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PAPER 1.1

AMERADA HESS LTD'S FIELD EXPERIENCE AND REQUIREMENTS FOR FLOW MEASUREMENT AND PRODUCTION ALLOCATION.

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1 INTRODUCTION

The object of this paper is to review the Amerada Hess' experience of metering in the last ten years, and explain the rationale for its current requirements for flow measurement. It also suggests the direction that we would like future developments to be focused.

Amerada Hess first operated North Sea production was in 1989. Since then, the Product Movements Section of the Company has been responsible for metering and allocation of a variety of oil fields operated from fixed platforms and floating production vessels. The various metering requirements for these facilities are determined by the need to safeguard the interests of the fields' Partners, the Government's tax revenues and the interests of the pipeline and downstream processors' shareholders, but also by commercial pressures to keep costs down.

As the UK's North Sea province has matured and the amount of premium rate Petroleum Revenue Tax has declined so has the need for the DTi to act as the Government's policeman in metering matters. There has been a change from the prescriptive formulas used a decade ago to the pragmatic approach being adopted today. This change is very much appreciated by the industry, and has made it possible to use new metering technology in marginal field developments, raising economic return to both oil companies and Government.

However, the industry has a long way to go before it can truly be considered up-to-date.

A major limit on progress is the continued use of rigid measurement provisions in inter-company contract agreements, which were possibly appropriate once, to ensure minimal standards across the board, but now often just result in expensive equipment and manpower being assigned to measure and allocate small value products. This is particularly a problem for oil producers with associated gas and NGL production.

The objective of construction project teams to minimise capital investment is often at odds with Product Movements' needs for hardware and software which remains useable for a significant period of time. This conflict can sometimes be worsened if the project engineer is unfamiliar with the specialised equipment used in oilfield flow measurement.

2 FIELD EXPERIENCE

The experience we have had with the AH001 semi-sub. production platform is typical of our experience with other facilities, and will be described in some detail. The other facilities, the Scott platform, and the leased Uisge Gorm and Glas Dowr will be described only to highlight other issues.

2.1 AH001

The metering equipment installed on the AH001 semi-submersible, AHL's first production facility, was typical of many platforms up to the late 1980s. It was installed with subsea tie-backs to three operated fields, Ivanhoe, Rob Roy and Hamish (IRRH), each fiscally distinct.

Export of oil is by pipeline to Flotta, and export of gas is to British Gas, via the Frigg pipeline system. The metering systems were designed to satisfy DTI, British Gas, and Pipeline Operator stated criteria.

2.1.1 Oil Fiscal Meter

Three parallel turbine meter streams complete with Meter prover, Twin densitometers, grab sampler, and manual sample/pyknometry point in pumped by-pass loop

The original Sarasota Flow Computers were replaced soon after start-up by Solartron 7915 instruments.

Spot samples were taken every 4 Hours for determination of water-in-oil by centrifuge in the Installation's Laboratory (for dry oil allocation)

A Weekly composite sample is taken and assayed onshore (for dry oil valuation)

2.1.2 NGL

Originally an orifice meter was used to measure the NGL spiked into the crude upstream of oil meters. Flow calculations used a fixed density with no pressure or temperature corrections within the Servelec Database system.

This was replaced by a Coriolis mass meter soon after start-up.

2.1.3 Gas Fiscal Meter

Three parallel orifice meter streams fitted with dual DP cells, originally connected to Sarasota Flow Computers. These were replaced soon after start-up by Solartron 7915 Flow computers.

H_2S, H_2O, grab sampler, on-line chromatograph (fitted soon after start up), and manual sample point in a vented fast sample loop.

Originally, weekly composite samples were taken and analysed onshore (for Pipeline allocation)

2.1.4 Test Separator

Gas Orifice Meter with single range DP cell. Fixed density was used in the Servelec Metering Database. No allowance was originally made for well testing.

The Liquid Orifice plate meter was replaced by a Coriolis mass meter soon after start-up

Produced Water measurement is by an Electromagnetic Meter

Manual sampling points for oil, water and gas.

The sample points were all upgraded to sample probes shortly after start up.

All flows were originally calculated in the Servelec Database Computer. A dedicated Solatron 7915 Flow Computer was fitted soon after start up.

2.1.5 Production Separator

Gas Orifice Meter with single range DP cell. Fixed Density was used in the calculations being made in the Servelec Database Computer. Upgraded to dual DP cells, and dedicated Solatron 7915 Flow Computer shortly after start-up.

Produced Water measurement is by an Electromagnetic Meter

Manual sampling points

All metering data was collated, reports printed, etc., by a Servelec Database Computer changed out shortly after start-up for a custom built MaxiVis / DAI computer (including parallel onshore workstation) soon after start-up

A schematic of the AH001's current equipment is shown in Fig 1.

2.1.6 Equipment Replacement

The need to replace some of the AH001's equipment so soon after first oil start-up has been typical of our experience in several developments.

