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Techniques of Water-Resources Investigations of the United States Geological Survey

Chapter A7

STAGE MEASUREMENT AT GAGING STATIONS

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Book 3

APPLICATIONS OF HYDRAULICS

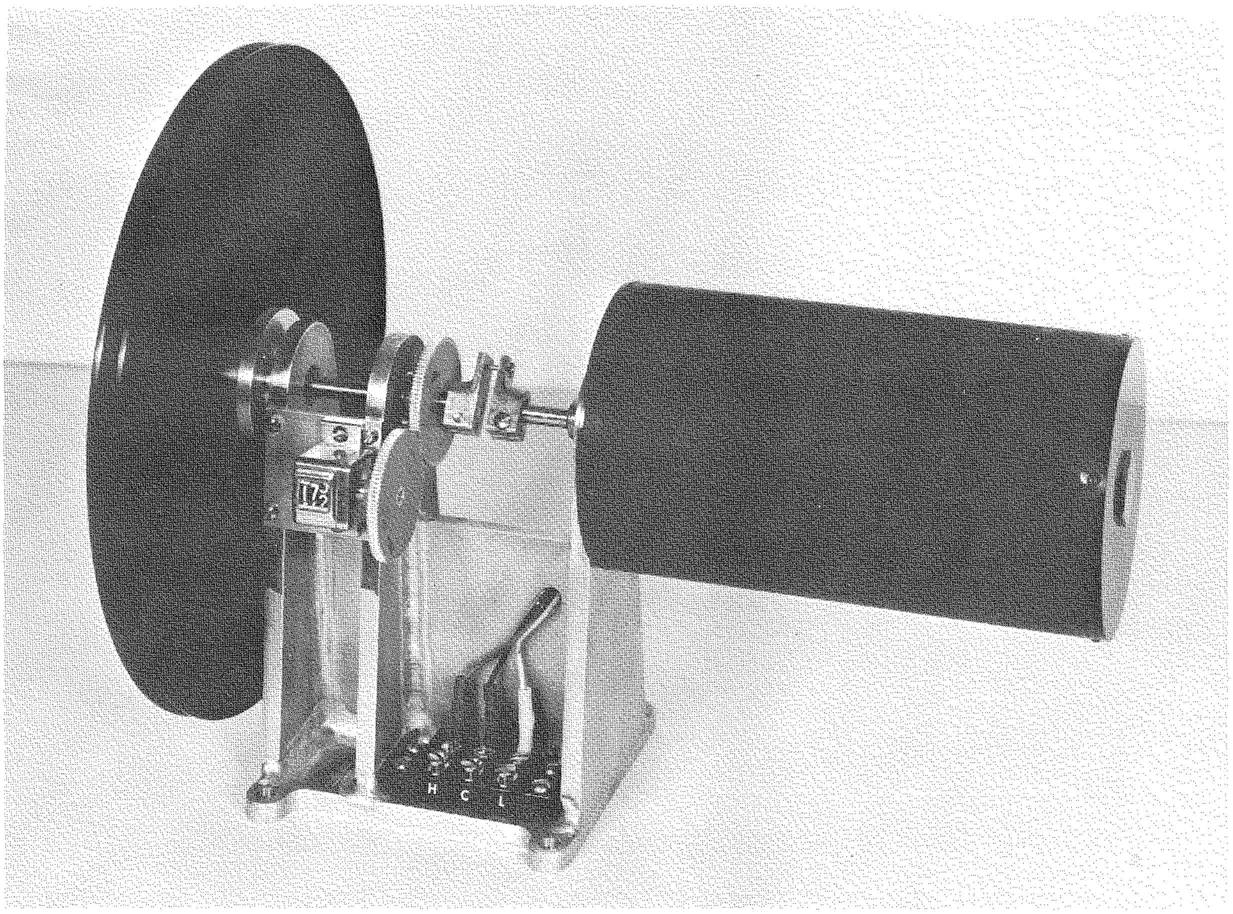

Figure 19.—Resistance system transmitter unit.

(See fig. 20.) By adjusting this potentiometer for a null balance on the meter, the gage height can be read directly to tenths of a foot from a dial coupled to the potentiometer shaft. This system operates on batteries, and three wires connect the unit.

Nonrecording gages

One method of obtaining a record of stage is by the systematic observations of a nonrecording gage. In the early days of the Geological Survey this was the means generally used to obtain records of stage, but now the water-stage recorder is used at practically all gaging stations.

The advantages of nonrecording gages are low initial cost and ease of installation. The disadvantages are the need for an observer and the lack of accuracy of the estimated continuous gage-height graph sketched through points of observation.

