North Sea

FLOW

Measurement Workshop

1998

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FISCAL FLOW MEASUREMENT IN THE MILLENNIUM - AN OPERATORS VIEW.

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Fiscal Flow Measurement in the Millennium
An Operators View

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ABSTRACT

A key factor in the continued successful production of hydrocarbons into the next century will be the development of low cost, fit for purpose metering and allocation systems. This paper outlines where the industry could be going, and addresses accounting, technical and organisational issues. The underlying themes of the paper are to challenge the *status quo*, and to promote commercial views on what has been hitherto a mainly technical subject.

The paper describes a typical gas (and associated liquid) commingling agreement explaining the key points in the allocation and attribution of energy to the field owners. The concept of borrowing and lending within a "pool" is outlined, and the overall accuracy of the measurements is put into typical value terms. A case is made to remove technical description from commercial agreements.

The current technical requirements, and a summary of possible future metering arrangements, are outlined, and placed in the context of the drive to increase overall production through existing assets.

The importance of Audit, proper planning and budgeting or work, and the steps made to align differing interests with a common goal to achieve "good metering" in the context of a commercial operation is described.

ABOUT THE AUTHOR

Mark has worked in the oil/gas industry since 1980, following a Short Service Commission with the RAF. He spent a period with a drilling company, followed by three years in Libya on a Methanol plant. Mark joined Conoco in 1984, and has worked in offshore operations, facilities and project engineering, and is currently Team Leader of the Production Management & Reporting group for Conoco (UK) Ltd, based in Aberdeen. The group is responsible for flow measurement, production control and subsequent hydrocarbon accounting processes. Mark is a Chartered Engineer and Corporate Member of the Institute of Measurement & Control.

1 INTRODUCTION

The Theddlethorpe Gas Terminal (TGT) is situated on the Lincolnshire coast in the East of England. It is a 2 Billion Standard Cubic Feet per day plant (2Bscf/d) and has the capacity to process approximately 20% of the UK daily gas supply.

The terminal began life in 1972 with the development of the Viking Gas Field, and has continued to be developed and expanded as further offshore fields have come into production. A brief chronology follows: (A glossary of terms is provided at the end of the paper)

- 1972 - Viking Field and Gas Terminal (VGT) developed
- 1984 - Victor Field comes on stream - commingled with Viking
- 1988 - LOGGS and LGT installed for V Fields
- 1989 - Audrey (Phillips) comes through LOGGS and LGT
- 1991 - Anglia (Ranger) added to LOGGS system
- 1992 - Pickerill (Arco) comes through new PGT
- 1993 - Caister (Total), Murdoch (Conoco) and Ann (Phillips) Fields developed. Terminal is integrated to allow for blending. TACA goes live.
- 1995 - Jupiter comes on stream through LOGGS
- 1996 - Schooner (Shell) is introduced through CMS
- 1998 - Phoenix (Viking Extensions)

In terms of both physical infrastructure and commercial activity, the TGT area represents significant challenge and complexity. Along with the increase in field development and gas production, there have been significant changes to the commercial environment:

As it was

- Monopoly Buyer
- Managed Market
- Depletion Contracts
- Stability of Long Term Contracts
- Known Price
- Unknown Demand
- UK Only

As it is

- Multiple Buyers
- Multiple Sales Contract Types
- Gas-to Gas Competition
- lower consumer prices
- lower beach prices
- Continental Opportunities from 1998
- Volatility in beach price
- Buyers keen to re-negotiate