The replacement flow computer and database software is easily configurable in the field, handles all the major calculation routines with ease and the mechanical and electronic hardware operation has been trouble-free since installation in 1991.

The installation of the Solatron computers gave the opportunity to replace the database computer. The chosen replacement was of industry-standard manufacture. The computer itself, with an engineer's keyboard and monitor and its I/O electronics, resides in an equipment room offshore. The primary colour display, specialist operator keypad, and colour printer are located on the console in the Central Control Room. A workstation onshore in Aberdeen provides a comprehensive 'mirror' of the offshore facilities, with the additional facility of a WORM disk system. (The WORM drive was used as the long-term archiving facility for the data, reports, and trend information, allowing us to look back in detail at any production period since the system was commissioned. These functions have been superseded to a large extent by our AMADAES system, although we kept the WORM facility in use until recently.)

Using a combination of a security key held by the OIM offshore and separate passwords held by the offshore technician and by the metering engineer in Scott House, it is possible to modify configuration data from onshore, and to operate some of the facilities. This capability was used during early operator training actually to conduct proving from Aberdeen.

This computer is capable of a wide range of useful functions:-

Versatile input / output handling, including analogue current loops, voltage status signals, current or voltage pulse handling, and frequency counting. Not all of these are used in our application.

2.1.7 Configurable Database

A powerful operator-programmable spreadsheet capability exists, with security protection. We use this facility to generate automatic period reports, printed proof reports, Well Test reports, automatic gas nomination telexes, etc. If we need to add new data to a report, for example, this is easily achieved from the onshore workstation, under security protection. An added reassurance on security is that the system archives previous versions of updated configuration files.

A powerful operator-configurable trending utility is available, usable on any tag in its database, with a selectable time base. This is used by the onshore metering engineer (as easily as it is by the offshore technician) for diagnostic purposes if there is any question on the performance of e.g., field instrumentation, or on process upset. Snapshots of trends may be sent to a colour printer if required.

The system is powerful, but simple to operate, with the facility to build mimics. These are used for example:-

> To allow the Control Room Operator to control meter proving (including the opening and closing of block valves, or sending a set point to flow control valves) from the integrated keypad.
>
> To give an overview of flow, temperature, pressure and ESD valve status throughout the Flotta and Frigg pipeline systems
>
> or to monitor / initiate well tests, etc.

2.1.8 Water-in-Oil Determination for Allocation

We believe it is worth the effort to continuously monitor the allocation results from the various pipelines into which we export our fluids. Although much of our effort is automated this is still manpower intensive.

This monitoring made us aware of continuous anomalies in the allocation of fluids from one pipeline system, which had substantial financial implications to the Partners. These anomalies were examined by a major, multi-discipline Third Party Audit, whose broad conclusion was that imbalances could probably be ascribed to the determination of water in oil elsewhere in the pipeline system. Subsequent prolonged discussion and R&D at NEL led to the adoption across the system of a determination of water-in-oil content by Karl Fischer coulometry, based upon new 24-hour flow-proportional samples acquired by a separate grab sampler. We anticipate upgrading this to on-line Water-in-Oil measurement in the near future. Current balances are now effectively low to neutral.

2.1.9 Gas Analysis for Allocation

A pipeline system gas allocation is calculated on the basis of the composition of each contributing field's inputs into the pipeline. This was traditionally determined by analysis onshore of weekly flow-proportional samples from each field.

The management and handling of sample containers both full and empty is invariably labour-intensive, occupying a specialist technician (who needs to know what he is about) for several hours weekly. When they go astray, shore-based Product Movements, Materials, and Logistics personnel know just what a time-consuming nuisance they can be. In addition, there is always the question of just how representative is the sample acquired in the event of inevitable process upset or minor miss-handling of the container.

The chromatograph's frequency of analysis is such that its results accurately reflect the composition of gas fed into the pipeline, and is automatically recorded along with the flow at all times. The instrument is calibrated automatically at least once per week. Otherwise, its operation is, to all extents and purposes, 'hands off'. In the event of anomaly in the results from the weekly sample sent onshore, chromatograph results were used.

The results from the on-line gas chromatograph are continuously recorded and archived automatically by our metering database/supervisory computer on the AH001. Because of the onshore workstation, results can be scrutinised by specialists, and compared with historical trends, at any time.

Results from the onshore analyses were also logged, and compared with those from the chromatograph.

The proven reliability of the on-line chromatograph, the accuracy of its determinations, and of our automatic recording of its output were all acknowledged by Pipeline Operator, the gas

Buyer, and by other pipeline users, who agreed to its use in the allocation system in place of the weekly composite sample.

We have saved several hours of expert technician time each week. We are more comfortable with the timeliness of the analysis data going into the allocation system on our behalf, and we were running the chromatograph and monitoring and recording its results in any case.

