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Testing of Well BO-5 at End of Drilling Operation

Ómar Sigurðsson

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Short Report
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INTRODUCTION

Well BO-5 has been drilled to 610 m (MD). It is directionally drilled with kick off point (KOP) at 225 m with an inclination buildup to about 32° in the direction of N45°E. All depth numbers refer to measured depth unless other is indicated. The well is cased with 9 5/8" casing to 500 m and with 7" drilled (11 mm) liner from 470 m to bottom.

During drilling circulation loss zones were encountered at 525 m and 549 m, but few meters deeper a back flow from the well was observed. The well was killed by injecting mud of 1.10 g/cm^3 density. A cement plug was set in the 9 5/8" production casing to equip the well with a master valve. The plug was drilled out and drilling continued with 1.08 g/cm^3 mud circulating at about 725 l/min (12.1 l/s). About 2/3 of the mud were lost in the well while drilling from 576 m to 610 m depth. Circulation was stopped on January 19, 2001 at about 11:00. The liner was landed on bottom the day after. In the afternoon on January 22 the master valve was changed with a new one. The well had by that time developed 0.8 bar-g wellhead pressure, which was quenched by injecting 4 m^3 of 1.08 g/cm^3 mud. During the following night preparation was made for the completion test.

This report describes the activity that the author participated in during his stay in Guadeloupe in January and February 2001. The data collected by the author during the completion test of BO-5 is reported. Some discussion is provided with the data and preliminary evaluation. The author received help and support of Mr. Bernard Herbrich and Mr. Hervé Traineau in performing the completion test. Furthermore, data collected during the first discharges of BO-5 are reported and discussed. A first approximate evaluation of the production capacity of the well for its conditions prevailing at discharge tests is given. The author thanks the support and help of Mr. Hervé Traineau during that task.

MAIN ACTIVITY IN JANUARY AND FEBRUARY 2001

January 17th: Traveled from Iceland to Paris and continued to Martinique and from there to Guadeloupe. Arrived in Guadeloupe at around 23:00 local time after more than 20 hours of travel.
January 18th: Met with Hervé and Michel at the Bouillante power plant and discussed with them the layout of the discharge test pipe line and rock muffler. Inquiries sent to VGK about few unclear points. Met with CFG personnel at the drilling site of BO-5 and conditions of the well discussed. Was informed of the loss zones encountered at 525 m and 549 m, and the back flow they got a little deeper. Pressure estimated at that zone 53-55 bar-g. Also, informed about problems with the installation of the new master valve, as it did not fit under the drilling rig. Recommended that drilling would be continued to at least the next feed zone to test the pressure conditions in the reservoir.
January 19th: BO-5 site visited, but drilling had been stopped yesterday at 610 m without encountering any new feed zones. Well BO-5 full of mud that was used to kill the well when back flow was obtained earlier and that was used to drill the additional 35 m. It had been decided to let the liner sit on bottom. Work was in progress of putting the liner into the well.

January 20th: Arriving to the BO-5 site the drilling crew with supervisor from Smith International was trying to land the liner the second time. Then the drill string needed to be taken out of the well and the rotary table substructure of the rig moved to allow swapping of master valves.
January 21st: Moving of rotary table substructure in preparation. Discussed with Bernard Herbrich the procedure for the injection test and possibility of obtaining high flow rate of sea water to the drilling site.
January 22nd: Preparation in progress of swapping the old valve from BO-4 with the new WKM-valve. Wellhead pressure about 0.8 bar-g. Well killed again by injecting 4 m^3 of 1.08 g/cm^3 mud. Wellhead pressure fell shortly after with mud level at 20-30 m depth. Wellhead valves swapped. Downhole pressure and temperature gauges made ready. Due to delays it was decided to postpone the completion test to next day.
January 23rd: Arrived early at BO-5 site to prepare measurements of temperature and pressure. Stuffing box had to be altered, but after that temperature was measured to 500 m and pressure to 504 m. The gauges would not sink deeper in the mud despite they had sinker bars. Pressure gauge set at 500 m for the injection test, but injection of about 180 l/min (3 l/s) of fresh water was started while going into the well with the pressure gauge. After slightly more than half hour fresh water injection, the injection rate was increased to about 554-560 l/min (9.2-9.3 l/s) and changed over to sea-water. That injection was maintained for roughly two hours and then stopped. During the relatively small injection the wellhead pressure increased by 8.4 bar-g. Pressure falloff was monitored for an hour before the pressure gauge was retrieved from the well. Temperature profile from 400 m measured again and could the gauge then go to 519 m. Charts from gauges read.
January 24th: Preliminary interpretation made of the completion test and a letter written describing the main findings. In the evening I went with Hervé Traineau and Bernard Herbrich to Pointe a Pitr to meet with Mr. Max Le Nir. Results of the completion test discussed and the possible potential and conditions of well BO-5.
January 25th: Well BO-5 had 2.2 bar-g wellhead pressure. Decided to bleed the well through the kill line to one of the mud tanks to accelerate the thermal recovery of the well and prepare it for discharge. First about 10 m^3 were bled in 23 minutes. The discharge was starting to warm up so the hose to the mud tank was changed with a flexible pipe. The wellhead pressure was 3.4 bar-g when the well was bled again. About 12 m^3 were produced in 14 minutes and boiling was starting when closed. Later that day, the well was bled the third time discharging about 18 m^3 in 20 minutes. When closed the wellhead pressure went to 4.2 bar-g.
January 26th: Logging winch unit overhauled by the drilling crew. Well BO-5 bled for 22 minutes for visitors with Mr. Max Le Nir. Discharge was about 12 m^3. Temperature and pressure profiles measured in the afternoon. Charts from gauges read.
January 27th: Discharge line to the atmospheric separator being installed. Weir box measured and level corrected. Well BO-5 put on discharge at 15:52 through 50 mm orifice to the atmospheric separator. The well discharged until 18:12, but had to be closed then for the night due to noise restrictions. Wellhead pressure rose to 16.2 bar-g and flow was stabilizing. The well appeared with small power, little cleaning occurred and wellhead pressure did not rise when the well was closed. Pumping of sea-water to the upper part of the atmospheric separator tried but did not have any affect to reduce the noise.
January 28th: Temperature profile measured in well BO-5. Gauge went to 511 m depth, but could not sink further into the mud. Well BO-5 discharged to the atmospheric separator trough 175 mm orifice. The well was fully opened at 11:15, but had to be closed at 12:00 due to complains of noise. The discharge started slowly, wellhead pressure rose in 8 minutes to 16 bar-g, fell then for awhile to 14.5 bar-g and rose again to 16-16.5 bar-g. Considerable amount of mud came with the discharge. The discharge rate was high or nearly 180 t/hr (50 kg/s). Temperature profile measured after the discharge to 554 m. Temperature higher than before and gas starts to accumulate at the wellhead after the discharge. Letter with the results of the first discharge trials prepared.
January 29th: Letter with results of the first discharge trials finished and faxed to Mr. Max Le Nir. Decisions had been taken yesterday to move the drilling rig to BO-6 site while construction of the

discharge testing line and rock muffler would be completed. Decided to leave Guadeloupe during this waiting period. Traveled to Paris, France that night.
January 30th: Continued traveling to Copenhagen, Denmark and then to Iceland.

February 7th: Traveled to Paris, France and was scheduled for continued flights to Guadeloupe. Due to long delay in continued flight to Martinique, the connection to Guadeloupe was not possible. The flight was rearranged for direct flight the next day. Stayed over night in Paris.
February 8th: Continued travel to Guadeloupe and arrived there after 16 o'clock at local time.
February 9th: Went to the power plant, where the change of wellhead on BO-2 was nearly finished. Later that day the workover crew fished two packers out of BO-2, but the rubber of the deeper one was left in the well at about 30 m depth. Late in the afternoon or around 17:10 well BO-5 was opened to the main discharge pipe line. It was closed shortly after due to leak at the first valve in the line. After tightening bolts on the valve the well was opened again for few minutes, but closed shortly after as leaking was still at the valve and considerable vibration on the pipe there.
February 10th: Gasket changed at the leaky valve to main discharge pipe line and supports for the pipe line fixed. Well BO-5 opened for few minutes around 12 o'clock, but closed due to leakage at a sampling port valve. Sampling valve tighten and well discharged to rock muffler until 12:45. Large water gushes from the rock muffler and a geyser up from a vertical pipe that was inside of it. Decided that the rock level in the muffler needed to be increased and the vertical pipe closed before further discharge of the well.
February 11th: Came to the BO-5 site around 10 o'clock, but then the well had been discharging for about an hour at fully open flow to the rock muffler. Michel Duvoid had opened the well without making any of the necessary improvements discussed with him the day before. Large water gushes 3-10 m high was up from the rock muffler and mud and salty water rained over the drilling site. Little noise, but its main source was from the old control valve used as a bypass for the high pressure separator. The well was discharged until 15:30 and during that time the wellhead pressure declined rather rapidly. When closed it was 7.3 bar-g. After closing the wellhead pressure rose to 28.5 bar-g in 6 hours. No flow measurements were made during the discharge. Coral rock in the rock muffler had been broken down to pebbles and thrown over its sides.
February 12th: Went to BO-5 site and worked on report. After a phone call from Mr. Le Nir a fax was prepared and sent to him. The fax included points about what was needed as minimum improvements to make the main discharge pipe line operational. No work was done on the line that day.
February 13th: Went to BO-5 site and assisted in rearranging the rocks in the muffler to have the heavier rock near the perforated pipes inside the muffler. Lighter coral rocks from the site were then on top of that. In the afternoon temperature and pressure profiles were measured in BO-5 to 594 m. Work with the discharge line could not be completed that day so discharging was postponed.
February 14th: Went to the site, but work regarding connection of the high pressure separator to the main discharge line and sampling ports was not finished. Around 13 o'clock all connections on the pipe line had been made up so it was ready for use. However, disputes with neighbors caused further postpone of discharge.
February 15th: The dispute with neighbors had been settled and well BO-5 was put on discharge at 9:18. The well discharged to 19:35, but was closed then due to noise complains which originated mainly from the old control valve. Several flow measurements were made during the day. The wellhead pressure declined rapidly as was observed earlier and the discharge became more and more steamy. Mainly it was the water phase that decline while small decline was observed for the steam phase as enthalpy increased to more than 2600 kJ/kg. Connections on valves to the high pressure separator on the separator side leaked when tested.
February 16th: During the night the shut-in wellhead pressure of BO-5 had reached at least 27 bar-g, declined again and was in the morning 12 bar-g. The well was produced at 12:40 for just over 10 minutes for demonstration to funding representatives of the project. Workers working on the high pressure separator connections and installing data acquisition ports to that part of the line.

Phone calls made to Mr. Le Nir to have some thing done about the control valve. Orifice plate changed from 175 mm to 75 mm. Late in the afternoon a glass wool insulation was put on the control valve and the pipe section after it as a trial to reduce the noise from it. At 17:08 well BO-5 was opened through the 75 mm orifice to the rock muffler for continuous discharge.
February 17th: Went to the BO-5 site to measure the flow rates for the well after nearly 16 hours of discharge. The discharge rates were measured again later the day. Interpretation of collected data and preparation of a letter to Mr. Max Le Nir specifying the estimated long term production potential of well BO-5.
February 18th: Letter sent to Mr. Max Le Nir along with another letter with points about what needed to be considered for the continued testing of well BO-5 and preparation for testing the new well BO-6. Discussions with Mr. Hervé Traineau regarding next steps with the testing and what needed to be done to refine the testing pipe line. Packing and caught the night flight to Paris, France.
February 19th: Arrived in Paris, France and continued travel to Iceland.

