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Comparison between three flare gas meters installed in a 36 inches process flare line

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1. Summary

A flare meter comparison test was conducted in the 36 in. process flare line at the Statpipe Gas Terminal at Kårstø, Norway. The hydrocarbons evacuated through the flare line range from methane to butane and nitrogen may also be present.

The main parameters of interest for the test were:

Velocity, Volume Flow Rate, Actual Density, Mass Flow Rate, Accumulated Volume, Accumulated Mass, Mole Weight, Velocity of Sound, Pressure and Temperature.

A Fluenta ultrasonic flare gas meter, FGM 100 MK II, a Panametrics ultrasonic flare gas meter, Model 7168, and a Dieterich Standard Diamond II Annubar were installed for the test. **The reader should be aware of the fact that there were no reference flow rate meter or reference densitometer available for the test. The meters can therefore only be compared to themselves.**

The Fluenta and Panametrics Ultra Sonic Meters, USM, have very similar performance.When a measured USM variable is compared to its corresponding variable of the other USM, there is in general little relative discrepancy, and the trend curves follow each other very well.

The Fluenta FGM 100 MK II measured higher than expected velocity (up to a factor 2) in some situations with large negative gas temperature gradients (rapidly decreasing temperature to a value well below zero °C). When the negative temperature gradient reversed, the Fluenta USM again showed expected values.

Before 29-06-93 the Fluenta had a time gate range unable to cover the range of velocity of sound for the heaviest hydrocarbons. This also influenced other parameters measured by this USM in such situations with high molecular weight gas present.

The Panametrics Model 7168 has also shown unexpected measurements in situations with large negative gas temperature gradients. The velocity dropped to zero on one such occurrence, and non-physical velocity of sound for gas (750 - 1000 m/s) has been logged in a few situations. This USM also showed values as expected when the negative temperature gradient reversed.

The Dieterich Standard Diamond II Annubar installed in a system with varying standard density fluids requires an additional densitometer to measure more accurately. At low densities, a velocity range below 5 m/s should be avoided.

Only velocities within the specified range of the meters were observed and logged during the test period.

Two gas samples were analyzed using a gas chromatograph, and the mole weights agreed very well with both USM measurements.

The pressure and temperature were common (analog) input for all meters. These variables were converted individually by each meter's analog to digital converter. The pressure sensor was located about 270 m upstream of the Panametrics USM, and there was still more than 25 m downstream to the Fluenta USM and the Annubar.. Especially at high flow rates this caused a larger absolute pressure error for all meters and a small relative pressure error between the meters. The PT 100 temperature sensor had a rigid thermo well and was mounted downstream of all meters. This caused a time lag between pressure, velocity and temperature inputs which may have caused problems related to transient flow conditions such as the large negative temperature gradients referred to above.

2. Conclusion

The Fluenta and Panametrics ultra sonic meters compared in this test are both comparable in performance. When a measured USM variable is compared to its corresponding variable of the other USM, there is in general little absolute discrepancy, and the trend curves follow each other very well. Situations where some USM parameters show unexpected values have been recorded for both meters, but no absolute trustworthy explanations have been identified for these occurrences.

The Dieterich Standard Diamond II Annubar cannot measure accurately in a system with varying standard density fluids unless an additional densitometer is utilized. The accuracy can be improved using multiple differential pressure transmitters of different range, but at low densities a velocity range below 5-10 m/s should be avoided.

When the mole weight of the gas present was low and the velocity well above idle condition, the Annubar has presented measurements as expected and comparable to the ultra sonic meters' measurements. Gas properties such as density, mole weight and velocity of sound cannot be measured by the Annubar.

Because there were no reference flow meter or reference densitometer present for the test, and for several other reasons, great care should be taken when comparing the results. One parameter may influence another and discrepancies between the meters may be explained and not necessarily caused by bad performance of a meter.

3. Introduction

This flare meter comparison test was conducted in the 36 in. process flare line from train 100 and train 200 at the Statpipe Gas Terminal at Kårstø, Norway.

The hydrocarbons evacuated through the flare line range from methane to butane with mole weights in the range 16 to 58 g/mole. Nitrogen may also be present. Normally, dry sales gas of a mole weight of about 18-19 g/mole is continuously purged through the flare line at a low (idle) flow rate to keep oxygen out.

A Fluenta ultrasonic flare gas meter, FGM 100 MK II, a Panametrics ultrasonic flare gas meter, Model 7168, and a Dieterich Standard Diamond II Annubar were installed for the test. The Fluenta FGM 100 is Statoil property whereas the other meters were kindly lent for the test by Panametrics Ltd. - Ireland through Pemac A/S, Kristiansand - Norway, and the Annubar from Fagerberg, Moss - Norway.

The comparison period started in May '93, more than a year behind schedule. Panametrics and Fagerberg deserves credit for lending their meters for the test as well as for their patience throughout the project.

Fluenta also deserves credit for upgrading the FGM 100 MK I to MK II at their cost, and for the effort in trying to solve the problem related to the RS-232 communication between the Fluenta USM and the logger.

The Statpipe Partners should have credit for financing the project.

4. Test programme

The purpose of the test was to compare the results from the three meters over a period of six months. The test period was originally planned to start early in 1992, but for several reasons the test was delayed. The comparison period started in May 1993 and the logging was stopped in September with this conference in mind.

Due to lacking personnel resources during the hectic Statpipe Gas Terminal periodic maintenance period and the startup of the Sleipner Condensate System, only 3 months of successful measurements were recorded in total. Several situations in late August and early September with high flow rates were attempted logged, but sadly these attempts failed. There are however large amounts of data available even if the total test period logged was 3 months instead of 6.

The measured parameters were:

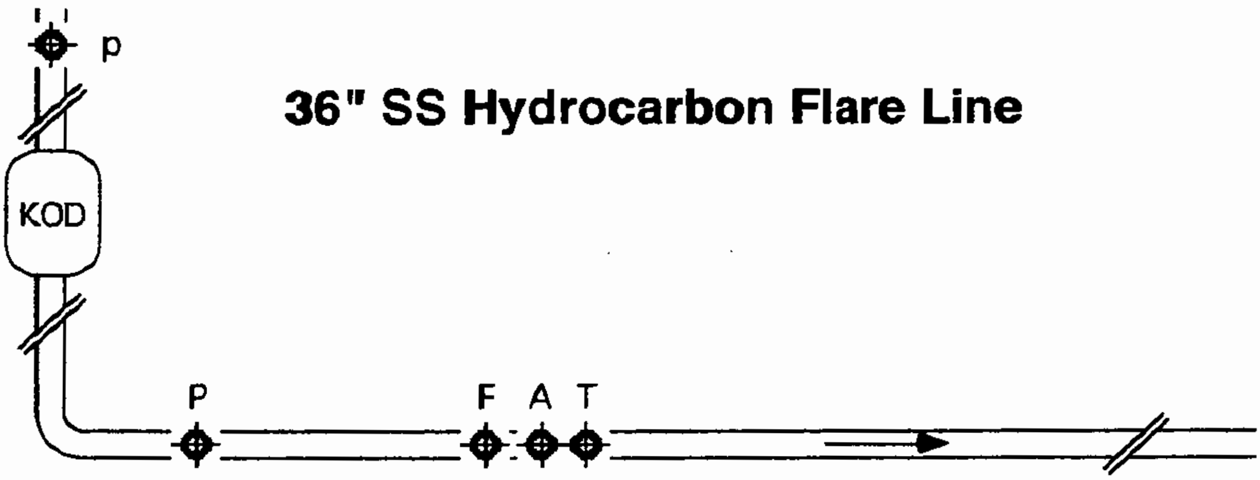
	A	B	C	D	E	F
1	Time	Pressure	Temperature	A-Velocity	A-MassRate	A-VolRate
2	hh:mm:ss	bara	°C	m/s	ton/h	kSm3/h
	G	H	I	J	K	L
1	A-TotMass	A-TotVol	A-ActDens	A-Selected DP	A-DP wide	A-DP mid
2	ton	kSm3	kg/m3	mmH2O	mmH2O	mmH2O
	M	N	O	P	Q	R
1	A-DP low	P-Velocity	P-MassRate	P-VolRate	P-TotMass	P-TotVol
2	mmH2O	m/s	ton/h	kSm3/h	ton	kSm2
	S	T	U	V	W	X
1	P-ActDens	P-MW	P-VOS	F-Velocity	F-MassRate	F-VolRate
2	kg/m2	g/mol	m/s	m/s	ton/h	kSm3/h
	Y	Z	AA	AB	AC	
1	F-TotMass	F-TotVol	F-ActDens	F-MW	F-VOS	
2	ton	kSm3	kg/m3	g/mol	m/s	

Fig. 4.1 Measured variables. A, F and P denotes Annubar, Fluenta and Panametrics respectively.

All variables were registered with a period of about 10 sec and logged as the average value every 5 minutes.

5. Installation

The installation in this flare line which is in continuous operation is not an everyday possibility. It has to be done during the periodic maintenance period when the Statpipe Gas Terminal is completely shut down, or hot tapping procedures must be followed. Hot tapping is expensive and makes inspection of the installation difficult. For these reasons the pressure sensor was located about 270 m upstream of the meters where a pressure tapping was available. Especially under high velocity conditions this introduces an absolute error, but since all meters read the same (too high) pressure, this makes no difference for comparison of the meters´ results. There is also a pressure drop over the distance between the Panametrics USM and the other meters.The pressure drop increases with velocity, and is considered negligible at low velocities. However, at high velocities this may cause a relative error between the meters.



p = pressure P = Panametrics USM F = Fluenta USM
A = Dietrich Standard Annubar T = Temperature
KOD = Knock Out Drum

Distances:
p-P ≈ 270 m P-F ≈ 19 m F-A ≈ 3 m A-T ≈ 1m T- Flare ≈ 1 km
Flare height ≈ 100 m

Fig. 5.1 Installation

The Diamond II Annubar has a square cross section, like a diamond (◊), with the pressure holes on one diagonal. The diagonal is 50.3 mm. The cross section area blocking ratio is 7 %. At the time of installation the blocking ratio was considered not to affect the Fluenta USM.

The differential pressure was measured using three Differential Pressure Transmitters, DPT, of 4-20 mA SMART type. The DPTs covered the ranges:

0 - 25, 0 - 333, and 0 - 5000 mm H_2O (2.5, 33 and 500 mbar)

The low range DPT was a Scope & Faeser APR 200 and the upper range DPTs were both Rosemount 1151.

The USM suppliers installed their respective meters for the test. The Annubar was installed by Statoil.

The pressure and temperature transmitters were also SMART type 4-20 mA transmitters covering the ranges 0.8 - 5 bara and ÷100 - +50 °C respectively. All meters read the same pressure and temperature signals using their own Analog to Digital Converters, ADC. The pressure and temperature readings of the different meters were checked against each other and showed small but acceptable discrepancies of typical 30 mbar and 1 °C. The USM ADCs were not checked by other methods by the test team.

The temperature probe was a PT 100 mounted in a rigid well intruding into the flare line. The mass of the thermo well caused a time lag in temperature relative to pressure and flow measurements. This time lag was enhanced by the downstream mounting position, but this position was chosen because of a potential flow disturbance problem if mounted upstream.

The Panametrics USM has two probes intruding almost radially into the flow with the sensor surfaces angled towards each other, whereas the Fluenta USM's sensor surfaces are mounted flush with the pipe wall. The sensors can be removed when the flare line is in operation.

The Fluenta USM is designed for measuring velocities up to 100 m/s in temperatures down to ÷30 °C. The Panametrics velocity range is specified up to 85 m/s and temperature input can be down to ÷50 °C.

The USMs were both sending their data via a serial RS-232 line. Both meters has this feature as well as analog outputs. The serial output makes more parameters available than the option of analog output.

The communication was established with the Panametrics USM after some trial and error. Parameters in one of three preselected scanning tables can be polled by sending a single character to ask for a parameter. The USM will then send this parameter at its own updating frequency until a new parameter is called on.

