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METERING STUDY TO REDUCE TOPSIDES WEIGHT

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1 SUMMARY

Alternative metering concepts with the same accuracy of todays conventional concepts, are investigated. The alternatives presented are:

Fiscal oil metering:

Alt. 1: Compact prover as alternative to conventional prover.
Alt. 2: Compact prover combined with turbine meters with extended range and K-factor calibration curves in the computer.

Fiscal gas metering:

Alt. 1: Alternative orifice plate metering (flow straightener, increased β-ratio and differential pressure range).
Alt. 2: Ultrasonic flow meter.

Alternative metering concepts with the same accuracy of todays conventional concepts, might reduce space and weight with more than 50 % compared to present layouts.

The total cost savings might be the double of the actual procurement cost of the metering skid.

2. INTRODUCTION

A group in Aker Engineering (AE) has completed a metering study as part of AE's continuous work in optimising platform topside weight and space. Three aspects have been basis for the work:

A The fiscal metering regulations in Norway have recently been revised. These NPD-regulations invite the operators to suggest alternative solutions, if these are superior and beneficial seen from an overall point of view.

B The global concern of carbondioxide emmission has as known initiated a CO2-fee in Norway - this has such increased the focus on other types of critical flow metering, as fuel and flare gas metering.

C The last couple of years new concepts for fiscal/critical metering has moved from "interesting products with potential" to "proven products". Out of several interesting and proven products and techniques, the following have been evaluated in this report:

* Compact prover as alternative to conventional prover (oil metering).

* Flowcomputers using K-factor calibration curves which enable use of turbine meters with extended range (oil metering).

* Ultrasonic meters as alternative to orifice plate metering (gas metering).

* Alternative orifice metering - as use of flow straighteners, increased orifice bore (β-ratio) and increased maximum differential pressure (gas metering).

* Coriolis meters as alternative to turbine meters (oil metering) and orifice plate metering (gas metering).

This paper will not focus on technical details of these new products, but will summarise key features and give an estimate of the space, weight and cost savings the alternative metering concepts will give.

3 NEW METERING PRINCIPLES

3.1 Compact Prover (Oil alternative 1)

A conventional oil metering system in the North Sea is shown in Fig.1. Typically, a number of turbine meter runs including instrumentation and valves, are physically surrounded by a huge calibration unit - a prover. As an alternative to conventional provers, new types with smaller volume - often called compact provers - have been on the marked for some years.

The Brooks compact prover is considered and presented here, as this type has been extensively tested by Statoil and is presently used offshore.

The Statoil tests were performed in 1987 with diesel oil and a "typical" amount of sand for a period which correspond to 10 years of proving operation for two turbine meters.

The repeatability for total of 64 750 strokes or "passes" (equals to 2590 final proving reports) were within 0.03%. Most of them were within 0.02%.

The average stability (long term repeatability) was less than 0.011% per. year.

This prover showed a better repeatability than a conventional prover. All other aspects (weight, cost, maintenance) are superior.

At a Dutch offshore oil platform, three compact provers were installed. After 26000 passes, the following failures were reported:

- Score marks which affected repeatability in one prover barrel, caused by a welding particle from the commissioning. The complete time for replacement of a spare tube was 24 hours.
- One defect poppet valve "O"-ring. Replaced.
- One unpredictable optical switch. Replaced.
- Total downtime: 4 days
- Recommendations: A vertical positioning of the prover may reduce the possibility of abrasive substances remaining in the tube and reduce the chance of severe wear.

An offshore oil platform on the Norwegian sector (Hod) has also recently installed a compact prover. The reports are positive so far (ref. paper from this Flow Metering Workshop).

References is given in Chapter 12.

Below is given a summary of evaluations of compact compared to a conventional prover.

ADVANTAGES

1) Less floor area (1/10 of conventional) and volume.

2) Less weight (1/4 of conventional)

3) Cheaper

4) Better repeatability and long term stability

5) Less instrumentation (no 4-way valve with leak detection, only one pressure and temp. transmitter required).

