A SUMMARY OF THE WORK OF THE

FEDERAL INTER-AGENCY SEDIMENTATION PROJECT

Report S

Prepared for the
Federal Inter-Agency Sedimentation Conference
of the
Subcommittee on Sedimentation, ICWR
Jackson, Mississippi
28 January - 1 February 1963

A Study of Methods Used in

MEASUREMENT AND ANALYSIS OF SEDIMENT LOADS IN STREAMS

A Cooperative Project
Sponsored by the
Subcommittee on Sedimentation
Inter-Agency Committee on Water Resources

Participating Agencies

Army Corps of Engineers	**	Geological Survey
Soil Conservation Service	**	Bureau of Reclamation
Agricultural Research Service	**	Coast and Geodetic Survey
Tennessee Valley Authority	**	Federal Power Commission
Bureau of Public Roads	**	Department of Labor
Forest Service	**	Bureau of Mines
Public Health Service		

REPORT S

A SUMMARY OF THE WORK OF THE INTER-AGENCY SEDIMENTATION PROJECT

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for the
Federal Inter-Agency Sedimentation Conference
of the
Subcommittee on Sedimentation, ICWR
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ABSTRACT

The Inter-Agency Sedimentation Project was initiated in 1939 mainly to develop improved sediment sampling instruments and techniques for measurement and analysis of sediment loads in streams. In 1956, the purpose of the project was expanded to include the solution of sedimentation problems that are of common concern to federal agencies on the Subcommittee on Sedimentation of the Inter-Agency Committee on Water Resources, with special emphasis on methods of sampling automatically.

Manually operated sediment samplers developed and currently recommended for field use include: (1) three depth-integrating suspended-sediment samplers which collect samples continuously from the stream as they are lowered from the surface to the bed and raised back to the surface; (2) two point-integrating suspended-sediment samplers with electrically operated valves; and (3) three bed-material samplers.

Instruments have been developed such as the single-stage sampler which is in widespread use, and the pumping samplers which are in the field-testing stage, for obtaining samples or sediment information automatically from flashy streams when no observer is present.

Two sediment size analyzers have been developed. The bottom-withdrawal tube is a sedimentation device for size analysis of sediments finer than 0.7 mm. The visual-accumulation tube is a sedimentation device for the particle size analysis of sand samples.

Methods for determining concentration and particle size gradation which are being explored are: electronic sensing, turbidity, ultrasonic sensing, and nuclear.

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HISTORY AND PROGRAM OF THE PROJECT

Several agencies of the United States Government organized an Interdepartmental Committee in 1939 to study problems in collecting sediment data and to develop, improve, and standardize methods and equipment for determining the quantity and character of sediment carried by streams. The initial project was under the general supervision of Professor E. W. Lane of the Iowa Institute of Hydraulic Research. In April 1946, the activities and functions of the Committee were transferred to the Subcommittee on Sedimentation of the Federal Inter-Agency River Basin Committee. One of the objectives of this Committee is the coordination of the hydrologic activities of the Federal Departments through the assistance of several subcommittees. In June 1948, the project was transferred from the Iowa Institute of Hydraulic Research to the St. Anthony Falls Hydraulic Laboratory of the University of Minnesota in Minneapolis, Minnesota. In 1955, the name of the parent Committee was changed to the current designation, Inter-Agency Committee on Water Resources.

In 1956, the Subcommittee on Sedimentation adopted a Guidance Memorandum that outlined the program and organization of the present Inter-Agency Sedimentation Project. The basic purpose of the project is to solve sedimentation problems of common concern to agencies that are represented on the Committee. Since 1956, major emphasis has been on development and improvement of equipment for the automatic collection and analysis of sediment samples.

The executive direction of technical phases of the project is the responsibility of a Technical Committee whose membership is made up of representatives from federal agencies actively interested in sedimentation problems. The Committee provides technical advice and assistance to the project staff, who carry out the development, testing, and calibration of instruments, preparation of technical reports, and other operational phases of the project. The agencies actively cooperating in the project and currently represented on the Technical Committee are: Army Corps of Engineers, Geological Survey, Bureau of Reclamation, Agricultural Research Service, Public Health Service, Forest Service, Tennessee Valley Authority, and Soil Conservation Service. Results of the cooperative study to date are incorporated in a series of technical reports listed in the Appendix. Many sediment sampling devices and analytical methods have been developed by the project.

The following personnel are currently active on the project: Frederick S. Witzigman, who prepared this paper, Russell P. Christensen, and Martin E. Nelson of the U. S. Army Corps of Engineers; and Byrnon C. Colby, Project Engineer, who reviewed this paper, Thomas F. Beckers, and John V. Skinner of the U. S. Geological Survey.

This paper was prepared to summarize major accomplishments of the project. The work of the project from 1939 to the present time may be divided into four phases. The three that relate to the development of sampling or analyzing devices

are discussed in this paper under 'Manual sediment samplers', 'Automatic samplers', and 'Sediment analyzing devices'. Work under a fourth title 'Theories and procedures' is not directly and closely related to the development of specific methods or instruments and is not discussed in this paper but is covered in the reports listed in the Appendix.

MANUAL SEDIMENT SAMPLERS

A series of suspended-sediment and bed-material samplers (some are shown in Fig. 1) that are operated manually have been developed by the project. These samplers are of three types: depth-integrating, point-integrating, and bed material.

Depth-Integrating Samplers

Depth-integrating samplers traverse the stream depth at the sampling vertical to within a few inches of the bed, move at a uniform vertical speed, and receive instantaneously at every point a small specimen of the water-sediment mixture which is later analyzed in the laboratory for sediment concentration and particle size. The nozzle is about 0.3 to 0.4 ft above the bottom of the sampler. The sample container is a round glass pint milk bottle. An exhaust line allows air to escape from the sample container as the sample enters. The sampler is limited to two-way sampling in depths not greater than 18 ft. One or another of the three types of depth-integrating samplers that have been developed by the project can be used satisfactorily for sampling many stream flows. (The 100-lb point-integrating sampler is used for depth-integration when depths or velocities are too great for the heaviest depth-integration sampler.)

The US DH-48 hand sampler is used to obtain suspended-sediment samples from streams that can be waded. The sampler is made of cast aluminum and weighs 4 1/2 lbs. It partially encloses the sample container. A brass intake nozzle points into the stream flow. A standard 1/2-inch wading rod is threaded into the top of the sampler body for suspension.

The US DH-59 hand line depth-integrating sampler, is made of cast bronze and partially encloses the sample container. It weighs about 22 lbs, and is equipped with tail vanes to orient the intake nozzle into the approaching flow. This sampler is suspended on a suitable hand line.

The US D-49 is a 62-lb bronze depth-integrating sampler. A hinged head from which the nozzle projects into the stream flow, permits access to the sample container, which is enclosed in the sampler body. Tail vanes orient the instrument into the stream flow. The sampler is suspended on a steel cable and is lowered and raised by means of a reel mounted on a crane.

Point-Integrating Samplers

Point-integrating samplers collect a water-sediment mixture at one point in the cross-section of a stream. The sample is integrated over the duration of the sampling time. The point-integrating samplers are shaped like the 62-lb depth integrating sampler (US D-49, Fig. 1) and are equipped with a valve that can be operated electrically after the instrument has been lowered to the sampling point. The valve has either two or three positions: (1) a position for equalizing the air pressure in the bottle with the hydrostatic pressure at the sampling point; (2) the sampling position, and (3) a closed position (in some samplers position (1) is used as a closed position). The samplers are made of cast bronze, and are equipped with tail vanes, a pressure-equalizing chamber, and a hinged head that contains the nozzle, valve, and valve operating mechanism. The hinged head provides access to the sample container which is a round glass pint milk bottle enclosed in the sampler body. An exhaust port on the side of each sampler head allows air to escape as the sample container fills. The samplers are suspended on a two-conductor steel cable, reel, and crane.

