EXPERIENCE OF OFFSHORE ON-LINE GAS DENSITY MEASUREMENT

by

M F MARSHALL
MARSHALL INSTRUMENTATION LTD

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M.F.MARSHALL

INTRODUCTION

The measurement of gas density using density transducers is common place on offshore fiscal gas metering stations. In this paper I have attempted to describe some of the problems I have encountered with these Instruments in the design & commissioning of offshore gas metering stations on both the U.K and the Norwegian sectors of the Northern North Sea. I have also given advice on avoiding some of the more common reasons for transducer failures . The paper contains some basic design guidelines to help alleviate problems in new Fiscal Gas Metering Systems .

THE DESIGN STAGE

At the design stage of a new gas metering project very little information will be available regarding the exact composition of the gas & the expected operating conditions of the new station . Normally the Instrument Engineer or Gas Metering Consultant will use the educated guesses of the Process Engineers in order to proceed with the design calculations . Inevitably he will guess wrong. The gas composition may be heavier in hydrocarbons (or lighter) than was assumed ,the actual operating conditions may not be as predicted or the Gas / Oil Ratio may have dramatically increased since then resulting in the metering station not being capable of the throughputs it was designed for .

Invariably the instrumentation will be ordered early on in the project and left in stores until required. In the case of Density Transducers this can be a fatal mistake . For fiscal applications the certificate given with a transducer is only valid for one year. As we all know one year is the typical timescale for the design and construction of an offshore Gas metering station. Invariably a few weeks before the system is due for final tests and inspection by the various interested parties and auditors, the Engineer responsible for organising the calibration checks and functional tests will be sitting in his office checking through the project paperwork and find that some if not all the Density Transducers will require re-certification. The turn-around time from the manufacturers is approximately 6 weeks (if you haven't hit upon the various two week holiday periods). The Engineer thus finds himself in a panic situation with telexes to the platform and to the manufacturers organising a quick turn-around and rapid transportation back to the platform. If all goes well, enough Instruments will be back in time for the tests. The density transducer vendor that I have been involved with in the past , has been very helpful in this type of situation.

The design criteria concerning the number of density transducers required per stream is a subject that over the years I have studied in great detail. In most cases I would recommend the fitting of dual density transducers per stream. This allows maximum flexibility of operations and gives the operator greater confidence in the density being used in the fiscal calculations.

The use of a back-up density calculation within the stream micro-computer has the advantage of allowing automatic fall back to the calculated density on detection of a discrepancy between the density transducers or between calculated and a single density transducer if only one is fitted.

THE INSTALLATION

The most practical method of installing gas density transducers is to use the "Pressure Recovery Method" . This method has proved itself over the years and is now the industry standard . This method relies on the recovered pressure downstream of the orifice carrier to provide a sample differential pressure back to the downstream tapping point of the orifice carrier . The typical hook-up shown in a manufacturers technical handbook (chapter 2) titled "Typical Orifice Plate Metering System" leaves a lot to be desired .

The diagram is lacking in several essential areas. The tubing itself should be 1/4in or 3/8ths in. diameter, any larger and you may encounter problems due to high velocity causing damage to the transducers. The tubing arrangement should be such that it is installed as close as possible to the meter tube and should be kept as short as possible .

Never install a needle valve between the density transducer and the orifice carrier downstream tapping sample return . Since we are trying to measure the density at the downstream tapping of the orifice carrier any restriction will invalidate the accuracy of the measurement .The use of a needle valve between the sample take off and the transducer is advantageous in that it allows the operator or Instrument Technician to slowly pressurise the transducers after any maintenance work without causing damage to the transducer .

Consideration should be given to installing external filters to the sample inlet of the density transducers . The location of the filters fitted to the inlet and outlet of the density transducers are difficult to access without having to remove the instrument from its sample pocket . The use of external filters has the added advantage of providing a sample supply liquid trap for installations where lub. oil carry-over is possible . The filter elements should be two microns . Ideally two filters should be installed in parrallel to allow changeout without having to shutdown the stream and depressurise the sample system .

