A STUDY OF METHODS USED IN

MEASUREMENT AND ANALYSIS OF SEDIMENT
LOADS IN STREAMS

REPORT K

OPERATOR'S MANUAL ON THE VISUAL-ACCUMULATION-TUBE METHOD FOR SEDIMENTATION ANALYSIS OF SANDS

REVISION

OCTOBER 1958

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

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 ** Public Health Service
Forest Service

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The cooperative study of methods used in
MEASUREMENT AND ANALYSIS OF SEDIMENT LOADS IN STREAMS
covers phases indicated by the following report titles.

Report No. 1
FIELD PRACTICE AND EQUIPMENT USED IN SAMPLING SUSPENDED SEDIMENT

Report No. 2
EQUIPMENT USED FOR SAMPLING BED LOAD AND BED MATERIAL

Report No. 3
ANALYTICAL STUDY OF METHODS OF SAMPLING SUSPENDED SEDIMENT

Report No. 4
METHODS OF ANALYZING SEDIMENT SAMPLES

Report No. 5
LABORATORY INVESTIGATIONS OF SUSPENDED-SEDIMENT SAMPLERS

Report No. 6
THE DESIGN OF IMPROVED TYPES OF SUSPENDED-SEDIMENT SAMPLERS

Report No. 7
A STUDY OF NEW METHODS FOR SIZE ANALYSIS OF SUSPENDED-SEDIMENT SAMPLES

Report No. 8
MEASUREMENT OF THE SEDIMENT DISCHARGE OF STREAMS

Report No. 9
DENSITY OF SEDIMENTS DEPOSITED IN RESERVOIRS

Report No. 10
ACCURACY OF SEDIMENT SIZE ANALYSES MADE BY THE BOTTOM-WITHDRAWAL-TUBE METHOD

Report No. 11
THE DEVELOPMENT AND CALIBRATION OF THE VISUAL-ACCUMULATION TUBE

Report No. 12
SOME FUNDAMENTALS OF PARTICLE-SIZE ANALYSIS

Report A ** -- PRELIMINARY FIELD TESTS OF THE U. S. SEDIMENT-SAMPLING EQUIPMENT IN THE COLORADO RIVER BASIN APRIL 1944

Report B ** -- FIELD CONFERENCES ON SUSPENDED-SEDIMENT SAMPLING SEPTEMBER 1944

Report C ** -- COMPARATIVE FIELD TESTS ON SUSPENDED-SEDIMENT SAMPLERS PROGRESS REPORT DECEMBER 1944

Report D -- COMPARATIVE FIELD TESTS ON SUSPENDED-SEDIMENT SAMPLERS PROGRESS REPORT -- AS OF JANUARY 1946

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** OUT OF PRINT

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1. Introduction--The visual-tube method for sedimentation analysis of sands was developed as a part of the general investigation titled "A Study of Methods Used in Measurement and Analysis of Sediment Loads in Streams." The method is one answer to the need for a simple, rapid, and inexpensive means of determining the sedimentation-size frequency analysis of sand samples containing particles less than one millimeter in size. For analysis of coarser sands see the Appendix, Section 13. Report No. 11 "The Development and Calibration of the Visual-Accumulation-Tube" is available for those who have further interest in this analysis.

The personnel who will be operating these units may have little or no previous knowledge of either the principles involved or the details of operating procedure. This manual is intended as an aid to them in setting up the apparatus, learning the analytical procedure, interpreting the results, and understanding the primary principles encountered.

2. Apparatus furnished--The specialized apparatus (Fig. 1) required for the visual tube method of analysis is furnished in units composed of the following:

a. Visual tube recorder with parts as listed (Fig. 2).

b. Electrical equipment for recorder (Fig. 3).

c. Valve mechanism (Fig. 4)

d. Sedimentation tubes (Fig. 5), as follows:

Two funnels.

Two of each size of visual tubes, eight tubes.

e. Accessories as follows:

Two rubber tubes 6 in. long for joining funnel and tube.

Five clamps for holding tubes.

One plug for each visual tube, eight plugs.

One stirring rod for use in mixing chamber.

Two hundred charts.

Tracing from which charts may be made.

Small bottle of ink.

Screws for mounting.

The basic apparatus does not include the larger tube and auxiliary equipment for analysis of very coarse sands discussed in the Appendix, Section 13. Orders for complete units, parts or repairs should be directed to the District Engineer, U. S. Army Engineer District, St. Paul, Corps of Engineers, 1217 U. S. Post Office and Customhouse, St. Paul 1, Minnesota.

3. Location for apparatus--The apparatus should be located on a wall where there is a width of at least 5 feet available, and where there is as much head room as possible up to a ceiling height of 12 feet. The area should be one where temperature variations are at a minimum. A small amount of work space such as a table or desk top should be adjacent if possible. Distilled water under at least 2 feet of pressure head should be available at the top of the apparatus which will be approximately 8-1/2 feet above the floor. At least two jets for the distilled water should be provided, one with a high rate of discharge for rapid filling of the sedimentation tube, and one with a small discharge for washing samples from containers into the funnel at the top of the apparatus. Access to the top of the apparatus will be required as well as to the recorder.

The recorder should be located so that the operator cannot touch any water pipes, steam pipes, metal conduit, faucets, or other electrical grounds while working at the recorder.

Fig. 6 shows a suggested mounting arrangement for the apparatus. This includes a false vertical wall or mounting board about 4 or 6 inches out from the room wall, and extending from a point 3 feet above the floor to a point 8 feet above the floor. The width should be 18 inches or over. The top of this forward extension should be finished off in a level shelf, as a small amount of shelf space is needed at this point. The tube mounting board and recorder may be mounted directly on the room wall but that requires an operating position which may be uncomfortable for routine work.

4. Installation of apparatus--Read the following instructions for assembling the apparatus completely through at least once and become familiar with Figs. 1 to 7. Then unpack the recorder and assemble as follows:

a. The bottom of the recorder should be set a minimum of 36 inches above the floor for average operators. The recorder may be held against the wall on which it is to be mounted while the operator or operators decide on the most satisfactory height. The height will depend not only on the operators but also on the height of chair or stool provided for a seat. The higher the recorder is set, the higher, and therefore the less readily accessible will be the valve and funnel at the upper end of the sedimentation tube. Two of the No. 12 round head wood screws with washers may be used to attach the recorder to the flat vertical wall or mounting board. The two wood screws are to be set 7-1/2 inches apart on a level line and a distance of 45-3/4 inches above the floor if the bottom of the recorder is to be 36 inches above the floor. (See Fig. 7). Attach the recorder so that the screws are at the centers of the mounting slots. The screws must be firmly anchored in the wall.

b. Make a tube mounting board 4 feet 2 inches long using a nominal 1 x 8-inch board or an 8-inch strip of 3/4-inch plywood. Draw a centerline the length of the board. Attach four clamps for tubes, spaced as shown in Fig. 7. Place small pads under the upper two clamps.

c. Attach the valve mechanism to the tube mounting board as shown in Fig. 7. Use four No. 6 round-head wood screws, 3/4 inch long. Establish one permanent horizontal reference line on the board 7-7/8 inches above the top of the valve mechanism, for use as discussed in "g" below.

d. Fasten the tube board on the wall with the extension of the centerline 1 inch away from the left edge of the recorder and the top of the valve mechanism 40-1/2 inches above the top of the upper plate of the recorder. This board must be vertical, and if necessary one end of the board must be blocked out away from the wall to correct for deviations of the wall from the vertical. Six No. 8 wood screws 1-1/2 inches long are included for attaching this board.

e. Establish a permanent horizontal reference line on the wall 49-5/8 inches below the top of the valve mechanism, for use in adjustment discussed in "f" below.

f. Place the visual tube in the lower two clamps and insert a tube plug in the bottom. Moisten the plug if necessary, start the center (stopper) part into the tube, and move up into place with a twisting motion and increasing upward pressure. The bracket of the recorder (part No. 33, Fig. 2) should be adjusted so that the top of the tube plug is level with the lower reference mark of "e" above.

g. The 6-inch piece of rubber tubing should be fitted over the bottom of the funnel, and the funnel mounted in the upper two brackets with the tube extending downward through the valve mechanism. The tubber tube should be fitted snugly into the top of the visual tube to make a watertight joint. If the fit is not snug enough, rubber tape may be wound around the rubber tube to build it up until a satisfactory fit is obtained. The joint between tube and funnel should be so made that the reference mark on the funnel will be level (within 1/4 inch) with the upper reference mark on the board described in "c" above.

h. Check the assembly to see that the tube and funnel form a straight vertical column, and that the tube joints are tight. Close the valve and add water above the valve to check for leaks. If valve leaks when in the fully closed position, open valve, slip valve blocks (part No. 7 of valve mechanism, Fig. 4) from the ends of part No. 3 and turn up 1/2 turn on threads of part No. 6. Then replace, and again check valve for leaks. Repeat if necessary.

i. With valve open, fill tube and funnel to above all joints and check for leaks, repairing same if necessary.

j. Inspect recorder, and reassemble and release any parts that have been removed or secured for shipping. Parts 27, 28, and 33 are packed separately and may be assembled by consulting Fig. 2.

k. Loosen the set screw and turn the keeper nut (part No. 22, Fig. 2) of the drum shaft upward against the hexagonal nut. With the keeper nut up and the release lever (part No. 20) down, the drum should rotate freely.

l. The telescope (part No. 27) should be mounted in the holder (part No. 26) so that the horizontal cross hair is horizontal and the sedimentation tube is in proper focus. If the knurled screw of the telescope holder is loosened, the telescope may be rotated to level the cross hair, and moved in or out to focus the instrument.

