science for a changing world

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

Chapter A7

STAGE MEASUREMENT AT GAGING STATIONS

By Thomas J. Buchanan and William P. Somers

Book 3

APPLICATIONS OF HYDRAULICS

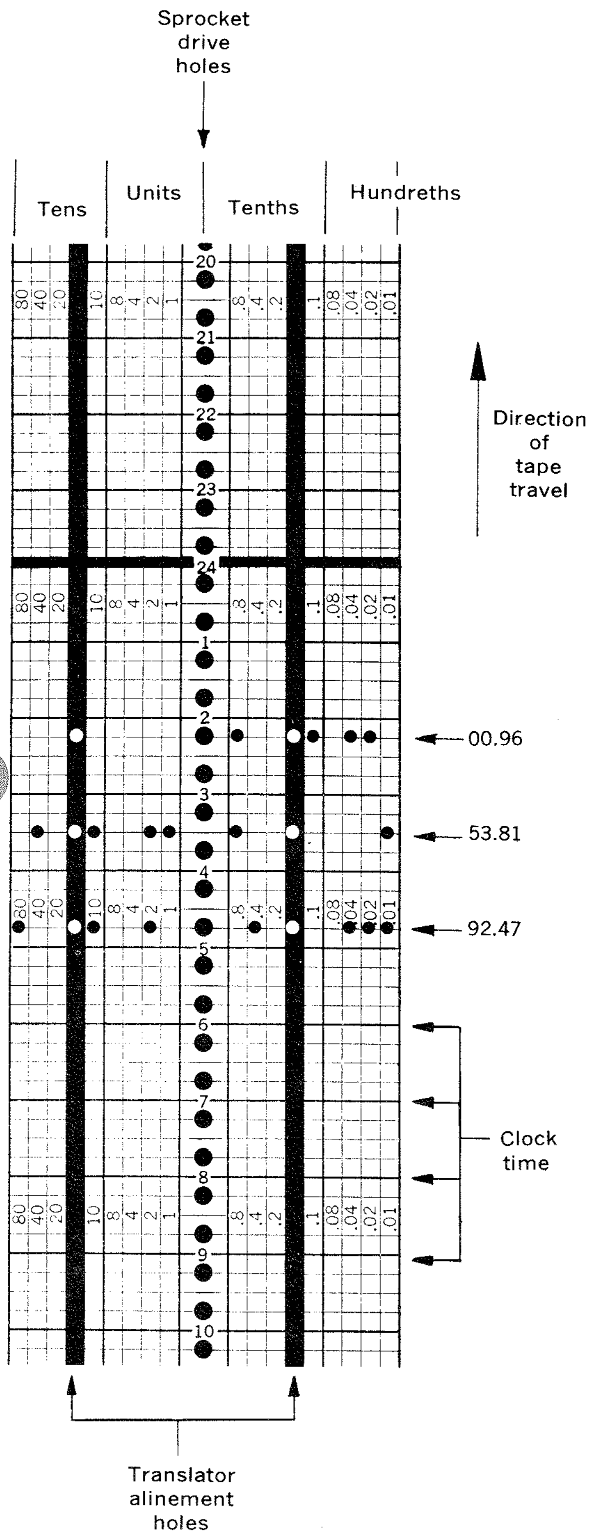

Figure 4.—Illustration of a digital recorder tape.

time on a chart. Usually the gage-height element moves the pen or pencil stylus and the time element moves the chart, but in some recorders this is reversed. The range of available gage-height scales is from 10 inches = 1 foot (10:12) to 10 inches = 20 feet (1:24). The width of strip charts is usually 10 inches. The range of available time scales is from 0.3 to 9.6 inches per day. Normally the 10 inches = 5 feet (1:6) or the 10 inches = 10 feet (1:12) gage-height scale is used along with 1.2, 2.4, or 4.8 inches per day time scale.

Most graphic recorders can record an unlimited range in stage by a stylus-reversing device or by unlimited rotation of the drum.

Most strip-chart records will operate for several months without servicing. Drum recorders require attention at weekly intervals. Figure 6 shows a commonly used continuous strip-chart graphic recorder, and figure 7 a horizontal-drum recorder that must be serviced at weekly intervals. Attachments are available for the recorder shown in figure 6 to record water temperature or rainfall on the same chart with stage.

Stilling wells

The stilling well protects the float and dampens the fluctuations in the stream caused by wind and turbulence. Stilling wells are made of concrete, reinforced concrete, concrete block, concrete pipe, steel pipe, and occasionally wood. They are usually placed in the bank of the stream (see figs. 8, 9, 10, 11, and 12), but often are placed directly in the stream and attached to bridge piers or abutments. (See figs. 13 and 14.) The stilling well should be long enough for its bottom to be at least a foot below the minimum stage anticipated and its top above the level of the 50-year flood. The inside of the well should be big enough to permit free operation of all the equipment to be installed. Normally a pipe 4 feet in diameter or a well with inside dimensions 4 by 4 feet is of satisfactory size, but pipes