The US P-46-R sampler weighs 100 lbs. It can be used for point-integration or to depth integrate on a round-trip basis to a depth of 18 ft or in one direction to a depth of 30 ft. Greater depths can be integrated by dividing the total depth into two or more sections of not more than 30 ft each. The sampler has a rotary valve which is operated electrically by a rotary solenoid that has the three positions mentioned above. A signal indicates when the valve is in the sampling position. The valve is operated by a telephone dial switch at the observer's station.

A new 100-lb US P-61 point-integrating sampler is being developed. Two different valve mechanisms have been tested. In the first mechanism a rotary solenoid, when energized, turns a rotary valve from the normally closed and pressure equalizing position to the sampling position and holds the valve open in the sampling position as long as the solenoid is energized. In the other mechanism, the rotary valve has three positions and the valve is turned by a spring and ratchet. A lever on the side of the head is used to cock the mechanism to the first or pressure equalizing position, and a solenoid trips the ratchet to let the spring turn the valve to the second and third positions, successively.

The US P-50 sampler is 3 ft 8 in. long and weighs 300 lbs. Either a 1 quart or a 1 pint round glass milk bottle is used as a sample container. An electrically operated slide valve has two positions. The valve is held in the equalizing position by a spring. Solenoids, when electrically energized, hold the valve in the sampling position. This sampler may be used in high velocities and in depths to 200 ft.

Bed-Material Samplers

A bed-material sampler collects a sample of the sediment mixture of which the stream bed is composed. It should not be confused with a bed-load discharge sampler which samples the rate of discharge of sediment moving as bed load. Only bed-material samplers are described here.

The US BMH-53 is a piston type hand sampler that is used to collect a sample of sediment from the bed of a stream which can be waded. The sampler consists of a cylinder that is 2 in. in diameter and 8 in. long which can be pressed into the stream bed manually. A piston inside the cylinder retracts as the cylinder is pressed into the bed. It helps retain the sample when the sampler is withdrawn and then is used to push the sample from the cylinder. The overall length of the sampler is 46 in.

The US BMH-60 is a 30-lb sampler 22 in. long, made of cast aluminum, and used from a hand line to collect a sample from the bed of a stream, lake, or reservoir. A cross-curved constant-torque (Negator) spring drives a single bucket that swings out of the sampler body to scoop up and completely surround a sample of about 160 cc from the top 2 in. of the streambed. When the sampler is supported by the hand line and the safety yoke is in place, the bucket can be cocked to the open position in which the bucket is completely retracted into the sampler body. As long as the safety yoke is in place on the hanger, the bucket mechanism cannot be released. When the sampler is supported by the hand line and the yoke is removed, a sample can be taken by lowering the sampler onto the stream bed until the suspension line is slack. When the sampler rests on the streambed, the mechanism trips and a sample is taken from the bed.

The US BM-54 is a 100-lb cast iron, bed-material sampler, 22 in. long. When supported by a steel cable, the bucket can be cocked to the open or sampling position. When tension on the cable is released by resting the sampler on the streambed, the mechanism is tripped; and the single bucket, powered by a spiral spring, swings out of the bottom of the sampler body and scoops a sample from the top 2 in. of the streambed. The bucket surrounds and encloses the sample in such a way that none of the sediment is washed out.

AUTOMATIC SAMPLERS

Two types of so-called automatic suspended-sediment samplers have been designed and tested by the project. One is called the single-stage sampler, and the other is the pumping sampler which has three methods for handling the sediment samples. These samplers are automatic in that they may be installed at the sampling station and set to collect samples even when unattended.

Single-Stage Sampler

A single-stage sampler is a simple device, which was developed for use on flashy and intermittent streams, at remote or not easily accessible sites where adequate samples cannot be obtained manually. 1/ The sampler (Fig. 1) consists of

1/ Reference Report 13, see Appendix

a container equipped with intake and exhaust tubes designed to obtain a single suspended-sediment sample automatically when the water surface first rises to a selected stage that submerges the sampler. The sample is collected with respect to gage height and not time.

Samples taken with single-stage samplers are not as representative of the sediment concentration in the stream cross section as are samples taken with manual samplers, therefore, the latter samplers should be given primary consideration at every station. However, the single-stage sampler provides a means of obtaining some suspended-sediment data for streams or storms which would not be sampled otherwise.

A single-stage sampler installation consists of five basic parts:

(1) A sample container such as a 1-pint glass milk bottle.

(2) A siphon-shaped copper air-exhaust tube, with an inside diameter of about 3/16 in.

(3) A siphon-shaped copper intake tube and nozzle, with an inside diameter of about 3/16 in.

(4) A tight-fitting stopper which seals the bottle and has two holes which hold the tubes tightly in place.

(5) A rack for supporting and protecting one or more samplers one above the other, to sample at different stages.

Single-stage samplers have the following desirable qualities:

(1) Samplers may be installed at the station well in advance of a flood or rising stage.

(2) No one need be present at the time of sampling.

(3) Samples may be obtained at predetermined stages of the stream.

(4) Sampling apparatus is inexpensive.

Limitations of the sampler which may cause errors are:

(1) Samples are collected at or near the stream surface, and usually near the edge of the stream or near a pier or abutment.

(2) Size, shape, and orientation of intake and air exhaust elements may fail to provide intake ratios (average velocity in nozzle to stream velocity approaching nozzle) sufficiently close to unity to sample sands accurately.

(3) Obstructions due to the presence of trash and drift during sampling may create unnatural flow lines at the sampler nozzle and cause inaccurate sampling, which may not be detectable later.

(4) Flow may circulate through the sampler after the original sample has been collected.

Four types of single-stage samplers have been designed for different sampling conditions. The vertical-intake type is accurate only for sediments finer than 0.062 mm, for water-surface surges less than 4 in. and for velocities that are reasonably low at the sampling point. Its sampling efficiency usually is little affected by drift and debris, by circulation through the sampler, or by a reasonable amount of shielding if the sediments are fine.

Any one of three horizontal intake nozzles may be used to sample sands as well as fine sediments. The intake nozzles are inclined downward at 20°, 15° or 10° to prevent deposition of sediment in the intake prior to sampling. The smaller angles are used with higher velocities because at high velocities sediment is less likely to deposit in the nozzle. The height of the siphon-shaped intake and exhaust tubes is selected to accommodate the velocity and surge conditions at the sampling site.

Pumping Samplers

Pumping samplers with three different sample handling systems have been developed and tested. 2/ These samplers automatically obtain frequent samples of suspended-sediment concentration of a stream that may not be readily accessible to an observer. Samples are taken from one point in the stream, the point at which the pumping intake is located. Each sampler consists of an intake, pumping system, and sediment handling system.

The intake can be a 1-in. opening in a plate mounted flush on the face of a guide wall that is parallel to the stream flow. The inflow is through a hose to a pump that delivers the sample to a collecting and recording system. A trap in the intake line prevents small fish from reaching and jamming the pump. Any obstruction lodged in the trap is flushed back to the stream just before sampling. The pumping system is operated by a timing device which can be adjusted to take samples at any desired frequency. A safety system shuts off the sampler for 12 hours if the water level falls below the intake or the intake is obstructed.

In the accumulated weight recording system, samples enter a settling tank where the sediment settles onto a tray. The accumulated weight of sediment is measured by a spring-transformer scale and recorded on a strip chart. The pumping, collection, and recording equipment are housed in an 8 by 10-ft shelter. The system has a total capacity of 1,300 lbs of sediment and records accumulated

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2/ Reference Report Q, see Appendix

weight to the nearest 2 or 3 lbs throughout each of thirteen 100-lb increments. The average concentration of suspended sediment is computed from the weight of sediment accumulated on the tray and the volume of pumped sample for the measurement period. This sampler obtains a time-weighted concentration that is accurate for fine sands and coarse silts during periods of steady flow; but sudden, or short time, changes in concentration may not be defined.

