OPERATING EXPERIENCE WITH A COMPACT PROVER - 1

by

G Ross
Caleb Brett International Ltd

Paper 5.1

NORTH SEA FLOW METERING WORKSHOP 1988
18-20 October 1988

National Engineering Laboratory
East Kilbride, Glasgow

1. INTRODUCTION

This paper is based on a 12" Standard Brooks Instruments Compact Prover, owned and operated since September 1982 by Caleb Brett International Limited, and covers operational experiences, highlighting the problem areas, not at first recognised.

Those not acquainted with Compact Provers will, it is hoped, achieve an understanding of the operation of these units. Those familiar with these units will obtain an insight into operational problems that can arise.

2. HISTORY

Compacts were first manufactured during 1967 (over 20 years ago) by Flow Technology of Phoenix, Arizona, USA. They were known as the ballistrak or Balistic Flow Calibrator. Flow Technology still manufacture similar equipment called the Omnitrak, this normally being a static calibration system - not portable.

Ballistic Provers were developed to provide greater accuracy of measurement and used on exotic applications, such as metering payloads of rocket fuel for attitude control rocket Motors used by NASA.

Flow Technology sold the rights of the Ballistic Provers to Brooks Instruments on December 30, 1981 (Brooks being part of the Emerson Electric Company). Brooks manufacture these units to order, at their Statesboro, Georgia plant in the USA.

They build them to America/Canada area classification standards, however provers with a 60% UK content can be built to meet the European Zone 1 Area Classification standards by Brooks UK Stockport.

Their application for recalibration of in-service hydrocarbon pipe provers, as well as meter recalibration, was first recognised by Caleb Brett & Son's Metering Personnel, during the early 1980's.

The introduction of the first Caleb Brett unit into the UK, took place during late 1982. A Demonstration was arranged during December 1982, at Phillips Petroleum's Seal Sands Terminal. This was followed by work on the Ekofisk Field conducted during February 1983. Thanks to Occidental Petroleum's interest to conduct further trials, the units emergence on the UK sector of the North Sea was established.

A copy of this unit's full operational history can be obtained from Caleb Brett's Aberdeen Operation.

3. OPERATION

A Compact Prover is a Flow Measurement Calibration Instrument employed mainly on liquid service, the main components being a chromium plated 17.4 PH stainless steel barrel section finely honed and a uniquely designed operating piston with an integral poppet valve plate. The Brooks Prover is unique because the operational fluid flows through it, unrestricted at all times, without the use of bypass valving. This is made possible by the poppet valve incorporated via the actuator shaft to the piston of the actuator cylinder. Pressure (set in accordance with line pressure) in the pneumatic spring plenum, serves to assist the closing of the poppet valve and, in conjunction with the calibration fluid flow, operates the piston through a proving pass. (Nitrogen pressure is used to compensate for frictional forces within the barrel, thus ensuring that no energy is removed from the flowing stream. The Nitrogen system is a closed loop and not consumable.

The Hydraulic System returns the piston upstream, holding the poppet valve open in the upstream position thus allowing the normal flow of fluid to pass through the open valve. A failsafe stop is provided at the downstream flange which opens the poppet valve and prevents accidental blockage of the fluid.

The piston position in the cylinder is detected by optical switches. A signal is generated when a "Flag" which is attached to the optic shaft, (this shaft being secured to the main piston) moves in conjunction with the prover piston, and passes through slotted optic switches, blocking the passage of "light" across the gap between the emitter and sensor sections of the switches. Three switches are used, one for sensing the upstream or standby position of the piston assembly and two for defining the displaced volume of the prover barrel.

This displaced volume is passed through a series of pipes to a reference turbine meter. The AC signal produced by the meter is conditioned by a pre-amplifier to match the Brooks dedicated electronics requirements, in our case a 5 volt TTL square wave signal. When the flag passes through the first volume switch and a signal is generated. The action of the flag passing through the first volume switch starts clock one (time for displaced volume) and gates clock two (time for number of flow meter pulses). Clock two starts when the electronics receive the first positive going meter pulse. Clock one is stopped when the "flag" passes through the second volume switch and this also gates clock two. Clock two stops when the electronics receives the next positive going meter pulse. These clocks are referenced to an extremely accurate 1 MHz quartz controlled oscillator circuit. The electronics have thus collected;-

(a) time for displaced volume
(b) time for a number of meter pulses
(c) total number of whole meter pulses.