We have adopted the same approach to analysis for gas allocation in our later systems where possible and appropriate. However, we may still be forced by rigid agreements to acquire and analyse onshore periodic samples.

2.1.10 Renee-Rubie Fields

The advent of the Phillips Petroleum Company operated R-Block fields (Renee and Rubie), whose production is expected to start this year as subsea satellites to the AH001, has necessitated major changes to the installation's process equipment, and therefore to its metering systems as shown in Fig. 2. As these fields have relatively short field life a major objective has been to keep metering costs as low as possible, and in particular to make use of the recent advances in ultrasonic metering technology to remove the need for bulky and expensive separate multi-stream meters and meter provers.

A new First Stage Separator has been installed. It is dedicated to R-Block fluids. Vapour from this separator is fed forward to the shared compression and drying facilities. Its hydrocarbon liquid stream joins the feed from the IRRH wells to be input into the existing, now shared Production Separator.

Water from the R-Block Separator is processed in a dedicated hydrocyclone system.

R-Block Separator vapour flow is determined by two single-path ultrasonic meters in series with a flare line take off between them. The hydrocarbon liquids are metered by a 5-path ultrasonic meter with a pumped fast loop containing an on-line water-in-oil meter, density transducer and manual sample point. Produced water is measured by an electromagnetic meter. New Solartron flow computers have been installed to interface stream measurement (see Fig.2).

The AH001 MaxiVis metering supervisory/database computer has been upgraded to cope with the new inputs and will perform the allocation calculations on an hourly basis. Each calculation will have separate reports archived for input data used, output data calculated hourly allocation report and most importantly, a validation report giving details of possible inaccurate allocation.

Inter-Field oil allocation will be by quantifying the dry oil leaving the Renee Rubie Separator, and calculating the IRRH share of Oil Export by difference. The Flotta Operator will carry out value adjustment, to take account of the different qualities of the respective fluids. Gas Allocation is somewhat more complicated and includes calculation of the ownership of the NGL spike. An offline calculation is performed to provide pseudo-oil export assays, based on well compositional data.

2.2 Scott and Telford fixed platform

Scott is a major oilfield located about 8km north of the AH001. In essence it has a similar separation system to the AH001, except that NGLs are recycled through the main separation process, rather than being spiked into the main oil line export, as on the AH001.

When Telford, a subsea satellite field with different field Partners, was tied into Scott two years ago the drive to reduce capital expenditure lead to the decision to use process simulation to determine the hydrocarbon allocation between the fields. This was principally because the size of the meter that would be required to measure total flow was large, and thus expensive, and the uncertainty in the measurement of the large Scott flow would magnify the uncertainty in the calculation of the Telford share of the Oil Export flow. However, the use of equation-of-state process simulation has proved to be difficult and time consuming in operation. We spent a lot of money in attempting to fully automate this allocation system, but found this to be an almost impossible task. The system is currently an off-line manual calculation.

2.3 Uisge Gorm and Glas Dowr Floating Production and Storage vessels

2.3.1 Uisge Gorm

Two fields are currently processed on the Uisge Gorm, Floating Production Storage and Offtake (FPSO), with a third field being brought on later this year. The lack of gas export, and straightforward oil-export by tanker means that overall metering on this facility is very simple.

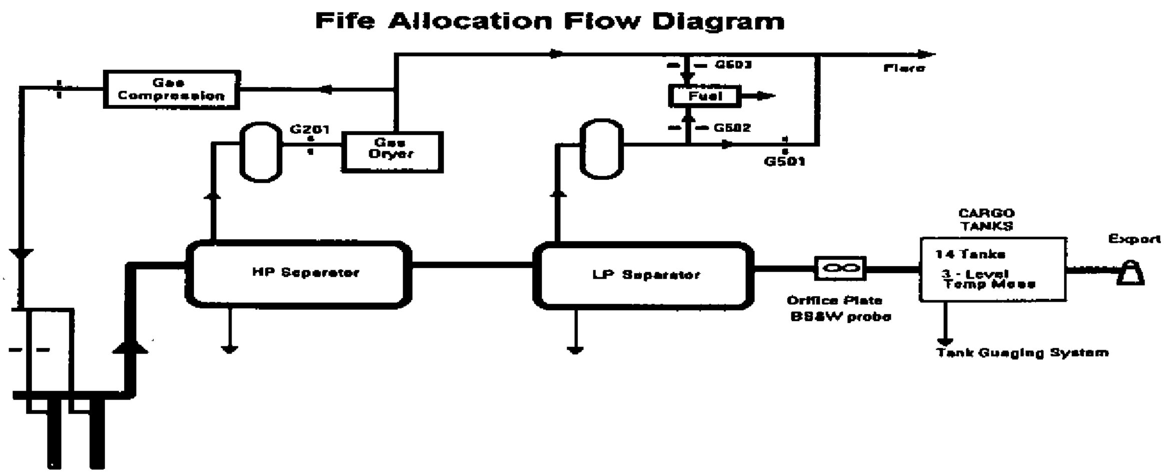

Fig 3 Flow measurement equipment on the Uisge Gorm FPSO.