The sediment volume recording system (Fig. 2) consists of: a rack which supports 12 sedimentation tubes each having a constricted section at the bottom for measuring sediment volume, a 16-mm movie camera for recording the column of sediment and the water level in the sedimentation tube, and a concentric bottle rack which carries 72 pink milk bottles for collecting check samples for analyses in the laboratory. A sample is pumped into one of the sedimentation tubes each half hour. About 5 1/2 hours later, the camera takes a picture of the accumulation of sediment in the constricted section of the tube and also of the height of water in the tube. Then the tube drains in preparation for taking another sample 6 hours after the previous sample was taken. The volume of each sedimentation tube has been calibrated against height of filling so that the volume of the sample and the volume of accumulated sediment can be determined from the picture. The relation of volume ratio to weight concentration is determined for various particle size ranges of sediment encountered at a sampling station. A splitter on top of one of the 12 sedimentation tubes diverts part of the sample to a pink milk bottle every 6 hours. The milk bottle sample may be analyzed later in the laboratory as a check on the concentration obtained from the pictorial record. This method is not always satisfactory where the percentage of clay and silt is high because the water may be too turbid for a good picture of the water-sediment interface.

The individual-sample bottling system (Fig. 2), collects samples in pink milk bottles for analysis in the laboratory. The sample handling system consists of two concentric bottle racks, one above the other, which carry a total of 145 pint milk bottles. Tubes through the upper rack guide the sample to bottles on the lower rack. A special pen records sampling cycles on a river stage recorder. The bottling system can be adjusted to operate for any desired sampling frequency and for any range of river stage by means of a cycling switch and float switch, respectively. This device can collect samples for as long as 72 days without servicing. It is relatively simple and can be made portable.

SEDIMENT ANALYZING DEVICES

Two sediment size analyzers, the bottom-withdrawal tube and visual-accumulation tube, have been developed and four other devices for determining suspended-sediment concentration, or concentration and particle size distribution, are being investigated. The devices include electronic sensing, turbidity, ultrasonic, and nuclear equipment.

Bottom-Withdrawal Tube for Size Analysis of Sediments

The bottom-withdrawal tube was developed to determine size distribution of particles up to 0.7 mm in samples of suspended sediment. 3/ This device is a glass tube 100 cm long and 1 in. in diameter with a volumetric scale along its length. The tube is open at the upper end and contracts to 1/4 in. at the lower end, which is equipped with a quick-acting outlet valve. The sample is uniformly dispersed in the tube. Then the tube is placed in an upright position and samples of known volume are drawn from the bottom at known time intervals. The sediment weight in each fraction is determined by drying and weighing. Then the particle size distribution can be computed by use of an Odén curve. The cumulative size frequency distribution is determined graphically by the intercepts, on the ordinate axis, of tangents to the Odén curve.

Visual-Accumulation Tube for Size Analysis of Sands

The visual-accumulation tube method is a rapid and accurate means for determining the sedimentation-size distribution of the sand in suspended-sediment samples and in stream bed and beach material samples. 4/ The size analysis is based on a stratified sedimentation system in which the sample is introduced at the top of a transparent settling tube containing distilled water (Fig. 3). The sediment accumulates in a contracted section at the bottom of the tube. A manually operated pen is used to trace the height of sediment accumulation on a chart (Fig. 4) which moves at a uniform speed.

The equipment consists of a sedimentation tube and a special recorder. Five sizes of tubes are available. Four tubes have lengths of 120 cm and inside diameters of 1 in. except for the lower ends which have a constricted sand-accumulation section with a diameter of 2.1, 3.4, 5.0, or 7.0 mm. Tubes of these sizes can be used for analysis of samples having a small quantity of sand mostly less than 1 mm in diameter. A fifth size tube is 180 cm long and 2 in. inside diameter and has an accumulation section of 10 mm inside diameter. It is used for analysis of bed and beach or other sands of coarse sizes when sufficient quantities of material are available.

For the visual-accumulation tube method of particle size analysis the sand portion of a suspended-sediment sample is separated from the silt and clay by sieving or by sedimentation. The 180 cm tube is satisfactory for analyzing samples containing sand up to 2 mm in diameter. Analyses are in terms of fall velocity of individual particles of which the sample is composed. A sample can be analyzed in less than 10 minutes, which is faster than a sieve analysis. Experience has shown that this sand size analyzer is a very satisfactory device for determining particle size distribution for sands in the size range from 0.062 to 2 mm.

3/ Reference Reports 7 and 10, see Appendix

4/ Reference Report 11, see Appendix

Electronic Sensing of Sediment

A commercial electronic sensing device (the Coulter Counter, Fig. 5) is being studied to determine its capacity to analyze fluvial suspended sediments for particle size distribution and sediment concentration.

The counter measures and counts individual particles as they pass through a small aperture. A known volume of an electrolyte (aqueous salt solution) that contains the particles in dilute suspension is drawn through the aperture. The resistance between electrodes on each side of the aperture changes whenever a particle displaces part of the liquid in the aperture. A constant voltage is imposed on the electrodes so that the change in resistance produces an electrical pulse that is proportional to particle volume. The electrical pulses are amplified so that they can be screened as to size and counted.

The counter has an adjustable threshold level below which electrical pulses are not counted. The threshold can be set so high that none or only a few of the largest particles are counted. Then it can be lowered in successive steps and a count of pulses larger than each step can be taken. The relation of pulse height to particle volume can be established by calibration with particles of a known size. Thus, the number of particles in each size range can be determined.

Tests indicate that composition or density of the particles has little or no effect on results of the analysis. The analyzer seems to be an accurate method for determining the number and size of particles in the silt size range.

Turbidity Method

The turbidity method of analyzing sediment is being studied. The equipment (Fig. 6) consists of a pump and re-circulating system, sedimentation chamber, and General Electric Recording Turbidimeter, which contains a turbidity detector and a recorder. Turbidity, which is the cloudiness in a liquid, is measured by a photovoltaic cell in the detector and interpreted in the recorder as the ratio of the light scattered by the particles in the liquid to the light transmitted through the liquid. The transmitted light is measured for 15 sec, the scattered light for 45 sec, and the ratio is computed and recorded during the latter period. This cycle is repeated continuously. Stability of the ratio measurement is achieved by using a single light source and a single photovoltaic cell.

The turbidity method for determining particle size distribution and concentration in a suspended-sediment sample consists of two steps. Turbidity of a sample being pumped through the detector is recorded continuously for determination of concentration. For particle size determination, the flow is suddenly stopped and turbidity is recorded against time as particles settle out of suspension. Particles of uniform density and shape fall at rates proportional to their size, and light is obscured in proportion to particle size and

concentration. The relative weight of each particle size group required to obscure light to a given degree is represented by a hiding factor. The weight of sediment in each size group is computed in percentage of the total for each incremental change in turbidity by using the equivalent hiding factor and making adjustment for concentration.

Calibration tests of this method were made to determine the relation of turbidity to the characteristics of various types of sediment. Observed turbidity and settling time were related graphically for each tested concentration. Particle size was computed by Stokes' Law for settling time and temperature observed in the tests. Then particle size was related to turbidity graphically through common values of settling time. Size distribution was computed as cumulative percentage of each size fraction and was presented by a log-probability plot on which cumulative percentage finer is plotted against size. Particle size distribution is defined by computing, from the log-probability graph, the geometric mean diameter and the geometric standard deviation.

After particle size has been determined, concentration is found from a calibration graph (Fig.7) in which turbidity is plotted with respect to concentration, and the geometric mean diameter, d_g, and the geometric standard deviation, σ_g, are used as additional parameters. A graph such as that of Figure 7 is prepared from tests on known samples of the particular type of sediment that is to be analyzed.

The turbidimeter can be adjusted to measure fairly accurately, a wide range of concentrations, from as small as 0 to 10 ppm to as large as 0 to 100,000 ppm. Also, it can measure the sizes of particles within the approximate range from 0.020 to 0.120 mm. Finer particles settle so slowly that a test may take an excessively long time, whereas coarser particles settle so rapidly that an unreasonably tall sedimentation chamber may be required.

