USING VORTAB FLOW CONDITIONERS TO IMPROVE VORTEX SHEDDING FLOWMETER PERFORMANCE

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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 flowmeter technologies, including Vortex Shedding Flowmeters, are adversely affected by flow disturbances within forty diameters upstream of the flowmeter. In addition, many flowmeter installations are not designed with the flowmeter manufacturer's recommended straight run of piping, because plant sizes are being reduced to save costs. Upstream flow disturbances result in poor flowmeter performance and unacceptable errors in flowmeter accuracy.

The opposing objectives of reducing plant size and improving flowmeter accuracy is resolved by using VORTAB Flow Conditioners to improve flowmeter performance in non ideal piping installations. This improvement is demonstrated through the use of flow visualization, a method that illuminates the flow profile and swirl of flow disturbances, and by empirically testing a number of different manufacturer's Vortex Shedding Flowmeters with VORTAB Flow Conditioners.

The results of these tests unequivocally prove the benefit of the VORTAB Flow Conditioner with Vortex Shedding Flowmeters. It is clear from the test data that VORTAB Flow Conditioners isolate adverse flow disturbance effects and improve the overall repeatability of the Vortex Shedding Flowmeters in both ideal and non ideal piping configurations. All this is accomplished with less than a 25% increase in the pressure drop normally encountered in a Vortex Shedding Flowmeter installation.

INTRODUCTION

Accurate flow measurement is vital to the safe, efficient operation of the modern process plants. Virtually all flowmeter 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 flowmeter. The typical effect of poor piping is an increase in flowmeter error, often outside of the specified performance limits of the flowmeter manufacturer. These errors often go undetected, as it is very difficult to make a comparative measurement of the actual flow and the flowmeter'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 Vortex Shedding Flowmeter error by isolating upstream flow disturbances with the use of a VORTAB Flow Conditioner.

VORTAB Flow Conditioners utilize anti-swirl tabs and vortex tabs that are attached to the inside diameter of the flow conditioner body (Figure 1) to remove fluid rotation and irregular flow profiles from the flow stream. The result is a flat, non swirling velocity profile at the flowmeter measurement location (Figure 2). This creates a repeatable, ideal condition to measure flow accurately regardless of upstream flow disturbances. The improvement in flowmeter performance is accomplished economically, with a minimum of pressure drop, in the very harsh and dirty environment encountered in the typical industrial plant.

These flowmeter performance improvements are described in this paper in two ways. First, the physical improvement in the flow velocity profile has been demonstrated through the use of a series of experimental techniques known as Flow Visualization. These techniques, described in the experimental section below, show the improvement from an agitated, swirling, irregular profile without the VORTAB Flow Conditioner to a uniform, non swirling, flat profile with the VORTAB Flow Conditioner. Second, the accuracy improvement in both water and air with the use of the VORTAB Flow Conditioner for Vortex Shedding Flowmeters was quantitatively determined by a series of calibration runs with different types of flow disturbances introduced into the flow stream. 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 VORTAB Flow Conditioner. The first disturbance was created by a divergence in which a two (2) centimeter diameter pipe expands to a four (4) centimeter diameter clear acrylic pipe. The second disturbance was created by setting up a "double out of plane elbow" piping configuration in which

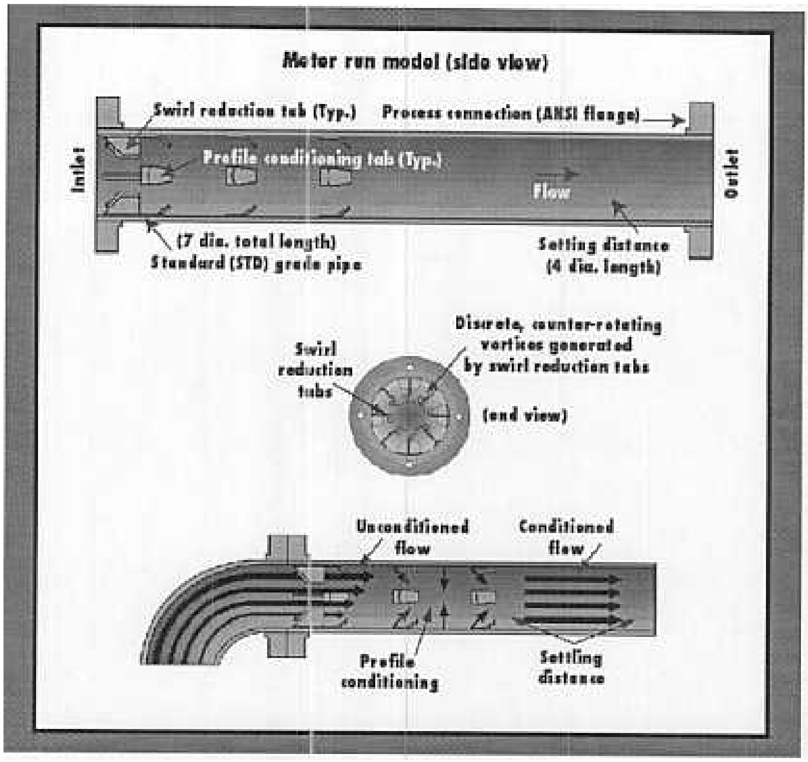

Figure 1
VORTAB Flow Conditioner Functional Description

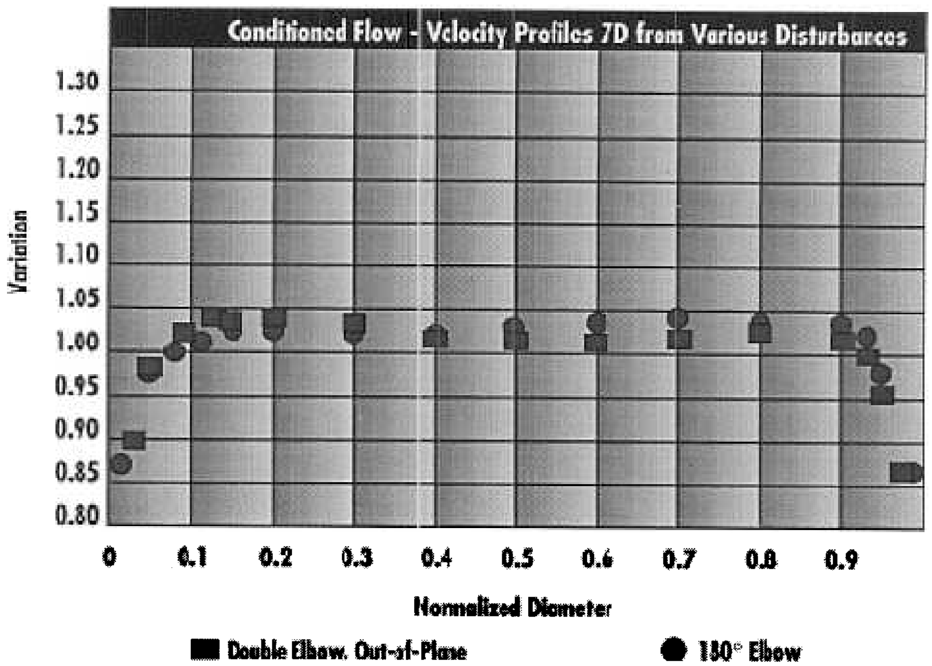

Figure 2
VORTAB Flow Conditioner Velocity Profile at flowmeter mounting location

a 4 centimeter diameter pipe joined a piping elbow and then traveled two diameters to another elbow that is adjusted so that it exits in a different plane from the first elbow. This double out of plane elbow arrangement is then connected to a four centimeter diameter clear acrylic pipe. The flow pattern in the pipe is illuminated and recorded on a videocassette recorder. Various "still" frames from the videocassette are included to demonstrate the flow conditions downstream of the disturbance. 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 flowmeter would ordinarily be mounted. A videocassette recorder is used to film the movement of the illuminated particles with and without a VORTAB Flow Conditioner.

The second technique utilizes a wire that passes horizontally through the vertical clear acrylic pipe that is connected to the noted double out of plane elbow piping configuration. 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 VORTAB Flow Conditioner are recorded.

The final flow visualization technique utilize a red and green dye stream that are released from opposite sides of the clear acrylic pipe downstream of a double out of plane elbow piping configuration. The dyes follow the swirl pattern in the flow stream, clearly demonstrating the improvement that occurs with the use of the VORTAB Flow Conditioner.

Vortex Shedding Flowmeter Performance With and Without VORTAB Flow Conditioning

Three different manufacturers' Vortex Shedding Flow Meters were evaluated with and without a VORTAB Flow Conditioner for the adverse effects of several different piping configurations that produce flow disturbances. The Vortex Shedding Flow Meters were connected to both a water and an air flow stand that utilized turbine flow meters as the calibration standard. The turbine meter calibration standard was mounted in accordance with the turbine flowmeter manufacturer's recommendations. Data was collected on the performance of the Vortex Shedding Flowmeter with various upstream disturbances. The data was compiled for all three manufacturer's flow meters and typical results were graphed to compare the performance with and without the use of a VORTAB Flow Conditioner positioned between the flow disturbance and the flowmeter.

Additional testing was performed to evaluate repeatability characteristics and measure the pressure drop through the typical Vortex Shedding Flowmeter with and without a VORTAB Flow Conditioner. The results of these tests are reported below.

RESULTS AND DISCUSSION

Flow Visualization

The improvement of the flow stream condition with the use of the VORTAB Flow Conditioner is clearly seen on the videocassette recording of the flow visualization techniques that are described in the experimental section. Copies of the complete videocassette are available upon written request from the VORTAB Company. A written description and accompanying "still" videocassette frame of the improvements are submitted 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 (Figure 3). The particles travel from side to side in the pipe. This is characteristic of a highly turbulent condition associated with the flow disturbance and indicates the position in the pipe downstream of the divergence is not a good location for flowmeter placement.

The flow stream downstream of the divergence with the VORTAB Flow Conditioner shows a much more orderly pattern of the illuminated particles (Figure 4). In this instance, the side to side movement of the particles is greatly diminished, and a regular pattern of vortices that

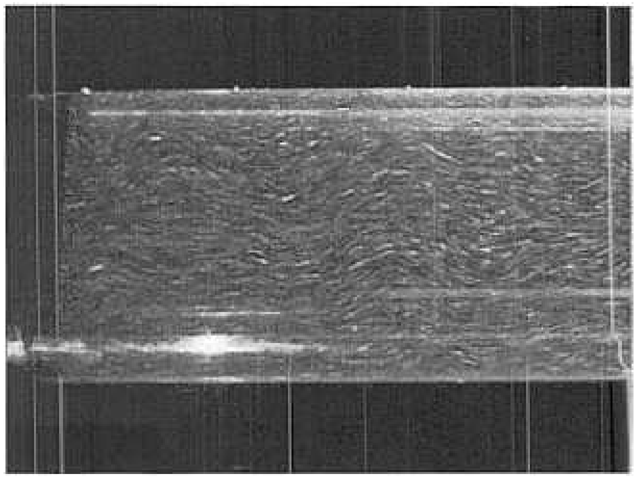

Figure 3
Laser sheet illumination of water/particle mixture reveals significant side to side turbulence of particles downstream of unconditioned flow disturbance

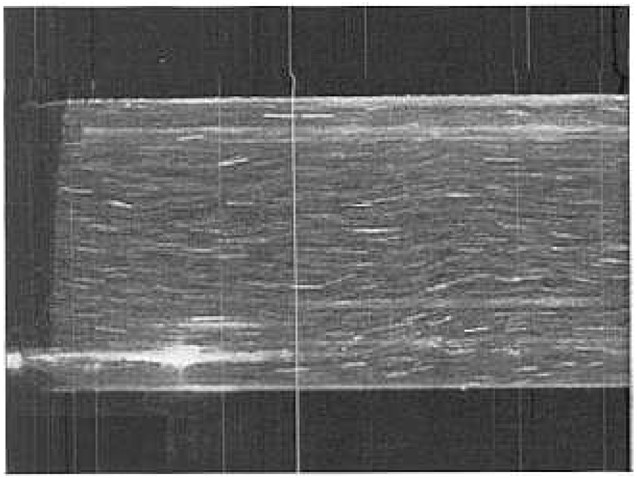

Figure 4
Laser sheet illumination of water/particle mixture reveals parallel flow path of particles downstream of flow disturbance with a VORTAB Flow Conditioner isolating the disturbance

are generated by the vortex tabs of the VORTAB Flow Conditioner are apparent. The improvement is dramatic, and the orderly progression of the particles in the flow reveals a significant improvement of the disturbance - making it an ideal location for a Vortex Shedding Flowmeter.

