USING FLOW CONDITIONERS TO IMPROVE FLOW METER PERFORMANCE AND REDUCE PIPING COSTS

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ABSTRACT

The process controls industry is required to measure flow more accurately to meet plant operation and cost accounting objectives. Recent studies have shown that the accuracy of many flow meter technologies are adversely affected by flow disturbances of up to forty diameters upstream of the flow meter mounting location. In addition, many flow meter installations are not designed with the flow meter manufacturer's recommended straight run of piping, because plant sizes are being reduced to save costs. This results in poor flow meter performance and unacceptable errors in flow meter accuracy. The opposing concerns of reducing plant size and improving flow meter accuracy is resolved by using flow conditioners to improve flow meter performance in non ideal piping installations. This improvement can be demonstrated through the use of flow visualization (a technique that visually demonstrates flow conditioner performance) and empirical testing of various flow meter technologies with flow conditioners.

INTRODUCTION

Accurate flow measurement is vital to the safe, efficient operation of the modern process plant. Virtually all flow meter technologies, including differential pressure, turbine, thermal, vortex shedding, ultrasonic, magnetic, and coriolis are adversely affected by flow disturbances created by non ideal piping configurations upstream of the flow meter mounting location. The typical effect of poor piping is an increase in flow meter error, often outside of the specified performance limits of the flow meter manufacturer. These errors often go undetected, as it is very difficult to make a comparative measurement of the actual flow and the flow meter's indicated flow in the field. This creates a challenge for the operator to determine the "real" flow in his plant.

This paper explores solutions to flow meter error in process plant installations through the use of "tab type" flow conditioners to isolate upstream flow disturbances from the flow meter installation location.

"Tab type" flow conditioners utilize antiswirl tabs along with vortex tabs that are attached to the inside diameter of the flow conditioner body to remove fluid rotation and irregular flow profiles from the flow stream. The result is a flat non swirling profile at the flow meter measurement location. This creates a repeatable, ideal condition to measure flow accurately regardless of upstream flow disturbances. The improvement in flow meter performance is accomplished economically, with a minimum of pressure drop, in the very harsh and dirty environment encountered in the typical plant.

These performance improvements are demonstrated in two ways. First, the physical improvement in the flow path is illustrated through the use of a series of techniques known as Flow Visualization. These techniques, described in the experimental section below, show the improvement from an agitated, swirling, irregular profile without the flow conditioner to a uniform, non swirling, flat profile with the flow conditioner. Second, the accuracy improvement with the use of the "tab type" flow conditioner for two flow technologies, vortex shedding and thermal mass flow, were quantitatively determined by a series of calibration runs with and without the flow conditioner. The results of these tests are presented in this paper.

EXPERIMENTAL

Flow Visualization

Experiments were conducted to demonstrate the improvement of the flow profile and elimination of swirl downstream of two types of flow disturbances through the use of a "tab type" flow conditioner. The first disturbance was created by flowing water through a 2 centimeter diameter pipe into a 4 centimeter diameter clear acrylic pipe. This piping arrangement will be described as "a divergence" in this paper. The second disturbance was created by setting up a "double elbow out of plane" piping configuration in which a 4 centimeter diameter pipe joins a piping elbow and then travels two diameters to another elbow that is adjusted so that it exits in a different plane from the first elbow. The double elbow out of plane arrangement connects to a 4 centimeter diameter clear acrylic pipe. The flow pattern in the pipe is illuminated and recorded on a videocassette recorder. The illumination of the flow profile is accomplished with three different techniques.

The first technique is accomplished by mixing small particles with the water flow stream and flowing the water/particle mixture at different velocities through the divergence flow disturbance. The particles are illuminated by using a laser sheet light that passes through the clear acrylic pipe at the location where a flow meter would ordinarily be mounted. A videocassette recorder is used to film the movement of the illuminated particles with and without a "tab type" flow conditioner.

The second technique utilizes a wire that passes horizontally through the vertical clear acrylic pipe that is connected to the noted double elbow out of plane disturbance. The wire is charged with a very short duration pulse of 150 Volts DC that results in the release of a small stream of hydrogen bubbles the length of the wire. These bubbles follow the swirl and velocity profile of the flow stream. They are illuminated with a conventional light and filmed with a videocassette recorder. The differences with and without the "tab type" flow conditioner are recorded.