The principle of the turbidimeter appears to be adaptable to a field instrument for monitoring concentrations and particle size distributions of suspended sediment pumped continuously from a stream.

The results of a particle size analysis (Fig. 8) of a prepared sample of glass beads were about the same whether made with the Coulter Counter, the turbidimeter, or the visual-accumulation tube.

Ultrasonic Method

Ultrasonic equipment is being developed to determine size distribution and concentration of sediments in sizes from 0.040 to 1.0 mm.

In this equipment (Fig. 9) a high frequency electrical current is imposed on a quartz crystal for about six micro-seconds at a repetitious rate of 200 times a second. The quartz crystal, which is mounted in the wall of a sedimentation tube, converts the electrical pulses into displacement pulses or sound waves. The

wave passes through the fluid in the sediment chamber and strikes a second crystal in the wall on the other side. The two crystals are of matched frequencies. The second crystal acts as a transducer and converts the sound wave to a secondary electrical current. The electrical current is fed back through an attenuator and displayed on an oscilloscope.

The effect of sediment on attenuation of the sound wave is determined as follows: With water in the sediment chamber, the top of the oscilloscope trace is adjusted to a reference line on the oscilloscope screen. Then sediment is introduced into, and circulated through, the sedimentation chamber. The presence of the sediment reduces the height of the trace. Electrical resistance is removed from the attenuator in the secondary electrical circuit until the trace is restored to the original height on the oscilloscope. The electrical resistance that was removed is a direct measure of the energy loss caused by the addition of the sediment. The energy loss varies directly as the concentration of sediment.

Unfortunately, attenuation of ultrasonic energy depends as much on particle size as on concentration. Although the ultrasonic equipment can be calibrated to determine quickly and accurately the concentration of sediment of a known single size, or a single size distribution, the determination of the concentration of sediment of an unknown size distribution is difficult. For sediments that have a size distribution that can be expressed by two parameters such as the geometric mean diameter and the geometric standard deviation, it is possible to determine the size distribution in an unknown sample. Calibration and analysis must cover a range of about 10 frequencies. After the size distribution is determined, the concentration can be found.

The ultrasonic equipment operates reasonably well in the laboratory, although further development will be needed before it will be competitive with more common laboratory methods of analysis. The potential for field use has not been evaluated.

Nuclear Approach to Analysis of Sediment

The possibility of using radioisotopes for determining the concentration of suspended sediments is being investigated. The Atomic Energy Commission and Parametrics, Incorporated, are cooperating with the Inter-Agency Sedimentation Project on a study of nuclear possibilities.

The first phase of the investigation is a study by Parametrics, Incorporated, of the feasibility of using x-ray emitting radioisotopes for the measurement of the solid-liquid ratio in natural waters. The investigation is both theoretical and experimental with emphasis on the following items:

(1) Chemical constituency and variation of sediment and flow.

(2) Investigation to determine whether x-ray, gamma, or beta emitters are best.

(3) After selection of a general type of emitter, determination of availability, cost, and licensing potential.

(4) If a single isotope is strongly suggested from 3, further study of this isotope only. Otherwise, the best two isotopes will be considered for the remaining parts of the investigation. If the multisource method seems best, several isotopes will be considered.

(5) Prediction of detector response, accuracy in determining percentage of solids, and source strength requirements as a function of liquid density and concentration of solids.

(6) Basic confirmation of predictions with limited laboratory experimentation. Modification or sophistication of response theory will be made as indicated.

(7) A preliminary study of the suitability of various detectors as a basis for recommendations.

(8) A preliminary investigation of circuitry techniques suitable for data processing to obtain solids concentration automatically.

FUTURE PROGRAM

Project efforts in the near future will emphasize: (1) preparation of an up-to-date report on the measurement of fluvial sediment discharge; (2) field tests of the pumping samplers, and (3) development work on the electronic sensing, turbidity, ultrasonic, and nuclear devices for analysis of suspended sediment samples in the laboratory and for automatic collection and analysis of suspended sediments in flowing streams.

APPENDIX

List of Project Reports

Reports on the cooperative study of methods used in Measurement and Analysis of Sediment Loads in Streams covers phases indicated by the following titles:

Report No. 1--"Field Practice and Equipment Used in Sampling Suspended Sediment", August 1940

Report No. 2--"Equipment Used for Sampling Bed Load and Bed Material", September 1940

Report No. 3--"Analytical Study of Methods of Sampling Suspended Sediment", November 1941

Report No. 4--"Methods of Analyzing Sediment Samples", November 1941

Report No. 5--"Laboratory Investigations of Suspended-Sediment Samplers", December 1941

Report No. 6--"The Design of Improved Types of Suspended-Sediment Samplers", May 1952

Report No. 7--"A Study of New Methods for Size Analysis of Suspended-Sediment Samples", June 1943

Report No. 8--"Measurement of the Sediment Discharge of Streams", March 1940

Report No. 9--"Density of Sediments Deposited in Reservoirs", November 1943

Report No. 10--"Accuracy of Sediment Size Analyses Made by the Bottom-Withdrawal-Tube Method", April 1953

Report No. 11--"The Development and Calibration of the Visual-Accumulation Tube", 1957

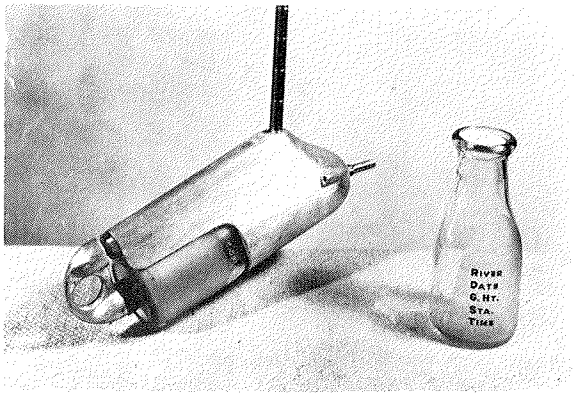
Report No. 12--"Some Fundamentals of Particle-Size Analysis", December 1957

Report No. 13--"Single-Stage Sampler for Suspended Sediment", 1961

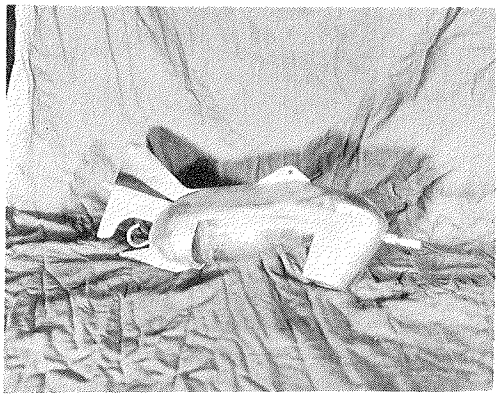
Report AA--Federal Inter-Agency Sedimentation Instruments and Reports, May 1959

Report P--Investigations of Differential Pressure Gages for Measuring Suspended-Sediment Concentrations, June 1961

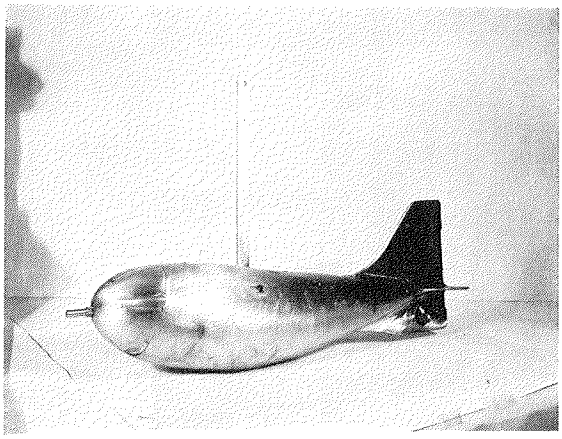
Note: Other lettered reports, A to O, are manuals on sediment sampler operation, or studies of sampler and equipment operation.