Nonrecording gages are still in general use as auxiliary gages at water-stage recorder installations to serve the following purposes:

1. As a reference gage to indicate the water-surface elevation in the stream.
2. As a reference gage to indicate the water-surface elevation in the stilling well. Gage readings on the stream are compared with the reference readings in the well to determine whether stream stage is being obtained in the well.
3. As a temporary substitute for the recorder when the intakes are plugged or there is equipment failure. The outside reference gage can be read as needed by a local ob-

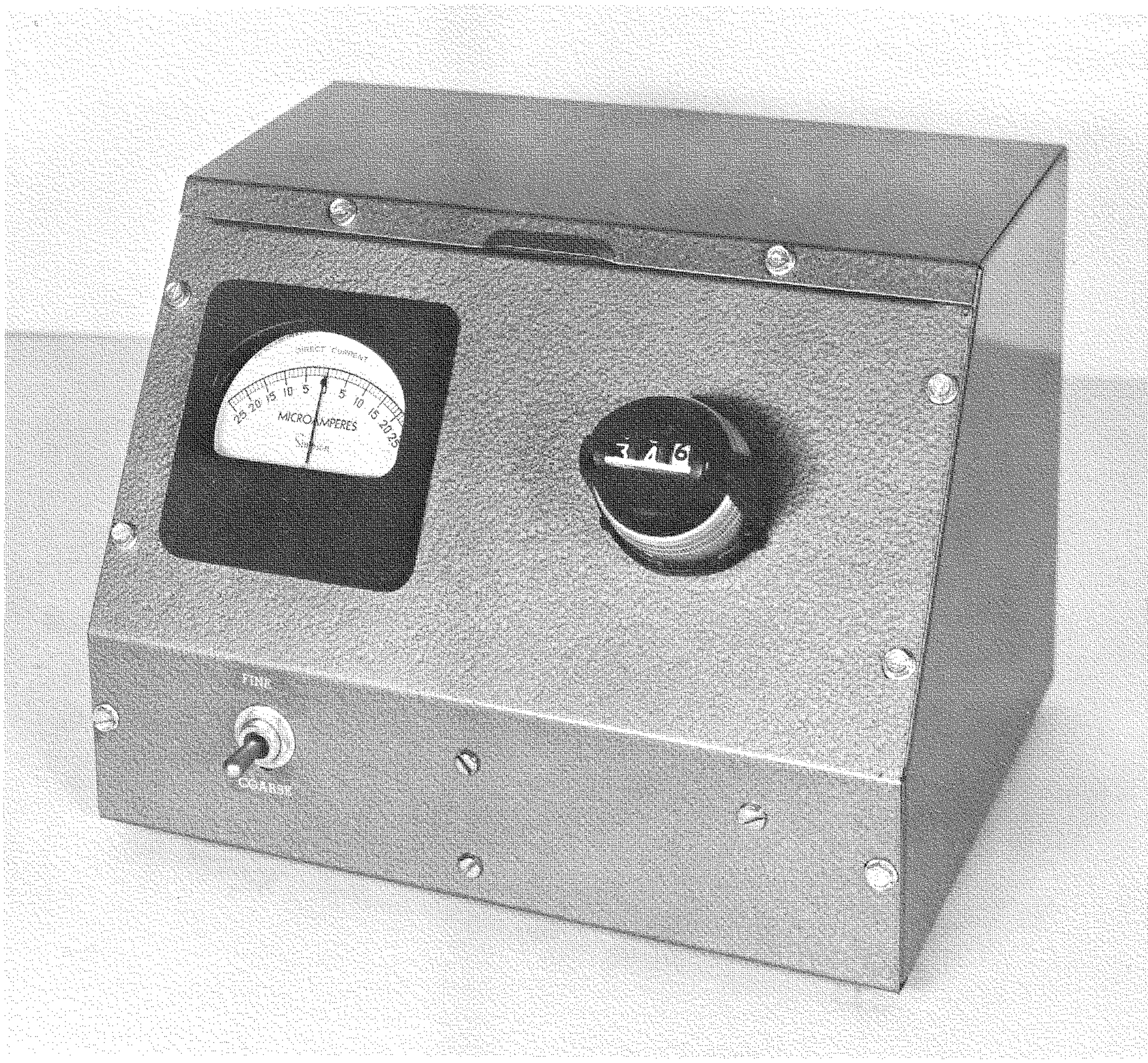

Figure 20.—Resistance system indicator unit.

server to continue the record of stage during the malfunction.

The types of nonrecording gages generally used are staff, wire-weight, float-tape, and electric-tape.

Staff and wire-weight gages are normally used at nonrecording gaging stations. They are also used as the outside reference gage at recording gaging stations. Float- and electric-tape gages and the vertical staff gage are used in stilling wells. Staff gages are read directly whereas the other three types are read by measurement to the water surface from a fixed point.

Staff gage

The staff gage is either vertical or inclined. The standard U.S. Geological Survey vertical staff gage consists of porcelain enameled iron sections 4 inches wide and 3.4 feet long and graduated every 0.02 foot. (See fig. 21.) The vertical staff gage is used in the stilling well as a reference gage or in the stream as an outside gage.

