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"Auditing the Management of Measurement"

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THE MANAGEMENT OF MEASUREMENT

INTRODUCTION

This paper is prepared for presentation to the Norwegian Society of Chartered Engineers at their North Sea Metering Workshop to be held in Haugesand, Norway 24 - 26 October 1989.

The paper will use the Engineering concept of a closed loop feedback system to develop principles for Management Control Systems appropriate to offshore oil and gas measurement, hydrocarbon accounting and allocation, and data manipulation within computer systems.

Measurement is the cash register of an upstream oil company and let no-one under-estimate its significance. A measurement understatement of just 0.1% to a 100,000 barrel per day producer could result in a pretax cash loss of over $600,000 a year. Ensuring the accuracy and auditability of measurement data is a challenging managerial role spanning the disciplines of Engineering, Production and Management.

As this paper is targeted on the "Management of Measurement", I shall place emphasis on crude oil measurement examples, rather than gas, primarily because of its greater economic value. Hence any weaknesses in control exposes the producer to a greater financial risk.

I shall then develop the role and benefits of Technical Audit, giving practical examples of typical control weaknesses identified, their cause, their effect on the business and the recommendations we made for improvement.

I am employed by BP Exploration, Aberdeen, as Head of Technical Audit, a branch of the Internal Audit Department. I am a Chartered Mechanical Engineer by profession with over 11 years in the oil industry, predominately in project related work. My team of three auditors comprise two Engineers and a Physicist within an environment of Financial Accountants.

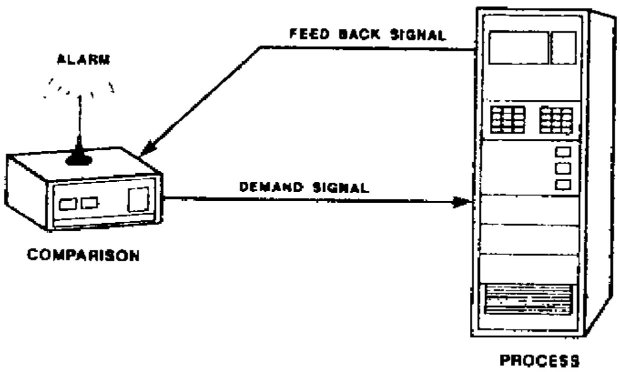
This structure is conducive to our mission which is to identify business risks arising from Engineering and Operational activities and to make practical recommendations for improvements to the control environment, where appropriate.

Oil and Gas Measurement Audits occupy about 50% of our Technical Audit program. Each audit requires a team to spend approximately four days on the producing platform and a further five to eight days in the Beach based offices, auditing hydrocarbon accounting and Management control procedures. We have undertaken measurement audits of most BP operated North Sea Platforms on behalf of our Senior Management; in addition we have conducted measurement audits of Third Party platforms and installations in UK, Norway and in Alaska where BP has operator and non-operator interests.

CONTROL ENVIRONMENT CONCEPT

Most of you will be familiar with the engineering concept of closed-loop control systems. A demand signal is used to initiate an action from a process, the process responds with a feedback signal indicative of the action actually performed. A black box then compares demand and feedback signals and if they match within a defined tolerance it will take no action. If they fail to reconcile an alarm is raised or some other correction automatically initiated.

CLOSED-LOOP CONTROL SYSTEM



This concept may be extended to the management control of a pipeline system transporting crude oil from a number of offshore platforms to an onshore processing plant.

The demand signal becomes the mass of live crude oil as measured by the platform meters. The feedback signal is the mass of all products and stock changes produced by the onshore plant over the same time period. Comparison of the offshore crude measurement with the onshore product quantities, a mass balance, will result in a discrepancy but by graphical trending of this imbalance and assigning warning and action limits based upon experience and statistical methods, a Management control over measurements within the pipeline system will have been effectively and economically produced.

