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Initating discharge testing of well BO4, Guadeloupe. Field report

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Field report.

by
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INTRODUCTION

The Guadeloupe island is one of the islands on the Antilles arc in the Caribbean Sea. Guadeloupe is like two islands with different geological settings that are grown together. The western part, called Basse-Terre, is mountainious and has had reasent volcanic activity while the eastern part, called Grande-Terre, is more flat. In Bouillante, a small town on the western cost of Basse-Terre, Geothermie Bouillante SA. a subsidary of Compagnie Francaise de Geothermie (CFG) operates a small geothermal power plant. Currently the power plant uses only one production well, BO2. Another well drilled in 1974, BO4, but considered a bad producer was stimulated successfully in 1998. Plans are to connect it to the power plant if a long term production test confirm its improvements.

In this report participation in dayly activity between June 26th and July 16th is desribed briefly, well logging in wells BO2 and BO4, warm up of well BO4 and its initiation of discharge. The data collected by the author during his stay in Guadeloupe is reported along with prelimenary evaluation. During the logging operations and initiation of the discharge test, a great assistance was provided first by Mr. Hervé Traineau and later by the chemists Mr. Eric Lasne and Mr. Michel Brach.

DAYLY ACTIVITY

June 26th: Travelled from Iceland to Paris, France and continued to Guadeloupe. Mr. Hervé Traineau met me at the airport in Guadeloupe and brought me to the hotel on the Basse-Terre island.
June 27th: Rested after more than 20 hours of travel. In the afternoon looked at the BO4 well site.
June 28th: Decision confirmed to continue the project. Went to the power plant in Bouillante and looked at the BO2 site. Boxes with Kuster downhole measuring instruments opened and measuring tools unpacked. In the afternoon the movable logging winch was fixed and new logging wire spooled on it. The length of the wire was 2.6 km.
June 29th: Work with winch unit continued, cover put on it and brake fixed. Operation of downhole fluid sampler tested and preparation to alter a sinker bar made for GO-devil logging in BO4.
June 30th: Fasteners made to fix caliper probing disks to a sinker bar and sinker bar altered to accomondate that. Winch unit taken to well BO4 and the lubricator altered. Probing the width of well BO4 was prepared. At 13:25 about one meter long sinker bar with 8" disk about 25cm from its lower end and 6" disk about 25cm from its upper end was lowered into the well. At 13:45 the sinker bar was at 510m depth and had not encountered any obstacles so the well was clear for the 8" caliper tool to that depth. Pulled out and disks changed on the sinker bar. At 14:35 the sinker bar was lowered into well BO4 again. Now it had a 4" disk at its lower end and nothing at the upper end. Top of liner was found at 543m depth, but reference was about 2m above ground. At 14:45 the sinker bar was at 702m depth and had not encountered any obstacles. It was then decided to go deeper and at 14:55 the sinker bar was at 1101m depth or below the perforations in

the 7" liner. When pulling out of the well the 4" disk grabed slightly at something at 920m, but other wise it did not encounter anything and was on the surface at 15:15. The WHP was about 3bar-g during this operation.

July 1st: Finished going over the downhole fluid sampler and explaning its function to the chemists. Kuster pressure and temperature gauges were put together. Static temperature profile was measured in well BO4 between 11:05 and 13:20 and static pressure profile between 13:45 and 15:33. Then downhole fluid sampling was prepared and the fluid sampler set at 330m depth at 16:47. Due to rain the sampler was moved to the power plant before extracting the fluid from it. About 790ml of fluid was collected. Diaphragm at extraction port on sampler got stuck.

July 2nd: The morgning was spent on removing the stucked diaphragm from the fluid sampler, but it had to be drilled out with modified drill bits. Sampler taken to well BO4 and set to 640m depth at 11:17. When at surface again at 12:20 it was found that the O-rings at the intake valve release mechanism had leaked and fluid reached the clock. About 600ml of fluid were collected from the sampler. Rest of the day was spent on cleaning and repairing the sampler clock.

July 3rd: Fluid sampler was put together and sampling in BO4 tried again. Sampler at 640m depth at 8:53 and on surface half an hour later. Push rod was stuck and had not opened the intake valve properly. However, 700ml of sample were collected due to leakage in O-rings in intake valve. Fluid sampler was taken apart and all O-rings changed. At 12:57 the sampler was again at 640m depth. When pulled out, fluid had leaked up to the clock, but more than 600ml of fluid was collected. Sampler rinsed, but clock taken to the hotel for repair in the evening.

July 4th: Day of from work.

July 5th: Preparation to measure dynamic profiles in well BO2. A car crane had been hired but it barely had enough lifting span for the operation, as the 3" valve on BO2 is at more than 5m height above ground and the length of the lubricator was more than 2m. At 12:03 the temperature gauge was in the well. At 84m depth the gauge had tendency to float and the flow from well BO2 had to be throttled (7-8 turns on the bypass valve). The WHP increased from 9.8bar-g to 11.2bar-g. At 194m depth the well had to be throttled slightly more (1.5 turns) and WHP rose to 11.6bar-g. Bottom was found at 340m, but reference is more than 5m above ground. Between 14:25 and 16:34 the dynamic pressure profile was measured. When the pressure gauge was in the well the WHP was 12.5bar-g so the bypass valve was opened 1 turn and WHP went down to 11.7bar-g. Small problem was encountered at 192m depth when the packing in the stuffing box was making the wire stick. The gauge was first pulled to 180m and then to 175m before the cap was loose enough to allow the gauge to go down.

July 6th: Buildup in well BO2 prepared. Some waiting was for the crane which had been modified to increase its lifting span. At 10:36 the pressure gauge was in the well. Wellhead pressure had increased to 12.3bar-g from yesterday so bypass valve was opened 1.25 turns causing WHP to drop to 11.75bar-g. Due to the stiffness in the stuffing box, the weight of the gauge was to little to sink it down when it reached 129m depth. With some manuvering it went to 192m depth, but then the well had to be closed to get the gauge to the bottom. It was at the bottom in less than two minutes after closing of the well was started. The gauge was pulled out at 14:44 to change chart and sent to bottom again at 16:23. The gauge was pulled out at 20:23. Maximum WHP obtained was 15.6bar-g shortly after shut-in.

July 7th: Finished repairing the sampler clock and fluid sampler. Changed the procedure for cleaning the sampler to prevent damage to the weaker O-rings that protect the clock. At 14:17 the downhole fluid sampler was at 320m depth in well BO2. A good sample of fluid and gas was obtained (more than 700ml). Later a logging operator (Brian) from Kinley arrived and introduced us to the multifingering caliper.