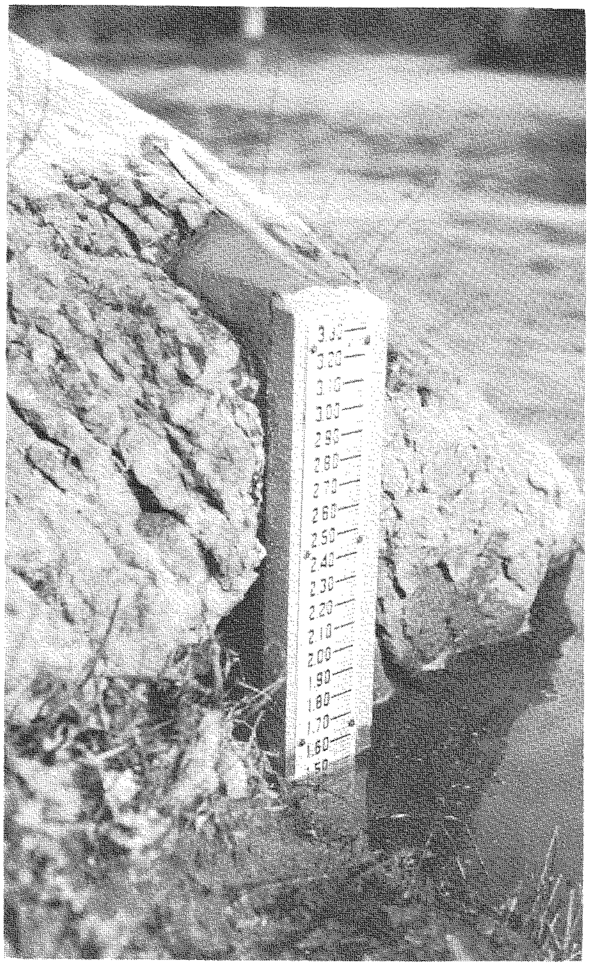

Figure 21.—Vertical staff gage.

An inclined staff gage usually consists of a graduated heavy timber securely attached to a permanent foundation. Inclined gages built flush with the streambank are less likely to be damaged by floods, floating ice, or drift than are projecting vertical staffs. Copper barrelhoop staples and bronze numerals are ordinarily used for the graduations. Inclined gages are used as outside reference gages.

Wire-weight gage

The type A wire-weight gage has replaced the Canfield wire-weight gage at most stations. The type A gage consists of a drum wound with a single layer of cable, a bronze weight attached to the end of the cable, a graduated disc, and a Veeder counter, all within a cast-aluminum box. (See fig. 22.) The disc is graduated in tenths and hundredths of a foot and is permanently connected to the counter and to the shaft of the drum. The cable is made of 0.045-inch diameter stainless-steel wire, and is guided to its position on the drum by a threading sheave. The reel is equipped with a pawl and ratchet for holding the weight at any desired elevation. The diameter of the drum of the reel is such that each complete turn represents a 1-foot movement of the weight. A horizontal checking bar is mounted at the lower edge of the instrument so that when it is moved to the forward position the bottom of the weight will rest on it. The gage is set so that when the bottom of the weight is at the water surface, the gage height is indicated by the combined readings of the counter and the graduated disc. The type A wire-weight gage is used as an outside reference gage.

Float-tape gage

The float-tape gage consists of float, graduated steel tape, counterweight, and pulley. (See fig. 1.) The float pulley is usually 6 inches in diameter, grooved on the circumference to accommodate the tape, and mounted in a standard. An arm extends from the standard to a point slightly beyond the tape to carry an adjustable index. The tape is connected to the float by a clamp which also may be used for making adjustments to the tape reading if the adjustments necessary are too large to be accommodated by the adjustable index. A 10-inch-diameter copper float and a 2-pound lead counterweight are normally used. The float-tape gage is used chiefly as an inside reference gage.

Electric-tape gage

The electric-tape gage consists of a steel tape graduated in feet and hundredths, to which is fastened a cylindrical weight, a reel in a frame for the tape, a 4½-volt battery, and a voltmeter. (See fig. 23.) One ter-