m. The electrical switch on the end of the 6-foot cord is in the timing circuit and should be installed on the tube board in such a position that the switch will make contact when the valve is fully opened. With the valve fully open, slide the switch box upward on the tube board and alongside the valve mechanism until the outer end of the actuating lever on the switch strikes the bottom of the rod (part No. 6, Fig. 4) of the valve mechanism. Continue moving the switch upward along the board until the pressure on the switch causes a small click, then move the switch box upward 1/32 inch farther on the board and fasten in place with two round head No. 6 wood screws 1/2 inch long. The bottom of the switch box should be level across the tube board during this entire process. A small square may be held against the side of the tube board and the switch box kept level against the edge of the other leg of the square.

n. There are four electrical switches on the recorder as follows:
(1) The main switch ("C_1," Fig. 3) is the rear switch in the box on top of the recorder. When this switch is in the "off" position, no part of the recorder will operate. When the switch is turned "on" the starter for the fluorescent light starts heating, and the light should come on as soon as heated sufficiently. Also, switch "C_2" is energized so other parts of the recorder may be operated.
(2) The forward switch, "C_2," in the box on top of the recorder is "hot" only when the main switch is "on." The switch "C_2" operates the tapper motor and energizes the timing motor circuit.
(3) The switch at the valve (Switch E) operates the timing motor to rotate the chart drum when the valve is fully open.
(4) The limit switch, located under the chart drum, is "on" except when the drum is near the limit of the recording chart and the switch is depressed by a pin on the under side of the drum. The timing motor will run only when the tapper motor is running. The switch at the valve, the limit switch under the chart drum and the forward switch "C_2" are in series so that all three switches must be closed to operate the timing motor and turn the chart drum. After the instrument is assembled the power cord should be plugged into a 110 volt, 60 cycle, AC electrical outlet and the action of all switches should be tested. The wiring layout and diagrams of Fig. 3 should be consulted in case of difficulty.

5. Care of apparatus--

NEVER WORK INSIDE THE ELECTRICAL BOXES, OR AROUND THE LIGHT AND LIGHT ACCESSORIES WITHOUT FIRST UNPLUGGING THE POWER CORD.

Tubes and funnel should be cleaned with Alconox or other suitable cleansing agent before starting use each day.

The pen should be cleaned and refilled as often as required for best operation.

The telescope lenses should be kept clean, and the telescope arm should be attached with snug tension to the carriage at all times.

The rate of pen travel should be checked against the time markings on the base of the charts by occasional timing with a stop watch. Time should be accurate to 2 percent.

Lubricate the threaded rods once a week with graphite and keep the rods and threaded holes in the carriage clean.

The recorder and valve mechanisms should be kept clean and bearings and moving parts oiled about once a month. In dusty locations, graphite is a more satisfactory lubricant than oil.

The lubrication needs of the electric motors are not uniform. Lubricate according to instructions received with each motor.

6. Samples to which the method is adapted--The visual-tube method presented here is intended primarily for size analysis of suspended-sediment samples composed mainly of sand sizes, or samples from which the finer material has been separated. If particles larger than one millimeter are present in a sample they should be removed by sieving, but sizes that large are believed to be so unusual in suspended-sediment samples that they will not constitute any serious problem.(See Appendix, Section 13, for analysis of coarser sands.) If any clay or much silt is contained in a sample, that should be removed before attempting analysis in the visual tube. The presence of some coarse silt will not destroy the accuracy, but will require more time for making the analysis.

Some bed-material samples are of fine enough material to be effectively analyzed by the visual tube method. Some beach and ocean bar sands have been found very easy to analyze, however, the range of sizes involved in these is often so small that samples of only 1 or 1-1/2 grams of material are best for the 5 mm. tube, and perhaps 3 grams for the 7 mm. tube. Longer tubes of larger diameter both in the main portion and in the collecting section are better for analysis of samples containing high percentages of the coarser sand sizes. See the Appendix.

7. Removal of silts and clays--Because most suspended-sediment samples contain silts and clays, the removal of the silts and clays prior to the analysis of the sands is a basic problem. Present solutions may not be adequate, and certainly further investigation of the problem is indicated.

For many of the size analyses now being made in sedimentation laboratories, the silts and clays are first separated from the sands by wet sieving methods, then the sands are analyzed by sieving, and the silts and clays are analyzed separately by the pipette or other methods. The purpose of the initial separation is to divide the particles smaller than 62.5 microns (1/16 mm.) from those larger. During the development of the visual tube method it was found that a sieve with a nominal opening of 62.5 microns will pass an appreciable quantity of material for which the sedimentation diameter is larger than that figure. A complete sedimentation analysis of samples so divided would requre the determination of the quantity of very fine sand (sizes just over 62.5 microns) contained in the material passing the wet sieve.

Possibly the initial separation should be made by wet sieving over a sieve with smaller openings. The material passed could then be divided into the desired classes of clay and silt. The retained material could be analyzed with the visual tube, by determining the proportion in each sand class and also the material finer than sands. The latter could be added to the coarsest silt fraction of the analysis.

Following is a second approach to this problem which has been given preliminary testing in connection with the development of the visual tube method. Samples containing sands, silts, and clays were prepared for analysis by dispersing in distilled water using a chemical dispersing agent. Samples containing organic matter were treated with hydrogen peroxide also. The purpose of treatment was to prepare the sample so that no flocculation would be present during separation in the sedimentation tube. (Most laboratories have developed methods of preparing samples for sedimentation analysis by the pipette, or bottom withdrawal tube method, and presumably these treatments would be satisfactory.) The prepared sample was introduced in the mixing chamber of the visual tube apparatus, but a bottom-withdrawal tube was used as the sedimentation tube in place of the usual visual tube. The sample was thoroughly stirred in the mixing chamber and the valve opened, allowing the sample to fall through the bottom-withdrawal tube. Seven minutes after the valve of the mixing chamber was opened, a withdrawal of about 40 ml. was made from the bottom of the tube. This withdrawal contained all the sands and some of the coarser silts in a form ready to be analyzed in the visual tube. The finer material which remained in the bottom withdrawal tube could have been analyzed by the pipette, or other method. In connection with the visual tube study, the fine material was merely collected, dried, and weighed.

The fine material remaining from the above type of initial separation was dispersed through what may have been an undesirably large quantity of fluid. A shorter than standard bottom-withdrawal tube could have been used for this initial separation. If desirable that the fines be entirely within the bottom-withdrawal tube, a large withdrawal might have been made prior to the timed withdrawal, and this first withdrawal would have reduced the volume of water in the tube to such a height that the entire remainder would be contained in the tube or in a given lower portion of the tube. In either of these instances, the total fall distance would have been reduced, and the time of fall would require reduction in proportion.

The more thoroughly the clays and fine silts are removed from the sample, the simpler and more rapid the visualtube analysis of the sand will be.

8. Preparation of the sand sample--A sand sample obtained from the fall velocity separation mentioned above should be all ready for visual tube analysis. A sample which is in the dry state must be dispersed in water before analysis, and if possible should be allowed to soak over night. A sample which has been stored for some time without treatment may require a chemical agent for dispersing or may require hydrogen peroxide to remove growth of algea. The action of some samples can be greatly improved by adding distilled water, stirring, allowing to settle, and decanting the supernatant liquid. The whole purpose of the preparation of the sample is to prepare the material so that each particle will fall as an individual unit.

The sample when finally prepared for analysis should be contained in about 40 mls. of water or less. If only sands and coarser silts are involved settling and decantation will rapidly remove excess water.

9. Choice of proper size of visual tube--For samples containing 0.05 to 0.8 grams of sand (100 to 1600 ppm on the basis of a one pint sample), the tube with the smallest collecting section, 2.1 mm, may be used providing there is no "significant" percentage of material over 250 microns in size. Coarser material will require a larger tube and preferably a greater quantity of material.

For samples containing 0.4 to 2.0 grams of sand (800 to 4000 ppm on the basis of a one pint sample), the 3.4 mm tube may be used if there is no "significant"percentage of material over 500 microns in size. Coarser material will require a larger tube and perhaps a greater quantity of material.

For samples containing 1.6 to 6.0 grams of sand (3200 to 12,000 ppm on the basis of a one pint sample), the 7.0 mm tube may be used.

The percentage of coarse material which is "significant" may depend on many items. If the sample is small in quantity for the given size of tube a larger percentage is permissible. If there is so much coarse material, or if the size is so great that the tube plugs up at the top of the collecting section, obviously the tube is too small for the sample. If the analysis of the coarser sizes is relatively important, the maximum sizes analyzed in a given tube should be limited more carefully.

Generally the approximate quantity of sand and upper size limits involved in a sample will be known from previous experience with the sampled stream or group of samples. Comparative samples may be made up containing, for example, about 0.6 grams of sand with a maximum particle size of about 250 microns. If a sample to be analyzed does not exceed this comparative sample in either quantity or particle size, it may be analyzed in the 2.1 mm tube. Similarly, comparative samples might be made up for the division points between other tube sizes.

Normally the best results are obtained by having the total height of accumulation in the bottom of the tube between 1 and 4 inches. If a sample is of very limited size range, or of predominantly coarser material, the use of maximum heights of accumulation less than 4 inches is expected to give better results. In case the wrong tube was chosen, or there is serious question as to whether the tube was properly chosen, it is a simple matter to rerun the sample in another size of tube.