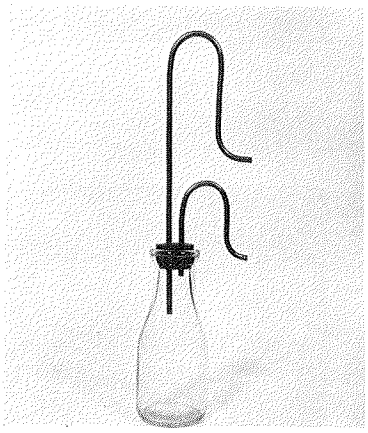
US DH-48 Suspended-Sediment Sampler



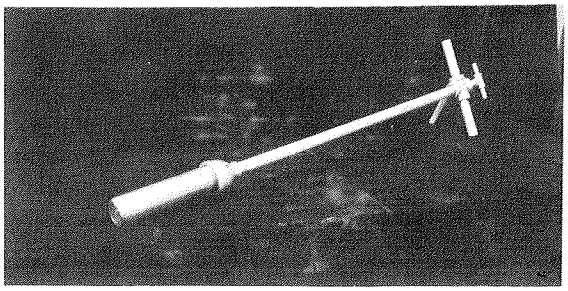
US DH-59 Suspended-Sediment Sampler



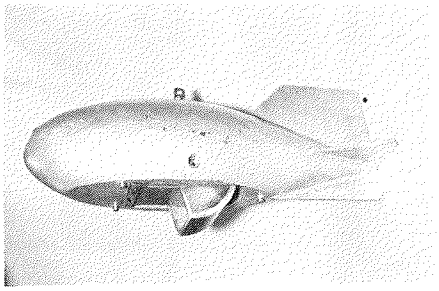
US D-49 Suspended-Sediment Sampler



Single-Stage Sampler



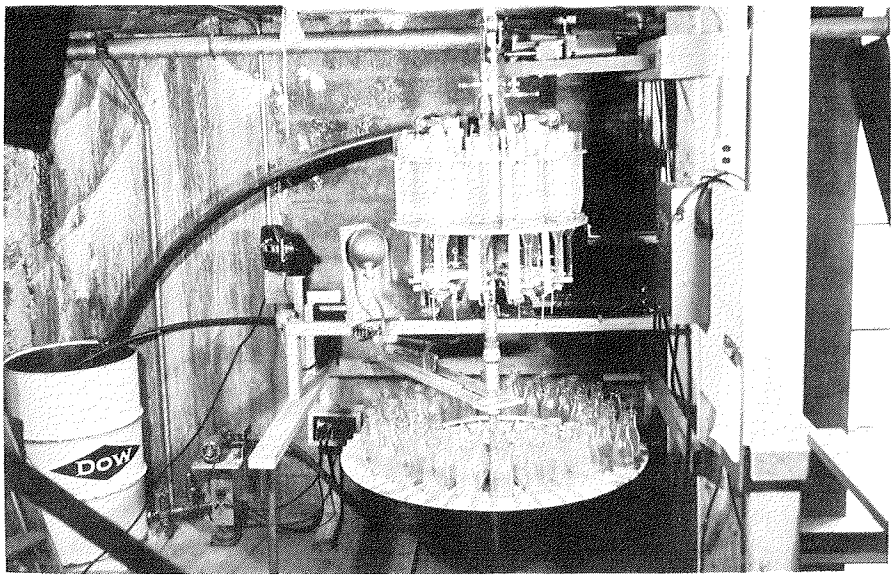
US BMH-53 Bed-Material Sampler



