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IDDP-2 Well Head and Flow-Line Design for IDDP-2

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ABSTRACT

The IDDP-2 drilling project at Reykjanes, Iceland, is the continuation of the ongoing Iceland Deep Drilling Project (IDDP). It was launched in the year 2000 and the IDDP-1 well was drilled during 2008-2009 in Krafla, North Iceland. An already existing well at the Reykjanes Power Plant was deepened to 4,5 km and is now called the IDDP-2 well. Super critical fluid has been observed at the bottom of the well. Enthalpy and chemistry of the expected fluid is not known due to mixture with two phase inflows at shallower depth.

Considering this uncertainty, the wellhead itself was designed assuming the worst-case scenario, i.e. 450°C and 300 bars. The valves and fittings are with corrosion resistant cladding and selected in ASME B16.5 Class 2500. A modulating orifice control valve used in HS Orka's installations at Reykjanes has been developed to withstand the severe corrosion and erosion environment. The main and the secondary back-up test flow-lines consist of fixed and variable orifices, flow measuring orifices, test tapping spools, reducing the high well pressure to atmospheric flash separator.

1. INTRODUCTION AND PREMISES

The wellhead equipment design and test setup has changed multiple times since its first conception in the end of 2013 due to stops and changes in the project. This paper will chronicle the design of the above ground testing installation from 2016 to 2019 with the RN-15 well at Reykjanesvirkjun as the selected IDDP-2 well.

IDDP-2 Well design, drilling and measurements

The IDDP-2 well uses the RN-15 production well of the Reykjanes Power Plant. This well was a vertical well drilled in 2004 to a depth of 2507m. The well was never a good producer but was connected to the power plant in 2006 with a well output of 2-3 MW. This well was later chosen as the new IDDP-2 well and plans were put in motion to deepen the well and reaching supercritical fluids.

The well was deepened to 3000 meters and a future production casing cemented. The well was then deepened to a depth of 4569 m from the rig floor and a perforated liner installed. Almost total circulation losses of drilling fluid were encountered throughout the drilling phase and continued to almost the end of drilling. The well design is introduced in a separate paper at this convention.

After well completion, the temperature at the bottom of the well was measured at 426°C with a pressure of 340 bar. Stable bottom temperature logs suggest that the bottom hole temperature could be as high as 535°C.

Estimated well output

In the initial concept design the well the output was estimated 30 kg/s at 100 bar well head pressure. Due to damage/leakage observed in production casing there will always be some mixture between the super critical fluid from the bottom and fluid inflow through the casing leakage. It has been difficult to get an estimation from the reservoir group of the output but numbers like 30 kg/s – 80 kg/s at 40 bar have been introduce. The design of the well head equipment takes notice this but also the fact that the must be prepared for a large flow and enthalpy interval.

Estimated fluid chemistry

In June of 2018 the fluid chemistry group published their findings. Their conclusions were as follows:

- "The reconstructed Reykjanes reservoir fluid at 350°C has seawater salinity and a pH of about 5.5. The H2S concentration is somewhat higher and Cu, Fe, Zn and Pb substantially higher, compared to the 295°C fluid in RN-12. The fluid is in equilibrium with anhydrite, quartz, garnet, epidote, actinolite, bornite, galena, millerite, sphalerite, and haematite.
- Mixing of this heated Reykjanes fluid and two supercritical seawater fluids (dilute and concentrated) yields fluids with slightly lower pH, higher SiO2 and substantially higher H2S.
- During boiling to 70 bar-a, the fluid mixtures precipitate 10–20 mg per kg produced, mainly anhydrite, haematite, bornite and phyllosilicates. The boiled fluid has pH ranging from 3.8 to 4.5, and high concentrations of H2S and sulphide forming metals. It is somewhat undersaturated with respect to amorphous silica.
- Upon further boiling of the fluid, it is likely to precipitate metal sulphides and amorphous silica"

Following this report, the decision of the material selection could be made on a scientific bases and a material selection specialist along with chemical specialists from ISOR were drafted to interpret the results to a reliable material selection. This material selection did influence the selected valve material, spool piece material and the material selection of the flow-line itself.

2. LESSONS LEARNED FROM IDDP-1

The lessons learned from IDDP-1 are very important to avoid the problems faced there. A few of these will be listed here and were used as a guide for the wellhead and flow-line design basis.

- Always have an alternate flow-line so there is no need to shut down the well in case of repair or modifications.
- Design the flow-line such that there is minimal risk of shutting down the well during repairs.
- Operate the wellhead at a high pressure to avoid erosion.
- Avoid all unnecessary complications of the flow-line design.
- Avoid all welded nozzles on the flow-line, since they will cause complications or break down/off.
- Always use two valves in series on all critical locations.
- Use cladded valves to avoid erosion.
- Use expanding gate valves for the wellhead and discharge valves.
- Keep flow-line pressure high and velocity low to avoid erosion and scaling.
- Have methods for vibration reduction ready.
- Use a counterweight support to compensate for well rise. Design supports to compensate as well.
- Use remotely controlled hydraulic jacks on wellhead valves.
- Consider using Inconel for sampling, i.e. for measurement piping.
- Use sophisticated materials for smaller sample valves, e.g. Inconel.
- Monitor all critical parameters and use an alarm system for warnings.
- Perform a risk analysis and establish a chain of command.
- Be able to kill the line in less than two hours.
- A red line through the lessons learnt is that extreme reliability is crucial as well as keeping all systems as simple as possible. The need for expensive materials for the critical parts is also noted as well as having as many redundancies in the system as possible in case of a fault. These lessons were the ones that were used as a benchmark for the design of the IDDP-2 wellhead and surface system.

3. WELLHEAD DESIGN

IDDP-2 wellhead design history

The wellhead design has been modified several times to accommodate the design philosophy and cost benefits. One of the main considerations was having no welds at the wellhead, meaning no weld fittings anywhere. The first draft of the wellhead consisted of conventional flanges and welded fittings to fit the bleed and kill valves as well as the two wellhead valves and flow-lines. This is very much a conventional wellhead with added redundancy for every valve in accordance to the lessons learnt at IDDP-1.