The Fluenta USM has a similar concept although one must send a string of characters for each parameter that is called upon. This concept was never established 100 % and a communication problem caused the USM to warm start, breaking the communication string from the Macintosh logger. When the logger was disconnected, no warm starting of the Fluenta USM was registered. The phenomenon can be seen as a negative ripple on some of the trend curves, caused by one or more lost samples in an average value. The problem did not occur in every average so the true Fluenta USM output can be seen represented by the smoother top of the trend curve. In general, the problem can easily be identified and is more of cosmetic art when viewing the trend plots from this test.

When the Fluenta FGM was upgraded from MK I to MK II all parameters wanted could be sent in a single string at each USM update. This concept is very convenient. The polling string was reduced to one character only. Still, the warm start problem continued, and both Statoil and Fluenta made an effort in solving this problem. In late June Fluenta identified a handshaking disagreement with the logger which made us believe the problem was solved. However, some problem related to the communication continued for the rest of the test. Unfortunately, the Statoil test team did not discover this until after quite some time. Time and personnel resources at Statoil did not allow for more trial and error to solve the problem at this time. RS-232 communication is sometimes hard to establish, and it could just as well have been the Panametrics USM which had problems "understanding" the logger or visa versa.

6. Measurements

A Macintosh IIsi computer using LabVIEW 2.2 software and a National Instruments NB-MIO-16 Analog to Digital Converter, ADC, as well as the two serial RS-232 ports were used for the data acquisition.

The analog signals from the barriers of the pressure-, temperature- and DP-transmitters were converted in the ± 10 V, 12 bit ADC using 475 Ω resistances. The system was checked using a Solartron 7061 DMM.

The temperature sensor was a PT-100 resistance thermometer device, RTD, mounted in a thermo well. The temperature response is somewhat delayed relative to the pressure and velocity measurements because of the mass of the rigid well and because of the distance between the sensors.

All Annubar calculations were performed using LabVIEW on the Macintosh.

All USM parameters were calculated internally in the meters except for the Panametrics standard density which was derived by dividing the mass flow rate by the volume flow rate. The total volume flow was derived by dividing the total mass by the standard density. The standard density was converted to actual density using the analog pressure and temperature. Unit conversion was also performed on some of the data from the USMs.

The Annubar had no density **measurement** input to its algorithm. It therefore had to rely on the standard density for the purge gas which was the most common quality in the line. This standard density of 0.78 kg/m^3 was corrected for pressure and temperature to derive the Annubar actual density. Thus variations in mole weight/standard density when other gases than sales gas were flared could not be taken into account by the Annubar. This would have required an additional densitometer.

7. Test data

The reader should be aware of the fact that there were no references available other than the the Kårstø Lab gas chromatograph used to analyze the two gas samples taken during the test. No reference flow rate meter or reference densitometer meter were available for the test. The meters can therefore only be compared to themselves.

Pressure:

The normal pressure is 0.94 bara during "idle" flow. This is due to a lower than air density for the gas used for idle flow and the friction loss in the 1.3 km flare line.

During high flow rates pressures above 1.5 bara have been experienced. A small pressure difference caused by friction loss over the distance between the meters was not accounted for. Also, the absolute error common to all meters, caused by the pressure transmitter being mounted about 270 m upstream of the meters should be noted. Both errors grow with increasing velocity.

The Annubar cross section area blocking ratio of 7 % should also be noted here although the effect on the USMs was assumed to be negligible.

Temperature:

The normal temperature fluctuates a lot due to daily variations of the surrounding conditions. At high flow rates, the temperature depends highly on which process vessel is vented. The composition, pressure and temperature of the vented fluid determine the gas temperature measured. Temperatures between ÷ 60 and + 40 °C have be seen. The lowest temperatures measured are below the lower temperature specification of both USMs. (Fluenta ÷ 30 °C, Panametrics ÷ 50 °C)

Velocity:

During flare idle, normal velocity is 0 - 0.3 m/s. Even negative velocities can be seen. This is possible due to batches of varying density gas flowing up the flare riser and flow fluctuations in the line. The Panametrics USM is capable of of measuring a maximum velocity of 85 m/s and the Fluenta USM 100 m/s maximum velocity. The flare line design allows for velocities twice as high, although such situations hardly ever occur.

At a limited high velocity range a loud noise was heard from the Annubar area, probably caused by resonance. If this could have had any influence on the USMs has not been identified.

Differential pressure:

This is the primary measurement for the Annubar velocity. Three different range transmitters cover the total velocity range of the Annubar. The low range transmitter drifted quite much causing large offsets when measuring low velocities. Assuming correct zero and correct standard density, the shift velocities should be at about 15 m/s and 55 m/s. The shift was determined by the upper range DPT.

Density:

The Annubar had no density measurement available. It relied on a fixed standard density corrected for pressure and temperature. This standard density represent light sales gas used for flare idle. When heavier gases was present, all parameters calculated by the Annubar algorithms are influenced.

Mole weight:

Hydrocarbon mole weight from methane to butane range from 16 - 58 g/mole. Nitrogen may also be present. Liquids should normally not be present, but traces may be caught in the knock out drums to slowly evaporate.

Velocity of sound:

The higher the mole weight, the lower is the VOS. It should be noted that the time gate of the Fluenta USM allowed 250 - 450 m/s before it was adjusted 29-06-93. This influenced other parameters of this USM when high mole weight gases were present before this date. The Fluenta USM range was set to 200 - 450 m/s. The Panametrics USM has a range of 150 - 1500 m/s.

Some of the test data is shown as trend plots in the appendix. **In general, there is little discrepancy between corresponding parameters of the two USMs. The trend curves follow each other very well. The Annubar shows a discrepancy to the USMs as expected in situations of low velocities and high mole weights.**

Below, some occurrences of special interest are reported.

20-05-93:

At about 20:30 a batch of 30-35 g/mole gas mix was vented. This was recorded by both USMs. The effect on density and mass flow measured by the Annubar is clearly seen as expected (since no densitometer was present in the Annubar system). The higher density from the high MW gas is hardly noticed in the Annubar density "measurement". The mass rate was somewhat less affected, but this was due to a positive offset in the Annubar velocity which was caused by a drifting low range DPT.

14-06-93:

At about 9:00 a sample was taken from the Annubar DPT pressure line and analyzed using the lab gas chromatograph. Both USMs showed a value of about 18.5 g/mole whereas the analysis showed 19.3 g/mole.

15-06-93:

In the periods 15:30-16:25, 16:50-19:03 and 19:30-20:10, the mole weight of the gas present was so high that the range of the Fluenta USM time gate was unable to cover the Velocity Of Sound, VOS, of this gas. This is believed to be the reason for the high velocity measurement of the Fluenta USM. The time gate range of the Fluenta USM was expanded on 29-06-93 to cover the VOS range 200-450 m/s.

Ca. 21:00 a batch of lower MW gas was released. The temperature dropped to ÷ 56 °C (below both

USMs´ ranges). All meters responded to the increasing velocity. The Fluenta showed a velocity higher than the others. The Panametrics and the Annubar showed comparable velocities, and in this occurrence the standard density of the gas was close to the constant standard density used by the Annubar algorithm. The Annubar velocity could therefore be assumed correct in this situation.

In the middle of the high velocity period, the Panametrics velocity suddenly dropped. A non-physical VOS for gas of 750 m/s was measured simultaneously, and the density and MW also showed values that can not be correct. Once the temperature drop stopped, however, the Panametrics USM again showed values in a believable range.

24-06-93:

A new GC lab analysis after trip of a compressor. Panametrics showed 36-37 g/mole, Fluenta showed 33-34 g/mole, and the lab analysis said 35.6 g/mole which is quite in the middle of the two USM measurements.

08-07-93:

Here we have two situations of cold, low MW (17-22 g/mole) gas release. This is similar to the occurrence of 15-06-93. Again, the Fluenta showed higher velocity than the two other meters, and again, we could assume the Annubar density to be nearly correct and therefore also its velocity.

It seems that the higher velocity (a factor of 2 or more) of the Fluenta can be linked to a sudden large drop in temperature to well below zero. However, when the steep, negative temperature gradient stops, the Fluenta velocity again comes back to expected values.

8. Comments

All meters included in this test need additional pressure and temperature transmitters. The Annubar will need another additional densitometer to measure accurately in a system where the standard density varies as in the system of this test. It will also need an ADC and a processor which was not provided by the supplier for this test. The USMs have an inboard ADC for pressure and temperature connections as well as a processor for calculations and display.

The Annubar velocity measurement (and all other flow variables dependent on the velocity) is less accurate below 5-10 m/s when the (constant) standard density is as low as in the test system. The function given in the Dieterich Standard Annubar Flow Handbook is plotted in fig. 8.1 - 8.2. The function clearly shows the Annubar velocity´s poor sensitivity to differential pressure in the low velocity regime. However, when the standard density increases, as seen in fig. 8.3, the Annubar velocity´s sensitivity in the low velocity range also increases.

During the test the Annubar low range DPT often showed a drifting zero which greatly influenced the velocity and the daily accumulated mass. In addition, if the DPT drifted into the negative range, the Annubar flow parameters could not be calculated because of a negative root.

The Annubar is a suitable instrument for an application where the velocity and density ranges have been carefully evaluated to suit its characteristics. In the process flare line at the Statpipe Gas Terminal, it has clear disadvantages compared to the USMs.

Both USMs will measure properties such as density, mole weight and velocity of sound in addition to the flow parameters velocity, volumetric flow rate and mass flow rate measured by the Annubar.

USMs will especially cover the low idle velocity range much better than the Annubar. As in this test, the Annubar accuracy and range can be improved by using multiple DPTs of different range, but this cannot overcome its characteristics at low velocities and low densities.

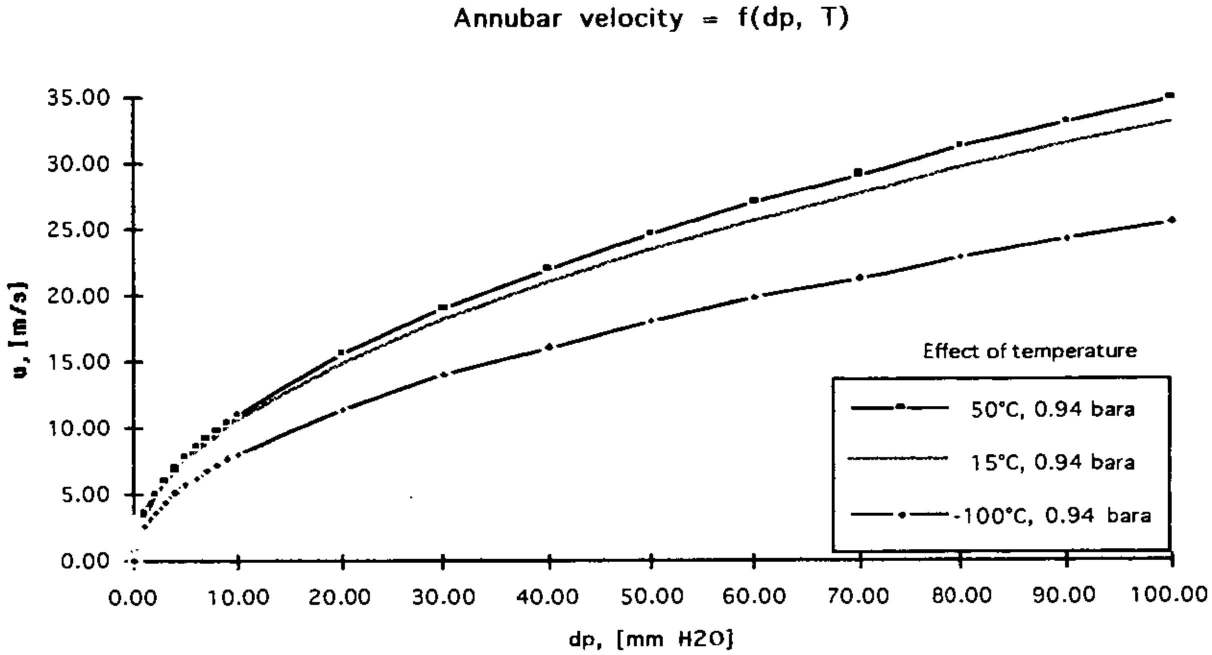


Fig. 8.1 Annubar velocity as function of differential pressure and temperature.