Technique 2. Hydrogen gas bubble illumination

Two views were employed to illustrate the differences in swirl and flow profile pattern with and without the VORTAB Flow Conditioner downstream of a double out of plane elbow piping configuration.

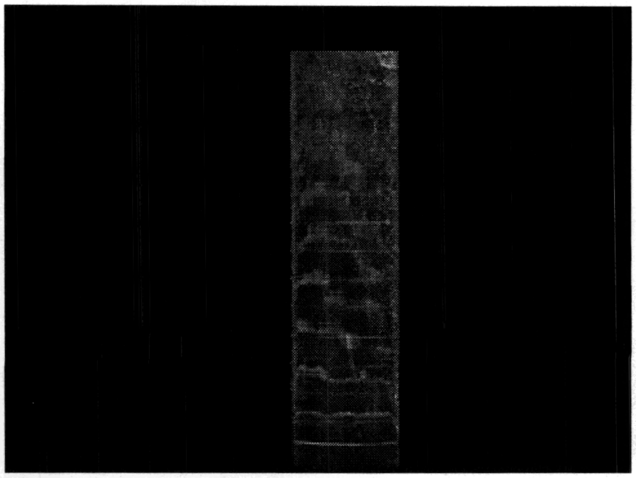

Figure 5
Front view of hydrogen gas bubble illumination reveals irregular flow profile and swirl downstream of a double out of plane elbow flow disturbance

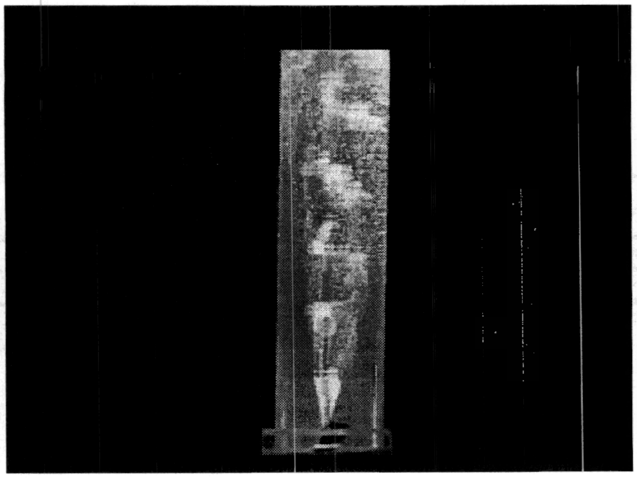

Figure 6
Side view of hydrogen gas bubble illumination reveals irregular flow profile and swirl downstream of a double out of plane elbow flow disturbance

In the first view, the flow disturbance is filmed without the installation of a VORTAB Flow Conditioner. A length of wire is mounted horizontally across a vertical flow plane (Figure 5), and the wire is pulsed with a 150 VDC electrical charge. This creates a line of hydrogen bubbles that follow the flow profile downstream. 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. The swirling motion of the flow steam is confirmed in the second view where the videocassette camera is mounted for a side view position looking down the length of the wire (Figure 6). In this case, the flow begins rotating immediately downstream of the

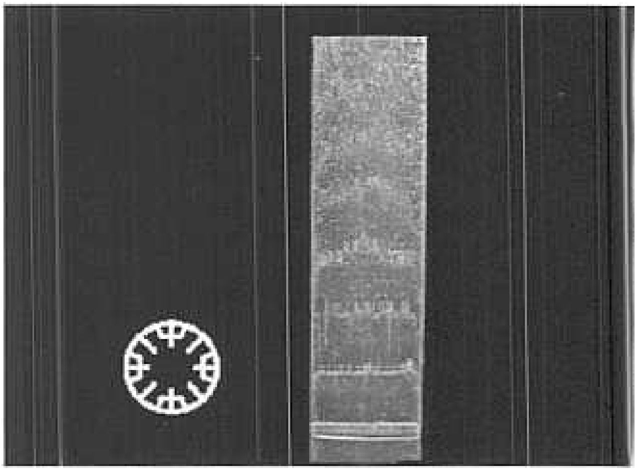

Figure 7
Front view of hydrogen gas bubble illumination reveals a homogeneous, flat profile downstream of a double out of plane elbow flow disturbance with a VORTAB Flow Conditioner isolating the disturbance

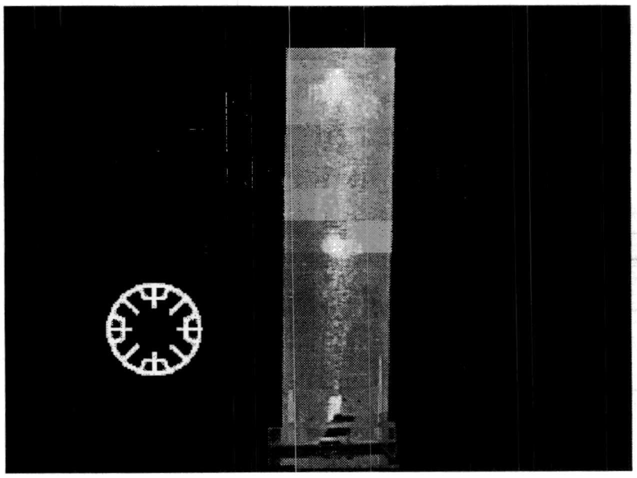

Figure 8
Side view of hydrogen gas bubble illumination reveals a non-swirling, stable profile downstream of a double out of plane elbow flow disturbance with a VORTAB Flow Conditioner isolating the disturbance

wire creating a spread of bubbles across the diameter of the pipe.

When the VORTAB Flow Conditioner is located between the flow disturbance and the camera position, the camera records a very different flow profile. With the wire mounted horizontally across a vertical plane, the bubbles leave the wire uniformly and move downstream in unison (figure 7). 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 (Figure 8) 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.

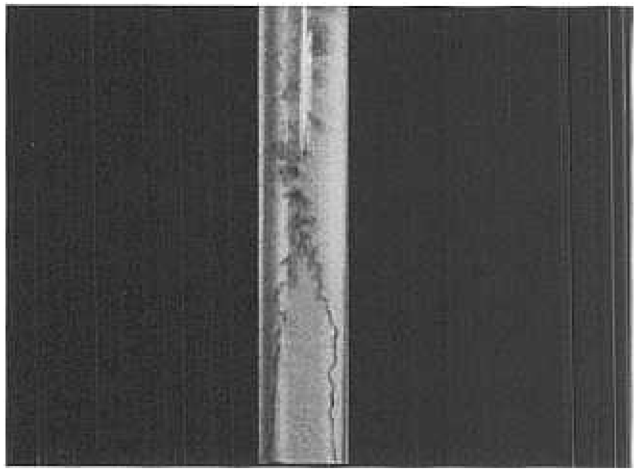

Figure 9
Colored dye injection into flow stream reveals swirl downstream of a double out of plane elbow flow disturbance

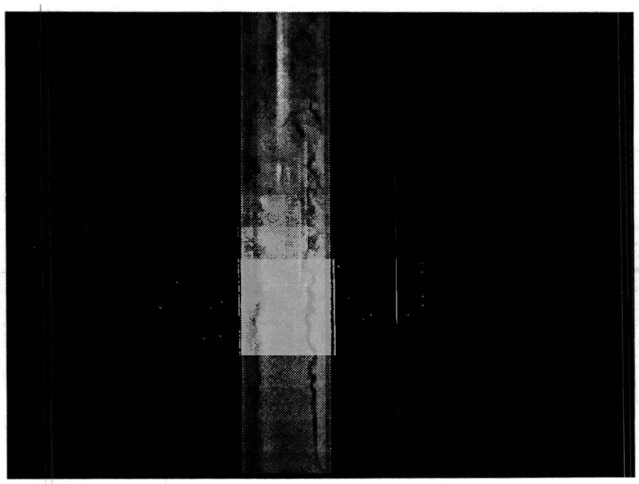

Figure 10
Colored dye injection into flow stream reveals the dye streams following the flow without swirl thus isolating the double out of plane elbow disturbance with a VORTAB Flow Conditioner

Technique 3. Colored dye injection

The presence of swirl downstream of a double out of plane elbow piping configuration without the VORTAB Flow Conditioner is clearly seen in the video cassette recording (Figure 9). The red and green dyes rotate over one another in the flow stream clearly indicating swirl. This effect is completely eliminated with the use of the VORTAB Flow Conditioner (Figure 10). Instead, the dyes follow the flow directly downstream staying in line with the injection point. It is evident that the flow conditioner stops the swirl that is introduced by the double out of plane elbow piping configuration.

Vortex Shedding Flowmeter Performance With and Without VORTAB Flow Conditioning

The data that was collected for the three manufacturers' Vortex Shedding Flow Meters was compiled and representative results are shown on Figures 11 - 20. The graphs show that the Vortex Shedding Flowmeter has errors of up to 2.5% of reading as a result of upstream flow disturbances. Various upstream piping configurations were used to introduce flow disturbances into both water and air flow streams. These piping configurations included a single elbow, a double out of plane elbow, and a reducing arrangement in which a four inch pipe is reduced down to a two inch pipe upstream from the VORTEX Shedding Flowmeter and the VORTAB Flow Conditioner. With the use of a VORTAB Flow Conditioner, the Vortex Shedding Flowmeter's error is reduced to below 0.5% of reading. In addition, the repeatability of the Vortex Shedding Flowmeter increased by an average of 29% in water (Figure 21) and 27% in Air (Figure 22) with a VORTAB installed. The repeatability graphs examine each data point and represent an average of all the test runs detailed in figures 11 - 20. The data presented shows conclusively that it is not necessary to pair the VORTAB Flow Conditioner with a VORTEX Shedding Flowmeter during calibration in water. In air, pairing of the VORTAB Flow Conditioner and the VORTEX Shedding Flowmeter is recommended during calibration to provide the best accuracy.

Vortex Shedding Flowmeter Pressure Drops With and Without VORTAB Flow Conditioning

Data was collected on pressure drop measurements through the Vortex Shedding Flowmeter and the VORTAB Flow Conditioner and was compiled with representative results shown in Figure 23. The pressure drop of a VORTAB Flow Conditioner adds less than 25% additional pressure drop over the pressure drop created by the Vortex Shedding Flowmeter without the VORTAB Flow Conditioner installed.

CONCLUSIONS

Flow disturbances adversely affect flowmeter performance by creating swirl and irregular flow profiles. The resulting errors often exceed the flowmeter 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.

VORTAB Flow Conditioners can greatly improve the performance of Vortex Shedding Flow Meters by eliminating swirl and creating an ideal flat flow profile at the measurement point. This can be demonstrated through techniques of flow visualization and empirical testing in the calibration laboratory. This performance improvement is accomplished with minimal pressure drop through the VORTAB Flow Conditioner.

