

Stress Corrosion Cracking of Inconel 182 Weld Material in Steam Generator Divider Plate

Thomas Wermelinger (KKG), Philipp Morath (KKG), Harry Müller (Framatome), Sandra Motschiedler (Framatome),

21. Oktober 2026

EDMS: 933799

Kernkraftwerk Gösgen

Table of content

01 NPP Gösgen

02 Outage 2022: Findings

03 Regulatory requirements

04 Outage 2023: Detection of the length and depth of the cracks

05 Outage 2023: Repair concept

06 Conclusion

NPP Gösgen





Facts:

- Reactor Typ: PWR, 3 loop
- Vendor: Siemens/KWU
- Commissioning: 1979
- Number of units: 1
- Electrical output: 1060 MW
- Number of employees: 610
- Expected plant life: 60+

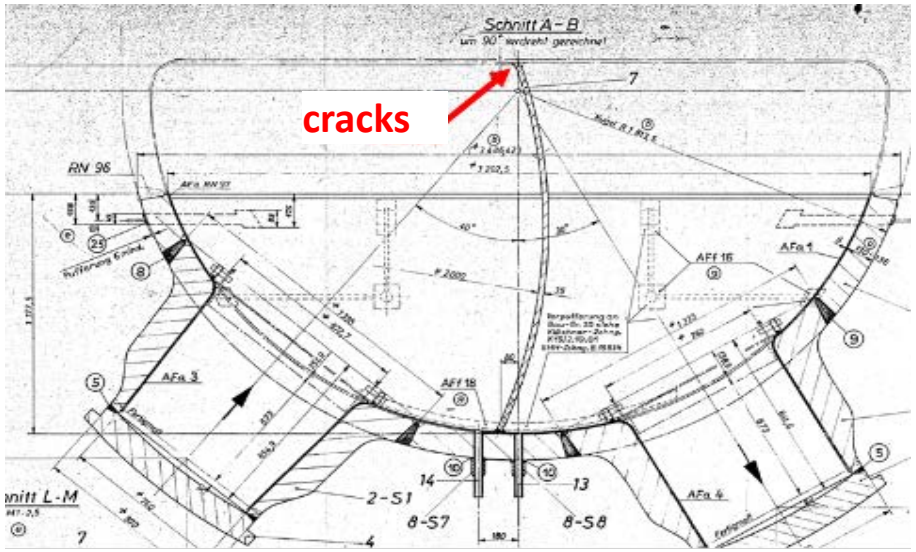
Kernkraftwerk Gösgen

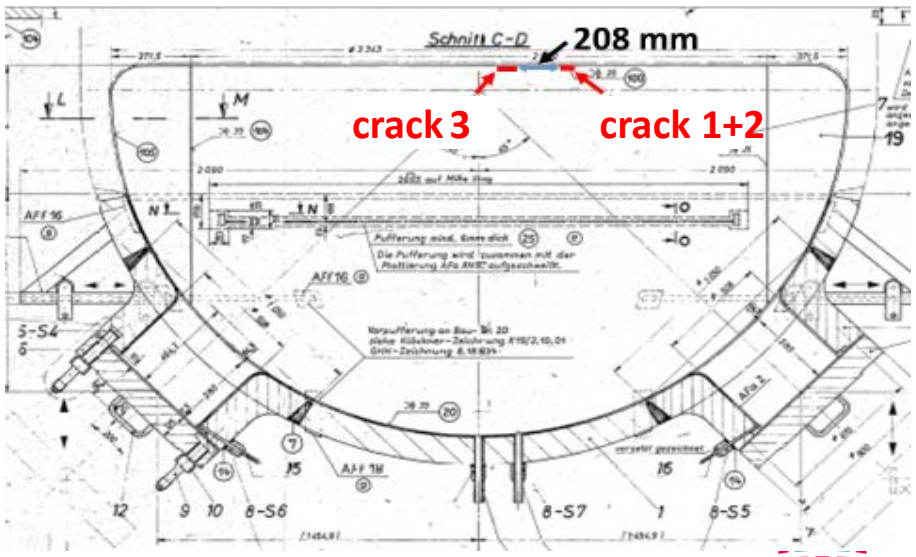
SCC in Steam Generator Divider Plate

Outage 2022: Findings

- ISI: every 6-8 year the primary water chamber is visually inspected
- During a visual inspection in the outage 2022 of the primary water chambers of the steam generator DE20 three cracks were detected.



