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

Float Sensor

The float sensor consists of a tape or cable passing over a pulley, with a float in a stilling well attached to one end of the tape or cable and a counter weight to the other. (See fig. 1.)[1] The float follows the rise and fall of the water level, and the water level can be read by using an index and graduated tape, or the pulley can be attached to a water-stage recorder to transmit the water level to the recorder.

Bubble-gage sensor

The bubble-gage sensor (Barron, 1963) consists of a gas-purge system, a servomanometer assembly, and a servocontrol unit. (See fig. 2.)

The gas-purge system transmits the pressure head of water in the stream to the manometer location. A gas is fed through a tube and bubbled freely into the stream through an orifice at a fixed elevation in the stream. The gas pressure in the tube is equal to the piezometric head on the bubble orifice at any gage height.

The servomanometer converts the pressure in the gas-purge system to a shaft rotation for driving a water-stage recorder. Mercury is used as the manometer liquid to keep the overall length to a minimum. The manometer has a sensitivity of 0.005 foot of water and can be built to record ranges in gage height in excess of 120 feet. The use of mercury in the manometer permits positioning of the pressure reservoir to maintain the float-switch contacts in null position. In this position, the vertical distance between mercury surfaces will be 1/13.6 times the head of water. A change in pressure at the reservoir displaces the mercury which in turn activates the float switch. This causes movement of the pressure reservoir until the distance of head of water divided by 13.6 is again maintained. This motion in turn is translated to the recorder.

The servocontrol unit provides the relay action necessary to permit the sensitive float switch to control the operation of the servomotor and also to provide an appropriate time delay between the closing of the float switch and the starting of the motor.

The proper placement of the orifice is essential for an accurate stage record. The orifice should be located where the height of water above it represents the stage in the river. If it is partly buried in sand or mud, the recorded stage will be greater than that in the river. An orifice preferably should not be installed in swift currents. If this is unavoidable, it must be kept at right angles to the direction of flow. A recommended mounting for swift-flow conditions is for the orifice to be mounted flush with the wall of the mounting structure. Care should also be taken to keep the orifice out of highly turbulent flow.

Water-stage recorders

A water-stage recorder is an instrument for producing a graphic or punched tape record of the rise and fall of a water surface with respect to time. It consists of a time element and a gage-height element which, when operating together, produce on a chart or a tape a record of the fluctuations of the water surface. The time element is controlled by a clock which is driven by a spring, by a weight, or by electricity. The gage-height element is actuated by a float or a bubble gage.

If a float sensor is used, the float pulley is attached to the recorder. The float and counterweight are suspended on a perforated steel tape or on a plain or beaded cable. Cone-shaped protrusions on the circumference of the float-tape pulley match perforations in the tape. As the float rises or falls the float pulley turns a proportional amount, thereby changing the gage-height reading on the recorder. A copper float 10 inches in diameter is normally used, but other sizes are used depending on the type of recorder, gage-height scale, and accuracy requirements.

[1] Figures 1, 6, 7, 18, and 22 are photographs used by permission of Leupold & Stevens Instruments, Inc.

Figure 1.—Float-type gage.

If a bubble-gage sensor is used the stage is translated to the recorder by a chain and sprocket arrangement. (See fig. 2.)

Stage recorders are either digital or graphic. Both types may be used with the float or bubble gage.

