SAGA Report No. 8

Report of the Workshop on Fluid Handling and Evaluation (FHE)
in relation to the First Flow Tests of the Well IDDP-1, at Krafla, Iceland.

Summary

The workshop held on 1st September 2009, in Reykjavik, Iceland, was convened to report on and discuss plans for the initial flow testing of the well IDDP-1. This well was completed to a depth of 2104 m in early July 2009, with a 13 3/8 inch casing to a depth of 1957 m (driller´s depth), and an inner sacrificial 9 5/8 inch cemented casing with a slotted liner. Drilling terminated at 2104 m depth, when a rhyolite magma flowed into the well and quenched obsidian cuttings were returned to the surface. Thus a flow test must consider how to deal with extremely hot, acid fluids of, as yet, unknown temperature, pressure and composition, and a reservoir of unknown permeability. Consequently, a phased series of three tests is planned, to build upon knowledge gained at each phase. Phase 1 is a short test designed to get initial data on the nature of the fluid and possible flow rates in order to optimize the next step. Phase 2 is a more comprehensive flow test designed to learn the capacity of the well and attempt to get “uncontaminated” reservoir fluids. The data obtained will be used to improve Phase 3 which is designed to use a basic pilot plant to study how best to utilize the fluid for geothermal power. In essence, this plan is in accordance with the earlier FHE plan to flow test the IDDP well, with slight modification.

An agenda of the workshop and a list of attendees are attached.

Presentations:

Guðmundur Ómar Friðleifsson, the IDDP-PI, welcomed the attendees and outlined the agenda and purpose of this workshop and reminded the audience that the goal of drilling into a supercritical reservoir still remains as a target for future drilling at Hengill and Reykjanes. He then briefly discussed requests for rock and/or fluid samples from IDDP investigators. Authors publishing work based on these samples should acknowledge Landsvirkjun´s role in drilling the well and in generously making samples available to the wider scientific community.

Sveinbjörn Hólmgeirsson, of Landsvirkjun Power, reported on the drilling history of the IDDP-1 and recounted the numerous problems that were overcome. The drilling reached 2074 m depth already in mid-April, but this was followed by numerous problems, lost circulation, caving, getting stuck, twist offs, fishing jobs, cement jobs, a failed coring attempt, and three sidetracks. The 13 3/8 inch anchor casing had to be set at 1957 m rather than at the 2,400 m originally planned (Figure 1). Then on June 24th the drill bit became stuck in a silica-rich magma. Circulation was not lost and the bit was freed 24 hours later. The decision was made not to attempt drilling deeper, and instead a 9 5/8 inch production casing was cemented inside the anchor casing, with a 9 5/8 inched slotted liner below. Presumably the unusual number of drilling problems might have been related to the high temperature of the rocks near 2100 m depth.

Kristinn Ingason, of Mannvit, began the report of the IDDP Fluid Handling and Evaluation group by describing the three stages of the planned flow testing. Given the unknowns, a conservative, phased, approach is needed. The first flow in Phase 1 will be through heavy walled 4 inch diameter pipe system, with class 2500 mat 1.9 valves, through orifice plates to measure flow rates (see Figure 2).

The design condition is 470°C and 180 bars and single phase flow. There will be provision for a gas bleed and various sample ports. The aim is to make an initial characterization of the nature of the fluid. The layout of the Phase 2 flow test, which will be through a 10 inch diameter system, will add a separator/scrubber and a muffler. This test should last long enough to get sufficient data to estimate the capacity of the well. In Phase 3 a basic pilot plant will be set up with the addition of a cooling loop, for a longer term flow test in the hope that "pristine" formation fluid, uncontaminated by the drilling fluid, will be produced and flow behavior will be measured under different conditions to test the economic potential of the discharge. If the enthalpy exceeds 2800 kJ/kg the discharge would be superheated steam and acid concentrate would **not** be condensing downhole. A flow rate of 0.67 m^3/s of superheated steam at 260 bars could generate ~50 MWe, or if the pressure is 160 bars it would be ~30 MWe.