The final flow visualization technique utilizes two dye streams, one red and one green, that are released from opposite sides of the clear acrylic pipe downstream of the flow disturbance. The dyes follow the swirl pattern in the flow stream, clearly demonstrating the improvement that occurs with the use of the flow conditioner.

Vortex Shedding Flow Meter Performance With and Without "Tab Type" Flow Conditioning

Three different manufacturers' Vortex Shedding Flow Meters were evaluated for the adverse effects of double elbow out of plane flow disturbances with and without a "tab type" flow conditioner. The Vortex Shedding Flow Meters were connected to a water flow stand that utilized a turbine flow meter as the calibration standard mounted in the turbine meter manufacturer's recommended pipe run. Data was collected on the Vortex Shedding Flow Meter's performance when mounted downstream of a double elbow out of plane disturbance. The piping layout is described in Figure 2. The data was compiled for all three manufacturer's flow meters and typical results were graphed to compare the performance with and without the benefit of a "tab type" flow conditioner positioned between the flow disturbance and the flow meter.

Thermal Mass Flow Meter Performance With and Without "Tab Type" Flow Conditioning

One manufacturer's Thermal Mass Flow Meter was evaluated for the adverse effects of a double elbow out of plane flow disturbances with and without a "tab type" flow conditioner. The Thermal Mass Flow Meter was connected to an air flow stand that utilized a turbine flow meter as the calibration standard mounted in the turbine meter manufacturer's recommended pipe run. Data was collected on the Mass Flow Meter's performance when mounted downstream of a double elbow out of plane disturbance. The piping layout is described in Figure 4. The data was then graphed to compare the performance with and without the benefit of a "tab type" flow conditioner positioned between the flow disturbance and the flow meter.

RESULTS AND DISCUSSION

Flow Visualization

The improvement of the flow stream condition with the use of the "tab type" flow conditioner is clearly seen on the videocassette recording of the flow visualization techniques that are described in the experimental section. A written description of the improvements are outlined below:

Technique 1. Laser sheet illumination of particle/water mixture

The flow stream downstream of the divergence without the flow conditioner shows a highly agitated condition of the illuminated particles. The particles travel from side to side in the pipe. This is characteristic of a highly turbulent condition associated with the flow disturbance, and it indicates that the location in the pipe downstream of the divergence is not a good location for flow meter placement.

The flow stream downstream of the divergence with the flow conditioner shows a much more orderly pattern of the illuminated particles. In this instance, the side to side movement of the particles are greatly diminished, and a regular pattern of vortices that are generated by the vortex tabs of the "tab type" conditioner is apparent. The improvement is dramatic, and the orderly progression of the particles in the flow reveals a good location to mount a flow meter.

Technique 2. Hydrogen gas bubble illumination

Two views were employed to illustrate the differences in swirl and flow profile pattern with and without the "tab type" flow conditioner downstream of the double elbow out of plane flow disturbance in this experiment.

The first view without the flow conditioner shows the length of the wire mounted horizontally across the vertical flow plane. As the bubbles leave the wire, the velocity is highest on the side of the pipe that is opposite the entrance to the elbow. In addition, rotation of the flow stream is apparent, as the bubbles begin twisting downstream of the wire. This swirl is very apparent in the second view where the videocassette camera is mounted for a side view position looking down the length of the wire. In this case, the flow begins rotating immediately downstream of the wire creating a spread of bubbles across the diameter of the pipe.

The performance with the "tab type" flow conditioner between the flow disturbance and the camera position is very different. In the first view, the bubbles leave the wire uniformly and move downstream in unison. The flat flow profile is very obvious. There is no evidence of rotation of the flow stream in this view. This is confirmed when the second view is observed as the bubbles stay in line with the wire as they move downstream. This clearly shows that there is no swirl in the flow stream.

Technique 3. Colored dye injection

In this technique, the presence of swirl downstream of the flow disturbance without the flow conditioner is clearly seen in the videocassette recording. The red and green dyes rotate over one another in the flow stream. The visual display shows a corkscrew effect to the flow. This effect is completely eliminated with the use of the "tab type" conditioner. Instead, the dyes follow the flow directly downstream staying in line with the injection point. It is very evident that the flow conditioner stops the swirl that is introduced by the double elbow out of plane.