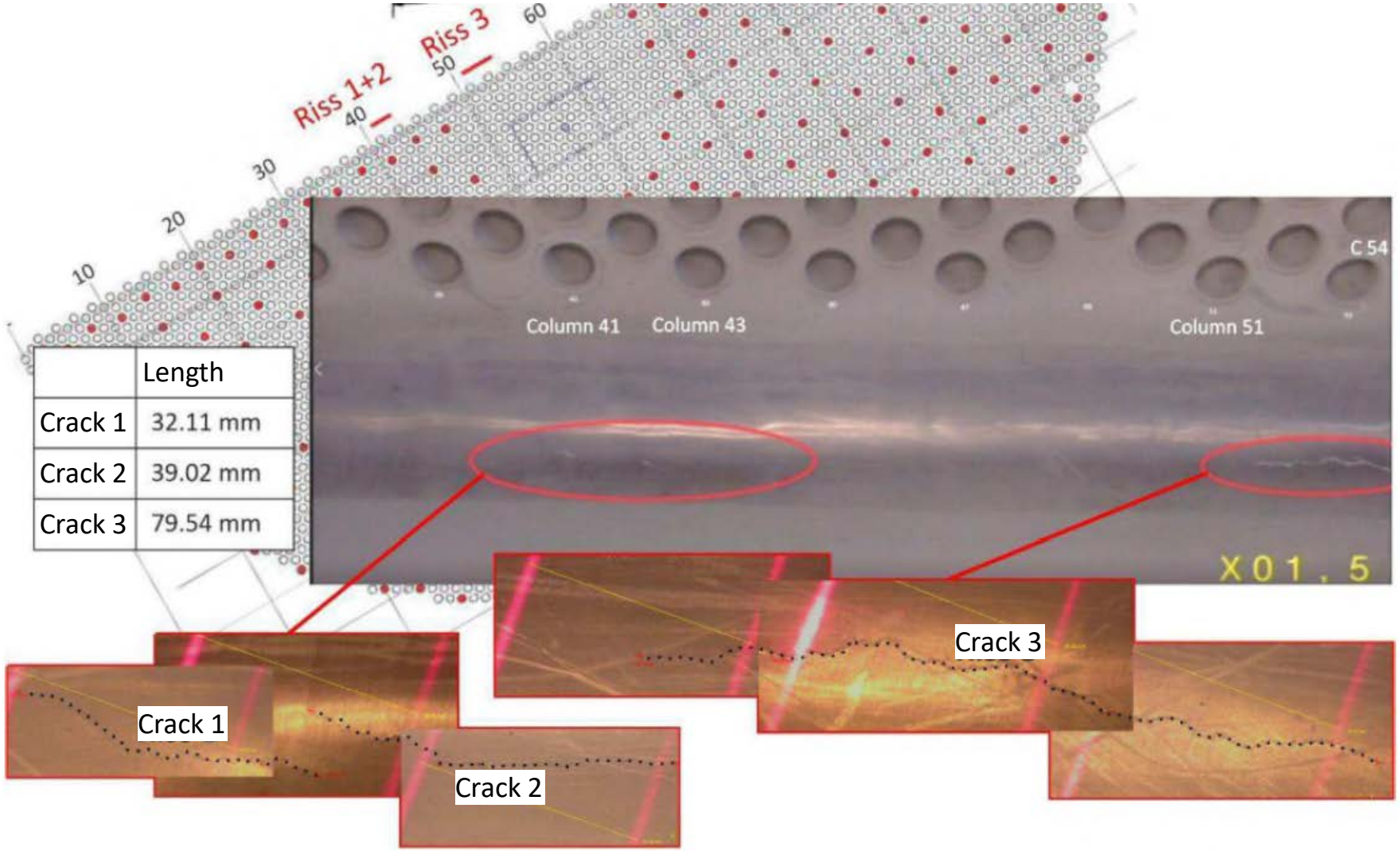




Kernkraftwerk Gösgen

SCC in Steam Generator Divider Plate

Outage 2022: Findings

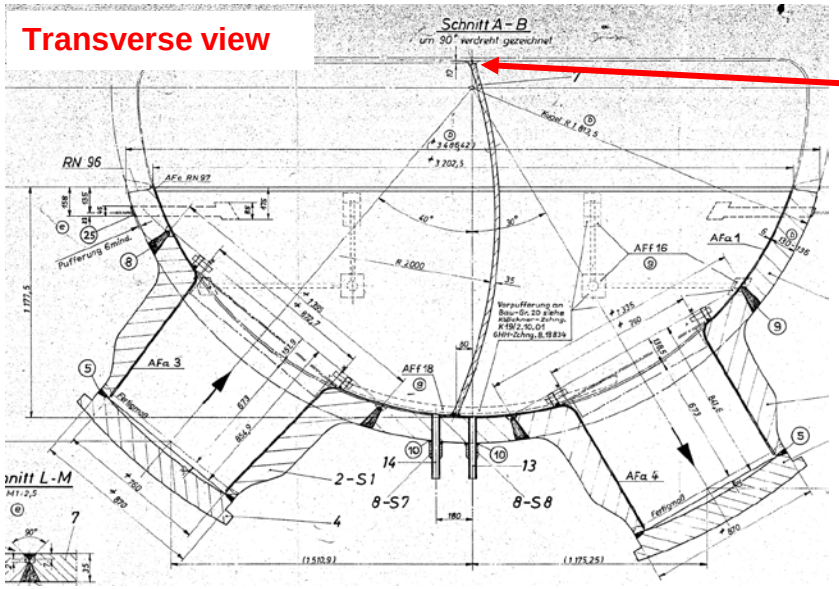


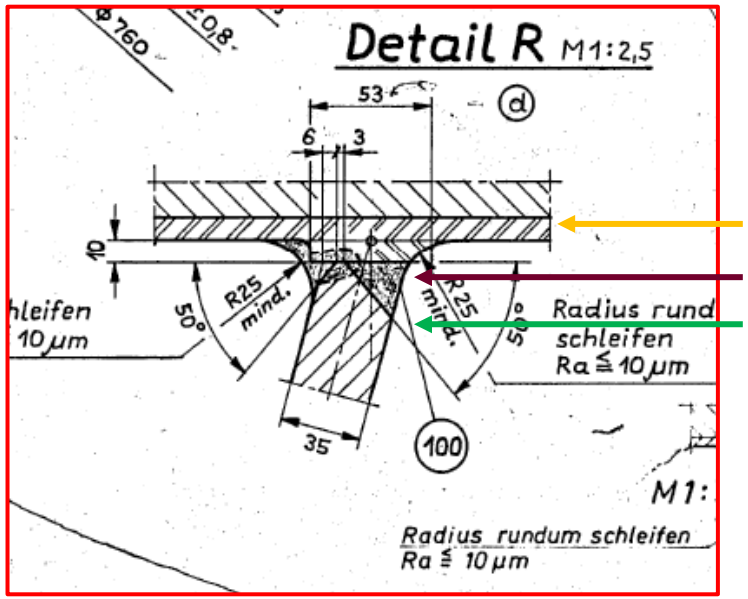
	Length
Crack 1	32.11 mm
Crack 2	39.02 mm
Crack 3	79.54 mm

Kernkraftwerk Gösgen

SCC in Steam Generator Divider Plate

Outage 2022: Findings - Structure of the divider plate





Detail of the weld at the divider plate:

Cladding tube sheet: Alloy 82/182

Weld: Alloy 182

Divider plate: X6CrNiNb18-10

Kernkraftwerk Gösgen

SCC in Steam Generator Divider Plate

Outage 2022: Findings

Findings:

- Cracks are parallel to weld
- Heavily branched
- Degradation mechanism: PWSCC
- Cracks only visible on hot side ➔ no trough-wall cracks ➔ depths of cracks not detectable (only inspected visually)
- Weld was tested in 2016 by means of visual inspection (lower camera resolution) ➔ post-evaluation of the camera footage after outage 2022➔ shape of crack 3 was already recognizable in 2016

Further Clarifications:

- No repairs during manufacturing
- Cladding of tube sheet was heat treated
- No heat-treatment of weld
- Welds were grinded heavily
- No cold deformation of the divider plates

SCC in Steam Generator Divider Plate

Regulatory requirements – start-up after outage 2022

To restart the plant the regulators requested the following assessments:

- Fracture-mechanical analysis ➔ Proofing the integrity of the divider plate for the next cycle. The following boundary conditions were used:
  - Depth of cracks were unknown ➔ trough-wall crack
  - Driving forces for crack growth ➔ PWSCC for small cracks, fatigue for large cracks

	Length of crack after 1 cycle	Allowable crack length: (normal operation)	Allowable crack length: LOCA (double-ended guillotine break, DEGB)
Through-crack	979 mm	2702 mm	1132 mm

- Safety-assessment for LOCA condition (double-ended guillotine break of the primary circuit):
  In case of a collapsing divider plate due to a DEGB of the main cooling pipe, the maximal occurring temperature in the fuel elements during the incident does not change significantly.

