Laboratory Testing of a New Design of Differential Pressure Cone Meter

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Abstract

For many years now there has only been one manufacturer of a differential pressure meter utilizing a sloping double cone system.

The previous device had a secure patent which prevented competition from developing in the U.S. market. The advent of the recent expiration of the patent allows manufacturing of the device to supplement and drive the marketplace.

The technology while simple has traits which allow cost savings to oil and gas applications were space and real estate are of the premium requirement.

This paper will describe the recent dry gas testing of a NuFlo ™ sponsored device that has all the indication of being equivalent in nature to the patented original.

Overview of the metering device

The meter consists of a differential producer fixed concentrically in the center of the pressure retaining pipe by which a differential pressure can be obtained across the interface of two cone frustums via an internal port-way system. This allows the downstream pressure *P2* to be measured in the center of the closed conduit.

The upstream pressure *P1*, being measured at the pipe wall. *(See fig 1.0and 2.0)*

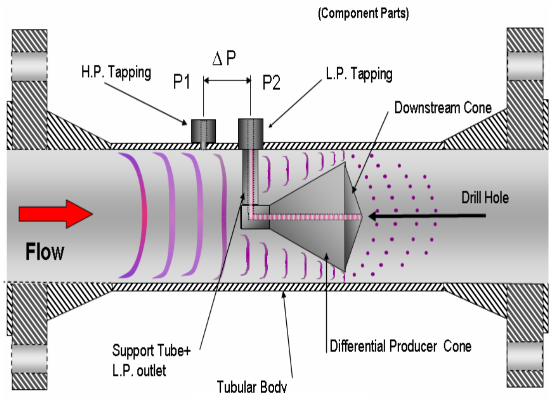


Fig 1.0

The concept of using the center of the cone above to collect the downstream pressure has certain advantages over conventional differential pressure devices such as the following:-

a) Flow Conditioning.
b) Large Turndown (circa 10-1)
c) Static Mixing
d) Wet Gas usage with Lockhart & Martinelli values up to 0.5

The primary basis for this paper will be the dry gas application for the NUFLO differential pressure cone meter type DPC 100 , this being a 4in. diameter meter with a beta of 0.45. Wet gas aspect will be dealt with on a further paper later on

Similitude is a concept used in the testing of engineering models.

A model is said to have similitude with the real application if the two share geometric similarity, kinematic similarity and dynamic similarity.

- **Geometric similarity** - The model is the same shape as the application, usually scaled.
- **Kinematic similarity** - Fluid flow of both the model and real application must undergo similar time rates of change motions. (fluid streamlines are similar)
- **Dynamic similarity** - Ratios of all forces acting on corresponding fluid particles and boundary surfaces in the two systems are constant

Recent API standards have concluded the acceptability of this method for acceptance in the scaling up of meter geometries, el at API chapter 22.2.

Mathematical Constants.

The general mass continuity equation applies to this differential pressure device as (figs*1.0a)* The fact that geometric similitude will be apparent in the design allows the use of a proven cone equation provided that :-

a) The angles and lengths of the frustums are similar to the original device.

b) The ratio sets are the same as the original with good concentricity of cone.

$$Qv = Cd \bullet At \bullet E \bullet \varepsilon \sqrt{\frac{2\Delta P}{\rho}}$$

Fig 1.0 a

NuFlo™ Cone Meter
Fig 2.0

The Y Factor equation for gas density correction, is derived from the work done at (NEL) and is as follows :

$$Y = 1 - \left[(0.649 + (0.696\beta^4)) \frac{\Delta P_g}{kP} \right]$$

This equation is used in many flow computers and is a standard feature in the NuFlo ™ "Barton range of Flow Computers".

Testing Facility and Parameters

The meter was tested at SWRI in San Antonio Texas This laboratory is one of the few test stations in the world that use a gravimetric measurement system for Natural Gas by a special weigh scale to calibrate the primary sonic nozzles. (This offers very good repeatability and a primary calibration uncertainty of between 0.10 - 0.25% of reading)

Baseline Testing

The test comprised of 5 x baseline straight run tests and 2 out of plane 90 deg elbow disturbance tests at 165 PSIG & 70degF

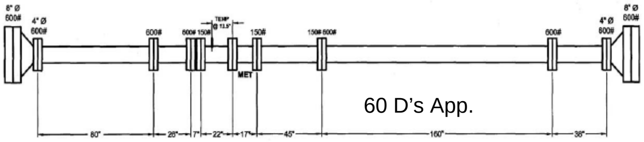
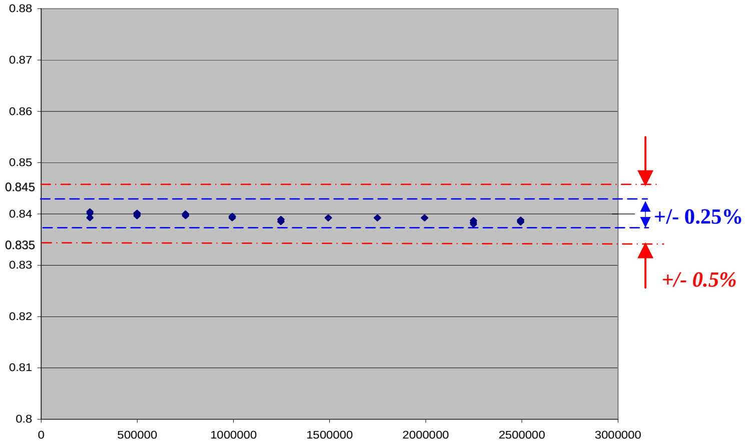


Fig 3.0

Test points taken were 60 points per test run over 10 ReD number ranges.

