Natural Gas Test Separator Measurement by Differential Pressure Cone Meters (Manufactured to ISO 5167 Part-5 2016)

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1. Multiphase separators can produce bias errors (over three phases) of about 15% - 25% due to various factors. These discrepancies can be due to operator control, vessel stabilization issues, incorrect design due to separator sizing and later the field generating more fluids than process estimates, thus increasing throughput outside of the original design parameters, this can also be an issue. The separator vessel location in respect to the pressure head requirement (on the liquid side of the separator) is also a contributing factor which requires for the produced hydrocarbon fluid vapor pressure to be reviewed during the design stage for the liquid measurement. (See DP meters in a separation system Figure 1.)

2. Orifice meters are very good measurement devices in pipeline applications when used offshore with production flows it may be necessary to perform plate changes to facilitate turndown (production loading) otherwise, the performance of the metering system may be compromised. The use of upstream flow conditioners to reduce straight lengths also adds cost to an orifice system. Measurement quality vulnerability using orifice plates in upstream production separators has been seen in many offshore fields due to incidental damage to the plate beta edge. It is necessary to confirm that the beta edge of the plate is both clean and has not been compromised due to trash or debris collection in the meter tube /stagnation region. Mitigation can be offered on land-based systems by maintenance scheduling however, offshore systems are subject to harsher conditions and accessibility is more difficult on remote systems.

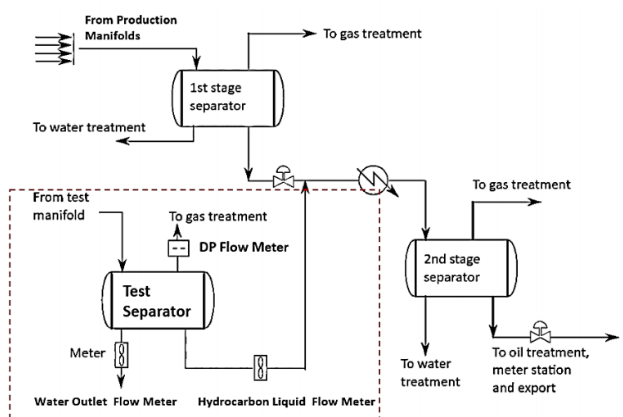


Figure 1. Typical Liquid & Gas Hydrocarbon Separation System.

3. Various other DP meter technologies are available to assist in combating this situation from differential pressure cone meters to venturi meters which are favored in certain international regions. The diagnosis of DP problems is also now available by using recently developed hardware and software combinations.

   This allows real time monitoring of the system allowing maintenance to be targeted at the correct location or metering point.

4. The DP Flow Meters discussed next have been applied in separator gas measurement over many years.

   <u>The Orifice Plate Meter (Standards: ISO 5167-2, AGA 3, API 14.3 - Pipeline Quality Gas)</u>

   The orifice plate itself is a much smaller and lighter device, consisting of a thin plate (1/8 --1/4 in) held between flanges. (See Figure 2. below)

   The pressure taps are situated in the flanges and do not experience a high velocity if operated according to national and international standards. The main feature of the orifice plate is the sharp-edged concentric hole, which makes the flow separate and contract downstream to the "Vena Contractor". This is like the Venturi throat,but formed by fluid streamlines and not solid surfaces. This is a point of interest mentioned earlier were damage or trash can affect the meter performance due to plate geometry changes, nicks, etc. (See Figure 3. Asphaltene Deposition: Source ASME MFC19 Technical Report)

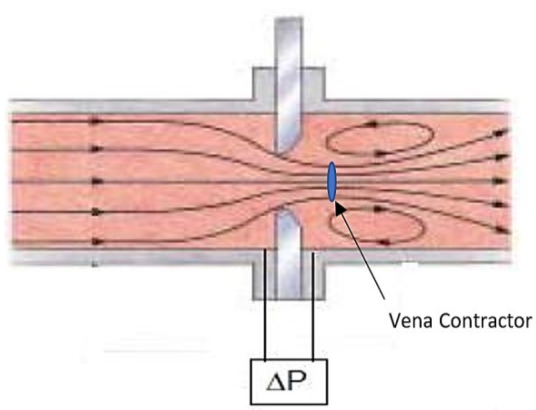


Figure 2. Orifice Plate Meter

Figure 3. Asphaltene Deposition (ASME MFC19)

The orifice coefficient of discharge (CD) = 0.6 usually, which reflects the "Vena Contractor" area being less that the orifice bore area.

