How Larger Flow Meters Speak Volumes

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Water is money. The price of water is increasing all over the world. As a result of these price increases it is necessary for the water industry to have the most accurate methods of flow measurement available. In large distribution networks flow meters over 48 inches in diameter measure tremendous volumes of water and with this size the smallest errors will be magnified. Meters in these large diameters are a challenge to calibrate because there are few suitable facilities able to accommodate them. This paper presents the different types of calibration and accreditation methods used to explain how volumetric flow measuring accuracies are achieved and certified.

Accreditation

One of the best methods to ensure that a measurement is accurate is through calibrating the primary measuring device on a calibration rig. Accreditation is the independent evaluation of conformity for that calibration rig against recognized industry standards. Certifying the accuracy of the calibration rig should only be done by a recognized entity to ensure compliance.

Each country has their own organization responsible for accrediting calibration facilities. For the US most people think that the National Institute of Standards and Technology (NIST)[1] calibrate facilities. Actually, the NIST does not directly accredit calibration facilities but oversees a separate program known as the National Voluntary Laboratory Accreditation Program(NVLAP)[2]that provides third-party accreditation to testing and calibration laboratories.The NVLA P accredited laboratories are assessed against the management and technical requirements published in the International Standard, ISO/IEC 17025:2005[3].While accreditation to ISO/IEC 17025:2005for calibration rigs is claimed; this requirement only certifies the competence of laboratories and personnel but does not actually accredit or certify the calibration rig itself.

Depending on the location, the actual calibration rig accreditation comes from that individual country's metrological organization. These accreditation bodies established in many countries are subject to oversight by an authoritative body. The International Laboratory Accreditation Cooperation (ILAC)[4] is an international cooperation of laboratory and inspection accreditation bodies. It was formed more than 30 years ago and each of its member organizations are evaluated by peers for acceptance to ensure conformity of products and services to support international trade. For example, the

[1] NIST: www.nist.gov)

[2] NVLAP: http://www.nist.gov/nvlap/

[3]ISO 17025:http://www.iso.org/iso/catalogue_detail.htm?csnumber=39883

[4]ILAC:www.ilac.org

United Kingdom Accreditation Service (UKAS) is equivalent to the Swiss Accreditation Service (SAS), and both are comparable to the American Association for Laboratory Accreditation (A2LA) in the United States and the Raad Voor Accreditatie (RvA) in the Netherlands.

So how would a flow meter user know if their measuring device has been calibrated to the stated accuracy by an accredited calibration facility? A user can determine this by looking at the flow meter manufacturer's[5] calibration facility accreditation organization to see if it is registered as a member of ILAC. Then the user must also verify that all available meter sizes have been calibrated.

Flow Meter Calibration Methods

Now that accreditation and competence has been discussed let's look at some of the actual calibration methods used. Most manufacturers use one of the two available methods. They use either the master meter method or the direct volume comparison method.

Master Meter Method

A master meter is a unit which has had its measurement performance proven by a recognized standard for the purpose of being used as a calibration device. Normally, these meters are highly accurate and stable but must be verified and periodically recalibrated to ensure their performance remains valid. Calibration rigs using the master meter method can achieve accurate calibrations. However, there are greater uncertainties with this method. If there are any uncertainties with the calibration rig then these uncertainties will be passed along to the meters they are calibrating. Also, in order to be truly effective the master meter should be comparable in size to the meter under test. For example, calibrating an 84 inch meter with a master meter of 42 inches cannot achieve ample volumes or velocities for calibration.

[5] KROHNE's calibration rig accreditation certificates are available from their website's download center.