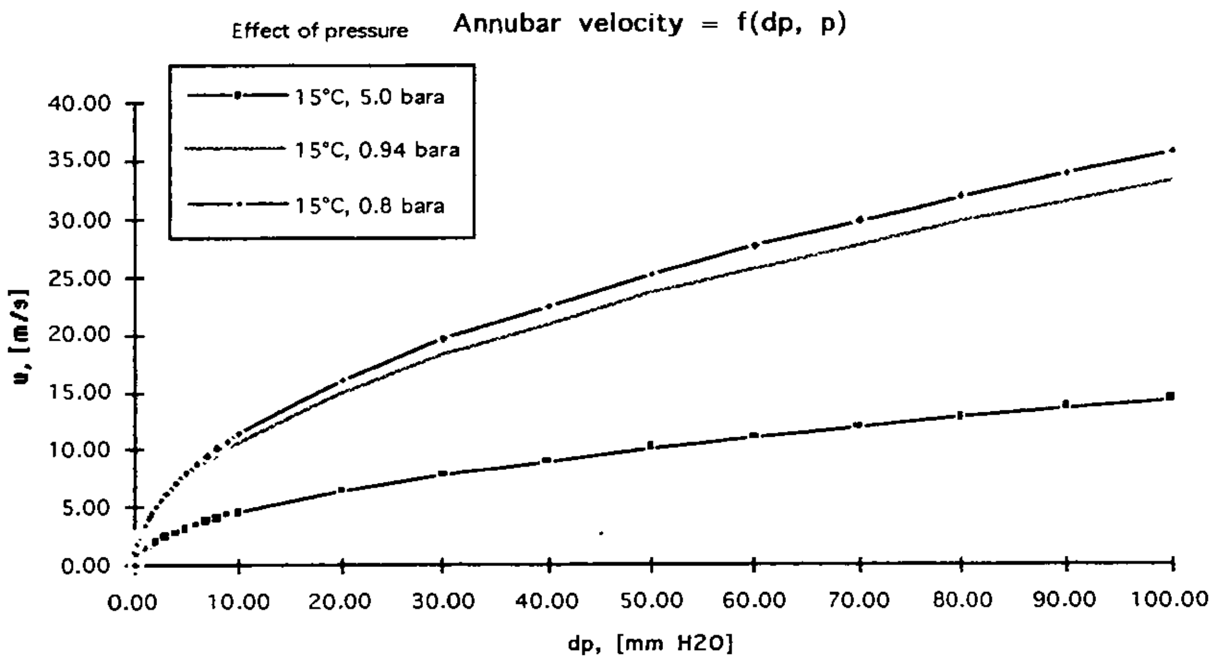


Fig. 8.2 Annubar velocity as function of differential pressure and absolute pressure.

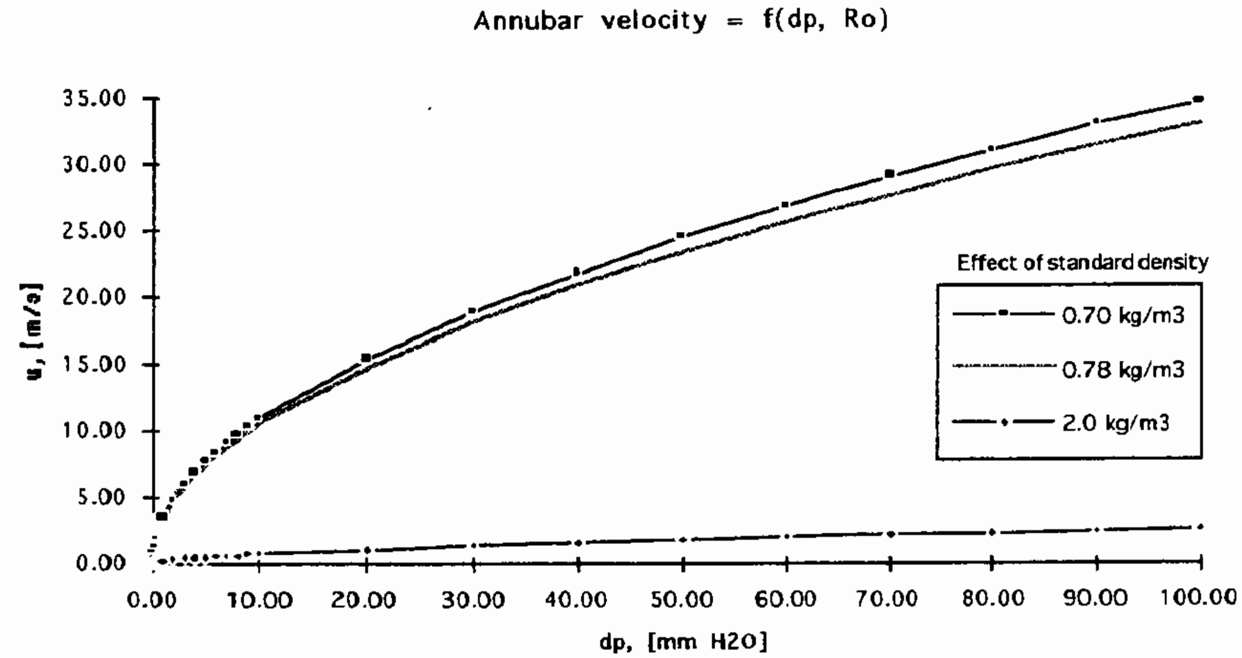


Fig. 8.3 Annubar velocity as function of differential pressure and standard density.

The negative ripples/spikes and complete dropouts seen on some of the trend curves is mostly due to communication problems between the USMs and the Macintosh logger. When the logger was connected to the Fluenta USM, the USM could sometimes warm start probably because of a handshaking problem of the RS-232 line. The warm start caused some data in the next averaging period to be lost, and this is seen as one or more fixed level negative spikes on the curves. The reason was one or more samples lost without being excluded from the averaging routine of the logger. The upper trend of the curves represent the true USM output.

Similar with the Panametrics' actual density. This parameter is calculated by the logger as mass flow rate divided by standard volume flow rate and corrected for pressure and temperature. If one of these variables were lost, the density was also lost. This can be seen as complete dropouts to zero. The upper trend of the curve represent the true USM output.

The Annubar's DPTs sometimes measured negative values probably because of DPT zero drift. Since differential pressure goes under a square root in the Annubar algorithms none of Annubar's parameters are calculated if this situation occurs for the selected (low range) DPT.

In general, the USMs followed each other remarkably well in all measurements. There always seemed to be a more or less constant offset. This was probably due to slightly inaccurate spacing between the two ultra sonic sensors of one or both USMs.

The Annubar follows the USMs well in high velocity conditions where the standard density of the gas is close to the constant standard density specified for the Annubar. When a high molecular weight gas is released, this effect on the actual density is detected by the USMs, but not by the Annubar. When the temperature or pressure influence the density, these effects are detected by all three meters.

A high volume noise has been heard from the test section of the flare line in a limited, high velocity range. This is believed to be resonance noise from the Annubar. If this disturbance could have had an effect on the measurements, we have not been able to identify.

Situations where the temperature suddenly drops to well below zero have been observed to produce unexpected measurements by both USMs. However, when the temperature gradient flattens and start to increase, the measurements go back to expected values. Although both USMs have a fault indicator (LED), these signals have not been logged. It is therefore possible that the occurrences reported here were alerted by the USMs. Further, the time lag between pressure, USM measurements and temperature in this installation may be part of the reason for the USM problems when unexpected measurements have been recorded related to sudden, large drops in temperature.

Both USM suppliers have been at Kårstø for service on their systems during the period the meters have been installed (1991-1993). The Fluenta USM has required more service than the Panametrics. This has been due to implementation of a new algorithm, and due to the communication (handshaking) problem. The Fluenta FGM 100 was upgraded from MK I to MK II before this comparison test started. Both USM suppliers have performed service on the sensors once. No service has been performed on the Annubar. However, the DPTs were calibrated and adjusted a few times by the Statoil test team.

Appendix 1

Test data trend plots

(On following pages)

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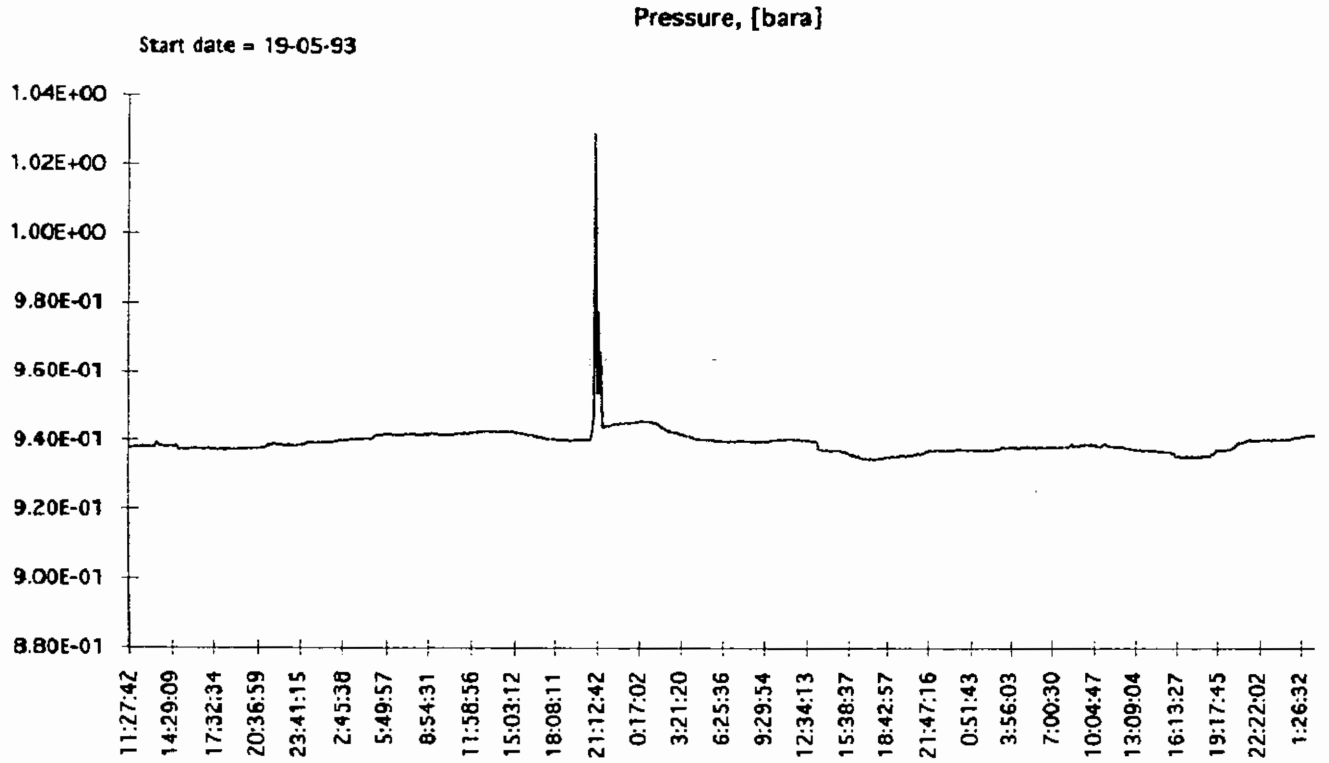