1st design

At this stage the well was still being drilled and to limit the height of the wellhead and therefore minimize the need for large amounts of scaffolding and simplify all maintenance the main master valve was located in the well cellar as low as possible along with the casing head and the expansion spool, see Figure 1. A spool piece with the kill and bleed valves was located between the master valves with a third valve, welded NPS 8 Class 2500 valve located upstream of the modulating orifice valve with a block and bleed concept introduced to relieve pressure between the modulating orifice valve and the NPS 8 stop valve. This is the valve between the NPS 8 gate valve and the orifice valve.

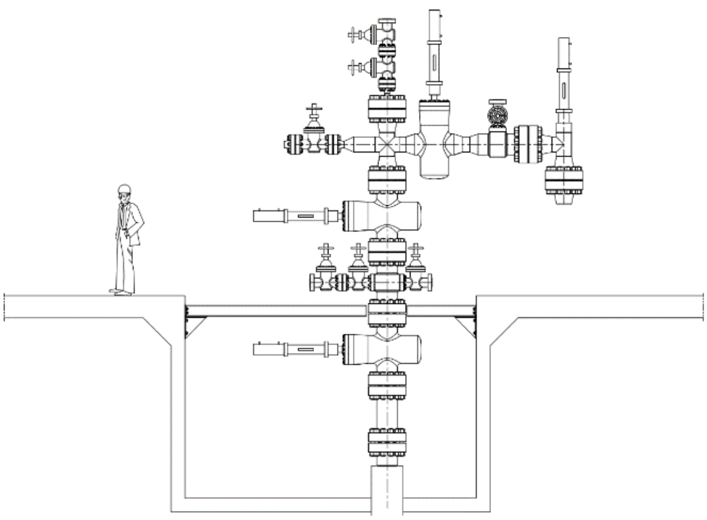

Figure 1: First draft of the IDDP-2 wellhead.

This was a good start which introduces the key lessons from the IDDP-1 about using valves in series for operational and operator safety. But soon, work started on minimizing the number of welds on the wellhead. This was also a key learning from the IDDP-1 wellhead where welds proved to be a problem due to failure and leakage. Therefore, it was suggested that instead of using the tee upstream of the second main valve a new spool would be fabricated that would enable the fastening of the necessary valves directly to the spool by means of studded bolts.

2nd design

A spool piece for the kill valve was also suggested with the valves bolted directly to the spool. This would eliminate all welds from the wellhead. Additionally, this could simplify the wellhead and its assembly and make it more reliable. This is a method commonly used in the oil and gas industry but not on Icelandic wellheads so far.

In Figure 2 and the first drafts of the spool pieces are shown. The spool pieces were designed as Class 2500 no-weld forged pieces with machined RTJ gasket grooves and threaded holes for the flange bolts. A 6 mm Inconel cladding inside the spool piece and the RTJ groove was added in later editions.

Figure 2 shows the downstream spool intended for installation between the two main valves. The spool consisted of an NPS 10 Class 2500 inlet/outlet and two NPS 3 Class 2500 outlets to each side for the kill and bleed valves. All connections were designed with RTJ grooves for optimal sealing.

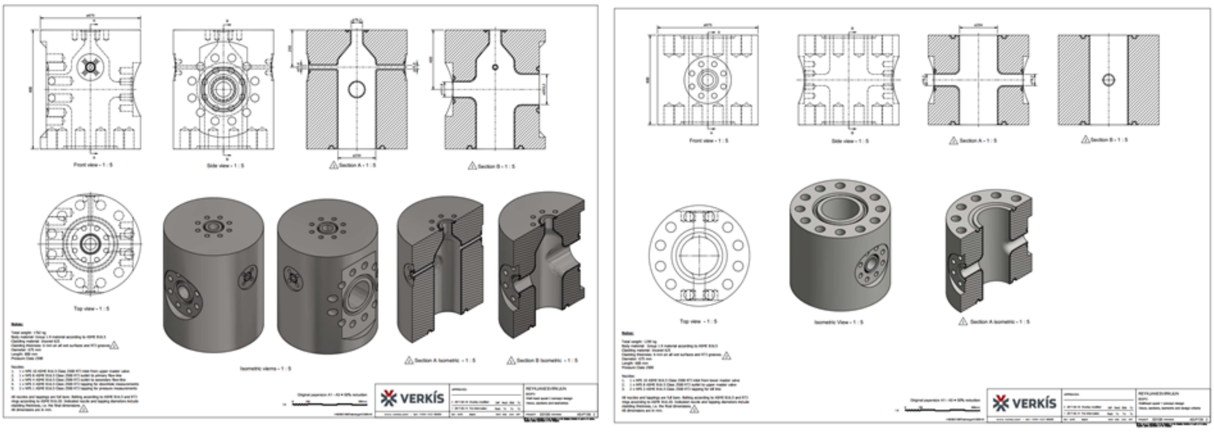

Figure 2: Right: Lower wellhead spool intended for kill/bleed valves. Left: Upper wellhead spool.

Figure 2, left, shows the second spool piece intended to replace the tee connecting the primary flow-line, secondary flow-line and measurement valve flange. This spool was equipped with the following nozzles:

- NPS 10 Class 2500 RTJ inlet
- NPS 8 Class 2500 RTJ outlet for the primary flow-line
- NPS 4 Class 2500 RTJ outlet for the secondary flow-line
- NPS 3 Class 2500 RTJ outlet for well measurement and access valves
- 2 x NPS 1 Class 2500 RTJ outlets for sampling and measurements valves (P, T, pH and sampling)

Figure 3 shows the wellhead with the spools added and shows the wellhead has decreased in height considerably. The master valve of the well was eventually installed above the well cellar since the casing could not be cut lower thus increasing the necessity of the wellhead spools to keep the wellhead at a reasonable height above ground and maintain easy access and increase safety of the operators. An Inconel 625 cladding of all internal wetted areas and ring groove was added to prevent corrosion of the base material. This included the NPS 1 measurement port.