The orifice does not have a diffuser and suffers a sudden expansion loss due to the shape, but despite this it has almost displaced the Venturi because of its simplicity in single phase flow applications in the USA.

The sharp edge is sensitive to damage and this led to the introduction of an orifice fitting that allows the orifice to be taken out of the line under pressure to examine the sharp edge.

The sharp edge however is not good with erosion, making the orifice less desirable for upstream applications where maintenance visits are not regular or easy, it's not good for multiphase flow, but it has been used in wet gas with certain wet gas algorithms to try to predict performance change.

The standardized orifice plate is available with beta ratios (β) from 0.2 to 0.6 to meet the 0.5% uncertainty of CD, as is mentioned in international standards operating on pipeline quality gas applications only.

Orifice primary elements are available in varying materials however stainless steel is commonly used in most devices for corrosion resistance. However as previously mentioned the stagnation region can attract asphaltene deposition and the device can cause a liquid hold up condition.

The Venturi Meter (ISO 5167-4)

The Venturi meter is a flow measurement instrument which use a converging section of pipe to give an increase in the flow velocity and a corresponding pressure drop from which the flow rate can be deduced. They have been in common use since early 1800's. In a Venturi meter, the flow velocity is measured by comparing pressure differences between the inlet and the throat of the device Figure 4.0 shows the original idea. The pressure recovery is very efficient and region is of interest for wet gas measurement application calculations. Coefficient of discharge is app.0.9, the meter has been used in separation applications in Europe, it also needs some straight run to function accurately.

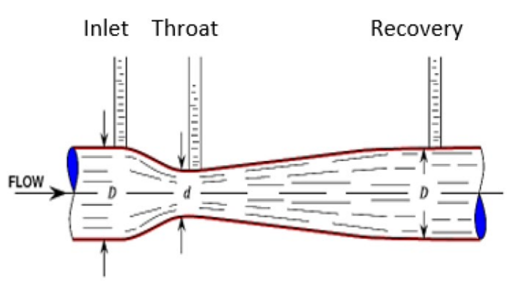


Figure 4. Venturi Meter

The Differential Pressure (DP) Cone Meter (Per ISO 5167-5 Issue 2016)

The DP cone meter is effectively an annular Venturi without a diffuser and the low-pressure tap is in the central base of a cone system comprising of 2 cone frustums (one large and one small) which define a beta edge boundary between the inner pipe wall, the meter has inherent flow conditioning abilities due to the design which suits offshore applications well !

The low-pressure tap (P2) is situated where it does not experience a high velocity or an erosion component with the static pressure derived at the pipe wall (P1) (See Figure 5. Horizontally Mounted Application)

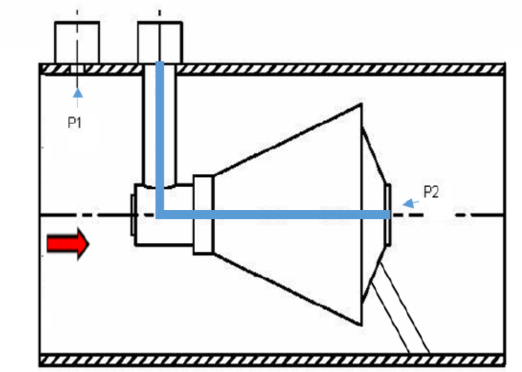


Figure 5. Horizontally Mounted Cone Type Meter (Normal)

The DP cone meter is available with beta ratios (β) from 0.45 to 0.75 (0.85 usually a special application) The American Petroleum Institute (API) chapter 22.2 DP test protocol, describes a method for performance type testing of these meter types and designs. Coefficient of discharge for these devices is slated as being 0.85 however this depends on the accuracy of the manufacture.

The International Standards Organization standard for this device (ISO) 5167 Part 5 was finally released in 2016 and details how this meter is used in custody transfer measurement applications with certain agreed factors, conditions and basic design criteria required to meet the standard. Cone meters have been used in separator applications in the Gulf of Mexico, North Sea, and other areas since the 90's, as of late they have been used in multiphase and wet gas applications as a primary element in such meter designs even sub-sea applications are available but special in nature.