The mass balance control will not be sufficiently sensitive to pick up minor mis-measurements nor identify the source of any data error but it will form the basis for triggering management investigation when necessary. Management, therefore, have a useful control tool and have established a good control environment.

OFFSHORE CONTROL ENVIRONMENT

The above was an example of the feedback control concept applied to a measurement system. Now let us apply the control principle to the work of offshore Operators and Technicians.

As reliable and sophisticated as metering equipment may be, it is all to no avail if the tasks and responsibilities of the individual Operators and Technicians are not clearly defined and there is no systematic check to verify they are being performed fully and diligently.

Tasks are usually defined in written procedures. Responsibilities, in our experience, are less clearly specified. We consider that the Offshore Operations Management is accountable for the quality of the measurement data produced by the Platform and that accountability must not be diluted even when certain tasks are undertaken by visiting Contractors. Regular instrument calibration, routine verification of approved constants within the flow computers, graphical trending of data all provide good quality controls.

However, in order to "close the loop" one needs a feedback signal. This is often achieved by making a Beach based Metering Engineer accountable for the quality assurance of measurement. Regular reviews of procedures and actions will ensure a consistency of approach between crews and between platforms. He will also produce greater awareness of the importance of measurement and provide feedback reassurance to the Technicians that their technical performance is acceptable.

Metering Engineers at BP perform regular and detailed measurement QA. Technical Audit takes a wider view covering measurement, organisation, data flow, responsibilities etc. and where weaknesses are found will identify the potential financial risk involved.

Procedures are important to control as they provide the approved basis for performing given tasks. Witnessing an offshore Technician actually performing the tasks is essential. The Technician's knowledge of the procedures, job training, adequacy of documentation and record keeping all become quickly evident. If a Technician's performance is not entirely satisfactory, it should not be viewed as a failing of the individual but as a failing of a Management control. Was Technician selection, training, supervision, equipment adequate?

DATA CONTROL ENVIRONMENT

Even on the best managed platforms, mis-measurement will occur due, for example, to flow computer breakdown, water samples incorrectly analysed or flow computer testing.

Production data from the platform is usually handed off to the Beach office via a daily telex or automatic transfer. Handling mis-measurements can cause confusion unless there is a clear procedure in place. Confusion has been known to exist as to which is the corrected quantity. Phone calls can resolve the difficulty or just add to the confusion.

Adjustments made to production data must have a clear audit trail. This data forms the basis upon which large sums of money are shared between Partners and vast tax bills are levied. Would you be happy if the electricity company increased your meter reading without full justification?

One method of feedback control to demonstrate the integrity of the daily data flow is to reconcile the month end fiscal quantities produced onshore by the hydrocarbon accountant, with the change in the appropriate non-resettable totalisers on the flow computers offshore, adjusted by sequentially numbered mis-measurement reports.

Computer systems are a potential risk area where data corruption can remain undetected unless adequate controls are in place.

When crudes from different unitised areas are commingled, usually within a pipeline system, agreements specify the basis upon which the blend is allocated back to the producers. Adjustments reflecting the sharing of apparent losses/gains, differential values, tariffs taken as allocated product rather than cash, over/underlift provision, all lead to complex computer systems. As with most computer systems procedures should be in place to ensure data archiving, authorised changes are documented, the confidentiality of information is maintained.

One simple method to demonstrate that complex software is unchanged over a period of time is to retain a set of old input data and the corresponding output. By re-running say one year old input data and comparing the output generated now with that of one year ago will provide reassurance that the software is probably unchanged.

COMPLIANCE CONTROL

However detailed the wording of any agreement or statutory obligation, there is always scope for interpretation. A Technical Auditor's review of a platform's operating and calibration procedures ensures an independent assessment of their compliance and a view as to whether the interpretation could result in a favourable or unfavourable measurement bias. Either could be considered a business risk of which Management should be aware.