10. Procedure for analysis--The suggested chronological procedure for sedimentation analysis of a sample is as follows:

a. With the chosen size of visual tube in place, the valve open, and a plug fitted into the bottom of the tube, fill the tube with distilled water up to a little above the valve. Take the temperature of the water by lowering a thermometer into the top of the tube, and record the temperature. A thermometer thrust through a one-inch rubber stopper so that the bulb hangs just above the valve provides a satisfactory arrangement for temperature determination. Turn on the rear switch on the recorder.

b. Place chart on drum: Turn wing nut down on release lever (part No. 20, Fig. 2) on the recorder until the drum may be rotated freely. Tuck one end of the chart under the arms of the top and bottom paper clips (part No. 21) and rotate the drum to carry the chart around. Slip the other end of the chart under the other arms of the paper clips. Smooth down the chart if necessary, being sure that the bottom guide line on the chart is parallel with the bottom of the drum. Rotate the drum until the pen will fall at least 1/8 inch to the right of the origin or zero time line on the chart. Turn the wing nut upwards so that the release lever is again free and the drum is engaged with the timing motor drive.

c. Set the pen: Turn the pen arm (part No. 28) toward the chart until it drops into place and the pen is against the chart. Be sure pen is marking properly. Clean pen or fill with ink if necessary. Turn hand wheel (part No. 32) to bring the pen exactly onto the base line of the chart. Turn on the forward switch, and the tapper and drum should start. Use this rotation of the drum to bring the pen up to the zero time line. Turn off the forward switch to stop the pen exactly on the zero time line. There is some play in the timing motor gear box and the pen should always be oriented on the time line by allowing the motor to bring the drum around into place. If the pen did not quite reach the right place, the drum may be moved ahead by a quick flip of the forward switch, or if the drum turned too far the release lever may be depressed, and the drum turned backward for another trial. The end result must be that the pen is oriented on both zero time line and the base line, with the forward switch in the off position.

d. Adjust the telescope: Using the knurled thumb screw on the recorder carriage (part No. 25), adjust the telescope so that the cross hair is at the top of the plug which is inside the bottom of the visual tube. Within limits, this adjustment will move the telescope upward for clockwise rotation of the knurled screw. Turning the screw in the reverse direction will, with the aid of slight pressure downward on the outer end of the telescope arm, adjust the telescope downward.

e. Close the valve in the sedimentation column.

f. Transfer sample to mixing chamber: Wash the sand sample from its container into the chamber above the valve and fill the chamber up to the reference mark on the funnel with distilled water. The temperature of the water added with the sample, or used as wash water, should in no case be less than that of the water in the main sedimentation tube. Temperature a degree higher is not objectionable except as it may cause subsequent raising of the temperature in the main column.

g. Turn on the forward switch and the tapper should start.

h. Mix and wash sample in mixing chamber. Agitate the plunger briskly up and down, going downward as far as possible. After about 5 seconds of agitation remove the plunger quickly, and immediately open the valve making sure that the valve is fully opened so that the recorder drum will start at once.

i. Tracking the sample: As soon as the first particles of sediment reach the bottom of the visual tube start following the accumulation upward with the telescope, turning the hand wheel to keep the cross hair as nearly on the upper surface of the accumulation as possible. The rapidity of accumulation determines whether the hand wheel should be turned with both hands on the handle, with one on the handle and one on the outside of the wheel, with both hands on the wheel, or with one hand alone. The best method is the one which for the given sample, allows the operator maximum control. The top of the accumulation will not always be level, and when it is not the cross hair should be kept as nearly at the average elevation of the accumulation as possible. Tracking of the sample should be continuous until the elevation of accumulation no longer rises, or until the 62.5 micron size lines on the chart have been passed. Continuous tracking may be continued until the chart is stopped by the limit switch. If only sand sizes are included in the sample it does not take long for the total sample to fall. However, if there is much fine material, the time will be longer, perhaps much longer, and for this reason the fine material should be mostly removed before the analysis. The accumulation may be tracked intermittently when fine material is settling slowly, until the maximum height of accumulation is reached.

j. Turn off the forward switch when the maximum height of accumulation has been established.

k. Extend maximum accumulation height across chart: Without moving the elevation of the pen after the maximum height of accumulation has been reached, use the wing nut to hold the release lever down, and turn the chart backward to extend the maximum height line all the way back to the zero time line.

l. Remove the chart: Lift up the pen arm and swing the pen back away from the chart. Take the chart from the drum. Make certain that all necessary notes are on the chart. Generally, notes are required to identify the sample, also date, time of day, operator, size of visual tube, tube number if desired (tubes of the same nominal size differ slightly in inside diameter and it is desirable to number all tubes for identification). The temperature of the water in the sedimentation column must be known and recorded to the nearest degree centigrade. With a good laboratory arrangement, the temperature may not change a full degree all day. However, determine temperature as often as necessary and record in such a way that the temperature is apparent for every sample.

m. Remove sample from visual tube: The telescope may be moved up with the hand wheel, or tipped up out of the way if desired. Close the valve. While holding tube plug in one hand swing tube bracket out of the way, and place beaker or other container under end of tube. (There is a small shelf under the recorder which may be pulled out and used as a support for the container while draining the tube.) Remove the plug, open the valve very slightly and allow accumulated sample and about 50 ml. of water to drain out. Close the valve. Wash any sediment from the plug into the sample container. Remove the container and insert the plug in the tube. Start the plug into the end of the tube and twist upward into place. The sample which has been removed may be dried and weighed to determine the total material.

If air bubbles form in the tube above the plug, they must be removed. If the sample is drained slowly from the bottom of the tube, bubbles seldom form in the tube. Bubbles will not form if the bottom of the tube is immersed in water during the withdrawal. If bubbles do form at any time, a little more water may be drained in an attempt to improve the previous technique, or the rubber tube below the valve may be pinched slowly, forcing the bubbles out of the tube so that the plug may be inserted. When the plug has been properly installed, swing the tube bracket under the plug as a support.

n. Preparation for another analysis: Open the valve. If necessary add distilled water to bring the level in the tube to just above the valve. Take the water temperature if that seems required. Start another analysis with preceeding item "b."

o. General comments: Normally the above procedure cleans the tube sufficiently so that the next sample may be analyzed in the water remaining after item "m." If it should appear necessary the tube can be completely washed out after each sample and the fines that are removed can be added to the fines previously separated.

One practice during development of this method has been to set up one size of tube in a cleaned condition, and starting with samples of the smallest quantities analyze samples more or less consecutively up to those of the largest quantities to be analyzed in that tube. If samples are set up in this manner it is an easy matter to know when to change to a larger size of tube.

When the apparatus is not to be used for a matter of some minutes, turn the rear switch to the "off" position, and open the valve. If out of operation for longer periods, cover the top of the tube funnel, and place dust cloth or other dust protection over the recorder.

11. Method for computing results--The procedure of section 10 results in a continuous curve with time as the abscissa and height of accumulated sediment as the ordinate, and this is a type of sedimentation analysis of the sample. Generally the results are desired in the form of percentages of the sample finer (or coarser) than certain definite sizes, and these sizes are printed on the charts provided for this method. The percentages finer than those sizes shown on the recorder chart may be obtained from the chart by use of the adjustable scale and method of Fig. 8, as follows: Check the points of intersection of the accumulation curve and the size curves for the temperature of analysis. Interpolate between temperatures for which the position of the size lines is shown.

The recorder chart may be placed flat and an adjustable scale divided into 100 equal parts oriented until the zero mark coincides with the total accumulation level and the 100 mark coincides with the zero accumulation level or base line. The scale may be moved horizontally to the intersection of the curve with the desired size and temperature line. The percentage finer than that size may be read directly from the scale and recorded in the place provided on the chart.

Several modifications of the method of reading percentages from the chart are possible. Any convenient scale divided into 100 parts may be used. Horizontal lines may be drawn through the desired intercepts so that all may be read from one position of the scale if desired. If 10 percent of material coarser than that analyzed in the visual tube was removed from the sample prior to this analysis, then the 90 mark may be used on the zero accumulation line so that percentages of the total sample may be read directly. If 40 percent of the total sample was removed as silt and clay prior to the visual tube analysis, the 40 mark may be used on the total accumulation line and percentages of the total sample read directly. To read percentages coarser directly, turn the scale upside down.

12. Significance of results--Particles in a sample in the visual tube settle with higher velocities than those for the same particles falling singly. The method has been calibrated on the basis of the fall velocities of the individual particles falling alone in a fluid of sufficient extent to avoid the effect of space limitations. Therefore, the size frequency analysis is based on the fall diameter" of the particles involved in the sample. The "fall diameter" may be defined as the diameter of a sphere having a specific gravity of 2.65 and having the same terminal uniform fall velocity as the given particle in quiescent distilled water, with the fall velocity understood to be independent of any effect from adjacent particles or vessel walls. The relation between fall velocity and fall diameter depends only on the relationship between the velocity of fall and the diameter of a sphere of specific gravity 2.65. The fall diameter of a particle is then independent of the type of material with which it is associated, the concentration in which it is found or analyzed, or the method of analysis, and is just as basic as the fall velocity. The diameter concept supplies a linear size designation where that is desirable.