These documented performance improvements enable plant operators to have higher confidence in their flowmeter measurements, while permitting plant designers to reduce the straight run lengths of their flowmeter installations. The use of VORTAB Flow Conditioners improve overall flowmeter performance in shorter straight run installations.

ACKNOWLEDGEMENT

The authors thank Steve Harrington, Ph. D., Flowmetrics, for his assistance in completing the flow visualization work presented in this paper. In addition, the authors thank Mike Barnwell, Yokogawa Industrial Automation; Jim Pomroy, Rosemount; and Dennis Ciricarelli, Bailey Fisher Porter, for providing Vortex Shedding Flow Meters to test. Finally, special thanks are expressed to Dan McQueen, Fluid Components Intl, for providing access to the FCI flow facility to complete the calibration work.

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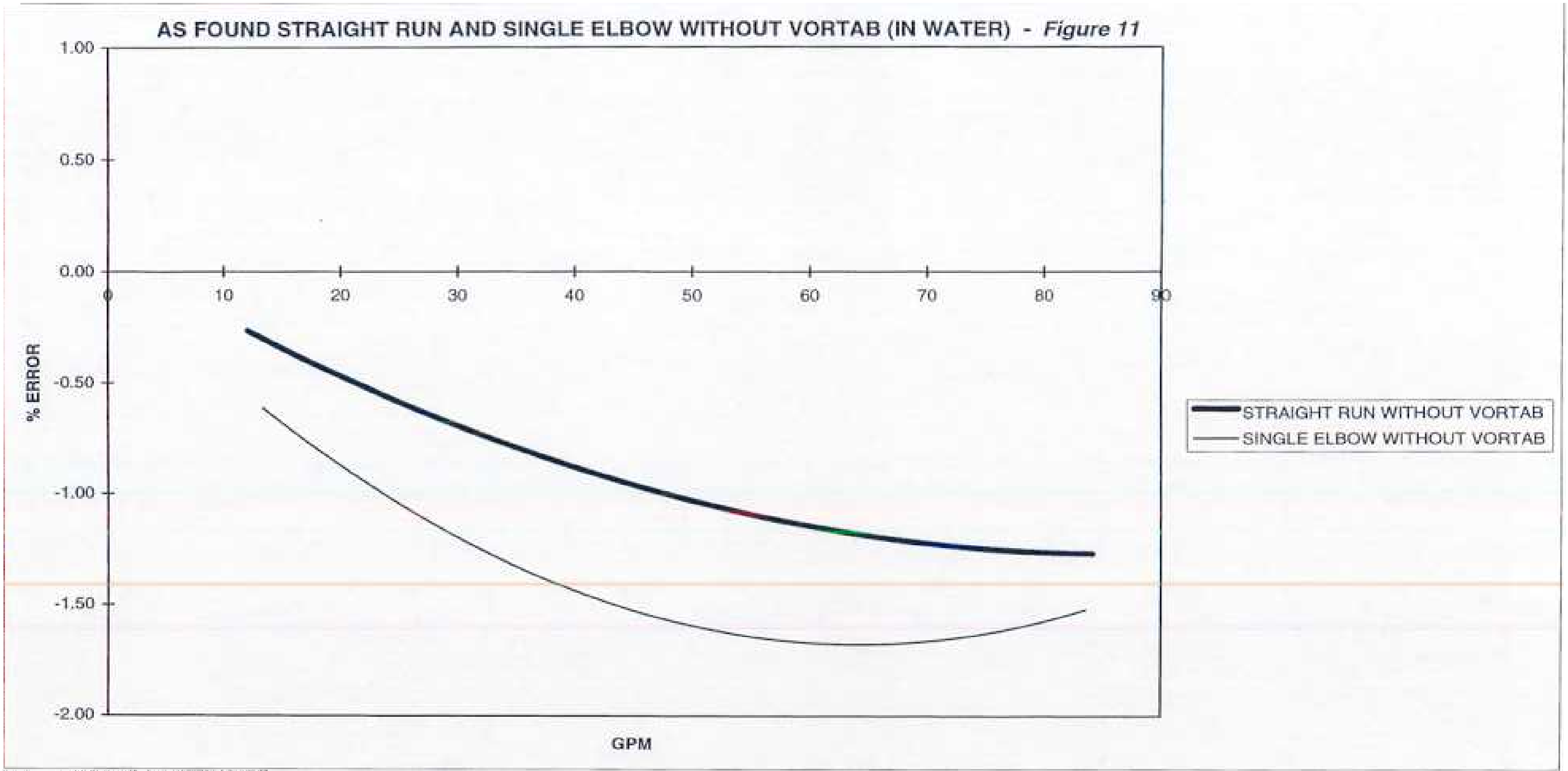
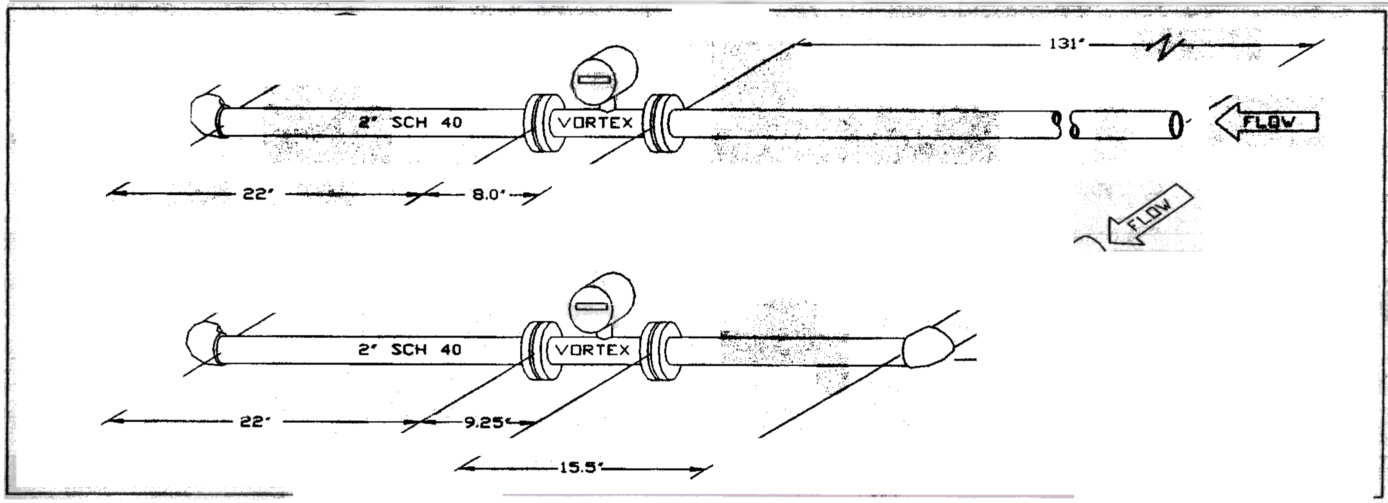
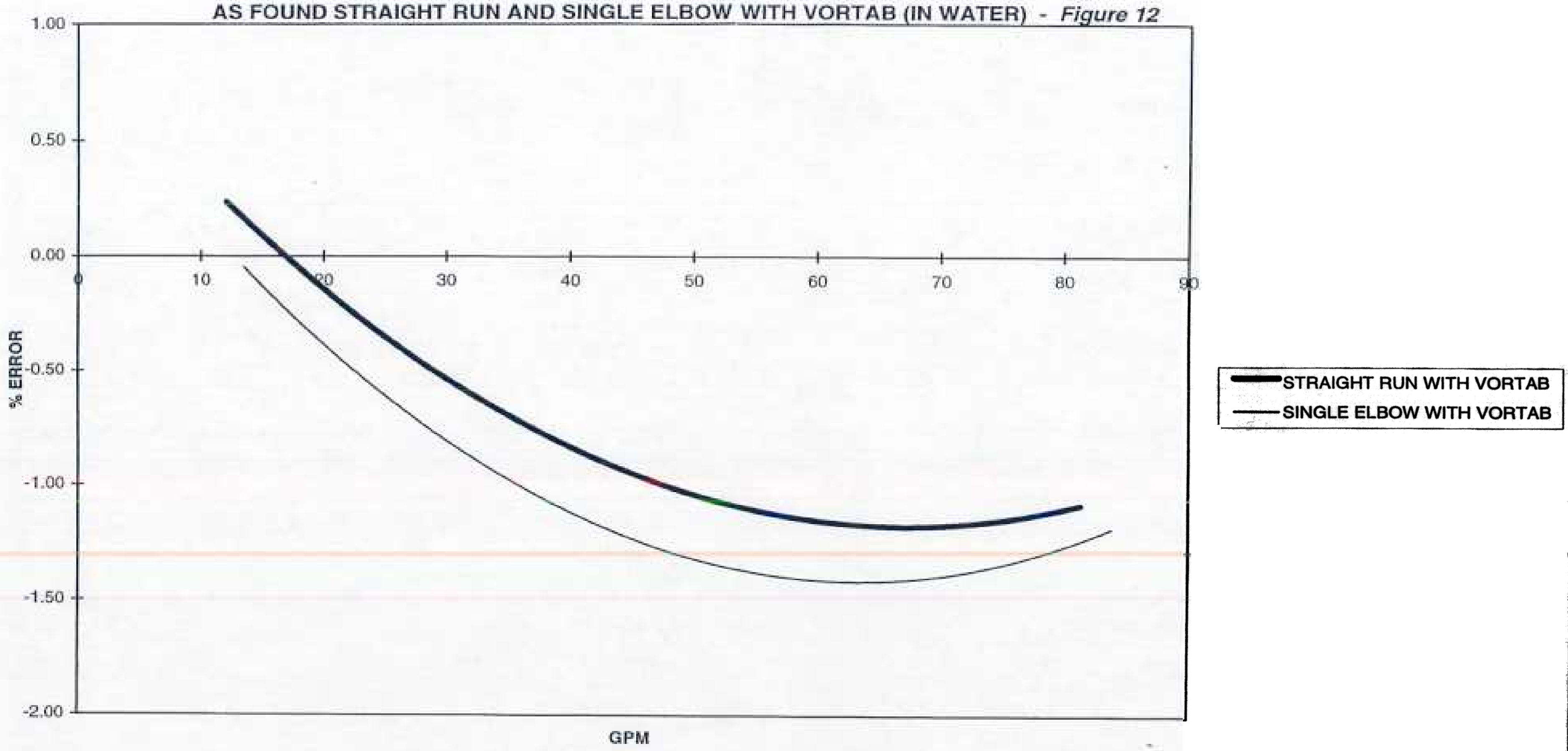
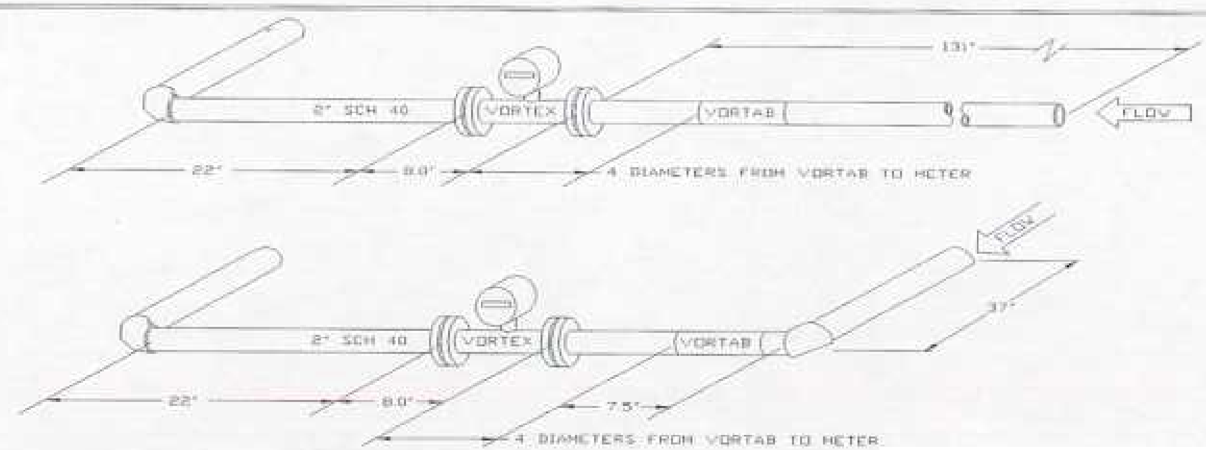