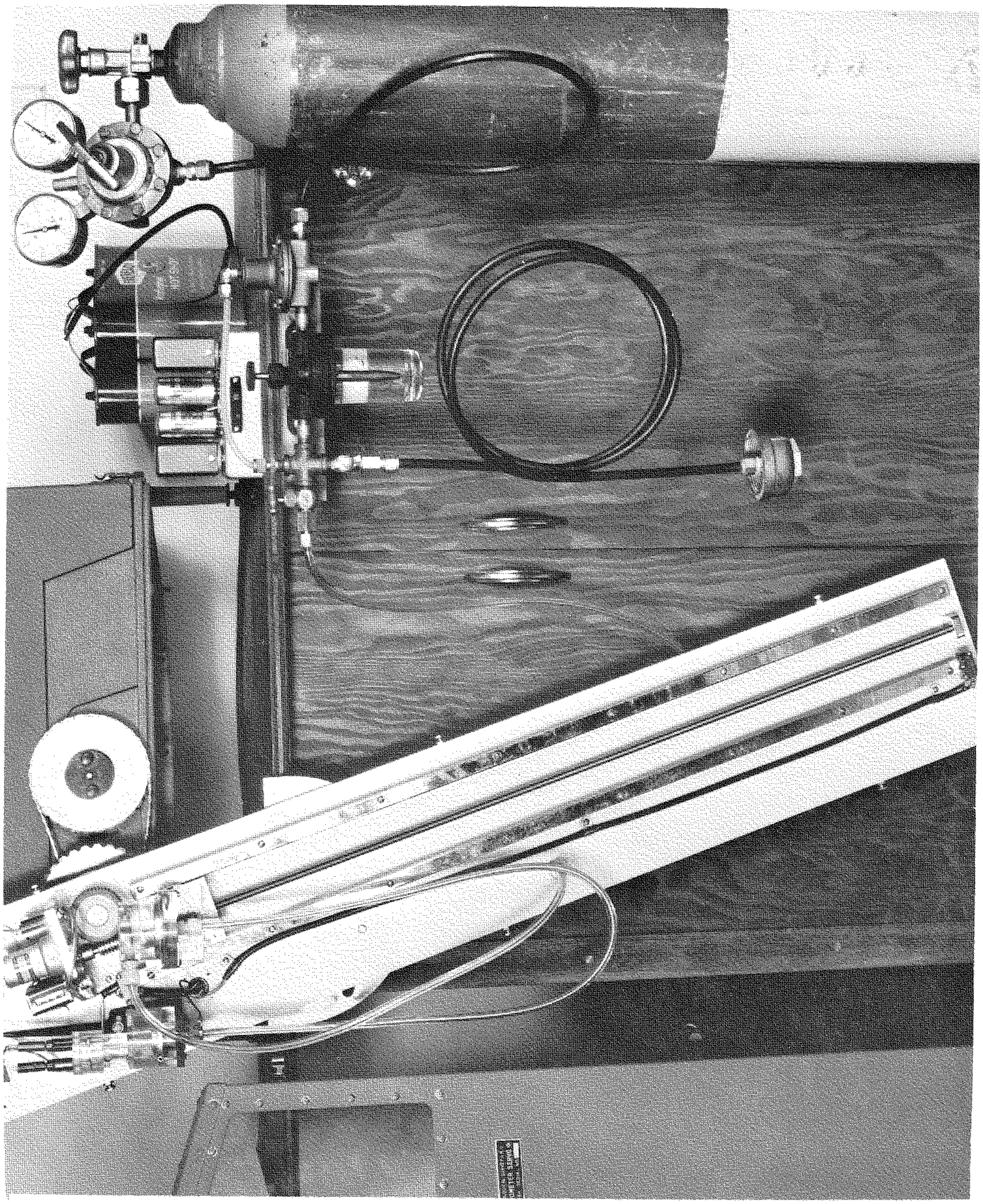

Figure 2.—Major units of the bubble gage.

Digital recorder

The digital recorder (Isherwood, 1963) is a battery-operated, slow-speed, paper-tape punch which records a 4-digit number on a 16-channel paper tape at preselected time intervals. (See fig. 3.)

Stage is recorded by the instrument in increments of a hundredth of a foot from zero to 99.99 feet and is transmitted to the instrument by rotation of the input shaft. Shaft rotation is converted by the instrument into a coded punch-tape record that is simple enough to be read directly from the tape. The code consists of four groups of four punches each. In each group, the first punch represents "1," the second "2,", the third "4," and the fourth "8." Thus a combination of up to three punches in a group represents digits from one to nine, with a blank space for zero, and the four groups of punches represent all numbers from 1 to 9,999. (See fig. 4.)

Coding is done by means of two discs containing raised ridges in accordance with the punch code outlined above. One disc is mounted directly on the input shaft. The second code disc is connected to the first by a 100:1 worm gear so that one hundred revolutions of the input shaft rotate the second, or high-order disc, one complete revolution. A paper tape is moved upward through a punch block which is mounted on a movable arm hinged at the base of the recorder. The punch block contains a single row of 18 pins, 16 pins for the information punches and 2 for punching feed holes.

The tape is punched when the punch block with its protruding pins is forced against the code discs by spring action. Those pins which strike the raised ridges of the discs punch through the paper tape and record the position of the discs at that instant. The readout cycle begins with an impulse from the timer which causes a 6-volt motor to turn a sequencing camshaft. The sequence of operations for one reading includes punching the paper, advancing the paper, and compressing the punch spring for the next readout cycle.

