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Den norske stats oljeselskap a.s

WELL 15/9-Gamma appraisal

CONTENT

Program Responsibility:

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S T A T O I L

W E L L   P R O G N O S I S

WELL NO.	15/9-Gamma appraisal
PROSPECT (field)	15/9, Gamma structure

General Data:

LOCATION

Country	Norway
Area	North Sea
Licence No.	046
Block No.	15/9

Coordinates 58° 24' 03,2" N, 01° 53' 41.9" E.

Seismic: Shotpoint No. 1369 Line No. 510 - 325

11 Km south of north Block Boundary

8 Km west of east Block Boundary

210 Km from Norwegian coast, "Jærens Rev"

19 Km from N/UK median line

8 Km N of nearest well 15/9-9

Deviation: 6°W

WATER DEPTH 75 Meters (MSL)

K.B.E. 25 Meters

PROJECTED TOTAL DEPTH 2800 Meters (RKB)

CONTRACTORS

Drilling platform	Ross Rig
Drilling Contractor	Ross Drilling Co.
Mudlogging Contractor	Baroid
Type Logging unit	ADT
Electric Logging Contractor	Schlumberger
Rig positioning Contractor	Geoteam and Decca
Bottom Survey Contractor	Geoteam
Helicopter Service	Helikopter Service
Supply Boats	From Statoil "Supply boat pool"
Core analysis	GECO (& Corelab)

BOR
JEH/akw
17.9.1981

TILLEGG TIL BOREPROGRAM BRØNN 15/9-11(γ).

a) Water depth according to the site survey report shall be approx 89 m. This means that sea bed will be at 89 + 25 m = 114 m RKB.

b) 20" casing will be set at 570 m (RKB)

c) Procedure for opening 12 1/4" hole to 26" :

   1) Drill 12 1/4" pilot hole to 585 m and log. If no gas is present from the log, displace the entire hole w/seawater in 3 stages, checking for flow at each stage for minimum 5 minutes.

   2) Open hole to 26" using underreamer or holeopener. Holeopener will only be used if no gas is present from the log.

d) Shut-in procedure when drilling below the 20" casing shoe:
   Maximum shutin depth :

$$D = \frac{\text{Leak-off 20" csg shoe} \times 570}{1.05} \text{ m}$$

Leak-off = 1.50 g/cm^3 eq.

$$D = \frac{1.5 \times 570}{1.05} \text{ m} = \underline{814 \text{ m}}$$

Below this depth, the well should not be shut in with the BOP to prevent possible breakdown of the formation at the 20" casing shoe.

e) APPENDIX
   20" casing design
   20" cement program
   Time estimate
   Well schematic

20" csg.

W_d = 1185 m X = 570 m

G_f = 1.50 g/cm^3 (0.147 bar/m)

G_i = 1.1 g/cm^3 (0.108 bar/m)

Z = 114 m

G_p = 1.03 g/cm^3 (0.1 bar/m)

G_{gas} = 0.01 bar/m

$G_{cem}1$ = 0.187 bar/m (1.91 g/cm^3)

$G_{cem}2$ = 0.153 bar/m (1.56 g/cm^3)

G'_i = 1.15 g/cm^3 (0.113 bar/m)

Design creteria:

1) Entire csg. filled with gas
2) Collapse load during cementering
3) Collapse load, lost circ.
4) Tension laod when bumping plug

Burst

Max burst load at wellhead if the csg. is filled with gas:

$P_B = X \times G_f - (x-z) \times G_{gas} - (z-25) \times G_p = 570 \times 0.147 -$
$(570-114) \times 0.01 - (114-25) \times 0.1 = \underline{70.33 \text{ bar}}$

Collapse

(cmt. displ. with seawater)

$P_c = (55-12)m \times (G_{cem}1 - G_i) + (X-Z-55m)\ (G_{cem}2 - G_i) =$
$(55-12)m \times (0.187 - 0.1)bar/m + (570-114-55)m \times (0.153-01)bar/m = 25bar$

Max. collapse load if circ. is lost to normal pressured formation at 1185 m

$$Y = W_D - \frac{W_D \times G_p}{G_i} = 1185 - \frac{1185 \times 0.1}{0.113} = \underline{136\ m}$$

$$P_c = 136 \times G^1{}_i = (136 \times 0.113)\ bar = \underline{15.4\ bar}$$

Select: 114-570 m: 94 lb/ft, X-56, Vetco LS

$$RES_C = 36\ bar$$

$$RES_B = 152\ bar$$

$$RES_T = 689 \times 10^3\ daN$$

Safety factor, burst:

$$SF_B = \frac{RES_B}{P_B} = \frac{152}{70.33} = \underline{2.16 > 1.1}$$

Safety factor, collapse:

$$SF_C = \frac{RES_C}{P_C} = \frac{36}{25} = \underline{1.44 > 1.3}$$

Tension:

Weight load in air:

$$(X-Z) \times M_C = (570-114) \times 140 \times 0.981 = \underline{62627\ daN}$$

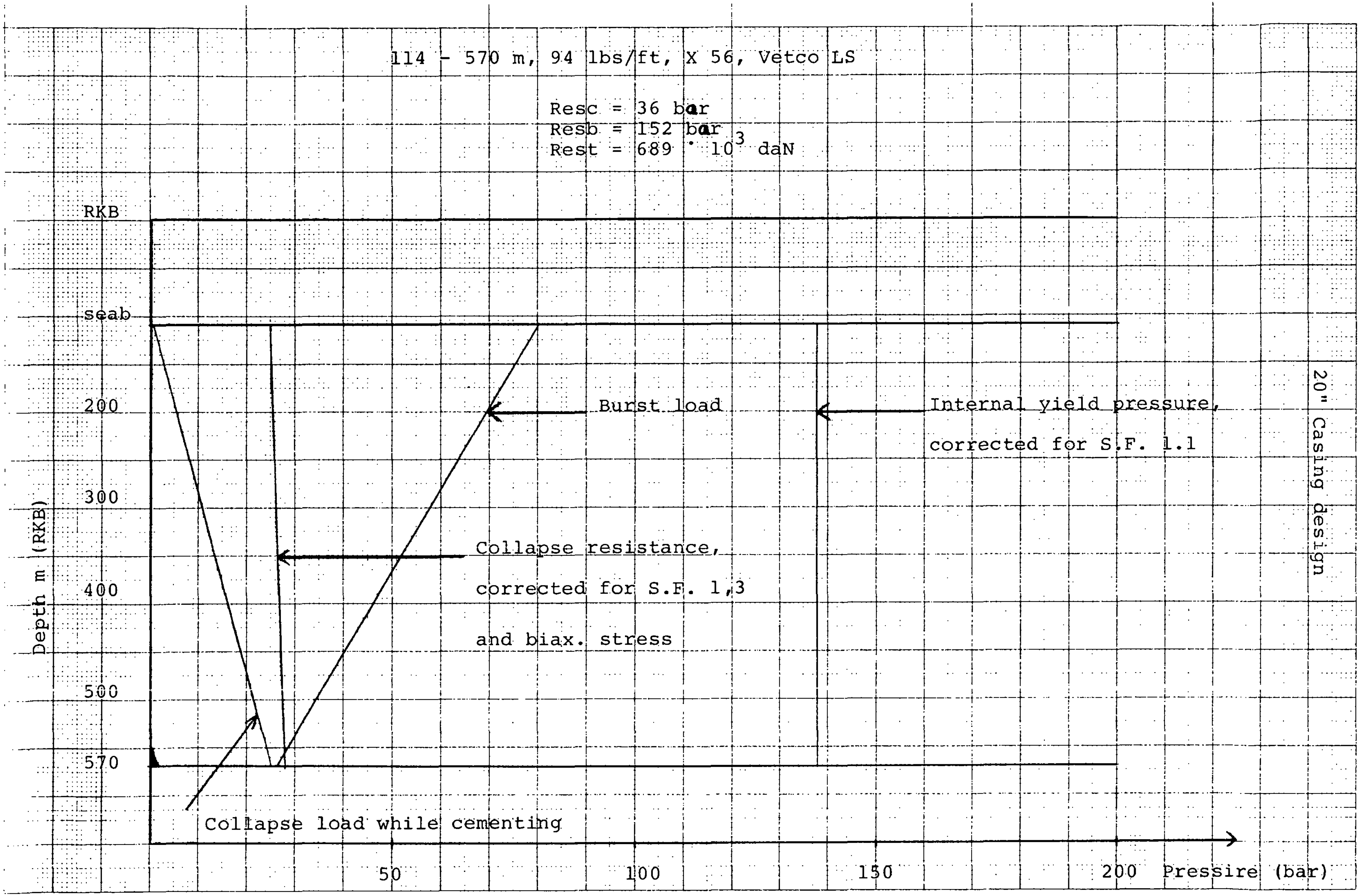
Extra tensile load when bumping plug:

$$\left(\frac{800}{14.5} - 25\right) 0.01 \left(\frac{455,7}{2}\right)^2 \times \Pi\ daN = 55903\ daN$$

Tot. weight load:

$$(55903 + 62627)\ daN = \underline{118530\ daN}$$

$$SF_T = \frac{RES_T}{118530} = \frac{689 \times 10^3}{118.530} = \underline{5.8}$$



114 - 570 m, 94 lbs/ft, X 56, Vetco LS
Resc = 36 bar
Resb = 152 bar
Rest = 689 · 10^3 daN
RKB
seab
200
300
400
500
570
Depth m (RKB)
Burst load
Internal yield pressure,
corrected for S.F. 1.1
Collapse resistance,
corrected for S.F. 1,3
and biax. stress
Collapse load while cementing
50
100
150
200
Pressure (bar)
20" Casing design

20" CASING CEMENT DATA AND CALCULATIONS, 15/9-

GENERAL: The cement volume is calculated at the basis of the theoretical annulus volume and the casing to be cemented to the sea bed with 100% excess volume in open hole.

WELL DATA:

Depth kb-sea bed...............................:	114	m
Depth kb-last shoe.............................:	166	m
Depth kb-casing set point......................:	570	m
Open hole dia..................................:	26	"
Annulus capacity, cased hole...................:	194.0	l/m
Annulus capacity, open hole....................:	139.4	l/m
Internal capacity, " casing....................:	185.3	l/m
Mud weight.....................................:	1.05	g/cm^3
Bottom hole hydrostatic pres. (BHHP)........:	59	bar
Est. bottom hole static temp. (BHST)........:	35	^oC
Est. bottom hole circulating temp. (BHCT)...:	29	^oC
Est. formation integrity.......................:	0.147	bar/m

	FILLER/LEAD SLURRY	TAIL IN SLURRY
CEMENT SLURRY COMPOSITION	CLASS + 3.20L D-75/100 kg cement	CLASS G-cement neat
Mix water 1/100 kg	93.04 sea	44.0 sea
Total liquid 1/100 kg	96.24	44.0
Slurry weight g/cm^3	1.56	1.91
Slurry yield 1/100 kg	128.00	75.8
TEST DATA @ BHCT		
Thickening time @ BHHP, hr:min	6:01	4:00
Crit. Turb. Flow rate: m/s (l/min)		
Fluid loss, ml/30 min, 70 bar		
TEST DATA @ BHST, BHHP		
Compr. strength, bar hr		
bar 24 hr	47	273
REMARKS:		319
Fann VG Readings 600/300/200/100		129/88/72/56

Volume calculations (20" casing):

Annular volume: 0.1394 m^3/m x (570 - 166)m	= 56.3 m^3
Volume between csg's: 0.194 m^3/m x (152-100)m	= 10.1 m^3
12 m plug at shoe: 0.1853 m^3/m x 12	= 2.2 m^3
100% excess on open hole:	= 56.3 m^3
Total volume	= 124.9 m^3

Lead slurry: Class G-cement + 3.2 l/100 kg D-75 mixed with seawater at 1.56 kg/c

90000 kg cement equivalent to 115,0 m^3 slurry

Tail-in slurry: Class G-cement mixed with seawater at 1.91 kg/l

13000 kg equivalent to 9.9 m^3 slurry

Job preparation

Total liquid lead slurry: 90000 kg x 96.24 l/100 kg = 86616 l

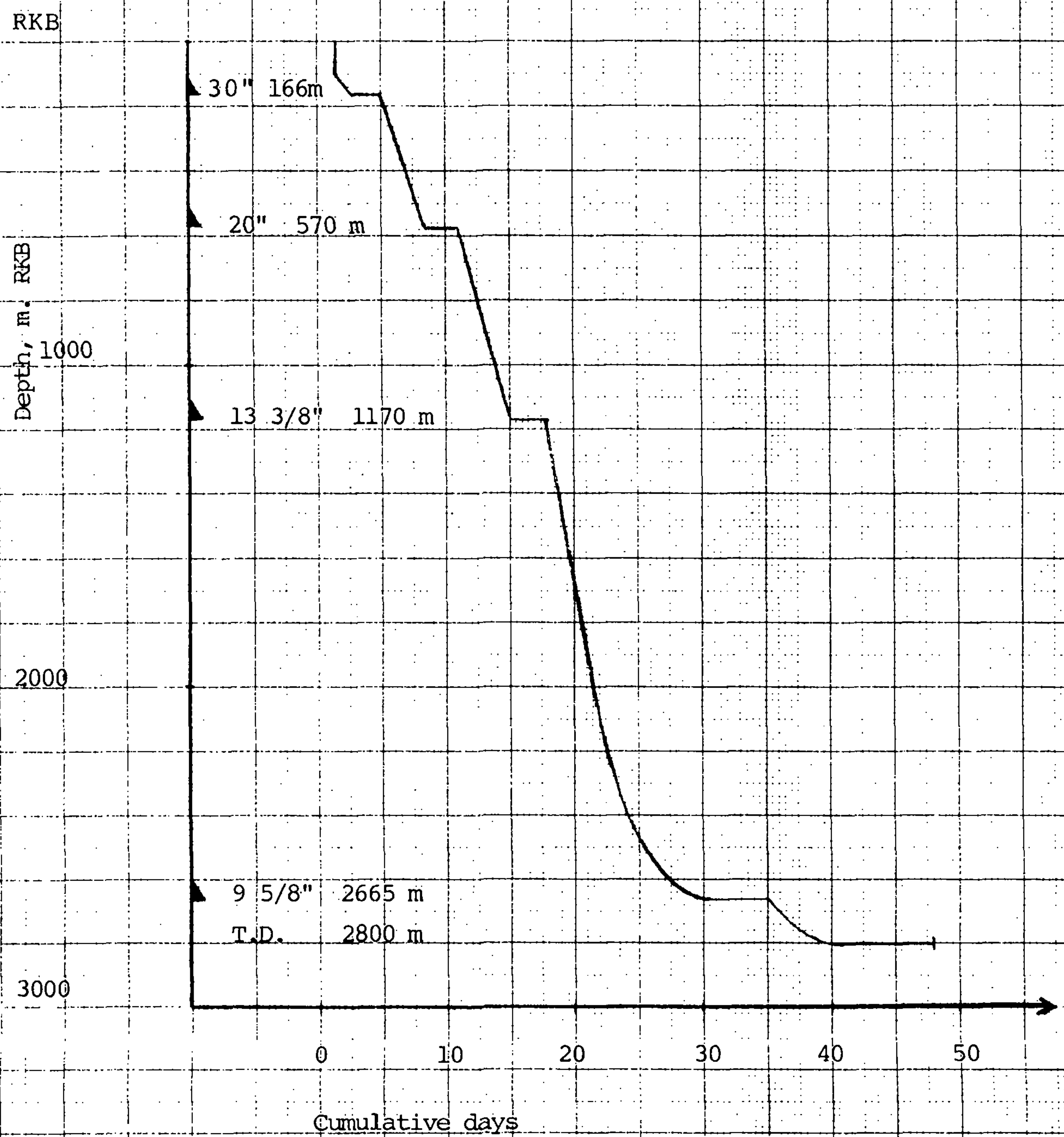
Volume of D-75 needed in each mixing tank

$$1590 \text{ l} \times \frac{3.20 \text{ l/100 kg}}{96.25 \text{ l/100 kg}} = 52.9 \text{ l}$$

Total volume of D-75 needed: 90000 kg x 3.2 l/100 kg = 2880 l

Total liquid tail-in slurry: 13000 kg x 44.0 l/100 kg = 5720 l

Time VS. depth, based on fair weather conditions. No testing included.



