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# Flow Conditioning for Irrigation Propeller Meters

## Technical Article

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# Flow Conditioning for Irrigation Propeller Meters

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**Abstract.** McCrometer and the University of Nebraska recently studied the effects of flow conditioning on flow meter accuracy. The results of the study indicate that the incorporation of a flow straightener into the design of an irrigation propeller flow meter provides ±2 percent measurement accuracy while greatly reducing the instrument's typically required straight pipe run.

This advanced propeller flow meter's design reduces the straight pipe run required by up to 80 percent , which greatly reduces pipe material and installation costs for new irrigation well sites. In the retrofitting of existing well sites to add flow meters for the first time, this new meter design also alleviates the problems associated with crowded equipment configurations where adding the meter has often resulted in significant re-layouts at high cost.

**Keywords.** Agriculture, water, irrigation, flow meter, propeller flow meter, saddle meter, flow conditioning, flow conditioner, flow straightening, flow straightener, pipe straight run, mandatory water metering, measurement accuracy,

## Introduction

Water agencies across the United States continue to require water flow meters for new agricultural irrigation well site installations and for existing well sites too. The need to balance the water needs of agriculture, other industries and residential use is driving water conservation as never before.

In agriculture, irrigation scheduling is the application of water to crops only when needed and only in the amounts needed. It involves studying, understanding, applying, then monitoring and controlling necessary instruments such as soil moisture analyzers, rain gauges, and flow meters to assure efficient use of energy and water in crop production. In turn, minimizing the waste of water and supporting water conservation while maximizing crop yields.

Good irrigation scheduling practices include knowing the volume of water applied to each field. Flow meters, when properly selected and installed correctly, accurately measure the water to verify the proper amount was applied. An *accurate* flow meter is essential to good irrigation scheduling practices.

### Typical Flow Meters

Flow meters come in all shapes, sizes, and price ranges. Types of irrigation flow meters include: propeller, turbine, magnetic, and insertion. Propeller meters are durable, reliable, easy to install, economical to purchase, and therefore make up the majority of the installed base of irrigation water meters in the US.

The propeller meter consists of a rotating device, a helical-shaped impeller, positioned in the flow stream. When fluid passes through the meter it contacts the impeller causing it to spin. The impeller’s rotational velocity is directly proportional to the velocity of the flow.

The impeller’s rotation is transmitted through mechanical linkages, which drive a mechanical register that displays both instantaneous and totalized flow. The irrigator can look at his meter register at any given time to collect instantaneous and totalized flow rate data.

### Propeller Meter Installation Requirements

To measure flow accurately, the installation of a typical propeller flow meter requires 5 to 10 pipe diameters of straight, unobstructed pipe run upstream from the meter inlet tube. The straight pipe run is necessary to provide a highly uniform liquid flow profile within the pipe that is stable enough for measurement.

Flow meter straight pipe run requirements are expensive in terms of pipe materials, installation labor and maintenance. In retrofit situations where a new flow meter is added to existing equipment, there is often not enough space to accommodate the straight pipe run necessary for accurate flow measurement.

This situation can result in costly redesigns and re-piping of existing sites that is time-consuming and costly.

### Flow Conditioning

McCrometer and the University of Nebraska recently studied the effects of flow conditioning on the installation requirements for propeller flow meters. This study was designed to determine if integrating a flow straightener (FS) into the design of a new propeller flow meter would result in accurate flow measurement while significantly reducing the need for straight pipe runs.

The saddle-style propeller meter developed for this study features a patent pending flow straightener to condition water flow. This integrated meter/straightener design is expected to maintain the propeller meter’s stated ±2 percent accuracy, while reducing the upstream straight run to 2 pipe diameters and the downstream run to 0 to 1.5 pipe diameters. The saddle-style propeller meter was selected for this test because it is easy to install as both a new and a retrofit device.

## Statement of Problem

Irrigation plays a major role in the Nebraska farm economy. There are over 100,000 wells in the state that contribute to approximately 90% of the annual groundwater consumption. In order to practice good irrigation water management, it is important to accurately measure the amount of water being pumped from these irrigation wells. Currently, propeller flow meters are the most common devices used for irrigation water measurement in Nebraska.

When selected and installed correctly, propeller meters can be accurate within ±2 percent of actual flow. To achieve this level of accuracy, the propeller meters must be placed in an “undisturbed flow of water”. Undisturbed flow is another way of saying that the velocity profile in the pipe has not been distorted causing swirl, secondary flows, asymmetrical profiles, or symmetrical non-reference profiles.

Propeller meters are designed to measure the flow rate in a full pipe that has an axially symmetrical, non-swirling, and parabolic reference distribution of velocity across the pipe (Figure 1). The flow measurement can be inaccurate when the water entering the metering section has been disturbed and the distribution of velocity across the pipe has been distorted (Figure 2). Apparatus in the pipeline, such as pumps, valves, and elbows, can cause distortions to the velocity profile. In Nebraska, common flow disturbances include pumps, chemigation check valves, and elbows.

One approach to obtain accurate water measurement in the vicinity of flow disturbances is to place the flow meter far enough downstream from the flow disturbance so that the water nearly returns to the normal expected velocity pattern, i.e., a fully developed velocity profile, before it enters the metering section. To achieve the desired pattern it is recommended that there be at least 10 pipe diameters (10D) of straight blank pipe between the disturbance and the metering section. However for many cases in the field there was not enough space built into the piping system to allow for the recommended 10D of distance. Thus, when retrofitting existing irrigation systems, the piping system must be altered significantly so that adequate distance is made available for metering. Since these alterations can be expensive it would be beneficial to the irrigation industry if the space requirements could be reduced.

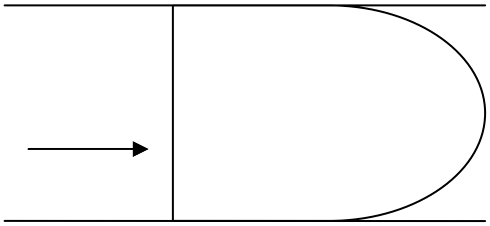

**Figure 1. Symmetric-parabolic velocity distribution.**

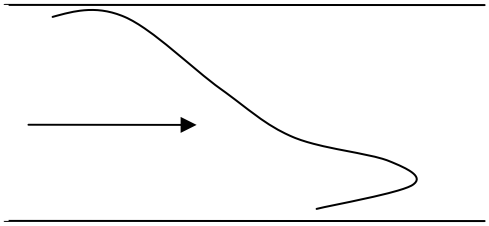

**Figure 2. Distorted velocity distribution.**

The use of flow conditioners is one approach for reducing the required distance of straight blank pipe. Straightening vanes are a common type of flow conditioner. McCrometer, Inc. uses a 6-vane arrangement for this purpose. McCrometer, Inc. recently developed a new flow conditioning and straightening device, the Mc SpaceSaver™ Flow Meter.