July 8th: Logging unit and multifinger caliper was brought to well BO4. A dummy run with 8" fixed centrallizing rings was made between 8 and 9:30. When pulling out, the tool was not brought fully to the top in the lubricator so when closing the upper wellhead valve the lower centrallizer was bent slightly. Clogging in the petroleum line on the winch unit had to be fixed. Between 11 and 13 the multifinger caliper log was performed and its preliminary results were available about one hour later, indicating no damages in the casing. Around 15 o'clock well BO4 was opened on the 2" bleeding line to start its warm up for discharge. About 10 minutes later it was closed again due to flow restrictions in the weir box. The wave breaker nearest to the intake in the weir box appeared to be to high giving a head between outflow from atmopheric separator and weir box of only 8cm. About 5-7cm were cut of the wave breaker to increase the head. At 16:08 the 2" line was opened again and at 16:52 it was fully open. WHP had increased during that time from 3bar-g to 10.1bar-g. At 17:45 the WHP was 18.0bar-g and the wellhead had gone up 9.3cm. It was then started to throttle the well on the 2" valve for the night. It takes 13 turns to move the 2" valve from fully closed position to fully open with effective length of valve stem 6cm. The valve was first throttled by partly closing it (8 turns) and at 18:02 another 3 turns so the effective lengt of the valve stem standing out was 1.3cm.

July 9th: Static profiles were measured in well BO2. Temperature between 9:06 and 10:17, and pressure between 11:02 and 11:55. Well BO4 had been discharging trough the 2" bleeding line since yesterday and at 13:55 it was swiched over to the 10" discharge line. Its WHP was then 21.8bar-g and the wellhead had gone up 10.7cm. Between 14:20 and 18:20 four steps were obtained for rough estimation of its characteristic discharge curve. When throttling the well for the night on the control valve the stem for the rattle bent. It turned out that the control valve turned the wrong way in the line. Assistant was obtained from the power plant to close the control valve, but the discharge was moved over to the 2" line for the night.

July 10th: Noise from the atmospheric separator was damped by putting rock wool on its first expansion steps. A 2" throtling valve was put on the 2" bleeding line. Charts from downhole measurements were read. Size of an orifice for about 80t/h flow rate was estimated from Russel James method to be 62mm.

July 11th: Day of from work. Others turned the control valve in the 10" discharge line.

July 12th: A square edge orifice plate had been made with ID=62mm. Around noon it was set into the 10" discharge line and the control valve was fully opened. The orifice plate restricted the flow from the well to about 90t/h. Noise level was measured during the day. When trying to throttle the well to lesser flow for noise measurements, the threads for the rattle stem in the control valve housing broke. The discharge was then moved over to the 2" line for the night. A new orifice plate for smaller flow rate was designed.

July 13th: Continuation of the discharge test was confirmed. At 9:30 the orifice plate in the 10" discharge line had been changed and the control valve fastened in a fully open position. The orifice in the new plate has ID=50mm. The discharge was moved to the 10" line and monitored during the day. With this orifice the discharge was about 65t/h.

July 14th: Checked on well BO4 which was operating as planed and discharging about 65t/h.

July 15th: Packing when informed that the plant staff had closed well BO4 late yesterday due to complains from neighbors over noise. Had phone discussion with Hervé and went briefly to the BO4 site to see how the 10" line had been disconnected from the wellhead. Then continued packing and flew to Paris, France.

July 16th: Continued travelling to Iceland.

PRELIMINARY DATA EVALUATION

Well BO2

Well BO2 is the only producer for the power plant. Due to scheduled maintenance in the power plant, well BO2 was put on the bypass to the steam condenser. This gave opportunities to log the well for both dynamic and static conditions as well as monitoring its buildup. Well BO2 is drilled to 338m depth, completed with 7" casing to 287m and open hole to bottom. Fully open for flow to the steam condenser the WHP was 9.8 bar-g. On July 5th dynamic temperature and pressure profiles were measured to the bottom. However, the flow from the well had to be throttled to prevent the floating of the gauges during the measurements. The WHP rose and was between 11.6-11.9 bar-g during the later part of the temperature measurement and most of the pressure measurement. When closed the maximum WHP was 15.6 bar-g. A discharge characteristic curve was not available for the well and no easy means of measuring the flow rate at that time. The discharge rate during the dynamic logging is therefore not known. The discharge rate maybe estimated from measurements of the output from the generator for different wellhead conditions with the power plant in operation. It could also be estimated form other measurements made later on the well.

The dynamic profiles are shown on figures 1 and 2. The profiles indicate that the well is boiling to the bottom or down to the feeding zone. The figures also show the static profiles, which were measured on July 9th. During discharge the drawdown in the well at the feed zone is more than 20 bar.

Well BO2 was shut-in on July 6th and the pressure buildup at the feed zone was monitored for more than 9 hours in two runs. Only a 6-hour reliable clock was at the site so further continuous recording was stopped. Less than two days later a static pressure point was available. The buildup data is presented in figures 3 and 4. Looking at the data in the figures it can be seen that further monitoring of the buildup pressure would have been required as the data collected ends in the transition zone where the reservoir starts to dominate the pressure response. From the data it can be estimated that the buildup takes about 24 to 36 hours (1400-2100 minutes), but after that it is controlled by the average reservoir pressure. Due to the smooth behavior of the pressure response, one can anticipate how the pressure buildup curve should look like. To help in the interpretation of the test, some data points were generated in the interval between the data from the continuous monitoring and the static point. These points are shown in the figures. As the production time has been very long compared to the shut-in time the test can be interpreted with models for drawdown. An analytical model based on Theis solution (assuming infinite acting system and line source well) was fitted to the data. The match with the model is fairly good, except for the last data, where the model no longer applies as the pressure behavior becomes bounded by the prevailing average reservoir pressure. Since the discharge rate from well BO2 before shut-in is not known, only indicative values for transmissivity and skin can be reported as their magnitude depends on the rate. Later when the discharge rate has been estimated their magnitude can be approximated from;

$$T = 0.79 \times 10^{-8} \times M/10$$
$$s = +1.06 \times M/10$$

where T is the transmissivity (m^3Pa/s), s is the skin factor and M is the discharge rate (kg/s). The wellbore storage and formation storage are not as well determined, but they are high as can be expected from the buildup behavior and the initial two-phase conditions at the feed zone. The wellbore storage (C_D) is around 9340 and the formation storage (S) is of the magnitude 29.8 x 10^{-8} Pa/m, but its value will depend on the final transmissivity. The buildup was fitted assuming the rate before shut-in to be 10 kg/s thus the actual rate will be divided by 10 in the above equations. The match for other discharge rates will be the same but the parameter values will change. Even for three times higher discharge rate the transmissivity for well BO2 can be characterized to fall in the range low to moderate for a productive geothermal well. The skin factor will then be in the higher range for a productive geothermal well.