WELL NO. 15/9 - gamma

(Not to scale)

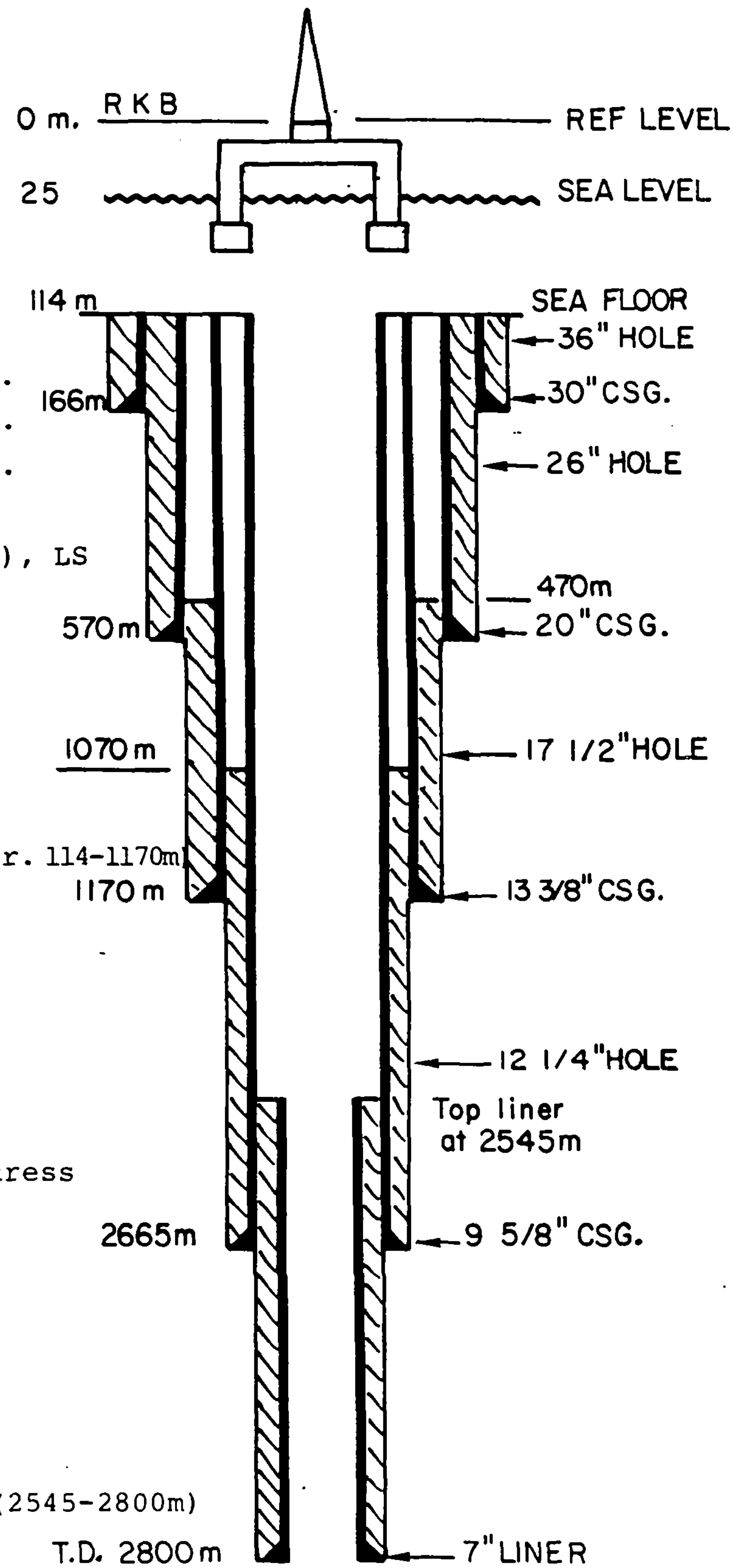
30", grade B, ATD-RB
1jt. 1½" wall th.
3jts. 1" wall th.
Cement to seabed + 150% excess.

20", X-56, 94 lbs/ft (100-570m), LS
Cement to seabed + 100% excess

13 3/8", K-55, 68 lbs/ft, buttr. 114-1170m
Cement to 470 m

9 5/8", 47 lbs/ft., N-80, buttress
Cement to 1070 m

7", 29 lbs/ft, N-80, buttr., (2545-2800m)
Cemented to full length



GEOLOGICAL PROGRAM
WELL 15/9-Gamma appraisal

PURPOSE OF TEST

15/9-Gamma is an appraisal well designed to deliniate the hydrocarbon accumulation found in the Heimdal Fm. of the 15/9-Gamma structure, and to test possible hydrocarbons in the Triassic sandstones. The well will be drilled into Triassic to an estimated total depth of 2800 m.

OBJECTIVES

The primary objective of well 15/9-Gamma is sandstones of Palaeocene age. Secondary objective is Triassic sandstones.

DRILLING HAZARDS

In 15/9-3, 15.5 km north west of this location, a high pressure zone at top of Jurassic occurs. This local high pressure zone is not expected in this well, but its presence should not be ignored.

SURVEY AND POSITIONING

The rig will be navigated by Pulse 8 and finally positioned by Satnav. Rig location accuracy is requested within a 100 m radius of the proposed location on sp. 1369 on seismic line 510-325.

STRATIGRAPHIC PROGNOSIS

UNIT	DEPTH (m)
Top Pliocene	510 m ± 30
Top Utsira Fm.	835 m ± 30
Top Oligocene	1295 m ± 30
Top Eocene	1720 m ± 40
Top Balder Fm.	2140 m ± 40
Top Heimdal Fm.	2390 m ± 40
Top Ekofisk Fm.	2515 m ± 40
Top Jurassic	2685 m ± 50
Top Triassic	2705 m ± 60
T.D.	2800 m or 100 m into Traissic

GEOLOGICAL WELL LOGGING AND SAMPLING PROSEDURES

Mud logging contractor: Baroid
A Baroid mudlogging unit will be employed to log the well for hydrocarbon shows, collect samples, prepare sample log and conduct certain other services throughout drilling operations.

Sampling interval

5 sets of unwashed samples (½ kg) will be collected at 10 meter intervals down to 2000 meters. Thereafter 3 or 5 meter's intervals will be collected. Over zones of interest, 2 meter sampling intervals may be requested by the wellsite geologist.

2 sets of washed and dried samples will be collected at the same intervals. One composite sampel will be canned at 30 meter's intervals from 30" casing to TD.

One set of washed and dried samples will be retained on the rig until the well is finished. The remaining samples will be sent to GECO, Stavanger periodically during drilling. Storage and distribution to partners and government agencies will be handled by GECO as per instructions.

LOGGING PROGRAM

Run	Hole size	Logging program
1	17 ½"	ISF/SONIC-GR, GR in 30" casing
2	17 ½"	ISF/SONIC-GR, FDC/GR, ST*
3	12 ½"	ISF/SONIC-GR, FDC/CNL*-GR, DLL/MSFL* RFT*, ST*, HDT*, CBL
4	8 ½"	ISF/SONIC-GR, FDC/CNL*-GR, DLL/MSFL* RFT*, ST*, HDT* CBL/VDL* Velocity Survey

* Optional

CORING PROGRAM

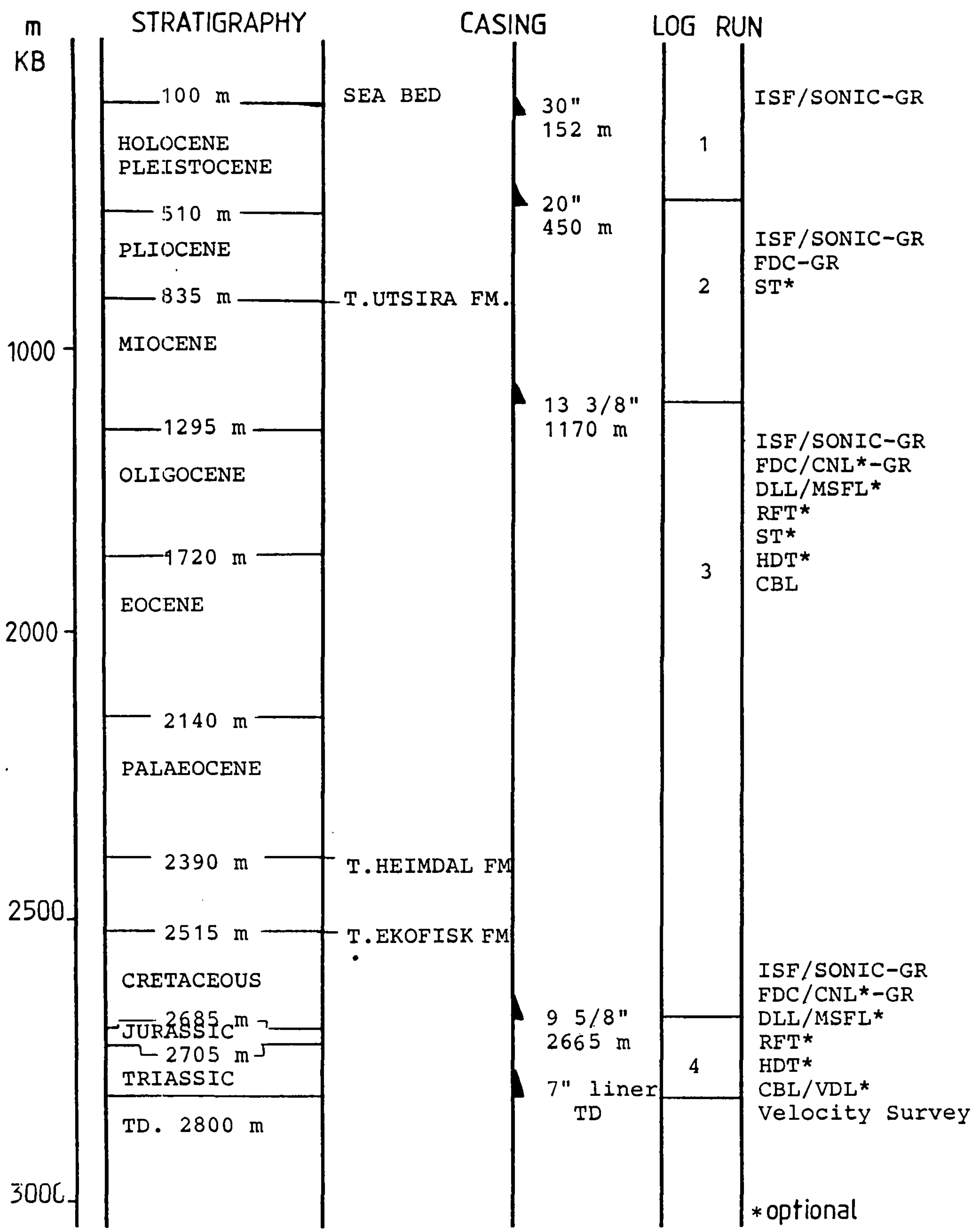
A minimum of one core will be cut in Paleocene sandstones (Heimdal fm) additional cores will be cut if significant hydrocarbon shows are encountered. The coring point, and the number of cores to be cut, will be at the discretion of the wellsite geologist, subject to review by the Operation Geologist.

All cores will be sent to GECO, Stavanger, for analysis, distribution and storage.

TESTING PROGRAM

If hydrocarbon accumulations are present, testing will be requested. These tests may be RFT's and/or production tests through casing, depending on analysis of well potential at the time. A supplementary work program will be issued if necessary.

WELL LOGGING PROGRAM-WELL



BASE

Statoil operations base at Dusevik will be utilized for the drilling of this well.

RESPONSIBILITY

a) Drilling Supervisor

The Statoil designated Drilling Supervisor will be immediately responsible for all operations on the rig in accordance with this program and drilling contracts. He will be advised by a Drilling Engineer and a Wellsite Geologist. The Drilling supervisor will report to the Statoil Drilling Superintendent.

b) Drilling Engineer

The Wellsite Drilling Engineer will provide technical assistance to the Drilling Supervisor. He will have special responsibility for pore pressure prediction and will work closely with the Baroid engineer.

c) Wellsite Geologist

The Wellsite Geologist will advise the Drilling Supervisor of any changes in the geological prognosis and of any shows of oil or gas as soon as encountered. He will supervise the mud loggers from Baroid during sampling and coring operations and together with the logging/testing engineer ensure that the Schlumberger logs are run properly and are of acceptable standard. He will recommend coring and testing intervals.

d) Logging and Testing Engineer

The wellsite logging/testing engineer will assist the Drilling Supervisor/Wellsite Geologist in supervising the logging/testing operations. He will perform the necessary quality control of logging/testing/sampling data and ensure optimal data gathering during logging and testing operations.

COMMUNICATION PROCEDURE

Confidentiality

All data are considered confidential and will be released to third parties only by decision of Statoil.

Delivery to participants

A daily well report will be sent by telex by the operator (Statoil) to all partners and to the Norwegian Petroleum Directorate. All other wellsite data, including field prints of logs, will be sent by post or messenger.

A final well report will be prepared for distribution to partners and to the appropriate norwegian Government agenices not later than six months after completion of the well.

STAFF

Staff of the Explortion and Drilling Department, Statoil, who are involved in the planning and drilling of well 15/9-Gamma Appraisal:

		TELEPHONE		
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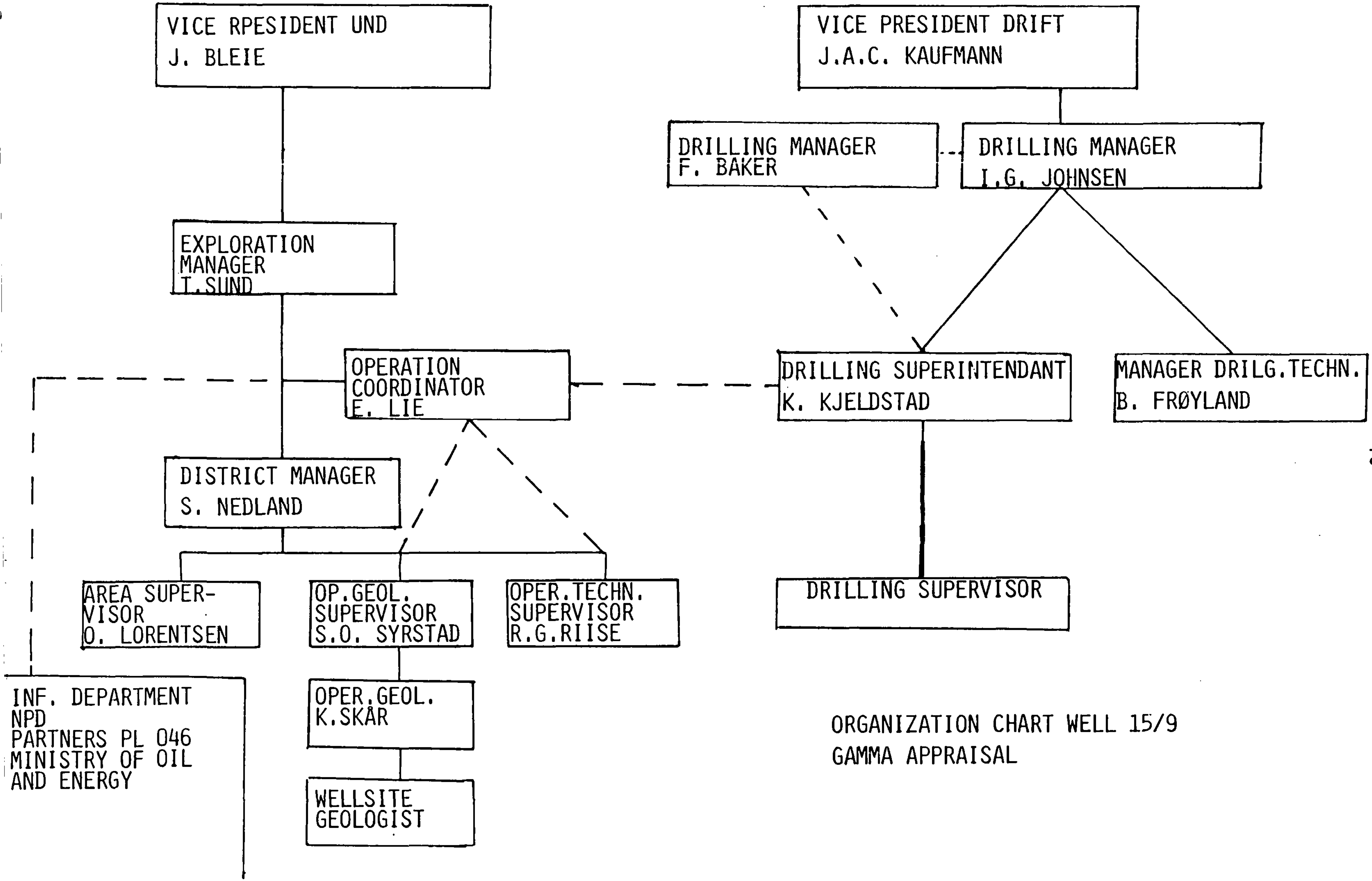
Kjeldstad, K.	Drlg.Superintendent	541099		
Lie, E.	Oper. Coordinator	533180	667411	57916
Nedland, S.	District Manager	577884	618723	
Riise, R.G.	Oper. Techn. Supervisor	577263	591401	
Syrstad, S.O.	Oper. Geol. Supervisor	577896	558641	57910
Lorentsen, O.R.	Area Supervisor	577886	618770	
Skår, K.	Oper. Geologist	577499	591388	



ORGANIZATION CHART WELL 15/9
GAMMA APPRAISAL

COMMUNICATION PERSONELL, 15/9

Esso Exploration and Production Norway Inc.:

NAME	TITLE	TELEPHONE OFFICE	HOME	NIGHT
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McReynolds	Oper. Manager	528540	589145	528542
Thomas, J.	Chief Geologist	528540	560729	
Eicher, L.J.	Geol. Supervisor	528540	(mobil 27064)	

Norsk Hydro Produksjon A/S:

NAME	TITLE	OFFICE	HOME	MOBILE
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Sæbøe, A.	Area Coordinator	543920	543805	40576
Leivestad S.I.	Oper. Geol. Manager	543920	121546	40576

Contact in Norwegian Petroleum Directorate:

Lysholm, S. 533160

DRILLING PROGRAM

Well designation	:	15/9 GAMMA
Vessel	:	Ross Rig
Type drilling rig	:	Aker H-3
Drilling draft	:	21.3 m
RKB to MSL	:	25 m
Air gap	:	15.2 m
Water depth	:	75 m
BOP system	:	18 3/4", 10000 psi single stack system
Wellhead system	:	Cameron 18 3/4", 10000 psi, 3-hanger weight set system

Depths referred to RKB except where otherwise specified.

I Location

See Geological program

II Mooring

As per general procedure.
Refer to site survey report for information on seabed conditions.

