Inspection of the Inlet and Outlet Nozzle to Shell welds at Beznau NPP Unit 2

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ABSTRACT

1. Introduction

DEKRA has successfully performed a mechanised inspection of the Inlet and Outlet Nozzle to Shell welds at Beznau NPP unit 2 during the outage in 2017. The inspection was performed in parallel with two manipulators and was completed in just over 5 days.

The inspection was performed from the inside of the Reactor Pressure Vessel (RPV) using DEKRA developed manipulator Grotte able to scan from both RPV wall as well as from the Nozzle Bore.

The manipulator Grotte and the inspection technique were qualified according to the Swiss regulation by QSt (Swiss Qualification Center).

The presentation will focus on two parts:

- New state of the art manipulator Grotte for inspection of the Inlet and Outlet Nozzles from the RPV wall and from the RPV Nozzle Bore.
- Qualified Phased Array technique used for inspection of the Inlet and Outlet Nozzle circumferential defects in the Volume zone.

2. Manipulator Grotte

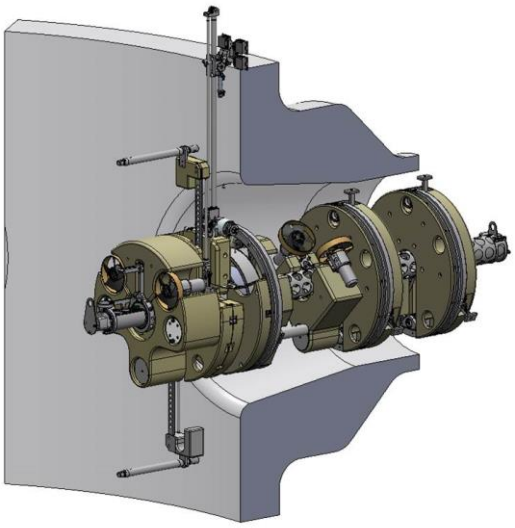
Manipulator Grotte is a DEKRA designed ROV (remotely operated vehicle) for inspection of Inlet and Outlet nozzles in PWRs. The manipulator is based on the former designed ROV:s Särimner and Gram. The manipulator is named after the famous mill in the Nordic mythology, Grotte; the magical mill which could produce gold, salt, fierce warriors and anything else you could wish for.

The manipulator is designed with several independent modules that can be move along the main structure. There are among others two centring unit, one rotation unit and one ROV unit. The modules can be placed at different positions depending on what to inspect. The modules are neutrally buoyant in water. The scanner unit can be mounted for scanning on the vessel wall or inside the nozzle bore, see Figure 1 and Table 1. For control of the manipulator, DEKRA designed Motion Control System “Muspelhem” and Software “Embla” are used.

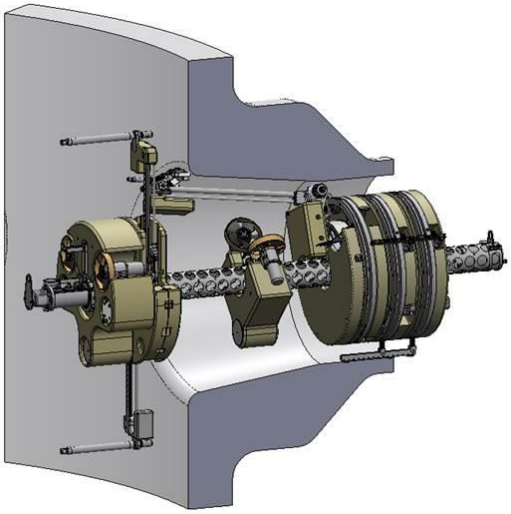
Table 1 Technical data of Manipulator Grotte

Parameter	*Value*
Length x Diameter	L: 2000mm x Ø650mm
Total weight in air:	100 kg
Total weight in water:	0 kg
Total radial/axial stroke:	~ 500 mm and ~580 mm (Different arms for radial or axial movements but same drive unit)
Total rotation angle:	400 °