AS FOUND STRAIGHT RUN AND SINGLE ELBOW WITHOUT VORTAB (IN WATER) - *Figure 11*
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
% ERROR
0
10
20
30
40
50
60
70
80
90
GPM
STRAIGHT RUN WITHOUT VORTAB
SINGLE ELBOW WITHOUT VORTAB

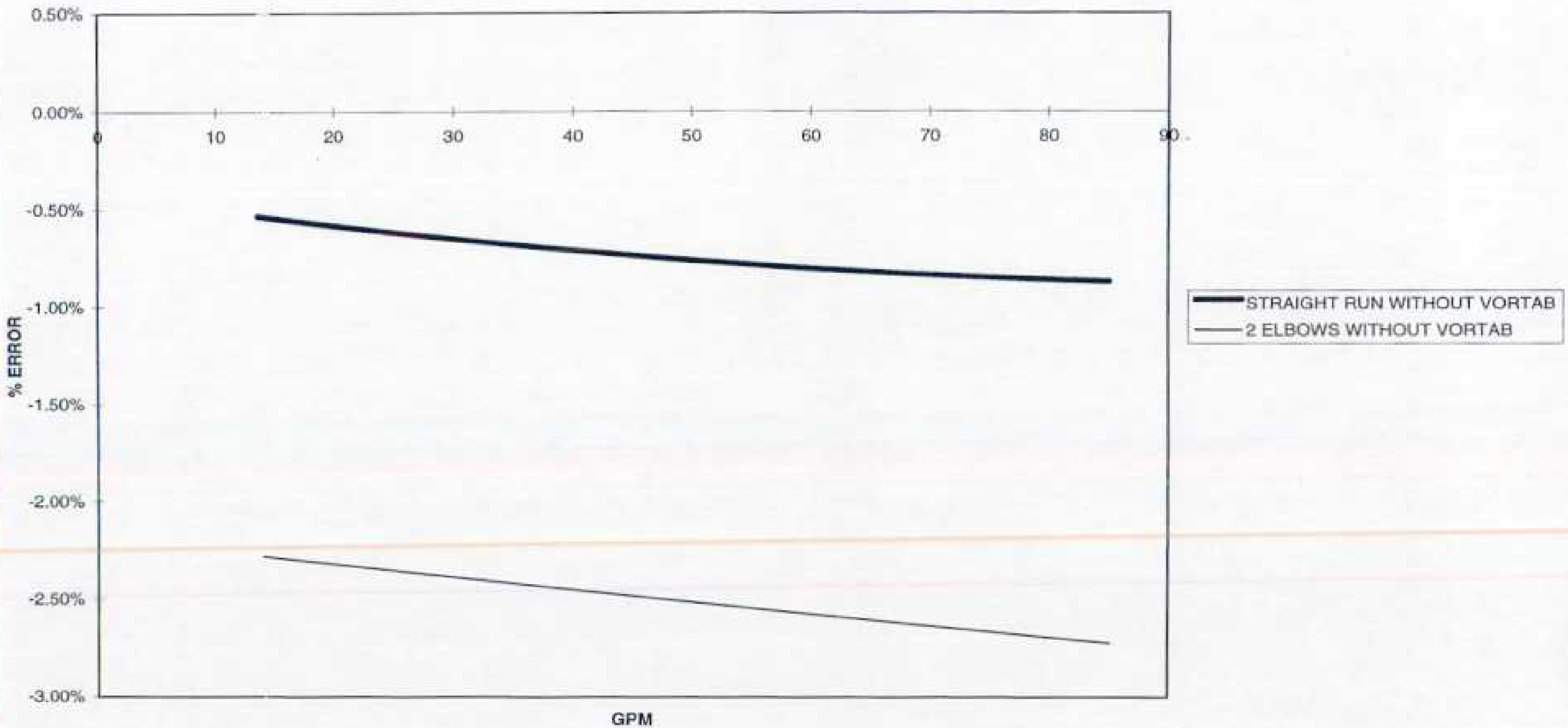

131'
2" SCH 40
VORTEX
FLOW
22'
8.0'
FLOW
2" SCH 40
VORTEX
22'
9.25'
15.5'

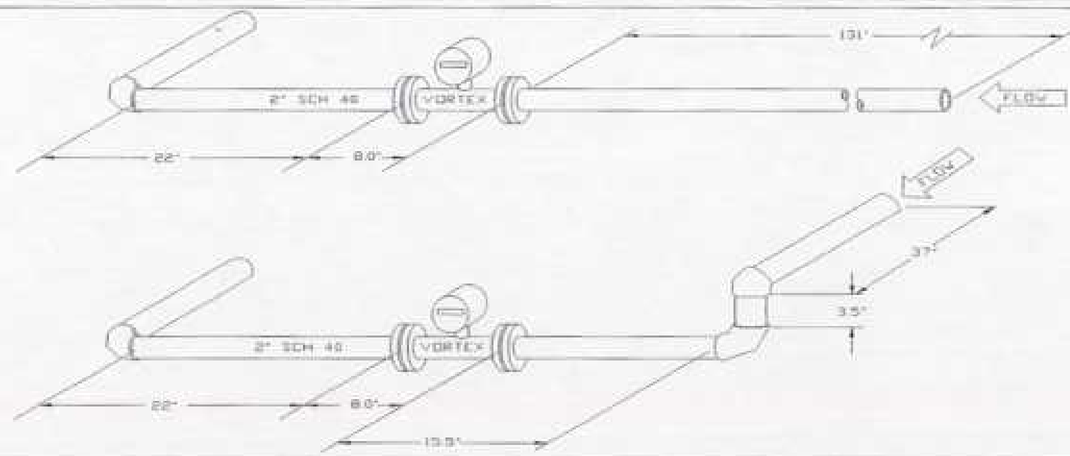
AS FOUND STRAIGHT RUN AND SINGLE ELBOW WITH VORTAB (IN WATER) - *Figure 12*



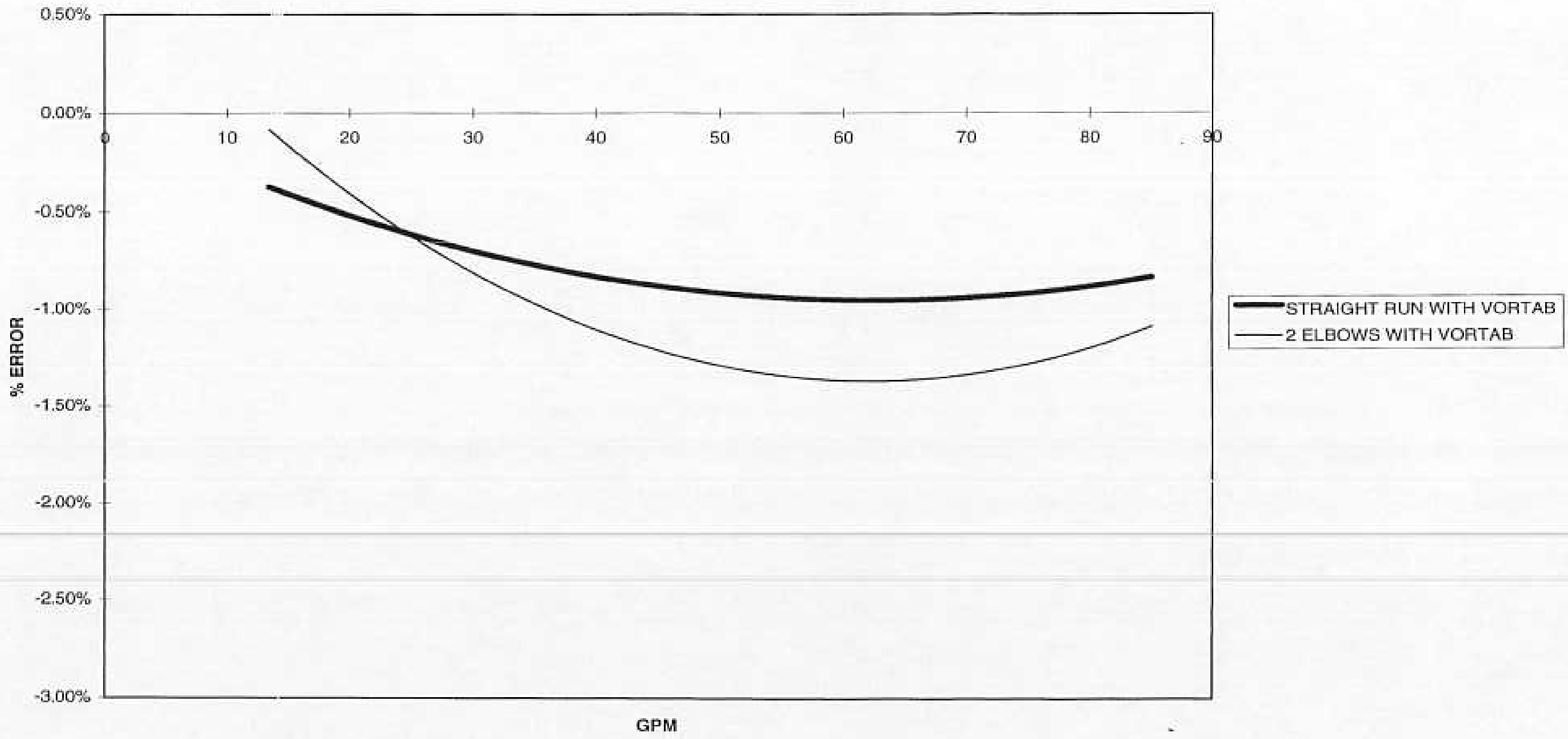


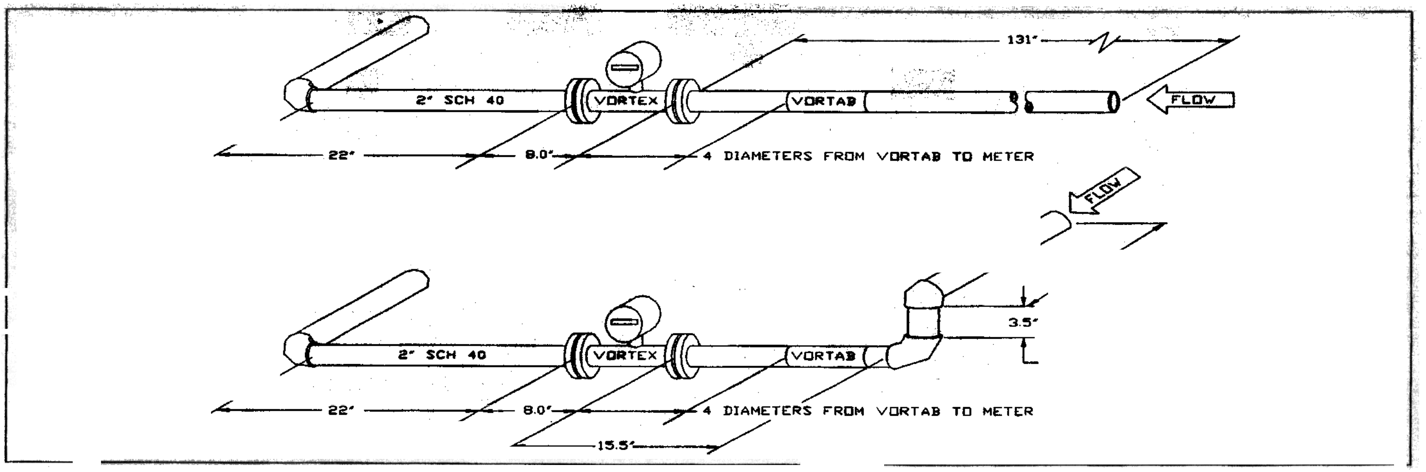
AS FOUND STRAIGHT RUN AND 2 OUT OF PLANE ELBOWS WITHOUT VORTAB (IN WATER) - *Figure 13*