III General drilling procedure

- Drill 36" hole with 26" x 36" H.O. to ± 152 m. Space out so that top of 30" housing will be positioned approx. 1.5 m above the sea bed. Do not use temporary guide base, - stab 30" casing blind.
- Drill out cmt + shoe w/26" bit. Run riser w/pin connector and attach diverter. Drill 12 1/4" hole to 465 m and log. The hole will be opened to 26" using underreamer (see drilling considerations). 20" casing will be set at 450 m.
- Run BOP and test according to procedure in chapter X. Drill 17½" hole to 1185 m, log and set 13 3/8" casing at 1170 m. This depth should be adjusted to be approx. 60 m below the "Utsira sand.
- Drill 12 1/4" hole to 2680 m. Log and set 9 5/8" casing at 2665 m. The setting depth should be adjusted so that the casing shoe is approx. 150 m below bottom Heimdal sand. (approx. 15m below top plenus marl).

- Drill 8½" hole to T.D. at 2800 m, core and log as programmed. The limestone section will be drilled using a rotary diamond bit.
- If it is decided to test the well, a 7" liner will be run through the test interval w/120 m overlap in 9 5/8" casing.

IV Drilling considerations

36" hole

After cementing casing, check bulls eye indicator on PGB. If angle is more than 1½^{o} off, consult with operations office before proceeding.

26" hole

For information on shallow gas refer to the site survey report. Procedure for opening hole to 26":

1) After 12 1/4" pilot hole is drilled to 465 m and the hole has been logged, displace entire hole w/seawater and check for flow.
2) Open hole to 26" using underreamer or holeopener after evaluation of logs and drilling information.
3) Displace the hole with mud, providing an overbalance > 2.5 bar at top of highest potential gas sand when the riser is disconnected. The mud weight will be reduced if necessary to prevent formation breakdown at the 30" shoe.
4) Disconnect riser, checking for flow.
5) During clean-up run w/26" bit, circulate w/mud weight as under ptk. 3.
6) Before running casing, spot 10m^3 of 1.25 g/cm^3 mud on bottom.

Remarks

- For information on well control, see "KICK PROCEDURE".
- When drilling this section, there should always be 50m^3 mud w/density 1.25 g/cm^3 in reserve.

17½" hole

The pore pressure is expected to be normal.

Remarks

- For information on well control, see "kick procedure".
- When drilling this section, there should always be 70m^3 mud w/density 1.25 g/cm^3 in reserve.

12 1/4" hole

The pore pressure is expected to be normal, possibly with a slight increase at the top of Heimdal sand. On previous wells on the 15/9 block, tight hole has been experienced down to 1800-1900m, on one well as far down as 2300-2400m. These problems seem to be caused by swelling clays and possibly differential sticking. To reduce the problems, mud weight should be kept at a minimum and a thin filter cake maintained. The hole is expected to stabilize after a few wiper trips.

8½" hole

The pore pressure is expected to increase rapidly from the base of Cretaceous and reach a maximum of 1.28 g/cm^3 eq. m.w. in the upper Jurassic shale around 2685m. Below this depth the pressure is expected to decrease to approx. 1.18 g/cm^3 eq. m.w. at top of the Triassic sand.

NOTE

- The upper Jurassic shale is believed to be very tight (low permeability, low productivity), so the possibility of a kick in this section should be small. For information on maximum kick sizes that can be taken before breaking down formation, see "kick limitations".

- The pressure estimate in the Triassic sand is based on pressure communication with 15/9 wells.

- On one previous well in the area, the 15/9-3 positioned to the north-west of the 15/9-block, there was encontered a thin, high pressure, low permeability turbidite lens, positioned at the top of upper Jurassic shale. Estimated pore pressure ranging between 1.8-2.0 g/cm^3 eq. m.w. Equal phenomena have been in the British sector. The possibility of encountering the turbidite on this well, the 15/9- , is considered relatively small.

- The high mud weight through upper Jurassic will increase the possibility of sticking the drill string in the Triassic sand. To prevent differential sticking:

a) Keep fluid loss at a minimum.
b) Maintain a thin filter cake.
c) Keep pipe moving at all time if possible.

Directional survey program

155 m:	Sperry Sun single shot
465 m:	Sperry Sun single shot
After 13 3/8"	casing is set: gyroscopic multi shot
Below 13 3/8"	casing: Sperry Sun single shot every 90m.

H_2S - check

Check the hole for H_2S - content in 100m intervals, starting at 2300m by means of Garret Gas Train (use fresh filtrate from the filter press only).

V MUD PROGRAM 15/9

Interval (m)	Hole size	Mud type	Mud weight g/cm^3	PV	YP	HTHP	pH
100-152	26" x 36"	Seawater, prehyd. bent, gel slugs	-				
152-465	12 1/4"	- " -	-				
152-465	26"	- " -	-				
465-1185	17½"	Seawater gel-lignosulfonate	1,06 - 1.15	low	15-20	25 or less	10.0-11.[illegible]
1185-2680	12 1/4"	- " -	1.2 - 1.4	low	15-20	25 or less	10.0-11.[illegible]
2680-2800	8½"	- " -	1.4	low	10-15	15 or less	10.0-11.[illegible]

REMARKS :

- Rheology properties will be tested and reported at 50°C. Reported mud weight is to be measured using a Pressurized Mud Balance.
- Maintain drill solids content at minimum by means of the desander, desilters/mud cleaners (150 - 120 mesh scr[illegible]
- Utilize the centrifuge for viscosity control and for barite salvage.
- See separate Mud Program for details.

VI 15/9 GAMMA BITS AND HYDRAULICS

DEPTH INTERVAL	HOLE SIZE	BIT TYPES	NOZZLES 32 NDS	WOB TONS	RPM	CIRC.RATE (Cum/min)	PUMP PR[illegible] (BARS)
00 - 152	26" x 36"	26" OSC-3AJ+H.O.	3 x 22	0-5	60-80	-	-
52 - 465	12 1/4"	X 3A	3 x 16	0-10	150	2.5 - 3.0	-
52 - 465	17½" + 26" H.O.	DSJ	3 x 18	0-7	120	3.6	
65 -1185	17½"	DSJ	3 x 18	0-10	120	3.4	
85 -2200	12 1/4"	X1G	3 x 15	5-12	120	2.2 - 2.7	200
00 -2680	12 1/4"	X1G,XV,XDV,DIAMOND (STRATAPAX) CORE	3 x 14	10-25	100-120	2.0 - 2.5	200
80 -2800	8½"	SDV,SVH,J3	3 x 12	10 - 20	50-90	0.9 - 1.3	230

REMARKS:
- Hydraulics and Drilling parameters will be optimized on the rig according to actual mud properties and hole conditions.
- Surface pressure is to be recorded at different circulating rates before the bit is pulled.

VII Well logging program

See geological program.

VIII Casing

Casing program

SIZE	DEPTH (m)	WEIGHT lbs/ft	GRADE	THREAD
30"	1 jt	1½" wall	B	Vetco ATD/RB
	3 jts	1" wall	B	Vetco ATD/RB
20"	100 – 450	94	X56	Vetco LS
13 3/8"	100 – 1170	68	K-55	Buttress
9 5/8"	100 – 2665	47	N-80	Buttress
7" liner (Optional)	2545 – 2800	29	N-80	Buttress

See "casing design"

Note:

- 20" casing to be run with float collar
- Make up torque (ft.lbs.) for Vetco LS connectors:

min	opt.	max
14000	19000	24000

Thread lubrication: Machine oil only
Make up speed: 10 RPM
Use 1/1000 mm feeler after first make-up.

Casing and seal assembly test pressure (see note below)

20" casing	-	800 psi	(55.2 bar)
13 3/8" casing	-	2500 psi	(172 bar)
9 5/8" casing	-	4800 psi	(331 bar)
7" liner	-	5000 psi	(345 bar)

Casing to be tested below shear ram.
The given test pressure should be the pressure measured at surface.

NOTE:- When testing casing: If cement has been brought up inside the previous casing shoe, a leak in the seal assembly may collapse the casing or burst the previous casing. Therefore, in these cases, when testing seal assembly first time, limit test pressure to collapse pressure of casing or burst pressure of last casing, which ever is lower.

- Max. test pressure for 9 5/8" csg. - 4800 psi is due to the high mudweight (1.4 sp.gr.) when running it.

Safety factors:	collapse	burst
20"		1.1
13 3/8"	1.3	1.1
9 5/8"	1.25	

IX Cementing

As per general procedure. See "cement calculation" for compositions and slurry amounts. A cement bond log will be run to check the top and quality of the cement for the 13 3/8" and 9 5/8" casing strings.

X BOP

BOP test pressures:

	Pipe rams	bags	choke and kill valves
1. On surface	10000 psi	3500 psi	10000 psi
2a. After initial and subsequent installation on wellhead	7500 psi	2500 psi	7500 psi

2b. Weekly test with 20" casing set	1500 psi	1500 psi	1500 psi
3a. After 13 3/8" seal assembly is tested with no leak	2500 psi	2500 psi	2500 psi
3b. Weekly test with 13 3/8" casing set	2500 psi	2500 psi	2500 psi
4a. After 9 5/8" seal assembly is tested	5000 psi	2500 psi	5000 psi
4b. Weekly test with 9 5/8" casing set	5000 psi	2500 psi	5000 psi

Shear ram will be tested to 10000 psi on surface. After BOP is mounted on wellhead, it will only be tested when testing casing. (Test pressures as given in chapt. VIII).

NOTE: If the BOP stack must be pulled after initial installation:

a) Pressure test on surface acc. to pt. 1. above.

b) Pressure test after reinstallation acc. to pt. 2a above. During this test, if 13 3/8" csg is set, observe pressure and volume pumped carefully to ensure that the seal assembly is not leaking.

- For more information on BOP testing, refer to general procedures in Statoils Floating Drilling Operation Manual.
- For information on BOP equipment, see "Statoil BOP manual"

XI Pressure Integrity test

The pressure integrity tests will be performed according to normal procedures.

XII Drills

As per general procedures.

XIII Abnormal pressure detection

The most effective abnormal pressure detection operation will be the result of theam effort involving the Drilling Supervisor, Drilling Engineer, Wellsite Geologist, and Mud Logging Engineer. Pressure indicators will be monitored continuously and any deviation investigated immediately. The reliability of each abnormal pressure indicator will have to be established during the course of operation.

A Mud Logging Unit will be utilized below the 30 inch casing shoe to collect and monitor abnormal pressure parameters. This unit will be programmed to record the following parameters relating to abnormal pressure:

1. Mud weight
2. Drilling rate
3. Weight on bit
4. RPM
5. Torque
6. "d" exponent
7. Mud gas
    a) Background gas
    b) Connection gas
    c) Trip gas
8. Mud temperature at flowline
9. Mud flow
10. Pit volume

In addition, shale density and chloride content in the mud will be measured manually.

Manual plots will be recorded and reviewed continuously by the Drilling Engineer and Drilling Supervisor. These plots will include drilling rate, lithology, mud weight, weight on bit, "d" exp., gas units, mud temperature and shale density, together with bit and hydraulics data.

Input parameters (weight on bit, RPM, hydraulics) should be held fairly constant. This is especially important in the pressure transition zone. Abnormal pressure detection data will be forwarded into the Stavanger Operations Office twice daily on a routine basis and more frequently if drilling a suspect transition zone. Any change in abnormal pressure detection parameters will be immediately reported by the rig to the Stavanger Operations Office.

XIV Production test

As per production test manual. A detailed testing program will be issued prior to each production test.

XV Plug and abondonment

As per procedures.

Approved

Expl. Manager Statoil

Drilling Manager Statoil

Kick procedure

If the well is observed flowing after flow check, the following procedures should be followed:

A. Drilling below 30" casing shoe (152 - 465m)

a) While drilling w/riser attached.
   1) Make sure the appropriate overboard line is open.
   2) Close shale shaker valve.
   3) Close diverter.
   4) Start pumping at maximum rate. Line up from reserve pit and start pumping heavy mud at maximum rate. At this point, notify supervisory personnel.
   5) Proceed as directed by supervisor.

b) While drilling w/o riser attached
   1) Notify supervisory personnel
   2) Follow pt. 4 above and proceed as directed by supervisor.

c) While tripping w/riser attached.
   1) Make sure the appropriate overboard line is open.
   2) Close trip tank valve.
   3) Notify supervisory personnel.
   4) Proceed as directed by supervisor.
      Recommended procedure: Go back to bottom if possible, otherwise close diverter and pump at maximum rate.

d) While tripping w/o riser attached.
   - When bit is below wellhead:
   1) Notify supervisory personnel
   2) Proceed as directed by supervisor.
      Recommended procedure: Depending on flow conditions, go back to bottom or drop string and pull off location.
      - When bit is above wellhead:
   1) Notify supervisory personnel
   2) Pull off location.

e) While out of hole w/riser attached.

1) Notify supervisory personnel.
2) Unlatch riser
3) Pull off location.

f) While out of hole w/o riser attached

1) Notify supervisory personnel.
2) Pull off location.

B. <u>Drilling below 20" casing shoe</u> (450 - 1185m)

Maximum shut-in depth:

$$D = \frac{\text{Leak-off 20" shoe} \times 450}{105} \text{ m}$$

Leak-off = 145 g/cm^3 eq.

$$D = \frac{1.45 \times 450}{105} \text{ m} = \underline{621 \text{ m}}$$

This calculation assumes zero gas gradient, giving some safety margin.

a) Drilling/tripping at well depth above D. (Bit below BOP)
   1) Position tool join to clear upper annular preventer
   2) Make sure choke line is open.
   3) Close upper annular preventer.
   4) Close hand adjustable choke.
   5) Notify supervisory personnel.
   6) Proceed as directed by supervisor.

b) While out of hole or tripping w/bit above BOP at well depth above D.
   1) Make sure choke line is open.
   2) Close blind ram.
   3) Close hand adjustable choke.
   4) Notify supervisory personnel.
   5) Proceed as directed by supervisor.

c) While drilling at well depth below depth D:
   Follow procedure A/a 1-5.

d) While tripping at well depth below depth D:
   Follow procedure A/c 1-4.

e) While out of hole at well depth below depth D:
   Proceed according to general procedure.
   Do not hesitate to close shear ram.

C. <u>Drilling below 13 3/8" casing shoe</u>

Refer to procedure in Statoil's BOP manual.

NOTE: The procedure under pt. A and B above are not accoring to Statoil's BOP manual.

KICK LIMITATIONS

Drilling below 20" shoe

Setting depth 450 m RKB

Estimated leak off value = 1.45 g/cm^3 eq.
Assuming pore pressure 1.05 g/cm^3 eq. at kicking depth, the well may be shut in without breaking down formation at the 20" csg. shoe at depths down to:

$$\frac{450 \times 1.45}{1.05} = 621 \text{ m}$$

Below this depth, kick size will be limited and the well should not be shut in to avoid possible breaking down of the formation at the 20" shoe. See "Kick procedures".

Drilling below 13 3/8"shoe

13 3/8" setting depth = 1170 m
9 5/8" setting depth = 2665 m

Estimated fracture gradient at 13 3/8" shoe = 1.65 g/cm^3 eq.
Estimated max mud weight on this interval = 1.40 g/cm^3
Assuming well kicks at 2665 m, pore pressure 1.45 g/cm^3, then max kick height on shut in (assuming zero gas gradient) before fracturing formation will be:

$$(2665-1170) \text{ m} - \frac{2665 \times 1.45 - 1170 \times 1.65}{1.40} \text{ m} = 114 \text{ m}$$

This corresponds to a kick volume:

$114 \times 0.0436\ m^3 = 5\ m^3$ = 31 bbls. (se attached figure)

Drilling below 9 5/8" shoe

9 5/8" setting depth = 2665 m
TD = 2800 m

Estimated fracture gradient at 9 5/8" shoe = 1.82 g/cm^3 eq.

Estimated max mud weight on this interval = 1.4 g/cm^3.
Assuming well kicks at 2800 m, pore pressure 1.45 g/cm^3 eq.,
then max kick height on shut in (assuming zero gas gradient)
before fracturing formation will be:

$$(2800 - 2665)m - \frac{(2800 \times 1.45 - 2665 \times 1.82)}{1.4} m \Rightarrow \quad \text{no limit}$$

20" csg

W_d = 1185 m
G_f = 1.10 g/cm^3 (0.108 bar/m)
G_i = 1.15 g/cm^3 (0.113 bar/m)
Z = 100 m
G_p = 1.03 g/cm^3 (0.1 bar/m)
G_{gas} = (0.01 bar/m)
$G_{cem}1$ = 0.187 bar/m (1.91 g/cm^3)
$G_{cem}2$ = 0.153 bar/m (1.56 g/cm^3)

Design creteria:

1) Entire csg. filled with gas.
2) Collapse load during cementering.
3) Collapse load, lost circ.
4) Tension load when bumping plug.

