485 Annubar® Primary Flow Element Installation Effects

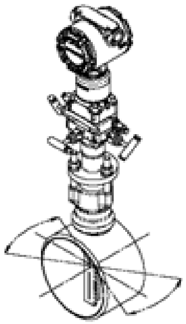
CONTENTS

Corrections can be made to the 485 Annubar signal which allow the user to make more accurate, reliable flow measurements.

APPLICATION

The performance of the 485 Annubar primary flow element can be influenced by various installation parameters such as mounting hole diameter, probe orientation, and upstream piping configurations. The 485 Annubar installation/operation instructions outline the limits that should be met for these important parameters in order to insure performance of the Annubar primary element within its design specifications. However, in some plant applications it may not be feasible or possible to maintain all of the installation parameters within their recommended limits. While the published accuracy of the flow measurement from the 485 Annubar may be compromised in those cases, it is usually possible to obtain a stable, repeatable differential pressure signal from the Annubar.

The 485 Annubar has been tested in the Emerson Process Management Boulder, Colorado water flow laboratory under conditions simulating many commonly encountered installation problems. While it is not possible to cover every conceivable combination of piping or installation abnormality, the information in this document gives expected flow coefficient shifts for many representative installations. With the data presented in this document, corrections can be made to the 485 Annubar signal which allow for more accurate, reliable flow measurements in difficult application situations.



485 Annubar®

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CHALLENGE

Mounting Hole Diameter

The size of the pipe mounting hole through which the Annubar primary flow element is installed is a critical aspect of the installation. The mounting hole must be drilled with a drill bit or cut using a hole-saw to the size specified in the installation/operation instructions included with the Annubar primary flow element. Those sizes are also shown in the table below. A hole that is undersized will not allow the probe to be inserted into the pipe. A hole that is oversized will cause a shift in the flow coefficient from its published value, resulting in a bias shift in the flow measurement.

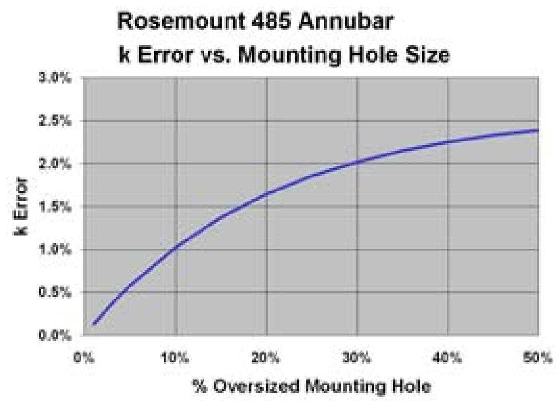


Figure 1: K Error vs. Mounting Hole Size

TABLE 1. 485 Annubar Mounting Hole Diameters

Sensor Size	1	2	3
Mounting Hole Diameter	$^{3}/_{4}$-in. (19mm)	1 $^{5}/_{16}$-in. (34mm)	2 $^{1}/_{2}$-in. (64mm)
Mounting Hole Tolerance	+1/32-in. (1mm)	+$^{1}/_{16}$-in. (1mm)	+$^{1}/_{16}$-in. (1mm)
	-0.00	-0.00	-0.00

Tests to characterize the effect of oversize mounting holes have shown the effect to be small and quite predictable. As shown in Figure 1, the shift in the flow coefficient (k) is positive and approaches 2.5% for mounting holes that are extremely oversized (>1.5X the nominal value)

Alignment Error

The 485 Annubar senses total pressure (impact plus static pressure) through the upstream slotted ports and a low pressure through the downstream ports. If the 485 Annubar is not aligned perpendicular to the axis of the pipe and to the fluid flow, one or both of the sensed pressures will be affected. The published flow coefficients have been determined experimentally with a carefully aligned Annubar primary element. Changes in the alignment angle, shown in Figure 2, will cause a shift from the published flow coefficient.

Tests at the Emerson Process Management Boulder flow laboratory have determined that these alignment errors are quite small for the 485 Annubar. Keeping the 485 Annubar oriented within the ±3^{o} as recommended in the installation guide results in a negligible shift in the flow coefficient (k). Even misalignments as great as 10^{o} shift the k factor by only slightly over 0.5%.