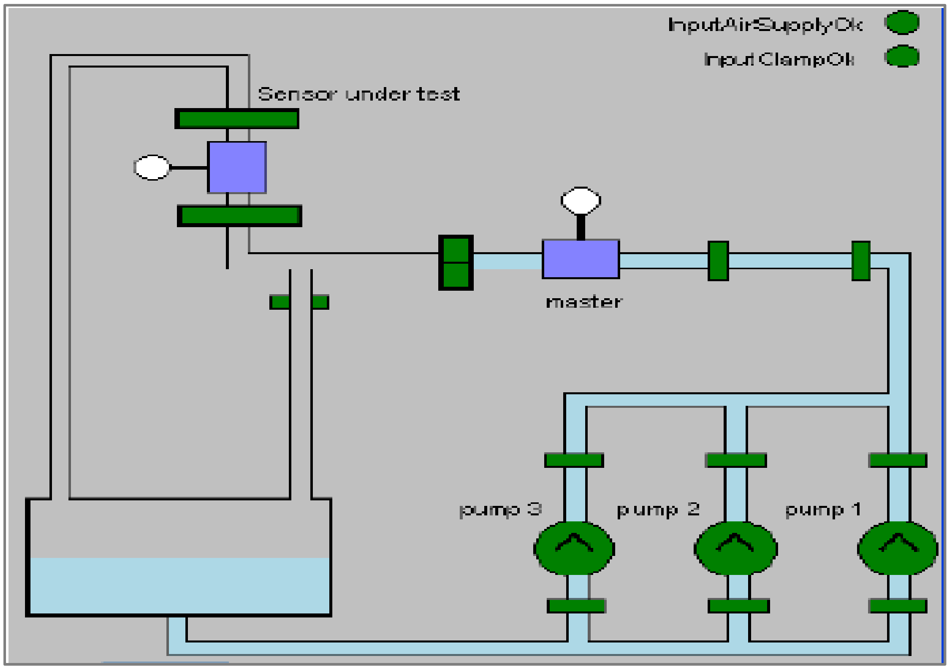

Figure 1 Block Diagram of a Master Meter Calibration Rig

Direct Volume Comparison

The other most commonly used calibration method is by direct volume comparison. This can be done with the use of a prover, a tower, or a tank. This method involves passing a known volume of liquid though a meter, recording the meter's output (usually a pulse per volume count), and comparing it to the known volume of the chamber used for the calibration.

On a prover, the flow is timed by use of high accuracy switches. The first switch is activated upon the piston or ball passing and the second high accuracy switch is activated when the piston passes it. Measurement of the meter's flow is compared to the known volume of the prover chamber and a meter factor, or a calibration factor is developed. This calibration method is widely used and accepted. These provers must be calibrated (water drawn) each year. The uncertainties of provers are normally lower than those of the master meters because the volume of the chamber is verified directly.

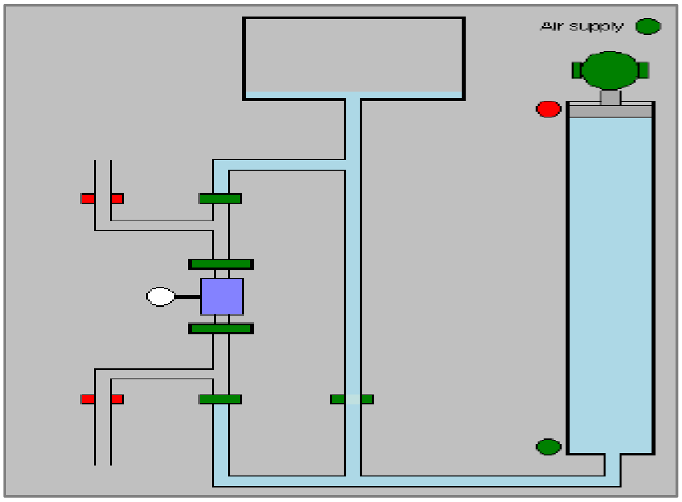

Figure 2 Block Diagram of a Piston Prover Calibration Rig

The final direct volume method to discuss is the tower or tank calibration. Much higher volumes of liquid are normally available for calibration with this method, although it can also be scaled down for use with very low liquid volumes for small diameter meters. Like in the piston prover, high accuracy switches are used to identify the precisely known volume and flowing time between two points of level in the tank or tower. This volume and flow rate is compared to the total reported on the flow meter being calibrated and a meter factor, or calibration factor is determined. Tank calibrations utilize the same methods but measurements between the switches is recorded while filling the tank rather than by emptying it.

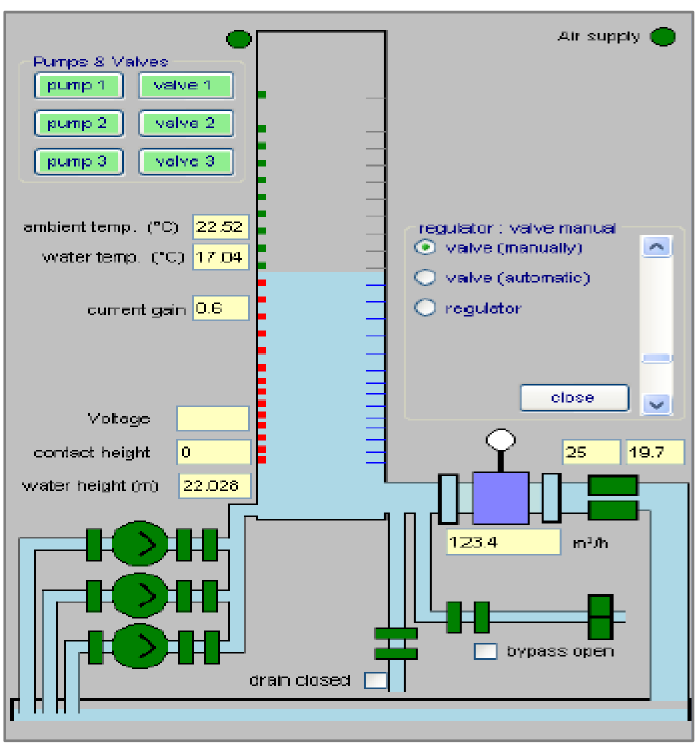

Figure 3 Diagram of a Tower or Tank Calibration Device

Manufacturers such as KROHNE boast towers as large as 144 feet (44 meters) tall and 13 feet (4 meters) in diameter for direct volume calibration of large diameter meters. These towers can flow over 130,000 gallons per minute (gpm) (1/2 million liters) of water for several minutes during calibration.