SCC in Steam Generator Divider Plate

Regulatory requirements – Long term operation

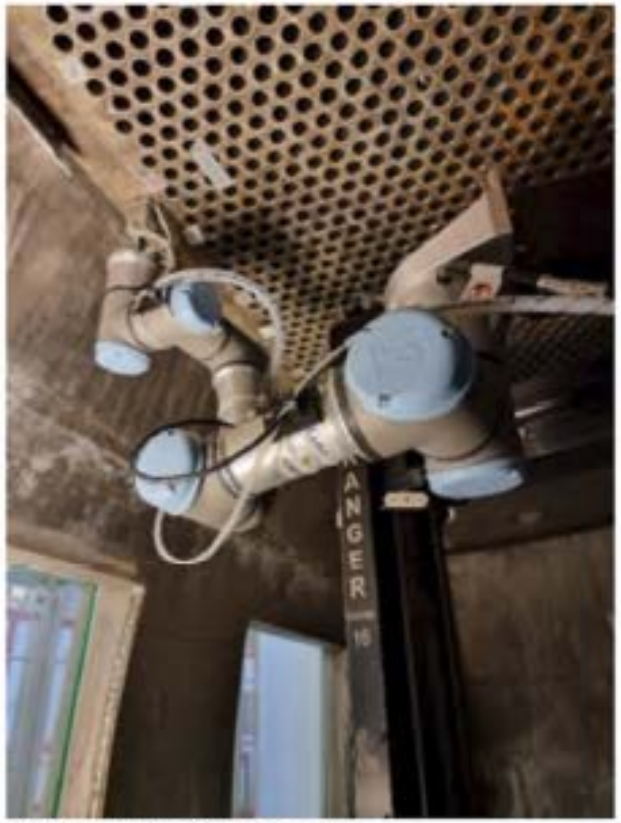
For long term operation, the following 4 regulatory requirements had to be fulfilled:

- **Request 01:** detection of length and depth of the cracks in outage 2023
  - KKG: developing and qualification of VT- and UT-systems (performed by Framatome)
- **Request 02:** Developing a repair concept
  - KKG: developing and qualification of a EDM-system (electrical discharge machining) (performed by Framatome)
- **Request 03:** reassessment of ISI-program for Inconel-Welds in primary circuit
  - KKG: reassessment of ISI-program based on international experience
- **Request 04:** reassessment of fracture-mechanical analysis
  - KKG: reassessment included pressure vibrations within the primary circuit

