North Sea FLOW Measurement Workshop

Keynote Paper

Influential Factors in Flow Measurement

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nel technology for life

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1 INTRODUCTION

In the dynamic and economically challenging world of oil and gas production, it is important that the developments in flow measurement and metering technologies, their enhancements, regulations and best practices are shared among flow measurement practioners.

This event is our opportunity to share information and to learn of the successes – almost certainly, - and the mistakes– if we are open and honest, made by our peers. Whilst its is easy to proclaim successes – and these are helpful – it is less so to raise ones hand and say – "I did it the wrong way – learn from me" – but please – if you have a subject we can learn from – then I would implore you to share your experience – so we can all learn.

Flow measurement and metering is unlike many of our peer disciplines in that we cannot improve the production of a facility – but – if we get it wrong – then our peer disciplines may not be able to demonstrate production improvements – or worse – still – the company's cash register may be wrong.

Whilst the conference will cover a large range of flow measurement topics – there are several areas which I will discuss in passing. They are by no means the most influential today, nor will I cover them in depth – but are of interest to me – and their influence will depend entirely on your business and business needs, but I believe that they are part and parcel of out future in flow measurement and metering.

2 NOT INVENTED HERE

For the past decade I have been employed by ConocoPhillips as the Corporate Upstream Technology Flow Measurement representative based in our Houston offices and have had the privilege of leading the company's Flow Measurement Technical Development programme.

One of the distressing things I have encountered across industry is the lack of knowledge sharing – and acceptance of the work we each do in the development of flow measurement – in the realm of standards or research in Europe and North America.

There is an apparent NIMBY (Not In My Back Yard) or NIH (Not Invented Here) attitude – or – maybe it is just lack of communication between what we as companies do here in Europe and 'over there' in North America.

Whatever the reason, there is a huge divide in the work carried out 'over there' and 'over here'. A typical example is the work that was carried out by the Pipeline Research Council Inc (PRCI) in flow measurement. This effort is funded by all the major operators' pipeline groups, and annually somewhere in the region of $650,000 to $750,000 is spent in flow metering R & D and Standards support.

Unfortunately – some of it is spent in redoing work already carried out elsewhere – and – whilst this may be no bad thing – if it were to confirm work previously done – it is often done in ignorance of earlier work, and cannot be used as confirmation because its basis is somewhat different. And of course the opposite is true as well.

This is a waste of effort – and we as a group must liaise with our corporate colleagues and each other to ensure hard won R & D monies are spent where it is needed.

3 DP METERS

Differential pressure meters are by several orders of magnitude the most common type and most used meter in service today. They are the most understood meter and also one of the most misunderstood meter type in service. Because the layman knows a little, there is a general body of thought that we have accumulated all the knowledge there is to know and that there is nothing left unknown.

If there was ever a case of a little knowledge being dangerous it pertains to the DP meter.

There are many DP meter types, and subdivisions, and it is likely that many of us have never used some of the more unusual types, and probably never will. The square edged, flanged tapped orifice meter, has a family of derivatives – only a few of which are accorded recognition by the API/AGA or ISO standards.

Even the 'normative' British Standard disregards most of the derivatives – describing merely the Orifice flow meters, nozzle, flow nozzles, venturi meters and venturi tubes. For the more esoteric orifice meters, you need to go back to the days when the British did things on their own without fear of let or hindrance. BS 1042 -1964 [Ref 1] would be a good reference in this respect.

Typical DP meter derivatives might include:

- Square edge orifice with flanged, corner or D & D/2 tappings, with or without drain or vent holes
- Special shaped orifice plates – eccentric, segmental, slotted plate, 4 hole conditioning orifice
- Conical entrance orifice
- Quarter circle orifice
- Venturi meter tubes, venturi nozzles and nozzles (of various designs)
- Flow Conditioner plates
- V Cones
- Elbow meters
- Wedge meters
- Combination meters incorporating an annubar and flow nozzle

Whilst this list of meter types is by no means complete, they all rely on the combination of Bernoulli's Principle and the conservation of energy (or momentum), and are ultimately reliant upon a head loss measurement ($\sqrt{(2\Delta P\rho}$). One of the many improvements in DP meter technology has been in the secondary instrumentation. Whilst they have all improved, the performance improvements in DP transmitters has seen a major improvement in DP flow meters.