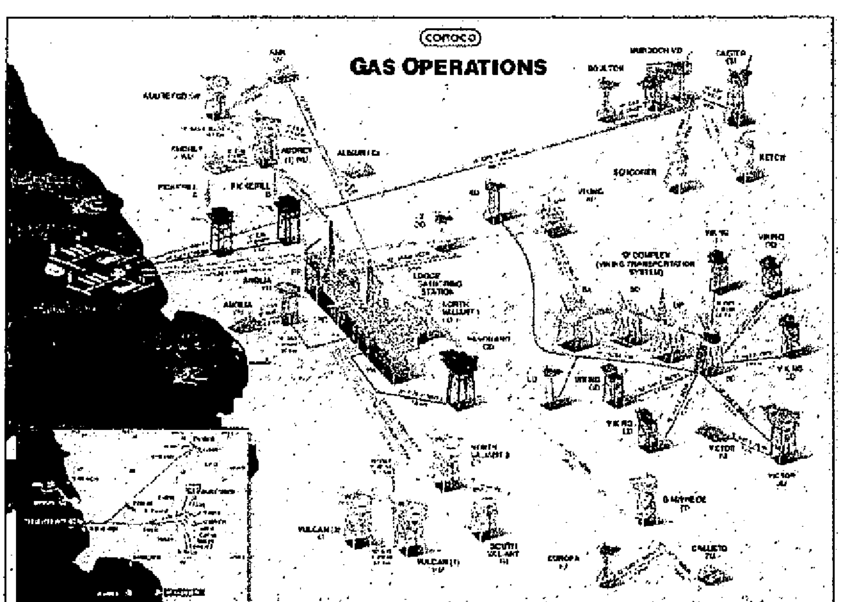


Figure 1 - Diagram of SNS Operations Area

The offshore infrastructure comprises some 100 producing wells, situated on over 30 platforms and 5 sub-sea manifolds. (See Figure 1). The offshore production is commingled at three manned gathering centres, where separation, metering and compression takes place. The fluids are then recombined for transport to TGT via 4 trunk lines. At the terminal, the fluids are again separated, with condensate being recovered and sent via dedicated pipeline to the Conoco refinery on

Humberside and the dry gas redelivered across three delivery points - two for Transco and one to Kinetica.

"In the day" activity is managed from TGT, with overall commercial activity and management being carried out in Aberdeen.

2 COMMERCIAL FRAMEWORK

There are a number of commercial arrangements that allow for the processing, transportation and delivery of gas to the customer. These include:

- Gas Lifting Agreement (GLA's) - these allow for owners of fields to produce their share of the hydrocarbons in place.
- Transportation Agreements (TA's), and Transportation and Processing Agreements (TPA's)- these permit the fields to be processed and handled by the gathering complexes
- Allocation and Commingling Agreements - these set up arrangements for the borrowing and lending of gas in a "pool" concept. These exist at an overall SNS level in the form of TACA (Theddlethorpe Allocation and Commingling Agreement) and also at sub-user level where required.
- Sales Agreements - initially field dedicated between producers and a single buyer, increasingly these are "supply" contracts, pulling gas from a number of fields to meet short term gas needs.
- Joint Operating Agreements (JOA's) - these define how the operator acts on behalf of the other field owners.
- Production / Services agreements - allow for the sharing of maintenance and other operational costs.

3 DEFINITION OF TERMS

There are terms used in allocation and commingling agreements which have specific meanings. These definitions sometimes differ from common usage, and may be specific to different agreements. For example;

- Production - the amount of gas (and liquids) that is actually produced from a field and measured at a metering station.
- Allocation - this is the share of gas produced by a field , after taking account of fuel gas and linepack adjustments. It is carried out on a component basis, and is derived from comparing the total gas redelivered at TGT with the ratio of the gas coming in from the fields. It determines the ownership of gas leaving TGT. See Table 1 in the following Section for details of this process.
- Attribution - this is the process by which the buyers demands, submitted in the form of a "nomination" are met. If there is a difference between the amount of gas "allocated" to a field and the amount required, then gas may be borrowed or lent by the field to make up the difference. There are limits to how much gas may be borrowed or lent, normally set in terms of a number of days booked Firm Capacity (FC).

The management of the TACA gas pool is carried out by Conoco as Theddlethorpe Operator. Whilst a fairly simple process in theory, the practice is somewhat more complex, due to changes in field production capacity, alterations to nominations and the need to manage the blend of the gas leaving TGT to meet the TRANSCO specifications.

Collection of metering data in real time, nomination handling, allocation and attribution calculations, daily, monthly and annual report generation are all achieved by using a computer system based on the Logica Prodis framework (TRACS - Theddlethorpe Reporting and Allocation Computer System).

The number of daily nominations received will be at least 18, and has been as many as 90 changes in one day; typically there will be 30 nominations. The degree to which flexibility is required has been brought about largely by the changes in the market place outlined above, with the move away from long term field dedicated contracts to shorter term non-dedicated supply agreements.

