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Initial testing of Bouillante wells 5, 6 and 7 at end of drilling operation

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INTRODUCTION

During the period from December 2000 to May 2001 three new wells were directionally drilled in the geothermal field at Bouillante. The geothermal field at Bouillante is located in the town of Bouillante on the western coast on Basse Terra, Guadeloupe. Guadeloupe is an island belonging to the islands on the Antilles arc in the Caribbean Sea. Géothermie Bouillante SA., which also operates a small power plant there, operates the geothermal field. In the 1970's four geothermal wells were drilled in the field by EURAFREP, but only well BO-2 turned out to be economically productive. It has now supplied the power plant with steam for over a decade, but with some interruptions. In 1998 well BO-4 was stimulated and is now considered economically productive. As a result of that and due to limited access to land for locating boreholes, the new wells BO-5, BO-6 and BO-7 were drilled from the BO-4 platform.

Compagnie Francaise de Geothermie (CFG) was responsible for the management and the scientific part of the drilling operation for the new wells. It subcontracted Orkustofnun GeoScience Division (ROS) to give consultancy on the completion and well testing part and to give independent evaluation on the initial productivity of the new wells. The work on site was carried out in compliance with the well testing program (Bouillante Geothermal Development – Phase 2, Well Testing Programme) set for the new wells to be drilled from the BO-4 site. To fulfill the subcontract a representative from ROS went a total of six trips to Guadeloupe and stayed there during the completion testing and the initial production testing for each of the new three wells. The main results of the tests were communicated by letters to CFG from the wellsite, but short reports submitted later. Two short reports have been submitted covering the welltesting results for the first drilling stage of well BO-5 and the initial testing of well BO-6 (see references).

This report describes the activity that the representative Omar Sigurdsson participated in during his stay in Guadeloupe in May and June 2001. In April the representative Benedikt Steingrimsson witnessed production testing of BO-6 and completion of BO-7. The data collected during the completion of the second drilling phase of well BO-5 and its initial production is reported. Data from extended production testing of well BO-6 is reported along with data from the completion of well BO-7 and its initial production trial. Some discussion is provided with the data and preliminary evaluation of the production capacity of the wells. The authors thank the help and support they received from Mr. Hervé Traineau, Mr. Bernard Herbrich, Mr. Jean-Marc Cheradame and Mr. Jules Cairo in performing their measurements and tests.

MAIN ACTIVITY IN MAY AND JUNE 2001

May 9th: Traveled from Iceland to Paris and continued to Martinique and from there to Guadeloupe. Arrived in Guadeloupe at around 22:00 local time after nearly 20 hours of travel.
May 10th: Woke up early to be at the drilling site for waterloss testing. Well BO-5 had been reamed to 1198 m. At 8:30 everything was ready to measure a temperature profile during injection. Injection rate was 1200 l/min (20 l/s), but when the temperature gauge was at 108 m

depth the wire broke at the winch. The gauge fell nearly 20 m before the wire got tangled up at the stuffing box. When the wire was pulled out it came clear that the fall had broken the gauge, which was with a small sinker bar, from the end of the wire. The Kuster temperature gauge KT-10077 was lost in the well. Additional 110 m of wire was cut off and another temperature gauge sent down shortly after 11 o'clock. The gauge sat at 774 m depth and could not go deeper. Most likely a cavity was there in the well. The gauge was pulled out and the drilling string sent down with a milling bit to make sure that no obstacles would hinder the setting of the liner. An obstacle was encountered at 765 m and about 100 m deeper. The temperature logs were used to decide the arrangement of the liner and position the plain and perforated pipes, as only 430 m of perforated pipes were available.

May 11th: Drill string went to 1197 m and was out of the well shortly after 12 o'clock. Liner started to go down about two hours later. The inhibitor had finished on May 9th and a slug of mud had been sent down on May 8th to clean cuttings from the well at the end of the drilling.

May 12th: Preparations made for the completion test. Drill string breaking out almost finished and seawater collected into mud tanks. Only 1020 l/min (17 l/s) were delivered to the rig from the seaside pumping station. At 12:58 a pressure gauge (KP-V3851) was sent down and was at the reference depth (1020 m) at 13:34. Injection was 720 l/min (12 l/s) and increased at 13:44 to 1188 l/min (19.8 l/s). That rate was maintained for about 160 minutes or until 16:26. The injection rate was then reduced to earlier stage and seawater collected into the mud tanks to fill them up. The injection was increased to 2412 l/min (40.2 l/s) at 17:28 and maintained so for 57 minutes (18:25). The rate was reduced to 720 l/min (12 l/s) and the gauge pulled out at 18:45. When pulling on the gauge it was stuck but broke free when pulled on with more force. Loose brownish scaling was rubbed of the wireline while pulling the pressure gauge out of the well, but no inhibitor was mixed with the seawater. When the gauge was opened it became clear that no recording was obtained of the completion test as the stem from the gauge to the recording stylus was stuck. Decided to repeat the test, in a shorter and simpler manner to obtain minimum information for the well. Seawater collected into the mud tanks.

May 13th: Around midnight a new pressure gauge was sent down to 500 m. That should be the reference depth for the repeated completion test. Injection had been maintained at 720 l/min (12 l/s) and the gauge was at 500 m at 00:22. The injection was increased to 2424 l/min (40.4 l/s) at 1:09 and maintained so for 57 minutes (2:06). Then the injection was reduced to its former value and kept like that until after the gauge had been pulled out. The gauge was pull out at 3:14 and the injection was stopped at 4:20. This measurement was successful. Late in the afternoon the first warm-up pressure and temperature profiles were measured. About 260 m were cut off the wireline before measuring the profiles, which was completed around 19:40.

May 14th: A letter with the main results of the completion test prepared and given to Mr. Max Le Nir in the afternoon. Closing ceremony for the drilling operations at the drilling site.

May 15th: Winch unit and gauges prepared for storage. Met with Mr. Bernard Herbrich and went over things needed for refurbishing the measuring gauges, both to buy and repair. Took the temperature gauge KT-10073 for calibration in Iceland as calibration table for it was not available. Packed and left to go to the airport in the afternoon. Traveled to Paris, France that night.

May 16th: Traveled to Paris, France and continued traveling to Iceland.

June 15th: Traveled from Iceland to Paris, France where I joined Mr. Hervé Traineau for a continued travel to Guadeloupe. Arrived there at around 20:00 local time after nearly 20 hours of travel.

June 16th: Went to the power plant and then to the BO-5 site. Several things were needed, but work on the discharge pipeline had just begun. The winch unit needed to be brought to the site and it took some time to find a car that could pull it from the plant and up to the site. The wellhead was dismantled, that is the T-spool and the operation or secondary master valve were taken of the main master valve. It was necessary as a spacer spool was missing. A blinding plate with a 3" valve and the lubricator was set directly on top of the master valve. The movable work

platform was adjusted to lower height. At around 15:00 in the afternoon was well BO-5 ready for measurements. A pressure gauge was put together and a static warm-up pressure profile measured.
June 17th: In the morning a temperature gauge was put together and a static warm-up temperature profile measured before noon. The charts from the pressure and temperature measurements were read, after that the rest of the day was off.
June 18th: Met Hervé at the BO-5 site and went over with him the things needed to finish the setup of the discharge pipeline. He made a list of the items and gave it to the workers and Mr. Jules Cairo. Among things needed was to dig a hole for the weir box to lower it under the atmospheric separator. Change flange on the T-spool at wellhead to 50 P/N rating. Assemble the wellhead and weld and lay out the discharge pipe to both the atmospheric separator and the rock muffler. Rather little was accomplished during the day as Hervé left for Saint Lucia. The lubricator and blind plate was moved from BO-5 to BO-7, but not bolted. The operation valve was set on BO-5 and the 20 P/N rating flange cut of the T-spool. The lip pressure pipe was exchanged to 5" (128 mm) and a hole dug for the weir box.
June 19th: Concrete blocks that were pushing against the pipeline to the rock muffler moved. The hole for the weir box had to be deepen which was completed later during the day. Work platforms moved to well BO-7. By the end of the day the discharge pipeline had been laid out, but make-up of bolts on connections was not finished along with some minor things.
June 20th: Weir box set in place and additional supports for the pipeline installed. Ran a pressure profile in well BO-7. Late in the afternoon the wellhead pressure of BO-5 (3.6 bar-g) was set on the discharge pipeline up to the valves that divert the flow either to the atmospheric separator or to the rock muffler. Leakage was found on most of the connections on the wellhead. Started to tighten bolts, decided to finish that tomorrow.
June 21st: Ran a temperature profile in well BO-7 in the morning. Shortly before noon was well BO-5 ready for bleeding and warm-up of the wellhead. Bleeding started at 11:27 and the well was bled for 8 minutes to the atmospheric separator. The wellhead pressure rose to 6.1 bar-g. Level of weir box fixed and some connection tightened better. The well was bled between 12:50-13:01 to the rock muffler risen the wellhead pressure to 8 bar-g. The wellhead pressure went from 7 bar-g to 9.3 bar-g when bled between 14:04-14:10. By that time the wellhead had come up by 2.5 cm. The well was then bled between 14:19-14:24 to WHP of 12 bar-g and between 14:32-14:38 to WHP of 15 bar-g. The well was then considered ready for discharge. It was started to open the well at 14:50 and the well was fully open at 14:55. The well discharged through a 75 mm orifice to the rock muffler. The wellhead pressure rose quickly to 21 bar-g and then slowly in 10 minutes to 24 bar-g. A short discharge measurement was made at 15:55, but leakage was at the connection of the lip pipe and the expansion part into the atmospheric separator oscillated, as straps had not been fastened.
June 22nd: Straps on expansion part into atmospheric separator fastened and lip pipe connections tighten. At 11:15 a discharge measurement was made and at 12:10 the well was closed to exchange the orifice plate. A 90 mm orifice was set in the pipeline and the well opened again at 12:40. A discharge measurement was made at 16:25 in the afternoon. The wellhead had then come up by 6 cm.
June 23rd: The discharge was measured on the 90 mm orifice before noon. In the afternoon a work was done on the data collected and on report.
June 24th: The discharge of BO-5 was measured in the morning and then a preparation was made to exchange the orifice to 60 mm. That orifice plate could not be found, but it was last used for testing BO-6. An older 62 mm orifice plate that was used in testing BO-4 in 1999 and was known earlier to be in storage at the power plant could neither been found. A plate with 2 ½" (63 mm) orifice was found at the power plant but with too large outer diameter to fit into the 10" discharge pipeline. Did cut the outer rim of the plate so it would fit into the pipeline. At 11:50 was well BO-5 closed to exchange orifices and at 12:10 it was opened on the 63 mm orifice. Worked on a letter on the first results for the discharge test of BO-5. The letter was E-mailed to Mr. Max Le Nir in the evening.

June 25th: Discharge measurement to the atmospheric separator made at BO-5 in the morning. A request came from Mr. Max Le Nir for a letter summing the discharge results for wells 5 to 7. The letter was sent before 11 o'clock. Well BO-5 was then closed at 11:08 so the upper part of the wellhead could be transferred on to well BO-7 for it's testing. Additional pipes needed to connect BO-7 to the existing discharge pipeline were cut from the old pipe use for testing BO-6. Worked on the data in the afternoon.
June 26th: Welding and setup of the extra pipeline was mostly finished during the day. Still missing were supports for the additional pipeline. Also unfinished was to set the reduction and 3" valve on top of the master valve on BO-5 to make it assessable for downhole measurements. Worked on data and report.
June 27th: The work around the discharge pipeline was finished shortly before noon. Then well BO-5 was bled through a 2" pipeline between the kill valves to the wellhead on well BO-7 and to the atmospheric separator to increase its wellhead pressure. When the WHP was about 8 bar-g the BO-7 wellhead was closed and well BO-5 bled into well BO-7 to warm it up for discharge, but it had a water level at about 32 m depth. Well BO-5 was bled in steps of few minutes into BO-7 for a total of about 15 minutes. The dilation of well BO-7 was then 1.5 cm and its wellhead pressure 6.3 bar-g. When opened at 13:00 the well did not initiate a flow. The procedure of bleeding well BO-5 into well BO-7 to warm it up in the process of initiating flow from BO-7 was repeated four more times during the day without success. A leakage was observed from the expansion spool on the BO-7 wellhead when pressure reached 10 bar-g or more. The leakage came from one of the stop screws for the centralizer.
June 28th: Information obtained about the configuration of the expansion spool. A packing material set in the expansion spool and a bleeding line installed for the annulus. This was finished around 12 o'clock. Decided to measure temperature profile in well BO-5 in the afternoon before it would be disturbed more in the process of initiating flow from BO-7. Shortly before 17:00 it was started to bleed well BO-5 to the atmospheric separator through well BO-7 as before and 20 minutes later the BO-7 wellhead was closed. At 17:50 were well BO-7 opened while a reduced bleeding was kept from BO-5. The wellhead pressure fell from 11 bar-g to 2 bar-g, but it appeared to be increasing when the bleeding from BO-5 was stopped at 18:46. Flow from BO-7 only continued for 5 more minutes.
June 29th: Bleeding of well BO-5 into well BO-7 started at 10:58. At 15:22 the wellhead pressure on BO-7 was 16 bar-g and about 16.2 bar-g on BO-5. Well BO-7 opened at 15:26 and the wellhead pressure fell to about 3.6 bar-g in 12 minutes, but after about 18 minutes the wellhead pressure started to increase. Discharge had been initiated from well BO-7. After about 50 minutes of discharge the wellhead pressure fell from 8 bar-g to 2.8 bar-g in 15 minutes. The discharge became almost dry steam, but then wellhead pressure rose again and the well discharged muddy water. Discharge measurements were made during the dry discharge and after the well came up again.
June 30th: When arriving on site at 8:45 well BO-7 was dead. From the signs on site it had stopped discharging 3-4 hours earlier. This can be determined better when data from the data acquisition system will be viewed. Equipment returned to storage and rest of day off.
July 1st: Packed and went to the airport for a flight to Martinique with connection to Paris, France. Prepared a letter with the main result for the discharge test of well BO-7.
July 2nd: Arrived in Paris, France and continued travel to Iceland. Letter with well BO-7 results sent to Mr. Max Le Nir after arriving to Iceland.

EQUIPMENT

In June 1999 a new stainless steel wireline was set on the winch unit. The length of the wire was about 2600 m. Over the past two years only few meters had been cut off the wire during measurements. In May 2001 the wire broke during a measurement. About 130 m broke off the wireline and additional 110 m was cut off, as the wire was brittle. When checking the wireline for later measurements another 260 m were cut off as the wire was brittle and considerable corrosion was found on it. In June 2001 over 120 m were taken off due to the brittleness of the wireline. The wireline has been shortened by about 660 m so left on the winch unit is about 1930 m. Corrosion is observed not far in on the wire so it needs to be shorten by another 100 m before further use. Best would be to put a new wireline on the winch unit.

When the wireline broke in May 2001, a complete Kuster temperature gauge KT-10077 with a short sinker bar was lost in well BO-5. In the gauge was the 6 hour clock V-4109. The gauge was milled down before the liner went into well BO-5.

WELL BO-5

Well BO-5 was drilled in two stages. It is directionally drilled with kick off point (KOP) at 225 m and with an inclination buildup to about 32° in the direction of N45°E. In the first stage the well was drilled to 610 m (MD) in January 2001. Due to lack of a rotating head to deal with over pressure observed in the well, the drilling operation was halted until after the completion of other wells in this drilling phase. The well was deepen in the second stage to 1198 m (MD) in May 2001. All depth numbers refer to measured depth unless other is indicated. The well is cased with 9 5/8" casing to 500 m and completed with 7" perforated (11 mm drilled perforations) liner from about 460 m to bottom (1197 m). Not all of the pipes in the liner are perforated.

A completion test and a short production test carried out at the end of the drilling of the first stage of well BO-5 has been reported (Omar Sigurdsson, 2001a). The results from those tests indicated that there were at least two active feed zones in the open interval from 500-595 m. The feed zones appeared to be fractures situated in low permeability rock formation. The reservoir was liquid dominated with temperature that could be near 260°C. The initial production was high while the liquid was unloaded from the well and the fracture volume. Due to the low permeability of the rock formation the pressure declined rather quickly in the well and boiling started, which escalated into the fractures and the rock formation. While the liquid phase of the discharge declined, the steam phase remained relatively stable. The enthalpy rose and the discharge became almost dry. Under those conditions the initial discharge was over the limit set for the success criteria, but with a wellhead pressure of only 9.5 bar-g, which was expected to decline further.

In the following chapters the additional data collected for well BO-5 will be discussed briefly, but the main emphasis will be on the completion test and the short discharge test after the deepening of the well.

Waterloss and completion tests

A waterloss test was performed at the end of the second stage of the drilling operation of BO-5 on May 9th 2001. Two temperature gauges were used in tandem, but one of them had an upper temperature limit around 210°C. The temperature gauges were inside a drillpipe that was lowered into the well by adding first pipestands of two pipes and then single drillpipes to the string. During the measurement about 720 l/min (12 l/s) were injected in the annulus between the drillstring and the borehole. Another waterloss test was performed on May 10th in open hole, but only to 774 m depth as the gauge sat there most likely in a small cavity in the well. During that waterloss test the injection was about 1200 l/min (20 l/s). Figure 1 shows the temperature measurements, but they were used to determine the location of perforated and plain pipes in the liner since only 430 m were available of perforated pipes for 700 m of open interval in the well.