COMPLETION TESTS

In compliance with the well testing program (Bouillante Geothermal Development – Phase 2, Well Testing Programme) for the new wells drilled from the BO-4 site it was envisaged to obtain the first estimation on the well potential from injection test after setting the liner in the well. In accordance with that the injection test was prepared when the liner had been landed in well BO-5 on January 20th. Preparation was made to obtain high flow rates of sea-water to the drilling site, as fresh water supply was limited. A course procedure was made for the completion test, but due to the conditions of the well prior to the test, it was clear that those procedures could have to be modified considerably. When well BO-5 was ready for testing on January 23rd the well was full of mud. Most of the mud had been sitting in the well since January 19th when circulation was stopped at about 11 o'clock. Additional 4 m^3 of 1.08 g/cm^3 mud had been used to kill 0.8 bar-g wellhead pressure the day before when master valves were swapped.

The completion testing procedure started with measuring the temperature and pressure profiles. The temperature gauge ran to 500 m depth, but could not go deeper as it did not sink into the thick mud, which had settled in the deeper part of the well. Next the pressure gauge was run into the well and while going down the injection of fresh water was started. The cementing pump was used for the injection. The fresh water injection was about 180 l/min (3 l/s). During that injection a wellhead pressure of 1.5 bar-g developed. The pressure gauge did not go deeper than 504 m due to same reasons as for the temperature gauge. It was therefore pulled back to 500 m for the remainder of the test. Fresh water was injected for nearly 70 minutes into the well during the first step of the injection test. In the second injection step treaded sea-water was used and the injection rate increased to about 560 l/min (9.3 l/s). The second injection step lasted for 128 minutes and the wellhead pressure rose to 8.4 bar-g. The injection was stopped and followed by a falloff step for 70 minutes during which the wellhead pressure fell to 3.6 bar-g. During the completion test some water bled of the well from the stuffing box. The temperature and pressure profiles are shown in Figures 1 and 2. Overview of the progression of the completion test is shown in Figure 3. Due the development and rise of the wellhead pressure the completion test was had short to minimize further invasion of mud into the feed zones.

Figure 4 shows the second injection step on semi logarithmic graph with a match to an analytical model (double porosity slap). Figure 5 shows the same step and the match on a log-log graph, but there the pressure change has been normalized with the injection rate. Figure 5 is useful when comparing different wells. The change in injection rate between the first and second step (6.3 l/s) is used here in interpretations, but could be less due to bleeding along the wire in the stuffing box. The results for transmissivity and injectivity could therefore be lower than presented here. The

response of the falloff step is not shown, but it appeared to be influenced by the bleeding from the stuffing box.

The following main conclusions can be drawn from the shape of the pressure response during injection and interpretations of the data:

- The injection test indicates that there are at least two feed zones active in the test.
- Estimated transmissivity is low, formation storage normal, and skin factor lower than could be expected given the conditions for the well prior to the testing. The negative skin factor is indicative of fractures, but since the well was full of thick mud a considerably higher value could have been expected, indicating damages to the near well permeability due to mud invasion.
- The injectivity index is lower than 54 l/min per bar (0.9 l/s per bar).
- The bleeding along the wire from the stuffing box heavily influences the main response of the falloff test.

FIRST DISCHARGE TRIALS

A temporary setup of the discharge test line to the atmospheric silencer/separator was finished in the afternoon on January 27, 2001 allowing the first discharge trials. Well BO-5 was discharged between 15:52-18:12 that day through a 50 mm orifice in the discharge line. The main objectives were to test the line and observe the development of the wellhead pressure. The reason being the anticipated higher reservoir temperature than in well BO-4 or a possible existence of a steam cap which could have increased the wellhead pressure above the designed pressure criteria for the discharge line (20 bar). The temperature and pressure profiles which had been measured the day before will be discussed later in this report. During the discharge the wellhead pressure rose to 16.2 bar-g and the total discharge rate appeared to be stabilizing around 73 t/hr (20.3 kg/s) (see Tables in appendix). Considering measurement errors the fluid enthalpy corresponded to less than 240°C reservoir temperature. High pressure steam produced was about 12 t/hr (3.4 kg/s). Little cleaning of mud and cuttings was observed during the discharge and the well characteristics indicated liquid dominated reservoir. A temperature profile measured in the morning on January 28th (15 hours after the discharge) could only go to 511 m depth, recording a maximum temperature of 250°C. During this first discharge the well was weak as mud blocked the known feed zones at 525 m and between 549-560 m. The test could not reveal the true capacity of the well.

After the temperature run in the morning on January 28th, the 50 mm orifice plate was replaced with a 175 mm orifice plate, thereby removing all restriction in the discharge line. The well was then discharged between 11:15-12:00, but had to be closed due to noise restrictions and complains there about. During this short discharge, the characteristics of the well were completely different from the first discharge (see Tables in appendix). The total discharge rate reached over 170 t/hr (over 47 kg/s) at the same wellhead pressure of 16 bar-g, but indications were that it was beginning to decline. High pressure steam produced was about 32 t/hr (8.9 kg/s). Mud was produced from the interval 511-554m, and after the discharge gas started to accumulate at the wellhead. Temperature recorded 4 hours later showed maximum of 257.5°C, about 10°C higher temperature than measured in well BO-4 at the same depth.

Permanent discharge pipe line was not ready for allowing well BO-5 to be put in continuous discharge. On February 10th the well was opened for half an hour to test the discharge line, but had to be closed due to leakage and large water gushing from the rock muffler. Without necessary improvements on the discharge line the well was opened again on Sunday February 11th and discharged for 6,5 hours in a fully open flow conditions. No flow measurements were made, but wellhead pressure declined from about 14.5 bar-g to 7.3 bar-g during the discharge (Figure 6). The wellhead pressure was still declining when the well was closed. Mud was produced from the

interval 554-594m. The characteristics of the well were similar to those at the second discharge, but the discharge was becoming dry. The wellhead pressure rose to about 28.5 bar-g in 6 hours after the well was shut-in (Figure 7). Temperature profile measured two days later indicated nearly 260°C reservoir temperature at 594m (Figure 1). On February 15th most of the required minimum improvements on the discharge pipe line were completed and well BO-5 was discharged to the rock muffler, but changed to the atmospheric separator/silencer for measurements. Unfortunately, the discharge had to be stopped after about 10 hours due to noise complains. Wellhead pressure appeared to be stabilizing at about 6 bar-g. Measured total discharge rate declined from about 145 t/hr (40.3 kg/s) to 42.5 t/hr (11.8 kg/s), but had nearly become dry (steam) so the high pressure steam rate was about 40 t/hr (11.1 kg/s). Figure 8 shows the evolvement of the flow rates, wellhead pressure and enthalpy for this discharge.

The rock muffler worked well as a silencer on the discharge even though a lot of the coral rocks in it were broken down to pebbles and thrown over its sides. The main source of noise in the discharge pipe line was after the control valve, which was used as a bypass valve for the high pressure separator. The tongue in the control valve caused some diversion on the flow thereby increasing the noise. A glass wool was put on that pipe section to reduce that noise. The orifice plate was changed from 175 mm to 75 mm. It was not until late in the afternoon on February 16th that well BO-5 could be put in continuous discharge or 27 days after the completion of the well. After nearly 24 hour discharge through the 75 mm orifice plate the wellhead pressure was 12.7 bar-g and declining. Total flow rate was 34.6 t/hr (9.6 kg/s) and high pressure steam rate was 25.8 t/hr (7.2 kg/s). Flowing enthalpy was estimated about 2230 kJ/kg.

The main conclusions that can be drawn from the first discharges for well BO-5 are:

- Three feed zones are active in the well. Feed zones at 525 m and 549-560 m found during drilling, and at 594 m, which became active during the second discharge.
- These feed zones act as small fractures situated in low permeability rock formations. The reservoir is liquid dominated with temperature near 260°C. The initial production is high and unloads the liquid from the fracture volume. The permeability of the rock formations cannot reload the fractures at that rate so the pressure falls to the boiling pressure and boiling starts in the fractures and the rock formations. Wellhead pressure and flow rates decline. The boiling escalates into the rock formations due to pressure drawdown and changes in relative permeabilities. The production becomes dryer (higher steam ratio) and produced enthalpy increases.
- For fully open well the current data indicates that the wellhead pressure will stabilize around 6 bar-g with total flow around 30 t/hr (8.3 kg/s). The enthalpy of the flow will be high or more than 2600 kJ/kg so most of it will be steam. The high pressure steam rate could be as high as 28 t/hr (7.8 kg/s) that can be considered as maximum for the steam rate over a longer term.
- On February 17th well BO-5 was producing through a 75 mm orifice plate with wellhead pressure of 12.7 bar-g. According to Russell James method the calculated total flow rate was 34.6 t/hr (9.6 kg/s), flowing enthalpy 2227 kJ/kg, and steam rate at 6 bar-a was 25.8 t/hr (7.2 kg/s).

TEMPERATURE AND PRESSURE PROFILES

Temperature and pressure profiles measured in well BO-5 are presented in Figures 1 and 2 along with profiles from well BO-4 for comparison. The temperature profiles from January 28th and February 13th should be representative for the formation temperature at well BO-5. In the cased section of well BO-5 the formation temperature appears to be about 20°C higher than at well BO-4. In the open part the formation temperature is about 10°C higher in BO-5. The highest recorded temperature in well BO-5 was 259°C at 594 m. The pressure profiles from January 26th and February 13th should be representative for the static pressure in well BO-5. Weak indication is that

the higher feed zones have slightly higher pressure than the zone at 594 m. It is clear from the temperature and pressure profiles that the reservoir is liquid dominated. Its pressure potential is very similar to that at well BO-4, which could be better visualized if the measured depth in BO-5 would be corrected to true vertical depth.

CONCLUSIONS

The reservoir temperature at well BO-5 below 500 m depth is about 10°C higher than at well BO-4. That indicates that well BO-5 is closer to the main reservoir source than well BO-4. On surface the distance between wells BO-4 and BO-5 is less than 10 m, but at nearly 600 m depth the distance between the wells is more than 120 m. As well BO-5 is directionally drilled and currently only to 610 m deep, the reservoir temperature could be higher than 260°C.

The static pressure profile measured in well BO-5 in warm conditions is about the same as the pressure profile obtained for well BO-4 under similar conditions. So the over pressure for a warm well (in eqilibrium with formation temperature) is about the same at both wells or only 3-4 bar-g. Indication of a higher over pressure at 554 m in well BO-5 during drilling was most likely caused by gas, as it has not been observed again.

The active feed zones in well BO-5 appear to be fractures situated in low permeability rock formation. The initial production is high, as the liquid is unloaded from the well and the fracture volumes. Due to the low permeability of the rock formation the pressure declines rather quickly in the well and boiling starts, which escalates into the fractures and the rock formation. The relative permeability of the formation changes, which further reduces the water flow to the fractures while increasing the steam flow and the discharge becomes dryer.

The only discharge data available now for well BO-5 has been obtained during short discharge periods. Nevertheless, it is estimated that during longer term production the high pressure steam production potential will be in the range 24-28 t/hr (6.7-7.8 kg/s). For that production the wellhead pressure could be as low as 6 bar-g (7 bar-a). However, this is above the economic criteria set for the continuation of the project at 19.3 t/hr (5.4 kg/s) of steam at 6 bar-a.