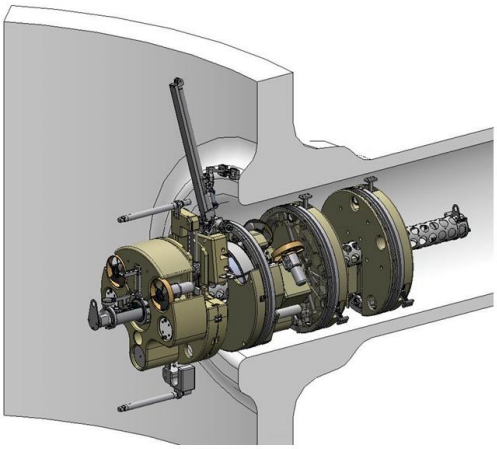
Grotte Configuration for inspection of Inlet Nozzle from the RPV wall



Grotte Configuration for inspection of Inlet Nozzle from the Nozzle Bore



Grotte Configuration for inspection of Outlet Nozzle from the RPV wall



Grotte Configuration for inspection of Outlet Nozzle from the Nozzle Bore

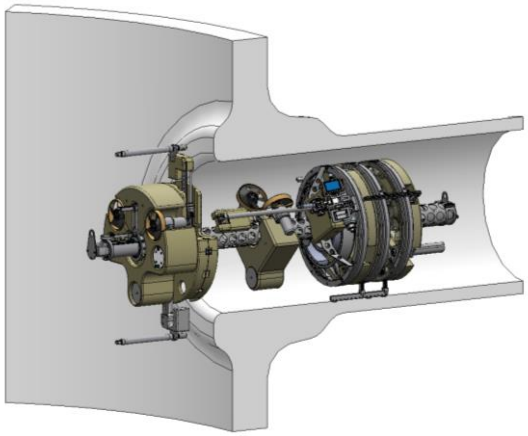


Figure 1 *Different Grotte configurations for inspection of the In- and Outlet nozzles*

3. NDE Technique

Beznau NPP requires that the inspection should be performed with qualified procedures for detection, characterisation, positioning, length and height sizing of:

- **ID Zone:** Circumferential and axial defects using both Ultrasonic (UT) and Eddy Current (ET) techniques for inspection of ID zone (wet surface to 26mm from the wet surface) at the Inlet and Outlet Nozzle to Shell welds, see Figure 2.
- **Inlet Nozzle Volume Zone:** Circumferential and Axial defects using Ultrasonic (UT) techniques for inspection of volume zone, see Figure 2.
- **Outlet Nozzle Volume Zone:** Circumferential defects using Ultrasonic (UT) techniques for inspection of volume zone, see Figure 2.