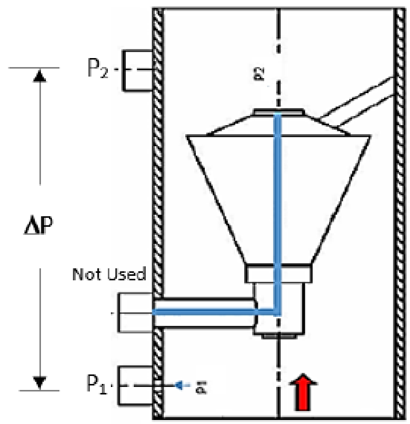


Figure 6. Vertically Mounted Cone Meter (Special)

Reducing Platform (Jacket) Weight and Increasing Available Space

Orifice fittings require up and downstream pipe lengths to 30 diameters in certain cases, this adds weight to the offshore platform jacket construction. Fabricators usually cost offshore support structures based on dollars per pound weight for the jacket structure when estimating a budget costing.

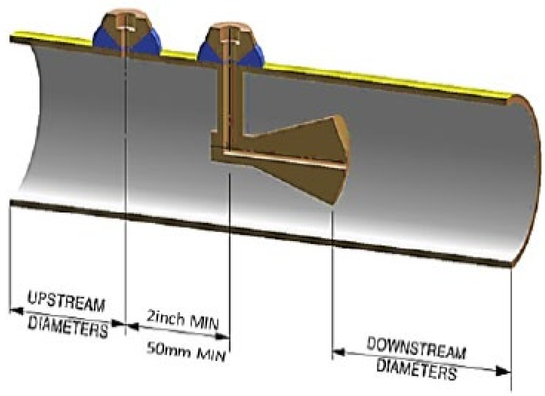
Current weight penalty costs in the Gulf of Mexico can be from app. 15$ per pound to 30$ per pound depending on materials of construction and complexity of the design. Installing a gas measurement system including all piping requirements and a cast carrier can amount to high dollar amounts in platform support requirements, this can be compounded on deep water platforms and say platforms in the North Sea.

Therefore, by using a cone meter on a platform with its lower installed weight and reduced up-downstream piping requirements makes good sense. The cost reductions available from the installation alone can be large. Using this type of DP meter also provides more space to install other equipment further assisting the space requirements (real estate) which we know can be a difficulty on platform structures.

Typical cost saving using a differential pressure cone meter install versus orifice run skid:

Orifice run typical 8 inch run with skid support 600Class etc. (say 5000lbs) 5000 x say 20$/lb. weight penalty = 100,000.00 dollars. Using a cone meter which requires minimum straight runs the install cost would be approximately 800 lb. @ 20$ = 16000$ this is a large saving of +80,000$ which can easily be used to pay for the cost of the cone meter plus install and also provide a solid meter for the application. The cost of the skid to support the orifice plate can be 40,000 dollars this is not required for a cone meter so overall the cost savings can approach $120,000 which is great for stretched CAPEX budgets excluding space saving which also is a benefit.

Typically cone meters can be installed with reduced straight runs this is detailed in ISO 5167 - 5. (See Figures 7. & 8. below)



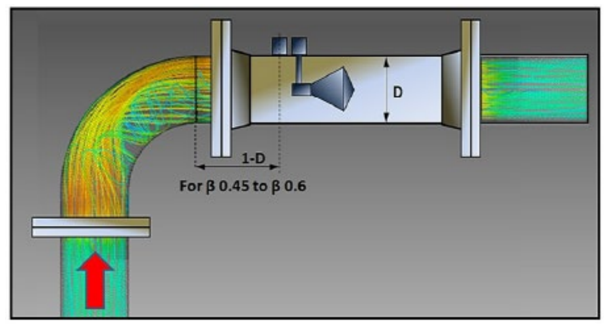


Figure 7. Cone meter straight run location Figure 8. Shortest Run Upstream Diameters

The downstream runs allowed according to the ISO standard is based on thermowell location which is common to all DP meters the standard describes a location at 3D which allows it to be built into the meter body if required. The sample point location should be 5 diameters downstream of anu disturbance and be situated to collect a sample in the middle third of the pipe in line with national and international standards. It is possible to use concentric expanders as detailed in 5167-5 or eccentric have been used this requires calibration with the eccentric expander in place not discussed in 5167-5. Some manufacturers require calibration of the device based on manufacturing / geometric accuracy others may not require it.