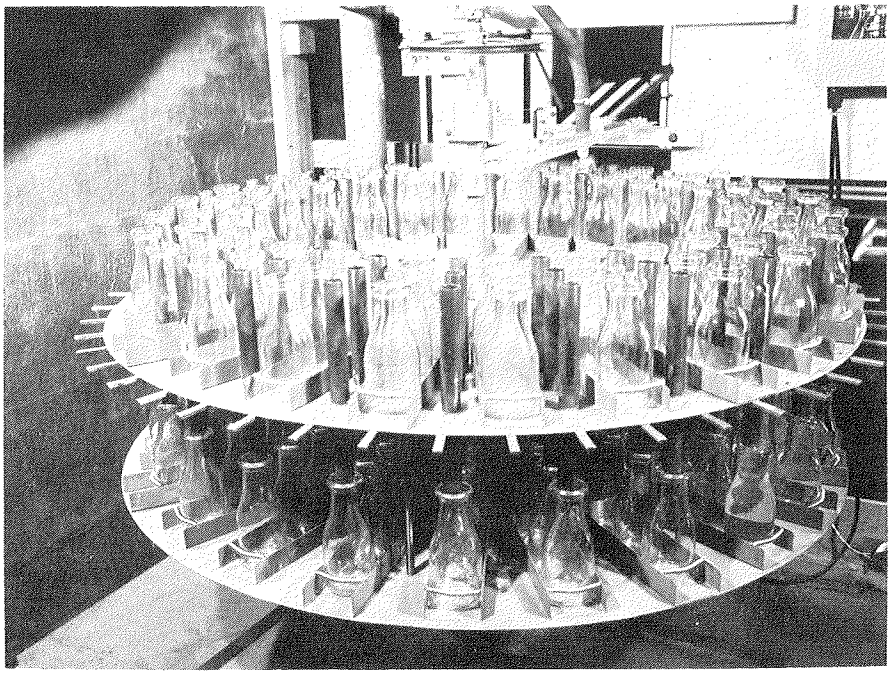
US BM-54 Bed-Material Sampler

SEDIMENT SAMPLERS

FIG. 1



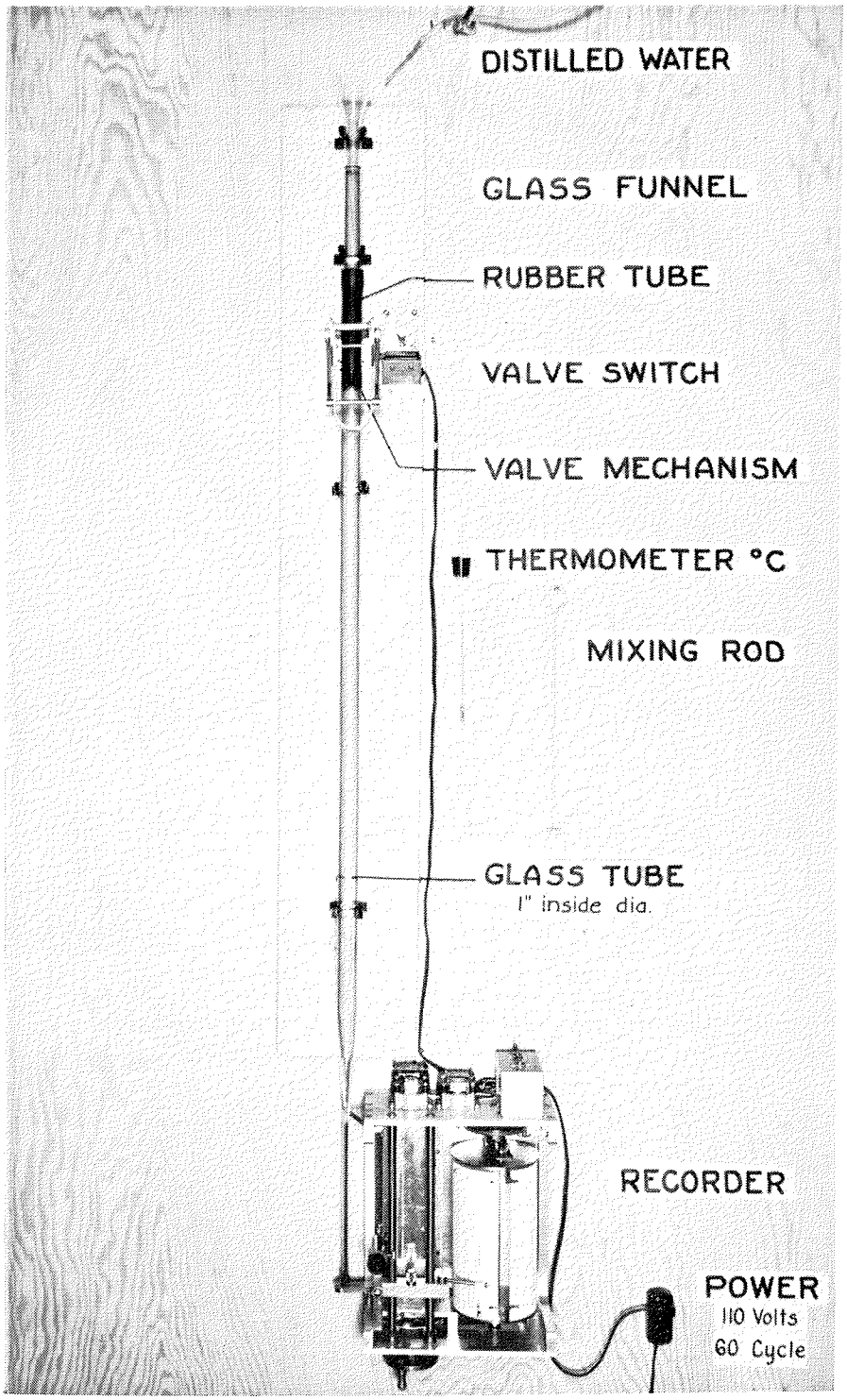
Sediment Volume Recording System



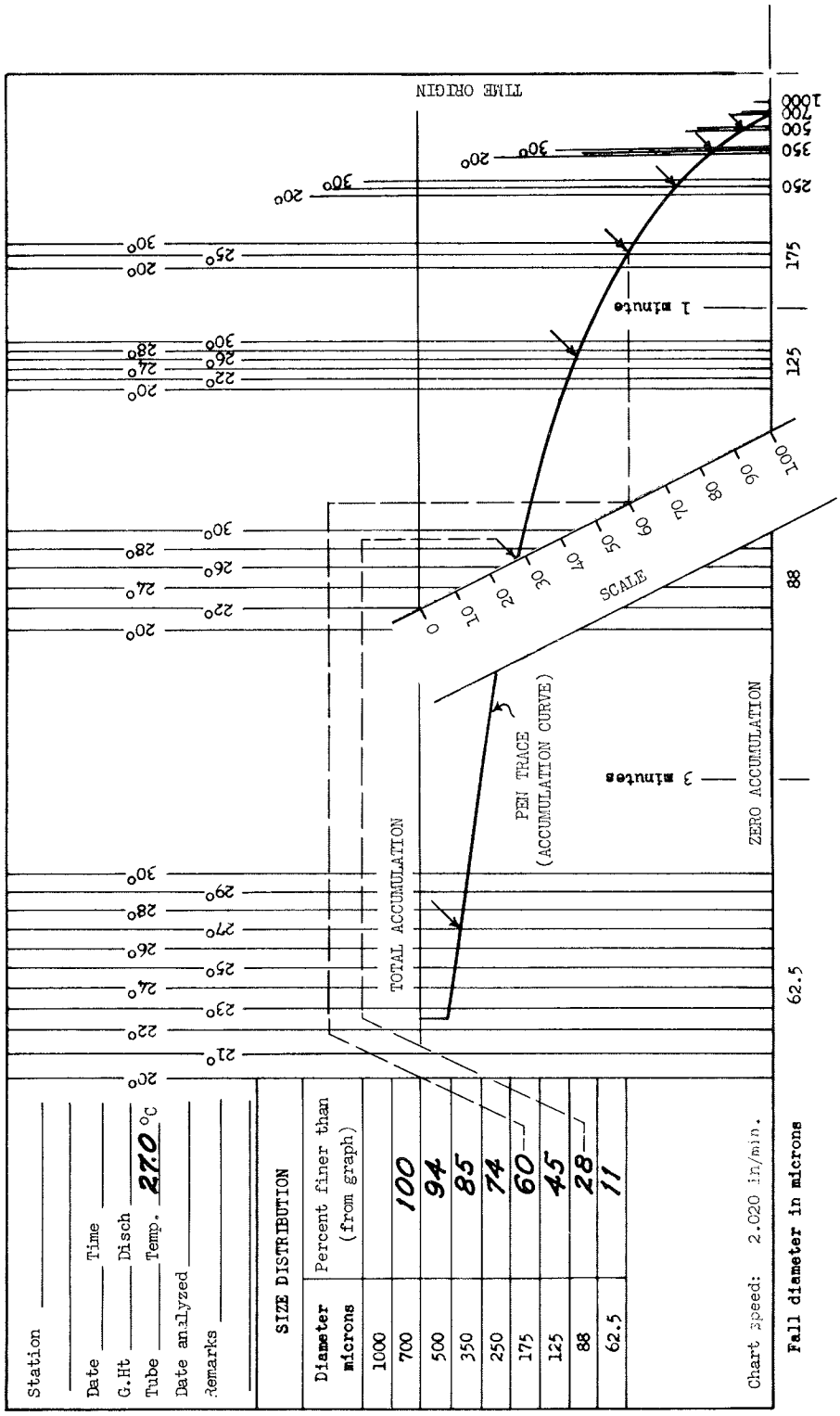
Individual - Sample Bottling System

SAMPLE HANDLING SYSTEMS FOR PUMPING SAMPLER

FIG. 2

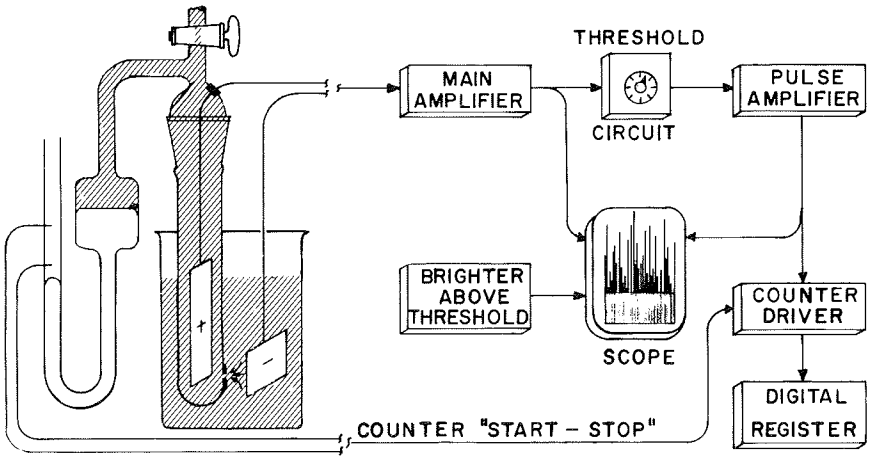