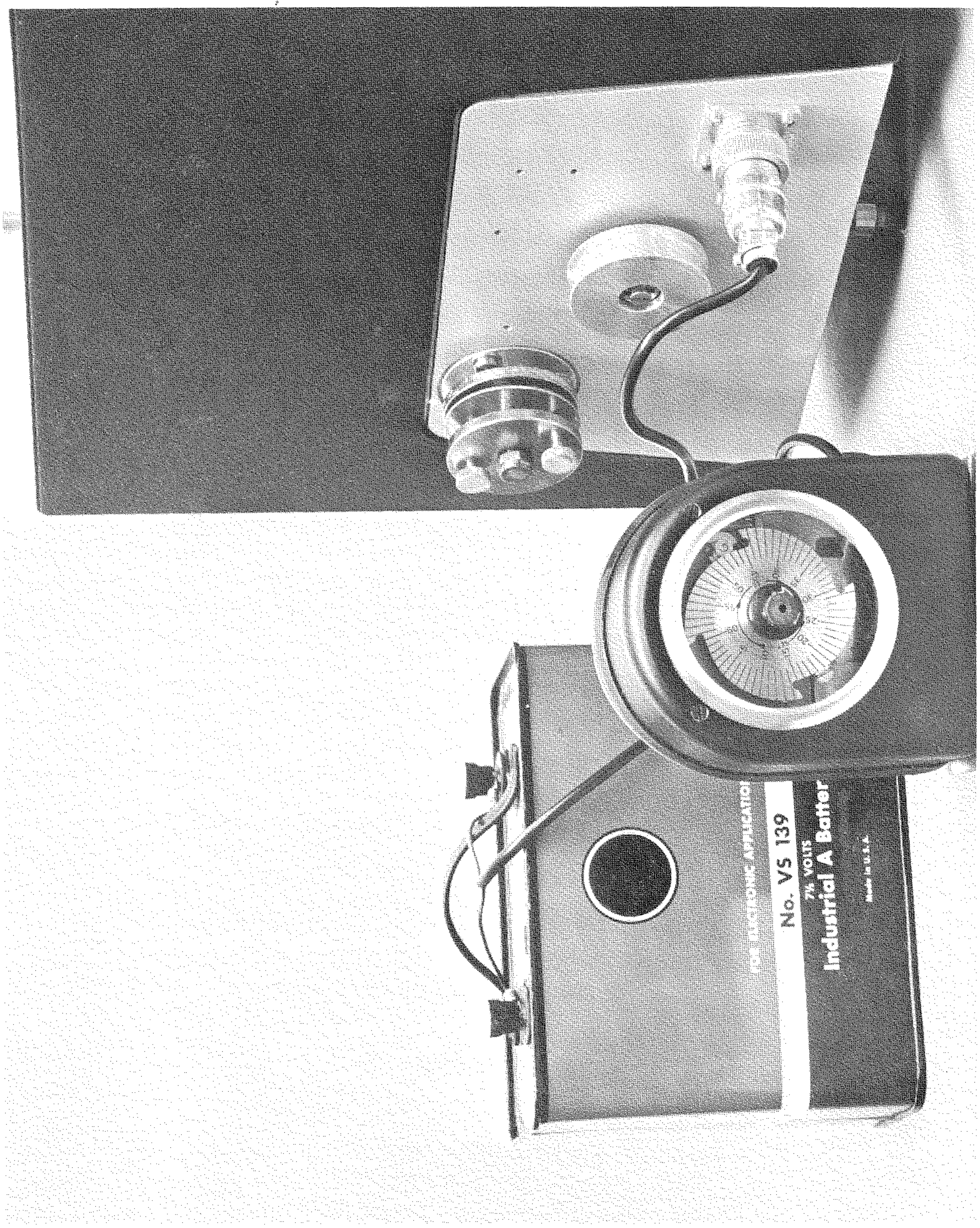

Figure 5.—Digital recorder timer.

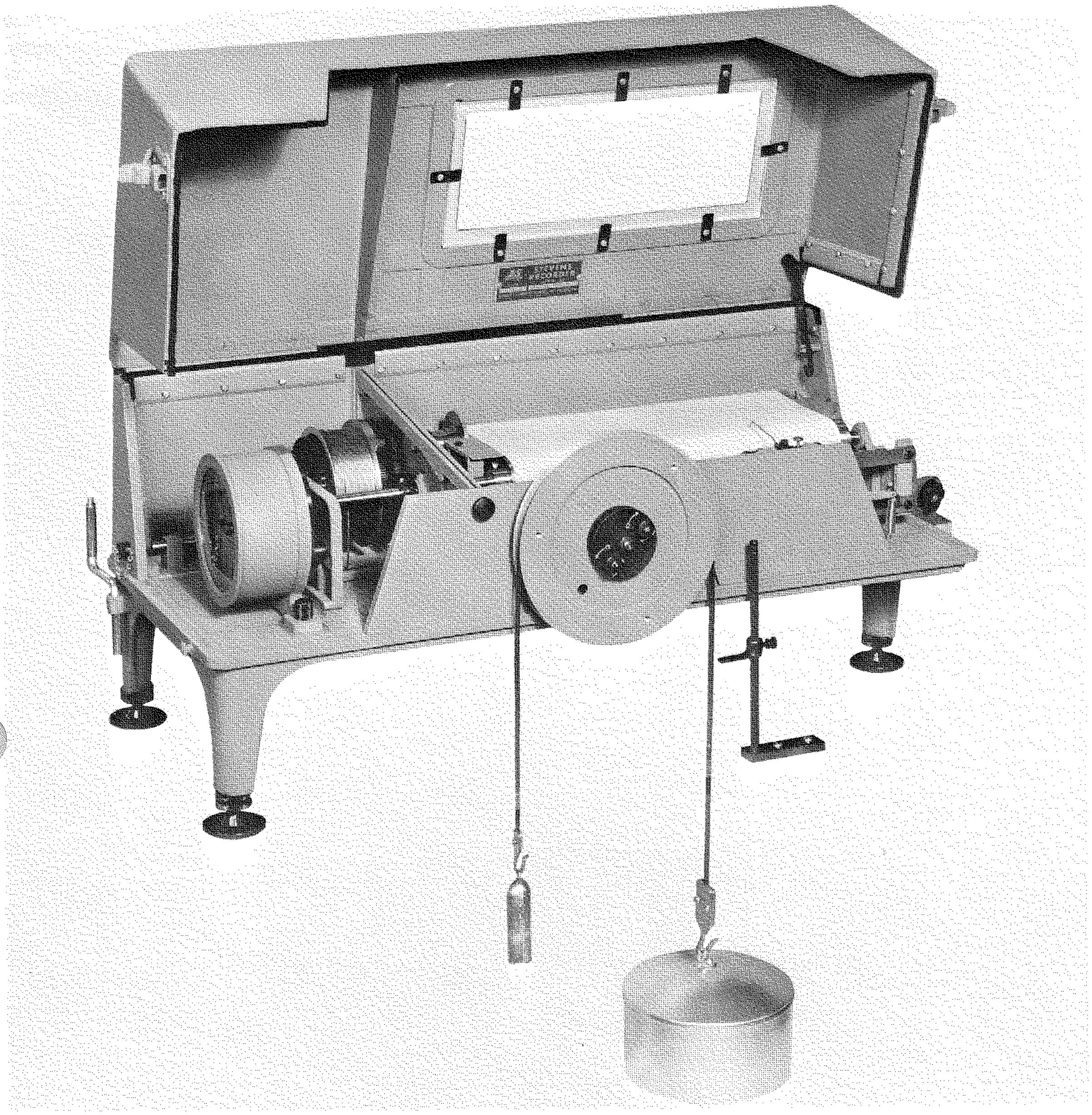

Figure 6.—Continuous strip-chart recorder.

18 inches in diameter have been used for temporary installations where a conventional water-stage recorder was the only equipment to be installed. The 4- by 4-foot well provides ample space for the hydrographer to enter the well to clean it or to repair equipment. The smaller metal wells and the deep wells should have doors at various elevations to facilitate cleaning and repairing. (See figs. 8 and 11.)

When placed in the bank of the stream the stilling well should have a sealed bottom so that ground water cannot seep into it nor stream water leak out.