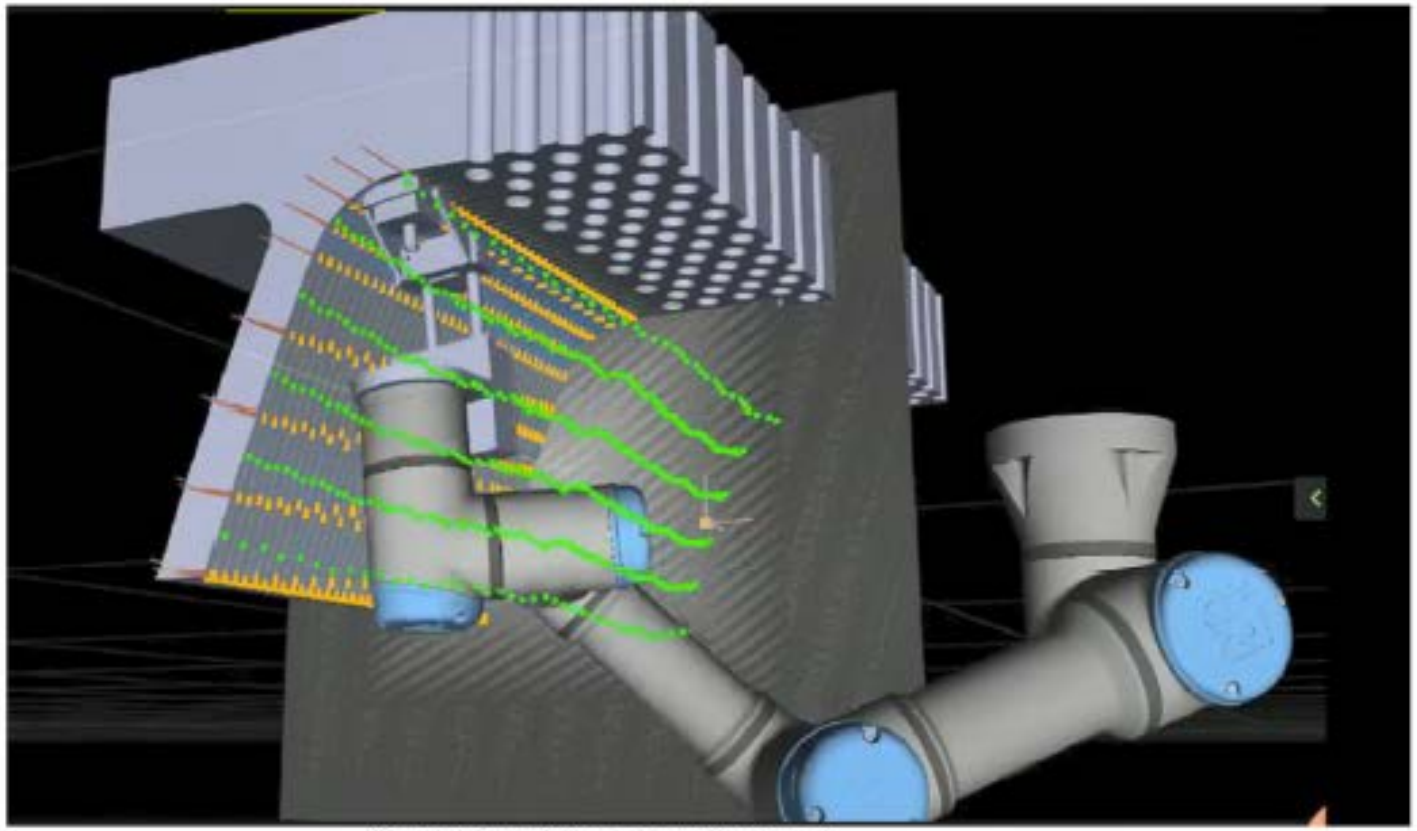
SCC in Steam Generator Divider Plate

Request 01: Detection of the length and depth of the cracks in the outage 2023

Development and qualification of VT- and UT-systems



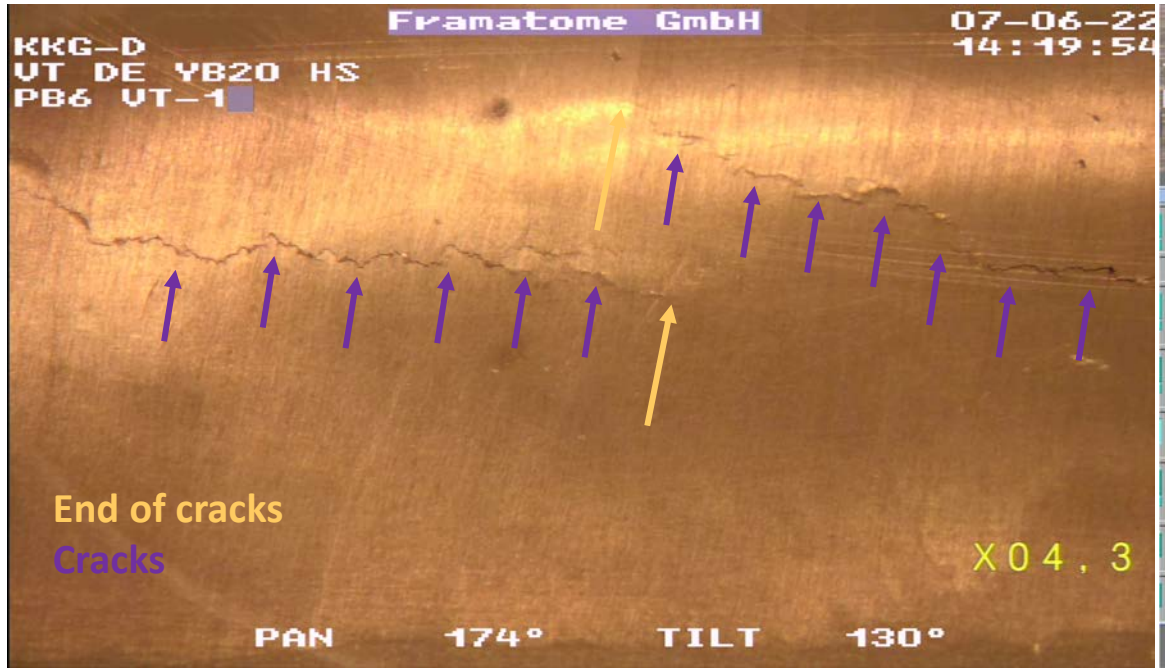