6) Easier prover calibration (only water draw can is needed).

7) Special material for special applications (cold products, etc.), beneficial experience for operators involved in LPG and LNG where conventional provers seem to fail easily.

8) Internal surface defects less critical (compact prover cylinder can be replaced easily, while a damaged internal surface on a conventional prover is a big problem).

9) Larger range (beneficial if max capacity is increased in connection with future tie-ins, etc. or if extended range is used for turbine meters) and better low flow performance (important late in the field life time and beneficial if other meters shall be used in the future).

10) Easier access to meter run instruments and valves.

DISADVANTAGES

1) Relatively new equipment with limited experience.

2) Not manufactured by metering supplier. (one additional interface to subsupplier).

3) More vulnerable to foreign solid particles (sand, welding particles, etc).

4) Require pulse interpolation in computers.

5) Require turbine meters with high stability due to pulse interpolation.

3.2 K-factor Calibration Curves and Extended Range Turbine Meters (Oil alternative 2)

Modern flow computers have the ability to calculate flow by using the turbine meters' full K-factor calibration curve - as an alternative to the traditional one K-factor for the complete range of the turbine meters. This will drastically reduce the linearity effect of the turbine meters. A typical K-factor curve is given in Fig. 2

Turbine meter manufacturers often operate with a normal flow range of about 1:10 (e.g. 50-500 m3/hr). This range is limited by the turbine meters linearity, as experienced by suppliers, engineering companies and operators during testing.

K-factor calibration curve reduce/ eliminate the linearity effect, and the turbine meters repeatability will be the limiting effect. However, turbine meter manufacturers use the same repeatability requirements for an extended flow range, typically 1:15 or 1:20. This will reduce number of meter runs or meter size required for a given flow capacity.

3.3 Alternative Orifice Plate Metering (Gas alternative 1)

A conventional gas metering system in the North Sea is shown in Fig. 3. Such systems are recognised by a number of orifice plate meter runs with long upstream straight lengths, instrumentation and valves.

Three alternatives are investigated in order to reduce space and weight for the orifice plate metering stations:

1) Flow straighteners
2) Increased orifice bore (β-ratio)
3) Increased maximum differential pressure (max dp)

The Kårstø Laboratory (K-Lab) has done promising testing with flow straighteners especially designed for developing a fully turbulent flow regime within 15 x ID in a gas flow line.

K-Lab report that accuracy requirements are maintained also at larger orifice bores (higher β-ratios) and higher differential pressures (dp) than given as maximum by NPD. This is confirmed by others. Metering suppliers' own calculations have shown that a $\beta = 0.70$ and dp = 700 mbar will not give decrease in accuracy.

Detailed investigations done by Statoil, Aker, KOS and PECO in a recent project show that an increase of differential pressure to max. 700 mbar will give no buckling effect on the orifice plate (additional uncertainty less than 0.001%).

3.4 Ultrasonic Flow Meters (Gas alternative 2)

Ultrasonic flow meters for fiscal gas applications have the following features:

ADVANTAGES

1) A multi-path ultrasonic high pressure gas meter is capable of metering accurately (i.e. to the best standards achieved by an orifice meter run or a gas turbine meter) with 10D straight pipe upstream and 3D downstream. There are also definite indications that the meter could be used in installation where 10D was not available upstream of the meter and still provide acceptable results, particularly if the meter is not operating at the maximum end of the flow range.

2) Degrees of swirl and turbulence in a disturbed flow can be indicated.

3) Small skids due to the meters high turndown and capacity.

4) One meter will in most applications be capable of taking full flow (due to large capacity and range); which will give a lot better flexibility with regards to operation of valves (manual or operated from PCDA).

6) Applicable for high pressure ratings.

7) Easy and cheap to calibrate and maintain.

8) Self checking, to a certain degree.

9) Interchangeable with turbine meters (beneficial for uncertainty diagnosis).