Halldór Ármannsson, of ISOR, discussed the strategy for collection of fluids for chemical analysis. At Krafla, wells KG-10, KG-12, KG-24, KG-25, KG-26, KJ-27, KJ-29, KJ-33, KJ-35, KJ-36, KJ-38, and KJ-39 have presented problems due to acid conditions, and that includes all the wells near the IDDP-1. He reminded us that increases in CO_2 concentration were widespread at Krafla during the 1975-84 eruptions. As a downhole fluid sampler will not be available for the IDDP-1, only wellhead sampling is possible. Single phase superheated steam will be quenched in a heat exchanger and a gas-liquid separator used to collect non-condensible gases. For two-phase flow, a corrosion-resistant steam-liquid separator will be used and attention will be given to possible high mineral concentrations. Multiple splits of both liquid and vapor phases will be made that are optimized for analysis of specific components (see Figure 3). The sampling will be most frequent at the outset of the flow, with the more important components being determined as fast as possible. Later the frequency will be modified as determined by the conditions experienced. A regular sampling run will require half a day. The time for extra samples for outside investigators depends on the number and size of the samples requested, but the intent is that there should be liberal access for the scientific teams.

Ari Ingimundarson, of (ISOR) then augmented this presentation from the FHE group by briefly describing the hardware to be used including the well-head lubricator and the sampling separator.

This was followed by a presentation from: Rolf Dirdal, of StatoilHydro, who gave a comprehensive discussion of the equipment and field procedures employed by his company in testing conventional hydrocarbon wells, and the separate procedures for hydrocarbon, water and gas sampling. This review included downhole and well-head equipment, and safety equipment and protocols.

After the coffee break there was a wide-ranging and energetic discussion led by Bjarni Pálsson, of Landsvirkjun Power. The injectivity index of the deep zone of the IDDP-1 well was initially 15 L/sec/bar and then declined to 2.5 L/sec/bar after 3 days of injection. One speculation is that there was a steam cap above the magma, which at that depth would have a pressure of ~150 bars. The water level in the well is 200 m below the surface at present. The well KG-25, 80 m south of the IDDP-1, is 2105 m deep and had a feed zone at 2040 m. It was flow tested for 10 weeks, producing from two different aquifers, and then had to be shut down because of corrosion and scaling by iron silicates. The IDDP-1 is cased to 1957 m and therefore has the possibility of producing superheated steam without mixing with shallower, cooler water, and thus minimizing problems due to acid condensate. Wilfred Allan Elders, of the University of California-Riverside (Co-PI of the IDDP), reported that an interpretation of initial studies of the glass from the IDDP-1 well by colleagues in California suggests that temperature of the melt might be as high as 1050°C, based on the plagioclase–glass geothermometry, and that it contains 1.7 wt% of H_2O. Discussion followed about how much chilling of the magma had occurred by the injection of 50 L/s for three months, and how long flow tests would have to continue before uncontaminated reservoir fluid reached the surface, if ever, as at the Krafla geothermal field production and injection has gone on for more than 35 years. The injected fluid is shallow groundwater and its magnesium and sulphate content may have caused precipitation. It is important to make a more precise estimate about the amount of injectate that has been absorbed by the IDDP-1, both during and after drilling.

Ragnar Ásmundsson, of ISOR, then briefed the group on the current status and future prospects of the HITI project, a diverse program of collaborative effort by a number of institutions to advance geothermal technology, funded by the EU. A test using sodium naphthalene Di-sulfonate tracers is underway at Krafla and injection into the IDDP-1 is part of it. The initial results from other wells show rapid break-through and results from the IDDP-1 should be reported soon. A spectral gamma televiewer has been tested to 300°C and a multi-sensor, temperature/pressure/flow/CCL logging tool is ready for delivery. In the second phase of HITI (termed HITI2) it is hoped that one of the methods applied will be 3 component Vertical Seismic Profiling for boundary shape identification and volumetric analysis of magma bodies.