The Challenge of Large Diameters

Why is calibration important to a design engineer or an end user? In a nutshell, accuracy equals money. For the purpose of this discussion we will consider large diameter magnetic flow meters.

A magnetic flow meter is actually a velocity device because it measures the velocity of the conductive fluid product passing through a magnetic field. As it travels through this field, the fluid's velocity creates a proportional induced voltage at two electrodes in the meter. The volumetric flow rate is determined by multiplying the fluid velocity by the cross-sectional area of the measured section. Most of the time, with large diameters, the meter's size is selected to operate at about 10 to12 feet per second (fps) for the maximum volumetric flow rate.

Magnetic flow meter accuracy is normally stated as a function of measured value or rate of flow. For example, a small meter with a stated accuracy of 0.5% measuring a flow rate of 200 gpm can be reasonably expected to be within 1 gallon. However, a large diameter meter with that same stated accuracy measuring a flow rate of 100 million gallons per day (mgd) is expected to be within .5 mgd or 34,700 gallons.

A calibration done to a smaller diameter meter can be readily done at the expected maximum velocity and therefore there is high confidence with the measurement throughout the full performance range.

You would agree that if a large diameter meter is selected to measure flowing velocities ranging between 7 to 12 fps, a flow rig with the ability to reach those velocities should be used for that meter's calibration. However, if that meter can only be calibrated at 10 or 20% of that velocity range, would you have the same high degree of confidence in its performance?

Let's consider a 72 inch flow meter with a maximum flow rate of 125 mgd or 86,800 gpm. This equates to a flowing velocity of 6.8 fps. This doesn't sound like an unreasonable velocity for calibration, but you may be surprised to learn that most magnetic flow meter manufactures cannot achieve near this velocity on this size of meter.

As mentioned earlier, in order to produce a recognized calibration certificate, each flow meter manufacturer's calibration rig should be accredited by a recognized agency. The accreditation certificate will list the total volume and the sizes of the calibration rigs. The certificate also lists the verified uncertainty of the calibration rig.

A brief summary of the published accreditation certificates of several manufacturers of large diameter flow meters is found in Table 1. They show the flowing velocities available to calibrate large diameter meters. These figures are based on a 72 inch diameter meter.

Table 1 Manufacturers' Maximum Available Calibration Flow Rates for 72 Inch Meter

MANUFACTURER	72" VELOCITY (fps)	RIG MAX FLOW RATE (gpm)	% OF FULL SCALE 125 (mgd)
A	3.50	44380	51.13%
B	4.16	52840	60.88%
C*	10.62	134727	155.22%
D**	10.62	134727	155.22%
E	1.99	25230	29.07%
F	3.47	44029	50.72%

Table 2 shows the largest diameter meter each manufacturer has accreditation of calibration for, along with the velocity which can be achieved. The rightmost column in this table shows flow rates for the largest common diameter from each manufacturer, and the velocities they have available for calibration.

Table 2 Table 1 Manufacturers' Maximum Accredited Meter Sizes and Flow Rates

Manufacturer	Rig maximum flow rate (gpm)	Max.diameter (Inch)	Max. calibrated velocity (fps)	Velocity (fps)in 84" meter
A	44380	86	2.45	2.57
B	52840	96	2.34	3.06
C*	134727	120	3.82	7.80
D**	134727	120	3.82	7.80
E	25230	84	1.46	1.46
F	44029	84	2.55	2.55

Demonstrated Measurement Uncertainty

When reviewing the calibration rig accreditation certificates, the remaining important factors to be considered are the Combined Measurement Capability (CMC) or the Best Measurement Capability (BMC) of each calibration rig.CMC or BMC are the percentage of uncertainty in which there is 95% confidence in the measurement. This is a statistical measure which states that in more than 95% of the occurrences the calibration will be within the stated certified accuracy in the CMC or BMC columns.

Interestingly, Table 3shows a wide variability in these stated factors. The accreditation of the calibration rig on which the meter is calibrated should not be overlooked. If the calibration rig is accredited to be 5 or 10 times better than the target accuracy of the calibrated meter, there can be a higher confidence in that meter's performance.

Table 3 Published Calibration Rig Accreditation CMC/BMC factors.

Manufacturers	A	B	C*	D**	E	F
CMC /BMC	0.17%	UNK	0.02%	0.02%	0.05%	0.15%

Conclusion

When selecting a large diameter flow meter, one should also take into consideration the calibration rig. The accreditation of that rig should demonstrate that the meter will be verified and calibrated to address the complete flow measurement range with a high degree of confidence when installed in accordance with the recommended upstream and downstream piping straight runs.

KROHNE towers above the others when it comes to calibration. KROHNE has the largest calibration facilities with the best combined measurement capabilities in the world.

Calibration Facilities shown in tables above:

C* KROHNE ALTOMETER calibration facility Dordrecht, The Netherlands
D** KROHNE/KMTS Calibration facility Shanghai, China

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