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# Drilling Operations of the First Iceland Deep Drilling Well (IDDP)

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## ABSTRACT

Landsvirkjun (The National Power Company in Iceland) drilled the first IDDP science well of three proposed by the research project, in NE-Iceland at Krafla. The IDDP consortium is composed of Landsvirkjun, HS Orka and Orkuveita Reykjavíkur, Alcoa Inc. Cananda, StaoilHydro ASA, Norway, ICDP, US NSF, Orkustofnun. Preparation for the drilling initiated in the year 2000 and continued until the drilling activity started with a pre drilling in the mid year 2008 and a drilling to 800 m started later in the same year. Drilling to 4,5 km continued in March 2009 in the search for a supercritical fluid. However, after almost three months of drilling problems, getting stuck, having twist offs, and having to sidetrack two times, the source of these problems became clear at 2104 m depth when the drillbit had obviously drilled into a magma pocket of some size. Quenched volcanic glass was returned to the surface, estimated to have been about 1050°C before cooling.

## 1. INTRODUCTION

High temperature geothermal resources in Iceland, at the volcanic rift zone, have been harnessed for decades for district heating and electricity production. Up to 200 high temperature wells have been drilled to depths of 2-3 km where temperatures above 300°C are found. Since 2000 preparations have been ongoing to drill to 4 - 5 km deep well with the aim of finding and investigating the feasibility to utilize supercritical fluid, where the temperature and the pressure are above the critical point for fresh water (374.15°C and 22.12 MPa).

Exploration drilling at the Krafla geothermal field began in 1974 in and was followed the year after by construction of the power plant and concurrently with production drilling. The 20th of December 1975 a volcanic eruption occurred within the Krafla caldera, followed by volcanic unrest for the following nine years, including 9 volcanic eruption and about 15 swelling and subsidence events. The volcanic activity severely affected the geothermal reservoir severely and limited the steam production. It also influenced the installation of the $2^{nd}$ power plant turbine, which was not commissioned until 1997, and it took to 1999 to reach full production of the 60 $MW_e$ installed.

A Drilling Contract was signed in August 2008 with Jardboranir hf., an Icelandic Drilling Company. The Contract was a day rate contract, which is unusual in the Icelandic geothermal industry, which is more used to meter or footage rated contracts.

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## 2. WELL SCENARIOS, DESIGN AND DRILLING

Several well designs, drilling and coring methods were evaluated (Þórhallsson et al 2009). This resulted in the following casing program:

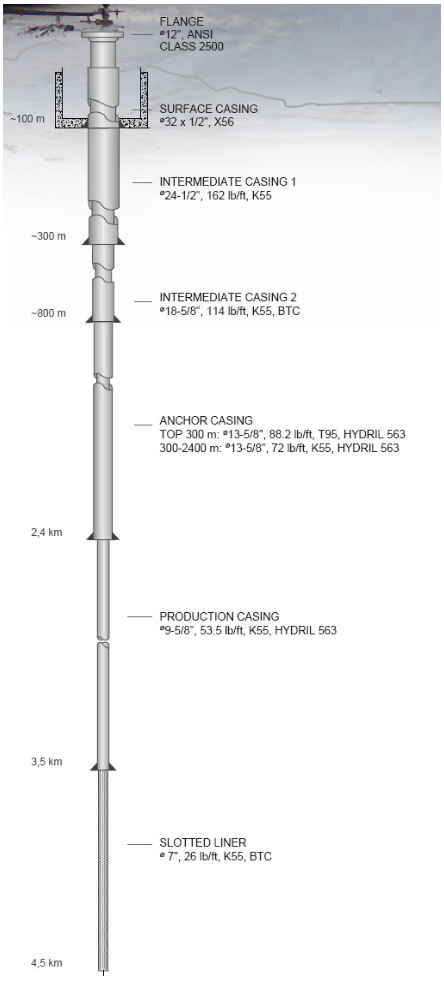


**Figure 1. Well design**

- Surface casing to -100 m – 32” x ½” X56 welded. Wellbore drilled with 26” roller cone bit and 36” under-reamer. Rotary drilled.

- Intermediate casing I to -300 m – 24 ½” 162 lb/ft K55, Tenaris/Hydril 563 threads. Wellbore drilled with 26 ½” roller cone bit. Rotary mud-drilled.

- Intermediate casing II to 800 m – 18 5/8” 114 lb/ft K55 BTC. Wellbore drilled with 23” roller cone bit. Rotary mud-drilled.
- Anchor casing to -2400 m – Top 300 m 13 5/8” 88,2 lb/ft T95 Tenaris/Hydril 563 threads and from -300 m to -2400 m 13 3/8” 72 lb/ft K55 Tenaris/Hydril 563 threads. Wellbore drilled with 16 ½” roller cone bit. Drilled with a mud and a mud motor.
- Production casing to -3500 m – 9 5/8” 53,5 lb/ft K55 Tenaris/Hydril 563 threads. Wellbore drilled with 12 1/4” roller cone bit. Rotary drilled.
- Slotted liner to 4500 m – 7” 26 lb/ft K55 BTC. Wellbore drilled with 8 ½” roller cone bit. Rotary drilled.

Enel Italy contributed personnel to consult the casing cementation and cementing design. Personnel from Schlumberger Well Services were hired for mixing the chemicals, assist with the cementing job and to carry out laboratory cementing tests in cooperation with Enel.

### 3. PRE DRILLING

Pre drilling of IDDP-1 began in June 2008, with a Drillmec G55 truck mounted rig, “Saga” (Figure 3. The rig Saga.). The well was drilled with a ø26” roller cone bit and a ø36” under-reamer (Figure 6. The 36” under-reamer.) and was drilled with mud down to 87 m depth in nine days. At that depth the formation was stable for the casing shoe and a decision to run the casing was reached. The casing was cemented with 29,5 m$^3$ of high temperature cement slurry.