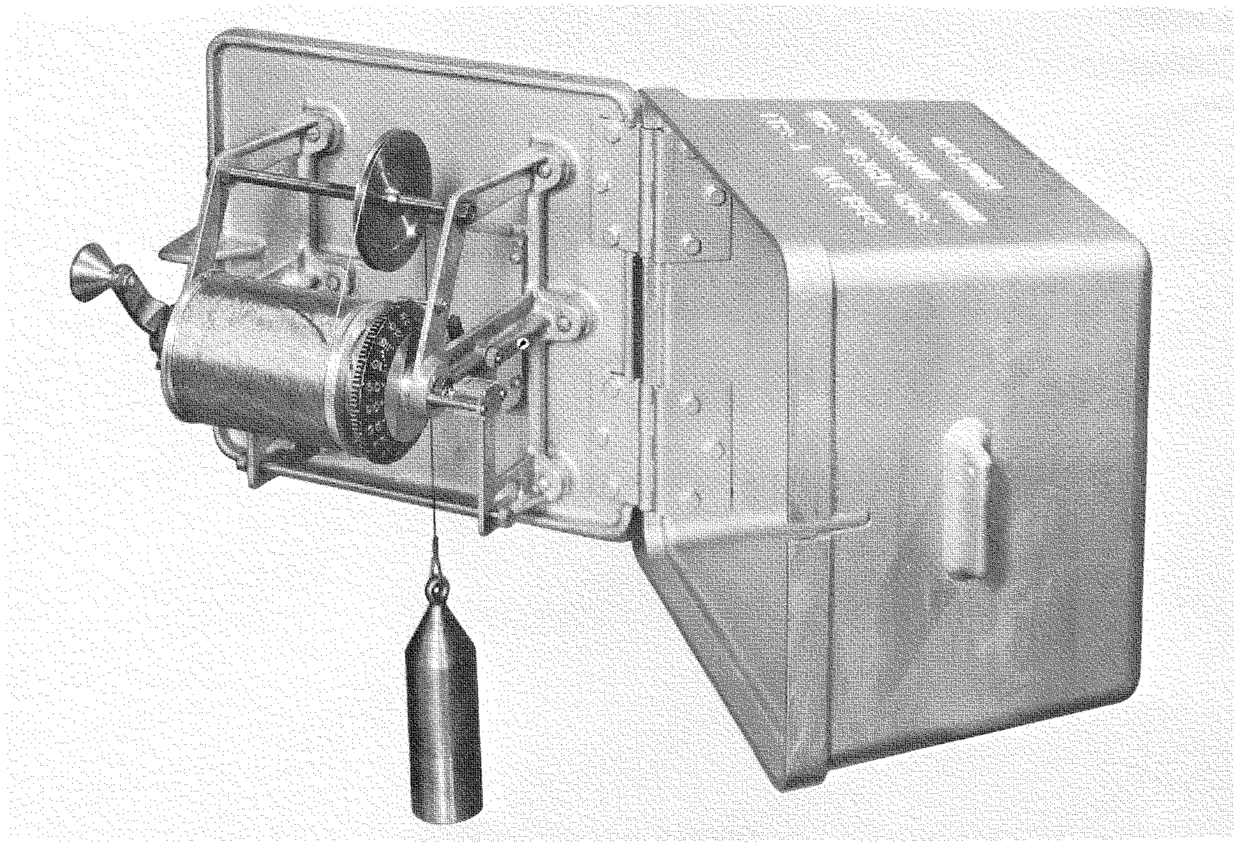

Figure 22.—Type A wire-weight gage.

minal of the battery is attached to a ground connection, and the other to one terminal of the voltmeter. The other terminal of the voltmeter is connected through the frame, reel, and tape, to the weight. The weight is lowered until it contacts the water surface; this contact completes the electric circuit and produces a signal on the voltmeter. With the weight held in the position of first contact, the tape reading is observed at the index provided on the reel mounting. The electric tape gage is used as an inside reference gage and occasionally as an outside reference gage. If oil is floating on the water surface, the gage will give the gage height of the interface, because oil is a dielectric.

Chain gage

A chain gage is used where outside staff gages are hard to maintain and where a bridge, dock or other structure over the water is not available for the location of a wire-weight gage. The chain gage can be mounted on a cantilevered arm which extends out over the stream, or which is made in such a way that it can be tilted to extend over the stream.

The chain gage consists of the cantilevered arm which is firmly held in place, one or more enamel gage sections mounted horizontally on the cantilever, and a heavy sash chain which runs over a pulley on the streamward end of the cantilever. A weight is attached to the streamward end of the chain, and a marker is attached to the chain near the other end. Additional markers can be attached to the chain at appropriate intervals to obtain gage heights greater than that directly obtainable from the mounted gage sections. The chain is mounted so that it moves along the gage sections.

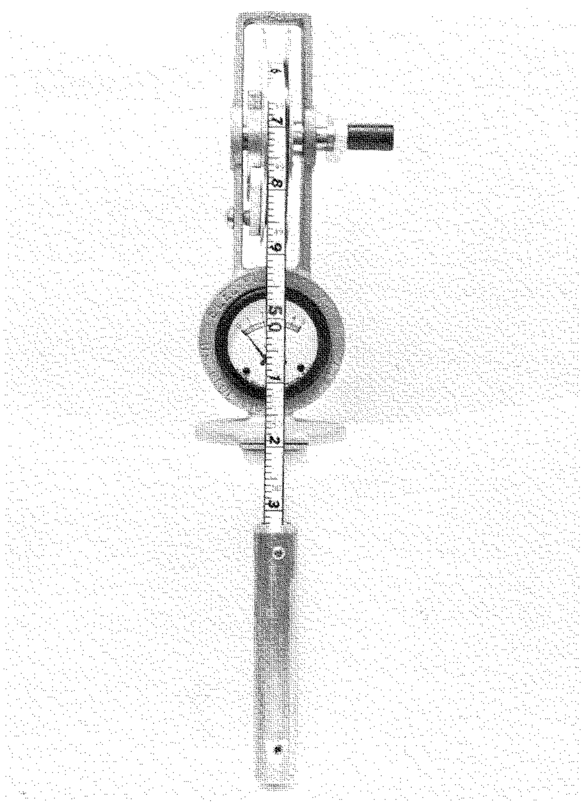

Figure 23.—Electric-tape gage.