Pressure, [bara]
Start date = 19-05-93
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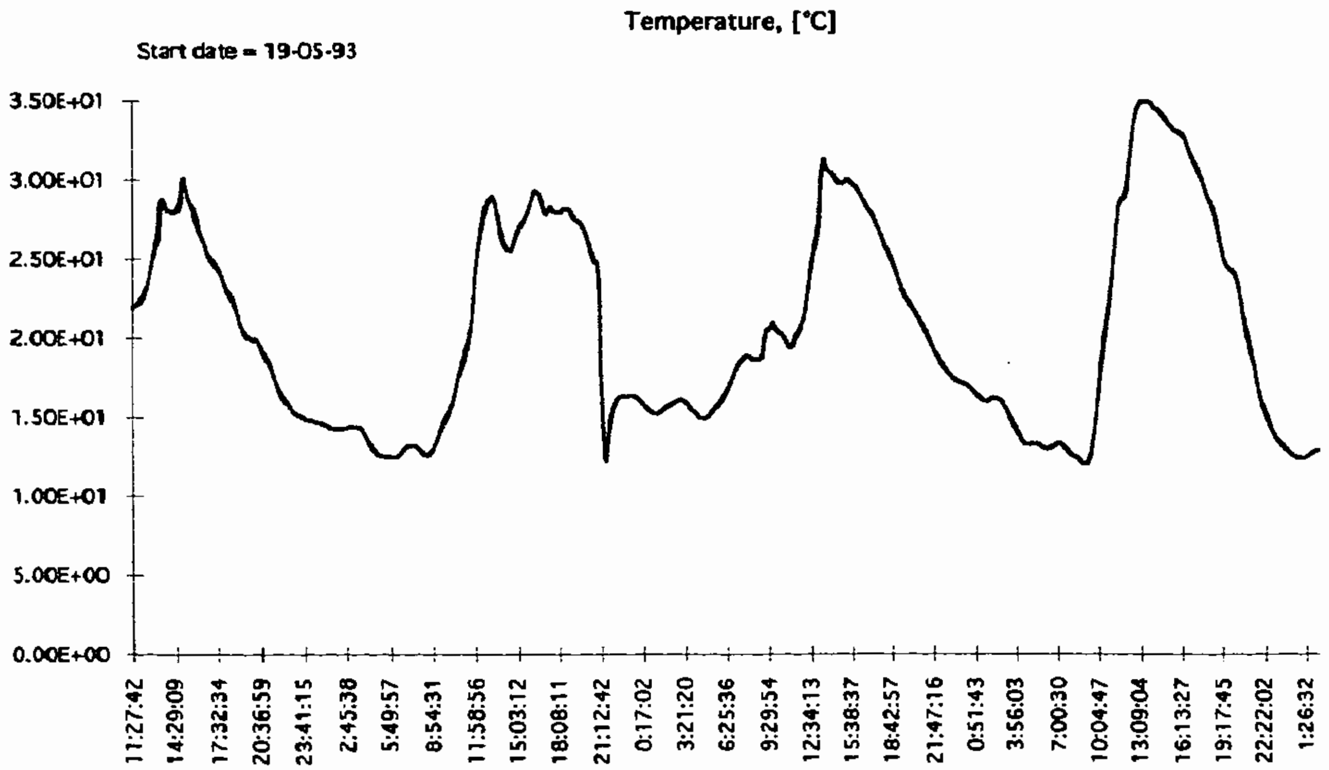
1.02E+00
1.00E+00
9.80E-01
9.60E-01
9.40E-01
9.20E-01
9.00E-01
8.80E-01
11:27:42
14:29:09
17:32:34
20:36:59
23:41:15
2:45:38
5:49:57
8:54:31
11:58:56
15:03:12
18:08:11
21:12:42
0:17:02
3:21:20
6:25:36
9:29:54
12:34:13
15:38:37
18:42:57
21:47:16
0:51:43
3:56:03
7:00:30
10:04:47
13:09:04
16:13:27
19:17:45
22:22:02
1:26:32



Temperature, [°C]
Start date = 19-05-93
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3.00E+01
2.50E+01
2.00E+01
1.50E+01
1.00E+01
5.00E+00
0.00E+00
11:27:42
14:29:09
17:32:34
20:36:59
23:41:15
2:45:38
5:49:57
8:54:31
11:58:56
15:03:12
18:08:11
21:12:42
0:17:02
3:21:20
6:25:36
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15:38:37
18:42:57
21:47:16
0:51:43
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13:09:04
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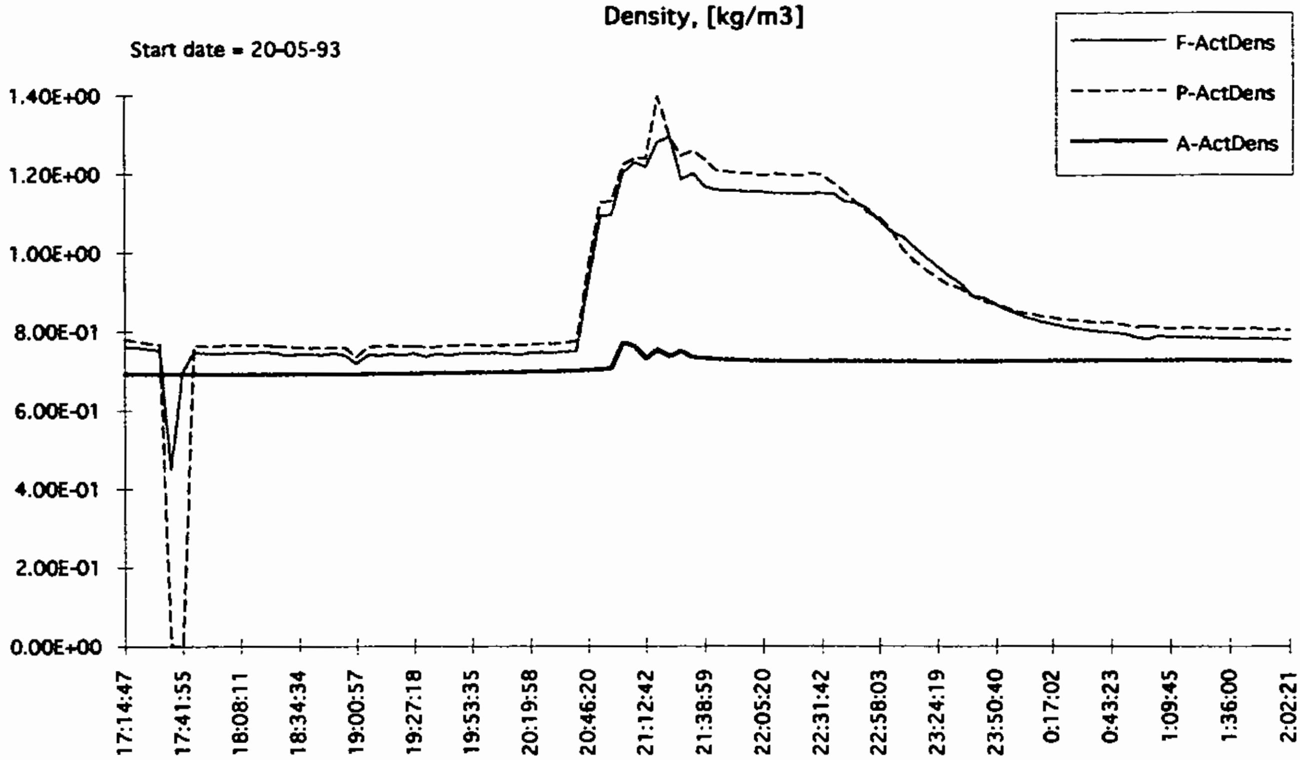
19:17:45
22:22:02
1:26:32


Density, [kg/m3]
Start date = 20-05-93
F-ActDens
P-ActDens
A-ActDens
1.40E+00
1.20E+00
1.00E+00
8.00E-01
6.00E-01
4.00E-01
2.00E-01
0.00E+00
17:14:47
17:41:55
18:08:11
18:34:34
19:00:57
19:27:18
19:53:35
20:19:58
20:46:20
21:12:42
21:38:59
22:05:20
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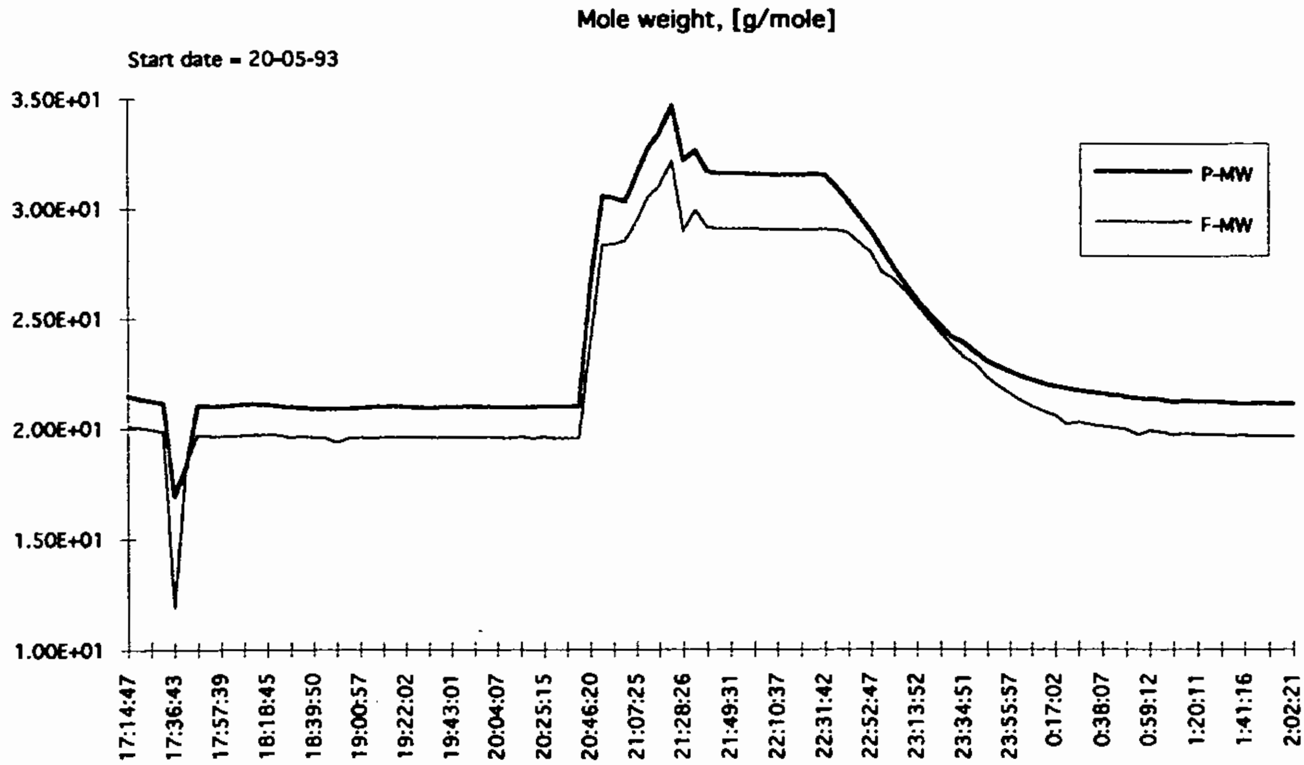
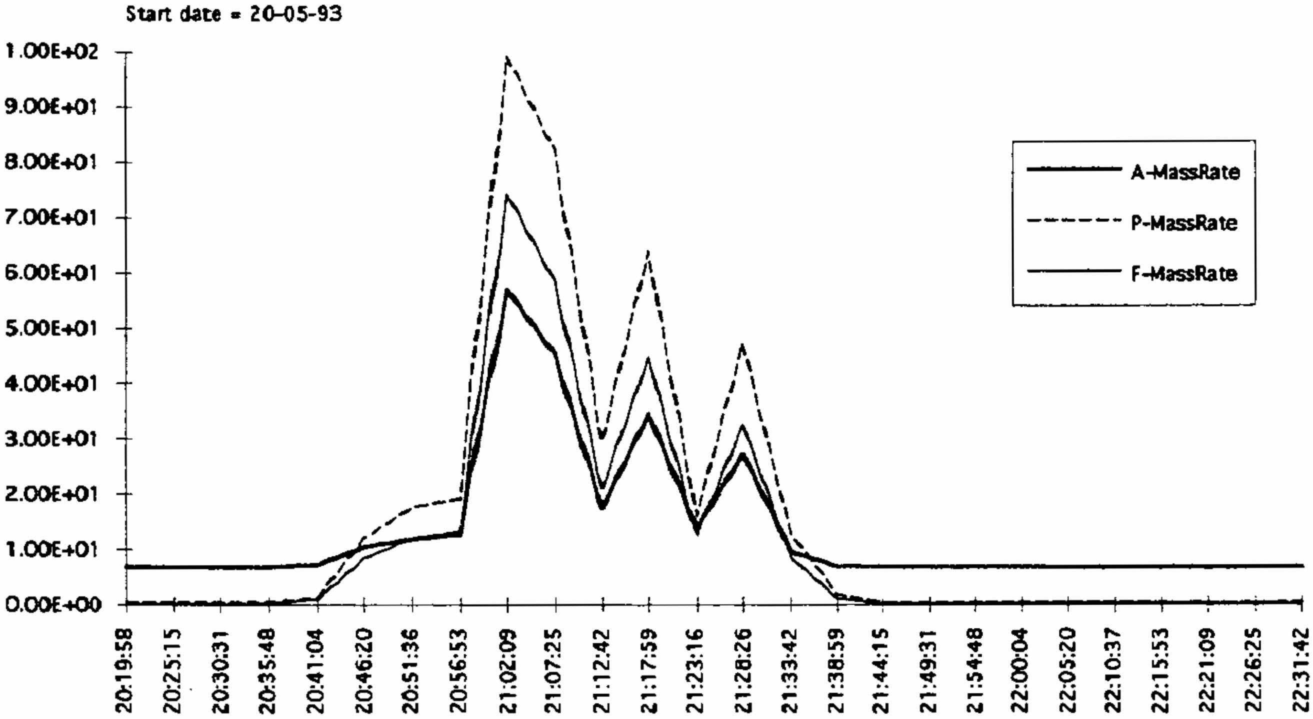
1:36:00
2:02:21