When a visual tube analysis shows that 45 percent of the material of a sample is finer than 125 microns the meaning is as follows: If the entire sample could be dropped one particle at a time in distilled water of infinite extent, 45 percent of the particles by weight would have fall velocities less than that for a sphere of diameter 125 microns and specific gravity 2.65 allowed to fall under the same conditions. However, the 45 percent is subject to whatever errors are included in the actual method of analysis. The method was calibrated by analyzing samples for which the fall velocity distribution was known and making corrections to the time of fall on the chart to give results best fitting the size frequency distribution known to be present in the original sample. From the analyses of hundreds of samples, the chart currently in use was derived as an average calibration for a range of sands. The calibration of the method is therefore contained in the charts provided for use with the visual tube recorder. The calibration consists in a reduction in the time allowed for a given size of particle to fall the length of the sedimentation tube. The reduction in time varies from about 10 percent for the coarser particles to about 30 percent for the finer particles. The calibration is an average for use with sands in general, and with the variety of visual tubes, sample concentrations and particle sizes of section 9. It appears that if the visual tube method is properly applied, the percentages finer will be quite accurate. If an analysis shows 45 percent of the total sample to be finer than 125 microns fall diameter, a large portion of the results will be within 45 ± 2 and most will be within 45 ± 5 percent.

APPENDIX

13. Visual tube analysis of coarse sands--The main part of this operator's manual was written on the basis of the equipment for size analysis of suspended sediments. That equipment included only the 120 cm length of tube. The tube diameters were not sufficient for very coarse sands, and the tube length was undesirably short for such sands. A larger visual tube is convenient and satisfactory for analysis of sands of sieve sizes from 1/16 to 2 mm. The larger tube is adapted to samples of 5 to 15 gm of material, except that the maximum quantities should be somewhat reduced for samples of limited size range. Although samples of 5 gm and greater may seldom be available in suspended sediment samples, generally the very coarse sands will be found in samples of bed, beach, or bank sands in which the sample quantity will not be closely limited.

The apparatus for the 180 cm tube is based on the equipment for use with the 120 cm tubes and the same methods of analysis are used. Extra parts needed for the long tubes are shown in Fig. 9. Details of the general arrangement and mounting of the two lengths of tube are somewhat different as a comparison of Fig. 6 and 7 with Fig. 9 will show. The best method of mounting the 180 cm tube depends on the amount of expected use. The advantages of having the two lengths of tube readily interchangeable should be considered.

The large visual tube is 180 cm long, with an inside diameter of 51 mm (2 inches) in the main sedimentation section. The inside diameter of the accumulation section is 10 mm. The 180 cm tube requires a ceiling height of nearly 12 feet to provide adequate headroom for operation.

Other equipment required with the longer tube consists of a slightly larger funnel than used with the 120 cm tube, a different rubber tubing connection through the valve mechanism, a rubber plug to fit the tip of the accumulation section, and a mounting board with attachments to support the tube and funnel. The recorder charts are necessarily different from those used with the 120 cm tubes. Film positives for use in making recorder charts are available on request. If justified by the demand, a supply of the charts and most of the other items of equipment will be stocked to satisfy orders. A stock of the 180 cm tubes will not be maintained because the cost of packing and shipping is excessive. It is believed that individual laboratories will find it possible to have such tubes made locally.

If a laboratory is already equipped with the regular visual accumulation tube recorder and apparatus, it should be possible to add this equipment for analysis of coarse sands at a cost not exceeding $50, plus one man day of labor for assembly and installation.