However the improvement is still limited by the square root function, and I would mention a pet hate here, where some vendors have made extraordinary claims for flow turndown on some meter designs, some exceeding 40 to 1, using DP turndowns, quoting say, 100mBar to less than 1mbar. Claims are 'substantiated' by flow tests done at some reputable flow laboratory, showing phenomenal performances.

Of course this disregards the Real World wherein: -

- Uncertainty in calibrating a ΔP cell in the field is probably greater or equal to 1mBar
- At low flow rates, noise may swamp the instrument signal [Ref 2].

As a result I would strongly recommend that care should be taken when considering any DP flow meter when claims for turndown exceed the conventional 3 or 4 to 1 with a single range DP cell.

In addition, the lack of standard or detail data in all but a few of the DP meter types means that some of the information about the less well known DP meters must be viewed judiciously with respect to the claims for the discharge coefficient and stability across a significant flow range.

Even Venturi meters, which have recovered in popularity since the 1990's should be considered with care if they are to be used and ISO 5167 should be referred to.[Ref 3].

What is being highlighted here is that there are a lots of DP meters out there, and whilst there is some knowledge available for most of them, it is often hidden away and care is needed – and should be sought – from whatever sources possible – whenever you need to use them.

As to the future of DP meters– if you talk with the 'technology' meter manufacturers then the DP meter is old hat and has no future. However – its likely that this is not so – and new developments keep coming along – the pressure recovery tap now being used as a DP meter diagnostic tool [Ref 4] as advocated by Dr R Stevens is likely to prolong the DP meters' life considerably.
In the mid 1990's it was premised at the NSFMW - by some – even as entertainment - that the orifice meter was done for – and a poem depicting its demise was penned. Like Mark Twain's obituary announcement – it was premature [See Appendix]

4 LNG

LNG is a growing energy source for the western world, growing over the past two or three decades from a few million tonnes per annum (MTPA) to what is expected to be in excess of several hundred MTPA in the near future.

Until very recently the fiscal measurement of LNG was by sampling and use of LNG Tankers Tanker loading/unloading of LNG has developed over the years as being the 'de facto' method for the determination of LNG energy. For years there has been no standard available and sales have been via individually agreed Sales Purchase Agreements, often based on the LNG Custody Transfer Handbook produced by the International Group of Liquified Natural Gas Importers – Paris (G.I.I.G.N.L.) [Ref 5].

API and ISO have been working on a combined standard for a number of years [Ref 6]..

Whilst the GIIGNL Handbook is an excellent basis from which to work it has only a small, and I feel a poorly explained section on measurement uncertainty. The ISO document does not appear to discuss uncertainty at all and has only a short section on dynamic measurement of LNG – in the form of an acknowledgement of the technology. Dynamic flow measurement would in principle have advantages over the current approach, but there are a number of barriers to the introduction at export and import terminals, including:

- Lack of traceable standards for flow meter calibration at low temperature with a cryogenic fluid at high flow rates
- Difficulties in ensuring single phase conditions at the flowmeter
- Long-term agreements based on the existing technology
- Significant effort invested in existing technology.

Nevertheless some flow meter manufacturers have developed LNG measurement solutions, with the focus being on Coriolis and Ultrasonic meters. A number of LNG flowmeter installations have already been established for both process, allocation and fiscal measurement, with a considerable number in construction.

A concerted effort is now needed by the flow measurement community to develop standards for dynamic measurement of LNG with an assessment of the uncertainty in the measurement by both tanker and dynamic systems.

Dynamic LNG flow measurement has meant that with some restrictions, good quality process metering and fiscal quality measurement is now possible. The implementation of quality process metering will improve both Processing and Regasification plant efficiencies. This is a good thing for both Suppliers and Users alike. *You can only improve if you can measure the system*.