Vortex Shedding Flow Meter Performance With and Without "Tab Type" Flow Conditioning

The data that was collected for the three manufacturers' Vortex Shedding Flow Meters was compiled and representative results are shown on Figure 1. The graphs show that the Vortex Shedding Flow Meter has an error of 1 to 3 % as a result of an upstream double elbow out of plane flow disturbance. With the use of a "tab type" flow conditioner, the error is reduced below 0.5%. The performance with the flow conditioner is virtually identical to the performance of the Vortex Shedding Flow Meter in its ideal piping configuration without any upstream disturbance.

Thermal Mass Flow Meter Performance With and Without "Tab Type" Flow Conditioning

The data that was collected from the Thermal Mass Flow Meter was compiled and graphed on Figure 3. The graph shows that the Thermal Mass Flow Meter may experience errors of up to 15%, as a result of the swirl and skewed flow profile downstream from a double elbow out of plane. This occurs because the Thermal Mass Flow Meter is a point sensor that is positioned in the center of the pipe. It is often used in larger pipes where the difference in flow velocity profile from the side to the center of the pipe can be quite pronounced. The Thermal Mass Flow Meter is calibrated with the assumption that the flow velocity will be highest in the center of the pipe. When this is not the case, as occurs with upstream flow disturbances, the errors can be quite large.

The use of a "tab type" flow conditioner is very beneficial with the single point Thermal Mass Flow Meter. The graph demonstrates that the error from the flow disturbance is virtually eliminated when the flow conditioner is employed.

CONCLUSIONS

Flow disturbances adversely affect flow meter performance by creating swirl and irregular flow profiles. The resulting errors often exceed the flow meter manufacturers' published accuracy specifications. This can create serious issues in process plants that depend on the performance of their flow meters for safe and efficient operation. This problem is becoming more serious as systems become more automated and plant sizes are reduced to save floor space.

"Tab type" flow conditioners can greatly improve the performance of flow meters by eliminating swirl and creating an ideal flat flow profile for the measurement point. This can be demonstrated through techniques of flow visualization and actual performance testing in the calibration laboratory. Vortex Shedding Flow Meters and Thermal Mass Flow Meter performance are significantly improved in plant installations through the use of "tab type" flow conditioners.

These documented performance improvements enable plant operators to have higher confidence in their flow meter measurements, while permitting plant designers to reduce the straight run lengths of their flow meter installations. The use of "tab type" conditioners improve overall flow meter performance in shorter straight run installations.