Burst

Max burst load at wellhead if the csg. is filled with gas:

$P_B = X \times G_f - (x-z) \times G_{gas} - (z-25) \times G_p =$
$P_B = 450 \times 0.142 - (450-100)\ 0.01 - (100-25)\ 0.1$
$P_B =$ 53 bar

Collapse

(cmt. displ. with seawater)
$P_c = (55m-12m) \times (G_{cem}1 - G_i) + (X-Z-55m) \cdot (G_{cem}2 - G_i)$
$P_c = (55m-12m) \times (0.187-0.1) + (450-100-55) \times (0.153-0.1)$
$P_c = 19.4$

Max collapse load if circulation is lost to normal pressured formation at 1185m.

$$Y = W_D - \frac{W_D \times G_P}{G_i} = \left(\frac{1185 \times 0.1}{0.113}\right) m = \underline{136\ m}$$

P_c = 136 m$\cdot G_i$1 = (136 x 0.113) bar
P_c=15.4 bar

Select: 100 - 450m: 94 lb/ft, x 56, Vetco LS
RES_C = 36 bar
RES_B = 152 bar
RES_T = 689 x 10^3 daN

Safety factor, burst:

$$SF_B \frac{RES_B}{P_b} = \frac{152}{53} = \underline{2.8 > 1.1}$$

Safety factor, collapse:

$$ST_C \frac{RES_C}{P_C} = \frac{36}{19.4} = \underline{1.85 > 1.3}$$

<u>Tension:</u>

Weight load in air:

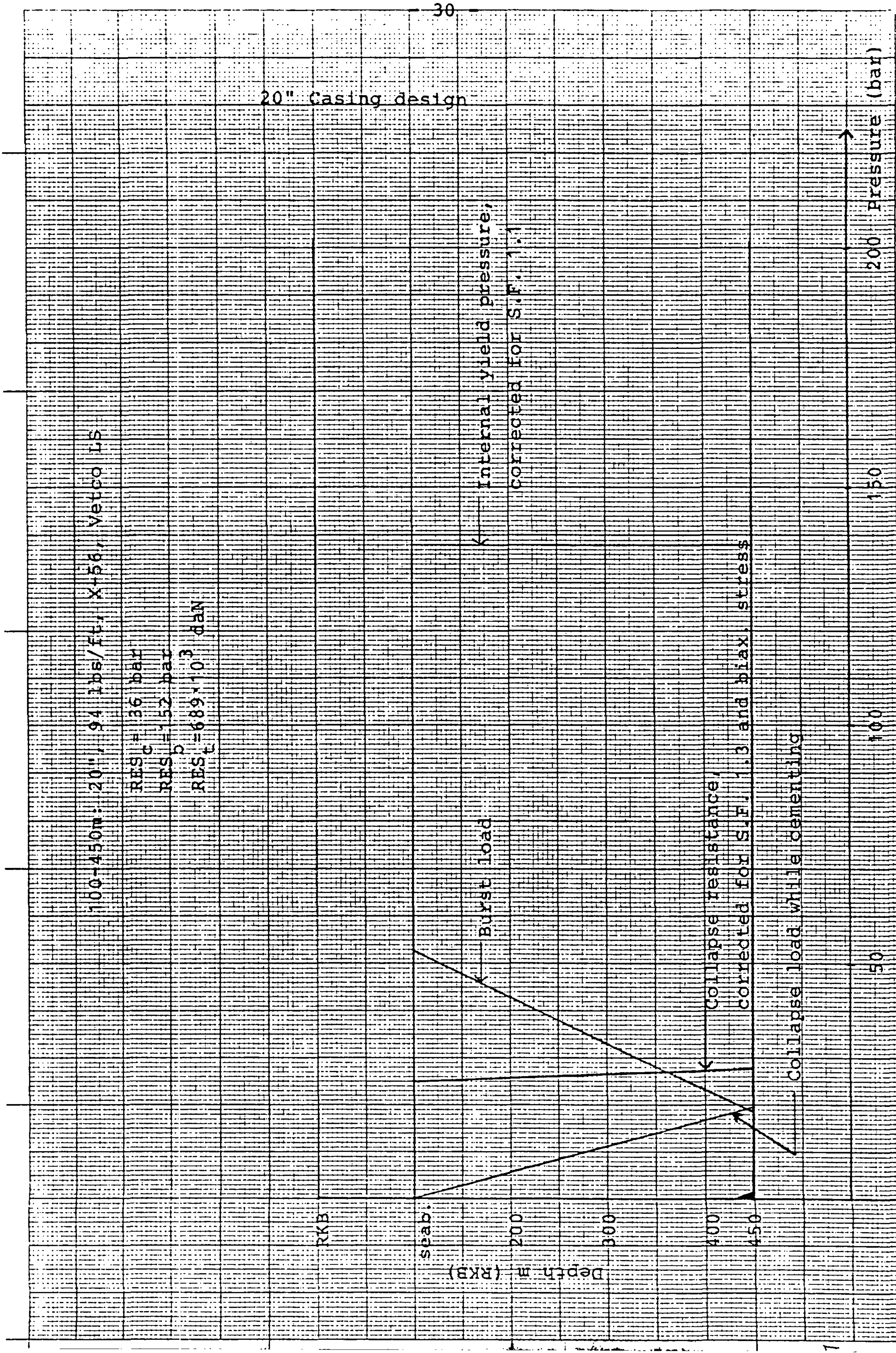
$(X - Z)\cdot M_c$ = (450-100)$\cdot$140 x 0.981 = <u>48069 daN</u>
Extra tensile load when bumping plug:

$$\left(\frac{800}{14.5} - 19.4\right) 0.01 \left(\frac{485.7}{2}\right)^2 \cdot \Pi\, daN = \underline{66280\ daN}$$

Total weight load:

(48069 + 66280) daN = <u>114349 daN</u>

$$\underline{S.F.}_T \frac{RES_T}{114349} = \frac{689000}{114349} = 6.0$$


20" Casing design
100-450m: 20", 94 lbs/Ft, X-56, Vetco LS
RES_c = 36 bar
RES_b = 152 bar
RES_t = 689·10^3 daN
Burst load
Internal yield pressure, corrected for S.F. 1.1
Collapse resistance, corrected for S.F. 1.3 and biax. stress
Collapse load while cementing
Pressure (bar)
50
100
150
200
RKB
seab.
200
300
400
450
Depth m (RKB)

13 3/8" csg.

W_D = 2680 m

X = 1170 m

G_i = 0.113 bar/m (1.15 g/cm^3)

G_p = 0.1 bar/m (1.03 g/cm^3)

G_f = 0.16 bar/m (1.65 g/cm^3)

G_{gas} = 0.02 bar/m

Z = 100 m

G_i1 = 0.137 bar/m (1.4 g/cm^3)

$G_{cem}1$ = 0.153 bar/m (1.56 g/cm^3)

$G_{cem}2$ = 0.186 bar/m (1.9 g/cm^3)

Design criteria

1) Entire casing filled with gas.
2) Collapse load during cementing.
3) Collapse load, lost circulation.
4) Tension load, when bumping plug.

Burst

Max burst load when testing csg:

(2500 psi test): $\frac{2500}{14.5}$ + 1170 (0.113-0.1) = 188 bar

Burst load at wellhead if the entire csg. is filled with gas:

$P_{BW} = (X \times G_f) - (X-Z) \times G_{gas} - Z \times G_p$

= (1170 x 0.162) - (1170-100) 0.02 - 100 x 0.1 = 158 bar

Min. burst load (at shoe):

1170 x G_f - 1170 x G_p = 1170 x 0.162-1170x0.1 = 73 bar

Collapse

Max. collapse while cmt. csg.:

$(X-24)\ (G_f - G_p) = (1170-24)\ (0.162 - 0.1) = \underline{71\ \text{bar}}$

Mud level if mud is lost to a pressure formation (resistance to mud flow into formation = 0.1 bar/m) at 2680 m when drilling with 1.4 s.g. mud.

$$Y = W_D - \frac{W_D \times G_p}{G_i} = 2680 - \frac{2680 \times 0.1}{0.137} = \underline{724\ \text{m}}$$

Collapse load:

$P_c = G_i \times Y = 0.113 \times 724 = \underline{82\ \text{bar}}$

Select 100-1170m: 13 3/8", 68 lb/ft, K-55, butts

$RES_c = 134$ bar

$RES_B = 238$ bar

$RES_T = 475 \times 10^3$ daN

Safety factor burst:

$$S.F._B = \frac{RES_B}{P_{BW}} = \frac{238}{158} = \underline{1.5 > 1.1}$$

Safety factor, collapse

$$S.F._c = \frac{RES_c}{P_c} = \frac{134}{82} = 1.63 > 1.30$$

Tension

Weight laod in air (csg. used as running string):

$X \times M_c\ 0.981 = 1170 \times 98.47 \times 0.981 = \underline{113 \times 10^3\ \text{daN}}$

csg. inside diameter: 315.3 mm

Differential pressure at shoe due to cmt. column:
(displaced by s.w.)

$(G_{cem}1 - G_i)\ 615\ m + (G_{cem}2 - G_1)\ (205-25) =$

$(0.153-0.1)\ 615 + (0.186-0.1)\ 180 = \underline{48\ bar}$

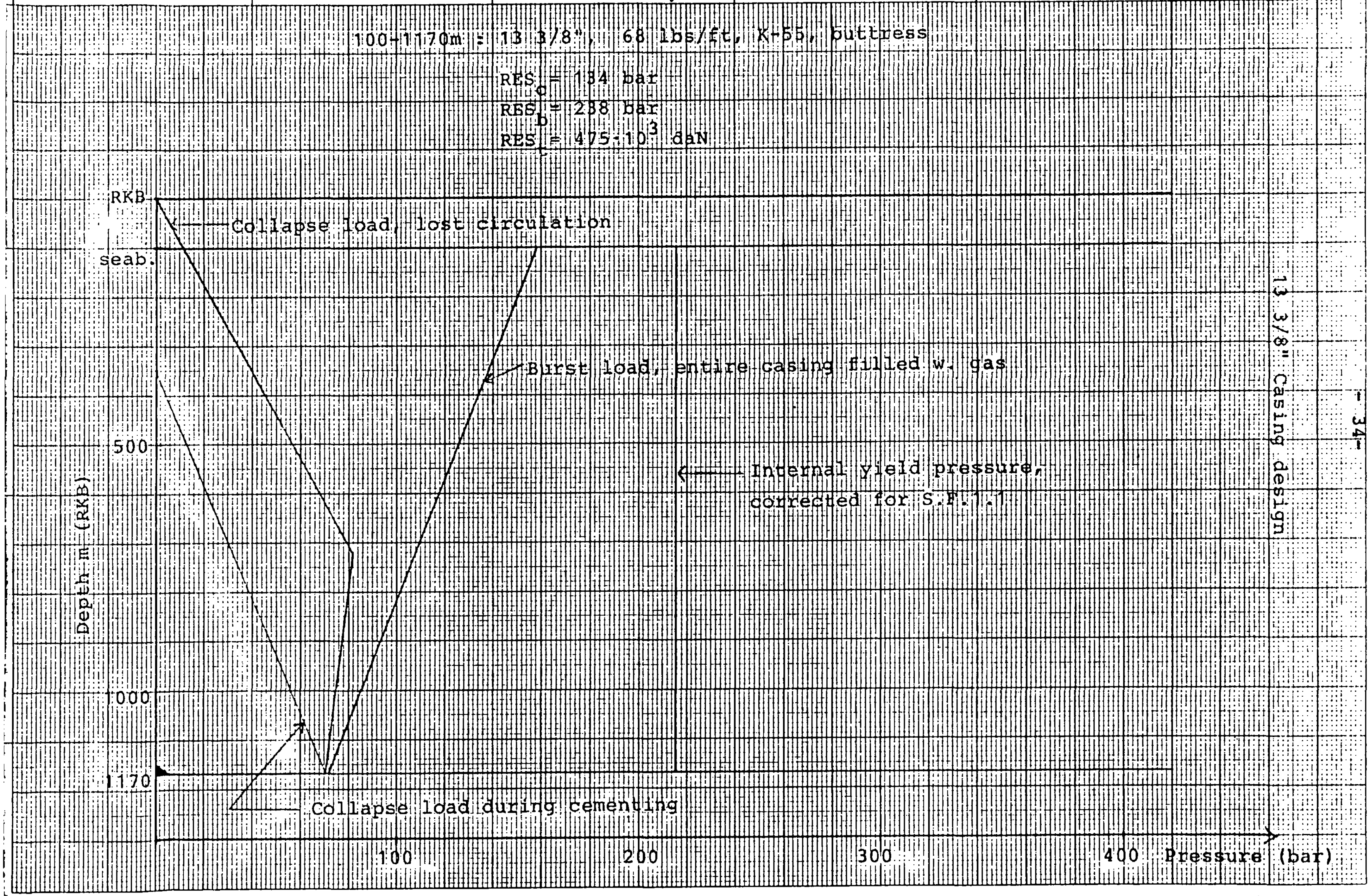
Extra tensile load when bumping plug:

$(\frac{2500}{14.5} - 48) \times 0.01\ (\frac{315.3}{2})^2\ \Pi\ daN = 97150\ daN$

Total weight load = $(113 + 97.15) \times 10^3\ daN = \underline{210.15 \times 10^3\ daN}$

$S.F._T = \frac{RES_T}{210.15x10^3} = \frac{475}{210.15} = 2.26 > 1.5$

13 3/8" Casing design



9 5/8" Casing

W_D = 2800 m

X = 2665 m

G_i = 0.137 bar/m (1.4 g/cm^3)

G'_i = 0.137 bar/m (1,4 g/cm^3)

G_p = 0,1 bar/m (1.03 g/cm^3)

G'p = 0.116 bar/m (1.18 g/cm^3) at 2800 m

G''_p = 0.124 bar/m (1.27 g/cm^3) at 2665 m

G_f = o.178 bar/m (1.82 g/cm^3)

G_{gas} = 0.023 bar/m (p = 405 bar,T = 60°C, δ = 0.6)

G_{cem} = 0.186 bar/m (1.9 g/cm^3)

Design criteria:

1) Entire casing filled with gas
2) Tubing leak while testing
3) Collapse load, lost circulation
4) Weight load of casing when bumping plug at 2500 psi.

Burst

Burst load at wellhead if there is a tubing leak just below the wellhead while testing at 2800 m:

$P_B = G'_P \times 2800 - G_{gas} \times 2800 - Z) - X \times G_p =$

0.116 x 2800 - 0,023 (2800-100) - (100 x 0,1) = 253 bar

Burst load at 2545 m if there is a tubing leak:

(253 +(2545-100) x (o,132 - 0,1) bar = 331 bar

Burst load at wellhead if the entire casing is filled with gas:

$x \quad G''_p - (x-z) \times G_{gas} - (z-25) \times 0,1 =$

(2665 x o,124 - (2665-100) x 0,023) bar = 271 bar

Max burst load while testing casing (test pressure 4800 psi)

$$\frac{4800}{14.5} + (Gi - G_p) \times X = \frac{4800}{14.5} + (0,137 - 0,1) \times 2665 \text{ m} = \underline{429,6 \text{ bar}}$$

Collapse

During cementing:

$P_{cl} = (G_{cem} - G_p)\ (2665 - 1070) = (0,186-0,1)\ (2665 - 1070) = 137$ bar

If mud is lost to formation at 2800 m

$$Y = W_D - \frac{W_D \times G_p}{G'i} = 2800 - \frac{2800 \times 0,1}{0,137} = 756 \text{ m}$$

Pc = Y x Gi = 756 x 0,137 = 104 bar

Min. bottom hole pressure when testing at 2800 m

$$G'p \times 2800 \text{ m} - \frac{RES_C}{1,25} = 0,116 \times 2800 - \frac{328}{1,25} = \underline{62,4 \text{ bar}}$$

Select: 100 - 2665 m, 9 5/8", N-80, 47 lb/ft, Buttress

RES_C = 328 bar

RES_B = 474 bar

RES_T = 482 x 10^3 daN

Safety factor burst:

$$S.F._B : \frac{474}{331} = \underline{1,41}$$

Tensile load at 756 m :

$0.98 \times (2665 - 756) \times 70$ daN $= 131 \times 10^3$ daN

Corrected RES_c = 275 bar

1) $S.F._{c_1} = \frac{RES_c}{P_c} = \frac{275}{104} = 2.64 > 1.25$

2) $S.F._{c_2} = \frac{RES_c}{P_c} = \frac{328}{137} = 2.39 > 1.25$

<u>Tension</u>

Weight load in air (casing used as running string) :

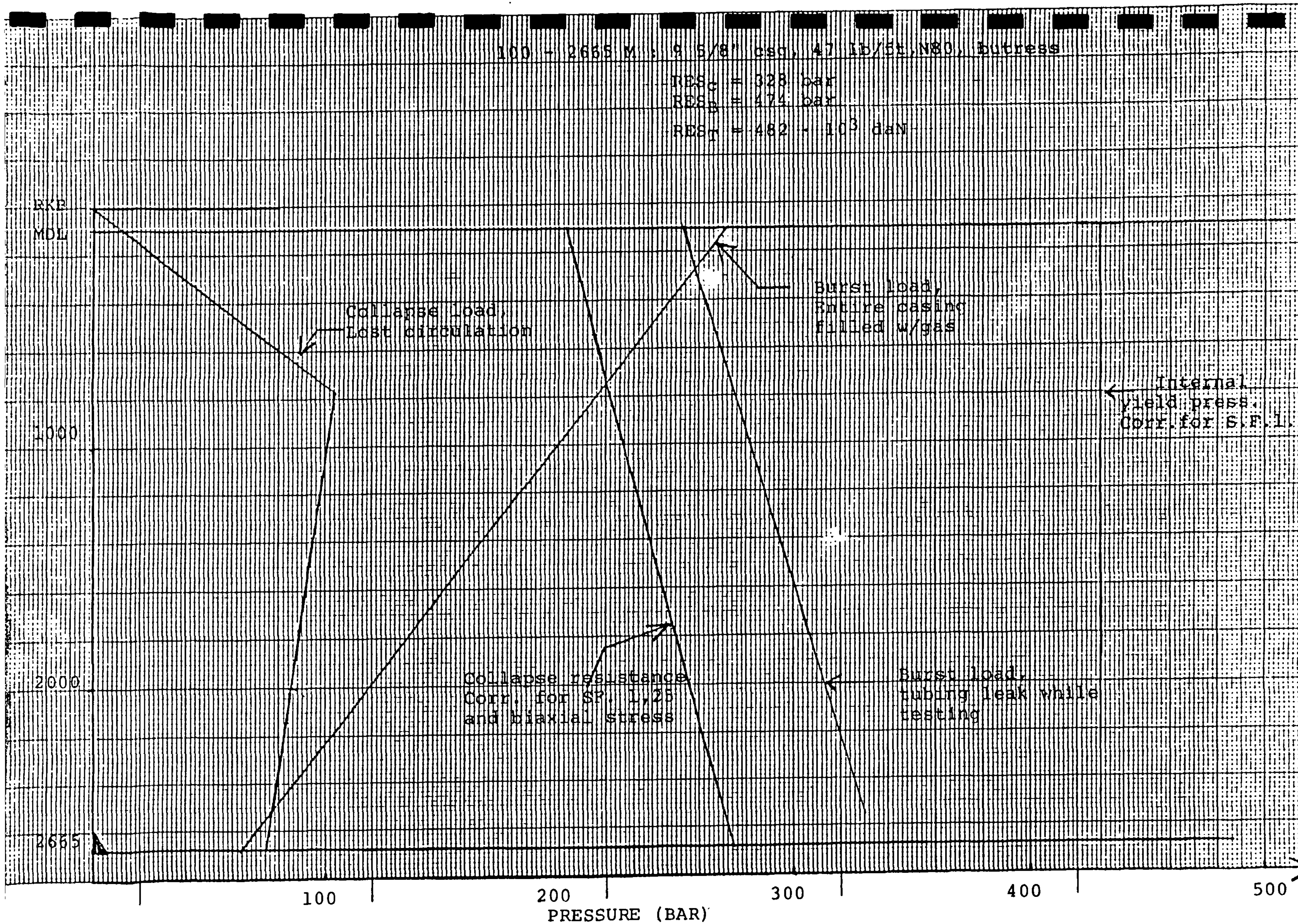
$2665 \times 70 \times 1.9807$ daN $= 182.9 \times 10^3$ daN