These data signals, along with the known volume of the compact's displacement (found by waterdraw calibration), are used by the electronics to compute the frequency of the input signal, the flow rate of the liquid through the meter, the K-Factor of the meter and other relevant parameters, required to allow calculation of prover volumes meter factors.

OPERATION (contd)

Having established the reference meter's K-Factor and the volume of the Compact, this instrument can then be employed as a volumetric transfer standard, to determine the volumes of other meters and/or mechanical displacement prover loops.

To comply with fiscal requirements Caleb Brett's system must be traceable to a national standard. In this case the certifing body being the National Weights and Measures Laboratory, who verify, gravimetrically, the volume of a field standard measure used by Caleb Brett to check the volume of their Compact Prover.

This vessel is used, as previously stated, to determine the volume of the compact barrel displacement, by the waterdraw method , whereby the volume of air-free, clean, fresh water is displaced from the barrel of the compact between the limits of the volume optics, into the field standard. This is repeated to prove the repeatability of displacement, until satisfactory results are obtained. After correction for temperature and pressure the volume delivered into the field standard will be the true volume displaced from the compact prover, to be used in future calculations.

4. PROBLEM AREAS

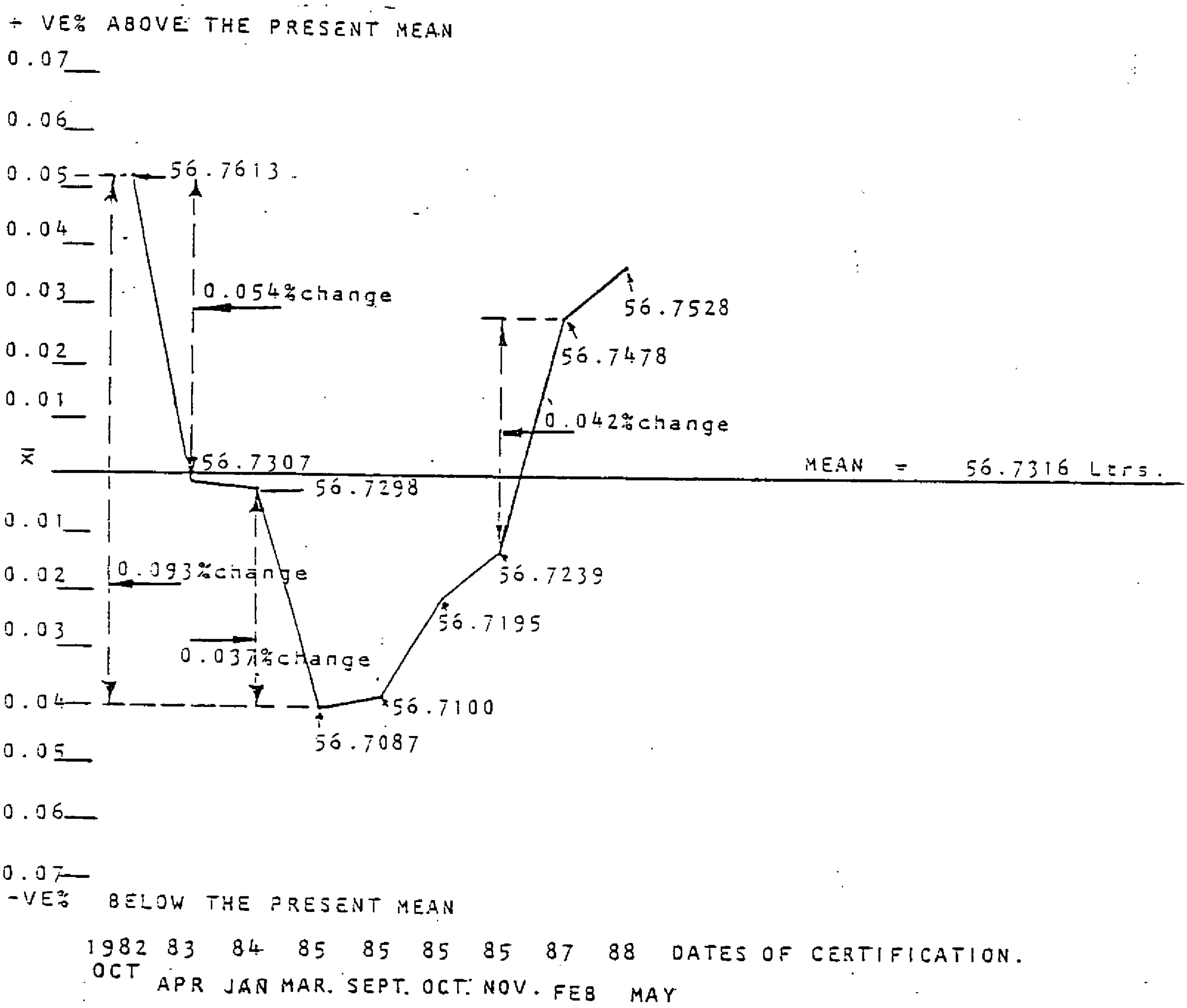
4.1 Measure

The measure is the first link in the volumetric accuracy required to certify the calibrated volumes of fiscal metering stations. Therefore it is of the utmost importance that this calibration be performed accurately, also that every effort is made to protect this measure from damage, which would affect the true volume of the measure. This traceable certification is performed annually or when the volume is suspect. The vessel used by Caleb Brett is a nominal 57 litre type made of stainless steel, and sealed after calibration at all points that could give rise to volumetric changes, i.e. the adjustable scale, the interface drain valve, the spirit levels used to level the vessel and so on. It is transported in its own foam blown packing case, which is carried inside the control cabin. Should any of the seals break, as with any certified device, then the vessel must be recalibrated and resealed. It can be seen that this vessel must be treated with great care. Should the vessel become dented or some materials become trapped inside, then it is obvious that the volume read on the scale would increase. The only way for the volume to decrease is if something is removed from the inside, i.e. if the vortex splitting weir was removed.