Reykjavik 27 February 2001

Omar Sigurdsson
Geothermal Reservoir Engineer

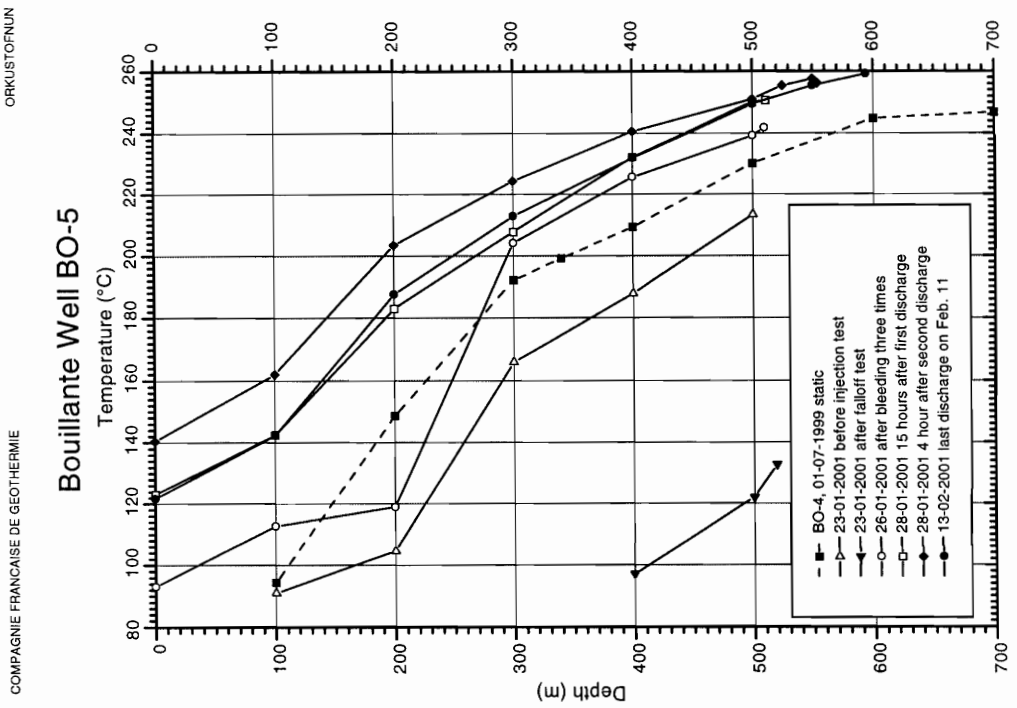

Figure 1. Temperature profiles measured in well BO-5 with comparison to temperature in well BO-4 from 1999.

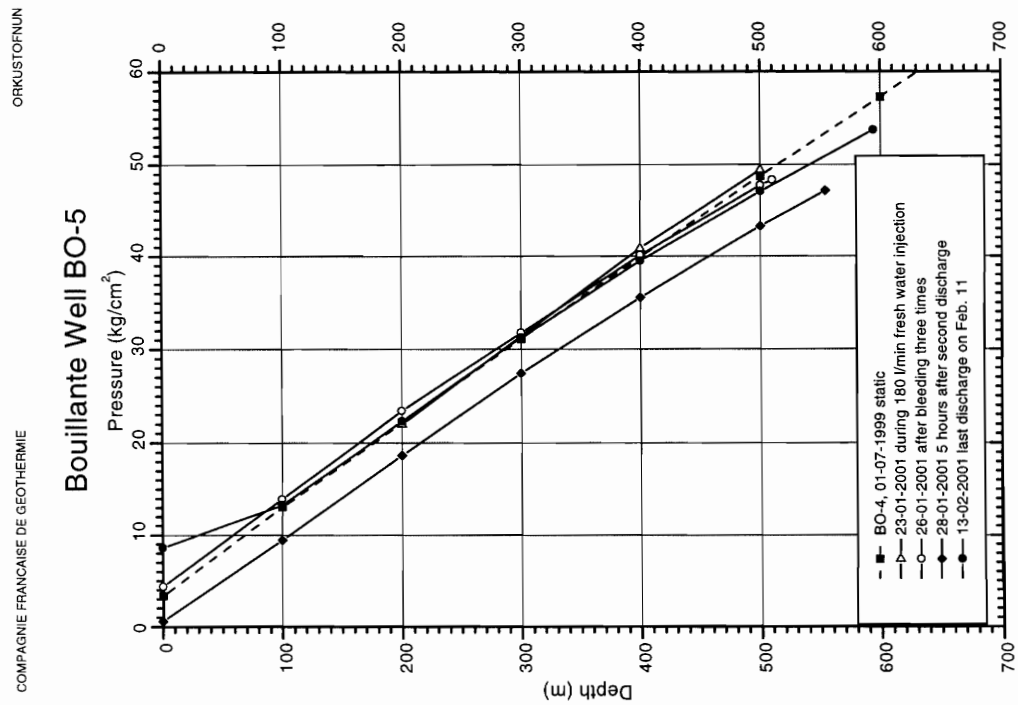

Figure 2. Pressure profiles measured in well BO-5 with comparison to pressure in well BO-4 from 1999.

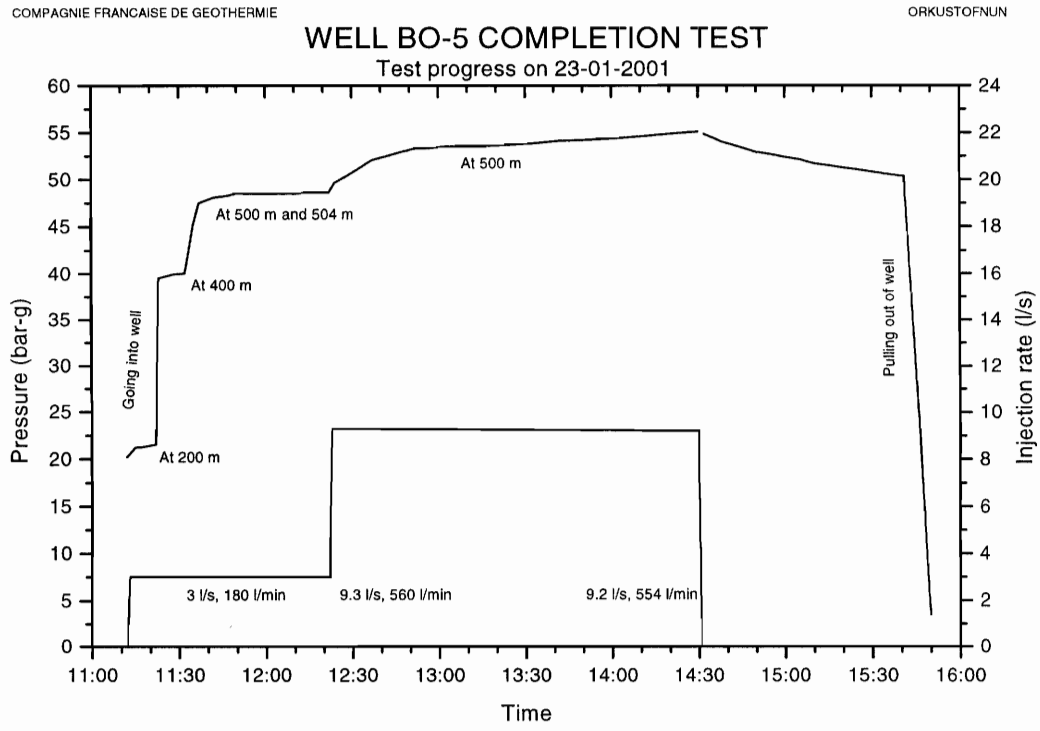

Figure 3. Progress of the completion test conducted on February 23rd 2001.

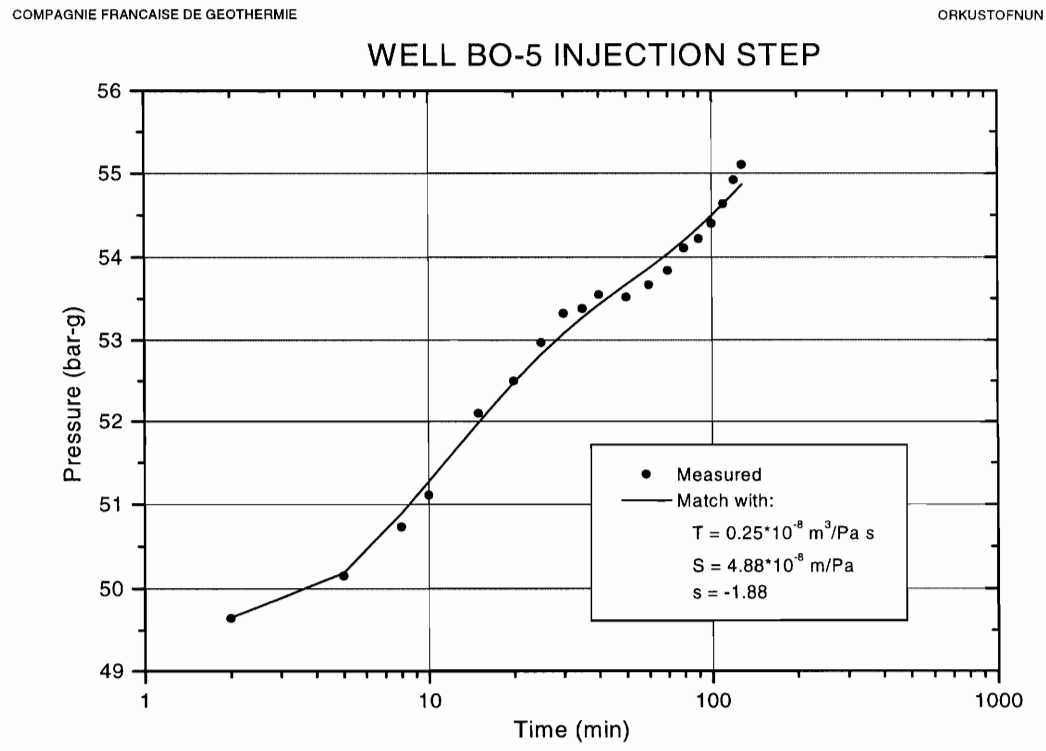

Figure 4. The second injection step during the completion test with a match to analytical double porosity model.

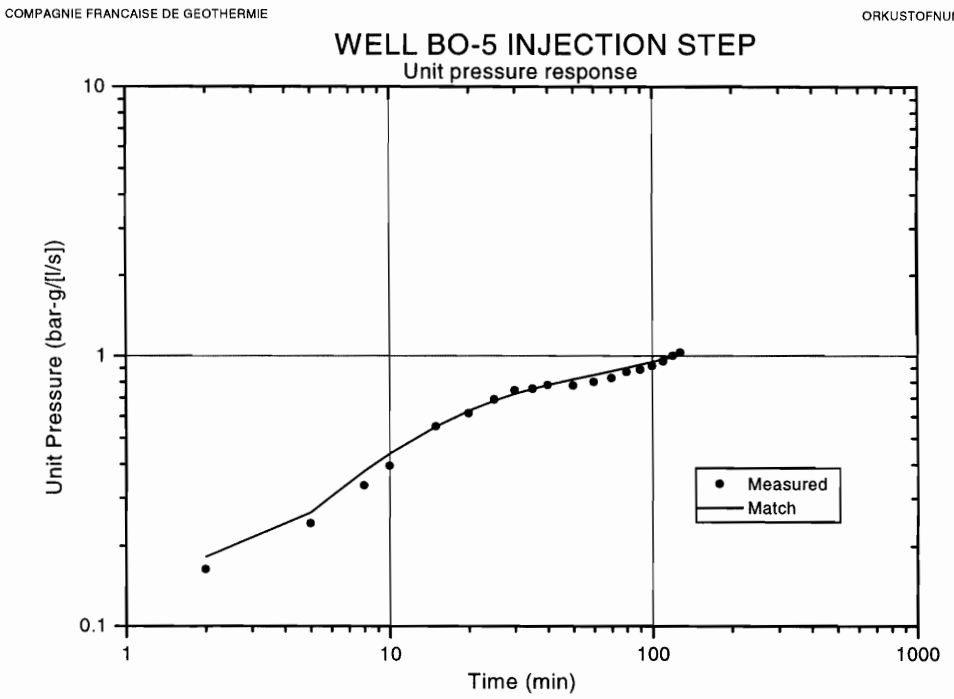

Figure 5. Normalized pressure response of the second injection step with match to analytical double porosity model.