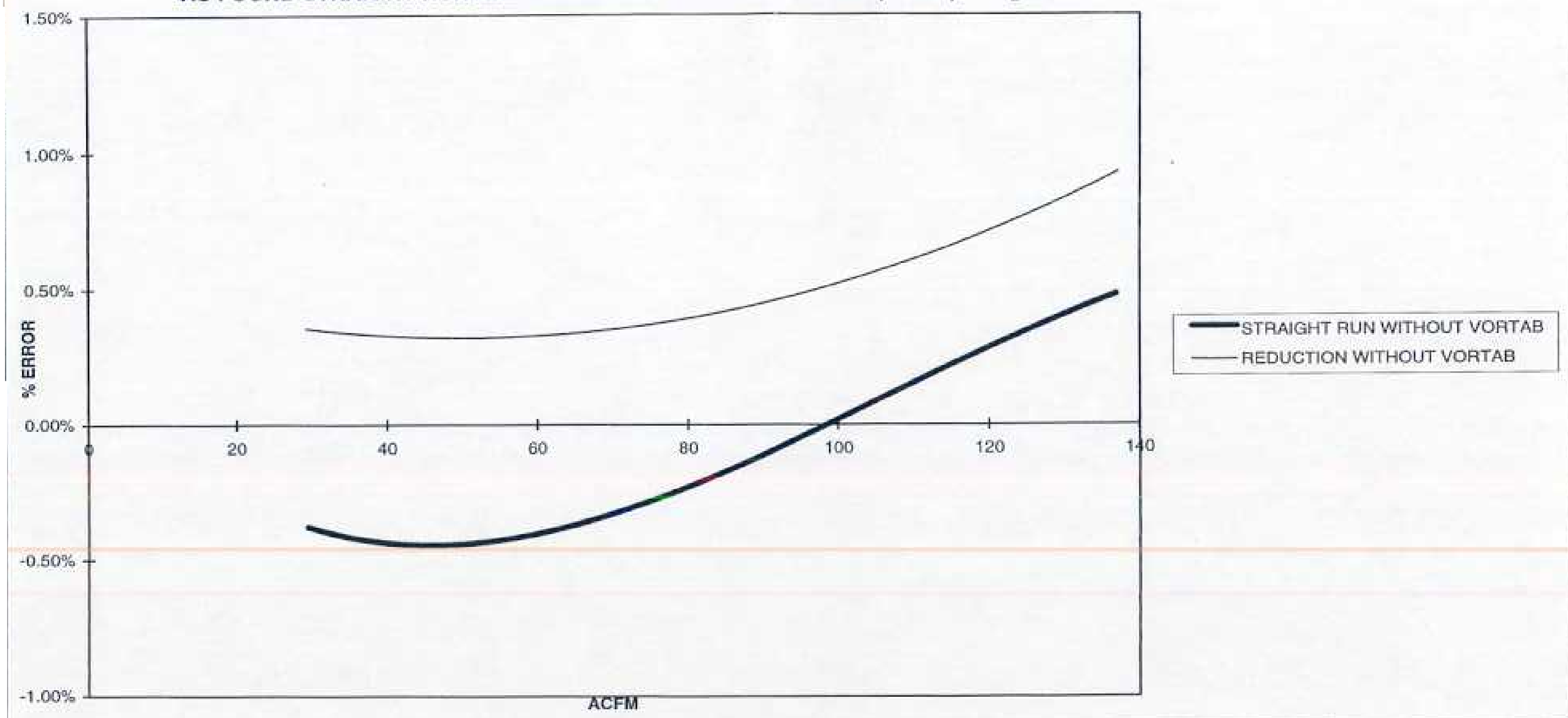


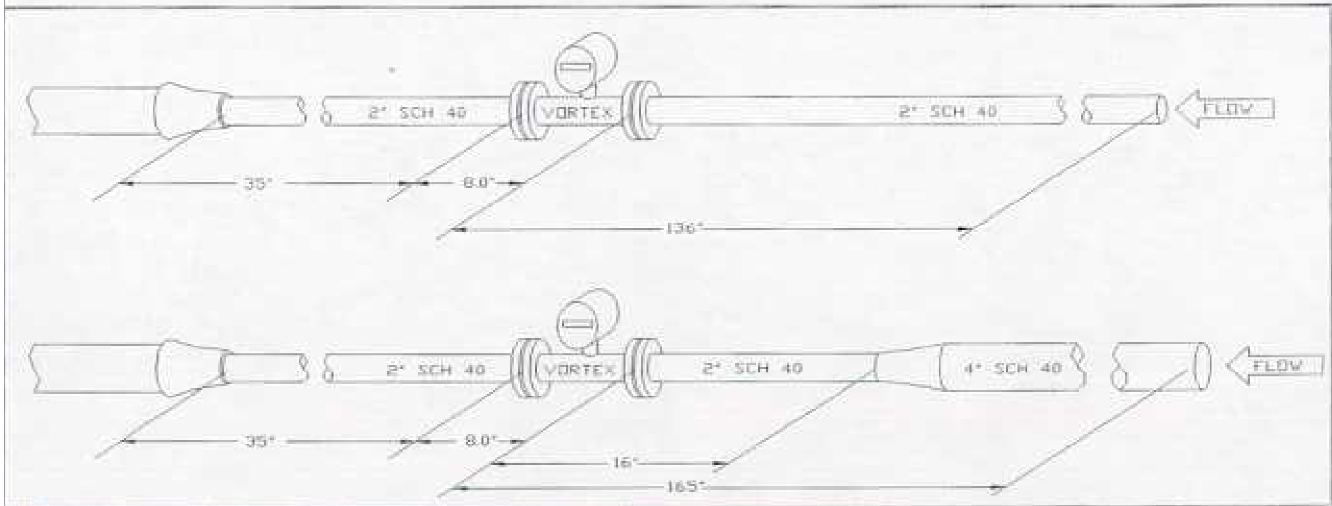
AS FOUND STRAIGHT RUN AND 2 OUT OF PLANE ELBOWS WITH VORTAB (IN WATER) - *Figure 14*



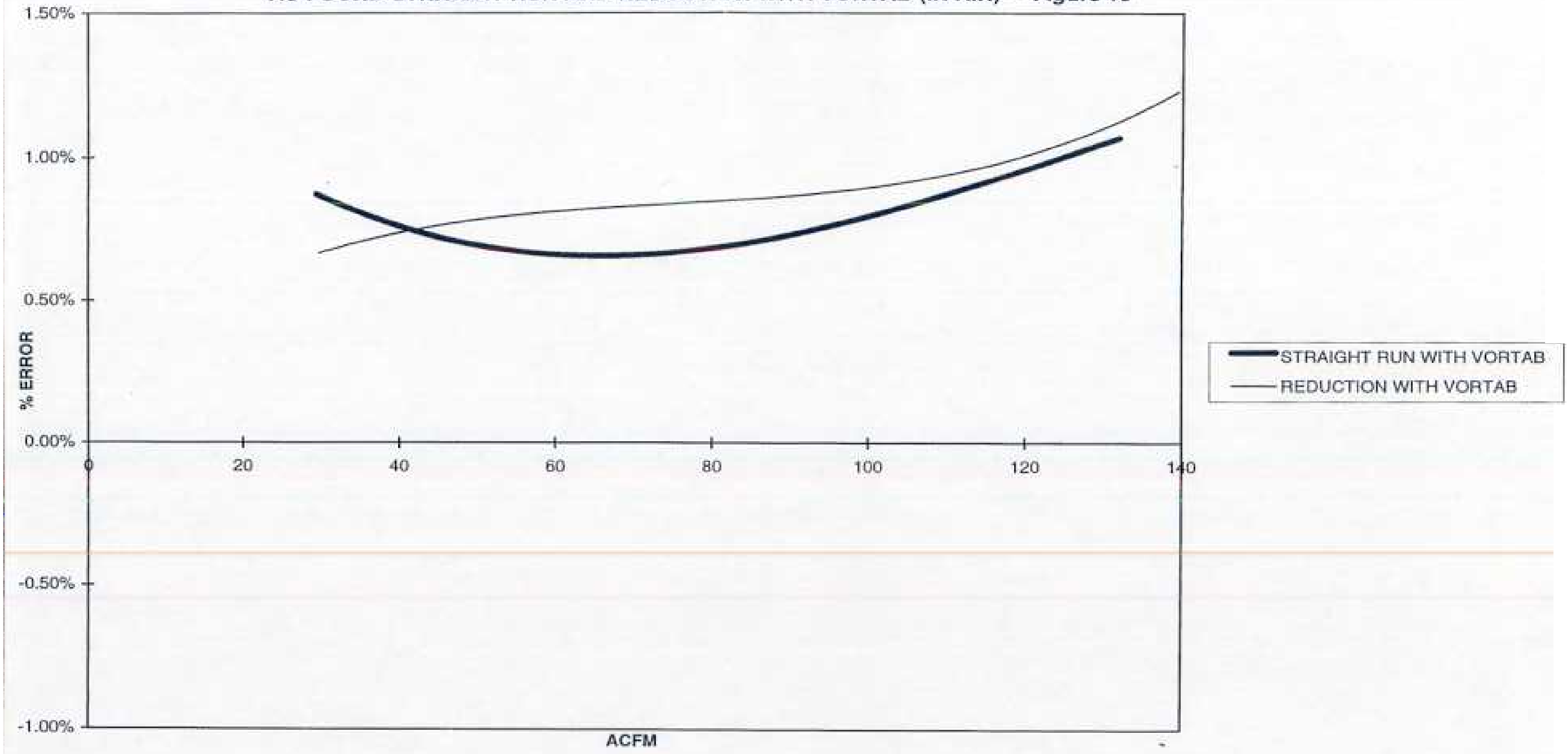


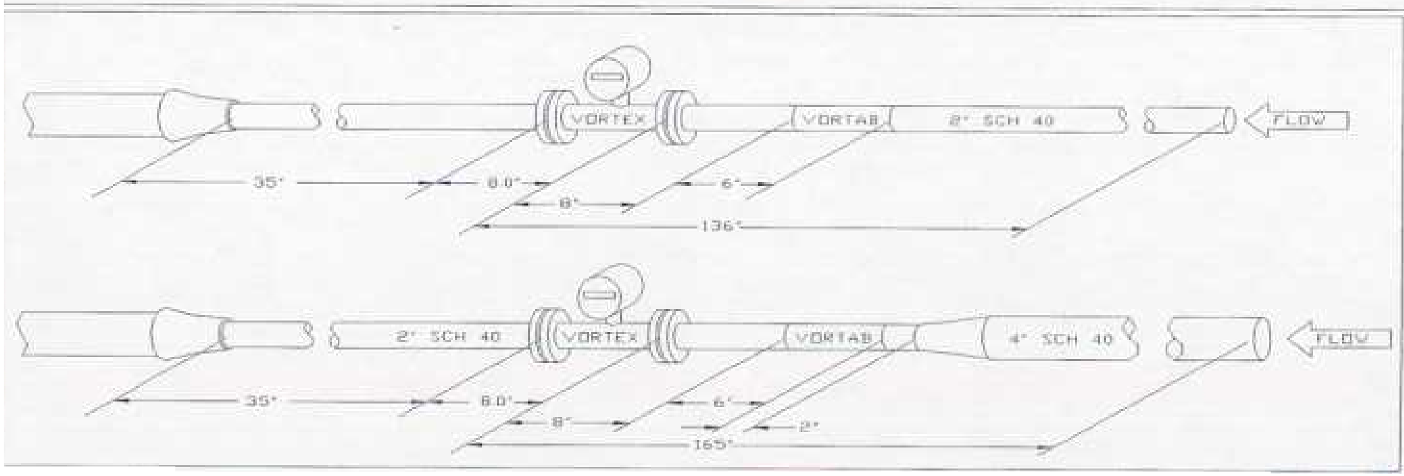
AS FOUND STRAIGHT RUN AND REDUCTION WITHOUT VORTAB (IN AIR) - *Figure 15*



