or masonry, especially in the case of works constructed by large associations or corporations. These dams, intended to resist the destructive action of floods, must be solidly constructed and carried down to bed rock.

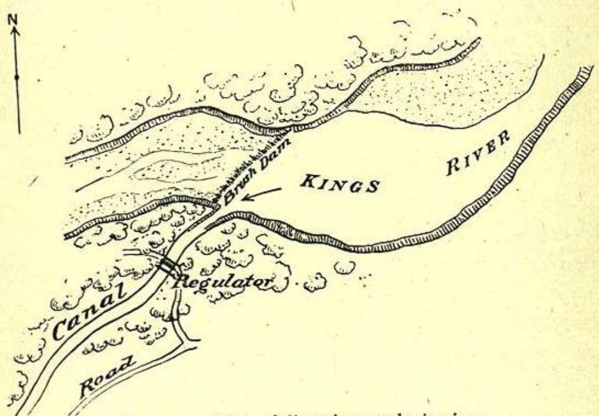


FIG. 25. — Plan of diversion works in river.

The temporary brush dams are cheaply constructed and suffice for most of the smaller ditches, and even for some of the larger canals. They possess the advantage that whenever a destructive flood occurs, modifying the channel, they can be rebuilt to suit the new conditions, the head of the ditch being extended, or located at a point whereever the dam can be most cheaply or effectively constructed. Sometimes, as shown in Fig. 26, two canals head near each other, and the temporary dams can be modified from time to time to divert

the water in the river according to the volume available.

Near the head of a ditch or canal is usually placed a head gate, or regulator. This consists of a suitable framework of plank, firmly bedded in the earth or rock, and containing one or more openings, each of which can be closed by a gate

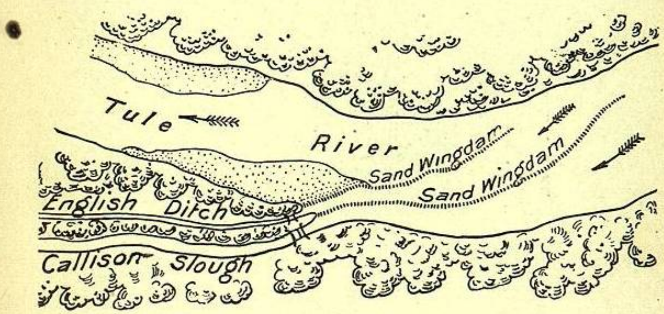


FIG. 26. — Brush dams of canals heading near each other.

sliding vertically. The water enters under the gates, the quantity being controlled by raising or lowering them. On the better-built canals permanent head gates are sometimes constructed of masonry, as shown by Pl. XV, *A*. The relative situations of the canal, dam, and regulator, where the conditions are favorable, are shown on Fig. 27.

The adjustment of these head gates is a matter of considerable importance in taking water from the river, and for large canals it is necessary to have a watchman stationed near the head, in order that the gates may be raised or lowered, according to the amount in the river and the quantity apportioned to the canal.

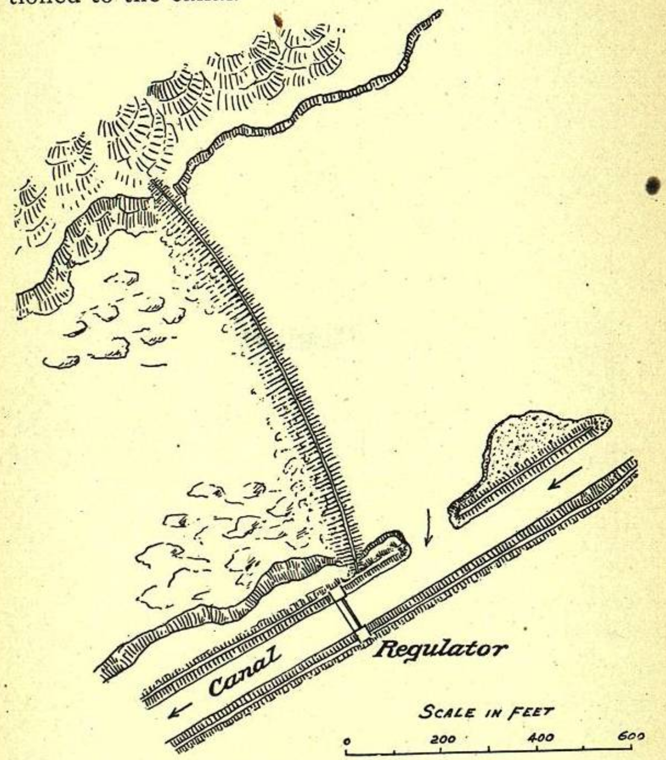


FIG. 27.— Plan of dam and regulator.