The following is a typical example for this type of installation as discussed in the ISO standard:

- Example: A 4" cone meter with a β = 0.75 at 3 Diameters downstream of a ¾ Diameter to Nominal Diameter concentric expander * gives an expected flow rate of error up to 0.3%.
- For cone meters with smaller β ratio values (0.45,0.5) , the error would be expected to be much less.
- In general, a concentric reducer (expander used in opposite direction) produces less significant flow disturbance than an expander. (See Figure 9. below)
- The ISO standard details a 3D location to the upstream tap position however from experience with this type of installation it is sometimes more convenient to measure 3 D from the meter front flange face and also makes sure that the upstream length is met without worry particularly on small sizes where weld interference may occur.

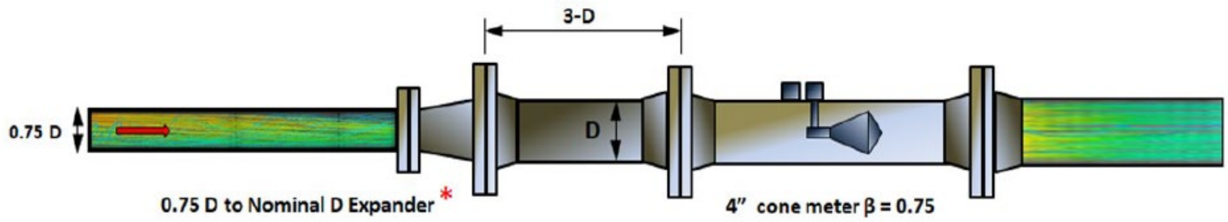


Figure 9. Concentric Expander Installation (ISO 5167-5)

A comparison is shown typically below to illustrate the difference in lengths for installation (See Figure 10.0) The pipework can be re-routed to save space in many instances the piping has to travel vertically to another deck on the platform which is much easier when a small meter footprint is available.

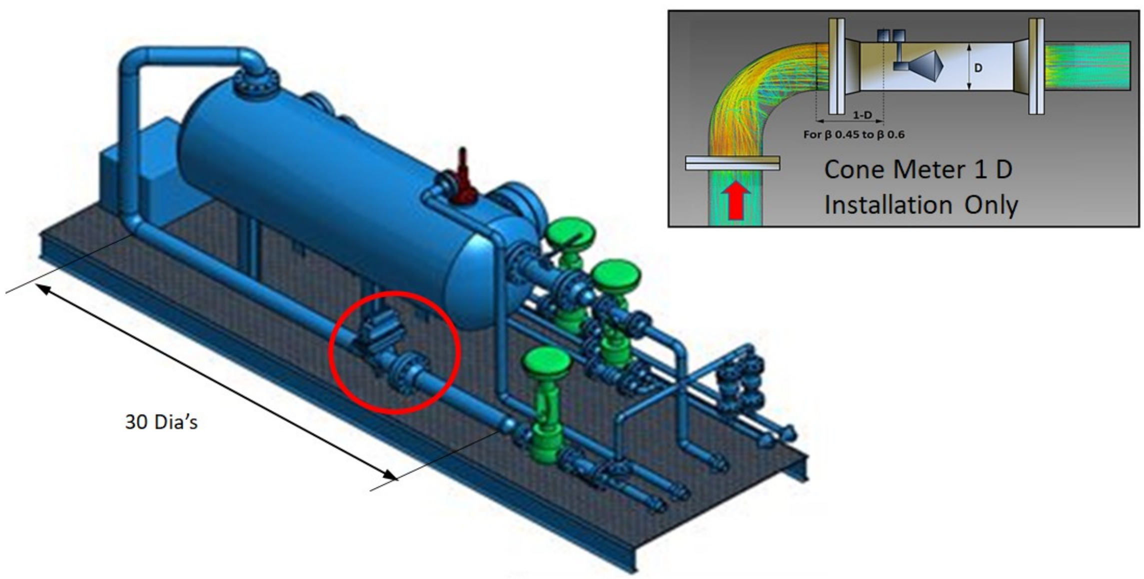


Figure 10. Test Separator Comparison Regarding Installation Length.