If the Transportation Agreements do not define the water-in-oil test procedure to be used, a Technical Auditor will recommend consistency of method to avoid the risk of one producer gaining a financial advantage over another. This method may not be the most accurate available but it should result in equality.

TECHNICAL AUDIT

A Technical Audit team works with the Operator to provide him with an independent assessment as to whether his control systems are in place and effective. Primarily, the Audit Team works for the Client to provide reassurance that his business risk is effectively controlled.

Technical Audit does not seek measurement perfection. All recommendations made must be justifiable against actual or potential business exposure. We accept that an audit is a snapshot in time, the alternate shifts could be adopting a different method of work. For this reason our audits concentrate on establishing suitable controls. A good control environment will highlight future operational weaknesses long after the Audit Team has left.

Technical Audit has the advantages that it is external to the operation being auditted and is therefore independent and objective. It brings together individuals from different disciplines and backgrounds creating a broader view. We consider it more of a independent consultancy service to both client and auditee. Our recommendations are not executive therefore Management's responsibility to manage remains undiluted.

A disadvantage with Technical Audit is that it is a detailed review over a limited time period. Additionally, being an audit, it is not ethical for us to refrain from reporting our professional conclusions, whatever the impact, provided they are factually accurate and without bias.

AUDIT PROCEDURE

Prior to an audit the lead auditor will have requested a copy of relevant documentation such as meter skid schematics, operating, calibration and maintenance procedures, Transportation and Operating Agreements, an organigram etc.

The lead auditor will propose a series of tests and procedures that he will wish to witness. Typically these include the proving of a turbine meter, calibration of an RTD, withdrawal of an orifice plate, injecting defined signals into stream micro-computers to verify computation, a temperature survey across the metering skid, taking and analysing a sample and densitometer validation. Responsibility for undertaking the tests remains with the platform operator.

The audit team will also gather production, laboratory, hydrocarbon accounting and allocation data for a selected month and verify there is accuracy and consistency throughout. The selected month(s) is not advised until the start of the audit.

AUDIT METHODOLOGY

Conventionally we audit within agreed Terms of Reference and against Company Standards and Agreements. Areas of concern to the Audit are termed FINDINGS. These may relate to actual errors (eg an incorrect constant in a flow computer) or, in the opinion of the Audit, there is a practical risk that they could exist (eg the absence of a critical spare metering component would create a finding if a breakdown occurred).

Findings have EFFECTS or potential effects, either a loss of revenue or an increased business risk. Where possible we will assess its significance and place an order of magnitude value on it although we see Technical Audit as more of a means of improving the control of operations rather than as a vehicle for looking for financial claims.

Findings also have CAUSES. An incorrect number in a flow computer happened because there was no routine check of the constants against a checksheet. Where possible we will identify the CONTROL WEAKNESS.

We will then make practical RECOMMENDATIONS to correct findings, mitigate effects and prevent control weaknesses. Our intention is to concentrate on preventing tomorrow's risk rather than apportion blame for yesterday's findings.

The written report invites Operator response to each of our recommendations together with his TARGET DATES for their implementation. Audit FOLLOW-UP by a client representative every six months or so, reporting implementation progress to his Management with copy to Audit, will complete the process. Follow-up ensures that the resources of the client and the audit team expended during the audit period generate maximum long term effect.

TYPICAL AUDIT FINDINGS

During the audit we look, question, analyse but above all listen. Many a finding exposing a substantial control weakness and business risk has been identified through interview and subsequently verified. The following are some of the typical audit findings ..... to date:

a) Meter Proving

Turbine meter proving is always an interesting test to witness. The Operators confidently select the stream, show the pulse counters, plot the result on a meter factor control chart and download the acceptable factor.

Having previously checked the procedures we then ask why, the block and bleed valves were not verified, how the operator is assured that the automatic leak detection on the four-way valve is working, why is the meter skid outlet RTD reading higher than the inlet?