The accompanying drawing (Fig. 28) shows the method of construction of one of the small timber head gates, or regulators, such as are used at the

head of small ditches leading from the stream or from some large canal. These are built of plank, each end being made flaring to meet the sides of the ditch and to form a firm junction with the

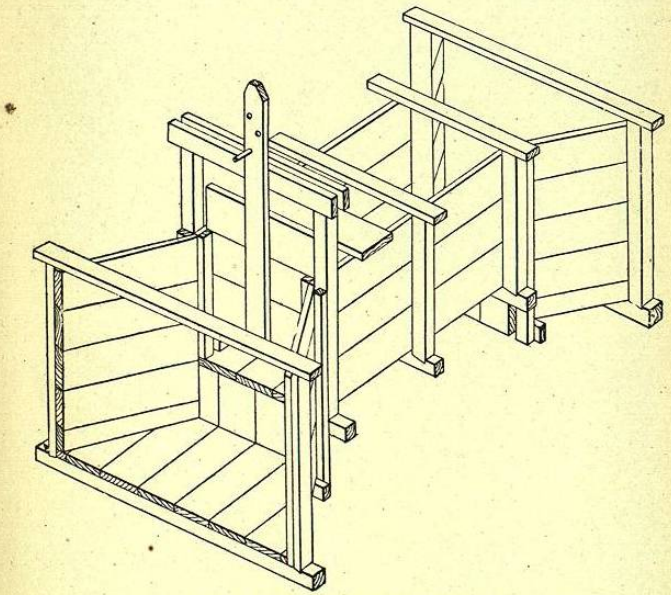


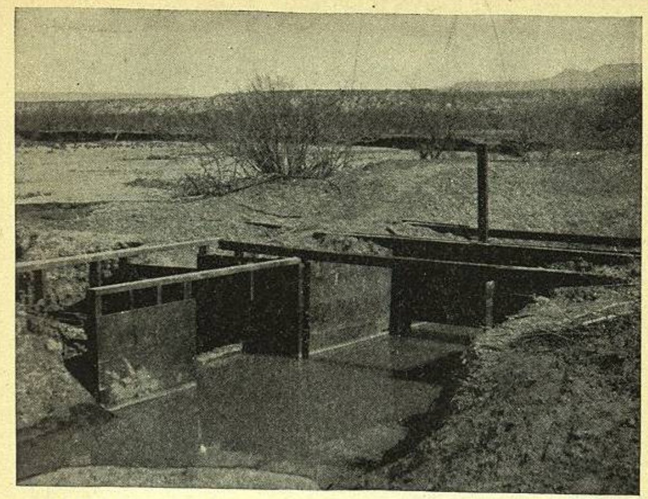
FIG. 28.— Details of small head gate.

earth. It is, of course, important to pack clay and impervious material around the head gate so as to prevent leakage, as a tiny stream working its way through the earth will quickly be enlarged and endanger the whole structure. Various forms of head gates are shown on Pls. XV and XVI.

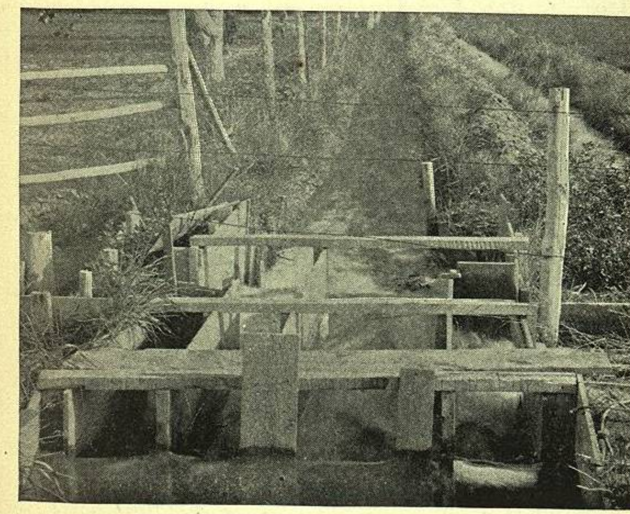
MEASURING DEVICES OR MODULES.