Water from the stream enters and leaves the stilling well through the intake so that the water in the well is at the same elevation as the water in the stream. If the stilling well is in the bank of the stream, the intake consists of a length of pipe connecting the

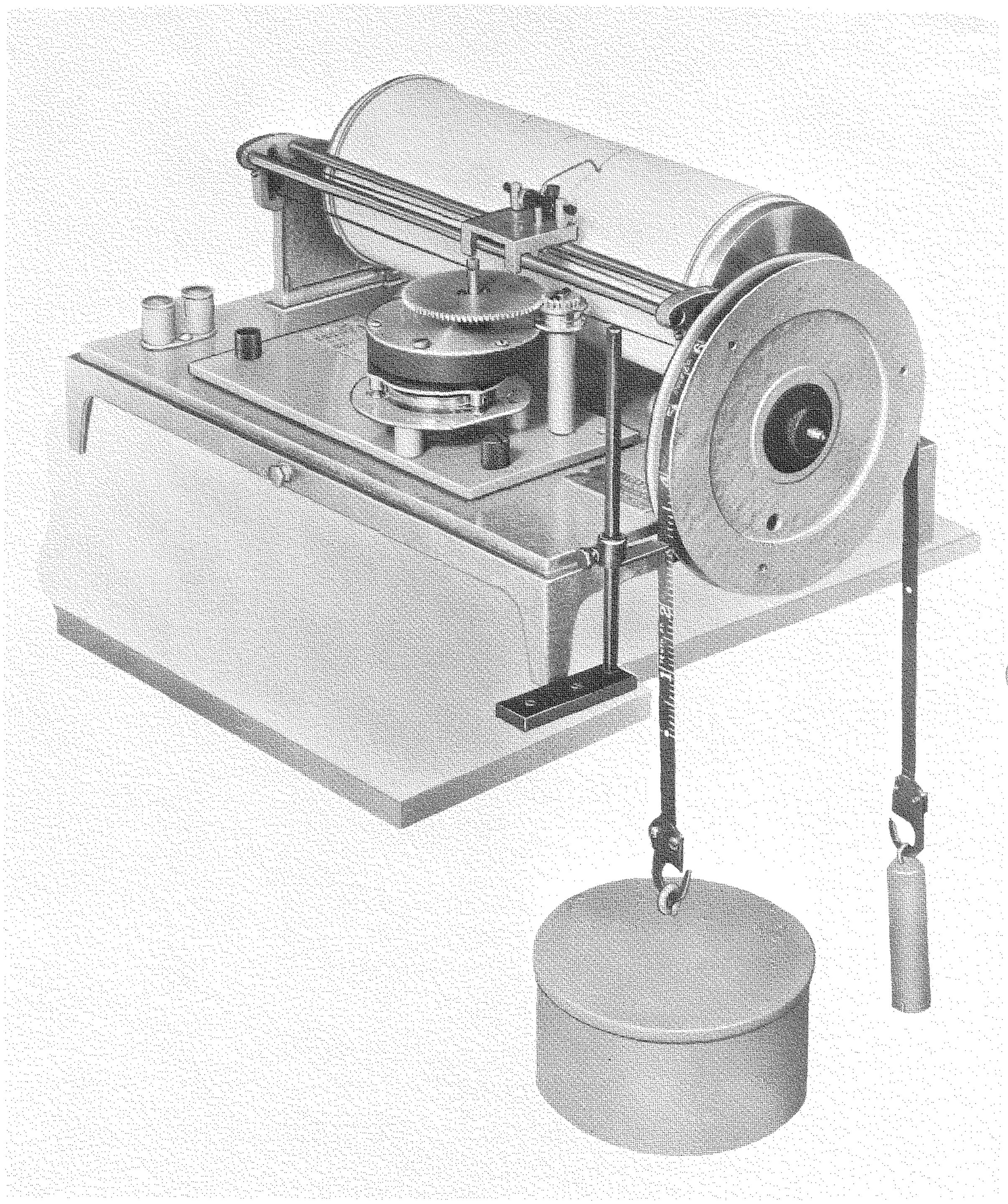

Figure 7.—Horizontal-drum recorder.

stilling well and the stream. The intake should be at an elevation at least 0.5 foot lower than the lowest expected stage in the stream, and at least 0.5 foot above the bottom of the stilling well to prevent silt buildup from plugging the intake. In cold

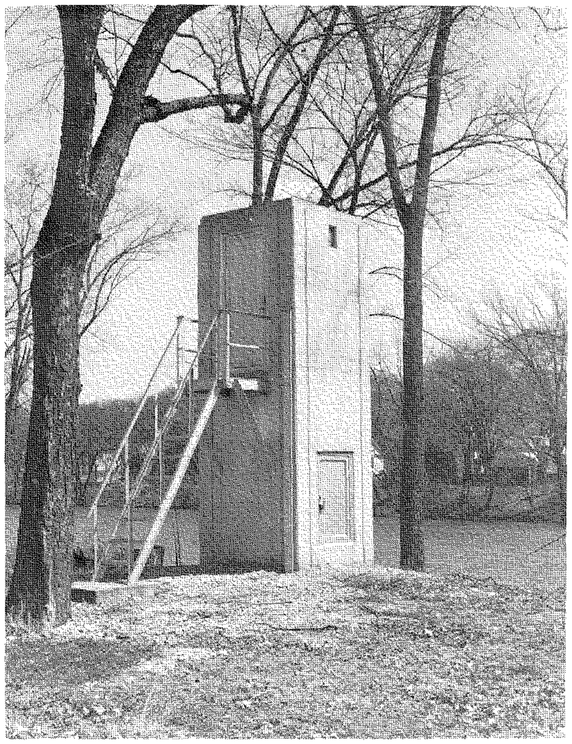

Figure 8.—Reinforced-concrete well and shelter. Note clean-out door.

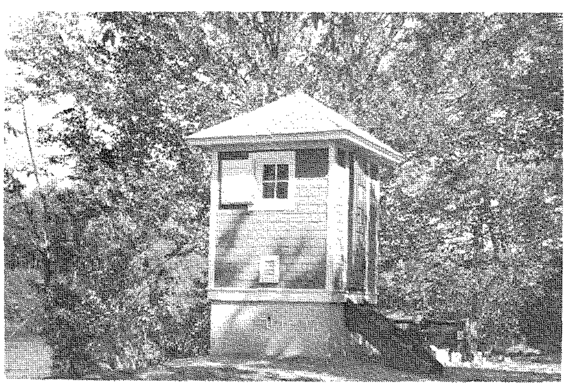

Figure 9.—Concrete well and wooden shelter with asphalt shingle siding.

climates the intake should be below the frostline. If the well is placed in the stream, holes drilled in the stilling well may act as an intake, taking the place of a length of pipe. Some wells placed in the stream have a hopper bottom which serves as an intake.