## Project Objective

The objective of this project was to determine the impact of the flow straightener (FS) on the metering accuracy of propeller meters in the presence of flow disturbances. The flow disturbances considered were two elbows out of plane, vertical turbine pumps, and vertical turbine pumps equipped with a spring-loaded swing check valve.

## Procedures

The project was conducted in the Biological Systems Engineering Water Hydraulics lab located in L. W. Chase Hall, University of Nebraska-Lincoln. A venturi flow meter system served as the standard for flow rate comparisons. The venturi size used for an individual test was based on flow rate. Flow rates less than 700 gpm were measured with a 6-inch venturi and flow rates greater than 700 gpm were measured with a 10-inch venturi. Our experience indicates that the venturi system measures flow within 1-2 percent of actual flow.

A redundancy meter, a McCrometer propeller meter, S/N 80-8-555, was used to verify the quality of the venturi data. The meter used in the test section, herein called the test meter, was a 6-inch McCrometer meter, Model Number MO 306-675, S/N 07-06548-06. The meter was mounted in a 20 inch long metering section with flanged fittings. The flow straightener (FS), a McCrometer FS106-2, was mounted in a 12 inch long flanged spool. The spool length was considered as part to the straight pipe length between flow disturbances and the metering section. All distance measurements were taken from the downstream flange of each disturbance to the tip of the propeller. The piping used in all conditions was flanged 6-inch nominal Schedule 40 PVC pipe with an inside diameter of 6.065 inches.

The various testing conditions are shown in Tables 1 and 2. In addition, a baseline test was performed on the test meter. The baseline test was conducted with 32D of straight blank pipe located between a standard vane and the metering section.

The two elbows out of plane configuration is shown in Figure 3 and the vertical turbine pump and check valve is shown in Figure 4.

The volume totalizer of the test meter was timed with a stop watch for flow rate calculation. The timing period was for approximately three minutes. Each test was replicated three times.

**Table 1. Two elbows out-of-plane test conditions.**

**Factors**

- Two flow conditioners – none and FS
- Three distances – 2D, 4D, and 8D
- Four nominal flow rates – 250, 550, 900, and 1200 gpm

**Table 2. Vertical turbine pump test conditions.**

**Factors**

- Two flow conditioners – none and FS
- Three distances – 2D, 4D, and 8D
- Two check valve conditions – none and chemigation check valve
- Two flow rates – 250 and 550 gpm