10) Negligible pressure drop.

DISADVANTAGES

1) No international standard yet (draft is expected shortly).

2) Not according to NPD-regulations (concession must be given).

3) Only one manufacturer on the marked which has a proven product.

4) Narrow temperature range: - 20°C + 40°C (valid for the applicable manufacturer).

Extensive tests have been done by Gasunie, Netherlands and K-Lab Norway (ref. ch. 12). About 40 meters have presently been sold, the first metering skid to fiscal standard in the Norwegian part of the North Sea was sold to Statoil this year.

3.5 Coriolis Flow Meter

Coriolis flow meters have been on the market for some years, the main features are:

ADVANTAGES

1) Direct mass flow measurements.
2) No upstream straight length required.
3) Density and temperature as a secondary reading. (Possible to measure water in oil).
4) Large temperature ranges.
5) Reliable instruments.
6) Relatively accurate.

DISADVANTAGES

1) Mainly small meters.
2) Accuracies not proven to be of fiscal standard yet.
3) Uncertainties with regard to pressure and erosion/sand problems due to thin walls.
4) High pressure loss at max. capacity.
5) Uncertainties with regard to installation effects.

References are given in Ch. 12

Based on the factors above, coriolis meters are not regarded to be an alternative for fiscal oil or gas metering in this paper. However, we are awaiting test results to be presented at this Flow Metering Workshop.

For critical flow metering with smaller quantities, as fuel or test separator metering, coriolis meters are considered to be an interesting substitute to conventional meters.

4 WEIGHT AND SPACE COMPARISONS

Conventional metering skids installed in the North Sea are compared with alternative concepts as described above. In this analysis, certain normalising assumptions have been made. In most projects, some non-typical decisions are made. This can be extra set of valves, pipe class higher than corresponding process data, etc. Such considerations are evaluated and "normalised" by calculations.

Another consideration which must be done when space and weight are compared, is to evaluate access. Simpler equipment make access easier. We can see a tendency all over the North Sea that due to low maintenance manning; the access requirements get stricter. This again require larger overall equipment sizes.

Three North Sea oil and gas metering installations are presented here, but five other installations have been evaluated and confirm the results. Savings are given as:

100 - (Alt.2/Conventional)*100 = Savings in %

Complimentary data are given in Table 1 and 2, behind in this paper.

OIL SPACE COMPARISONS

Capacity (Sm3/hr)	Conv. (m3)	Alt. 1 (m3)	Alt. 2 (m3)	Savings (%)
1051	148	80	56	62
1457	205	112	80	61
8600	729	364	301	59
			Average:	61 %

OIL WEIGHT COMPARISONS

Capacity (Sm3/hr)	Conv. (tonnes)	Alt. 1 (tonnes)	Alt. 2 (tonnes)	Savings (%)
1051	22	14	9	59
1457	26	18	13	50
8600	106	71	56	47
			Average:	52 %

GAS SPACE COMPARISONS

Capacity (mill.Sm3/d)	Conv. (m3)	Alt. 1 (m3)	Alt. 2 (m3)	Savings (%)
3.9	70	34	12	83
4.6	97	51	12	88
35.0	625	327	54	91
			Average:	87 %

GAS WEIGHT COMPARISONS

Capacity (mill.Sm3/d)	Conv. (tonnes)	Alt. 1 (tonnes)	Alt. 2 (tonnes)	Savings (%)
3.9	20	13	10	50
4.6	23	17	10	57
35.0	133	106	50	62
			Average:	44 %

6 TOPSIDE SAVINGS

In order to discuss cost benefits due to savings in space and weight, it is useful to know which factors are generating the cost, and the effect of these. Even if the cost benefit of a small metering skid in itself is small, the overall savings will be considerable.

First of all, platform topside represent a major part of the total platform cost. The fraction of the cost will vary dependant of the reservoir, quantities, infrastructure, etc. - but might be as high as 75 % of total, and should be (but are not always) the main target for cost reductions.