The solid points on Figure 1 are read at the depths where the lowering of the gauges was stopped for few minutes to allow them to adjust to the surrounding temperature, but the open points are read at depths where additional pipes were added to the drillstring. Doing that helps identifying the loss zones in the well. Many loss zones can be seen, but most noticeable are at about 545 m, 575 m, 615 m, 695-750 m, 805-830 m, 845-870 m, 920 m, 1015-1040 m. The perforated pipes were arranged in the liner based on the identification of the loss zones as indicated on Figure 1.

One can see on Figure 1 that gauges KT-10077 and KT-10078 do not compare at temperatures lower than 160°C, which indicates that there is a calibration problem for one or both of the gauges. There is almost a constant difference of about 20°C between them. Gauge KT-10073 was calibrated in June 2001 and the difference seen for that gauge in Figure 1 is due to the higher injection rate.

The main completion test for well BO-5 after its deepening was carried out on May 12th, but due to malfunctioning of the pressure gauge no recording was obtain for the test. Only about 17 l/s (1020 l/min) of seawater were delivered to the drilling site from the seaside pumpstation, as one of the booster pumps was getting worn and could not be run at full capacity. Therefore, it took some time to collect seawater again into the mud tanks in order to be able to inject at high injection rate. No inhibitor was available to mix with the seawater to reduce the risk of anhydrite scaling. A shorter version of the completion test was carried out during the night of May 13th with the pressure gauge near the casing end at 500 m instead of near the deepest expected feed zone from the waterloss test at about 1020 m. Figure 2 shows the pressure changes during this shorter completion test. Some noise is observed due to effects from the multiple feed zones in the well, but the basic pressure change is less than 1 bar for a change in injection rate of 28.4 l/s (1704 l/min). The small pressure change indicates that the main feed zones encountered by the well have high permeability. The indicated injectivity index from the completion test after the deepening of the well is more than 20 times higher than the index from the completion test when the well was only 610 m deep and full of mud.

Short discharge test

The installation of the discharge test line for well BO-5 was finished on June 21st. Warming up of the well started the same day at 11:27 and the well was fully open at 14:55. It discharged through a 75 mm orifice until the next day when the orifice was exchanged and increased to 90 mm. The well discharged through that orifice until June 24th when it was exchanged with a 63 mm one. The discharge test lasted until 11:08 on June 25th or for four days. The progress of the discharge test is shown in Figure 3. During the first six hours of discharge the wellhead pressure was slowly rising to 25 bar-g and when the orifice size was increased the day after the wellhead pressure dropped only by 0.5 bar. Decreasing the orifice size increased the wellhead pressure to 25.5 bar-g and when the well was shut-in the wellhead pressure rose to 26 bar-g (see Tables in appendix). The well discharged 121-222 t/hr (33.6-61.5 kg/s) with wellhead pressure changing only between 25.5-24.5 bar-g. The corresponding high-pressure steam production was in the range of 29-53 t/hr (8.2-14.6 kg/s) and calculated fluid enthalpy corresponded to water at 265-270°C. That temperature is about 10-20°C higher than measured in the well at static conditions before and after the discharge test. That could indicate either boiling into the reservoir (excess steam) or a calibration problem with the Kuster gauges.

The discharge characteristics for the well are shown in Figure 4. The characteristic curves are very steep so there is a large increase in flow rates for a small decrease in wellhead pressure. It can be seen from the figure that the production characteristics have greatly improved from those measured before the deepening of the well. Also that the discharge is restricted at the highest tested discharge rate (on the 90 mm orifice), so the production capacity of the well is higher than shown in the figure. However, it should be pointed out that these are the initial production characteristics for the well, which can be expected to decline some given a longer production period. Nevertheless, the production capacity of the well is high and assuming a conversion factor of 8 t/hr high pressure steam per MW_e produced, the capacity of the well could be around or higher than 7 MW_e.

Temperature and pressure profiles

Temperature and pressure profiles measured in well BO-5 after the deepening of the well in May 2001 are presented in Figures 5 and 6 along with profiles from well BO-4 for comparison. The first temperature profiles were measured during the waterloss tests and have been discussed in that chapter. Those profiles were measured during injection of cold seawater into the well and their purpose was to locate feed zones in the well. The latter profiles were measured during warm-up of the well and their purpose was to give an indication of the formation temperature. The temperature profile from May 13^{th} shows that the formation has been cooled during the injection tests in the depth interval 950-1150 m. That could indicate that the main feed zones in the well are in that depth interval and that the strongest feed could be around 1150 m (MD) depth. Some feeds in that depth interval could be behind a plain liner-pipe, which could cause some increase in pressure losses during production. The temperature profiles measured before and after the short discharge test give the highest temperature of 250.3°C around 1000 m depth and a slightly lower temperature deeper. It is too early to say if there is a temperature inversion at that depth, as the formation may not have reached temperature equilibrium by that time. Temperature profiles measured before the deepening of the well resulted in higher temperatures, up to 260°C at 595 m depth, and the discharge enthalpy indicates a reservoir temperature of 265-270°C. These temperatures are not seen in the well after the deepening, which could indicate a problem with the calibration of the Kuster gauges, but different gauges were used before and after its deepening.

Figure 6 shows the measured pressure profiles in well BO-5 after they have been corrected to true vertical depth. The pressure potential is very similar to that at well BO-4, which is shown on the figure for comparison. It is difficult to find a pivot point in the profiles, but it appears to be in the interval 850-1050 m TVD (935-1145 m MD). The controlling feed zone is therefore deep in the well and in the cooled depth interval as indicated by the temperature profile.

WELL BO-6

Well BO-6 was drilled in February 2001 to 1248 m (MD). It is directionally drilled with kick off point (KOP) at 230 m and with an inclination buildup to about 36° in the direction of N20°W. All depth numbers refer to measured depth unless other is indicated. The well is cased with 9 5/8" casing to 498 m and completed with 7" perforated (11 mm drilled perforations) liner from 462 m to bottom.

A completion test and a short production test were carried out in early March 2001. The tests indicated high injectivity and high productivity of well BO-6 (Omar Sigurdsson, 2001b). The well had high total discharge rates of 130-220 t/hr (36.1-61.1 kg/s) for a small change in wellhead pressure of only about 2 bar (26.5-24.5 bar-g). Measured temperature profiles and discharge enthalpy indicated a formation temperature of 265-270°C.

After the drilling rig had been moved to the BO-7 location, a longer discharge test was conducted for well BO-6. Well BO-6 was discharged from March 28^{th} to April 20^{th} 2001 and the main results of that test are discussed in the following chapter.

Extended discharge test

At the end of the drilling operation for well BO-6 the well was discharged for nearly four days between March 10th to March 14th. After moving the drillrig to the BO-7 location, well BO-6 was opened for discharge again on March 28th. The well discharged continuously through a 75 mm orifice plate until April 17th, but was closed then temporary to repair leakage on the bypass valve to the rock muffler. In the next days the well was discharged through larger orifice plates to measure points for its production characteristics curve. During the continuous discharge period, wellhead pressure was measured regularly and discharge rates few times by local and CFG personnel.

During the three weeks of continuous discharge, the discharge rates and wellhead pressure remained fairly stable. The wellhead pressure was 26.0-26.5 bar-g and the total discharge rate around 165 t/hr (46 kg/s) with calculated enthalpy in the range 1180-1210 kJ/kg. Indications were that the discharge rates were slightly higher than during the initial short discharge test and with higher enthalpies. Also the wellhead pressure was slightly higher. For the characteristics curve the discharge was measured with a 90 mm orifice plate and 6" lip pipe. The well was also discharged for half an hour with a 120 mm orifice plate, which lowered the wellhead pressure to 23.5 bar-g. However, at those conditions the discharge rates and testline pressure were over the limitation for the equipment so a measurement was not obtained and the test terminated. Figure 7 shows the measurements for the production characteristic curves from the short discharge test along with measured points from the extended discharge. A minimum flow is estimated for the discharge with the 120 mm orifice plate and put on the figure. All the points from the extended discharge test fall above the production characteristics curves estimated from the short discharge test. Furthermore, the calculated enthalpies during the extended discharge are slightly higher in comparison with those estimated during the short discharge test. The calculated enthalpies could indicate a reservoir temperature of 270-275°C, but the highest measured downhole temperature is 272°C. Some caution should be made about the calibration of the Kuster temperature gauge.

During the extended discharge the well was throttled by the orifice plates used in the discharge testline. Generally the production characteristics of well BO-6 improved during the extended discharge test. The slight increase in calculated enthalpy could indicate heating of the well during the discharge period. The increase in the discharge rates is partly due to the rise in enthalpy and partly to improved permeability as the discharge has cleaned mud and drillcuttings from the production fractures. The production characteristics curves are steep, as seen in Figure 7, so the flow rates increase rapidly as the wellhead pressure is slightly lowered. As the discharge is restricted at the highest tested discharge rate (on the 90 mm orifice) and even at the estimated rates for the 120 mm orifice, the production capacity of the well can be expected to be as high or higher than shown in Figure 7. Assuming a conversion factor of 8 t/hr of high pressure steam per MW_e produced, the capacity of the well can be estimated around 10 MW_e.

WELL BO-7

Well BO-7 was drilled in April 2001 to 1400 m (MD). It is directionally drilled with kick off point (KOP) at 230 m and with an inclination buildup to about 37° in the direction N130°W. The inclination drops off below 1000 m and is 23° at 1300 m. All depth numbers refer to measured depth unless other is indicated. The well is cased with 9 5/8" casing to about 500 m and completed with 7" perforated (11 mm drilled perforations) liner from 463 m and to 1100 m. The liner shoe is supposedly closed, hindering possible flow from deeper parts of the well.

Before the completion of the well attempts were made to stimulate it, but with a limited success. The stimulation process and the initial discharge of well BO-7 are discussed in the following chapters.

Stimulation

Well BO-7 reached 1400 m depth on April 18th. Circulation losses were only 90-120 l/min (1.5-2 l/s) and it was decided to circulate for some time to clean the well and in hope that the circulation losses would increase with cooling of the well. However, a mud was used as the circulating fluid instead of treated seawater and circulation losses did not increase even after it had been diluted and later replaced with seawater. Attempts were then made to stimulate the well on April 20th and 21st by injecting into the well and raise the pressure on the fluid column. Due to limited supply of seawater to the drillsite and fresh water the injection was carried out by increasing the injection rate slowly to equal the supply to the rig, which was about 1200 l/min (20 l/s). This phase of the stimulation was ended by increasing the injection rate to 2430 l/min (40.5 l/s) for about 20 minutes. The pressure on the wellhead was around 10 bar-g during the injection, but reached a maximum of about 14 bar-g for the highest injection rate. When the injection was stopped the pressure fell to 10 bar-g and then slowly to 5 bar-g in 1.5 hours. An additional 2.5 hours injection step was carried out during measurement of a downhole temperature profile. A small improvement was observed in injectivity during this operation as the injectivity index increased from about 72 l/min per bar (1.2 l/s per bar) to about 120 l/min per bar (2 l/s per bar). Therefore, it was decided to continue this operation after setting the liner in the well.

Before setting the liner two 20 m intervals had to be reamed at 700 m and 780 m and when running the liner it had to be hammered down from 783 m to 839 m, but after that it sunk freely into the well. The second phase of the stimulation operation was carried out on April 25th and April 26th. For this phase the injection rate was as high as the rig pumps allowed while the mud tanks were emptied and then stopped while the mud tanks were filled again. This cycle was repeated ten times giving injection rates up to 3000 l/min (50 l/s) which could be maintained some 20 minutes while the filling of the mud tanks took some 40 minutes. Each step lasted therefore about one hour. The wellhead pressure rose to 13.1 bar-g during the injection and fell to 6.8 bar-g during the fill up periods. After ten cycles a pressure falloff was monitored for three hours, followed by a three hours injection step of 780 l/min (13 l/s). During the falloff step the wellhead pressure fell from 13.5 bar-g to 1.6 bar-g in about 3 hours. No trend was observed in the pressure data during the second phase of the stimulation operation that could indicate further changes in the well conditions. That was confirmed with the final three hours injection step which indicated that the injectivity index was about the same as after the first phase or nearly 120 l/min per bar (2 l/s per bar). Therefore, the permeability of the well did not change during the second phase of the stimulation.

Figures 8 and 9 show matches to the last three hours falloff and injection steps. The matches are to an infinite acting reservoir model which means that outer boundary is not detected by the test steps. The match parameters change some, as can be seen from the figures, depending on the test procedure. The falloff step indicates slightly higher permeability (transmissivity) than the injection step and a zone of reduced permeability around the well. The injection step indicates that there might be open fractures at the well. Small fractures could be connected to the well that open when pressurized, but close again when the pressure is released. Therefore, it is likely that under production the well will act as there is a damaged zone around it with reduced permeability due to mud invasion. The transmissivity is in the lower range for a commercially productive geothermal well and is of similar magnitude as for well BO-4.

Discharge test

After two months of warm-up well BO-7 was still relatively cold in the upper most 300 m and with a water level at more than 30 m depth. It was clear that some assistance was needed to initiate the discharge from the well. It was decided to connect a 2" pipeline from the killvalve on well BO-5 to the killvalve on BO-7. Well BO-5 was first bled through the wellhead of BO-7 to the atmospheric separator to warm it up and increase its wellhead pressure. The master valve on BO-7 was later closed and the about 190°C steam-water mixture from BO-5 bled into well BO-7. The idea was to warm up the upper most part of well BO-7 and change the pressure gradient in the well to enable it to discharge. This operation started on June 27th, 2001 as well BO-5 was bled for short times into well BO-7. When the wellhead pressure on BO-7 reached 6-7 bar-g the master valve was opened and checked if the well could discharge. This was repeated five times during the day with wellhead pressure of up to 15 bar-g on BO-7 without success (see Tables in appendix). The next day a similar approach was used, but with continuous bleeding from BO-5 while it was tried to initiate the discharge from BO-7, but without success. The following day the orifice in the discharge pipeline was changed from 75 mm to 90 mm. Well BO-5 was bled into well BO-7 for 4.5 hours until almost a stable wellhead pressure of about 16 bar-g was reached on both wells. Well BO-7 was then opened to the atmospheric separator and rock muffler to minimize back pressure and a discharge was established. The discharge rate was low as the wellhead pressure on BO-7 rose slowly to 8 bar-g, but then it dropped rather quickly and the discharge became almost dry steam. The well recovered and the earlier blackish water, which probably mostly originated from well BO-5, was replaced with muddy water from the well. The wellhead pressure was lower and appeared to be stabilizing around 4.5 bar-g. However, the next day the discharge had desisted and the discharging period had only been 14-15 hours.

The discharge from BO-7 oscillated between dryer and wetter periods and one such cycle may have quenched the discharge. The water phase was still very muddy so the short discharge did not manage to clean the well of the drilling mud and cuttings. The calculated enthalpy during the dryest cycle of the discharge indicated that boiling was occurring down to the reservoir or at least down to the upper most feed zone at around 600 m depth. Even during the wetter cycles the calculated enthalpies indicate some boiling down to the reservoir, which is due to low permeability, especially near the wellbore, and therefore slow feeding rate to the wellbore. The low permeability causes a large drawdown in the well, which results in low wellhead pressures. If the wellhead pressure can not be increased by further cleaning of the well, it will be too low for operating the well on line with other wells.

Temperature and pressure profiles

The temperature and pressure profiles measured in well BO-7 are presented in Figures 10 and 11 along with profiles from well BO-4 for comparison. The first temperature profile indicates that permeable zones are at 600-700 m and 900-1000 m. The second temperature profile was measured during the first phase of the stimulation operations and indicates that the injected seawater is mainly lost to permeable zones above 1000 m. Furthermore, that a feed zone near 600 m depth shows the fastest recovery. The last two profiles show the warm-up in the well, but it has been little at 1100 m over a two months period. It could indicate that the well was approaching the formation temperature at that depth. That could mean that temperature around well BO-7 is lower than around well BO-4 down to about 1000 m (TVD) depth. Unfortunately, the liner shoe hinder measurements deeper in the well, but there temperature could be similar as at BO-4. The temperature profiles could indicate a low permeable zone near the bottom of the well. With mud deep in the well and blocked liner shoe, that zone may be too weak to participate in the discharge of the well.

The pressure profile before the discharge test of well BO-7 indicates that the pressure potential at BO-7 is at least 4 bar lower than at well BO-4. Comparing with the earlier profile that is measured to the bottom of the well (Figure 11) would indicate that the deepest permeable zones have similar pressure potential as observed at BO-4, but those zones are currently blocked.

FIELD DISCUSSIONS

Figure 12 shows selected pressure profiles from wells BO-4, BO-5, BO-6 and BO-7, which have been corrected to true vertical depth (TVD). It can be seen that the pressure potential is very similar at all the wells except well BO-7. The difference between the first three wells is within the error limit in the measurements, but well BO-6 could have the highest potential, then well BO-5 and BO-4. The potential at BO-6 could be 1-1.5 bar higher than at BO-4. Lastly is well BO-7 with potential that is at least 4 bar lower than at BO-4. If true that would indicate that well BO-7 is a peripheral well, outside the main reservoir, which the other wells intersect.