Casing inside diameter = 220.5 mm

Extra tensile load when bumping plug at 2500 psi (neglecting buoyancy of steel) :

$$\left(\frac{2500}{14.5} - 137\right) \times 0.01 \times \left(\frac{220.5}{2}\right)^2 \pi \text{ daN} = \underline{196.4 \times 10^3 \text{ daN}}$$

$$SF_T = \frac{RES_T}{198,7 \times 10^3 \text{ daN}} = \frac{482}{196.4} = 2,45$$


100 - 2665 M : 9 5/8' csg, 47 lb/ft, N80, butress
RES_C = 328 bar
RES_B = 474 bar
RES_T = 482 · 10^3 daN
RKB
MDL
1000
2000
2665
Collapse load,
Lost circulation
Burst load,
Entire casing
filled w/gas
Internal
yield press.
Corr. for S.F.1.1
Collapse resistance
Corr. for SF. 1,25
and biaxial stress
Burst load,
tubing leak while
testing
100
200
300
400
500
PRESSURE (BAR)

7" liner

W_D = 2800 m

X = 2800 m

G_i = 0.137 bar/m (1.4 g/cm^3)

G_p = 0.1 bar/m (1.03 g/cm^3)

G_p1 = 0.116 bar/m (1.18 g/cm^3)

G_{gas} = 0.023 bar/m

Z = 100 m

G_{cem} = 0.186 bar/m (1.9 g/cm^3)

Design criteria:

1) Tubing leak while testing
2) Collapse load while testing
3) Weight of liner when bumping plug at 2500 psi

Burst at 2600 m, testing at 2800 m:

$P_B = G_p1 \times 2800 - G_{gas} \times (2800-100) + (2600-100) \times (G_i-0.1)$

$= 0.116 \times 2800 - 0.023 \times (2800-100) + (2600-100) \times (0.137-0.1)$

= 355 bar

2545 - 2800 m : 7", 29 lb/ft, N-80 butts.

RES_c = 484 bar

RES_b = 563 bar

RES_T = 300 x 10^3 daN

$S.F._B = \frac{RES}{355} B = \frac{563}{355} = \underline{1.58 > 1.1}$

Collapse:

$P_c = (G_{cem} - G_i) \times (2800-2545)$

$= (0.186 - 0.137) \times 255 = \underline{12.5 \text{ bar}}$

Minimum flowing bottom hole pressure when testing at 2800 m:

$P_{WF} \text{ min.} = (2800 \times G_p1) - \frac{RESc}{1.25}$

P_{WF} min. = $(2800 \times 0.116) - \frac{484}{1.25}$ = <u>0 bar</u>

<u>Tension</u>

Weight load in air: (2800-2545) x 42.74 x 0.981 daN=10681 daN

Casing I.D. = 157.1mm

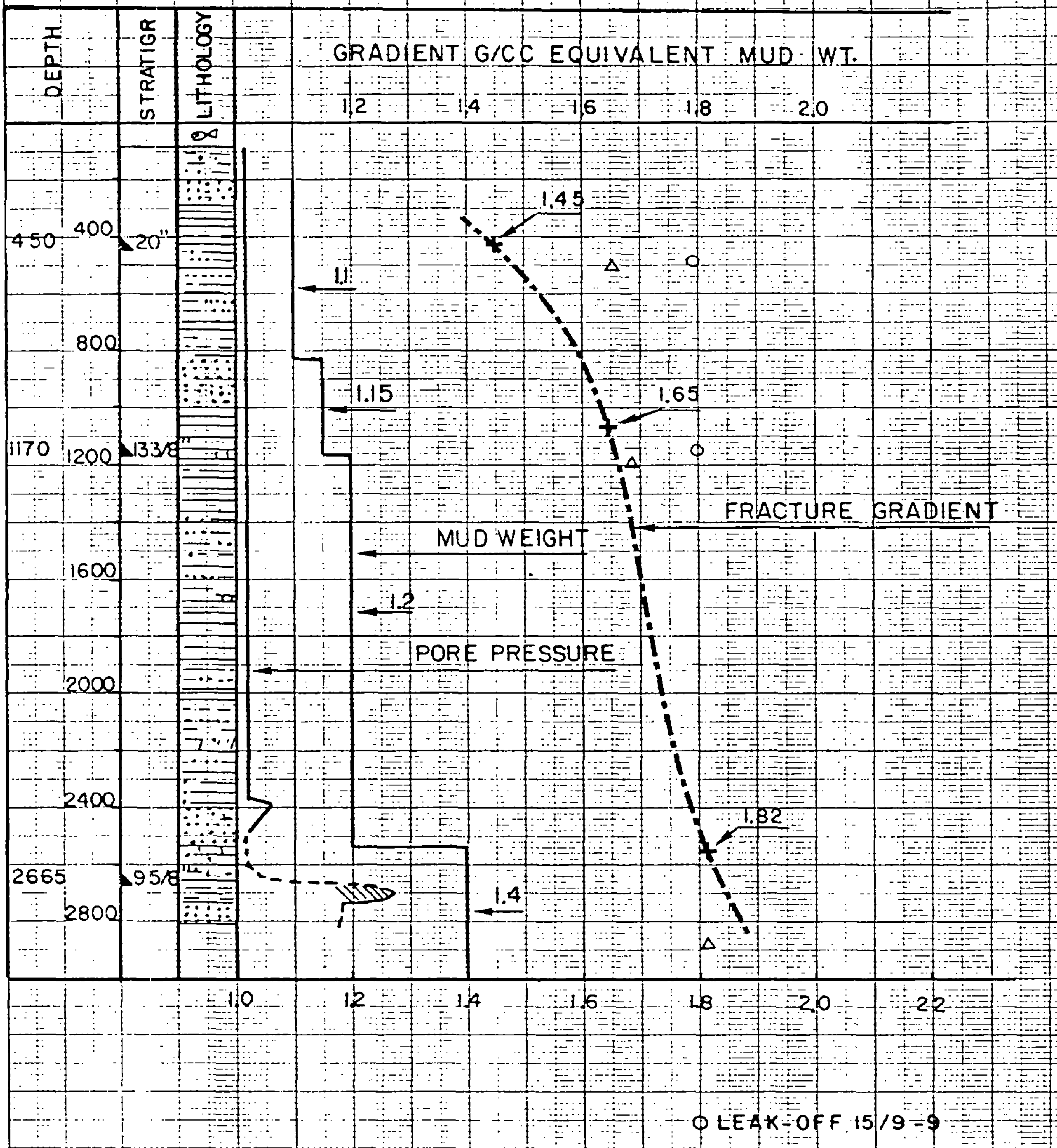
Exstra tensile load when bumping plug:

$$\left(\frac{2500}{14.5} - 12.5\right) \times 0.01 \times \left(\frac{157.1}{2}\right)^2 \times 3.14 \text{ daN} = 31.10^3 \text{ daN}$$

Total tensile load = $(10.7 + 31)\ 10^3$ daN = 41.7×10^3 daN

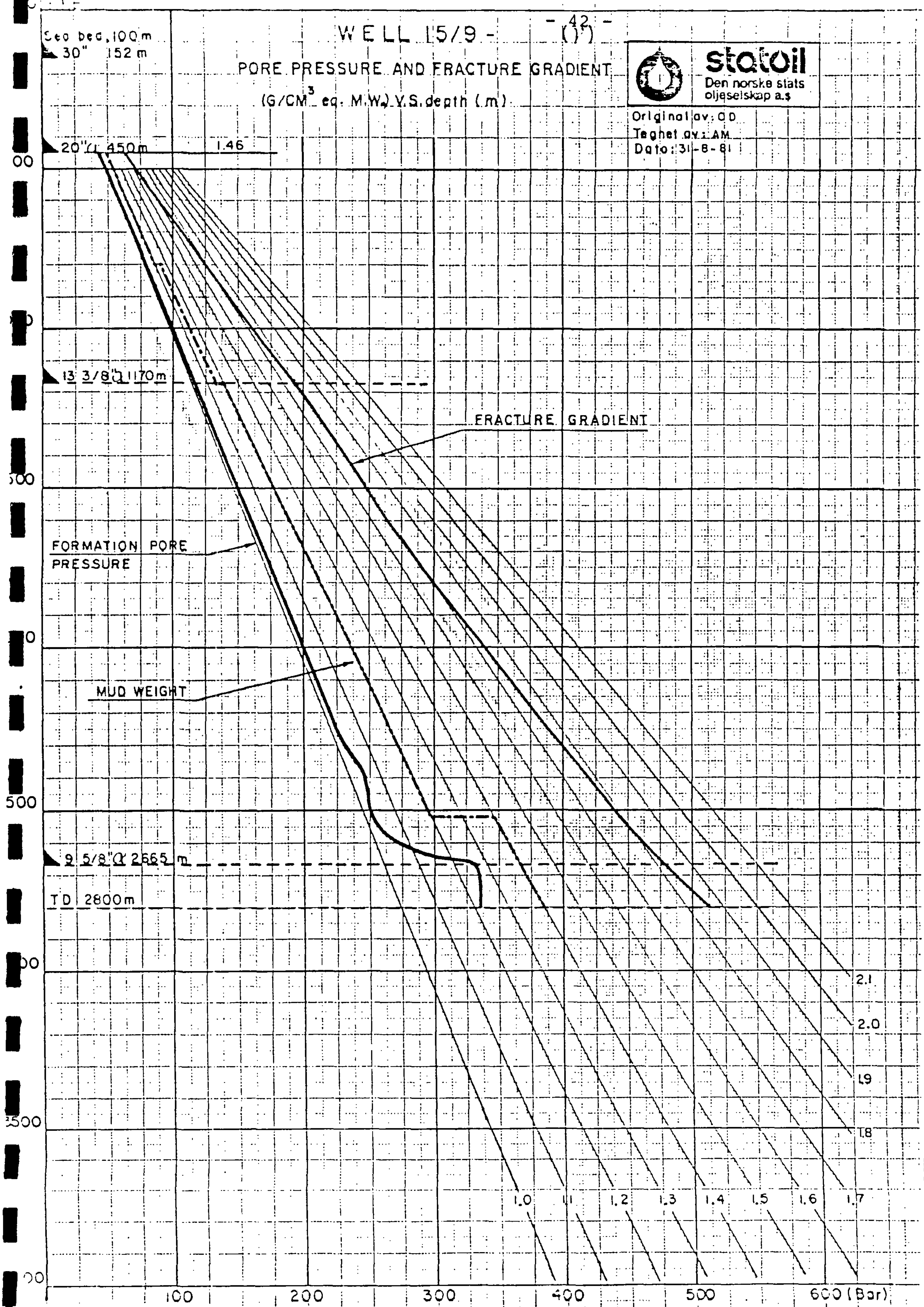
$$SF_T = \frac{RES_t}{41.7 \times 10^3 \text{daN}} = \frac{300 \times 10^3}{41.7 \times 10^3} = 7.19$$

15/9-10 PRESSURE PREDICTION



statoil
Den norske stats oljeselskap a.s

ORIGINAL AV: DD
TEGNET AV: AM
DATO: 31-8-81


WELL 15/9 - ( )
PORE PRESSURE AND FRACTURE GRADIENT
(G/CM3 eq. M.W.) V.S. depth (m)
statoil
Den norske stats oljeselskap a.s
Original av: OD
Teghet av: AM
Dato: 31-8-81
Sea bed, 100 m
30" 152 m
20" @ 450 m
1.46
13 3/8" @ 1170 m
9 5/8" @ 2665 m
TD 2800m
FRACTURE GRADIENT
FORMATION PORE PRESSURE
MUD WEIGHT
500
2.1
2.0
1.9
1.8
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
100
200
300
400
500
600 (Bar)

30" CASING CEMENT DATA AND CALCULATIONS, 15/9-γ

GENERAL: The cement volume is calculated on the basis of the theoretical hole volume, and the casing to be cemented to sea bed with 150% excess volume in open hole.

WELL DATA:

Depth kb-sea bed..............................:	100	m
Depth kb-last shoe............................:	-	m
Depth kb-casing set point.....................:	152	m
Open hole dia.................................:	36	"
Annulus capacity, cased hole..................:	-	l/m
Annulus capacity, open hole...................:	200	l/m
Internal capacity, 30" casing. 1,0" thickness.:	397,0	l/m
Mud weight....................................:	1.05	g/cm^3
Bottom hole hydrostatic pres. (BHHP)..........:	-	bar
Est. bottom hole static temp. (BHST)..........:	27	^oC
Est. bottom hole circulating temp. (BHCT)....:	27	^oC
Est. formation integrity......................:	-	bar/m

	FILLER/LEAD SLURRY	TAIL IN SLURRY
CEMENT SLURRY COMPOSITION	CLASS G - cement + 3,2 l D-75/100 kg cement	CLASS G - cement + 1 % $CaCl_2$ (By w.t. of cement)
Mix water 1/100 kg	93 sea	44,4 sea
Total liquid 1/100 kg	96,2	44,4
Slurry weight g/cm^3	1,56	1,91
Slurry yield 1/100 kg	128	76,2
TEST DATA @ BHCT		
Thickening time @ BHHP, hr:min	6:20	4:20
Crit. Turb. Flow rate: m/s (l/min)		
Fluid loss, ml/30 min, 70 bar		
TEST DATA @ BHST, BHHP		
Compr. strength, bar hr		
bar 24 hr	41	172
REMARKS:		
Pumpability: hr:min	5:10	2:50

Volume calculation (30" casing):

Annular volume: $0,200\ m^3/m \times (152-100)\ m$	=	$10,4\ m^3$
3 m plug at shoe: $0,397\ m^3/m \times 3\ m$	=	$1,2\ m^3$
Total volume	=	$11,6\ m^3$
150% excess in open hole:	=	$15,6\ m^3$
Total slurry volume:		$27,2\ m^3$

Lead slurry: Class G cement + 3,2 l D-75/100 kg cement mixed with seawater at 1,56 1,56 kg/liter. 13600 kg cement equivalent to 17,3 m^3 slurry.

Tail in slurry: Class G cement + 1% $CaCl_2$ (By w.t.of cement) mixed with seawater at 1,91 kg/ liter. 13000 kg cement equivalent to 9,9 m^3 slurry.

Job preparation:

Total liquid lead slurry: 13600 kg x 96,2 l/100 kg = 13083 liter

Volume D-75 needed in each 10 bbls (1,59 m^3) displacement tank:

$$\frac{1590\ l \times 3,2\ l/100\ kg}{96,2\ l/100\ kg} = 53\ \text{liter}$$

Total volume of D-75: 13600 kg x 3,2 l/100 kg = 435 liter

Total liquid for tail in slurry: 13000 kg x 44,6 l/100 kg = 5798 lit[illegible]

Amount of $CaCl_2$ needed: 13000 kg x 0,01 = 130 kg

20" CASING CEMENT DATA AND CALCULATIONS,15/9-10

GENERAL: The cement volume is calculated at the basis of the theoretical annulus volume and the casing to be cemented to the sea bed with 100% excess volume in open hole.

