STRUCTURES AND METHODS FOR MEASURING IRRIGATION WATER

by

Charles W. Thomas, Hydraulic Engineer
Bureau of Reclamation
United States Department of the Interior
Denver, Colorado

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Charles W. Thomas*

SUMMARY

Successful operation of irrigation projects is dependent upon adequate control and measurement of flows throughout the conveyance system. Good measurements are usually difficult to obtain because of the inherent nature of an irrigation flow net.

An acceptable method or structure for measuring water flowing in an irrigation system must have certain characteristics among which are: low loss in head, easy readability, accuracy and consistency, adaptability to conditions of flow at the site, and economy of installation and operation. In a typical irrigation system flow should be measured at certain points to ensure conformance with legal requirements, for an equitable distribution of flows, for operational information, and to serve as a basis for charges made for the water.

The means to measure flows which are in current use in the western United States utilize the principle of varying heads. Those best suited for use in the different locations in the system are described to include the characteristics of each regarding relative cost, advantages, and disadvantages. Particular attention is directed toward the means for measurement at the farm turnout for both delivery by gravity and by pumping. In general, this paper is concerned with flow measurements in open channel systems in which current meters, Parshall flumes, critical depth structures, weirs, and propeller-type meters are among the methods and structures which may be utilized.

It is concluded that there are a number of presently developed structures and methods which may be considered standard for measuring flows in an irrigation system, but each has certain advantages and disadvantages. Some of them require more study to develop better calibration data and to establish the limits under which they will operate in the most satisfactory manner. There exists a definite need for further development and standardization to satisfactorily meet the requirements particularly in regards to a means of continuously recording the variation of head at the point of measurement.

INTRODUCTION

Adequate control and accurate measurement of flows throughout an irrigation system from storage to farm delivery are necessary: (1) for

*Hydraulic Engineer, Bureau of Reclamation, United States Department of the Interior, Denver, Colorado.
successful business management, (2) to meet legal obligations concern-
ing water priorities, (3) for water conservation, (4) to insure an equi-
table distribution of water to the land areas served, and (5) to establish
and maintain a cordial relationship among owners, operators, and water
users.

The measurement of water is a difficult problem in many areas
where irrigation is practiced. Gradients of the conveyance channels are
normally low to extend the irrigated area to a maximum. This causes a
deficiency of head to accomplish accurate measurement. The water require-
ment on the farms varies from day to day thus causing increases and de-
creases in flows in the conveyance channels which are of fixed dimensions.
This results in varying water surfaces or varying velocities, or both, de-
pending on the control structures utilized. The presence of weeds and silt,
the difficulty of maintaining close tolerances during construction, and many
other factors are present to reduce the accuracy of flow measurements.

An acceptable measuring device for most irrigation systems must:

1. Have a low resistance to flow with consequent low head
   loss.

2. Permit easy readability of flow.

3. Provide reasonably accurate and consistent results.

4. Be adaptable to fluctuations of head or be used in con-
   junction with equipment for controlling this variable.

5. Have initial costs and operation and maintenance costs
   that are consistent with the economic return of the area
   being irrigated.