The commercial framework can be summarized by the following diagram, (Figure 2) where the "TACA Envelope" is shown by the dashed line:

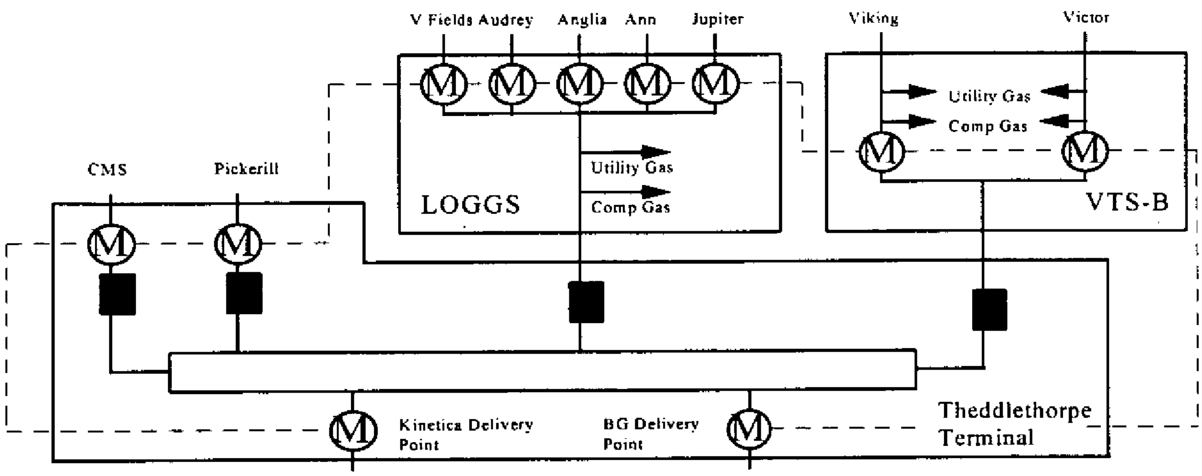


Figure 2 - Schematic of TACA Envelope

Allocation and attribution is calculated in terms of energy, and is expressed in Millions of Megajoules (MMJ). Consequently sampling and analysis, either by manual sampling/well tests, grab samples or on-line chromatographs all play an important part in the overall measurement process. An audit committee comprising key company technical representatives is in place (Joint Audit Steering Committee - JASC) to ensure that all interested parties are treated fairly.

4 COMMERCIAL AND TECHNICAL CONFLICTS

It is very important when fields are in the early stages of development that the commercial and technical teams work closely together. This will help ensure that what is commercially desirable is technically possible. Commercial documents should also be written in a way that allows recognition of changing priorities as fields decline.

The wording of many existing allocation agreements is very prescriptive in terms of the methods of measurement to be used. They often describe the equipment that is to be used for the measurement, specify the equations to be implemented and the hardware to be fitted. Whilst this was a good approach in the market at the time, it now means that new fields wishing to join the allocation system have to comply with old technology requirements.

Typically, no account is taken of the relative value of the produced hydrocarbons, and measurement requirements are normally specified in terms of a maximum permitted uncertainty in the production - 1.0% for gas measurement and 0.5% for liquids, irrespective of production volume or value. It should be noted that agreements below primary allocation level, (sub-allocation agreements) may allow for metering with increased uncertainty tolerance at 2 or 3%.

No provision is made in the agreements to relax the measurement uncertainty limits for low producing fields, and due to the prescriptive technical nature of the measurement schedules, alternative measurement technologies are not permitted without modifying the principle agreements, which may require the signatures of many separate organizations. (35 companies are signatories to TACA, for example.)

The following Table (Table 1) illustrates the inter-dependence between fields using a common allocation and commingling system. In this example, each field produces a given quantity of gas and is allocated an amount expressed as a percentage of the total redelivered to the customers, determined by the proportion input to the system. If we now assume that a given field has been in error at +1.0%, a new allocation is produced. It can be seen that the field in error (for example Field Beta) "picks up" the additional gas, but not the full 1%. Similarly, all the other field's allocation would be reduced by an amount proportional to their input quantities. In the second example, the small producer Field Alpha is assumed to have an error - again all fields are affected.

FIELD	GAS PRODUCED	GAS ALLOCATED	ERROR IN BETA @1%	GAS ALLOCATED	% CHANGE	ACTUAL CHANGE
ALPHA	50	48.00	50	47.81	-0.40%	-0.19
BETA	100	96.00	101	96.57	0.60%	0.57
CHARLIE	100	96.00	100	95.62	-0.40%	-0.38
TOTAL	250	240.00	251	240.00		
DELIVERED	240					
			ERROR IN ALPHA @1%			
ALPHA	50	48.00	50.5	48.38	0.80%	0.38
BETA	100	96.00	100	95.81	-0.20%	-0.19
CHARLIE	100	96.00	100	95.81	-0.20%	-0.19
TOTAL	250	240.00	250.5	240.00		
DELIVERED	240					

