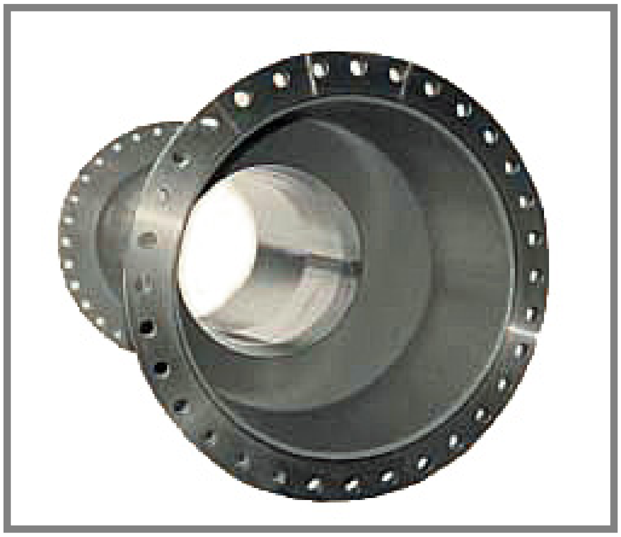
LVM TECHspec

Wyatt Engineering Liberty Venturi Tube
Primary Flow Element Design



Pressure Vessel, Nonimpact Design

Based on the classical venturi design, nonimpact venturi meters are those that sense only axial components of the line fluid's velocity profile; nonaxial vectors are considered insignificant in standard piping. The resulting flow meter has a discharge coefficient (C_D) that approaches unity, is not a function of fluid velocity and beta ratio (d/D), and is constant above a given threshold pipe Reynolds number. In general, designs that utilize this flow metering mechanism are less sensitive to upstream pipe fittings than those designs that employ other types of pressure sensation.

The LVM nonimpact design conforms to all those characteristics that make venturi meters the preferred flow meter when accuracy, reliability, and low permanent pressure loss are required.

Insert-Type, Impact Design

Insert-type, impact venturi meters sense a nonaxial velocity component in their high pressure sensation. As a result, the meter discharge coefficient is dependent on beta ratio; however, C_D is not a function of line velocity and is still constant above a given threshold pipe Reynolds number.

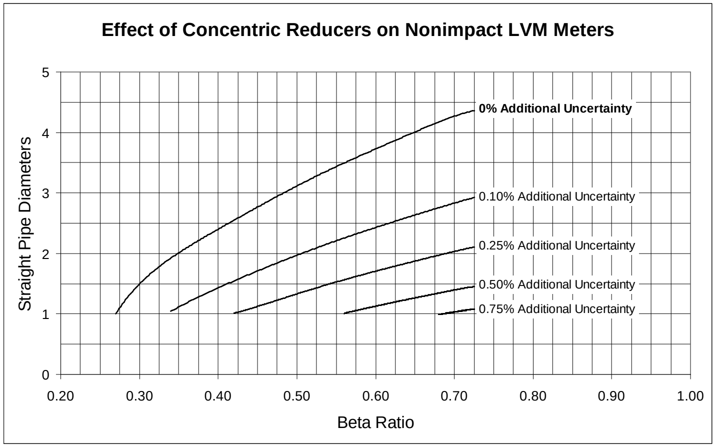
The LVM impact flow meter is a cost-effective alternative to the nonimpact pressure vessel design. While slightly more sensitive to upstream piping than the nonimpact design, these insert-type venturi meters provide the same accuracy, reliability, and low pressure loss as that of the nonimpact design.

