Flow Measurement In Refineries: A Short Summary

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In order to make material and energy balances it is mandatory to be able to measure the amount of oil and gas imported and product exported in any hydrocarbon facility. This difference is the refinery loss and world-class benchmarked installations have figures well below 0.5%. There are many ways to measure flow and these have been classified by BS EN 7405 (1991) according the basic technology used.

Crude Oil inlet (American PD meters shown)

Light hydrocarbon blending station

In North and South America, DP meters seem to dominate the gas side, with displacement and turbine meters being used for liquids. This is largely historical because API, ASME and other standards from the USA dominate the industry in this part of the world. When I first went to work in the USA in the early 1980s, orifice plates ruled! In the large chemical company where I was Staff Engineer and Senior Flow Technologist, there were more than 1500 plates of differing sizes in one plant alone. I was responsible for developing the corporate standards for metering. I am proud to say the use of Coriolis meters for hydrocarbons was pioneered by me in 1981. I have many stories to tell about the rapid development of this technology from 1982 to 1990. Coriolis technology is an ideal way to measure hydrocarbons in refineries and I am happy to see my first attempts have led to many successful applications all over the world on many fluids.

Returning to the orifice plate (and DP meters generally), these are not as stable as many people believe. I recently was asked to perform a test in a 16 foot Venturi tube in the USA and found the wall pressure can vary significantly from one side of the pipe to the other. Standards say this does not happen but my research work questions this statement very seriously.

The simplicity of orifice plates is the key to its long life in process applications and its enduring popularity especially in North America. However I have been able to show that same simplicity can significantly undermine its accuracy, as fluid dynamics, surface deposits and the presence of droplets or particles in gas stream and gas bubbles in liquid stream increases measurement uncertainty. The ability to be stable over time is a significant question mark in my opinion and standards do not address this adequately.

Recently I was in South America at a major oil refinery and was asked to review all the metering throughout the installation. The initial survey took 5 days and the draft report ran to 50 pages! My study looked at crude oil and natural gas imports and then on the downstream side at refined petroleum products, LPG and heavy hydrocarbon fluids. Very many installations were orifice meter based and almost everything I saw was at least 20 years old, with the exception of one installation. Two pictures below show the crude oil inlet terminal and one of the product blending stations (this is less than 3 years old).

Crude oil inlet (American PD meters shown) Light hydrocarbon blending station

PD meters require clean fluids so the station inlet is fitted with filters and air eliminators making the pipework unnecessarily complicated. The orifice station shown above right is designed to US standards. Inlet lengths really should be longer and the product quality will be directly affected by the condition of the orifice plate itself. I understand this is not checked regularly. The DP cells also require recalibration and adjustment every 30 days, making the whole installed maintenance based.

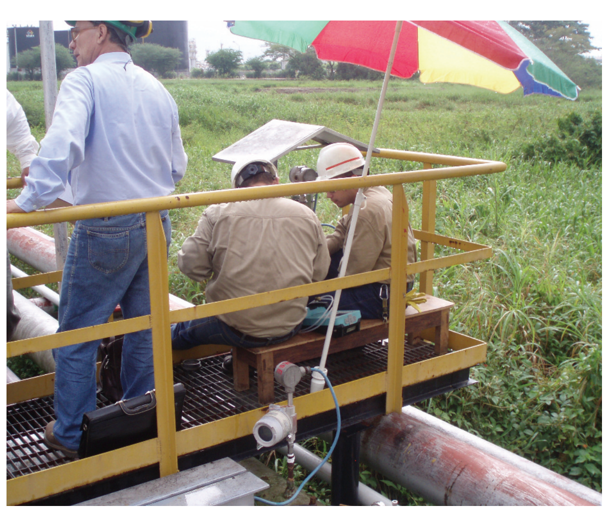
Many people are not aware that the condition of the orifice plate face directly affects its accuracy. Also the sharpness of the edge requires special attention. If solid particles are present, these can cause edge rounding: a 0.1mm rounding is equivalent to a 1% error in metering, with the orifice plate reading high. Surface effects are equally damaging. A covering of grease or oil over 25% of the surface raises the measurement by around 1%. Below (left) is one of the many orifice plates examined. Uncertainty here is completely unknown. In the middle is a routine DP Cell calibration: performed even though the plate is never pulled and examined! Finally a twin sensor vortex meter is shown. This is a better option for the future.

Typical process orifice plate In-situ calibration of DP cell New twin sensor gas meter

Metering stations such as those earlier above represent, in my view, the old approach to metering in refineries. For gas measurement, vortex or ultrasonic technology is more accurate and certainly more stable over time. For small gas flows to boilers for example, a vortex meter is now a good way to measure boiler efficiency and I am recommending a refinery wide introduction of this technology in place of the orifice meters for the South American installation I have audited. The existing plates are rarely checked anyway so the actual amount of gas going into the boiler is not known for certain.

Typical process orifice plate

New twin sensor gas meter



In-Situ calibration of DP cell

Poor design of LPG meter installation

Modern inlet mass meters used for fiscal applications

However even when a newer technology is chosen, the user needs to be careful of the design of meter offered by the supplier. Take LPG metering for example. During my recent audit work, I came across an LPG meter shown below left. This design and the installation actually increase the possibility of flashing (where the lighter fractions present in the LPG come out of solution). Note the inlet contraction where the pipe area is reduced too quickly. The end result is that proving of this meter was very poor. Alongside is a modern approach where the inlet is correctly designed and pressure drop across the meter is lower.

In general, no moving part, in-line and electronically based technologies are better than most conventional meters traditionally found in many refineries. It is quite surprising that old ideas methodologies and standards persist in an industry where accuracy and stability is needed. The newer technologies of in–line Coriolis mass, ultrasonic and vortex provide better accuracy and longer term stability and so represent better value and accuracy than DP, PD or turbine based technologies from the recent work we have performed. Measurement standards always seem to lag behind technological advances and this lag places the user in a dilemma. Again we can advise that new designs and recent applications are strong evidence that older design standards can be dispensed with.