Table 1 - Basic Allocation Example

Another problem that is often not considered concerns the relative value of the condensate and gas produced, and how the quantity produced impacts the overall value returned from

Field Alpha - Condensate Tonnes	125
Field Alpha Gas Tonnes	6660
Value of Gas	299700
Value of Condensate	10625
Value of 1% Gas	2997
Value of 0.5% of Condensate	53
Ratio	57

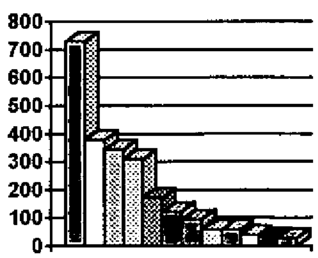


Figure 2 - Error Value Ratios

the field. Consider the case of Field Alpha, a declining gas field, with some liquid production. The table in Figure 2 shows that the value of 1% of the gas production is approximately 57 times that of 0.5% of the condensate production, on an average monthly basis. Put another way, we would need to mis-measure the condensate in the order of 25-30% to have the same *value* error as 1% of the gas production. This has clear implications in the way in which the systems should be designed and operated. The graph in Figure 2 shows different ratios for a typical range of fields. The interdependence of the fields in the system, and the differing relative values means that design, operation, maintenance and audit must be holistic in their approach. In the future, measurement and allocation systems will need to concentrate on *total* field value, rather than on each phase individually.

5 SPECIFIC COMMERCIAL CHALLENGES

Metering costs are often included in the tariff the field pays to the transporter, or may be allocated on a shared basis amongst different fields as part of an Operating Services agreement. This approach effects the way future value can be generated. It is important that the cost of measurement is clearly identified so that where cost saving ideas have been identified, there is advantage to the field to implement them, and an incentive to drive through changes. Where measurement and allocation costs and processes are not properly understood, with costs being unidentified, there is no incentive to discuss changes through field life. Operating costs are therefor maintained at an unnecessarily high level. Ensuring a linkage between metering costs and field costs helps reinforce the link between the commercial and technical management of the asset and so will assist in future development options.

Where commercial documents contain technical description, future marginal fields requiring entry are obligated to install high Capex equipment, thus elevating project costs and reducing the amount of new low cost gas coming into the gas pool. It is no exaggeration to say that a traditional approach to measurement and allocation in the future will inhibit future hydrocarbon reserve developments.

For very low liquid producing fields, the cost of measurement can be higher than the revenue produced. It is illuminating to consider the cost of measurement on a "by field" or "per MMJ" basis. The following graphs (Figures 3 and 4) show that some fields are more cost effective than others - typically onshore metering is less expensive than offshore, and meters with complex commercial commitments are more expensive than those with simpler arrangements. Note that this analysis is based on Opex only; when cost of capital, design, procurement and construction is considered, more fields are pushed into the marginal category.

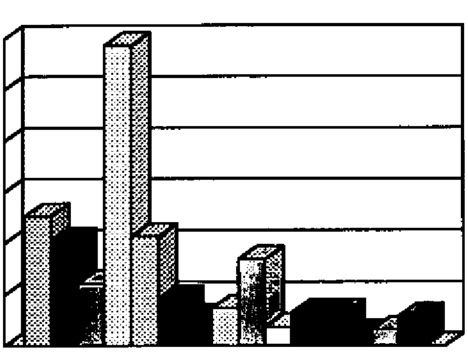


Figure 3 - Cost per MMJ/Year

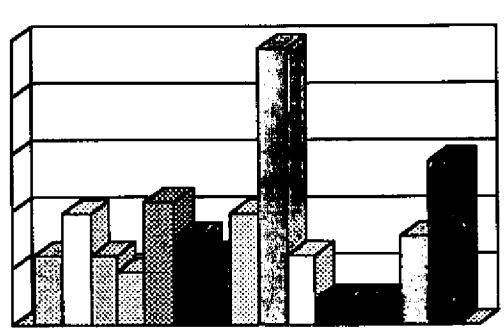


Figure 4 - Cost per Meter System/Year

In the case of declining fields, it is worth noting the relative value of an error in measurement as the field declines. The graph (Figure 5) shows the value of 1% of the production, assuming a systematic error that existed for a 24 hour period. It can be seen that in the early part of the life of the field, the value of the error is quite large, but that towards the end of field life the value of the same magnitude of error is quite small. However, the commercial agreement in place does not allow for the modification of practices or procedures to recognise this shift. Is $\pm$ 1% the correct uncertainty limit for this field? The other significant item about the decline curve when expressed in error value is the increase in 1998/99. This is due to the transportation of a new field through the existing line. In terms of increasing value to the company, it therefor follows that our attention from a metering and hydrocarbon accounting perspective must be focused on increasing throughput, and not by "chasing" errors in measurement at the end of field life.