Since the original certification on 14th October 1982, we have seen the volume certified drop until a check calibration carried out during September 1985 showed the volume to be on the increase. This is illustrated on figure 1 attached. The actual changes between years are shown. It can be seen that some quite large changes in volume have occurred. Caleb Brett's standard procedure is to carry out waterdraws before and after each metering installation's calibration. The spread of the pre/post waterdraw results, must be within the 0.02% criteria. This procedure can give rise to a slight chance of contamination of the field measure, if the water delivered into the measure is not free from oil or suspended solids. Any residual hydrocarbons would adhere to the inner surface of the vessel, leading to a change in the drain down characteristics. So attention to cleaning of the vessel must be kept in mind, prior to recertification as well as during normal usage.

4.1 Measure (contd)

Shown below is a graphic plot of the certified volume of Caleb Brett's field measure since its first certification, all these tests have been conducted by the National Weights and Measures Laboratory.



DATE	CERT VOLUME	YEARLY % CHANGE	OVERALL % CHANGE
14 October 1982	56.7613		* Highest
18 April 1983	56.7307 Shift Down	-0.0539	
20 January 1984	56.7298 Shift Down	-0.0016	
26 March 1985	56.7087 Shift Down	-0.0372	* Lowest -0.0927
5 September 1985	Shift Up 56.7100	+0.0023	
23 October 1985	Shift Up 56.7195	+0.0167	
28 November 1985	Shift Up 56.7239	+0.0077	

DISPENSATION APPLIED BETWEEN NOVEMBER 1986 - FEBRUARY 1987 DUE TO WORK LOAD.

3 February 1987	Shift Up 56.7478	+0.0421	
May 1988	Shift Up 56.7528	+0.0088	

EXTRACT FROM NATIONAL WEIGHTS AND MEASURES LABORATORY CALIBRATION REPORTS.

4.2 Optics

These slotted Optic switches are sensitive to changes in ambient light conditions if exposed under operating conditions. It should be stressed that the unit should not be operated with the optic switch cover off unless some sort of shade/cover can be arranged over the unit. Having said this, it is often necessary to remove the optic cover to allow visual access to the operating optic shaft, for inspection purposes.

If uncovered under high light i.e. sunlight conditions, the logic can become confused by the different signals it is receiving from the switches, i.e. if the piston is in the upstream optic position and the volume optics switch due to sun light, the logic flip flop can assume an indeterminate state and neither sets nor resets the logic circuitry.

The displaced volume of the compact has been noted to change by one or two cubic inches when the optic cover having been installed is removed and vice versa, under strong light conditions.