Wilfred Elders ,IDDP co-PI, closed the meeting with a short discussion on the former magma energy program of the US Department of Energy. Resource estimates for magma energy in the USA are huge, if the considerable technical challenges can be overcome. At Krafla there is a potential for creating a very hot engineered geothermal system, by injecting treated water into a nearby well and producing from the IDDP-1, or alternatively using the IDDP-1 as an injection well, and producing from the nearby well. Another strategy that could be considered is to alternate injection into and production from the IDDP-1. In any of these cases acidity and scaling problems might be mitigated by appropriate treatment of injected water. Given the very high temperature at Krafla and the apparent good communication between wells, the possibility of engineering the reservoir to control the hydrologic regime should be considered.

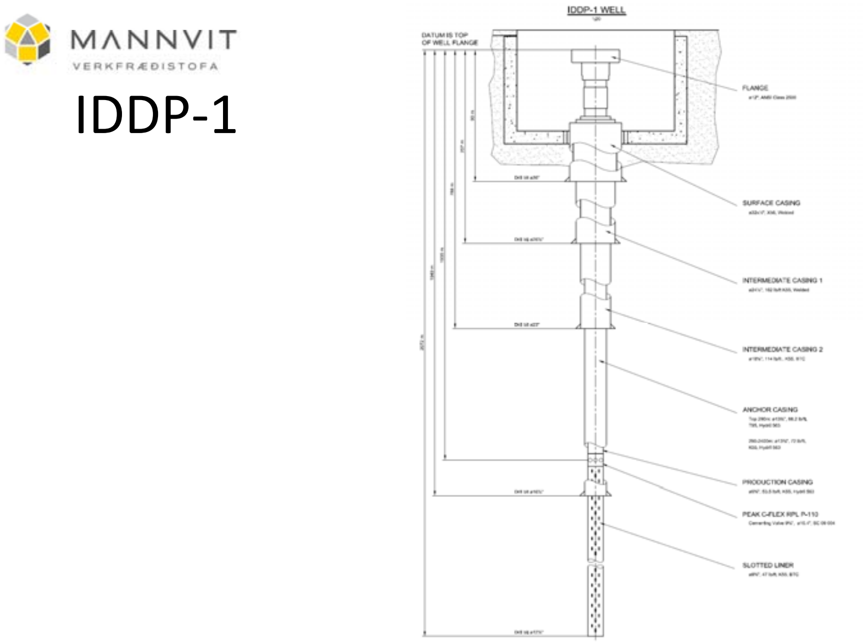

Figure 1. The IDDP-1 design as completed (Sveinbjörn Hólmgeirsson)

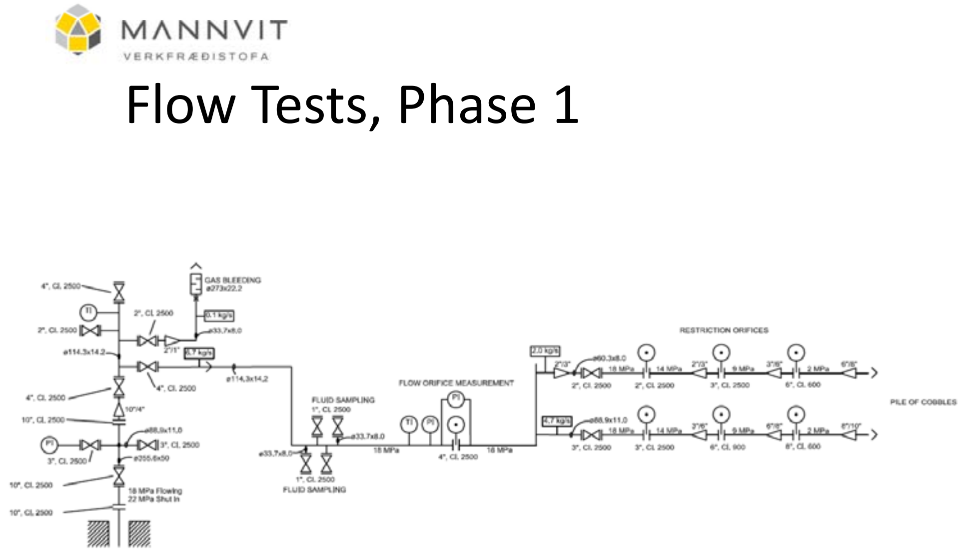

Figure 2. Layout for Phase 1 (Kristinn Ingason)

