between $6 and $12 per ton in the concrete. Fly ash has been used as far west as Ice Harbor Dam in the State of Washington. Material for this project was supplied from Chicago and the price in concrete was $15.25 per ton. Price of natural pozzolan produced in Portland, Oreg., which is being used at John Day Dam is $16 per ton. Available information indicates that natural pozzolans such as the calcined shales are priced at about $12 per ton f.o.b. source. As a basis of comparison with the price of pozzolans, portland cement costs from $22 to $28 per ton on mass concrete.

Slag and natural cements.—Neither of these materials are new, but not until 1954 and 1957, respectively, were there Federal specifications covering these materials. Both had been used by the corps before

these dates. The current Federal specifications for these materials were largely developed from the corps research on and experience with these materials.

Slag cement is a finely divided material consisting essentially of water-quenched granulated blast-furnace slag and hydrated lime. The corps has used slag cement as a 20-percent replacement by volume for portland cement in lean mass concrete.

Natural cement is finely pulverized calcined argillaceous limestone. The corps has used natural cement as a 25- to 30-percent replacement by volume for portland cement in lean mass concrete.

Slag cement is available from only one source (in Alabama) in the United States. Natural cement is available from three sources (in Indiana, Kansas, and New York) in the United States. Slag cement in large volumes has usually been priced at about $0.40 to $0.50 per barrel (1.91 cubic feet solid volume) less than portland cement. Natural cement has usually been priced at about $0.20 per barrel less than portland cement.

Since pozzolans have come into widespread use both these materials have lost their competitive position in mass concrete construction.

Trief cement.—This is a cementing material made by a process patented in Belgium. The material may consist of either of the following:

(1) Sixty-eight to seventy percent pulverized granulated blast-furnace slag cement, 28 to 30 percent portland cement, and 2 percent sodium chloride.

(2) Ninety-seven percent pulverized granulated blast-furnace slag, 1.5 percent sodium chloride, and 1.5 percent sodium hydroxide. A principal feature of the process is the wet grinding and storage of the slag at the point of use. Another feature is the use of sodium chloride (common salt) as a catalyst.

The combination described in (1) above resembles portland blast-furnace slag cement, but contains a greater proportion of slag than is allowed for PBFS.

The process has never been used in this country so no costs are available. It is understood also that it has had very limited use in Europe. It is unlikely that the process would be economical in our economy unless its use became widespread.

Ready-to-use readily available dry materials such as portland cement, slag and natural cements, and pozzolans would seem to have an economic advantage over the Trief process because they fit into the practices and plant of most contractors better than the Trief process material. In order to use the Trief process contractors would have to add materially to their capital investment in plant and make major modifications in their practices.

Supersulfated cement.—This material is essentially granulated blast-furnace slag, calcium sulfate and a small amount of portland cement. It is a European cement which as far as is known is not available nor has it ever been used in the United States. The corps cooperated with the National Bureau of Standards in a limited investigation of this material several years ago. Strengths were comparable to strengths obtained with portland cements manufactured in the United States, but concrete made with this material demonstrated poor resistance in both laboratory freezing and thawing tests and in natural weathering tests.

WATER-REDUCING AND RETARDING CHEMICAL ADMIXTURES

General.—As far as classes of material are concerned, there are no new chemical admixtures for concrete but the situation with respect to one class (set-retarding and water-reducing admixtures) has changed materially within the last 5 years as a result of expiration of a patent by which the manufacture of the lignin base material was controlled. As a result there has been a resurgence of interest in this class of materials and there have appeared on the market possibly 40 or more new trade name materials in this class most of which are believed to be lignin base materials. There has also been a resurgence of interest in purchase specifications and methods of evaluation of performance of these materials. Although no standard purchase specification for this class has ever been adopted by either ASTM or the Federal Government, ASTM has now undertaken to develop purchase specifications for chemical admixtures which will cover this class and accelerating admixtures. A proposed specification is currently under consideration for adoption. It is understood that the proposed specifications will cover five types of chemical admixtures as follows:

Type A, water-reducing admixtures.
Type B, retarding admixtures.
Type C, accelerating admixtures.
Type D, water-reducing and retarding admixtures.
Type E, water-reducing and accelerating admixtures.

This general class has been further classified into four chemical classes as follows:

(1) Lignosulfonic acids and their salts.
(2) Modifications and derivatives of lignosulfonic acids and their salts.
(3) Hydroxylated carboxylic acids and their salts.
(4) Modifications and derivatives of hydroxylated carboxylic acids and their salts.

Investigations and use problems.—The corps and others have carried on investigations of this class of materials during the last 4 or 5 years. The aims of the corps investigations have been to develop information on the characteristics and performance of this class of materials to determine whether or not their use would be beneficial in corps work and if so to provide a basis for preparation of suitable purchase specifications and criteria for use of these materials. The corps has contributed to the work of ASTM on development of the purchase specification for chemical admixtures referred to previously through participation in Subcommittee III–h of ASTM Committee C–9 which has developed the proposed specification. These investigations have shown that behavior of these materials is variable and unpredictable. Differences in composition of cement seems to be the primary factor which influences the variable performance of these materials. At their best, the water-reducing agents have been demonstrated to reduce water requirements by 15 to 20 percent. At their worst some of the agents with some cements give no reduction in water required.

In addition to the problem of variable performance there are two other problems with these materials for which no satisfactory solution has yet been developed. One of these is the "slump loss" problem. Some of these materials cause concrete to tend to lose slump (become

stiffer in consistency) more rapidly than similar concrete without the agent. This tendency complicates the practical problems of transporting and placing the concrete. The other problem is that of abnormal hardening. Some of the lignin materials have been known to delay hardening of concrete to such a degree that no appreciable gain in strength occurs up to as much as 4 days after placing. In a tunnel lining project in California the concrete in the crown came down with the forms when they were removed about 10 hours after the concrete was placed. (See Journal of the American Concrete Institute for March 1961.) Removal of forms at such an early time is common practice in lining tunnels with concrete. Following removal of the forms the concrete in this case remained soft enough to mold by hand for a period of 4 days. The admixture used was a lignin base material. It is understood that occurrences of this type have been frequent with lignin base admixtures. (See Journal of the American Concrete Institute for September 1961.) The case cited is one of the very few that have been publicized. The cause of the abnormal hardening in this case is believed to have been due to the fact that the sulfur trioxide content of the portland cement used was lower than required for normal hardening with the agent used.

To date the corps has made limited use of retarders and some but even less use of water-reducing agents. When used, contract specifications have been adaptations of the proposed ASTM specifications. Use of this class of materials will be possible in corps work when satisfactory purchase specifications have been developed and the problems discussed have been solved. Also it will be necessary to develop a basis by which economic benefit will be assured and protected. This is one of the difficult problems because the corps uses entrained air in essentially all concrete placed and air-entrainment results in a dependable reduction in water requirement of from 10 to 15 percent from that required for comparable concrete made without entrained air. On the matter of retardation there will evidently be hot weather placing situations where it will be necessary to delay and control the rate of stiffening (set) of the concrete in order to properly execute the construction and in these instances use of a retarder will be especially advantageous.

OTHER CHEMICAL ADMIXTURES

Air detraining admixture.—This is a new admixture for use in concrete where the combination of materials being used entrains too much air. This agent reduces the amount of air entrained to the desired amount. Under the corps practice of thorough preconstruction investigation of concreting materials and addition of the air entraining admixture at the mixer this problem is not confronted. Thus the corps finds essentially no use for this material.

Integral hardeners.—This is not a new class but new products in the class have come on the market in the last few years. Investigations conducted over the years by the corps and others have universally revealed that well-designed, well-controlled, and properly placed concrete is adequate for any service condition to which corps concrete is subjected in civil works. The corps has no apparent need for this class of material in civil works.

Surface hardeners.—This is not a new class but new products periodically appear on the market. These materials are intended primarily for alleviation dusting which results from wear and which is characteristic of poor quality concrete floors. The corps does not normally have a requirement for this material in civil works.

Accelerating agents.—This is not a new class but new materials do occasionally come on the market. The material used most frequently is calcium chloride. There is considerable evidence available that calcium chloride is not suitable for use in prestressed concrete, since it apparently contributes to corrosion causing so-called "stress corrosion" failure. A need exists for materials which will accelerate hardening (strength gain) but will not cause corrosion of prestressing steel.

Expanding agents.—This is not a new class but new materials do occasionally become available. These materials perform the function of counteracting the shrinkage (setting shrinkage) which occurs during the early stages of stiffening. They find usefulness primarily in mortars and concrete for setting machinery bases and in certain special types of concrete such as preplaced aggregate concrete. Small quantities of aluminum powder are useful for this purpose and some of the products on the market sold for this purpose are basically aluminum powder. Others use other metallic forms including finely divided iron. The behavior of these materials particularly those including iron is difficult to predict and control. Composition of the portland cement used with these materials substantially affects their behavior and performance. The corps is currently engaged in an investigation aimed at developing improved purchase specifications and practices for use of these materials. When perfected these will eliminate the need to refer to these materials in contract specifications by trade name "or equal" and will provide for improved performance of these materials in corps work.

Waterproofing agents.—This is not a new class but new products in the class occasionally become available. There are two types in the class, namely, integral (included in the mix) and surface treatment. These materials are not generally used in corps civil works construction since good quality materials and proper manufacturing will normally provide the desired degree of water tightness.

Inhibitors of corrosion of reinforcing steel.—A process for use of sodium benzoate as an inhibitor of corrosion of reinforcing steel has been patented in England. As far as is known the process has not been used in the United States. The corps has had no major corrosion problems with reinforcing steel since most of the corps structures are in nonsaline surroundings.

JOINT CLEANUP

Construction joints (stoppages) in monolithic (bonded) concrete are usually cleaned by washing with high velocity water or air and water before the concrete has hardened or by wet sandblasting after the concrete has hardened. To be effective, the first of these procedures must be carefully timed and timing varies with weather conditions, particularly ambient temperature. The only new development in this connection is a chemical (in liquid form) put on the market about 5 or 6 years ago. It is a retarder which is applied to the

surface to be cleaned immediately after the concrete is placed and compacted. It delays the setting of the mortar to a depth of about ¼ to ⅜ of an inch thus allowing a longer period of time for completion of the cleanup operation when performed by washing with water or air and water.

