Well design and drilling plans of the Iceland Deep Drilling Project (IDDP)

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Drilling of IDDP-1, 2009

Iceland Deep Drilling Project (IDDP)

- The plan for IDDP is to drill three (3) wells 4.5-5.0 km into the roots of high-temperature geothermal systems in Iceland and seek to reach supercritical conditions >374°C and >22.1 MPa.
- A generic well to achieve the above objectives was designed to serve the dual purpose of a production- and a science well.
- The first well completed at Krafla in August 2009, but reached only to 2.1 km as magma was intersected.

Production vs. scientific well

Design premises:

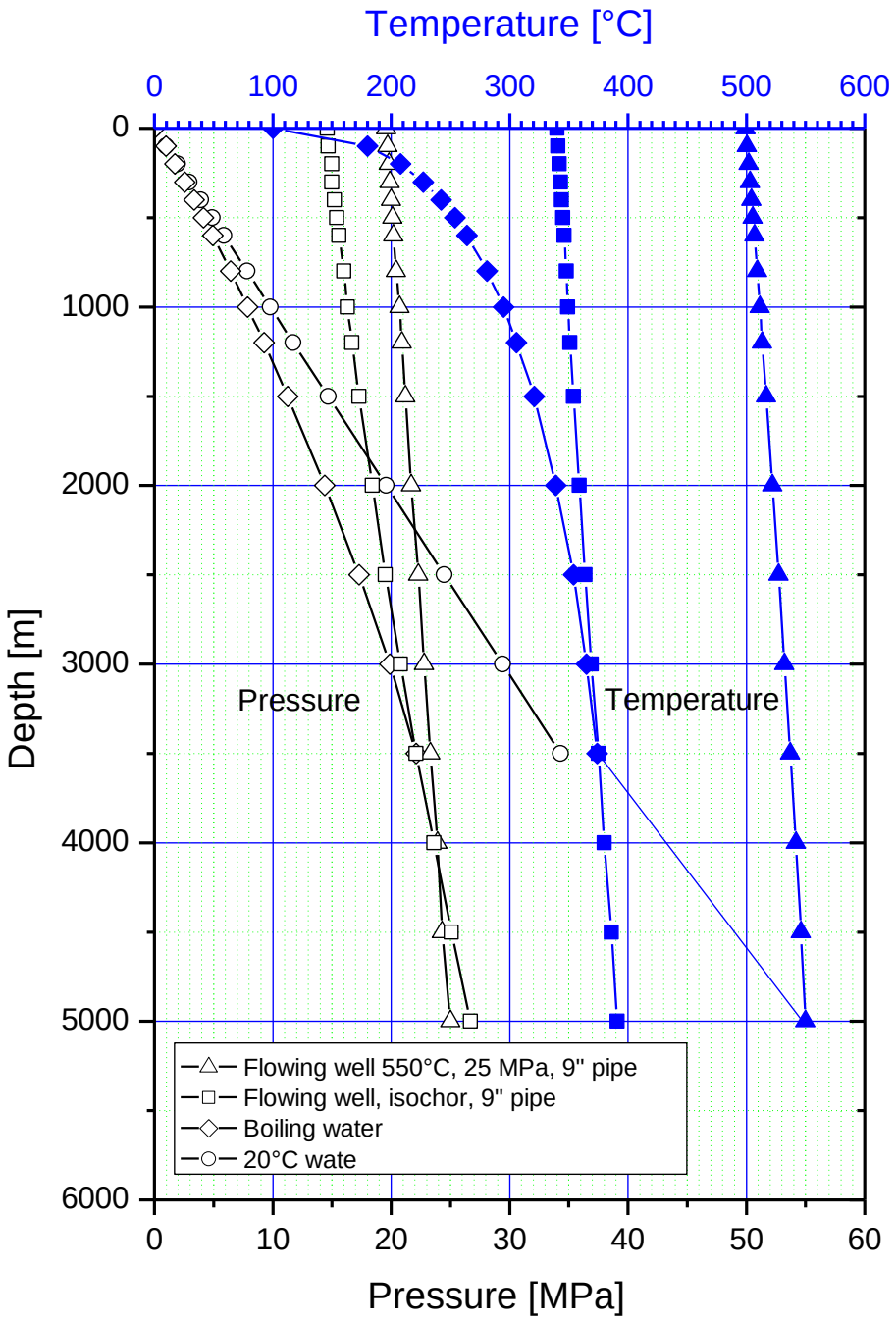
- The well should be of sufficient diameter to be suitable as a production well.
- Coring should be done in the expected transition to and inside the supercritical zone, to the extent that science funds would allow.
- Several well designs and coring systems were considered and the conclusion was that the final section below 3500 m should be drilled 8 ½” and 10 m long spot cores collected, rather than the initial idea of continuous coring (HQ) below 2400 m in a 4” diameter hole.

Expected geological conditions

- The T&P basis of the casing design were boiling point depth (BPD) curve to the Critical Point (~3500 m) and a maximum temp. of 500°C in the well. Lithostatic pressures not expected.
- The wells are to be drilled within three (3) geothermal fields with more than 30 wells each, <3000 m each. Drilling there has been trouble-free, with a few exceptions, and the geological conditions are well known down to 2.5 km.
- The lithology is composed of basaltic lava formations and sub-glacial hyaloclastite formations above ~ 1.5 km depth, and more frequent intrusive rocks, of different type, below that depth.

T&P design premises

- The static reservoir T&P, the undisturbed conditions at depth.
- Well flowing T&P, dynamic profile.
- Predictions were also made of circulation temperatures for each section of the well at different rig pump flow rates during drilling.