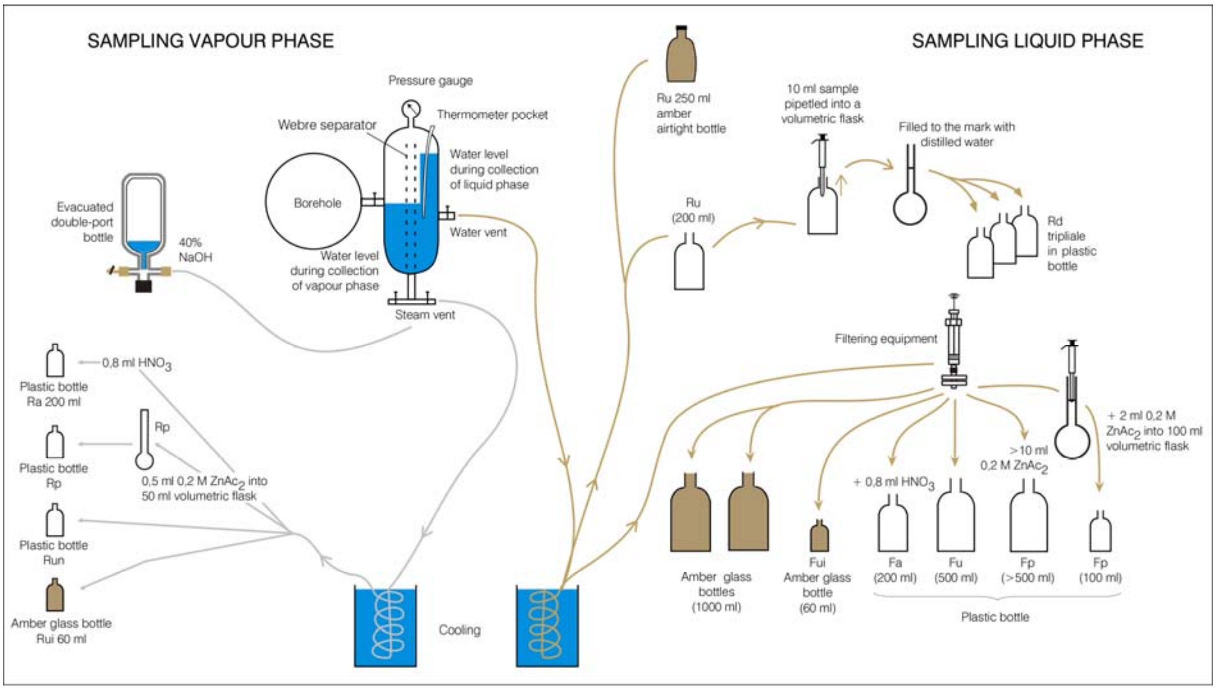

Figure 3. Sample Handling Scheme (Halldór_Ármannsson),

Appendix 1

FHE-Workshop 1 September 2009
At Orkugarður

AGENDA

Opening and Introduction	Guðmundur Ómar Friðleifsson, IDDP-PI, HS Orka
IDDP-1 drilling story, present situation	Sveinbjörn Hólmgeirsson, Landsvirkjun Power
Plan for flow testing IDDP - 1	Kristinn Ingason, Mannvit
Flow testing – sampling	Halldór Ármannsson and Ari Ingimundarson, ISOR
Well testing in North Sea	Rolf Dirdal, StatoilHydro
Coffee break	
Discussion lead by	Bjarni Pálsson, Landsvirkjun Power
HITI-2 introduction	Ragnar Ásmundsson, ISOR
EGS system at Krafla ?	Wilfred A. Elders, IDDP-PI, UC Riverside, USA

Appendix 2

PARTICIPANTS

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Ari Ingimundarson	ISOR
Jón Örn Bjarnason	ISOR
Knútur Árnason	ISOR
RagnarÁsmundsson	ISOR
Halldór Ármannsson	ISOR
Hannes Sverrisson	Mannvit
Richard Lamarche	Alcoa
Bruce Christensen	GNS Science, New Zealand
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Kristján Einarsson	Landsvirkjun Power
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