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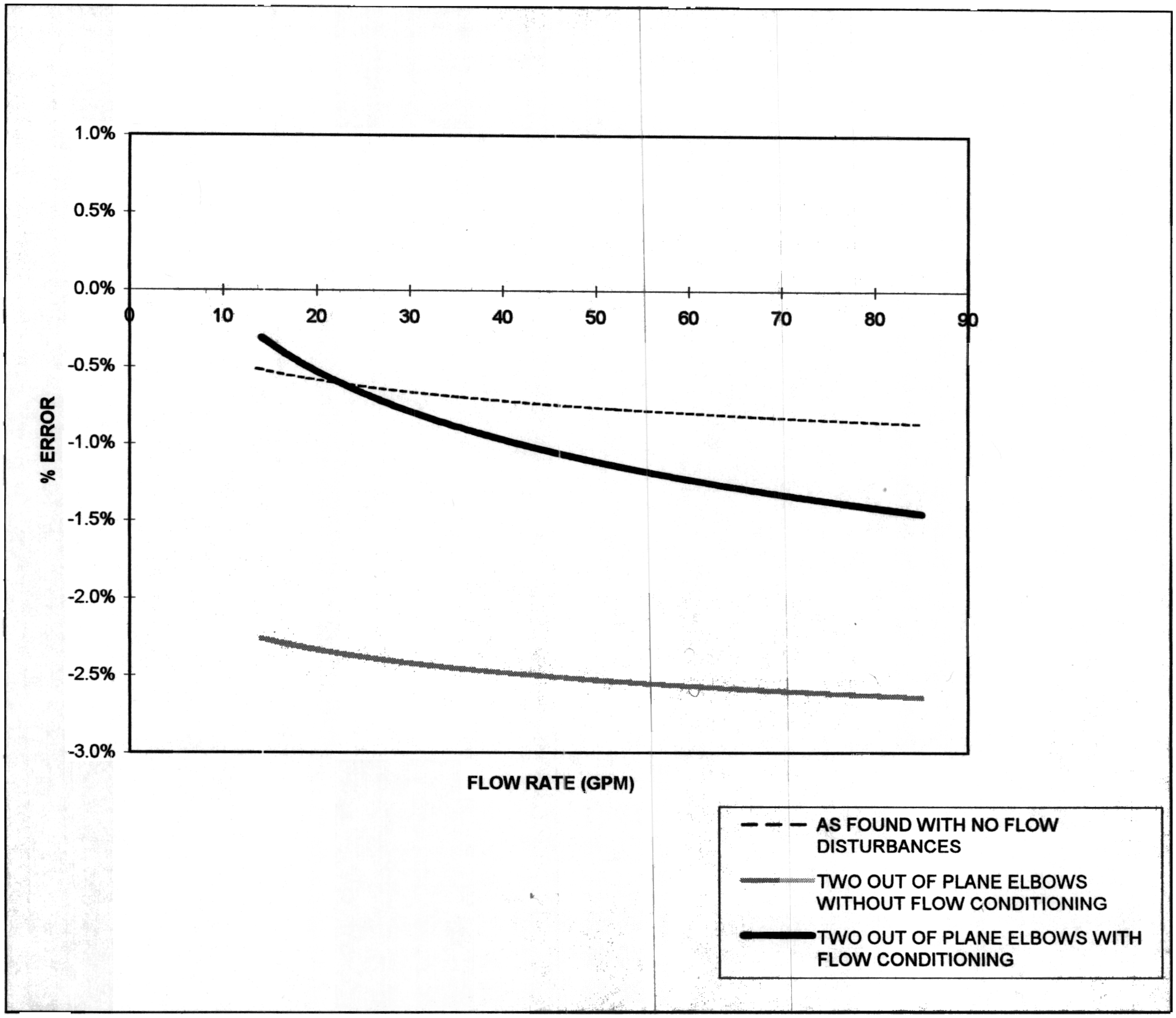

Fig. 1 Vortex Shedding Flow Meter technology utilizing tab type flow conditioning in a double out of plane elbow configuration (in water)