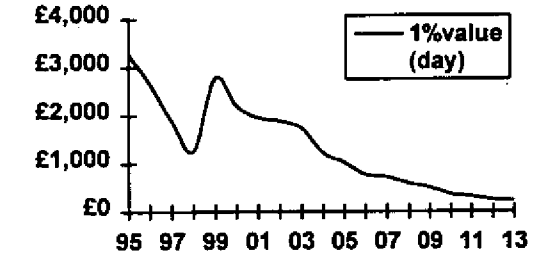


Figure 5 - Value of 1 day, 1% error over time

6 COMMERCIAL AND CONTRACTUAL ENABLERS TO INCREASE VALUE

There are a number of items that can increase value in a mature or declining gas province. These will include establishing the correct commercial framework within which the technical community must operate, and establishing relationships with vendors, suppliers and service companies that focus on adding value to the whole, rather than on short term "win-lose" arrangements.

Early commercial work will have an effect on the whole field life. It is very important that commercial agreements recognise that the field will have changing measurement priorities, and must be worded so as to allow changes to be made with the minimum cost, whilst assuring appropriate standards. This may mean that technical requirement are not embodied in the main text of the agreements, but are contained in a separate technical manual.

The uncertainty allowed in measurement systems has been determined by regulatory guidelines and, typically, detailed in agreements. In the future, uncertainty limits will be determined by agreement between co-venturers and regulators.

The ownership of the technical manual for the transportation system should be under the guidance of a steering committee made up of the key technical staff from the co-venturers. This team will oversee the audit process, and have the authority to make and allow changes to metering and allocation practice through field life.

The importance of having the right incentive to discuss change has been mentioned earlier; having the cost of measurement clearly identified and charged to the field, instead of the transporter, will help ensure that optimum design, operation and maintenance is carried out. This approach will also ensure that fields which do not modify their requirement through field life will pick up the correct cost.

The interdependence of the metering systems, and the reliance of good data transfer into computer allocation systems has been discussed in Section 3. This means that organisations must be set up that cross discipline boundaries. An effective allocation group will need to include metering, hydrocarbon accounting, communications and software skills.

In the SNS, we have increasingly developed relationships with our maintenance and metering service companies to give them more accountability and responsibility for the metering function. The metering staff are employed by the service company, and the establishment of procedures, project interfaces and ownership of maintenance planning rests with them.

There are many advantages in having a metering company "own" more of the problem. They can better manage career development for technicians, establish strong links with sub-suppliers and so reduce costs, and can provide detailed technical engineering and consultancy knowledge to solve specific problems. With a suitably incentivised contract, the service company can share in the cost savings achieved through improved management processes. Ideally, the service company should be able to take ownership of the entire metering system, adopting a "cradle to grave" approach including design, maintenance, operation, data transfer/validation and allocation processes.

There are a number of key performance indicators that can be put in place, the following list is indicative of the type of measurements that can be made to assess, and reward, performance.

- Stream/system availability
- audit performance
- staff competency
- safety record
- minor project performance - budgets, schedule, as builts
- sub-vendor selection /management

The "outsourcing" approach does leave the threat that the long term "corporate memory" of the operator can decline, so in addition a Staff metering engineering position, and A Staff Hydrocarbon Accountant, are still seen as being key roles in the organisation.

7 TECHNICAL CHANGES

A number of technical breakthroughs have been made in recent years that change the approaches possible for gas field metering, for example the advances made in Ultrasonic Flow Meters (USM), the development of high stability differential pressure cells, acceptance of coriolis meters and the increased understanding and use of venturi meters for wet gas metering. In addition, modern digital electronics and communications has lead to the development of more reliable data transfer, and the ability to carry out remote diagnostics and fault sensing. These developments will drive down both Capex and Opex.