Two or more pipe intakes are commonly installed at vertical intervals of about one

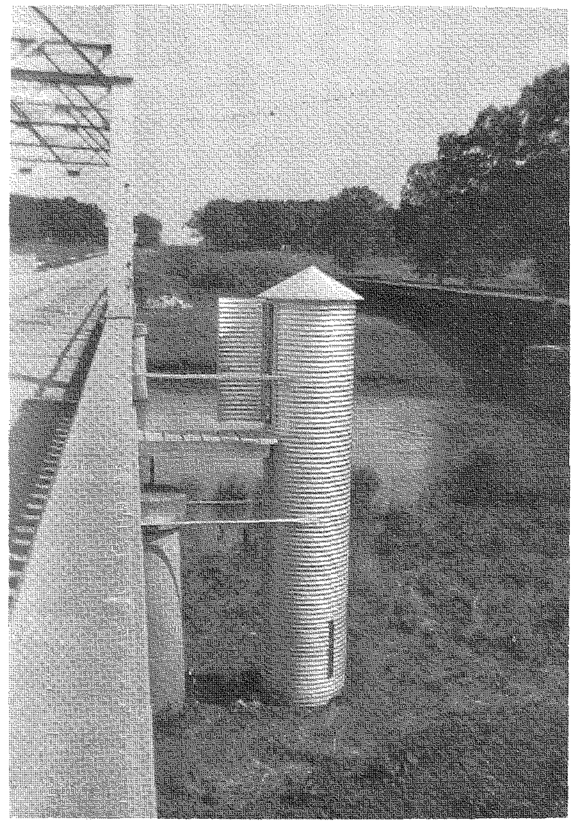

Figure 10.—Corrugated-galvanized-steel-pipe well and shelter.

foot. During high water, silt may cover the stream end of the lower intakes while the higher ones will continue to operate.

Most stations that have intakes subject to clogging are provided with flushing systems (see fig. 15) whereby water under several feet of head can be applied to the gage-well end of an intake. Ordinarily a pump raises water from the well to an elevated tank. The water is then released through the intake by operation of a valve. Intakes without flushing systems may be cleaned with a plumber's snake or rod, or by building up a head of water in the well with a portable pump to force an obstruction out of the intakes.

The intakes for stations placed in the bank of the stream are usually galvanized-steel pipe. The most common size used is 2-inch-diameter pipe, but in some places up to 4-inch-diameter pipe is used. After the size and location of the well have been decided, the size and number of intakes should be determined.

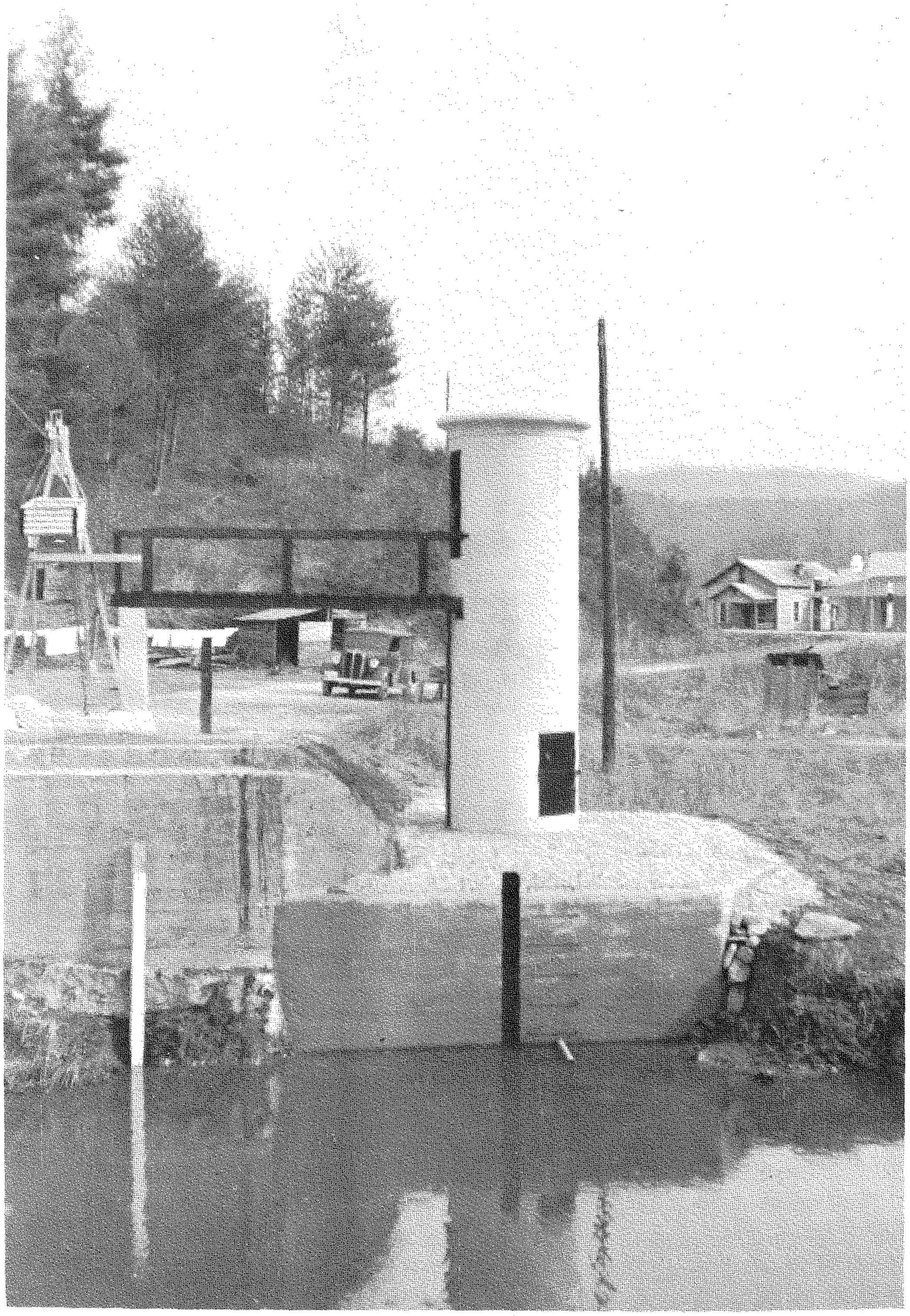

Figure 11.—Concrete-pipe well and shelter. Note clean-out door, staff gage, and upper intake pipe.

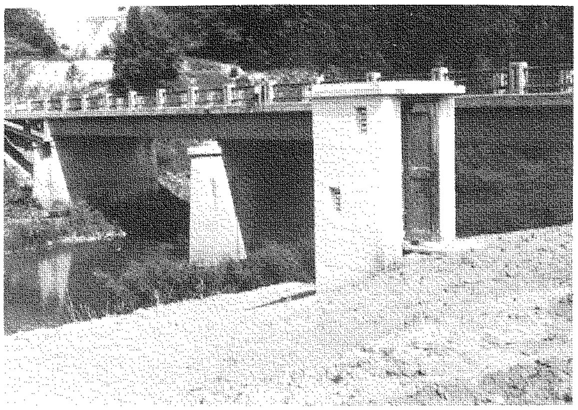

Figure 12.—Concrete-block shelter.