When an optic is broken or malfunctions and is replaced again the compacts volume can change, even though the movement of the optic horizontally is less than 1mm, vertical movement being between 4mm to 6mm, to allow for flag clearance and realignment upon replacement of an optic switch. Uncertainty of realignment of the emitter/sensor light path being the problem. Caleb Brett use a master rod of a fixed length made of invar to gauge between the volume optics to check alignment if optics are changed. This also shows up any distortion along the length of the optic assembly.

Another area of concern is the end volume optic which is mounted so that the expansion of the Invar rods accounts for and corrects the linear expansion of the barrel. This spring loaded mounting can lead to changes in volume if the mounting plate becomes displaced or is accidentally moved when the optic cover is replaced. A horizontal movement of as much as 1mm will lead to a 4.64 cubic inch change in the volume of the prover. Since the overall allowable volume change between displacements is +/-0.35 cubic inches, then it can be seen that 4.64 cubic inches is a large error.

Again, if the Invar rods become fouled in some way or dirt becomes trapped between the rod and the optic contact block then again problems will occur. The optic assembly must be in good condition, and no binding or dragging of the optic flag on the optic, or support rods, should occur as this will affect the functioning of the system.

4.3 Seals (Leak Check)

The seals on the compact piston could start to leak at any time during proving. It has been our experience that if a leak check is conducted as recommended by the Brooks Operating Procedure, that leaking seals will be detected prior to any proving and should leakage occur during proving, that this will show up as bad repeatability. Conducting the leak test is simplicity itself, all that is required is a good dial indicator and a good mounting point. This is normally conducted as part of the waterdraw procedure at one point of the piston's travel. The compact is filled with water and has all outlets closed off. Then the operating piston is launched and the dial test indicator applied to the flag rod to indicate any movement. Once again if the water pressure is fluctuating this will affect the leak test.This test can be conducted at any point along the length of the pistons displacement, to check for seal leakage. There is no doubt that a leak exists when one watches the pointer of the dial test indicator. Here again it takes only minor damage of the barrel/seals to cause a leak. This being the only draw back with these units, although the new stainless steel flow tubes with internal chrome plating exibit greater resistance to mechanical damage than the older carbon steel flow tubes.

4.4 Water Supplies

Water Supply problems appear from time to time. The problem is thought to be mainly due to loss of pressure on the rod end this results in the relaxation of the poppet valve and inaccurate deliveries of the displaced volume thereby accurate calibration will not be obtained, this phenomena again on new units, does not appear to our knowledge, as yet. This is in evidence when nitrogen pressure is set at, or below line pressure.

Air in the system will lead to reduced displacement as with any other system, here the air bleed sequence conducted between each withdrawal must be adhered to consistently to ensure no air entrapment in the high points of the compact. The water supply used should be clean, fresh, airfree and of constant pressure.

4.5 Power Supplies

Brooks recommend two separate supplies, one for the unit, and one for the electronics, both of which must be clean supplies, that have no sudden loading due to other machinery. We have in the past operated using the same power supply to power the unit and electronics, without any major problems.

Offshore we normally tie into a circuit which is on the Platform Shut Down System, so that if an alert status arises our equipment is automatically isolated.

4.6 Interface Connections

Cable connections that are repeatedly connected and disconnected are a source of problems. When we had the old electronics hardware we found most of the problems that manifested themselves were, when eventually tracked down, caused by bad connections, or broken wires. Intermittent contacts are difficult to trace and appear as all kinds of faults such as hydraulic lock out of the unit after a single pass, this being caused by a faulty connection between the scaler gate cable and the electronics console. We have eliminated this problem with the new system we are commissioning by using better quality connectors.

4.7 Suspended Solids

Damage to the barrel, or flow tube as it is called, has given us the largest headache. The unit has an inlet fluid filter and we have, in the past, encountered everything from sand, welding slag, prover lining, small rocks to chunks of prover sphere, trapped in the filter. The items that become trapped are not a problem, it's the smaller pieces that pass the filter and enter the flow tube that cause the damage or, in certain cases where the suspended solids are so numerous that the filter chokes and bursts, here again we have suffered flow tube damage. These solids, in many cases, were due to new installations or pipework modifications or because the meter prover calibration connections are normally dead legs on most metering stations and trap all manner of solids.

We use a 40 mesh filter element on the inlet line of the unit, which is removed and inspected after every job. This is conducted for two reasons: 1. It allows us to check the solids caught, and in the case of prover lining, we can inform the client of our findings and 2. Gives us peace of mind that nothing is wrong with the element of the filter.