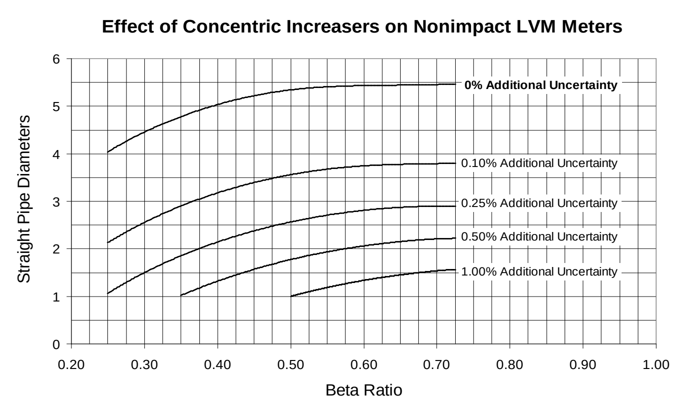
The value and behavior of the LVM C_D indicate an extremely efficient metering shape and independence of line velocity; pipe Reynolds number (R_D) is a concern if less than 75 000. If your application's pipe Reynolds number is greater than 75 000, the substantiated uncertainty of the LVM design is better than ± 0.50%; for $R_D < 75\ 000$, the C_D is known and repeatable. Contact Wyatt Engineering for further information.

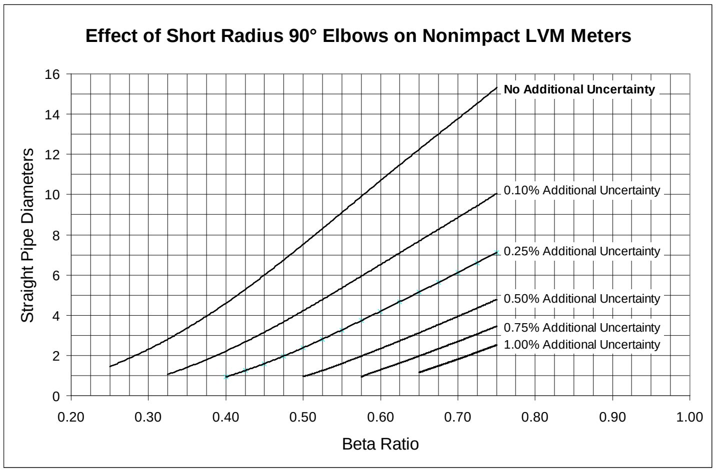
Installation Effects

The differential pressure produced by the LVM design is an indication of the difference in the kinetic energy of the line fluid between the high and low pressure tap cross sections. Due to differing velocity profiles, a given flow rate can possess different kinetic energies, and thereby introduce errors in the indicated flow rate. This is the essence of the study of installation effects and installed accuracy.

These curves summarize the results of flow tests on nonimpact LVM flow meters. The "nonimpact" term reflects the condition that neither the high nor the low pressure tap senses nonaxial velocity components. This refers to meters commonly (but erroneously) labeled "static tap" design. The most common Wyatt Engineering model numbers appropriate for these data are: LVM, LVM-B, LVM-EV, LVM-F, and LVM-U.


Effect of Concentric Reducers on Nonimpact LVM Meters


Effect of Concentric Increasers on Nonimpact LVM Meters


Effect of Short Radius 90° Elbows on Nonimpact LVM Meters

One concept made clear immediately by these test results is meter sensitivity to an upstream disturbance decreases with decreasing beta ratio (d/D). Put more simply: **The smaller the beta ratio, the smaller the effect of upstream piping.** Note that a similar relationship exists for orifice meters, flow nozzles, and nozzle venturi meters. Stated differently, if E_I is the installation error function, then