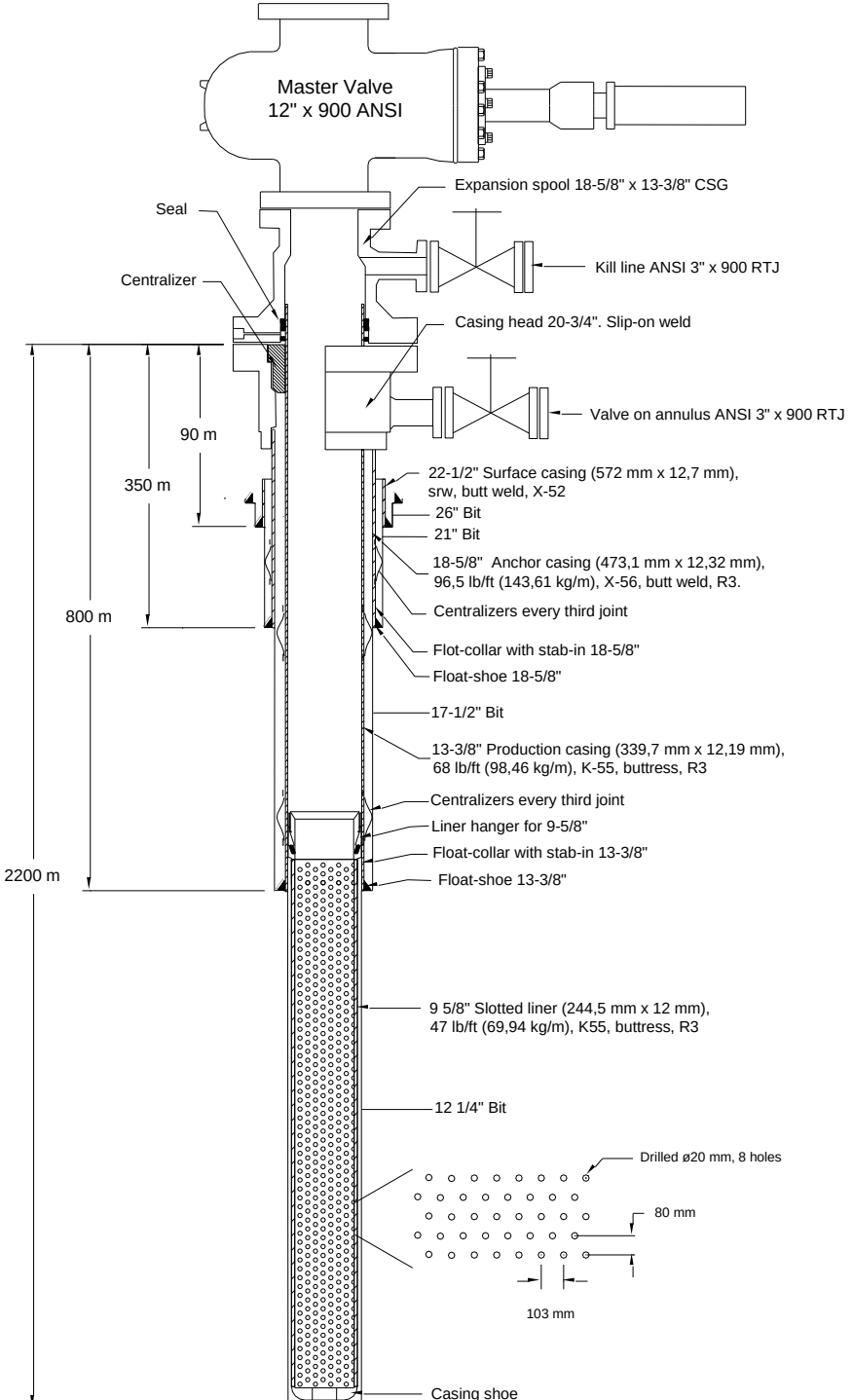


New challenges

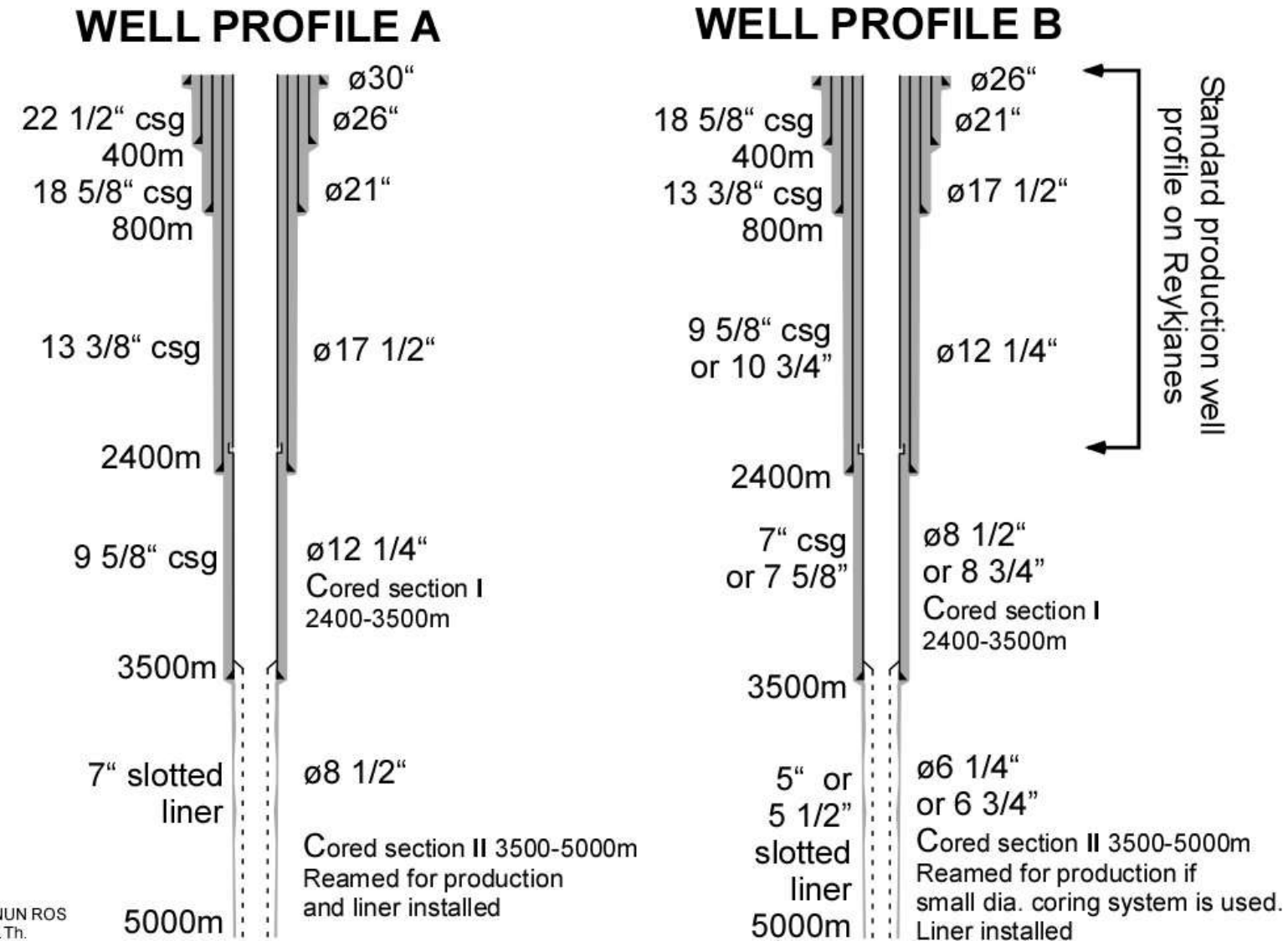
- Risk of intersecting magma and acid fluids, as have been encountered at Krafla over the past few years.
- Greater depths and temperatures than before.
- Circulation temperatures and life of bits.
- Cementing of long casing strings where formation temperatures are high and losses are to be expected.
- Cement design and mud program.