Manipulator in mock-up


Simulation of the measuring head

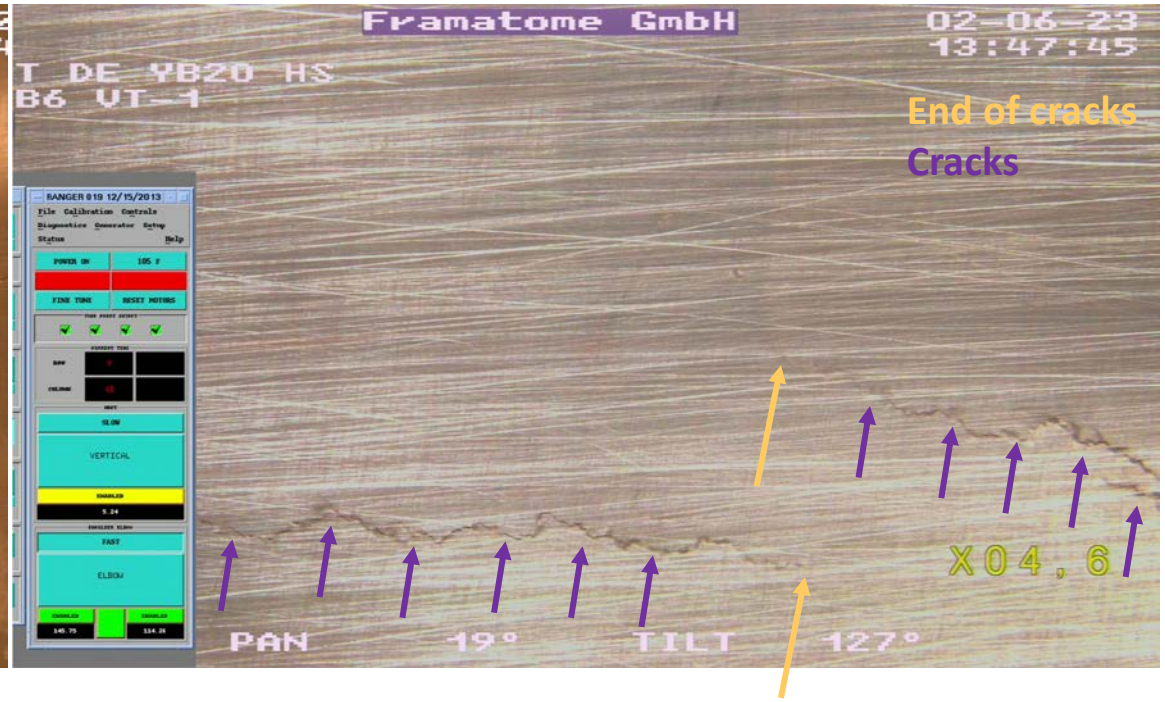
SCC in Steam Generator Divider Plate

Request 01: Detection of the length and depth of the cracks in the outage 2023 - Comparison 2022 vs 2023