The timers used on the digital recorders are electro-mechanical timing devices that are powered by the same 7½-volt battery that operates the 6-volt motor. The timers provide contact closure for actuating the digital recorder at preselected time intervals of 5, 15, 30, or 60 minutes by using a different cam for each different time interval.

The cam on the timer corresponds to the minute hand on a clock, that is, it makes one revolution per hour in a clockwise direction. If the cam has one dropoff point the recorder will punch hourly, if it has two dropoff points it will punch every 30 minutes, and if it has four dropoff points it will punch every 15 minutes. The timer in figure 5 has four dropoff points. The arm positioned by the cam operates a single-pole double-throw switch. When the cam dropoff point passes the arm, the switch initiates the major part of the readout cycle which includes punching of the tape. A preset action returns the switch to the initial position prior to the next readout cycle. Alternating-current timers can be used with the digital recorders at places where reliable alternating-current power is available.

Digital recorders may miss the absolute peak, especially on flashy streams. However, a measure of the maximum peak that occurs between inspections of the recorder can be obtained by attaching a paper clip or small magnet on the float tape just below the instrument shelf in such a manner that it will slide along the tape as the stage rises but remain in a fixed position as the stage declines.

Mechanically punched tape is the most practical for field use under widely varying conditions of temperature and moisture. Electronic translators are used to convert the 16-channel punch-tape records to a tape suitable for input into a digital computer for computation of daily mean gage height and daily mean discharge.