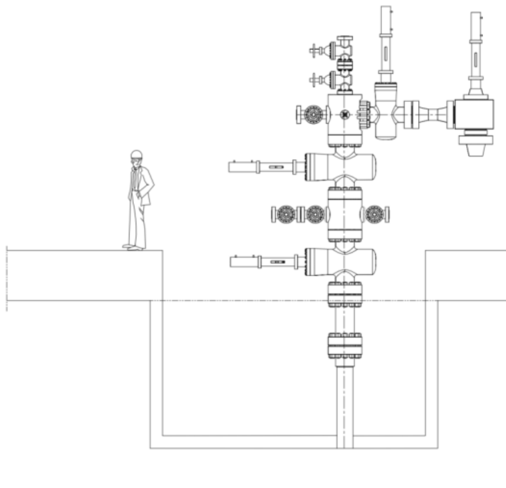

Figure 3: 2017 wellhead design with spools.

HS Orka had received the two NPS 10 Class 1500/2500 TIX valves used by Landsvirkjun at the IDDP-1 wellhead. These valves are expanding gate valves with ASME B16.5 Class 2500 flanges with a Class 1500 rated body made by TIX-IKS from Japan. The valves had failed to close at the IDDP-1 site but were rebuilt by HS Orka, cladded and refurbished. The following additional valves had to be procured for the wellhead:

- 1 x NPS 8 Class 2500 RTJ
- 2 x NPS 4 Class 2500 RTJ
- 6 x NPS 3 Class 2500 RTJ
- 4 x NPS 1 Class 2500 RTJ

Not many manufacturers do manufacture expanding gate valves in these sizes and therefore long lead times were to be expected. The valves were to be cladded with Stellite 706 and Inconel 625 to avoid corrosion.

This was the design chosen for the wellhead in 2016/2017. Procurement of the spool pieces and valves was started in late 2016 with the tender documents sent to wellhead and valve manufacturers. A few manufacturers were interested in the build of the spool pieces and sent offers. At this time, in April 2017, before the manufacturing could commence the project was stopped for an indefinite amount of time. The reason was he observed damaged casings. The valve procurement was also stopped.

3rd Design

In the summer of 2018, the project was restarted. The aim was to use the well with the damage casings. More financial constraints were imparted on the design of the wellhead and surface equipment. This meant that the wellhead design had to be modified. The most expensive parts of the wellhead are the valves and the spools. To reduce the cost of the wellhead, the NPS 8 Class 2500 side valve and the bleed valve for the orifice valve were removed from the design as well as the lower wellhead spool. The pressure rating of the orifice valve was also changed and instead of making a new Class 2500 solid body valve with ASME B16.5 connections for the wellhead the already in use modulating orifice valve for the Reykjanes wells (DN 300 PN 160/Class 900) was to be used and modified to serve the flowline. For further information about the design and build of the valve refer to section *4. Orifice* valve.

The new design of the wellhead is shown in Figure 4. The bleed and kill valves were removed and instead of having two NPS 10 master valves in series one of them was moved to the primary flow-line, essentially serving in series with the master valve for the primary flow-line with the secondary flow-line valves serving as bleed valves. The killing of the well can be performed by injecting water either at the secondary flow-line valves (NPS 3) or the measurement valves (NPS 4). This simplified the procurement of the wellhead equipment. A new 90° angled wellhead spool was designed with a few modifications, the top outlet was changed to a 4 in outlet while the secondary flow-line outlet was reduced to an NPS 3 port. The final wellhead spool is shown in Figure 5.

The primary flow-line outlet was modified to an NPS 10 to mount the second master valve. An adaptor flange to modify the connection between the NPS 10 Class 2500 RTJ flange and the DN 300 PN 160 orifice valve was added to the project and was manufactured with the orifice valve. Table 1 shows the wellhead components and their specifications.

Table 1: Wellhead components pr. final design.

Item (KKS)	Size	Location	Material	Rated pressure class
Expansion spool	NPS 10	Between well top flange and main control valve	ASTM A182 Gr. F11 Cl. 2 cladded with Inconel 625	ASME class 2500
Wellhead spool	NPS 10	On top of the main control valve	ASTM A182 Gr. F11 Cl. 2 cladded with Inconel 625	ASME class 2500
Main stop valve	NPS 10	Between expansion spool and wellhead spool	Various, cladded with stellite.	Body: ASME class 2500 Flanges: ASME class 1500
Secondary stop valve	NPS 10	Between wellhead spool and modulating orifice valve	Various, cladded with stellite.	Body: ASME class 2500 Flanges: ASME class 1500
Secondary flow-line valves	NPS 3	Between wellhead spool and secondary flow-line	Various, cladded with stellite.	ASME class 2500
Testing valves	NPS 4	On top of wellhead spool	Various, cladded with stellite.	ASME class 2500
Pressure tapping valves	NPS 1	On side of wellhead spool	Various, cladded with stellite.	ASME class 2500

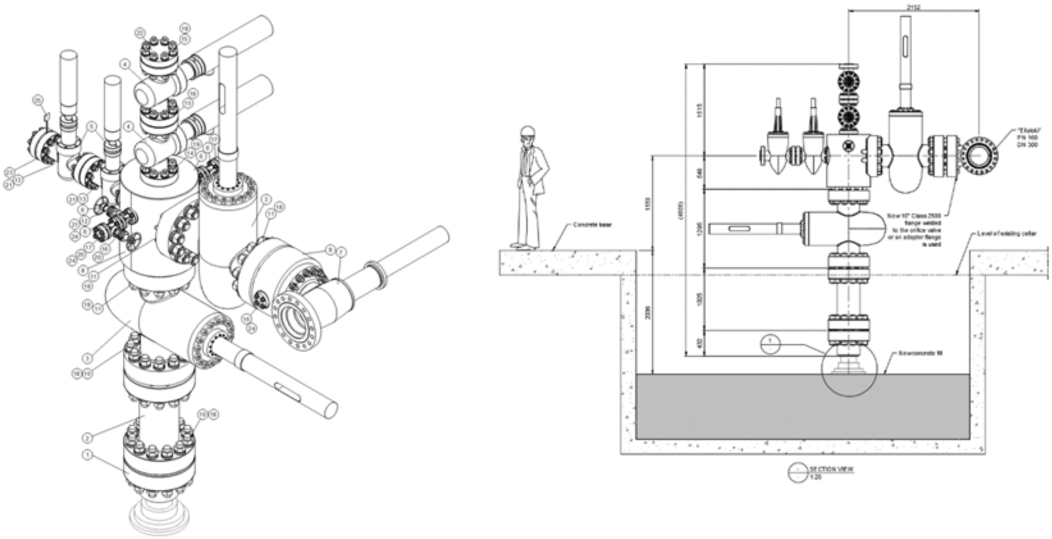

Figure 4: Isometric and side view of the final version of the wellhead.

