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Classification

Requested by

O. Nygaard - PL 050.

Subtitle

Reservoir fluid study on samples from well 34/10-13.

Co-workers

Arne M. Martinsen, Jarle M. Grande, Gro Aksnes.

Title

RESERVOIR FLUID STUDY
FOR
STATOIL, WELL 34/10-13

STATOIL
EXPLORATION & PRODUCTION LABORATORY

Tone Ørke

May 1982

LAB.82.20

Prepared

4/5-82 Tone Ørke

Approved

4/5-82

SUMMARY

This report presents PVT and compositional data on samples from 34/10-13.

Compositional analyses are performed on 3 sets of samples, two bottom hole samples from DST no. 2, collected at 2003-2009 m, and one RFT sample, collected at 1940 m.

Constant mass, constant volume and viscosity experiments are performed on one bottom hole sample at 74.6°C (166°F).

This report also includes a comparison of the crude oils from the Statfjord formation of 34/10-11 and 34/10-13. The reason for this comparison is to establish the similarities of the crudes. Based on this, one should be able to use TBP destillation data performed on 34/10-11, DST no. 1 from the Statfjord Formation (Lab. report 81.25).

Representative data of the fluid system are set up on the next page.

Summary of representative data from analyses.

Reservoir fluid composition	(mole %)	Molecular weight	Density g/cm^3
Carbondioxide	0.16		
Nitrogene	0.90		
Methane	47.12		
Ethane	5.97		
Propane	4.62		
iso-butane	0.99		
n-butane	2.50		
iso-pentane	1.09		
n-pentane	1.46		
Hexanes	2.19	87	0.681
Heptanes	3.56	97	0.736
Octanes	4.27	106	0.754
Nonanes	3.18	118	0.776
Decanes +	21.99	273*	0.871*
	100.00		

Density of res. fluid (g/cm^3) at 74.6°C and 233 Barg	0.662
Bubble point at 74.6°C (Barg)	233.0
Gas/oil ratio from single flash (flash cond. 15°C, 1 atm) (Sm^3/m^3)	162.0
Gas/oil ratio from differential flash liberation (Sm^3/m^3)	162.6
Formation volume factor from single flash (Sm^3/m^3)	1.507

Formation volume factor from differential vaporization (m^3/m^3)	1.491
Viscosity of reservoir fluid at bubble point (cp.)	0.425
Density of stock tank oil at 15^oC (g/cm^3)	0.8330
Mol. weight of stock tank oil (g/g mole)	204

Densities and molecular weights are measured values from TBP destillation reported in LAB.81.25.

* Calculated values (measured values from TBP destillation M_{10}^+ 273, Density 10^+ 0.8695).

1. INTRODUCTION

Statoil ProLAB was requested by the 34/10 license to perform PVT analyses on three different samples from well 34/10-13. Two bottom hole samples from DST no. 2 collected at 2003-2009 m and one RFT sample from 1940 m.

The request was to perform a complete PVT study at 74.6^{o}C on one of the samples, and a short PVT program and compositional analyses on the other samples.

2. SAMPLE DESCRIPTION

2.1 RFT sample from 1940 m

The RFT sample was transferred on the rig, and the laboratory received the RFT sample in Flopetrol oil sample bottle marked 20584-4.
The opening pressure of the bottle was approx. 67 barg and the bubble point pressure was determined to about 168 barg at ambient temperature.

2.2 Bottom hole samples from dst no. 2

The bottom hole samples were collected during the test in perforated interval 2003-2009 m.
The bottle marked 2560-10 had an opening pressure of approx. 140 barg. A validity check gave a bubble point pressure of about 202 barg at ambient temperature.

The other bottle was marked 8151-31. The opening pressure of this bottle was approx. 95 barg and the bubble point pressure at ambient temperature about 204 barg.

See sampling sheets in Appendix.

3. METHODS AND EQUIPMENT

3.1 PVT analyses

PVT analyses were performed in a Ruska visual PVT cell at 74.6°C. Constant mass pressure-volume relation-ship and differential vaporization were carried out. Single flash to standard conditions (15°C and 1 atm) was performed in a Ruska Flash Seperator. The gas was sampled in a Ruska Gasometer.
The viscosity of reservoir fluid was measured using a Ruska rolling ball viscosimeter.

3.2 Compositional analysis

Component analyses were performed using a Hewlett Packard 5880 gas chromatographic system. For gas analysis, non hydrocarbons are determined on a poropack R 1/8" x 3 m steel column with TC detector, and hydrocarbons on chromapack Cp $\frac{tm}{}$ Sil 5 50 m x 0.22 mm quartz capillary column with FI detector. Oil analysis are performed on a gas chromatograph fitted with chromapack cp $\frac{tm}{}$ Sil 5 25 m x 0.22 mm quartz capillary column and FI detector.

Carrier gas:	Helium
Over temp. profile for oil analyses:	10° (4 min) 4°/min 310° (200 min)
Over temp. profile for gas analyses:	-50° (4 min) 32°/min 160°

Molecular weights are determined by freezing point depression using a Knauer molecular weight instrument. Benzene was used as a reference substance.

Densities are determined by Paar DMA 602 frequency densiometer.

4. RESULTS

4.1 Results from the RFT sample, 1940 m, bottle no. 2584-4

The constant mass pressure-volume analysis gives a bubble point of 197.5 barg. (See table 1 and fig. 1). Results from single flash and the calculated reservoir fluid composition are given in Table 2.

4.2 Results from bottom hole samples

4.2.1 Bottom hole sample no. 2560-10

The bubble point pressure is determined to 233 barg (see Table 3 and Fig. 2). Table 4 presents the results from single flash and the calculated reservoir fluid composition.

Data from the differential vaporization are given in Table. 5 and Fig. 4. Viscosity data are given in Table 6. and Fig. 5.

4.2.2 Bottom hole sample no. 8151-31

From Table 7 and Fig. 3 one can see that the bubble point is established to 232.9 barg. Results from single flash, and the calculated reservoir fluid composition are given in Table 8.

4.2.3 The comparison of crude oils

The four samples compared are crudes from single flash of oil systems ProLAB has analysed from 34/10-11 and 34/10-13, Statfjord formation.

Fig. 6 and fig. 7 show the chromatograms of crudes from 34/10-11 seperator sample and 34/10-13 RFT, and fig. 8 and fig. 9 show the chromatograms of the crudes from the bottom hole samples from 34/10-11 and 34/10-13.

4.2.4 A correlation between oil systems in the Statfjord Formation

Fig. 10 shows a plot of GOR vs bubble point pressure at some of the PVT samples ProLAB has analysed from the Statfjord Formation in 34/10-11 and 34/10-13.