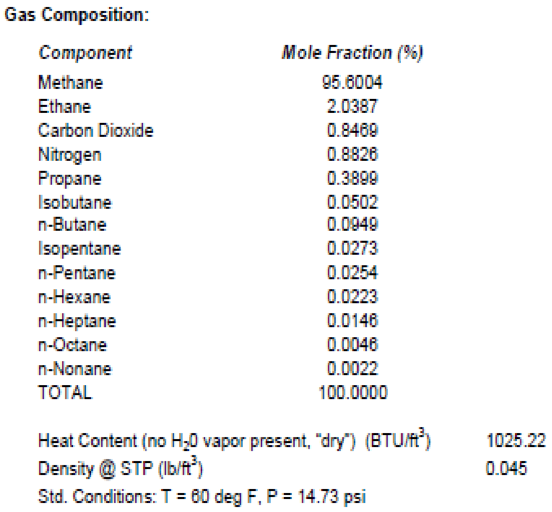
Some 420 data points were collected for the two test regimes. *(See fig 4.0 baseline 2.0)*

C.d. *(Average)*



Reynolds No Ranges 250 K – 2.5 M
Fig 4.0

The 2 x 90 degree out of plane elbow testing regime was set up by SWRI and 120 data points over 2 run sets were submitted. The gas composition is listed next.


Gas Composition:

Component	*Mole Fraction (%)*
Methane	95.6004
Ethane	2.0387
Carbon Dioxide	0.8469
Nitrogen	0.8826
Propane	0.3899
Isobutane	0.0502
n-Butane	0.0949
Isopentane	0.0273
n-Pentane	0.0254
n-Hexane	0.0223
n-Heptane	0.0146
n-Octane	0.0046
n-Nonane	0.0022
TOTAL	100.0000

Heat Content (no $H_2$0 vapor present, "dry") (BTU/ft^3)	1025.22
Density @ STP (lb/ft^3)	0.045
Std. Conditions: T = 60 deg F, P = 14.73 psi	

Flow Conditioning Effect

It is known that the use of a cone shape concentrically mounted in a closed conduit (pipe) can facilitate a flow conditioning effect by "velocity profile re-distribution".

This effect seems to occur over quite a wide ReD range and appears to be more pronounced farther away from the transition region were changing flow patterns occur. (App. ReD ;- 8000 -10,000)

90Deg Out Of Plane testing (*fig 5.0& 6.0)*

The piping layout and graphical test results are shown next for the 90deg out of plane test regime.

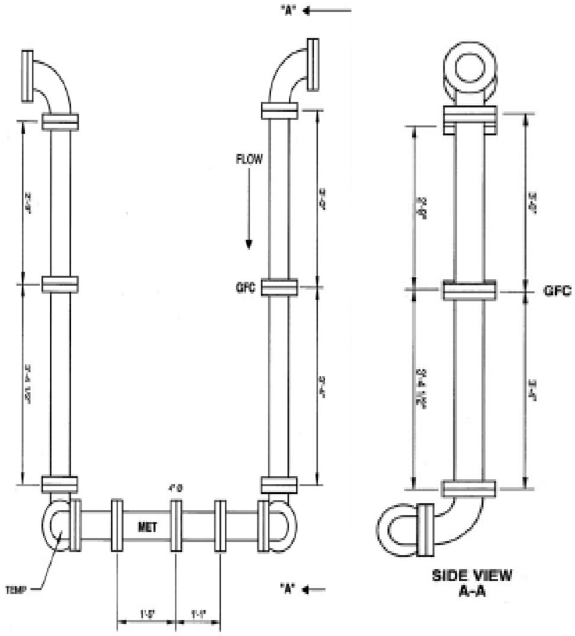


Fig 5.0 Top View 90deg O.P.

The flow conditioning effect given by the cone allows a compact installation package in the field. This space saving parameter can give big savings financially for the operator.

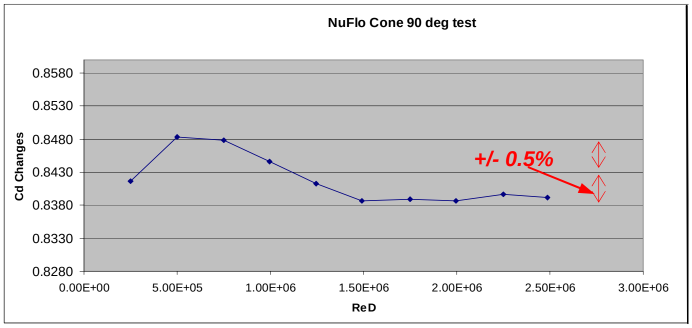


Fig 6.0

Such installations as shown here in *fig 7.0* are achievable with good confidence.