The allocation of production to fields is by well test.

Originally crude oil in storage was to be measured by radar tank gauges. This proved to be unworkable. Instead the stabilised oil export to the shuttle tanker is measured by a clamp-on ultrasonic flow meter. There is no gas flow measurement, apart from on the test separator.

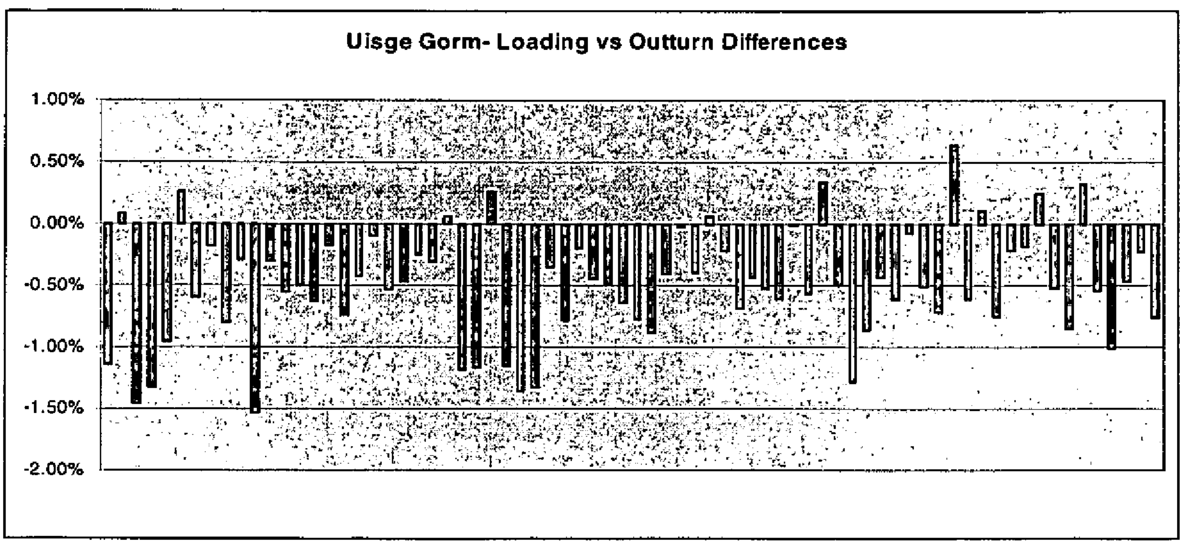

Fig 4 – Outturn discrepancies Uisge Gorm.

Tracking the quantities determined on the Uisge Gorm (see Fig. 4) with respect to those determined at discharge ports has shown marked differences between the two locations. With the exception of a very few cargoes, these are overwhelmingly negative. We would normally have expected the differences to be closer to zero, with an approximately equal number of positive as well as negative discrepancies.

Either the vessel's meters are inaccurate, or the method of determination at the ports is inaccurate. It is not possible to say which is the correct method.

2.3.2 Glas Dowr

As a result of our experience with the Uisge Gorm, the Glas Dowr which is currently on Durward and Dauntless fields, utilises an extensive network of ultrasonic meters. These have the advantage of low maintenance and enhanced accuracy, giving major benefits for process and field management.

The more sophisticated measurement system on the vessel, where the fluids produced are tracked as accurately as possible at various stages throughout the process, is expected to add the reassurance of internal consistency to the performance of the meters, and to safeguard our interest if cargoes must be discharged when the vessel's export meter is not available for some reason.