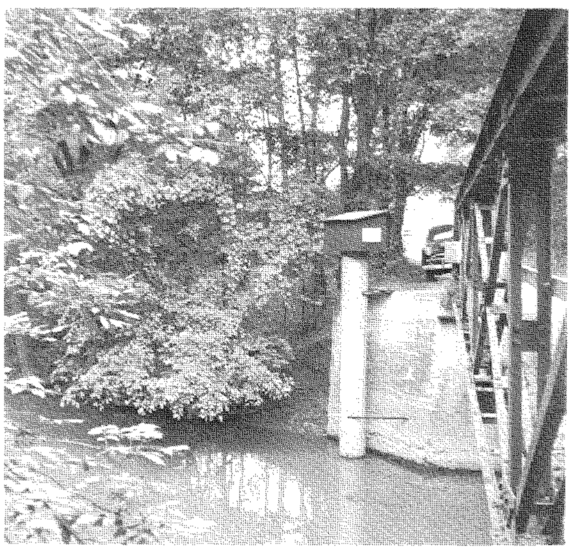

Figure 13.—Steel-pipe well and look-in shelter attached to bridge abutment.

The intake pipe should be large enough for the water in the well to follow the rise and fall of stage without significant delay. The following relationship may be used to determine the lag for an intake pipe for a given rate of change of stage:

$$\Delta h = \frac{0.01}{g} \frac{L}{D} \left(\frac{A_w}{A_p}\right)^2 \left(\frac{dh}{dt}\right)^2,$$

in which

Δh = lag, in feet,
g = acceleration of gravity, in feet per second per second,

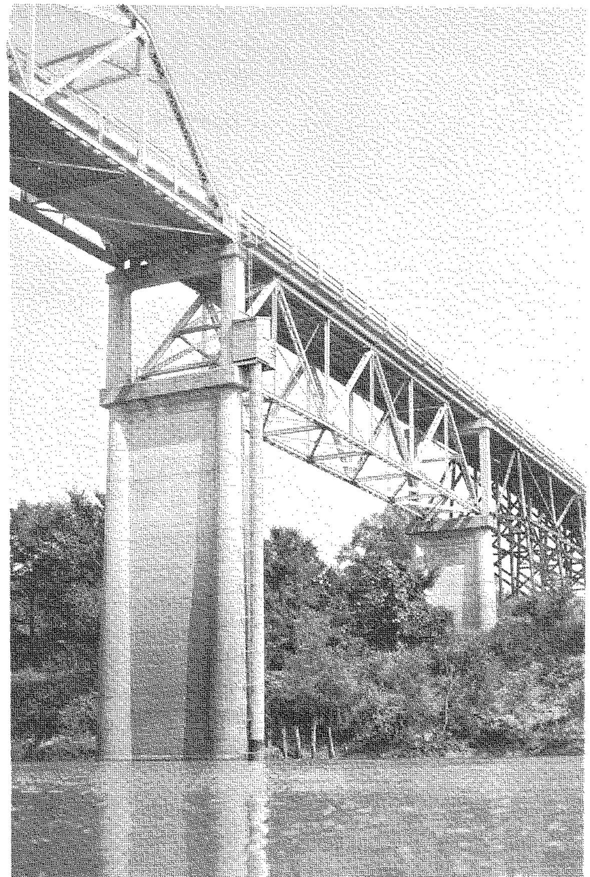

Figure 14.—Corrugated-steel-pipe well and wooden shelter attached to bridge pier.

L = intake length, in feet,
D = intake diameter, in feet,
A_w = area of stilling well, in square feet,
A_p = area of intake pipe, in square feet, and
$\frac{dh}{dt}$ = rate of change of stage, in feet per second.

Smith, Hanson, and Cruff (1965) have studied intake lag in stilling-well systems, relating it to the rate of change of stage of the stream and to the various types and sizes of components which are used in the stilling-well intake system.

The intake pipe should be placed at right angles to the direction of flow, and it should be level. If the velocity past the ends of the intake is high, drawdown or pileup of the water level in the stilling well may occur.