Stage is determined by lowering the weight until the bottom of the weight just touches the water surface. The gage height then is read from the mounted gage at the location of the appropriate chain marker.

Remote indicating staff gage

The remote indicating staff gage, (developed by George Smoot, Hydraulic Engineer, U.S. Geological Survey) was designed as an aid for obtaining a record of stage where outside gages are difficult to maintain owing to ice conditions. The gage is a mercury manometer having a stainless-steel reservoir and a vertical glass tubing with a graduated scale. Pressure exerted by the height of water above the orifice is transmitted to the reservoir through a plastic tube by a gas bubbling technique similar to that used with the bubble-gage sensor described earlier. Figure 24 shows the main components of the gage.

Gas is supplied by gently pumping a bicycle pump, attached to the unit, just prior to taking a reading. A check valve is provided in the line to maintain pressure and to prevent water from backing up and freezing in the tube. The length of tubing which can be used is, from an operational viewpoint, unlimited as the system is static at the time of reading and no error due to friction losses is involved.

Limited vertical adjustment to the scale for datum correction can be made by movement of the scale relative to the manometer tubing. Since no temperature correction is provided, the gage should be located in a heated shelter, such as the observer's house if nearby.

Water-level finder

The water-level finder is useful for determining the outside stage at locations where

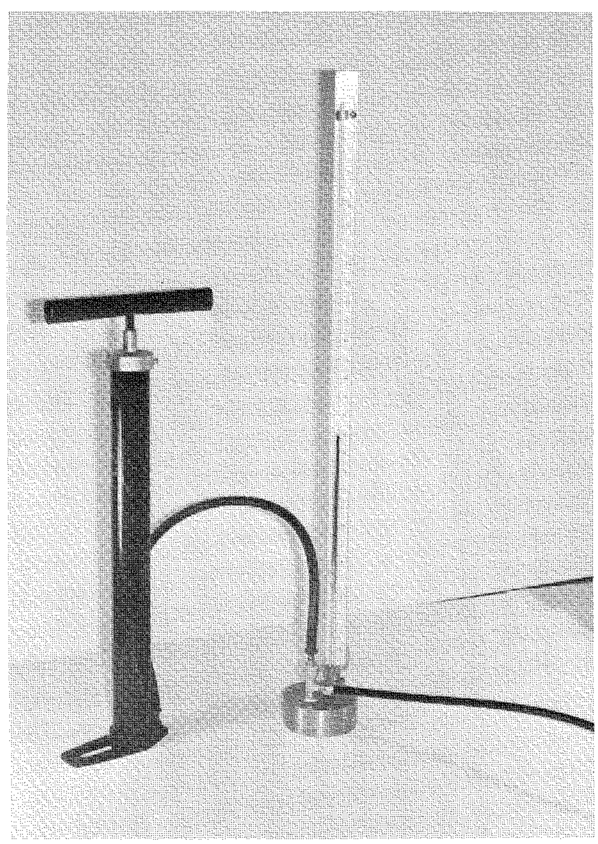

Figure 24.—Remote indicating staff gage.

waves or excess fluctuations of the water surface are present. A sensor is suspended from a graduated tape which is mounted on a reel whose elevation, relative to the gage datum, is known. Mounted with the reel is a milliammeter, battery, and index. The sensor consists of a 10-inch length of 1-inch-diameter pipe with a cap on one end and a brass rod inserted through a hole in the cap. The piece of 10-inch pipe has a small vent near its upper end. The graduated tape is attached to the brass rod which is insulated from the pipe and extends to about the midpoint of the pipe.

The gage height is determined by lowering the sensor to the water surface. When the lower end of the pipe touches the water, the milliammeter will show a small deflection. The sensor is then further lowered until the brass rod touches the water, at which time the milliammeter will show a large deflection. When the large deflection occurs, a reading is made from the tape at the index. Since the pipe acts as a miniature stilling well, an accurate reading can be obtained even in rather rough water.

Operation of stage gages

Continuous records of discharge at a gaging station are computed from the record of stage and the stage-discharge relation. For this purpose stage records to an accuracy of 0.01 foot are generally needed. This accuracy can be obtained by use of the stage-recording systems previously described. Strip-chart or digital recorders are designed to give a continuous record of stage, but careful attention is necessary to prevent malfunctions during unattended periods of 4-6 weeks. Attention to the following items will increase the accuracy and continuity of the stage record:

1. The datum of the gage should be maintained to 0.01 foot by running levels to reference marks at least once every 2–3 years. If conditions are known to be unstable, then levels should be run more often.
2. The recorded gage height should be checked against the water level in the stream during each visit of engineering personnel to insure that intakes are open or that there is no malfunction in the gas-purge system of the bubble gage.
3. Intakes to stilling wells should be properly located and sized to prevent surge. Static tubes or other devices should be installed to insure that the water level in the well is virtually the same as in the stream at all times. Comparison of inside and outside gage readings or comparison of floodmarks with recorded peak gage heights should be made at every opportunity.
4. Malfunctions of the recorder can be reduced by the periodic cleaning and oiling of the recorder and the clock.
5. Excessive humidity and temperatures in the gage house should be reduced to a minimum by proper ventilation.
6. Extremely cold temperatures in the gage house should be modified by providing heat, if this is feasible.