The key items on the platform are the process equipment itself. Other items - such as steel, cables, lights, fire protection, lifeboats, ... - can be regarded as a function of the process equipment (bulk and steel function). A larger and more complex mechanical package will give more instruments and cables, and need more structural steel and lights. Engineering will be more complex, construction will be more time consuming and commissioning will require more resources.

A smaller and simpler equipment will then of course give the same savings. The question is how much ? Aker Engineering have data bases which estimate such savings.

A metering station in the North Sea will have a procurement cost of about 100-300 NOK/KG, somewhat dependant of pressure classes, quantities, etc., but an average of 200 NOK/KG apply. Adding the cost for engineering, construction at site, atshore, inshore and offshore commissioning and modifications will give the metering package a price tag of about 600 NOK/KG.

Structural steel will have a total price of 44 NOK/KG and bulk (anything which is not equipment or steel) 255 NOK/KG in the examples investigated. This following cost reductions can therefor be calculated:

Oil capacity	Reductions				
	Dry weight (tonnes)		Cost (in mill. NOK)		
(Sm3/hr)	Metering	Bulk & Steel	Metering	Bulk & Steel	Total
1051	13	16	7.8	1.7	9.5
1457	13	13	7.8	1.3	9.1
8600	50	59	30.0	6.2	36.2

Gas capacity	Reductions				
	Dry weight (tonnes)		Cost (in mill. NOK)		
(mill. Sm3/d)	Metering	Bulk & Steel	Metering	Bulk & Steel	Total
3.6	10	7	6.0	0.4	6.4
4.6	13	16	7.8	1.7	9.5
35.0	80	89	48.0	9.3	57.3

So, even if the alternative metering equipment in itself will not give major savings, the total cost will be considerably reduced.

Combining the cost for fiscal oil and gas metering, adding cost for fuel and flare metering and other critical metering as test separator, reinjection and produced water metering - and then adding the cost for operation and maintenance the total topside savings will reach 50 - 100 mill. NOK.

6 CONCLUSION

Alternative metering concepts with the same accuracy of todays conventional concepts, might reduce space and weight with more than 50 % compared to present layouts.

The total cost savings might be the double of the actual procurement cost of the metering skid.

FISCAL OIL METERING, CONVENTIONAL

Capacity (Sm3/hr)	Length (m)	Width (m)	Height (m)	Area (m2)	Weight* (tonn)	Number of runs	Max.press (Bara)
1051.00	10.0	3.7	4.0	37.0	20.3	3 x 6"	36.0
8600.00	18.0	9.0	4.5	162.0	89.0	5 x 12"	40.0
1457.00	12.0	3.8	4.5	45.6	24.1	4 x 6"	48.1

* Dry weight

FISCAL OIL, ALT. 1; COMPACT PROVER

Capacity (Sm3/hr)	Length (m)	Width (m)	Heigth (m)	Area (m2)	Weight* (tonn)	Number of runs	Max.press (Bara)
1051.00	7.6	2.5	3.5	21.3		3 x 6"	36.0
	+1.5	+1.5	+6.0				
8600.00	18.0	5.4	3.5	101.2		5 x 12"	40.0
	+2.0	+2.0	+6.0				
1457.00	10.0	2.8	3.5	30.5		4 x 6"	48.1
	+1.5	+1.5	+6.0				

* Dry weight

FISCAL OIL, ALT. 2; COMPACT PROVER & EXTENDED RANGE TURBINE METERS

Capacity (Sm3/hr)	Length (m)	Width (m)	Height (m)	Area (m2)	Weight* (tonn)	Number of runs	Max.press (Bara)
1051.00	7.6	1.6	3.5	14.4		2 x 6"	36.0
	+1.5	+1.5	+6.0				
8600.00	18.0	4.4	3.5	83.2		4 x 12"	40.0
	+2.0	+2.0	+6.0				
1457.00	7.6	2.5	3.5	21.3		3 x 6"	48.1
	+1.5	+1.5	+6.0				