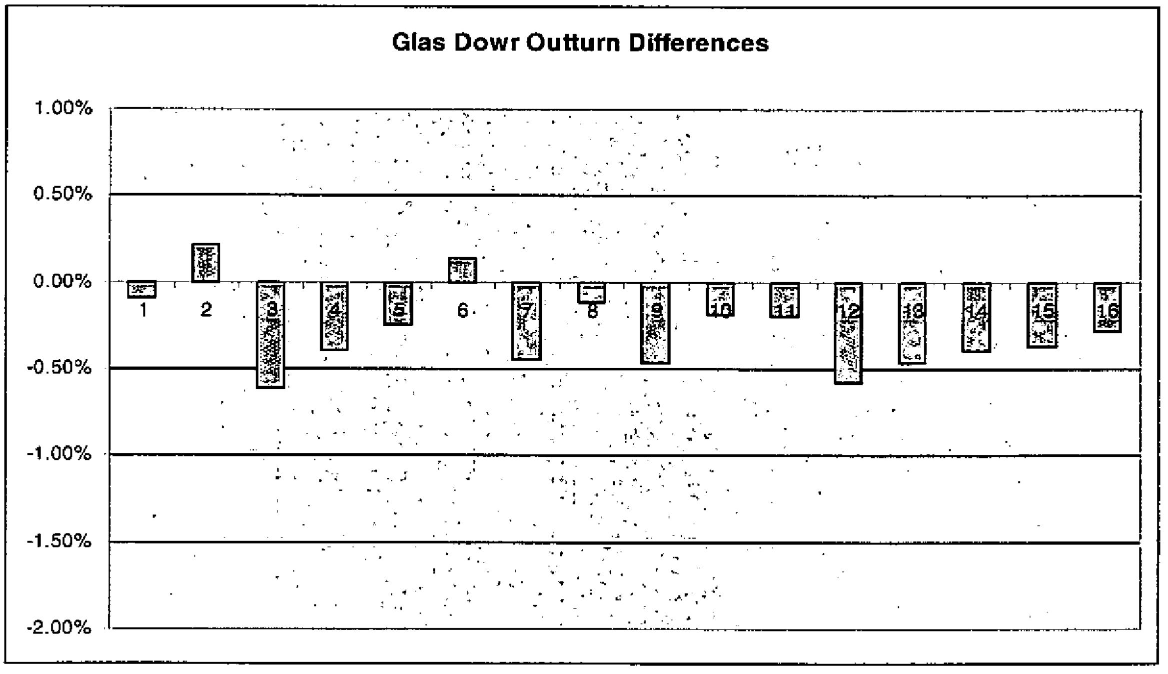

Fig 5 – Outturn discrepancies Glas Dowr

3 PROJECT CONSTRAINTS

The need to replace much of the AH001's equipment so soon after first oil start-up has been typical of our experience in several developments.

Much of it is the direct result of the pressures construction projects face to minimise capital investment. The other influence is the frequent lack of metering experience of the project engineer involved, for whom this equipment is 'just instrumentation'.

This tends to force them to buy equipment considered to be that 'always used' for the particular category of service, or "fit for purpose" i.e., minimal specification and cheap equipment which is not suitable for the installation's lifetime use. Unsuitable, for example, by virtue of the fact that it requires frequent attention offshore from scarce, expensive, specialist technicians, or because its use forces the need for repeated manual transcription of its data within the allocation calculations, etc.

For example, the conventional wisdom as seen by many project engineers, and frequently by the commercial person drafting an agreement, is that an orifice meter is the method of choice for gas flow determination even though, because of the limited measurement range of an orifice plate meter they require duplicate pipework and meters, which is very expensive in terms of weight and space. The benefits - technical, financial and in operational use - available from using, instead, a multi-path ultrasonic meter, which appears initially to be a very expensive instrument, may not be apparent to either project or commercial personnel.

We sometimes suspect that a project engineer's judgement of an equipment's 'fitness for purpose' may be based on uncritical acceptance of claims made by its manufacturer. The Amerada Hess Product Movements Section's consistent approach is to urge aspiring suppliers of equipment to have the equipment's performance verified by e.g., NEL or similar independent body, or by extensive testing under 'real life' operating conditions.

4 ALLOCATION

The objective of allocation is to split costs and revenues equitably according to the contracts developed by the companies involved in the production and transportation of hydrocarbons.

A good Allocation System should follow the following rules:-

1. It should be Fair and Equitable
2. It should be fully Auditable
3. It should as far as possible, reflect Reality!

4.1 Non-systematic Errors

Broadly speaking measurement errors which are likely to be random and non-systematic are unlikely to be of concern if they cause relatively small overall miss-allocation of costs or revenues.

For example, a common situation might be two oil fields, owned by different Partnerships, being produced through a single FPSO. Modelling the effect of errors in each measurement in the system, for typical flow rates and measurement uncertainties, might look as follows:-

		Typical Value	Uncertainty %	Dry Volume Error % Field A	Dry Volume Error % Field B
Oil to Storage					
Volume	m^3	15000	0.15	0.15	0.15
Temperature	degC	35	0.5	-0.014	-0.014
Pressure	barg	2	0.5	0.001	0.001
Oil density	kg/m^3	850	0.2	0.007	0.007
BS&W	%	2	1.0	0.0007	-0.0007
Water Density	kg/m^3	1050	0.5	-0.0003	0.0003
Effect of uncertainty in Field A's separator oil outlet measurements					
Volume	m^3	9000	0.15	0.06	-0.09
Temperature	degC	44	0.5	-0.008	0.01
Pressure	barg	40	0.5	0.0007	-0.001
Oil density	kg/m^3	820	0.5	0.008	-0.01
BS&W	%	15	1.0	-0.06	0.1
Water Density	kg/m^3	1030	0.5	0.03	-0.05
Effect of uncertainty in Field B's separator oil outlet measurements					
Volume	m^3	5000	0.15	-0.05	0.08
Temperature	degC	40	0.5	0.006	-0.01
Pressure	barg	30	0.5	-0.0005	0.001
Oil density	kg/m^3	830	0.5	-0.03	0.05
BS&W	%	10	1.0	0.2	-0.3
Water Density	kg/m^3	1040	0.5	-0.02	0.03
Effect of uncertainty in Test Separator oil outlet measurements					
Volume	m^3	1000	0.15	-0.009	0.02
Temperature	degC	40	0.5	0.001	-0.002
Pressure	barg	30	0.5	-0.0001	0.0002
Oil density	kg/m^3	830	0.5	-0.001	0.002
BS&W	%	25	2.0	0.03	-0.06
Water Density	kg/m^3	1045	0.5	-0.01	0.02
Overall Error %				0.25	0.36