Temperature profiles are probably similar at wells BO-4, BO-5 and BO-6, but calibration problems make it difficult to determine the true formation temperature around these wells. However, indications are that the reservoir temperature is higher at wells BO-5 and BO-6 than at BO-4 and could be highest at BO-6. The formation temperature is lowest around well BO-7 down to 1000 m (TVD) depth, but at greater depth the temperature could approach similar temperature as observed at well BO-4.

With the directional drilling from the old BO-4 platform the new wells (BO-5, BO-6, BO-7) were targeted to intercept several faults or fracture zones, which have a main trend from west to east. Wells BO-6 and BO-5 were directed to NNW and NE, respectively, while well BO-7 was directed to SE. Two fault/fracture zones are north of the site, "Faille de Plateau" and "Faille de Cocagne". Very small permeability could be associated to the "Faille de Plateau" fault while the "Faille de Cocagne" fault had a very high permeability and is the main production zone in wells BO-5 and BO-6. South of the site is the "Faille de Descoudes" fault that well BO-7 intercepts, but small permeability could be associated with it.

The drilling of the new wells confirmed a high permeability and productivity associated with the "Faille de Cocagne" fault, which intersects the main geothermal reservoir. However, it is not possible to determine if the main reservoir is to the NW or NE of the BO-4 site from the currently available data. Also the reservoir might be bounded to the south by the "Faille de Descoudes" fault, at least down to 1000 m (TVD) depth.

A small interference is observed between well BO-4 and wells BO-5 and BO-6. The interference observed in the wellhead pressure of well BO-4 is 0.2-0.6 bar when either BO-5 or BO-6 discharge. The magnitude of the interference was greater during the extended discharge of BO-6 than during the short discharge of BO-5. As well BO-4 has a liquid column to the wellhead, a similar pressure change is expected at the reservoir depth. This means that the Bouillante wells 4, 5 and 6 are located within the same reservoir. The distance between the main productive zones in wells BO-5 and BO-6 to well BO-4 is about 375 m, respectively, while the distance is about 400 m between wells BO-5 and BO-6 along the "Faille de Cocagne" fault. No interference was observed at BO-4 wellhead during the stimulation operation on BO-7. Its existence can though not be excluded based on the currently available data.

CONCLUSIONS AND RECOMMENDATION

Deepening of well BO-5 to intercept the "Faille de Cocagne" increased the productivity of the well considerably. A short discharge test carried out shortly after the completion of the well indicated that its initial production capacity of high pressure steam (at 6 bar-a) is more than 53 t/hr (14.6 kg/s). Using a conversion factor of 8 t/hr of high pressure steam per MW_e produced, the initial capacity of the well corresponds to about 7 MW_e.

A discharge test extending over three weeks for well BO-6 indicated that the well was further warmed up compared to the short discharge test carried out when the well was completed. Furthermore, the productivity of the well improved some during that period and no decline in output or wellhead pressure was observed during the three weeks that the test lasted. The initial production capacity of well BO-6 for high pressure steam is estimated to be 80 t/hr (22.2 kg/s). Using the same conversion factor as above, the initial capacity of the well corresponds to 10 MW_e.

Unfortunately, well BO-7 did not intersect high permeable zones and attempts to stimulate the well had limited success. Furthermore, pressure profiles indicate that the reservoir pressure around the well is 4 bar lower than at the other wells drilled from the BO-4 site (BO-4, BO-5, BO-6). That can be interpreted as well BO-7 being outside the main reservoir that the other wells intersect. This is further supported by lower reservoir temperature in well BO-7 than in the wells from the BO-4 platform. Well BO-7 has similar permeability as encountered at well BO-4, which is in the lower range for a commercially productive geothermal well. In its current stage the discharge wellhead pressure is too low (4 bar-g) for the well to be operated with other wells on a common transport pipeline.

This report describes the current conditions and initial production capacity of the three new wells drilled from the BO-4 platform. Although well BO-7 can currently not be operated on line with other production wells, the initial production potential of wells BO-5 and BO-6 does more than make up for that when compared with world wide average expectation for a productive geothermal well, which is just over 3 MW_e. **The over all result for this drilling phase has been very successful with estimated initial generating capacity of about 17 MW_e from the new wells**. This initial capacity can be expected to decline some during a long term production, but that decline will depend on the properties and capacity of the main Bouillante geothermal reservoir. As mentioned has well BO-2 supplied steam to the current power plant for 3 MW_e production for over a decade with apparently only small decline in reservoir pressure. Assuming that the increased production load will not increase that decline much, one can estimate that the long term production decline will be in the order of or less than 30% from its initial potential. That would indicate that the long term generating capacity of the new wells is in excess of 11 MW_e.

It is recommended that before discharging any of the wells drilled from the BO-4 site, that static pressure and temperature profiles will be measured in all the wells with the same gauges. Using the same gauges in all the wells will limit calibration problems of the gauges. The measurements should give, relatively, the undisturbed formation temperature around the wells and their pressure potential. The measurements should indicate which well is nearest to the main upflow in the geothermal reservoir and thereby determine the direction towards the hottest part of the reservoir.

It is recommended that further discharge testing will be carried out for well BO-7. The purpose of the test would be to try to clean the well more of drilling mud and cuttings. During the few hours initial discharge test the water phase was still very muddy, indicating that the well had not cleaned itself. Drilling mud and cuttings could therefore still be sitting in the permeable zones intersected by the well, as interpretation of the pressure response at the end of the stimulation operation indicated an existence of zone of reduced permeability around the well. Furthermore, the deepest permeable zones were probably inactive during the initial discharge test. If further cleaning of the well would be successful, the well might become a useful backup well. If not, the well could serve as a monitoring well to evaluate pressure and temperature changes in the Bouillante reservoir due to future production.

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Omar Sigurdsson, 2001a: *Testing of well BO-5 at end of drilling operation.* Orkustofnun, GeoScience Division, short report Omar/2001-02, 36p.

Omar Sigurdsson, 2001b: *Testing of well BO-6 at end of drilling operation.* Orkustofnun, GeoScience Division, short report Omar/2001-03, 24p.

Reykjavik 10 October 2001

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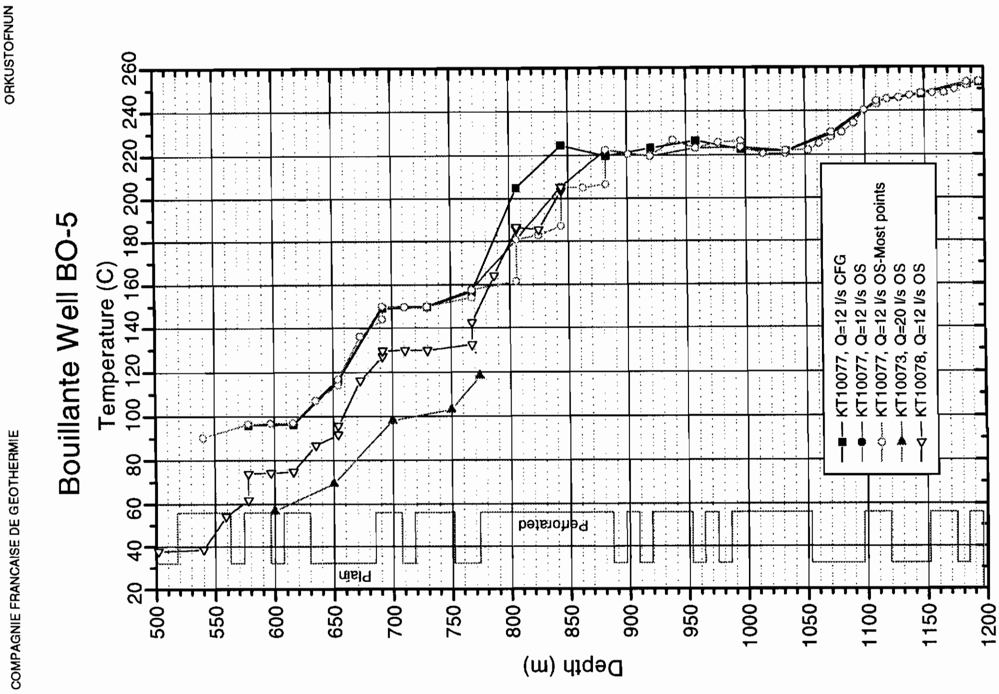

Figure 1. Temperature profiles measured in well BO-5 during waterloss tests and location of perforated and plain pipes in the BO-5 liner.

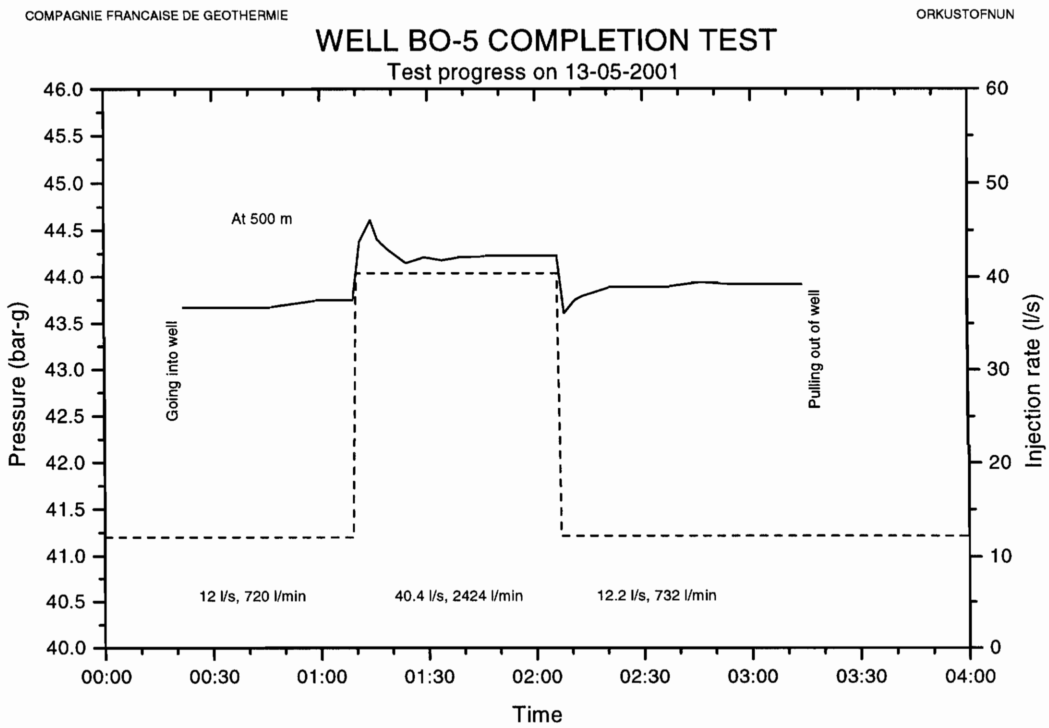

Figure 2. Progress of the short completion test conducted on May 13th, 2001 after deepening of well BO-5. Pressure gauge set at 500 m (MD) depth.

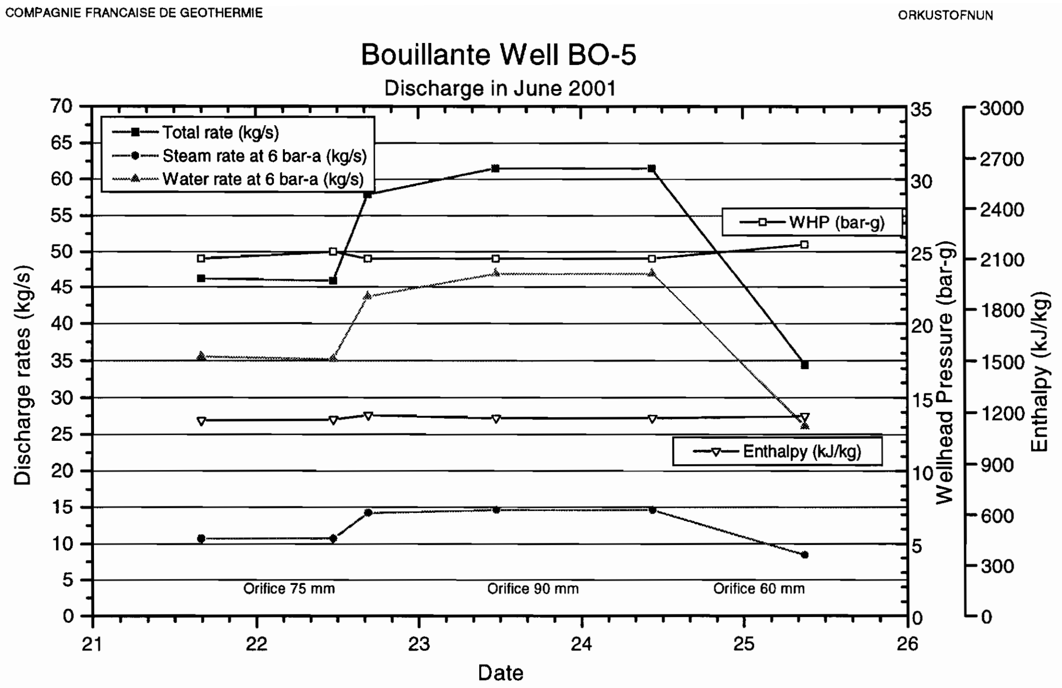

Figure 3. Flow rates, wellhead pressures and enthalpies during the discharge test of well BO-5 in June 2001.

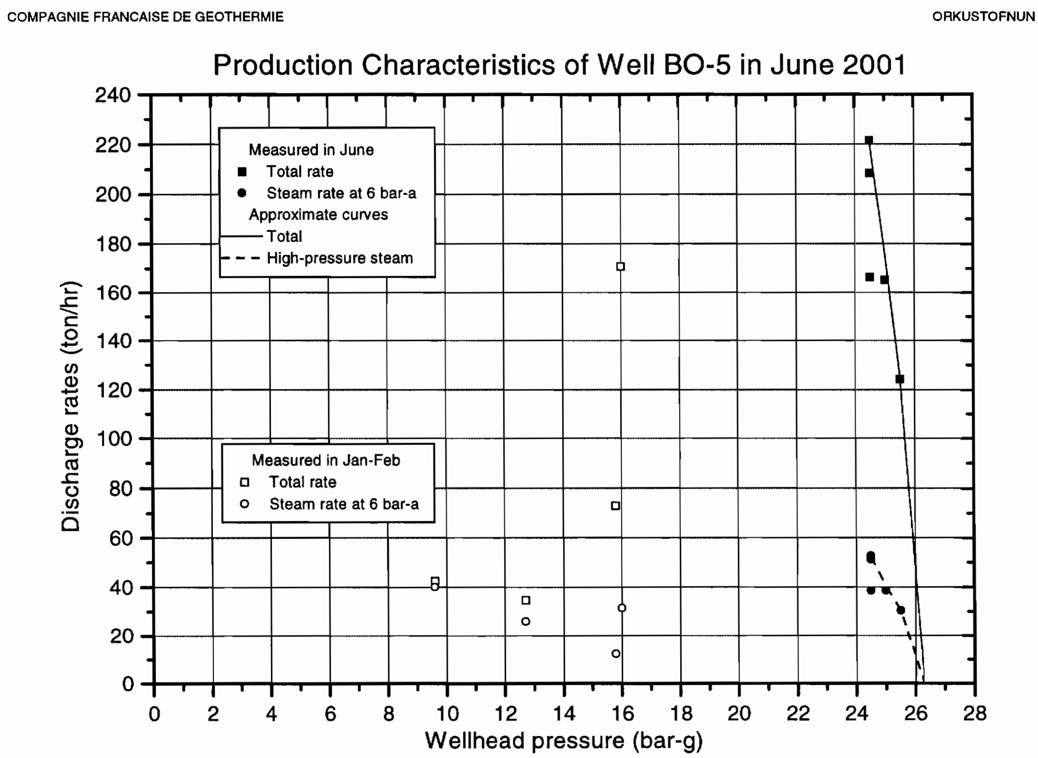

Figure 4. Production characteristics of well BO-5. The filled points are from the discharge test after deepening the well in June 2001. The open points are from short discharges in January and February 2001.