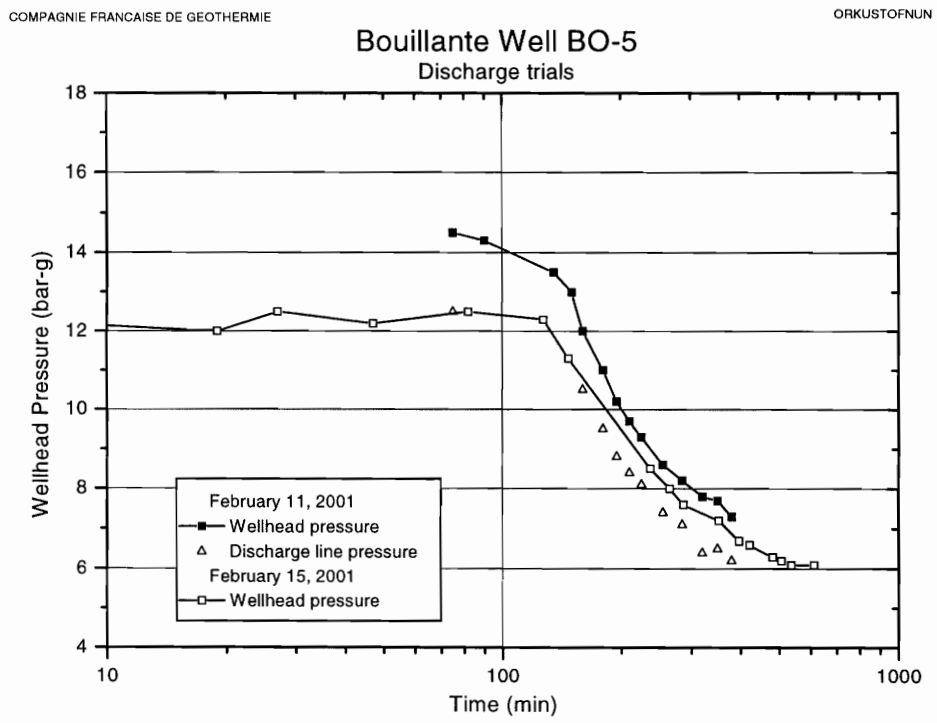

Figure 6. The development of wellhead pressure during two discharge trials at fully open flow conditions.

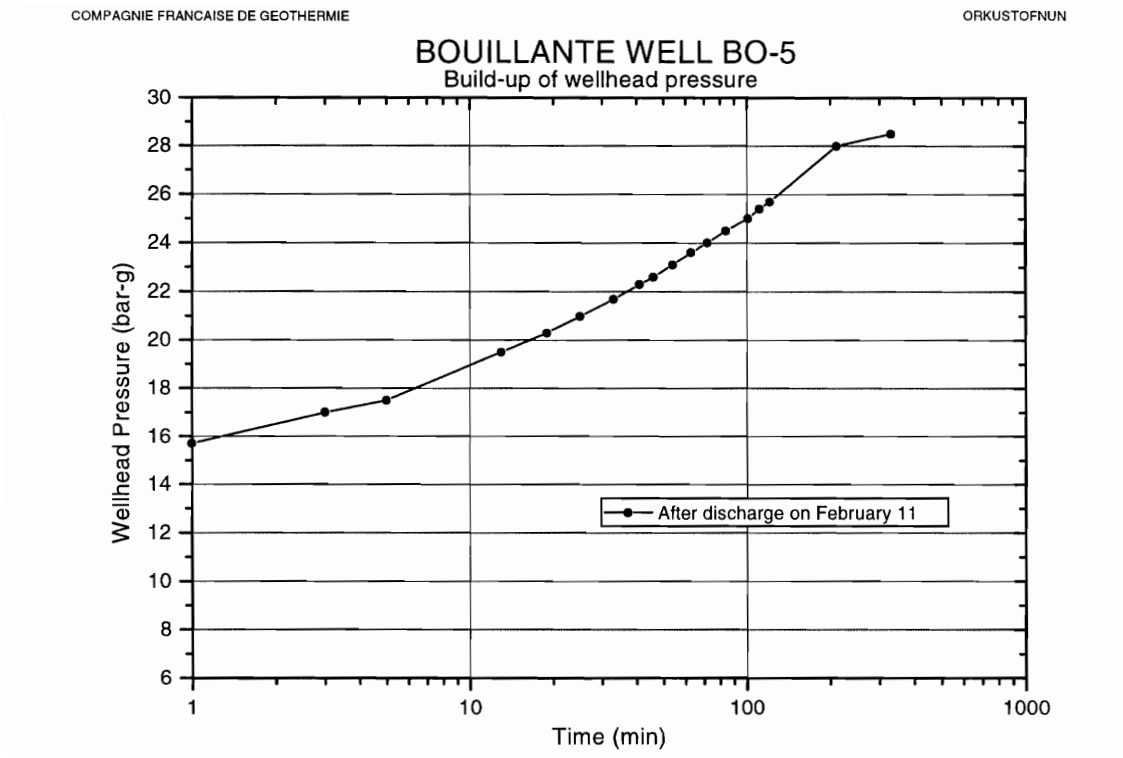

Figure 7. Recovery of wellhead pressure after a discharge at fully open flow conditions.

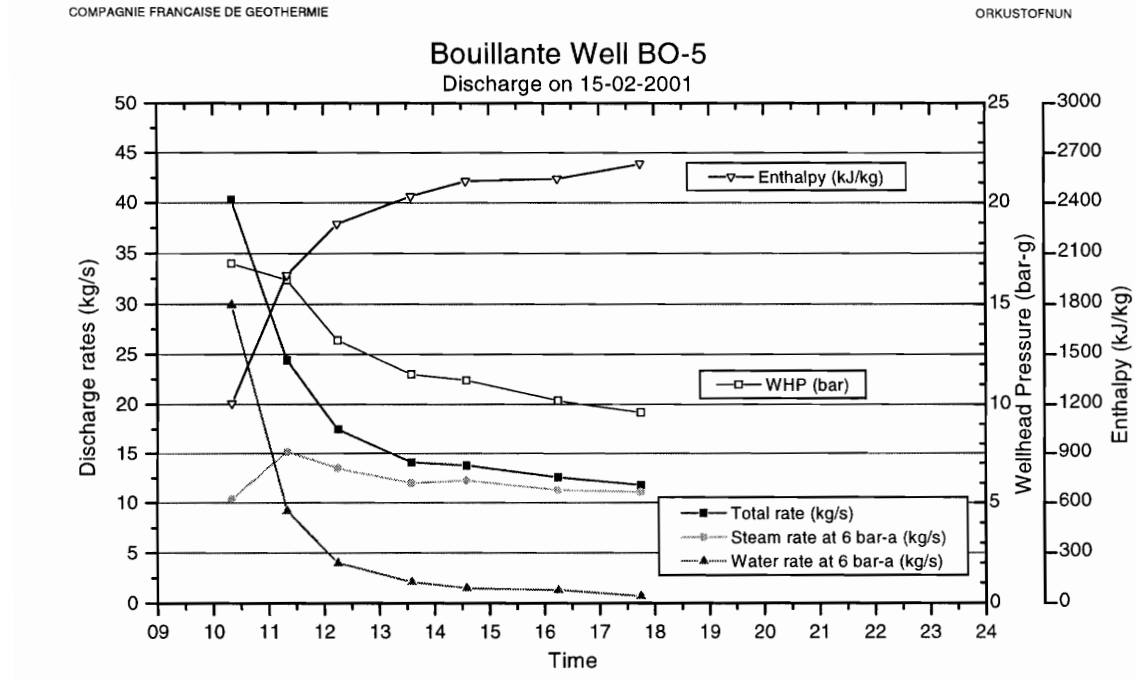

Figure 8. Flow rates, wellhead pressure and enthalpy changes during a discharge at fully open flow conditions.

APPENDIX

Static temperature and pressure logging in well BO-5

Completion test in well BO-5

Discharge measurements at well BO-5

Discharge from well BO-5 in kg/s and ton/hr

Four letters sent to CFG during testing of well BO-5

STATIC TEMPERATURE PROFILES IN WELL BO-5

Date: 23-01-2001

Temperature gauge KT-10077; Clock 6h, serial no. V4109; Time 9:20-10:20
Temperature gauge KT-10077; Clock 6h, serial no. V4109; Time 16:20-17:00
Zero reference at stuffing box, which is about 3m above cellar.

TEMPERATURE				TEMPERATURE			
Depth (m)	Deflection (cm)	Temperature (°C)	Observations (Temp. Logging)	Depth (m)	Deflection (cm)	Temperature (°C)	Observations (Temp. Logging)
100	0.020	91.0					
200	0.258	104.6					
300	1.367	165.9					
400	1.777	187.8		400	0.126	97.10	
500	2.275	213.3	Gauge stops on thick mud	500	0.562	122.00	
				519	0.754	132.70	Gauge stops on thick mud

Remarks: Circulation of 1.08 g/cm3 mud stopped around 11:00 on 19-01-2001. For change of master valve 4 m3 of 1.08 g/cm3 mud were injected on 22-01-2001. Between the temperature logs an injection test was carried out with fresh water and treaded sea-water.

COMPAGNIE FRANCAISE DE GEOTHERMIE ORKUSTOFNUN

STATIC TEMPERATURE AND PRESSURE PROFILES IN WELL BO-5

Date: 26-01-2001

Temperature gauge KT-10077; Clock 6h, serial no. V4109; Time 14:25-15:25
Pressure gauge KP-V3851; Clock 6h, serial no. V4109; Time 16:00-16:50
Zero reference about 3m above cellar.

TEMPERATURE				PRESSURE			
Depth (m)	Deflection (cm)	Temperature (°C)	Observations (Temp. Logging)	Deflection (cm)	Pressure (bar)	Pressure (kg/cm^2)	Observations (Press. Logging)
0				0.151	4.28	4.36	WHP=4.3 bar-g
100	0.399	112.7		0.486	13.68	13.95	
200	0.507	118.9		0.815	22.96	23.41	
300	2.097	204.2		1.119	31.15	31.76	
400	2.514	225.6		1.406	39.33	40.10	
500	2.775	239.2		1.668	46.83	47.75	
510	2.825	241.8	WHP=4.3 bar-g	1.689	47.42	48.35	
0	0.056	93.0		0.154	4.36	4.45	WHP=4.3 bar-g

COMPLETION TEST IN WELL BO-5
Injection steps

Date: 23-01-2001

Pressure gauge KP-V3851; Clock 6h, serial no. V4109; Time 11:10-14:30
Zero reference at stuffing box, which is about 3m above cellar.
Main injection and falloff step at 500m.