After water has been received into a canal and at various points along its course to the fields of the irrigators, there frequently arises the necessity of making measurements of the volume, or of dividing the flow proportionately among the users. The methods employed are in general similar to those in river measurements, described in preceding pages. The quantity of water is, however, often so small, and the means at hand so restricted, that different ways are occasionally adopted. The persons whose business it is to divide the water rarely have instruments, such as a current meter, and their knowledge of hydraulics is too limited to enable them to make measurements of any considerable accuracy. They usually judge of the amount of water by its appearance, at most measuring the width and depth, and guessing at the velocity, or not taking it into account. There is thus little attempt at accuracy, and, in fact, absolute quantities are not often obtained, but rather proportional parts of the flow. An irrigator usually receives a quarter or one-tenth of the water in the ditch rather than a certain number of gallons or cubic feet per second. Thus the measuring boxes or flumes are generally made with the idea of taking a certain proportion of the whole amount of water irrespective of the volume.

One of the simplest devices for apportioning



A. REGULATING OR MEASURING DEVICE NEAR HEAD OF CANAL.



B. DISTRIBUTION BOX ON FARMER'S LATERAL.

ditch water is shown diagrammatically in the accompanying plan (Fig. 29). The water, flowing toward the left, is divided by the partition marked *A*. The water passing on the left-hand side of the partition *A* is conducted off by a side channel or lateral, while that flowing on the right-hand side of *A* continues in the ditch. This partition *A* may be movable, so as to divert different quantities of water at various times, or may be fixed, if it is understood that a certain proportion of the water is always to pass out of a lateral at this point.

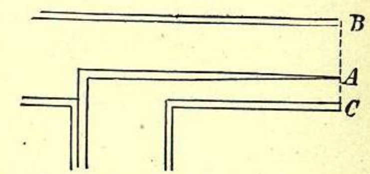


FIG. 29.— Plan of device for dividing water.

If the partition *A* is in the centre of the stream, equal amounts of water will be diverted on each side, except as this may be affected by the retarding influence of the channel beyond. In the condition shown in the diagram, the right-angled turn would probably cause a slightly less amount of flow on the left-hand side than on the right-hand side, where the channel is straight. If, as shown in the drawing, the partition *A* is one-third of the distance across the channel, the amount diverted on the left side will probably be a trifle less than one-third of the whole amount, because of the increased friction in the narrower channel, and also because of the right-angled turn beyond. Other forms of boxes for dividing water are shown on Pl. XVI.

The devices for measuring water flowing in open ditches differ widely from those employed for measuring in pipes, such as those of a city supply, where various forms of water meters are utilized, nearly all of these requiring a decided pressure and rapid flow. The water in irrigating ditches has usually only a trifling fall, and it is not possible to obtain a head or pressure of more than a few inches. Any measuring device, to be generally successful, must be so constructed as to pass a considerable amount of water flowing at low velocity and with little fall or loss of head. An apparatus of this kind is generally known as a module, the name being derived from Italian usage. The term has not come into general use in the United States, but the measurements of water from ditches are usually spoken of as being made through boxes, flumes, or over weirs. The device in use which may be termed "module," and the one most generally employed, is that for measuring the miner's inch.

This unit, the miner's inch, is the one most used throughout the West in speaking of quantity of water. Irrigators frequently state that they receive so many miner's inches, or that to irrigate ten acres it is necessary to have 8 miner's inches. The term, although common, is not definite, the actual quantity known as a miner's inch differing according to the method of measurement.

It is comparable to the local usage of the word "shilling," which has been commonly used in New England to mean 16⅔ cents, while in New York it has been equally well known as 12½ cents. So the miner's inch in California may represent a fiftieth part of a second-foot, and in Arizona a fortieth part.

The miner's inch is also often confused with the sectional area of a flowing stream, or even with the number of cubic inches per second. In Utah, for example, a stream 20 inches wide and 3 inches deep has been incorrectly described as discharging 60 miner's inches, because the width multiplied by the depth gives this number of square inches. The term, although indefinite, has entered so largely into popular usage that it cannot be easily abandoned, and it may be retained to advantage if defined as a certain definite part of the second-foot.