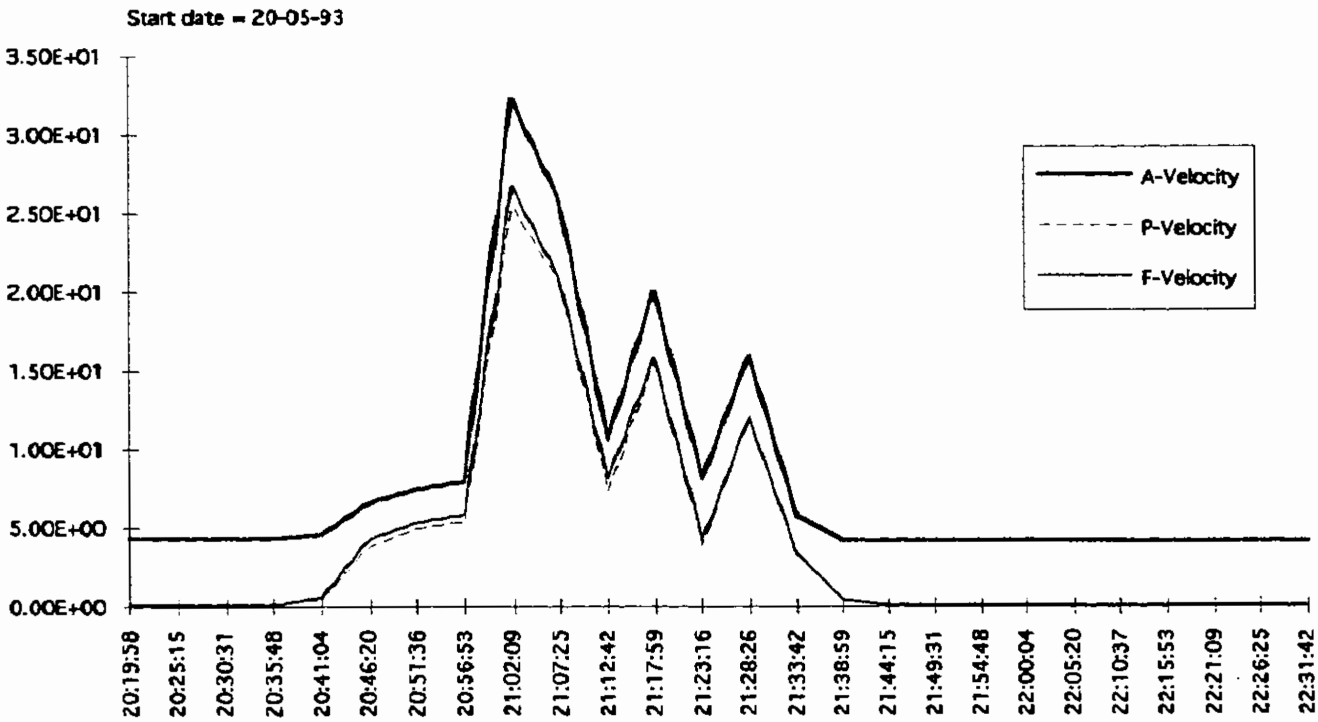

Mole weight, [g/mole]
Start date = 20-05-93
P-MW
F-MW
3.50E+01
3.00E+01
2.50E+01
2.00E+01
1.50E+01
1.00E+01
17:14:47
17:36:43
17:57:39
18:18:45
18:39:50
19:00:57
19:22:02
19:43:01
20:04:07
20:25:15
20:46:20
21:07:25
21:28:26
21:49:31
22:10:37
22:31:42
22:52:47
23:13:52
23:34:51
23:55:57
0:17:02
0:38:07
0:59:12
1:20:11
1:41:16
2:02:21

STATOIL

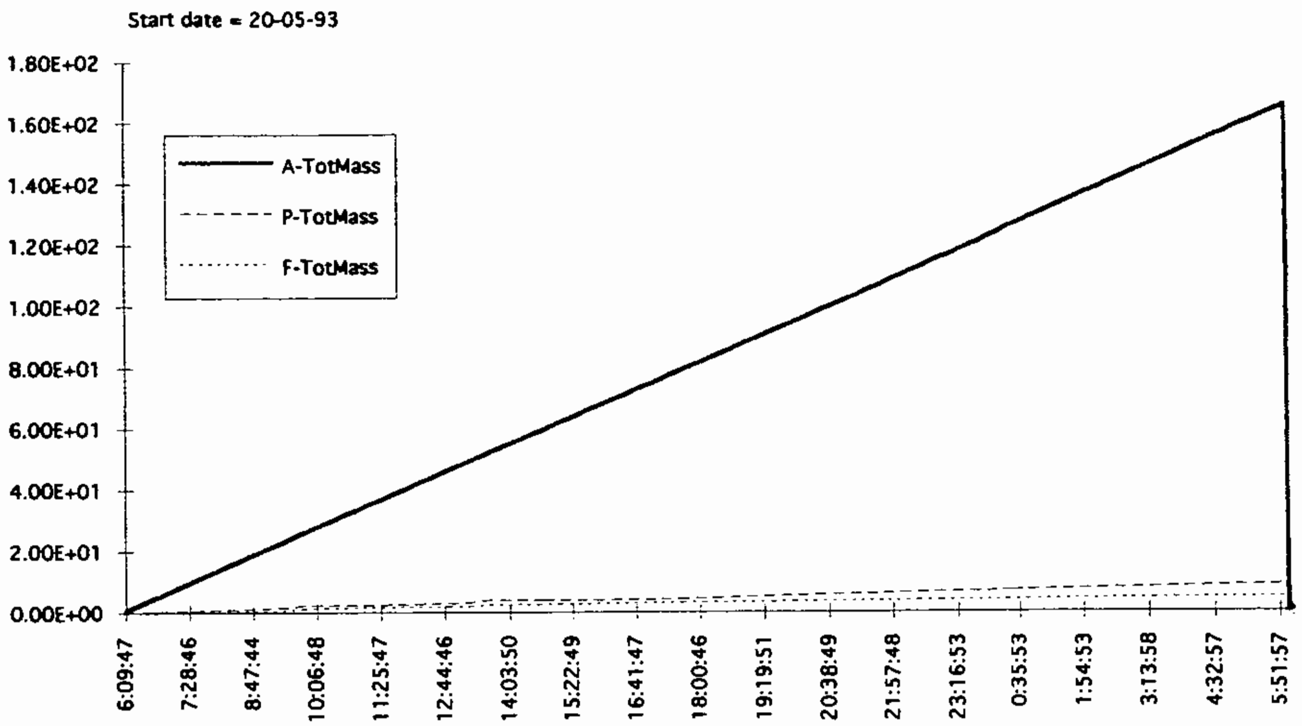
Mass rate, [ton/h]