A drawback may be the lack of operationally sized LNG calibration facilities, which presents an additional uncertainty. A key issue being the concern that a calibration using water may not transfer to LNG with sufficient accuracy. It is probable that further research and testing of flow meters in LNG service is needed, although the ability to transfer a calibration from water to LNG would be attractive. The use of dynamic metering in LNG is also attractive and early cryogenic prover tests were carried out in the early 1970's [Ref 7].

Some areas for consideration are:

- Precise measurement of LNG during vessel cool-down. A considerable quantity of LNG is converted to BOG during this process and is returned to the LNG plant in the form of 'hot' gas, requiring energy to convert back to LNG.
- Precise knowledge of the LNG boil off when loading a cold (or hot) LNG vessel. Boil off is a function of the LNG composition, LNG and vessel temperatures and loading rates. The ability to meter whilst loading could lead to optimisation to minimise boil off.
- The ability to balance LNG loaded and BOG returned for each load and vessel.
- Lack of Standards – the development of an ISO Standard is underway, although this will not actively endorse dynamic LNG flow measurement.
- Some Regulators have begun to require additional LNG measurement to determine the quantities of LNG delivered/received. With the increasing growth and value of LNG, it is not unlikely that these Regulatory concerns will increase.
- Lack of the ability to prove field meters in situ. This may require some thought, with different approaches for different technologies. It is likely that we may need to get away from the "one – fix – fits - all" approach for verifying a flow metering system.

Typically:-
- o Coriolis meters might need a water draw prove approach with an agreed water-to-product transfer, whilst
- o Ultrasonic meters might have an initial water prove and subsequent verification by meter diagnostics

Figure 1 below is a typical schematic of an LNG production facility, where LNG measurement is primarily at the LNG Tanker with Figure 2 showing BOG and LNG flow meters proposed for loading and facility optimisation.