The one product so far available for this purpose was tested by the corps for the primary purpose of determining whether or not its use would be harmful. Test revaled that it was not harmful and could be used without fear of detriment to the quality of the work.

The product has not been very widely accepted because of its cost and because there is a lack of information on behavior and effectiveness in varying weather under field conditions.

As far as is known only one product is currently being promoted for this purpose. It seems logical to assume that any retarder in such form as to be readily and uniformly applied to a construction joint surface would be equally as effective for this purpose as the one material now being promoted for this purpose.

Estimated cost of the material is about $0.05 per square foot of surface cleaned. The use of this material thus potentially increases the cost of cleanup by about this amount. In order to be attractive to a contractor, this material must thus provide some benefit which will offset or balance the cost of the material on the concrete. This might be in the form of reduced overtime costs resulting from the extended period for cleanup which would permit all cleanup to be performed during regular shift hours. This possibility seems rather remote on the large mass concrete job where cleanup is usually conducted around the clock. This product has had limited use on corps projects.

CURING AND PROTECTION

General.—Essentially all permanently exposed surfaces of corps concrete structures and all surfaces to which other concrete is to be bonded (construction joints) are moist cured. The method of applying the necessary water is optional with the contractor. Surfaces which are not to be permanently exposed such as bulkhead faces in dams, and surfaces to be covered by backfill, and surfaces such as in galleries of dams which are protected when in service may be cured with membrane forming compounds or moist cured at the option of the contractor.

Membrane forming curing compounds.—This is not a new class of materials but is of interest because of the manner in which it is specified. For corps work any material which will form a continuous membrane and which when tested under controlled conditions will meet the moisture retention requirements of the corps specifications, and which does not interfere with hardening of the concrete may be used. Thus any new material which meets these conditions and is economically attractive will be of interest to both contractors and the corps. In corps work the contractor is required to furnish the curing compound and thus the primary interest in new materials is largely shared by the producers and contractors.

Most of the compounds available are so-called wax (or paraffin) base compounds. Resinous materials make excellent compounds but are somewhat more expensive than wax base materials on the market.

Curing compounds cost about $0.005 per square foot of surface covered for material. There are many sources of supply and competition is very keen.

Moist curing.—Contractors are using devices made from some of the new plastics. Some are using the so-called "soakers" which are plastic hose with perforations which open under pressure of water thus providing dispersed water sprays. Contractors will probably also make use of lightweight rigid pipe made from plastics for distributing curing water because they offer the advantage of being noncorrosive and thus protect the water from pickup of staining contaminents. Cost will have a substantial bearing on the degree to which rigid plastic pipe is used. Here again the primary interest is largely shared by producers and contractors.

Insulating materials.—These find two uses in construction of concrete dams. One is in providing protection against freezing of fresh concrete and the other is in protecting exposed surfaces during extremely cold weather against temperature cracking. New materials for this purpose consist mainly of the cellular plastics such as polyurethanevinylcopolymer foam, expanded polystryene and others. Corps specifications for both applications are performance specifications thus selection of materials is up to the contractor.

The corps is interested in the ability of these new materials to resist change in insulating properties when exposed to weather for a period of several months. Thus some research on this is planned and will be undertaken as soon as funds become available.

Plastic sheets.—Polyethelene and other plastics are made into sheets which are useful in "housing in" work areas in winter for protection of the work against freezing. These materials are of interest primarily to contractors.

BONDING MATERIALS

General.—In most of the concrete construction by the corps fresh concrete is bonded to hardened concrete by thoroughly cleaning the surface of the hardened concrete and by application of a layer of sand-cement grout to the surface of the hardened concrete immediately prior to placing of the fresh concrete. In two-course (bonded) floors the same procedure is followed except that a neat cement mortar is applied to the hard concrete to which floor topping is to be bonded. In repairing concrete the practice in the past has been essentially the same as described above with choice of sand-cement grout or neat cement depending on thickness of repair or in cases where repairs are to generally vertical surfaces no grout is used.

Proprietary bonding materials.—During recent years a substantial number of bonding agents have been put on the market. These materials are claimed to provide better bond between fresh concrete and hardened concrete than can be obtained by the conventional methods described above. They are recommended for bonded floors and for patching damaged concrete. Tests by others indicate that when an old surface is properly cleaned none of the proprietary materials produce better bond than that obtained by using portland cement grout. In view of these tests the corps has continued to use portland cement grout as the bonding agent.

Epoxy resins for repair and protection of concrete.—In the tests referred to above epoxies for bonding fresh concrete to hardened

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concrete for bonded floors did not show any advantage over conventional methods. Nevertheless, they do show promise for use in repair of damaged concrete and for protection of concrete against erosion or cavitation when subjected to high velocity flow of water. In making repairs on essentially vertical surfaces where it is not practical to use sand-cement or neat cement grout, epoxies seem to offer an opportunity to secure better bond than is obtained by placing fresh concrete against hardened concrete without grout. Epoxies also seem to be useful as the binder to make epoxy grout or concrete for patching. They also appear to have possibilities as protective coatings on concrete which will be subjected to high velocity flow of water. Research is underway by the corps and possibly by others to determine whether or not epoxies can be successfully used for the purposes described and if so to determine how they should be used to get maximum benefits. We plan to accelerate our investigations into the uses of epoxies.

Epoxy resins are readily available from many sources. One of the problems in investigating epoxies is the large number of epoxy resins on the market and the lack of information regarding the chemical composition of these materials. In spite of this problem it may be possible to develop a performance-type specification which will permit purchase of epoxy resins without regard to chemical composition.

Epoxy resins are quite expensive. Prices range from $14 to $16 per gallon f.o.b., place of manufacture.

Polyvinyl acetate.—This material which is a synthetic organic chemical compound was reported to be useful in combination with portland cement for bonding fresh concrete to hardened concrete for bonded floor topping and similar work. It was also reported to be useful as an admixture in concrete. A review of the experience of others with this material indicated that it performed as claimed in a dry atmosphere but did not perform well in water or in high humidity atmosphere. Since most corps concrete is subject to one or both of these conditions in service polyvinyl acetate has limited application to our work.

CONSTRUCTION MATERIALS FOR FOUNDATION TREATMENT, AND EARTH AND ROCKFILL DAMS

FOUNDATION TREATMENT

Frequently, soil and rock foundations of large structures such as dams require consolidation over and above that provided by nature. Natural fractures, faults, or subsurface water courses which might endanger the integrity of structures or result in excessive seepage, must be sealed to obtain sound foundation conditions. This objective is achieved by several methods and materials, of which two in particular are constantly changing with new demands and construction experiences. The two methods referred to are foundation grouting and rock bolting. The first involves injection of liquid cementitious compounds into the subsurface materials, at controlled pressures. The second, rock bolting, employs high-strength steel bolts with expanding anchor ends to literally pin or bolt rock masses together.

Chemical grout.—Grout is generally considered to be any combination of liquid and/or solid cementitious materials which, when injected into subsurface materials, will result in their consolidation. Grouts composed of portland cement and water are used most frequently to accomplish this objective in the case of fractured rocks.

However, to consolidate soils such as sand and gravel, chemical solutions which after injection and combination underground will react to produce gels or precipitates, generally afford the only satisfactory grouting medium. While several chemical solutions have been tested and used with varying degrees of success in the past, rather recently a product known as AM–9 has received considerable attention from both engineers and the construction industry. This product is manufactured by the American Cyanamid Co., and consists of a water-soluble mixture of two organic chemicals, acrylamide and N.N′-methylenebisacrylamide, in proportions that can be made to combine chemically to produce stiff gels. Two catalysts, ammonium persulfate and B-dimethylaminopro-pionitrile, are used to initiate and control the gelling process as the chemicals are injected underground. The manufacturer claims that AM solutions will gel in concentrations as low as 3 percent by weight and as high as 50 percent, the solubility limit.

AM–9 chemical grout and the two catalysts may be mixed together as batches and injected underground with conventional grout pumps, or the chemical solutions may be injected separately by a metering process, which permits closer control of the gel time by separate injection of the ammonium persulfate. The corps proposes to conduct tests of this material, along with those including other chemical solutions, in connection with the 1963 fiscal year research program.

Rock bolts.—While bolting of rock masses to preserve their integrity has been used in mining and tunneling for roof support for almost 100 years, scientific modification of bolts to meet requirements of large engineering structures is a relatively recent development. The

common mine roof bolts which have been adapted to rock bolting are of two basic designs, the slot-and-wedge and the expansion-shell types. Anchorage of the slot-and-wedge type of bolt is obtained by driving the slotted bolt over the wedge at the bottom of the hole, causing the slotted end of the bolt to expand against the side of the hole. Tensioning of the bolt is obtained by tightening a nut against a steel bearing plate. The expansion-shell type bolt is anchored to the rock in the hole by expansion of a shell similar to that of the conventional Molly bolt, while the bolt is being tensioned against the bearing plate on the rock face.

Two more recent developments of rock bolting are the perforated-sleeve bolt and the modified rock anchor bolt. The perforated-sleeve bolt was first designed for use for rock support where it was necessary to have a greater degree of permanence than obtained by unprotected steel bolts. In this method perforated steel pipes are cut in two longitudinally, and filled with plastic mortar. Both half-round parts are then wired together and inserted in the hole, after which the bolt is driven through the mortar, resulting in essentially complete filling of the hole by the extruded mortar, tube, and bolt. This grouted type of bolt anchorage is superior in low-strength rocks which are not adapted to the more conventional rock bolt.

The modified rock anchor bolt was developed by industry from a design prepared by geologists in the Office, Chief of Engineers. It is essentially a modification of the basic rock bolt design, with an extension to the outer end of the bolt to which reinforcing steel can be attached. The initial development of this bolt was dictated by the need in many instances for a device which would not only serve to hold rock together before covering it with concrete, but which later could serve also as a foundation anchor for the concrete structure.

The use of rock bolts by the Corps of Engineers is very extensive, and will continue to increase as experience in this form of rock stabilization is acquired by the construction industry. The cost of rock bolting varies with the style and size of bolts used, as well as the specific geologic conditions in which they are used.