Depth (m)	Time	Δtime (min)	Deflection (cm)	Estim. Temp. (°C)	Pressure (bar-g)	Pressure (kg/cm^2)	Observations
200	11:12		0.716	104.0	20.21	20.61	No pumping
200	11:15	3	0.752	104.0	21.24	21.66	Injecting 3 l/s started
200	11:17	5	0.754	104.0	21.30	21.72	
200	11:22	10	0.763	104.0	21.56	21.98	WHP=1.0 bar-g
400	11:23	11	1.398	165.0	39.51	40.29	Bleeding with wire
400	11:28	16	1.413	165.0	39.94	40.73	
400	11:32	20	1.417	165.0	40.06	40.85	WHP=1.2 bar-g
500	11:35	23	1.599	187.0	45.19	46.08	WHP=1.25 bar-g
504	11:37	25	1.678	187.0	47.49	48.42	Gauge sitting on thick mud
504	11:42	30	1.698	187.0	48.07	49.02	
504	11:47	35	1.705	187.0	48.27	49.22	
504	11:50	38	1.713	187.0	48.51	49.46	Gauge lifted, WHP=1.3 bar-g
500	11:55	43	1.707	166.0	48.48	49.43	
500	12:00	48	1.707	166.0	48.48	49.43	WHP=1.5 bar-g
500	12:05	53	1.707	166.0	48.48	49.43	
500	12:10	58	1.707	166.0	48.48	49.43	
500	12:15	63	1.707	146.0	48.62	49.58	
500	12:20	68	1.707	146.0	48.62	49.58	
500	12:22	70	1.707	146.0	48.62	49.58	Injection increased
500	12:24	2	1.739	132.0	49.65	50.63	Injecting 9.3 l/s, WHP=3.7 bar-g
500	12:27	5	1.756	132.0	50.15	51.14	
500	12:30	8	1.776	132.0	50.73	51.73	
500	12:32	10	1.789	132.0	51.11	52.12	WHP=5.1 bar-g
500	12:37	15	1.823	132.0	52.10	53.13	WHP=6.0 bar-g, fluctuating
500	12:42	20	1.837	132.0	52.50	53.53	
500	12:47	25	1.853	132.0	52.97	54.01	
500	12:52	30	1.865	132.0	53.32	54.37	WHP=6.2 bar-g, fluctuating
500	12:57	35	1.867	132.0	53.38	54.43	
500	13:02	40	1.873	132.0	53.55	54.60	
500	13:12	50	1.872	132.0	53.52	54.57	
500	13:22	60	1.877	132.0	53.67	54.73	WHP=6.7 bar-g
500	13:32	70	1.883	132.0	53.84	54.90	
500	13:42	80	1.892	132.0	54.11	55.17	WHP=7.5 bar-g
500	13:52	90	1.896	132.0	54.22	55.29	
500	14:02	100	1.902	132.0	54.40	55.47	
500	14:12	110	1.910	132.0	54.63	55.71	WHP=8.0 bar-g
500	14:22	120	1.920	132.0	54.92	56.00	Injecting 9.2 l/s, WHP=8.2 bar-g
500	14:30	128	1.926	132.0	55.10	56.18	Pump stopped, WHP=8.4 bar-g

COMPLETION TEST IN WELL BO-5

Falloff step

Date: 23-01-2001

Pressure gauge KP-V3851; Clock 6h, serial no. V4109; Time 14:30-15:41
Zero reference at stuffing box, which is about 3m above cellar.
Main injection and falloff step at 500m.

Depth (m)	Time	Δtime (min)	Deflection (cm)	Estim. Temp. (°C)	Pressure (bar-g)	Pressure (kg/cm^2)	Observations
500	14:32	2	1.918	132.0	54.84	55.92	WHP=7.9 bar-g
500	14:35	5	1.904	132.0	54.46	55.53	WHP=7.5 bar-g
500	14:38	8	1.890	132.0	54.05	55.11	Bleeding with wire
500	14:40	10	1.885	132.0	53.90	54.96	
500	14:45	15	1.869	132.0	53.44	54.49	
500	14:50	20	1.853	132.0	52.97	54.01	
500	14:55	25	1.844	132.0	52.71	53.75	WHP=5.5 bar-g
500	15:00	30	1.834	132.0	52.42	53.45	
500	15:05	35	1.825	132.0	52.16	53.19	
500	15:10	40	1.810	132.0	51.72	52.74	WHP=4.7 bar-g
500	15:15	45	1.803	132.0	51.51	52.52	
500	15:20	50	1.795	132.0	51.28	52.29	
500	15:25	55	1.787	132.0	51.05	52.05	
500	15:30	60	1.779	132.0	50.82	51.82	
500	15:35	65	1.771	132.0	50.58	51.58	
500	15:40	70	1.764	132.0	50.38	51.37	WHP=3.6 bar-g
500	15:41	71	1.764	132.0	50.38	51.37	Gauge pulled out
0			0.124	132.0	3.47	3.54	

COMPAGNIE FRANCAISE DE GEOTHERMIE

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STATIC TEMPERATURE PROFILE IN WELL BO-5

Date: 28-01-2001

Temperature gauge KT-10077; Clock 6h, serial no. V4109; Time 9:20-10:20
Zero reference at stuffing box, which is about 3m above cellar.

TEMPERATURE				TEMPERATURE			
Depth (m)	Deflection (cm)	Temperature (°C)	Observations (Temp. Logging)	Depth (m)	Deflection (cm)	Temperature (°C)	Observations (Temp. Logging)
0	0.582	123.1	WHP about 3 bar-g				
100	0.930	142.4					
200	1.686	183.0	Small bleeding through line valve				
300	2.167	207.8					
400	2.640	232.1					
500	2.986	250.1					
511	2.994	250.6	Gauge stops on thick mud				
			WHP about 5 bar-g				

Remarks: Discharge of about 73 t/hr (20.3 kg/s) from 15:52 to 18:12 on January 27.

STATIC TEMPERATURE AND PRESSURE PROFILES IN WELL BO-5

Date: 28-01-2001

Temperature gauge KT-10077; Clock 6h, serial no. V4109; Time 16:00-17:00
Pressure gauge KP-V3851; Clock 6h, serial no. V4101; Time 17:30-18:30
Zero reference at stuffing box, which is about 3m above cellar.

TEMPERATURE				PRESSURE			
Depth (m)	Deflection (cm)	Temperature (°C)	Observations (Temp. Logging)	Deflection (cm)	Pressure (bar)	Pressure (kg/cm^2)	Observations (Press. Logging)
0	0.895	140.4	Unclear reading, WHP about 2 bar-g	0.020	0.56	0.57	WHP 0.6 bar-g
100	1.294	162.0	Bleeding of gas from stuffing box	0.335	9.27	9.45	Bleeding of gas from stuffing box
200	2.082	203.5		0.671	18.32	18.68	Wire sticking in stuffing box
300	2.488	224.3		0.977	26.88	27.41	
400	2.803	240.6		1.256	34.87	35.56	
500	3.001	251.0		1.519	42.44	43.28	
525	3.086	255.4					
550	3.127	257.5					
554	3.101	256.2		1.651	46.26	47.17	WHP 1.1 bar-g
0				0.048	1.34	1.37	

Remarks: Full discharge of upto 175 t/hr (48.5 kg/s) from 11:15 to 12:00 on January 28.

COMPAGNIE FRANCAISE DE GEOTHERMIE

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STATIC TEMPERATURE AND PRESSURE PROFILES IN WELL BO-5

Date: 13-02-2001

Temperature gauge KT-10077; Clock 6h, serial no. V4109; Time 13:50-15:00
Pressure gauge KP-V3851; Clock 6h, serial no. V4101; Time 15:20-16:30
Zero reference at stuffing box, which is about 3m above cellar.

TEMPERATURE				PRESSURE			
Depth (m)	Deflection (cm)	Temperature (°C)	Observations (Temp. Logging)	Deflection (cm)	Pressure (bar)	Pressure (kg/cm^2)	Observations (Press. Logging)
0			WHP 13.5 bar-g	0.300	8.42	8.59	WHP 9.0 bar-g
100	0.928	142.3	Bleeding of gas from stuffing box	0.468	13.04	13.30	Bleeding of gas from stuffing box
200	1.773	187.6		0.795	21.87	22.30	
300	2.263	212.8	WHP 11.9 bar-g	1.104	30.65	31.25	WHP 8.4 bar-g
400	2.633	231.8	WHP 11.7 bar-g	1.387	38.73	39.49	
500	2.971	249.4	WHP 11.5 bar-g	1.648	46.18	47.09	WHP 8.0 bar-g
550	3.085	255.4					
594	3.156	259.1		1.873	52.70	53.74	
0	0.557	121.7		0.223	6.28	6.40	WHP 7.0 bar-g

Remarks: Temperature gauge not stabilized at 100m and 200m so readings there could be higher.
Well was discharged on a fully open flow for 6.5 hours on February 11.

COMPAGNIE FRANCAISE DE GEOTHERMIE

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DISCHARGE MEASUREMENTS AT WELL BO-5 ON JANUARY 27 AND 28

Separator pressure set at 6 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
27.1.2001	15:52		2.0												Well opened, range of WHP-gauge 40 bar
27.1.2001	15:55						36.0	14.5			10.8				Orifice 50 mm
27.1.2001	15:58						37.2	13.3			8.7				
27.1.2001	16:05		1.0				36.2	14.3			10.5				
27.1.2001	16:08		1.8												
27.1.2001	16:12		3.0		0-0.5	0.3	36.4	14.1	12.2	809.3	10.1	2.1	11.4	0.8	Boiling starting
27.1.2001	16:17			5.5	1-2	1.5	32.0	18.5	23.6	782.1	19.8	3.8	22.3	1.3	
27.1.2001	16:23		12.2	7.0		2.5	32.2	18.3	25.6	973.9	19.3	6.3	21.9	3.7	
27.1.2001	16:28		14.5			1.8	34.0	16.5	20.1	999.8	14.9	5.2	16.9	3.2	
27.1.2001	16:43		15.5	6.5-7.0		1.8	34.0	16.5	20.1	999.8	14.9	5.2	16.9	3.2	
27.1.2001	17:10		16.0			1.9	27.0	23.5	41.9	1019.7	14.9	5.4	16.9	3.4	21.6 kg/s of seawater pumped to separator
27.1.2001	17:25		16.2	7.0		1.9	34.0	16.5	20.3	1019.7	14.9	5.4	16.9	3.4	Pumping of seawater stopped
27.1.2001	17:50		15.8	6.5		1.9	34.0	16.5	20.3	1019.7	14.9	5.4	16.9	3.4	
27.1.2001	18:10		16.2			1.8	33.9	16.6	20.3	991.0	15.1	5.1	17.2	3.1	
27.1.2001	18:12		16.0												Well closed after test of flow line
28.1.2001	11:14		5.0												Start to open on 175 mm orifice
28.1.2001	11:15		1.0												Well fully open
28.1.2001	11:19		4.5			2.8			22.7						
28.1.2001	11:21		8.5												
28.1.2001	11:23		16.0												
28.1.2001	11:27		15.0												
28.1.2001	11:30		14.5												
28.1.2001	11:34		16.0												
28.1.2001	11:38		16.5		6-7	6.5	27.2	23.3	48.9	1049.9	35.2	13.7	40.0	8.9	Approximate readings due to high flow
28.1.2001	11:45		16.5			6.5	27.4	23.1	48.2	1062.8	34.5	13.8	39.1	9.1	
28.1.2001	11:55		16.0			6.3	27.5	23.0	47.4	1053.7	34.1	13.3	38.7	8.7	
28.1.2001	12:00		16.0												Well closed due to noise complains