Well BO4

Static temperature and pressure profiles were measured in well BO4 on July 1st to 1100m depth. The profiles are shown in figures 5 and 6. Measurements made in connection with the stimulation project in 1998 were only able to go to depths less than 800m. The last profile measured in 1998 could have been taken deeper but it was not attempted. Probing the well on June 30th with caliper disks (4"-8") had revealed the well to be open to more than 1100m depth and that both the 7" liner and the 9 5/8" production casing to be relatively clean from scaling. The top of the 7" liner was found at 543m depth or 541m depth from surface. The known productive and perforated interval is therefore fully open. The temperature profile shows increasing temperature down to 1100m and those temperature values are slightly higher than obtained in earlier measurements. Earlier measurements indicate that a temperature reversal exists in the well starting at about 1050m depth. This can not be seen in the present measurement, indicating that the reversal must start at depth greater than 1100m. The maximum recorded temperature was 254°C at 1100m. Discharge measurements confirm the reservoir temperature to be in the range 250-253°C as indicated by the discharge enthalpy.

Warm up of well BO4 for discharge was started in the afternoon on July 8th. After some modifications in the weir box the well was opened on a 2" bleeding line and in 50 minutes the 2" valve was fully open. The wellhead moved up due to thermal expansion, mostly in steps, and had in two hours moved up by 9.3cm. The well was throttled over the night and on July 9th the discharge was moved over to the 10" discharge line. During the warm up, the wellhead came up 10.7cm and the WHP rose from 4 bar-g to 21.8 bar-g. That day a rough check was made to approximate the characteristic discharge curve for the well. Four discharge steps lasting 1-1.5 hours were measured. The flow measurements are given in the appendix and shown as rings on figure 7. Also shown on figure 7 are calculated characteristics curves from matches to dynamic logs made before and after the stimulation job in 1998 along with the only measured point obtained then. Other discharge measurements made the next few days when orifice plates where installed are also presented in figure 7. In general the measurements confirm the second improved characteristic curve. Further the calculated enthalpy from the combined measurements of the lip pressure and liquid flow phase confirms the temperatures obtained with the static temperature profile.

In the beginning scaling occurred in the weir box and the water phase had a grayish to brownish color. However, after several hours of discharge the water phase became clear and scaling became considerably less.

DISCUSSIONS AND CONCLUSIONS

Dynamic profiles measured in well BO2 indicate that the well is boiling into the feed zone at the bottom of the well (338m). Discharge measurements are needed for that well at conditions similar to those prevailing during the logging operation in July to fully interpret the data collected then. Most likely a portion of the well characteristic curve can be determined by throttling the well and measure the output from the power plant. In any event it should be considered to establish a characteristic curve for that well.

The pressure buildup in well BO2 occurs rather slowly and takes about 24 to 36 hours. The slow buildup infers low permeability, but other factors have role in that also. Limited interpretation of the buildup data indicates similarly that the transmissivity (permeability) is in the lower range for what can be expected for a productive geothermal well. Furthermore, the skin factor, which is a measure of near wellbore flow restrictions, is in the higher range, but it could be influenced by the boiling taking place in the reservoir. Together these parameters classify well BO2 to be an intermediate producer on the poorer side.

Temperature measurements in well BO4 result in slightly higher temperatures than earlier measurements have indicated. Furthermore, no temperature reversal is observed down to 1100m depth. During drilling of well BO4 fluid losses were reported for the depth interval 580-1050m with the highest losses in the interval 950-1050m. Temperature reversal was observed to begin below 1050m depth. In the interval with the highest losses the present temperature measurement give temperatures in the range 250-254°C. That temperature is confirmed by measurements made during initiation of discharge from the well. The enthalpy determined from the discharge corresponds to single phase water in that temperature range.

The production test equipment connected to well BO4 performed as expected. When fully warmed up the wellhead had gone up by 10.7cm, lifting and tilting slightly the 10" discharge line. The extendable jacks under the discharge line gave full support to it at all times. For flow upto 140t/h only small and expectable vibration was on the discharge line. The small problems encountered during the initiation of discharge were mostly related to the control valve that was installed in the discharge line. The problems were mechanical relating to difficulties in closing the valve. However, after the orifice plat had been installed to control the flow rate, the control valve could be fastened in fully open position. The maximum discharge rate attempted during the initial test was about 140t/h. At that rate the wave breaker plate nearest to the inlet to the weir box is about to restrict the capacity of the weir box. To be able to take the well to higher discharge rates for the current configuration it will be necessary to put holes in the wave breaker plate to reduce its flow restrictions.

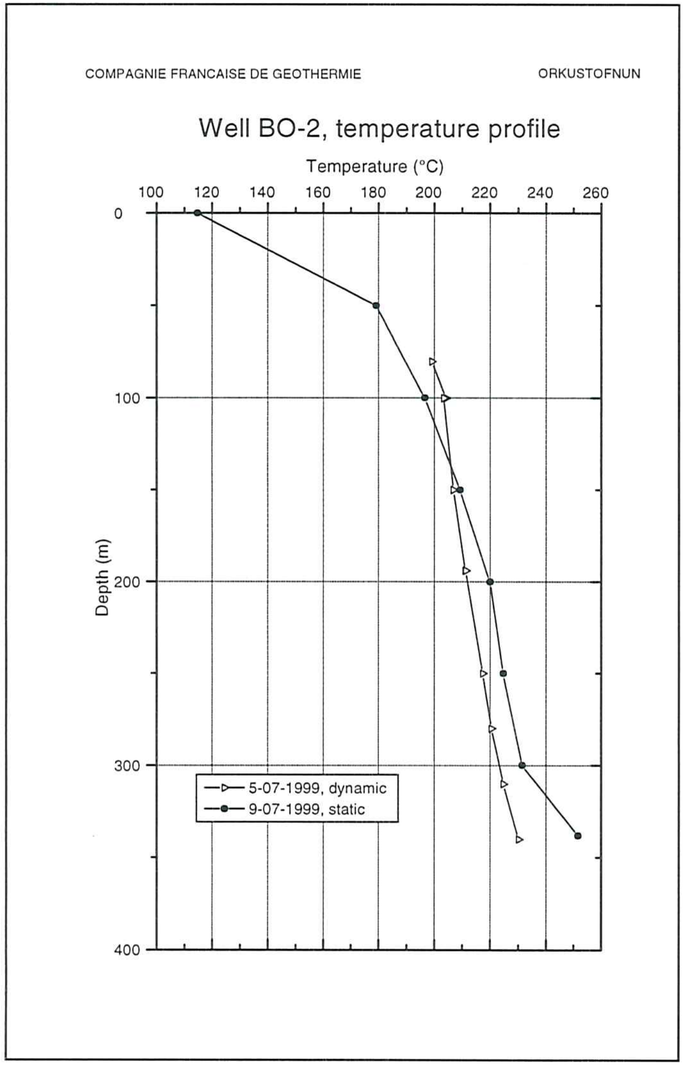
Small leakage was observed on the atmospheric separator on welding joints. It was on the drum for one of the towers. The leakage was mostly selfsealed by scaling in the beginning of the discharge. Small vibration on the wellhead caused some leakage from the connection between the wellhead-T and the reduction flanges for the 3" top valve. Tightening the bolts easily stopped the leakage, but this has to be checked on regularly for the first few days after initiating discharge.