Experience has shown that a program of careful inspection and maintenance will result in a complete gage-height record about 98 percent of the time.

Special purpose gages

Model T recorder

The model T recorder (see fig. 25) is a graphic recorder which has a 1:6 gage-height scale and a time scale of 2.4 inches a day. It is limited in its use to a 3-foot range in stage and should be serviced weekly, although it will record more than one trace on the 7-day chart. The model T recorder is operated by a motor-wound spring-driven timer, and power is supplied to the timer by a 4½-volt battery. A timer is also available which operates on a 1½-volt battery. The housing of the recorder is designed to fit on the top of a vertical 3-inch-diameter pipe which can be used as the stilling well. This recorder is much cheaper and more compact than the conventional graphic re-

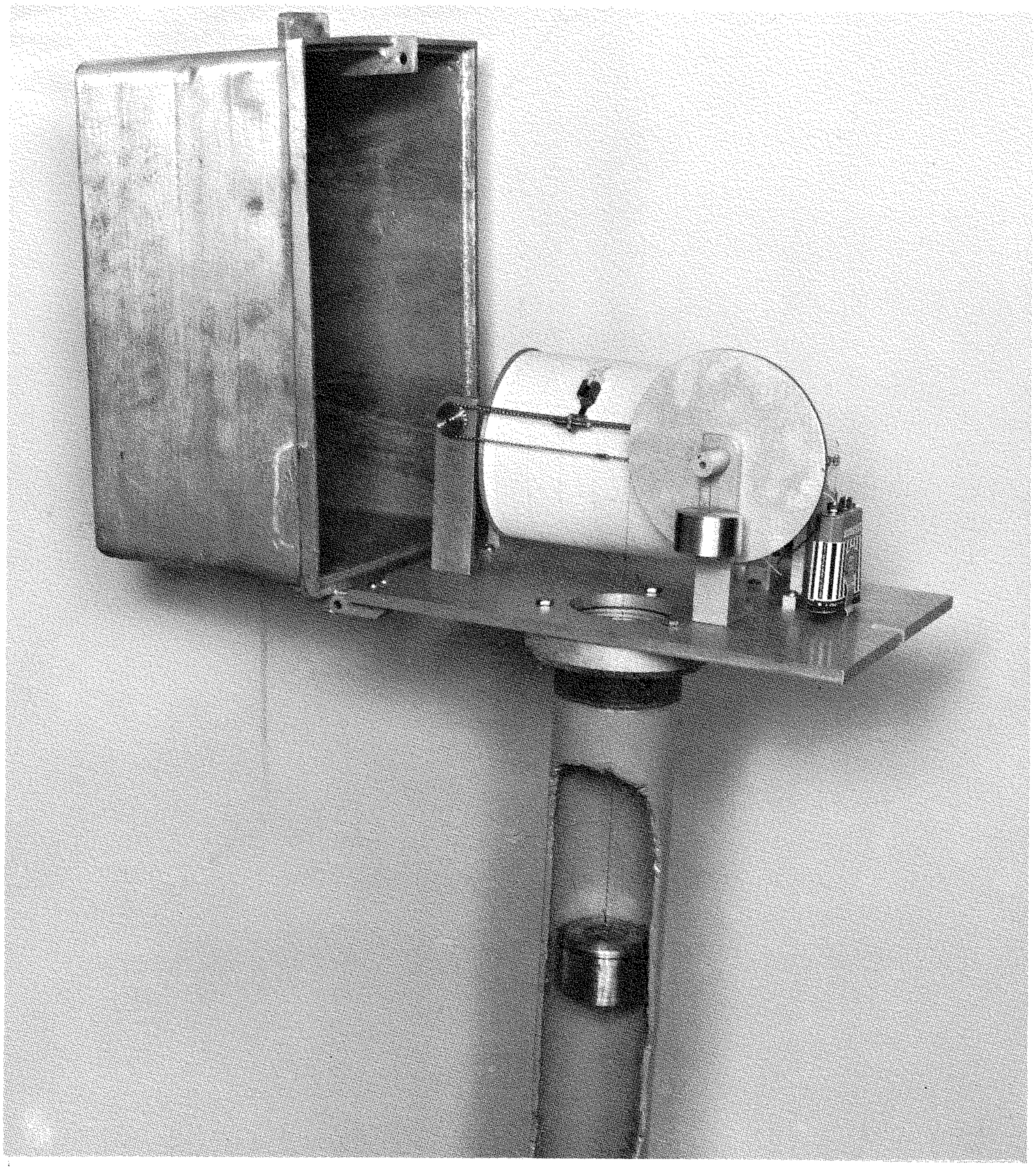

Figure 25.—Model T recorder.

corders and is well suited for temporary installations for low-flow studies. The recorder is not used at continuous-record gaging stations.