Earth and rockfill dams.—Studies are underway as part of the civil works investigation program to determine more reliable test methods of soil properties. This includes the stress-strain characteristics of sand and gravels, the influence of large gravel sizes on the densities and shear strength of compacted gravels, the influence of pore water pressures on the shear strengths of compacted and undisturbed clays, and the most reliable method of measuring such pressures. Studies are also in progress as to the influence of time on the strain characteristics of compacted clays. It is planned to include studies of weak broken rocks and gravels to determine the most suitable means of determining their strength-strain properties which will be useful in the design of high embankments where such materials may be available for construction. Studies are also planned for the strength-strain properties of weak stratified rocks such as shales which are often encountered in the foundations of hydraulic structures.

OTHER CONSTRUCTION MATERIALS

ACRYLIC PLASTIC FOR CONTROL ROOM CEILING

Clear acrylic plastic panels (methyl methacrylate) in the form of corrugated sheets or molded control lenses suspended below suitably arranged fluorescent lights have been used in the construction of luminous ceilings in the control rooms of hydroelectric power plants. (See fig. 14.) Luminous ceiling-type lighting systems are particularly suitable for control rooms as they provide practically uniform lighting intensity on horizontal surfaces over the entire area and also provide adequate lighting of indicating instruments on the vertical panels of switchboards without objectionable glare. Acrylic plastic material has a high and constant light transmission factor, good light diffusion characteristics, excellent color stability, and good dimensional stability. Where luminous ceilings are provided, the use of this material is evaluated along with formed glass control lenses and open aluminum or plastic egg-crate type ceiling panels on the basis of the quality of illumination provided, installed first cost, annual cost, and cost of maintenance. The material is known under trade names of Lucite and Plexiglas and can be procured under Federal specifications L–P–391, October 23, 1956, and L–P–507, July 6, 1961, and under MIL Specifications P–5425B(1).

POLYVINYL CHLORIDE ELECTRICAL CONDUIT

Polyvinyl chloride (PVC) rigid plastic electrical conduit is acceptable as an alternate to other types of electrical conduit for use in duct banks and in other locations where its use can be justified on the basis of economy or corrosion control. This type of conduit is particularly suitable for use in certain locations where severe corrosive conditions exist, such as some of the high-voltage switchyards at hydroelectric projects and certain coastal installations. Plastic conduit is evaluated along with other suitable corrosion-resistant types of conduit on the basis of economy in installed first cost, reduced maintenance, and increased life. The plastic conduit material and conduits are specified to conform to the chemical and physical characteristics and tests required in OCE Guide Specification CE–303.06, June 15, 1961, which are more rigid, in certain respects, than the requirements of Interim Federal Specifications L–C–00740 (GSA–FSS), February 15, 1961, for "Conduit and Fittings, Plastic." This material is commercially available from at least three sources.

PAINTS

Vinyl resin.—Spray-applied vinyl resin coatings have been used extensively in recent years for the protection of ferrous surfaces subjected to water immersion or atmospheric exposure. It has replaced the coal-tar enamel coats previously used on penstocks because of application advantages, and it provides the additional advantage of a

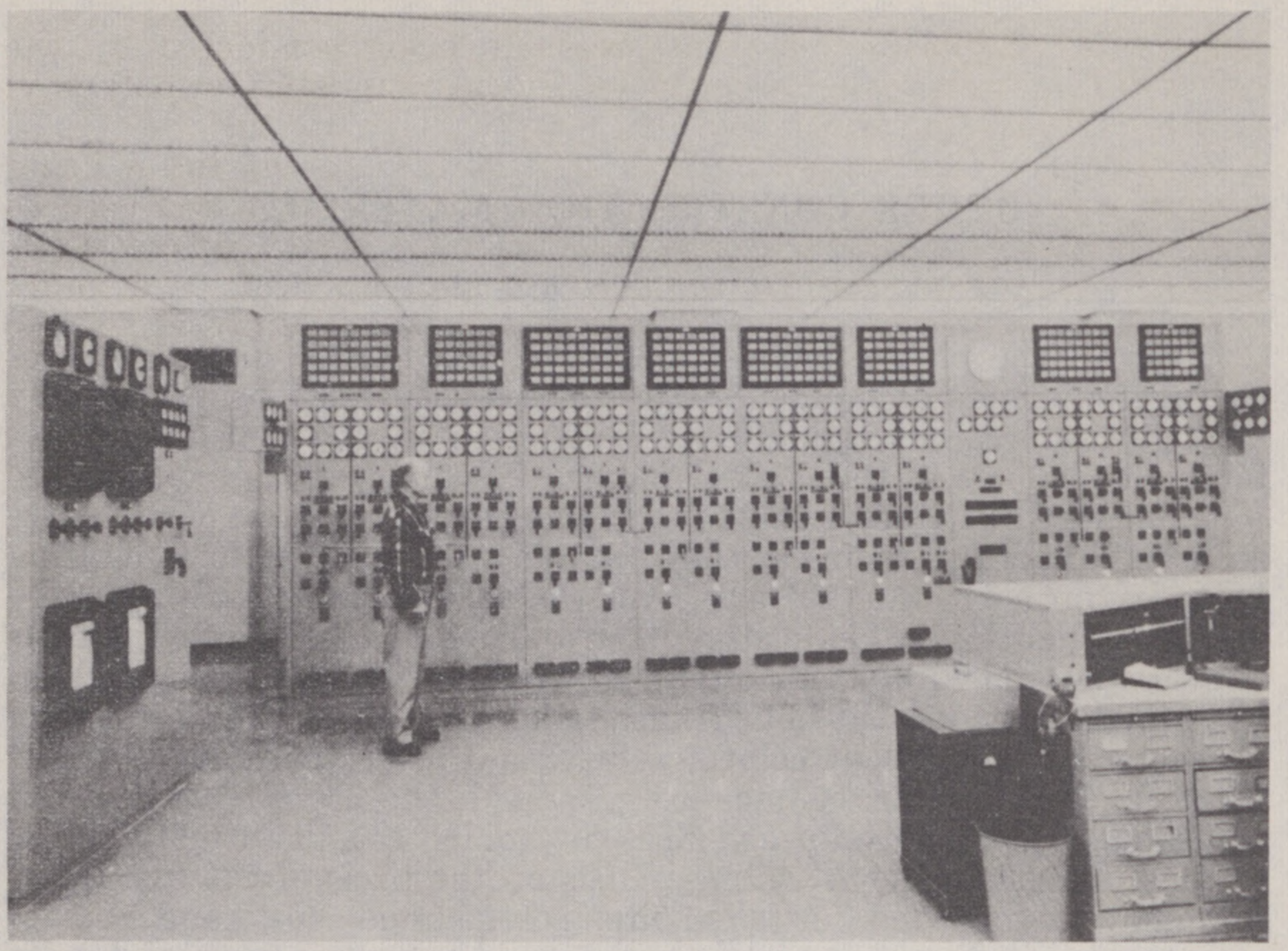

FIGURE 14.—Control room of hydroelectric power plant having luminous ceiling-type lighting.

smaller friction loss. Present activities at the corps' Rock Island Paint Laboratory include the search for improvements in the formulations and in procedures for surface preparations.

Urethane coatings.—These relatively new coatings are being investigated extensively. The problem concerns the development of a formula that will serve adequately on water-immersed steel surfaces. Some urethane paints formulated by the corps' Rock Island Paint Laboratory, and which are presently being tested, give promise of performing well. A principal advantage appears to be its good resistance to abrasion.

Epoxy resin-coal tar coatings.—Various formulations of this type of coating have recently been evaluated at the corps' Rock Island Paint Laboratory to determine their service and application properties. This program is being continued to improve the paint's properties. Problems involved which are being investigated include the slow cure time, only fair abrasion and adhesion qualities, blistering underwater and unpleasant odor.

JOINT MATERIALS

Plastic water stops.—Extruded polyvinyl chloride has been used for water stops in recent years on a limited basis. The labyrinth type has important installation advantages and is presently being used at tunnel monolith joints. For a long time, rubber was considered the best material for flexible water stops needed at joints subjected to differential movements. However, attention also is being given to polyvinyl chloride for this application because it promises to have

longer life. Exposure tests are presently being conducted by the Corps of Engineers to determine longevity characteristics for polyvinyl chloride relative to rubber.

Styrofoam.—This material, which is a polystyrene plastic, is being used in conjunction with concrete construction. It has been used as a filler material for concrete joints, particularly where new concrete is placed adjacent to existing concrete. It also has been used under concrete structures to control critical foundation pressures at specific locations.

OPERATING EQUIPMENT

POWER GENERATION

Turbine discharge measurements with radioactive tracers.—There is a need for a simple, expeditious method of making accurate measurements of turbine discharge in low-head hydroelectric powerplants. Discharge measurements are used for determining turbine efficiency and compliance with procurement contract performance requirements. At present, the only practicable method of making these measurements on low-head plants is by the use of current meters. This method is laborious, time-consuming, and expensive and furthermore, has not been accepted in the United States as being capable of producing results of the required accuracy. Field studies are now being made to establish feasibility of measuring discharges by the use of radioactive tracers. This project is sponsored by the Atomic Energy Commission, Division of Isotope Development. Tests are being made on Corps of Engineers hydroelectric plant intallations as a cooperative investigation by the U.S. Geological Survey.

Teflon for hydraulic packing.—In hydraulic turbines a packing box is required where the main shaft passes through the head cover. Because of is location, the packing box is not readily accessible and adjustments are not easily made. Teflon, a fluorocarbon resin developed by E. I. du Pont de Nemours & Co., is now being used by the Corps of Engineers for the packing material. It is more durable, has longer life, requires less adjustments and requires less lubrication than the asbestos braid type previously used for this application. The initial cost is greater than the asbestos type previously used but its longer life and less maintenance more than offsets the initial greater cost. Because of its superior characteristics as a packing material, Teflon is also used in the packing glands on the wicket gate stems and on the wicket gate servomotor shafts, and for Kaplan-type turbines, is used in the packing glands in the oil head. Teflon packing material is readily available and can be supplied by all of the turbine manufacturers.