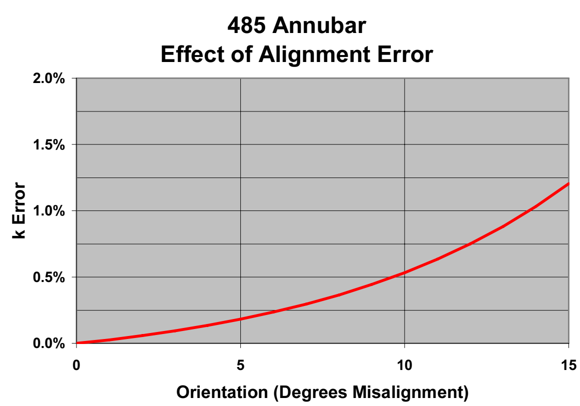


Figure 2: Effect of Alignment Error

Piping Geometry Induced Flow Disturbances

The Annubar flow sensor is an averaging, differential pressure device. The sensing ports are positioned to provide an accurate, repeatable differential pressure signal when the sensor is positioned across a fully developed, turbulent flow profile. While the location and design of the sensing ports also allow the Annubar to give an accurate pressure signal under many non-ideal flow profiles, the averaging functions of the Annubar primary element will not accommodate large asymmetries in the flow profile. Extremely skewed flow profiles can cause a change in the flow coefficient (k) from the published values.

Any upstream device that disturbs the flow can influence the flow profile. Examples are valves, elbows, diameter changes, etc. Sufficient lengths of straight run of pipe upstream of the Annubar primary element will allow a turbulent flow profile to develop. Given a long enough distance between the flow disturbance and the Annubar, the viscous forces in the fluid will overcome the inertia of the swirl or profile asymmetry and cause the velocity profile to become fully-developed. A flow straightener or straightening vanes may be used to reduce the length of straight run required. These are available in several configurations from many piping supply houses. Table 1 shows the suggested minimum straight run requirements both with and without the use of vanes or flow straighteners.

The Annubar primary element will produce a repeatable signal even if the straight run requirements have not been met and the k factor has been shifted. In many flow applications, the ability to monitor changes in flow is more critical than flow measurement accuracy. In these applications, it may be possible to use the uncorrected output of the Annubar installed with less than the recommended amount of straight run. However, in those flow measurement applications where flow accuracy needs to be maintained with less than ideal straight run, the data in this document can be used to improve the accuracy of the Annubar flow output.

The number of possible upstream and downstream piping configurations is infinite. Therefore, it is not possible to calculate a correction factor for all possible changes in upstream piping. Fortunately, in many cases flow disturbances such as valves, elbows, reducers, etc. cause relatively small and predictable shifts in the meter output. Even though the flow profile may not be fully developed, testing indicates that the Annubar can be located inside the recommended straight pipe distance with no effect on the repeatability of the meter and relatively predictable effects on the accuracy.

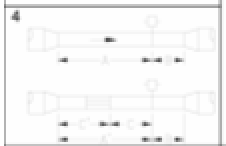
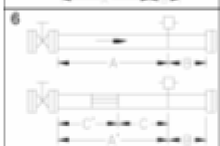
	Upstream Dimensions					Downstream
	Without Vanes(2)		With Vanes(3)			
	In Plane A	Out of Plane A	A'	C	C'	
1 	8	10	—	—	—	4
	—	—	8	4	4	4
2 	11	16	—	—	—	4
	—	—	8	4	4	4
3 	23	28	—	—	—	4
	—	—	8	4	4	4
4 	12	12	—	—	—	4
	—	—	8	4	4	4
5 	18	18	—	—	—	4
	—	—	8	4	4	4
6 	30	30	—	—	—	4
	—	—	8	4	4	4

Table 1: Straight Run Requirements

In the Emerson Process Management Boulder flow lab, several common pipe configurations have been set up. The Annubar has been tested at various distances downstream of these configurations and the resulting mean k-factor shifts have been determined. These graphs are shown on the following pages. Although the upstream disturbance may cause a shift in the k-factor, the repeatability of the Annubar is normally not affected. Testing also indicates that while the k-factor is affected by upstream piping, the linearity of the meter remains within design specifications. Errors created by shorter than recommended straight run can be compensated for by adjusting the Annubar k-factor to correct for these piping effects.

A note of caution about the use of the corrections shown in the following charts: Along with the shift in the k-factor, the increased swirl and profile distortion from upstream disturbances may also cause the uncertainty of the Annubar measurement to increase. For instance, at a location that is half the recommended straight run, the k-factor uncertainty will typically be twice the normal 0.75% value. At one-third of the recommended distance, the uncertainty can be expected to triple, and so on. The corrections given in this document are not a substitute for a well-engineered flow meter installation with adequate straight piping runs.

When optimum accuracy is required in shorter than recommended piping runs, an in-line calibration of the Annubar installation may be necessary. The results of a single point pitot traverse of the flow profile are compared to the output of the Annubar at various flow rates and corrections to the k-factor are made based on those measurements. Depending on the piping configuration, Annubar installation and flow conditions, accuracies approaching that of a normal installation can be obtained using the results of a pitot traverse calibration.