SR recorder

The model SR (see fig. 26) is a graphic recorder which records flood stages and rain-

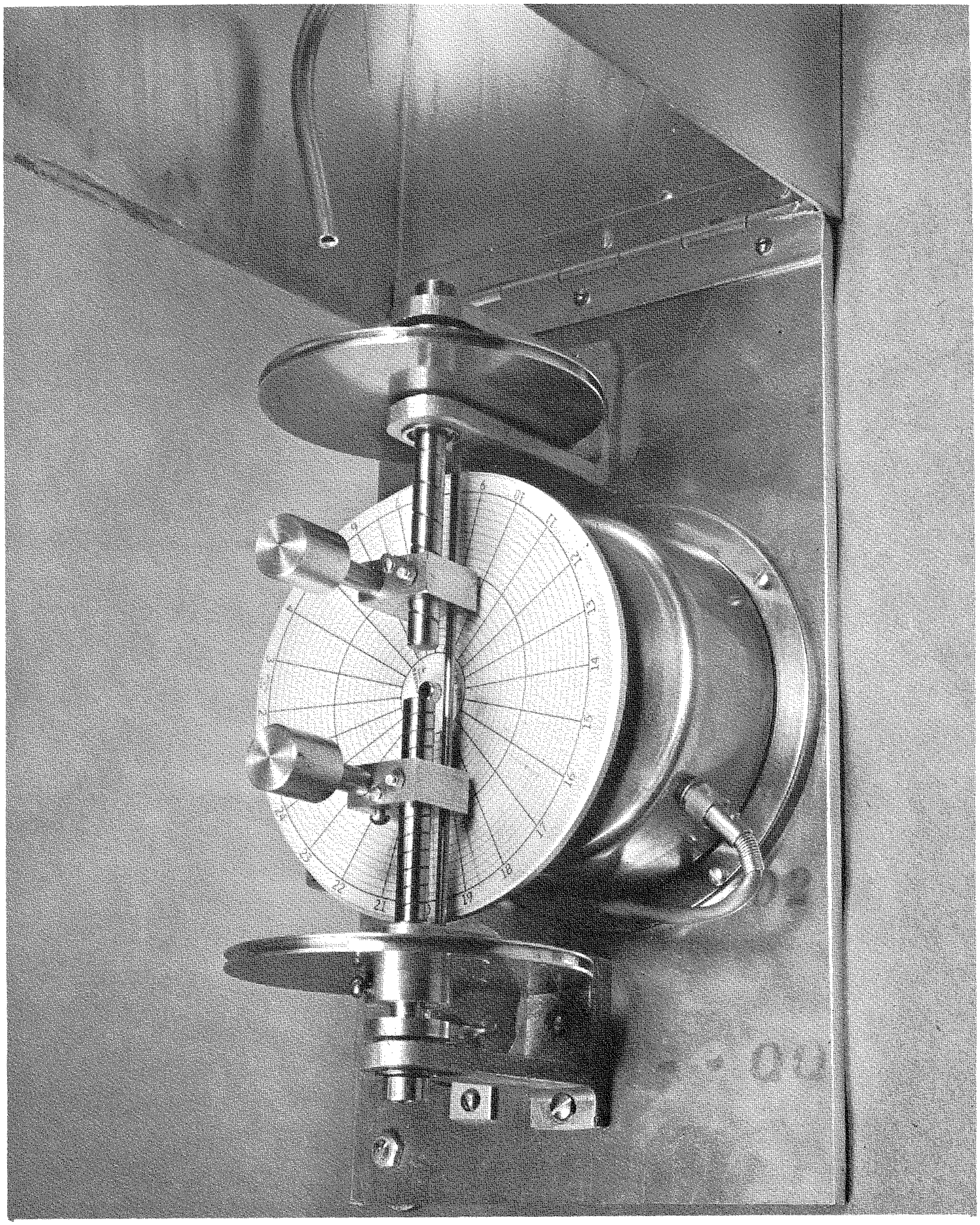

Figure 26.—Model SR recorder.

fall. A 5-inch-diameter flat circular disc is rotated by a battery-wound clock. The power source is a 1½-volt battery. The chart is circular and turns one revolution in 24 hours. Three ranges in stage are available for the effective chart width of 2 inches: 5, 10, or 20 feet. The recorder sits on a 2-inch-diameter pipe which serves as the stilling well (similar to the model T). Five inches of rainfall can also be recorded on the effective width of the chart, but the rainfall reservoir can be equipped with a siphon which will allow an unlimited amount of rainfall to be recorded. The rainfall reservoir is a separate 2-inch-diameter pipe that fills at the rate of 1 foot for each inch of rainfall. After the pipe has filled five feet, the siphon is tripped to empty the pipe.

