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TECHNICAL INFORMATION Bulletin

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CAPACITY MEASUREMENTS IN THE FIELD

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Accurate field measurement of capacity can be exceedingly difficult. Factory test labs are carefully designed by specialists to insure high accuracy, but field installations are rarely if ever designed around the requirements for running a field test. The amazing fact is that there are not *more* complaints based on field tests and one can only conclude that many tests shown the pump to be better than the guarantee. Customer engineers who run field tests often ignore even the most simple considerations in capacity measurement. For example in one job the penalty was $10,000.00 per point of efficiency and capacity was measured volumetrically in a large concrete reservoir where the dimensions of the reservoir were assumed to be exactly equal to the dimensions on the construction drawing. Nevertheless, there can be and are field tests run by qualified people with proper instrumentation which yield accurate results. For example P.G. & E. has run over 100,000 field tests on deep well pumps; their results for the most part have performed a valuable service to both user and manufacturer alike.

The pitot tube is perhaps the most versatile field test instrument. We will discuss it first and then cover propeller meters, venture meters, orifices and weirs.

PITOT TUBES

The experiments of Henry Pitot in 1732 contributed heavily to the work done by Bernoulli, who published the famous Bernoulli equation in 1738.

In these experiments, Pitot showed that when a small tube was placed in a flow with the open end facing upstream, the liquid in the tube rose above the free surface a distance of $\frac{V^2}{2g}$.
This work represents the foundation on which we have built a large variety of flow measuring devices.

Today the term "pitot tube" usually refers to a combination device, that is, one which measures not only stagnation pressure but also static pressure. In more accurate terms, the device should be called a "pitot-static tube."

The pitot tube in general has the following advantages as a field instrument:

1. Usually easily installed.

2. Instrumentation is very simple and requires only the tube itself plus a differential gage.

3. Tube is easily transportable.

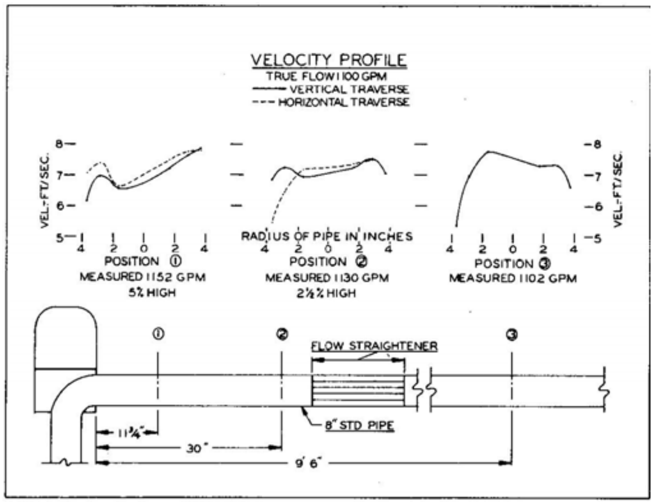

Figure 1

4. Tube is particularly useful in obtaining velocity profiles which can be used as a graphical check on the accuracy of the capacity measuring procedure. For example Figure 1 shows three different velocity profiles which illustrate that the profile for position three (which most closely follows the theoretical profile for smooth flow) produced the most accurate results. Position one, which was the point of measurement adjacent to the pump discharge, shows an unusual velocity profile due to the elbow and produced the least accurate measurement (5% high).

5. Many pitot tube designs are insensitive to the angle of yaw so that even though the tube is not exactly facing upstream, very little if any correction is needed.

6. Considerable research has been devoted to the design of pitot tubes so that good designs are readily available. Perhaps one of the best references along these lines is the paper written by Professor Folsom entitled “Review of the Pitot Tube,” read before the ADME Fluid Meters Research Committee in 1955.

7. Cost of manufacturing a pitot tube is reasonable when compared to other flow measuring devices.

8. The accuracy of a calibrated pitot tube in terms of a field test instrument is probably as high, if not higher than any form of field test instrument. When properly applied, a calibrated pitot tube is probably within plus or minus 2% accuracy.