### 4. DRILLING FOR INTERMEDIATE CASING I.

Drilling for the Intermediate casing I began 1$^{st}$ of November 2008 with mobilization, maintenance and adjustments to fit the large diameter drilling assembly of the rig “Jötunn” (Figure 4. The rig Jotunn.). The drill string was inspected according to DS-1, Service Category 4 before RIH for the first time. Before each RIH after that the string was ultrasonic inspected. The rig, Gardner Denver 700 E, began drilling the 18$^{th}$ of November through cement at the bottom. The first section was drilled with ø26 ½” Hughes Christensen Roller cone rock bit and water based mud. No mud motor was used in this section.

The drilling procedure was rather slow because of hard formation and the average ROP was 2.5 m/hr. No circulation losses were detected while drilling and the depth of this section was 275 m. The well was cased with ø24 ½” K55 casing and while running the casing it stopped at 260 m due to problems in the wellbore despite for wiper trips before pulling out. Several attempts were made to get the casing lower without any progress. The cementing job was done on the 24$^{th}$ of November.

The cement slurry used was a standard high temperature blend and the density was 1.65 kg/l. The job was planned with a stab-in with a float shoe and a float collar 24 m above the shoe. Total volume of slurry pumped through the string was 37 m$^3$ until acceptable density was returned.

### 5. DRILLING FOR INTERMEDIATE CASING II.

The drilling continued the 27$^{th}$ of November with a ø23” Hughes Christensen Roller cone bit. Arctic weather conditions were on the site, blizzard, and wind up to 52 m/s and temperature -8 °C.

Drilling progressed rather slowly due to hard formation and the WOB was kept rather low in order to keep the hole as close to vertical as possible. The drilling works was delayed by four days due to a broken mud pump. Some losses were detected while drilling this section but the losses were healed by LCM. The well reached 788 m depth on the 8$^{th}$ of December. It was cased with ø18 5/8” 114 lb/ft K55, BTC and the casing shoe was set at 784 m.

The 10$^{th}$ of December the cementing job was carried out. The cement slurry was the same as used for cementing intermediate casing I. The job was planned with a stab-in with a float shoe and a float collar 24 m above the shoe. Losses appeared while running the casing and the cementing job was planned to cement the well through inner string and up to the losses at 420 m and afterwards fill up the annulus from top through the kill-line. Total volume of slurry pumped through the string was 47 m$^3$ and 55 m$^3$ through the kill-line until the annulus was fully cemented. After the cementing the rig “Jötunn” was prepared for demobilization.

### 6. DRILLING FOR ANCHOR CASING.

The rig Týr Drillmec HH-300 (Figure 5. The rig Tyr.) was mobilized to the wellsite in middle of March 2009 and RIH commenced 24$^{th}$ of March. The drill string was inspected according to DS-1, Service Category 4 before RIH for the first time. Before each RIH after that the string was ultrasonic inspected. The BHA consisted of a ø16 ½” roller cone bit, ø9 ½” mud motor and a sleeve, two stabilizers, Anderdrift tool, ø9 ½” and ø8” drill collars, shock sub, jar and heavy wall drill pipes. The cement was drilled out to 788 m and drilled into formation to 803 m before replacing the water with drill-mud for circulation. A mud specialist and a mud engineer from AVA S.p.a. Italy were hired for mixing and maintain the properties of the circulation fluid. A sudden pressure drop on the stand pipe was observed the 29$^{th}$ of March at 1194 m depth and simultaneously the torque dropped dramatically. A float sub had twisted apart in the BHA and a fish was in the hole. The string was pulled out and what remained in hole was the bit, the mud motor, a stabilizer and the other part of the twisted float sub. Fishing tools were mobilized to the site but due to bad weather conditions and blocked roads the mobilization was delayed for 20 hours. Just before midnight on the 30$^{th}$ of March an over-shot was RIH and 23 hours later the fish was on surface. The mud motor was blocked and had to be replaced.

In the morning 2$^{nd}$ of April drilling commenced again at 1194 m. ROP varied from 3-5 m/hr and small losses were detected at 1362 m and healed with LCM pills. ROP decreased and testing showed that either the bit or the mud motor was failing and at 1400 m a decision was made to POOH. The bit was 2/16” under-gauged but the stabilizers were in gauge. The mud motor was not working properly and had to be replaced. At 1432 m depth losses of 20 l/s were detected. LCM pills were pumped down hole without progress and at 1447 m it was decided to POOH and cement off the losses to minimize the mud losses and secondly to prevent interflow between loss zones during the casing procedure. The bit was in surprisingly bad condition after only 47 m drilling. Almost all carbides were broken off on the outer most rows of the cones (Figure 7. New roller cone bit. and Figure 8. Worn roller cone bit.). Temperature log was performed to locate the loss zones. At that time the well, however, appeared to be tight and no losses were detected probably due to previous LCM jobs and the cementing was abandoned. The 7$^{th}$ of April a Junk Basket was RIH trying to retrieve the missing carbides.

Eight hours later the junk bit was on bottom and two hours spent in the cleaning operation. Just before midnight the Junk basket was back on surface only containing formation cuttings and small amount of tiny metal fragments.