The miner's inch, as the name implies, is a unit of measurement borrowed from the miners, who first took out the water of flowing streams, conducted it through ditches or flumes, and divided it among themselves. The apportioning of water was found to be most easily done by cutting a rectangular hole in the side of a flume and allowing a certain quantity of water to flow through this aperture. The amount discharged depends not only upon the size and shape of the hole, but also upon the pressure or height of water standing behind the aperture. That is to say, more water will flow through a hole an inch square if behind this hole the water is standing 6 inches deep, than will be discharged if the water is only 4 inches deep. In the same way, less water will flow through an aperture 10 inches wide and 1 inch high than through an aperture 1 inch wide and 10 inches high, the water standing the same depth above the top of the hole. These simple facts are often overlooked, and the laws prescribing how the miner's inch shall be measured frequently omit necessary qualifications. Exact justice cannot be done to all persons obtaining water by this form of measurement.

The accompanying drawing (Fig. 30) illustrates a simple form of a device for measuring miner's inches. This consists of a flume, in the end of which is placed a partition with an aperture closed by a sliding bar or gate, marked *B*. Water flowing in the flume passes out through the orifice, which in this case is 2 inches high and of a width dependent upon the space opened by the sliding gate. Above the top of the orifice is a plank 5 inches wide. To measure the flow in the flume, the sliding gate *B* is pushed in until the water stands at the top of the end plank and is on the point of overflowing. When this occurs, the pressure or head is exactly 5 inches, and the size of the orifice in square inches gives the equivalent number of miner's inches flowing in the box.

In the example shown, the gate is drawn open 43.5 inches, and as it is 2 inches high, the whole flow is 87 miner's inches.

In case it is desired to measure out a certain amount of water, the gate *B* can be set at this

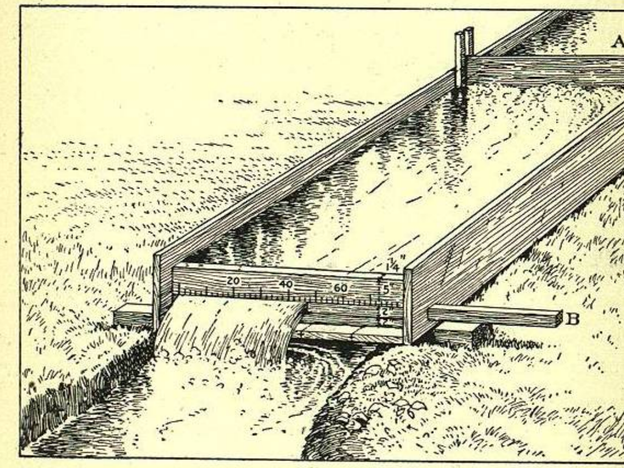


FIG. 30. — Flume for measuring miner's inches.

quantity, and a gate above, marked *A*, adjusted so as to bring the height of the water in the measuring box to the point where it nearly overflows the end plank. In this way small quantities of water can be divided with sufficient accuracy for ordinary purposes. If, however, it is necessary to measure greater quantities, and the orifice cannot be made long enough to accommodate these, it is necessary to make it higher, increasing it, say, from 2 inches in height to 10; there will then flow through such an orifice more than five times as much water for a given width of opening. Thus, in attempting to measure large quantities of water in this way, serious errors are introduced in favor of the large users of water.

One of the chief difficulties in attempting to measure a constant volume by this apparatus is due to the fact that in many ditches and streams there are occasional and rapid fluctuations of the height of water. When the height increases, a larger amount will be discharged from the orifice; and when it falls, a less amount. To secure a constant head or pressure a number of devices have been made, one of the most interesting of which is that invented by Mr. A. D. Foote. The measuring box (Fig. 31) *B* is placed by the side of the ditch marked *A*. The water in the ditch is checked by the small gate *D*, and a part is forced to flow through the gate *E*, raised for the purpose, filling the box *B*; the desired quantity escapes through the aperture *F*, into the lateral *G*. Any excess of water entering *B* spills back into the main ditch at *C*, so that a nearly constant head can be maintained behind the orifice *F*.

The method of measuring small brooks or creeks is illustrated by the accompanying figure (32). A stout plank is placed across the stream, held in position by stakes, and made tight by tamping clay on the up-stream side, so that water cannot pass

around or under the obstruction. In the plank is a slot of sufficient size and width to pass the ordinary discharge of the stream. This slot is from