5. DISCUSSION

5.1 RFT and bottom hole samples

The two bottom hole samples are very similar both in composition and PVT properties. If we compare the two bottom hole samples to the RFT sample, the results from RFT samples indicates a heavier reservoir fluid system. The plot in Fig. 10 shows great difference in PVT properties. The linearity of this plot, however, indicates the similarity of the oil systems, and it is most probable that this difference is a results of leakage or bad sampling techniques.

5.2 Comparison of the crude oils

The "ower-lay" method shows no difference between the four crude oils, when comparing the pattern of the chromatographic peaks lying between the several n-paraffins. Also the relative distribution of n-paraffins is almost identical.

Because of this, we can assume that the crude oils from 34/10-11 and 34/10-13 will behave similarily, regarding to the PVT- and chemical properties.

6. CONCLUSION

6.1 Sample validity

Fig. 10 shows great divergences in PVT data in oil systems from 34/10-11 and 34/10-13, Statfjord formation.

The two different bottom samples from 34/10-13 collected from the same perforated interval are almost identical in PVT properties (table 4 and table 8). This may be an indication of representative samples, and we can assume that the reservoir fluid properties of the bottom hole samples from 34/10-13 can represent the fluid system in the Statfjord Formation.

TABLE 1 Constant mass pressure volume analysis of RFT sample at 77.8°C

Pressure Barg	Relative Volume	Y-factor	Compressibility of saturated oil
383.4	0.9709		
303.0	0.9818		Average compressibility above bubble-point: 16.0×10^{-5} vol/vol/bar
292.2	0.9838		
246.1	0.9915		
209.8	0.9981		
197.5 (Bubble point)	1.0000		
196.1	1.0021	3.37	
178.3	1.0326	3.31	
159.2	1.0747	3.23	
132.7	1.1648	2.97	
97.1	1.3900	2.65	
67.2	1.8081	2.40	

Y-factor: $\left(\frac{P_B - P}{P}\right) \Big/ \left(\frac{V}{V_B} - 1\right)$

P_B = bubble point pressure
V_B = bubble point volume
$p < P_B$

TABLE 2 Analysis of products from single flash of RFT sample from 1940 m and calculated reservoir fluid composition.

Components	Oil wt%	Oil mole%	Density* g/cm^3	mol.weight* g/g mole	Gas mole%	Reservoir fluid mole%
Carbondioxide	-	-			0.19	0.11
Nitrogen	-	-			0.96	0.54
Methane	-	-			73.83	41.67
Ethane	0.042	0.27			9.58	5.52
Propane	0.196	0.86			7.00	4.32
iso-Butane	0.146	0.49			1.36	0.98
n-Butane	0.551	1.83			3.33	2.68
iso-Pentane	0.561	1.50			1.00	1.22
n-Pentane	0.867	2.32			1.14	1.65
Hexanes	2.158	4.89	0.681	87	0.79	2.57
Heptanes	4.876	9.70	0.736	97	0.55	4.54
Octanes	7.318	13.32	0.754	106	0.24	5.94
Nonanes	6.453	10.56	0.776	118	0.03	4.62
Decanes+	76.832	54.26	0.871**	273**	-	23.64
	100.000	100.00			100.00	100.00

Gor, SM^3/M^3	: 127.0
Bo, M^3/M^3	: 1.420
Density of oil, g/cm^3	: 0.8321
Gravity of gas	: 0.83
Density of res. fluid, g/cm^3 at 77.8°C and 197.5 Barg	: 0.680
Mol. weight of oil, g/g mole	: 193

* From TBP destillation reported in LAB 81.25.

** Calculated; measured values from TBP destillation are 0.8695 and 273 respectively.

TABLE 3 Constant mass pressure volume analysis of BHS sample from DST no. 2 at 2003-2009 m, Bottle nó. 2560-10.

Pressure Barg	Relative Volume	Y-factor	Compressibility of saturated oil
390.8	0.9743		
365.3	0.9781		Average compressibility above bubble-point: 16.3×10^{-5} vol/vol/bar
304.5	0.9823		
267.2	0.9942		
233.0 (Bubble point)	1.0000		
231.4	1.0018	3.87	
225.1	1.0087	4.05	
219.2	1.0162	3.89	
207.9	1.0318	3.80	
185.3	1.0717	3.59	
172.6	1.1014	3.45	
166.7	1.1171	3.39	
143.7	1.1962	3.17	
114.7	1.3564	2.89	

Y-factor: $\left(\frac{P_B - P}{P}\right) \Big/ \left(\frac{V}{V_B} - 1\right)$

P_B = bubble point pressure
V_B = bubble point volume
$p < P_B$

TABLE 4 Analysis of products from single flash of BHS DST no. 2, and calculated reservoir fluid composition. Bottle no. 2560-10.

Components	Oil wt%	Oil mole%	Density* g/cm^3	mol.weight* g/g mole	Gas mole%	Reservoir fluid mole%
Carbondioxide	-	-			0.25	0.16
Nitrogen	-	-			1.41	0.90
Methane	-	-			73.75	47.12
Ethane	0.022	0.15			9.25	5.97
Propane	0.126	0.59			6.89	4.62
iso-Butane	0.103	0.36			1.34	0.99
n-Butane	0.396	1.39			3.13	2.50
iso-Pentane	0.448	1.27			0.99	1.09
n-Pentane	0.723	2.05			1.14	1.46
Hexanes	1.902	4.56	0.681	87	0.85	2.19
Heptanes	4.134	8.69	0.736	97	0.67	3.56
Octanes	5.884	11.32	0.754	106	0.28	4.27
Nonanes	5.048	8.73	0.776	118	0.04	3.18
Decanes+	81.214	60.89	0.861**	272**	0.01	21.99
	100.000	100.00			100.00	100.00

Gor, SM^3/M^3	:	162
Bo, M^3/M^3	:	1.507
Density of oil, g/cm^3	:	0.8330
Gravity of gas	:	0.83
Density of res. fluid, g/cm^3 at 74.6^{o}C and 233 Barg	:	0.662
Mol. weight of oil, g/g mole	:	204

* From TBP destillation reported in LAB 81.25.

** Calculated; measured values from TBP destillation are 0.8695 and 273 respectively.

TABLE 5 Differential vaporization of BHS, Bottle no. 2560-10 from DST no. 2 at 74.6°C.