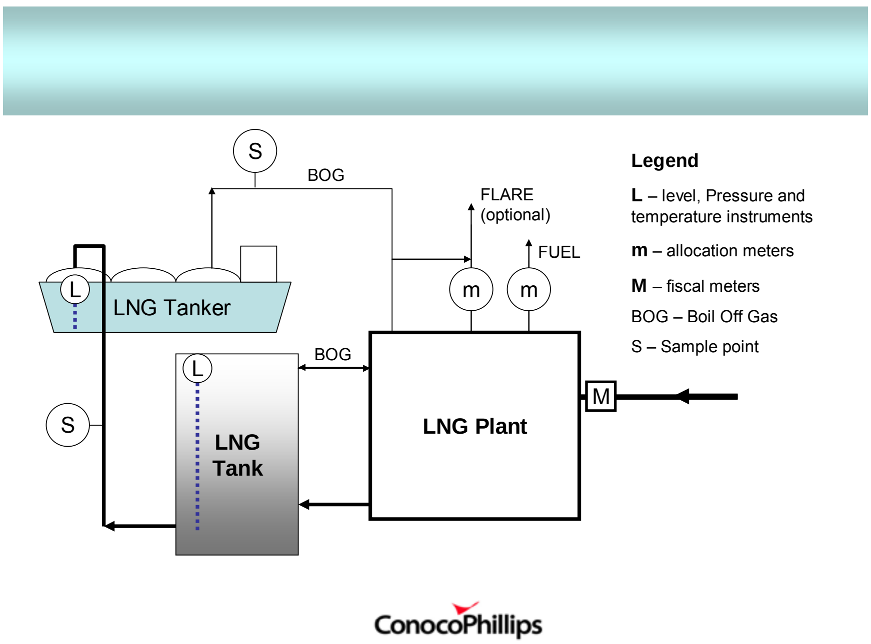

Figure 1 – A Typical LNG Facility Schematic

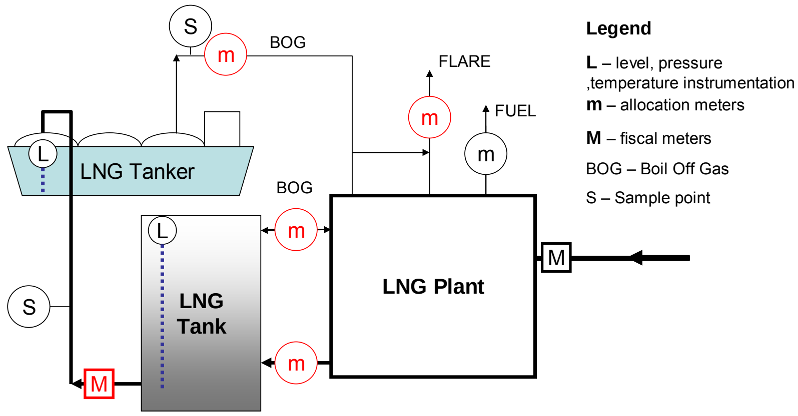

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Figure 2 – Proposed LNG Facility Schematic with meters for facility optimisation

5 ULTRASONIC METERS

Multipath ultrasonic meters use has increased since the first were introduced. The promise of high meter turndown and meter diagnostics have helped the introduction. USM's have a prodigous turndown and provide a significant body of diagnostic information on both the state of the fluid and the meter. There has however been a large gap between

- the vendors knowledge and the users understanding and
- the vendors knowledge and the users need

in respect of meter diagnostics and how and where the diagnostic data can be used.

The early diagnostics gave much in qualitative information but little in the way of quantified data.
The lack of quantified data led to PRCI and its members to develop a diagnostics package for two USM designs (multipath bounce path and chordal) and have presented proposals and an interpretation of the state of the meter under diagnosis [Ref 8].

Timing Parameters	Test	Actual	Status
Average VOS	Agrees with AGA 10 VOS calculation within	Ave VOS 1322.75ft/s vs. Computed VOS 1322.60ft/s Diff 0.01%	**Pass**
VOS Fingerprint	Spread of chordal VOS values is < 0.2%.	Ave spread = 0.047% Max spread = -0.043% Min spread = -0.052%	**Pass** **Pass** **Pass**
Eta	Eta values no greater than +/-2 μs	Eta A-B = 7.483E-07 Eta C-D = -1.9342E-06 Eta A-C = -4.683E-07 Eta B- D = -7.166E-07	**Pass** **Pass** **Pass** **Pass**
Turbulence	Values range from 2 – 5 % at	A = 5.768, C = 2.834, B = 2.382 D = 4.542	**All Acceptable**

Transducer Parameters	Test	Actual	Status
Transducer Gain	All should agree within 6 db, bear fixed relationship to one another.	112/115, 117/117, 119/117, 113/109	**Pass**
Transducer S/N	Should be > 100, the same magnitude, & bear fixed relationship to one another.	All in the 27,000-48,000 range.	**Pass**
Transducer Performance	All should be in the range of 50% to 100%.	All transducers 100%	**Pass**
Status Indicators	Will be 0x00000000, Performance = 100%.	All @ 0000	**Pass**

Velocity Profile Parameters	Test	Actual	Status
V_B and V_C	$V_{B/C}$ / V_{avg} = 1.04 ± 0.01	V_B/V_{AVE} = 1.03 Vc/V_{AVE} = 1.027	**Pass** **Borderline OK**
V_A and V_D	$V_{A/D}$ / V_{avg} = 0.89 ± 0.03	V_A/V_{AVE} = 0.927 V_D/V_{AVE} = 0.924	**Borderline OK** **Borderline OK**
V_B / V_C	1.00 ± 0.02	1.00285	**Pass**
V_A/ V_D	1.00 ± 0.06	1.00421	**Pass**
(V_A + V_B) / (V_C + V_D)	1.00 ± 0.02 (Asymmetry)	1.003	**Pass**
(V_A + V_C) / (V_B + V_D)	1.00 ± 0.02 (Cross Flow)	1.001	**Pass**
(V_B + V_C) / (V_A + V_D)	1.17 ± 0.08 (Profile Factor)	1.111	**Pass**
(V_B + V_C - V_A - V_D) / V_{avg}	0.30 ± 0.14 (Swirl)	0.2059	**Pass**

Table 1 – PRCI Proposal for Chordal Multipath USM Diagnostic Data – showing ten minute diagnostic data during a series flow test

A diagnostic evaluation of a USM is presented in Table 1. It is of interest that the meter is in an installation which would not be considered favourable and has minimal upstream lengths and no flow conditioners. The two meters are in series flow and the diagnostic indicate that they are providing acceptable flow measurement results.