* Dry weight

Table 1: Space and weight data for 3 North Sea oil metering skids

7 ACKNOWLEDGEMENTS

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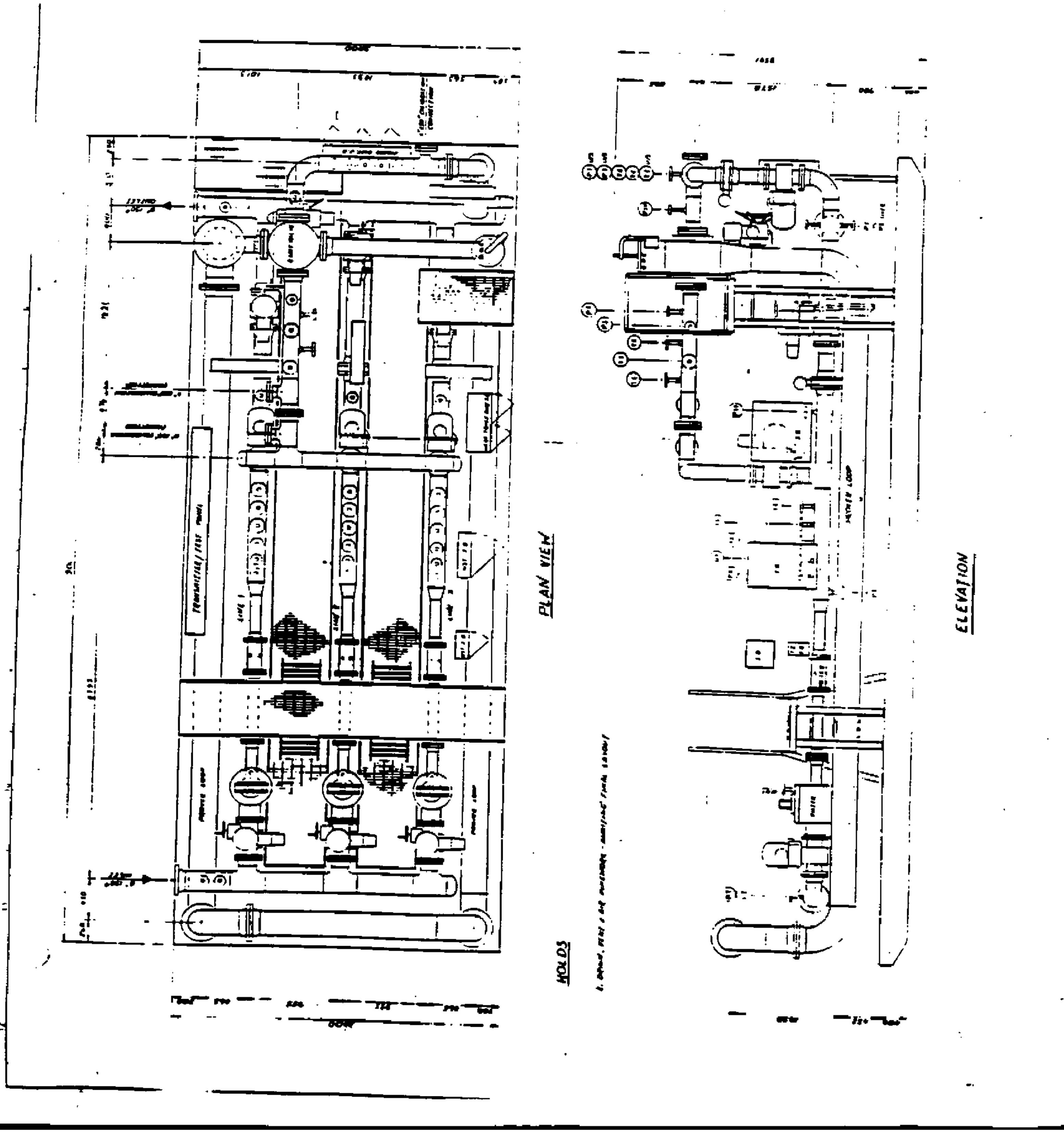
Fig. 1: Conventional Fiscal Oil Metering Skid (printed with permission from KOS/PECO)