- Casing and connection strength.
- Wellhead temperature and pressure.

Conventional large well in Iceland

- Depth 2000-3000 m
- Temperature 240°C-340°C
- Anchor casing 18 5/8” to 300-400m
- Prod. casing 12 ¼” to 800-1200 m
- Wellhead ANSI 900



Initial well designs considered



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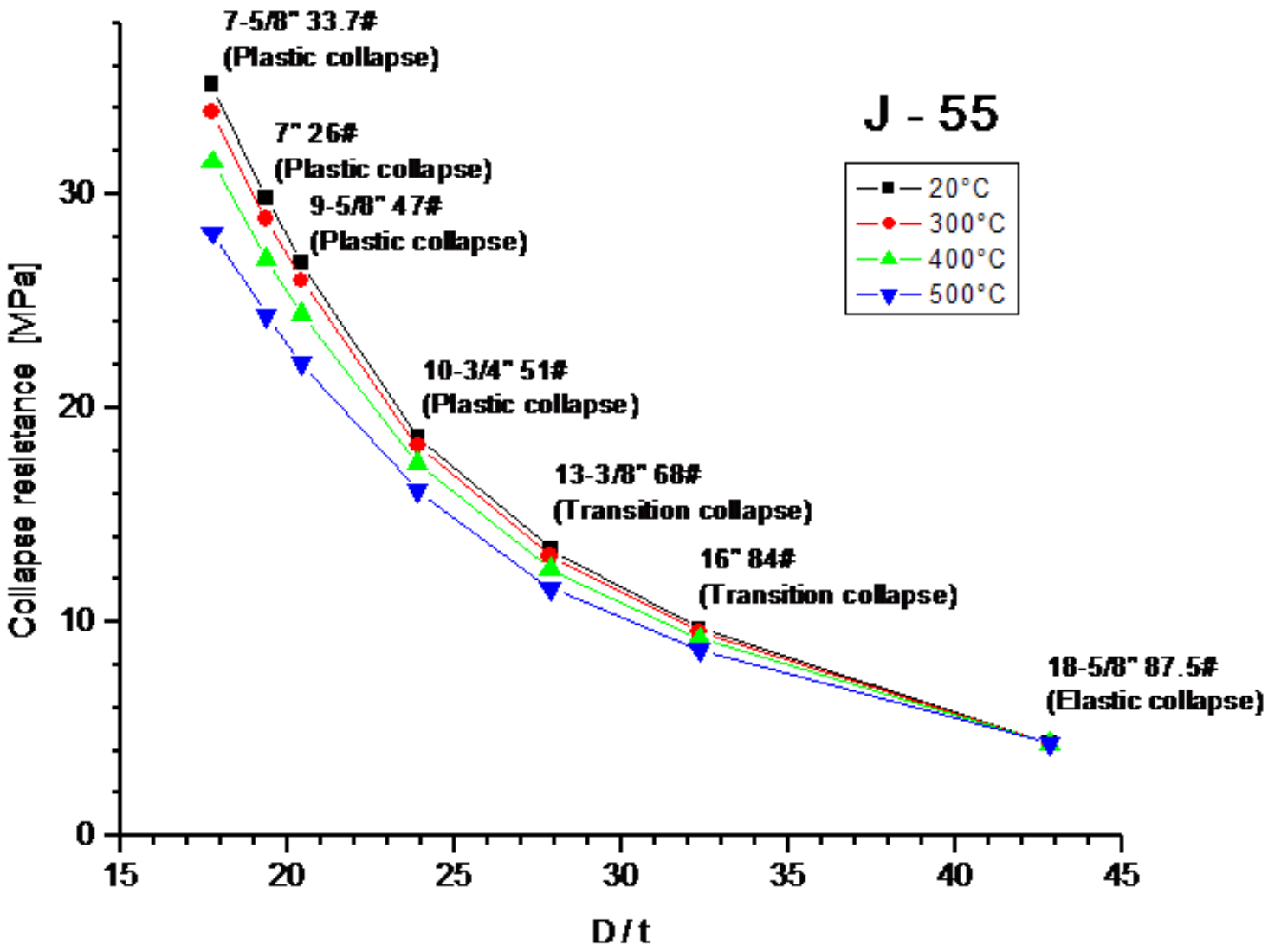
Drilling/coring options from IDDP workshop on drilling in 2002