WELL DATA:

Depth kb-sea bed..............................:	100	m
Depth kb-last shoe............................:	152	m
Depth kb-casing set point.....................:	450	m
Open hole dia.................................:	26	"
Annulus capacity, cased hole..................:	194.0	l/m
Annulus capacity, open hole...................:	139.4	l/m
Internal capacity, " casing...................:	185.3	l/m
Mud weight....................................:	1.05	g/cm^3
Bottom hole hydrostatic pres. (BHHP)..........:	46	bar
Est. bottom hole static temp. (BHST)..........:	35	°C
Est. bottom hole circulating temp. (BHCT)....:	29	°C
Est. formation integrity......................:	0.138	bar/m

	FILLER/LEAD SLURRY	TAIL IN SLURRY
CEMENT SLURRY COMPOSITION	CLASS + 3.20L D-75/100 kg cement	CLASS G-cement neat
Mix water 1/100 kg	93.04 sea	44.0 sea
Total liquid 1/100 kg	96.24	44.0
Slurry weight g/cm^3	1.56	1.91
Slurry yield 1/100 kg	128.00	75.8
TEST DATA @ BHCT		
Thickening time@ BHHP, hr:min	6:01	4:00
Crit. Turb.Flow rate: m/s (l/min)		
Fluid loss, ml/30 min, 70 bar		
TEST DATA @ BHST, BHHP		
Compr. strength, bar hr		
bar 24 hr	47	273 319
REMARKS:		
Fann VG Readings 600/300/200/100		129/88/72/56

Volume calculations (20" casing):

Annular volume : 0.1394 m^3/m x (450 - 152)m	= 41.5 m^3
Volume between csg's : 0.194 m^3/m x (152-100)m	= 10.1 m^3
12 m plug at shoe : 0.1853 m^3/m x 12	= 2.2 m^3
100% excess on open hole :	= 41.5 m^3
Total volume	= 95.3 m^3

Lead slurry : Class G-cement + 3.2 l/100 kg D-75 mixed with seawater at 1.56 kg/c

70500 kg cement equivalent to 90.3 m^3 slurry

Tail-in slurry : Class G-cement mixed with seawater at 1.91 kg/l

6600 kg equivalent to 5.0 m^3 slurry

Job preparation

Total liquid lead slurry : 70500 kg x 96.24 l/100 kg = 67850 l

Volume of D-75 needed in each mixing tank

$$1590 \text{ l} \times \frac{3.20 \text{ l/100 kg}}{96.24 \text{ l/100 kg}} = \underline{52.9 \text{ l}}$$

Total volume of D-75 needed : 70500 kg x 3.2 l/100 kg = 2256 l

Total liquid tail-in slurry : 6600 kg x 44.0 l/100 kg = 2904 l

Hydrostatic pressure at 20" csg shoe

Height of tail-in slurry : $(5.0-2.2)\ m^3/0.1394\ m^3/m$ = 20 m

Hydrostatic head of lead slurry :
0.153 bar/m x (450 - 100-20) m = 50.5 bar
Hydrostatic head of tail-in slurry:
0.187 bar/m x 20 m = 3.7 bar

Hydrostatic head of sea-water :
0.101 bar/m x (100-5) m = 7.6 bar

Total hydrostatic pressure = 61.8 bar

Equivalent pressure gradient at 20" shoe :

$$\frac{61.8\ bar}{450\ m} = 0.137\ \frac{bar}{m}$$

Estimated formation integrity: 0.138 bar

13 3/8" CASING CEMENT DATA AND CALCULATIONS, 15/9

GENERAL: The cement volume is calculated on the basis of the theoretical annulus volume and the casing to be cemented 100 m into the 20" casing.

WELL DATA:

Depth kb-sea bed.............................:	100	m
Depth kb-last shoe...........................:	450	m
Depth kb-casing set point....................:	1170	m
Open hole dia................................:	17½	"
Annulus capacity, cased hole.................:	94.5	l/m
Annulus capacity, open hole..................:	64.4	l/m
Internal capacity, 13 3/8"casing..69.lbs/ft......:	78.1	l/m
Mud weight...................................:	1.15	g/cm^3
Bottom hole hydrostatic pres. (BHHP).........:	132	bar
Est. bottom hole static temp. (BHST).........:	45	°C
Est. bottom hole circulating temp. (BHCT)....:	36	°C
Est. formation integrity.....................:	0.165	bar/m

	FILLER/LEAD SLURRY	TAIL IN SLURRY
CEMENT SLURRY COMPOSITION	CLASS "G" cement + 3.2 l/100 kg D75 + 1.33 l/100 kg D80 + 0.90 l/100 kg D81	CLASS "G"cement
Mix water l/100 kg	91.7 sea	44.0 fresh
Total liquid l/100 kg	97.2	44.0
Slurry weight g/cm^3	1.56	1.90
Slurry yield l/100 kg	128.8	75.60
TEST DATA @ BHCT		
Thickening time@ BHHP, hr:min	5:50	3:50
Crit. Turb.Flow rate: m/s (l/min)		
Fluid loss, ml/30 min, 70 bar		
TEST DATA @ BHST, BHHP		
Compr. strength, bar 24 hr	41	124
bar hr		
REMARKS:		
Fann VG - readings	19/10/8/6/3/3 10 sec Gel:7 10 min Gel: 18	

Volume calculations: (13 3/8" casing)

Annular volume: 0.0644 m³/m x (1170 - 450)m	=	46.4	m^3
Volume between casings: 0.0945 m³/m x 100 m	=	9.5	m^3
24 m plug inside casing: 0.0781 m³/m x 24 m	=	1.9	m^3
Total cement slurry volume	=	57.8	m^3

Lead slurry: Class G-cement + 3.2 L/100 kg D-75 + 1.33 L/100 kg D-80 + 0.90 L/100 kg D-81 mixed with seawater at 1.56 kg/L

37000 kg cement equivalent to 47.9 m^3 slurry.

Tail-in slurry: Class G-cement mixed with fresh water at 1.90 kg/L.

13000 kg cement equivalent to 9.9 m^3 slurry.

NOTE: These calculations are based on gauge hole and cement volumes must be recalculated after caliper logs are ran to give top of lead slurry at approximately 350 m, and top of tail-in slurry at approximately 1050 m.

Remarks: Use fresh water mud as preflush/spacer.
The fresh water mud should consist of:
Caustic soda mixed with fresh water to give a pH of 11.0.
Add 15 - 20 ppb bentonite to give a viscous slurry, and barite to give a weight of 1.30 g/cc. No lignosalfonate must be added to the slurry.

Recommended volume : 6.4 m^3

Job preparation:

Total liquid lead slurry: ....37000.... kg x ....97.2........ 1/100 kg = 35964 l

Volume of ......D-75.......... needed in each mixing tank:

$$1590\ \text{l} \times \frac{3.20\ \ \text{l/100 kg}}{97.2\ \ \text{l/100 kg}} = 52.3\ \text{l}$$

Volume of ......D-80.......... needed in each mixing tank:

$$1590\ \text{l} \times \frac{1.33\ \ \text{l/100 kg}}{97.2\ \ \text{l/100 kg}} = 21.8\ \text{l}$$

Volume of ......D-81.......... needed in each mixing tank:

$$1590\ \text{l} \times \frac{0.90\ \ \text{l/100 kg}}{97.2\ \ \text{l/100 kg}} = 14.7\ \text{l}$$

Total liquid tail-in slurry: ......13000...... kg x ......44.0...... 1/100 kg = 5720 l

Total volume of ....D-75........................ needed: = 1184 l

Total volume of ....D-80........................ needed: = 492 l

Total volume of ....D-81........................ needed: = 333 l

Hydrostatic pressure calculations:

Height of mud:	= 282 m
Height of spacer/preflush:	= 68 m
Height of lead slurry:	= 696 m
Height of tail-in slurry:	= 124 m

Hydrostatic head from spacer/preflush: 0.127 bar/m x 68 m	= 8.6 bar
Hydrostatic head from mud: 0.113 bar/m x 282 m	= 31.9 bar
Hydrostatic head from lead slurry: 0.153 bar/m x 696 m	= 106.5 bar
Hydrostatic head from tail-in slurry: 0.186 bar/m x 124 m	= 23.1 bar
Total hydrostatic head at 13 3/8" shoe	= 170.1 bar

Equivalent pressure gradient at 13 3/8" shoe: $\frac{170.1 \text{ bar}}{1170 \text{ m}}$ = 0.145 bar/m

Estimated formation integrity at 13 3/8" shoe = 0.165 bar/m

Hydrostatic head at 20" casing shoe:

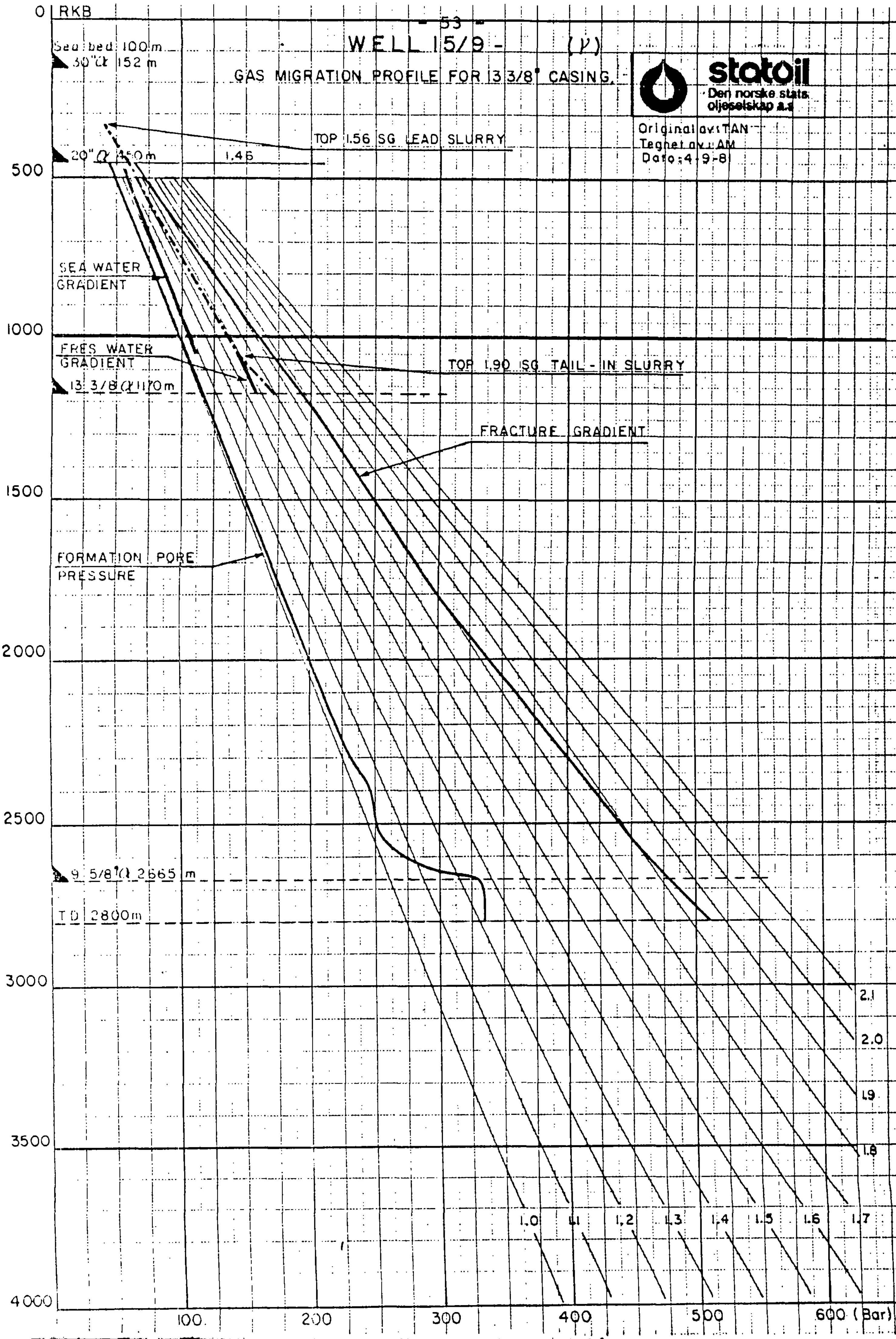
(8.6 + 31.9) bar + 0.153 bar/m x 100 m = 55.8 bar

Equivalent pressure gradient at 20" shoe: $\frac{55.8 \text{ bar}}{450 \text{ m}}$ = 0.124 bar/m

Estimated formation integrity at 20" shoe = 0.138 bar/m

Gas migration calculations (see graph)

Top cement:	= 350	m
Hydrostatic head at top of tail-in slurry: (8.6 + 31.9 + 106.5) bar	= 147.0	bar
Hydrostatic head of tail in slurry's mix water: 0.098 bar/m x 124 'm	= 12.2	bar
Hydrostatic head at 13 3/8" shoe as tail-in slurry sets	= 159.2	
Estimated pore pressure at 13 3/8" shoe	= 117	bar
Hydrostatic head at top of lead-slurry: (8.6 + 31.9) bar	= 40.6	bar
Hydrostatic head of lead slurry's mix water: 0.101 bar/m x 696 m	= 70.3	bar
Hydrostatic head at top of tail-in slurry as lead slurry sets:	= 110.9	bar
Estimated pore pressure at 1046 m	= 104	bar


WELL 15/9 - (ν)
GAS MIGRATION PROFILE FOR 13 3/8" CASING.
statoil
Den norske stats oljeselskap a.s
Original av: TAN
Tegnet av: AM
Dato: 4-9-8
0 RKB
Sea bed 100 m
30" Ct 152 m
20" Ct 450 m
TOP 1.56 SG LEAD SLURRY
1.46
SEA WATER GRADIENT
FRES WATER GRADIENT
TOP 1.90 SG TAIL - IN SLURRY
13 3/8 Ct 1170 m
FRACTURE GRADIENT
FORMATION PORE PRESSURE
9 5/8" Ct 2665 m
TD 2800m
500
1000
1500
2000
2500
3000
3500
4000
100
200
300
400
500
600 (Bar)
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1

9 5/8" CASING CEMENT DATA AND CALCULATIONS, 15/9

GENERAL: The cement volume calculations is based on the theoretical hole volume and the casing should be cemented 100 m into the 13 3/8" casing.

WELL DATA:

Depth kb-sea bed.............................:	100	m
Depth kb-last shoe...........................:	1170	m
Depth kb-casing set point....................:	2665	m
Open hole dia................................:	12 1/4"	
Annulus capacity, cased hole.................:	31.0	l/m
Annulus capacity, open hole..................:	28.9	l/m
Internal capacity, 9 5/8" casing 47.0 lbs/ft.....:	38.2	l/m
Mud weight...................................:	1.40	g/cm^3
Bottom hole hydrostatic pres. (BHHP).........:	366	bar
Est. bottom hole static temp. (BHST).........:	86	°C
Est. bottom hole circulating temp. (BHCT)...:	59	°C
Est. formation integrity.....................:	0.179	bar/m

		FILLER/LEAD SLURRY	TAIL IN SLURRY
CEMENT SLURRY COMPOSITION		CLASS G-cement + 0.89 l D - 80/100 kg + 1.78 l D-73/100 kg + 0.36 l D-81/100 kg	CLASS G-cement + 0.89 l D - 80/100 kg + 1.78 l D-73/100 kg + 0.27 l D-81/100 kg
Mix water	l/100 kg	41.7 fresh	41.7 fresh
Total liquid	l/100 kg	44.7	44.6
Slurry weight	g/cm^3	1.90	1.90
Slurry yield	l/100 kg	76.3	76.3
TEST DATA @ BHCT			
Thickening time @ BHHP, hr:min		5:20	3:55
Crit. Turb. Flow rate: m/s (l/min)		1400	1400
Fluid loss, ml/30 min, 70 bar		141	137
TEST DATA @ BHST, BHHP			
Compr. strength,	bar hr		
	bar 24 hr	172	207
REMARKS:			
K/N		8.218.10 -4/0.968	8.218.10 -4/0.968
N_{RE} turb/plug		3000/300	3000/300
Fann VG-readings		68/34/23/12	67/34/23/12

Volume calculations: (...9...5/8" casing)

Annular volume: 0.0289 m^3/m x (2665 - 1170)m	=	43.2	m^3
Volume between casings: 0.031 m^3/m x 100 m	=	3.1	m^3
24 m plug inside casing: 0.0382 m^3/m x 24 m	=	0.9	m^3
Total cement slurry volume	=	47.2	m^3

Lead slurry: Class G-cement + 0.89 L/100 kg D-80
+ 1.78 L/100 kg D-73 + 0.36 L/100 kg D-81
mixed with fresh water at 1.90 kg/L.

43000 kg cement equivalent to 329 m^3 slurry.

Tail-in slurry: Class G-cement + 0.89 L/100 kg D-80
+ 1.78 L/100 kg D-73 + 027 L/100 kg D-81
mixed with fresh water at 1.90 kg/L.

18700 kg cement equivalent to 14.3 m^3 slurry.

NOTE: These calculations are based on gauge hole and cement volumes must be recalculated after caliper logs are ran to give top of lead slurry at approximately 1070 m, and top of tail-in slurry at approximately 2200 m.