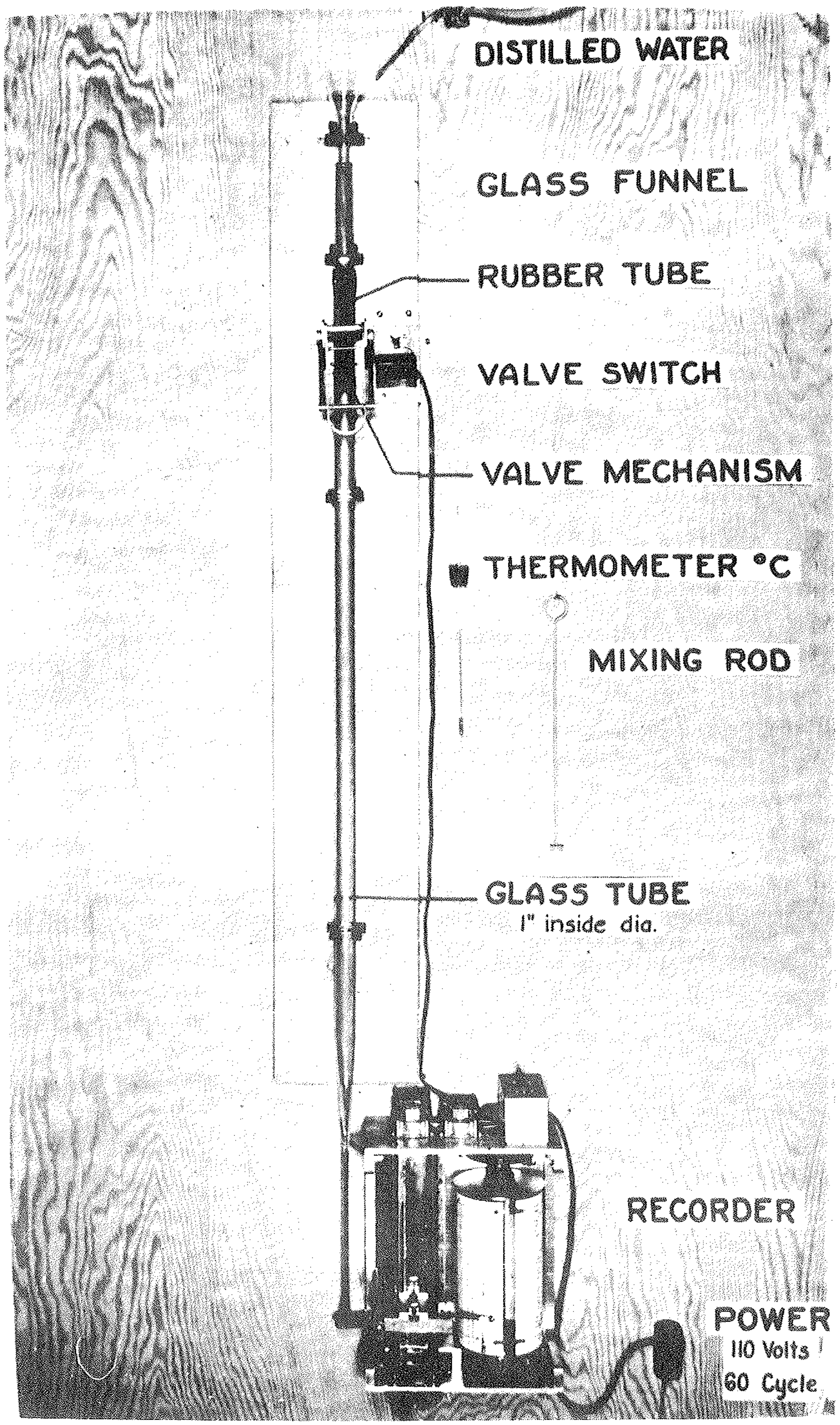


FIG. 1

VISUAL TUBE APPARATUS

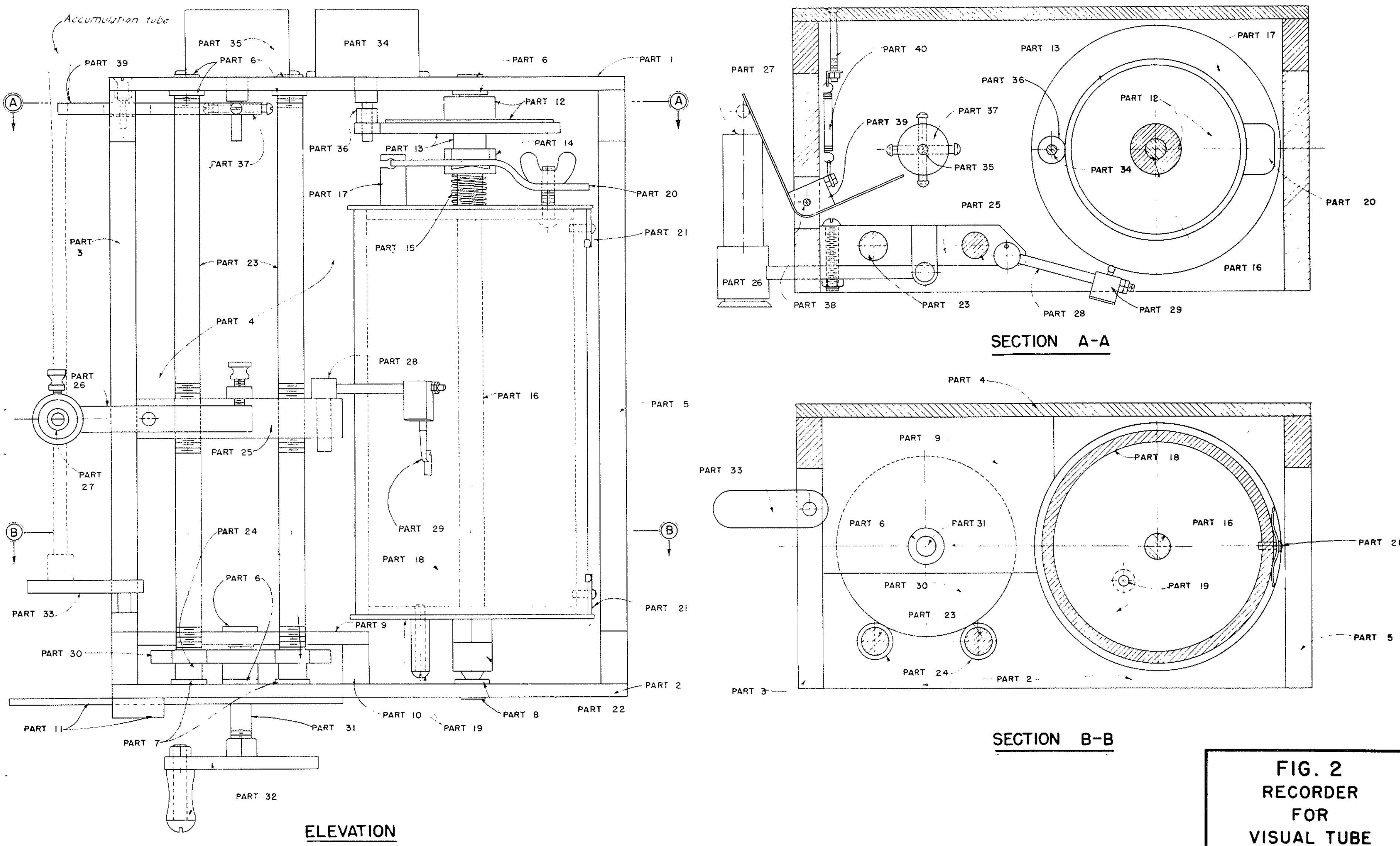


FIG. 2
RECORDER
FOR
VISUAL TUBE

RECORDER FOR VISUAL TUBE

PARTS LIST FOR FIG.2

Part No.	Name	Material	Quantity	Remarks
1	Top plate	Aluminum Plate $\frac{1}{4}$"	1	With 6 fh 10-24 st.st. screws 3/4" long
2	Bottom plate	Aluminum plate $\frac{1}{4}$"	1	With fh 10-24 screws, 4 are 3/4" long, 2 are $1\frac{1}{4}$" long
3	Left end bracket	Aluminum plate $\frac{1}{2}$"	1	With 2 fh 6-32 st.st. screws 3/4" long
4	Back plate	Aluminum plate $\frac{1}{4}$"	1	12 fh 10-24 screws 3/4" long, 3 fh 6-32 screws $\frac{1}{2}$" long
5	Right end bracket	Aluminum plate $\frac{1}{2}$"	1	
6	Bearing (1)	Bost Bronz or equal	5	$\frac{1}{2}$" O.D., 3/8" I.D., Boston Gear Works FB-68-3. See note below.
7	Bearing (1)	Bost Bronz or equal	2	$\frac{1}{2}$" O.D., 5/16" I.D., Boston Gear Works FB-58-3. See note below.
8	Bearing (2)	St.st.-brass or bronze mount	1	Angular contact bearing No. 6A. See note below.
9	Plate	Aluminum plate $\frac{1}{4}$"	1	
10	Block	Aluminum plate $\frac{1}{2}$"	1	
11	Shelf assembly	Aluminum and st.st.	1	With 2 fh 10-24 screws 1" long
12	Collar	Brass	1	With No. 0 taper pin 1" long or 1/8" roll pin 1" long
13	Gear (3)	Brass	1	32 pitch, 112 teeth, hub to be reamed and shortened. See note below.
14	Slide	Brass	1	
15	Spring	Steel or phosphor bronze	1	If steel must be stainless or plated
16	Drum shaft	Stainless steel	1	With $\frac{1}{2}$"-20 brass nut and 1/8"D. st.st. pin 1" long
17	Drum top	Brass	1	2 rh $\frac{1}{4}$"-20 brass screws 1" & $\frac{1}{2}$" long, 1 brass wing nut
18	Drum shell	Lucite or textolite	1	
19	Drum base	Brass	1	With 1 rh 10-24 brass screw $1\frac{1}{4}$" long
20	Release lever	Brass	1	
21	Paper clip	Spring grade brass	2	With 2 rh 4-40 brass screws 3/8" long
22	Keeper nut	Brass	1	With 1 rh 4-40 brass screw $\frac{1}{4}$" long
23	Threaded rod	Stainless steel	2	
24	Gear (4)	Steel	2	24 pitch, 16 teeth, with slotted, headless set screws. See note below.
25	Carriage	Brass	1	With 2 fh 6-32 brass screws $\frac{1}{2}$" long, 1/16"D. brass pin
26	Telescope arm	Brass	1	With 1 rh $\frac{1}{4}$"-20 brass screw $1\frac{1}{4}$" long and hex nut
27	Telescope		1	See note below
28	Pen arm	Brass	1	With 2 brass nuts
29	Pen	Brass and spring grade brass	1	Pen point and reservoir. See note below.
30	Gear (5)	Brass	1	24 pitch, 84 teeth, with slotted set screw. See note below.
31	Shaft	Stainless steel	1	With 3/8"-24 brass nut
32	Hand wheel	Brass	1	With rh $\frac{1}{4}$"-20 brass screw $1\frac{1}{2}$" long
33	Bracket	Brass	1	With 8-32 set screw
34	Timing motor	Hagen electric motor(note below)	1	1 RPM counterclockwise. 110 volt, 60 cycle, Model 50, "D"-shaft
35	Tapper motor	Hagen electric motor(note below)	1	120 RPM clockwise, 110 volt, 60 cycle, Model 56, "F" or "D" shaft
36	Gear (6)	Steel	1	32 pitch, 16 teeth. See note below.
37	Tapper wheel	Brass	1	With 4 rh 6-32 brass screws $\frac{1}{2}$" long, assembled
38	Tapper pin	Stainless steel	1	With 10-24 brass nut, and No. 6 brass washer
39	Tapper arm	Brass and spring grade brass	1	2 rh 4-40 brass screws 3/8" and 1" long, 2:4-40 nuts
40	Tapper spring	Brass and plated steel	1	Assembly

NOTES

(1) Boston Gear Distributor
(2) Miniature Precision Bearings Inc., Keene, New Hampshire for angular contact bearing. Pt. 7 may be modified for a mounting.
(3) Boston gear - Cat. No. G186 or equal
(4) Boston gear - Cat. No. H2416 or equal
(5) Boston gear - Cat. No. G269 or equal
(6) Boston gear - Cat. No. H3216 or equal

ABBREVIATIONS: st.st. for stainless steel; fh for flat head; rh for round head.

MACHINE SCREWS: All round head screws and the two 6-32 by $\frac{1}{2}$" flat head screws of Pt. 25 are to be brass. Six 10-24 by 3/4" flat head screws for the top plate, one 10-24 by 1" flat head screw for Pt. 38 and the two 6-32 by 3/4" flat head screws of Pt. 3 are to be stainless steel or monel metal. All other machine screws may be stainless steel, monel, plated or unplated brass.

COMPLETION: All parts made by the contractor shall be drilled, tapped, countersunk, or otherwise completed to the dimensions shown in the plans even though the holes are not essential to the assembly of parts by the contractor. All parts shall be finished all over, except that the finish provided on commercially purchased gears shall be considered sufficient.

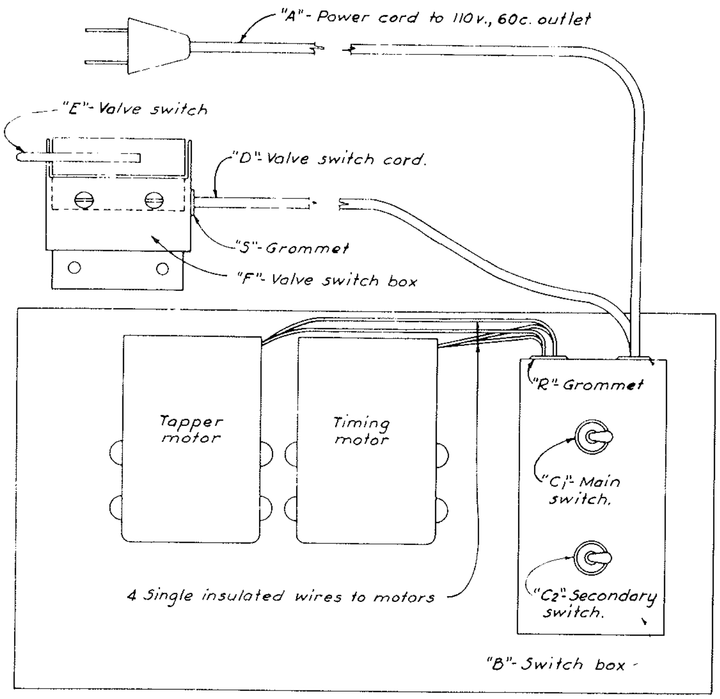
ASSEMBLY: All parts shall be made or supplied by the contractor, completely assembled, and the mechanism adjusted to operate freely.

Part No. 27: Telescope, eyepiece assembly section only, for Eberbach telescope, removable eyepiece with horizontal hair, item 12-630, Page 130 of Geo. T. Walker Catalog W50. Before installation, remove image correcting (glass) lens from front lens assembly and replace the remaining small blank lens retainer ring to hold the remainder of the telescope assembly section in place.

Part No. 29: Pen. The Beta Fountain Pen, Type 200, obtainable from American Recording Chart Co., 3113 East Eleventh St., Los Angeles 23, California, is an acceptable equal to the pen detailed as Part No. 29.

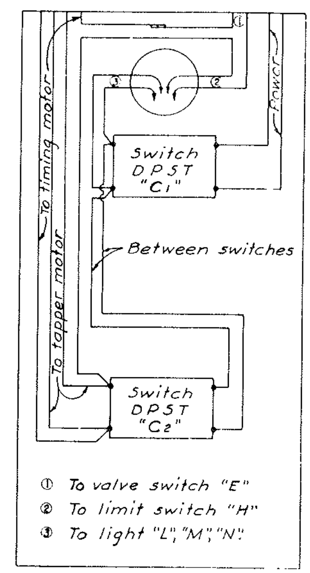
Part No. 34: Timing Motor. Hagen synchronous motor, Model 50, 110 volt, 60 cycle, Type "D" shaft, 1 RPM output, counter-clockwise rotation. Mount with 4 round-head brass machine-screws No. 4-40 NC by 3/8-inch long. Hagen Mfg. Co., Inc., 202 20th Street, Moline, Illinois.