Pressure Barg	Relative volume(1) M^3/M^3	Solution GOR RS(2) SM^3/M^3	Density of sat. oil g/cm^3	Gas spesific gravity (air=1)	Z-factor gas
390.8	1.452		0.698		
365.3	1.458		0.695		
336.9	1.464		0.692		
304.5	1.472		0.688		
267.2	1.482		0.684		
233.0	1.491	162.6	0.680		
205.9	1.449	144.2	0.688	0.70	0.853
177.5	1.401	124.2	0.700	0.69	0.844
147.1	1.356	104.7	0.711	0.68	0.850
117.2	1.304	86.2	0.728	0.67	0.855
88.5	1.263	68.8	0.740	0.67	0.879
58.8	1.221	51.2	0.754	0.67	0.908
31.9	1.181	34.3	0.767	0.73	0.940
atm*	1.050	-	0.794	-	-
atm at 15°C	1.000	-	0.834	-	-

1) Cubic meter of oil at indicated pressure and temperture per cubic meter of residual oil at 15°C.

2) Cubic meter of gas at atm. and 15°C per cubic of residual oil at 15°C.

* NB' 1 atm = 1.01325 Bar.

TABLE 6 Viscosity at reservoir fluid vs, pressure at 74.6°C of BHS, from DST no. 2. Bottle no. 2560-10.

Pressure Barg	Oil viscosity centipoise	Calculated* gas viscosity centipoise	Oil/Gas viscosity ratio
341.3	0.513		
319.7	0.467		
277.5	0.455		
249.1	0.433		
233.0 (Bubble point)	0.425		
218.0	0.441		
205.4	0.460	0.0135	34.1
176.0	0.505	0.0118	42.8
144.2	0.574	0.0102	56.3
109.5	0.696	0.0091	76.5
79.9	0.810	0.0082	98.8
45.6	1.085	0.0075	144.7
atm	1.610	0.0047	342.6

* gas viscosities are calculated from Lee, AL. Conzales and Eakin's Correlations, J.P.T August 1966, p. 997.

TABLE 7 Constant mass pressure volume analysis of BHS sample from DST no. 2 at 74.6°C. Bottle no. 8151-31.

Pressure Barg	Relative Volume	Y-factor	Compressibility of saturated oil
441.3	0.9668		
405.0	0.9717		Average compressibility above bubble-point: 17.0×10^{-5} vol/vol/bar
375.6	0.9760		
345.2	0.9807		
317.2	0.9853		
287.3	0.9903		
257.9	0.9957		
232.9 (Bubble point)	1.0000		
223.1	1.0113	3.88	
211.8	1.0268	3.71	
202.7	1.0403	3.70	
192.0	1.0596	3.57	
179.0	1.0874	3.45	
159.2	1.1428	3.24	
145.6	1.1927	3.11	
115.0	1.3633	2.82	
104.7	1.4491	2.72	
93.2	1.5709	2.63	
78.9	1.7731	2.52	
69.6	1.9523	2.46	

Y-factor: $\left(\frac{P_B - P}{P}\right) \Big/ \left(\frac{V}{V_B} - 1\right)$

P_B = bubble point pressure

V_B = bubble point volume

$p < P_B$

TABLE 8 Analysis of products from single flash of BHS, DST no. 2. and calculated reservoir fluid composition. Bottle no. 8151-31.

Components	Oil wt%	Oil mole%	Density* g/cm^3	mol.weight* g/g mole	Gas mole%	Reservoir fluid mole%
Carbondioxide	-	-			0.27	0.17
Nitrogen	-	-			1.58	1.02
Methane	-	-			74.26	47.81
Ethane	0.019	0.13			9.07	5.89
Propane	0.116	0.54			6.67	4.48
iso-Butane	0.101	0.36			1.29	0.96
n-Butane	0.383	1.35			3.02	2.43
iso-Pentane	0.448	1.27			0.96	1.07
n-Pentane	0.704	2.00			1.11	1.43
Hexanes	1.873	4.41	0.681	87	0.83	2.11
Heptanes	4.143	8.76	0.736	97	0.65	3.53
Octanes	5.906	11.42	0.754	106	0.24	4.23
Nonanes	4.984	8.66	0.776	118	0.04	3.11
Decanes+	81.323	61.10	0.863**	272.9**	0.01	21.76
	100.000	100.00			100.00	100.00

Gor, SM^3/M^3	:	166.8
Bo, M^3/M^3	:	1.512
Density of oil, g/cm^3	:	0.8345
Gravity of gas	:	0.82
Density of res. fluid, g/cm^3 at 74.6°C and 232.9 Barg	:	0.663
Mol. weight of oil, g/g mole	:	205

* From TBP destillation reported in LAB 81.25.

** Calculated; measured values from TBP destillation are 0.8695 and 273 respectively.

FIG. 1 Constant mass pressure relationship at 77.8°C
RFT from well 34/10-13.