COMPAGNIE FRANCAISE DE GEOTHERMIE ORKUSTOFNUN

DISCHARGE FROM WELL BO-5, IN kg/s AND ton/hr ON JANUARY 27 AND 28

Separator pressure set at 6 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)
27.1.2001	15:52											
27.1.2001	15:55			10.8					38.9			
27.1.2001	15:58			8.7					31.3			
27.1.2001	16:05			10.5					37.8			
27.1.2001	16:08											
27.1.2001	16:12	12.2	809.3	10.1	2.1	11.4	0.8	43.9	36.4	7.6	41.0	2.9
27.1.2001	16:17	23.6	782.1	19.8	3.8	22.3	1.3	85.0	71.3	13.7	80.4	4.5
27.1.2001	16:23	25.6	973.9	19.3	6.3	21.9	3.7	92.2	69.5	22.7	78.8	13.4
27.1.2001	16:28	20.1	999.8	14.9	5.2	16.9	3.2	72.4	53.6	18.7	60.9	11.4
27.1.2001	16:43	20.1	999.8	14.9	5.2	16.9	3.2	72.4	53.6	18.7	60.9	11.4
27.1.2001	17:10	41.9	1019.7	14.9	5.4	16.9	3.4	150.8	53.6	19.4	60.8	12.2
27.1.2001	17:25	20.3	1019.7	14.9	5.4	16.9	3.4	73.1	53.6	19.4	60.9	12.2
27.1.2001	17:50	20.3	1019.7	14.9	5.4	16.9	3.4	73.1	53.6	19.4	60.9	12.2
27.1.2001	18:10	20.3	991.0	15.1	5.1	17.2	3.1	73.1	54.4	18.4	61.9	11.2
27.1.2001	18:12											
28.1.2001	11:14											
28.1.2001	11:15											
28.1.2001	11:19	22.7						81.7				
28.1.2001	11:21											
28.1.2001	11:23											
28.1.2001	11:27											
28.1.2001	11:30											
28.1.2001	11:34											
28.1.2001	11:38	48.9	1049.9	35.2	13.7	40.0	8.9	176.0	126.7	49.3	144.0	32.0
28.1.2001	11:45	48.2	1062.8	34.5	13.8	39.1	9.1	173.5	124.2	49.7	140.9	32.6
28.1.2001	11:55	47.4	1053.7	34.1	13.3	38.7	8.7	170.6	122.8	47.9	139.3	31.3
28.1.2001	12:00											

COMPAGNIE FRANCAISE DE GEOTHERMIE

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DISCHARGE OF WELL BO-5 TO ROCK MUFFLER ON FEBRUARY 11

First long term discharge trial

Date	Time	WHP range (bar-g)	WHP best (bar-g)	Line P 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)	Observations
11.2.2001	09:00		5.0									Well opened, time approximate
11.2.2001	10:15		14.5	12.5								No conditions to measure flow rates
11.2.2001	10:30	14-14.5	14.3									due to limitation of noise
11.2.2001	11:15		13.5									
11.2.2001	11:30		13.0									Flow rates high, water gushing over
11.2.2001	11:40		12.0	10.5								sides of rock muffler
11.2.2001	12:00		11.0	9.5								
11.2.2001	12:15		10.2	8.8								
11.2.2001	12:30		9.7	8.4								Flow becoming dryer
11.2.2001	12:45		9.3	8.1								
11.2.2001	13:15		8.6	7.4								
11.2.2001	13:45		8.2	7.1								
11.2.2001	14:20		7.8	6.4								Water fraction seemingly small
11.2.2001	14:50		7.7	6.5								
11.2.2001	15:20		7.3	6.2								
11.2.2001	15:30		15.7									Well closed
11.2.2001	15:32		17.0									
11.2.2001	15:34		17.5									
11.2.2001	15:42		19.5									
11.2.2001	15:48		20.3									
11.2.2001	15:54		21.0									
11.2.2001	16:02		21.7									
11.2.2001	16:10		22.3									
11.2.2001	16:15		22.6									
11.2.2001	16:23		23.1									
11.2.2001	16:32		23.6									
11.2.2001	16:41		24.0									
11.2.2001	16:53		24.5									
11.2.2001	17:10		25.0									
11.2.2001	17:20		25.4									
11.2.2001	17:30		25.7									
11.2.2001	19:00		28.0									Approximate reading
11.2.2001	21:00		28.5									
12.2.2001	09:30		13.5									
12.2.2001	13:30		11.5									
12.2.2001	16:00		11.0									
13.2.2001	08:45		13.0									Gas accumulated on wellhead
13.2.2001	09:30		13.5									
14.2.2001	08:15		5.5									Gas bled during measurement of
14.2.2001	09:50		5.5									T and P profiles yesterday
14.2.2001	14:25		5.3									

COMPAGNIE FRANCAISE DE GEOTHERMIE

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DISCHARGE MEASUREMENTS AT WELL BO-5 ON FEBRUARY 15

Separator pressure set at 6 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
15.2.2001	09:15		5.3												Well closed
15.2.2001	09:18														Well opened, range of WHP-gauge 40 bar
15.2.2001	09:22		3.2												Open to silencer and rock muffler
15.2.2001	09:23		13.0												Orifice 175 mm
15.2.2001	09:25		12.5	10.0											
15.2.2001	09:42		12.0	9.5		4.1	28.8	21.7	38.3	937.1	29.5	8.8	33.4	4.9	The part to the silencer, + RM
15.2.2001	09:50		12.5	10											
15.2.2001	10:10		12.2	9.5											Nearly closed to rock muffler (RM)
15.2.2001	10:20		17.0		5.8-7.0	6.2	29.8	20.7	40.3	1207.1	26.2	14.1	29.9	10.4	Flow measurement only to silencer
15.2.2001	10:45		12.5												Open on both legs
15.2.2001	11:05		11.5	8.2		3.1	36.0	14.5	19.5	1426.9	10.8	8.7	12.4	7.1	Only part of flow
15.2.2001	11:20		16.2	15.5		6.5	37.9	12.6	24.4	1970.6	7.6	16.8	9.2	15.2	Flow measurement only to silencer
15.2.2001	11:30		12.3												Open on both legs
15.2.2001	11:50		11.3	9.4											
15.2.2001	12:15		13.2	12.3		5.3	41.7	8.8	17.5	2272.5	3.1	14.4	4.1	13.4	Flow measurement only to silencer
15.2.2001	12:20		13.2	12.3		5.2	43.3	7.2	16.3	2411.7	1.9	14.4	2.7	13.6	Water carried with steam
15.2.2001	13:20		8.5	7.2											Open on both legs
15.2.2001	13:35		11.5	10.6		4.4	44.0	6.5	14.1	2438.7	1.5	12.6	2.1	12.0	Flow measurement only to silencer
15.2.2001	13:40		11.5	10.6		4.5	44.5	6.0	14.0	2479.4	1.2	12.7	1.9	12.1	Water carried with steam
15.2.2001	13:48		8.0												
15.2.2001	14:10		7.6												
15.2.2001	14:35		11.1	10.5		4.3	44.0	6.5	13.9	2434.9	1.5	12.4	2.1	11.8	Flow measurement only to silencer
15.2.2001	14:40		11.2	10.5		4.5	45.2	5.3	13.8	2529.2	0.9	12.9	1.5	12.3	Flow measurement only to silencer
15.2.2001	15:15		7.2												Open on both legs
15.2.2001	16:00		6.7	5.8											
15.2.2001	16:10		9.9	9.3		3.8	45.3	5.2	12.2	2517.3	0.9	11.3	1.4	10.8	Flow measurement only to silencer
15.2.2001	16:15		10.2			4.1	45.6	4.9	12.6	2543.8	0.7	11.9	1.3	11.3	Flow measurement only to silencer
15.2.2001	16:25		6.6	5.7											Open on both legs
15.2.2001	17:25		6.3	5.4											
15.2.2001	17:35		9.4	9.0		3.7	45.1	5.4	12.0	2499.7	0.9	11.1	1.5	10.5	Flow measurement only to silencer
15.2.2001	17:45		9.6	9.2		3.9	47.5	3.0	11.8	2633.4	0.2	11.6	0.7	11.1	Flow measurement only to silencer
15.2.2001	17:50		6.2												Open on both legs
15.2.2001	18:20		6.1												
15.2.2001	19:35		6.1												Well closed due to noise complains

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DISCHARGE FROM WELL BO-5, IN kg/s AND ton/hr ON FEBRUARY 15

Separator pressure set at 6 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)
15.2.2001	09:15											
15.2.2001	09:18											
15.2.2001	09:22											
15.2.2001	09:23											
15.2.2001	09:25											
15.2.2001	09:42	38.3	937.1	29.5	8.8	33.4	4.9	137.9	106.2	31.7	120.3	17.6
15.2.2001	09:50											
15.2.2001	10:10											
15.2.2001	10:20	40.3	1207.1	26.2	14.1	29.9	10.4	145.1	94.3	50.8	107.8	37.3
15.2.2001	10:45											
15.2.2001	11:05	19.5	1426.9	10.8	8.7	12.4	7.1	70.2	38.9	31.3	44.7	25.5
15.2.2001	11:20	24.4	1970.6	7.6	16.8	9.2	15.2	87.8	27.4	60.5	33.1	54.8
15.2.2001	11:30											
15.2.2001	11:50											
15.2.2001	12:15	17.5	2272.5	3.1	14.4	4.1	13.4	63.0	11.2	51.8	14.6	48.4
15.2.2001	12:20	16.3	2411.7	1.9	14.4	2.7	13.6	58.7	6.8	51.8	9.7	49.0
15.2.2001	13:20											
15.2.2001	13:35	14.1	2438.7	1.5	12.6	2.1	12.0	50.8	5.4	45.4	7.7	43.0
15.2.2001	13:40	14.0	2479.4	1.2	12.7	1.9	12.1	50.4	4.3	45.7	6.7	43.7
15.2.2001	13:48											
15.2.2001	14:10											
15.2.2001	14:35	13.9	2434.9	1.5	12.4	2.1	11.8	50.0	5.4	44.6	7.7	42.3
15.2.2001	14:40	13.8	2529.2	0.9	12.9	1.5	12.3	49.7	3.2	46.4	5.4	44.3
15.2.2001	15:15											
15.2.2001	16:00											
15.2.2001	16:10	12.2	2517.3	0.9	11.3	1.4	10.8	43.9	3.2	40.7	5.0	38.9
15.2.2001	16:15	12.6	2543.8	0.7	11.9	1.3	11.3	45.4	2.5	42.8	4.6	40.8
15.2.2001	16:25											
15.2.2001	17:25											
15.2.2001	17:35	12.0	2499.7	0.9	11.1	1.5	10.5	43.2	3.2	40.0	5.3	37.9
15.2.2001	17:45	11.8	2633.4	0.2	11.6	0.7	11.1	42.5	0.7	41.8	2.5	40.0
15.2.2001	17:50											
15.2.2001	18:20											
15.2.2001	19:35											

DISCHARGE MEASUREMENTS AT WELL BO-5 FEBRUARY 16 AND ONWARDS

Separator pressure set at 6 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
16.2.2001	12:00														Well closed, orifice 75 mm
16.2.2001	12:40		13.0		3.2-5.0	4.1	28.5	22.0	39.2	917.7	30.5	8.7	34.6	4.6	Well opened, range of WHP-gauge 40 bar
16.2.2001	12:50		13.5		3.4-4.2	3.8	31.5	19.0	30.3	1098.6	21.2	9.1	24.1	6.2	Opened for show
16.2.2001	12:55														Well closed
16.2.2001	17:07		6.6												
16.2.2001	17:08		4.0												Well opened
16.2.2001	17:10		6.0	5	3.8-5.0	4.4	27.8	22.7	42.0	904.6	33.0	9.0	37.3	4.7	
16.2.2001	17:25		14.0	4.0		3.3	31.0	19.5	30.4	996.7	22.6	7.8	25.7	4.7	Small bleed to rock muffler
16.2.2001	17:30		14.0	3.7											Open to rock muffler
16.2.2001	17:50	15-15.6	15.3	3.2											
16.2.2001	18:25	15-16	15.5	3.3											
16.2.2001	19:15		18.0	3.5											
16.2.2001	23:50		17.5												
17.2.2001	09:30		13.5	2.7											
17.2.2001	09:55		13.5												
17.2.2001	10:00		13.6	6.7		2.4	44.0	6.5	9.5	2325.4	1.5	8.1	2.0	7.5	Flow measurement only to silencer
17.2.2001	10:05		13.6			2.4	43.6	6.9	9.8	2278.7	1.7	8.0	2.2	7.6	Flow measurement only to silencer
17.2.2001	10:10		13.6			2.4	43.5	7.0	9.8	2266.7	1.8	8.0	2.3	7.5	Flow measurement only to silencer
17.2.2001	10:18		13.4	2.7											Open to rock muffler
17.2.2001	15:55		12.6												
17.2.2001	16:05		12.7	6.3		2.2	43.6	6.9	9.3	2259.0	1.7	7.6	2.2	7.1	Flow measurement only to silencer
17.2.2001	16:15		12.7	6.4		2.3	43.3	7.2	9.6	2226.8	1.9	7.7	2.4	7.2	Flow measurement only to silencer
17.2.2001	16:20		12.5	2.8											Open to rock muffler
18.2.2001	09:30		11.0	1.3											Well on continuous flow