6 CONCLUSIONS

Flow measurement has been in existence since the earliest days of human endeavour. Pharoah's instructions to the priests to measure the inundation of the Nile in order to predict the following years crops is one of the earlier examples.

We need to be aware that there are still many things we do not know about the older technologies, and as new technologies develop – we either forget what we knew and have to relearn it or never learn or learn from them. Or we find that the new technologies drive us to relearn what we knew from a different perspective.

We as engineers need to keep up with old technologies and adapt them to the current technology and use our engineering skills and ingenuity in order that flow metering maintains – and improve its performance and becomes more cost effective.

***Engineering** is the discipline, art and profession of acquiring and applying scientific, mathematical, economic, social, and practical knowledge to design and build structures, machines, devices, systems, materials and processes that safely realize a solution to the needs of society.*

APPENDIX

An Orifice Plate's Autobigraphy

Life isn't easy, being an orifice plate,
But Bernoulli and I have always been mates!
It's time to look back to what I have done,
Almost a whole century has gone!

A Standard is built around my soul,
Can you imagine a more famous hole?
ISO 5167, for me
This is just like music from Heaven!

I haven't changed much through these years,
But you have been faithful,
And that brings out my tears!

From my cave, the Senior fitting,
I have seen and I have felt
What it is to be beaten.

From dirty wet gas streams with nuts and bolts
To warm dry midsummer storms
Both upstream and downstream,
I've a tremendous view,
But my relatives say: "that's not the clue!"

Don't worry, an orifice can handle everything,
We can even stand it,
When Trond Hjorteland sings!

Once, I really had a shock,
A Coke can passed by my slot,
Maron Dahlstrøm's name was written on its side
So what? I heard Mr Stobie shout,
That's normal here on the British side!

Sometimes you take me carefully out,
Oh How I love a gentleman's wipe
You touch me so gently with your finger tips
I don't really know what to think!

NPD show up now and then,
I'll tell you honestly,
Even amongst them I have a friend.

But right is right, and wrong is wrong
Disgrace I find wherever I go
Don't pay attention to all these new techniques
Too many components is not what you need!

Its not right, what they say about Multiphase,
I know the game, of Hans Berentsen's play
Don't leave me behind, my dear old friends,
I'm old and wise, but not more a trend!

I don't want to see any of you cry,
I'll do my best, at least till I die!
If you conclude there's nothing more I can do,
Don't hang me up in your office loo,
Shiny and sharp, I deserve a better place!
"Amazing Grace" is the melody to play!

I want you to raise your glass for me,
Despite this workshop, tis not an anniversary
In a toast to the honour you've offered me!
I know this workshop will not be the last time
you'll talk about me!!

6 REFERENCES

[1] BS 1042: Part 1:1964 Methods for the Measurement of Fluid Flow in Pipes. Part 1 Orifice Plates, Nozzles and Venturi Tubes

[2] Operational Factors that Affect Orifice Meter Accuracy GRI-00/0141 Gas Research Institute (PRCI) April 2002

[3] ISO-5167-4:2003(E) Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full. Part 4: Venturi tubes., Table B.2 - Values of Cd & Guidance for Uncertainty of Venturi Meters

[4] Significantly Increased Capabilities of DP Meter Diagnostic Methodologies, Dr R Steven, North Sea Flow Measurement Workshop , Norway, 2009

[5] LNG Custody Transfer Handbook - International Group of Liquified Natural Gas Importers, Paris (G.I.I.G.N.L.) -2001.

[6] ISO/WD 10976.6 Refrigerated light hydrocarbon Fluids – Measurement of cargoes on board LNG carriers.

[7] Bi-directional Piston Prover Tests Turbines fro Cryogenic Liquid Measurement. F.F. Shamp, LNG Economics & Technology 1974 Library of Congress Catalog Card 74-19766

[8] SMART Ultrasonic Meter. A. Floyd, et al Production and Upstream Flow Measurement Workshop. February 2008, Houston, USA