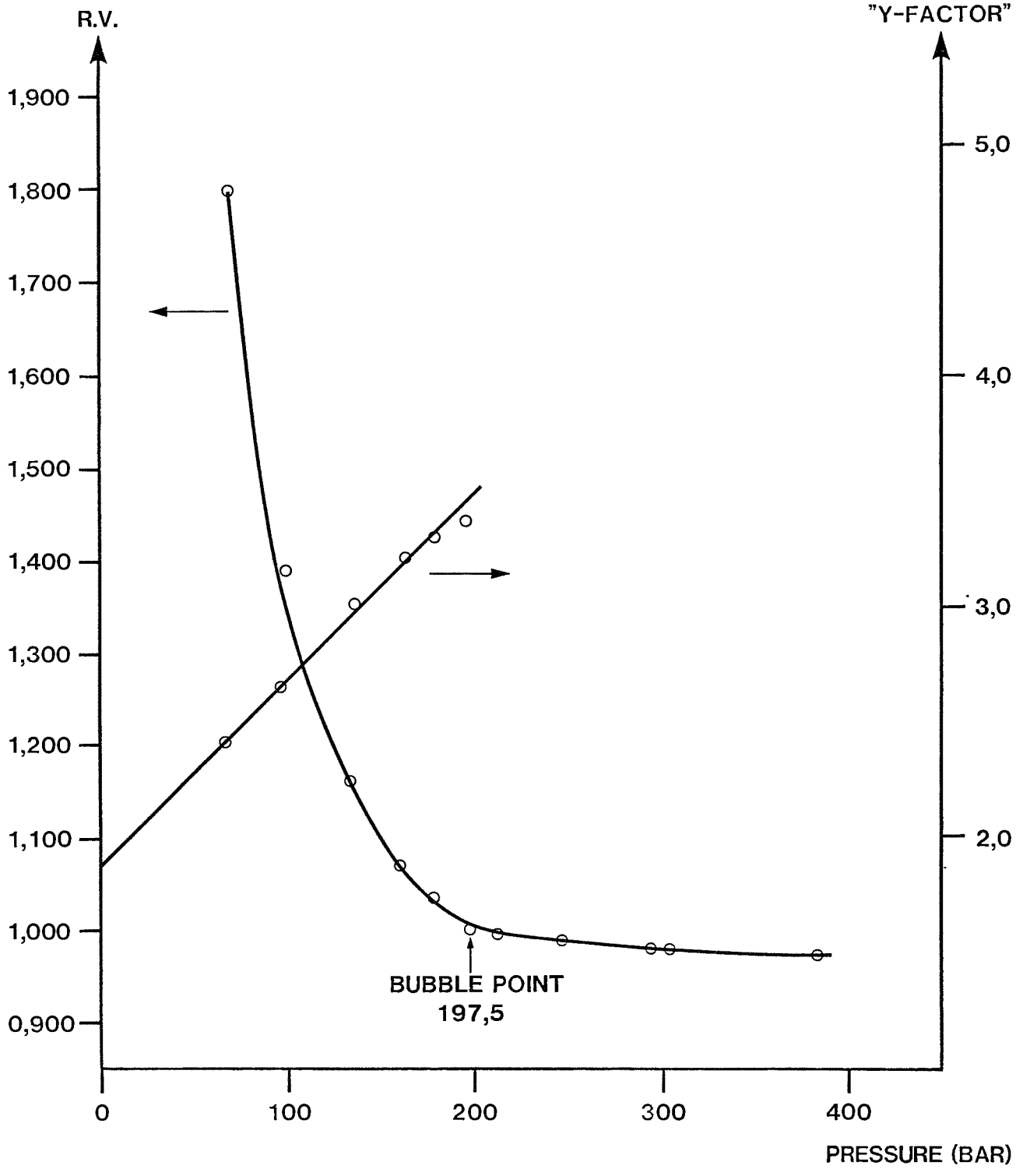


FIG. 2 Constant mass pressure relationship at 74.6°C
Well 34/10-13
BHS no. 2560-10 from DST no. 2

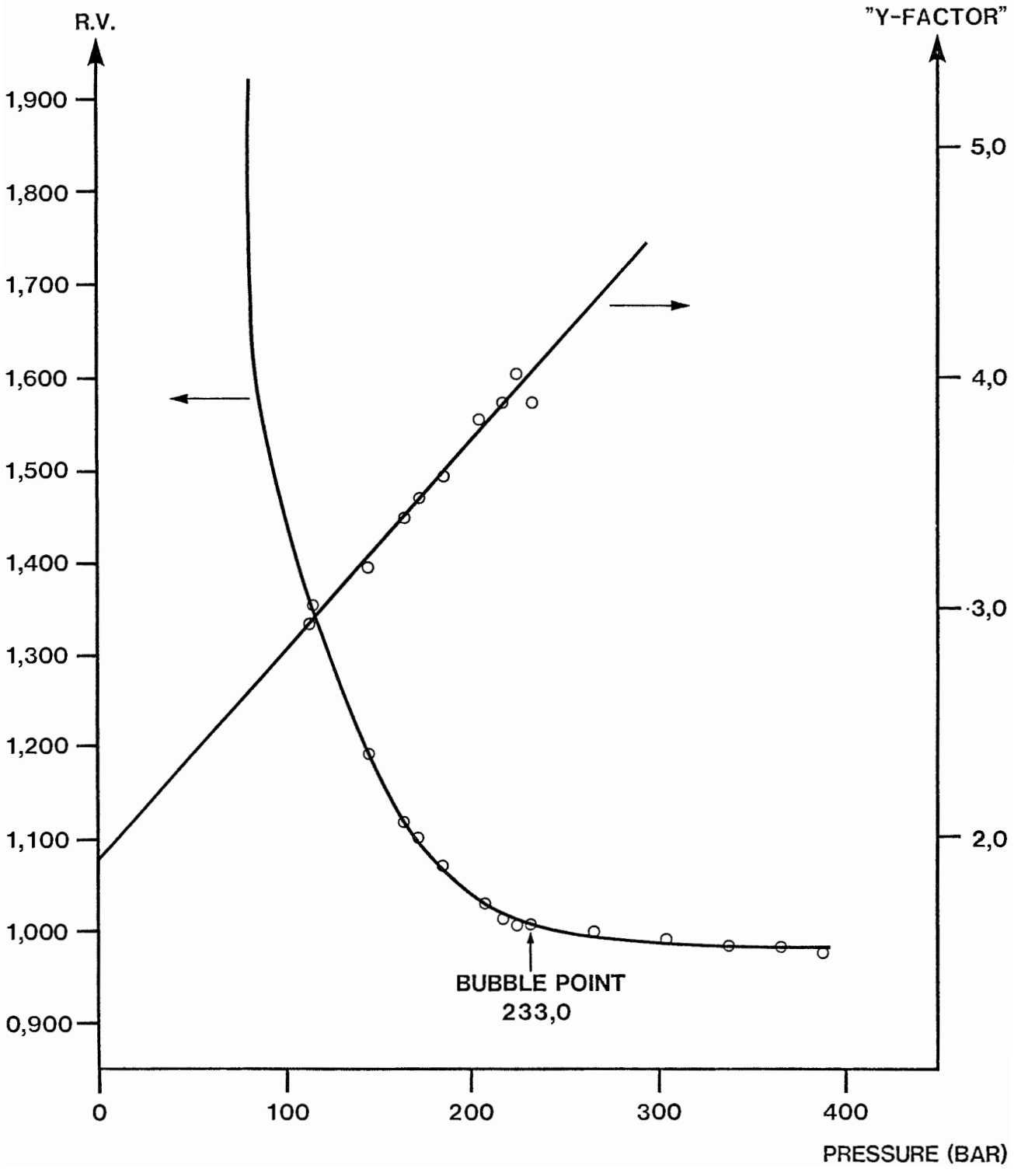


FIG. 3 Constant mass pressure relationship at 74.6°C
Well 34/10-13.
BHS no. 8151-31, from DST no.2