2022



2023



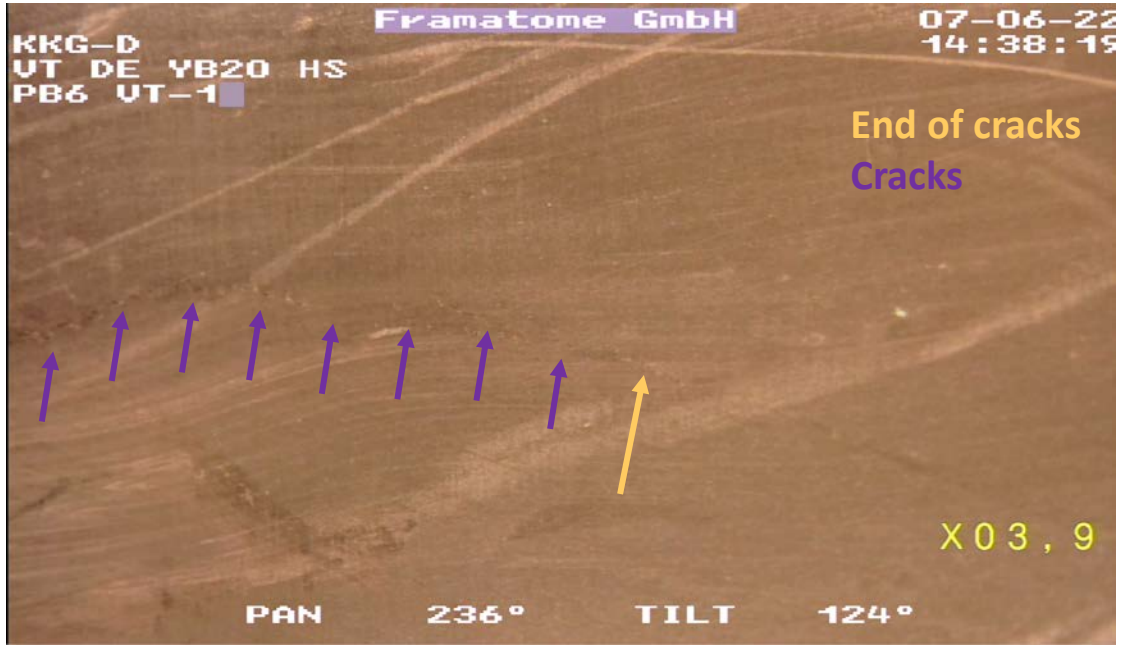
Results: VT-Testing shows no change in crack lengths

Kernkraftwerk Gösgen

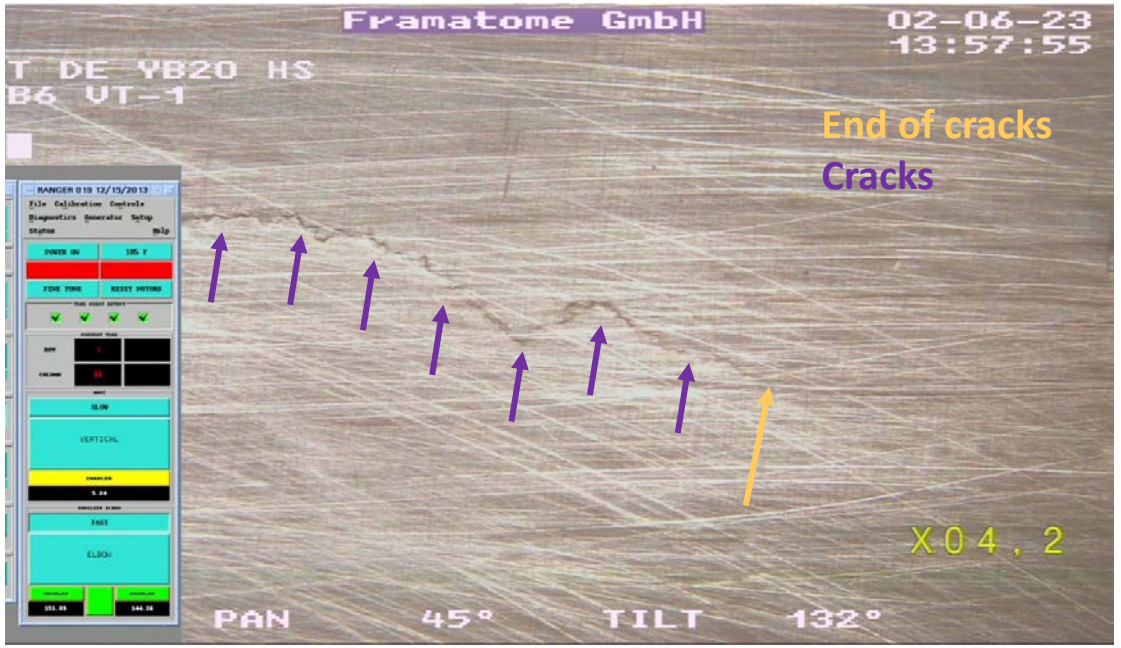
SCC in Steam Generator Divider Plate

Request 01: Detection of the length and depth of the cracks in the outage 2023 - Comparison 2022 vs 2023

