Design, Construction, and Evaluation of a Water Measurement Device for On-Farm Application

by

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Abstract

There is an increasing need for much more effective water management than what has been applied in the past. The need for flow measurement accuracy has become of utmost importance because of lowering water tables from extreme use of the agriculture producers.

An area of this problem that the farmer could direct his efforts toward, that would have a substantial impact on the misuse of water resources, would be to use flow rates from sprinkler heads or gated pipe as determined by the Soil Conservation Service.

The two devices described are intended to be simple yet accurate systems of measuring flow that will save the farmer time and money over existing technology and other applicable devices. By providing the farmer with information on construction and calibration, a working model can be built and used as needed to directly benefit the farmer.

Acknowledgments

I would like to take this opportunity to thank Lehmann's Welding of Dime Box, Texas, for the use of their facilities and supplies during the actual construction of the devices.

I would also like to thank the Agricultural Engineering Department here at Texas A&M for the use of their facilities and for obtaining materials used in construction.

Finally I would like to thank Dr. Marshall J. McFarland, my advisor on this project, for his support and ideas.

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Introduction

Irrigation agriculture in Texas is faced with a major problem with two aspects: Irrigation accounts for over 70 percent of the water consumed in Texas each year. A substantial portion of this is pumped from ground water reserves that are being depleted at a rate greater than the recharge (TDWR, 1983). In areas where the water is available, the costs of pumping the water are increasing. The producers are caught in a classical cost-price squeeze: Costs of applying water are increasing faster than the additional value of the crop production generated by the water. To cope with decreasing supplies of water and for increasing costs of energy, the producers must increase the efficiency of their irrigation.

An accurate measurement of the water is necessary for a maximum efficiency of irrigation. If the producer does not know the amount of flow into each furrow or from each sprinkler nozzle, the chances are very high that his irrigation is inefficient. As simple as this sounds, virtually all producers do not maintain the precise knowledge of the flow that they need for the management of the irrigation. One extreme example comes from the Soil Conservation Service (SCS) in their extensive program to increase the efficiency of irrigation in the High Plains region of the state. One producer needed to apply about four inches of water to the root zone in a preplant irrigation. The SCS tests showed that he applied eleven inches of water - four to the root zone while the remainder drained below the root zone.

Simple, portable and inexpensive water measurement devices are needed for the measurement of flow in an individual furrow, from a sprinkler nozzle or from a gate in a gated pipe. The authoritative references (e.g., Merriam and Keller, 1978) recommend a rubber hose, a five gallon bucket and a stop watch for the evaluation of sprinkler nozzles. This method is cumbersome, time-consuming and subjects the evaluator to frequent showers from adjacent sprinkler nozzles. Cost considerations rule out a permanently mounted flow measurement device on each nozzle, since the nozzle cost is in the vicinity of five dollars and several hundred nozzles may be needed. Similar problems exist for measurement of furrow systems.

Reasons Behind Project

In choosing one aspect of this area to research, it was noted that there was no middle ground of measurement devices. In other words, there was the extremely sophisticated devised which meant that they were also expensive, or on the far other end was the extremely simple type of device which, although fairly accurate, took a great deal of time to use in correctly setting flow rates. As might be expected, farmers using irrigation are already expending more money than they want to in terms of water management and even though they might spend enough to obtain one highly sophisticated flow meter for the main line from the pump, they very rarely will go to the added expense of buying any more measurement devices for each main line or laterals. Inversely, farmers are usually limited on time and manpower and although there exists appropriate devices to measure water application without a greatly added expense, they have not been used to the extent that would greatly affect water use because of cumbersome and time-consuming techniques. For these reasons it was felt that a type of device that would work with accepted accuracy, yet would be inexpensive, easy to construct and calibrate for the individual farmer, was needed.

Construction Of Device For High Pressure Flow

Two designs that could provide an adjustable orifice with a constant centerline and geometry were examined. The first was based on the system that is used to control the aperture on a camera lens. The other consists of two plates that, when moved together with a thumbscrew, would form a square orifice of decreasing size. Keeping in mind the stressed simplicity needed in the design for the farmer's sake, the latter design was chosen as most practical to construct as a model.

Actual construction of this design was possible from materials normally found in any metalworking shop. A frame constructed from 16 gauge sheet metal was formed through a few simple bends with the seams welded together (Figure 1). A removeable face plate was cut to the dimensions of the frame and attached with sheet metal screws (Figure 2). A round hole was cut in the face plate and a hole with a ninety degree angle at the bottom was cut out of the frame (Figures 1 and 2). The latter hole was used to form the lower half of the square orifice. These holes are used for an inlet and outlet. Three inch steel pipe was welded over each hole to facilitate easy attachment to couplers such as those used in high pressure systems (Figure 3). The inner workings of the device were again kept simple but the parts were numerous and are as listed: one faucet handle, two 3/8" nuts, ten inches of 3/8" all-thread, two four inch pieces of two inch angle iron and a three inch by six inch piece of 16 gauge sheet metal.