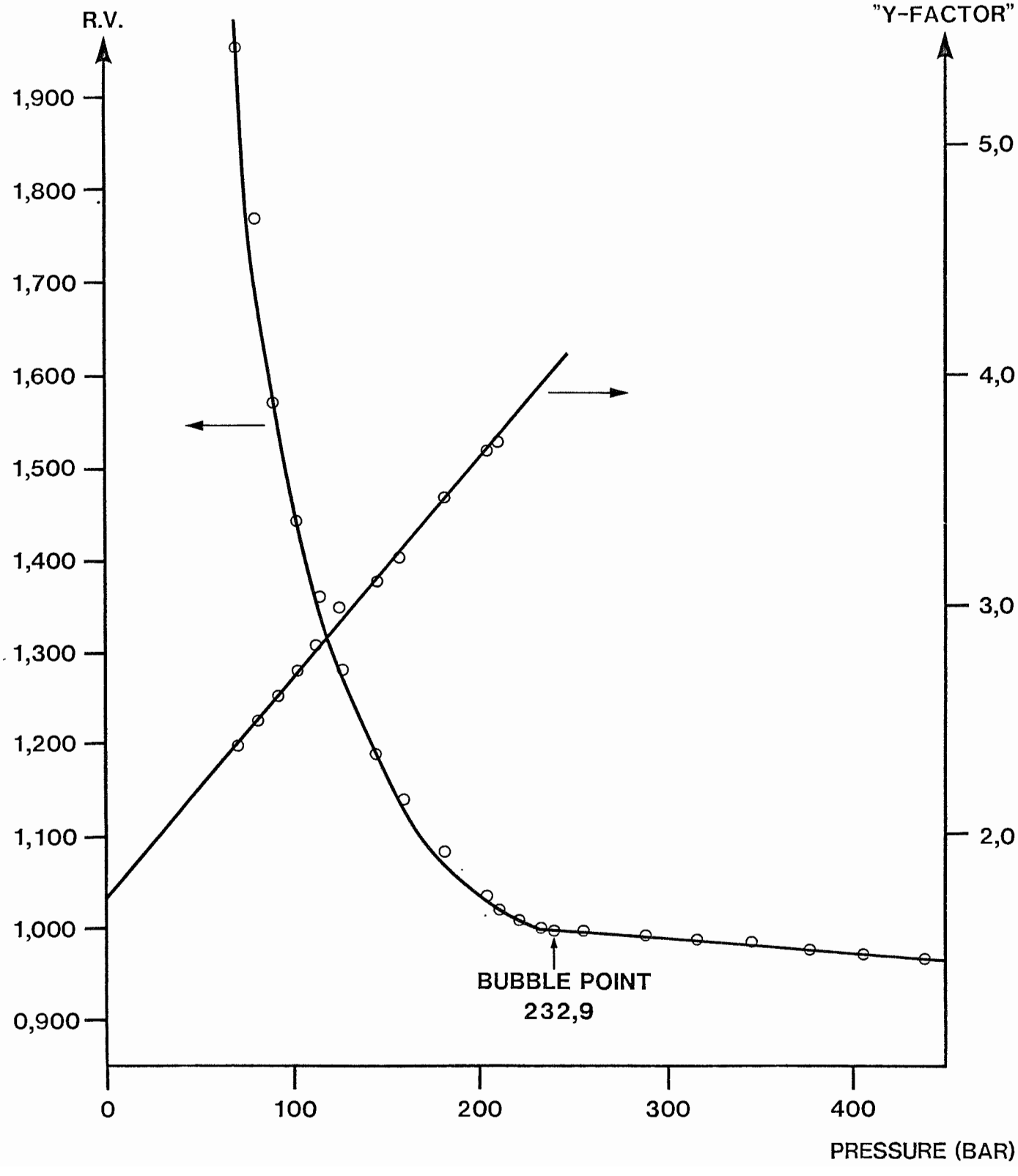


FIG. 4 Relative vol. v.s. pressure and solution GOR v.s. pressure at 74.6°C
Well 34/10-13,BHS no 2560-10,
from DST no 2