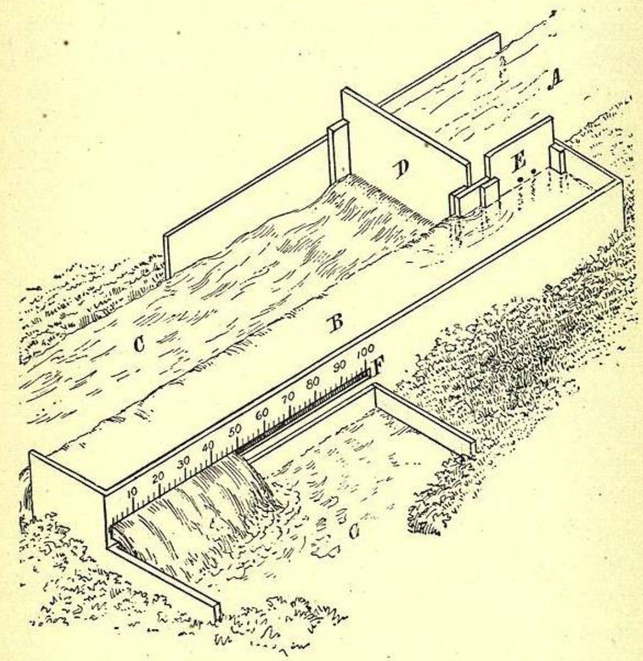


FIG. 31.—Foote measuring box.

4 to 6 inches below the top of the plank, and is closed by a gate or board sliding in front of the slot, and held in position by a small cleat or projection passing through the slot. This gate is gradually closed until the water in the stream is about

to overflow the plank; then the size of the orifice gives the discharge in miner's inches, the exact quantity being dependent upon the head of water, or height above the top of the slot, and its relative proportions.

The standard miner's inch, taking the arid region as a whole, may be considered as the flow through

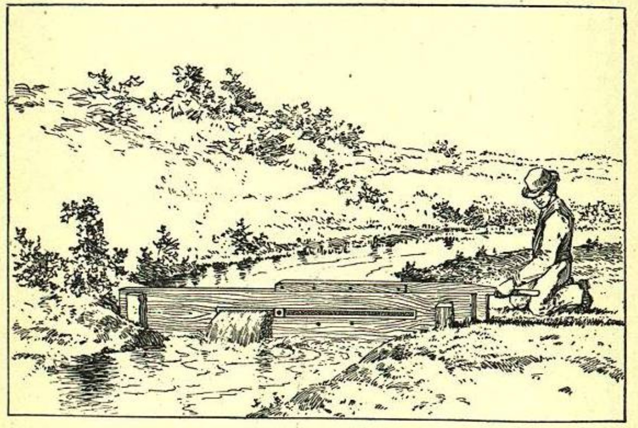


FIG. 32. — Method of measuring miner's inches in ditch.

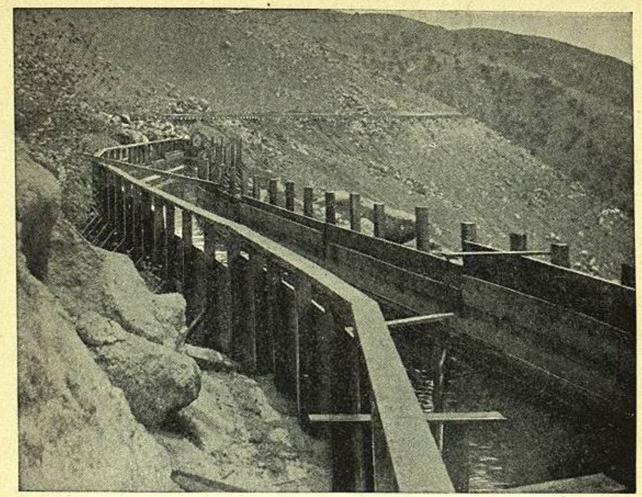
an orifice 1 inch square with a head or pressure above the top of the orifice of 6 inches. The actual quantity is dependent also upon the thickness of the plank or plate in which the orifice is made, and the character of the edges, whether sharp or square. It has been estimated, however, that the average value of a miner's inch of this character is 1.5 cubic feet per minute, or .025 second-foot, — in other words, $\frac{1}{40}$ of a second-foot. In different counties in California it has been found in use to range from .020 to nearly .030 second-foot. In Montana a method of measurement in customary use was through an orifice 1 inch deep with a head of $3\frac{1}{2}$ inches above the top. This has been estimated to furnish .021 second-foot.

The state of California by statute has prescribed that the miner's inch shall be a fiftieth part of a second-foot, and Arizona by court decision has settled upon a fortieth part. In Colorado it has been stated that 38.4 miner's inches made a second-foot, but this figure has been based on a single determination. It is sufficiently exact to state that in this state 40 miner's inches equal a second-foot.