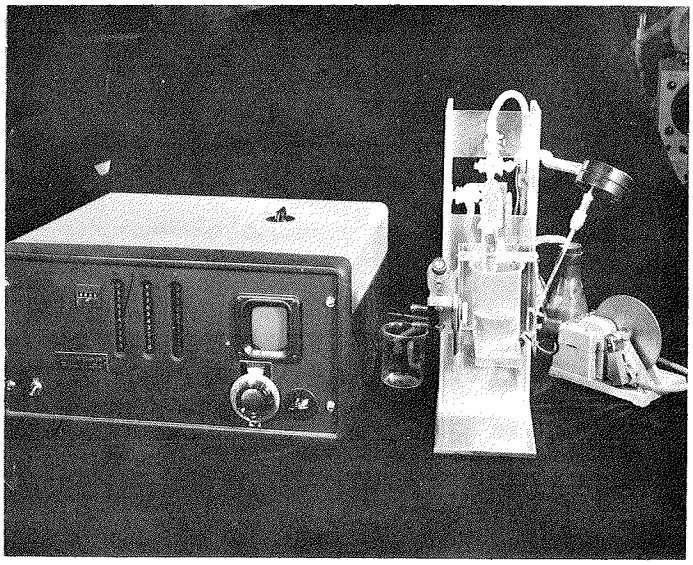
VISUAL-ACCUMULATION-TUBE SAND SIZE ANALYZER
FIG. 3



VISUAL-ACCUMULATION-TUBE SAND SIZE ANALYZER. RECORDER CHART FOR 120 CM TUBE SHOWING METHOD OF READING SIZE DISTRIBUTION

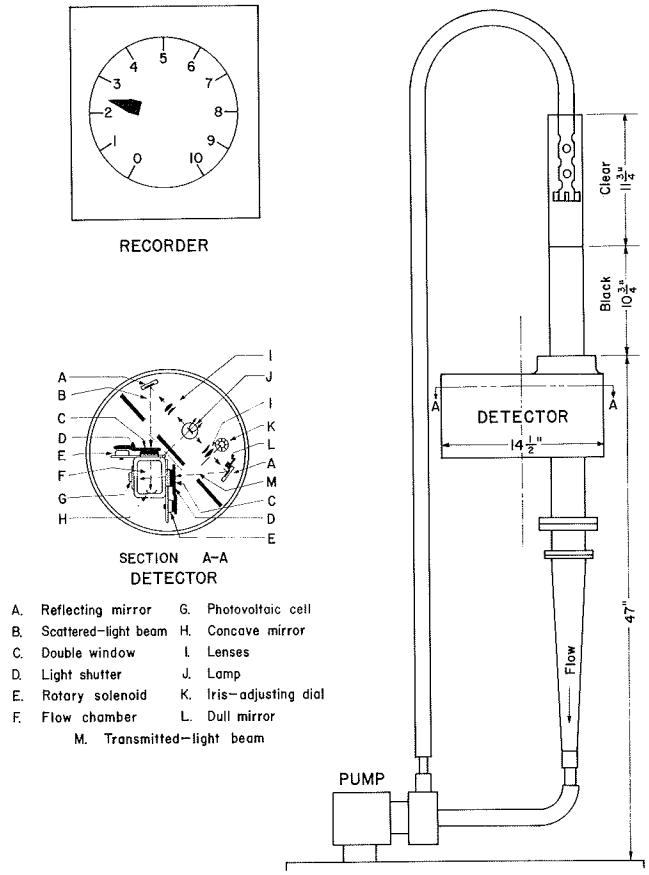
FIG. 4

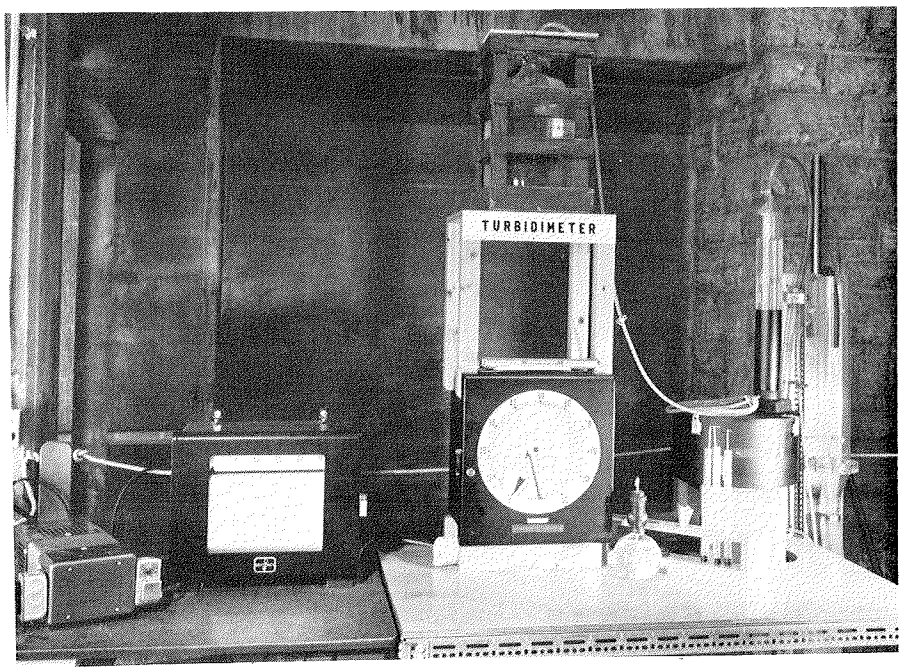




COULTER COUNTER

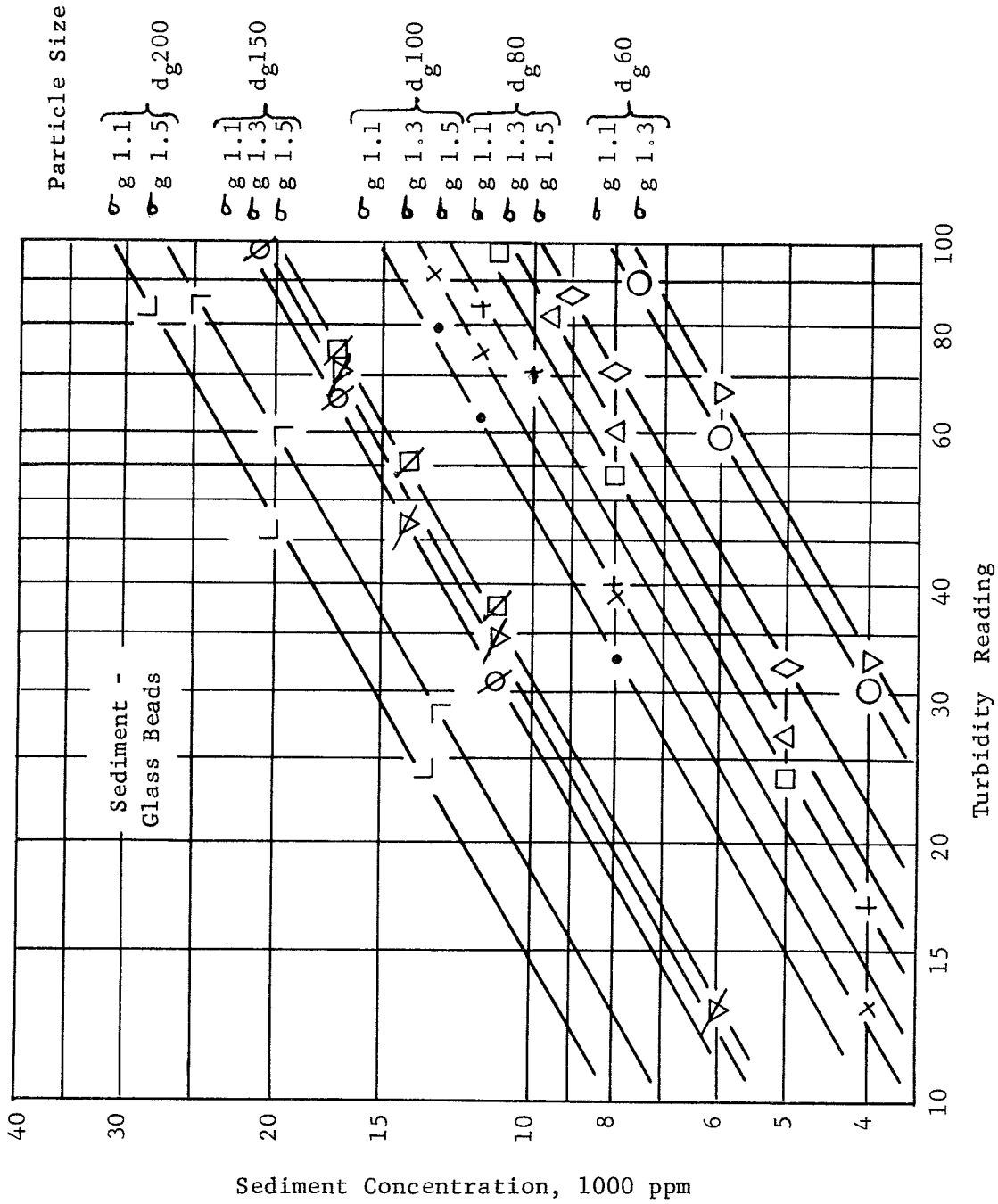
FIG. 5