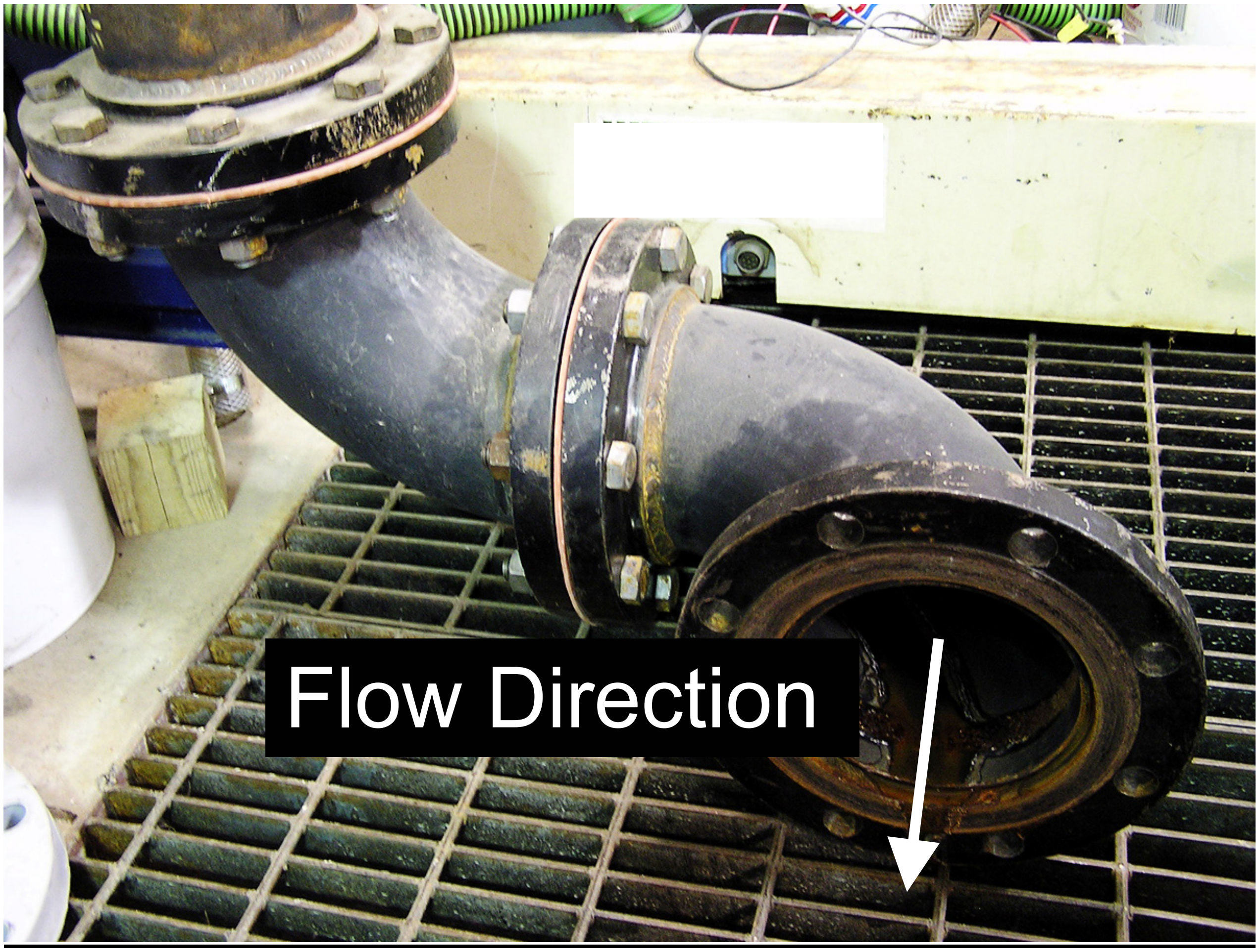

**Figure 3. Two elbows out-of-plane configuration.**

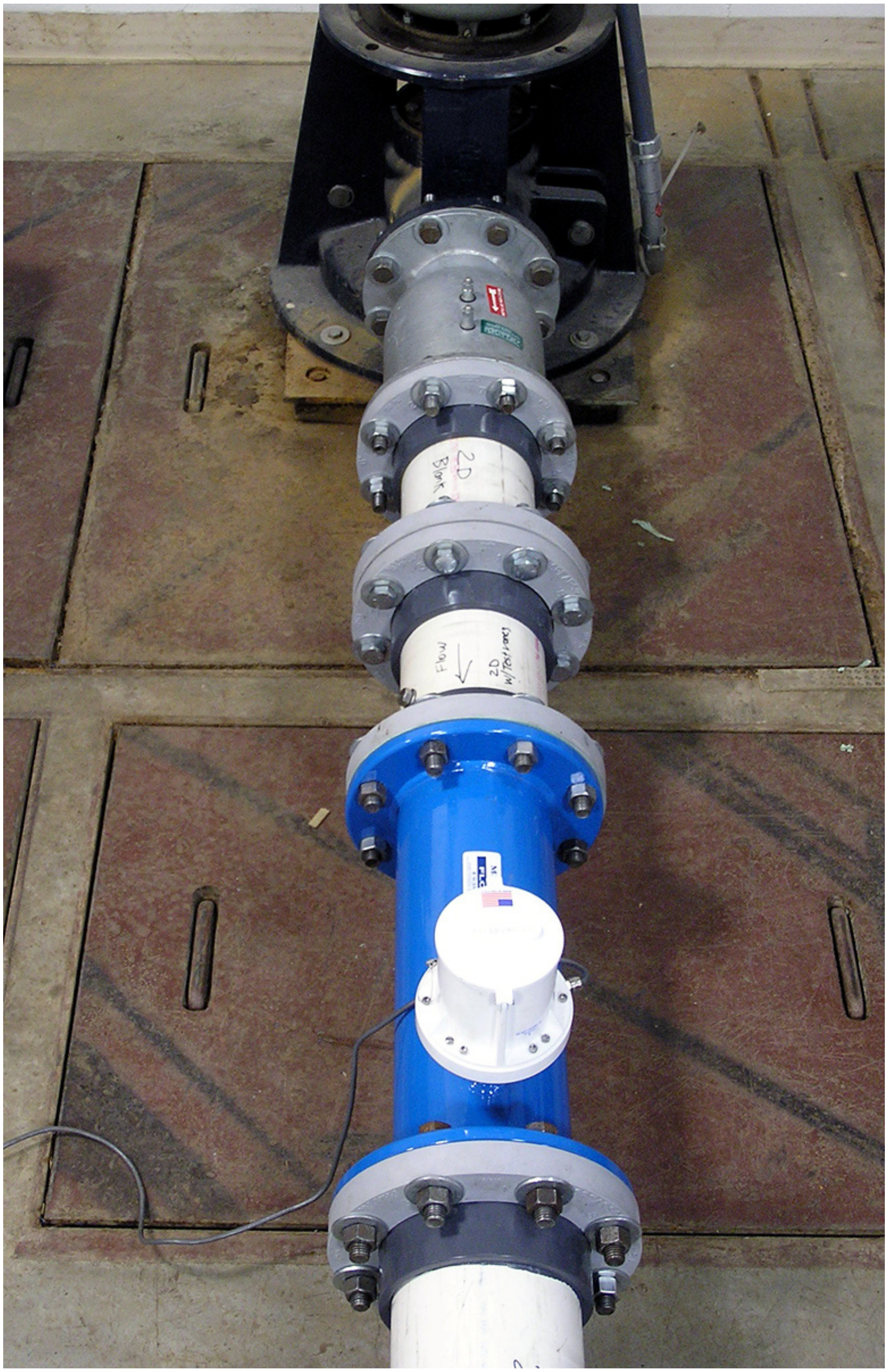

**Figure 4.  Vertical turbine pump with check valve configuration.**

## Results

The test results are summarized in Table 3 and are presented graphically in Figures 5-14. Actual flow rates were always very near to the planned nominal flow rates with all flows being within 20 gpm of planned and with the majority being within 5 gpm of planned. The metering accuracy or uncertainty was quantified by the flow ratio, the ratio of the test meter flow rate divided by the laboratory standard flow rate. A flow ratio of 0.98 indicates that the test meter registered 2 percent lower than the laboratory standard.

All data, except for the baseline test data, have been corrected for meter measurement bias, i.e., the baseline data were used to correct the test meter flow rates. The meter measurement bias is based on the difference between the test meter flow rate and the laboratory standard flow rate that was observed in the baseline test. It is caused by a combination of the laboratory standard bias and the test meter bias.

The test data were corrected for meter measurement bias by dividing the observed test meter flow rate by 0.98, the mean flow ratio of the baseline tests. The confidence intervals presented on the graphs are 95 percent intervals. The 95 percent confidence intervals were calculated by multiplying the standard deviation of the data by two and then adding and subtracting this number from the mean of the three replications. When calculated over all of the tests, the flow ratio of the laboratory redundancy meter (McCrometer S/N 80-8-555) was 1.00 with a range of 0.985-1.015 confirming that experimental errors did not lead to erroneous laboratory standard data.