Remarks: Pump 2.4 m^3 of cw100 as preflush ahead of lead slurry

Job preparation:

Total liquid lead slurry: 43000 kg x 44.7 1/100 kg = 19221 l

Volume of D-80 needed in each mixing tank:

$$1590\,l \times \frac{0.89\ \ l/100\,kg}{44.7\ \ l/100\,kg} = 31.7\ l$$

Volume of D-73 needed in each mixing tank:

$$1590\,l \times \frac{1.78\ \ l/100\,kg}{44.7\ \ l/100\,kg} = 63.3\ l$$

Volume of D-81 needed in each mixing tank:

$$1590\,l \times \frac{0.36\ \ l/100\,kg}{44.7\ \ l/100\,kg} = 12.8\ l$$

Total liquid tail-in slurry: 18700 kg x 44.6 1/100 kg = 8340 l

Volume of D-80 needed in each mixing tank:

$$1590\,l \times \frac{0.89\ \ l/100\,kg}{44.6\ \ l/100\,kg} = 31.7\ l$$

Volume of D-73 needed in each mixing tank:

$$1590\,l \times \frac{1.78\ \ l/100\,kg}{44.6\ \ l/100\,kg} = 63.5\ l$$

Volume of D-81 needed in each mixing tank:

$$1590\,l \times \frac{0.27\ \ l/100\,kg}{44.6\ \ l/100\,kg} = 9.6\ l$$

Total volume of D-80 needed: = 550 l

Total volume of D-73 needed: =1100 l

Total volume of D-81 needed: = 205 l

Hydrostatic pressure calculations:

Height of mud:	=	993 m
Height of spacer/preflush:	=	77 m
Height of lead slurry:	=	1130 m
Height of tail-in slurry:	=	465 m

Hydrostatic head from spacer/preflush: 0.098 bar/m x 77 m	=	7.5 bar
Hydrostatic head from mud: 0.137 bar/m x 993 m	=	136.0 bar
Hydrostatic head from lead slurry: 0.186 bar/m x 1130 m	=	210.2 bar
Hydrostatic head from tail-in slurry: 0.186 bar/m x 465 m	=	86.05 bar
Total hydrostatic head at 9 5/8" shoe	=	440.2 bar

Equivalent pressure gradient at 9 5/8" shoe: $\frac{440.2 \text{ bar}}{2665 \text{ m}}$ = 0.165 bar/m

Estimated formation integrity at 9 5/8" shoe = 0.179 bar/m

Hydrostatic head at 13 3/8" shoe:

(7.5 + 136.0) bar + 0.186 bar/mt 100 m = 162.1 bar

Equivalent pressure gradient at 13 3/8" shoe: $\frac{162.1 \text{ bar}}{1170 \text{ m}}$ = 0.139 bar/m

Estimated formation integrity at 13 3/8" shoe = 0.165 bar/m

Gas migration calculations (see graph)

Top cement: = 1070 m

Hydrostatic head at top of tail-in slurry:
(7.5 + 136.0 + 210.2) bar .... = 353.7 bar

Hydrostatic head of tail in slurry's mix water:
0.098 bar/m x 465 m .... = 45.6 bar

Hydrostatic head at 13 3/8" shoe as tail-in slurry sets = 399.3 bar

Estimated pore pressure at 13 3/8" shoe = 330 bar

Hydrostatic head at top of lead-slurry:
(7.5 + 136.0) bar .... = 143.5 bar

Hydrostatic head of lead slurry's mix water:
0.098 bar/m x 1130 m .... = 110.7 bar

Hydrostatic head at top of tail-in slurry as lead slurry sets: = 254.2 bar

Estimated pore pressure at 2200 m = 220 bar

Flow rate calculations

Estimated formation integrity at 9 5/8" casing shoe: = 1.83 g/cc

Situation in annulus when all cement is displaced:

40 % of annulus height is filled with mud
60 % of annulus height is filled with cement

Formula for calculating maximum allowable annular pressure drop (ECD max = 1.83 g/cc):

$$ECD\ (ppg) = (MW \times 0.4 + Cem.w \times 0.6)\ (ppg) + \frac{Pann\ (psi)}{0.052 \times Depth\ (ft)}$$

$$Pann\ (max) = [1.83 \times 8.347 - (1.40 \times 8.347 \times 0.4 + 1.90 \times 8.347 \times 0.6)] \times 0.052 \times 2665 \times 3.28$$

Pann (max) = 493 psi = 34.0 bar

Formula for determination of annular pressue losses:

$$p = \frac{7.7 \times 10^{-5} \times p^{0.8} \times Q^{1.8} \times PV^{0.2} \times L}{(D_h - D_p)^3 \times (D_h + D_p)^{1.8}}$$

P : annular pressure loss (PSI)
p : density (ppg)
Q : flow rate (GPM)
L : depth (ft)
D_h : hole diameter (in)
D_p : pipe diameter (in)

Height of cement slurry in open hole: (2665-1170)m = 1495 m

Height of mud and preflush in cased hole = 1070 m

Height of cement in cased hole = 100 m

Plastic viscosity cement = 34 cP

Pressure loss in open hole (cement):

P : 15.9 ppg

L : 4904 ft

D_h : 12 1/4"

D_p : 9 5/8"

$P_1 = 1.477 \cdot 10^{-3} \times Q^{1.8}$

Pressure loss in cased hole (cement)

P : 15.9 ppg

L : 328 ft

D_h : 12.41

D_p : 9 5/8"

$P_2 = 8.315 \cdot 10^{-5} \times Q^{1.8}$

Pressure loss in cased hole (mud) (PV = 30)

P : 11.7 ppg

L : 3510 ft

D_h : 12.41

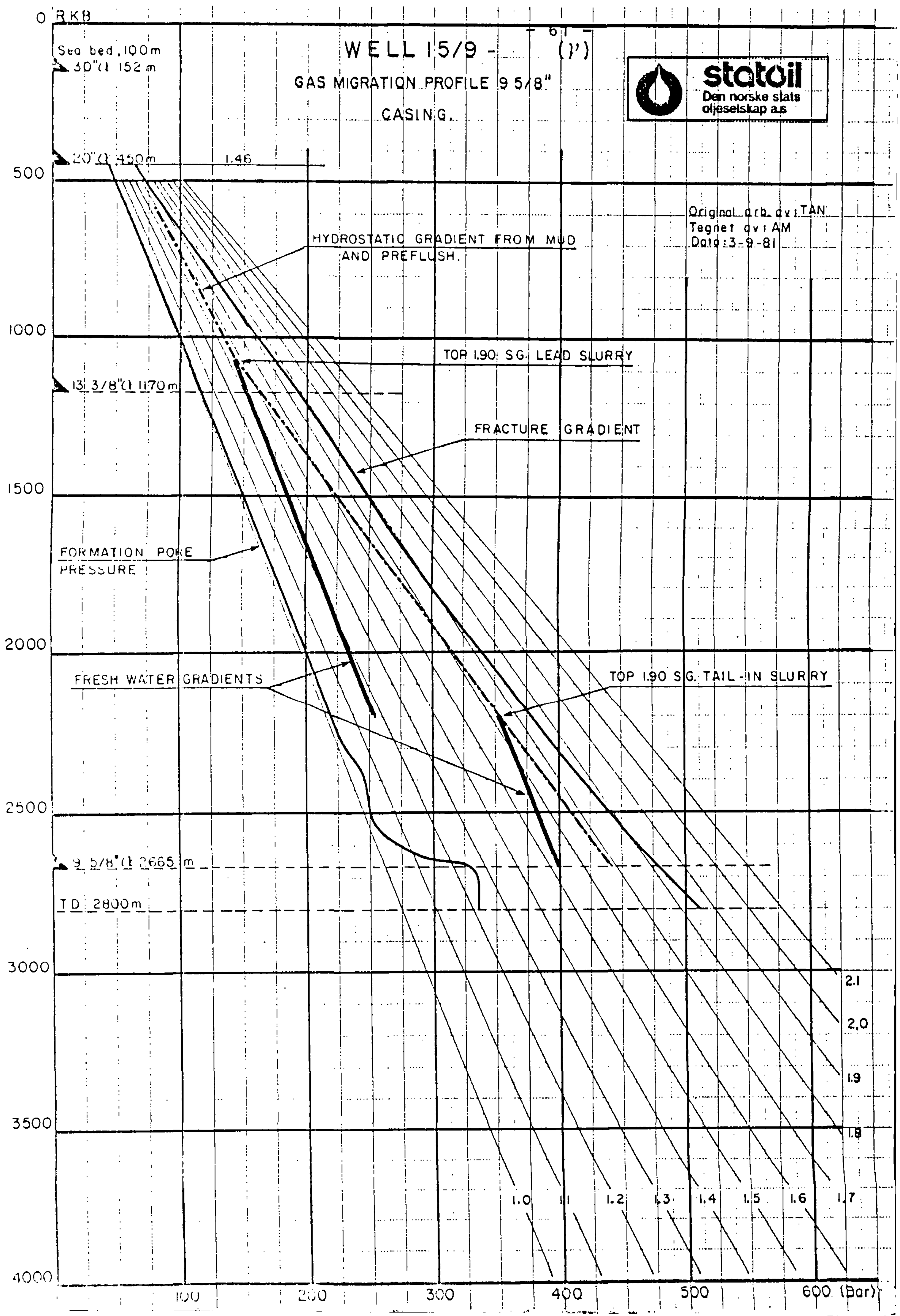
D_p : 9 5/8"

$P_3 = 6.790 \cdot 10^{-4} \times Q^{1.8}$

$(P_1 + P_2 + P_3)$ max = 493 psi

$2.239 \cdot 10^{-3} \times Q^{1.8} = 493$ psi   Qmax = 929 GPM

Qmax = 3516 l/min



WELL 15/9 - 61 - (P)
GAS MIGRATION PROFILE 9 5/8" CASING.
statoil
Den norske stats oljeselskap a.s
Original arb. av: TAN
Tegnet av: AM
Dato: 3-9-81
0 RKB
Sea bed, 100m
30" @ 152 m
20" @ 450 m
1.46
13 3/8" @ 1170 m
9 5/8" @ 2665 m
TD 2800m
HYDROSTATIC GRADIENT FROM MUD AND PREFLUSH.
TOP 1.90 SG. LEAD SLURRY
FRACTURE GRADIENT
FORMATION PORE PRESSURE
FRESH WATER GRADIENTS
TOP 1.90 SG. TAIL-IN SLURRY
500
1000
1500
2000
2500
3000
3500
4000
100
200
300
400
500
600 (Bar)
2.1
2,0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0

7" LINER CEMENT DATA AND CALCULATIONS, 15/9-

GENERAL: The cement volume calculations is based on the theoretical hole volume and the liner should be cemented 120 m into 9 5/8" casing

WELL DATA:

Depth kb-sea bed.............................:	100	m
Depth kb-last shoe...........................:	2665	m
Depth kb-casing set point....................:	2800	m
Open hole dia................................:	8½	"
Annulus capacity, cased hole.................:	13,31	l/m
Annulus capacity, open hole..................:	11,73	l/m
Internal capacity, 7" liner 29 lbs/ft........:	19,38	l/m
Mud weight...................................:	1,40	g/cm^3
Bottom hole hydrostatic pres. (BHHP).........:	384	bar
Est. bottom hole static temp. (BHST).........:	90	°C
Est. bottom hole circulating temp. (BHCT)....:	62	°C
Est. formation integrity.....................:	0,182	bar/m

	FILLER/LEAD SLURRY	TAIL IN SLURRY
CEMENT SLURRY COMPOSITION	CLASS G cement + 1,78 l D-80/100 kg + 1,78 l D-73/100 kg + 0,36 l D-81/100 kg	CLASS
Mix water l/100 kg	41,0 fresh	
Total liquid l/100 kg	44,9	
Slurry weight g/cm^3	1,90	
Slurry yield l/100 kg	76,7	
TEST DATA @ BHCT		
Thickening time @ BHHP, hr:min	5 : 20	
Crit. Turb. Flow rate: l/min	940	
Fluid loss, ml/30 min, 70 bar	44	
TEST DATA @ BHST, BHHP		
Compr. strength, bar hr		
bar hr		
REMARKS:		
Fann V G Readings	63/33/22/12	
K/n	$9{,}399 \cdot 10^{-4}$/0,9395	
NRE turb./plug	3000/300	

Volume calculations: (7" liner)

Annular volume: 0,01173 m^3/m x (2800 - 2665)m = 1,58 m^3

Volume between casings: 0,01331 m^3/m x 120 m = 1,60 m^3

24 m plug inside casing: 0,01938 m^3/m x 24 m = 0,46 m^3

Total cement slurry volume = 3,64 m^3

Lead slurry: Class G - cement + 1,78 l/100 kg D-80
+ 1,78 l/100 kg D-73 + 0,36 l/100 kg D-81
mixed with fresh water at 1,90 kg/l

4750 kg cement equivalent to 3,64 m^3 slurry.

Remarks: Pump 1,6 m^3 of CW 100 ahead of cement slurry

Job preparation:

Total liquid lead slurry 4750 .... kg x ....44,9.......... l/100 kg = 2130 l

Volume of ......D-80........ needed in each mixing tank:

$$1590\,l \times \frac{1,78 \ l/100\,kg}{44,9 \ l/100\,kg} = 63,0 \ l$$

Volume of ......D-73........ needed in each mixing tank:

$$1590\,l \times \frac{1,78 \ l/100\,kg}{44,9 \ l/100\,kg} = 63,0 \ l$$

Volume of ......D-81........ needed in each mixing tank:

$$1590\,l \times \frac{0,36 \ l/100\,kg}{44,9 \ l/100\,kg} = 12,7 \ l$$

Total volume of ....D-80.................. needed: = 85 l

Total volume of ....D-73.................. needed: = 85 l

Total volume of ....D-81.................. needed: = 17 l

Hydrostatic pressure calculations:

Height of mud:	= 2481 m
Height of spacer/preflush:	= 64 m
Height of cement slurry	= 255 m

Hydrostatic head from spacer/preflush: 0,098 bar/m x 64 m	= 6,3 bar
Hydrostatic head from mud: 0,137 bar/m x 2481 m	= 339,9 bar
Hydrostatic head from cem.slurry: 0,186 bar/m x 255 m	= 47,4 bar
Total hydrostatic head at 7" shoe	= 393,6 bar

Equivalent pressure gradient at 7" shoe: $\frac{393,6 \text{ bar}}{2800 \text{ m}}$ = 0,141 bar/m

Estimated formation integrity at 7" shoe = 0,182 bar/m

Hydrostatic head at 9 5/8" shoe:

(6,3+339,9) bar + 0,186 bar/m + 120 m = 368,5 bar

Equivalent pressure gradient at 9 5/8" shoe: $\frac{368,5 \text{ bar}}{2665 \text{ m}}$ = 0,138 bar/m

Estimated formation inte

Estimated formation integrity at 9 5/8" shoe = 0,179 bar/m

Gas migration calculations (see graph)

Top cement:	=	2545 m
Hydrostatic head at top of cement slurry (6,3 + 339,9) bar	=	346,2 bar
Hydrostatic head of cement slurry's mix water 0,098 bar/m x 255 m	=	25,0 bar
Hydrostatic head at 7" shoe as cement slurry sets	=	371,2 bar
Estimated pore pressure at 7" shoe	=	337 bar

Flow rate calculations

Estimated formation integrity at 7" liner shoe: = 1,86 g/cc

Situation in annulus when all cement is displaced:

91 % of annulus height is filled with mud
9 % of annulus height is filled with cement.

Formula for calculating maximum allowable annular pressure drop (ECD max = 1,86 g/cc):

$$ECD\ (ppg) = (MW \times 0{,}91 + Cem.w \times 0{,}09)\ (ppg) + \frac{Pann\ (psi)}{0.052 \times Depth\ (ft)}$$

$$Pann\ (max) = \left[1{,}86 \times 8.347 - (1{,}40 \times 8.347 \times 0{,}91 + 1{,}90 \times 8.347 \times 0{,}09)\right] \times 0.052 \times 2800 \times 3.28$$

Pann (max) = 1654 psi = 114 bar

Formula for determination of annular pressure losses:

$$P = \frac{7.7 \times 10^{-5} \times p^{0.8} \times Q^{1.8} \times PV^{0.2} \times L}{(D_h - Dp)^3 \times (D_h + D_p)^{1.8}}$$

P	:	annular pressure loss	(PSI)
p	:	density	(ppg)
Q	:	Flow rate	(GPM)
L	:	depth	(ft)
D_h	:	hole diameter	(in)
D_p	:	pipe diameter	(in)

Height of cement slurry in open hole: (2800-2665)m	=	135 m
Height of cement slurry in cased hole:	=	120 m
Height of mud in annulus (RKB)	=	2545 m

Plastic viscosity cement = 30 cP

Pressure loss in open hole (cement):

p : 15,9 ppg
L : 443 ft
D_h : 8½"
D_p : 7"

$$P_1 = 1,3139 \cdot 10^{-3} \times Q^{1.8}$$

Pressure loss in cased hole (cement):

p : 15,9 ppg
L : 394 ft
D_h : 9 5/8"
D_p : 7"

$$P_2 = 1,91001 \cdot 10^{-4} \times Q^{1.8}$$

Pressure loss in cased hole with PV mud = 30 cP

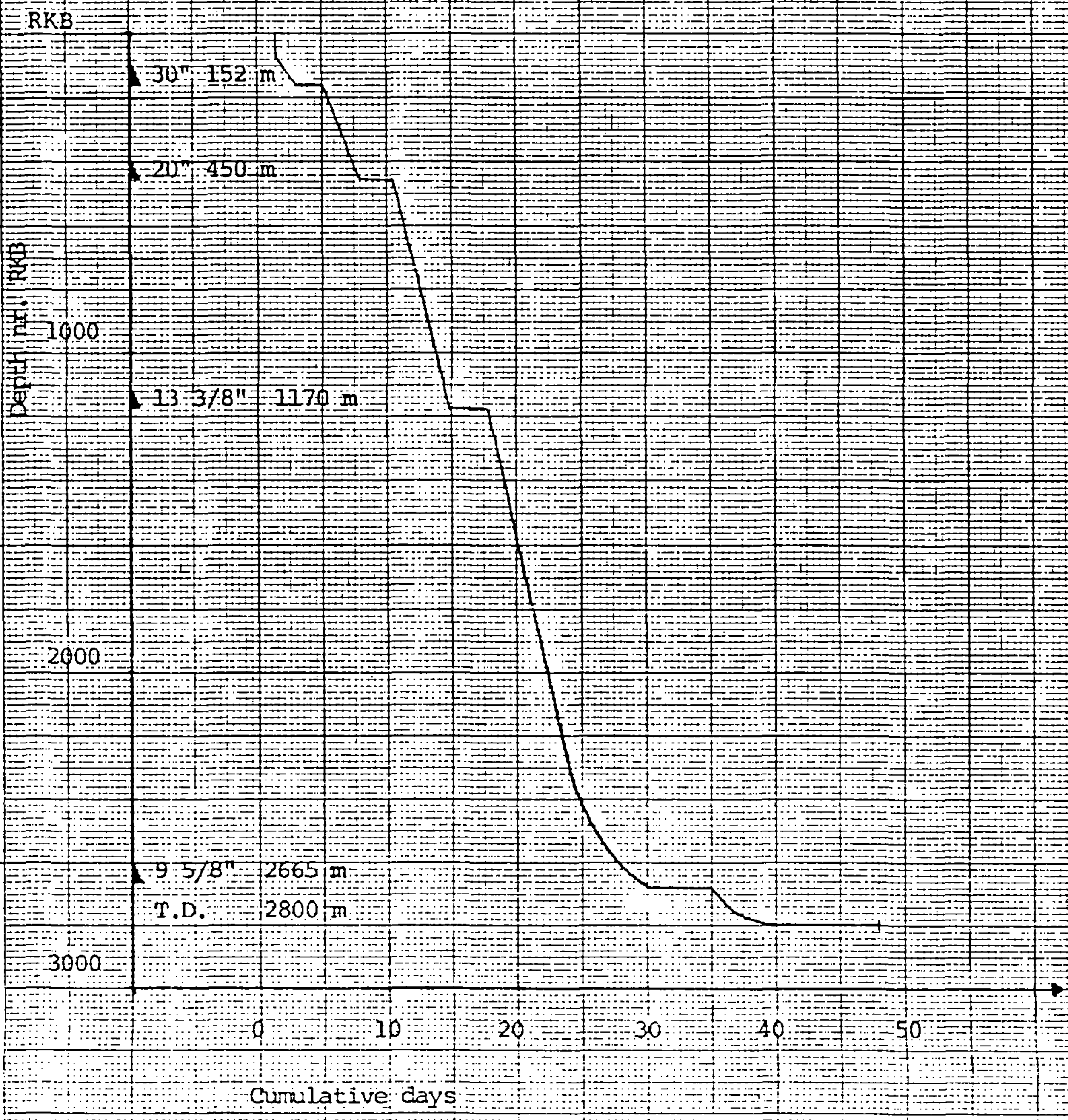
p : 11,7 ppg
L : 8348 ft
D_h : 9 5/8"
D_p : 5"

$$P_3 = 7,30909 \cdot 10^{-4} \times Q^{1.8}$$

$(P_1 + P_2 + P_3)$ max = 1654 psi

$2,2358 \cdot 10^{-3} \times Q^{1.8} = 1654$ psi Qmax = 1822 GPM
Qmax = 6900 l/min

Time VS. depth, based on fair weather conditions. No testing included.