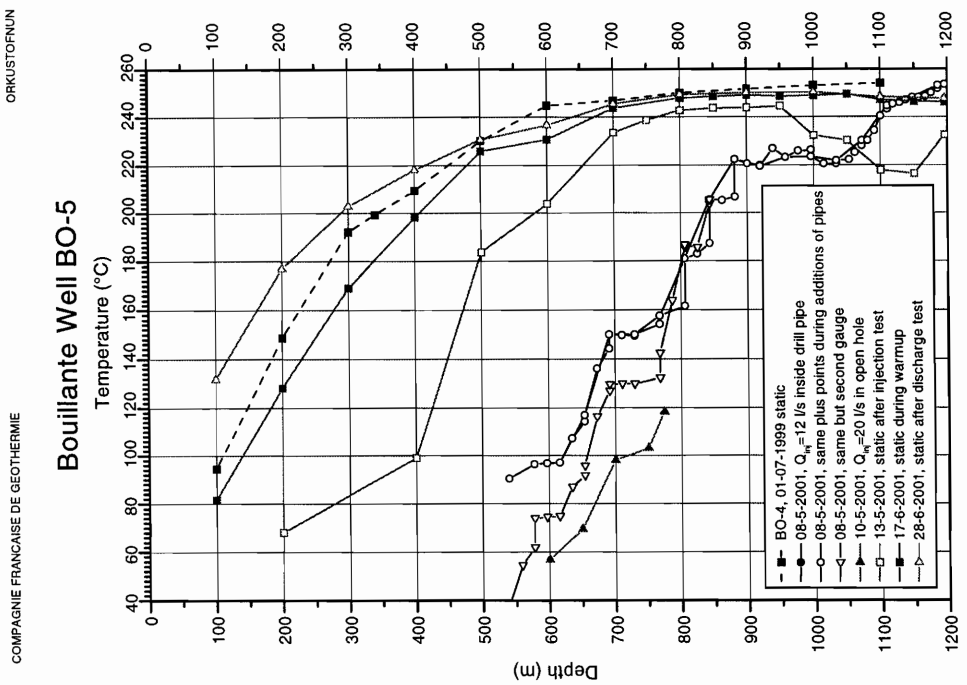

Figure 5. Temperature profiles measured in well BO-5 after its deepening with comparison to temperature in well BO-4 from 1999.

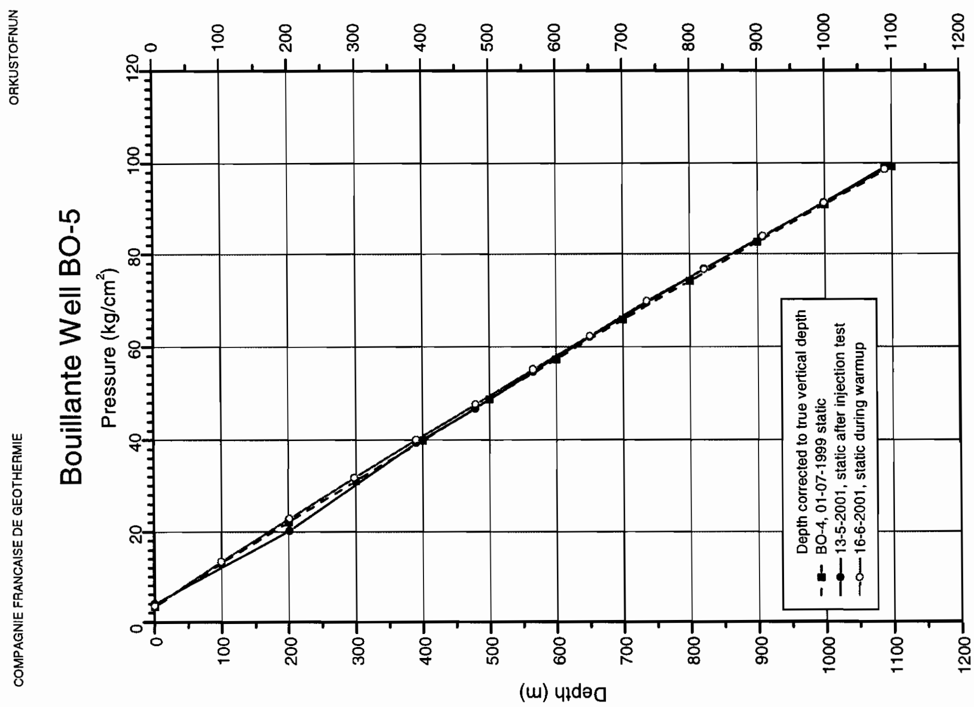

Figure 6. Pressure profiles measured in well BO-5 after its deepening with comparison to pressure in well BO-4 from 1999. The profiles are corrected to true vertical depth (TVD).

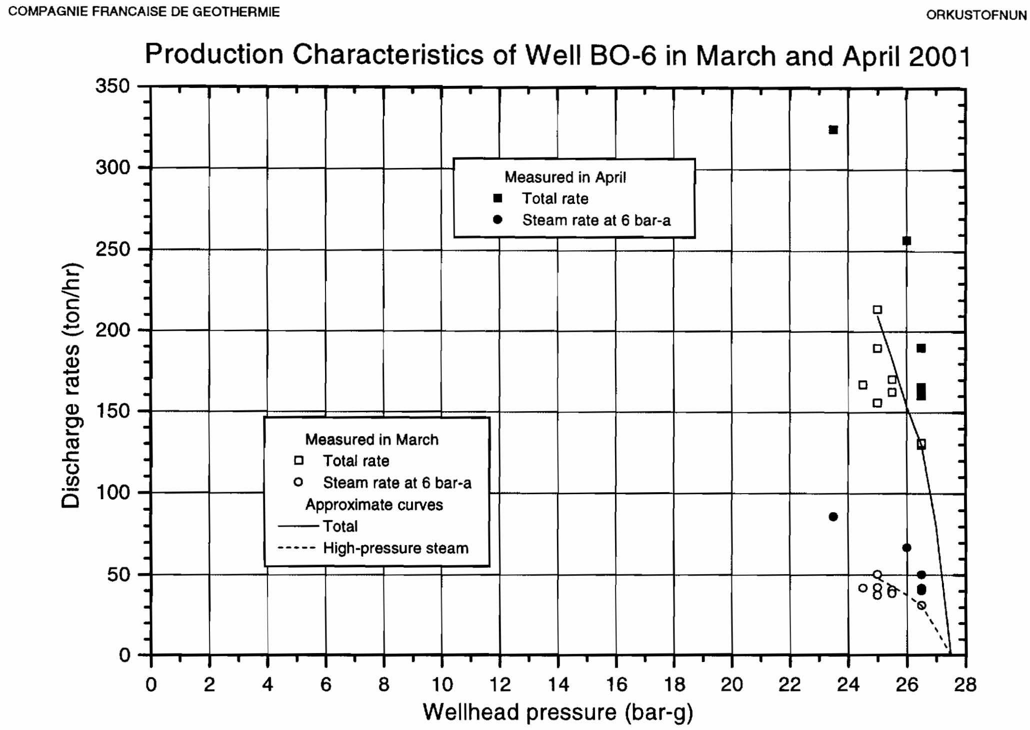

Figure 7. Production characteristics of well BO-6. The filled points are from the extended discharge test while the open points are from the short discharge test at the end of the drilling.

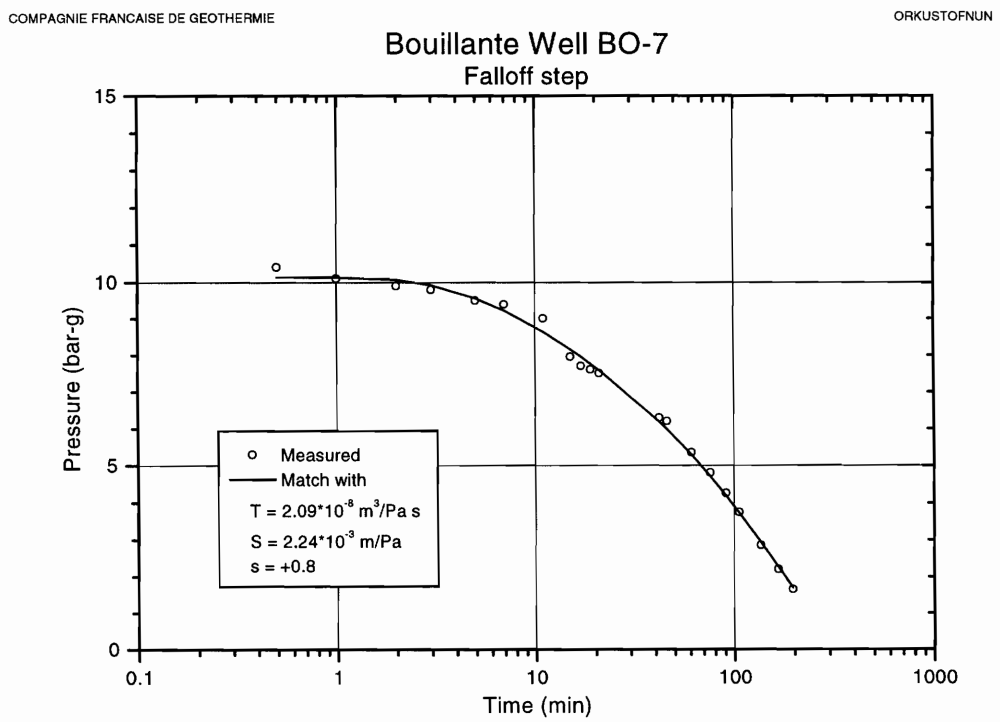

Figure 8. Falloff step during stimulation of well BO-7 with a match to infinite acting reservoir model (Theis solution).

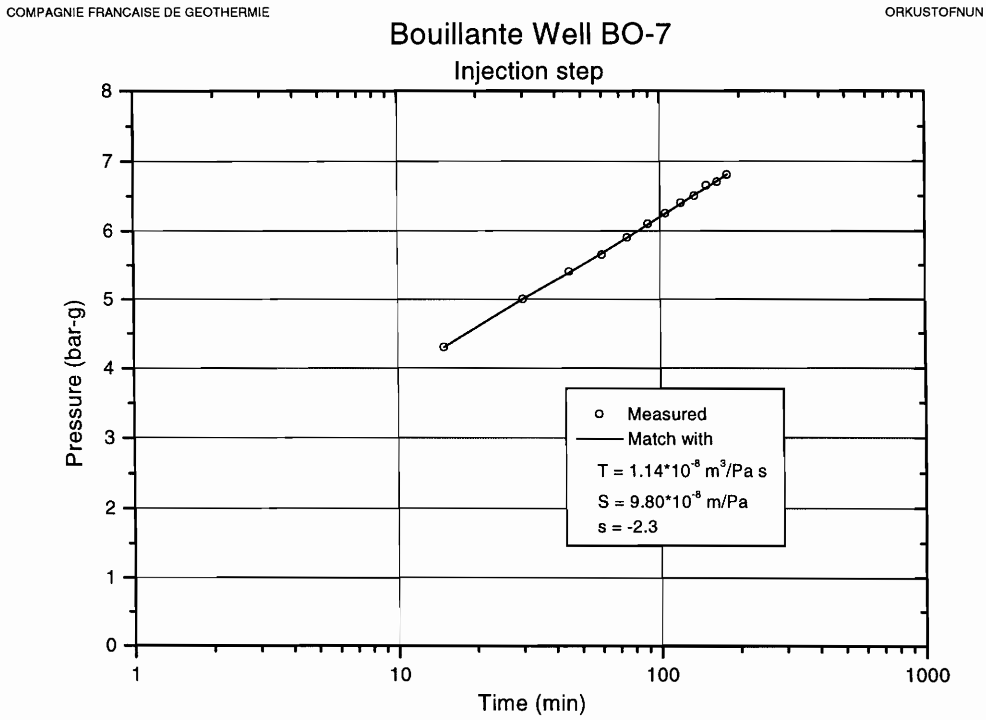

Figure 9. Injection step during stimulation of well BO-7 with a match to infinite acting reservoir model (Theis solution).

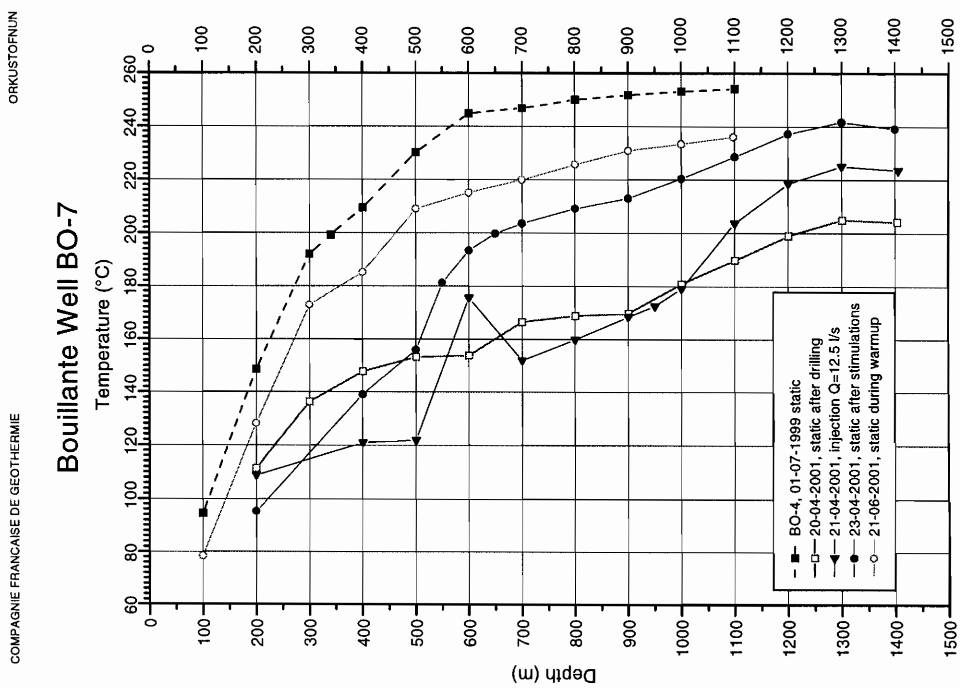

Figure 10. Temperature profiles measured in well BO-7 with comparison to temperature in well BO-4 from 1999.

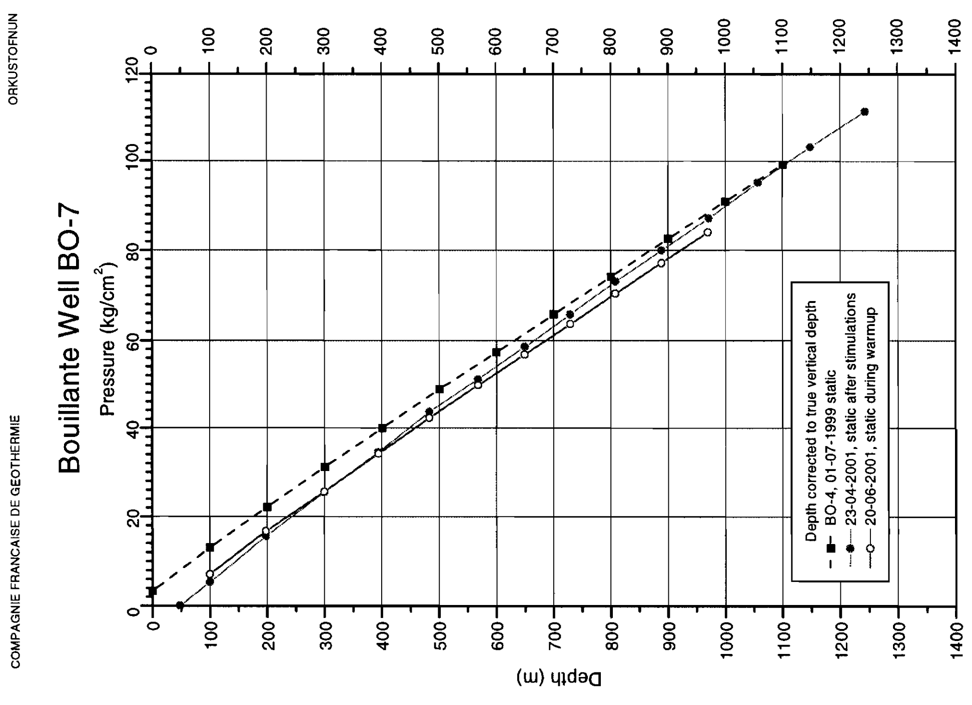

Figure 11. Pressure profiles measured in well BO-7 with comparison to pressure in well BO-4 from 1999. The profiles are corrected to true vertical depth (TVD).

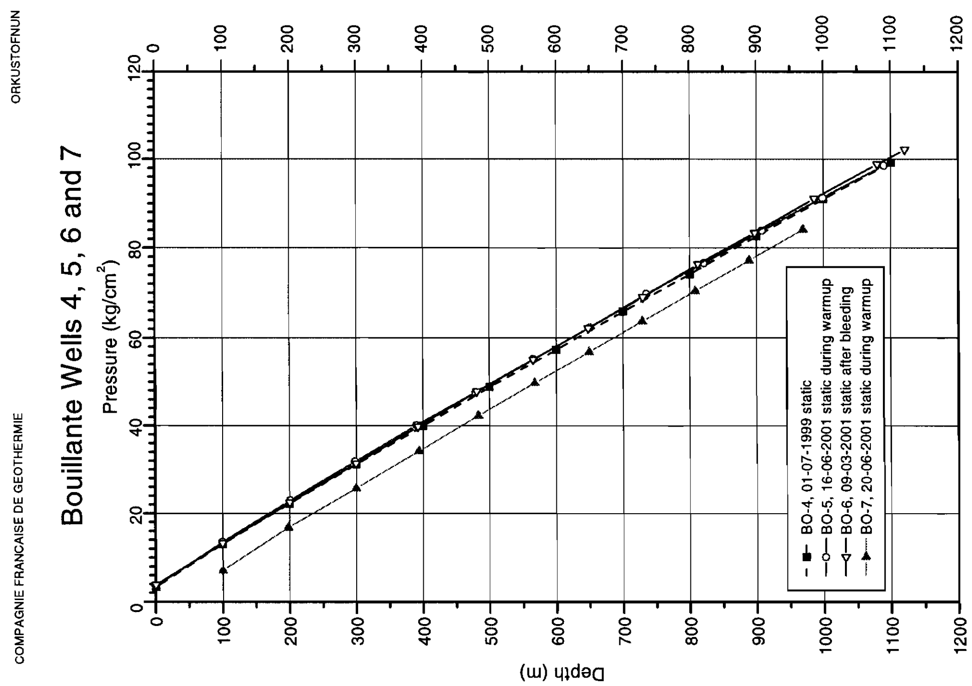

Figure 12. Selected pressure profiles from wells BO-4, BO-5, BO-6 and BO-7. The profiles are corrected to true vertical depth (TVD).