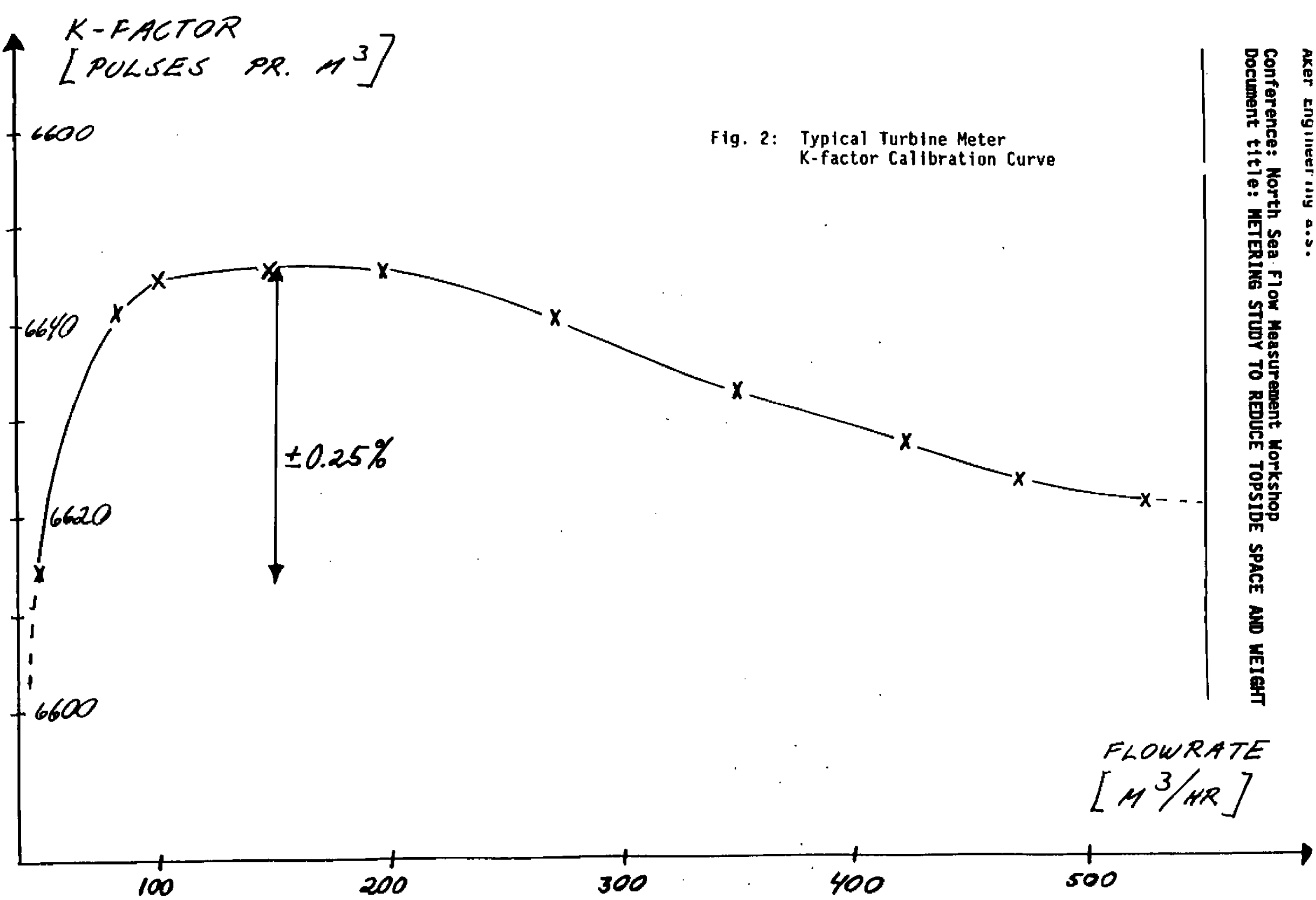