The discussion in this paper is limited to practices generally
followed in the western part of the United States where the developed
areas are almost entirely dependent upon irrigation for crop production.
The author has had the privilege of observing and studying means of flow
measurement utilized in irrigation systems in other parts of the world.
In general, it may be stated that the measuring devices involve at least
three basic criteria: (1) the type for which the head upstream is held
nearly constant by auxiliary means and the measuring device has fixed
dimensions for delivering certain discharges which remain near constant
unless there is considerable change in downstream levels; (2) the type
which delivers a nearly constant discharge without effect from upstream
and downstream levels. In this class may also be considered those de-
vices which deliver a nearly constant discharge with variations of up-
stream head, provided the downstream conditions remain relatively
unchanged; and (3) the measuring device which gives a range of discharge,
depending on upstream and downstream heads.
The first type is used extensively in southern Europe and North Africa. The second type is used particularly in India and Pakistan. The devices commonly used in the United States are of the third type. In the use of the first type of device, special equipment is employed to control the level in the conveyance system upstream from the measurement. Since the equipment normally operates fully automatic, the need for periodic regulation of each turnout is negated. The second type of measuring device is so designed that the levels in the conveyance system may vary over a wide range and all deliveries will remain proportional if not almost constant. This insures an equitable distribution without periodic regulation of each individual turnout. For the third type of measuring device the turnout must be regulated periodically to insure required delivery since any change in water level in the conveyance system, and generally in the delivery downstream from the measurement, is reflected in a change of discharge through the measuring structure. The frequency of regulation is dependent upon the flow changes made in the conveyance system. Practicability is also involved since it may not be advantageous to make changes with such frequency that the flow conditions never reach a state of stability.

There are certain advantages and disadvantages of the systems. By automatic control of the water levels in the conveyance and the use of distributors that deliver a constant or near constant discharge for the head to which the upstream level is controlled, there is almost constant delivery of a fixed discharge. Hence, once the distributor opening is set the consumer receives a definite rate of flow until such time as the adjustment of the distributor is changed. Charges can be based on flow rates and be equitable. In the event of a malfunction of the equipment, the distribution is in error until adjustments are made.

In the Indian system the flow rate in the conveyance may change but the equitable distribution of water to each consumer is maintained. Charges can be made on a basis of the maximum delivery to each customer or on the basis of land area served by each turnout.

In the United States water is usually distributed on the basis of rate of flow, in most instances cubic feet per second, although this rate combined with time may be used to give a volume, acre-feet, as a basis for charges. Weirs, critical depth structures, Parshall flumes and similar means of measurement, require that the head be known to obtain discharge. When the water surface in the conveyance is permitted to fluctuate, adjustment of a turnout gate or similar installation is necessary to obtain the desired head at the point of measurement. The usual practice is to make this adjustment daily and then obtain a reading of head on the measuring structure to serve as a basis for charges and to regulate distribution. As a general rule, only the larger metering stations, propeller-type meter installations excepted, are equipped with apparatus to record the head continually at the measuring section. An exception to this practice may be found in areas where the cost of water is high. Since the discharge varies with respect to head and the head is subject to variation with changes of water level in the canal, assuming that the operator is not present at all times to adjust the turnout gate, it is probable that the rate
of flow does not remain entirely constant during the interim between observations of the gage height. Since major changes in flow are not made over short periods of time, the rate of discharge at the turnouts remains relatively constant. However, a continuous record of gage height would be desirable. The cost of providing such a record is in most cases not justifiable.

FLOW MEASUREMENTS IN THE CONVEYANCE SYSTEM

In most of the recently developed irrigation projects of the western United States, a storage reservoir is provided to regulate the seasonal run-off of the stream. Here the water is held until needed on the farmland later in the year. Below the storage area there is a conveyance system to transport the stored water to the farms. This system will normally consist of a combination of natural water courses, canals, and laterals. If the water is conveyed by a natural stream channel, a diversion dam and headworks are nearly always necessary to divert the water into the irrigation system. The distribution system may be of open channel or closed conduit construction. A sketch of such an irrigation system as described above is shown in Figure 1.

In an ideal arrangement flow should be measured at storage outlets, canal headworks, at strategic points in canals and laterals, and at delivery to the consumers. Such points of measurement are indicated in Figure 1.

Water in storage represents a volume which may be determined from area-capacity curves, based on surveys of the reservoir area, and measurement of the level of the stored water. The water is released from the reservoir through suitable control devices in accordance with irrigation demand in terms of rate of flow.

In order to insure that the irrigation demands and legal obligations are met, to minimize wastage and to permit orderly administration of the water, the rate of flow is measured at or near the point of release. These measurements are made by either primary or secondary devices.

The generally used primary devices are current meters, critical depth flumes, some type of a weir, Venturi meters in the outlet tubes, or others.