Figure 5: 90° angle well head spool.

The following valves had to be procured for the new design:

- 1 x Flexible wedge NPS 3 Class 2500 RF RTJ
- 1 x Flexible wedge NPS 4 Class 2500 RF RTJ
- 1 x Expanding gate NPS 3 Class 2500 RF RTJ
- 1 x Expanding gate NPS 4 Class 2500 RF RTJ
- 4 x Solid wedge NPS 1 Class 2500 RF RTJ

Figure 6: NPS 4 and NPS 3 Class 2500 valves from TIX.

All valves were ASME B16.5 Class 2500 double flange. Body and bonnet material WC6 with 4 mm Inconel 625 on all wetted internal surfaces of the valve body. The seat ring surface as well as the gland and wedge seat surface were to be cladded with Stellite 6.

The specifications were sent to potential valve manufacturers with only a few able to comply with the specifications and the procurement time. Finally, only the NPS 1 valves were bought as they would arrive within a reasonable timeframe. The other valves were procured from Landsvirkjun, made by TIX and were refurbished in Iceland.

The wellhead spool was manufactured in Houston, Texas USA by Triple J Coil Tubing Products LLC. The spool itself is 908 mm tall and 750 mm in diameter and weighs around 2.400 kg. The weight of the spool has to be looked at in context with the weight of Class 2500 flanges, each one weighing about 500 kg. The spool piece was as before made from ASTM A182 F11 Cl. 2 material with Inconel cladding on all wetted parts and the RTJ groove. One of the main challenges was to clad the internal area of the NPS 1 measurement ports. The diameter is too small for conventional cladding despite efforts to find a shop capable of this. The solution was to thread an Inconel 625 rod with the desired internal diameter into the spool and welding it together, see Figure 5. The wellhead spool was delivered in June of 2019.

Figure 7: 90° angle wellhead spool being milled at Triple J.

Flange washers

Serious problems occurred in the IDDP-1 wellhead and flowline with regards to loosening of bolts due to both vibration and thermal expansion of the flanged connections. Bolted connections do get loose or lose preload for several reasons; gasket creep, temperature differences leading to differential thermal expansion, bolt creeps and vibration may affect the connection. This problem may be difficult to solve by a single measure, however by insulating the equipment thoroughly some improvements may be implemented.

When dealing with extreme high temperature differences in process fluid temperature insulation has proven not to be enough to maintain the preload of the bolted connections. When high temperature fluid enters the flanged connections the flange and gasket expand faster than the bolts due to proximity to the fluid. This leads to higher tension on the bolts and thus further stresses on the gasket. The gasket compresses more than at the time of the assembly and since it is not fully elastic it will not reach its original thickness when the bolts have expanded as well, and the bolted joint will therefore lose preload. Therefore, Belleville springs will be used to maintain the preload of the bolts. The springs or flange washers are "bowl" shaped and can exert considerable load with a small compression distance. These flange washers will therefore counteract the loosening of the bolted connections by acting as a spring and maintaining the bolt load. Quite a bit of research went into calculating the ideal preload of the bolts and nuts for the selected bolt and nut material (ANSI B1.1/ASME B18.2 A193 B8M/A194 Grade 2HM) according to *ASME BPVC VIII.1-2015 – App. 2* and *Guidelines for Pressure Boundary Bolted Flange Joint Assembly PCC-1 – 2013,* whose description is as follow:

> *„The bolted flange joint assembly (BFJA) guidelines described in this document apply to pressure-boundary flanged joints with ring-type gaskets that are entirely within the circle enclosed by the bolt holes and with no contact outside the circle. By selection of those features suitable to the specific service or need, these guidelines may be used to develop effective joint assembly procedures for the broad range of sizes and service conditions normally encountered in industry. Guidance on troubleshooting BFJAs not providing leak-tight performance is also provided in this document (Appendix P). "*

The main goal of the calculations was to select the correct size and magnitude of washers capable of maintaining the bolt preload in case of thermal expansion and vibration. Figure 8 shows the configuration of the flange washers for an NPS 3 ASME B16.5 Class 2500 flanged-flanged connection using two flange washers in series to obtain full compression of the washers at optimum bolt and connection preload. If the connection loses its preload the washers will compensate up to the original preload.

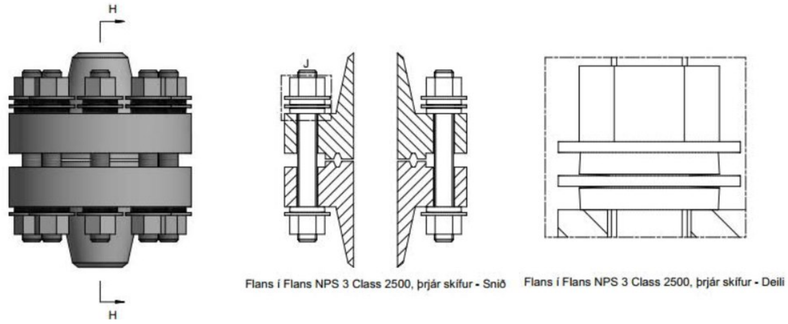

Figure 8: Configuration of flange washers for an NPS 3 flanged-flanged connection.

Insulation

Aerogel insulation was tried for the insulation of the wellhead and parts of the flow-line. Aerogel is a synthetic material made from gel. It has superior insulation performance compared to conventional rock-wool insulation if comparing the same thickness. This was chosen as the material is easier to install than conventional rock-wool and aluminium cladding insulation. For the wellhead, the Aeroegel insulation was delivered in ContraFlex insulation jackets for easier installation and removal.