Part No. 35: Tapper Motor. Hagen synchronous motor, Model 56, 110 volt, 60 cycle, Type "D" shaft, 120 RPM output, clockwise rotation. Mount with 4 round-head brass machine-screws No. 4-40 NC by 3/8-inch long. Hagen Mfg. Co., Inc. (Alternate--Type "F" shaft will satisfy requirements for Part No. 35.)

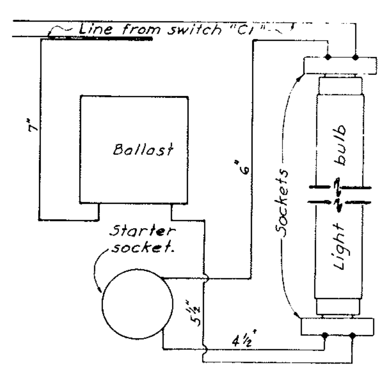


PLAN

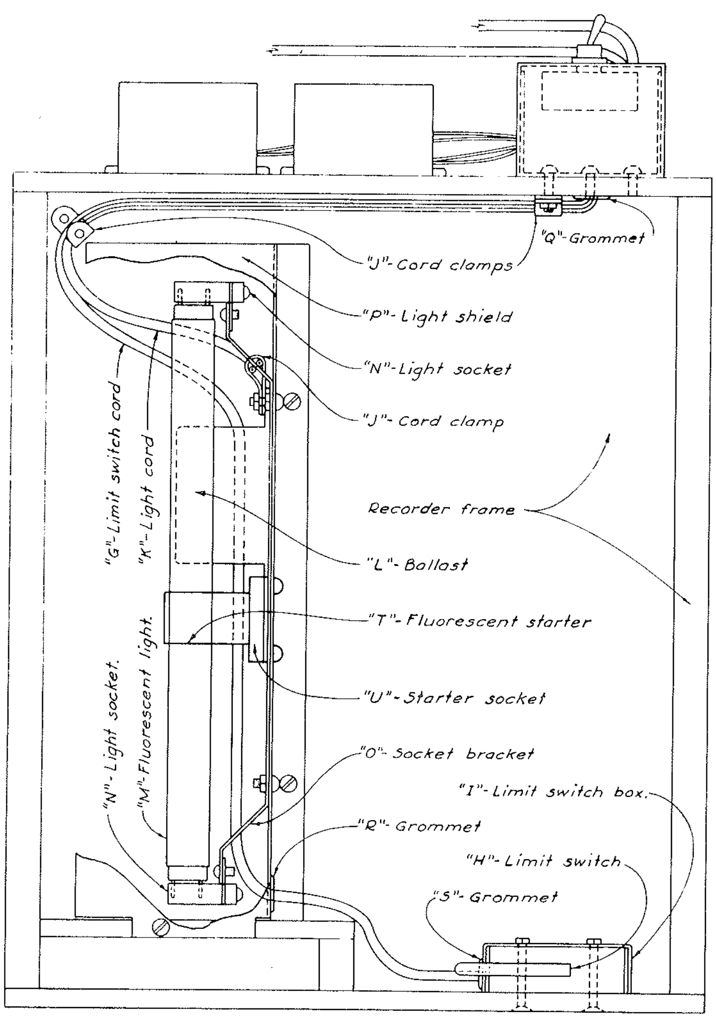
ELECTRICAL EQUIPMENT FOR ONE VISUAL TUBE RECORDER			
Part	Name	Quantity	Remarks
A	Power cord	1	No. 18 tandem cord 7' long with plug
B	Switch box	1	Aluminum box 4" x 2-1/8" x 1-5/8" see detail
C	Power switches	2	1/2 horsepower, double pole, single throw
D	Valve switch cord	1	No. 18 tandem cord, 51" long (74" for tall tube)
E	Valve switch	1	Micro switch, leaf type, normally open
F	Valve switch box	1	Make from sheet aluminum, see detail
G	Limit switch cord	1	No. 18 tandem cord, 29" long
H	Limit switch	1	Micro switch, leaf type, normally closed
I	Limit switch box	1	Make from sheet aluminum, see detail
J	Cord clamp or hook	3	Make from detail or use commercial clamp
K	Light cord	1	No. 18 tandem cord, 19" long
L	Ballast	1	6 watt fluorescent ballast
M	Fluorescent light	1	6 watt fluorescent bulb 5/8" x 9"
N	Light sockets	2	6 watt fluorescent, pair, right and left
O	Socket bracket	1	Make from sheet aluminum, see detail
P	Light shield	1	Make from sheet aluminum, see detail
Q	Grommet, 1/4" I. D.	1	For 15/32" D. hole in 1/4" wall
R	Grommet, 1/4" I. D.	3	For 3/8" D. hole in 1/16" wall
S	Grommet, 3/16" I. D.	2	For 5/16" D. hole in 1/16" wall
T	Fluorescent starter	1	6 watt fluorescent starter
U	Starter socket	1	Fluorescent starter socket, Tap 6-32 NC
4-40 NC Rd. Hd. Br. mach. screw		3	Two 1/4" long; one 1/2" long
4-40 NC Flat Hd. Br. mach. screw		2	Two 1-1/4" long
4-40 NC brass nuts		3	
6-32 NC Rd. Hd. Br. mach. screw		12	Ten 1/4" long; two 1" long
6-32 NC brass nuts		6	