8 ULTRASONIC FLOW METERS

The principle of USM for fiscal flow metering are now well established [1], [2], and will not be discussed in detail in this paper. However the marked increase in turndown ratio, and the inherent redundancy of the devices when multiple paths are used means that a substantial decrease in deck weight and space can be achieved, due to elimination of multi-tube meter systems [3]. Once the principle of metering by USM is established in a transportation system, the subsequent addition of gas fields will be easier to achieve.

Together with good communications, the ability exists now to put all the meter data, in real time, onto the desk of the metering and allocation staff in the office [4]. Given their inherent reliability and fault tolerance, USM's are more suited to remote un-manned operation than conventional ISO-5167 orifice plate meter skids.

In the future, it is possible that these devices will also operate in two-phase mode, and hence give a reasonable measurement of the liquid production. This will allow the addition of future reserves into existing infrastructure by using sub-sea production systems or minimum facility platforms.

9 HIGH STABILITY INSTRUMENTATION

New devices are on the market, based on resonant frequency technology, that allow maintenance intervals to be extended to six monthly or longer. The reduction in Opex over field life from the use of these devices will be substantial.

Where multiple instruments are fitted, these can be compared, and provided drift between instruments is within limits, a significant reduction in manned intervention can be achieved, with no compromise to system uncertainties. So in the case where there are older metering systems that cannot support the cost of retrofitting with USM, there is the opportunity to reduce operating costs.

10 THE FUTURE

So what could the future SNS look like, from the measurement and hydrocarbon accounting perspective? A possible future scenario is outlined below.

- All new fields are metered using USM. Substantial liquid production is metered using coriolis devices, with small liquid producers being metered using wet gas corrected figures, fixed ratios, or not at all.
- All metering data is transmitted to the metering and allocation team on the beach. Offshore intervention is practically eliminated.
- Where legacy orifice plate meters are still in use, these are all fitted with advanced instruments in comparison mode, requiring minimum intervention maintenance only.
- The ownership of spares and maintenance procedures rests with the metering service company, who are well rewarded for gains in efficiency and cost reduction. The field metering crews are working as a unified team, with no cross functional/location interface problems.
- A "cradle to grave" approach is accepted as the best way forward, with total ownership of the metering system and data transfer being with the service companies.
- New small gas fields are brought on stream at minimum cost, and effective best practices are incorporated in the design, installation and operations phases.
- Metering costs are being paid by the producing fields.
- The Joint Audit Steering Committee is embodied in the agreements, and has authority to alter metering requirements. The Partners view SNS as being "best in class" for its metering and allocation services.

11 REFERENCES

[1] K-E FROYSA et al, Operation of multipath gas flow meters in noisy environments, Paper 12, 1996 North Sea Flow Measurement Workshop.

[2] T COUSINS, Review of operation of ultrasonic time of flight meters, Paper 10, 1996 North Sea Flow Measurement Workshop.

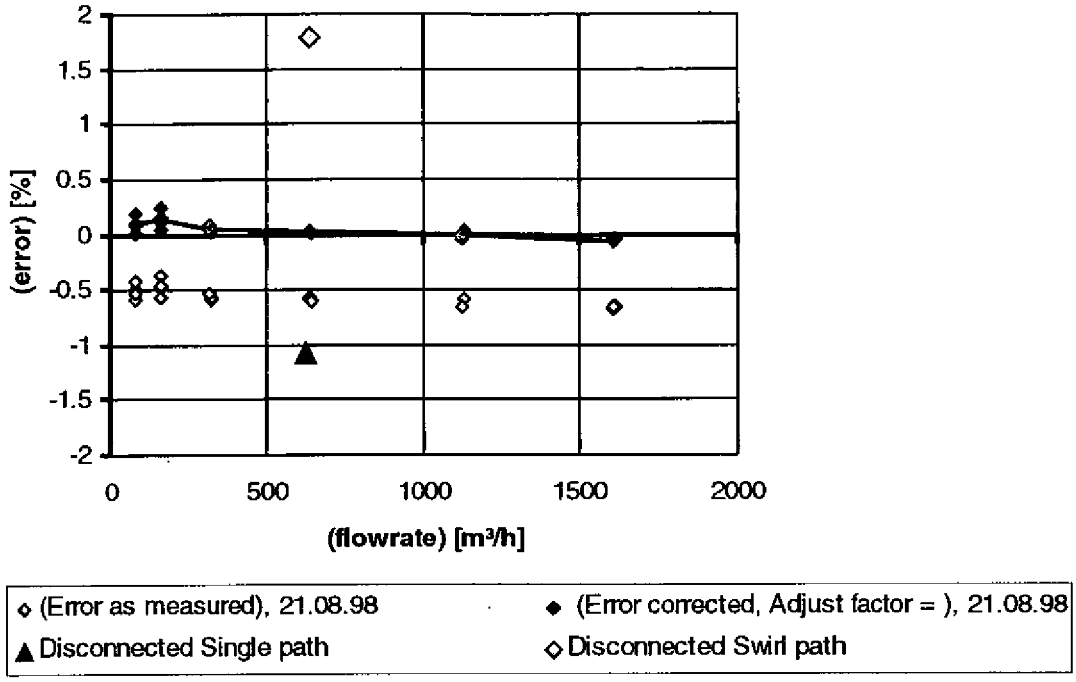
[3] DTI OIL AND GAS OFFICE, Guidance notes for standards for petroleum measurement, Section 3.2.4, September 1997, Issue 5.