APPENDIX

Waterloss temperature logging in well BO-5

Static temperature and pressure logging in well BO-5

Completion test in well BO-5

Static temperature and pressure logging in well BO-5

Static temperature logging in well BO-5

Discharge measurements at well BO-5 in June 2001

Discharge from well BO-5 in kg/s and ton/hr in June 2001

Wellhead pressure in wells BO-4, BO-5, BO-6 and BO-7

Temperature logging in well BO-7

Static temperature and pressure logging in well BO-7

Static temperature and pressure logging in well BO-7

Discharge measurements at well BO-7 in June 2001

Discharge from well BO-7 in kg/s and ton/hr in June 2001

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

One letter sent to CFG during testing of well BO-6

Three letters sent to CFG during testing of well BO-7

WATERLOSS TEMPERATURE PROFILE IN WELL BO-5

Date: 10-05-2001

Temperature gauge KT-10073; Clock 6h, serial no. V4101; Time 11:00-11:45

Zero reference at rotary of drill rig, which is about 4m above cellar.

TEMPERATURE				TEMPERATURE			
Depth (m)	Deflection (cm)	Temperature (°C)	Observations (Temp. Logging)	Depth (m)	Deflection (cm)	Temperature (°C)	Observations (Temp. Logging)
600	0.076	56.7	Injection 20.2 l/s				
650	0.284	69.4					
700	0.757	98.0					
750	0.840	103.0					
774	1.092	118.2	Gauge sit likely in a cavity				

Remarks: Second run after loosing gauge KT-10077 into the well. Injection of 20.2 l/s of untreated seawater.

STATIC TEMPERATURE AND PRESSURE PROFILES IN WELL BO-5

Date: 13-05-2001

Temperature gauge KT-10073; Clock 6h, serial no. V4101; Time 17:10-19:20
Pressure gauge KP-K8238; Clock 3h, serial no. V4304; Time 15:00-16:20
Zero reference about 3m above cellar, or 1m below rotary of rig.

TEMPERATURE				PRESSURE			
Depth (m)	Deflection (cm)	Temperature (°C)	Observations (Temp. Logging)	Deflection (cm)	Pressure (bar)	Pressure (kg/cm^2)	Observations (Press. Logging)
0				0.144	3.88	3.96	WHP=4.2 bar-g
200	0.261	68.0	WHP=1.0 bar-g	0.745	19.80	20.19	
400	0.774	99.0		1.451	38.58	39.34	
500	2.172	183.7		1.747	45.88	46.78	
600	2.497	203.6		2.040	53.55	54.60	
700	2.981	233.5		2.325	60.91	62.11	
750	3.064	238.7					Obstacle at 754m
800	3.128	242.7		2.597	68.09	69.43	
850	3.146	243.7					
900	3.147	243.8		2.864	75.20	76.68	WHP=1.75 bar-g
950	3.158	244.5					
1000	2.963	232.3		3.120	82.14	83.76	
1050	2.929	230.3					
1100	2.727	217.8		3.392	89.56	91.32	
1150	2.702	216.2					Obstacle at 1120m while pulling
1196	2.967	232.6		3.681	97.12	99.03	
0				0.075	2.02	2.06	WHP=1.0 bar-g

COMPLETION TEST IN WELL BO-5
Injection steps

Date: 13-05-2001

Pressure gauge KP-K8238; Clock 6h, serial no. V4101; Time 00:10-02:06
Zero reference at rotary of drill rig, which is about 4m above cellar.
Main injection and falloff steps at 500m.

Depth (m)	Time	Δtime (min)	Deflection (cm)	Estim. Temp. (°C)	Pressure (bar-g)	Pressure (kg/cm^2)	Observations
500	00:22		1.624	40.0	43.67	44.53	Gauge at reference depth
500	00:30		1.624	40.0	43.67	44.53	Injection 12 l/s and
500	00:45		1.624	40.0	43.67	44.53	filling mud tanks
500	01:00		1.627	40.0	43.75	44.61	
500	01:09		1.627	40.0	43.75	44.61	Injection increased
500	01:11	2	1.649	35.0	44.38	45.25	Injecting 40.4 l/s, WHP=0 bar-g
500	01:14	5	1.656	30.0	44.61	45.49	
500	01:16	7	1.648	30.0	44.40	45.27	
500	01:19	10	1.644	30.0	44.29	45.16	
500	01:24	15	1.639	30.0	44.15	45.02	
500	01:29	20	1.641	30.0	44.21	45.08	
500	01:34	25	1.640	30.0	44.18	45.05	
500	01:39	30	1.641	30.0	44.21	45.08	
500	01:49	40	1.642	30.0	44.23	45.10	
500	01:59	50	1.642	30.0	44.23	45.10	Mud tanks almost emptied
500	02:06	57	1.642	30.0	44.23	45.10	Injection reduced to 12.2 l/s

COMPLETION TEST IN WELL BO-5
Falloff step

Date: 13-05-2001

Pressure gauge KP-K8238; Clock 6h, serial no. V4101; Time 02:06-03:30
Zero reference at rotary of drill rig, which is about 4m above cellar.
Main injection and falloff steps at 500m.

Depth (m)	Time	Δtime (min)	Deflection (cm)	Estim. Temp. (°C)	Pressure (bar-g)	Pressure (kg/cm²)	Observations
500	02:08	2	1.619	30.0	43.61	44.47	Injection 12.2 l/s
500	02:11	5	1.625	33.0	43.75	44.61	WHP=0 bar-g
500	02:13	7	1.627	35.0	43.79	44.65	
500	02:16	10	1.629	37.0	43.83	44.69	
500	02:21	15	1.632	40.0	43.89	44.75	
500	02:26	20	1.632	40.0	43.89	44.75	
500	02:31	25	1.632	40.0	43.89	44.75	
500	02:36	30	1.632	40.0	43.89	44.75	
500	02:46	40	1.634	40.0	43.94	44.80	
500	02:56	50	1.633	40.0	43.92	44.78	
500	03:06	60	1.633	40.0	43.92	44.78	
500	03:14	68	1.633	40.0	43.92	44.78	Gauge pulled out

STATIC TEMPERATURE AND PRESSURE PROFILES IN WELL BO-5

Dates:

17-6-2001 Temperature gauge KT-10073; Clock 6h, serial no. V4101; Time 9:20-12:00
16-6-2001 Pressure gauge KP-K8238; Clock 3h, serial no. V4304; Time 16:20-18:10
Zero reference about 1m 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				0.128	3.43	3.50	WHP=3.7 bar-g
100	0.484	81.5	WHP=3.6 bar-g	0.497	13.16	13.42	
200	1.255	128.1		0.857	22.44	22.88	
300	1.928	168.9		1.192	31.14	31.75	
400	2.409	198.2		1.503	39.25	40.02	
500	2.857	225.8		1.789	46.67	47.59	
600	2.936	230.7		2.068	54.08	55.14	
700	3.145	243.7	Sits at 701m going down	2.335	61.09	62.29	
800	3.210	247.8		2.611	68.42	69.77	
850	3.222	248.5					
900	3.230	249.0		2.861	75.07	76.55	
950	3.223	248.6					
1000	3.227	248.8		3.129	82.22	83.84	
1050	3.237	249.4					
1100	3.199	247.1		3.402	89.52	91.28	
1150	3.188	246.4					
1196	3.191	246.6		3.668	96.63	98.53	
0				0.118	3.15	3.21	WHP=3.6 bar-g

Remarks: Small bleeding from stuffing box.

STATIC TEMPERATURE PROFILE IN WELL BO-5

Date: 28-6-2001

Temperature gauge KT-10073; Clock 6h, serial no. V4101; Time 14:50-16:50
Zero reference about 1m 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=5.0 bar-g				
100	1.315	131.7	Temp. still increasing				
200	2.060	176.9					
300	2.482	202.7					
400	2.730	218.0					
500	2.936	230.7					
600	3.030	236.6					
700	3.172	245.4					
800	3.234	249.3	WHP=5.5 bar-g				
900	3.247	250.1					
1000	3.250	250.3					
1100	3.219	248.3					
1196	3.207	247.5					
0	0.878	105.3					

Remarks: Small bleeding from stuffing box. Well stopped discharging 25-6-2001

DISCHARGE MEASUREMENTS AT WELL BO-5 IN JUNE 2001

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
21.6.2001	14:50		15.0												Well opened, range of WHP-gauge 40 bar
21.6.2001	14:55		21.0												Well fully open, orifice 75 mm
21.6.2001	14:58		22.0												Wellhead up by 3 cm
21.6.2001	15:04		24.0	8.0											Water blackish
21.6.2001	15:30		24.5	8.0											
21.6.2001	15:50		24.5			3.8	28.9	21.6	44.0	1181.9	29.2	14.8	33.2	10.8	Lip 5" or 128 mm
21.6.2001	15:55		24.5		3.8-4.0	3.9	28.3	22.2	46.2	1151.8	31.2	15.0	35.5	10.7	
21.6.2001	17:30	24.5-25.0	24.5	8.0											Water clear, wellhead up by 4 cm
21.6.2001	21:30		25.0	8.0											Wellhead up by 4.5 cm
22.6.2001	10:15	25.0-25.2	25.0												Wellhead up by 5.5 cm
22.6.2001	11:15		25.0	10.0		3.9	28.4	22.1	45.9	1158.8	30.9	15.0	35.2	10.7	
22.6.2001	11:20		25.0	10.0-10.2	3.8-4.0	3.9	28.4	22.1	45.9	1158.8	30.9	15.0	35.2	10.7	
22.6.2001	12:10		24.0												Closed for change of orifice
22.6.2001	12:40		23.5												Opened, lowest WHP 21 bar-g
22.6.2001	13:00	24.0-24.5	24.0	10.5											
22.6.2001	16:25		24.5	13		5.4	26.4	24.1	57.9	1183.7	38.3	19.6	43.7	14.2	Orifice 90 mm
22.6.2001	16:30		24.5		5.2-5.6	5.4	26.4	24.1	57.9	1183.7	38.3	19.6	43.7	14.2	Maybe small leakage to rock muffler
23.6.2001	11:20	24.5-24.7	24.5	13.5	5.6-6.0	5.8	25.8	24.7	61.5	1181.7	40.7	20.8	46.4	15.1	Wellhead up by 7 cm
23.6.2001	11:25		24.5		5.4-6.0	5.7	25.7	24.8	61.5	1166.6	41.1	20.4	46.9	14.6	
24.6.2001	10:25	24.5-24.7	24.5	13.5	5.6-6.0	5.7	25.6	24.9	61.9	1160.3	41.6	20.3	47.4	14.5	
24.6.2001	10:30		24.5		5.4-6.0	5.7	25.7	24.8	61.5	1166.6	41.1	20.4	46.9	14.6	Wellhead up by 7.5 cm
24.6.2001	11:50		24.5												Closed to change orifice
24.6.2001	12:10		21.0												Well opened, orifice 63 mm
25.6.2001	08:50		25.5	7.5	2.4-3.0	2.6	31.1	19.4	33.6	1177.0	22.3	11.3	25.4	8.2	Wellhead up by 8 cm
25.6.2001	09:00		25.5	7.5	2.5-2.8	2.7	30.9	19.6	34.5	1177.5	22.9	11.6	26.1	8.4	
25.6.2001	11:08		26.0	0											Well closed
															Transfer of equipment to BO-7

DISCHARGE FROM WELL BO-5, IN kg/s AND ton/hr IN JUNE 2001

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)
21.6.2001	14:50											
21.6.2001	14:55											
21.6.2001	14:58											
21.6.2001	15:04											
21.6.2001	15:30											
21.6.2001	15:50	44.0	1181.9	29.2	14.8	33.2	10.8	158.4	105.1	53.3	119.6	38.8
21.6.2001	15:55	46.2	1151.8	31.2	15.0	35.5	10.7	166.3	112.3	54.0	128.0	38.4
21.6.2001	17:30											
21.6.2001	21:30											
22.6.2001	10:15											
22.6.2001	11:15	45.9	1158.8	30.9	15.0	35.2	10.7	165.2	111.2	54.0	126.6	38.7
22.6.2001	11:20	45.9	1158.8	30.9	15.0	35.2	10.7	165.2	111.2	54.0	126.6	38.7
22.6.2001	12:10											
22.6.2001	12:40											
22.6.2001	13:00											
22.6.2001	16:25	57.9	1183.7	38.3	19.6	43.7	14.2	208.4	137.9	70.6	157.2	51.3
22.6.2001	16:30	57.9	1183.7	38.3	19.6	43.7	14.2	208.4	137.9	70.6	157.2	51.3
23.6.2001	11:20	61.5	1181.7	40.7	20.8	46.4	15.1	221.4	146.5	74.9	167.2	54.2
23.6.2001	11:25	61.5	1166.6	41.1	20.4	46.9	14.6	221.4	148.0	73.4	168.8	52.6
24.6.2001	10:25	61.9	1160.3	41.6	20.3	47.4	14.5	222.8	149.8	73.1	170.5	52.3
24.6.2001	10:30	61.5	1166.6	41.1	20.4	46.9	14.6	221.4	148.0	73.4	168.8	52.6
24.6.2001	11:50											
24.6.2001	12:10											
25.6.2001	08:50	33.6	1177.0	22.3	11.3	25.4	8.2	121.0	80.3	40.7	91.6	29.4
25.6.2001	09:00	34.5	1177.5	22.9	11.6	26.1	8.4	124.2	82.4	41.8	94.0	30.2
25.6.2001	11:08											

WELLHEAD PRESSURE IN WELLS BO-4, BO-5, BO-6 AND BO-7

Date	Time	BO-4 (bar-g)	BO-5 (bar-g)	BO-6 (bar-g)	BO-7 (bar-g)	Observations
16.6.2001	16:30		3.7			During pressure logging
21.6.2001	11:35		6.1			Bleeding 11:27-11:35
21.6.2001	13:01		8.0			Bleeding 12:50-13:01
21.6.2001	14:00		7.0	3.45		
21.6.2001	14:10		9.3			Bleeding 14:04-14:10, wellhead up by 2.5 cm
21.6.2001	14:24		12.0			Bleeding 14:19-14:24
21.6.2001	14:38		15.0			Bleeding 14:32-14:38
21.6.2001	14:55		21.0			Start to opened at 14:50, fully open at 14:55
21.6.2001	14:58		22.0			Wellhead up by 3.0 cm, water blackish
21.6.2001	15:04		24.0	3.45		
21.6.2001	15:30		24.5			BO-5 discharging 46 kg/s
21.6.2001	16:20		24.5			
21.6.2001	17:30		24.5			
21.6.2001	21:30		25.0	3.45		BO-5 wellhead up by 4.5 cm
22.6.2001	10:15	2.52	25.0	3.40		
22.6.2001	11:40	2.54	25.0	3.35		BO-5 discharging 46 kg/s
22.6.2001	12:10		24.0			BO-5 closed to change orifice
22.6.2001	12:40		23.5	3.30		BO-5 opened on 90 mm orifice
22.6.2001	13:00		24.0	3.30		BO-5 discharging 58 kg/s
22.6.2001	16:10	2.54	24.5	3.25		
22.6.2001	16:30		24.5			BO-5 wellhead up by 6 cm
22.6.2001	22:20	2.54	24.5	3.30		
23.6.2001	11:05	2.48	24.5	3.20		BO-5 discharging 61 kg/s
24.6.2001	10:30		24.5			BO-5 wellhead up by 7.5 cm
24.6.2001	11:40	2.41		3.15		BO-5 discharging 61 kg/s
24.6.2001	11:50					BO-5 closed to change orifice
24.6.2001	12:10		21.0			BO-5 opened on 63 mm orifice
24.6.2001	12:15	2.40	25.3	3.15		
24.6.2001	16:25	2.41	25.4	3.20		
25.6.2001	08:40	2.47	25.4	3.25		BO-5 discharging 34 kg/s
25.6.2001	11:08		26.0			BO-5 closed, wellhead up by 8 cm
25.6.2001	11:13		25.0			
25.6.2001	11:18	2.45	24.5	3.22		
25.6.2001	11:55		23.0			BO-5 wellhead up by 7.5 cm
25.6.2001	12:30		21.8			
25.6.2001	13:20	2.45	17.7	3.22		
25.6.2001	14:25	2.47	14.7	3.25		
25.6.2001	17:30	2.50		3.27		BO-5 wellhead up by 7.5 cm
26.6.2001	09:35	2.56	6.3	3.33		BO-5 wellhead up by 5.5 cm
26.6.2001	14:00	2.55	6.0	3.25		BO-5 wellhead up by 5 cm
26.6.2001	17:45	2.55	5.0	3.30		BO-5 wellhead up by 4 cm