The 8th of April BHA number 9 was RIH without a mud motor. No circulation losses were detected. The Anderdrift tool measured 1.5° inclination. POOH to replace the bit was on the 13th of April when the depth was 1907 m. The existing bit had already passed over one million revolutions. A few carbides were broken off the bit and the stabilizers were badly worn with almost no hard facing left. Drilling commenced 15th of April with rather slow ROP due to hard formation. At 2030 m a small loss of circulation was noticed (< 5 l/s) but at 2043 m total losses occurred (> 60 l/s). LCM pills were pumped down to plug it without progress. The mud was replaced with water as the losses could not be healed. High viscous pills were used to clean the hole before drilling continued.

A sudden pressure drop on the stand pipe was observed the 18th of April at 2074 m and the torque dropped dramatically. A box of ø8" drill collar had twisted apart and a fish of 7 tons was in the hole. An over shot was run in hole and two hours were needed for freeing the fish. A new BHA was run in hole on the 20th of April and drilling commenced again at 2074 m.

In the morning on the 21st of April at 2101 m the torque was fluctuating and three singles were pulled out for reaming. The bit was run to bottom again where the torque increased significantly and the string was pulled from bottom again. Three singles were pulled out and when pulling the last single the weight dropped by 20 tons and the standpipe pressure decreased. The BHA was broken again and the third fish was in the hole. The bit was at 2087 m depth and the top of the fish was at 1999 m depth. Freeing attempts of the fish for six days were carried out without any progress. The over shot used for the fishing could not be disengaged and explosive experts from the Icelandic Coast Guard arrived to the site to cut the collar below the over shot. On the 28th of April the bomb was placed at 2056 m. It was located at the connection of the XO sub between the 8" and the 9" collars. After the blast the torque had dropped to zero and a part of the fish was loose. The detonation had ripped the collar 2 m above the connection of the XO sub, but the connection between the collar and the sub remained unaffected (Figure 11. The 8" DC after the explosion.). The total length of the fish left in hole was 32 m. On the 1st of May it was decided to run in the hole again with heavy BHA and connect with the XO sub, furthermore jarring down and rotate. Connection to the XO sub was successful. However when the torque reached 2200 daNm and simultaneously the string was pulled the connection broke apart. Because of this poor connection it was impossible to reload the Jar and the fishing string was pulled out of hole. Left in hole was following equipment: ø16 ½" bit, 2 x Stabilizers, 3 x ø9 ½" DC, Anderdrift tool, Shock sub and a XO sub.

For further drilling a side track passing the fish was necessary. A 100 m cement plug was arranged above the fish. Conditions in the well were difficult and complicated. A total loss of circulation made the cementing job difficult. Three attempts of cementing in ten days in total were needed before cement plug, hard enough for Kick Off process was in the well. The 12th of May the bit was in formation at 1934 m.

The condition in the well had become difficult. Sufficient hole cleaning was hindered by washouts and circulation losses. It was decided to modify the casing program because of this and to have the anchor casing 2000 m instead of the 2400 m originally planned. This would make hole cleaning more effective and no hazards of cave in from surface to 2000 m.

The drilling for the anchor casing was completed at 2005 m depth. The plan was to circulate for three hours with high viscous pills in between. Unfortunately the string got stuck after only 25 minutes of circulation. The torque increased suddenly while circulation was ongoing. At that time the bit was on the way down, approx. 8 m off bottom. Circulation was maintained and attempts for freeing the string were carried out for three days until the string was loose on the 15th of May. Several loggings were carried out, but the logging tools stopped at 1970 m. After the logging it was decided to run a wiper trip before running the anchor casing and also try to circulate the cuttings from the bottom to the fractures higher up in the well. While cleaning out the bottom fill the torque increased and few attempts were tried before it was decided to POOH and run the casing. It was evaluated to be safer to circulate the cuttings to surface after the casing had been installed and cemented.

On the 18th of May the casing job started. The anchor casing consisted of tow section of different thickness. The top 300 m were ø13 5/8" 88 lb/ft T95 with Hydril/Tenaris 563 threads while the rest of the casing was ø13 3/8" 72 lb/ft K-55 with Hydril/Tenaris 563 threads. The casing shoe was set at 1949 m and 24 m above the shoe was a stab-in float collar. Because of known losses in the well it was planned to cement it in two steps, i.e. an inner string job up to the losses at 1600 m and fill up to surface through the kill-line. The cement slurry consisted of Dyckerhoff cement, 40% Silica, retarder and a water loss agent. The density was 1.9 kg/l. The drill string was stabbed into the float collar and thereafter the casing was filled with water to prevent collapse. 80 $m^3$ of cement slurry were pumped through the string. At the top of the string a Peak cementing head was placed to pump a dart in the end of the first part of the cement job. It was released and displaced with water. The dart landed in the float collar and it was necessary to use to prevent the water inside the casing from washing the cement from the shoe when the stinger would be pulled out of the float collar. The water level outside the casing was estimated at 400 m. The well was CBL and temperature logged and the results showed that the top of cement was at 1600 m depth. The second cementing job was carried out. The calculated volume required was 100 $m^3$ and the volume criterion was set at maximum 155 $m^3$. The slurry was pumped through the kill-line. After the cementing CBL and a temperature logs were carried out indicating the top of cement at 100 m depth. The CBL log had to be stopped at 1600 m due to high temperature in the well. The log interpretation showed that no cement was in the annulus from 1410 m and down to 1600 m. The cement seems to have stopped at the feed zone at 1360 m. It was essential to run another CBL-log at an appropriate time to verify this measurement.