One main feature besides the short installation length regarding the cone meter design is the ability to resist ashphatene build up due to the acceleration in the control volume. (area around the cone). This has been seen to move particulate through the meter and away from the measurement section, this has been seen on coal tar gas by one user were the previously used orifice technology had tar deposition which prevented the plate from being removed from the carrier. The beta edge is downstream of the flow and so is not subjected to the same direct forces as per those impacting an orifice plate edge. (See Figure 11. Beta Edge Contour)

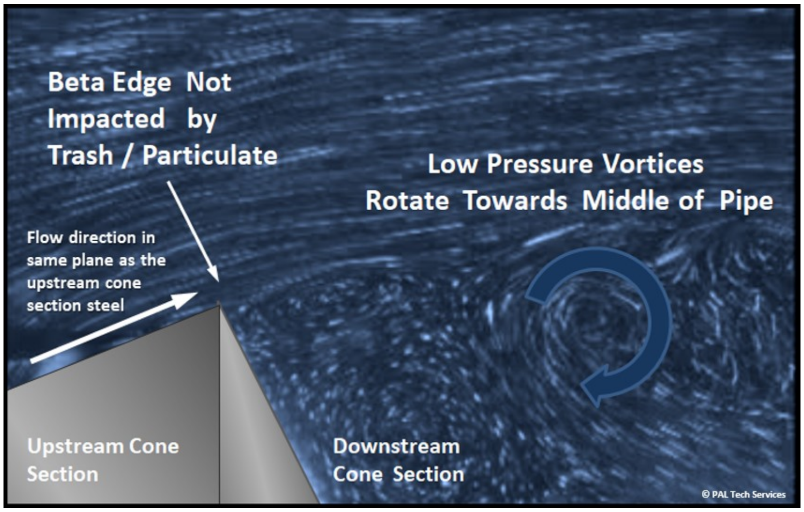
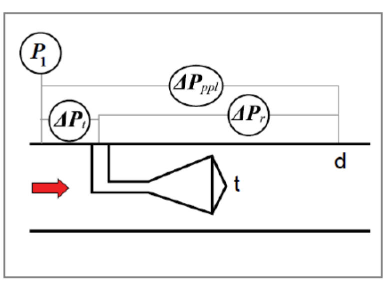


Figure 11. Cone meter Beta Edge Location and Contour

One final discussion regarding recently invented and supplied diagnostic systems for DP meters, this has long been a need within the industry to help provide / maintain good measurement through the ability to read a DP meter's heath and view what is occurring in real time with the DP meter to predict any measurement issues it is available on all the family of DP meters mentioned before for any gas or vapor application including steam quality measurement.

DP diagnostic systems are used with a second pressure tap installed in a downstream section at a 6D location downstream of the rear face of the primary element which by using 2 extra transmitters allows diagnostic info to be sent via SCADA or other systems. The Main MVT transmitter reads the normal primary flow data pressure and temperature for say the custody/allocation flow rate calculations, however 2 extra DP transmitters are installed to measure the recovery pressure (high side at the 6D location) and the permanent pressure loss during flowing conditions at the 6D pressure tapping, (See - Figure 12. & 13) from this data and specific algorithms a diagnosis can be performed regarding meter performance and its fidelity.



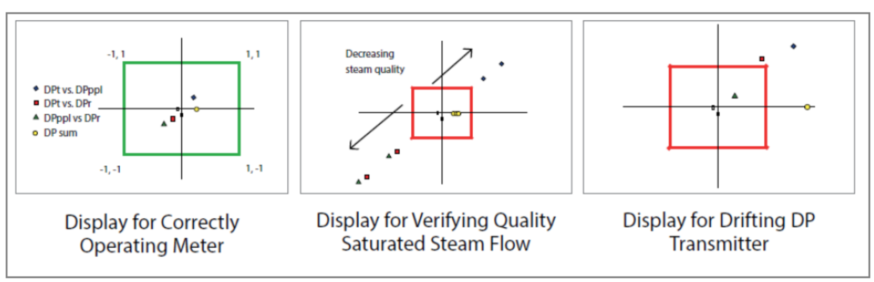


Figure 12. Transmitter Installation Figure 13. Typical Display Showing

Conclusions

Currently there are many installations around the world using cone meters as a primary measurement device on separator outlets many of these were installed before the ISO 5167 part 5 cone meter document was written and they have been operating successfully for years with good results in the offshore environment.

The ISO standard 5167-part 5 document is a great move forward in allowing this type of meter to be used for Fiscal transactions. One word of caution, it is important that the geometry of the cone meter and its assembly is produced with high quality welding procedures and also care and attention to the dimensional accuracy when manufacturing such devices. Removal of welding beads within the meter body were weld neck flanges are used is a factor that from experience is required in providing a solid robust measurement.

The meter having an annulus within the meter body itself assists in allowing liquid droplets to pass the meter without causing a hold up condition.

It is hoped that the cone meter will further develop as a main stay for separator applications based on its differential pressure heritage which many field technicians understand and have confidence in!

References

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