For measuring large flows in open channels, the current meter has been widely adopted in the United States. By means of this primary device, secondary devices may be rated, but the accuracy of the measurement through the secondary device can be no better than that obtained from the primary device.

Recently, considerable effort has been put forth to make use of the control devices at the outlets from the storage reservoir as a means
FIG. 1. TYPICAL IRRIGATION SYSTEM

Figure 1--Typical Irrigation System
of measuring the releases to the stream channel below the storage. Models of control gates and valves can successfully be calibrated in a hydraulic laboratory and the results transferred to the prototype, thus permitting their use as measuring devices in the field. It can be demonstrated that such calibrations may be used without reservation. To enhance the value to users and operators a few field checks are desirable. Normally, such a procedure will be more economical than complete field calibration. Certainly if control devices may be utilized for flow measurements, considerable savings can be effected in an irrigation system by omitting separate measuring devices.

When a current meter is used in the stream channel below the storage, it is common practice to establish a rating station at this point, Figure 2. By successive current meter gageings and observation of corresponding stage, a gate height-discharge relationship can be established for the section. If a continuous recording of stage is made, the rate of flow at any time can be determined from the charts taken from the recorder used in conjunction with the rating curve.

A combination of more than one basic means may be used. Figure 3 shows a 15-foot Parshall measuring flume installed in the center of a broad-crested weir below Olympus Dam near Estes Park, Colorado. This combination provides measurement at the point of release from storage over a considerable range of discharge. The normal range of release is measured through the flume, the higher flows over the ogee crest and through the flume. The broad-crested weir is so designed that a close approximation of discharge may be had initially. After continued flows over the crest, the quantity is more definitely determined by current meter gaging. At this particular installation observations have been made over a range of flows, and the gage height-discharge relationship has been established for the combination structure.

Assuming that the water has been released from storage and flows through a natural water course to some point near the irrigable area, it is then diverted to a canal for conveyance to the land. Measurement is again necessary because the stored water has probably mingled with public water belonging to others who have rights to the use of water from the stream. Measurements are also necessary for determining conveyance losses and for proper administration. These measurements may be made by the methods previously mentioned.

Figure 2--Current Meter Rating Station
Figure 3--15-foot Parshall Flume in Broad-crested Weir
The Parshall flume has found general usage for measurement of flow at the point of diversion from the stream. Figure 4 shows a 12-foot Parshall flume near a canal inlet. There is adequate grade at this site to permit the flume to operate without submergence throughout the normal range of flows. The flume may be set to operate with a degree of submergence where low loss in head is necessary. This concrete structure has been in service for a number of years and has served very well as an accurate measuring structure. It is self-cleaning, the head loss is low, and maintenance and operating costs are low.

A critical depth measuring section\textsuperscript{5} is shown in Figure 5. This particular control is located below Marti Gomez Dam in northern Mexico. It is economical, offers little resistance to flow, is self-cleaning, and is as accurate as the ratings obtained in the field or from the models. The structure shown was rated in place by the use of current meters.

In the interim period when a project is being settled and the water requirement is considerably below the design capacity of the system, discharge measurements are difficult. A notch-measuring structure may be installed to provide measurement of the reduced flows. Such a structure is shown in Figure 6. It is rated in the field, usually by means of a current meter. The notches produce considerable loss of head but when the canal is carrying only a small portion of its capacity, this is not objectionable and may be helpful in that a check is formed to reduce velocities and consequent scour. The openings are large enough to be essentially self-cleaning, although some difficulty may be experienced if considerable large foreign debris is present in the flow. The wall containing the notches may be removed when the project develops and design capacity of the conveyance is approached. Some protection from erosion may be necessary immediately downstream from the structure for unlined canals unless it is built in connection with a conveyance structure as shown in Figure 6.