## 7. DRILLING FOR PRODUCTION CASING

On the 25th of May the wellhead flange was screwed on the anchor casing and an expanding gate valve (12" Class 1500) was installed. The BOP stack was also put on consisting of blind ram, pipe ram, shear ram, annular preventer and a rotating head. RIH with ø12¼" bit started on the 27th of May and the bit was on the float collar the day after and the cement was drilled out. The challenge ahead was to circulate the cuttings from the bottom with ø12¼" drill bit in a 16½" hole. The plan was to drill the fill carefully with high viscous pills with relatively low ROP and low pumping rate. Afterwards the pumping rate was increased and the string rotated and moved up and down. This process was repeated every 3 m of drilling until the bottom of the well was reached at 2005 m. The cleaning job by circulation was time consuming and difficult where spikes in the torque were frequently observed.

The 29th of May at 2016 m depth circulation was totally lost (>50 L/s). It was decided to POOH and heal the losses as well as by cementing the ø16½" section below the casing shoe (from shoe 1957 m to 2005 m) to avoid problems caused by lower circulating velocity in the larger diameter hole. The well was circulated for two hours before POOH. A temperature log showed fractures close to the bottom. Fiberglass pipes, designed for use in cementing plug jobs, had arrived to the site. Those pipes can easily be twisted off and are easily drillable if the string becomes stuck while cementing in open hole. On the 30th of May the plug was cemented and the end of the string was pulled up to 1550 m. Four hours later a sinker bar was lowered down and located the top of the cement at 1892 m, 65 m above the casing shoe. The sinker bar was pulled out of the hole and water pumped in the well to check if losses still remained. The well was tight and the cementing string was POOH.

RIH with a drilling assembly commenced the 31st of May and decision made to drill down to 2040 m depth and then drill a 9 m spot core in a known fracture zone, observed in previous track. A coring specialist from ROK-MAX (UK) Ltd. arrived to supervise the coring job. After having circulated the well clean on the 1st of June the string was POOH and the coring equipment was prepared. The bit was worn and marred on the skirts and the hard facing on the stabilizers were worn and the blades were also marred. On the 2nd of June the coring job started at 2040 m. The drilling progressed slowly and after 3½ hours only 2 m had been drilled. It was decided to POOH and checks the equipment. In the morning of the 3rd of June the POOH was completed. The core bit was completely worn down (Figure 9. New Core bit. and Figure 10. The Core bit after the coring attempt.) and some inserts of the core barrel stabilizers were broken off and along the barrel the surface was marred by grooves. No core was in the barrel, while the core catcher had been pressed approx. 70 cm up. Flaky chips of cement were found inside the core barrel probably from the last plug cementing. The flakes probably got the core catcher stuck which had unscrewed inside the barrel. Due to the worn equipment it was suspected that some junk was in the hole.

Based on the suspicion that junk was in the hole it was decided to RIH with an ø12⅛" Mill tooth bit and a Junk Basket to retrieve the junk and the rest of the core bit. The plan was to drill down to 2060 m, pull out and cement the losses. On the 5th of June at 2054 m total loss of circulation occurred but the well was drilled to 2060 m before POOH. POOH finished on the 6th of June and the junk in the basket consisted of formation fragments, small metal shavings and diamond fragments from the core bit.

The cementing string was RIH for cementing of losses and possible junk in the well. Initially 12 $m^3$ of slurry were pumped and the top of cement was found at 2002 m. Another cementing job was carried out and 7.5 $m^3$ were pumped and the string was POOH. RIH with ø12¼" drilling assembly started on the 7th of June. TOC was found at 1970 m. The cement was drilled out and drilling in formation commenced at 2060 m. Circulation losses became intermittent from 2067 m and from 2076 m total loss of circulation occurred.

In the morning of the 8th of June at 2103 m a sudden rise in torque was observed and the string got stuck for two minutes. By pulling 160 tons the string was free. One single was pulled out and the well was circulated for one and a half hour. High viscous pills were frequently pumped down to circulate possible cuttings. Run to bottom was carefully performed during circulation. When the bit was back on the bottom the torque suddenly increased again and the bit was pulled up 13 m (one single) and few minutes later the torque increased again and the drill string was stuck. Almost immediately the stand pipe pressure increased and the string was blocked for circulation. For 24 hours attempts were made to free the string before it was decided to go for a blind back off as the jar was not working. On the 9th of June the string was gradually torqued up (made up) to the joint between the lowest Heavy Wall Drill Pipe and the uppermost DC. Back off was performed and the string was loose but part of the fish was missing as expected. On the 10th of June the string was on surface. The connection of the top sub of the Anderdrift tool had unscrewed. The fish left in hole consisted of the bit, 2 x stabilizers, 1 x 8" DC and the Anderdrift tool. The top of the fish was located at 2072 m. A fishing BHA was RIH to make connection to the Anderdrift tool which managed to perform.

Fishing attempts with jarring and pulling were carried out for two days without progress. One of possible reason for the string being stuck was thought to be cementing cave in. It was decided to pump down two pills of hydrochloric acid to dissolve possible cement. The acid was diluted to 25% and an inhibitor was added to protect the drill string. The connection on the top sub of the Anderdrift tool was disconnected for opening the string to inject the acid. The acid pill was pumped inside the string and given two hours for working on the cement. Few hours were spent attempting to free the string without results. It was decided to inject the second acid pill and when the back off was performed as before a connection disconnected at 500 m depth. The string was POOH and three singles were laid out due to failure on the threads. On the 13th of June a new fishing assembly was RIH and connection made at 500 m. The string was torqued up as before and back off was performed which resulted in that the connection at the Anderdrift tool disengaged. The string was POOH.