**Table 3. Summary of flow ratio results (data corrected for meter measurement bias detected in the baseline test).**

| | --- Flow Ratio--- | | |
|---|---|---|---|
| Flow Condition | Mean | Range[2] | Standard Dev.[3] |
| Baseline without vane @ meter | 0.980 | 0.967-0.993 | 0.004 |
| Two elbows, 2PD, w/o FS | 0.892 | 0.879-0.899 | 0.010 |
| Two elbows, 2PD, w/FS | 0.984 | 0.972-0.989 | 0.003 |
| Two elbows, 4PD, w/o FS | 0.895 | 0.882-0.902 | 0.005 |
| Two elbows, 4PD, w/FS | 0.981 | 0.970-0.987 | 0.003 |
| Two elbows, 8PD, w/o FS | 0.904 | 0.891-0.908 | 0.005 |
| Two elbows, 8PD, w/FS | 0.982 | 0.969-0.988 | 0.003 |
| Pump, no check valve, 2PD, w/o | 0.954 | 0.949-0.959 | 0.004 |
| Pump, no check valve, 2PD, | 0.978 | 0.971-0.985 | 0.002 |
| Pump, no check valve, 4PD, w/o | 0.964 | 0.960-0.968 | 0.002 |
| Pump, no check valve, 4PD, | 0.981 | 0.974-0.988 | 0.001 |
| Pump, no check valve, 8PD, w/o | 0.973 | 0.971-0.975 | 0.004 |
| Pump, no check valve, 8PD, | 0.983 | 0.975-0.990 | 0.002 |
| Pump, check valve, 2PD, w/o | 0.937 | 0.920-0.954 | 0.004 |
| Pump, check valve, 2PD, w/FS | 0.980 | 0.978-0.982 | 0.002 |
| Pump, check valve, 4PD, w/o | 0.945 | 0.930-0.959 | 0.003 |
| Pump, check valve, 4PD, w/FS | 0.981 | 0.973-0.989 | 0.002 |
| Pump, check valve, 8PD, w/o | 0.951 | 0.943-0.959 | 0.002 |
| Pump, check valve, 8PD, w/FS | 0.981 | 0.975-0.987 | 0.002 |

[1] Mean flow ratio over all flow rates

[2] Range of the mean flow ratios for each flow rate

[3] Mean standard deviation over all flow rates

## Baseline Tests

The results of the baseline tests are shown in Figure 5. The mean flow ratios varied from 0.967-0.993 with a mean of 0.980. As was true with many of the tests where the flow had been conditioned in this project, the lowest flow ratio occurred at the nominal flow rate of 550 gpm.

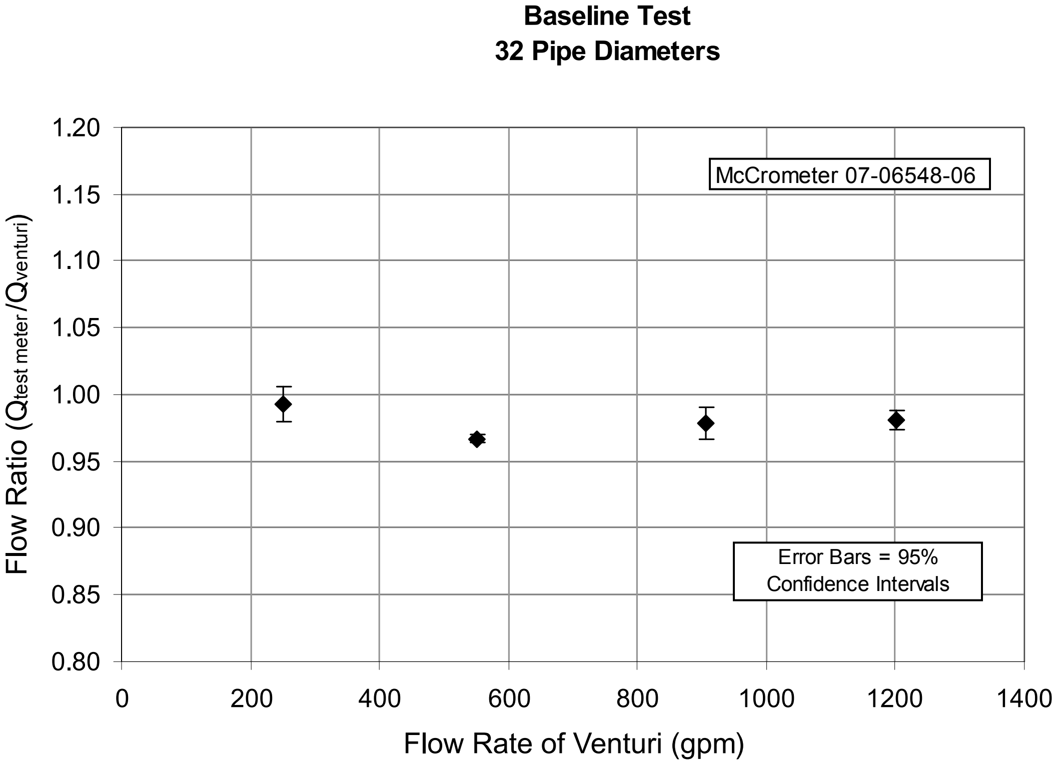

**Figure 5. Flow ratios in relation to flow rate for baseline tests (data not corrected for directional meter bias).**

## Two Elbows Out-of-Plane

The two elbows out-of-plane results are shown in Figures 6, 7, and 8. The data shown have been corrected for the meter measurement bias. The two elbows out-of-plane was the disturbance that cased the most inaccuracy in flow measurement in our tests. Measured flow averaged about 11 percent low 2PD downstream of the elbows. At 8PD the meter still registered over 10 percent low. The FS significantly improved the metering accuracy with measured flows being within about 2 percent of the laboratory standard for all three straight pipe distances upstream. As can be noted by the error bars and the standard deviation data presented in Table 3, the FS greatly reduced the variability in the data.