The errors listed above are for positive applied errors. Because of the differences in production between the two fields, and the different oil and gas properties and gas-oil ratios, the effect of negative applied errors is not quite the same as for positive applied errors, but the absolute size of the difference is very small compared to the overall size of the error.

Clearly the most important measurement is the oil volume measurement, as all other measurements lead to very small overall errors, and if both Fields A and B were owned by the same Partnership there would be very little need to meter these to the accuracy shown above, unless there were some over-riding fiscal requirement because of, e.g., different PRT status for one of the fields.

The real usefulness of the spreadsheet used above is to investigate the effect of deviations from expected operational performance. For example, should the water content determination in Field A's separator oil outlet drift, for example, to 10 percent, then the overall error would be expected to increase from 0.25% to 0.64%.

4.2 Systematic Errors

Most oil companies would not be concerned to measure to these accuracies if they were thought to be truly non-systematic. Although the actual value of the miss-allocation is relatively high, for example a 0.25 % error in 80 Mbopd is equivalent to £0.8 million/year, it is still only 0.25% of the total annual revenue. The error could be in either field's favour.

However, we do need to ensure that unfair advantage may not be gained because one party or another plays on anomalies in the assessment of 'random' uncertainty.

The real value of vigilant metering and hydrocarbon accounting occurs when the errors are not systematic. This is generally the case in the North Sea for oil fields of different stages of maturity exporting in to common pipeline systems. Most of the major oil pipeline systems were put in by the owners of the giant oil fields found in the early days of North Sea development. These fields are generally producing at high water contents, through platforms which are no longer in their first flush of youth, where there is little commercial incentive to export essentially dry crude, and uncertainties in the determination of their export water content may be significant for the allocation of commingled fluids to other users of the shared pipeline. This is in contrast to the small fields which Amerada Hess has typically produced from over the last decade. These relatively small fields start off dry, so they have rather different characteristics to the giant fields.

Because of our experience of the effect of miss-allocation of water and oil in shared pipeline systems we place particular emphasis on water content determination in oil exported from our operated platforms. However, we have not yet defined internally exactly what our standard for this should be. It still is the case that the cost of measuring water content to a high standard is still a small fraction of the potential harm that can arise through not paying sufficient attention to this source of error. Typical measurement errors which we feel comfortable with at the present time are those listed above, although we would welcome new technological advances which would help improve the water content determination further.

5 RECENT CHANGES IN REGULATORY REGIMES

5.1 Change in DTi Policy

The changes that the Department of Trade and Industry have made to offshore metering requirements have been profoundly beneficial. The dictum 'Let commercial forces dictate standards and methods' is exactly what is required, bearing in mind that Government is also one of the commercial forces acting on oil companies producing in the North Sea, and that the DTi has statutory obligations, including a new emphasis on environmental concerns.

This sensible approach is welcomed, with the only caveats that:-

- The shortcomings of others are very difficult/expensive to prove
- Data is difficult to gather from others, and everybody's allocation is inter-dependent
- Many Operators are short-handed, so can not scrutinise allocation properly
- It is difficult for a single Operator to complain effectively in the face of inertia from others

The DTi, however, can and has acted swiftly to right wrongs. Commercial pressure can be slow-acting, and if disputes go to law the resulting costs can be expensive and time consuming.

The DTi has had a major influence in promotion of new technology within the UK metering business. For example, the use of onshore computer terminals at the DTi linked to AHL's offshore installations has reduced the need for DTi audit inspections offshore, with consequent savings to both Operator and Government.

However, as the DTi scales down its operation there is a need for another organisation to take the lead, and set direction for the future. The North Sea Flow Measurement Workshop should be part of the debate that is required.

5.2 Gas

One of the most significant changes in the UK North Sea is the changed position since BG lost its monopoly position as buyer of gas. The Network Code now sets ground rules, while individual agreements specify the detail. This has considerably enhanced the economic attractiveness of the numerous small gas accumulations in the Southern North Sea, as their owners can sell their gas to the independent gas marketers, as for example, Amerada Hess Limited has done to its downstream subsidiary Amerada Gas.