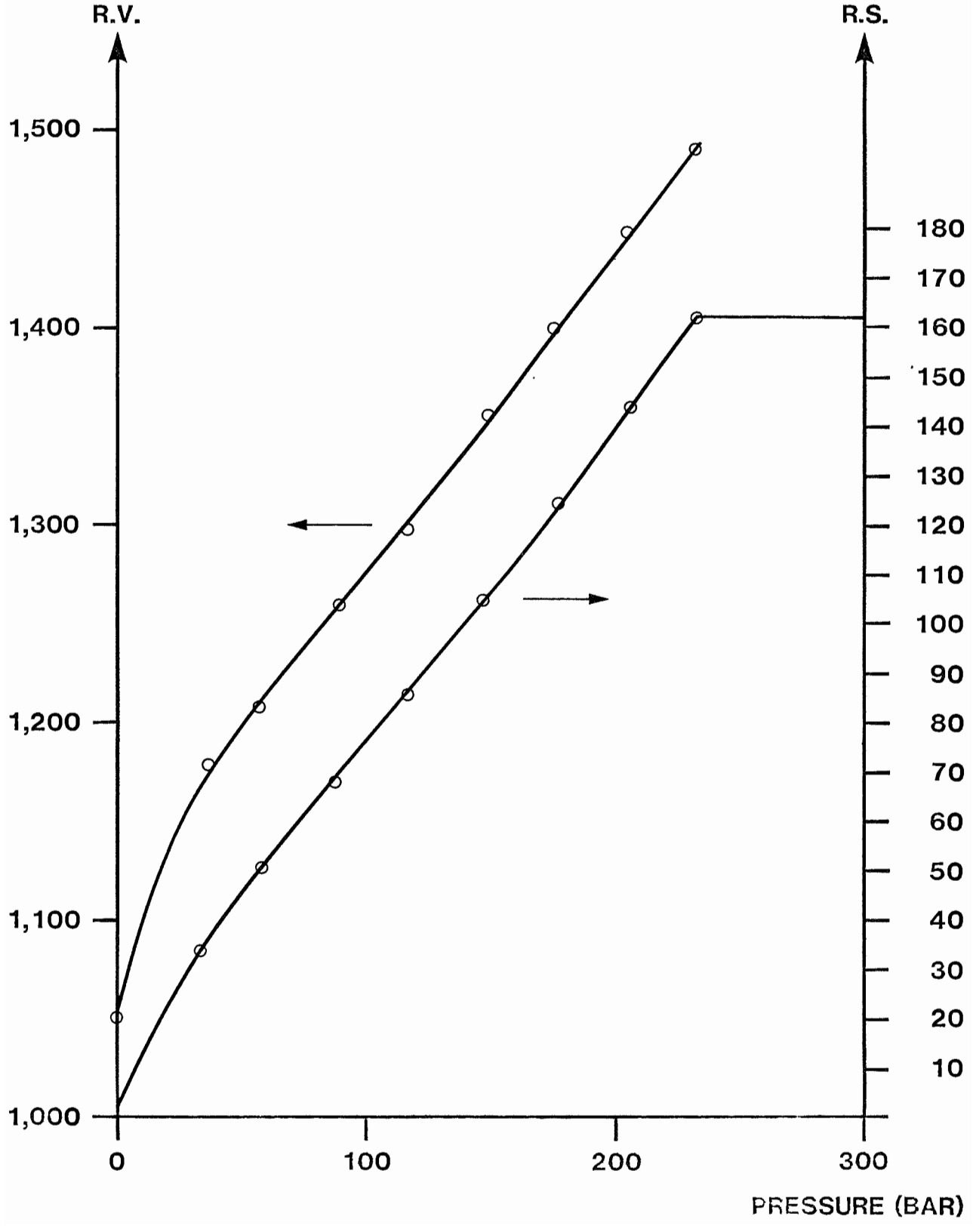
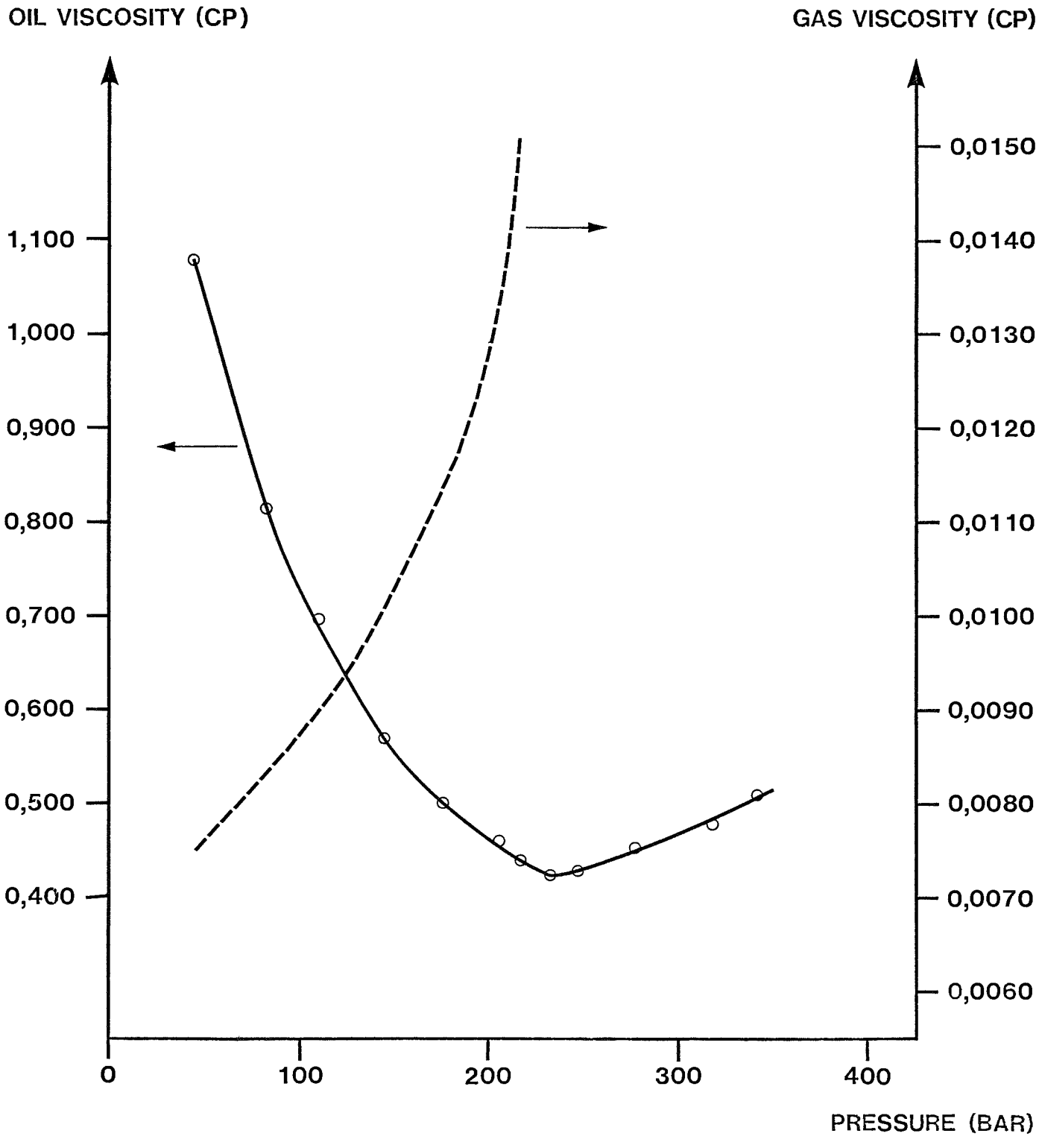


FIG.5 Oil and gas viscosities v.s. pressure at 74.6°C
Well 34/10-13, BHS no 2560-10
from DST no 2