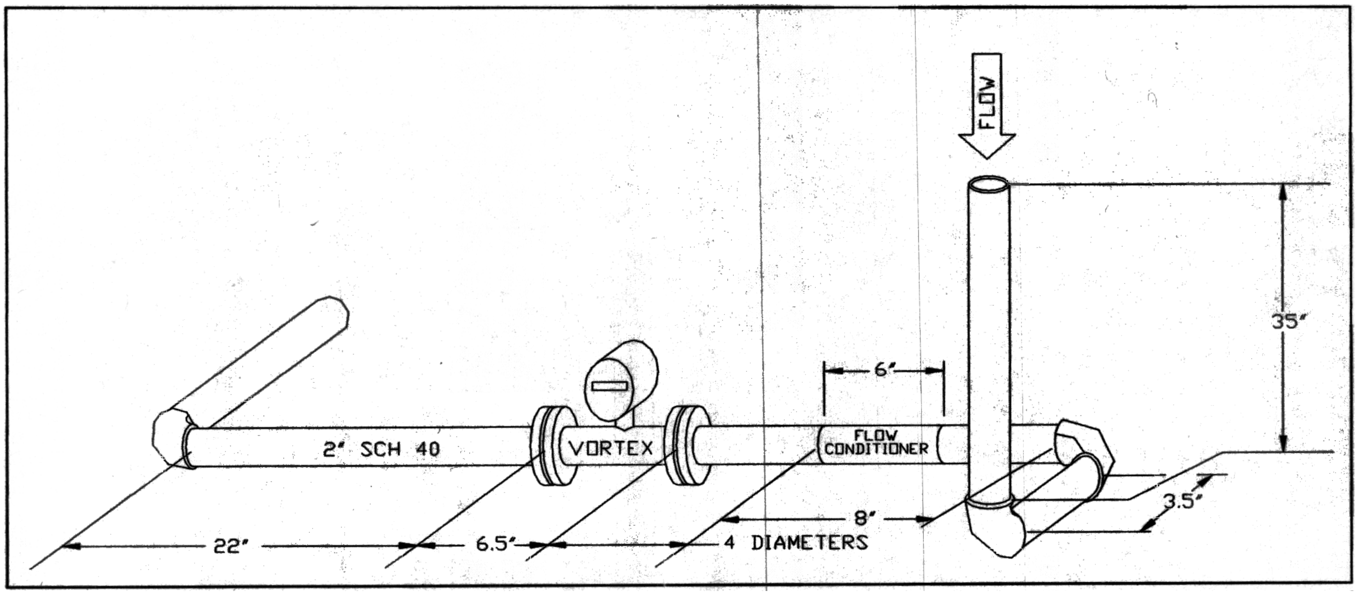

Fig. 2 Piping layout of Vortex Shedding Flow Meter utilizing tab type flow conditioner

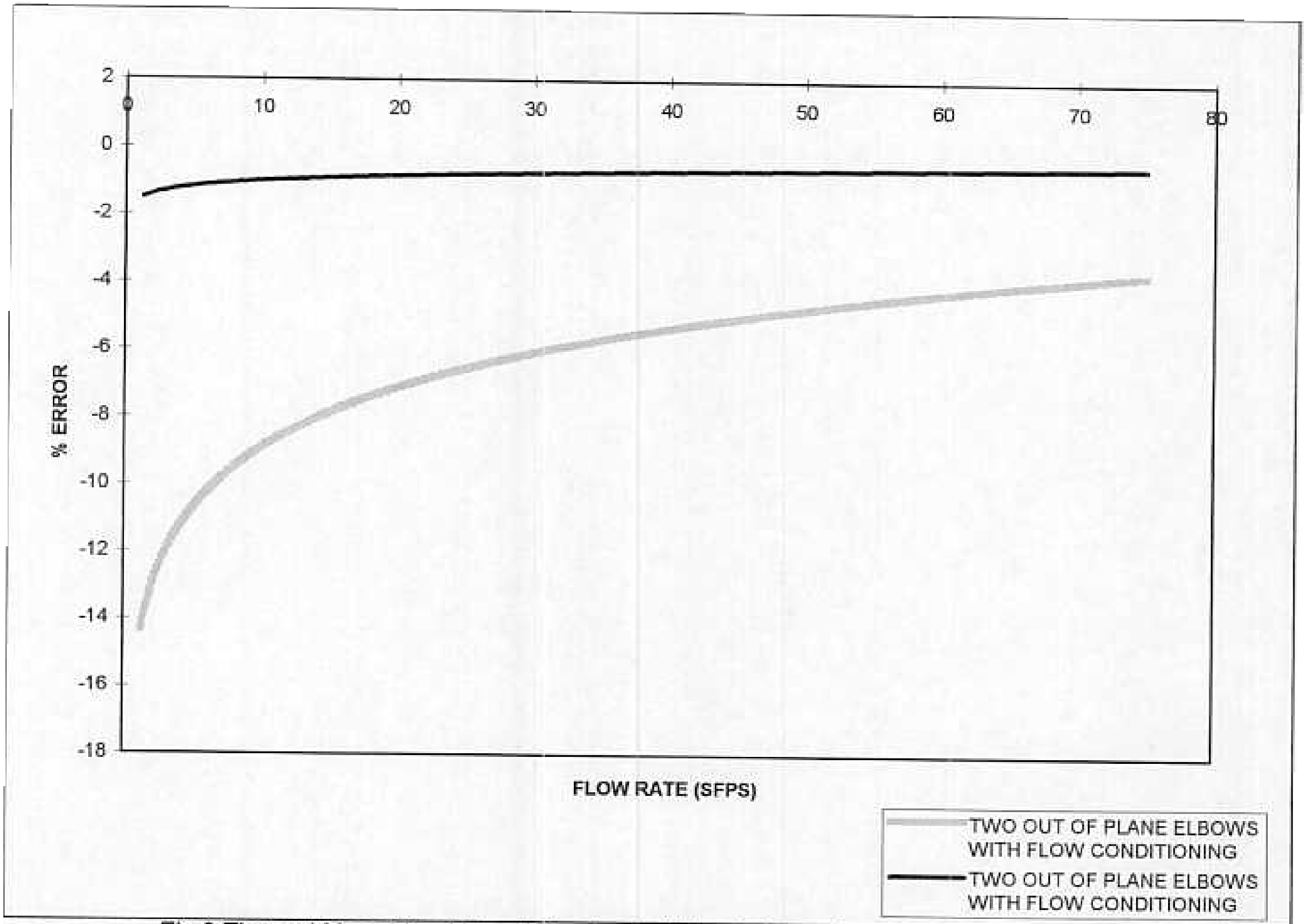

Fig.3 Thermal Mass Flow Meter technology utilizing tab type flow conditioning in a double out of plane elbow configuration (in air)