Making agreements which are appropriate for the new fields with the long-standing agreements for gas transportation and sales is one of the major challenges affecting oil companies. There is a need to strike a balance between getting agreements as tight as possible, because recourse to the Law is very expensive, but also the relatively small size of most of the new fields precludes lengthy negotiation.

The large variations in gas prices that are available to sellers may invite disruption, regardless of agreements, since it may be more profitable for the buyer to accept legal cost than to accept supply. This may have a major impact on oil production.

As gas may now be traded as a commodity, with an hourly nomination regime, the timescale for needing operational production data has become much smaller, forcing increased dependence on accurate current data, with minimal operator intervention. Fortunately the technology needed to achieve this is available, and this trend is forcing more standardisation of software and hardware.

6 FUTURE NEEDS, FUTURE TRENDS

Equipment reliability and maintainability has improved dramatically. From an Operator's perspective we hope this will continue to get even better in the future. There is thus a gradual shift in AHL's effort, from focus mainly on metering matters requiring technical specialists, to more and more attention to allocation issues.

The DTi, BG and Pipeline Operators all have audit rights, and the Pipeline Operator has a special duty to protect interests of other users. As offshore equipment improves, the need for frequent audit is reduced.

There is a substantial effort by several meter manufacturers to make multiphase flow meters, some for subsea operation. There is no doubt that this technology will be of very great value to Operators, but so far our experience has been that we have had more value from downhole flow measurements than from topsides or subsea multiphase meters. However, we are still very enthusiastic about the potential of the technology. It has however, a poor track record for reliability, mainly because of interface problems between equipment from different suppliers.

Although the current low oil prices have meant that the North Sea exploration activity has reduced, the industry will respond and we expect to bring on more fields in the years to come. The economics however, are likely to be marginal, so, once project sanction is given, the timescale for any development will always be short. To help make sure that we keep overall life of field costs down we are in the process of developing company standards to allow flow measurement to be better integrated into the Project schedule than we have achieved in the past.