Rock wool was put on the first expansion step on the atmospheric separator. It reduced the noise considerably so one could stand nearly beside the atmospheric separator without hearing protection and not feel uncomfortable. Unfortunately this noise reduction was not enough, but the noise near to the separator was about 60dB. Annoying noise was at the house that is close to the well site and a little higher up the road. At other nearby houses the noise was more a change in the background sound, but the bass sound from the separator drum can be heard over some distances. The layout and the equipment would have been fully acceptable for long-term production testing in all circumstances in slightly more remote area or further away from households. To reduce the noise considerably more it has been suggested to CFG to install a so-called rockmuffler. In that case the discharge is piped into a pond full of water and rock boulders disperse the flow jets. Cooling of the discharge is enhanced by convection in the pond. The atmospheric separator would then only be used for some hours during flow measurements.

The first results on what might be expected from well BO4 are promising. For a nominal output of about 65 t/h, the steam production at 7 bar-a separation pressure is equivalent to about 1.5MW_e. The results should interest CFG to have the information from BO4 long term testing soonest possible to facilitate decision making for pipe line, increasing output from the geothermal power plant and further explorations.

Reykjavik August 12^{th}, 1999

Omar Sigurdsson


COMPAGNIE FRANCAISE DE GEOTHERMIE
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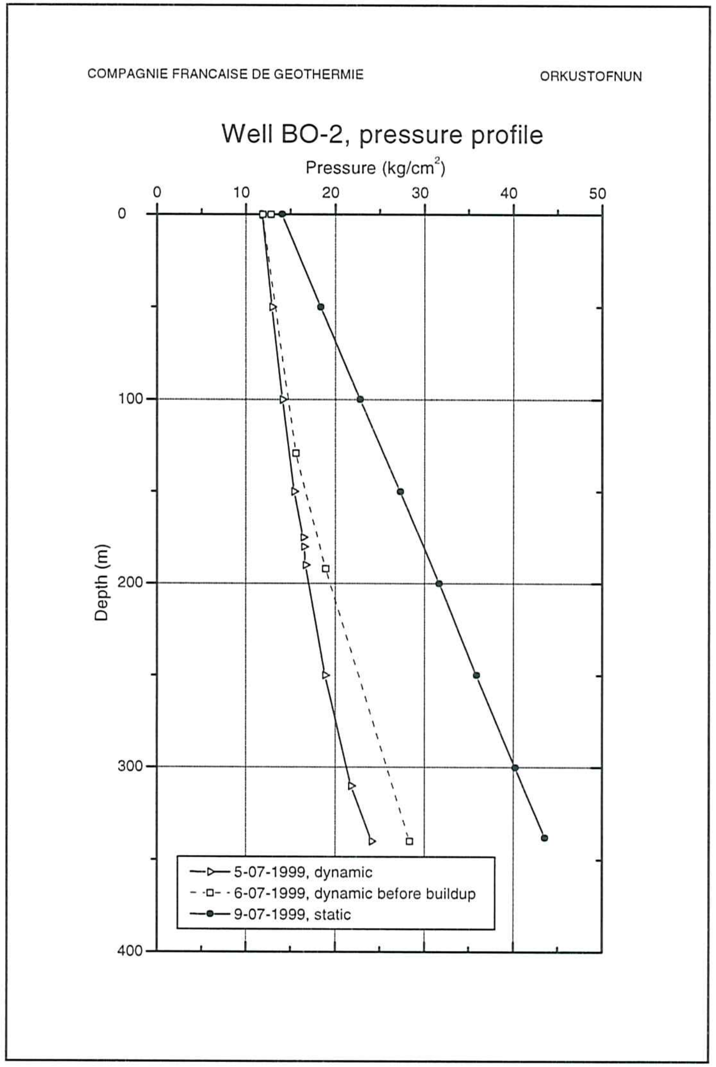
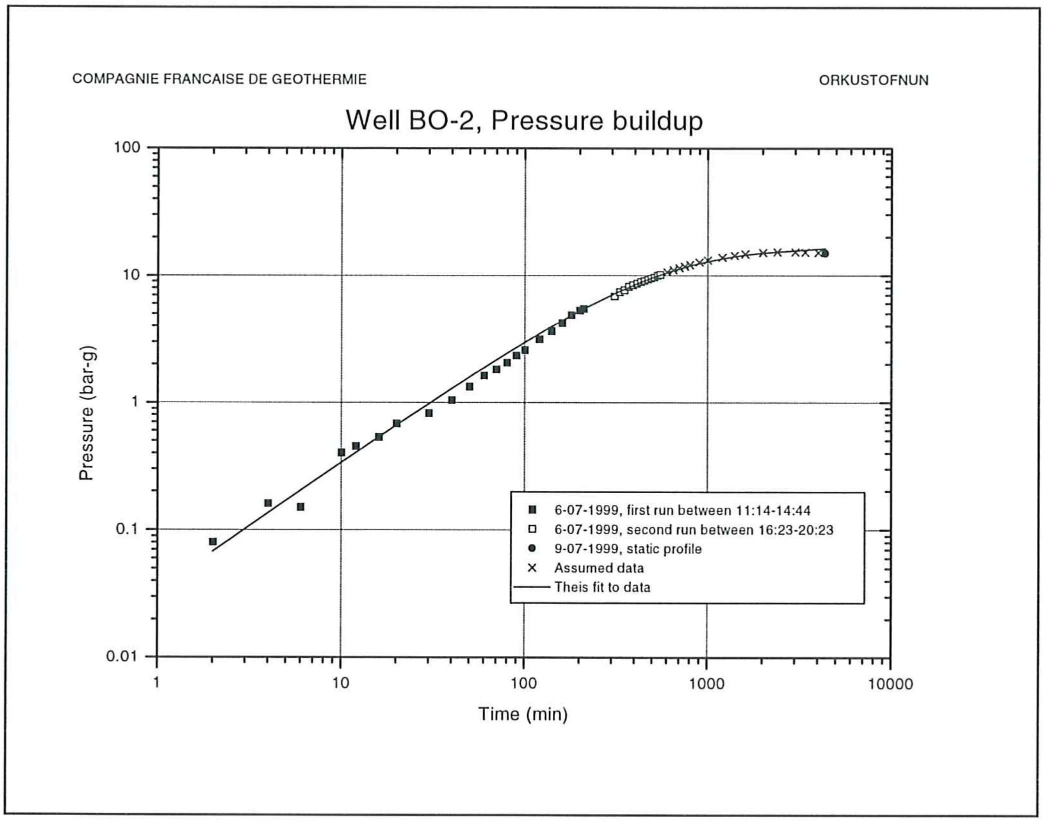
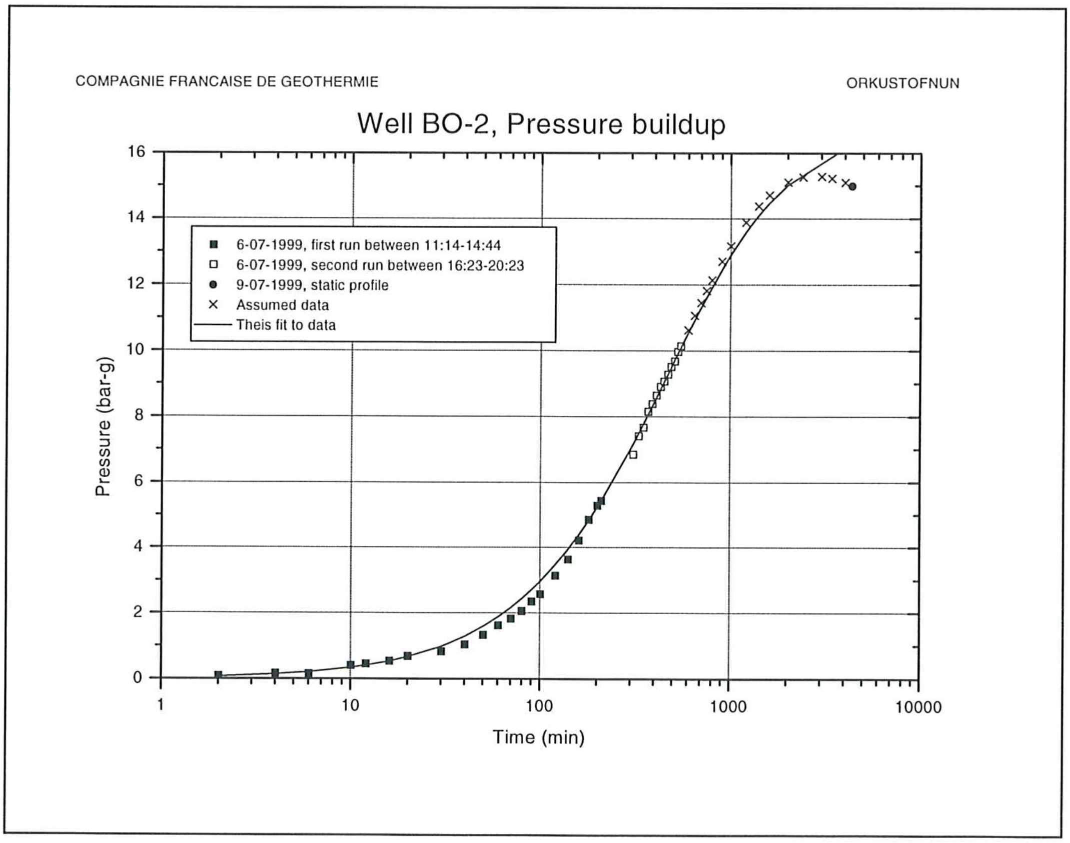
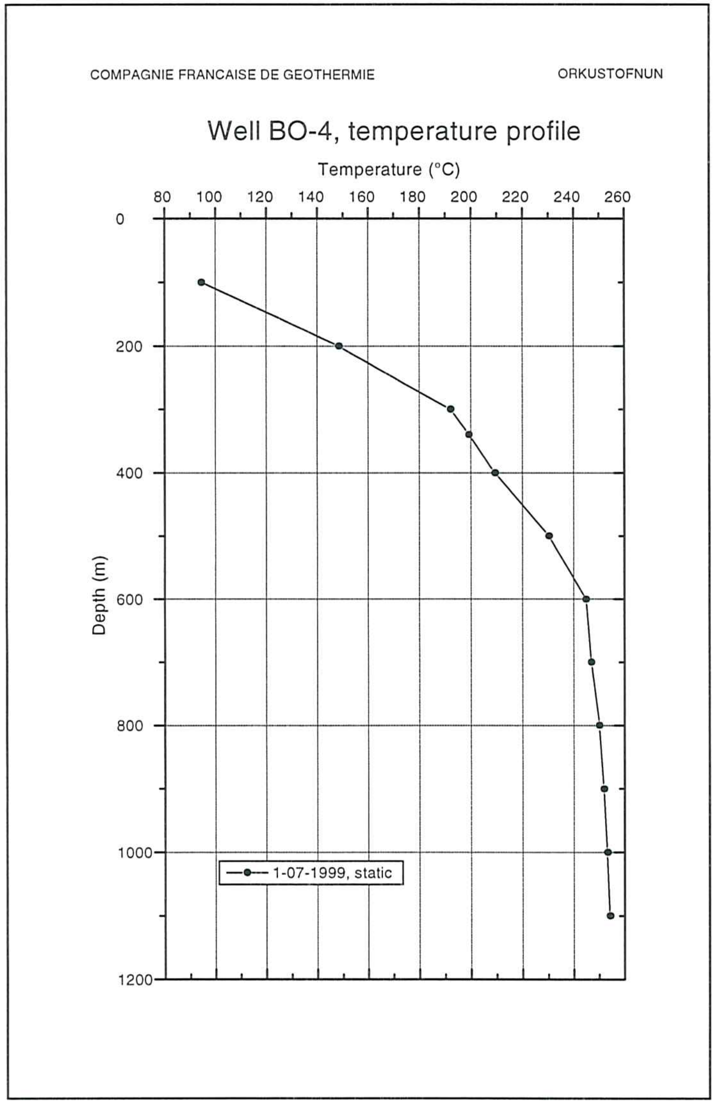
Well BO-2, temperature profile
Temperature (°C)
100
120
140
160
180
200
220
240
260
Depth (m)
0
100
200
300
400
5-07-1999, dynamic
9-07-1999, static