4.8 Calibration Fluids

Although this unit has been mainly employed on crude oil service since late 1982, other calibration fluids have been employed. These include diesel, premium spirit, naphtha, white oils, black oil and various LPG cocktails of butane and propane.

Bunker fuel or black oils and LPG's give rise to problems. Due to the high viscosity and the glue like nature of black oil, we had a problem once where the piston seals were pulled off the piston. We suspect, but have no means by which to check our suspicions, that a degree of ovality was present in the barrel supplied, or that tolerance problems existed. i.e.if the piston meets the lowest tolerance on its diameter and the barrel meets the highest tolerance on its internal diameter then clearance/seal integrity is affected which can lead to premature failures. We hasten to add, that the time between finishing the proving on black oil and flushing with a lighter product, was sufficiently long to allow the black oil to set in the barrel, albeit that the unit was drained down. Had there been a lengthy flush of lighter fuel oil directly after using the black oil, to clean the internal parts of the compact, this would not have occurred. Unfortunately circumstances were such that it was not possible to conduct a flush immediately.

4.8 Calibration Fluids (contd)

Used on LPG's the unit must be clean to reduce contamination of the product from Black/Crude Oils. LPG's being cleaner fluids of lower viscosities and lower evaporation temperatures, show up slight seal leakage on atmospherically exposed seals straight away. Therefore the units seals must be in good condition before proving LPG's.

Brooks manufacture low temperature stainless steel units capable of operating at -40°C whereas the carbon steel units are limited to a minimum of -20°C. Below this exceeds the steels temperature parameters. Safety precautions when metering LPG's are of a higher level, due to the greater explosive nature and rapid expansion that occurs with gases. Purging with nitrogen before and after proving is one company's policy.

4.9 Corrosion

Corrosion of these units only becomes a problem on non stainless components as with any machinery when its internal parts are unprotected and where the machinery is likely to be idle for a period of more than a few days. The internal parts should always be inhibited as soon as it is anticipated that a period of shutdown or non-use will ensue. This is especially true where the last fluid in use was water or an LPG product. We have in the past during major overhauls found quite thick corrosion build up on the end flanges of the prover.

5.

5.1 Damage in Transit

Damage due to poor handling during shipping has caused considerable set backs. The unit is seen by most offshore personnel as just another lump of steel, although it's construction is fairly rigid, it is still a calibration instrument and should be treated as such.

We normally ship the unit and control cabin in a 20 foot long by 8 foot wide by 8 foot high open top container. We experience no damage under normal transit conditions as the unit and cabin are strapped into the container, but when forklifts are used to lift this container, containing a very unbalanced load, it is little wonder that the container ends up on it's side with the equipment inside damaged. Under these circumstances no amount of custom built container equipment would sustain a six foot roll and drop on to concrete.

Part of Caleb Brett's policy is to witness the loading and unloading of this equipment in person wherever possible, but sometimes we have to trust to our clients employees to pack the equipment away, and generally these are the times that the damage occurs. Refer to photocopy in appendix showing damage sustained due to poor packing practice.

5.2 **Summary**

Having spent some time covering the problem areas it is worth reflecting on just how many of these problems are of human origin. Owing to the nature of this work it is expected by clients that calibrations should be conducted from start to finish irrespective of interruptions. This leads in some cases to excessive periods of work which not only results in errors during calibration, due to tiredness but, to possible operational unsafe practices by cutting corners in an attempt to finish a calibration quickly. Therefore it must be stressed, this work is performed once a year and during this once yearly period that time should be taken to carry out the calibration correctly. Rushing to meet shipping or helicopters schedules only increases the error margin.

Measure

Considering the field measure, where any amount of errors can be directly attributed to human error.

(i) Lack of cleaning of the measure prior to calibration,
(ii) Possible ingress of foreign materials,
(iii) Calibration values that shift the volume,
(iv) Mechanical damage to the vessel, ie dents etc.

Optics

The optics, other than malfunction which has been the least of our problems, since they operate with success, time and time again unless they are disturbed. Generally only mechanical damage or physical misalignment give rise to problems when in use, this again depends on the operator.

Water

Water supplies, use of aerated supplies, or as previously stated dirty supplies will cause problems.

Connections

Interface connections, we have not encountered any problems in this area, since changing connectors, but the simple act of bad preparation of cable connections can lead to intermittent connection problems due to dry soldered joints.