Graphic recorder

The graphic recorder supplies a continuous trace of water stage with respect to

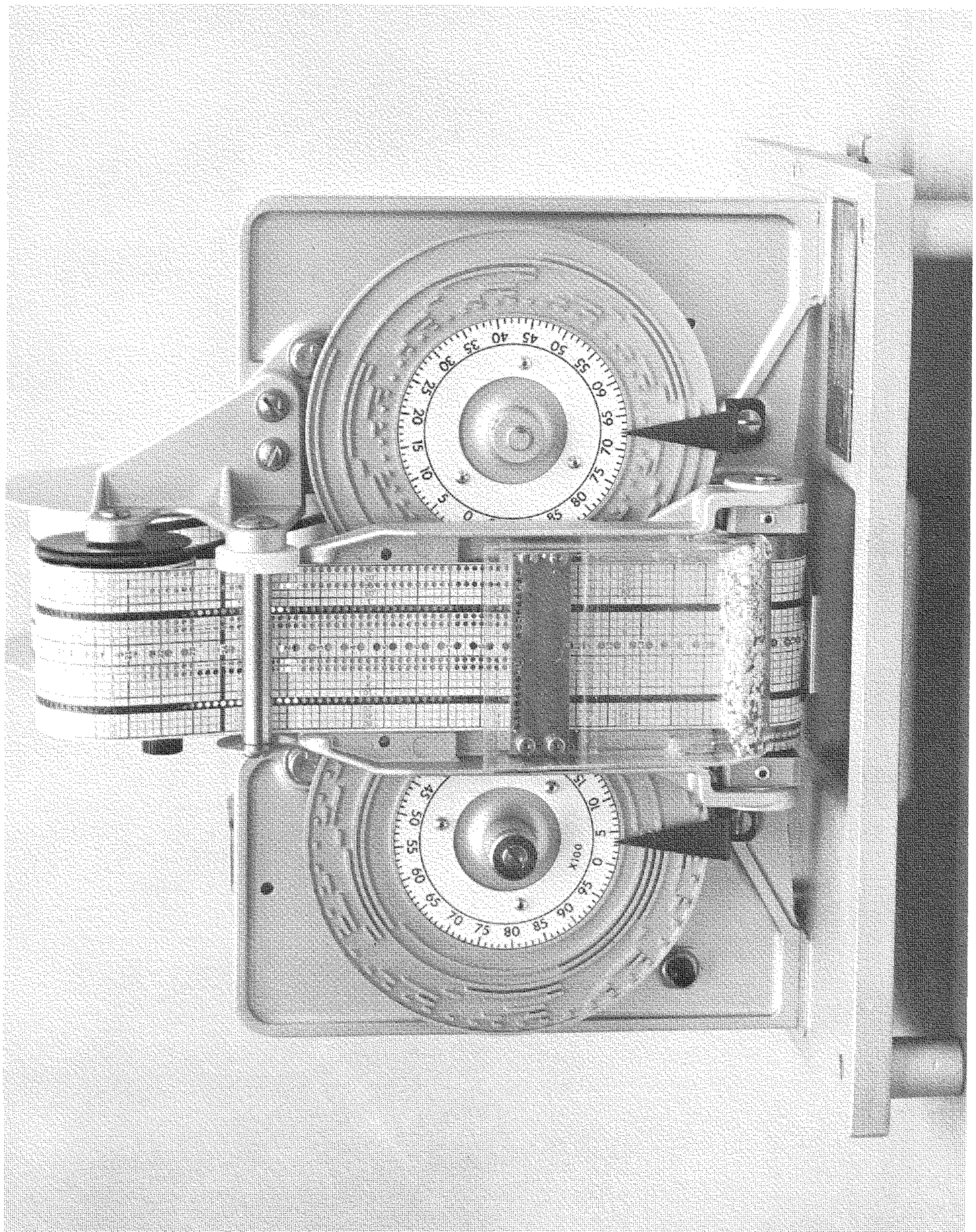

Figure 3.—Digital recorder.

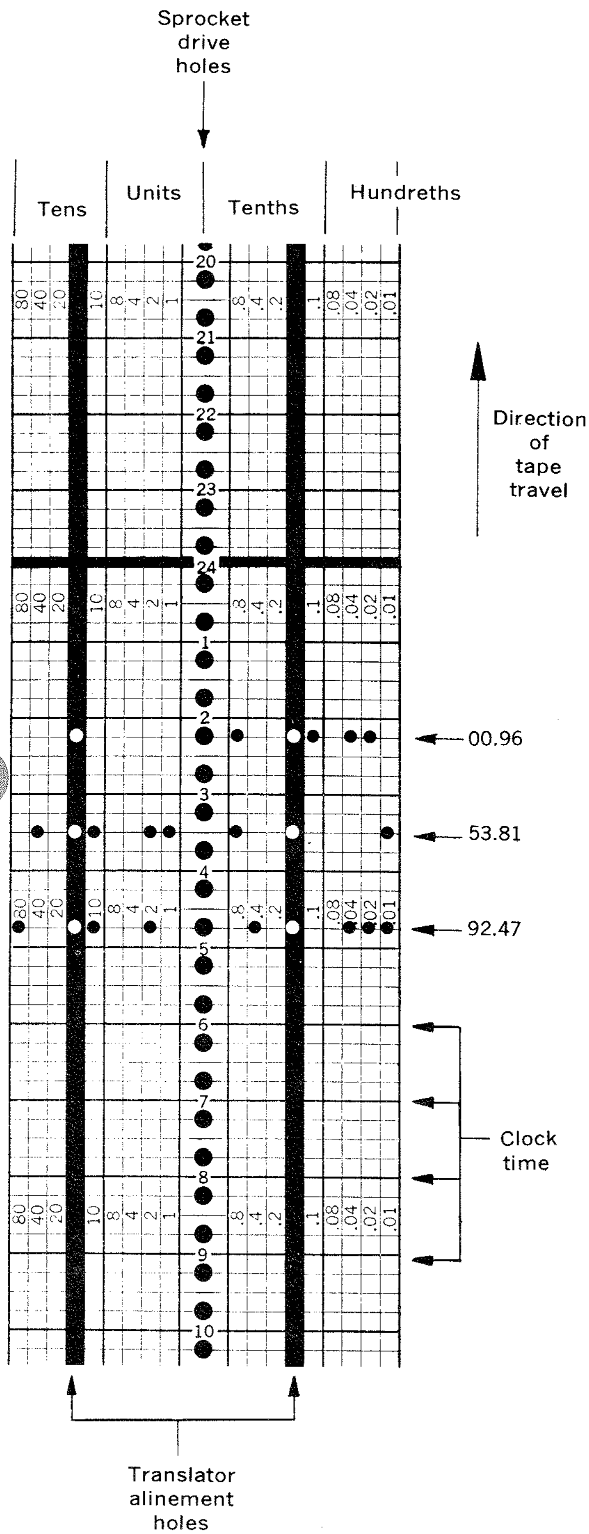

Figure 4.—Illustration of a digital recorder tape.

time on a chart. Usually tne 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