[4] P ROBBINS, Ultrasonic metering on an offshore gas platform, Paper 11, 1996 North Sea Flow Measurement Workshop.

12 GLOSSARY

A&A	Allocation and Attribution
CMS	Caister Murdoch System
GLA	Gas Lift Agreement
JOA	Joint Operating Agreement
LGT	LOGGS Gas Terminal
LOGGS	Lincolnshire Offshore Gas Gathering Station
LTS	LOGGS Transportation System
MMJ	Million Mega Joules (1×10^{12} J = 9478 Therms = 1×10^{6} SCF approx)
PGT	Pickerill Gas Terminal
PSA	Production Services Agreement
SALA	Sub Allocation Agreement
SATA	Sub Attribution Agreement
TA	Transportation Agreement
TACA	Theddlethorpe Allocation and Commingling Agreement
TPA	Transportation and Processing Agreement
VGT	Viking Gas Terminal
VTS	Viking Transportation System

4.3 Three path meters



The meter shown was undergoing factory acceptance testing, the opportunity was taken to establish its footprint curve and some of its operating characteristics. The meter was found to be linear in response with a negative 0.5% offset. In order to ascertain the meters response to path failures we disconnected in turn the single path then a swirl path.

The resultant shift with the single path disconnected was a negative 0.5%, while the swirl path shifted a positive 2.2%. Having ensured the meter was reconnected for all paths the original curve was adjusted to the zero datum line and two check flows completed.

These tests would indicate the performance of the three-path meter follows that of the five-path meter, regarding single path and dual path failures. Single path failures, although shifting the value, could possibly be acceptable for short periods whilst a replacement probe or suitable window for rectification is planned. The swirl path (which is used in the swirl calculation altering the single path values), however, has a much larger impact on the resultant output and renders the meter virtually unusable.

5 ADVANTAGES AND DISADVANTAGES OF ULTRASONIC METERS

As a quick reference guide we have outlined some of the disadvantages and benefits of ultrasonic meters:

Disadvantages of ultrasonic meters

- Internal surface condition of meter effects the measurement accuracy.
- Process noise can effect the measurement integrity.
- Lack of local facilities, at present, capable of performing annual recertification of the meters leading to expensive transport costs and long turn around times.

Advantages of ultrasonic meters

- No line obstruction.
- No pressure loss.

- Minimal installation requirements. Only 10 diameters of straight matching pipe upstream and 3 diameters downstream to achieve accuracy.
- Bi-directional capability. If this is a requirement, then 10 diameters of straight matching pipe must be present in each direction. Testing should be done in both flow directions.
- No moving parts.
- No lubrication or periodic maintenance.
- Large turndown ratio.
- Digital waveform sampling and detection.
- Powerful noise reduction technology.
- Extensive self-diagnostics.
- Immediate alarm reporting.
- Ultrasonic paths configuration means better measurement of asymmetric and swirling flow.
- Built in redundancy, measurement can continue after path failures.

6.0 CONCLUSIONS

Ultrasonic meters have been shown to be suitable for application in fiscal service, achieving the dual objectives of cost reduction and high accuracy.

The design and operating principles of ultrasonic meters give accurate measurement of velocity. However, changes in the surface conditions of the meter result in variations in the value of flow rate.

Ultrasonic meters tell us much more about the flow conditions inside the pipes than previous technologies. They have revealed issues that have been hidden up to now. In practice, for the measurement of gas flow they are as good as if not better than other meter types.

At present it is essential to calibrate ultrasonic meters for a particular installation until the historic evidence shows that the meters are stable.