The start-up of any system can give instrument problems . With gas density transducers it is during pressurisation and start-up that most problems occurr . Dirt and contamination tend to collect on the downstream area of an orifice carrier . During pressurisation the gas will take the path of least resistance to pressurise the transducers . This path unfortunately is also the path of least protection to the instrument with only a 90 micron filter fitted at the outlet . This can be prevented by automating the downstream sample valve and tying it into the valve control logic of the metertube upstream (or downstream) shutoff valves . The use of a nonreturn valve is not recommended as this can introduce a pressure drop in the sample return line .

DESIGNED FOR CONVENIENCE

Fiscal regulations on both sides of the North Sea , require operators to check the accuracy of their gas metering stations monthly. The practice I have recommended in the various metering stations that I have been involved with , is to pull a vacuum on the density transducers to ensure that they still can achieve the periodic time given on their original calibration certificate. This has given good results & it is very seldom that a density transducer will pass this test & fail online.

The most common cause of failure of density transducers under vacuum is hydrocarbon liquid drop-out created during depressurisation. It is important to depressurise density transducers slowly to prevent this.

Failures and damage can also occur if the density transducer to be vacuum tested is removed from the line . Inevitably the inlet and outlet threaded fittings of the density transducer are damaged by regular removal . Problems can also occurr with the electrical connections which are part of a certified encapsulated assembly . To avoid this I would advocate that a skid mounted air driven vacuum pump and valve assembly be purchased and installed in a suitable location adjacent to the density transducers . The vacuum pump can be permanently connected by small bore pipework to more than one metering tube density installation without too many problems . Good quality fittings should be used throughout, and the complete piping system thoroughly vacuum and leak tested at regular intervals. The pipework should include double block valves and relief valves to protect the maintenance technician from accidently applying line pressure to the vacuum pump .

To allow maintenance of the density transducers without the necessity of depressurising the complete metering tube, double block valves should be installed both upstream and downstream of the instrument . The connectors on the density transducer side of the valving should be arranged in such a way as to allow removal of the instrument without disturbing the rest of the pipework.

The vacuum pump assembly should include a good quality vacuum gauge with a resolution down to less than 1mm of mercury. There should also be a line pressure gauge upstream of the double block valves to allow the operator to perform a final safety check before proceeding with any further actions. A good idea would be to clearly number all valves and prepare procedures for their operation.

A purge point should be allowed for in the design to facilitate nitrogen purging of the pipework if hydrocarbon liquid dropout is suspected .

A QUESTION OF TEMPERATURE

The measurement of gas density is not easy to make accurately in the environments encountered on offshore production platforms. At the design stage it is important to consider the effects of the environment on the accuracy of the density measurement you are trying to make. The insulation of the installation should be designed in such a way as to allow easy access for technicians to replace or check the calibration of the density transducer without having to have the insulation replaced every few months. The insulation should also be of the highest standard available to ensure good thermal stability throughout the length of the downstream portion of the meter-run.

Measurement of the density transducer outlet temperature is to be recommended . The stream micro-computer can be programmed to provide an alarm on deviation between the line temperature and the density outlet temperature measurements. This alarm is an indication to the operator that perhaps something is amiss with the density measurement. It can either mean that the insulation has not been put back around the instruments properly after the last maintenance check or that the flow through the density transducers is restricted (perhaps a valve is closed?).

As a rough guide , if the line temperature is 40 oC,the density outlet temperature should ideally be 39.5 oC or higher. Since nothing is ever ideal a discrepancy limit of approximately 2 oC is acceptable in normal operations. The choice of the density transducer outlet temperature sensor should be carefully made . Consideration should be given to the mass of the sensor itself and the location of the installation . The ideal sensor would be a surface mounted R.T.D. located on the piece of instrument tubing immediately downstream of the Density Transducer itself.

In general, older metering stations have not got the facilities within the stream computers to perform temperature correction to the density signal . The correction may in some circumstances be small but should not be assumed as negligable . The magnitude of correction can vary from instrument to instrument. For these reasons I would strongly recommend the inclusion of temperature correction to density in any new Fiscal gas metering system.