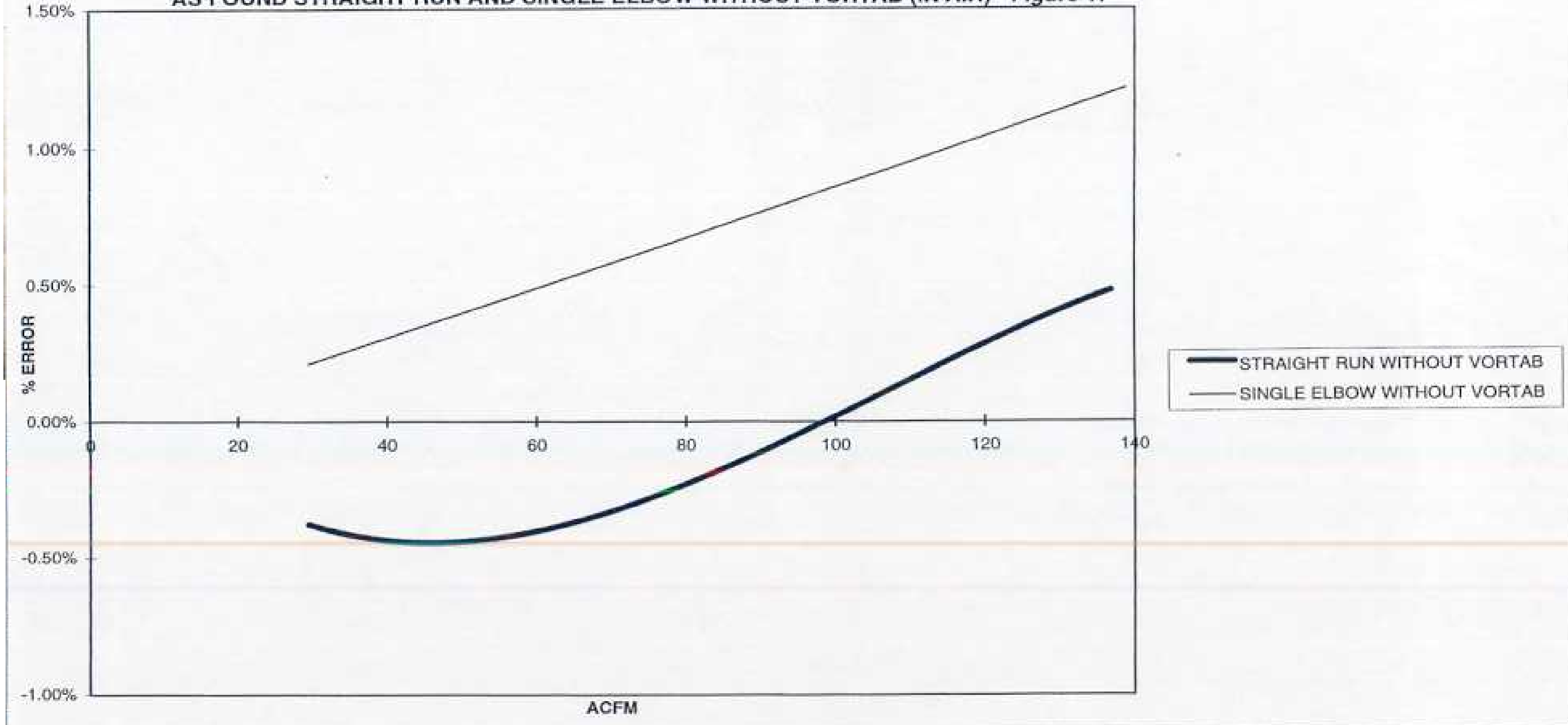


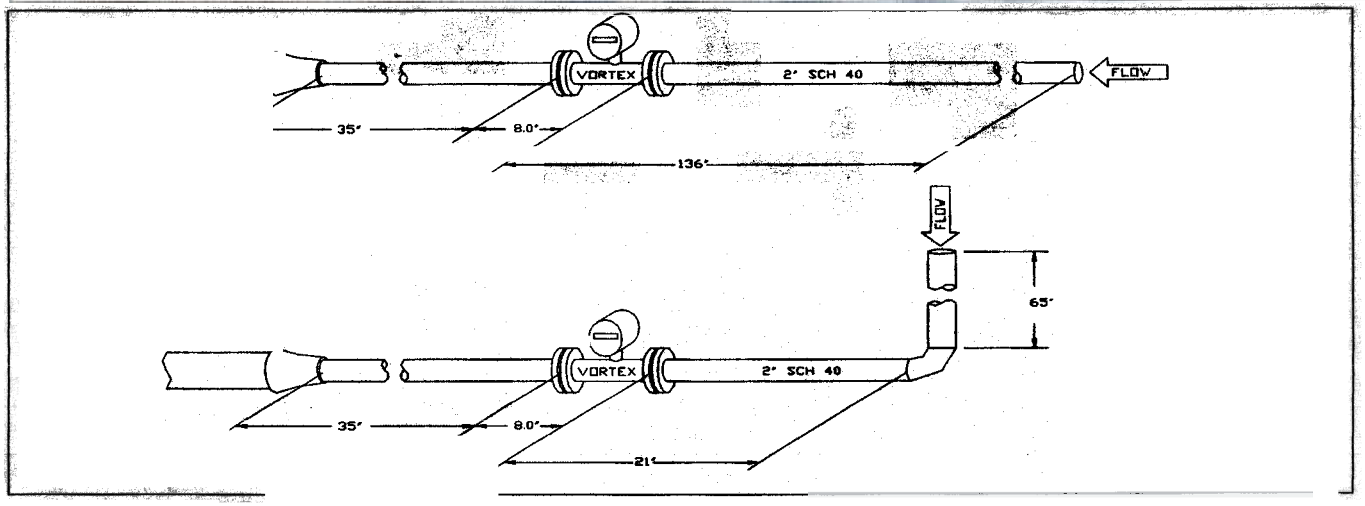
AS FOUND STRAIGHT RUN AND REDUCTION WITH VORTAB (IN AIR) - *Figure 16*