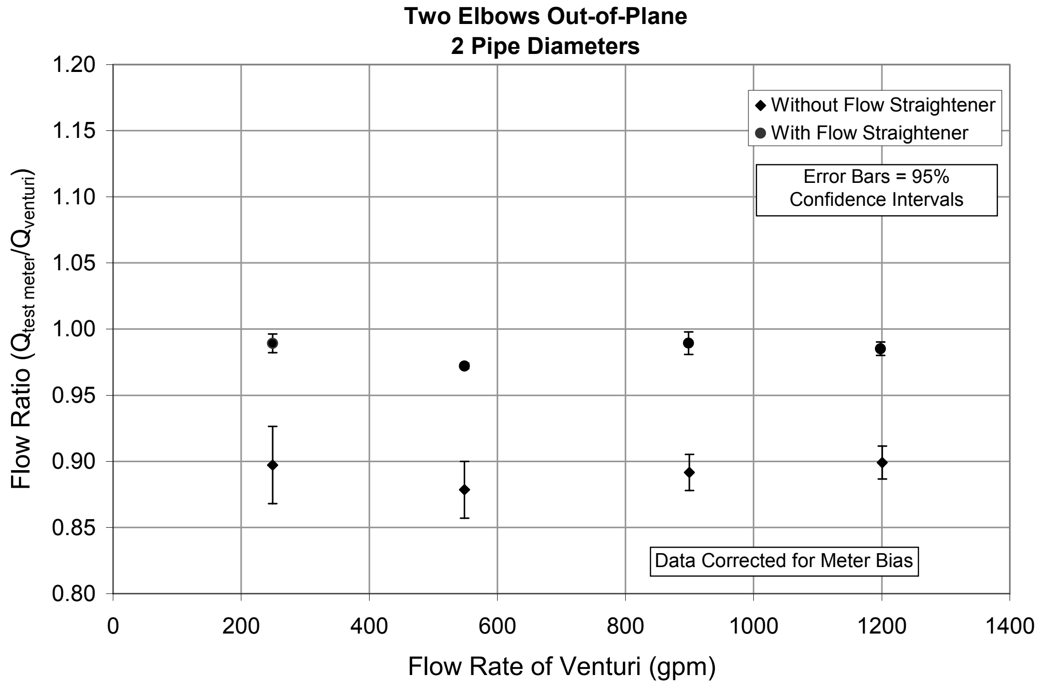

**Figure 6. Flow ratios in relation to flow rate for two elbows out-of-plane, 2 PD upstream straight pipe (data corrected for meter measurement bias).**

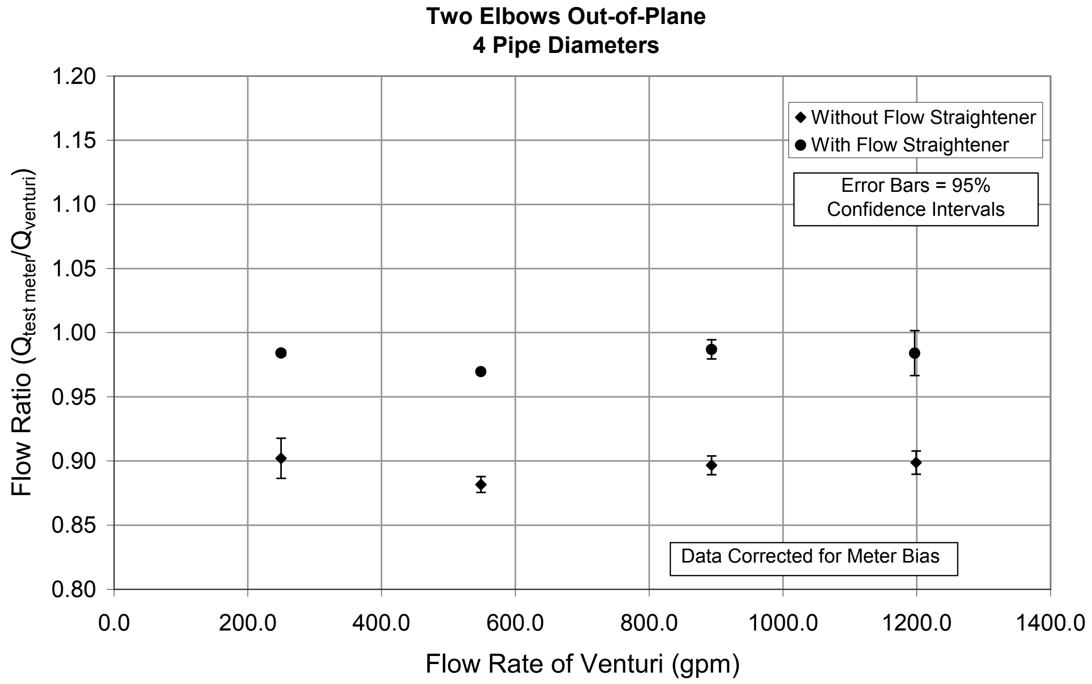

**Figure 7. Flow ratios in relation to flow rate for two elbows out-of-plane, 4 PD upstream straight pipe (data corrected for meter measurement bias).**

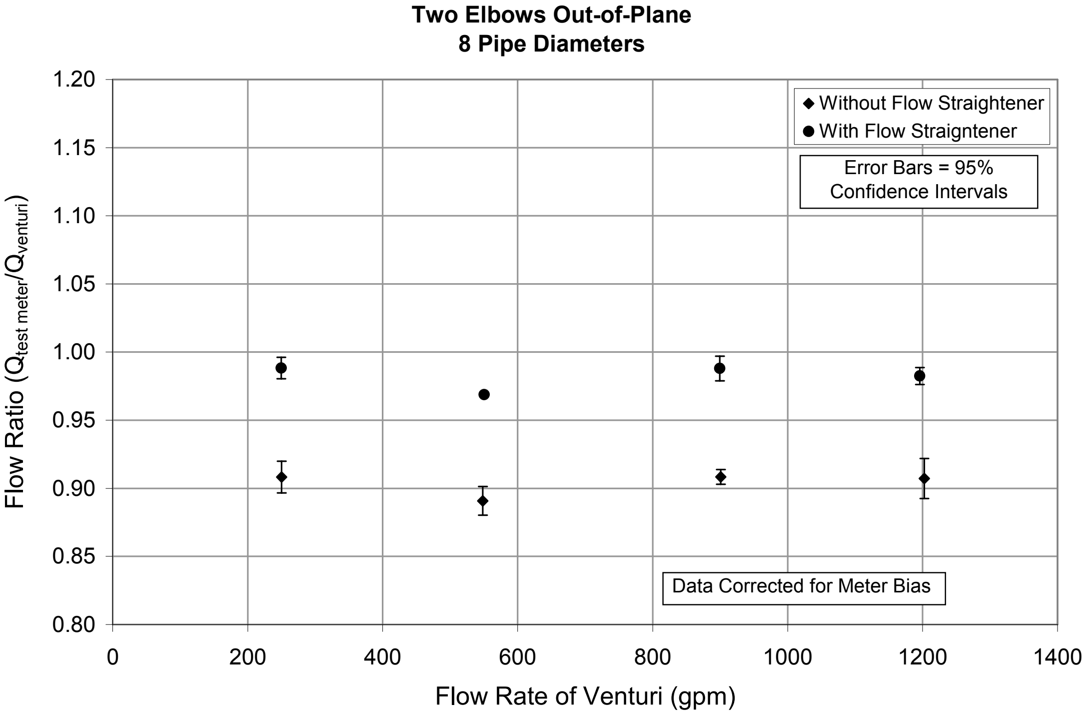

**Figure 8. Flow ratios in relation to flow rate for two elbows out-of-plane, 8 PD upstream straight pipe (data corrected for meter measurement bias).**