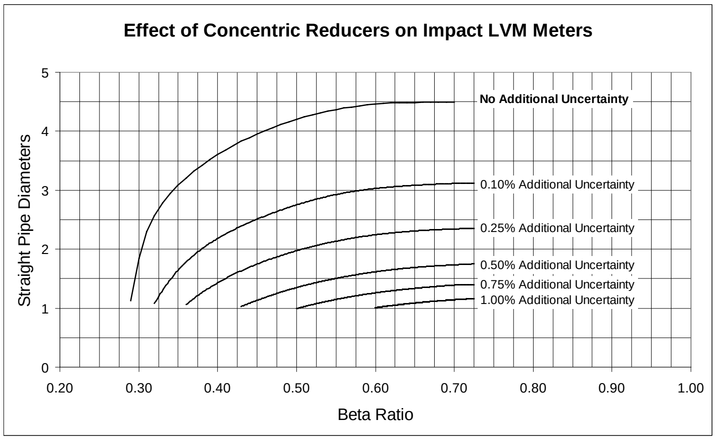
$$\lim_{\beta \to 0} E_I = 0$$

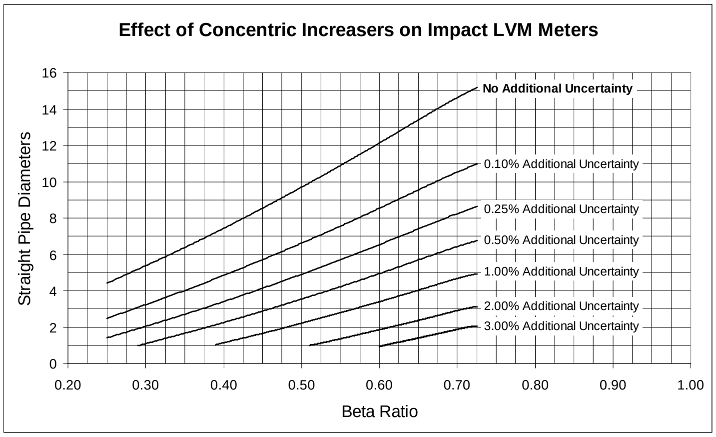
Given this relationship by itself, logically, one should design differential producers with beta ratios approaching zero! In general, the great compromise is: The smaller the beta ratio, the higher the permanent pressure loss. While the desire is to minimize both the specific headloss and installed uncertainty, increased permanent pressure loss is sometimes the cost of improved installed accuracy.

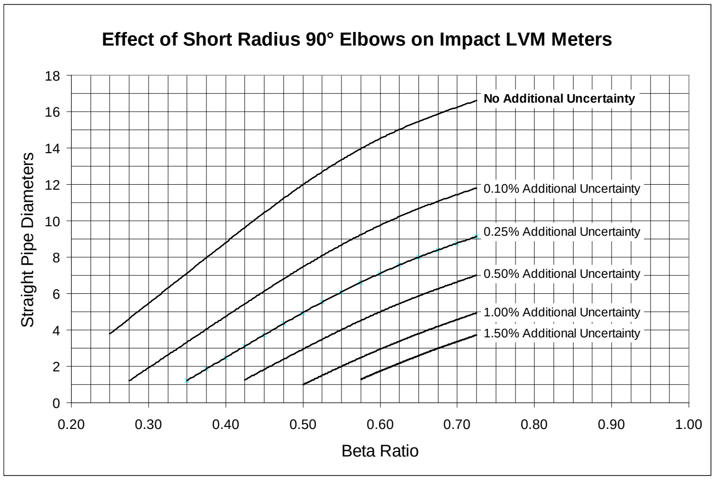
Flow patterns that change the behavior of the discharge coefficient can be caused by pipe fittings, Reynolds number, and/or pipe surface/diameter irregularities. From flow testing, we have learned the following: The smaller the meter beta ratio, the smaller is the effect of pipe fittings; and irregular flow patterns that are nonrotational, that is, those caused by reducers, single elbows, etc., are self-attenuating, while irregular flow patterns that are rotational, for example, those caused by two elbows direct-coupled in perpendicular planes, are relatively stable and users should consider flow straighteners in such cases.

With respect to downstream piping requirements, pipe fittings, valves, etc. may be direct-coupled to the outlet of the LVM venturi meter without affecting the accuracy. Note that some meters' recovery sections are truncated, so direct-coupling a butterfly valve may, in some instances, cause the valve disk to interfere with the meter outlet and full valve disk movement may not be possible. Let us know if this configuration is required and the meter outlet will be modified accordingly. It should be noted also that the pressure loss of the direct- or close-coupled valve or pipe fitting will be somewhat higher than is calculated assuming a blunt velocity profile. If this is a concern, please contact Wyatt Engineering for further assistance.

Installation and Energy Considerations







Energy loss, called specific headloss, is typically expressed in terms of pounds per square inch, inches of water column, kilopascals, etc. Losses for some different meter types are shown in Figure 1. In terms of generalized units, however, the true description is “Units of Energy per Units of Mass Flow.” Consequently, the specific headloss of a meter, fitting, etc., represents an ongoing energy expense, “the cost of doing business,” and it is everyone’s duty to minimize that cost. For reference, an LVM sized for the same differential pressure consumes is less than one-eighth the energy of an orifice plate.