High strength steel for hydraulic turbine spiral cases.—Hydraulic turbine spiral casings are manufactured of cast iron, cast steel, and steelplate. Generally large capacity medium head turbines have had steelplate spiral cases fabricated from low and intermediate strength plate field assembled by riveting and a relatively small percentage by welding. Field welding of spiral cases has generally been avoided by the Corps of Engineers due to the difficulty in obtaining adequate thermal stress relieving of field welded joints in accordance with the requirements of the ASME Code for Unfired Pressure Vessels. With the advent of high strength, heat treatable steel capable of providing high efficiency welded joints without the need for stress relief annealing, impetus has been given to the field assembly of spiral cases by welding. On large, medium to high head, turbines which would require spiral case thicknesses of 1½

inches or more if built of ordinary steelplate, an economy may be effected by the use of these high strength weldable steels if a reduction in plate thickness can be made and still maintain the minimum thickness necessary for assembly purposes. Turbine manufacturers do not maintain erection forces for field assembly work and the field assembly is usually performed by the powerhouse contractor, with the assistance of erecting engineers supplied by the turbine manufacturer. The turbine manufacturer is therefore not directly responsible for the erection work. However, in cases where high strength steel is used for the spiral cases and field welding is permitted, the field erection of the spiral case is included under the turbine contract and the turbine manufacturer is then also responsible for this phase of the work. This high strength steel is produced by at least five of the leading steel producers.

Solid state electronic equipment.—Solid state construction which includes no electron tubes, mechanical relays, or moving parts is now commercially available from numerous manufacturers of powerplant annunciators, operation recorders, carrier current transmitters and receivers, supervisory control equipment, VHF and microwave radio equipment, and certain types of protective relays for power stations and transmission lines. Solid state equipment is smaller and lighter than conventional equipment and usually requires less maintenance. It is permitted to be furnished as an alternate to conventional construction wherever this construction is commercially available and operation of the equipment has demonstrated that its performance is reliable and satisfactory.

Grain-oriented silicon steel.—This type of steel, containing 3.0 to 3.3 percent silicon, known under trade names of Hipersil, Corisil, and others, has very high permeability, low hysteresis loss, and excellent nonaging characteristics. It is extensively used in power transformers, motors, generators, and other electrical and electronic equipment, and has resulted in substantial reductions in core losses, increase in efficiency, and reduction in weight of the equipment. It is commercially available for use by all manufacturers.

INSULATING MATERIALS

"Butyl" compounds for electrical insulated wire.—The insulating compounds for electrical wires and cables installed on most civil works projects must be resistant to heat, moisture, and ozone in addition to having adequate insulating characteristics. The search for better rubber and rubber-like insulating compounds that would have a service life approaching that of the project is a continuing one. The recent development of a synthetic rubberlike compound known as Butyl meets the above requirements for an electrical conductor insulation better than any compound developed to date, especially for the higher voltage applications (8,000 volts and above). It has excellent heat, moisture, and ozone resistant characteristics. Industry standards issued by the Insulated Power Cable Engineers Association (No. S–19–81, 3d ed.) and the National Electrical Manufacturers Association (Pub. No. WC 3–1959) have been revised to include this type of insulation. Generally, it is more expensive than other types of synthetic rubber or oil-base rubber compounds more commonly used. Because of its superior characteristics, especially its ozone resistant

characteristics, this insulating compound is being specified in civil works procurements for insulated wire and cables for circuit-rated voltages of 8,000 volts and above. For applications below 8,000 volts, the superior characteristics of Butyl are not considered as essential and other synthetic rubber or oil-base compounds having satisfactory characteristics are permitted as an alternate to the Butyl insulating compound.

Epoxy resin for electrical machinery insulated windings.—Many motors used on civil works hydraulic structures are exposed to extreme moisture conditions and special insulated windings and enclosed frames, with heating units inside the frames, are required to keep the windings dry. Epoxy resin insulating compounds have been recently developed which are particularly suitable for the above applications. The epoxy resin has high dielectric strength, is impervious to moisture and is fully resistant to attack by oils and solvents. It can be applied so that the stator windings including the end turns are fully encapsulated in a void-free homogeneous mass. The use of this epoxy material on motors used in camp locations allows the omission of the otherwise required winding heaters and the use of a less-expensive frame construction.

Mylar electrical insulating tapes.—Mylar, a polyester film, developed by E. I. du Pont de Nemours & Co., is a very versatile plastic material and is especially suitable as an electrical insulating material. It is highly resistant to moisture, resistant to solvent and chemical attack, has very high dielectric strength, has an operating temperature range of from −60° C. to 150° C., and has high tensile strength. These characteristics make it particularly applicable for insulating formed coils on electrical motors and generators. Because of the low moisture absorption of Mylar, general purpose motors insulated with it may be used under service conditions formerly requiring special motors. Mylar tape is also used as a binder in mica flake tapes used for insulating high voltage motors and generators. Because of its high tensile strength, the taped material can be wrapped tighter to the coils, thereby resulting in a more dense and more corona-free insulation. It is readily available and its use is competitively selected by electrical equipment manufacturers to meet specified operating conditions.

REGULATING WORKS FOR DAMS AND NAVIGATION LOCKS

High strength corrosion-resistant steel for gate wheels, rollers, and tracks.—In the application of dam regulating gates which operate on wheels or rollers on vertical tracks, there sometimes occurs a combination of extremely high wheel or roller loading and an environment which is unusually corrosive to ferrous metals. Gate wheels, rollers, and tracks for service under these conditions require the use of metals which have a high degree of corrosion resistance, have high strength and hardness, adequate ductility, and which are capable of being heat treated with little or no distortion. These properties are supplied by the new precipitation-hardening, corrosion resisting, chromium-nickel steels. Furthermore, their weldability enhances their value as it permits these steels to be fabricated into forms which would not otherwise be practicable. This material is produced by at least two steel mills in the United States and is procured under Federal speci-

fication QQ–S–763B entitled "Steel Bars, Shapes, and Forgings—Corrosion-Resisting Classes 322 and 322A."

Teflon for bearing material.—In connection with the fish passage facilities in some of the Columbia River dams certain of the regulating gates rise and lower continuously in correspondence with the stage of the river downstream from the dam. The wheels on which the gates are mounted are submerged in the river water at all times. Operation of the gate is by its own buoyancy. Because of the low operating force, wheel bearings need to be as near frictionless as possible yet the use of antifriction bearings is economically impracticable in view of their high initial cost and the expense of maintenance and repair. Plain journal bearings with metal bushings do not have the low-friction properties required and are short lived because it is not possible to provide them with adequate lubrication. The most satisfactory design has been found to be a journal bearing using a plastic bushing. The bushing material is a fluorocarbon plastic manufactured in the United States by E. I. du Pont de Nemours & Co., and marketed under the trade name "Teflon". This material is self-lubricating, has an extremely low coefficient of friction, has excellent load-carrying properties, and is practically unaffected by water.

PUMPING EQUIPMENT—HIGH-NICKEL METALS FOR CORROSION RESISTANCE

High-nickel cast iron for corrosion resistance is now being specified for pumps to be used in a sea water environment. Due to the nature of the water, its low resistivity, the solids in suspension and the velocities involved, the pumps are subjected to a combination of corrosion and erosion to which these metals have been found to be unusually resistant. The tests conducted by the International Nickel Co., Inc., on pumps constructed of a high-nickel metal have shown that sea water has little effect on the metal and that years of satisfactory service can be expected. The metal is readily available from several sources and is covered by military specification No. MIL–G–858A. While this metal is slightly more expensive than the metal normally used in the construction of pumps, reduced operation and maintenance costs will more than offset the initial higher cost.

CONSTRUCTION EQUIPMENT AND PRACTICES FOR MANUFACTURE OF CONCRETE

BATCHING AND MIXING

Plant manufacturers standards.—For many years there has been a need for standard nomenclature and definitions for use in designating classes of batching plants. In 1960, the Concrete Plant Manufacturers Bureau issued the first edition of Concrete Plant Standards. In these standards five classes of batching systems are defined on the basis of three types of batchers. Thus for the first time there is standard nomenclature and definitions which may be used in specifying classes of batching plants. The corps is adopting the nomenclature and definitions of the concrete plant standards and these will be used in guide specifications for civil works concrete which are currently being revised for issue. Use of nomenclature and definitions which are recognized as standard by both manufacturers and contractors should largely eliminate misunderstandings with respect to plant requirements which have sometimes occurred in the past.

Turbine mixer.—Prior to about 1957, in the United States essentially all concrete was mixed in drum-type mixers. These mixers rotate around a horizontal axis and the mixing action is generated by blades which are attached to the inside of the mixer drum and thus rotate with the drum. In contrast to the drum-type mixer, the turbine mixer is composed of a doughnut-shaped pan inside of which blades or plows rotate around a vertical axis to produce the mixing action (fig. 15). The mixed concrete is discharged through a door in the bottom of the pan.

Tests by the corps on the turbine mixer indicated that it mixes concrete in less time than do the drum-type mixers. Tests indicated that it mixes concrete containing 1½-inch maximum-size coarse aggregate very well, and concrete containing 3-inch maximum-size aggregate satisfactorily, but is not adapted to mixing of concrete containing 6-inch maximum size-aggregate. Tests were made on a mixer of 1½ cubic yard capacity which was the largest available at that time. These mixers are now available in sizes up to 4 cubic yard capacity. Currently, use of turbine mixers is permitted on corps work for mixing concrete with up to 3-inch maximum-size aggregate.

Until recently turbine mixers were available from only one U.S. manufacturer but it is understood that there are now two U.S. manufacturers and a Canadian manufacturer offering turbine mixers for sale. On a production basis, first cost of turbine mixers is said to be substantially less than first cost of drum-type mixers. Other cost factors including the cost of supporting structures for mixers and batchers are also said to favor turbine mixers.