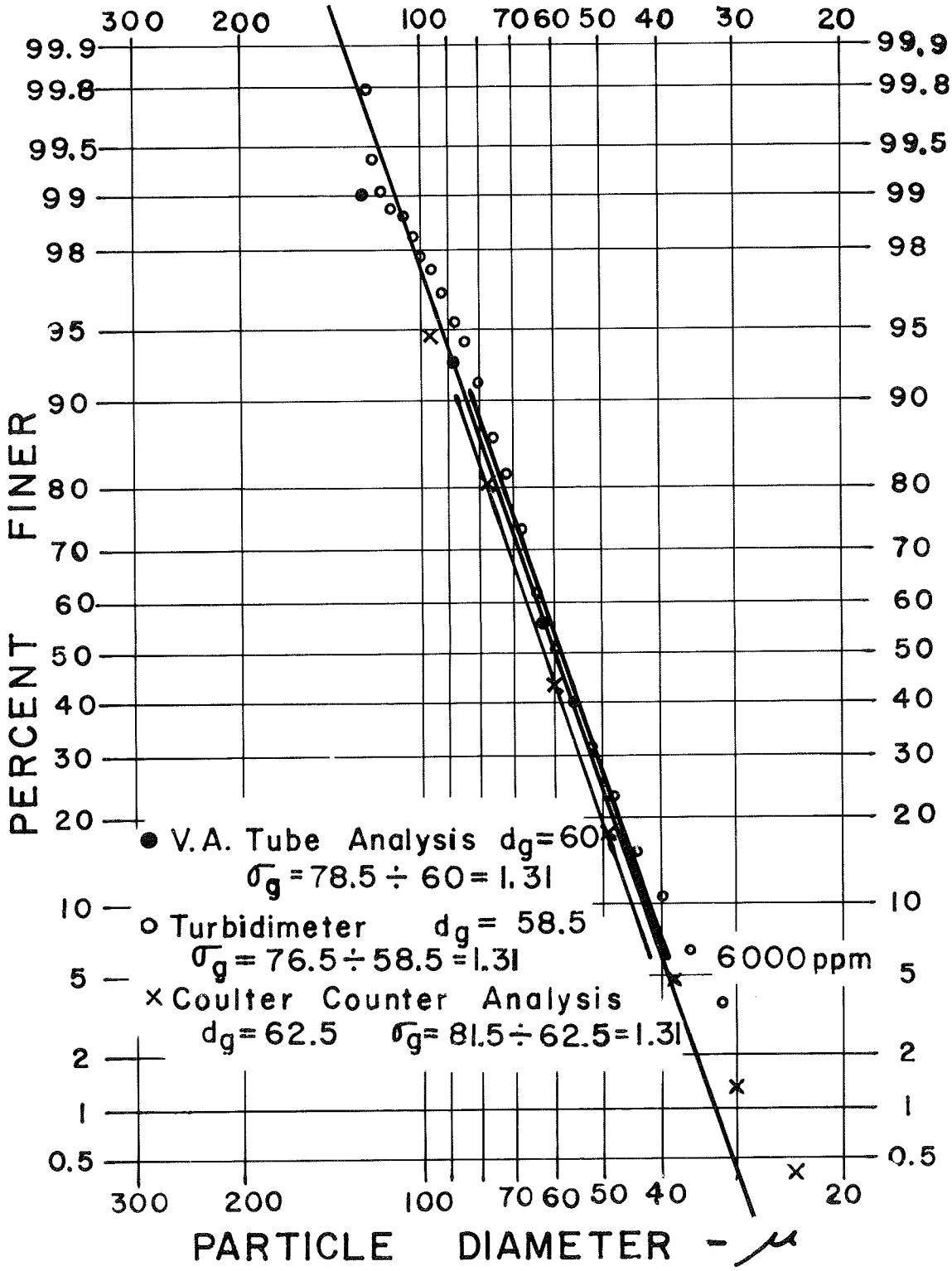


TURBIDIMETER

FIG. 6

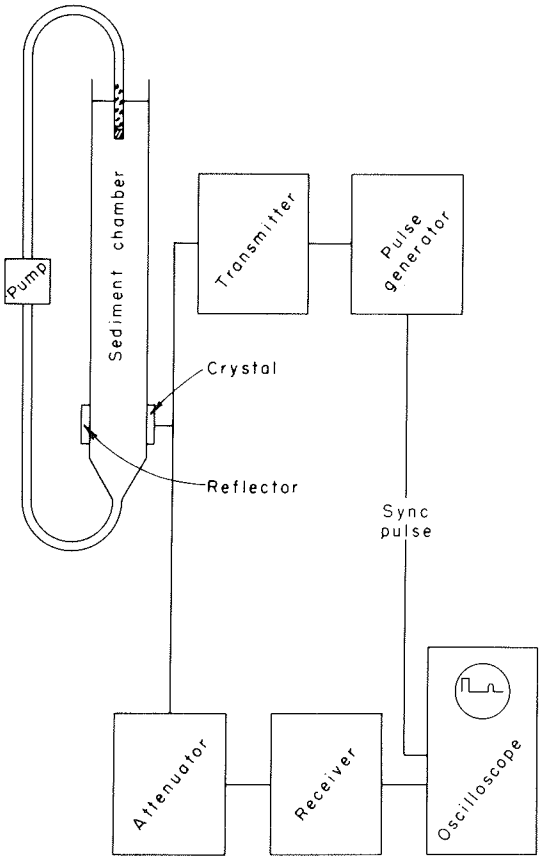


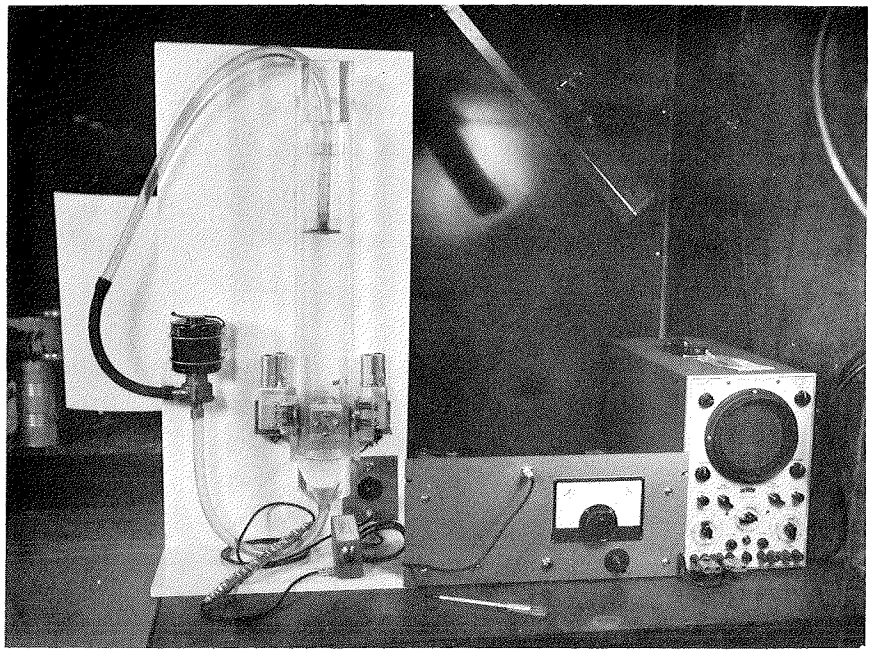
CONCENTRATION - TURBIDITY CALIBRATION GRAPH FIG. 7



RESULTS OF VISUAL-ACCUMULATION-TUBE, TURBIDIMETER, AND COULTER COUNTER PARTICLE SIZE ANALYSES OF GLASS BEADS

FIG. 8





ULTRASONIC EQUIPMENT

FIG. 9