SWITCH BOX WIRING DIAGRAM

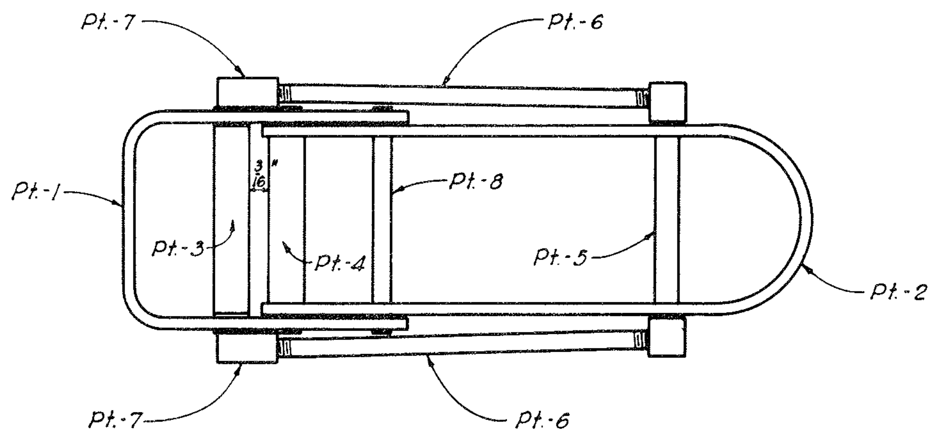


LIGHT WIRING DIAGRAM



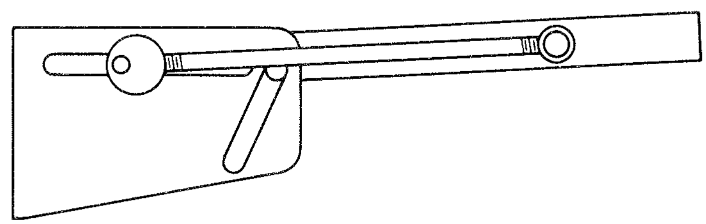
ELEVATION

FIG. 3
ELECTRICAL EQUIPMENT
FOR
VISUAL TUBE RECORDER



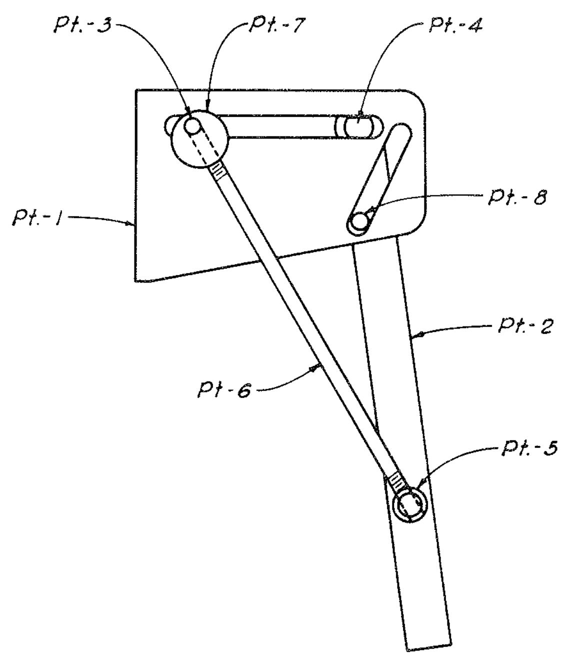
PLAN

CLOSED POSITION



ELEVATION

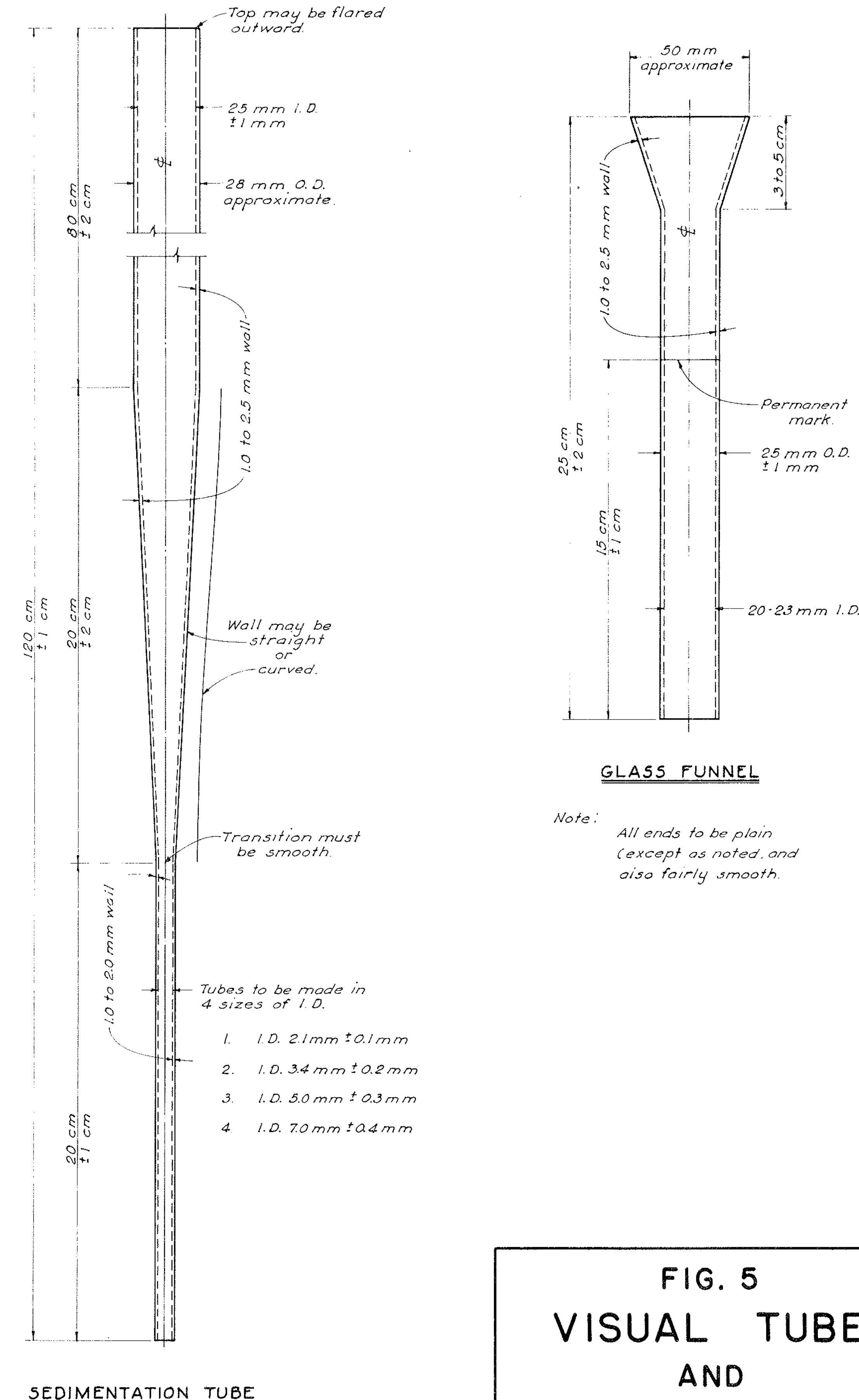
CLOSED POSITION



ELEVATION

OPEN POSITION

FIG. 4
VALVE MECHANISM
FOR
VISUAL TUBE



Note: All ends to be plain (except as noted, and also fairly smooth.