Rapid moisture indicators.—One of the essentials to control of quality of concrete is knowledge of the amount of "free water" (water on the surface of aggregates which becomes mixing water) in the aggregates, particularly the fine aggregate. This knowledge is essen-

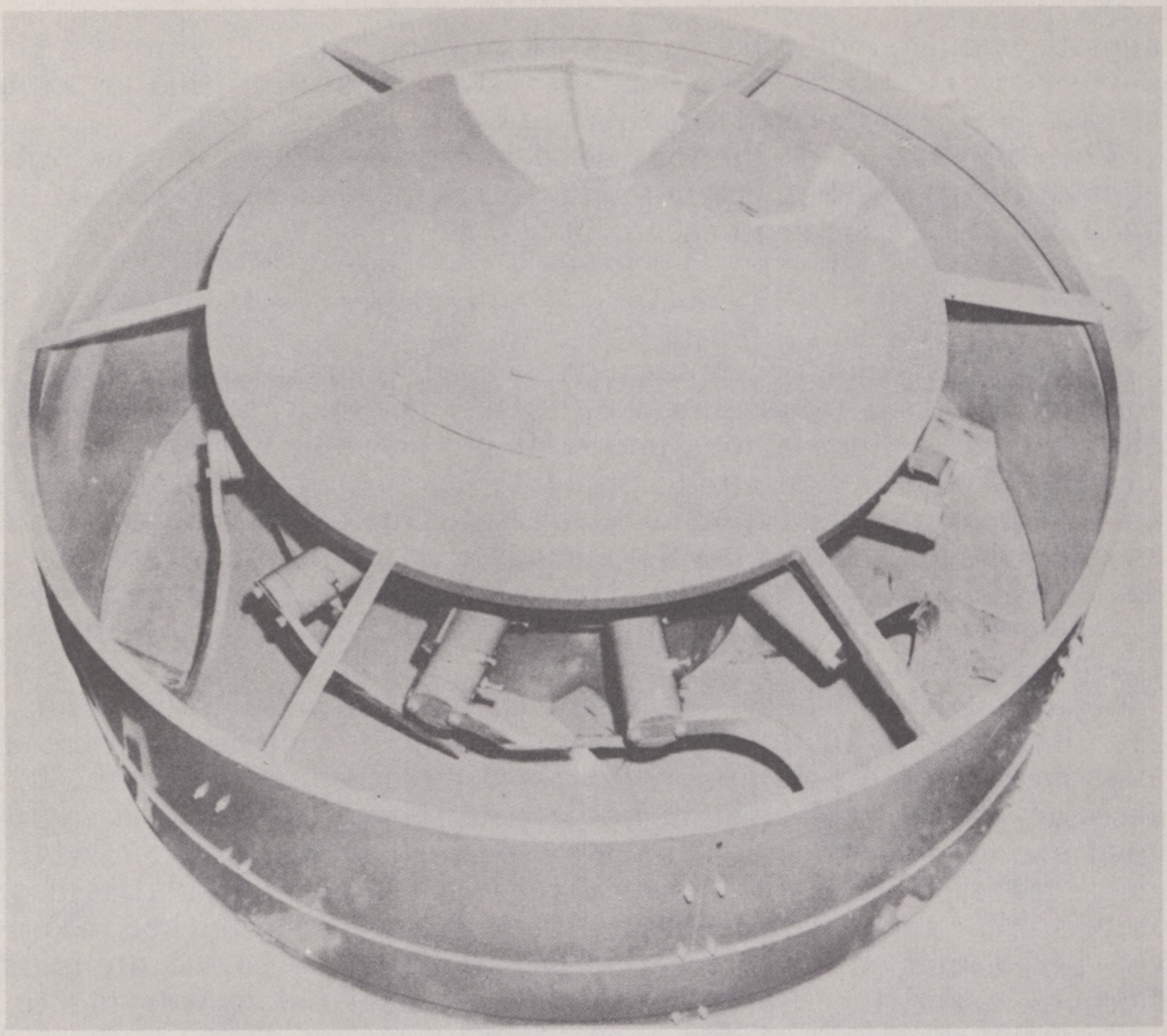

FIGURE 15.—Turbine-type mixer.

tial in order to be able to batch the correct amount of additional water needed for mixing the concrete. Ordinary methods of determining free moisture in the fine aggregate (sand) which carries the greatest amounts and undergoes the widest variation in amount do provide data as rapidly or as frequently as desirable. Thus for a number of years work has been underway to develop means for making instantaneous determinations of amount of free moisture in fine aggregates.

At least four devices using the electrical resistivity principle have been developed and are commercially available. Three of these were laboratory-tested by the corps and one of the three was field-tested. All three were found to be capable of indicating changes in moisture content of fine aggregate but none could be depended on to continuously give accurate measures of moisture content. All three require frequent recalibration in order to maintain reasonable accuracy. In spite of their limitations, instruments based on the principle of resistivity are considered useful in controlling the water content of concrete but do not entirely fulfill the need for an accurate and continuously dependable instrument for this purpose. Price of these instruments range from about $200 to about $1,200.

As far as is known, one instrument has been developed using the nuclear principle. One of these was laboratory-tested by the corps. The instrument showed considerable promise but there was a clear indication of need for further developmental work on the instrument

and it is understood that such work is currently underway by the developer. As far as is known, no instruments using this principle are available commercially at this time.

The corps has made limited use of instruments based on the principle of resistivity but has not found it prudent so far to require an instant moisture meter in each concrete plant.

TRANSPORTING CONCRETE

General.—No new principles have been developed for transporting concrete in recent years; however, at least one new application of an old principle and two innovations of an old principle have been made. The new application of an old principle was in the use of compressed air (pneumatic) in transporting concrete. One of the innovations in an old principle was the development of a hydraulic bucket-dumping device which is self-contained and self-recharging; the other innovation was the development of a radio device for remote control of the dumping of a concrete bucket.

Concrete bucket.—The hydraulic principle has been utilized for a good many years for dumping large concrete buckets used in placing mass concrete. A source of compressed air in the forms has been a necessary part of this system until recently when a concrete equipment manufacturer developed a self-contained hydraulic system which recharges itself when the empty bucket is seated on a platform or other similar support for refilling. The dump of the bucket is activated by a pull on a short section of cord attached to the dumping mechanism and the rate of dump can be regulated by varying the pull on the cord. The same bucket can be equipped so that it can be dumped by radio control from a considerable distance. The remote dump has not been used so far because of the safety hazards involved.

Air extrusion.—A device using air for transporting concrete for short distances through a pipeline has recently been developed. Transporting concrete by air in the past has been largely limited to the high-pressure method of transporting and placing concrete in tunnel linings known as the pneumatic method of tunnel lining. The new device utilizes low-pressure air and the movement of the concrete through the pipeline is described as air extrusion. The device has had limited use on corps work so far.

PRECAST SLABS FOR FORMS

Except for a few isolated cases the practice in the United States has been to use forms made of wood, steel, or other materials to contain and shape concrete as it is placed. In Russia in recent years precast slabs of concrete have been widely used as forms. The precast slabs are left in place and become a part of the structure. Cost comparisons made in the past have favored conventional forms of wood, steel or other materials over precast slabs. There have also been technical questions about use of precast slabs for forms which have not been satisfactorily answered and for this reason use of precast slabs as forms has not gained favor in the United States. In spite of past indications the question of use of precast slabs for forms is being reexamined to determine whether or not there is now any advantage to be gained in corps work by this practice.

PREPACKED CONCRETE MIX

A device consisting of a two-compartment rubber bag has been developed by a ready-mix-concrete producer in California for delivering "prepacked concrete mix" to a mixer at the construction site.

Aggregates, water and cement thus may be batched at one location and delivered to another location many miles away for mixing. Aggregate and water are placed in one compartment and cement in the other compartment sealed from the water. The bags which were manufactured by a rubber manufacturing company, are like an automobile tire in construction with rubber coating over nylon cord. The bags are estimated to have a life of about 1,000 reuses.

As far as is known, this device has been used only by the developer up to now. For most civil works it would not be applicable but in unusual situations it might find usefulness and its use is permissible under the corps specifications.

CONSTRUCTION EQUIPMENT AND PRACTICES—EARTH AND ROCK FILL DAMS; GROUTING; TUNNELING; DREDGING; REVETMENTS

EARTH AND ROCKFILL DAMS

Private industry has been encouraged to produce devices which will improve the construction of embankment fills. One item so developed is the heavy-rubber-tired roller which permits more economic compaction of earthfill. Such rollers are made by Bros, Inc., Southest Welding & Manufacturing Co., and Shovel Supply Co., among others. Another compaction item is the vibrating steel wheel roller for use in constructing roller granular fills for embankment. Vibration results in more uniform and greater density than is possible by pneumatic or tamping compaction. Principal suppliers of this equipment are Bros, Inc., and Shovel Supply Co.

GROUT PUMPS

Grout slurries or pastes for consolidation of subsurface materials may be injected by a variety of conventional pumps. To date the principal specifications which these machines have been required to meet have been stipulated as follows: "They shall be double-action, duplex-slush pumps of long-stroke type, having large valve openings and removable valve seats and removable liquid-end liners, and shall be of ample capacity and able to safely withstand the greatest pressure required." A variety of pumps have met these general requirements for grouting. The frequent tendency for thick portland cement grout to "choke" the pipeline through which it is pumped underground has been associated, in part, with the stroke pulse of conventional pumps. In an effort to remedy this pulse effect in the grout fluid line, a slush pump of the type described below has been developed and manufactured by Robbins & Myers, Inc., of Springfield, Ohio.

Progressing cavity (Moyno type) pump.—This recent development in the field of grout pumping equipment has received considerable attention by foundation engineers and construction contractors. Its principal application has been in connection with foundation consolidation by neat portland cement, or portland cement and sand, grouts. It has already been used with very satisfactory results on the Corps of Engineers Beaver and Greers Ferry Dams in Arkansas.

The pump derives its designation, "Progressing Cavity," from its functional design. Stated simply, the device consists of a helical or screw-like rotor that turns within a double-helical or stator or cylinder. The screw-like movement of the rotor within the stator during operation of the pump, produces a cavity in the column of grout moving along the rotor. This discontinuity, however, is immediately rectified by the constant air pressure applied to the premixed grout entering the pump. The result is an even, pulsation-free movement of grout fluid from pump to ground. Observations of operations in the field indicate that control of grout pressures and grout consistencies at the

ground injection point have been greatly improved through use of this pump.

No functional weaknesses or use limitations have been reported to date.