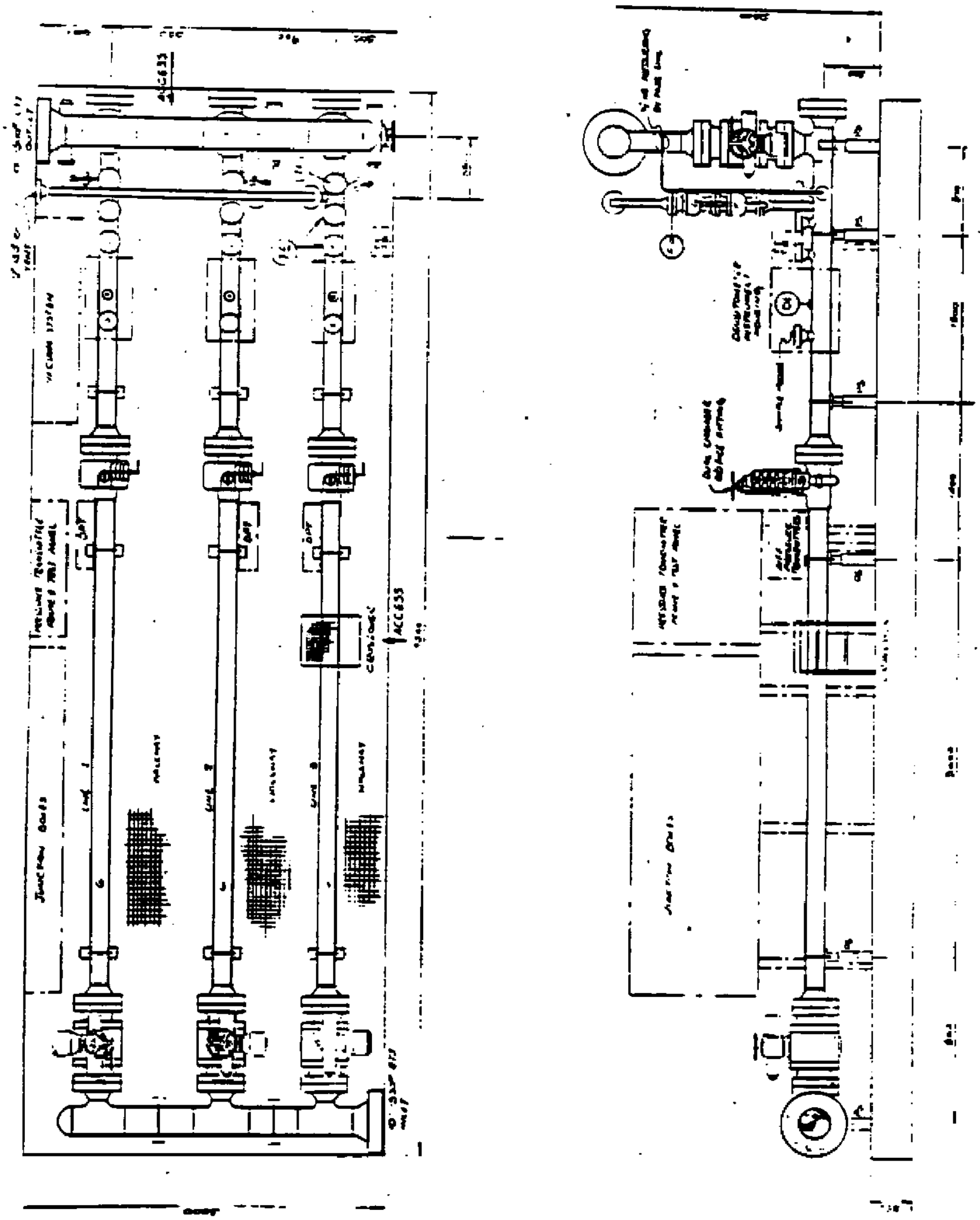