## Vertical Turbine Pump/Check Valve Combinations

The results for the vertical turbine pump without the check valve are shown in Figures 9-11. Without flow conditioning the measured flow averaged between 2.7 and 4.6 percent low relative to the laboratory standard. The FS conditioned flow averaged 2.2, 1.9, and 1.7 percent low for the 2PD, 4PD, and 8PD of straight upstream pipe, respectively. Conditioning the flow with the FS reduced the standard deviation by approximately 50% for these tests.

When the spring-loaded check valve was in place downstream of the pump discharge and upstream of the test meter, the metered flow averaged 6.3, 5.5, and 4.9 percent lower than the laboratory standard for the 2PD, 4PD, and 8PD straight pipe upstream distances respectively. These inaccuracies were reduced to about 2 percent low by use of the FS. As was the case for the other tests, in general the variability in the data was also reduced by the FS as indicated by the reduction of the standard deviation.

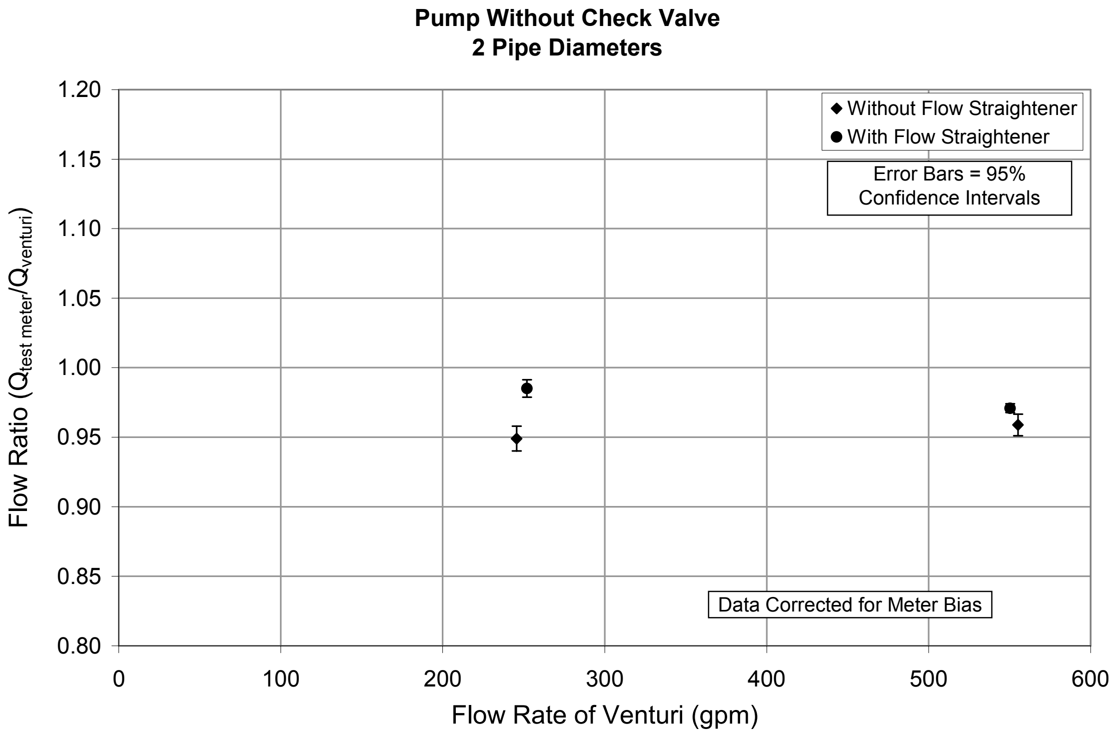

Figure 9. Flow ratios in relation to flow rate for vertical turbine pump without check valve, 2 PD upstream straight pipe (data corrected for meter measurement bias).