Four Options	Rig Capacity	Production Casing	Last Hole Dia	Core Size	Hole Size		Cored Sec	Option
							km	
Small Diameter Hole	180 ton	7"	6 1/4"	2.4"	3 7/9"	DOSECC	2.3-3.4	**op-1**
							3.4-5.0	
		7 5/8"	6 3/4"	4.0"	6 3/4"	BRR	2.3-3.4	**op-2**
							3.4-5.0	
Large Diameter Hole	250 ton	9 5/8"	8 1/2"	2.6-3.1"	8 1/2"	CCS	2.3-5.0	**op-3**
				2.4"	3 7/9"	DOSECC	2.3-5.0	
				4.0"	6 3/4"	BRR	2.3-5.0	
				2.6-3.1"	8 1/2"	CCS	3.4-5.0	**op-4**
				2.4"	3 7/9"	DOSECC	3.4-5.0	
				4.0"	6 3/4"	BRR	3.4-5.0	

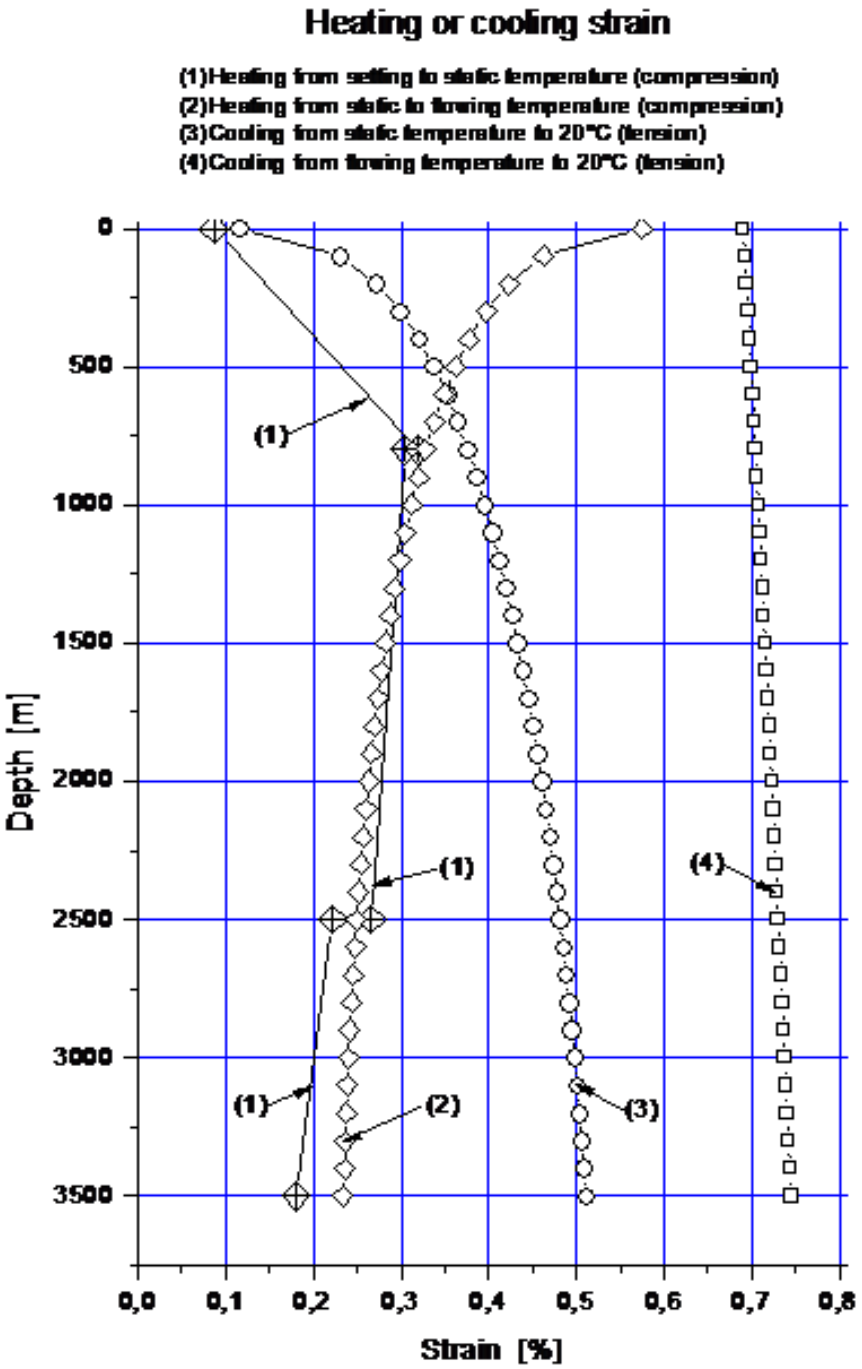
Collapse resistance of IDDP casings



Temperature strain on casing

DESIGN STANDARDS

- API for conventional conditions.
- ASME Boiler and Pressure Vessel Code for creep and rupture design.
- New Zealand Std. NZS 2403 for guidance of conditions.