Fig. 2: Typical Turbine Meter K-factor Calibration Curve

Fig. 3: Conventional Fiscal Gas Metering Skid (printed with permission from KOS/PECO)



FISCAL OIL METERING, CONVENTIONAL

Capacity (Mill.Sm3/day)	Length (m)	Width (m)	Height (m)	Area (m2)	Weight* (tonn)	Number of runs	Max.press (Bara)
1051.00	10.0	3.7	4.0	37.0	20.3	3 x 6"	36.0
8600.00	18.0	9.0	4.5	162.0	89.0	5 x 12"	40.0
1457.00	12.0	3.8	4.5	45.6	24.1	4 x 6"	48.1

* Dry weight

FISCAL OIL, ALT. 1; COMPACT PROVER

Capacity (Mill.Sm3/day)	Length (m)	Width (m)	Heigth (m)	Area (m2)	Weight* (tonn)	Number of runs	Max.press (Bara)
1051.00	7.6	2.5	3.5	21.3		3 x 6"	36.0
	+1.5	+1.5	+6.0				
8600.00	18.0	5.4	3.5	101.2		5 x 12"	40.0
	+2.0	+2.0	+6.0				
1457.00	10.0	2.8	3.5	30.5		4 x 6"	48.1
	+1.5	+1.5	+6.0				

* Dry weight

FISCAL OIL, ALT. 2; COMPACT PROVER & EXTENDED RANGE TURBINE METERS

Capacity (Mill.Sm3/day)	Length (m)	Width (m)	Height (m)	Area (m2)	Weight* (tonn)	Number of runs	Max.press (Bara)
1051.00	7.6	1.6	3.5	14.4		2 x 6"	36.0
	+1.5	+1.5	+6.0				
8600.00	18.0	4.4	3.5	83.2		4 x 12"	40.0
	+2.0	+2.0	+6.0				
1457.00	7.6	2.5	3.5	21.3		3 x 6"	48.1
	+1.5	+1.5	+6.0				

* Dry weight

Table 1: Space and weight data for 3 North Sea oil metering skids

FISCAL GAS METERING, CONVENTIONAL

Capacity (Mill.Sm3/day)	Length (m)	Width (m)	Height (m)	Area (m2)	Weight (tonn)	Number of runs	Max.press (Bara)
35.0	26.9	7.3	3.1	196.0	133.2	5 x 16"	173.0
4.6	10.3	4.7	2.0	48.4	22.5	4 x 8"	231.0
3.9	11.6	3.0	2.0	34.8	19.8	3 x 8"	201.0

FISCAL GAS, ALT. 2; ULTRASONIC METERING

Capacity (Mill.Sm3/day)	Length (m)	Width (m)	Height (m)	Area (m2)	Weight (tonn)	Number of runs	Max.press (Bara)
35.0	9.0	3.0	2.0	27.0	50.0	3 x 16"	173.0
4.6	6.0	1.0	2.0	6.0	10.0	2 x 6"	201.0
3.9	6.0	1.0	2.0	6.0	10.0	2 x 6"	231.0

Ultrasonic meters: two meters on top of each other

FISCAL GAS, ALT. 1; ALTERNATIVE ORIFICE PLATE METERING

Capacity (Mill.Sm3/day)	Length (m)	Width (m)	Height (m)	Area (m2)	Weight (tonn)	Number of runs	Max.press (Bara)
35.0	17.6	6.0	3.1	105.6	106.0	4 x 16"	173.0
4.6	7.8	3.3	2.0	16.9	16.9	3 x 8"	201.0
3.9	8.6	2.0	2.0	17.2	13.2	3 x 8"	231.0

Table 2: Space and weight data for 3 North Sea gas metering skids