RTJ gasket hardness

Another challenge of the design team was to procure the necessary hardness of flanges, valves and RTJ gaskets. When using RTJ gaskets the difference in hardness between the material of the RTJ groove and the RTJ gasket itself is extremely important. The sealing is made with the RTJ gasket plastically deforming into any irregularity of the RTJ groove. Therefore, the gasket needs to be softer than the flange material or the material of the RTJ groove. By using Inconel 625 RTJ gaskets and cladding the RTJ grooves with the same material the design team had to make sure that enough of a difference in hardness to provide an effective seal. Documentation of the hardness of each groove was therefore required along with procuring as soft as possible Inconel 625 RTJ gaskets. This proved to be a challenging task but necessary to maintain the integrity of the seal and simultaneously fulfilling the requirements set forth by the chemical analysis of the brine.

Pressure rating and material selection

The wellhead pressure and temperature ratings are shown in Figure 9 for material group 1.9 which is the main material of the wellhead components. The wellhead pressure and temperature rating are based on this base material. These two parameters are interlinked and therefore design rating of one parameter depends on the other and vice versa.

In order to set numerical value for the pressure and temperature rating the rated design pressure is set at 250 barg at 475°C, selected as a possible scenario. The pressure and temperature rating may vary with changes in either parameter, see Figure 9. For reference the IDDP-1 well was measured at 138 bars at 452°C.

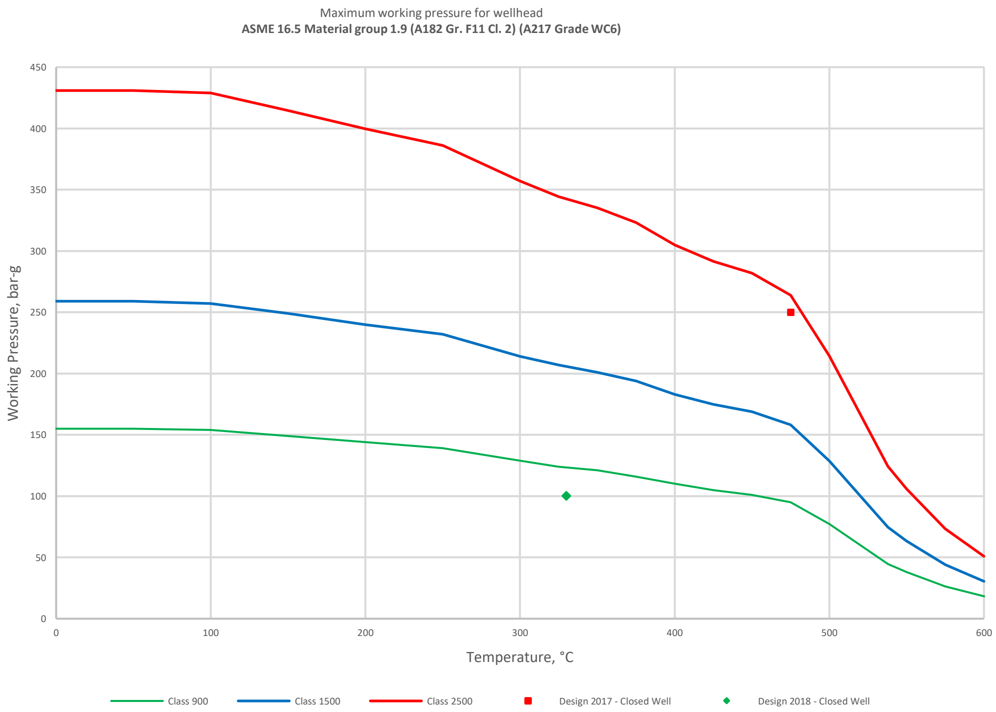

Figure 9: Wellhead temperature and pressure rating diagram.

4. ORIFICE VALVE

The development of the modulating orifice valve is introduced in an another paper by Mr. Thorolfsson at this conference. Figure 10 shows the final drawing of the modified Class 900 valve and Figure 11 shows photos from the production phase of the valve

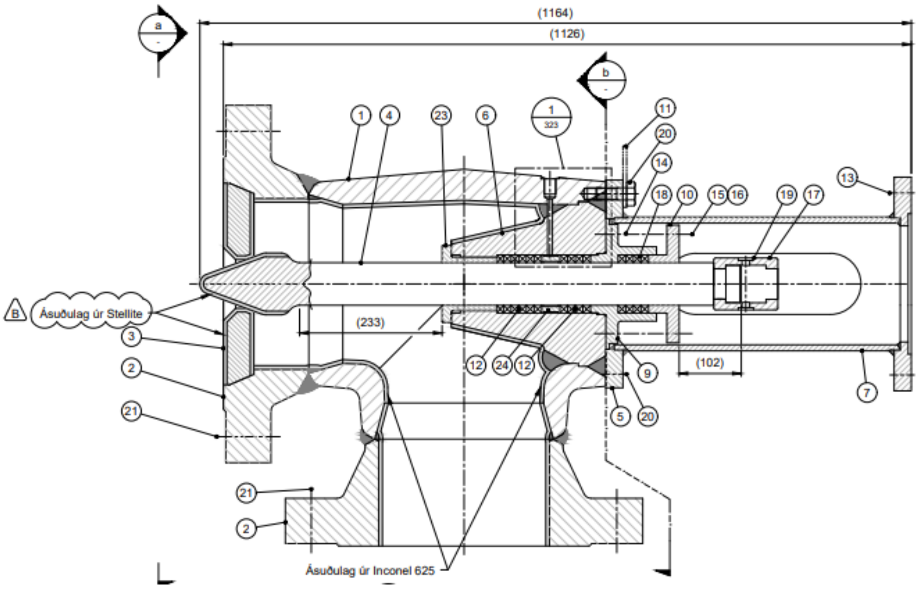

Figure 10: Modified version of the HS-Orka Class 900 valve.

Figure 11: Orifice valve manufacturing process.

5. FLOW-LINE

Design philosophy

The design of the flow-lines is based on the expected flow and pressure from the well. The flow to the flow-line will be contoled by the modulating orifice valve. To avoid damage to the equipment and piping the flow velocity will be kept low to avoid erosion, lower than 30 m/s. A crucial learning from the IDDP-1 flow-line was that in order to control the scaling and control the fluid, high pressure and low velocity was key. Additionally, a secondary flow-line to bleed the well while repairing or modifying the primary flow-line with the well flowing was paramount.