WELLHEAD PRESSURE IN WELLS BO-4, BO-5, BO-6 AND BO-7

(cont. 2)

Date	Time	BO-4 (bar-g)	BO-5 (bar-g)	BO-6 (bar-g)	BO-7 (bar-g)	Observations
27.6.2001	08:40	2.60	5.2	3.40		BO-5 wellhead up by 3.5 cm
27.6.2001	12:13		5.2			BO-5 bled to BO-7
27.6.2001	12:27		8.0		4.0	BO-7 wellhead up by 1 cm
27.6.2001	12:33		8.7		6.0	Bleeding stopped
27.6.2001	12:38		5.5		3.5	BO-5 bled again to BO-7
27.6.2001	12:40		8.2		6.7	
27.6.2001	12:42		8.5		7.0	Bleeding stopped, BO-7 wellhead up by 1.5 cm
27.6.2001	12:52				2.6	
27.6.2001	12:55		7.0		2.2	BO-5 bled again to BO-7
27.6.2001	12:58		7.5		6.3	
27.6.2001	13:00				1.9	BO-7 opened
27.6.2001	13:07					BO-7 dead and bleeding of BO-5 to BO-7 started
27.6.2001	13:14		10.0		7.6	BO-5 bled to BO-7, BO-7 wellhead up by 2 cm
27.6.2001	13:17				3.5	BO-7 opened
27.6.2001	13:24					BO-7 dead and bleeding of BO-5 to BO-7 started
27.6.2001	13:36		12.0		10.5	
27.6.2001	14:10		14.0		13.2	BO-7 wellhead up by 3 cm, bleeding stopped
27.6.2001	14:13				6.0	BO-7 opened
27.6.2001	14:20				2.0	
27.6.2001	14:32					BO-7 dead and bleeding of BO-5 to BO-7 started
27.6.2001	15:32		15.5		15.0	
27.6.2001	15:33				7.5	BO-7 opened
27.6.2001	15:41				2.5	
27.6.2001	15:58					BO-7 dead and bleeding of BO-5 to BO-7 started
27.6.2001	16:17				11.5	
27.6.2001	17:32				6.0	BO-7 opened
27.6.2001	17:48					BO-7 dead and bleeding of BO-5 to BO-7 started
27.6.2001	18:02				11.0	BO-7 wellhead up by 4.5 cm, bleeding stopped
27.6.2001	19:30				2.0	
28.6.2001	10:05	2.60	6.0	3.35		
28.6.2001	16:57					BO-5 bled to BO-7 and silencer, BO-7 wellhead up by 2.5 cm
28.6.2001	17:17		10.0		5.0	Bleeding to silencer closed
28.6.2001	17:43				11.2	
28.6.2001	17:50		11.8		5.0	BO-7 opened with reduced bleeding from BO-5
28.6.2001	17:58		13.0		2.0	
28.6.2001	18:20		14.5		2.0	
28.6.2001	18:46				2.2	Bleeding from BO-5 stopped

WELLHEAD PRESSURE IN WELLS BO-4, BO-5, BO-6 AND BO-7

(cont. 3)

Date	Time	BO-4 (bar-g)	BO-5 (bar-g)	BO-6 (bar-g)	BO-7 (bar-g)	Observations
29.6.2001	10:35	2.62	5.5	3.40	0.0	BO-7 wellhead up by 2 cm
29.6.2001	10:58					BO-5 bled to BO-7
29.6.2001	12:40		15.5		14.5	
29.6.2001	15:22		16.2		16.0	BO-7 wellhead up by 6 cm
29.6.2001	15:26				9.0	BO-7 opened to rock muffler and silencer
29.6.2001	15:27				7.5	
29.6.2001	15:30				5.2	
29.6.2001	15:34				4.0	
29.6.2001	15:42				3.6	
29.6.2001	15:47				4.8	
29.6.2001	15:52				6.0	BO-7 water discharge almost black
29.6.2001	15:57				6.3	
29.6.2001	16:04				7.0	
29.6.2001	16:15				8.0	BO-7 wellhead up by 6 cm
29.6.2001	16:19				5.5	
29.6.2001	16:25				4.3	
29.6.2001	16:30				3.0	Only steam coming from BO-7
29.6.2001	16:48				6.5	Muddy water coming from BO-7
29.6.2001	17:06				5.7	Sound of cuttings in discharge pipe
29.6.2001	17:18				5.0	
29.6.2001	17:28				4.3	
29.6.2001	17:49				4.8	BO-7 on 90 mm orifice
29.6.2001	17:53				4.5	
29.6.2001	21:30	2.62		3.40	4.0	Muddy water coming from BO-7
30.6.2001	08:40		5.7		0.0	BO-7 dead, wellhead up by 4 cm
30.6.2001	09:25	2.64		3.45		

TEMPERATURE PROFILES IN WELL BO-7

Dates:

20.4.2001 Temperature gauge KT-10077; Clock 6h, serial no. V4101; Time 11:10-13:30
21.4.2001 Temperature gauge KT-10077; Clock 6h, serial no. V4101; Time 12:50-15:30
Zero reference at rotary of drillrig.

TEMPERATURE				TEMPERATURE			
Depth (m)	Deflection (cm)	Temperature (°C)	Observations (Temp. Logging)	Depth (m)	Deflection (cm)	Temperature (°C)	Observations (Temp. Logging)
100				100			
200	0.373	111.3		200	0.328	108.7	Start injection of 12.5 l/s
300	0.782	136.2		300			or 750 l/min
400	1.025	147.7		400	0.541	120.8	
500	1.127	153.2		500	0.558	121.8	
600	1.139	153.7		600	1.545	175.5	
700	1.375	166.4		700	1.103	151.9	
800	1.418	168.7		800	1.252	159.8	
900	1.539	169.6	Injection 20.2 l/s	900	1.411	168.3	
				950	1.488	172.4	
1000	1.645	180.8		1000	1.611	179.0	
1100	1.812	189.8		1100	2.084	203.6	
1200	1.995	199.0		1200	2.375	218.5	
1300	2.110	204.9	Gauge sit likely in a cavity	1300	2.502	225.0	
1404	2.097	204.2		1406	2.473	223.5	

STATIC TEMPERATURE AND PRESSURE PROFILES IN WELL BO-7

Date: 23.4.2001

Temperature gauge KT-10077; Clock 6h, serial no. V4101; Time 14:30-16:30
Pressure gauge KP-V3851; Clock 3h, serial no. V4304; Time 12:30-14:00
Zero reference at rotary of drillrig

TEMPERATURE				PRESSURE			
Depth (m)	Deflection (cm)	Temperature (°C)	Observations (Temp. Logging)	Deflection (cm)	Pressure (bar)	Pressure (kg/cm^2)	Observations (Press. Logging)
100				0.183	5.21	5.31	
200	0.092	95.1		0.539	15.26	15.56	
300				0.883	24.95	25.44	
400	0.868	139.0		1.197	33.86	34.53	
500	1.178	155.9		1.509	42.79	43.63	
550	1.651	181.1					
600	1.888	193.5		1.769	50.08	51.07	
650	2.010	199.8					
700	2.082	203.5		2.024	57.41	58.54	
800	2.189	209.0		2.270	64.52	65.79	
900	2.268	212.9		2.516	71.66	73.07	
1000	2.412	220.4		2.752	78.48	80.02	
1100	2.572	228.6		2.995	85.49	87.17	
1200	2.734	237.1		3.265	93.30	95.14	
1300	2.822	241.6		3.536	101.17	103.16	
1400	2.774	239.1	Water level 48m	3.811	109.22	111.37	

STATIC TEMPERATURE AND PRESSURE PROFILES IN WELL BO-7

Dates:

21.6.2001 Temperature gauge KT-10073; Clock 6h, serial no. V4101; Time 9:30-11:10
20.6.2001 Pressure gauge KP-K8238; Clock 3h, serial no. V4304; Time 14:20-15:50
Zero reference about 1m 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							
100	0.434	78.4		0.263	6.97	7.11	
200	1.255	128.1		0.626	16.36	16.68	
300	1.990	172.7		0.967	25.10	25.59	
400	2.195	185.1		1.285	33.52	34.18	
500	2.582	208.9		1.587	41.41	42.22	
600	2.682	215.0		1.863	48.73	49.69	
700	2.761	219.9		2.123	55.64	56.73	
707				2.134	55.93	57.03	Problem with wireline
800	2.854	225.6		2.378	62.40	63.63	
900	2.939	230.9		2.629	69.05	70.41	
1000	2.980	233.4		2.878	75.67	77.16	
1098	3.022	236.1		3.132	82.42	84.04	

DISCHARGE MEASUREMENTS AT WELL BO-7 IN JUNE 2001

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
27.6.2001	13:00		1.9												Well opened on 75 mm orifice
27.6.2001	13:03		0.2												
27.6.2001	13:07		0.0												Well dead, wellhead up by 2 cm
27.6.2001	13:17		3.5												Well opened
27.6.2001	13:24		0.0												Well dead
27.6.2001	14:13		6.0												Well opened, wellhead up by 3 cm
27.6.2001	14:20		2.0	0.5-1	<0.0		39.5	11.0	7.7	1085.9	5.4	2.3	6.2	1.5	Water blackish, Pc assumed -0.3 bar-g
27.6.2001	14:32		0.0												Well dead
27.6.2001	15:33		7.5												Well opened
27.6.2001	15:58		0.0												Well dead
27.6.2001	17:32		6.0												Well opened
27.6.2001	17:36		3.5		<0.0		38.9	11.6	8.4	1006.9	6.2	2.2	7.0	1.4	Partly open to rock muffler
27.6.2001	17:48		0.0												Well dead
28.6.2001	17:50		5.0												Well opened
28.6.2001	17:58		2.0				42.3	8.2			2.6				Some bleeding from BO-5 to BO-7
28.6.2001	18:06		2.0				45.5	5.0			0.8				
28.6.2001	18:46		2.2												Bleeding from BO-5 stopped
28.6.2001	18:51		0.0												Well dead
29.6.2001	15:26		9.0												Well opened on 90 mm orifice
29.6.2001	15:27		7.5												Open to silencer and rock muffler
29.6.2001	15:34		4.0				37.5	13.0			8.2				
29.6.2001	15:52		6.0				36.0	14.5			10.8				
29.6.2001	15:57		6.3			0.4	36.0	14.5	15.2	1068.1	10.8	4.4	12.3	2.9	Minimum flow, loss to rock muffler
29.6.2001	16:25		4.3			0.6	46.2	4.3	6.8	2497.1	0.6	6.2	0.8	6.0	Discharge oscillating
29.6.2001	16:48		6.5												Muddy water
29.6.2001	17:49		4.8	3.5-4.0	0.6-1.0	0.8	37.6	12.9	14.3	1400.3	8.1	6.2	9.3	5.0	Water very muddy
29.6.2001	17:53		4.5		0.6-1.1	0.8	38.1	12.4	13.6	1462.7	7.3	6.3	8.4	5.2	
29.6.2001	21:30		4.0												Muddy water
30.6.2001	08:40		0.0												Well dead and closed

DISCHARGE FROM WELL BO-7, IN kg/s AND ton/hr IN JUNE 2001

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)
27.6.2001	13:00											
27.6.2001	13:03											
27.6.2001	13:07											
27.6.2001	13:17											
27.6.2001	13:24											
27.6.2001	14:13											
27.6.2001	14:20	7.7	1085.9	5.4	2.3	6.2	1.5	27.7	19.4	8.3	22.2	5.5
27.6.2001	14:32											
27.6.2001	15:33											
27.6.2001	15:58											
27.6.2001	17:32											
27.6.2001	17:36	8.4	1006.9	6.2	2.2	7.0	1.4	30.2	22.3	7.9	25.4	4.9
27.6.2001	17:48											
28.6.2001	17:50											
28.6.2001	17:58			2.6								
28.6.2001	18:06			0.8					2.9			
28.6.2001	18:46											
28.6.2001	18:51											
29.6.2001	15:26											
29.6.2001	15:27											
29.6.2001	15:34			8.2					29.5			
29.6.2001	15:52			10.8					38.9			
29.6.2001	15:57	15.2	1068.1	10.8	4.4	12.3	2.9	54.7	38.9	15.8	44.3	10.4
29.6.2001	16:25	6.8	2497.1	0.6	6.2	0.8	6.0	24.5	2.2	22.3	3.0	21.4
29.6.2001	16:48											
29.6.2001	17:49	14.3	1400.3	8.1	6.2	9.3	5.0	51.5	29.2	22.3	33.5	18.0
29.6.2001	17:53	13.6	1462.7	7.3	6.3	8.4	5.2	49.0	26.3	22.7	30.4	18.6
29.6.2001	21:30											
30.6.2001	08:40											

ORKUSTOFNUN
GeoScience Division

Our date. 14-5-2001 *Your ref.*

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Results of completion tests after deepening of well BO-5

Well BO-5 was directionally drilled in January 2001 to 610 m depth. It was cased with 9 5/8" casing to 500 m and completed then with 7" perforated liner from 470 m and to 610 m. The plan was to drill the well to 1200 m depth, but due to over pressure and lack of equipment to deal with such conditions the drilling was stopped at that time at 610 m. When discharged, the well started at a high flow rate that declined rather quickly due to low permeability in the production zones. The well had not cut the targeted fault zones at that time. The well had therefore a promising potential to be a good producer if deepened to the targeted fault zones, which could have higher permeability. This opinion was further strengthen by the successful discharge testing of well BO-6, which did cut the same targeted fault zones as planed for BO-5. Well BO-5 was deepened by directional drilling in May 2001 to 1198 m depth. The well was completed with a mix of perforated and plain 7" liner from 458 m and to bottom on May 11, 2001. A completion test was carried out the day after, but due to malfunctioning of the pressure gauge used for the test, a shorter and less complete completion test was repeated which ran into the morning of May 13.

In the afternoon on May 12 a six hours step rate test was carried out with a pressure gauge set at 1020 m depth. When pulling the gauge out of the well it appeared to be stuck, but broke free when pulled with some force. Scaling was observed on the wireline during recovering of the pressure gauge, but untreated sea-water at an average rate of 732 l/min (12.2 l/s) had been injected into the well for at least three days. Unfortunately, there was a malfunction in the gauge so a usable record of the test was not obtained. It was decided to repeat the test, but with only one high injection rate and with the pressure gauge at shallower depth to limit the risk of loosing the gauge in the well. It took few hours to recollect sea-water in the rigs mud tanks for the test. Therefore, the second completion test started shortly after midnight on May 13. A new pressure gauge was set at 500 m depth while injecting 732 l/min (12.2 l/s). When the mud tanks were full the injection rate was increased to 2424 l/min (40.4 l/s). That rate lasted for 57 minutes or while the mud tanks were emptied. The injection rate was then decreased again to 732 l/min (12.2 l/s) and the pressure monitored for one hour more before pulling the gauge out of the well. During the completion tests no pressure was observed at the wellhead.

Reading the chart from the pressure gauge it is clear that the measurement is influenced by temperature changes in the fluid column in the well, as it was set at a rather shallow depth. This was expected when selecting this setting depth for the gauge, but was considered to have minimal effects on the main features of the completion test. Taking this into account the pressure change observed in the test is only 1.5-2.0 bar-g. This gives a high injectivety index for well BO-5 or 14-18 kg/s per bar. This is a much higher injectivety index than observed before the deepening of the well and it is of the same order as obtained for well BO-6. The water level in well BO-5 was at about 40 m depth.

The main results of the completion tests after deepening of well BO-5 are:

- The injectivety of the well has improved greatly compared to what it was before deepening of the well.
- The injectivety index for well BO-5 is now 14-18 kg/s per bar or of the same order as obtained for well BO-6.

It is too early to say where the main feed zone is in well BO-5 now, but feed zones are observed down to 1150 m depth. First indications after deepening of well Bo-5 are that its production potential has improved. How much is impossible to say until the well has been discharged, but with comparison to well BO-6 a first guess could be about 40 ton/hr (11 kg/s) of high pressure steam.

Guadeloupe 14-5-2001

Omar Sigurdsson
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Results of well BO-5 short discharge test after deepening

Well BO-5 was directionally drilled in January 2001 to 610 m depth. It was cased with 9 5/8" casing to 500 m and completed then with 7" perforated liner from 470 m and to 610 m. The plan was to drill the well to 1200 m depth, but due to over pressure and lack of equipment to deal with such conditions the drilling was stopped at that time at 610 m. When discharged, the well started at a high flow rate that declined rather quickly due to low permeability in the production zones. The well had not cut the targeted fault zones at that time. The well had a promising potential to be a good producer if deepened to the targeted fault zones, which could have higher permeability. This opinion was strengthening by the successful discharge testing of well BO-6, which did cut the same targeted fault zones as planed for BO-5. Well BO-5 was deepened by directional drilling in May 2001 to 1198 m depth. The well was completed with a mix of perforated (11 mm) and plain 7" liner from 458 m and to bottom on May 11, 2001. A completion test was carried out the day after, but due to malfunctioning of the pressure gauge used for the test, a shorter and less complete completion test was repeated which ran into the morning of May 13.