Casing program for IDDP

	Depth [m]	*Drill Bit*	*Diameter*	*Thickness / weight*	*Min. Drift [mm]*	*Material*	*Connection*	*Collapse [MPa]*	*Burst [MPa]*
Surface Casing	0 – 100	ø36″	ø32″	0,5″		X56	Welded		
Intermediate Casing I	0 – 300	ø26-1/2″	ø24-1/2″	162 lb/ft	585,8	K55	Welded or	5,7	17,0
Intermediate Casing II	0 – 800	ø23″	ø18-5/8″	114 lbs/ft	438,9	K55	BTC	9,8	20,6
Anchor Casing	0 – 300	ø16″	ø13-5/8″	88,2 lbs/ft	311,15	T95	Hydril 563	29,4	52,6
Anchor Casing	300 – 2400	ø16″	ø13-3/8″	72 lbs/ft	311,15	K55	Hydril 563	15,4	25,5
Production Casing	0 – 3500	ø12-1/4″	ø9-5/8″	53,5 lbs/ft	215,9	K55	Hydril 563	35,4	37,6
Slotted Liner	3500 - 4500	ø8-1/2″	ø7″	26 lbs/ft	156,2	K55	BTC		

Drill bits – drill string

- Tri-cone insert bits as have been used in the past .
- Drilling with mud motor to 2400 m.
- Anderdrift tool in the drill string for logging of inclination.
- Two check valves in drill string.

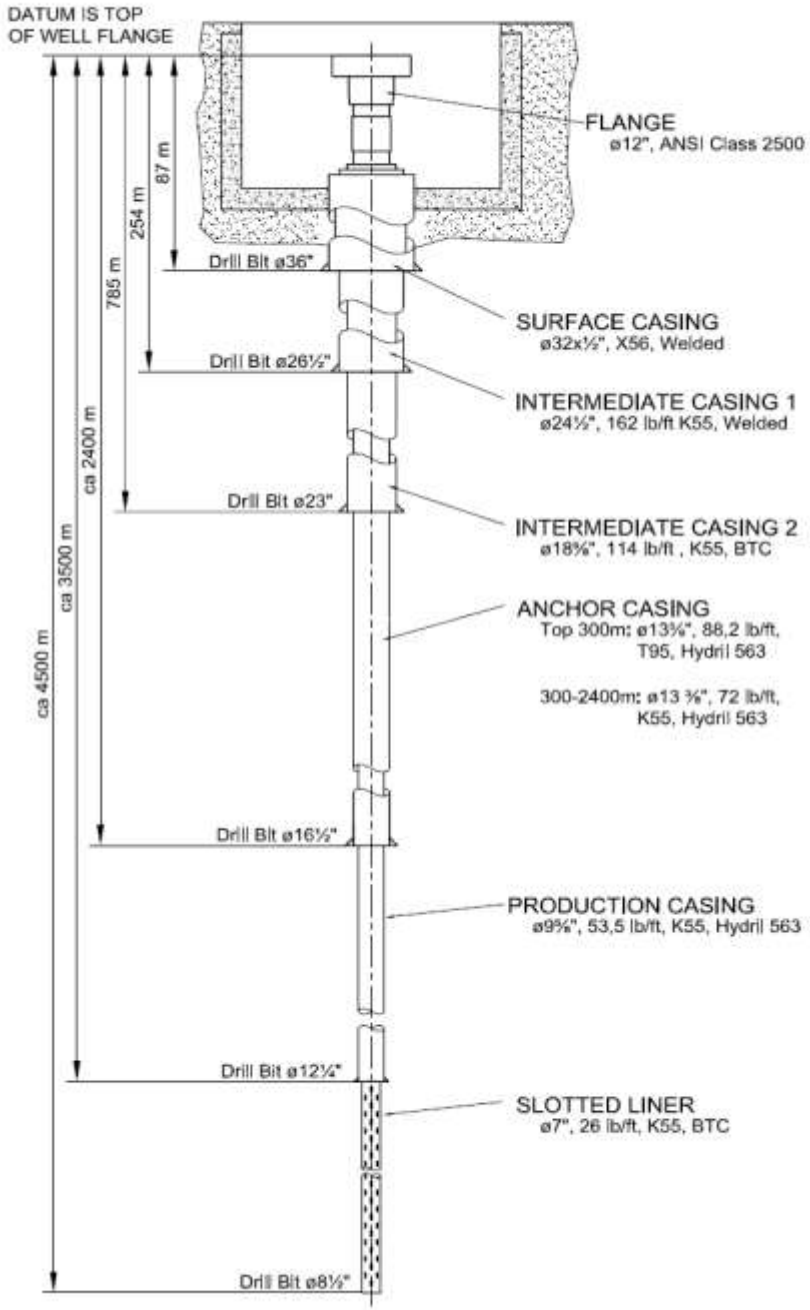
Cementing program

- For the first three casing strings to 800 m the conventional inner-string method. If there are large losses cement up to loss zone and then a top-job, maintaining the loss zone open.
- For the 2400 m and 3500 m anchor- and production casing. Stage cementing by use of C-Flex tool. Then first stage inner string and fill-up. Then the annulus packer is set and cementing to surface through the ports.