Unfortunately these obvious measurement findings are not the exception. The cause invariably results from inadequate operator awareness of the importance of measurement, weaknesses in quality assurance and failings in the overall measurement control environment.

The meter control charts provide good measurement control, if interpreted correctly. A control chart without action limits or with action limits that are regularly adjusted without full justification, miss their objective. Limits may be changed if the viscosity of the crude changes but should not be changed to reflect bearing wear, unless approved by the Beach Metering Engineer.

Meter control charts indicate achieved linearity and compliance with Department of Energy/NPD requirements for reproving procedure. They also show whether standby meter stream capability exists, that is whether 100% flow rate could be achieved with one meter stream out of commission and no increase in measurement uncertainty. Significant business risk will occur if findings are identified.

b) <u>Calibration</u>

The request to witness the calibration of a temperature RTD is usually well received. We meet with the Technician and, just prior to leaving his workshop enquire why he has not verified his field instruments against the Instrument Shop transfer standard. To calibrate using non-verified instruments may result in a measurement bias.

One site possessed not one but two certified resistance transfer standards - unfortunately they differed by a resistance equivalent to $1^{O}F$ which in itself resulted in a volume measurement uncertainty of over 0.05%.

We expect the Technician to have a proforma on which he enters the 'as found' reading, a defined acceptance tolerance band, and an 'as left' reading. This will permit analysis of instrument stability and permit the frequency of recalibration to be optimised. The use of the back of a restaurant bill to record data was not acceptable! I should note that our criticism was directed at the training and quality assurance exercised over the Technician's work and not at the performance of the individual.

In the North Sea BP frequently use contractors for calibration. It is obviously pointless to have a BP Technician accompanying a contractor to verify his work. However,if prior to signing acceptance of the calibration, the Technician exercises control by comparing the reading of a suitable located mercury in glass thermometer with the flow computer display. Agreement to within 0.2°C is indicative of a good calibration. This control ensures responsibility for calibration remains clearly defined and demonstrates to the contractor that his employer has controls in place. Such recommendations have been implemented.

c) <u>Orifice Plate</u>

Withdrawal of an orifice plate to inspect for edge sharpness and contamination is a standard test.

Although constructed to ISO 5167 standards we verified an instance where upstream swirl effects in a gas measurement system produced a significant discrepancy in the measured flow between primary and stand-by meter tubes. This discrepancy had been been identified by the Beach Metering Engineer through his data monitoring. However, supported by an Audit recommendation, together with the quantified business risk, his Management supported expenditure on improved pipework routing. An example of working with the Auditee to achieve improvement.

d) <u>Flow Computers</u>

Controls over flow computer constants is always a measurement risk area. Audit confidence is increased when there is an authorised list of constants and evidence that the Instrument Technician regularly verifies those and only those constants are in place. We also check. In addition we use independent computer programs and hand calculation to validate the constants. Whenever possible we request the inclusion of a pulse counter to verify totaliser summation. These checks verify compliance with appropriate standards but also demonstrate the level of awareness offshore of the flow measurement parameters.

Incorrect constants or any confusion usually suggest a need for tighter procedural control and greater awareness of their importance. During one audit we found that the tag number on one flow computer had been transposed with another, as had all the relevant constants. Fortunately they were measuring process quantities rather than fiscal quantities - but that was good fortune. Our recommendation for improved control was unambiguous.

e) Temperature Survey

The importance of temperature in crude oil measurement is often overlooked in the offshore operating environment; an error of only 1°C will result in a volume error of 0.1% worth $400,000 per year from a 60,000 bbls/day field. The error can be either to over or understate quantity.

Although modern flow computers will compensate for temperature differences between flow meter and prover outlet, measurement uncertainty is reduced when that difference is very small.

Using the turbine meter RTD as a reference we use a certified mercury-in-glass thermometer, positioned, with good thermal contact, in available thermowells throughout the meter and prover runs. Temperature drop across the skid and a comparison between the mercury and RTD readings can then be made.