COMPAGNIE FRANCAISE DE GEOTHERMIE ORKUSTOFNUN

DISCHARGE FROM WELL BO-5, IN kg/s AND ton/hr FEBRUARY 16 AND ONWARDS

Separator pressure set at 6 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)
16.2.2001	12:00											
16.2.2001	12:40	39.2	917.7	30.5	8.7	34.6	4.6	141.1	109.8	31.3	124.4	16.7
16.2.2001	12:50	30.3	1098.6	21.2	9.1	24.1	6.2	109.1	76.3	32.8	86.7	22.4
16.2.2001	12:55											
16.2.2001	17:07											
16.2.2001	17:08											
16.2.2001	17:10	42.0	904.6	33.0	9.0	37.3	4.7	151.2	118.8	32.4	134.3	16.9
16.2.2001	17:25	30.4	996.7	22.6	7.8	25.7	4.7	109.4	81.4	28.1	92.3	17.1
16.2.2001	17:30											
16.2.2001	17:50											
16.2.2001	18:25											
16.2.2001	19:15											
16.2.2001	23:50											
17.2.2001	09:30											
17.2.2001	09:55											
17.2.2001	10:00	9.5	2325.4	1.5	8.1	2.0	7.5	34.2	5.4	29.2	7.1	27.1
17.2.2001	10:05	9.8	2278.7	1.7	8.0	2.2	7.6	35.3	6.1	28.8	8.1	27.2
17.2.2001	10:10	9.8	2266.7	1.8	8.0	2.3	7.5	35.3	6.5	28.8	8.3	27.0
17.2.2001	10:18											
17.2.2001	15:55											
17.2.2001	16:05	9.3	2259.0	1.7	7.6	2.2	7.1	33.5	6.1	27.4	8.0	25.5
17.2.2001	16:15	9.6	2226.8	1.9	7.7	2.4	7.2	34.6	6.8	27.7	8.8	25.8
17.2.2001	16:20											
18.2.2001	09:30											

ORKUSTOFNUN
GeoScience Division

Our date. 24-1-2001 *Your ref.*

Mr. Max Le Nir
Compagnie Francaise de Geothermie
Avenue Claude Guillemin – B.P. - 6429
45064 Orleans cedex 2
France

Main conclusions for well BO-5 short completion test

Well BO-5 is directionally drilled to 610 m depth. It is cased with 9 5/8" casing to 500 m and was completed with 7" liner from 470 m and to bottom on January 20, 2001. Due to the drilling procedure and the change of master valve, the well was full of mud when it came to test it to obtain a rough idea of it's potential. Therefore, only a short completion test was carried out on January 23, 2001.

The procedure started with measuring the temperature profile to 500 m depth, but the gauge could not go deeper as it did not sink into the thick mud, which had settled in the deeper part of the well. Next pressure gauge was run into the well and while going down about 180 l/min (3 l/s) of fresh water was injected. During that injection a wellhead pressure of 1.5 bar-g developed. The pressure gauge did not go deeper than 504 m due to same reasons as for the temperature gauge. It was therefore pulled back to 500 m for the remainder of the test. Fresh water was injected for nearly 70 min to the well during the first step of the injection test. In the second injection step treaded sea-water was used and the injection rate increased to about 560 l/min (9.3 l/s). The second injection step lasted for 128 min and the wellhead pressure rose to 8.4 bar-g. The injection was stopped and followed by a falloff step for 70 min during which the wellhead pressure fell to 3.6 bar-g.

First interpretations on the data collected indicated the following main results:

- The injection test shows that there are at least two feed zones active in the test. The test is not long enough to allow calculation of transmissivity and formation storage, but it indicates high skin. That could be anticipated given the thick mud in the formation interval.
- The injectivity index is lower than 54 l/min per bar (0.9 l/s per bar).
- The bleeding along the wire from the stuffing box heavily influences the main response of the falloff test.

Speculation based on comparison of these results to similar results for well BO-4 and other wells could indicate that the current generating potential for well BO-5 would be 0.5 Mwe or little better. As it is known that there is thick mud blocking the formation interval in BO-5 one could expect that the well would improve during production. However, it is not certain that the weakest production zones could clean out the mud. The potential of the well would have to improve drastically to meet the economic criteria set at about 3 Mwe.

Guadeloupe 24-1-2001

Omar Sigurdsson
Geothermal Reservoir Engineer

Mailing address
ORKUSTOFNUN
Grensásvegur 9
IS-108 REYKJAVÍK, ICELAND

Telephone
+354 569 6000
Id number
500269-5379

Telex
2339 orkust is
Telefax
+354 568 8896

Bank
NATIONAL BANK OF ICELAND
Laugavegi 77, IS-101 REYKJAVIK
ACCOUNT 4669

ORKUSTOFNUN
GeoScience Division

Our date. 29-1-2001 *Your ref.*

Mr. Max Le Nir
Compagnie Francaise de Geothermie
Avenue Claude Guillemin – B.P. - 6429
45064 Orleans cedex 2
France

Main results of first discharge trials for well BO-5

Well BO-5 is directionally drilled to 610 m depth. It is cased with 9 5/8" casing to 500 m and was completed with 7" liner from 470 m and to bottom on January 20, 2001. Due to the drilling procedure and the change of master valve, a thick mud has been encountered at about 510 m hindering gauges to go deeper into the well. A temporary setup of the discharge test line to the atmospheric silencer/separator was finished in the afternoon on January 27, 2001 allowing the first discharge trials.

The first discharge trial was carried out between 15:52-18:12 on January 27. The well was discharged through 50mm orifice in the discharge line and the main objectives were to test the line and observe the development of the wellhead pressure. The reason being anticipated higher reservoir temperature than in well BO-4 or possible existence of steam cap which could have increased the wellhead pressure above the designed pressure criteria for the discharge line (20 bar).

During this first discharge, the wellhead pressure got to about 16 bar-g and the total discharge rate appeared to be stabilizing around 73 t/hr (20 kg/s). Considering measurements errors the fluid enthalpy corresponded to 240°C reservoir temperature. High pressure steam produced was about 11.9 t/hr (3.3 kg/s), which could correspond to about 1.5 MWe. Little cleaning of mud and cuttings was observed during the discharge and the well showed characteristics of liquid filled wellbore. A temperature profile measured in the morning on January 28 (15 hours after the discharge) was only able to go to 511 m depth and giving a maximum temperature of 250°C. During this first discharge the well was weak as mud blocked the known feed zones at 525 m and between 549-560 m.

After the temperature run on January 28, the 50mm orifice plate was replaced with a 175mm orifice plate causing all restriction in the discharge line to be removed. The well was discharged between 11:15-12:00, but had to be closed then due to noise restrictions and complains there about. During this short discharge, the characteristics of the well were completely different from the first discharge. The total discharge rate was more than two times higher at the same wellhead pressure of 16 bar-g, mud was produced, and after the discharge gas started to accumulate at the wellhead.

The discharge during this second trial reached nearly 180 t/hr (50 kg/s), but indications were that it was beginning to decline. High pressure steam produced was about 34 t/hr (9.4 kg/s), which could correspond to 4.2 MWe. Gauges were able to go to 554 m depth in the well after this discharge or to the middle of the lower known feed zone. Temperature recorded 4 hours later showed maximum of 257.5°C. That is about 10°C higher temperature than has been measured in well BO-4 at the same depth and about 5°C higher than the maximum temperature in that well. The pressure profile indicated at least 4 bar drawdown about 5 hours after the discharge. That could either be an indication of reduced permeability near the well or small permeability in the reservoir. The former explanation is more likely here due to mud invasion and as the discharge only lasted 45 minutes, which is generally to short duration to yield reservoir permeability.

Mailing address
ORKUSTOFNUN
Grensásvegur 9
IS-108 REYKJAVÍK, ICELAND

Telephone
+354 569 6000
Id number
500269-5379

Telex
2339 orkust is
Telefax
+354 568 8896

Bank
NATIONAL BANK OF ICELAND
Laugavegi 77, IS-101 REYKJAVIK
ACCOUNT 4669

First interpretations and discussion on the results for the short discharges trials:

- The aim of the first nearly 2.5 hr discharge trial was to test the surface equipment and observe the development of the wellhead pressure. The well produced about 73 t/hr (20 kg/s) at 16 bar-g wellhead pressure.
- The aim of the second discharge trial was to try to clean the well of some of the mud that was left in it. Unfortunately the discharge had to be terminated due to noise restrictions and complains there about.
- During the second trial the discharge rate was as high as 180 t/hr (50 kg/s) at 16 bar-g wellhead pressure.
- The high pressure steam discharge was as high as 34 t/hr (9.4 kg/s), which could correspond to 4.2 MWe, given 8 t/hr per 1 MWe.
- The recorded temperature of 257.5°C at 550 m depth indicates a 5-10°C higher reservoir temperature than at well BO-4.

First indications both from observation made during drilling and of the second discharge trial are promising. However, there is mud in the well and the short discharge trial was not able to clean the main known feed zones. Further long term discharge maybe able to clean those zones more, but it is unlikely that possible deeper weaker feeds will be cleaned, unless being done mechanically by a drilling rig.

Indications were that the discharge had started to decline near the end of the second trial. That is a normal behavior for a high temperature geothermal well. At the moment it is impossible to predict with any accuracy at what level the well will stabilize. For that the current discharge trials are much to short. Normally, a well shows its main production characteristics during the first two weeks of discharge and should have reached near stabilized conditions after 2-3 months of production. To get an idea of the possible potential of well BO-5, one can assume that the decline will be about 30%, which is not an unreasonable estimate for a clean well during its early stage of discharge. Assuming a total rate of 165 t/hr (45.8 kg/s) and discounting that by 30%, results in 115 t/hr (32 kg/s). At 6 bar-a separation the steam fraction is about 21% so the high pressure steam would be 24 t/hr (6.7 kg/s).

The above speculation indicates that the productivity of well BO-5 could be above the limiting criteria of 19.3 t/hr for high pressure steam. However, the margin is small and the actual behavior of well BO-5 can only be obtained through a discharge test.