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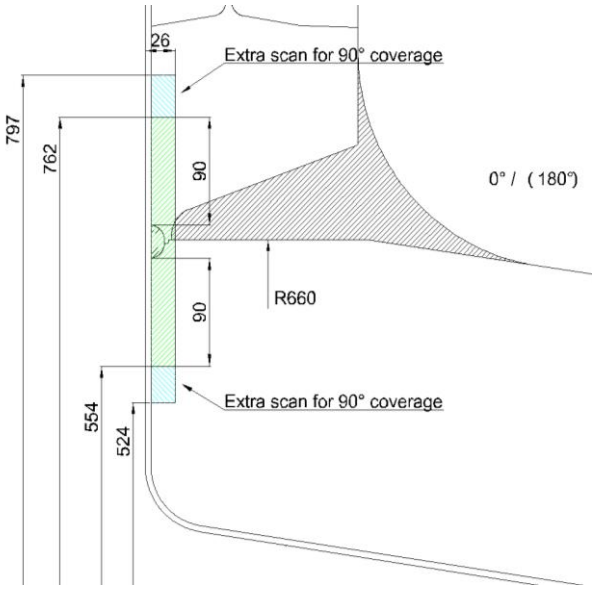
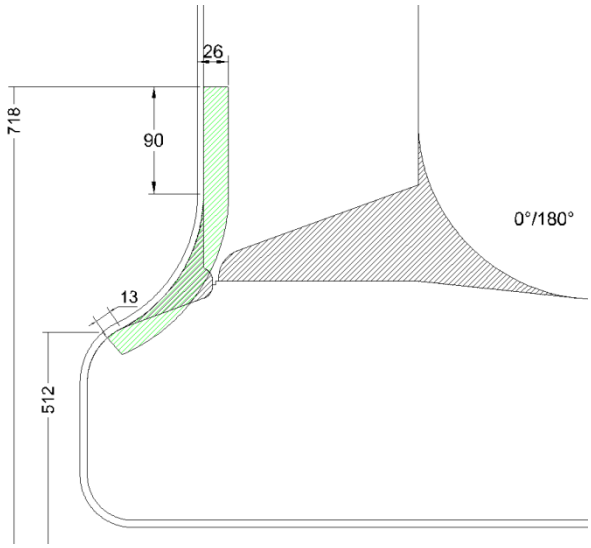
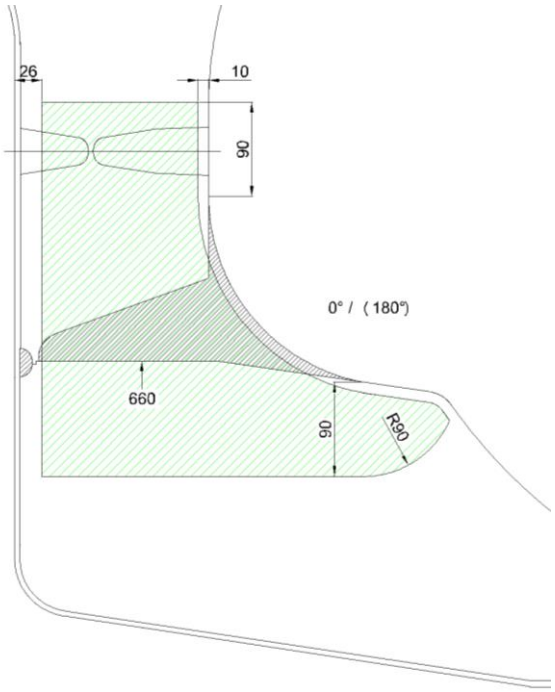
Inlet Nozzles – ID zone



Outlet Nozzles – ID zone



Inlet Nozzles – Volume zone



Outlet Nozzles – Volume zone

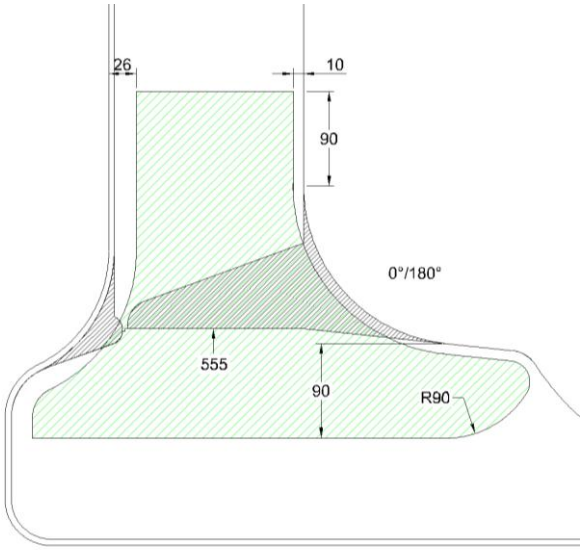


Figure 2 *Inspection Volume for Inlet and Outlet Nozzle to Shell Welds*

3.1 Technique for Inspection of In- and Outlet Volume zone Circ. defects

The inspection of the circumferential defects in the Volume zone of the Inlet and Outlet Nozzle to Shell welds is a very challenging task due to:

- Relatively small size of defects ((12x36) mm for Inlet Nozzle and (11x33) mm for Outlet Nozzles).
- Complex geometry
- Long metal path

DEKRA developed an inspection technique based on Phased Array technique inspecting from both RPV wall and Nozzle bore. In order to be able to detect, characterize, length and height size the circumferential defects Phased Array probes with very high performance using different static channels were used. The dynamic depth focusing (DDF) was used in order to keep the sound beam aperture as small as possible.

The probes used for this inspection are described in Table 2.