There are some disadvantages to the use of the pitot tube for field purposes:

1. Because of the relatively small holes used to measure static pressures, most tubes cannot be used where there is a great deal of suspended matter in the fluid.

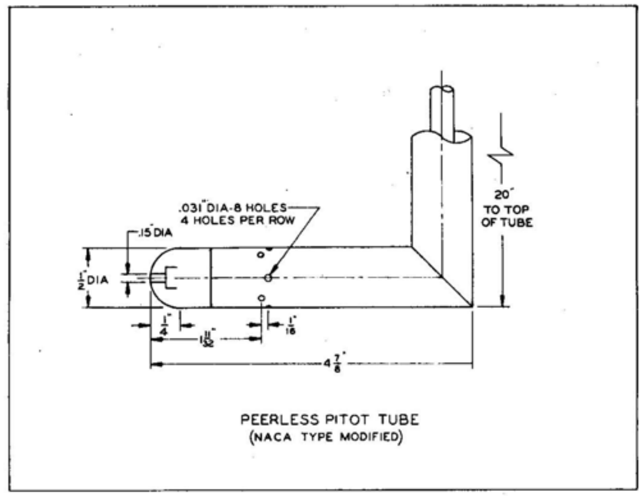

Figure 2

2. Where multi-point readings are taken, heads and therefore capacities can vary with time, thus detracting from the accuracy of the readings. Some tubes avoid this by using single readings which can be quickly made along with other readings such as power and head. However, single setting pitot tubes using a series of impact hoses do not necessarily reflect an average velocity and should be used with caution.

3. Calibration of a pitot tube when used near a free surface of a liquid is not normally available, so that in the case of pump testing, a full pipe of water is required to obtain reliable results.

Peerless has found the pitot tube to be a most useful field device. The tube used is shown in Figure 2. Figure 3 shows the location points of the nose of the pitot tube for a multi-point traverse. Figure 4 shows the calibration curves for various pipe sizes.

TRAVERSE DATA TO BE USED WITH V3529c PITOT TUBE

	5 " O.D. 4.696" I.D.		5" STD. 5.047" I.D.		6" O.D. 5.672" I.D.		6" STD. 6.09" I.D.		7" O.D. 6.652" I.D.		7" STD. 7.023" I.D.	
*	r_n	SC.RD.	r_n	SC.RD.	r_n	SC.RD.	r_n	SC.RD.	r_n	SC.RD.	r_n	SC.RD.
1	2.03	14.41	2.18	13.99	2.45	13.49	2.64	13.08	2.88	12.56	3.04	12.24
2	1.18	15.26	1.26	14.91	1.42	14.52	1.52	14.18	1.66	13.78	1.76	13.52
3	1.18	17.61	1.26	17.44	1.42	17.36	1.52	17.21	1.66	17.10	1.76	17.03
4	2.03	18.46	2.18	18.35	2.45	18.39	2.64	18.31	2.88	18.32	3.04	18.31

	8" O.D. 7.628" I.D.		8" STD. 8.071" I.D.		9 " O.D. 8.608: I.D.		10" O.D. 9.582" I.D.		10" STD. 10.021" I.D.	
*	r_n	SC.RD.	r_n	SC.RD.	r_n	SC.RD.	r_n	SC.RD.	r_n	SC.RD.
1	3.48	11.46	3.68	10.95	3.93	10.32	4.37	9.57	4.64	8.93
2	2.70	12.24	2.86	11.77	3.04	11.21	3.38	10.56	3.60	9.97
3	1.56	13.38	1.65	12.98	1.76	12.50	1.96	11.98	2.08	11.49
4	1.56	16.50	1.65	16.28	1.76	16.01	1.96	15.90	2.08	15.65
5	2.70	17.64	2.86	17.49	3.04	17.29	3.38	17.32	3.60	17.17
6	3.48	18.42	3.68	18.31	3.93	18.18	4.37	18.31	4.64	18.21