Figure 7 shows a 20-foot Cippoletti weir\textsuperscript{6} in a canal system. This weir has considerable merit and reasonable initial cost. It is subject to a number of possible errors, considerable maintenance to keep the approach pool free of silt and debris, and can be partially obstructed by floating detritus. To reduce loss of head to a minimum, and for economy of installation, the weir crest is made long. Such practice introduces the probability of a serious error in discharge because of the inability to obtain the necessary accuracy in determination of head on the crest. A slight error in the head determination results in an appreciable error in discharge.


Figure 4--12-foot Parshall Flume in a Canal
Figure 6--Notch Measuring Structure
A commercial instrument that has gained considerable favor recently is the open flow meter. This is a totalizing meter that has been designed to attach to the downstream headwall of an existing structure thus alleviating the necessity of installing a special structure. One requirement is that the water passages in the structure must flow full at all discharges to be measured. The meters are manufactured in a range of sizes to fit the structures existing in the conveyance system. Special adaptations are also available. A factory rating of the meter to fit the particular conditions at the site can be quite good. A more precise rating can be obtained in the field if found necessary. A very low loss of head is incurred in the measurement and the design of the impeller and mounting is such that the collection of weeds and trash on the impeller is held to a minimum. At velocities for which the impeller is designed the accuracy can be expected to be very good. The initial and maintenance costs are comparable to the other devices enumerated above. The advantage of having a totalized record of flows saves considerable office work in calculating the flow from, for instance, the recorded head on a weir. Figure 8 shows an installation of two open flow meters on the downstream headwall of a double barrel structure in a Bureau of Reclamation canal. Each barrel is 54 inches square. These two meters are equipped with dual recording instruments.

All measuring devices previously mentioned are adaptable to open channels, either natural water courses or excavated canals. Only representative structures have been described. It is not intended to convey the impression that these are the only means employed. There are many others.

MEASUREMENT IN THE LATERALS

After the water leaves the main canal it may be distributed to the farm units through either open channels or closed conduits—that is, underground pipe systems. Measuring structures for open channels will be discussed in this paper. However, devices applicable to closed systems will not be considered, except those used on pump discharge lines.

In general, there is a wider choice of measuring devices for the laterals than for canals or natural streams. It is probable that selection of a means of measurement that will fit conditions at the site in regard to loss of head, bedload, cost, etc., will be difficult. Measurement should be carried out in the lateral at the point where it leaves the canal and at intermediate points downstream, particularly at bifurcations. In some irrigation systems the carrying capacity of the laterals may be greater than that of the main canal in other systems. Therefore, the devices previously mentioned as being applicable to canals are equally well suited for measurement in large laterals.

In general, it may be said that measurements in the lateral system can be made by means similar to those used at the farm turnouts, or in case of large laterals, by means similar to those used in the canal.
Figure 8--Two Open Flow Meters in a Canal (Photograph courtesy of Sparling Meter Company)
systems. Therefore, only brief mention is made of measurement in the lateral system; the emphasis will be placed on the measuring devices which are used at the point of delivery to the farm.

MEASURING DEVICES AT FARM TURNOUTS

Probably the most important point of measurement in the entire irrigation system is at the farm turnout. It is for this ultimate consumer that the elaborate and costly system has been constructed. It is at this point where the individual meets the officials operating the system and where the final distribution between users is effected. Measurement must be made here to insure an equitable distribution of the water supply, provide a basis for charges, and to establish and maintain a cordial relationship among owners, operators, and water consumers. There may be legal points such as rights to the water to be considered.

The means of measurement at the farm turnout must be selected to meet exacting conditions. For instance, low loss in head is very important at a turnout serving land adjacent to the canal or lateral either by gravity flow or pumping. Fluctuation of water surface both upstream and downstream from the point of measurement must normally be anticipated.

In many systems the range of discharge that is required to be accurately measured at the farm turnout is small, but in other systems the discharge requirements may vary over a wide range.

The cost of the measuring device of the farm turnout is of primary consideration, particularly where the farm units are small or the economic return is low.