COMPAGNIE FRANCAISE DE GEOTHERMIE
ORKUSTOFNUN
Well BO-2, pressure profile
Pressure (kg/cm²)
0
10
20
30
40
50
Depth (m)
0
100
200
300
400
5-07-1999, dynamic
6-07-1999, dynamic before buildup
9-07-1999, static


COMPAGNIE FRANCAISE DE GEOTHERMIE
ORKUSTOFNUN
Well BO-2, Pressure buildup
Pressure (bar-g)
100
10
1
0.1
0.01
1
10
100
1000
10000
Time (min)
6-07-1999, first run between 11:14-14:44
6-07-1999, second run between 16:23-20:23
9-07-1999, static profile
Assumed data
Theis fit to data


COMPAGNIE FRANCAISE DE GEOTHERMIE
ORKUSTOFNUN
Well BO-2, Pressure buildup
Pressure (bar-g)
16
14
12
10
8
6
4
2
0
1
10
100
1000
10000
Time (min)
6-07-1999, first run between 11:14-14:44
6-07-1999, second run between 16:23-20:23
9-07-1999, static profile
Assumed data
Theis fit to data


COMPAGNIE FRANCAISE DE GEOTHERMIE
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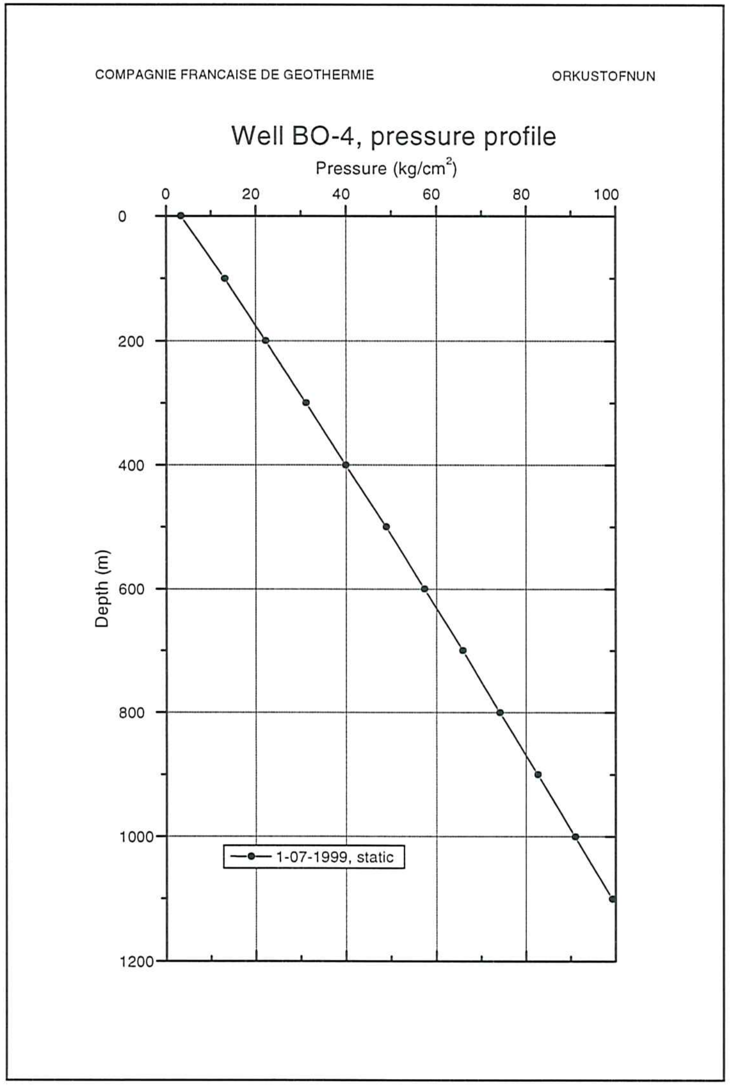
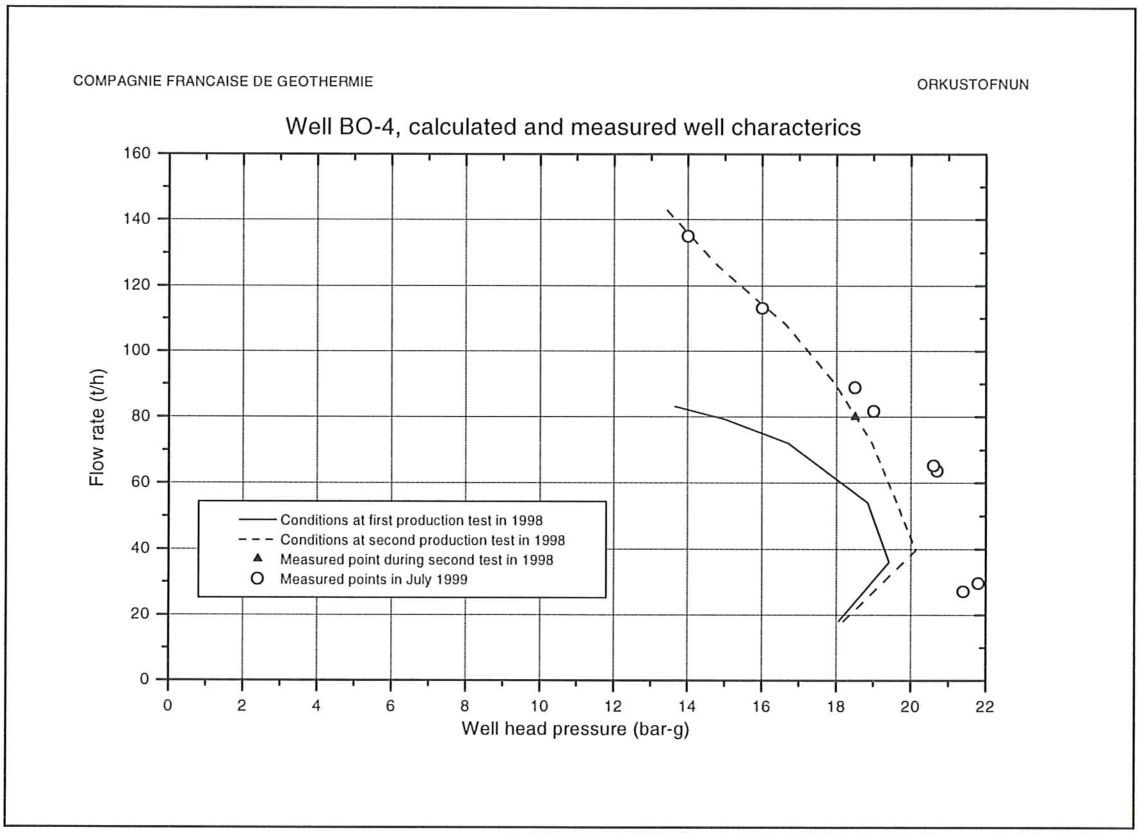
Well BO-4, temperature profile
Temperature (°C)
80
100
120
140
160
180
200
220
240
260
Depth (m)
0
200
400
600
800
1000
1200
1-07-1999, static


COMPAGNIE FRANCAISE DE GEOTHERMIE
ORKUSTOFNUN
Well BO-4, pressure profile
Pressure (kg/cm²)
0
20
40
60
80
100
Depth (m)
0
200
400
600
800
1000
1200
1-07-1999, static



COMPAGNIE FRANCAISE DE GEOTHERMIE
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Well BO-4, calculated and measured well characterics
Flow rate (t/h)
Well head pressure (bar-g)
0
20
40
60
80
100
120
140
160
0
2
4
6
8
10
12
14
16
18
20
22
Conditions at first production test in 1998
Conditions at second production test in 1998
Measured point during second test in 1998
Measured points in July 1999

APPENDIX

Data from down hole logging in wells BO-2 and BO-4. Discharge data for well BO-4.

DYNAMIC TEMPERATURE AND PRESSURE LOGGING IN WELL BO-2

Date: 05-07-1999

Temperature gauge KT-27786; Clock 6h, serial no. V4101; Time 12:03-13:29
Pressure gauge KP-V3851; Clock 6h, serial no. V4101; Time 14:58-16:34
Zero reference at 3" valve, which is about 5m above ground.