	12" O.D. 11.514" I.D.		12" STD. 12.09" I.D.		14" O.D. 13.25" I.D.		16" O.D. 15.25" I.D.	
*	r_n	SC.RD.	r_n	SC.RD.	r_n	SC.RD.	r_n	SC.RD.
1	5.38	7.56	5.66	6.90	6.19	5.75	7.12	3.82
2	4.55	8.39	4.78	7.78	5.23	6.71	6.02	4.92
3	3.52	9.42	3.70	8.86	4.05	7.89	4.66	6.28
4	2.04	10.90	2.14	10.46	2.35	9.59	2.70	8.24
5	2.04	14.98	2.14	14.71	2.35	14.29	2.70	13.64
6	3.52	16.46	3.70	16.27	4.05	15.99	4.66	15.60
7	4.55	17.49	4.78	17.35	5.23	17.17	6.02	16.96
8	5.38	18.32	5.66	18.23	6.19	18.13	7.12	18.06

r_n = Distance in inches between station location and center of pipe.

SC.RD. = Scale reading in inches.

*Number of readings required for transverse

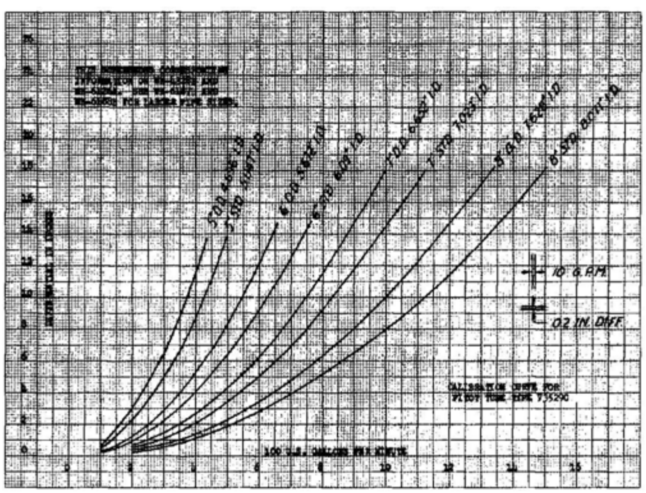

Figure 4

VELOCITY METERS

A velocity meter is one whose rotating element is kept in motion by the direct movement of the fluid stream. One type is the so-called propeller meter. It is not recommended as a field test device, but is mentioned here because propeller meters are in widespread use. These devices are usually geared to some type of revolution counter to indicate either rate of flow or total flow. Of all the instruments available for field capacity measurement, this is probably the least accurate. Most often these meters are installed just beyond an elbow or other flow disturbing fitting. It has been found that any spiraling of liquid as it enters the meter would probably have an appreciable effect on the accuracy of the meter. Also, a marked departure from a uniform velocity distribution may affect accuracy. The ASME Fluid Meters Report recommends the following precautions, many of which are not found on most installations:

1. Propeller meters should be preceded by a sufficient length of straight pipe to yield uniform flow or use flow straighteners.

2. In addition to the above, the meter should be calibrated in the installation in which it will be used or in a model of the installation.

Other precautions involve the problem of protecting the meter against entrained materials as well as wear. And finally, if there is air in the water, the meter will fail to see the difference between water and air, and will thus give a false reading.

VENTURI METERS

A venturi meter is composed of a converging section, a short constricted section and then a diverging section. The object is to accelerate the fluid and temporarily lower its static pressure. The general shape and equation are shown in Figure 5. Since this measuring device is normally made by a company specializing in this type of instrument, the coefficient can be furnished by the manufacturer. Some comments are in order about this coefficient as a guide to field use of the venturi meter:

1. The coefficient drops rapidly at low velocities as that care should be taken to avoid very low flows.

2. Pipe roughness in the approach pipe will tend to increase the coefficient, while roughness in the converging cone decreases the coefficient.

3. For high precision, a meter should be calibrated from time to time.

4. When installing a meter, it should be preceded by a run of straight smooth pipe.

In addition to having an accuracy of plus or minus ¾%, it has the advantage of low head loss and is therefore useful in both test labs as well as large field installations where head loss represents a large power cost.