Crest-stage gage

The crest-stage gage is a device for obtaining the elevation of the flood crest of streams. The gage is receiving widespread use because it is simple, economical, reliable, and easily installed.

Many different types of crest-stage gages have been tested by the Geological Survey. See, for example, Friday (1965) and Carter and Gamble (1963). The one found most satisfactory is a vertical piece of 2-inch galvanized pipe containing a wood or aluminum staff held in a fixed position with relation to a datum reference. (See fig. 27.) The bottom cap has six intake holes located so as to keep the nonhydrostatic drawdown or superelevation inside the pipe to a minimum. Tests have shown this arrangement of intake holes to be effective with velocities up to 10 feet per second, and at angles up to 30 degrees with the direction of flow. The top cap contains one small vent hole.

The bottom cap or a perforated tin cup or copper screening in cup shape attached to the lower end of the staff contains regranulated cork. As the water rises inside the pipe the cork floats on its surface. When the water reaches its peak and starts to recede the cork adheres to the staff inside the pipe, thereby retaining the crest stage of the flood. The gage height of a peak is obtained by measuring the interval on the staff between the reference point and the floodmark. Scaling can be simplified by graduating the staff.

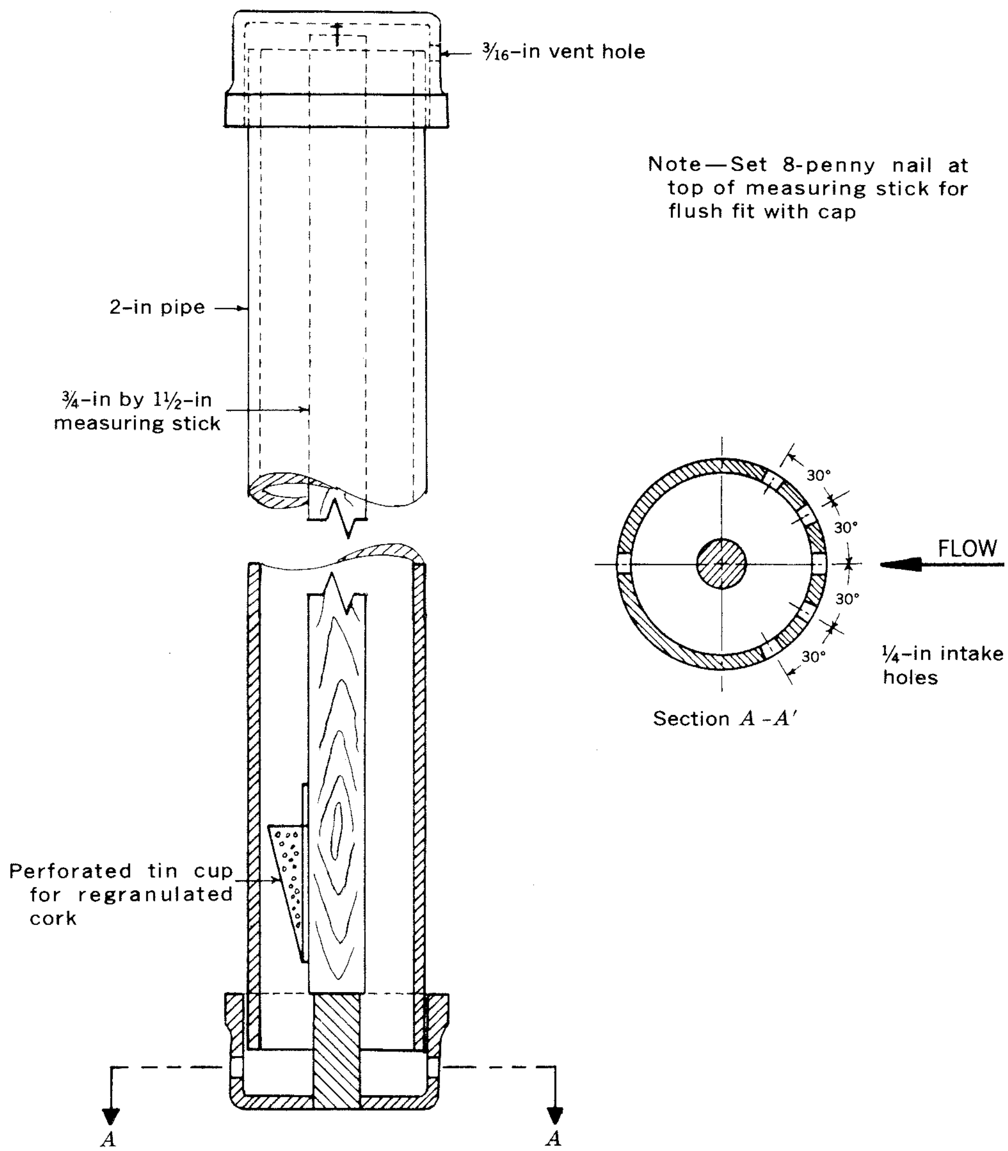

Figure 27.—Crest-stage gage.

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