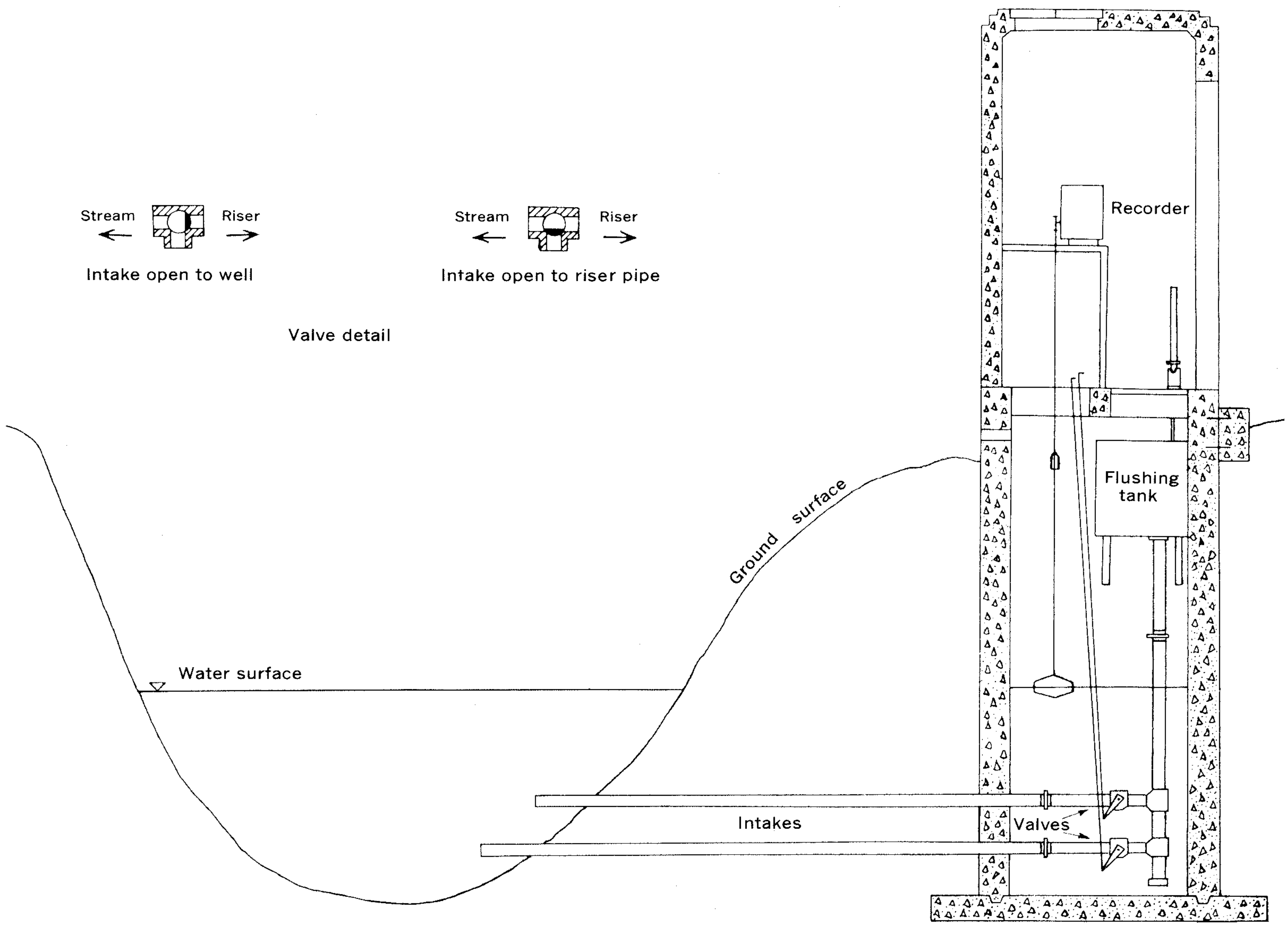

Figure 15.—Flushing system for intakes.

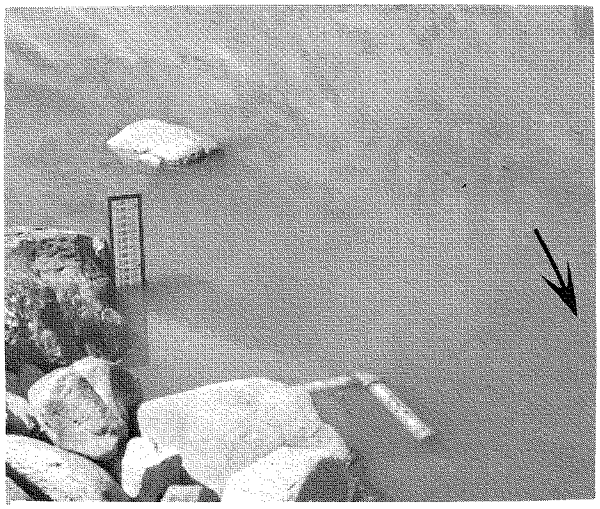

Figure 16.—Static tube for intakes. Note outside reference gage.

To reduce the effect, static tubes can be attached on the stream end of the intake pipe. A static tube is a short length of pipe attached to an elbow or tee on the end of the intake pipe and extending horizontally downstream. (See fig. 16.) The end of the static tube is capped and water enters or leaves through holes drilled in the tube.

The usual means of preventing the formation of ice in the well during cold weather are: (1) subfloors, (2) heaters, and (3) oil.

Subfloors are effective if the station is placed in the bank and has plenty of fill around it. If the subfloor is built in the well below the frostline in the ground, ice will not normally form in the well as long as the stage remains below the subfloor. Holes are cut in the subfloor for the recorder float and weights to pass through, and removable covers are placed over the holes. Subfloors prevent air circulation in the well and the attendant heat transfer.

An electric heater or heat lamps with reflectors may be used to keep the well free of ice. The cost of operation and the availability of electric service at the gaging station are governing factors. Heating cables are often placed in intake pipes to prevent ice from forming.

Oil is used in two ways: (1) where the well is small and leakproof, the oil may be poured into the well, and (2) where the well is large or not leakproof, a tube of sufficient diameter to accommodate the recorder float is placed in the well standing just off the bottom, and oil, usually kerosene, fuel oil, or diesel oil, is put in the tube. The oil tube should be long enough to contain the oil throughout the range in stage expected during the winter. When oil is put in a well, the oil surface stands higher than the water surface in the stream. A correction must therefore be made to obtain the true river stage.

Stilling wells often fill with sediment, especially those located in arid or semiarid parts of the country. If a well is placed on a stream carrying heavy sediment loads it must be cleaned out often to maintain record. In such locations, traps can greatly reduce the work of removing the sediment. A sediment trap consists of a large boxlike structure located between the intake and the main well. Inside it are one or more baffles to facilitate settlement before sediment reaches the well. The trap is made to open for easy removal of the settled material.

The determination of gage height at an outside gage should be made each time the gaging station is serviced. Intakes can become plugged, floats can leak water, oil can leak out of wells or oil tubes, and several other things can happen which can cause the recorded gage height to differ from the stream gage height. Often a comparison of the outside and inside gage heights will reveal the problem, and proper maintenance can be done, corrections can be made, and loss of additional record can be prevented.

Instrument Shelters

Shelters are made of almost every building material available and in various sizes depending on local custom and conditions. (See figs. 8–14). The most convenient type of shelter is one that the hydrographer can enter standing. A shelter with inside dimensions 4 by 4 feet with ceiling height 7 feet above the floor is about the ideal size. Look-in shelters (see fig. 13) are also used at sites where a limited amount of equipment is to be installed and a portable and inexpensive shelter is desired.

In humid climates, shelters are well ventilated and have a tight floor to prevent entry of water vapor from the well. Screening and other barriers are used over ventilators and other open places in the well or shelter to prevent the entry of insects, rodents, and reptiles.

The bubble gage does not require a stilling well. The instrument shelter for a bubble gage may be installed at any convenient location above the reach of floodwaters. This gage may be used to take advantage of existing natural or artificial features in a stream without costly excavation for well or intake and without need for any external structural support. The bubble gage is especially well suited for short-term installations because the entire station is readily dismantled and relocated with practically no loss of investment.

A shelter with inside dimensions 4 by 4 by 7 feet is needed to accommodate the equipment for a bubble gage. Shelters similar to those in figures 8, 9, and 12 would be adequate. The shelter can be placed on a concrete slab or other suitable foundation. The bubble orifice is placed at least 0.5 foot below the lowest expected stage in the stream. The plastic tube connecting the orifice and the instrument is encased in metal pipe or conduit, or buried to protect it from the elements, animals, and vandalism. A typical