The sizes of the flow-lines were chosen as NPS 10 and NPS 4 for the primary and secondary flow-line respectively. This corresponds to the flow-lines of the last IDDP-1 installation. The flow-lines were chosen to correspond to ASME B16. Class 900 flange pressure class. By assuming a temperature of 325°C and 100 bars in the flow-lines, approximately 80% of the Class 900 pressure class, material group 1.9, and 2 mm of corrosion allowance. This limited the materials available for selection for the flow-line piping due to high wall thicknesses. First drafts assumed P235GH TC1 material for the piping but finally the same material as in the orifice valve and adapter flange was selected, 16 Mo3, ø273,1x16 mm for the primary flow-line and ø114,3x11 mm for the secondary flow-line.

Based on experience the ideal pressure for the RJ nozzle is to be kept relatively low. Three scenarios for the design of the flow-line will be presented based on different well enthalpy and flow-line pressure and are shown in Table 2.

Table 2: Flow parameters.

Parameter	Reference enthalpy	Maximum flow
P: 5 bara V: <30 m/s	1.200 kJ/kg	30 kg/s
	1.600 kJ/kg	12 kg/s
	2.000 kJ/kg	6 kg/s
P: 10 bara V: <30 m/s	1.200 kJ/kg	97 kg/s
	1.600 kJ/kg	27 kg/s
	2.000 kJ/kg	13 kg/s
P: 20 bara V: <30 m/s	1.200 kJ/kg	135 kg/s
	1.600 kJ/kg	31 kg/s
	2.000 kJ/kg	14 kg/s

As can be seen the enthalpy is rather low which corresponds the latest expectation of the super critical and liquid mixture expected from the well.

Measurement and orifice spools

Another key lesson from the IDDP-1 well and flow-line was to reduce or avoid welds and welded nozzles at all costs. This was a primary objective for the flowline. This meant that new solutions for measurement valves, flow orifices and test nozzles had to be found. After some analysis a path of using spools similar to the wellhead spools was chosen. Four pieces were designed, two for each flow-line; a flow measurement orifice spool based on D and D/2 orifice flow measurement theory as described in *ISO EN 5167-2* and a nozzle spool equipped with lugged nozzles for ASME B16.5 class 900 RTJ valves.

The orifice spool, shown in Figure 1, is as previously mentioned based on the ISO 5167-2 standard. To avoid unnecessary welded nozzles, the spool is made from a solid forged round bar with drilled nozzles for the measurement valves. The inlet and outlet are also equipped with lugged connections for Class 900 RTJ connections. The material for the spool was chosen as 16 Mo3, the same material as in the flow-line and the adapter flange for the orifice valve. The orifice inside the spool is fastened to a notch inside the spool and can be replaced if necessary. The orifice is made from Duplex steel. The basis of the spool is to use a pressure drop over the orifice to calculate the flow of fluid, see Figure 12.

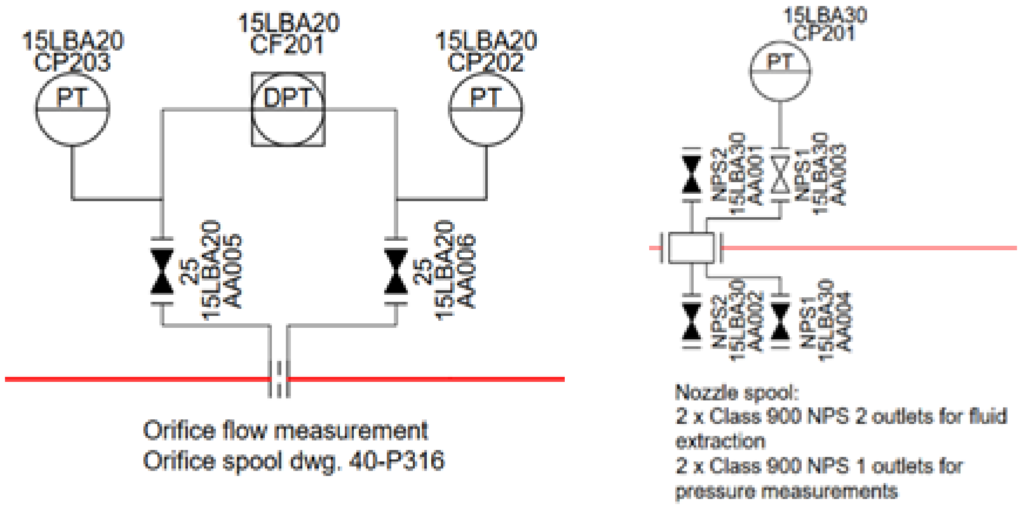

Figure 12: Orifice and nozzle spool setup.

The nozzle connection spools are also made from forged bars of 16 Mo3 material. They consist of ASME B16.5 Class 900 RTJ inlets and outlets and four nozzles on each spool; two NPS 1 ASME B16. Class 900 RTJ and two NPS 2 ASME B16. Class 900 RTJ nozzles equipped for lugged connections. By providing these nozzles with the option of taking samples from the orifice spool necessary sampling points should be provided without welded connections.