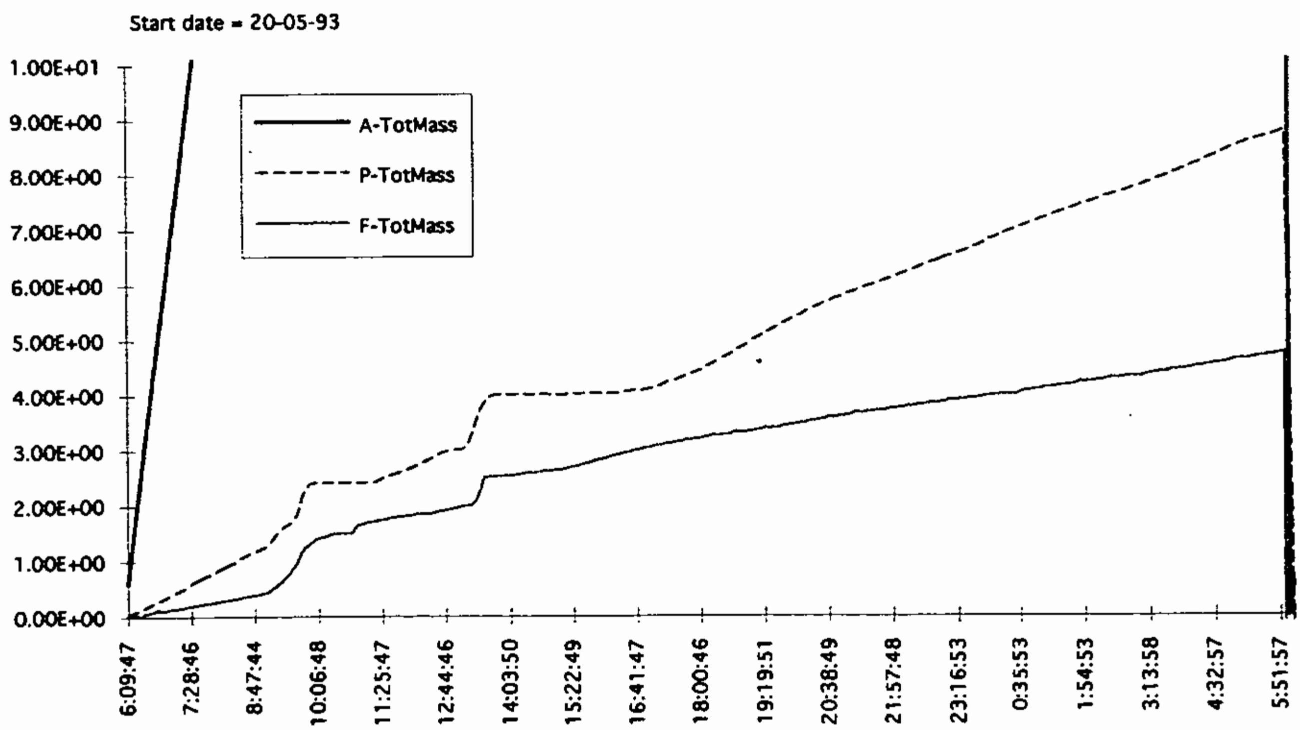


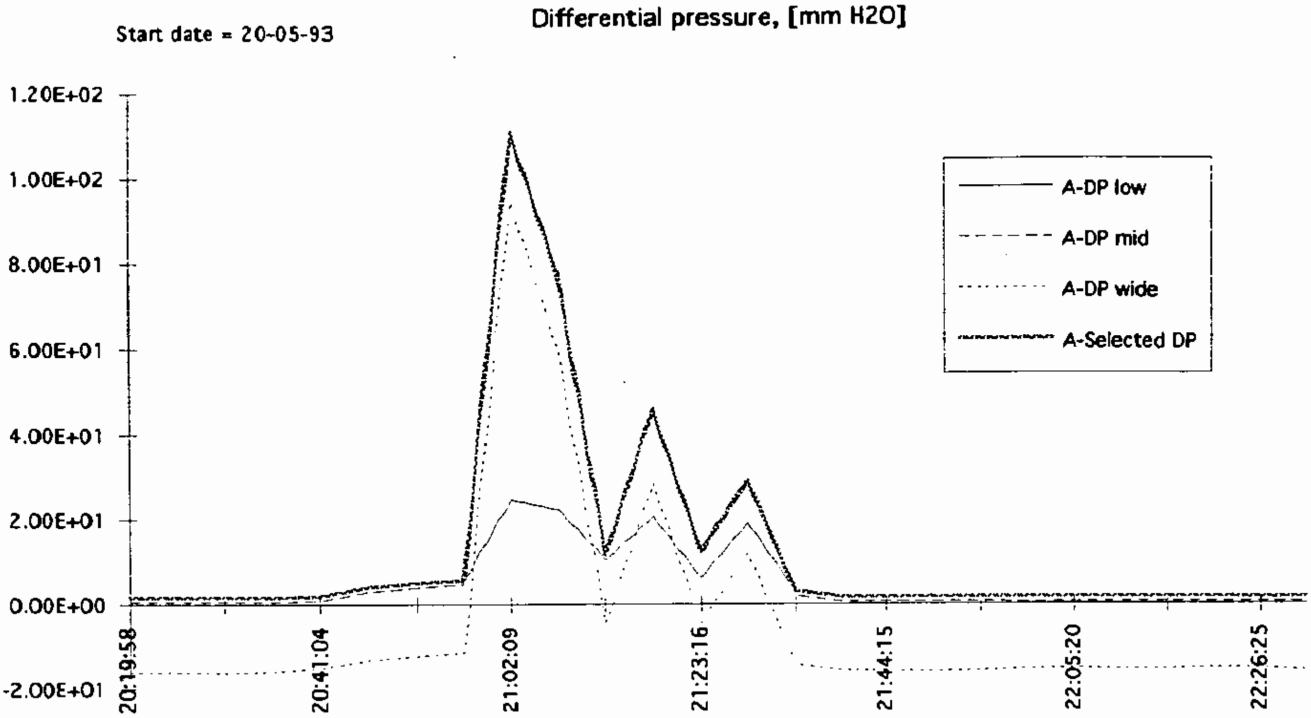
Velocity, [m/s]

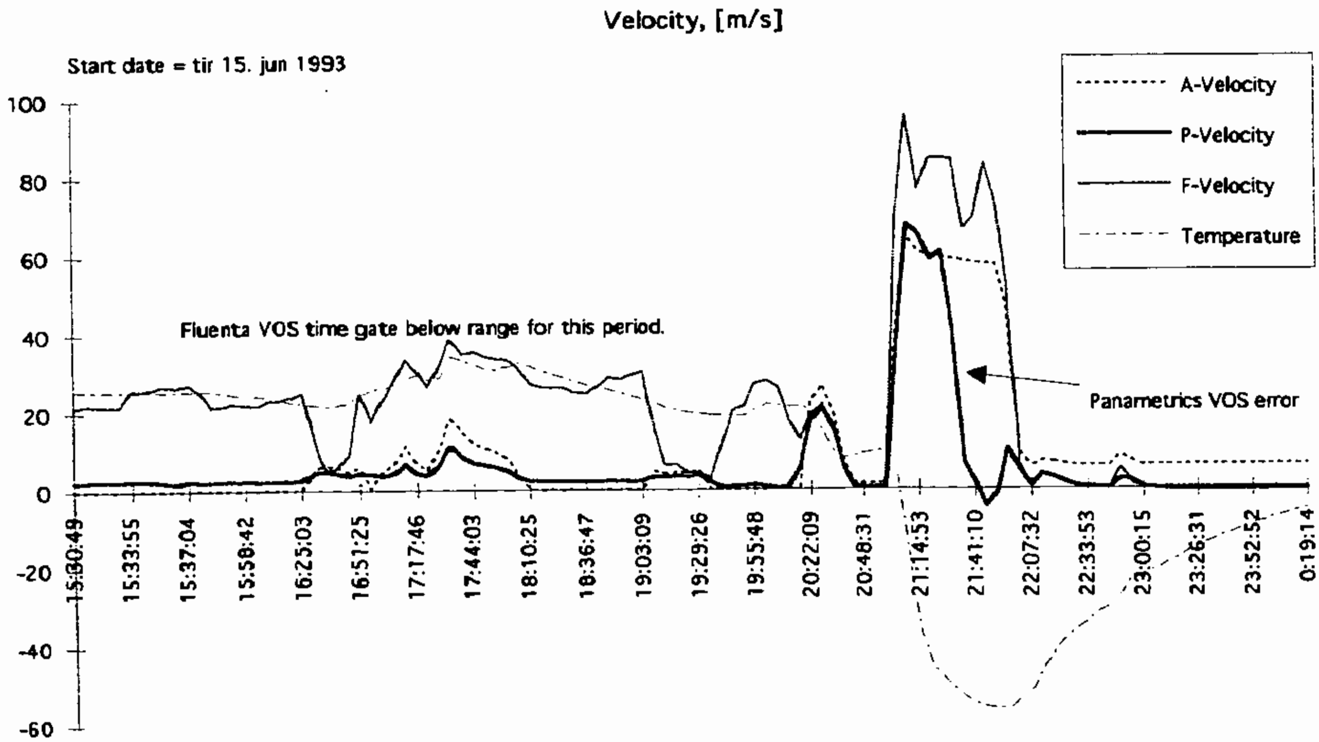


STATOIL


Totalized mass, [tons]
Start date = 20-05-93
1.80E+02
1.60E+02
1.40E+02
1.20E+02
1.00E+02
8.00E+01
6.00E+01
4.00E+01
2.00E+01
0.00E+00
A-TotMass
P-TotMass
F-TotMass
6:09:47
7:28:46
8:47:44
10:06:48
11:25:47
12:44:46
14:03:50
15:22:49
16:41:47
18:00:46
19:19:51
20:38:49
21:57:48
23:16:53
0:35:53
1:54:53
3:13:58
4:32:57
5:51:57

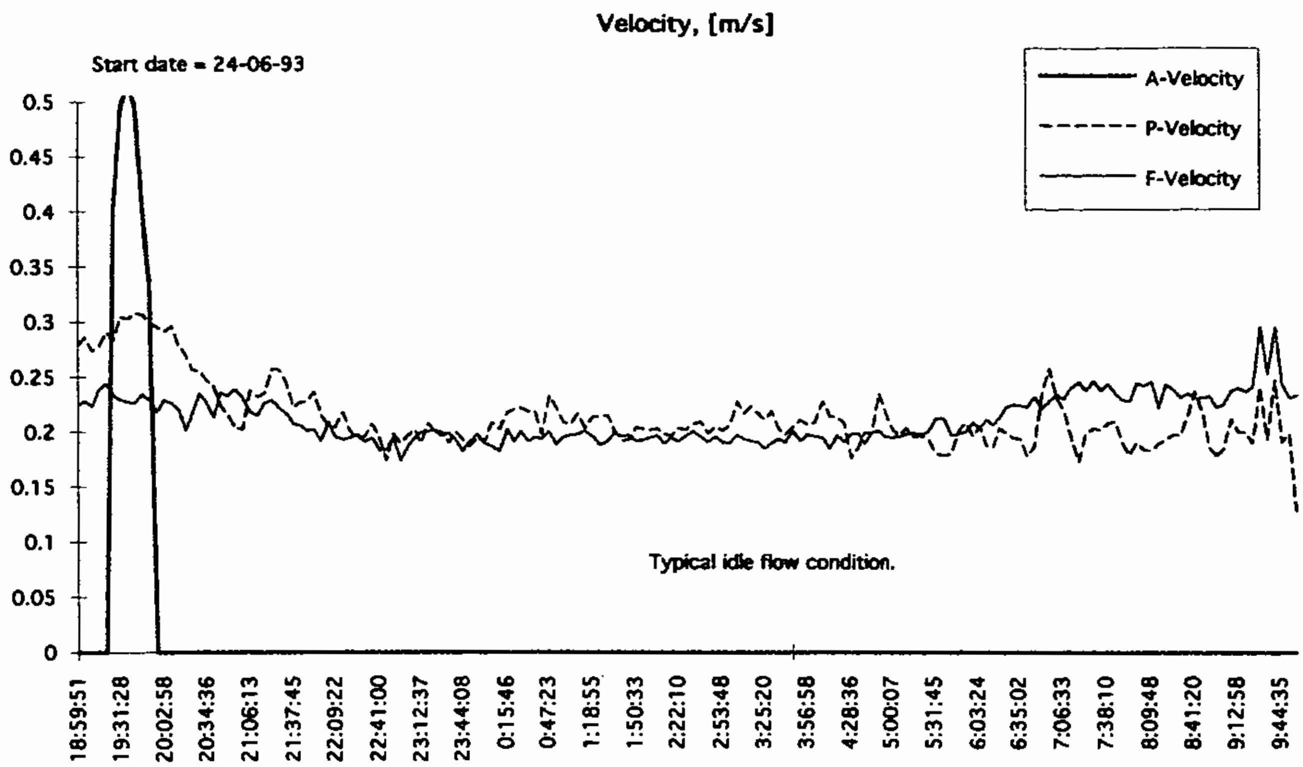

Totalized mass, [tons]
Start date = 20-05-93
1.00E+01
9.00E+00
8.00E+00
7.00E+00
6.00E+00
5.00E+00
4.00E+00
3.00E+00
2.00E+00
1.00E+00
0.00E+00
A-TotMass
P-TotMass
F-TotMass
6:09:47
7:28:46
8:47:44
10:06:48
11:25:47
12:44:46
14:03:50
15:22:49
16:41:47
18:00:46
19:19:51
20:38:49
21:57:48
23:16:53
0:35:53
1:54:53
3:13:58
4:32:57
5:51:57


Differential pressure, [mm H2O]
Start date = 20-05-93
1.20E+02
1.00E+02
8.00E+01
6.00E+01
4.00E+01
2.00E+01
0.00E+00
-2.00E+01
20:19:58
20:41:04
21:02:09
21:23:16
21:44:15
22:05:20
22:26:25
A-DP low
A-DP mid
A-DP wide
A-Selected DP