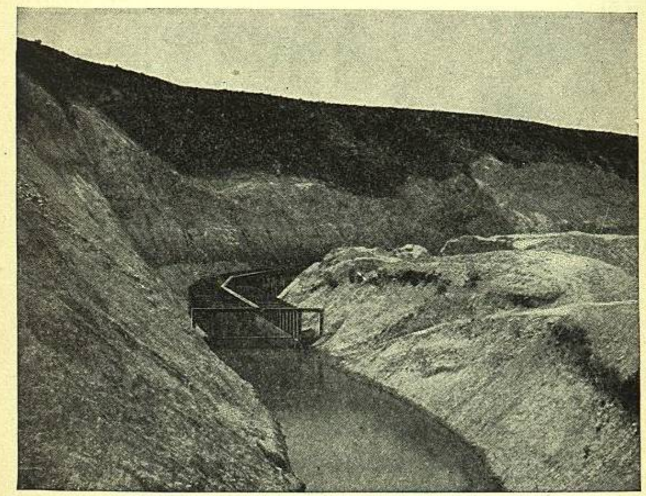
After trying many devices, the engineers and canal superintendents have, as a rule, usually adopted some form of open flume or weir, such as that described on page 99 in connection with the discussion of river measurements. These are least likely to be obstructed by floating sticks or weeds, and are most easily kept in good order. The method of flume measurement consists in measuring the width and depth of water in the flume, and in ascertaining by floats or current meters the velocity for different heights of water. By so doing it is possible to construct a table showing the approximate amount of water flowing in the flume when it is 1 inch in depth, 2 inches, 3 inches, and so on up to the full capacity of the flume. This method of estimation of discharge is known as rating the flume. When a rating table has once been made, it is usually assumed that the relation between height and quantity of water remains fairly constant.

For flume measurement either one of the structures needed to conduct the water across some depression is used, or short sections of the flume, at least sixteen feet in length, are set in the canal at some designated point especially for the purpose of making the measurement. The floor is smoothly laid and the sides are made either vertical or flaring, the width of the bottom of the flume being the same as that of the ditch both above and below, the cross-section of the flume being as nearly as possible similar to that of the ditch. A scale is permanently marked on the side of the flume, so as to give the depth of water at a glance. The construction of the flume should be such as to avoid all cross-currents or disturbance of the water, the object being to make a portion of the canal in such manner that the sides and bottom will be smooth and permanent.

To insure greater accuracy than that obtained in the ordinary flumes, various forms of weirs are used, these generally having complete contraction at the sides and bottom, as shown by the accompanying diagrams (Figs. 33, 34, and 35). In the first of these (Fig. 33) a rectangular weir is shown, the width of the opening being such as to contract



A. FLUME ON ROCKY HILLSIDE.



B. FLUME ACROSS EARTH IN A SIDEHILL CUT.

the stream on both sides and at the bottom, the distance *AB* from the bottom of the flume or ditch to the crest of the weir being at least twice that of the height *H* of the water passing over the crest. With this form of weir it is possible

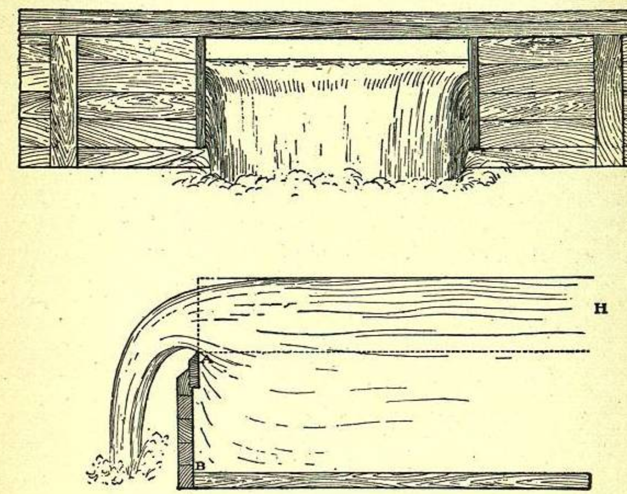


FIG. 33.—Rectangular weir.

to compute the discharge by use of the simple formula prepared by Mr. James B. Francis, from results of elaborate experiments carried on through many years in the canal built for water power at Lowell, Massachusetts. The discharge in cubic feet per second is 3.33 times the length in feet into the height in feet when the latter quantity has been cubed, or multiplied by itself twice in succes-