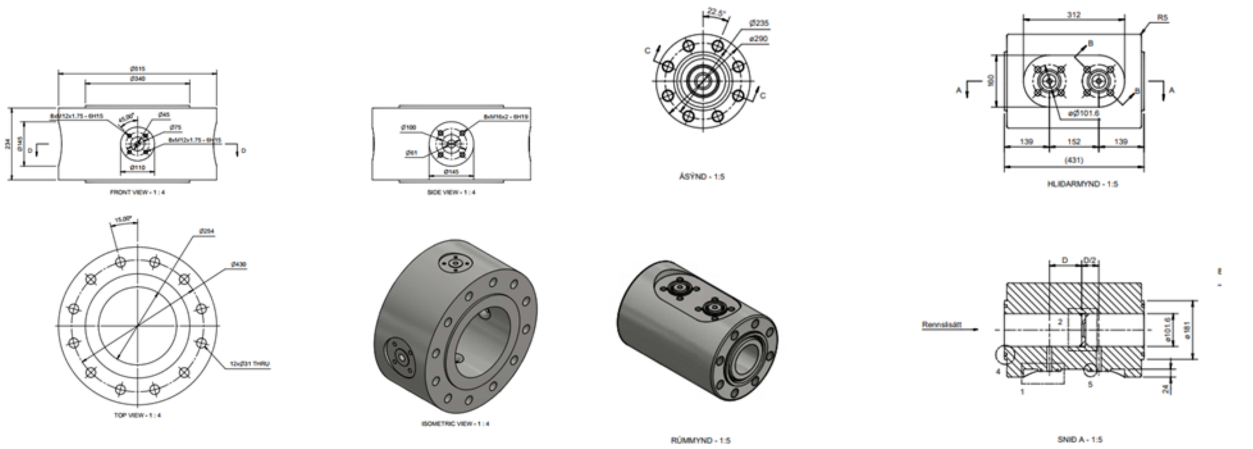

Figure 13: Flow-line test and orifice measurement spool

Thermal design and supports

The flow-line was calculated fully for thermal expansion, seismicity and for wind and snow. Figure 14 shows the results for the thermal and deflection analysis. The design had to compensate for both extreme temperature and pressures as well as the rise of the wellhead itself due to expansion of the well casing. This meant that the design had to be extremely flexible to fulfill the *ISO EN 13480 Metallic industrial piping* conditions.

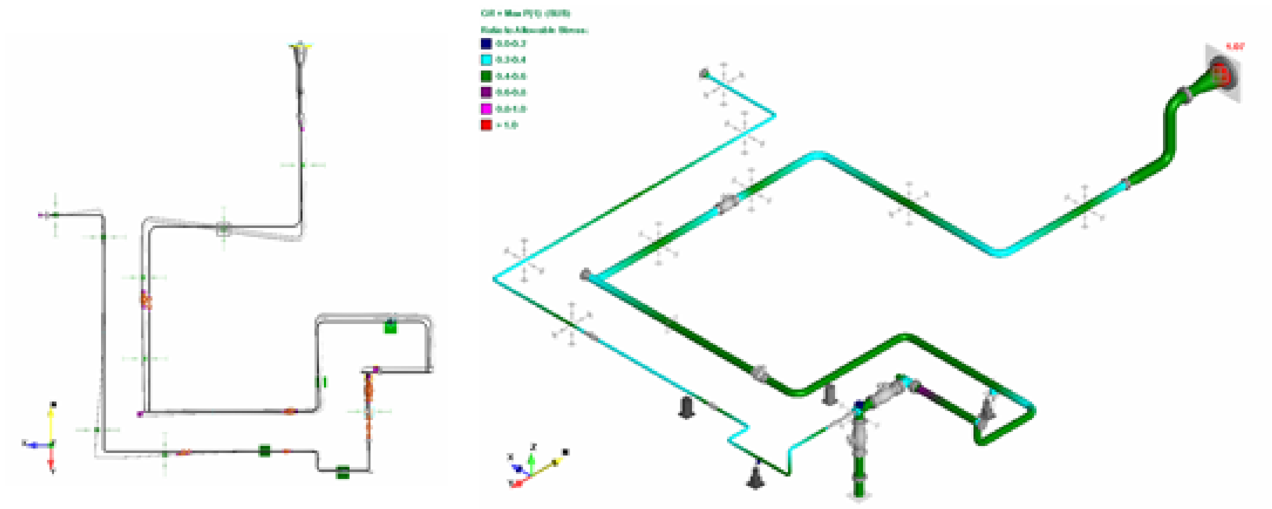

Figure 14: Thermal and deflection analysis of the flow-line.

The supports for the flow-line are modified conventional Reykjanes gathering pipeline supports but could not be welded to the pipe and were therefor modified to be clamped. At the wellhead two constant force spring supports are used to compensate for the wellhead rise as well as a variable support. The clamped supports and variable support are shown in Figure 15.

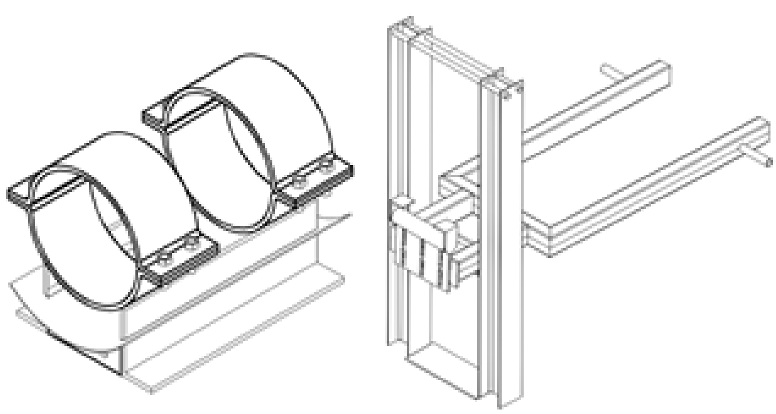

Figure 15: Left: Flow-line saddle clamp. Right: Flow-line variable support.

Rock muffler

The rock muffler on the 4 in secondary flowline is designed to be able to keep the well bleeding and curb the noise when flashing brine or venting steam to atmospheric pressure. The muffler must be able to handle the flow of the flow-line without choking and subsequently keep noise emissions as low as possible. The muffler is made of concrete with a retractable pipe with multiple orifices. On top of the pipe are steel gratings that will support the rocks used for the muffler. At the inlet of the muffler an orifice can be placed clamped between flanges.