Other corrections are required to the density signal before it can be used in a Fiscal installation . The density should first be corrected for temperature after the basic calculation from frequency and then corrected for velocity of sound differences between the calibration gas and the actual sample gas . The density value should then be corrected to upstream conditions and it can then be used in the flow calculation . If a corrected Expansion factor is used it is difficult to use a calculated density back-up routine without further manipulating the pressure signal .I would therefore recommend correcting the density value rather than the Expansion factor.

THE COMMISSIONING STAGE

This is the stage of the project where for various reasons we use up all of our spare instruments.

Some rules :-

(A) Never believe the mechanical engineers who will tell you that the pipework has been completely dried after the hydro testing , because somewhere a valve is full of water just waiting to be opened & flood your metering instrumentation.

(B) Always leave your density transducers isolated and under vacuum until required.

(C) Order double the number of spares you first thought of since you are going to use one set as target practice for the slug of water as metioned in (A) , one set is always going to be at the manufacturers for refurbishment & re-calibration and the other set is somewhere in stores but no-one is quite sure where.

Its during this phase of a gas metering project that the Engineer responsible can suffer from a nervous breakdown or severe hair loss . To avoid this he must be in control of the situation . This is not always possible since a gas metering station is probably only a small part of a large mechanical project . Co-ordination between disciplines is therefore essential. Management should be kept informed of the status of the project to help to prevent misunderstandings .

START-UP

The start-up of any new process plant is a testing time for everyone and everything involved in the project . In a new Gas Metering project it is the gas density transducers that are most likely to fail spectacularly . Failures can be caused by various types of contamination in the sample lines . The best way of preventing this is to keep the density transducers isolated from the metering tube until the system is fully on line and flow has been established for approximately 15 to 20 minutes . During this time the flow computers can be instructed to use the back - up density calculation in the main flow calculation routines.

VELOCITY OF SOUND

The velocity of sound correction to a particular make of gas density transducers has caused a great deal of controversy over the years. About 2 years ago I was involved in approaching the transducer vendor on the possibility of calibrating high range Density transducers on Nitrogen instead of Argon as it appeared that this was a possible way round the problem. In May 1985 the transducer manufacturer was able to accomodate this.

It is not easy to change from Argon to Nitrogen Certified Density Transducers overnight . This had to be a phased change over with density transducers certified on both nitrogen and argon until all density transducers had dual certificates available .

When all the density transducers had been re-certified on both Nitrogen and Argon the stream micro computers were reconfigured to use the nitrogen certificate constants .

UNNECESSARY PROBLEMS

Earlier this year an unexpected new format suddenly appeared to the certificates being sent offshore with all recently re-furbished and re-certified density transducers. It was only when questions started coming in from various platforms that it was discovered that the vendor had made changes to the 'K' factors and the user gas equation . Since our flow computers had been programmed to accept inputs within certain limits we were unable to use the new values without calling out a software engineer to reprogramme the stream micro computers . My recommendation would be that vendors of this type of equipment should publish regular customer bulletins containing application notes and discussion on forthcoming changes in either product specification or procedures in certification . I am sure this would ease the present tensions between them , and the customers , us !

CERTIFICATE COMPARISONS

As I mentioned earlier ,I had a unique opportunity to study the differences between Nitrogen and Argon certificates. I also had the opportunity to study User Gas Offset certificates against standard Argon certificates and later against Nitrogen certificates. The results were interesting !

I have attached a typical printout of the comparison calculations that I performed on the dual certified transducers . The offset was consistant throughout at approximately 0.3% . This I found disturbing in that the nitrogen and argon standards used for the calibration at the Vendors were prepared in the same standards laboratory . It is even more suprising when compared with the stated accuracy of the transducers of +/- 0.2% !

The use of User Gas Offset certificates is one that I have often been offered by a transducer vendor when discussing new projects. I have compared the use of these certificates against using a standard Argon or Nitrogen derived certificate . I have come to the conclusion that if the gas analysis is constant with only small percentage changes in components and the operating pressure and temperature are very stable ,then a user gas certificate can be used . If however there is any substantial change in gas components and/or operating conditions then the use of a User Gas Certificate is no longer valid. I have calculated the difference in final density ,comparing a standard certificate and a User Gas certificate . The results show that the user gas calculated density compares well with a standard certificate calculated density within the operating range specified . Beyond these limits the accuracy of the calculation is questionable . It is particularly important to standardise spares in systems with more than one gas metering station , but it is very rare that the gas analysis and operating conditions will ever be identical . In these cases the use of User Gas Certificates can be an expensive exercise .