A shutoff is in most instances required at a farm delivery because the farm operator may not desire water or may not be legally entitled to it at all times when there is flow in the canal or lateral. Economy in installation can be obtained if the shutoff at the farm delivery also serves as a means of measurement. There have been numerous attempts to effect this combination. A certain degree of success has been acquired if accuracy alone is considered. Numerous other advantages have been gained.

Open channel distribution systems. Where a high degree of accuracy is not required, but where an equitable and consistent distribution of water is desired, many irrigation systems have been equipped with meter-gates7 such as the one shown in Figure 9. One of the stilling wells is connected to the canal and the other to the delivery pipe on the downstream

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Figure 9--12-inch Metergate
side of the gate. The difference in water levels and the gate opening is measured and the discharge obtained from tables derived from standard calibrations. The head loss in this type of device is very low, being no more than that required in a conventional regulating and shutoff gate. The initial cost is low compared with other means because of the combined features of measurement, regulation and shutoff. When installed properly, the maintenance cost is low and reasonable accuracy may be expected. It can be noted from the figure that the gate leaf is circular, thus at partial openings a crescent-shaped orifice is formed.

Another turnout gate that has been calibrated over certain ranges is known as the Denver screw-lift gate. This gate is manufactured under more than one trade name. The leaf is square, and the orifice created by opening the gate is always a segment of a circle until the gate is completely open when the full circular section of the pipe passing through the canal or lateral bank is exposed. Complete calibrations are not presently available but additional work is being done. The gate has characteristics similar to those enumerated in the previous paragraph.

The constant-head orifice turnout shown in Figure 10 has become a popular measuring device for farm turnouts as well as for installation in canals and laterals.\(^8\) This means of measurement has been calibrated for the following method of operation. The upstream gate is set at the required opening to deliver the desired discharge as given in the rating tables. The downstream gate is then regulated until there is a 0.2-foot differential head across the upstream gate as indicated by two enameled scales, one located upstream of the upstream gate and the other between the two gates. Users of this device report very satisfactory operation and good accuracy. However, the initial cost is relatively high because two gates are necessary. Some savings have been effected by using a cheaper downstream gate. This gate need not be watertight since it is used for regulation only, the shutoff being accomplished by the upstream gate. The structure containing the gates is designed so that it is essentially self-cleaning except for very low flows or excess backwater caused by checks downstream.

The open flow meter, Figure 11, previously mentioned as a means of measuring the flow in a canal, is more generally used for measurement at turnouts. This totalizing meter has been designed to attach to the downstream headwall of the turnout pipe by means of brackets. The meter is manufactured in a range of sizes to cover the needs and to fit the size of the turnout. A very low loss in head is incurred in the measurement and the design in such that the collection of weeds and trash on the impeller is held to a minimum. At velocities for which the impeller is designed the accuracy can be expected to be very good. The initial and maintenance costs exceed those of many of the other devices but the record keeping saved by the totalizing feature

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Figure 10--Constant Head Orifice Turnout
METER TOTALIZER OR TRANSMITTER FOR REMOTE RECORDER

MOUNTING BRACKETS

MINIMUM WATER SURFACE

DROP PIPE

CONCRETE HEADWALL

FLOW FROM CANAL

LONGITUDINAL SECTION

FIG. II. OPEN-FLOW METER ON FARM TURNOUT

Figure 11--Open Flow Meter on Farm Turnout
somewhat offsets these costs. Where deliveries are rotated the meters may be moved from area to area as the rotated deliveries are moved.

Parshall flumes are used extensively at farm turnouts. This type of flume creates a relatively low loss in head, is moderate in initial cost, is self-cleaning, and is not appreciably affected by downstream water surface elevations that may be incurred from changes made by the farmer in the course of his irrigations. Figure 12 shows a 12-inch Parshall flume installed in a farm ditch below a turnout.