Fluid Contamination

Suspended Solids, if adequate filtration is employed then this would no longer cause alarm. Generally good housekeeping and better engineering practices would see these units in more frequent useage, for either in-house or in-field work.

The present Caleb Brett Unit has worked harder than any other known unit of its kind and has proved itself over and over again as a small lightweight, reliable volumetric transfer standard.

5.3 Further Reading

Various documents have been written about these units: below are listed a few titles and authors who in the past have strengthened the case for use of compact provers.

Practical Field Operation Of Compact Provers For Master Proving.

By M.D.H. Bayliss of Occidental Petroleum.

The Application And Operation Of Compact Provers As Used For The Recalibration Of In-Service Mechanical Displacement Pipe Provers Offshore.

By G.E. Inglis of ICE.

Performance Of The Brooks Compact Prover On Air.

By J. Reid, National Engineering Laboratory.

Experiences With Compact Provers On Live Crude Oil (Extracted From North Sea Flow Metering Workshop, 5 - 7 November 1985).

By Mr John Stokes of Unitech.

Evaluation Report E2479 T 84 Published By WIB, Dated January 1985. Evaluation Of A Model BCP-PS-6623-LPM-12-6-600 Prover.

Reports On Tests Carried Out On A Brooks' Compact Prover By ICI Petrochemicals & Plastics Division Olefine Works, Wilton.

By D D Powell, 11/5/1983.

Mont Belvieu Prover Test (Mid-America Pipeline Co)

W A Latimer (Senior Measurement Engineer), 5th May 1982.

USER/STANDARDS LIST

1. REGULATORY AUTHORITIES (PROVERS ACTUALLY IN USE/ORDERED).

Sweden	Weights and Measures	Prime	Standard
Holland	Weights and Measures	Prime	Standard
UK	National Eng. Lab	Prime	Standard
Hungary	Government Standard Lab	Prime	Standard
Yugoslavia	Government Standard Lab	Prime	Standard

2. INDEPENDENT CALIBRATION COMPANIES.

Scotland	Caleb Brett	Meter Prover/Transfer	Standard
France	SGS	Meter Prover/Transfer	Standard
Australia	SGS	Meter Prover/Transfer	Standard
Norway	Contech	Meter Prover/Transfer	Standard

3. END USERS - EUROPE.

Norway	Norsk Hydro	Transfer Standard
Norway	Phillips	Meter Prover - Deisel
		Meter Prover - LPG
Holland	Shell	Meter Prover - Hydrocarbons + Crude Oil
Holland	Union Oil	Meter Prover - Crude
UK	ICI	Meter Prover - Ethylene
UK	Texaco	Meter Prover - White Oils
Italy	AGIP	Meter Prover - Gasoline

The above is a selection of our European Customer base.

Please also note that the Brooks Compact has now been approved by Weights and Measures in Norway for use as a Prime Calibration Standard.

CALEB BRETT COMPACT FLOW PROVER

ACCEPTED BY: United Kingdom Department of Energy
Norwegian Petroleum Directorate
Netherlands Weights and Measures

Witnessed and accepted by the authorities listed.

CUSTOMERS INCLUDE:-

British Pipeline Agency - Pipeline Provers	Crude Oil) Diesel Oil) Fuel Oils)	Customs and Excise
BP Petroleum Development - Forties (Kinneil) Pipeline	Crude Oil	Department of Energy
BP Refinery, Grangemouth -	Black & White Fuel Oils	Customs & Excise
BP Chemicals, Grangemouth	Naphtha, Ethylene	Customs & Excise
Shell UK - Brent, Dunlin, Fulmar Cormorant Platforms	Crude Oil	Department of Energy
Occidental Petroleum - Piper, Claymore Platforms	Crude Oil	Department of Energy
Texaco North Sea - Tartan Platform	Crude Oil	Department of Energy
Mobil North Sea - Beryl Alpha Platform	Crude Oil	Department of Energy
Phillips Petroleum UK Maureen Alpha Platform	Crude Oil	Department of Energy
Phillips Petroleum - Seal Sands, Ekofisk Platforms	Crude Oil	Norwegian Petroleum Directorate & Department of Energy
Phillips Petroleum Norway - Ekofisk Platforms	Crude Oil	Norwegian Petroleum Directorate
BP Petroleum Development - Buchan Alpha Platform	Crude Oil	Department of Energy

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.