A second cementing plug for side tracking the well was planned. The aim was to cement from the top of the fish at 2072 m and up to 1927 m (30 m inside the casing). Two attempts were needed to get desired top of the cement and the job was completed on the 15th of June and same day the sidetrack BHA was in the hole. The cement was relatively soft for side tracking and the bit was pulled up few meters following waiting time of four hours. Below the shoe the cement got harder and of sufficient quality for a kick off. The motor was however not working properly and the directional drillers suggested to POOH and RIH with a new motor. On the 19th of June side track commenced again. At 1985 m depth the bit was in the formation and no cement was observed in the returns. The torque and the pressure were fluctuating and big chips of fine grained basalt were observed on the shakers. One way to explain these unexpected returns is the long time with an open hole below the casing shoe. The formation temperature at this location is above 340°C and has been cooled down repeatedly, which may result in thermal cracking of the formation. At 1992 m it was decided to POOH and lay down the mud motor before drilling further to minimize the financial risk if the string would get stuck.

On the $23^{rd}$ drilling commenced again at 1992 m. The ROP was rather low as before and irregular losses of circulation until 2071 m where total losses occurred. It was decided to pump high viscous pills two times on every single to keep the well perfectly clean before entering 2100 m depth. In the morning on the $24^{th}$ of June the string was pulled up into the casing after having drilled down to 2100 m. High viscous pill was pumped down before running back down to bottom. The well was perfectly clean and drilling continued.

At 2104.4 m the ROP doubled (from 2 m/hr to 4 m/hr), the torque increased and the string was stuck and had to be pulled (125 tons) to free it. A single was pulled out and the well was circulated for 1 ½ hour. The bit was run down to bottom again slowly and the torque increased again at the same depth as before and a single was pulled out again and waited for a few minutes. When running in again (2 m) the top drive and the single on the floor moved upwards and the weight decreased by 45 tons and immediately the string was stuck (Figure 14. The events from the rig´s data logging system when drilled into magma for the third time.). The crew managed to maintain the circulation and the returns were pulsating but in a short while it came steady. No smell of $H_2S$ gas was detected but the returns became red-brown in color and after that, cuttings of quenched glass were observed on the shakers. Circulation was maintained for 24 hours without moving the string, but after a while there was no return. After that the string was pulled and it was loose. POOH commenced and the bit was in excellent condition (Figure 12. The bit pulled out after having drilled into magma.). Nothing could be seen on the other parts of the BHA. After it came clear that it had been drilled into magma, further drilling was pointless and impossible.

On the $26^{th}$ of June the well was logged and injectivity tested to decide what to do with the well. The Injection Index was found out to be 2.5 l/s/bar, lowest number so far compared to previous measurements. A decision was taken to run in a ø9 5/8” casing to 1935 m and a ø9 5/8” slotted liner from there to 2072 m and attempt to flow test the well. The casing was conceived as a sacrificial casing due to possible acidic fluid and the liner to maintain the wellbore in the open hole section. The casing job started on the $29^{th}$ of June. An annulus packer (Figure 13. The Annulus packer.) was set in between the ø9 5/8” casing and the slotted liner and above the packer a cementing stage tool was installed. The plan was to inflate the packer and cement with an inner string through the stage tool to surface. Because of the circulation losses below the casing it was possible maintain the well cool (temp. < 30°C). The cooling process would continue after the cementing job. The packer failed and could not be inflated. The options available were to pull the casing out of hole and order a new casing packer or do a balanced cementing from surface. The latter procedure was chosen. The plan was to make the cement slurry form a plug and displace the water in the annulus and therefore no water pockets should be between casings. By locating the water level in the well when pumping water at the same volumetric rate as the cementing, the balance in the well was found. Calculations were based on that the cement slurry would balance at 1800 m. The bottom of the cement slurry was not that critical thus the plug would be ideally within 1700 to 1950 m range.

The first cementing job started on the $3^{rd}$ of July. While cementing the pressure was logged real time and the water level was controlled by adjusting the pumping rate inside the casing. The challenge was not to having cement slurry in the open hole section. On the $4^{th}$ of July a run of CBL-log was performed to locate TOC. The top was found at 725 m and the bottom at 1700 m. The second cementation started the same day and the annulus was filled up.

The wellhead valve was to be replaced by ø10” special Class 1500 valve with Class 2500 flanges. Also a casing pack off and an expansion spool was to be installed. This work had to be carried out with the well open and before that was done it was necessary to know the behavior of the well. The pumps were shut in for ample of time taken to replace the wellhead. After the test the well was considered safe for changing the wellhead which was done on $6^{th}$ of July. The well was closed on the $7^{th}$ of July and the rig was prepared for demobilizing.

## 8. CONCLUSIONS

Landsvirkjun, was the leading company in drilling the first IDDP well in Iceland. The well was located in the high temperature geothermal area in Krafla and the drilling project executed during the years 2008-2009. Instead of 4500 m deep well it ended unexpectedly in magma at 2104 m depth.

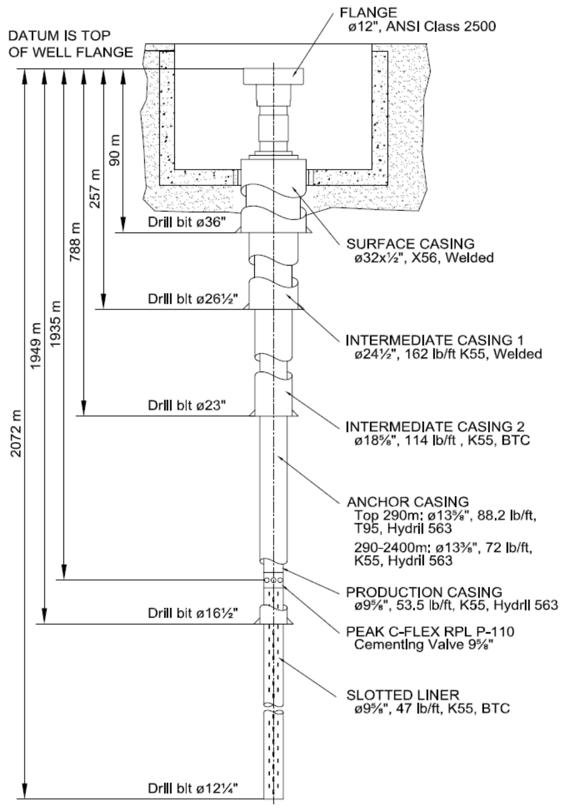


**Figure 2. “As built” drawing of the well.**

The main goal was to drill into supercritical conditions, but it failed. Nevertheless it is believed the feed zone is in a superheated environment. The well will be flow tested during the winter 2009/10.