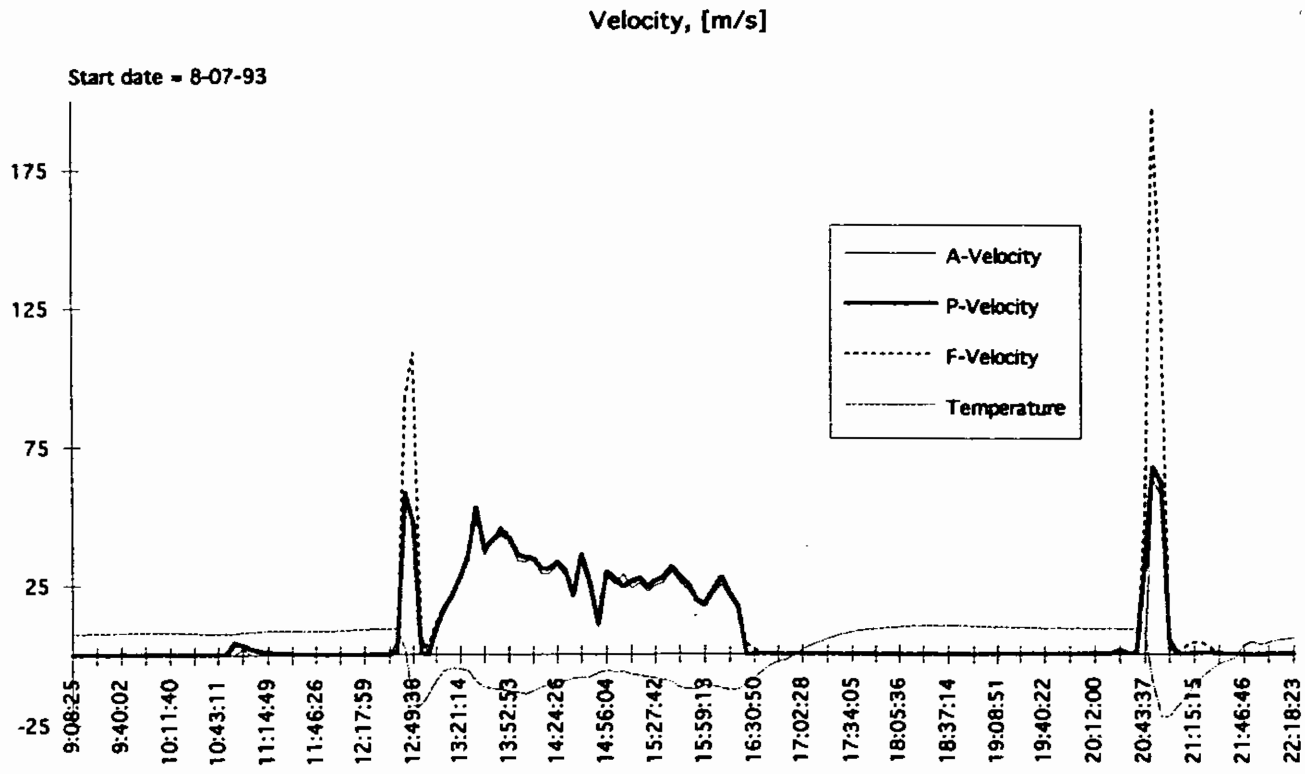

Velocity, [m/s]
Start date = tir 15. jun 1993
100
80
60
40
20
0
-20
-40
-60
Fluenta VOS time gate below range for this period.
Panametrics VOS error
15:30:49
15:33:55
15:37:04
15:58:42
16:25:03
16:51:25
17:17:46
17:44:03
18:10:25
18:36:47
19:03:09
19:29:26
19:55:48
20:22:09
20:48:31
21:14:53
21:41:10
22:07:32
22:33:53
23:00:15
23:26:31
23:52:52
0:19:14
A-Velocity
P-Velocity
F-Velocity
Temperature