WELL NO. 15/9- gamma

(NOT TO SCALE)

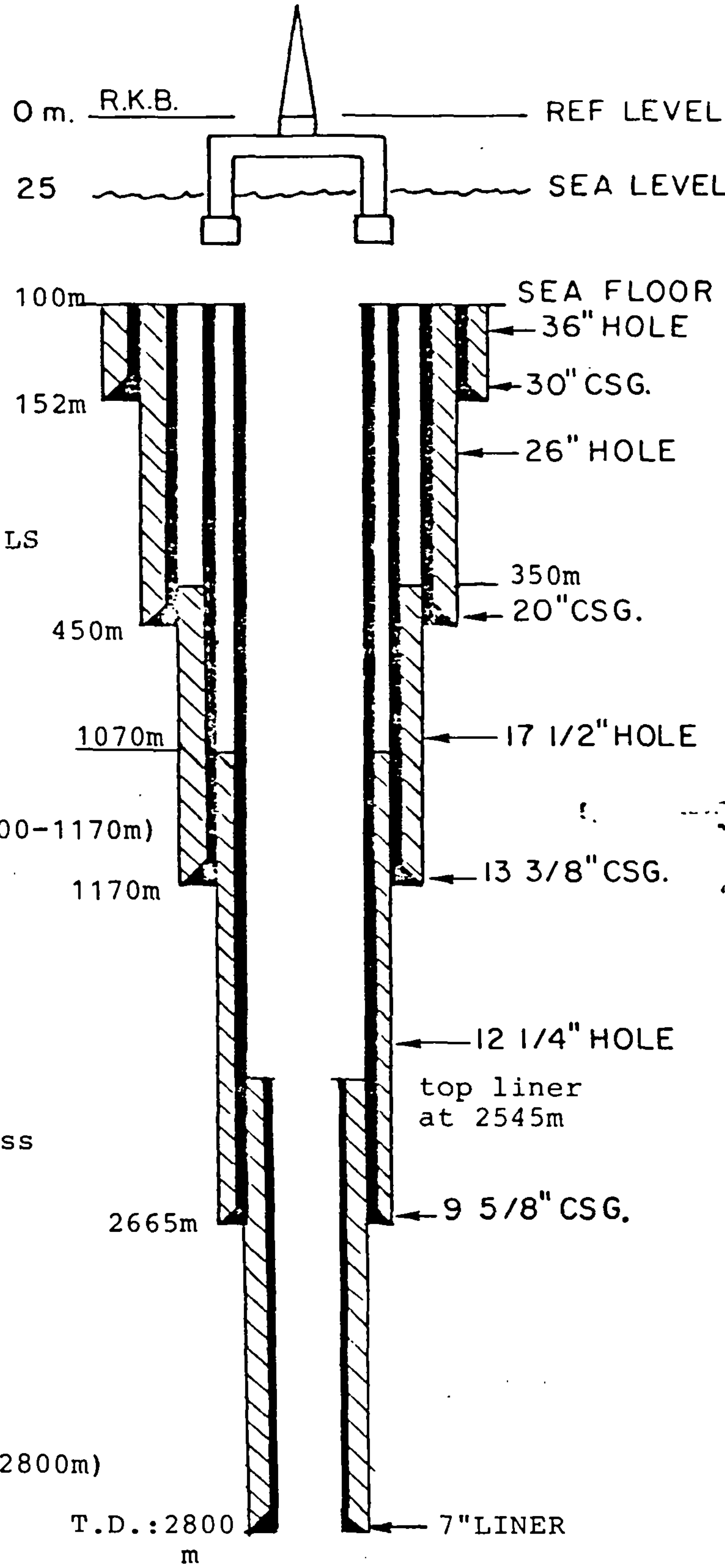
30",grade B, ATD-RB
1jt. 1½"wall th.
3jts. 1"wall th.
Cement to seabed + 150% excess.

20",X-56 , 94 lbs/ft (100-450m),LS
Cement to seabed + 100%excess

13 3/8",K-55,68 lbs/ft,buttr.(100-1170m)
Cement to 350m

9 5/8", 47 lbs/ft., N-80, buttress
Cement to 1070m.

7",29 lbs/ft,N-80,buttr.,(2545-2800m)
Cemented to full length



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17.9.1981

TILLEGG TIL BOREPROGRAM BRØNN 15/9-11(8).

a) Water depth according to the site survey report shall be approx 89 m. This means that sea bed will be at 89 + 25 m = 114 m RKB.

b) 20" casing will be set at 570 m (RKB)

c) Procedure for opening 12 1/4" hole to 26" :

   1) Drill 12 1/4" pilot hole to 585 m and log. If no gas is present from the log, displace the entire hole w/seawater in 3 stages, checking for flow at each stage for minimum 5 minutes.

   2) Open hole to 26" using underreamer or holeopener. Holeopener will only be used if no gas is present from the log.

d) Shut-in procedure when drilling below the 20" casing shoe:

Maximum shutin depth :

$$D = \frac{\text{Leak-off 20" csg shoe} \times 570}{1.05} \text{ m}$$

Leak-off = 1.50 g/cm^3 eq.

$$D = \frac{1.5 \times 570}{1.05} \text{ m} = \underline{814 \text{ m}}$$

Below this depth, the well should not be shut in with the BOP to prevent possible breakdown of the formation at the 20" casing shoe.

e) APPENDIX

20" casing design
20" cement program
Time estimate
Well schematic

20" csg.

W_d = 1185 m   X = 570 m

G_f = 1.50 g/cm^3 (0.147 bar/m)

G_i = 1.1 g/cm^3 (0.108 bar/m)

Z = 114 m

G_p = 1.03 g/cm^3 (0.1 bar/m)

G_{gas} = 0.01 bar/m

$G_{cem}1$ = 0.187 bar/m (1.91 g/cm^3)

$G_{cem}2$ = 0.153 bar/m (1.56 g/cm^3)

G'_i = 1.15 g/cm^3 (0.113 bar/m)

Design creteria:

1) Entire csg. filled with gas
2) Collapse load during cementering
3) Collapse load, lost circ.
4) Tension laod when bumping plug

Burst

Max burst load at wellhead if the csg. is filled with gas:

$P_B = X \times G_f - (x-z) \times G_{gas} - (z-25) \times G_p = 570 \times 0.147 -$
$(570-114) \times 0.01 - (114-25) \times 0.1 = \underline{70.33 \text{ bar}}$

Collapse

(cmt. displ. with seawater)

$P_c = (55-12)\text{m} \times (G_{cem}1 - G_i) + (X-Z-55\text{m})\ (G_{cem}2 - G_i) =$
$(55-12)\text{m} \times (0.187 - 0.1)\text{bar/m} + (570-114-55)\text{m} \times (0.153-01)\text{bar/m} = 25\text{bar}$

Max. collapse load if circ. is lost to normal pressured formation at 1185 m

$$Y = W_D - \frac{W_D \times G_p}{G_i} = 1185 - \frac{1185 \times 0.1}{0.113} = \underline{136 \text{ m}}$$

$$P_c = 136 \times G^1{}_i = (136 \times 0.113) \text{ bar} = \underline{15.4 \text{ bar}}$$

Select: 114-570 m: 94 lb/ft, X-56, Vetco LS

$RES_c = 36$ bar

$RES_B = 152$ bar

$RES_T = 689 \times 10^3$ daN

Safety factor, burst:

$$SF_B = \frac{RES_B}{P_B} = \frac{152}{70.33} = \underline{2.16 > 1.1}$$

Safety factor, collapse:

$$SF_c = \frac{RES_c}{P_c} = \frac{36}{25} = \underline{1.44 > 1.3}$$

Tension:

Weight load in air:

$$(X-Z) \times M_c = (570-114) \times 140 \times 0.981 = \underline{62627 \text{ daN}}$$

Extra tensile load when bumping plug:

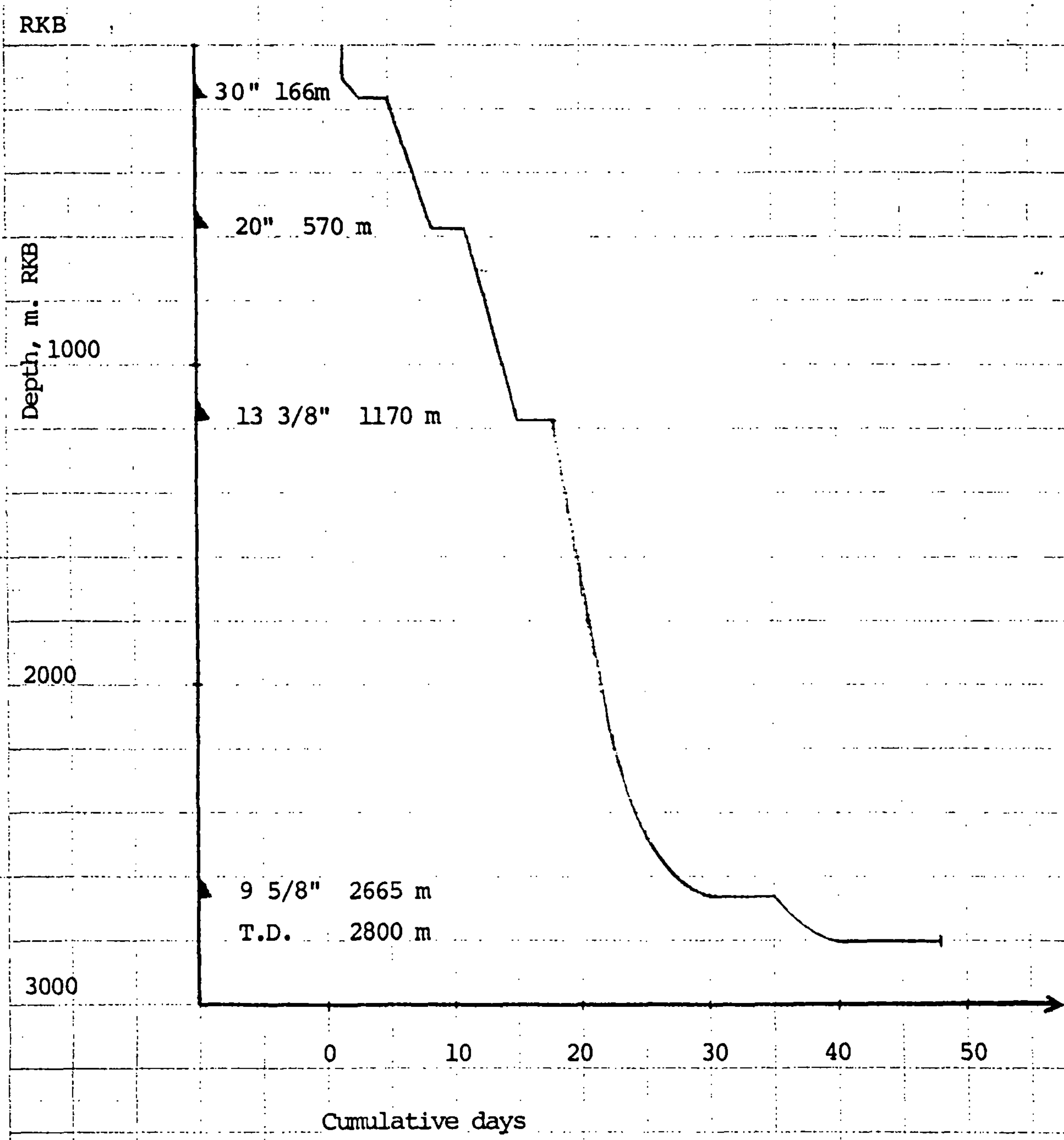
$$\left(\frac{800}{14.5} - 25\right) 0.01 \left(\frac{455,7}{2}\right)^2 \times \Pi \text{ daN} = 55903 \text{ daN}$$

Tot. weight load:

$$(55903 + 62627) \text{ daN} = \underline{118530 \text{ daN}}$$

$$SF_T = \frac{RES_T}{118530} = \frac{689 \times 10^3}{118.530} = \underline{5.8}$$

Time VS. depth, based on fair weather conditions. No testing included.



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Cement to 470 m

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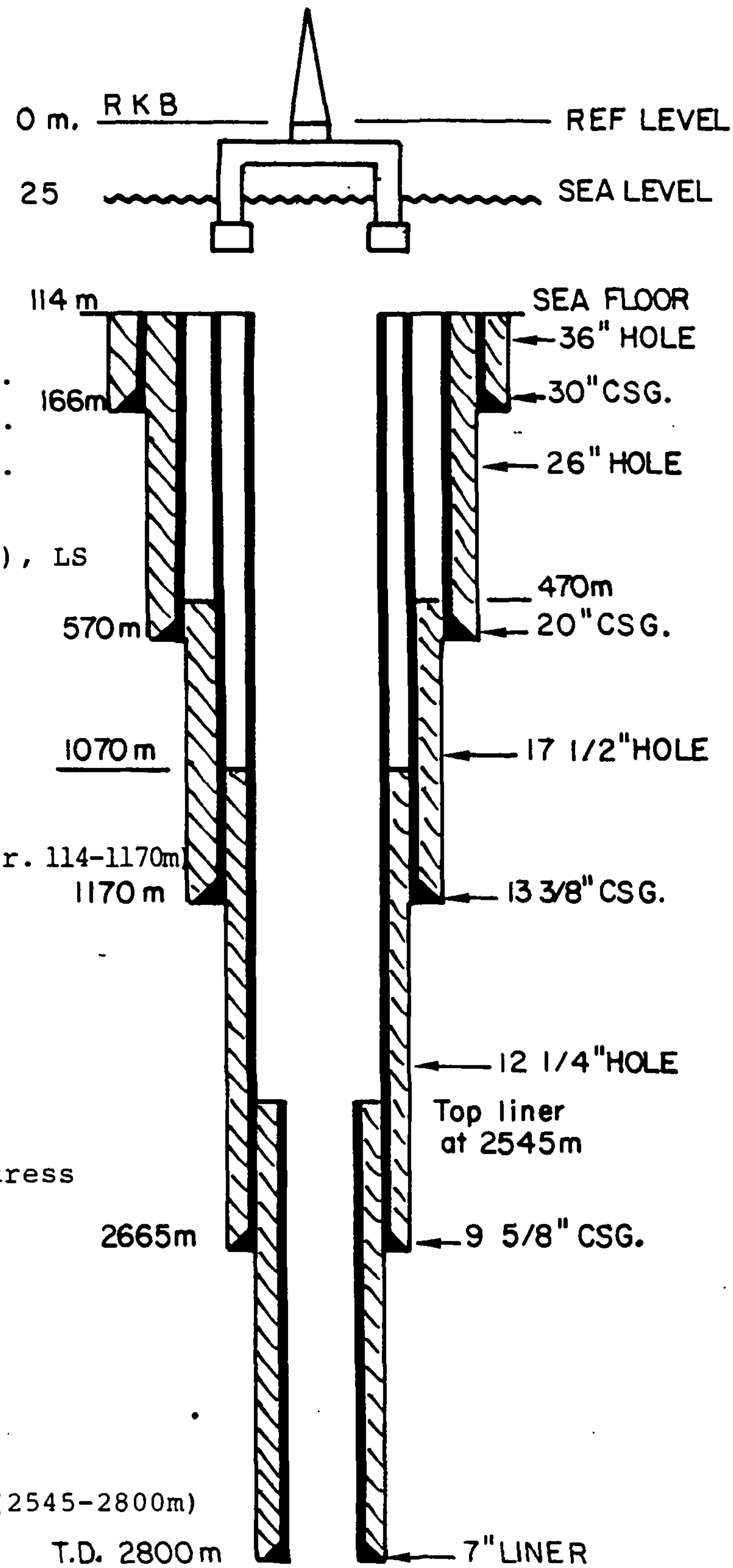
Cement to 1070 m

7", 29 lbs/ft, N-80, buttr., (2545-2800m)
Cemented to full length



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