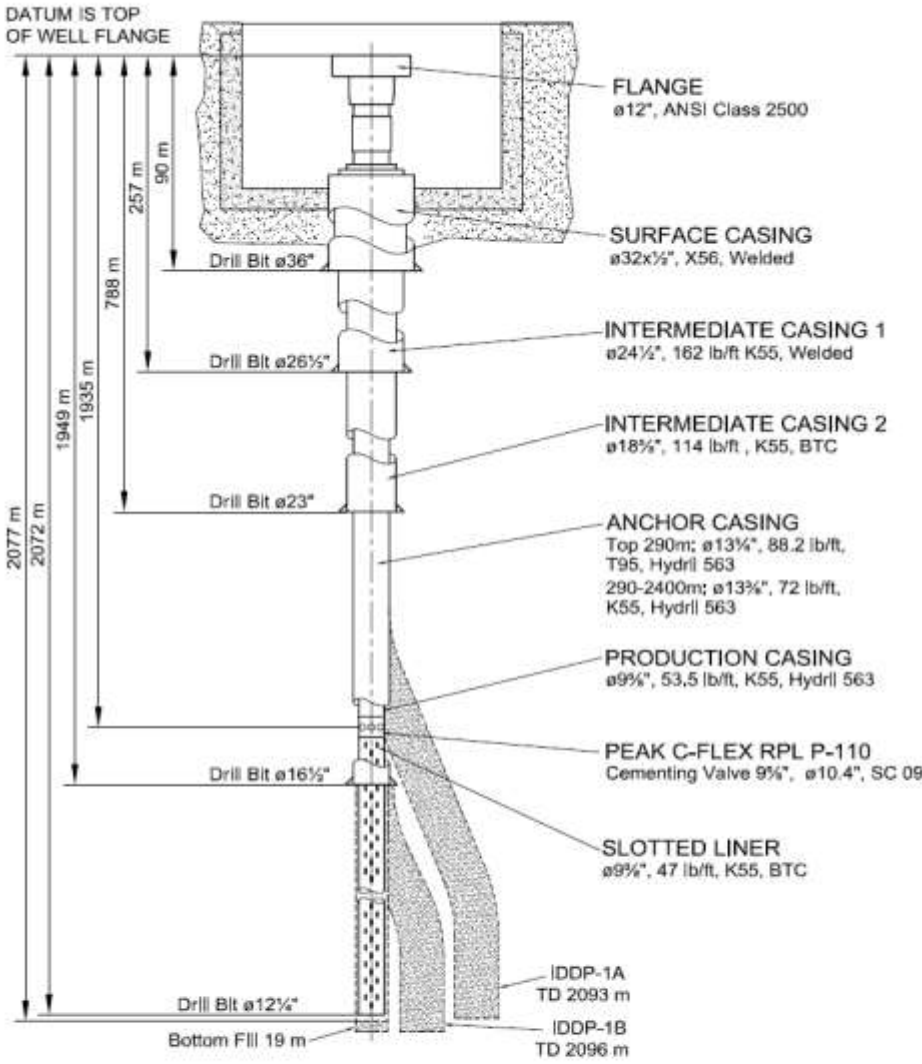
Mud program

- Bentonite-water mud treated for the temperature for all drilling to 2400 m (16.5" hole). Additional cooling tower was installed to maintain mud temperatures below 100°C.
- Below 2400 m (<12 ¼" hole) water only and high-viscosity polymer pills, if there is inadequate hole cleaning.