MAINTENANCE

The procedures for the repair and re-certification of density transducers are generally not suitable for use in the enviroments found in the North Sea . If a transducer fails either on-line or when tested under vacuum , good results can usually be achieved in cleaning the transducer and retesting . If this fails send the instrument back to the Vendor for repair and recertification. The cost in manhours offshore is far greater than the costs charged by the Vendor. So the motto here is "If at first you don't succeed - give up!"

I have in the past attempted replacing the spool piece of a failed instrument with a certified spare purchased from the Vendor. The results were not encouraging with only a 50% success rate. The costs of the exercise were high when the material cost and manhours were added together .

THE FUTURE

The measurement of gas density using the currently available type of transducers is possible with patience and "tender loving care". The trend with new Gas metering projects currently being designed has been towards the use of a density calculation rather than on-line density transducers . The reasoning behind this move is that density transducers have been unreliable in similar applications. The calculation routine that is proposed is based on the GRI final report. This routine requires a stream micro computer with a larger memory and faster processor than micros currently in use to perform the calculations and iterations that are required. The retro-fitting of this is almost certainly cost prohibitive in the current financial climate that we are all experiencing.

During discussions with the representatives of a well known density transducer Vendor I once asked if it was possible to manufacture a density transducer that is not affected by liquids. The reply that I received was that they had been making one for years and it was better know as an Oil density transducer!

New technology is appearing almost daily . Perhaps an alternative will soon be with us. Until then we must make the most of what we have .

I hope this paper may be useful to engineers faced with density transducers for the first time . Perhaps we can stop the trend towards baldness in new instrument engineers!

DENSITY CERTIFICATE COMPARISON

DATE :08-11-1986 TIME :09:22:22

DENSITY TRANSDUCER SERIAL No. 4114

	ARGON FACTORS	NITROGEN FACTORS
K0	= -81.25611	-81.7502
K1	= -.024119	-.023923
K2	= 4.3774E-04	4.3974E-04
K3	= 724	312
K4	= 63.5	45
K18	= -.0000194	-.0000187
K19	= .000182	.000262

PERIODIC TIME (microsecs) = 900
SPECIFIC GRAVITY = .778
RATIO OF SPECIFIC HEATS = 1.27
OPERATING TEMPERATURE = 40

UNCORRECTED DENSITY (ARGON CERT.) = 251.6062
TEMP.CORR.DENSITY (ARGON CERT.) = 251.5122
USER.CORR.DENSITY (ARGON CERT.) = 252.0115
UNCORRECTED DENSITY (NITROGEN CERT.) = 252.9085
TEMP.CORR.DENSITY (NITROGEN CERT.) = 252.8192
USER.CORR.DENSITY (NITROGEN CERT.) = 252.9129

PERIODIC TIME	ARGON DENSITY	N2 DENSITY	DIFFERENCE %
900	252.0115	252.9129	.3563703
880	236.9099	237.7413	.3497359
860	222.1578	222.9214	.3425539
840	207.7552	208.4531	.334788
820	193.702	194.3363	.3263657
800	179.9982	180.5711	.317241
780	166.6437	167.1574	.3072893
760	153.6384	154.0952	.2964219
740	140.9821	141.3845	.2845958
720	128.6748	129.0253	.2716361
700	116.7162	117.0175	.2574634
680	105.1063	105.3611	.2418991
660	93.84466	94.05608	.2247788
640	82.93116	83.10235	.2059879
620	72.36543	72.49983	.1853895
600	62.14709	62.24843	.1628013
580	52.27562	52.34799	.1382598
560	42.75041	42.79842	.1121634
540	33.57068	33.59941	8.550295E-02
520	24.73545	24.75067	6.149589E-02
500	16.24337	16.25172	5.138147E-02
480	8.092742	8.101885	.1128488

References

[1] Paper presented at the North Sea Flow Measurement Workshop, a workshop arranged by NFOGM & TUV-NEL

Note that this reference was not part of the original paper, but has been added subsequently to make the paper searchable in Google Scholar.