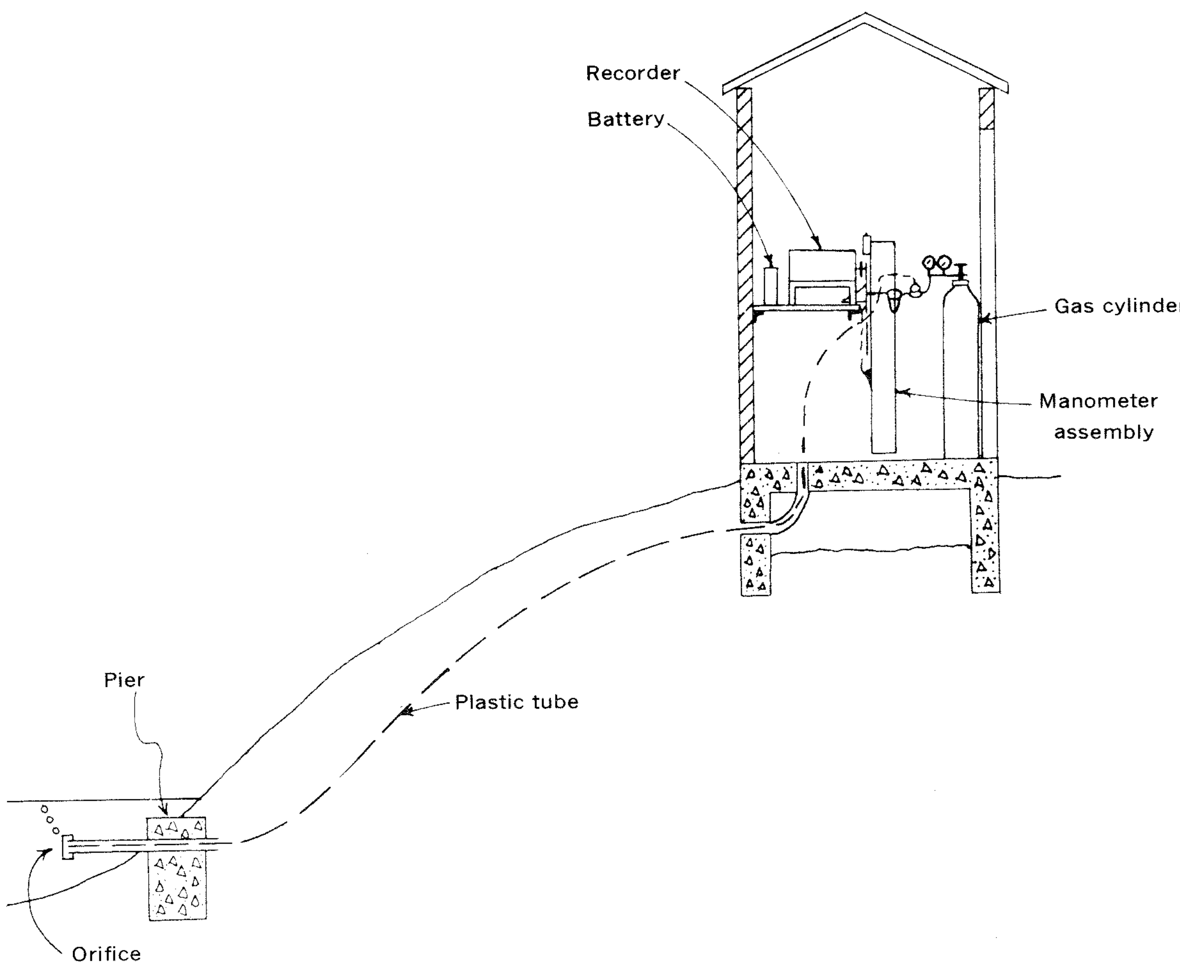

Figure 17.—Typical bubble-gage installation.

bubble-gage installation is shown in figure 17.

Telemetering systems

Telemetering systems are used when current information on stream stage is needed at frequent intervals, and it is impractical to visit the gaging station each time the current stage is needed. Current stage information is usually necessary for reservoir operation, flood forecasting, prediction of flows, and for current-data reporting. The types of telemetering systems are:

1. Those which continuously indicate or record stage at a distance from the gage site. Examples of this type are the position-motor and impulse telemetering systems.
2. Those which report instantaneous gage readings on call or at predetermined intervals. Examples of this type are the Telemark and resistance telemetering systems.

Position-motor system

The position-motor system provides remote registering of water levels on graphic recorders or on counter or dial indicators over distances up to 15 miles. This system employs a pair of self-synchronizing motors—one on the transmitter, whose rotor is actuated by a float-tape gage or a bubble gage, and the other on the receiving unit, whose rotor follows the rotary motion of the transmitting motor to which it is electrically connected. Alternating current is used to operate the system and a five-wire transmission line is required—two excitation wires and three line wires

Impulse system

The impulse system provides remote registering of water levels on graphic recorders or on counter and dial indicators over longer distances than does the position-motor system. This system will operate over leased telephone lines or other metallic circuits. The impulse sender at the gaging station is actuated by a float-tape gage or a bubble gage and sends electrical impulses over the line connecting it to the receiver. This system usually has a battery for the power source at the sender and alternating current at the receiver, though direct current or alternating current may be used at both ends. The advantage of this system over the position-motor system is that it will operate over long distances.

Telemark system

The Telemark system codes the instantaneous stage and signals this information either audibly over telephone circuits or by coded pulses for transmission by radio. The distance of transmission is unlimited since signals can be sent over long-distance telephone circuits or by radio. Telemark response to a telephone ring is automatic. When used in radio transmission, the signals are started by a timing device set for a predetermined broadcast schedule, or the Telemark may be interrogated by radio channel to start the signal.

The Telemark consists of (1) the positioning element which is actuated by a float-tape gage or a bubble gage (see fig. 18), and (2) the signaling element which, when signaled, drives a contact across the signaling drums that are postioned in correspondence with the stage. The Telemark may be operated by either alternating current or by batteries.

A Telemark that operates directly off a digital recorder is available and will probably be increasingly used. This Telemark does not need its own stage sensor; it uses that of the digital recorder. A memory system is used so that when the Telemark is signaled, the last gage height recorded on the digital recorder is transmitted.

Telemarks for radio reporting are equipped with an auxiliary switch and coding bar for transmitting identifying radio station call letters and numbers in international Morse code, in addition to transmitting the stage.