Table 2 *Phased Array probes*

No	*Type*	*Wave/ Frequency*	*Number of Elements*	*Purpose*
1	PA Probe in TRL Configuration	Long./ 2.25MHz	Linear 2 x 32	Inspection from RPV wall
2	PA Matrix Probe	Long./ 2.0MHz	Matrix10x12	Inspection from both RPV wall and Nozzle Bore
3	PA Probe in a Shear wave wedge	Shear/ 2.0MHz	Linear 32	Inspection from Nozzle Bore

The positioning of detected indications is performed using the UltraVision Ray Tracing software "Full 3D" version of UltraVision (UV). For this purpose 3-D models of nozzles were created. Using known probe position and distance to a defect (metal path), the defect will be plotted into the model.

The technique was developed and qualified on test samples with representative geometry and defects.

4. Inspection of Beznau NPP unit 2

The inspection of the Inlet and Outlet Nozzles was performed with two manipulators (Grotte 1 and Grotte 2) working in parallel:

- One of the manipulators was configured for inspection from the RPV wall.
- The second manipulator was configured mainly for inspection from the Nozzle bore. However, when the inspection from Nozzle bore was finished the manipulator was re-configured for inspection from RPV wall, see Figure 3.

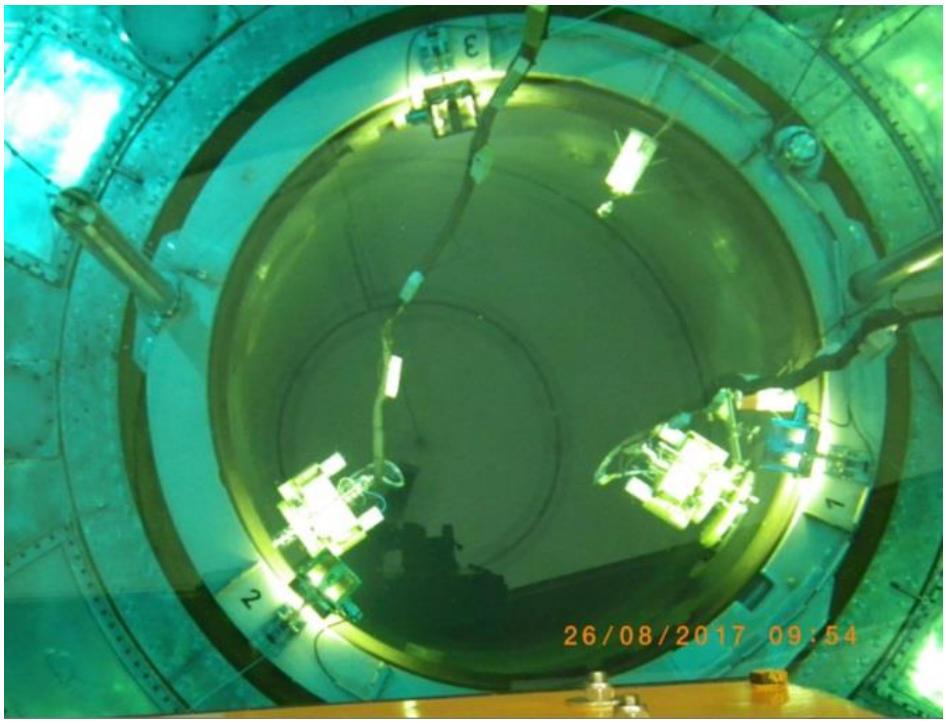


Figure 3 *Inspection of Inlet and Outlet Nozzle to Shell welds with two manipulators working in parallel*

The complete inspection of Nozzle to Shell welds of the four nozzles (2 Inlet and 2 Outlet nozzles) was performed successfully in just over 5 days.

5. Conclusions

- DEKRA developed a state of the art manipulator Grotte to inspect the Inlet and Outlet Nozzle to Shell welds from both RPV wall and Nozzle Bore.
- DEKRA developed and qualified a state of the art Phased Array technique that permits detect, characterize and size the required detection target for circumferential defects in the volume.
- DEKRA developed all necessary tools for defect positioning and plotting using the UltraVision Ray Tracing software “Full 3D” version of UltraVision.
- DEKRA successfully performed the full inspection of the Inlet and Outlet Nozzle to Shell welds in just over 5 days performing the inspection with two manipulators working in parallel.