The curves to the left summarize the results of flow tests on impact LVM flow meters. In this case, the term “impact” indicates the high pressure tap senses nonaxial velocity component. This is due to the location of the high pressure tap located either behind the meter inlet cone or at the intersection of the converging section and the upstream pipe. Meters employing this type of high pressure sensation are sometimes, though incorrectly, referred to as using “full or partial Pitot effects.” Due to the nonaxial velocity component that influences the high pressure sensation, the meter discharge coefficient (C_D) is dependent on beta ratio, independent of line velocity, and still constant for pipe Reynolds numbers greater than about 75 000. The impact design typically refers to insert-type meters. The most common Wyatt Engineering models appropriate for the use of these data are: LVM-IF, LVM-IL, and LVM-IP.

Energy Considerations

Pressure measured at a given point that does not have a nonaxial velocity vector is an indirect indication of the potential energy content of the flowing fluid at that cross section. Consequently, pressure drop is a measure of the energy dissipated between two points.

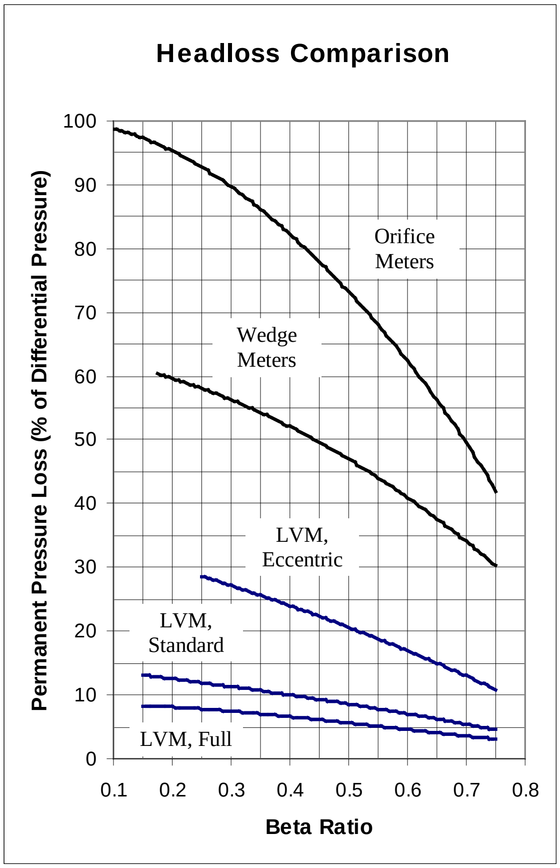


Figure 1

Uncertainty Substantiation

Sample No.	Inlet Diameter	Throat Diameter	Beta Ratio	Calibrated C_D	Predicted C_D	Deviation in C_D	Test Facility
1	0.957	0.5069	0.5297	0.9732	0.9715	0.17%	ARL
2	1.233	0.6066	0.4920	0.9894	0.9920	-0.26%	ARL
3	1.500	1.000	0.6665	0.9404	0.9376	0.30%	ARL
4	1.601	1.101	0.6877	0.9963	0.9920	0.43%	UWRL
5	1.606	1.101	0.6856	0.9895	0.9920	-0.25%	UWRL
6	1.938	1.353	0.6981	0.9913	0.6921	-0.07%	ARL
7	2.243	1.749	0.7799	0.8604	0.8620	-0.19%	ARL
8	2.900	0.9530	0.3286	0.9875	0.9920	-0.45%	ARL
9	2.664	2.001	0.7510	0.9010	0.8997	0.14%	ARL
10	2.664	2.001	0.7510	0.8971	0.8997	-0.29%	ARL
11	3.381	1.377	0.4073	0.9931	0.9920	0.11%	ARL
12	3.812	1.388	0.3642	0.9703	0.9732	-0.30%	UWRL
13	3.812	1.388	0.3642	0.9715	0.9732	-0.17%	UWRL
14	3.812	1.388	0.3642	0.9779	0.9732	0.48%	UWRL
15	4.026	1.988	0.4938	0.9945	0.9920	0.25%	ARL
16	4.026	2.020	0.5017	0.9934	0.9920	0.14%	ARL
17	4.026	2.760	0.6855	0.9865	0.9920	-0.55%	ARL
18	4.028	2.922	0.7254	0.9886	0.9920	-0.34%	ARL
19	5.071	3.499	0.6900	0.9367	0.9361	0.06%	ARL
20	5.071	3.499	0.6900	0.9350	0.9362	-0.13%	ARL
21	5.071	3.500	0.6902	0.9340	0.9361	-0.22%	ARL
22	5.071	3.501	0.6904	0.9356	0.9360	-0.04%	ARL
23	7.621	3.477	0.4562	0.9916	0.9920	-0.04%	ARL
24	7.113	3.749	0.5271	0.9682	0.9664	0.19%	ARL
25	7.981	5.003	0.6269	0.9920	0.9920	0.00%	ARL
26	7.996	5.380	0.6728	0.9922	0.6676	0.02%	ARL