Probably the most extensively used device for the measurement of deliveries to the farm is the weir. The use of this device causes considerable loss of head. There is considerable maintenance, particularly in cleaning of the pool upstream from the weir, and protection of the banks and bed of the channel downstream from the weir. The accuracy (if the device is properly installed and maintained) is quite good.

The Cippoletti, Figure 13, is probably the most used type of weir for the measurement of irrigation water. However, a considerable number of rectangular weirs, both contracted and suppressed, may be found in irrigation systems. Where discharges from small turnouts are to be measured, a V-notch weir is used.

The installation requirements and the particular characteristics of the several types of weirs are found in published text books and handbooks and will not be repeated here. Calibration curves and tables have been developed for the standard type weirs mentioned above, and discharge through the weir can be obtained readily by reading the head on the weir blade and entering the table for determination of the actual rate of flow.

Closed conduit systems. Because land for right-of-way is becoming more valuable and water so scarce and costly that losses due to seepage, evaporation and waste can no longer be tolerated, more and more underground pipe systems are being used to distribute the water from the canals to the farm lands.

Although a number of devices have been developed for use in domestic or municipal water systems, most have been found too costly to be practical in irrigation systems. Therefore, we find the choice of measuring devices for closed conduit irrigation systems somewhat limited. Recent engineering research closely associated with development by commercial concerns has alleviated this condition somewhat, but there is yet much to be desired.

10 "Water Measurement Manual," (see footnote 8).
Closed conduit systems are usually built in highly developed areas where the land is subdivided into smaller tracts than are usually found under the open systems. The cost of $200 for a measuring device to serve 100 acres may be tolerated, since the cost per acre would be only $2; however, the same device on the turnout serving 5 acres would make the cost per acre $40, which is, in most instances, prohibitive. Therefore, we find that the measuring devices in many underground pipe systems are means which have been developed for open flow measurements. The water is conducted from the underground pipe to the surface, measured, and then returned underground. In addition to economy, there are two other reasons for this procedure. One is that a measuring device underground is not readily accessible for maintenance and repair, and the other is that the consumer likes to see the water running and can estimate the flow to his own satisfaction. Some of the most recently developed means for measurement of flow in closed systems are placed above ground or in "stands" where they may be inspected and repaired easily, and may be readily observed.

Among the devices which may be placed in the underground lines for the measurement of flow are: Venturi meters, both metal and concrete or a combination of the two; flow nozzles, usually cast of concrete to reduce cost; propeller-type meters, especially developed for irrigation systems; turbine and disc-type meters, of the type developed for domestic systems when the quantity to be measured is quite small; and deflection meters in which the velocity of flow acts on a pendulum or vane and the movement of the vane is translated to rate of flow.

Turnouts served by pumps. To extend the area which is served by an irrigation system, delivery to lands located above the conveyance may be accomplished by pumping, Figure 1. Water to these farm lands may be measured by some type of installation in the discharge lines or in the open distribution conveyances. If measured in the open channels, the means previously described may be employed. Methods of measurement applied to closed conduit systems may be utilized if the water is measured in the pump discharge lines.

Pumping is usually employed to serve single farm units although in the more recent systems the pumped water is delivered to laterals whence it is distributed to the farms. The measuring devices are similar, the main difference being in the size.

Venturi meters and propeller-type meters are probably the most commonly used means of measuring flow in the pump discharge lines. These devices produce a low loss in head which is very important in the case of pumped water since each additional increment of head adds to the pumping costs.

Venturi meters have been applied to domestic water systems. The initial cost of this type of installation is quite high. However, the recovery of head in the downstream cone results in a relatively low net head loss.
Figure 12--12-inch Parshall Measuring Flume in Farm Turnout
To reduce the cost of the metal Venturi meters normally used in domestic systems, the meters have been cast of concrete, using only metal rings at the measuring sections. The initial cost is further reduced by casting the entire meter of concrete. In the latter case it has been found difficult to hold the form so that precise upstream and throat diameters are maintained. Hence, considerable loss in accuracy results unless each meter is calibrated and individual discharge tables prepared.