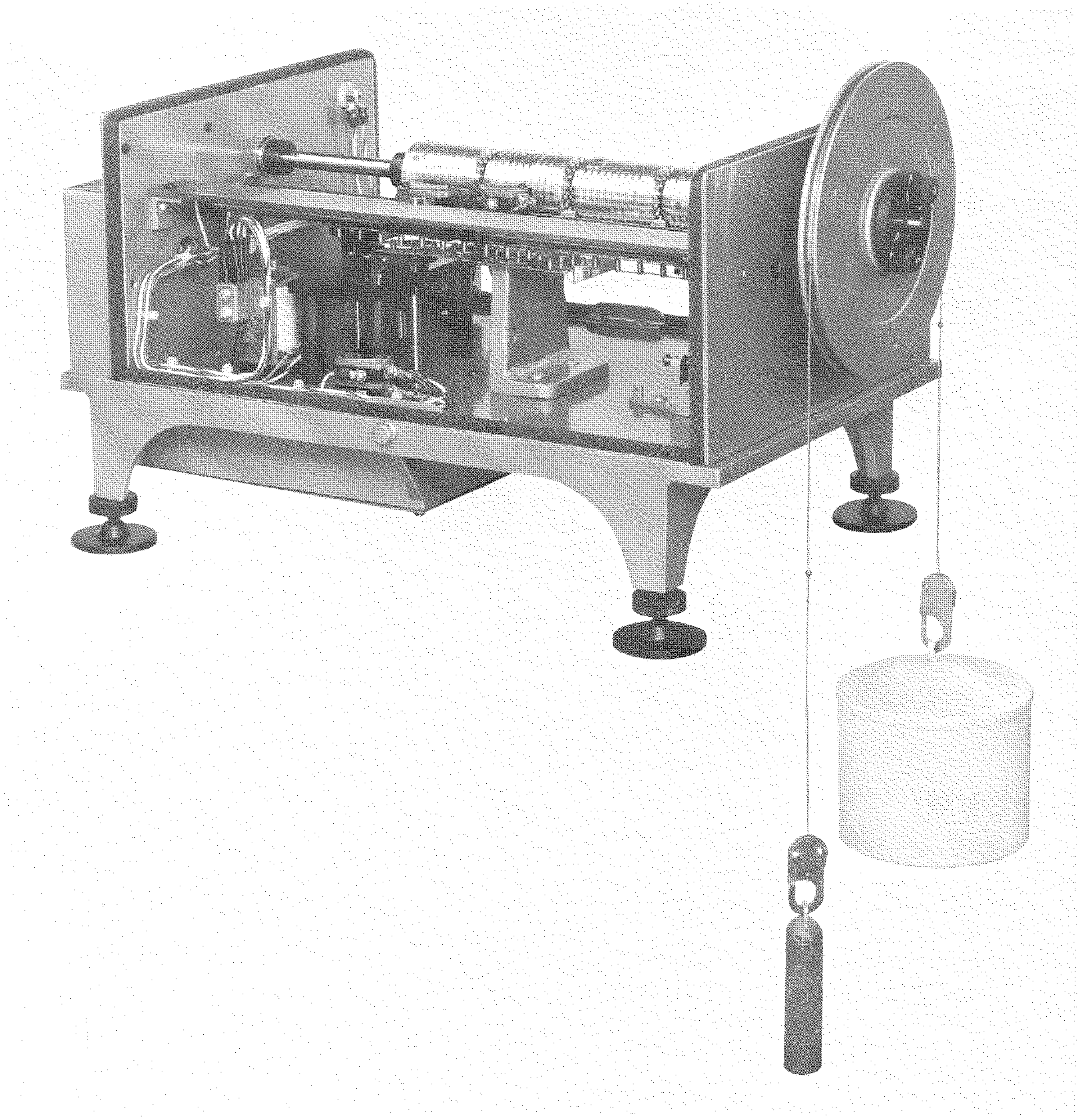

Figure 18.—Telemark gage.

Resistance system

The resistance system was developed by the U.S. Weather Bureau. It provides remote indications of water level for distances up to about 40 miles. Two models are available, one for distances of about a mile and the other for longer distances. The system consists of two potentiometers in a wheatstone-bridge circuit with a microammeter null indicator. One of the potentiometers is located in the gage house and is actuated by a float and pulley assembly. (See fig. 19.) The other potentiometer and the null indicator are housed at the observation site.

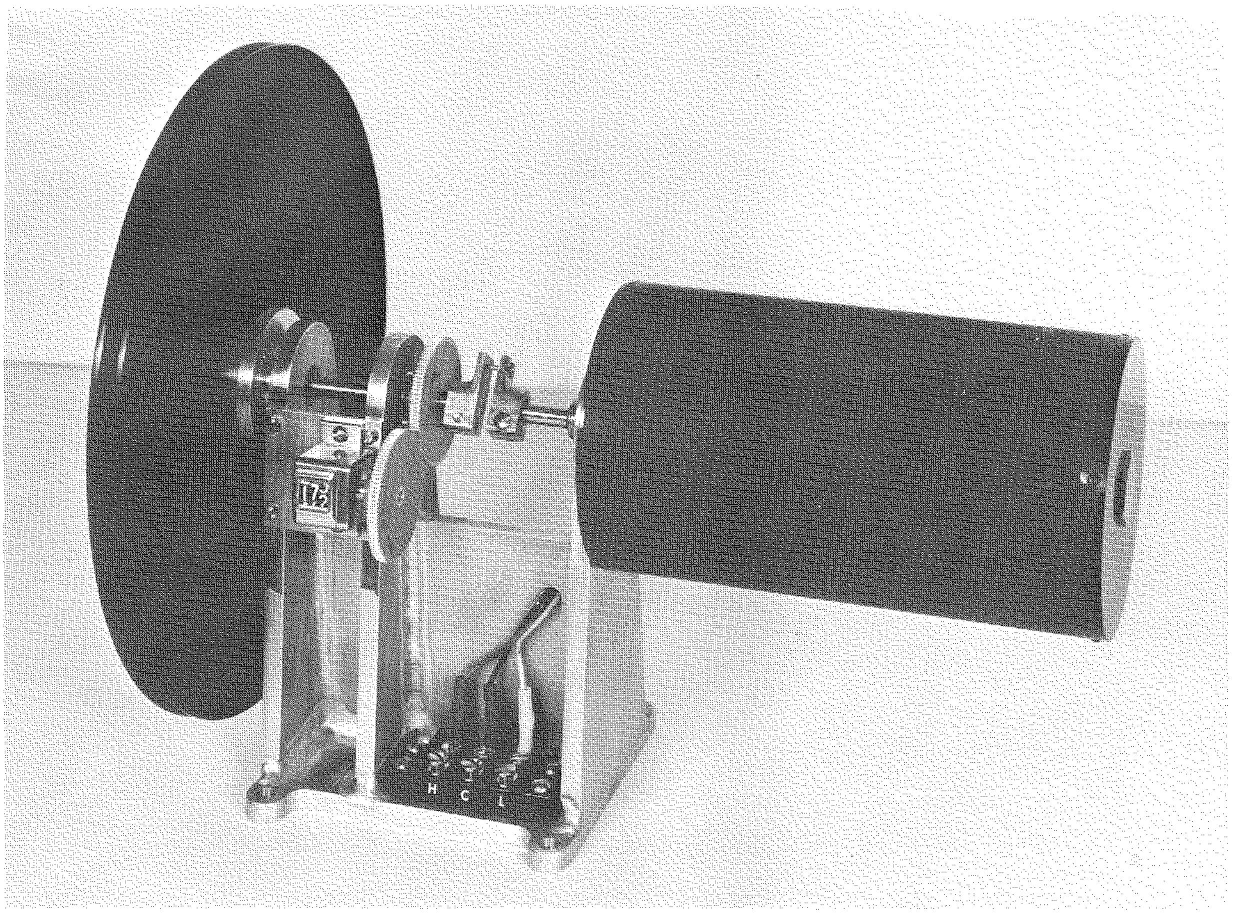

Figure 19.—Resistance system transmitter unit.

(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-