The first action to be performed on the frame was to drill a 7/16" hole in the middle next to the side opposite the face plate. This hole allows the all-thread to be placed through the frame. A ninety degree cut in the plate of 16 gauge sheet metal is used to form the upper half of the orifice and a 3/8" nut was welded parallel to the opposite end from the angled cut. The all-thread is then positioned through the nut and is used in helping line up the sliding plate over the outlet hole in the frame. The two pieces of angle iron are ground down to 1/8" on one side each. These are then palced over the ocrrectly positioned plate and welded into position forming a slot for the plate to move up and down. Another 3/8" nut is welded to the top end of the all-thread inside the frame but allowing enough all-thread to stick out of the frame for attachment of the handle. A small bead is welded on the lower end of the all-thread to stop travel after the plate has completely closed the orifice. The faucet handle is then attached to the top end of the all-thread that protrudes through the top of the frame. Once these steps are complete the plate should move up and down as the handle is turned to open and close the orifice. The nut on the top of the all-thread inside the frame and the lower part of the handle will work to keep the all-thread stationary and provide the force to move the plate (Figure 4).

Calibration Of Device

As it may have already been realized, the device just described does not meet the entire criteria need for high pressure flow because it does not provide a constant centerline although geometry remains constant. This problem should and can be easily overcome with a few minor modifications and will then be ready for calibration. This can be done using a monometer attached to either side of the device when connected to a water source (Figure 5). Measurement of head loss across the system will provide a coefficient that can be used in a general equation for orifice flow based on Bernoulli's principle. The equation is

$Q = CA(2gh)^{1/2}$ where, in consistent units

Q = flow — C = loss coefficient of the orifice

A = area of the orifice — g = gravity

h = depth of water above orifice centerline

Need For Alternate Device

At the beginning of this project it was felt that a device as described earlier in this paper would be applicable to all types of irrigation systems, but as time progressed, it was realized that this device would not work sufficiently on many low pressure systems. Fortunately there was a design already in use that could easily be expanded and improved as far as ease of operation was concerned. This device again maintained the aspect of being easy to construct and calibrate so that a farmer could do it himself or have one made at a local welding shop for a minimal cost, yet the device would provide an accepted accuracy on the flow rates required.

Basis For Design

The system was developed at the North Plains Research Field at Etter, Texas, and allowed rapid determination of flow rate from gated irrigation pipe. This device incorporated the orifice flow principle but used interchangeable orifices. To meet the required flow rates twenty or thirty separate orifices of varying diameter would need to be developed (Figure 6).

Construction Of Low Pressure Device

To simplify the use of this sytem in terms of reducing the need for developing and keeping up with the required number of orifices, the device was modified to use an adjustable orifice. Construction was practically the same as the initial device in that the body was a one gallon paint thinner can, but the snout originally used for attachment of the separate orifices was removed. Instead a slot was formed on the can by riveting two small pieces of sheet metal to either side of the outlet. This facilitated the use of a sliding plate to form an orifice and control the flow rate. In keeping with the need for constant geometry, the sliding plate and lower half of the outlet were cut so as to form a square orifice that was adjustable from the top of the paint thinner can by moving a control lever. The lever, attached to the sliding plate through a connecting rod, is easily pushed up or down as needed, increasing or decreasing the size of the orifice (Figure 7).

This system can be easily calibrated through experimental determination of the needed orifice opening to obtain required flow rates by using the bucket and stopwatch technique. However, once flow is determined at a specific opening, the sliding plate can be marked in relation to a stationary point on the can. This will allow the user to return to the exact opening as needed for required flow once the marks have been made for all the needed flow rates.

Use of this modified system in gated pipe should allow for rapid and accurate adjustments in flow rates and should prove easier to work with than its predecessor. Actual adjustment of the gate should be made when the orifice is opened to the required flow rate and water is allowed to flow into the rear of the can. Once the water begins to flow over the back of the can, the gate should be moved closed until the water remains at a constant level near the rear edge. This device, even if not calibrated perfectly, has a use in that it will allow the adjustment of each gate in the pipe to exactly the same flow rate.