Pipe Reducers

Tests have been conducted in Emerson Process Management Boulder flow laboratory to determine the effect of reductions in pipe diameter upstream of the 485 Annubar. Tests were run in several line sizes and at several downstream locations after a single line size change (e.g. 8"-6", 6"-4", 4"-3"). Industry standard concentric pipe reducers were used for all of these tests. As can be seen in Figure 3, the tests showed a pattern of an increasing k factor as the Annubar location was moved closer to the pipe size reduction.

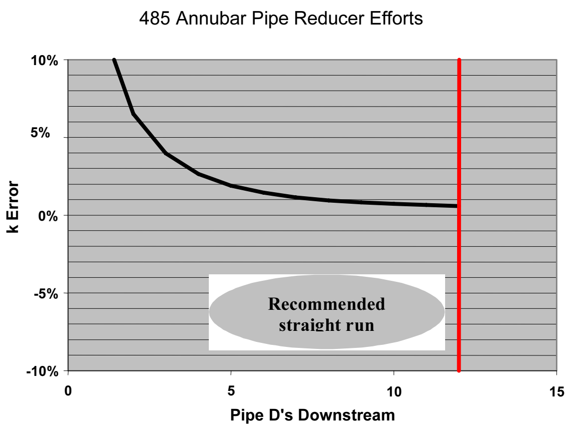


Figure 3: Pipe Reducer Efforts

Pipe Expansions

Tests have been conducted in the Emerson Process Management Boulder flow laboratory to determine the effect of expansions in pipe diameter upstream of the 485 Annubar. Tests were run in several line sizes and at several downstream locations after a single line size change (e.g. 6"-8", 4"-6", 3"-4"). Industry standard concentric pipe expansions were used for all of these tests. These tests showed a pattern of first an increasing, and then rapidly decreasing k factor as the Annubar location was moved closer to the pipe size expansion.

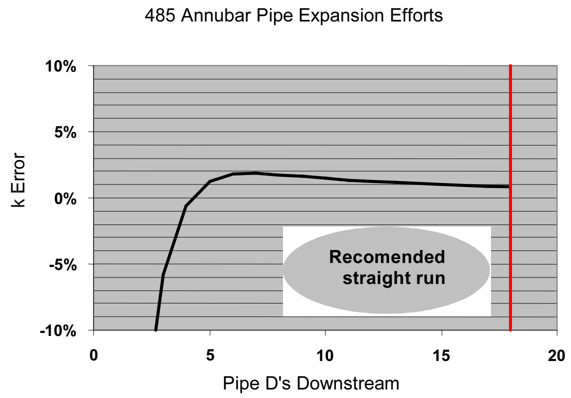


Figure 4: Pipe Expansion Efforts

Control Valves

Tests were conducted in the Emerson Process Management Boulder flow laboratory to determine the effect of control valves upstream of the 485 Annubar. Tests were run in several line sizes and at several downstream locations after a butterfly-type control valve. In addition to varying the Annubar downstream location, the effect of valve position and orientation was also considered during these tests.

As shown in Figures 5 and 6, the control valve tests resulted in an increasing and then rapidly decreasing k factor as the Annubar location was moved closer to the valve. The valve position has a marked effect on the k shift when the Annubar is oriented parallel to the valve axis while valve position is less of a factor when the Annubar is 90° off of the valve axis.

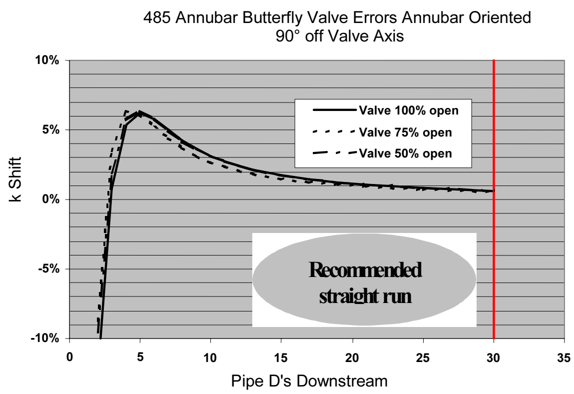


Figure 5: Butterfly Valve Errors 90° Off Valve Axis

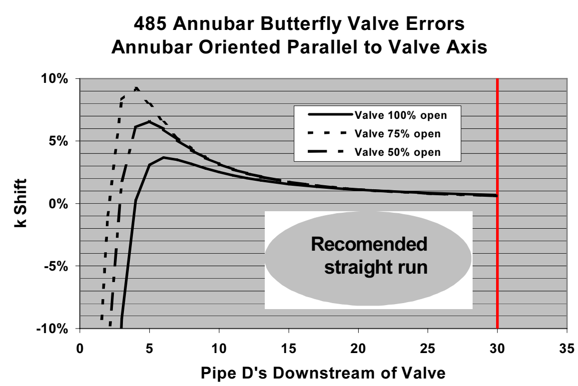


Figure 6: Butterfly Valve Errors Parallel to Valve Axis

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