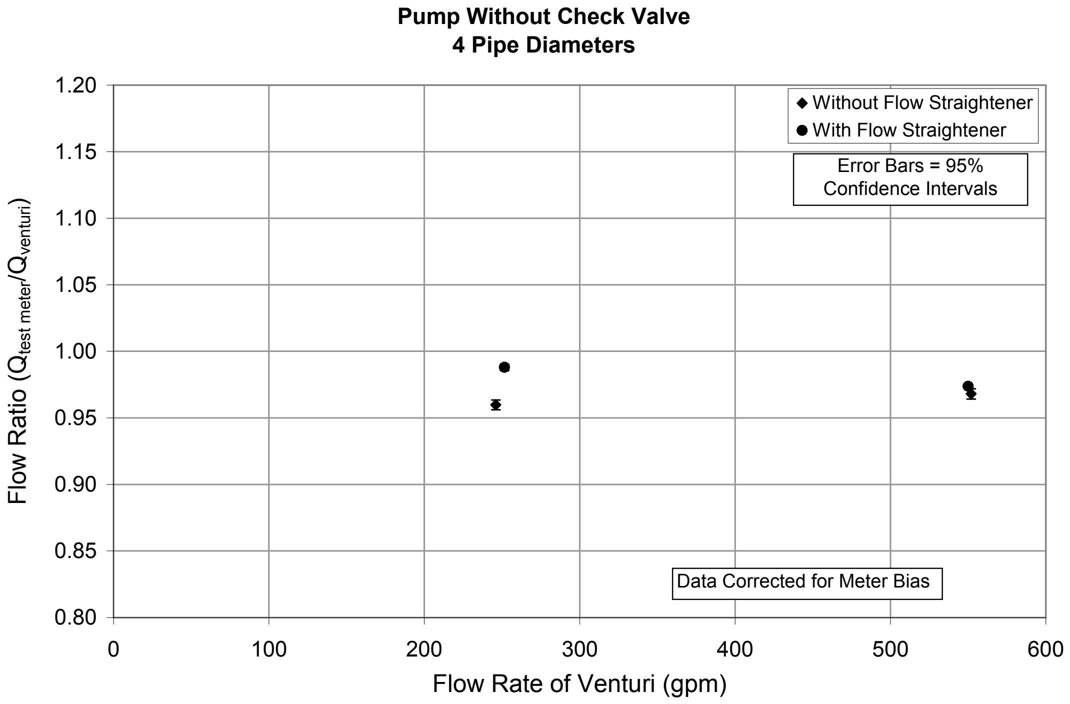

**Figure 10. Flow ratios in relation to flow rate for vertical turbine pump without check valve, 4 PD upstream straight pipe (data corrected for meter measurement bias).**

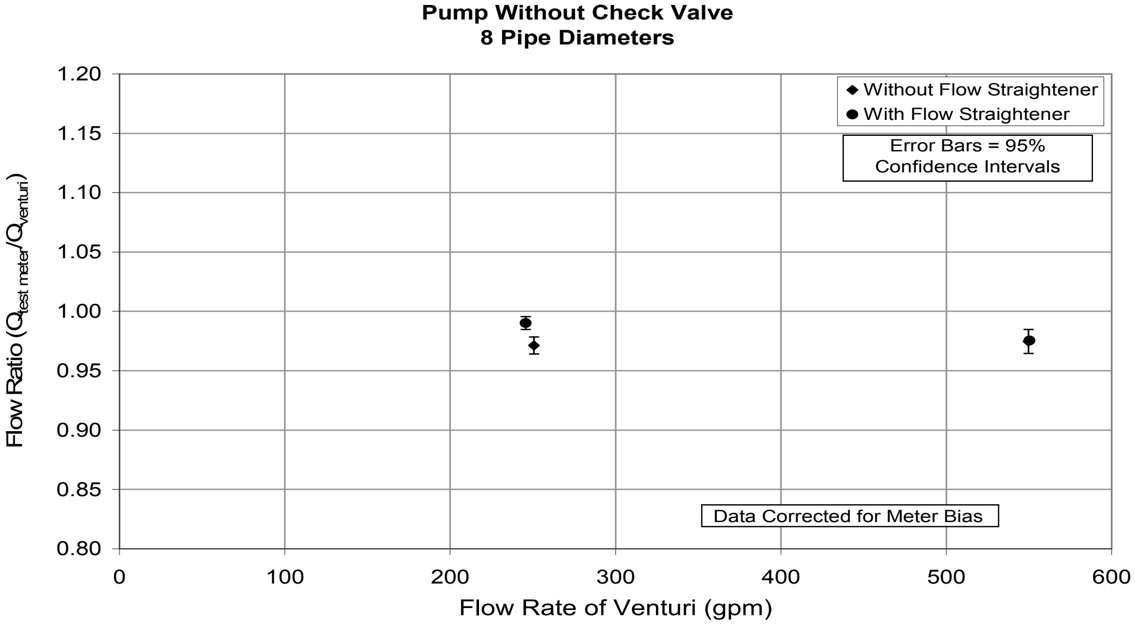

**Figure 11. Flow ratios in relation to flow rate for vertical turbine pump without check valve, 8 PD upstream straight pipe (data corrected for meter measurement bias).**

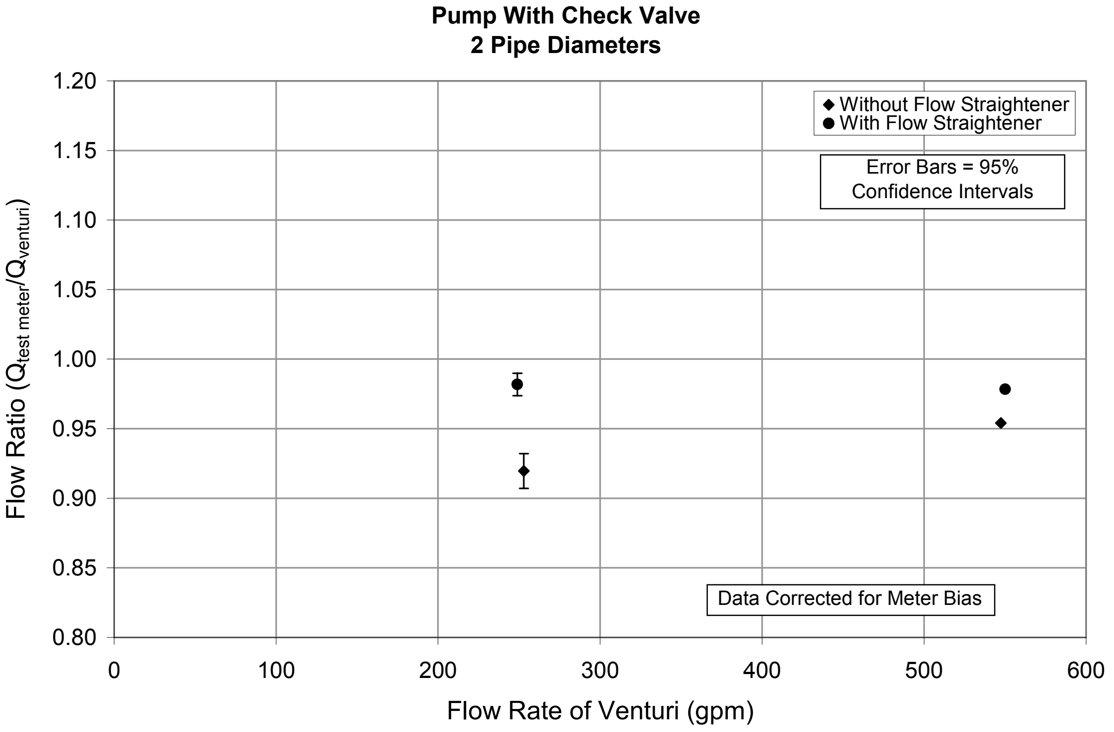

**Figure 12. Flow ratios in relation to flow rate for vertical turbine pump with check valve, 2 PD upstream straight pipe (data corrected for meter measurement bias).**