18-6-93.xls Chart 13

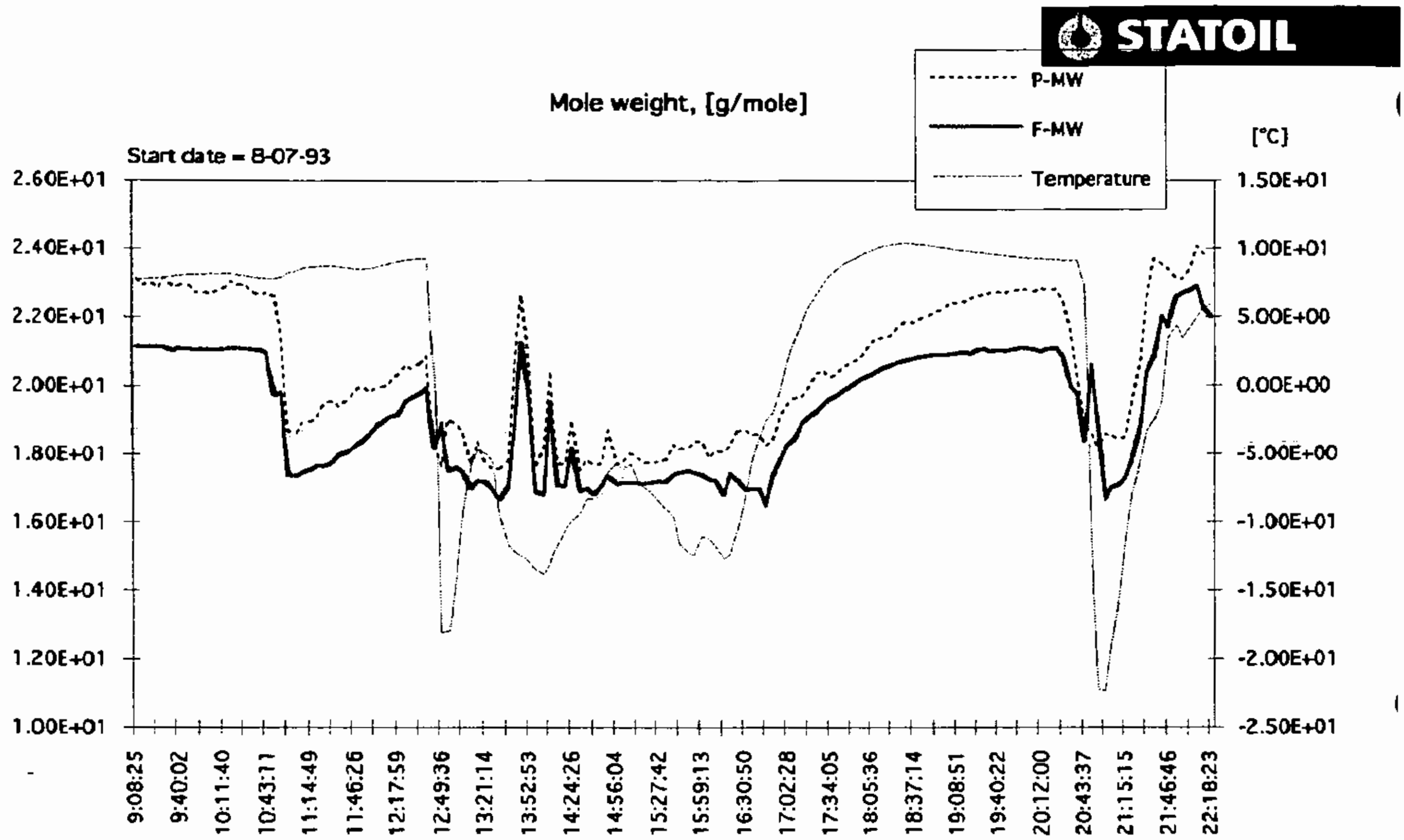
STATOIL



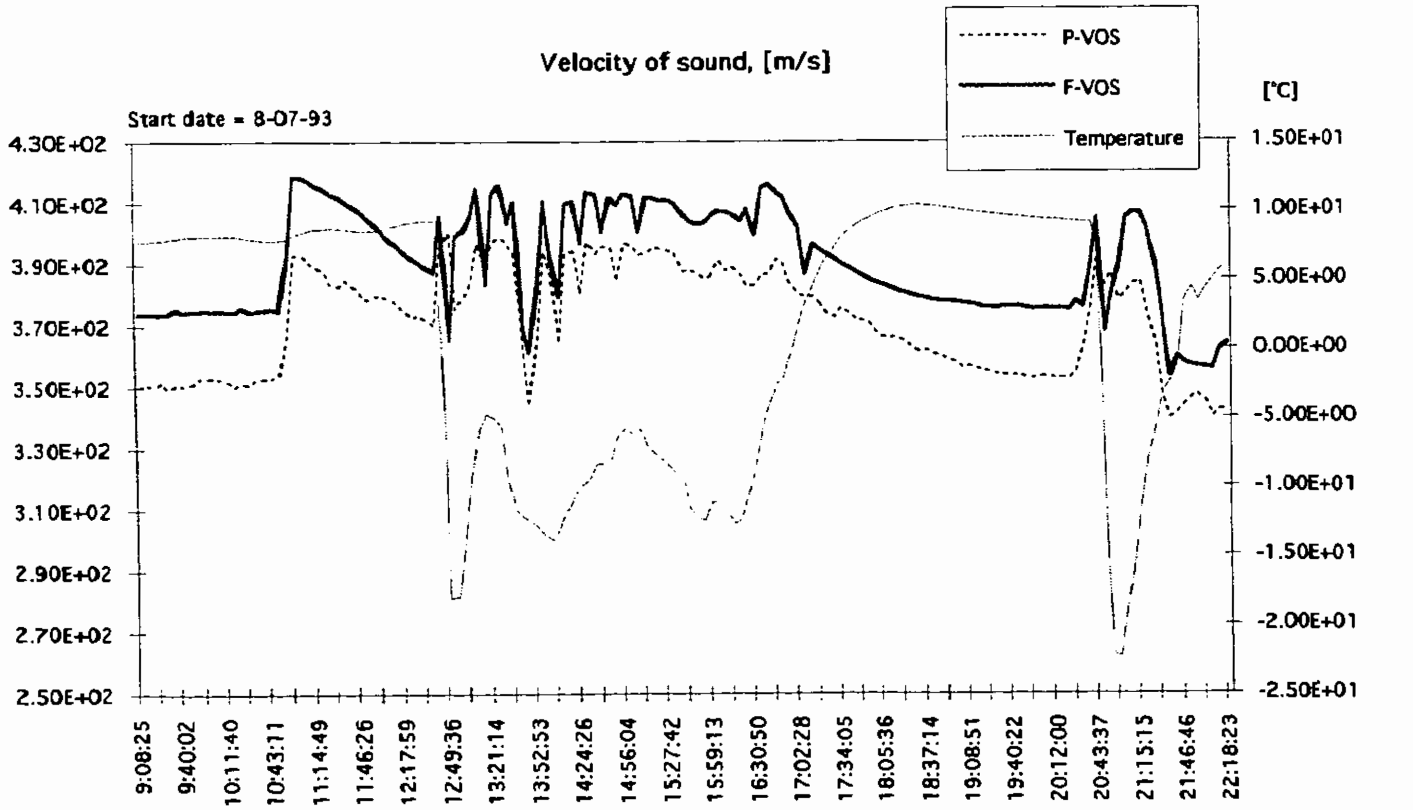
29-6-93.xls Chart 7



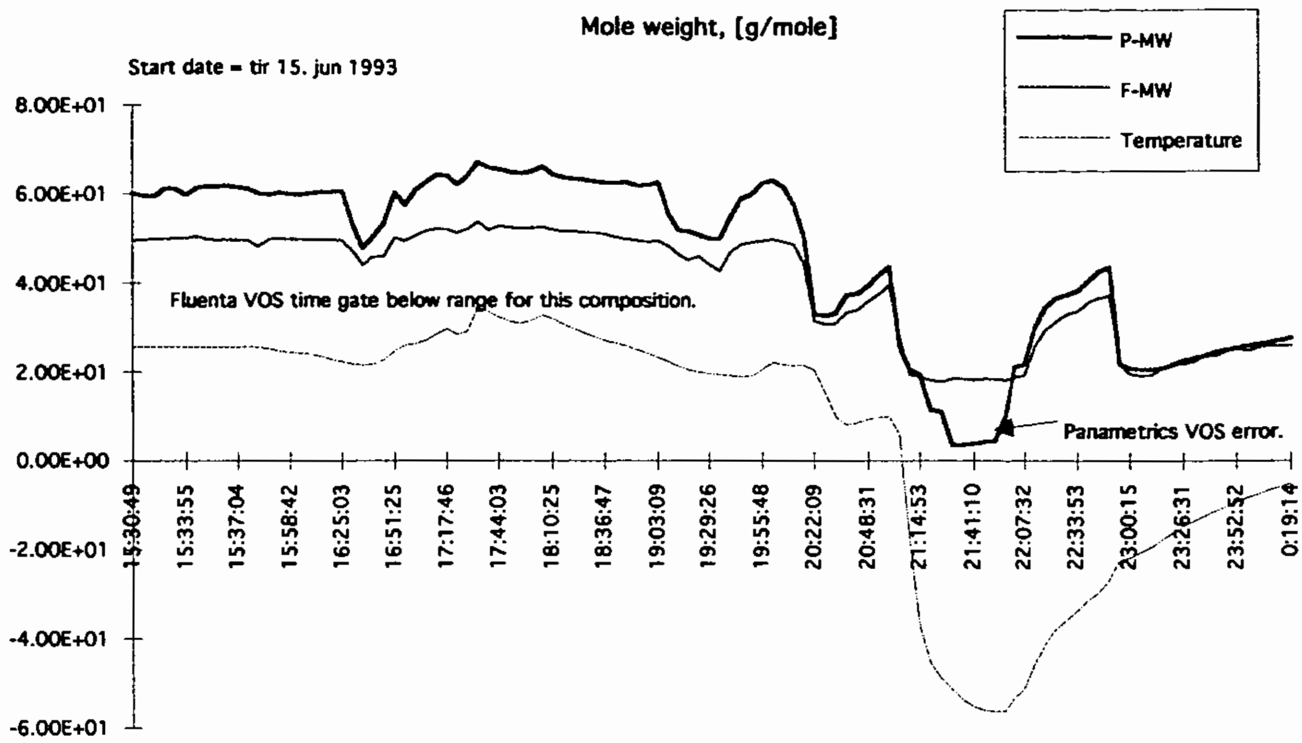
29-6-93.xls Chart 8

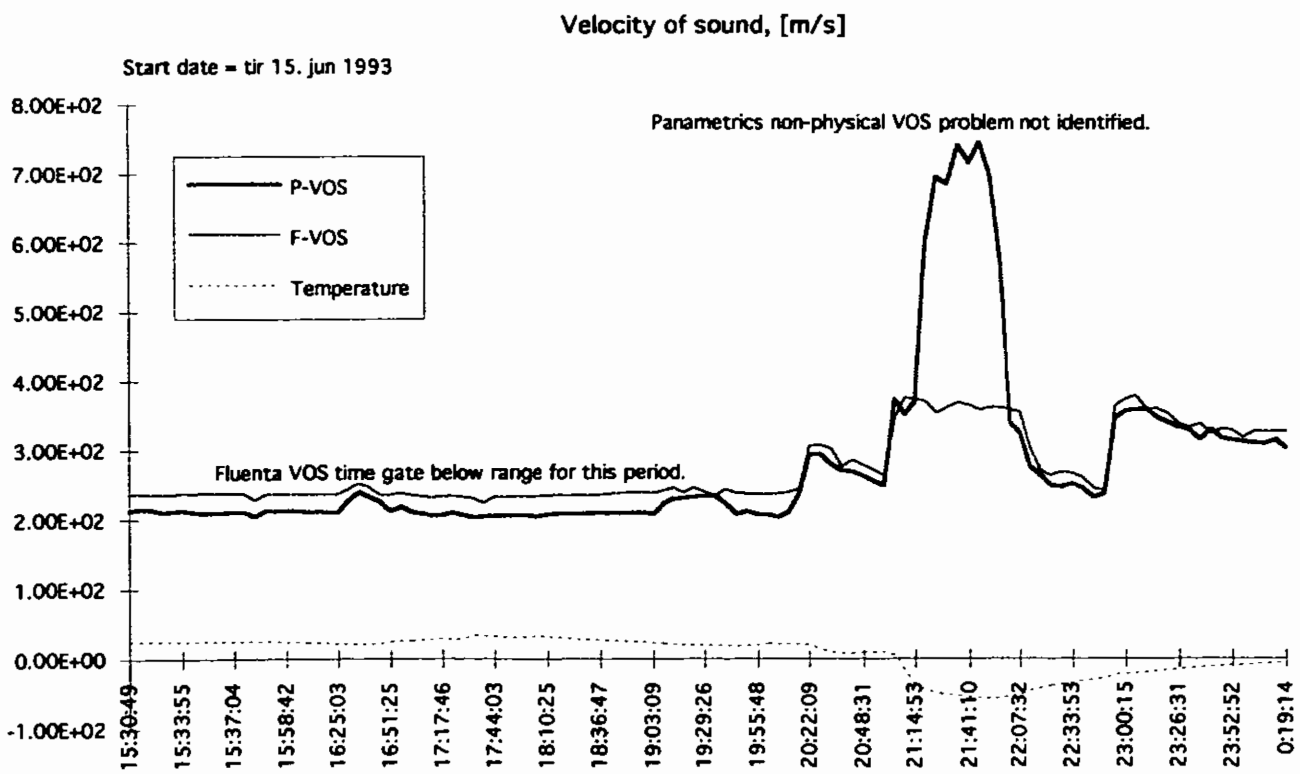


29-6-93.xls Chart 9



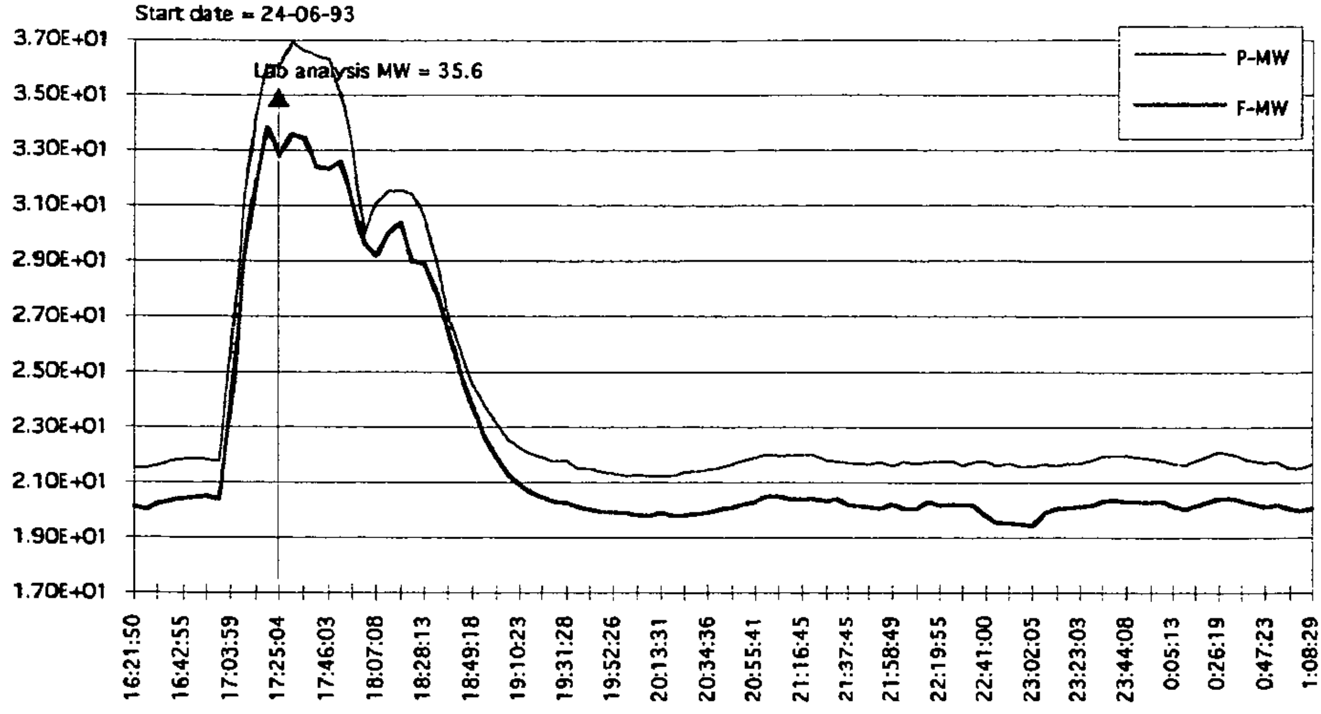
STATOIL


Mole weight, [g/mole]
Start date = tir 15. jun 1993
P-MW
F-MW
Temperature
8.00E+01
6.00E+01
4.00E+01
2.00E+01
0.00E+00
-2.00E+01
-4.00E+01
-6.00E+01
Fluenta VOS time gate below range for this composition.
Panametrics VOS error.
15:30:49
15:33:55
15:37:04
15:58:42
16:25:03
16:51:25
17:17:46
17:44:03
18:10:25
18:36:47
19:03:09
19:29:26
19:55:48
20:22:09
20:48:31
21:14:53
21:41:10
22:07:32
22:33:53
23:00:15
23:26:31
23:52:52
0:19:14


Velocity of sound, [m/s]
Start date = tir 15. jun 1993
P-VOS
F-VOS
Temperature
8.00E+02
7.00E+02
6.00E+02
5.00E+02
4.00E+02
3.00E+02
2.00E+02
1.00E+02
0.00E+00
-1.00E+02
Panametrics non-physical VOS problem not identified.
Fluenta VOS time gate below range for this period.
15:30:49
15:33:55
15:37:04
15:58:42
16:25:03
16:51:25
17:17:46
17:44:03
18:10:25
18:36:47
19:03:09
19:29:26
19:55:48
20:22:09
20:48:31
21:14:53
21:41:10
22:07:32
22:33:53
23:00:15
23:26:31
23:52:52
0:19:14

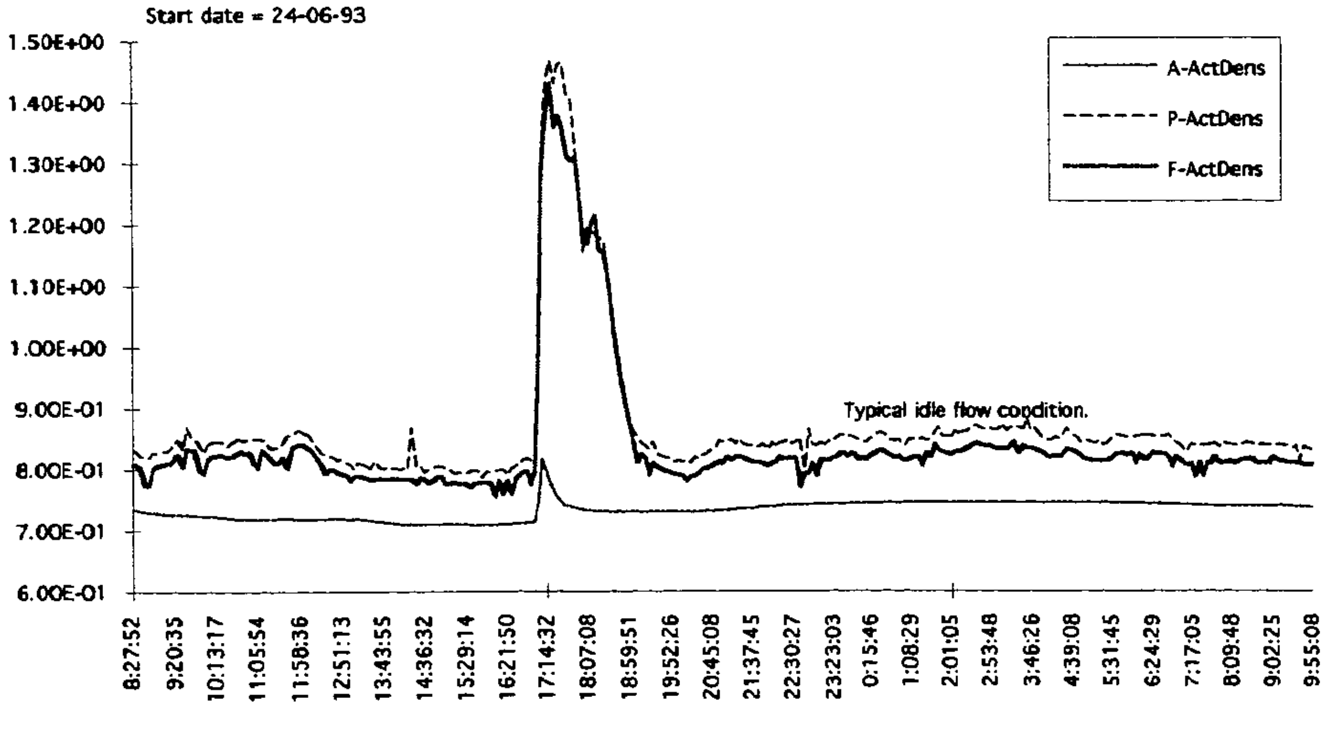
STATOIL

Mole weight, [g/mole]



18-6-93.xls Chart 7

Density, [kg/m3]



12

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.