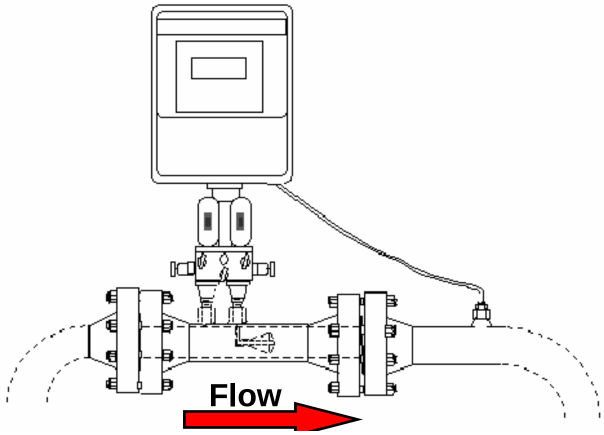


Fig 7.0

Typical cost savings on offshore jacket design can be considerable considering costs between 15 to 40$ US per lb to place items offshore on a platform or FPSO

Allocation Systems

The use of this technology with onshore systems also can enhance the overall cost savings with regard to these installation types.
Areas were this has been seen in the recent past is in the CBM (coal bed methane) fields of Wyoming USA and Canada.

Typical installations can be assembled with minimum components (as per fig 7.0) which allow small weather proof containments, And skid size, particularly with single well head methodology as is now being currently used in Gillette W.Y.

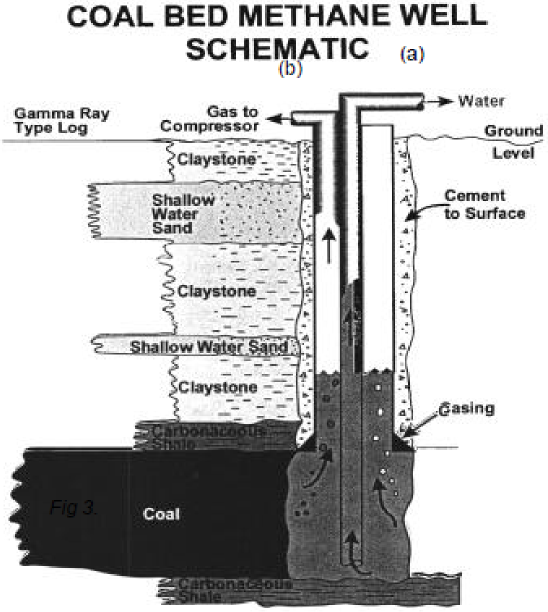


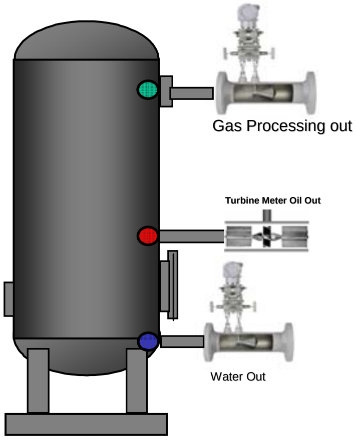
Fig 3.

Other areas of operation for the cone meter are for allocation measurement at production separators on the gas and produced water legs.

The self flushing characteristic provided by the flow streamlines passing the beta edge allows no stagnation region in the throat area of the meter. This is particularly effective were wax build up can be a problem. *(Paper 5.1 from the North Sea Flow Measurement Workshop (NSFMW) in 2000 details this phenomenon)*

The wet gas effect on wellhead applications has also been detailed on numerous technical papers, the main performance enhancement criteria being the lack of liquid hold up when operating a separator that is producing liquid carry over.

This allows a consistent repeatability for the separator gas measurement was other devices which hold up liquid in the meter throat can cause measurement errors.



Test Separator.

Current design of multiphase separators can allow overall uncertainty (on all three phases) of up to 15% - 20% according to past API discussions, this can be due to operator control, time delay in stabilization of the vessel, incorrect design involving future fluid levels, position of vessel in respect to the pressure head requirement (on the liquid side) and also the main crude oil measurement uncertainty.

In particular where orifice meters are used it is necessary to perform, plate changes to facilitate turndown otherwise the performance of the system could be compromised, and also its necessary to use upstream flow conditioners or velocity profile devices which add cost to a system.

Long-term vulnerability using orifice plates in production separators can be demonstrated by examining public documents in the measurement field.

(Example Cited above from Phillips Petroleum Embla Platform North Sea NSFMW Paper Early 90's)

Research in this field by Chevron and others indicates a Cd movement of over 2% - 3% outside of the predicted AGA requirements due to wet gas with small liquid loads of 0.33bbl/MMscf as indicated in this research.

Other References Cited:

TING: Chevron Corp Effect of Liquid Entrainment on Orifice Meters circa 1995.

Lawrence: Dp Metering for the new Millennium AFMS Lafayette 1998

Miller: Handbook (latest edition).

SWRI Photographs :

Straight Run Test Regime

Out of Plane Double Elbows Test Regime