TEMPERATURE				PRESSURE				
Depth (m)	Deflection (cm)	Temperature (°C)	Observations (Temp. Logging)	Depth (m)	Deflection (cm)	Pressure (bar)	Pressure (kg/cm^2)	Observations (Press. Logging)
0			WHP=9.8 bar-g, fully open	0	0.430	11.76	11.99	WHP=12.5 bar-g, open 1 turn
				0	0.425	11.63	11.86	WHP=11.7 bar-g
			WHP=9.8 bar-g	50	0.463	12.66	12.91	WHP=11.6 bar-g
80	3.276	199.0	Gauge floating at 84m					
100	3.405	204.1	Throttle 7 turns	100	0.507	13.84	14.11	WHP=11.7 bar-g
100	3.387	203.3	WHP=11.2 bar-g					
150	3.472	206.7	WHP=10.4 bar-g	150	0.554	15.11	15.41	WHP=11.6 bar-g
				190	0.601	16.36	16.68	Wire stuck in stuffing box
194	3.575	211.0	Floating, WHP=10.4 bar-g	180	0.595	16.20	16.52	Pulled to loosen wire
194	3.581	211.2	Throttle 1.5 turns, WHP=11.6 bar-g	175	0.591	16.10	16.42	WHP=11.6-11.8 bar-g
250	3.719	217.3	WHP=11.75 bar-g	250	0.681	18.50	18.86	WHP=11.9 bar-g
280	3.788	220.4	WHP=11.7 bar-g					
310	3.875	224.7	WHP=11.75 bar-g	310	0.786	21.34	21.76	WHP=11.9 bar-g
340	3.979	230.1	WHP=11.8 bar-g	340	0.866	23.62	24.09	WHP=11.9 bar-g
0	3.210	196.6		0	0.433	11.85	12.08	

STATIC TEMPERATURE AND PRESSURE LOGGING IN WELL BO-2

Date: 09-07-1999

Temperature gauge KT-27786; Clock 6h, serial no. V4101; Time 9:06-10:17
Pressure gauge KP-V3851; Clock 6h, serial no. V4101; Time 11:02-11:55
Zero reference about 2m below 3" valve, which is about 5m above ground.

	TEMPERATURE			PRESSURE			
Depth (m)	Deflection (cm)	Temperature (°C)	Observations (Temp. Logging)	Deflection (cm)	Pressure (bar)	Pressure (kg/cm^2)	Observations (Press. Logging)
0	0.821	114.6		0.490	13.78	14.05	WHP=14.5 bar-g
50	2.735	179.0	WHP=14.6 bar-g	0.654	18.00	18.35	
100	3.209	196.5	Wire stuck in stuffing box	0.813	22.33	22.77	
150	3.531	209.1		0.968	26.73	27.25	
200	3.777	219.9		1.119	31.04	31.65	
250	3.873	224.6		1.263	35.18	35.87	
300	4.004	231.4		1.411	39.43	40.21	
338	4.365	251.6		1.528	42.70	43.54	Time 11:55
0				0.529	14.88	15.17	Well shutin on July 6th, at 11:14

PRESSURE BUILDUP IN WELL BO-2

Date: 06-07-1999

Pressure gauge KP-V3851; Clock 6h, serial no. V4101; Time 10:36-14:44
Zero reference at 3" valve, which is about 5m above ground.
Pressure buildup at bottom of well. First run.

Depth (m)	Time	Δtime (min)	Deflection (cm)	Estim. Temp. (°C)	Pressure (bar-g)	Pressure (kg/cm^2)	Observations
0	10:36		0.459	197.0	12.56	12.81	WHP=12.3 bar-g, open 1.25 turns
0	10:42		0.425	197.0	11.63	11.86	WHP=11.75 bar-g
129	10:54		0.560	205.0	15.28	15.58	WHP=11.6 bar-g
192	11:12		0.681	211.0	18.54	18.91	Gauge floating, start to close, WHP=12.3 bar-g
340	11:16	2	1.010	231.0	27.79	28.34	WHP=15.6 bar-g
340	11:18	4	1.013	233.0	27.87	28.42	
340	11:20	6	1.013	234.0	27.86	28.41	WHP=15.1 bar-g
340	11:24	10	1.022	235.0	28.11	28.66	
340	11:26	12	1.024	236.0	28.16	28.72	WHP=14.5 bar-g
340	11:30	16	1.027	237.0	28.24	28.80	
340	11:34	20	1.032	237.0	28.39	28.95	WHP=13.9 bar-g
340	11:44	30	1.037	238.0	28.53	29.09	
340	11:54	40	1.045	239.0	28.75	29.32	
340	12:04	50	1.055	239.0	29.04	29.61	
340	12:14	60	1.065	240.0	29.33	29.91	
340	12:24	70	1.072	240.0	29.53	30.11	WHP=11.2 bar-g
340	12:34	80	1.080	240.5	29.76	30.35	
340	12:44	90	1.090	240.5	30.05	30.64	
340	12:54	100	1.098	241.0	30.28	30.88	
340	13:14	120	1.118	241.5	30.85	31.46	
340	13:34	140	1.135	242.0	31.34	31.96	WHP=7.6 bar-g
340	13:54	160	1.155	242.0	31.92	32.55	
340	14:14	180	1.177	242.5	32.56	33.20	
340	14:34	200	1.192	243.0	32.99	33.64	
340	14:44	210	1.197	243.0	33.14	33.79	WHP=7.7 bar-g
0			0.250	168.0	6.91	7.05	

PRESSURE BUILDUP IN WELL BO-2

Date: 06-07-1999

Pressure gauge KP-V3851; Clock 6h, serial no. V4101; Time 16:17-20:23
Zero reference at 3" valve, which is about 5m above ground.
Pressure buildup at bottom of well. Second run.

Depth (m)	Time	Δtime (min)	Deflection (cm)	Estim. Temp. (°C)	Pressure (bar-g)	Pressure (kg/cm²)	Observations
0	16:17		0.259	168.0	7.16	7.30	WHP=7.6 bar-g
340	16:23	309	1.246	244.0	34.55	35.23	
340	16:44	330	1.265	244.0	35.11	35.80	
340	17:04	350	1.274	244.0	35.37	36.07	
340	17:24	370	1.291	244.0	35.86	36.57	
340	17:44	390	1.299	244.5	36.09	36.80	
340	18:04	410	1.308	244.5	36.35	37.07	
340	18:24	430	1.317	244.5	36.61	37.33	
340	18:44	450	1.323	245.0	36.78	37.51	
340	19:04	470	1.330	245.0	36.99	37.72	
340	19:24	490	1.338	245.0	37.22	37.95	
340	19:44	510	1.344	245.0	37.39	38.13	
340	20:04	530	1.354	245.5	37.68	38.42	
340	20:23	549	1.360	245.5	37.85	38.60	WHP=10.0 bar-g
0			0.400	130.0	11.19	11.41	

STATIC TEMPERATURE AND PRESSURE LOGGING IN WELL BO-4

Date: 01-07-1999

Temperature gauge KT-27786; Clock 6h, serial no. V4101; Time 11:20-13:20
Pressure gauge KP-V3851; Clock 6h, serial no. V4101; Time 13:57-15:33
Zero reference at 3" valve, which is about 2m above ground.