TUNNELING TECHNIQUES

One of the most important developments in tunnel construction in recent years has been the successful use of continuous mining machines. The construction contractors used four such machines to drill the tunnels at Oahe Dam on the Missouri River, S. Dak. The tunnel diameters ranged from 23.25 to 29.0 feet. The miners' cutting heads consisted of rotating discs with cutting teeth mounted on the front surface. Buckets were installed around the periphery of the cutting-heads which, at the bottom of their cycle, scooped up the loose material from the working face, and upon reaching the top, deposited the material through an opening onto a conveyor. A belt conveyor then carried the material to the tunnel portal. Steel tunnel supports were placed from an erection jig located on the forward end of the machine. The cutting, mucking, and support-erecting operations were performed simultaneously while hydraulic rams were moving the machines forward. The continuous mining machines eliminate blasting and provide greater speed, economy, and safety.

DREDGING

Controllable pitch propellers.—The repowering of the hopper dredge *Harding*, in 1958, included the incorporation of C–P propellers along with new propulsion equipment. The advantages of C–P propellers include the possible elimination of reverse gears, or electrical reversing equipment, and precludes the necessity for tailshaft brakes. A more efficient propulsion system operation is possible due to the ability of a C–P propeller to operate at the most advantageous combination of revolutions per minute and torque for all power requirements. Also, an infinite range of thrust is available, from zero to full power, as opposed to the standard fixed throttle and pitch conditions inherent in conventional propeller drives. Figure 16 and figure 17 show schematic diagram and control system.

C–P propellers will be included in the design of the new SWD hopper dredge, and were included in the recently completed MV *Mississippi*.

Hopper dredge sidecasting.—This is a method of agitation dredging with hopper dredges whereby dredged material is removed from the channel bottom and deposited a short distance on either side of the channel by discharging through a boom-supported pipe projecting over the side of the dredge. Data gathered from the operation of the commercially operated dredges *Sealane* and *Zulia* reflect outstanding savings over other dredging methods in areas where sidecasting can be utilized. The hopper dredge *Hains* has been adapted to this technique by the Detroit district and the new SWD hopper dredge will have this capability incorporated in the design.

Hopper dredge direct pumpout.—A means of depositing dredged material in remote areas on shore via pipelines was incorporated in the hopper dredge *Markham*. The hopper dredges *Comber* and *Essayons* will soon be modified to provide this capability, and the new SWD dredge will also include this feature.

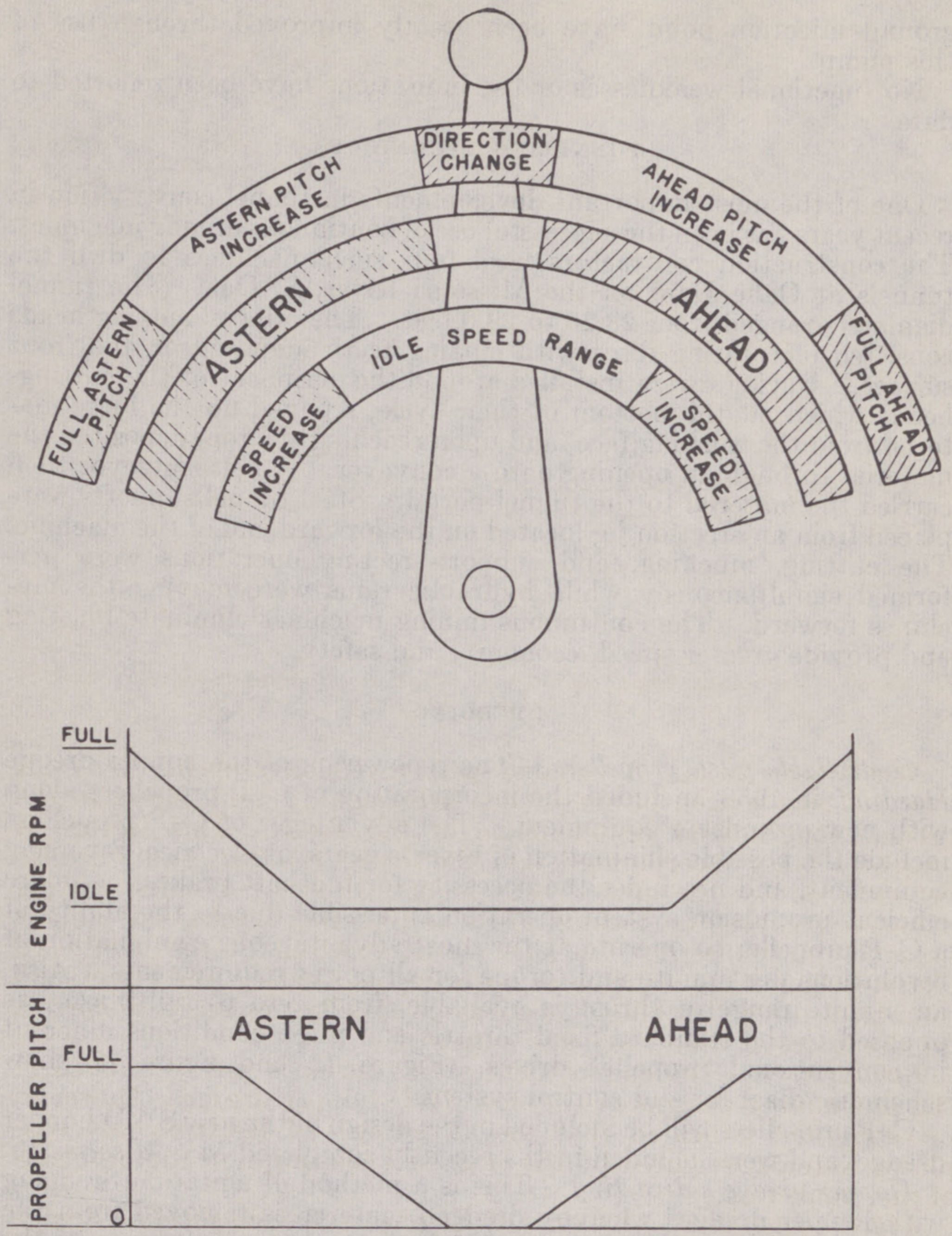

FIGURE 16.—Controllable pitch propellers. Engine rpm and propeller pitch in relation to control handle position for single lever control operation.

Direct pumpout is accomplished by connecting the two (or more) dredge pumps in series, and through proper valving sequence, pumping the dredged material from the hopper bins of the dredge through an overboard discharge connection which has been connected to a pipeline system providing shore disposal. The additional power required by the dredge pumps to overcome the pipeline back pressure inherent in this operation is obtained by utilizing the greater capacity of the hopper dredge's propulsion generators to energize the pump motors.

This arrangement eliminates the necessity of a separate rehandler unit (such as the *New Orleans*) or the requirement of dumping into a sump area for rehandling with pipeline dredges.

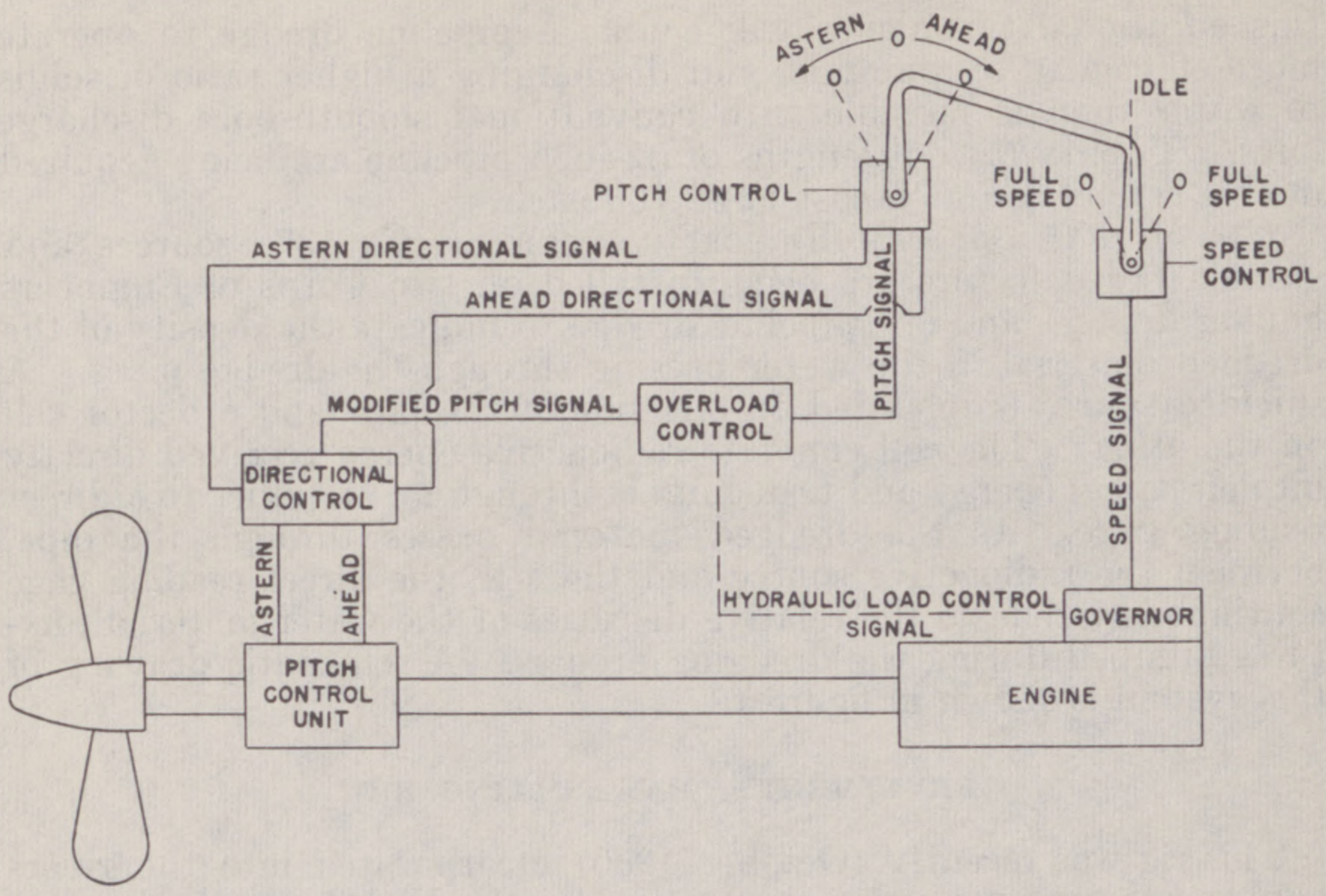

FIGURE 17.—Pneumatic engine speed and propeller pitch control system for U.S. Army Corps of Engineers.