FIG. 5
VISUAL TUBE AND FUNNEL

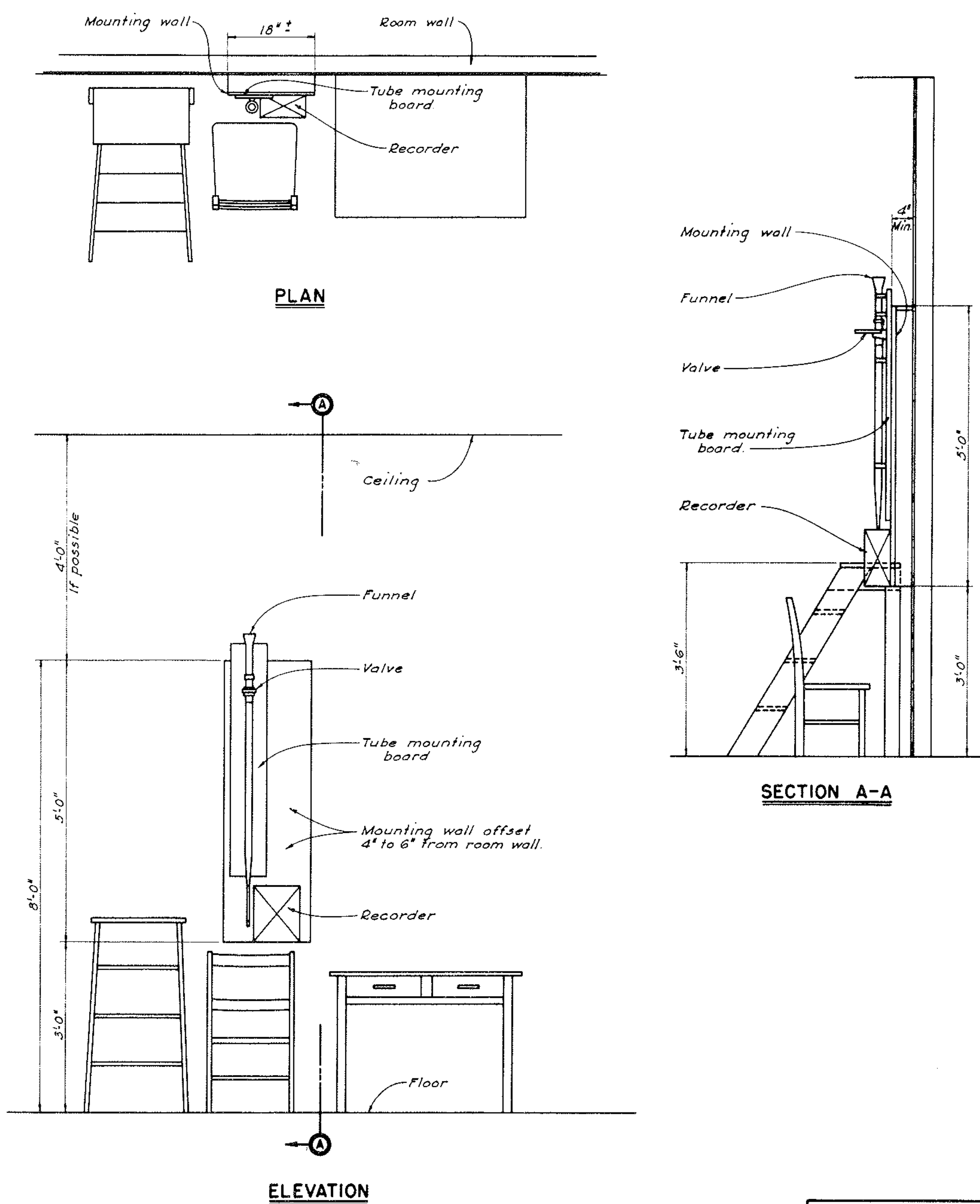


FIG. 6

GENERAL ARRANGEMENT FOR VISUAL TUBE APPARATUS

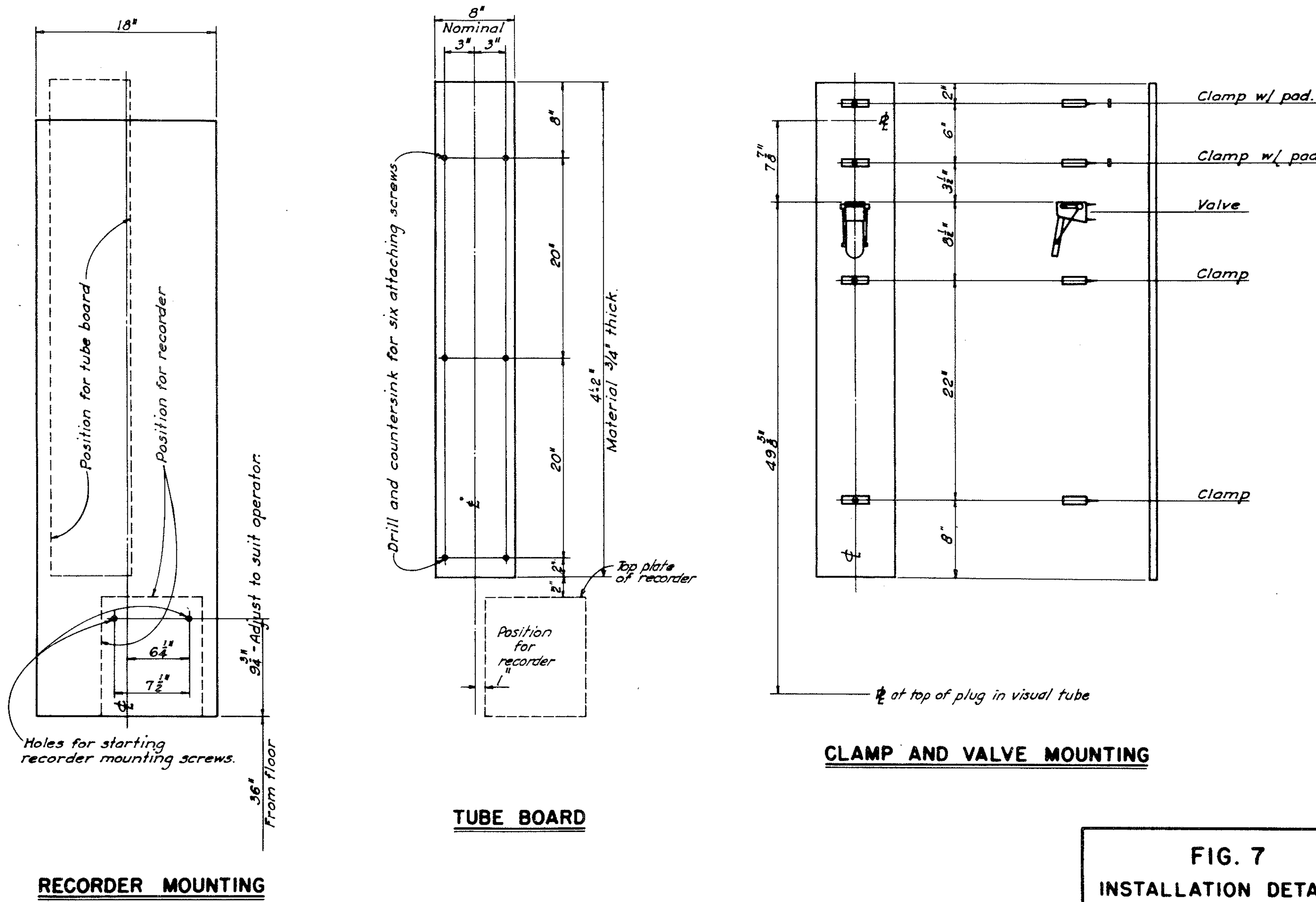


FIG. 7
INSTALLATION DETAILS FOR VISUAL TUBE APPARATUS

SIZE DISTRIBUTION	
DIAMETER MICRONS	PERCENT FINER
700	
500	100
350	90
250	77
175	60
125	43
88	22
62.5	6

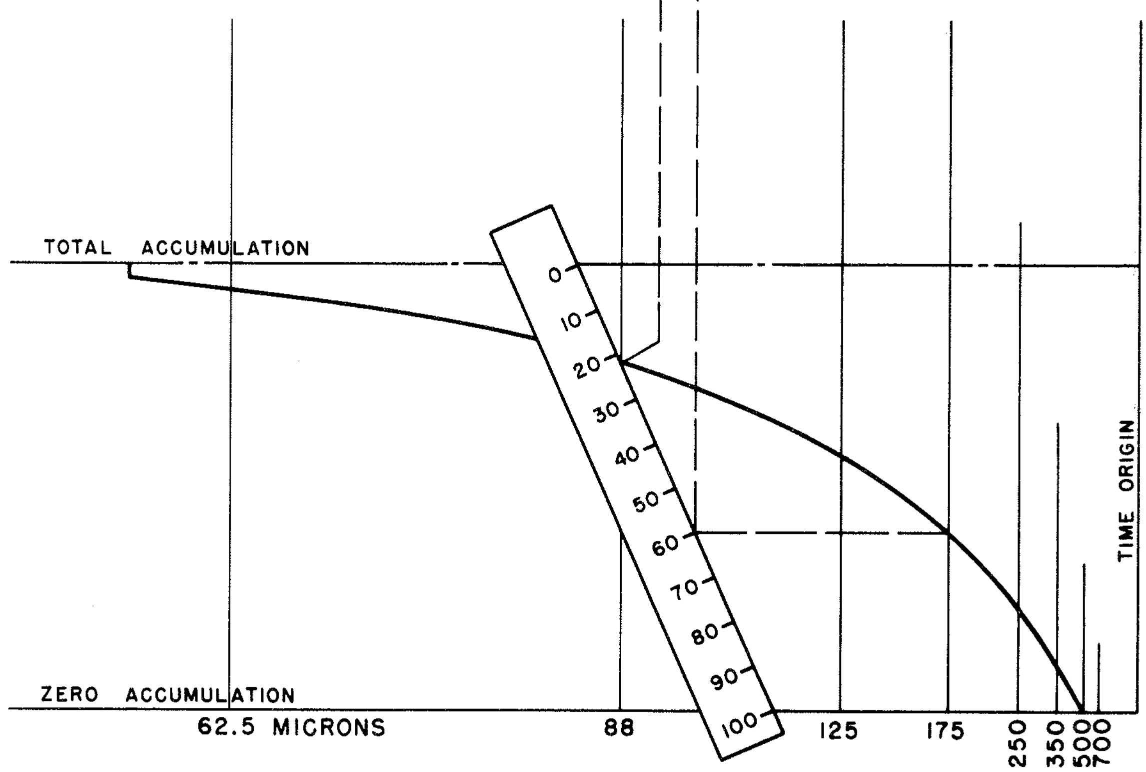
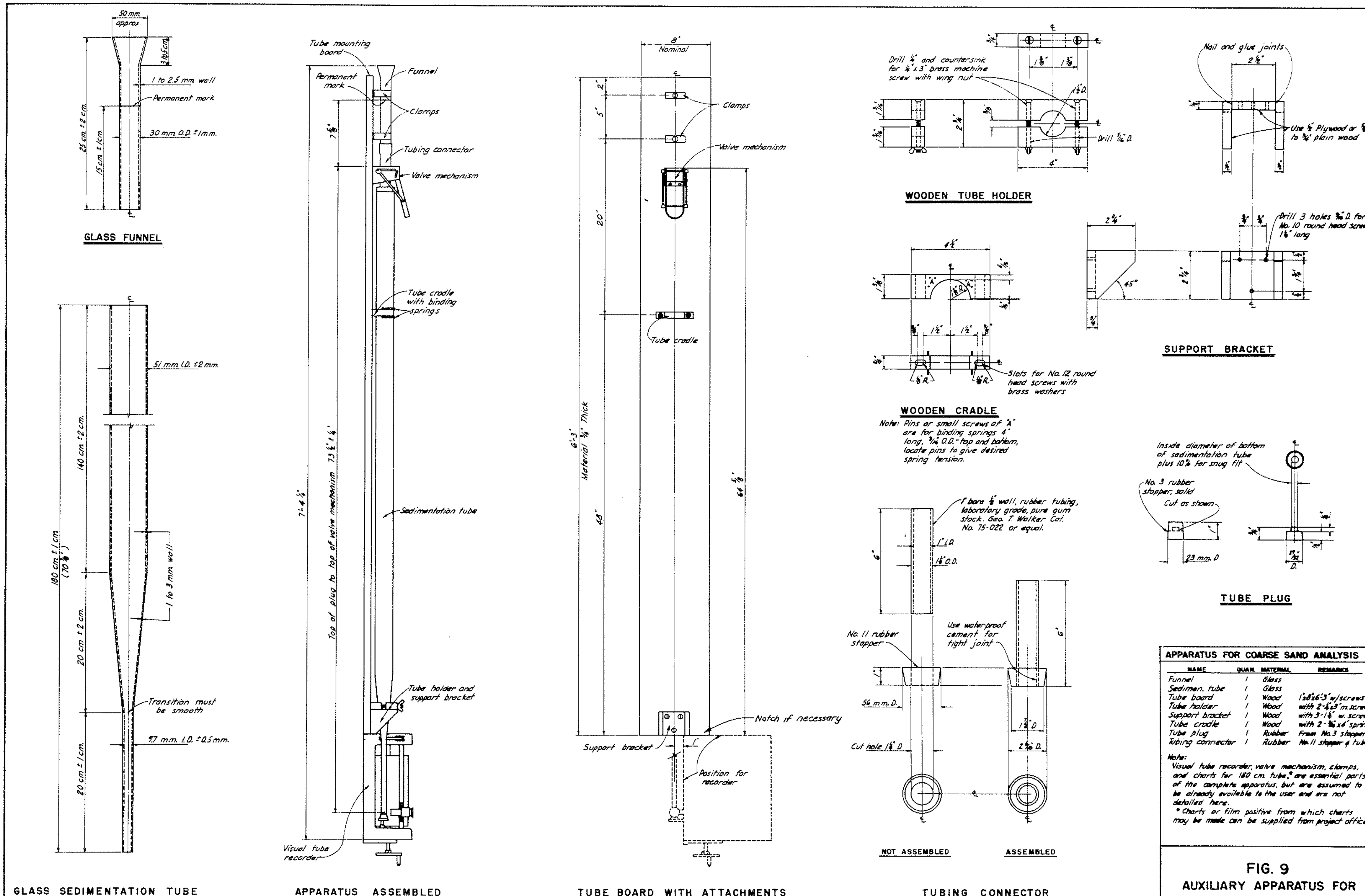


FIG. 8
DETERMINATION
OF
SIZE DISTRIBUTION



APPARATUS FOR COARSE SAND ANALYSIS

NAME	QUAN.	MATERIAL	REMARKS
Funnel	1	Glass	
Sedimen. tube	1	Glass	
Tube board	1	Wood	1"x8"x6'-3" w/screws
Tube holder	1	Wood	with 2-¼"x3" m. screws
Support bracket	1	Wood	with 3-1¼" w. screws
Tube cradle	1	Wood	with 2-3/16"x4" springs
Tube plug	1	Rubber	From No. 3 stopper
Tubing connector	1	Rubber	No. 11 stopper & tube

Note:
Visual tube recorder, valve mechanism, clamps, and charts for 180 cm. tube,* are essential parts of the complete apparatus, but are assumed to be already available to the user and are not detailed here.
* Charts or film positive from which charts may be made can be supplied from project office

FIG. 9
AUXILIARY APPARATUS FOR VISUAL TUBE ANALYSIS OF COARSE SANDS