Our understanding of this technology, whilst improving all the time is still relatively small. Manufacturers and the test facilities have been very proactive in the discussion and resolution of the development / teething problems we experienced. This networking must be actively encouraged.

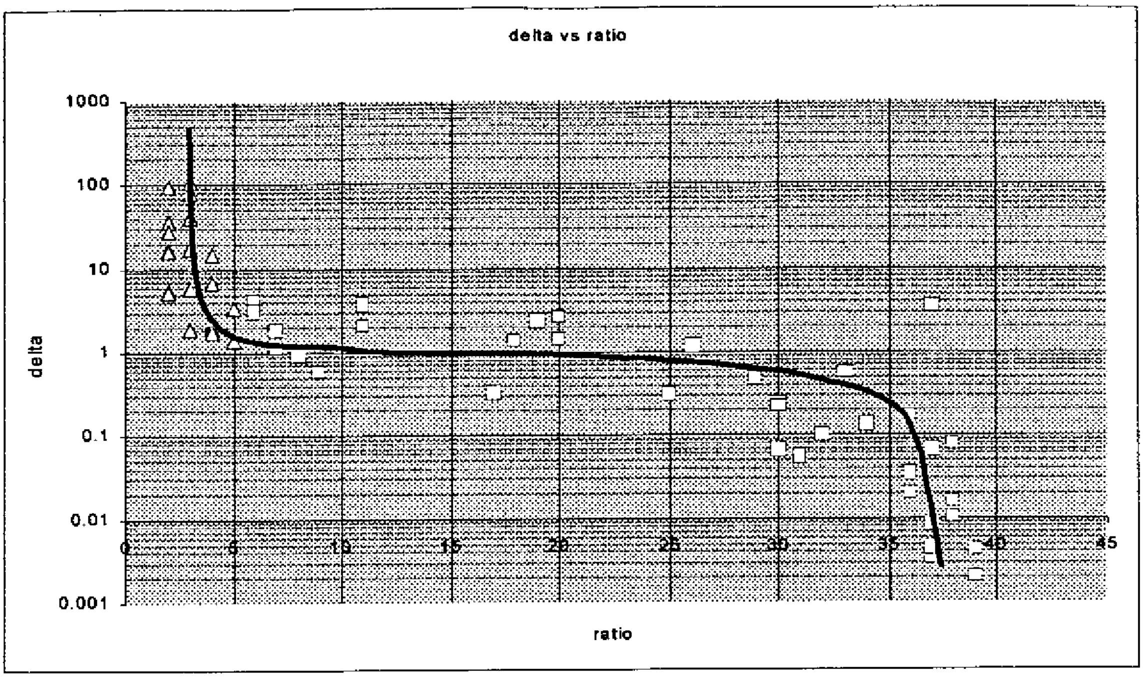


Figure 5 - Good functionality of the ultrasonic flowmeter

Figure 5 shows a typical graph of the AGC_ratio (Autmatic Gain Control_ratio) versus the δ-factor. As long as the AGC ratio is larger than 5 the instrument is functioning properly (level has not reached the limit). Figure 5 shows that a rapid decrease of the AGC ratio occurs starting from a δ-value of about 1.

8 CONCLUSION

The objective was to establish a model capable of predicting the performance of an ultrasonic flowmeter in a specific application.

This report shows that based on installation (piping) drawings, the control valve characteristics and relevant process parameters, it is possible to calculate a δ-factor value that predicts whether the ultrasonic flowmeter can function properly in a specific application. If not, it can be calculated to which extent additional measures are required to assure proper operation of an ultrasonic meter in the installation under study.

9 FINAL REMARK

For the calculation of the indicator (δ) a first approach can be made by using a valve characteristic value N_v of 1 as default value. For a more accurate assessment it is recommended to use the valve characteristic value. In case this value is not available Instromet has the equipment and capability to perform measurements on a site where a representative model of the particular valve is in operation as long as provisions can be made to install ultrasonic measuring microphones. In this way most applications can be analyzed for acoustic noise behavior and an advice can be given for the applicability of our ultrasonic gasflowmeters analyzers.

ACKNOWLEDGEMENT

Instromet wants to thank Verbundnetz Gas for organising and conducting this project. Especially the enthusiastic co-operations of Dr. Stoll, Mr. Slawig, as well as the support of Mr. Müller from PLE are greatly appreciated.

We also want to mention Dr. Dane who contributed in the processing and analysing of the ultrasonic sound measurement data.