Bow thruster units.—A variable speed reversible propeller was built into the bow section of the dredge *Markham* at right angles to the vertical longitudinal center plane of the vessel. This feature is currently being incorporated into the dredge *Goethals* and will also be included in the new SWD hopper dredge. Besides cutting maneuvering time in docking areas and turning basins, this unit is valuable in countering the side thrust reaction of the overhoard discharge line when a dredge is operating as a sidecasting vessel, and minimizes other "crabbing" maneuvers usually necessary to correct for the forces of wind, tide, and current.

Gas turbines.—The employment of gas turbines was considered in the preliminary designs of the new SWD hopper dredge. However, investigations indicated that the advantages of lightness and simplicity were outweighted by the large fuel consumption and problems of fuel bunkering.

Rifled dredge pipe.—A Corps of Engineers 32-inch pipeline dredge operating in the Mississippi River is being experimentally equipped with several sections of rifled discharge line. The rifling is accomplished by attaching three helical strips, spaced 120° apart, to the interior surface of the experimental pipeline sections. The helical strips extend one-third the length of the sections and are pitched to make one complete turn in each 26 feet of the 32-inch-diameter pipe. Rubber, stainless steel, and mild steel are each being utilized in the fabrication of these strips, to determine which is the most suitable for this application. The strips have a radial dimension of 4 inches or one-eighth of the diameter of the dredge pipe. The purpose of these helical forms is to add turbulence to the dredged material and water mixture as it leaves the dredge pump and travels through the pipeline. The tests are being conducted to determine whether or not

this additional turbulence will enable a pipeline dredge to operate more efficiently by pumping and discharging a higher ratio of solids to water than is possible with conventional smooth-bore discharge lines. Twenty 52-foot lengths of 32-inch pipeline are being acquired in this connection at a cost of $2,700 each.

Use of radioisotopes.—Radioactive cesium (Cs 137) sources and gamma ray defectors are being installed on two Corps of Engineers hopper dredges and one pipeline dredge to indicate the density of the dredged material in the water passing through the dredge pipes. A shielded source is mounted on one side of the pipe and a dector cell on the other. The cell converts radioactive energy received directly into electrical energy and transmits it through an amplifier to a direct reading gage. As the dredged material passes through the pipe, between the radioactive source and the cell, the direct reading gage continuously reflects the relative densities of the water-material mixtures pumped during the dredging process. A schematic drawing of this system is shown in figure 18.

REVETMENTS—MAT PULLING RIG

This rig was recently (October 1960) incorporated into the river-bank protecting mat laying operation by the Vicksburg district. It consists of a series of large earthmover-type pneumatic tired wheels connected by a loose jointed frame. This frame accommodates the

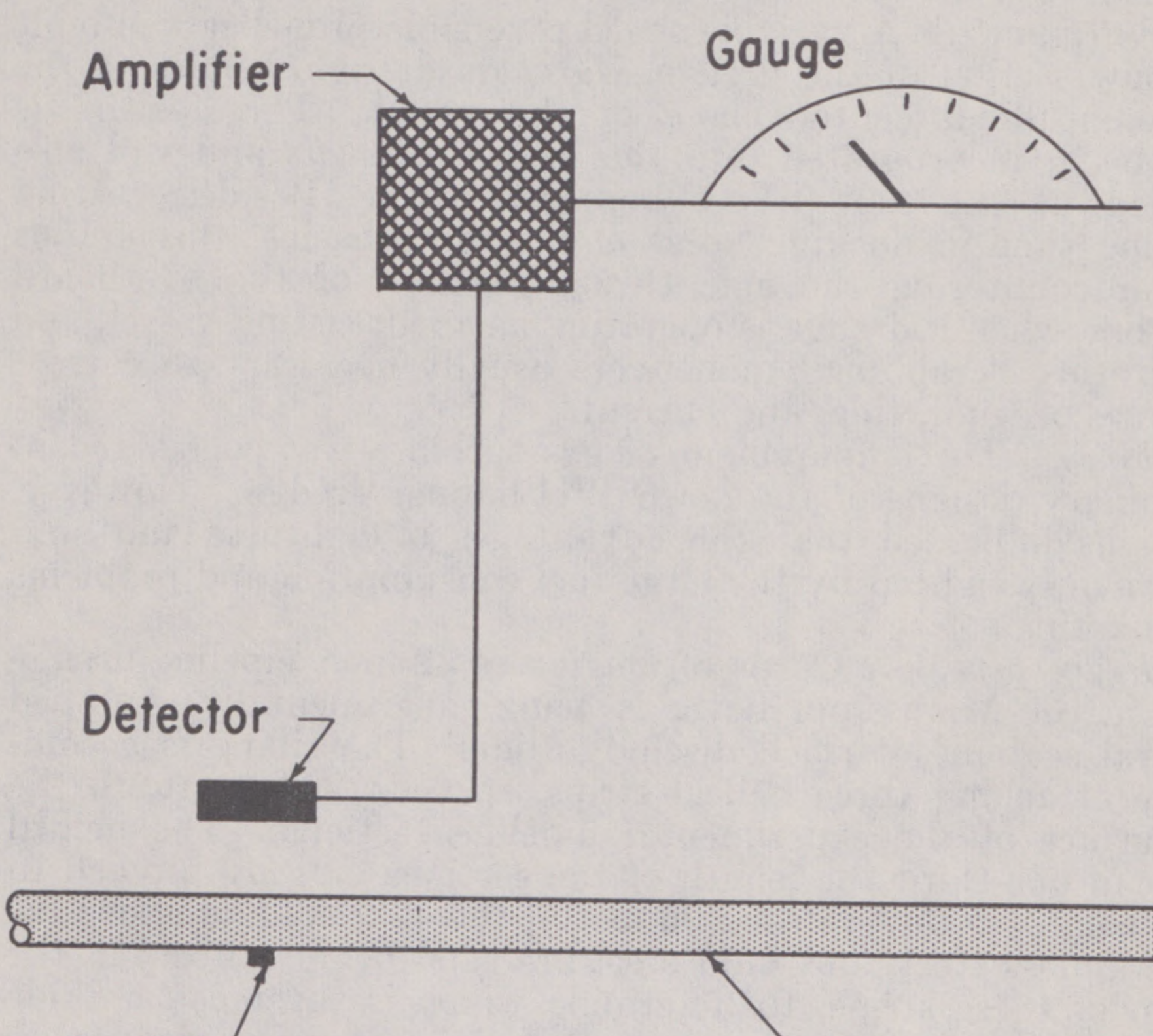

FIGURE 18.—Radioactive cesium—Cs 137 dredge pipe density guage.

full width of the leading edge of the articulated concrete mattress as it leaves the mattress construction barge. The buoyancy of the large tires keeps the pulling rig afloat until sufficient length of mattress has been assembled on the barge to allow the leading edge to reach the shoreline. By means of three winch-equipped D–8 tractors, the leading edge of the mattress is pulled up to the desired elevation on the riverbank and is supported by the pulling rig. After the mattress is anchored in place on the bank, the pulling rig is allowed to roll back down the bank over the top of the installed mat, and floats into position alongside the mattress fabricating barge to receive the next section of mattress. Use of this rig minimizes the strain on the hauling winches and the connecting linkage of the articulated concrete mattress thus helps prevent breakage of cables, saves labor, time, and repair costs.

OPERATION AND MAINTENANCE

CLOSED-CIRCUIT TELEVISION

A closed-circuit television system is in use at the Dalles hydroelectric project to permit remote surveillance by the powerplant control room operators of the dam spillway and navigation lock gates for increased safety of operation and to permit surveillance of the project entrance areas for security. Four strategically located television cameras equipped with remotely controlled pan, tilt, and multiple lenses provide both detailed and general surveillance of the areas involved. Video signals are transmitted from the pickup cameras to the monitor screen in the control room through approximately 2 miles of triaxial cable. Two cameras are used in the spillway gate system. One camera upstream is used for observation of the forebay and upstream gates areas. A second camera downstream is used to observe the downstream spillway gate area including downstream river and lock areas. Spillway gate position, the presence of small craft in the intake and downstream areas, and the presence of trash in the immediate gate area are easily observed by these cameras.

Two cameras are used in the security system. One camera at the north entrance gate to the project is used for identification of personnel and general project access area surveillance. This installation also includes remote gate opening and closing and voice communication between the security building and the gates. The second camera is used to observe the visitors area around the Washington shore fish ladder and to keep equipment storage areas under general surveillance. The TV installation is capable of 600-line horizontal resolution under normal lighting conditions and provides excellent picture detail.

It is expected that the use of this equipment will increase the safety and efficiency of project operations and will permit a reduction in the number of security personnel required. This equipment is available from five or more manufacturers.

ELECTRONIC OPERATION RECORDERS

Electronic operation recorders using static solid state construction except for the printing mechanism have been provided in the control rooms of hydroelectric powerplants to provide printed records of abnormal conditions, equipment troubles, and selected equipment operations. Their use simplifies and saves time in trouble-shooting and increases plant operating efficiency. This equipment is available from at least three manufacturers.

SEMIAUTOMATIC LOAD-FREQUENCY CONTROL

Facilities are being installed at Bonneville, McNary, The Dalles, and Chief Joseph powerhouses to operate in conjunction with facilities provided in the load dispatcher's office of the Bonneville Power

Administration, Portland, Oreg., which will provide semiautomatic load control of selected generating units at five Federal hydroelectric powerplants on the Columbia River. Provisions are also being made for future extension of the facilities to include semiautomatic load control at other Federal hydroelectric plants in this area. The equipment is being furnished by the Leeds & Northrop Co., Philadelphia, Pa., and consists of a system deviation console and a station alocator console from which control signals will be transmitted to each of the controlled powerplants by microwave radio. It is anticipated that the use of this load-frequency control equipment will result in increased efficiency in the use of water for power production, improved system frequency regulation, closer control of power interchanges over tielines, and better control of the interconnected power system during emergencies.