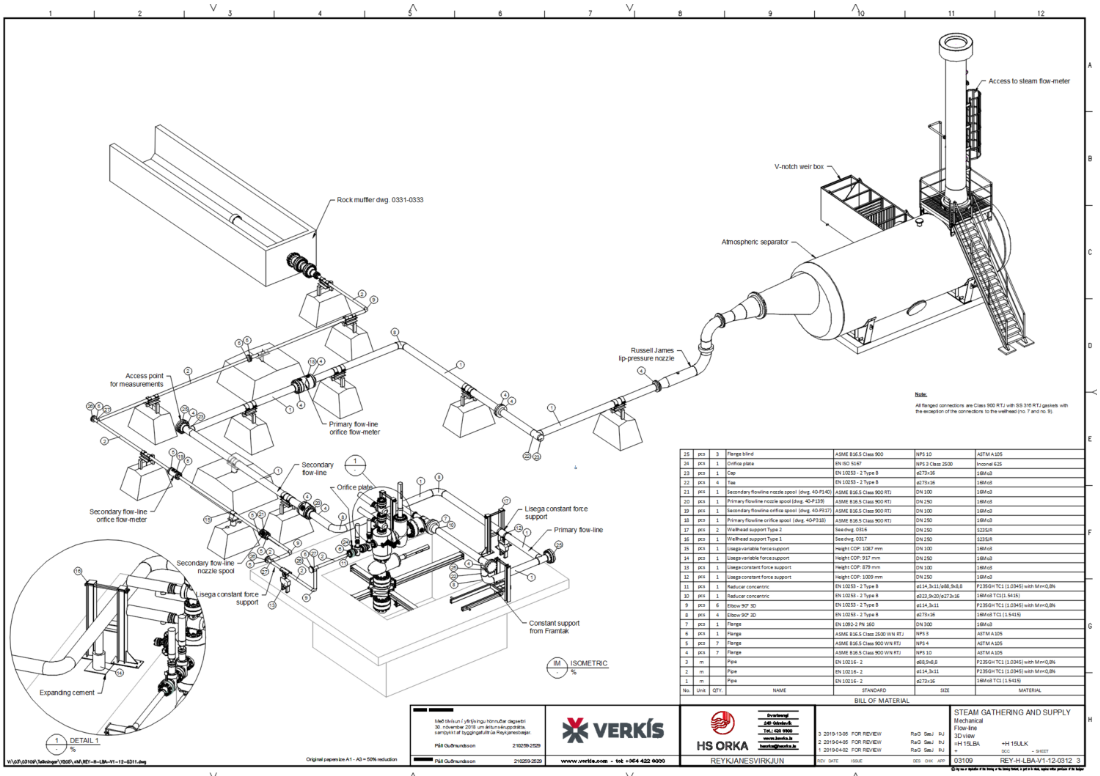

Figure 16: Isometric view of the flow-line and rock muffler plan and section drawing.

Atmospheric test separator

The atmospheric test separator concept has been used HS Orka for many decades. A larger and slightly modified version was built for the IDDP-2 project. The test separator has a diameter of 3.2 m, length of body is 8.0 m and is equipped with an inlet nozzle and an inlet momentum breaker. Its purpose is to separate the steam and brine phase of the well fluid. At the inlet nozzle a Russel James lip pressure nozzle is used to calculate the enthalpy of the well fluid. The well fluid is then efficiently separated inside the separator. The steam is ejected through the chimney where a vortex flow meter records the steam flow. The brine flows out of the separator and through a Weir tank with a sharp-edged V-notch Weir where the flow-rate is measured. Combining this information regarding the steam flow, brine flow and the results of the lip pressure nozzle the well-output can be simulated quite accurately. The atmospheric test separator design criteria are shown in Table 3.

Table 3: Atmospheric test separator design criteria.

Parameter	Unit	Value
Temperature	°C	111,3
Pressure	barg	0,5
Steam flow	kg/s	25,0
Water flow	kg/s	75,0
Corrosion allowance	mm	2,0
Separator weight	kg	10.000
Separator volume	m^3	71,9

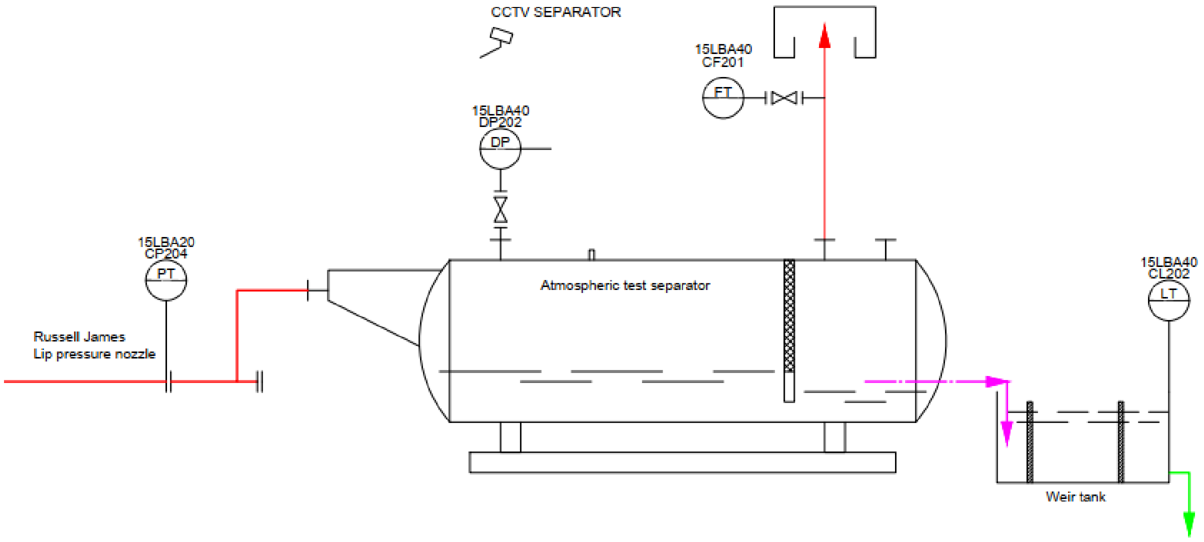

Figure 17: Schematic drawing of the atmospheric separator.

Instrumentation and control

As no welded nozzles or thermowells were allowed on the flow-line traditional temperature measurements were not possible. Therefore, the temperature had to be measured externally. This was done with a pT100 flexible temperature sensor attached to the flow-line piping under the insulation.

Figure 18: Control office container.

The design philosophy of the control system was to design a simple and safe system, with remote access for data viewing and alarms for power-plant staff. Most of the control system was located inside an office container located a few dozen meters from the well. From there all signals from various transmitters are gathered to a data logging SCADA system and valves can be controlled. The system includes a PLC system as well as a stand-alone SCADA system. The data logs can be accessed by a selection of Universities and relevant parties via a remote access. In case of an alarm the system sends a SMS to the power plant operators for shorter response time.

6. CONCLUSION

The design of the well head, flowline and all related mechanical equipment has been rather challenging. Lot of non-conventional items and design issues have been adopted to suit the expected flow and pressure from the IDDP-2. Presently the equipment are being installed and the first drops of fluid out of the system are expected early fall this year.

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