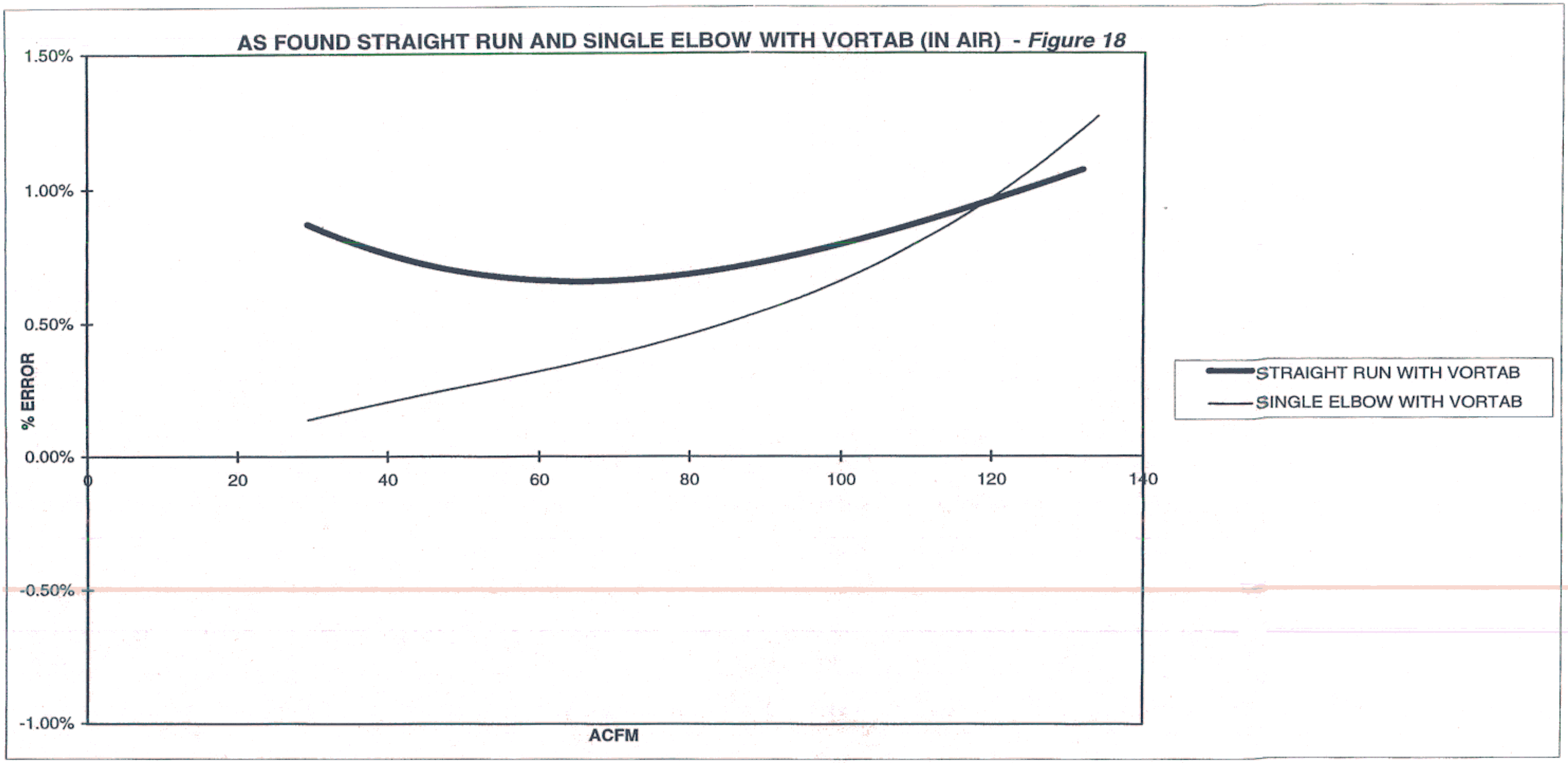


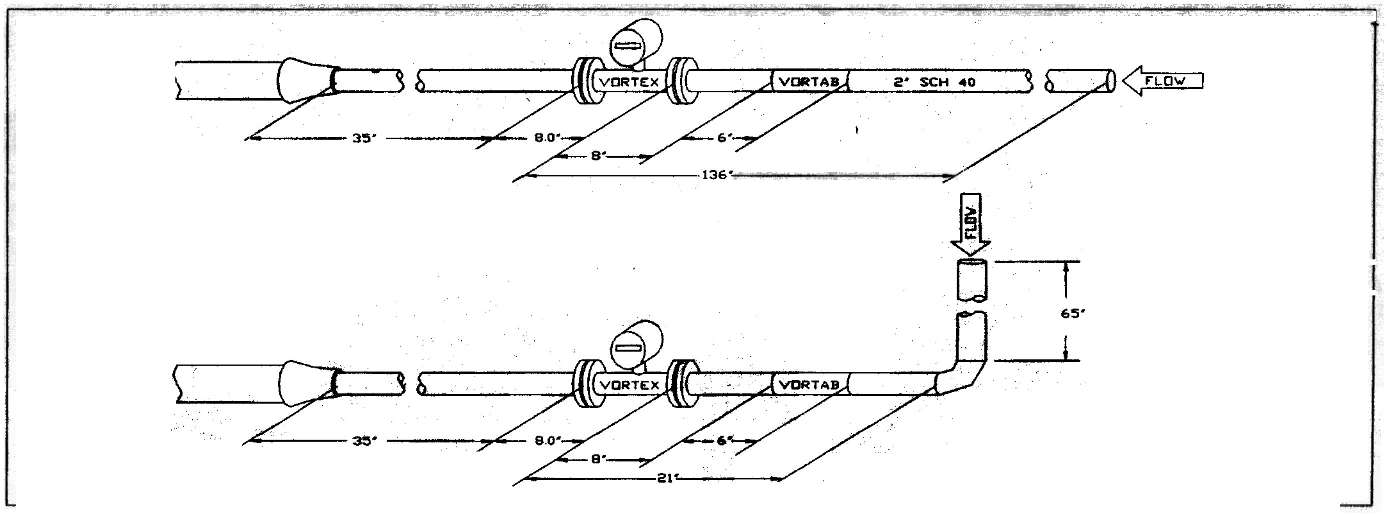


AS FOUND STRAIGHT RUN AND SINGLE ELBOW WITHOUT VORTAB (IN AIR) - *Figure 17*

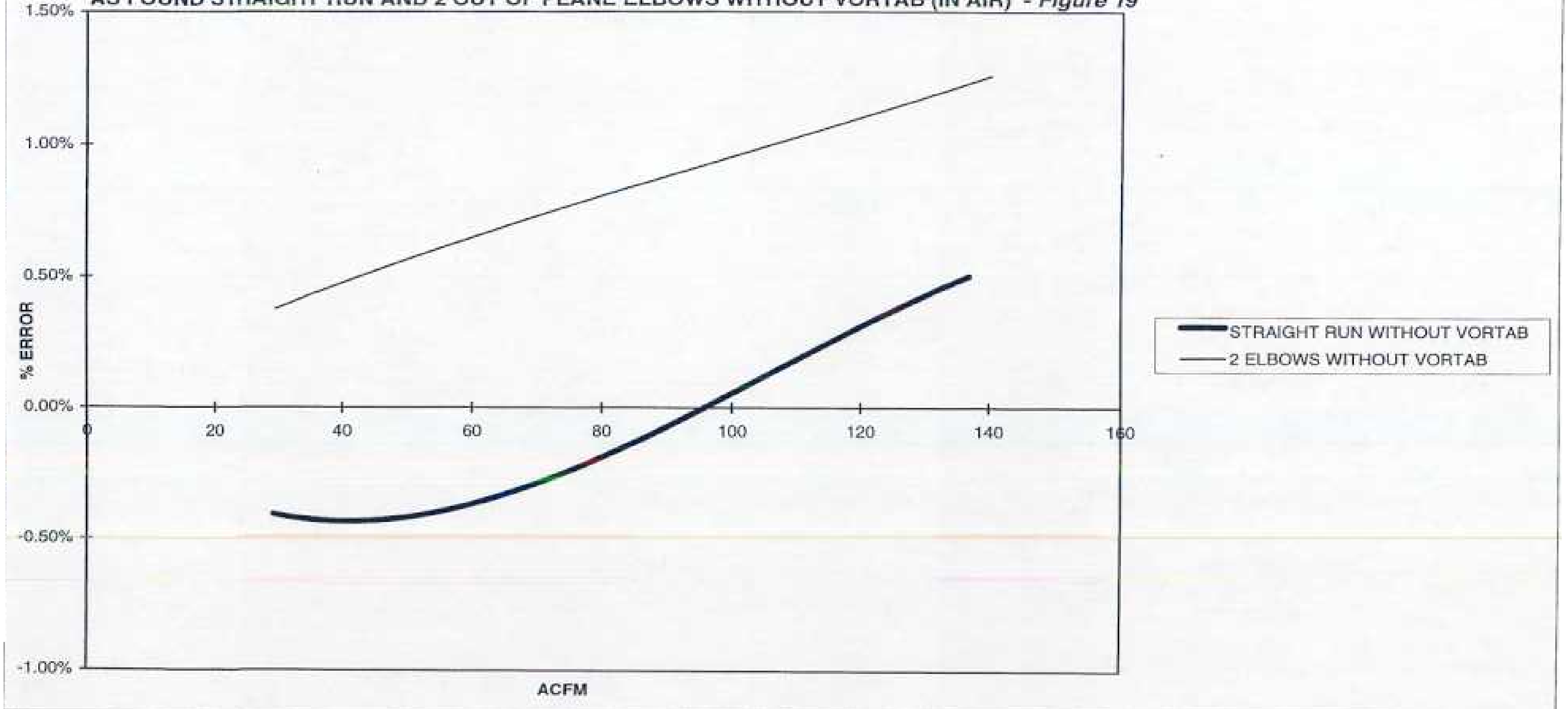


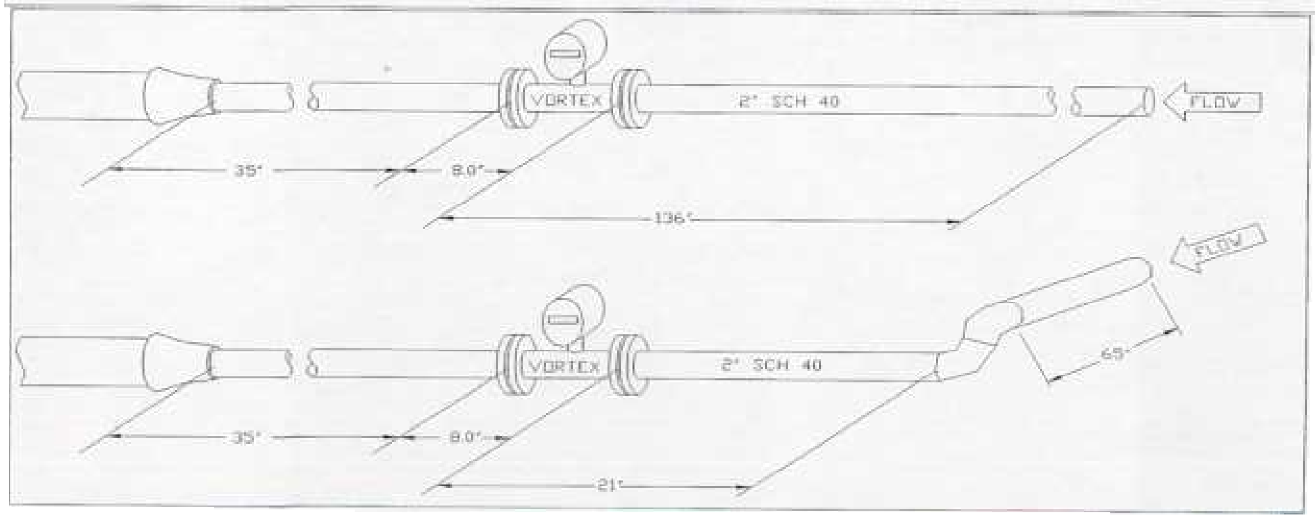



AS FOUND STRAIGHT RUN AND SINGLE ELBOW WITH VORTAB (IN AIR) - Figure 18
1.50%
1.00%
0.50%
0.00%
-0.50%
-1.00%
% ERROR
0
20
40
60
80
100
120
140
ACFM
STRAIGHT RUN WITH VORTAB
SINGLE ELBOW WITH VORTAB

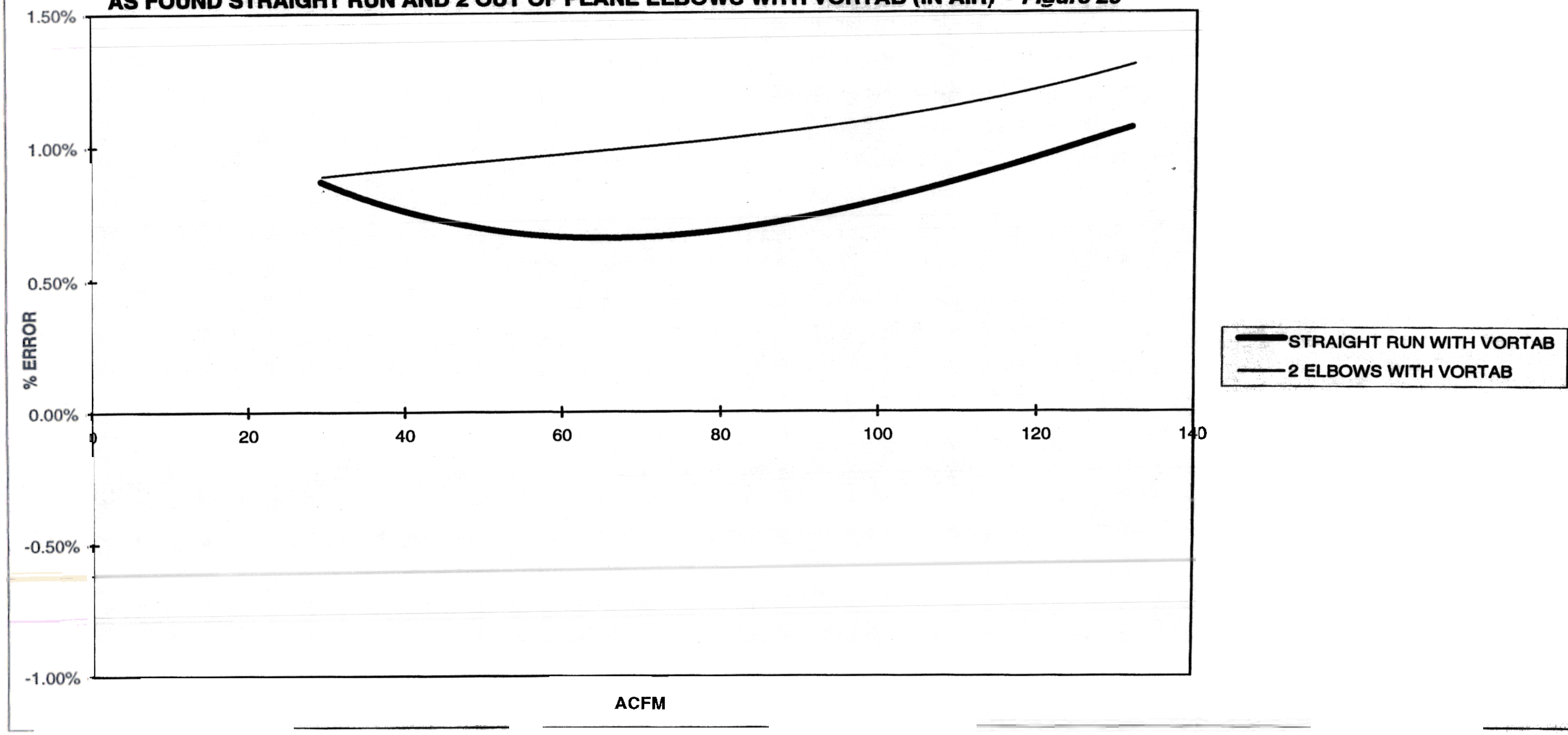

VORTEX
VORTAB
2" SCH 40
FLOW
35'
8.0'
8'
6'
136'
FLOW
65'
VORTEX
VORTAB
35'
8.0'
8'
6'
21'