SUPERVISORY CONTROL AND SUPERVISION OF HYDROELECTRIC POWERPLANTS FROM REMOTE LOCATIONS

Seven Corps of Engineers hydroelectric powerplants currently in operation and under construction are designed for unattended operation (except for maintenance personnel) with control from other remote attended plants, using direct wire, powerline carrier, or microwave radio channels for supervisory control, supervision and telemetering. Other powerplants under design will also be controlled in a similar manner wherever this type of control is determined to be suitable and economical.

AUTOMATIC COMPUTER CONTROL OF HYDROELECTRIC POWERPLANTS

Studies are being made to determine the feasibility and economy of providing closed loop automatic electronic computer control of groups of hydroelectric powerplants, particularly in cases where several plants are located on the same river or in the same watershed. It is believed that such control will result in optimum operation of such multipurpose plants for flood control, power generation, navigation, and related purposes.

CATHODIC PROTECTION TO REDUCE PAINTING COSTS FOR SUBMERGED STEEL

Painted submerged hydraulic structures, in general, will corrode at breaks in the paint film and, after a number of years, in those places where the paint has deteriorated. To mitigate this corrosion, a cathodic protection system is installed. The purpose of this system is to eliminate galvanic (electrochemical) action which occurs between dissimilar metals or areas of the same metal when in a corroding medium. This is accomplished by impressing an external cathodic current onto the structure which polarizes the corrosion cells and neutralizes the corrosion current. Tests have been conducted in the laboratory and on field installations to determine design criteria and installation techniques to produce a cathodic protection system which will give complete protection at maximum efficiency without destroying the paint coating. Experience has shown that a paint coating will last twice as long when cathodically protected. In those cases

where the structure is submerged in sea water, it has been determined that the most economical protection can frequently be obtained by eliminating the paint coating on those surfaces continually submerged and applying cathodic protection to the bare steel. Thus the cost of maintaining submerged hydraulic structures has been substantially reduced by increasing the life of the paint coatings and in special cases by the elimination of the paint coating.

ELECTRONIC SURVEYING

Numerous types of electronic distance measuring and radiolocation systems have been investigated and are used in civil works activities for the precise measurement of distances in land surveys and for the accurate location of soundings in hydrographic surveys of rivers, harbors, dam reservoirs, and the Great Lakes. The use of the above electronic devices and systems has resulted in faster and more accurate surveys; reduction in personnel required; ability to make surveys during fog, darkness, and rough weather when conventional survey methods would not be feasible; and, in general, more efficient and economical operations.

The types of electronic equipment used and investigated for precise distance measurements include:

Tellurometer.—This equipment is manufactured by Tellurometer (PTY) Ltd., Cape Town, Union of South Africa, and distributed by Tellurometer, Inc., Washington, D.C. The system uses microwave radio and the commercial version costs about $11,000 for a complete system.

AGA Geodimeter.—This equipment is manufactured by Svenska AB Gasaccumulator, Stockholm-Lidingo, Sweden, and distributed by Berg, Hedstrom & Co., Inc., New York, N.Y. The system used reflected modulated light and therefore is restricted to nighttime use. The estimated cost is $12,000 to $15,000 for a complete system.

Model DM–20 electrotape.—This equipment is manufactured by the Cubic Corp., San Diego Calif. This equipment is similar to Tellurometer, using microwave radio, and the estimated cost for a complete system is $12,500.

Type DM Raydist range system.—This equipment is manufactured by Hastings-Raydist, Inc., Hampton, Va., and measures distance by means of phase comparison of continuous wave signals. This equipment is particularly applicable where extreme accuracy is not required and where errors in distance of a few feet can be tolerated. It is also particularly suitable for use with boats and moving vehicles. The equipment for measuring single distances is estimated to cost $25,000.

Radio location systems.—The types of radiolocation systems investigated and used for the location of soundings in hydrographic surveys include the following:

Raydist—manufactured by Hastings-Raydist, Inc., Hampton, Va. All Raydist systems used phase-comparison of continuous wave signals as the means of measurement. The type E system is a hyperbolic system requiring three shore-based stations at known points in addition to the master station aboard the boat. The type DM system presents the data in terms of distances from the boat to two separated stations located at known points on shore. The location of the boat is determined by plotting fixes using the measured dis-

tances. The estimated costs of type E and type DM Raydist systems are $50,000 and $40,000, respectively. The accuracy of plotted positions obtainable with the above systems is in the order of 5 to 10 feet at distances up to 10 miles from the shore-based stations.

Shoran.—This equipment obtained from the Air Force is used by the U.S. Lake Survey for the location of offshore soundings in the Great Lakes. Shoran measures the distances from the moving boat to two transponder stations located on shore by measuring the time required for round-trip transmission of signals, and the position is determined from plotted fixes. This equipment is used in areas beyond the range of conventional survey methods and in areas where Raydist is not applicable. The cost of a complete Shoran system is estimated to exceed $100,000.

RADIO EQUIPMENT—COMMUNICATIONS

Many Corps of Engineers civil works radio communication installations are now using single sideband units for communication between districts and divisions. This system is utilized to insure better voice communications because of its spectrum and power economy and because it is less susceptible to the effects of selective fading and interference than AM systems.

RESERVOIR CLEARING

In a continued effort toward reducing the cost of clearing reservoirs, the Le Tourneau tree crusher has been tested recently in clearing a reservoir. With the massive machine, trees and brush are literally crushed into a compressed mat. The machine used had an overall length of 39 feet, 10 inches, overall height of 15 feet, and weighed approximately 50 tons. The purchase price of this machine is approximately $82,000. Although the data compiled in the test have not been completely analyzed at this time, it appears that the use of this type of machine may result in substantial savings in some instances.

NUCLEAR TECHNIQUES—PEACEFUL PURPOSES

GENERAL

The Atomic Energy Commission, through its Plowshare program, has made extensive studies of past underground nuclear explosions to determine the feasibility of using nuclear explosives for peaceful purposes. These studies have cast considerable light on the characteristic effects of underground explosions and have suggested a number of peaceful applications. The suggested uses include, but are not limited to, excavation and the construction of aquifers. These two applications are of particular interest to the Corps of Engineers. The techniques of using nuclear explosives for such purposes are still in the early stages of development; however, present scientific data are sufficient to indicate the feasibility of using this new method of construction for large-scale excavation projects. The application of nuclear energy for peaceful purposes has tremendous potential since it can make possible many large excavation projects which are not now feasible or economically justified by present excavation methods. The Civil Works Division of the Office of the Chief of Engineers is keeping abreast of the new developments and techniques in order that they may be applied to applicable civil projects. Recent studies indicate that nuclear excavating can be employed with complete safety for human life and that it may result in great cost savings on certain large-scale excavation projects. Additional investigations will be required to perfect the techniques so that projects can be engineered and executed with optimum success and the greatest cost savings. The application of nuclear devices to civil projects and the securing of additional data is being closely coordinated with the Atomic Energy Commission and the Department of Defense.

EXCAVATION

When chemical high explosives are used in excavation work, they are normally used to break up the rock so that it can be moved by mechanical means. The earthmoving by machinery is the major cost in such projects. In nuclear excavation, the forces of the explosion can be used to move the materials from the excavation, thus eliminating the need for costly earthmoving equipment.

By detonating the nuclear devices fairly deep underground optimum crater dimensions are obtained, thus increasing their efficiency. When the devices are detonated at slightly greater than optimum depth, the blast effects are significantly reduced and only a few percent of the radioactivity escapes to the surface. By the use of the cleaner nuclear explosives the release of activity is reduced even further. Most of the radioactivity which does escape is scavenged by the heavy dust cloud formed by the explosion and falls back to earth very close to the excavation.

Construction—Harbors, canals, waterways, dams.—Specific applications for nuclear excavation are projects such as harbors, canals, waterways, and dams. It is feasible to execute many of these projects now, but possibly not with optimum success.

The construction of channels for harbors and canals is done by detonating rows of nuclear devices underground. It has been found that when the charges are spaced at approximately one crater radius apart, simultaneous detonation results in a relatively smooth channel. Proper choice of yields and depths of burst enable one to form a channel meeting or exceeding the desired specifications.

The potential use of explosions to purposely create a landslide dam is not new. Such a possibility was considered several years ago. Recent events suggest that the landslide dam concept may be worthy of additional study. As a result of the Hebgen Lake earthquake in Montana, there now exists in Madison Canyon, Mont., an excellent example of a natural landslide dam. Under certain circumstances nuclear techniques might be used for constructing dams at desired locations by placing nuclear devices in a canyon wall to initiate a rockslide to form the dam. If such a dam were to be used for flood control, water supply or other uses requiring an impervious structure, considerable addtitional work would be involved.

Quarrying and mining—Rock, coal, etc.—Usually open-pit mining requires the removal of large quantities of waste material to recover the rock ore or coal beneath. It appears feasible to use nuclear explosions to remove the overburden at a reduction in cost. The use of these devices for mining would perhaps open a new look at what are presently low-grade ores. It is understood that the Bureau of Mines has given some consideration to this subject.

During one of the nuclear tests at the AEC's Nevada Test Site, several million tons of rock were produced as a direct result of the explosion. This created a highly permeable zone which extends from the ground surface to some depth below the shot point. These results suggest that it might be possible to use nuclear explosions in mining or producing large quantities of rock for riprap purposes. There are probably other uses of nuclear explosions in mining and quarrying operations.

AQUIFERS

Part of the Plowshare program has been concerned with the investigation of ways in which the movement of underground water can be influenced by nuclear explosions. Some preliminary studies along these lines have been made. Some attempt has been made to determine the extent to which nuclear energy can be utilized to improve the water situation. In a region where water is removed from an underground supply faster than it is being returned by either natural processes or by human effort, there is a lowering of the water table and in some cases, inferior quality water may infilter, also the ground overlying the water supply may subside. In areas where the subsurface material is impermeable and the natural water supply depends on precipitation, the ground water balance may be improved by the detonation of a nuclear device to shatter the impermeable layer. In other words, it may be possible to create a region of apparently high permeability out of almost impermeable material.

In streams which are characterized by seasonal high flows of good quality water, followed by periods of low flow saline water, it may be feasible to use nuclear explosives to divert the saline water by creating an off-channel reservoir or by creating a conduit to divert the saline water through natural mineralized aquifers. The use of nuclear explosives affecting ground water supply would be preceded by extensive tests of the behavior of fission products in the appropriate medium, in order to guarantee that there would be no danger to public health.

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