Flow nozzles and orifices have not proved very satisfactory because of the induced head loss.

Propeller-type meters were developed previously for domestic and municipal water systems. These are velocity-type meters. The flow is measured by the velocity of the water acting on a vaned impeller which drives a tally head through an appropriate gear train. By proper calibration, the meter registers the volume of water passing. Meters installed in the line, but built of lighter material and otherwise modified, have been adapted to low-pressure irrigation pipe systems and pump deliveries. Operation has been quite satisfactory, particularly where relatively clean water is being metered. Initial cost of this type of meter is comparatively high, but is less than for the metal Venturi meters. Maintenance is also an item over a period of years, since there are moving parts in this type of measuring device. Accuracy of a properly maintained meter is very good. Because of the very low loss in head incurred by use of propeller meters, they are well adapted to measurement in pump discharge lines. Where sales of water are based on acre-feet deliveries, the totalizing feature of these meters saves on bookkeeping costs.

The open flow meter, a propeller-type meter previously mentioned, may be used in pump discharge lines. Figure 14 shows an installation using this type of meter. The impeller of this meter is supported from the rear, thus alleviating the catching of weeds and grass. The head loss is very low.

Straightening vanes are ordinarily provided with all impeller-type irrigation meters to reduce or remove inaccuracies caused by any spiral flow that may be present in the line.

The impeller-type meters when maintained in accurate operating condition give a positive indication of quantity of water delivered over a period of time regardless of changes of rate during the period. Accuracy over the range of flows anticipated must be maintained. If the rate of flow fluctuates from normal and the accuracy varies, it is not possible to apply a correction factor because the elapsed time for each rate is not reflected in the totalized quantity.

**NEW DEVELOPMENTS**

There is at least one development of a velocity-type meter in which the velocity of flow deflects a vane. A recording of the amount of deflection combined with a recording of the depth of flow in the section
FIG. 14. OPEN-FLOW METER IN PUMP DISCHARGE LINE

Figure 14--Open Flow Meter in Pump Discharge Line
is used as an index of rate of flow. The constants must be obtained in the field by calibration with a primary device, usually a current meter. Two recorders are necessary for operation of the station. The method has not been standardized to a point where it may be used without considerable field rating and checking.

The very recent attempts to develop a vane meter that will indicate or record rate of flow show promise. The two experimental types are shown in Figure 15. The vane is so shaped that changes in water surface are reflected in the deflection of the vane which is activated primarily by velocity. The meters are designed to be placed in a structure of rectangular cross section. One such meter combines a very simple recorder which, when perfected, should be a valuable contribution to the field of measurement of irrigation water.

A deflection meter has been successfully developed for use in pipe lines. An indicator shows the rate of flow at the section, but no permanent record is produced. Accuracy, at present, can be improved but the cost of the device is relatively low.

CONCLUSIONS

In view of the large number of means of measuring irrigation water that have been enumerated, it may appear that it would not be difficult to select a device or structure that would serve well at a particular site. However, local conditions existing at the point where the measurement is desired will probably negate the efficient use of a number of the devices. A careful study is necessary to determine the best available means. What purpose the measurement will serve, the degree of accuracy required, the probability of the device operating successfully under the local existing conditions of silt, weeds, etc., the cost of both initial installation and operation and maintenance, and the characteristics of each device considered are among the many factors to be examined.

With regard to accuracy, the basic principles upon which the operation depends, the limitations with regard to capacity and other hydraulic conditions, and the extent of previous calibration and study must be understood when making the selection. Care must be exercised to meet tolerances during construction, and maintenance during operation must be diligently carried out to insure the expected accuracy.

There is need for development of additional means for measuring irrigation water. Perhaps some of the studies now in progress may yield results which will simplify the problems. Development of a simple and reliable recorder of nominal cost for application to presently used devices would improve the methods used and should increase the accuracy.
Figure 15--Two Experimental Types of Vane Meters