TEMPERATURE				PRESSURE			
Depth (m)	Deflection (cm)	Temperature (°C)	Observations (Temp. Logging)	Deflection (cm)	Pressure (bar)	Pressure (kg/cm^2)	Observations (Press. Logging)
0			WHP about 3 bar-g	0.113	3.27	3.33	WHP about 3 bar-g
100	0.150	94.4	Small bleeding from stuffing box	0.452	12.80	13.05	Small bleeding from stuffing box
200	1.889	148.5		0.779	21.70	22.13	
300	3.090	192.1		1.094	30.51	31.11	
340	3.281	199.2					
400	3.535	209.3		1.395	39.12	39.89	
500	3.979	230.1		1.700	47.82	48.76	
600	4.256	244.8		1.992	56.18	57.29	
700	4.291	246.8		2.281	64.55	65.82	
800	4.342	250.0		2.561	72.69	74.12	
900	4.365	251.7		2.846	80.99	82.59	
1000	4.384	253.1		3.127	89.18	90.94	
1100	4.398	254.1		3.406	97.30	99.22	
0				0.130	3.76	3.83	

DISCHARGE MEASUREMENTS AT WELL BO-4

Separator pressure set at 7 bar-a for calculations

Date	Time	WHP range (bar-g)	WHP best (bar-g)	Line P range (bar-g)	Pc range (bar-g)	Pc best (bar-g)	Weir level (cm)	Weir height (cm)	Total flow (kg/s)	Enthalpy (kJ/kg)	Water flow (kg/s)	Steam flow (kg/s)	Water at sep (kg/s)	Steam at sep (kg/s)	Observations
9.7.1999	13:07		21.3				39.2	11.3			5.9				On 2" bleed line
9.7.1999	14:00		21.8			0.3	39.5	11.0	8.2	1155.4	5.5	2.7	6.4	1.8	Control valve leaking, stem 1.0 cm
9.7.1999	14:20		21.4	2.5		0.3	40.2	10.3	7.5	1256.8	4.7	2.8	5.5	2.0	Valve stem 1.8 cm
9.7.1999	15:55		19.0	6-9	1.8-2.7	2.4	33.5	17.0	22.7	1058.8	16.3	6.4	18.7	4.0	Valve stem 2.5 cm
9.7.1999	17:10		16.0	8-12	3-6	4.2	31.5	19.0	31.4	1138.9	21.4	10.0	24.7	6.7	Valve stem 4.0 cm
9.7.1999	18:20		14.0	11-14	4.4-5.8	5.1	30.0	20.5	37.5	1117.0	25.9	11.6	29.9	7.6	Valve stem 6.5 cm
10.7.1999	08:05		18.3	0.5		0.1	42.5	8.0	4.9	1521.7	2.5	2.4	2.9	2.0	
12.7.1999	08:25		21.1	1.5		-0.1	41.0	9.5	5.8	1162.6	3.9	1.9	4.5	1.3	Control valve closed
12.7.1999	12:25					3.8			30.2						Opened on orifice 62 mm
12.7.1999	12:45					3.3			27.2						
12.7.1999	14:50		18.5	9	2.6-3.2	2.9	33.1	17.4	24.7	1103.5	17.2	7.5	19.8	4.9	
13.7.1999	09:05		21.9				39.5	11.0			5.5				On 2" bleed line
13.7.1999	09:40		22.3	7.0-7.5		2.0	34.6	15.9	19.6	1086.6	13.8	5.8	15.9	3.7	Opened on orifice 50 mm
13.7.1999	10:35	20.5-21.2	21.0	6.0-7.5	1.7-2.0	1.8	34.8	15.7	18.7	1065.6	13.4	5.3	15.4	3.3	Water clear
13.7.1999	11:30	20.4-21.0	21.0	5.5-7.5	1.7-2.0	1.8	34.9	15.6	18.5	1075.1	13.1	5.4	15.1	3.4	
13.7.1999	16:30		20.7			1.8	35.3	15.2	17.7	1103.8	12.3	5.4	14.2	3.5	
14.7.1999	13:35	20.0-20.6	20.6	6.5	1.7-1.9	1.8	35.1	15.4	18.1	1084.0	12.7	5.3	14.7	3.4	
15.7.1999	10:10		7.5						0.0						Well was closed late yesterday

DISCHARGE FROM WELL BO-4, IN kg/s AND ton/hr

Separator pressure set at 7 bar-a for calculations

Date	Time	Total flow (kg/s)	Enthalpy (kJ/kg)	Water flow (kg/s)	Steam flow (kg/s)	Water at sep (kg/s)	Steam at sep (kg/s)	Total flow (t/h)	Water flow (t/h)	Steam flow (t/h)	Water at sep (t/h)	Steam at sep (t/h)
9.7.1999	13:07			5.9					21.2			0.0
9.7.1999	14:00	8.2	1155.4	5.5	2.7	6.4	1.8	29.5	19.8	9.7	23.0	6.6
9.7.1999	14:20	7.5	1256.8	4.7	2.8	5.5	2.0	27.0	16.9	10.1	19.7	7.3
9.7.1999	15:55	22.7	1058.8	16.3	6.4	18.7	4.0	81.7	58.7	23.0	67.4	14.3
9.7.1999	17:10	31.4	1138.9	21.4	10.0	24.7	6.7	113.0	77.0	36.0	88.8	24.2
9.7.1999	18:20	37.5	1117.0	25.9	11.6	29.9	7.6	135.0	93.2	41.8	107.5	27.5
10.7.1999	08:05	4.9	1521.7	2.5	2.4	2.9	2.0	17.6	9.0	8.6	10.6	7.0
12.7.1999	08:25	5.8	1162.6	3.9	1.9	4.5	1.3	20.9	14.0	6.8	16.2	4.7
12.7.1999	12:25	30.2						108.7				
12.7.1999	12:45	27.2						97.9				
12.7.1999	14:50	24.7	1103.5	17.2	7.5	19.8	4.9	88.9	61.9	27.0	71.4	17.5
13.7.1999	09:05			5.5					19.8			
13.7.1999	09:40	19.6	1086.6	13.8	5.8	15.9	3.7	70.6	49.7	20.9	57.2	13.3
13.7.1999	10:35	18.7	1065.6	13.4	5.3	15.4	3.3	67.3	48.2	19.1	55.3	12.0
13.7.1999	11:30	18.5	1075.1	13.1	5.4	15.1	3.4	66.6	47.2	19.4	54.4	12.2
13.7.1999	16:30	17.7	1103.8	12.3	5.4	14.2	3.5	63.7	44.3	19.4	51.2	12.6
14.7.1999	13:35	18.1	1084.0	12.7	5.3	14.7	3.4	65.2	45.7	19.1	52.9	12.2
15.7.1999	10:10	0.0						0.0				