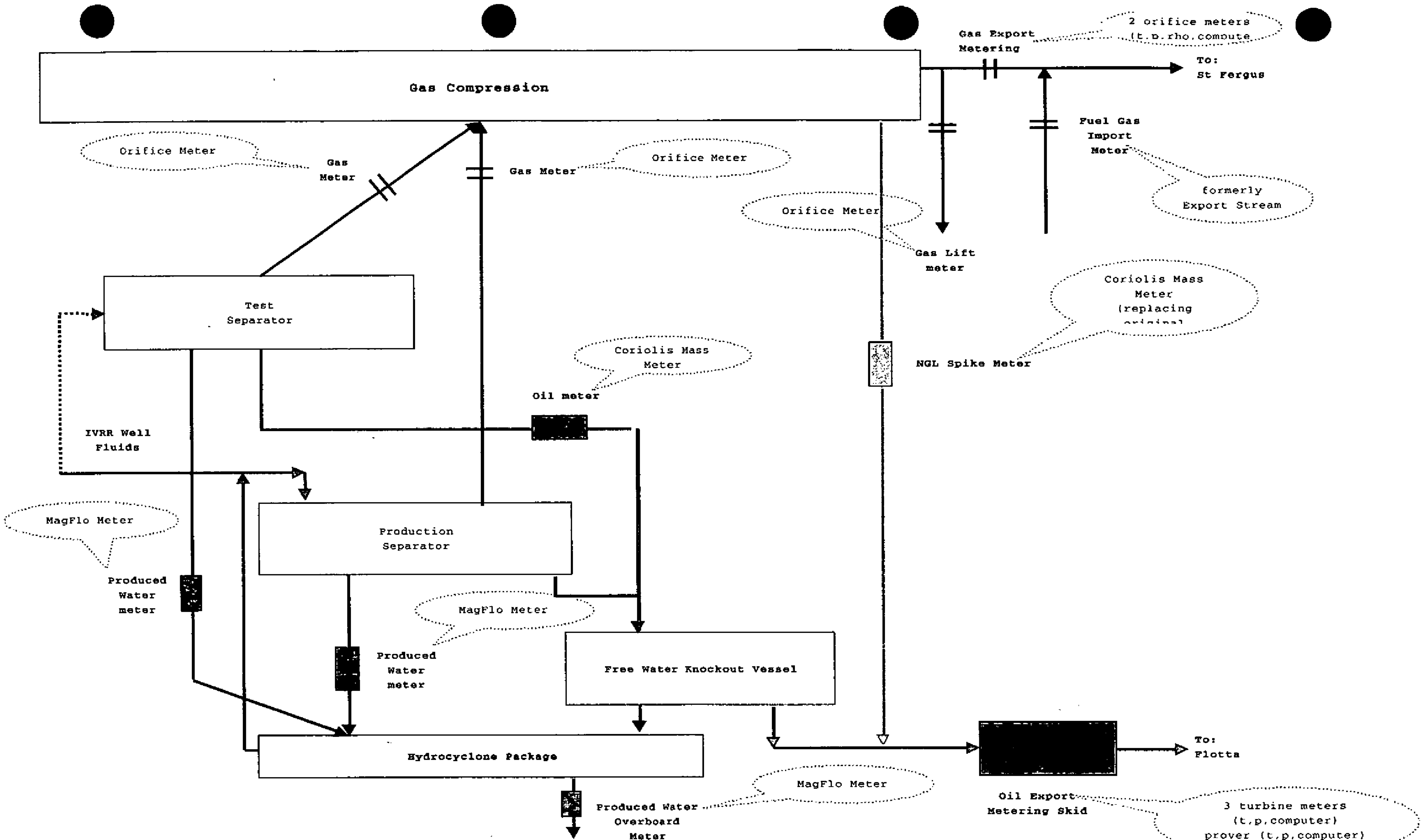

Fig. 1 AH001 original metering system

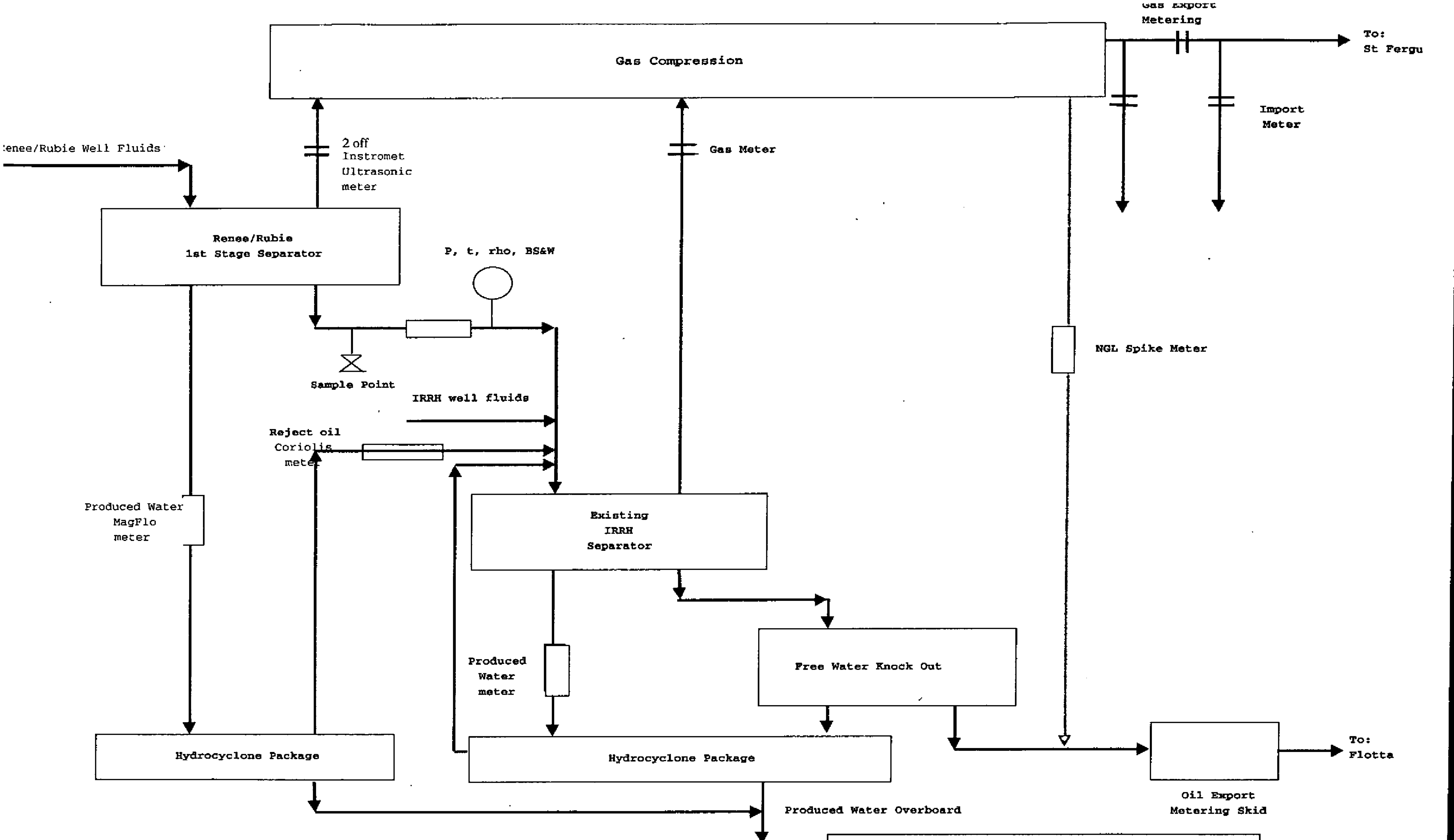

Fig. 2 AH001 Current metering system

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.