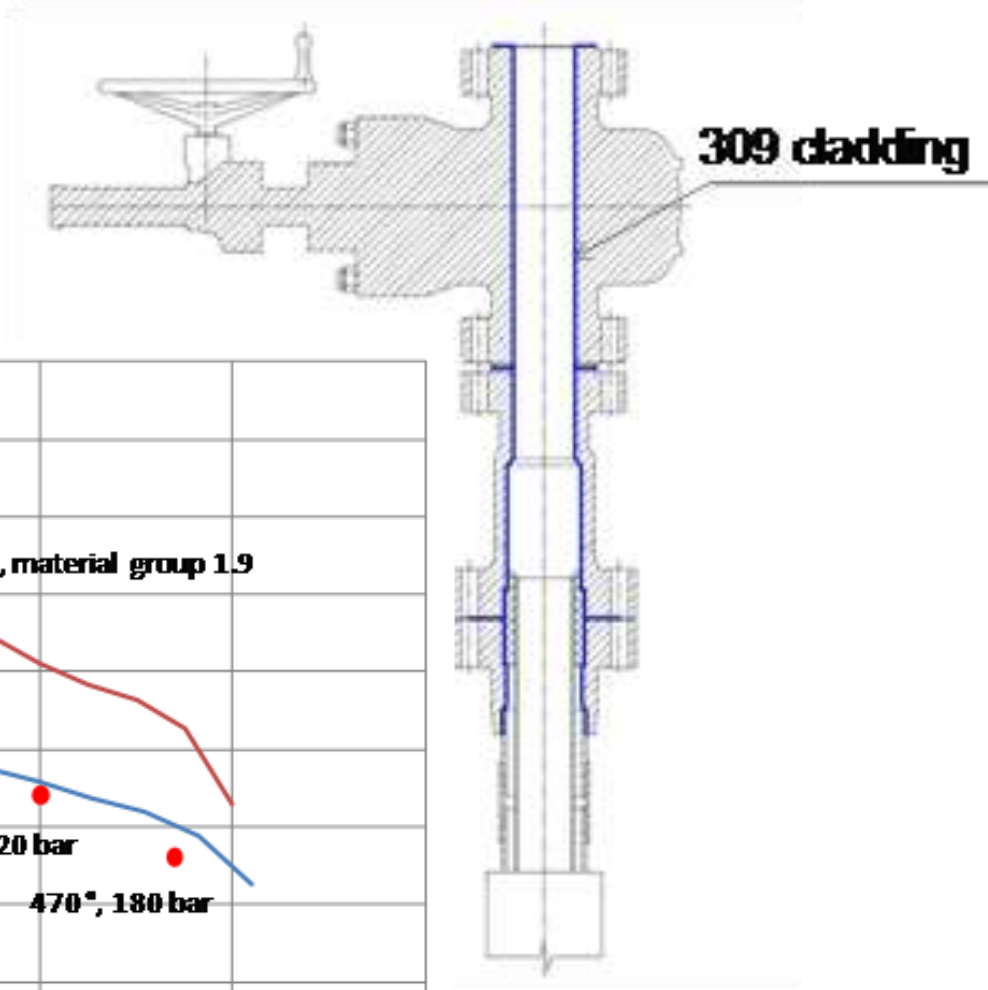
IDDP-1 WELL DESIGN

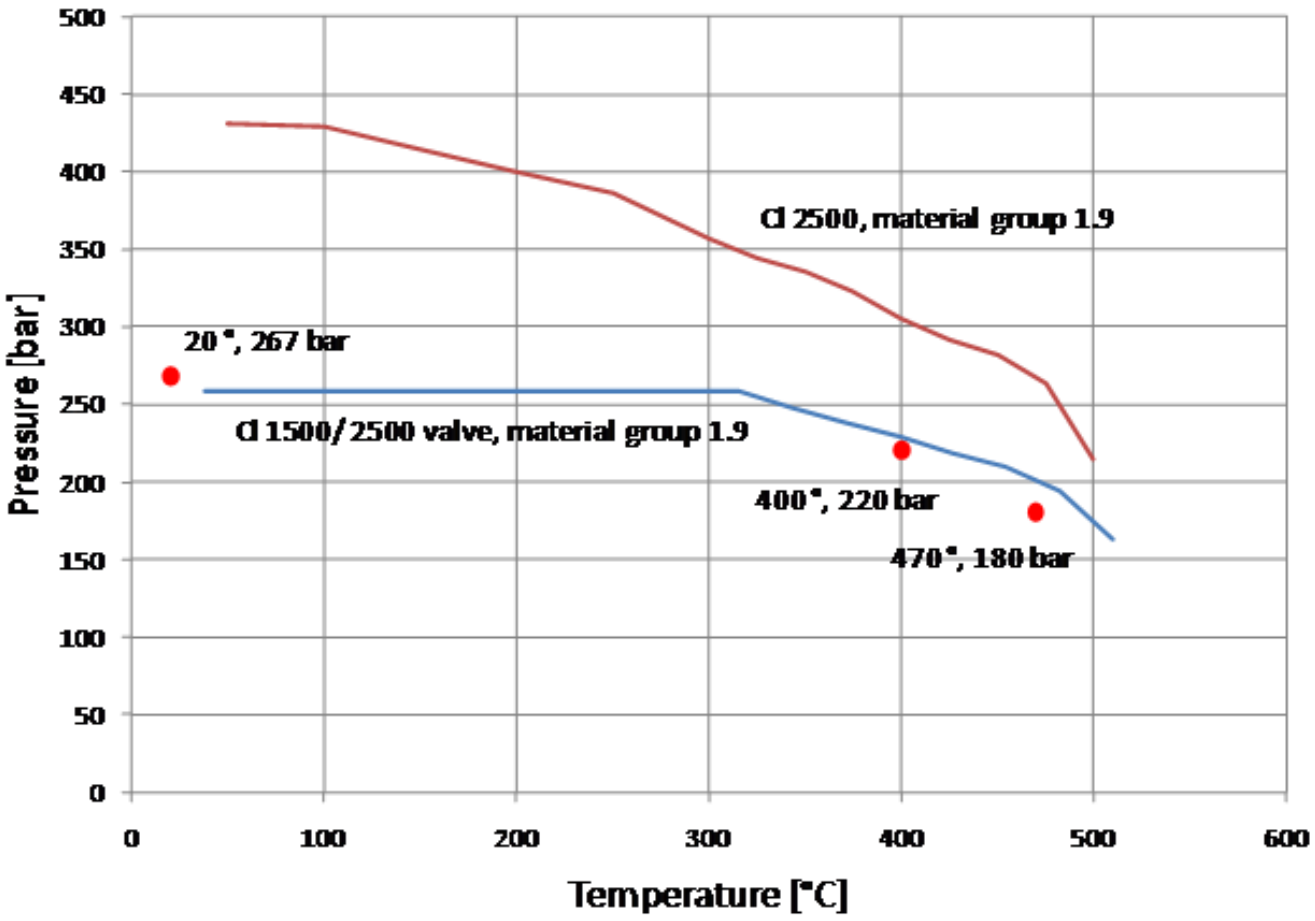


IDDP-1 AS BUILT

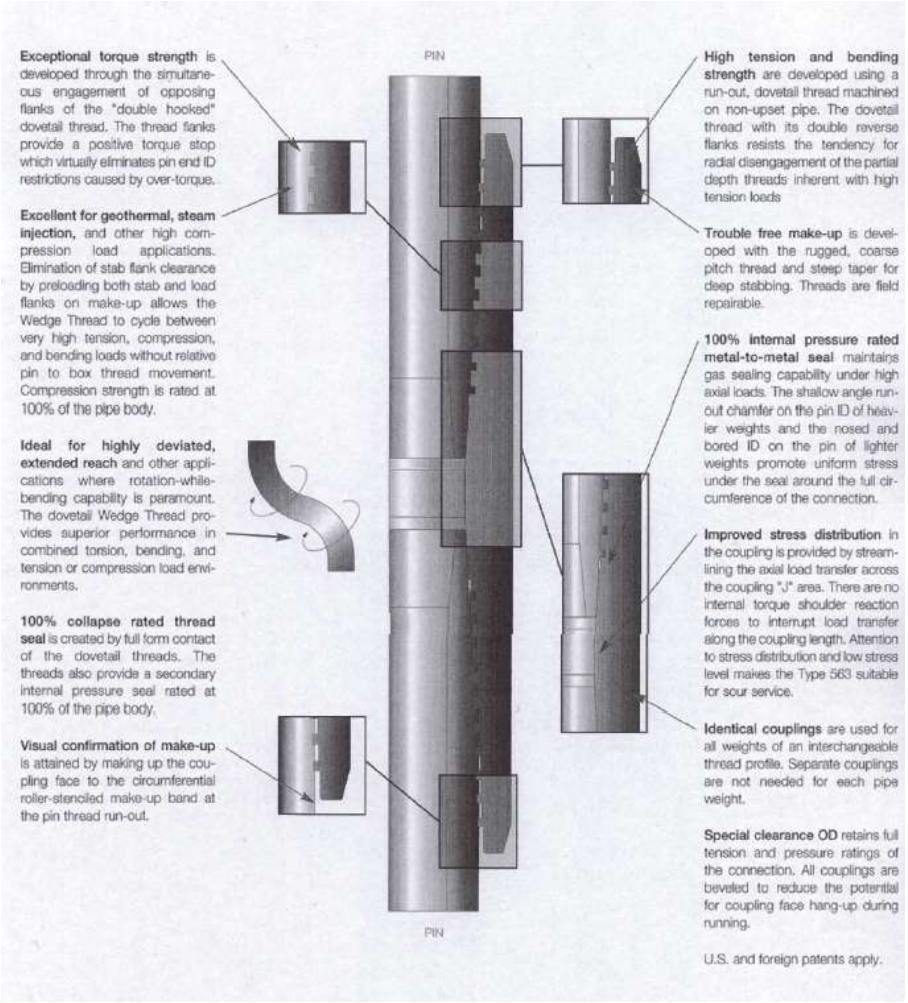


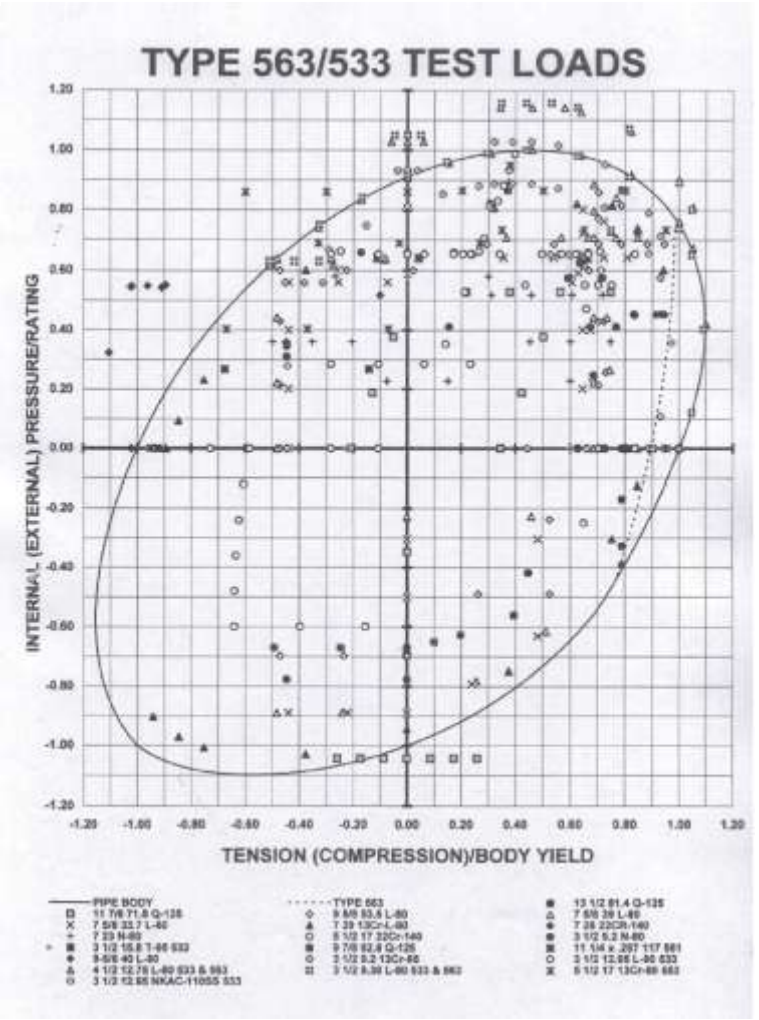
Wellhead 10" 2500 ANSI





HYDRIL connections, type 563





Conclusions

- The drilling of the IDDP well is a major step for geothermal drilling. Compared to existing HT drilling in Iceland in the past:
  - Extend drilling depth from 3 km to 4.5 km
  - Temperature from 340°C to 400-500°C
  - Cementing casing to twice the depth before.
  - Larger hole and casing sizes.
  - More coring and at extreme temperatures.
  - Four times the cost of a conventional well.


Thank you !