Conclusion

The orifice principle is adaptable for use in many applications where accuracy and simplicity are required. The two devices described previously are rough models constructed in an attempt to provide farmers with flow measurement systems using this principle for high pressure measurement in sprinkler applications and low pressure systems such as gated pipe. These devices are intended to allow the farmer the option of mid-level technology that does not sacrifice accuracy, yet is practical in the sense that there is not great cost involved and can save time if used as suggested.

Refinements performed to the devices could increase ease of operation and adaptability to many irrigation systems other than those referred to in this paper. In time and with a little investment in experimentation into different methods of control for the movement of the orifice, a highly sophisticated yet easy to construct design could be devised that will still remain available to each individual farmer.

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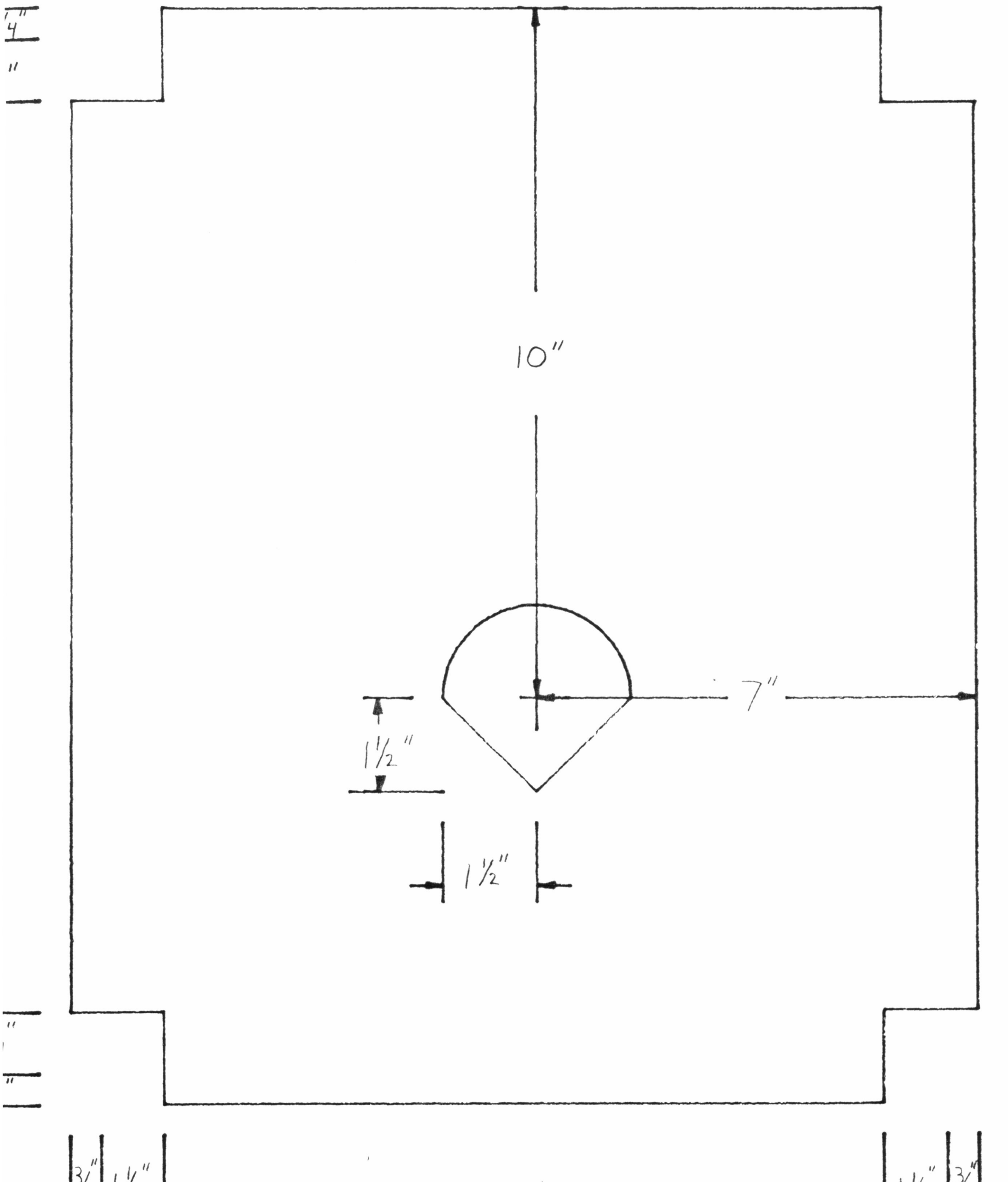
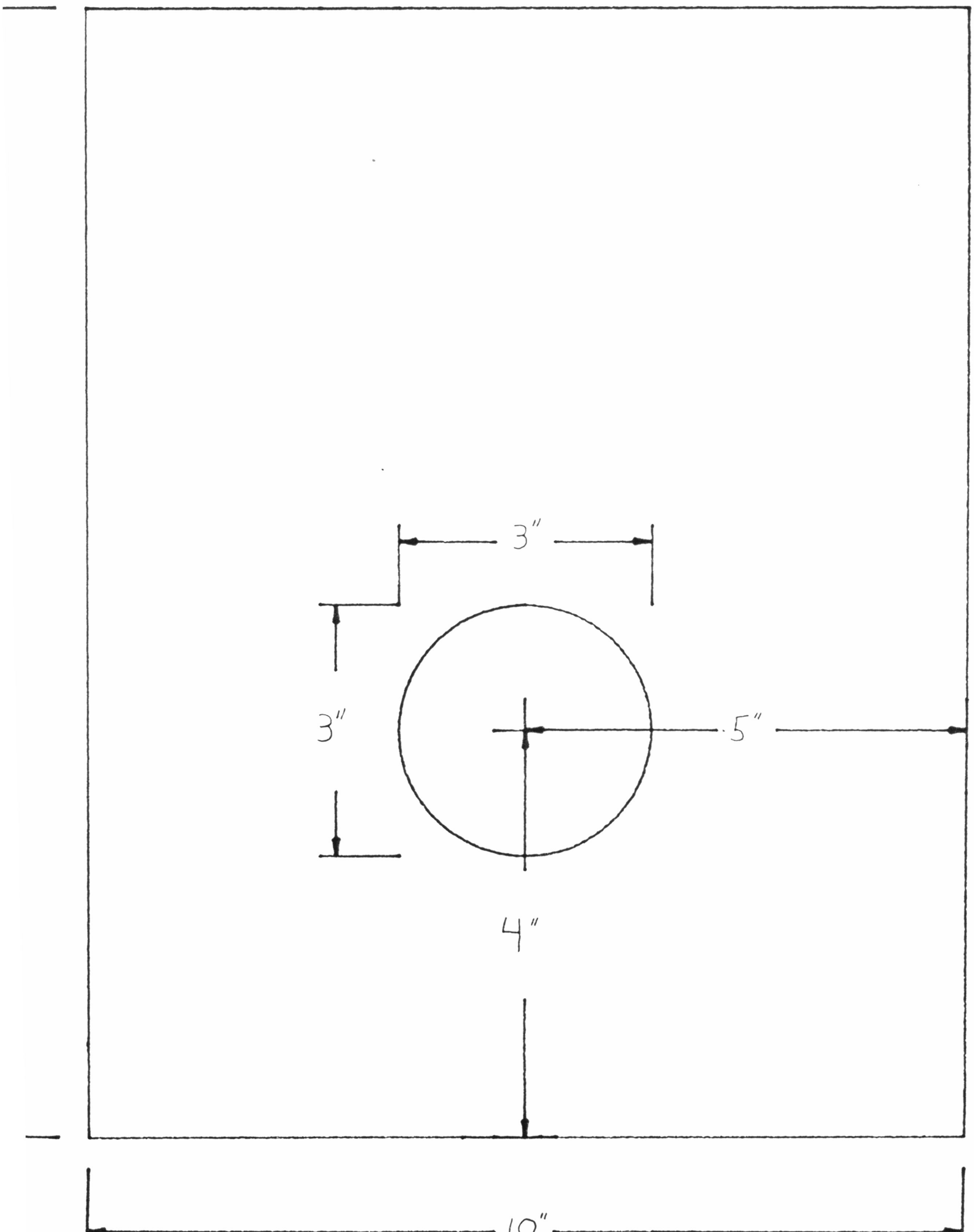
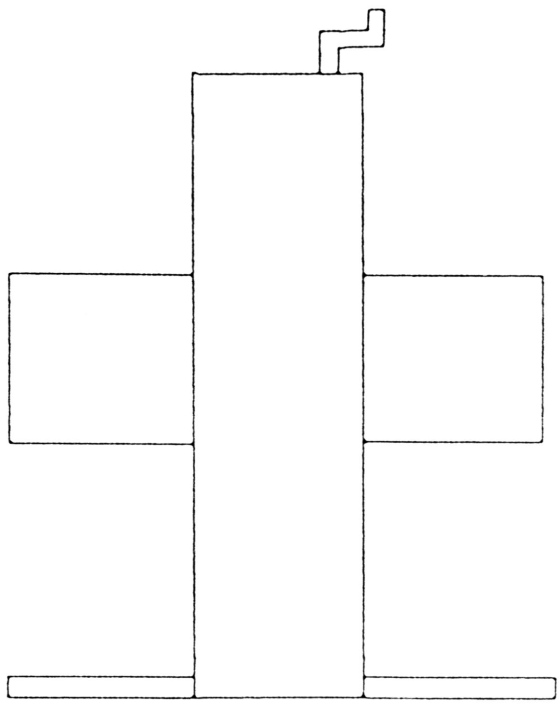