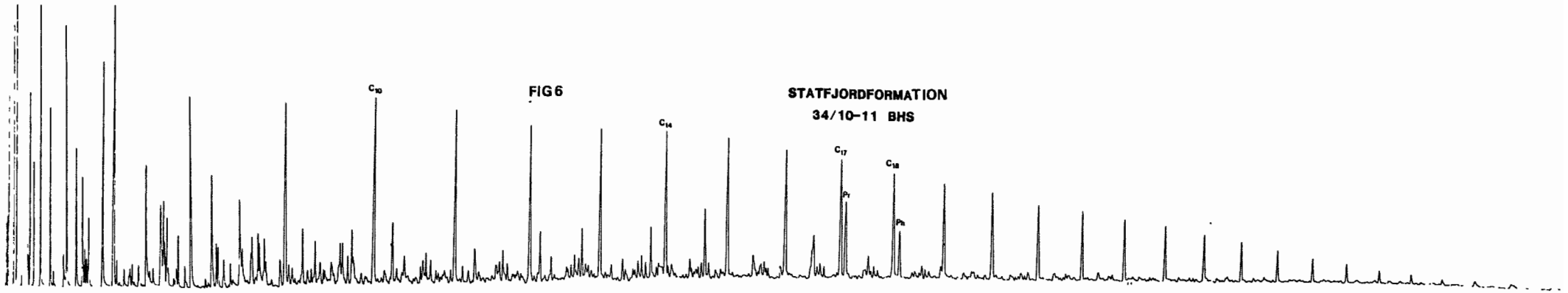


FIG 6

STATFJORDFORMATION
34/10-11 BHS

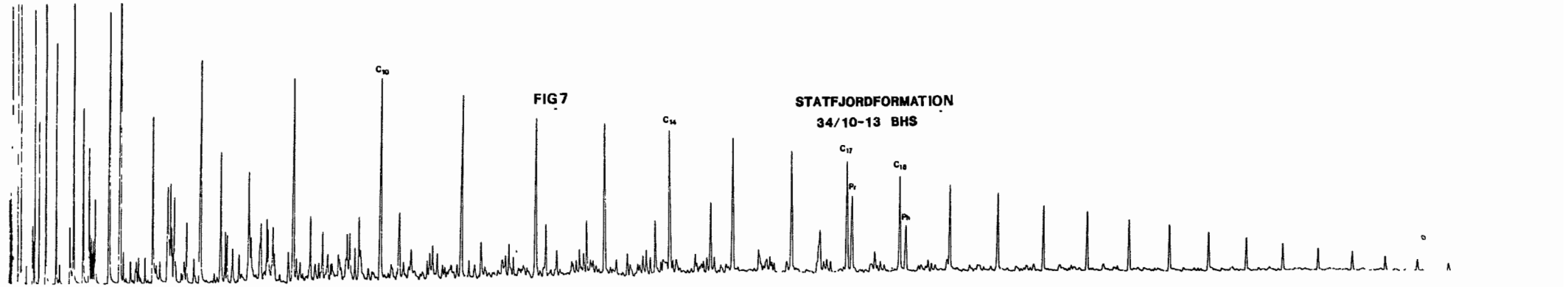


FIG 7

STATFJORDFORMATION
34/10-13 BHS

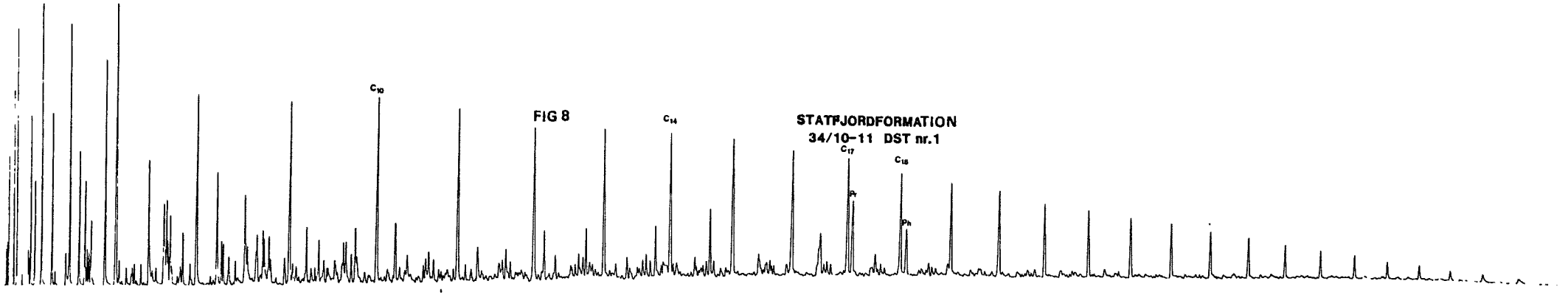


FIG 8

STATFJORDFORMATION
34/10-11 DST nr.1

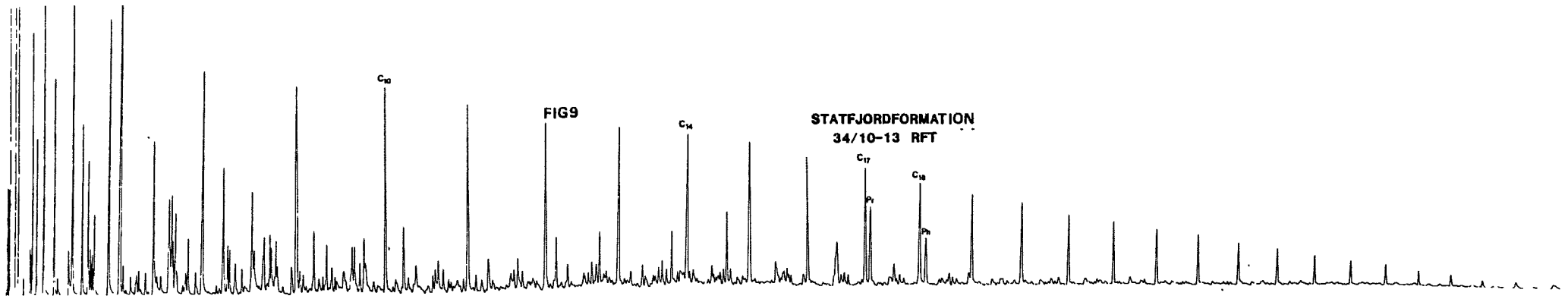
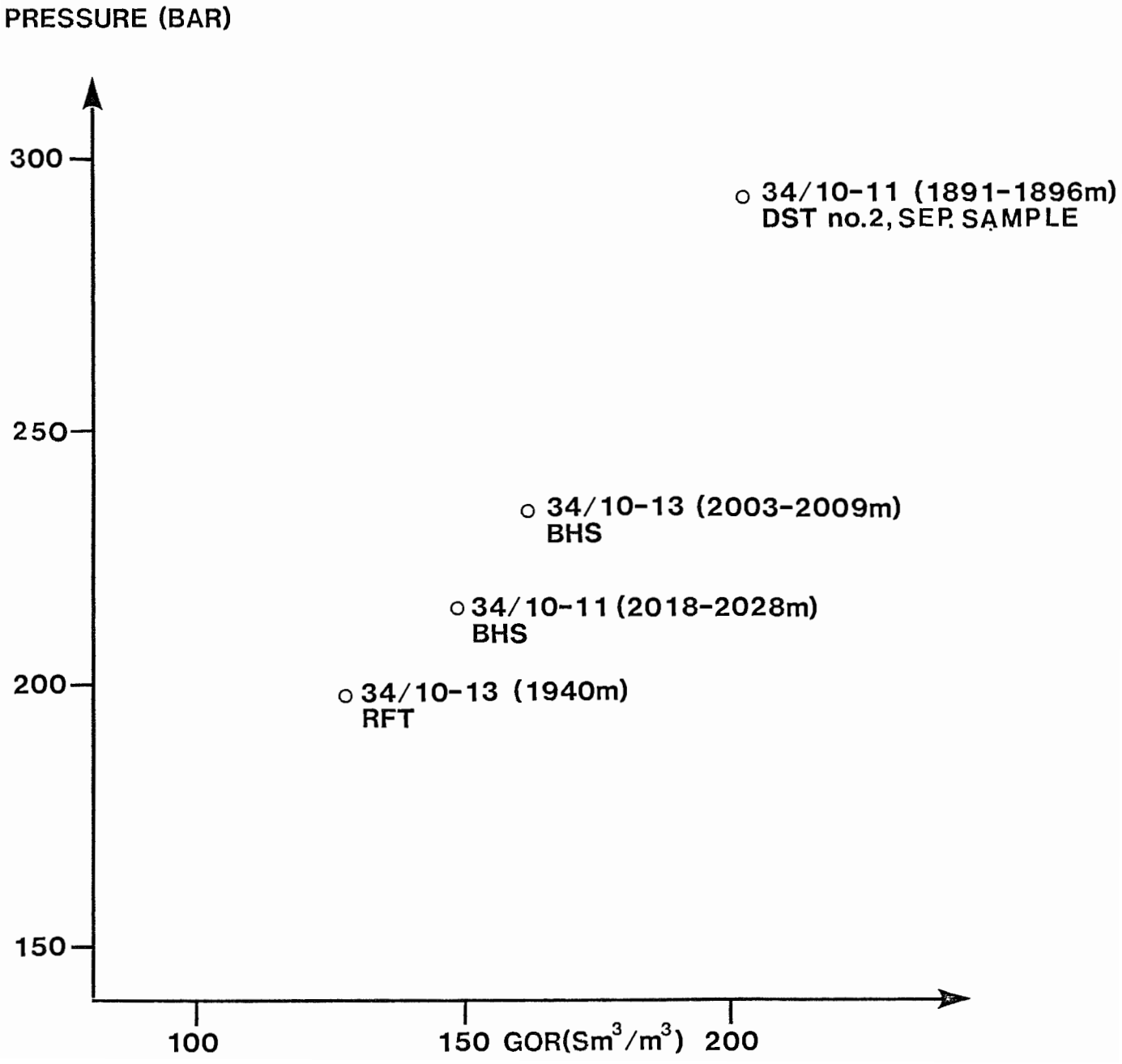