The results of the short completion tests after deepening of well BO-5 were good, indicating that its injectivity had greatly improved compared to what it was before the deepening. The injectivity index was estimated to be about 14-18 kg/s per bar and resemble the injectivity of well BO-6.

The installment of the discharge test line for BO-5 was finished on June 21st. Warming up of the well started at 11:27 and the well was fully open at 14:55. It discharged through a 75 mm orifice until the next day when the orifice was exchanged to 90 mm. The well discharged through that orifice until June 24th when it was exchanged with a 63 mm one. When writing this letter the well has been discharging for 3.5 days. During the first six hours of discharge the wellhead pressure was slowly rising to 25 bar-g and when the orifice size was increased the day after the wellhead pressure dropped only by 0.5 bar. Currently, only two points have been measured for the production characteristics curve for the well. The well has been discharging 158-221 t/hr (44.0-61.5 kg/s) with wellhead pressure changing between 25.0-24.5 bar-g. The corresponding high-pressure steam production has been in the range of 39-52 t/hr (10.8-14.6 kg/s) and calculated fluid enthalpy has corresponded to water at 265-270°C. That temperature is about 15-20°C higher than measured in the well at static conditions before the discharge.

The discharge from well BO-5 has been very short, but by comparing it to well BO-6 one can make the following conclusions:

- The discharge rate and enthalpy from well BO-5 are about the same as when well BO-6 was first discharged after drilling. However, the wellhead pressure on BO-5 is about 0.5 bar lower than was on well BO-6. This could be due to slightly higher-pressure losses in well BO-5 as not all the pipes in the liner are perforated so some plain pipes could be opposite to a feed zone.
- Increasing wellhead pressure during discharge could indicate an increasing inflow temperature. The calculated enthalpy (1150-1180 kJ/kg) corresponds to an inflow temperature of 265-270°C. Initial discharge test of BO-6 indicated temperatures in the same range, but later and longer discharge of well BO-6 indicated that the inflow temperature could be as high as 275°C.

- Small interference is observed between wells BO-6, BO-4 and BO-5. The observed interference wellhead pressure change has been less than 0.5 bar-g. Since well BO-7 has water level at about 30 m depth it has not been monitored for interference, but it can be expected to be there on the same order as observed in well BO-4.

From the above conclusions and with comparison to results obtained for well BO-6 it is estimated that the longer-term high-pressure steam production from well BO-5 can be at least 50 t/hr (14 kg/s), which is well above the success criteria of 19.3 t/hr (5.4 kg/s) of steam at 6 bar-a.

A report on the initial testing on wells BO-5, BO-6 and BO-7 will be submitted later when this testing phase is over.

Guadeloupe 24-6-2001

Omar Sigurdsson
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Subject: Current potential of new wells drilled at Bouillante, Guadeloupe.

Currently wells BO-5 and BO-6 have been tested for a short period. Well BO-7 will be tested in the next days. The tested total production of high-pressure steam (at 6 bar-a) for wells BO-5 and BO-6 is at least 120 t/hr. Well BO-7 will add to that output. It is therefore estimated that the long-term high-pressure steam production from the three wells will be in excess of 85 t/hr. Depending on plant design that should be sufficient to run a geothermal power plant of 11 MWe on a long-term basis.

Bouillante, Guadeloupe 25-6-2001

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DISCHARGE TESTING OF WELL BO-6 IN BOUILLANTE IN GUADELOUPE IN MARCH AND APRIL 2001.

Well BO-6 is directionally drilled to 1248 m depth. It is cased with 9 5/8" casing to 498 m and was completed with 7" liner from 462 m and to the bottom on March 3rd, 2001. The well was discharged tested initially during March 10th to March 15th. The well was then shutin but opened again on March 28th and discharged continuously until April 17th through a 75 mm orifice. The pressure on wellhead was measured regularly during this period and the flow from the well was measured few times. This was done by diverting the flow from the rock muffler to an atmospheric separator. For each measurement the following parameters were recorded: (1) Wellhead pressure; (2) lip pipe pressure and (3) water level in the weir box. Some averaging of the measured values was necessary due to fluctuations. Also some leakage was observed through the valve to the rock muffler, so some small fraction of the flow bypassed the atmospheric separator when the flow measurements were carried out.

Well BO-6 was closed on April 17th to stop the leakage on the valve. The well was open for discharge the following day and the flow measured in the afternoon and the following morning. In order to have more information on the flow characteristics of the well, the 75 mm orifice and the 128 mm lip pipe were replace by a 90 mm orifice and a 146 mm lip pipe. The well discharged for some 20 hours for stabilization before the flow was measured. Finally the 90 mm orifice was replaced by a 120 mm orifice and the well discharged to the rock muffler. It was obvious that the surface piping and the atmospheric separator were not designed for the high flowrate of well BO-6 at this orifice opening and further testing of the well was stopped and the well closed.

All the discharge measurements that have been carried out in well BO-6 are shown in an Excel table. Preliminary analysis of the data shows the following:

1. Measured enthalpy values have increased in time. During the initial discharge in March most enthalpy values were in the range of 1130-1170 kJ/kg. Whereas the latest values in April exceed 1200 kJ/kg. This indicates heating of well during the discharge and possible boiling in the formation. If we ignore the boiling and assume pure liquid inflow the enthalpy of 1160 kJ/kg corresponds to inflow temperature of 265°C whereas 1210 kJ/kg corresponds to 275°C inflow temperature.

2. The total flow from well BO-6 has also increased during the flow test period. Part of the flow increase is due to the rise in the enthalpy but it is also quite possible that the discharge has clean mud and drillcuttings from the production fracture and improved the permeability of this already high permeable well.

3. Well BO-6 has a shutin pressure of 27-28 bar. The flow characteristics show that the flow increases very rapidly when the well head pressure is lowered. All the data points are measured at highly throttled flow with only 60-90 mm orifice. For these opening the flowrate is up to 70 kg/s. A 30 minutes discharge through a 120 mm orifice lowered the wellhead pressure to some 23.5 bar.

4. The test BO-6 from March 28th until April 20th showed some connection (interference) with BO-4 but no changes were observed in the wellhead pressure of BO-5. This data will be analyzed later.

Preliminary analysis of the production data of well BO-6 shows that the well is a very good producer and it is estimated that the longer-term high pressure steam production from well can easily be more than 20 kg/s or more than 72 t/hr. The longer-term behavior will, however, be controlled by the capacity of the Bouillante reservoir. Therefore it is important in the future to monitor closely the production from the field as well as parameters such as reservoir pressures, temperatures and fluid chemistry. My first impression is, however, that the present utilization of Bouillante (well BO-2) puts a very little load on the reservoir. I base the impression on the fact that reservoir pressures are still very high and little or no indications of pressure a drawdown in the reservoir.

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Guadeloupe 22-4-2001

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DISCHARGE MEASUREMENTS AT WELL BO-6

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
10.3.2001	14:30		24.0	8.5-9.0											Orifice 75 mm
10.3.2001	14:55	24.5-25.0	24.5	>16	5.5-9.0	7.2	28.5	22.0	46.4	1190.2	30.5	15.8	34.8	11.6	
10.3.2001	15:00		24.5	14-?	6.0-8.5	7.2	28.5	22.0	46.4	1190.2	30.5	15.8	34.8	11.6	
10.3.2001	17:10	25.0-25.5	25.0	13-?	5.8-7.2	6.5	29.0	21.5	43.3	1172.6	28.8	14.4	32.9	10.4	
10.3.2001	17:20		25.0		6.2-6.8	6.5	28.5	22.0	44.8	1137.0	30.5	14.2	34.8	10.0	
11.3.2001	11:05	25.5-26.0	25.5	14-?	6.2-7.8	7.0	28.2	22.3	46.8	1154.4	31.6	15.3	35.9	10.9	
11.3.2001	11:10		25.5		6.4-8.0	7.2	28.2	22.3	47.3	1169.2	31.6	15.7	36.0	11.3	
12.3.2001	09:30		25.5	13-?	6.0-7.4	6.7	28.9	21.6	44.0	1181.1	29.2	14.9	33.2	10.8	BO-5 WHP=4.0 bar-g
12.3.2001	09:40		25.5		6.1-7.5	6.8	28.6	21.9	45.1	1167.4	30.2	15.0	34.4	10.7	Well closed at 10:50 for orifice change
12.3.2001	13:30		18.0												Orifice 90 mm, lip pipe 14.6 cm
12.3.2001	13:38	24.0-24.5	24.0												Leakage at rupture disk
12.3.2001	17:00		25.0		2.8-3.8	3.3	25.0	25.5	60.3	1025.8	44.1	16.2	50.0	10.3	Oscillation of level in weir box 3cm
12.3.2001	17:10		25.0		2.8-3.6	3.2	27.0	23.5	52.7	1135.6	36.0	16.7	41.0	11.7	Approximate level due oscillation
															Not completely closed to rock muffler
13.3.2001	09:40		25.0	10	3.4-4.4	3.9	25.5	25.0	61.3	1131.5	42.0	19.4	47.8	13.5	Weir height oscillates 22-28 cm
13.3.2001	09:50		25.0		3.6-4.3	3.9	26.0	24.5	59.5	1162.7	39.9	19.6	45.5	14.0	
13.3.2001	17:00	26.5-27.0	26.5	11.5-14.5	4.2-6.2	5.2	30.5	20.0	36.1	1171.1	24.1	12.0	27.4	8.7	
13.3.2001	17:05		26.5		4.2-6.4	5.3	29.9	20.6	38.0	1135.0	25.9	12.0	29.5	8.5	
14.3.2001	09:10	26.0-26.5	26.5		4.0-6.3	5.1	30.4	20.1	36.1	1153.7	24.4	11.8	27.7	8.4	Weir height osci. about 1 cm
14.3.2001	09:15	26.5-27.0	26.5	12-15	4.9-5.5	5.2	30.4	20.1	36.4	1163.4	24.4	12.0	27.8	8.6	Final measurement for this period
2.4.2001	15:00	26-26.5	26.5	10-12	4+/-0.5	4	28-29	22	46	1178	30.5	15.5	34.7	11.2	Lip pipe 12.8 Orifice 72
4.4.2001	15:30	26-26.5	26.5	10-11	4+/-0.5	4	28-30	21.5	44.5	1214	28.8	15.7	32.8	11.6	Lip pipe 12.8 Orifice 73
11.4.2001	16:00	26-26.5	26.5	9-10	4+/-0.5	4	29-30	21	41.2	1187	27.2	14	30.9	10.3	Lip pipe 12.8 Orifice 74
17.4.2001	15:30	26-26.5	26.5		3-6	4.5	28	22.5	49.4	1199	32.3	17.1	36.8	12.6	Lip pipe 12.8 Orifice 75
18.4.2001	17:45	26-26.5	26.5	11-12	3-6	5.0	27-28	23.0	52.8	1218	34.1	18.7	38.8	13.9	Lip pipe 12.8 Orifice 75
19.4.2001	10:45	26-26.5	26.5		3-6	5.0	27-28	23.0	52.8	1218	34.1	18.7	38.8	13.9	Lip pipe 12.8 Orifice 75
20.4.2001	12:15	25.5-26	26.0	12	4.4-5.6	5.2	25-26	25.5	71.3	1211	46.3	25.0	52.7	18.6	Lip pipe 14.6 Orifice 90
20.4.2001	15:45	23-24	23.5	14?											Orifice 120 mm

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COMPLETION TESTING OF WELL BO-7
IN BOUILLANTE GUADELOUPE

MAIN ACTIVITY IN APRIL 2001

April 16th: Traveled from Iceland to Paris and continued to Guadeloupe. Arrived in Guadeloupe at around 19:00 local time. Hervé met me at the airport and guided me Bouillante. Stayed the first night at Hervés bungalow as the Jardin Tropical was fully booked. The rig was getting close to 1200 m depth. A total loss of circulation was observed at 980-984 m depth for about 30 minutes. The loss then decreased fast and only minor loss of circulation had been observed after that. Down to 980 m drilling mud was used but seawater after that. Hervé expected that it would be decided later that night to deepen the well to 1400m

April 17th: The decision of deepening well BO-7 had been taken. The morning depth was about 1280 m. A directional survey showed dropping angles to 23° from some 37°. Wiper trip underway but the drilling continued later in the afternoon. Still no loss of circulation. Discussed possible ways of increasing the permeability of the well with Hervé and Didier. A following tentative plan was agreed on and faxed to Max Le Nir for approval.

1. Circulation at 1400 depth for cleaning (1 hr)
2. Circulation to open up fractures (6-10 hr) Monitor water loss every 15 minutes
3. If the water loss would not increase drastically with circulation. Then pull out drill string to above the casing shoe (about 4 hr)
4. Injection then on the wellhead or through drillstring to stimulate well (minimum 12 hr). Use all available seawater and fresh water (assumed less than 22.5 l/s) and the capacity of the tanks. Monitor flowrate and pressure on wellhead (kill line)
5. Go to bottom for cleaning and then pull out the drill string (about 10 hr)
6. Liner in or not (depending on the results of phase 2 and 4)
7. T-log to determine depth of loss zones (3 hr)
8. Heating and cooling with drill pipes at bottom (depending on phase 4). Start with a circulation for 2-4 hr and measure loss. Then stop circulation for 12-24 hours and then circulate again for 4 hours and measure loss. Repeat the heating/cooling if the circulation losses increase considerably.

Well BO-6 had been discharging to the rock muffler since March 28th with occasional flow to the atmospheric separator for flow measurements. The flow was controlled by a 75 mm orifice. A flow measurement was carried out. The lip pipe (5" or 128 mm) pressure oscillated between 3-6 bars and very difficult to determine the average (best) value. Some leakage was also through the valve on the rock muffler line so not all the flow did go to the separator.. Decided to clean the valve so all the flow would go to the atmospheric separator and also to fill the oil trap at the lip pressure manometer and install a ½"-valve to damp the oscillations. BO-6 was shut-in for about 24 hours while this was done.

April 18th: The 1400 m depth was obtained in well BO-7 early in the morning. After cleaning the well circulation started according to the plan at about 5 o'clock. Loss of circulation was only 1.5-2 l/s. and did not increase. It was then observed that drilling mud was used for the circulation and not pure seawater. The mud was then diluted with limited amount of seawater and finally the circulation was stopped at about 15:00 for cleaning of the mudtanks and filling of them with seawater. This took until next morning.

BO-6 was ready for discharge at about 16:00. The leakage in the valve was mainly caused by drill cuttings blocking the seat in the valve. At 17:45 the well was flowed to the atmospheric separator for 15-30 minutes for determining the flow. A more stable value was obtained for lip pressure this time. The well continued flowing until next day.

April 19th: BO-7. The tanks had been cleaned and circulation with seawater started at 6 a.m. The circulation loss was about 2 l/s or similar as with the mud and did not increase with time. Circulation stopped after 8 hours and it was decided to go to stimulation of the well by injection of seawater (phase 4 in the plan). Due to an oil strike and uncertainty in gasoline supplies it was decide to pull the drill string out of the well and do the injection directly on wellhead. The injection could though not start immediately after pulling out as no inhibitor to treat the seawater was at the drillsite and new supplies still in custom. The idea was then to carry out a water loss test (T-log) with injection of fresh water but as no fresh water was available this idea had to be abandoned.

BO-6. A flow measurement in the morning gave same result as previous night. The total flow was about 53 kg/s of which 34 kg/s was water and 19 kg/s steam at atmospheric conditions. At 6 bar-absolute the high pressure steam amounted to 13 kg/s. The wellhead pressure was 26.5 bar. The well was then closed to change orifice to 90 mm and lip pipe to 6" (146 mm). The well was opened again in the afternoon and discharged until next morning. As the 6" lip pipe had to be repaired the well was not ready for flow measurements until next morning.

Jean Marc and Herlander arrived this Thursday, which is considered this year the first day of summer in Iceland (the old Nordic calendar). Herlander said it snowed in Orleans.

April 20th BO-7. Still waited for inhibitor, which arrived at about 16:00. No injection was on the well and water level in the wellhead. A temperature log carried out to 1404 m in the afternoon as a reference for logs after injection. The log showed possible permeable zones at 600-700 m and 900-1000 m. Injection (stimulation) started at about 16:45 with a flow of 12.5 l/s, but was increased in steps up to 20 l/s by midnight. The pressure was monitored on standpipe and in the annulus and recorded on the datalogger in the geological cabin along with the flowrate. The drillers wrote down these parameters every 15 minutes.

BO-6. The 6" lip pipe was installed in the morning and a flow measurement was carried out at noon. For this change in orifice and lip pipe the flow from the well increased by some 40% as the total flow was now estimated as 71 kg/s with 46 kg/s water and 25 kg/s steam at atmospheric conditions. At 6 bar-a the steam flow rate was

18-19 kg/s. The wellhead pressure during the flow test was 26 bar or only 0.5 lower than for the 75 mm orifice. After the flow measurement the well was closed for changing to an 120 mm orifice. The well was opened again but was only allowed to discharge for about 30 minutes due to vibrations in the piping system, which is obviously not designed for the rate of flow that well BO-6 can deliver. During these 30 minutes the wellhead pressure was 23.5 bar. This was the end of the flow test of well BO-6 which started on March 28

April 21st: The stimulation of BO-7 continued with 20 l/s. As this was approximately the amount of seawater pumped to the site further stimulation was limited. It was therefore decided to complete the stimulation by increasing the injection to some 30 l/s and maintain that rate while we had water in the seawater tanks. Due to some pump problems the injection was very irregular for the first few minutes but then stabilized at 43 l/s at this rate the tanks were emptied in about 20 minutes. The pumping was then stopped and the pressure recovery (P in the annulus) monitored for 1.5 hour. At that time the pressure had dropped from 12.5 to 6.1. The BOP were then opened and the flowed for about one hour. At the beginning the flowing temperature rose rapidly but was more or less stable at 80-83°C after 30 minutes. The flow rate also decreased in time but no measurement was possible. Estimated flow after one hour was some 5 l/s. Gas was observed in the flowline so this was not only backflow of the injected water. When closed a pressure of 2-2.5 was measured in the annulus.