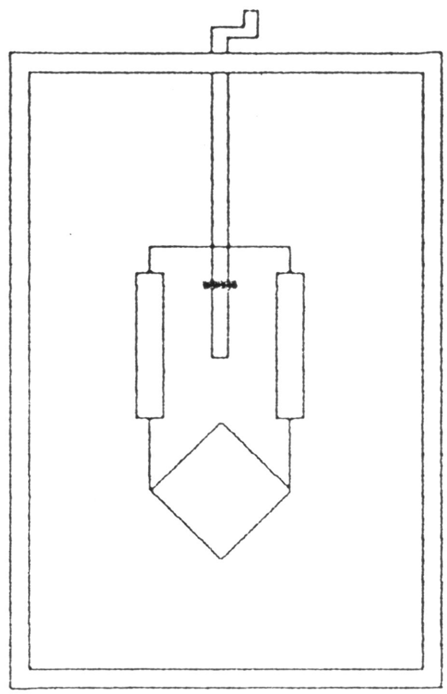
Dimensions of Frame
(Figure 1)



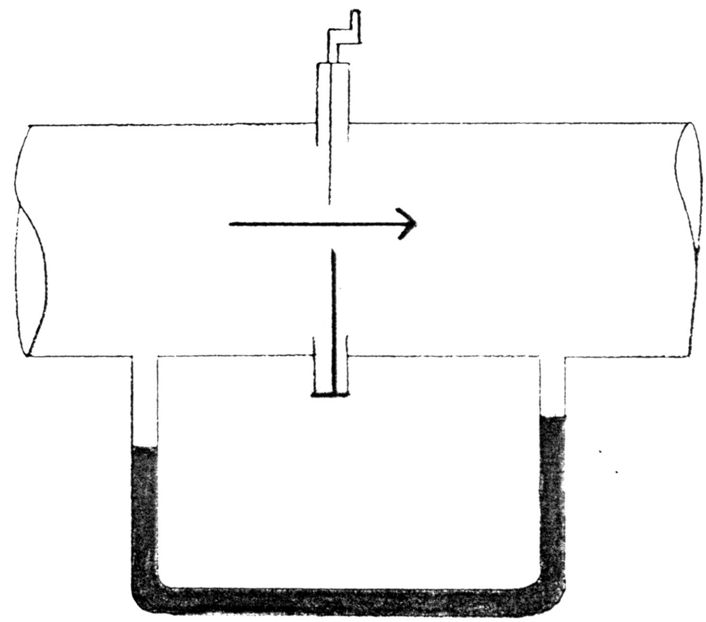
Dimensions of Face Plate
(Figure 2)



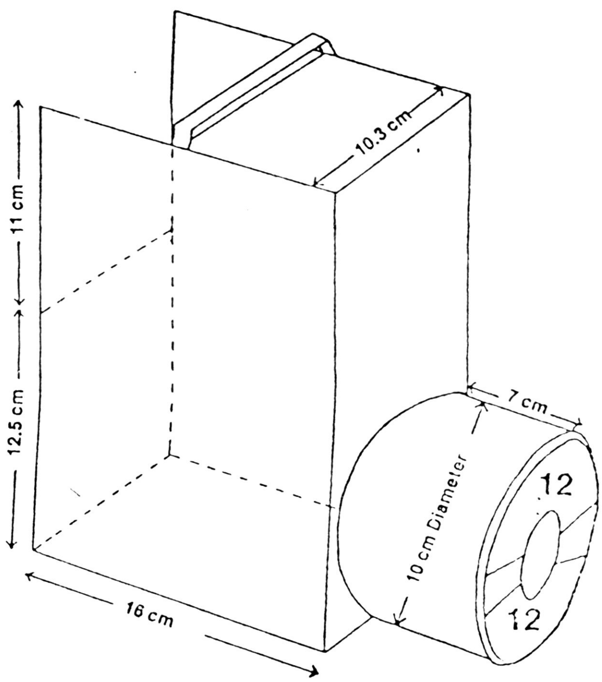
Side View Showing Inlet and
Outlet Pipes Attached
(Figure 3)



View Showing Inner Workings With
Face Plate Removed
(Figure 4)



Calibration Using Monometer
(Figure 5)



Schematic of Etter Device
(Figure 6)