NOZZLES

The ASME long radius flow nozzle is also described in Figure 5. Nozzles are generally designed to be clamped between the flanges of a pipe and are essentially the same as a venturi tube, except the diffuser cone found in the venture is omitted. Therefore, a nozzle has greater losses than a venturi meter, although it has a lower initial cost to offset this.

Extensive research on various types of flow nozzles has been sponsored by the ASME and I.S.A. and data on coefficients with examples can be found in the ASME Report on Fluid Meters. Although the coefficients are constant over a wide range of flows, care should be taken not to use the orifice at excessively low capacities because the coefficient reduces at low Reynolds numbers. In general, the same precautions about installation, change in coefficient with pipe roughness, and other field factors which apply to the venturi tube, also apply to the flow nozzle.

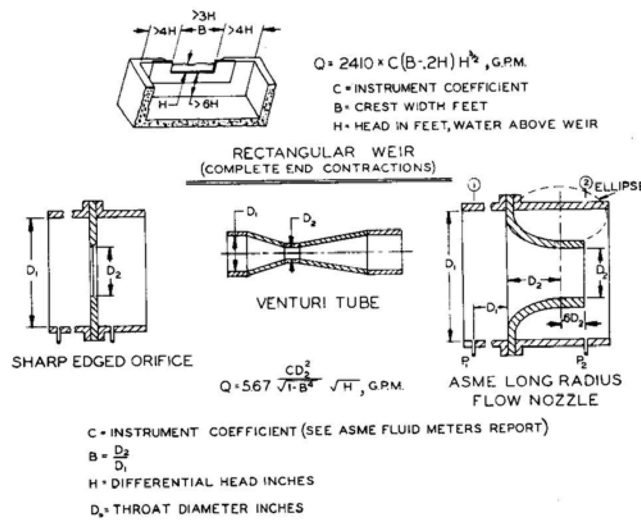

Figure 5

ORIFICES

The orifice is possible one of the oldest devices used for measuring the flow of fluids and dates back to Caesar's time. A so-called sharp-edged orifice is sometimes used on fluid tests by placing the orifice at the end of the pipe and recording the pressure upstream from the orifice. There are other types of orifices used and the description and applications are amply covered in the ASME Fluid Meters Report. This ASME report includes a great deal of valuable data on the coefficient for various factors such as Reynolds number and general configuration of the orifice.

Because the orifice meter dissipates head to a large degree, it should never be installed as a permanent fixture in the discharge line. For example an orifice with a throat to main diameter ratio of 0.7 will dissipate as much as 51% of the head available. For this reason, an orifice has limited use in field testing.

WEIRS

For measuring flows in open conduits, weirs find wide application in both the lab and the field. They are relatively simple to make, but along with their physical simplicity goes an exceedingly complex flow problem which does not lend itself to rigorous theoretical solution.

For best accuracy, a weir should be calibrated in place, since poor velocity distribution can have an appreciable effect. Effort should be made to provide a good length of approach channel with stilling devices such as racks or screens to prevent abnormal velocity distribution and turbulence. The weir must be normal to the flow, the crest level and the face vertical.

Perhaps the most commonly used weir, is the rectangular contracted weir also shown in Figure 5. The coefficient of a weir and thus its accuracy is subject to variations due to the following factors:

1. Relative sharpness of the upstream edge of the weir.

2. Roughness and velocity in the upstream channel.

3. Length of approach channel and also exact configuration of the weir itself.

Once a proper weir is constructed, the critical item is the proper measurement of the head. A hook gage is commonly used although other methods can be used. Regardless of the method used, the measurement should be made at a distance upstream at least four times the head reading. This will insure that the surface is undisturbed by the reading.

In general, there is no substitute for the accuracy obtainable in a test lab. Where it becomes necessary to run field tests, great care must be taken in the selection of the measuring device, the location of the device, the technique in using the device, and finally the analysis of the results.