A temperature log was then carried out. With the temperature tool at 200 m depth injection of 12.5 l/s was started and maintained through out the measurement. The log showed that the injected water had been lost into aquifers above 1000 m. It also showed that the aquifer that recovered fastest during the flowing hour is at about 600 m depth.
From the data of the wellhead injection it is clear that well BO-7 was stimulated during the injection. Pressure in the annulus fell during the first injection step and was fairly stable during the later steps except the final short injection while the tanks were emptied. The injection in the afternoon while the temperature log was carried out show also much lower pressures than during the first injection step even though the injection rate is the same. After discussion with the CFG personnel (Hervé, Jean-Marc and Didier) and Herlander it was decided to stop further stimulation of the well. The injectivity indicates that this is a low permeability well but a potential producer and should therefore be equipped with a perforated liner. The preparations for setting the liner will however wait until the oil strike is over or new supplies found. This waiting after oil supplies might take few days. The first impression of the injection data is that the well BO-7 has a similar permeability as well BO-4.

April 22nd: Worked on the data of the flow test of well BO-6 and the stimulation data and temperature logs of well BO-6. Prepared activity report and discussed over the phone with Ómar Sigurdsson the progress of the work and the interpretation of the data.

The activity for the next days. Well BO-7 is a low permeability well with similar injectivity as well BO-4 after stimulation in 1998. With that in mind a first guess of the power potential of BO-7 is therefore in the range of 1-2 MW depending on the actual temperature in the reservoir; boiling information and possible cleaning of fractures during discharge. Further stimulation of the well is therefore recommended when the liner has been set. The next steps in completing well BO-7 will then be:

1. A cleaning/reaming trip to bottom of the well.
2. Setting of the liner from the casing shoe to at least 1000-1100 m.
3. Stimulation by short-term injection of high flow rate. Starting with the tanks full and full pumping rate from the coast (20 l/s) some 40-50 l/s will be pumped until the tanks are emptied. The pumping is then stopped, the tanks filled again and the pump test repeated. This will be done several times period of some 24 hours.
4. When the stimulation is over the well is prepared for discharge test. It is expected that the well and the wellhead equipment will be ready for discharge few days after stimulation is stopped.
5. Discharge test. We assume that the discharge test will be carried out with rig on the well even though it is not a necessity for the test.

April 23rd 2001

Benedikt Steingrimsson

ORKUSTOFNUN
GeoScience Division

Our date. 27-4-2001 | Your ref.

Mr. Max Le Nir
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ACTIVITY 23RD-27TH OF APRIL 2001. STIMULATION OF WELL BO-7

Dear Max Le Nir
The stimulation test of well BO-7 was carried out on April 25th-26th, but it does not seem to have improved the permeability of the well. The conclusion is therefore the same as before that based on the injectivity data the well BO-7 is a low permeability well and its potential is likely to be in the range of 1-2 MW or similar to well BO-4. The discharge test will of course give more reliable data on the productivity of the well. It might also clean the fractures feeding the well and increase the permeability. It might also be worth while to consider further injection/stimulation of the well after the heating up and the discharge test.
I have included here, for your information, the temperature logs of BO-7 and the pressure data during the stimulation on April 25th-26th and the activity report for the last few days.

April 23rd Faxed a letter on the preliminary evaluation of the discharge test of BO-6 to Max Le Nir and also the activity report to this date and the scheduled activity for the coming days. This includes stimulation with injection when the liner has been set and then a discharge test.
Used the opportunity, now that the drilling rig was stopped due to shortage of oil, to run Kuster logs (temperature and pressure) in well BO-7. The maximum temperature was found at 1300 m 241°C but at bottom (1400m) the gauge read 239°C. These high temperatures after such a short heating period indicates that the bottom section of well BO-7 is within the hot part of the geothermal reservoir. The oil arrived late in the afternoon. Hervé left in the afternoon.

April 24th Fax from Max Le Nir informed this morning that it had been decided to postpone the discharge test of well BO-7 until after the deepening of well BO-5. The final part of the present activity will therefore be the stimulation of the well by injection. The drillers completed reaming well BO-7 to bottom and had actually to ream two 20 meters intervals in the well at about 700 m and again at 780 m depth. Work with the liner started in the evening.

April 25th The setting of the liner from 463 to 1100 meters depth was completed at noon. Running in with the liner was not without problems as it had to be hammered down from 783 to 839 m. This corresponds to one of the intervals that had to be reamed the day before. Below 839 m depth the liner sunk freely into the well. The drillpipes were out of the well at about 13:00 and everything ready for the stimulation. The following plan was set for the stimulation:

Preparation: Full pumping of seawater to site(about 20 l/s) during the test. Tanks full at the start and inhibitor mixed with the seawater in each injection step.

1. Injection/Stimulation: Inject through kill line at maximum pump rate until tanks are empty. Monitor pressure in annulus.

2. Filling –up period: Stop the pumping and wait until the tanks are again full. Monitor the pressure fall-off in the annulus.

3. Repeat item 1 and item 2 up to 10 (ten) times.

4. After 10 injection steps: Monitor annular pressure fall-off for 3 hours.

5. Injection: Inject for 3 hours at minimum rate (12.5 l/s) and monitor the annular pressure.

After some problems in the beginning with pump 2 at the rig the injection test went according to plan. The injection rate was about 50 l/s which could be maintained some 20 minutes and the filling tanks took some 40 minutes. Each step lasted therefore about one hour. The annular pressure went up to some 13 bar during injection and fell to about 7 bars during the filling up periods and there is no trend in the pressure data showing increased permeability during the test or in other words. The stimulation was not successful. The pressure measured during 12.5 l/s after the stimulation confirmed this and that the permeability of well BO-7 is similar after the stimulation as before.

April 26th. The injection after stimulation was completed at 6 in the morning. Used the day for organizing the data. Herlander and Jean-Marc left in the afternoon.

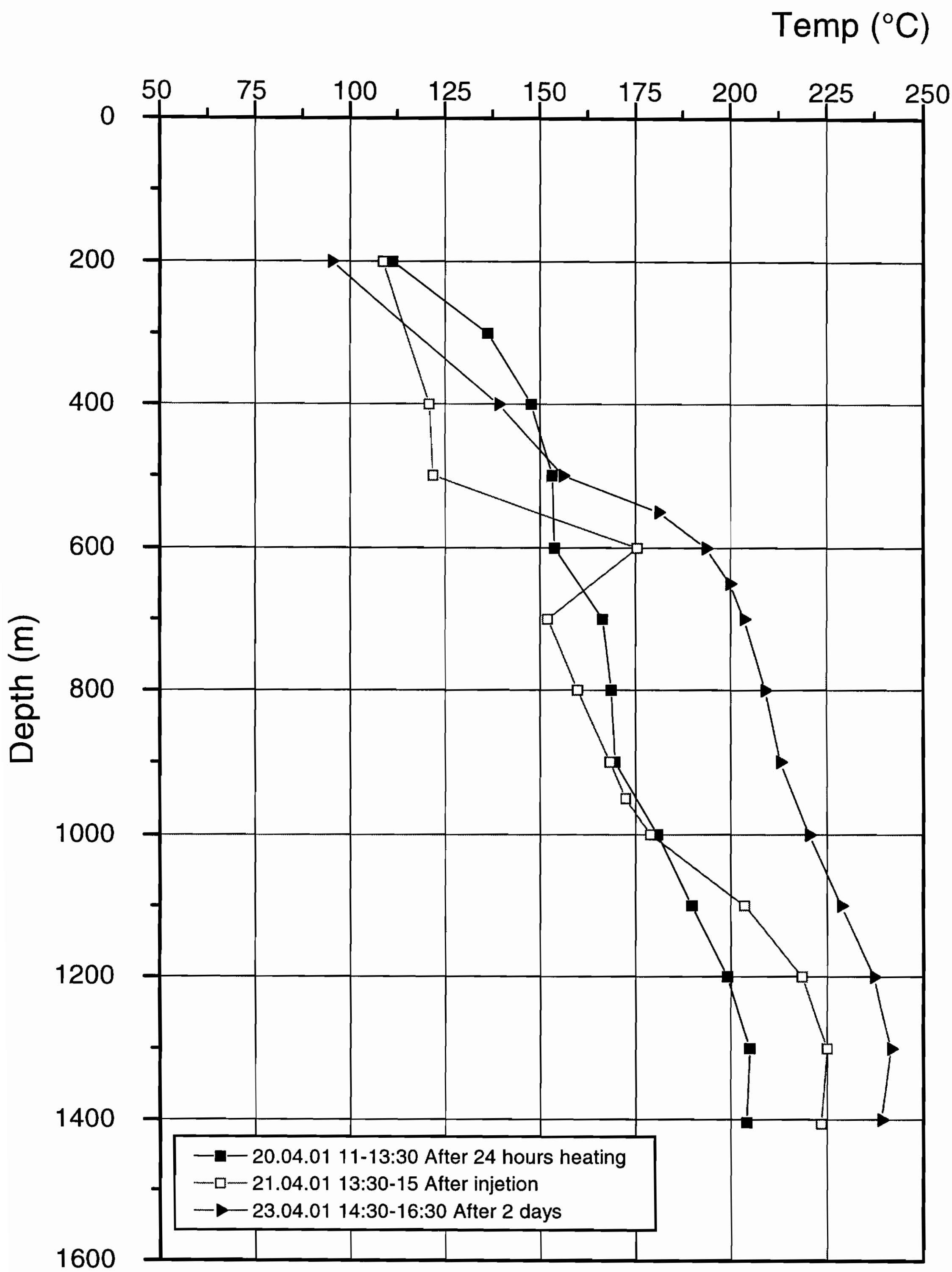
April 27th. Completed the activity report and faxed it to Max Le Nir.

The activity for the next few days. Will take the rest of Friday and the Saturday off as I have a flight out of Pointe-á-Pitre on Sunday 29th of April and continuing flight Paris-Reykjavik on Monday.

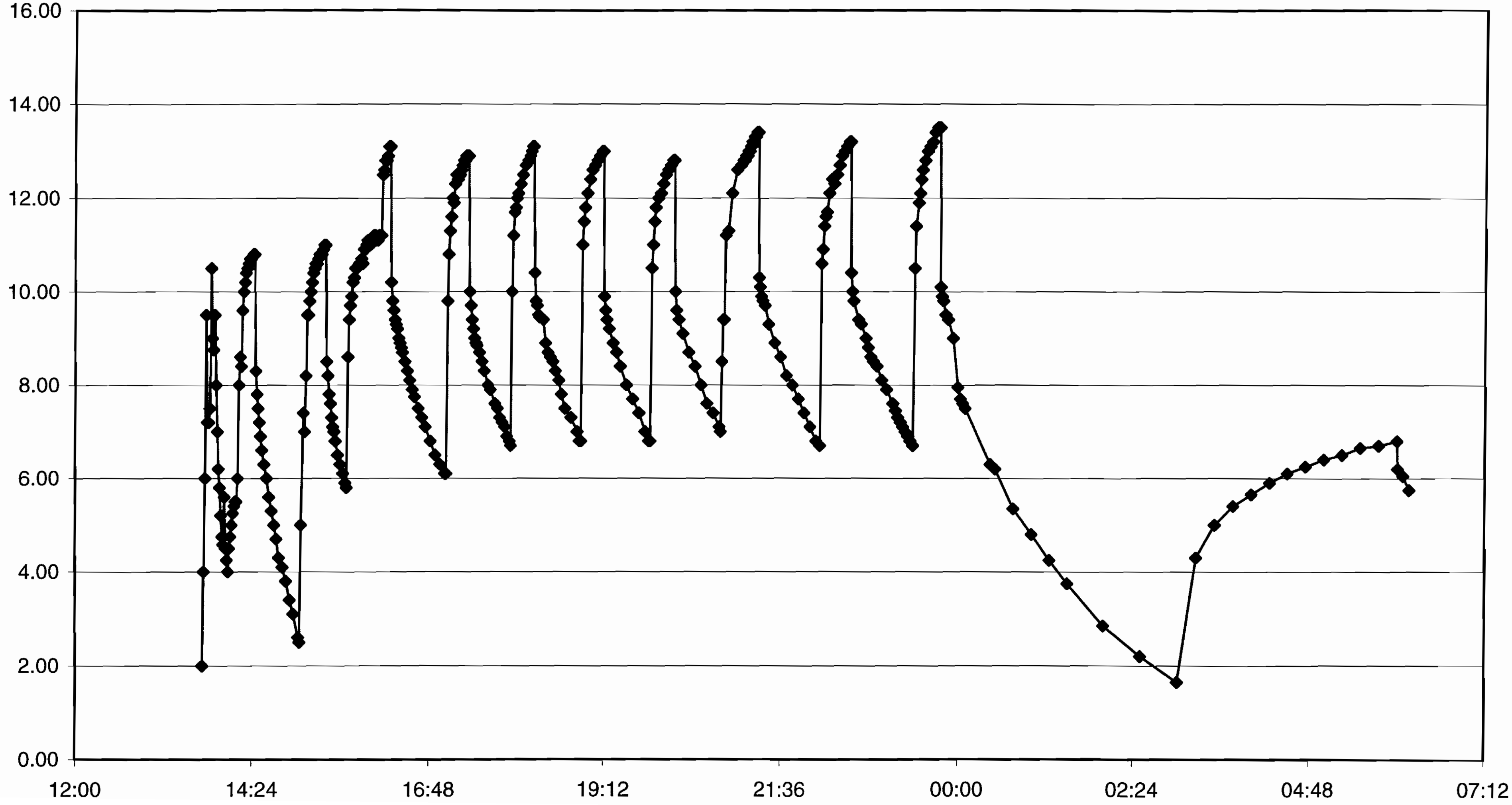
Boillante April 27th 2001

Benedikt Steingrimsson

BOUILLANTE WELL BO-7
TEMPERATURE LOGS



Well BO-7 Annular pressure during stimulation April 25-26



ORKUSTOFNUN
GeoScience Division

Our date. 1-7-2001 *Your ref.*

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Main results for the short discharge test of well BO-7

Well BO-7 is directionally drilled to 1400 m depth. It is cased with 9 5/8" casing to about 500 m and was completed with 7" liner from 463 m and to 1100 m on April 25, 2001. The liner shoe is supposedly closed, hindering possible flow from deeper parts of the well. Before the completion of the well attempts had been made to stimulate it, but with a limited success. The injectivity data from the stimulation steps indicated that the permeability of the formations that well BO-7 had intersected was low and that its production potential would be low.

Preparation for the discharge of well BO-7 started on June 25th 2001. A discharge pipeline was build and connected to the existing pipeline from earlier test on well BO-5. Since well BO-7 had a water level at about 32 m depth it was clear that some assistance was needed to initiate the discharge from the well. It was chosen to bleed about 190°C steam-water mixture from well BO-5 into well BO-7 to warm-up the upper most part of the well and to change the pressure gradient in the well to enable it to discharge. Due to the low permeability encountered by well BO-7, a high wellhead pressure was developed during these bleeding procedures. Few attempts were made to initiate the discharge before the well started discharging on June 29th. In the morning the next day the discharged had desisted so the discharging period was only 14-15 hours. Measured total discharge rate was about 40 t/hr (11 kg/s) at wellhead pressure of 4.5 bar-g. About 6 hours after initiations of the discharge the water from the well was still very muddy. Calculated enthalpy of the discharge was over 1250 kJ/kg.

The calculated enthalpy indicates that boiling is occurring down to the reservoir, which is due to the low permeability and slow feeding rate to the wellbore. The low permeability and boiling deep down the well causes increased pressure losses in the well that results in the low wellhead pressure. Some cycling between dryer and wetter conditions could be occurring in the boiling process and one such cycle could have quenched the well.

The main results for the flow tests on well BO-7 are:

- The formations intersected by the well have low permeability, and the same applies to the fault zones.
- The reservoir pressure at BO-7 could be 5-6 bar lower than in wells 4, 5 and 6. This could indicate that well BO-7 is out side the reservoir that those well intersect.
- During discharge the boiling is at least down to the upper most feeding zone of the well (600 m).
- During the short discharge the well did not clean itself of drilling mud and cuttings.
- The current discharge potential of the well is small and the well is not suited to be operated on line with other wells.

Well BO-7 does not meet the success criteria for steam rate of 19.3 t/hr (5.4 kg/s) at 6 bar-a. In the current conditions the well is not suited to be operated on line with other wells.

Guadeloupe 1-7-2001

Omar Sigurdsson
Geothermal Reservoir Engineer

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