FIG9

STATFJORDFORMATION
34/10-13 RFT

FIG. 10 GOR v.s. Bubblepoint. Well 34/10-11 and 34/10-13 Statfjord formation.



A P P E N D I X

Base : STAVANGER | Field : [illegible] BLOCK | Page :
Well : 31/[illegible]-13 | Report N°:

BOTTOM HOLE SAMPLING

Date of sampling : 25/12/1981 . Service order : _____ Sampling No : 2
Sample nature : OIL Sampling depth : 1290 m RKB.

A - RESERVOIR AND WELL CHARACTERISTICS

Producing zone : [illegible] Perforations : 8003 - 8009 m Sampling interval : _____
Depth origin : _____ Tubing Dia : _____ Casing Dia : _____
Surface elevation : 6 METRES Shoe : _____ Shoe : _____

Bottom hole static conditions				
	Initial pressure : _____	at depth : _____	date : _____
	Latest pressure measured : _____	at depth : _____	date : _____
	Temperature : _____	at depth : _____	date : _____

B - SAMPLING AND TRANSFER CHARACTERISTICS

Sampler Type and No . SCHLUMBERGER PSHC n° 1.81.792 Capacity : 2000 cc

Time at which sample was taken : 14:57 | Test duration | Running start : 13:42 | Pulling end : 16:00

☐ Well shut in since : _____ | Time elapsed since closing well : -
☐ Well flowing through choke : 8/64" | Production duration through this choke : 60 mn

Production conditions during sampling or remarks

Bottom hole _____ ft	pressure: _____ temp : _____	Well head	pressure: 2733 psi temp. : 48°F	Separator	pressure: 180 psi temp. : 44°F
Flow rates: 7.200 M3/D SCFD 73 M3/D BOPD		W.L.R : - Prod.G.O.R : 100		Specific gravity	Gas (air 1) : .950 Oil : .830

Opening pressure of the first valve (if necessary) : 2130 psi (146.87 BAR.

Estimated bubble point under bottom hole conditions :
Temp. : 54°F (°C) Pressure : 2220 psi (157.21 BAR)

Transfer conditions. ☐ By gravity ☒ By pumping
Temp : 54°F (°C) Pressure : 3000 psi (206.85 BAR).

Hg collected at transfering end : -
volume remaining in the shipping bottle : 5 cc

Final conditions of shipping bottle after decompression :
Temp : 54°F (°C) Pressure : 1880 psi (129.63 BAR.)

Hg volume withdrawn for bottle decompression : -

C - IDENTIFICATION OF THE SAMPLE

Shipping bottle No : 8151.31 sent on : _____ by : _____ Shipping order No : _____
Addressee : _____

Coupled with	LIQUID	GAS
Bottom hole samples No	2560.10	
Surface samples No		

D - REMARKS :

Visa Chief [illegible]

Base : STAVANGER | Field : GOLDEN BLOCK | Page : | Well : 34/10-13 | Report N°:

BOTTOM HOLE SAMPLING

Date of sampling : 25/12/1981 Service order : Sampling N° : 1
Sample nature : OIL Sampling depth :

A - RESERVOIR AND WELL CHARACTERISTICS

Producing zone : STATFJORD Perforations : 3003m - 3009m Sampling interval :
Depth origin : RKB Tubing Dia : 3½" IDS Casing Dia : 7" LINER
Surface elevation : Shoe : Shoe :

Bottom hole static conditions	Initial pressure :	at depth :	date :
	Latest pressure measured :	at depth :	date :
	Temperature :	at depth :	date :

B - SAMPLING AND TRANSFER CHARACTERISTICS

Sampler Type and No : SCHLUMBERGER PSMC n° 2.79.771 Capacity : 600 cc

Time at which sample was taken : 14:55
Test duration : Running start : 13:42 ; Pulling end : 16:00

☐ Well shut in since : -
☐ Well flowing through choke : 8/64"
Time elapsed since closing well : -
Production duration through this choke : 60 mn (187.4 BAR)

Production conditions during sampling (or before reducing)

Bottom hole ____ ft.	pressure :	Well head	pressure : 2733 psi	Separator	pressure : 180 psia
	temp. :		temp. : 48°F		temp : 41°F
Flow rates : 1300 M3/D ~~SCFD~~ 73 M3/D ~~BOPD~~		WLR : -		Specific gravity	Gas (air=1) : .650
		Prod. GOR : 100 m³/m³			Oil : .820

Running pressure of the first valve (if necessary) : 2140 psi (147.56 BAR)

Estimated bubble point under bottom hole conditions :
Temp. : 54°F (°C) Pressure : 2300 psi (158.59 BAR)

Transfer conditions. ☐ By gravity ☒ By pumping
Temp : 54°F (°C). Pressure : 3000 psi (206.85 BAR)

Hg volume : collected at transfering end : -
remaining in the shipping bottle : 5 cc

Final conditions of shipping bottle after decompression :
Temp : 54°F (°C) Pressure : 2160 psi (148.93 BAR) (600 cc Shipping bottle)

Hg volume withdrawn for bottle decompression : -

C - IDENTIFICATION OF THE SAMPLE

Shipping bottle No : 2560.10 sent on : by : Shipping order No :
Addressee :

Coupled with	LIQUID	GAS
Bottom hole samples No	8151.31	
Surface samples No		

D - REMARKS