We rarely find the temperature drop to be excessive although we often find anomalies in the calibration of the RTDs. The system may have been designed to the required measurement uncertainty, its operation is perhaps another matter.

f) <u>Sampling and Sample Analysis</u>

We generally find that the key areas of risk associated with crude oil sampling are the representivity of the sample stream, sampler hardware and the extraction of a subsample out on the skid. Fiscal analysis performed by dedicated Technicians within well equipped laboratories is usually well managed.

The oil velocity in the sampler bypass loop is isokinetic or greater by design. Wear in the pump or a partially blocked filter can reduce this flow rate resulting in the flow in the sample line becoming non-representative.

The reliability of some flow proportional samplers leaves much to be desired. On certain platforms, from log book entries, it is easier to count the days when the sampler is working rather than count when it is down.

Mixing a large sample (10 litres or more) at the sample skid and extracting a sub-sample for laboratory analysis is undesirable. Mixing procedures using a circulating pump for 30 minutes should be adequate but we would question the control to ensure the full mixing time is always used. Layering, resulting from inadequate mixing, could result in the subsample containing excess water. Proof is difficult but the business risk of overstating water is not worth taking.

The above all lead to increased uncertainty in water measurement and hence dry oil determination

g) Densitometer

Mass measurement systems are essential if there is to be control over systems containing commingled crudes. Volume shrinkage effects preclude accurate reconciliation in volume terms and hence the control environment is compromised. Mass measurement systems require a measure of density. This is usually achieved using densitometers situated in a bypass loop.

Control over these instruments is best achieved by using one as master and a second as an on-line comparison. Significant discrepancy can then be alarmed. But what if they both degrade together due to wax build-up on the probe, for example?

A third densitometer kept off-line and used as a transfer standard provides one alternative validation control. An alternative is to cycle three densitometers between master, comparison and Beach recalibration. Saving a few thousand pounds on the purchase of densitometers could expose the business to risks of millions through increased measurement uncertainty. It is cheap insurance.

h) Hydrocarbon Accounting

Allocating commingled production between several owners, in compliance with all the Agreements, is the responsibility of the Hydrocarbon Accountant. Data processing is obviously a prime role. However BP encourage the Hydrocarbon Accountant to exercise quality assurance checks to ensure the reasonableness of the source input data and to question anomalies. Responsibility for the accuracy of the data remains with the Operator.

The feedback control is provided by the owner of the crude. Although he does not have the full picture a set of trend graphs will give him a good idea, within a defined tolerance, of his expected product entitlement after transportation, processing and losses. Circumstances may change and the product yield may legitimately fall. The Hydrocarbon Accountant would be willing to answer the owner's query or, if necessary, initiate an investigation. In the final analysis the owner is responsible for ensuring he receives full and fair allocation.

i) Business Accountability

A poignant example of devolved business accountability arose during one audit when we were trying to determine responsibility for monitoring and minimising crude oil shipping and transportation losses. Losses typically were 0.2% but had a pretax value of $0.75 million per year.

We were advised that Fred in the Shipping Offi.. compares Bill of Lading and Out-turn reports and would report if excessive losses occurred. When we asked to interview Fred we learnt he had passed away three months previously - no one had taken this role. The control weakness resulted from the geographic remoteness between the two offices and their separate Management structures. This weakness has been rectified.

SUMMARY

This paper has attempted to put into a practical context the concept of the "control environment" and its application to the "**Management of Measurement**" within the oil industry. The paper has also developed the role of **Technical Audit** as an important element of that control environment and has stressed the importance that such audits, though independent in opinion, are conducted as a partnership with the operator, are practical and are forward looking.

When a Technical Audit Team arrives, look upon it as an opportunity for a constructive, informed opinion - I hope it will be.

L C BRITTON
31 August 1989

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.