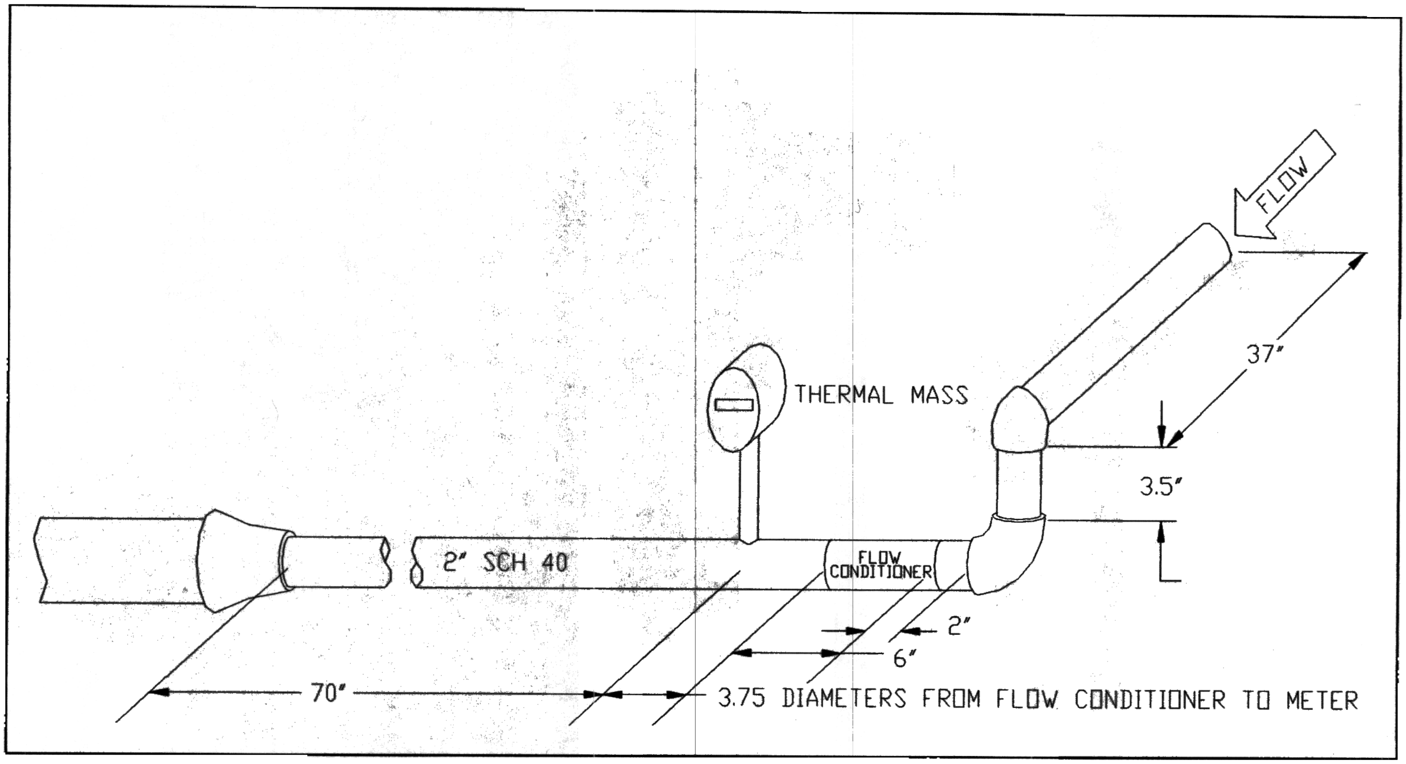

Fig. 4 Piping layout and of Thermal Mass Flow Meter utilizing tab type flow conditioner