Guadeloupe 29-1-2001

Omar Sigurdsson
Geothermal Reservoir Engineer

Mailing address
ORKUSTOFNUN
Grensásvegur 9
IS-108 REYKJAVÍK, ICELAND

Telephone
+354 569 6000
Id number
500269-5379

Telex
2339 orkust is
Telefax
+354 568 8896

Bank
NATIONAL BANK OF ICELAND
Laugavegi 77, IS-101 REYKJAVIK
ACCOUNT 4669

Addendum to letter with main results of first discharge trials for well BO-5

Low allowable noise limit heavily restricts the discharge testing of BO-5 using atmospheric silencer/separator. Other parts of the discharge testing line were not finished. Furthermore, promising indication on the productivity of BO-5 observed during the short second discharge and recommendation set forth to Mr. Max Le Nir to mechanically clean well BO-5 and continue drilling it to at least the first targeted fault zone anticipated at depth less than 700m acted to the following next steps.

Taking into account waiting time of drilling rig, time to move the rig to next well, necessary time to finish construction of rock muffler and other permanent parts of the discharge line the following steps were suggested by Mr. Max Le Nir and agreed to by others at the drill site:

1. Move drilling rig to second place of drilling (BO-6).
2. Finish during step 1 the construction of the rock muffler and the discharge line to it.
3. Simultaneously, start drilling of second borehole and start cleaning (by discharge) and testing well BO-5 during about one week.
4. Decide if well BO-5 is good enough to supply the required equivalent of 3 MWe or not.
5. If not then stop every thing, drilling campaign finished. Else if positive, continue the drilling program and bring to site a rotating (BOP) drilling head.
6. Decision to deepen well BO-5 after completion of BO-6 or BO-7.

ORKUSTOFNUN
GeoScience Division

Our date. 18-2-2001 *Your ref.*

Mr. Max Le Nir
Compagnie Francaise de Geothermie
Avenue Claude Guillemin – B.P. - 6429
45064 Orleans cedex 2
France

Results of well BO-5 first discharge tests

Well BO-5 is directionally drilled to 610 m depth. It is cased with 9 5/8" casing to 500 m and was completed with 7" liner from 470 m and to bottom on January 20th, 2001. Due to the drilling procedure and the change of master valve, a thick mud was encountered at about 510 m hindering gauges to go deeper into the well. A temporary setup of the discharge test line to the atmospheric silencer/separator was finished in the afternoon on January 27th, 2001 allowing the first discharge trial.

The first discharge trial was carried out between 15:52-18:12 on January 27th. The well was discharged through 50mm orifice in the discharge line and the main objectives were to test the line and observe the development of the wellhead pressure. The reason being anticipated higher reservoir temperature than in well BO-4 or possible existence of steam cap which could have increased the wellhead pressure above the designed pressure criteria for the discharge line (20 bar). During this trial, wellhead pressure rose to about 16 bar-g and the total discharge rate appeared to be stabilizing around 73 t/hr (20 kg/s). The calculated fluid enthalpy corresponded to 240°C reservoir temperature. High pressure steam produced was about 11.9 t/hr (3.3 kg/s). Little cleaning of mud and cuttings were observed and the well characteristics indicated liquid filled wellbore. A temperature profile measured on January 28th (15 hours after the discharge) could only go to 511 m depth, recording a maximum temperature of 250°C. During this first discharge the well was weak as mud blocked the known feed zones at 525 m and between 549-560 m.

After the temperature run on January 28th, the 50mm orifice plate was replaced with a 175mm orifice plate, thereby removing all restriction in the discharge line. The well was discharged between 11:15-12:00 that day, but had to be closed due to noise restrictions and complains there about. During this short discharge, the characteristics of the well were completely different from the first discharge. The total discharge rate reached nearly 180 t/hr (50 kg/s) at the same wellhead pressure of 16 bar-g, but indications were that it was beginning to decline. High pressure steam produced was about 34 t/hr (9.4 kg/s). Mud was produced from the interval 511-554m, and after the discharge gas started to accumulate at the wellhead. Temperature recorded 4 hours later showed maximum of 257.5°C, about 10°C higher temperature than measured in well BO-4 at the same depth and about 5°C higher than the maximum temperature in well BO-4.

Permanent discharge pipe line was not ready for allowing the well to be put in continuous discharge. On February 10th the well was opened for half an hour to test the discharge line, but had to be closed due to leakage and large water gushing from the rock muffler. Without necessary improvements on the discharge line the well was opened again on Sunday February 11th and discharged for 6,5 hours in a fully open flow conditions. No flow measurements were made, but wellhead pressure declined from about 14.5 bar-g to 7.3 bar-g during the discharge. The wellhead pressure was still declining when the well was closed. Mud was produced from the interval 554-594m. The characteristics of the well were similar to those at the second discharge, but the discharge was becoming dry. Temperature profile measured two days later indicated nearly 260°C reservoir temperature at 594m. On February 15th most of the required minimum improvements on the discharge were done and well BO-5 was discharged to the rock muffler, but changed to the atmospheric separator/silencer for measurements. Unfortunately, the discharge had to be stopped after about 10 hours due to noise complains. Wellhead pressure appeared to be stabilizing at about 6 bar-g. Measured total discharge declined from about 145

Mailing address
ORKUSTOFNUN
Grensásvegur 9
IS-108 REYKJAVÍK, ICELAND

Telephone
+354 569 6000
Id number
500269-5379

Telex
2339 orkust is
Telefax
+354 568 8896

Bank
NATIONAL BANK OF ICELAND
Laugavegi 77, IS-101 REYKJAVIK
ACCOUNT 4669

t/hr (40.3 kg/s) to 42.5 t/hr (11.8 kg/s), but had nearly become dry so the high pressure steam rate was about 40 t/hr (11.1 kg/s). It was not until late in the afternoon on February 16th that well BO-5 could be put in continuous discharge or 27 days after the completion of the well. After nearly 24 hour discharge through a 75mm orifice plate the wellhead pressure was 12.7 bar-g and declining. Total flow rate was 34.5 t/hr (9.6 kg/s) and high pressure steam rate was 25.9 t/hr (7.2 kg/s). Flowing enthalpy was estimated about 2230 kJ/kg.

Construction of the discharge testing line has been slow and is not fully completed 28 days after the completion of well BO-5. During this time well BO-5 has only discharged continuously for one day. An initial characteristics discharge curve has yet not been determined for the well. The conditions on site for the required testing to determine the success/failure criteria for the drilling project have been difficult and with lots of constrains. Personal conflicts between managing personnel and disputes with neighbors have caused considerable delays. If these matters are not greatly improved it will be impossible to obtain the necessary information for evaluating the criteria within the 15 day time frame allotted for later wells.

Interpretations of the available data leads to the following conclusions for well BO-5:

- Three feed zones are active in the well. Feed zones at 525 m and 549-560 m found during drilling, and at 594 m which became active during the second discharge.
- These feed zones act as small fractures situated in low permeability rock formations. The reservoir is liquid dominated with temperature near 260°C. The initial production is high and unloads the liquid from the fracture volume. The permeability of the rock formations cannot reload the fractures at that rate so the pressure falls to the boiling pressure and boiling starts in the fractures and the rock formations. Wellhead pressure and flow rate declines. The boiling escalates into the rock formations due to pressure drawdown and changes in relative permeabilities. The production becomes dryer (higher steam ratio) and produced enthalpy increases.
- For fully open well it is anticipated from the current data that the wellhead pressure will stabilize around 6 bar-g with total flow around 30 t/hr (8.3 kg/s). The enthalpy of the flow will be more than 2600 kJ/kg so most of it will be steam. The high pressure steam rate could be 28 t/hr (7.8 kg/s) that can be considered as maximum for the steam rate over a longer term.
- On February 17th well BO-5 was producing through a 75mm orifice plate with wellhead pressure of 12.7 bar-g. According to Russell James method the calculated total flow rate was 34.5 t/hr (9.6 kg/s), flowing enthalpy 2227 kJ/kg, and steam rate at 6 bar-a was 25.9 t/hr (7.2 kg/s).

From the above conclusions it is estimated that the longer term high pressure steam production from well BO-5 will be in the range of 24-28 t/hr (6.7-7.8 kg/s), which is above the success criteria of 19.3 t/hr (5.4 kg/s) of steam at 6 bar-a.

A report will follow shortly with the data collected on the testing of well BO-5 and its first interpretation.

Guadeloupe 18-2-2001

Omar Sigurdsson
Geothermal Reservoir Engineer

Mailing address
ORKUSTOFNUN
Grensásvegur 9
IS-108 REYKJAVÍK, ICELAND

Telephone
+354 569 6000
Id number
500269-5379

Telex
2339 orkust is
Telefax
+354 568 8896

Bank
NATIONAL BANK OF ICELAND
Laugavegi 77, IS-101 REYKJAVIK
ACCOUNT 4669

ORKUSTOFNUN
GeoScience Division

Our date. 18-2-2001 *Your ref.*

Mr. Max Le Nir
Compagnie Francaise de Geothermie
Avenue Claude Guillemin – B.P. - 6429
45064 Orleans cedex 2
France

Preparation and action needed for further testing of well BO-5 and later wells

Following are just some points that come to mind when looking over the current condition of the discharge test line and the time it took to get it into current stage. From that it is obvious that material needed for constructing the test line portion from well BO-6 has to be acquired very quickly.

During drilling of well BO-6 the following needs to be recorded for well BO-5 assuming that it will be in production as anticipated in the Well Testing Program for the Bouillante Geothermal Project Phase 2.

- Record wellhead pressure and pressure on discharge line after orifice plate minimum twice a day
- Preferably make a flow measurement with the atmospheric separator/silencer once a day, but minimum once a week.
- Make square-edge orifice plates with 60-70-80-90-100-110-120 mm holes from 8-10 mm steel plates.
- When drilling of well BO-6 is at about 800 m depth start measuring a characteristic curve for well BO-5 by putting in one of the orifice plates and discharge through it for one day. Start with the smallest diameter plate.

For completion of the main discharge line to the rock muffler the following is at least needed.

- Fill the rock muffler up to about 50-70 cm level with lava-rocks of size 25-50 cm in diameter. The low density and weak coral rock breaks down to pebbles in the muffler and flows of or is thrown over the sides of the muffler.
- Put wave breaker boards on the inner side of the muffler to throw water gushes into the muffler.
- Lower the off flow from the muffler and make a weir to measure the water rate some distance away from the muffler.
- The current control valve needs to be replaced by a regular valve to close the bypass from the high pressure separator. This is needed if the high pressure separator will be used for measurements, as the current valve does not close completely, therefore making measurements with the high pressure separator wrong.

If the high pressure separator is to be used for measuring later wells at least the following is needed.

- Finish connecting the measuring devices and the sampling ports.
- Make available the calibration constants and calculation formulas for the flow measurements.

For interference testing connection of pressure gauge to the wellhead of BO-4 is needed. Readings should be made a minimum once a day.

Mailing address
ORKUSTOFNUN
Grensásvegur 9
IS-108 REYKJAVÍK, ICELAND

Telephone
+354 569 6000
Id number
500269-5379

Telex
2339 orkust is
Telefax
+354 568 8896

Bank
NATIONAL BANK OF ICELAND
Laugavegi 77, IS-101 REYKJAVIK
ACCOUNT 4669

For testing of well BO-6 and later wells the following is needed. The needed material has to be obtained soon if the testing line is expected to be ready in time or at the completion of the well.

- Collect the material needed to construct the initial testing pipe line from well BO-6 to an atmospheric separator/silencer. The material should be of the same pressure rating as that connected to well BO-5, but that well can have up to 28.5 bar-g pressure at the wellhead. Another atmospheric silencer may need to be constructed, as measurements on BO-5 are not completed.
- Obtain and lay out the needed material for connecting well BO-6 to the main discharge pipe line.

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Omar Sigurdsson
Geothermal Reservoir Engineer

Mailing address
ORKUSTOFNUN
Grensásvegur 9
IS-108 REYKJAVÍK, ICELAND

Telephone
+354 569 6000
Id number
500269-5379

Telex
2339 orkust is
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