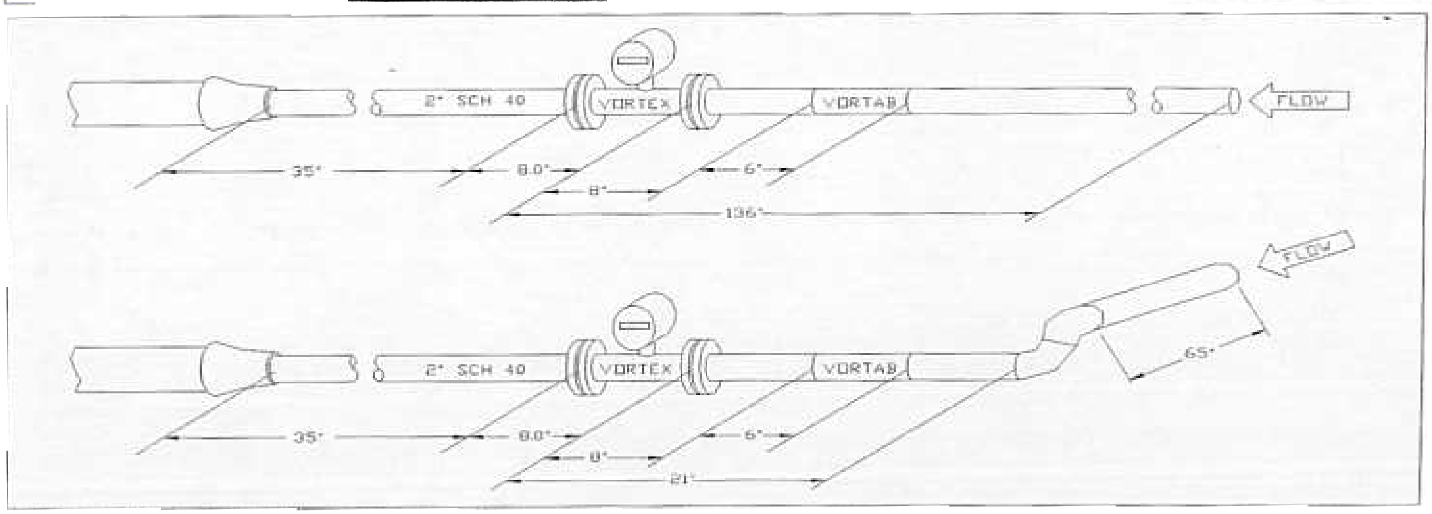
AS FOUND STRAIGHT RUN AND 2 OUT OF PLANE ELBOWS WITHOUT VORTAB (IN AIR) - *Figure 19*

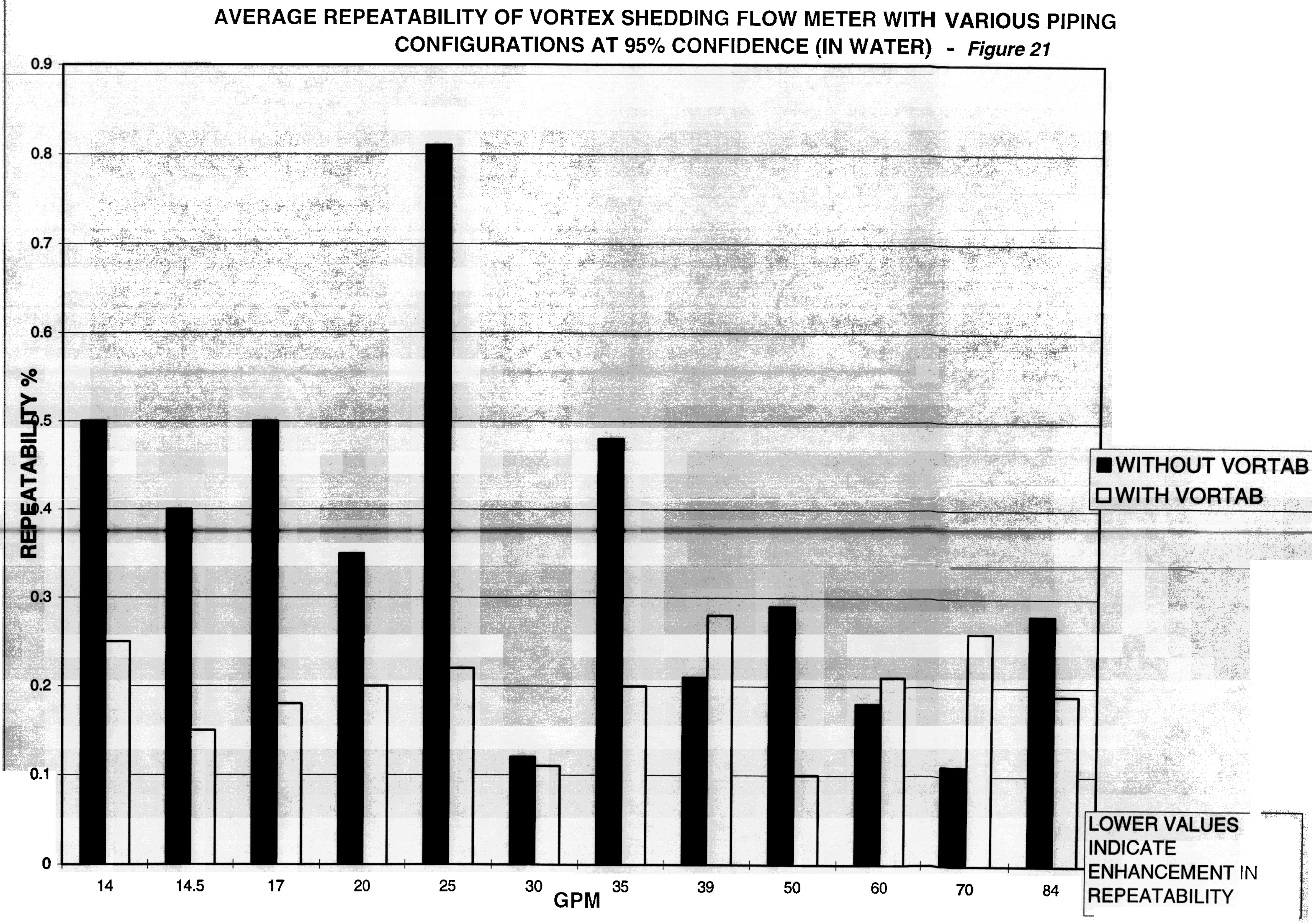




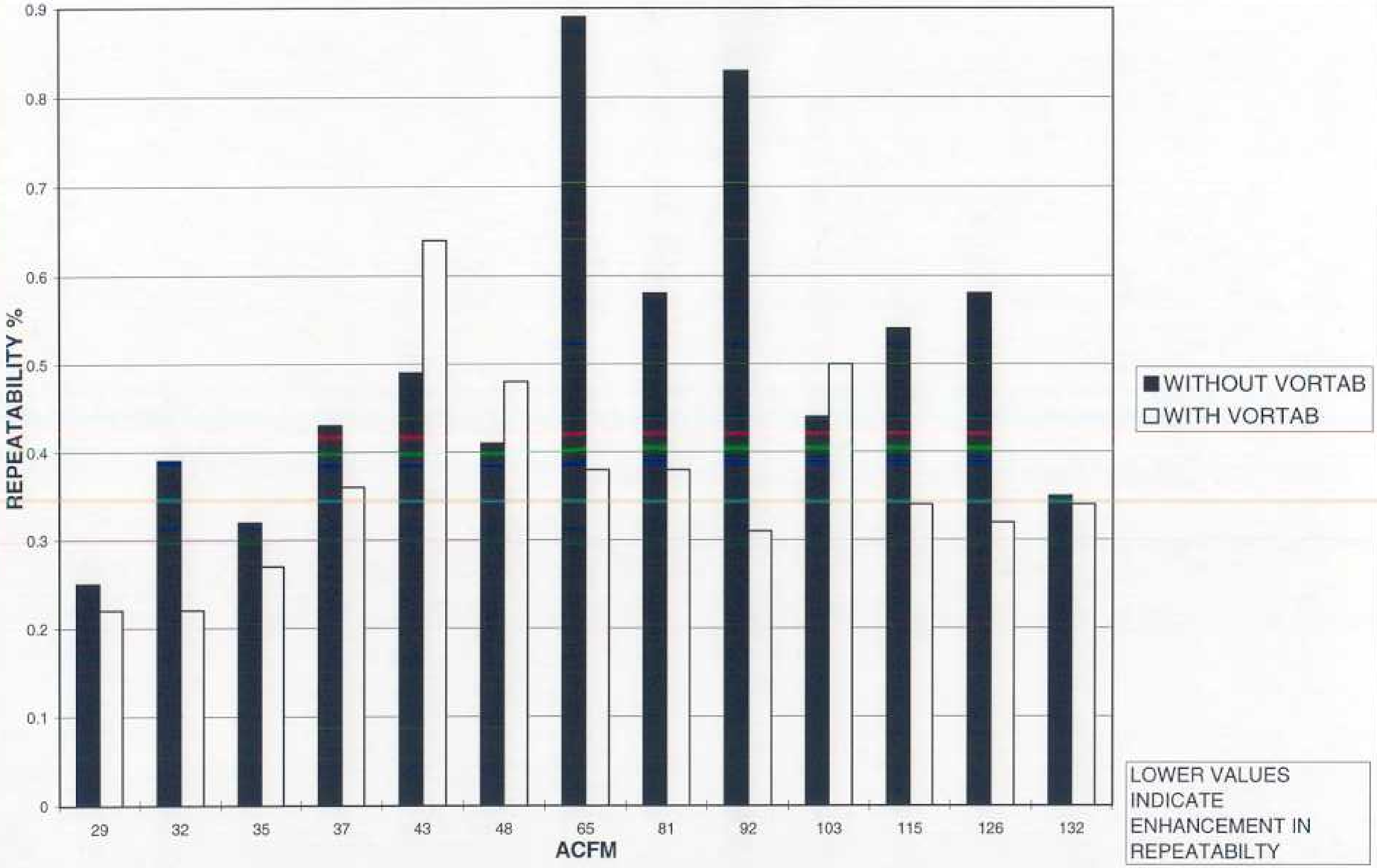
AS FOUND STRAIGHT RUN AND 2 OUT OF PLANE ELBOWS WITH VORTAB (IN AIR) - *Figure 20*






AVERAGE REPEATABILITY OF VORTEX SHEDDING FLOW METER WITH VARIOUS PIPING CONFIGURATIONS AT 95% CONFIDENCE (IN WATER) - Figure 21
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
REPEATABILITY %
14
14.5
17
20
25
30
35
39
50
60
70
84
GPM
WITHOUT VORTAB
WITH VORTAB
LOWER VALUES INDICATE ENHANCEMENT IN REPEATABILITY

AVERAGE REPEATABILITY OF VORTEX SHEDDING FLOW METER WITH VARIOUS PIPING CONFIGURATIONS AT 95% CONFIDENCE (IN AIR) - *Figure 22*



PRESSURE DROP ACROSS A VORTEX SHEDDING FLOW METER - *Figure 23*

AIR			
FLOW RATE (ACFM)	FLOW METER PRESSURE DROP (PSI)	FLOW CONDITIONER PRESSURE DROP (PSI)	TOTAL PRESSURE DROP (PSI)
27	0.004	0.002	0.006
61	0.036	0.018	0.054
110.5	0.13	0.04	0.17
130	0.18	0.06	0.24

WATER			
FLOW RATE (GPM)	FLOW METER PRESSURE DROP (PSI)	FLOW CONDITIONER PRESSURE DROP (PSI)	TOTAL PRESSURE DROP (PSI)
20	0.06	0.018	0.078
40	0.22	0.1	0.32
70	0.79	0.12	0.91
85	1.26	0.16	1.42