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**Figure 3. The rig Saga.**

**Figure 4. The rig Jotunn.**

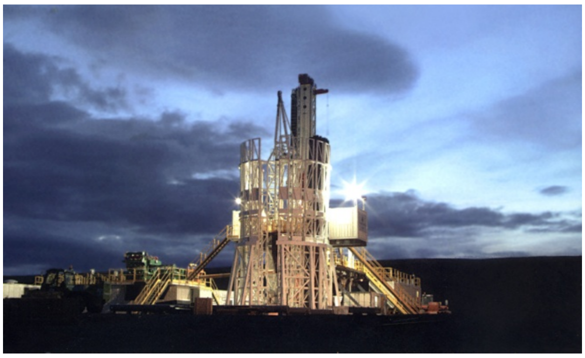

**Figure 5. The rig Tyr.**

**Figure 6. The 36” under-reamer.**

**Figure 7. New roller cone bit.**

**Figure 8. Worn roller cone bit.**

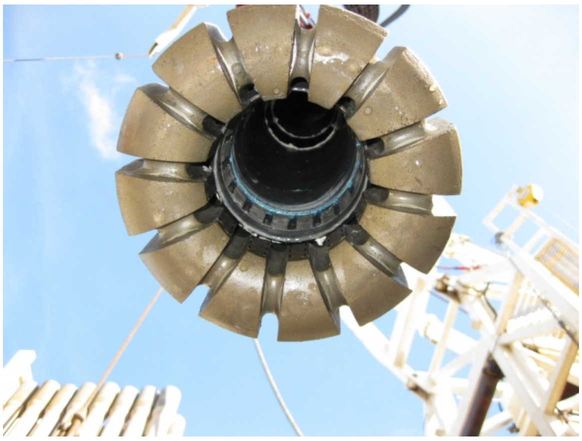