27	7.995	5.417	0.6775	0.9903	0.6710	-0.17%	ARL
28	7.981	5.695	0.7136	0.9908	0.9920	-0.12%	ARL
29	8.230	4.836	0.5876	0.9852	0.9852	0.00%	UWRL
30	8.230	4.836	0.5876	0.9867	0.9852	0.15%	UWRL
31	8.230	4.836	0.5876	0.9875	0.9852	0.23%	UWRL
32	10.020	4.136	0.4128	0.9832	0.9874	-0.43%	ARL
33	10.020	5.863	0.5851	0.9910	0.9920	-0.10%	ARL
34	12.000	5.933	0.4944	0.9903	0.9920	-0.17%	ARL
35	12.000	6.188	0.5157	0.9937	0.9920	0.17%	ARL
36	10.750	7.140	0.6642	0.9901	0.9920	-0.19%	Daniel
37	12.125	8.742	0.7210	0.9953	0.9920	0.33%	UWRL
38	12.873	7.015	0.5449	0.9912	0.9920	-0.08%	ARL
39	14.700	9.571	0.6511	0.9959	0.9920	0.39%	ARL
40	14.505	9.774	0.6738	0.9928	0.9920	0.08%	Daniel
41	23.241	12.846	0.5527	0.9778	0.9758	0.20%	ARL
42	29.422	11.531	0.3919	0.9946	0.9920	0.26%	ARL
43	35.250	22.607	0.6413	0.9582	0.9616	-0.35%	ARL

Data covers a pipe Reynolds number range of 36 000 to 5 600 000 (Compiled11/9/10).

The Uncertainty of a LVM without Flow Calibration

The vast majority of LVM flow meters are provided without flow calibration. This is due to our ability to substantiate the uncertainty of the LVM to within ± 0.50% of indicated flow rate for pipe Reynolds numbers greater than 75 000.

For the LVM meter design, there is a "true" discharge coefficient (C_D). The true C_D can be estimated only through repeated observations, but those observations (flow calibrations) will have uncertainties associated with them. The observed C_D, therefore, equals the true C_D plus an attendant uncertainty band. The error on the estimated discharge coefficient, C_D, is reduced to zero as the number of flow calibrations approaches infinity.

Since there are not an infinite number of flow calibrations, we must consider the contribution of the finite sample size to the combined uncertainty. Note that this allowance, formerly referred to as precision, is a factor that is often neglected in the "two-sigma" uncertainty calculations provided by ill-informed or inexperienced. It is necessary, however, because it accounts for the finite size of the sample.

For the calibrations shown, the standard uncertainty of the data is ± 0.243% and consideration for the small sample is ± 0.037%. Together, this provides a combined uncertainty of ± 0.246%, which, in turn, results in an expanded uncertainty of ± 0.482% at a 95% confidence interval.

LVM Uncertainty without Flow Calibration

± 0.482%

Uncertainty is a calculated value, not an opinion. The method outlined above is the correct approach; anything else is sales talk.

WYATT ENGINEERING
Intelligent Flow Measurement

ISO 9001:2015 Quality System CERTIFIED

2014 / 68 / EU
Pressure Equipment Directive