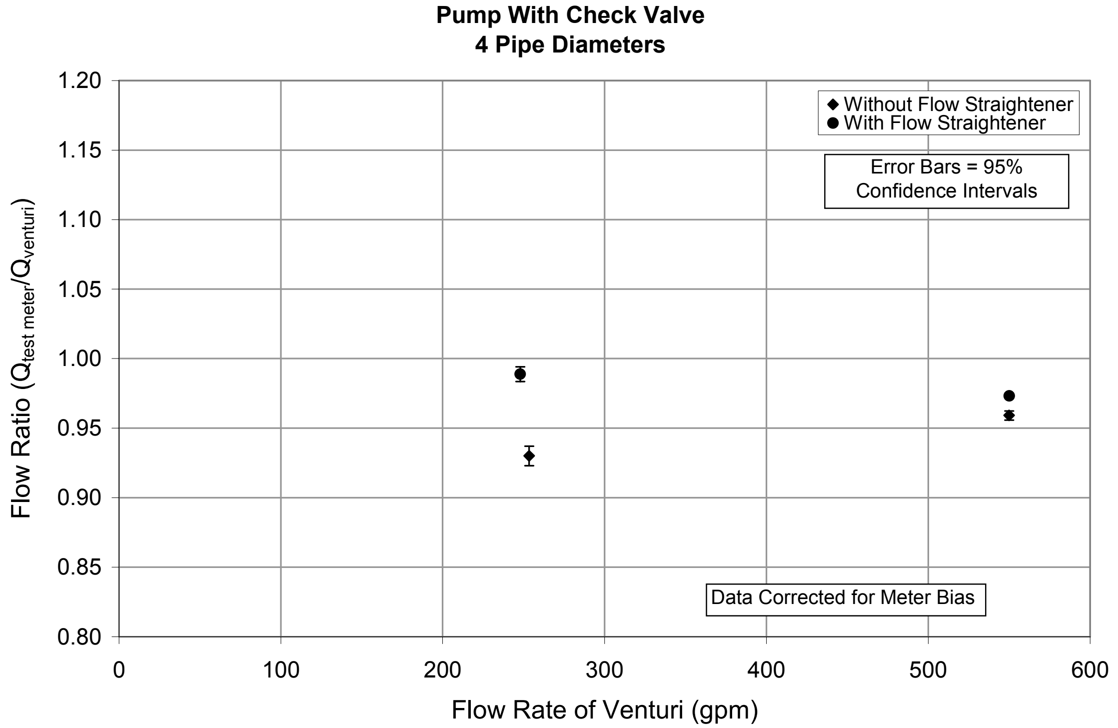

**Figure 13. Flow ratios in relation to flow rate for vertical turbine pump with check valve, 4 PD upstream straight pipe (data corrected for meter measurement bias).**

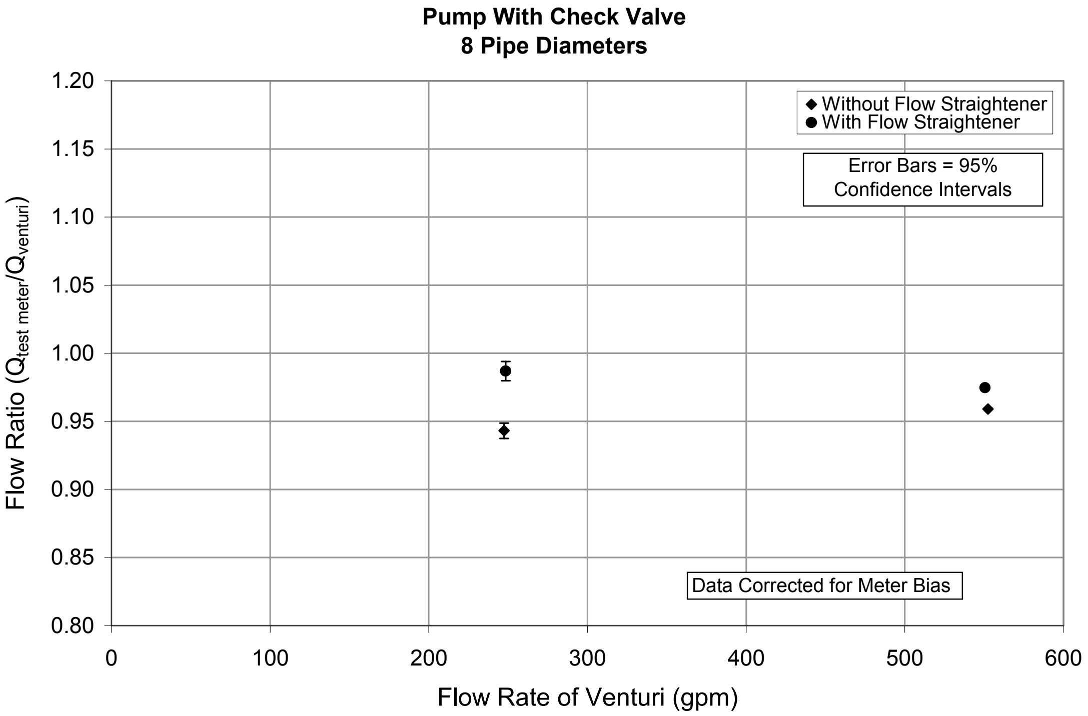

**Figure 14. Flow ratios in relation to flow rate for vertical turbine pump with check valve, 8 PD upstream straight pipe (data corrected for meter measurement bias).**

## Conclusions

The objective of this project was to determine the impact of the McCrometer SpaceSaver Flow Straightener (FS) on the metering accuracy of propeller meters in the presence of flow disturbances. The flow disturbances considered were two elbows out of plane, vertical turbine pumps, and vertical turbine pumps equipped with a spring-loaded swing check valve.

In total, 34 tests, replicated three times, were conducted in the Hydraulics Laboratory of Biological Systems Engineering, University of Nebraska, Lincoln. All data were collected in 6-inch PVC pipelines. A venturi system was used as the laboratory standard for comparison. Measurement uncertainty was corrected for meter measurement bias. While the flow disturbances caused average uncertainties as high as 10.8 percent low, the FS conditioned the flow so that mean measured flow was within 2.2 percent of actual flow in all cases.