**Figure 9. New Core bit.**

**Figure 10. The Core bit after the coring attempt.**

**Figure 11. The 8” DC after the explosion.**

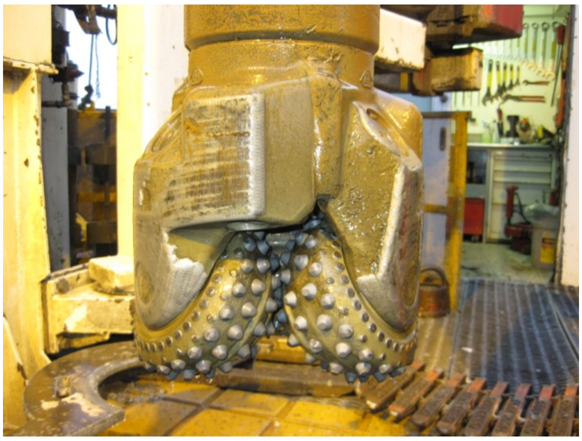

**Figure 12. The bit pulled out after having drilled into magma.**

**Figure 13. The Annulus packer.**

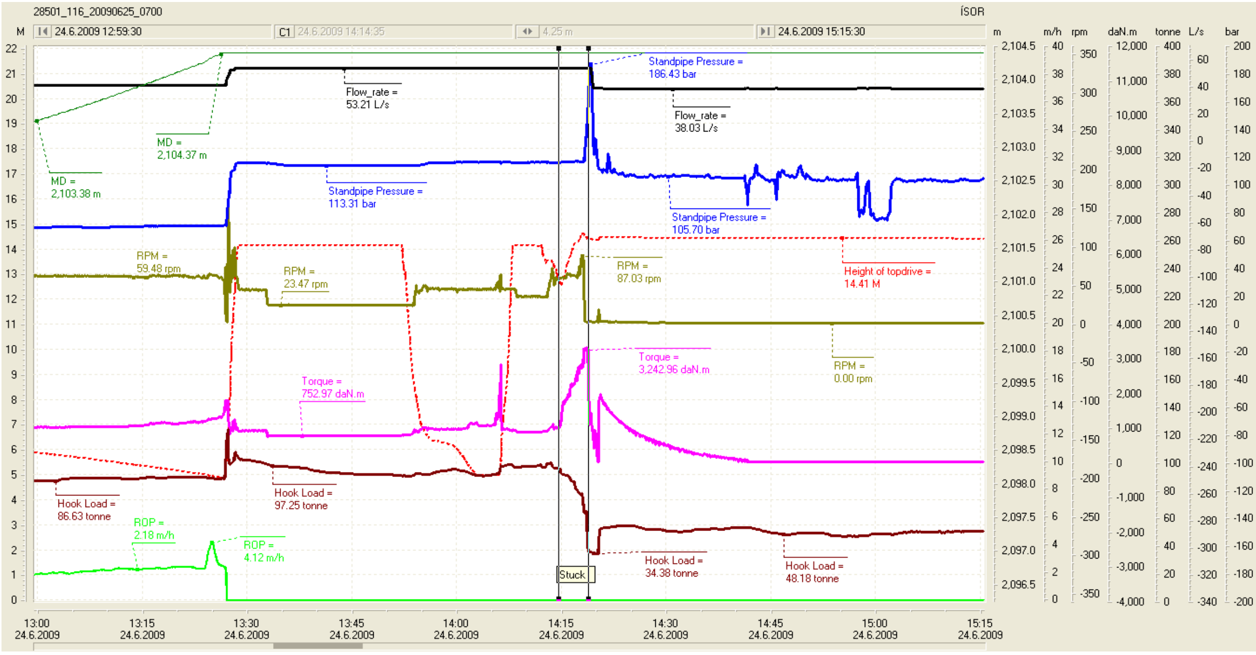


**Figure 14. The events from the rig´s data logging system when drilled into magma for the third time.**

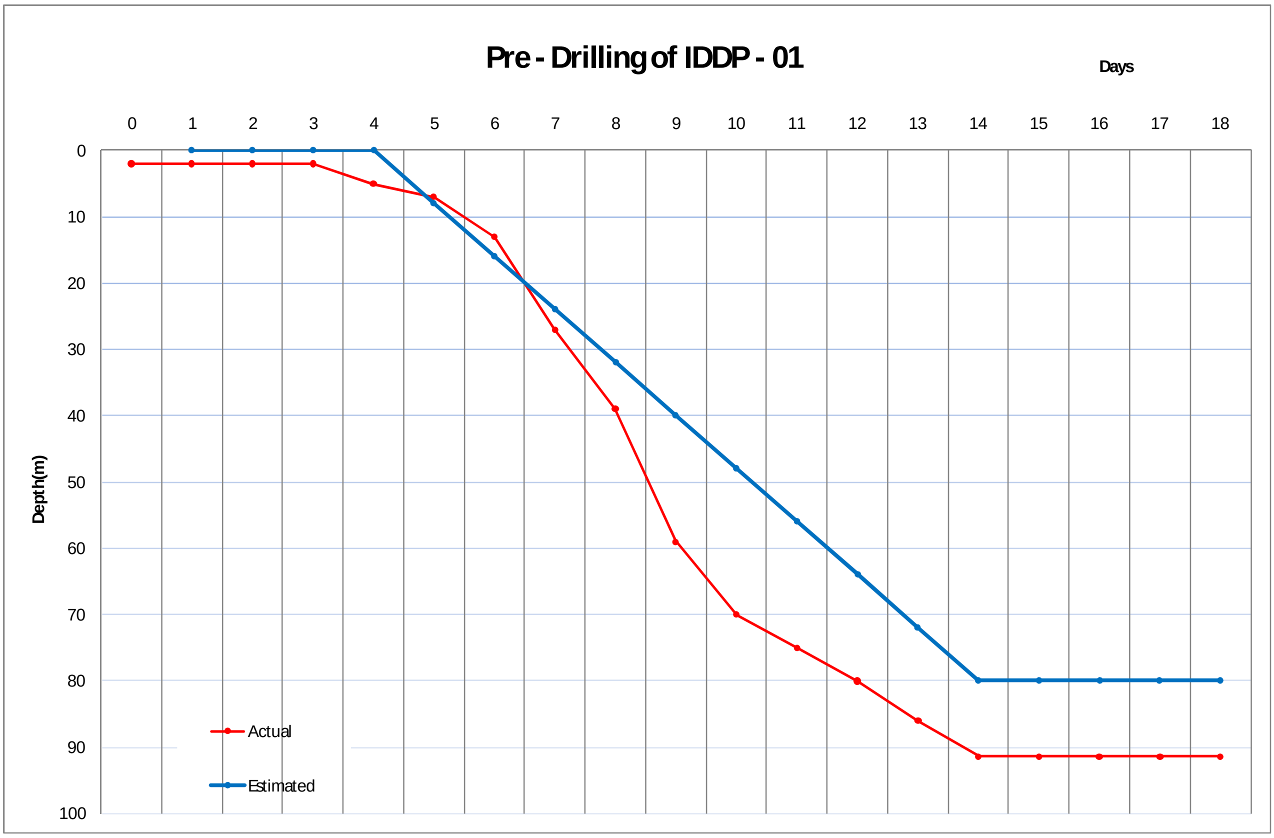


**Figure 15. Pre drilling. Drilling program versus actual drilling time.**

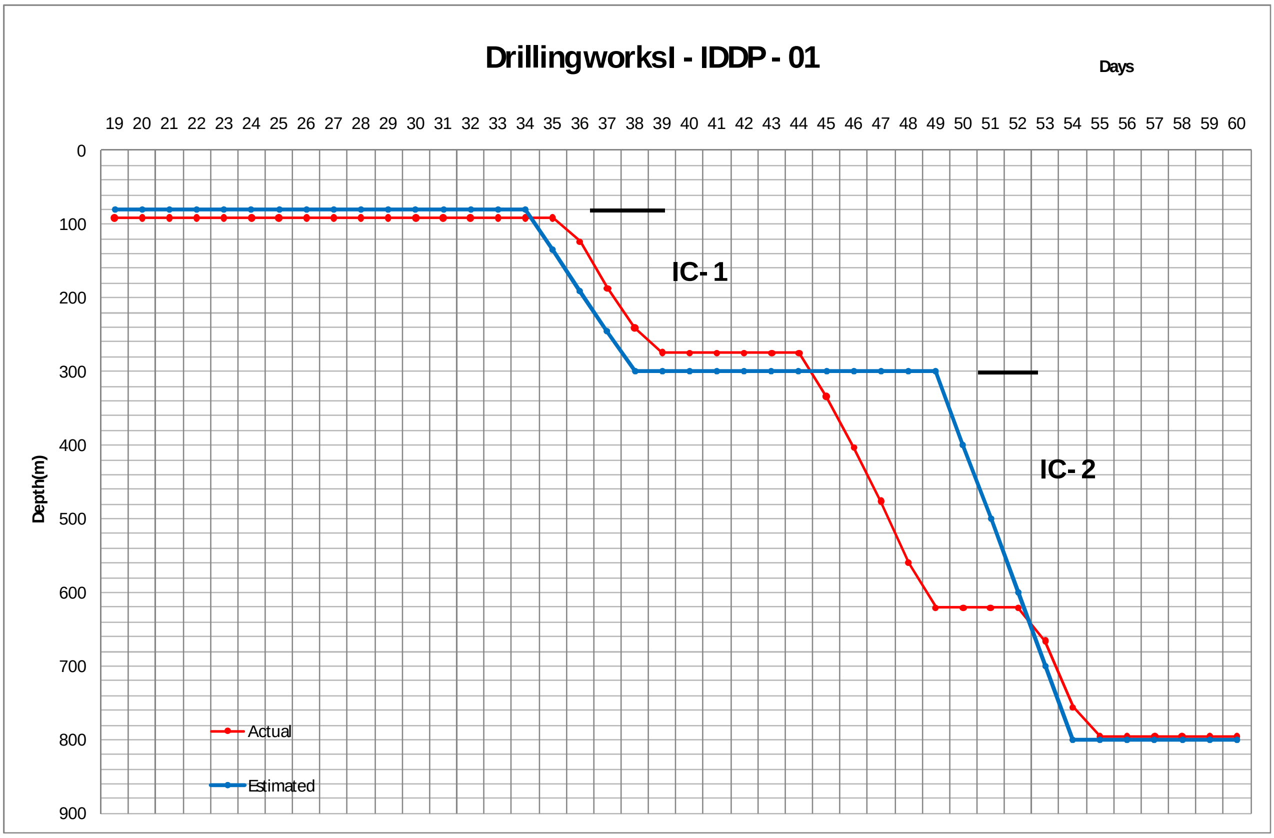


**Figure 16. Drilling works I. Drilling program versus actual drilling time.**

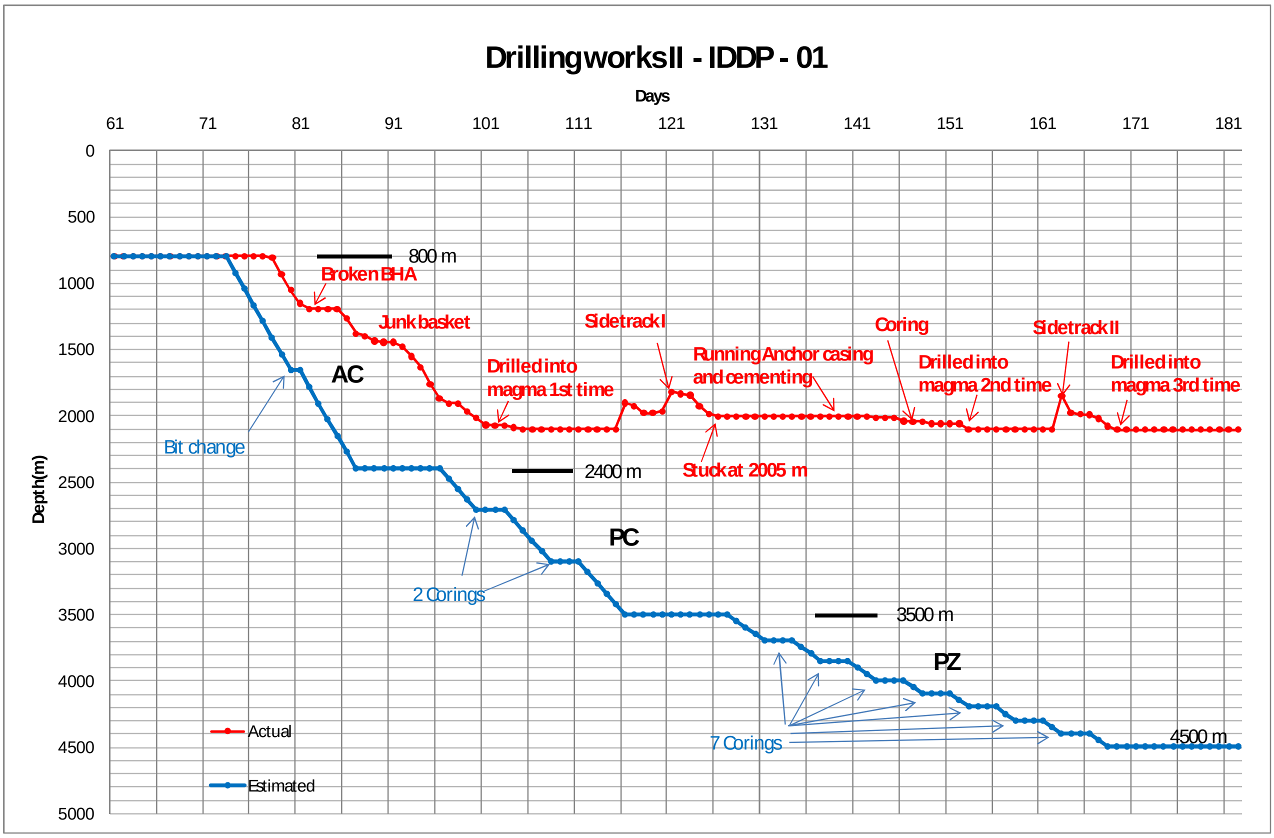


**Figure 17. Drilling works II. Drilling program versus actual drilling time.**