2022



2023

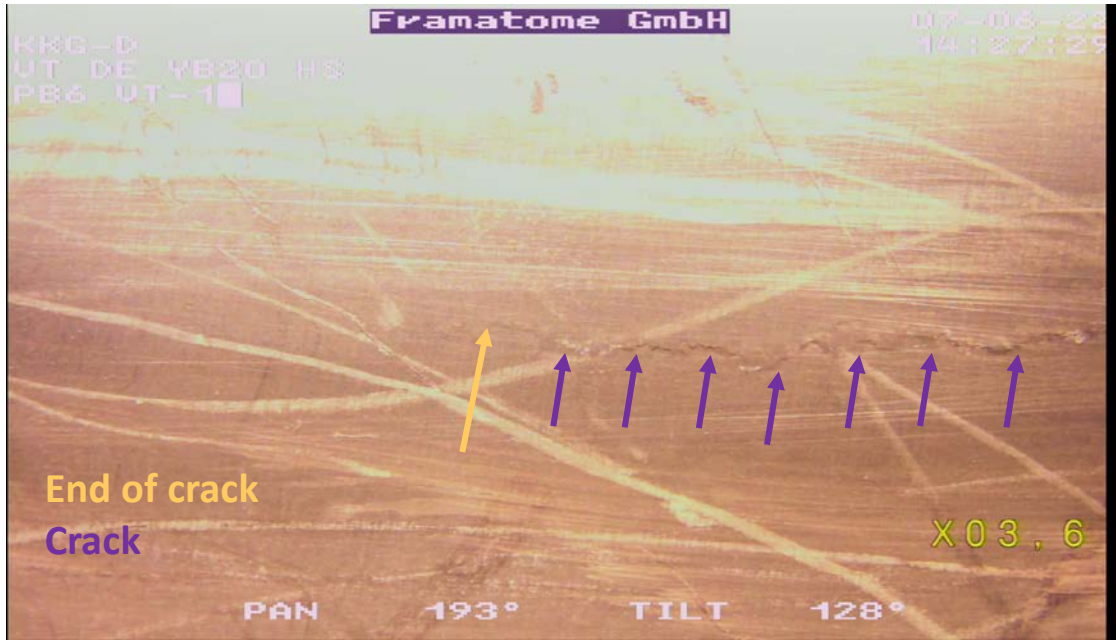


Results: VT-Testing shows no change in crack lengths

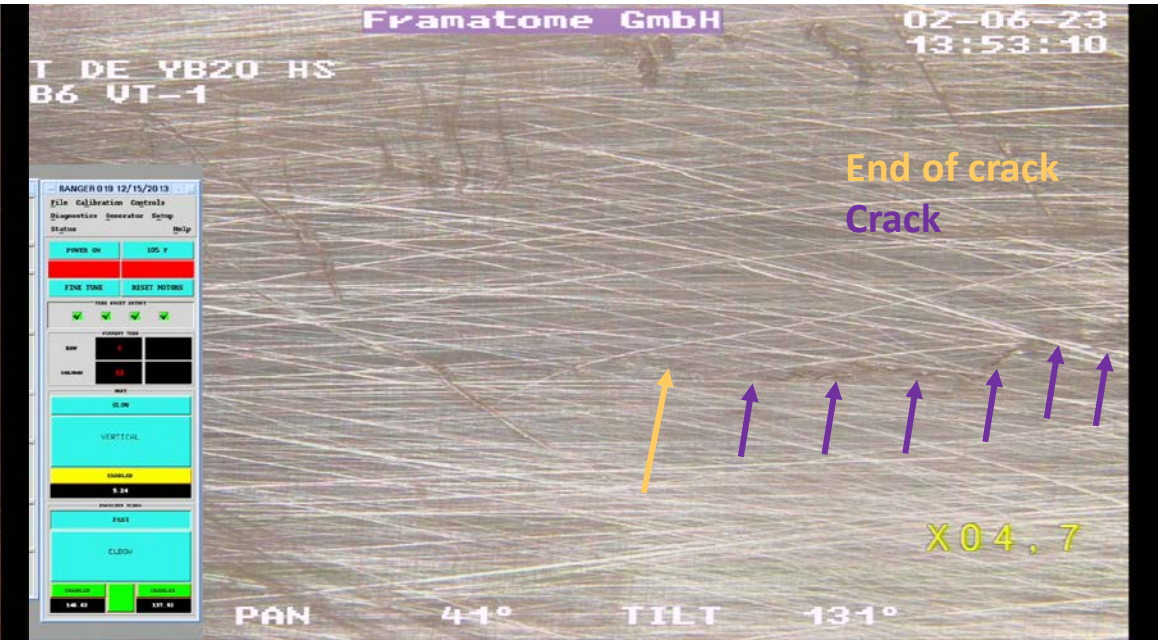
SCC in Steam Generator Divider Plate

Request 01: Detection of the length and depth of the cracks in the outage 2023 - Comparison 2022 vs 2023

2022



2023

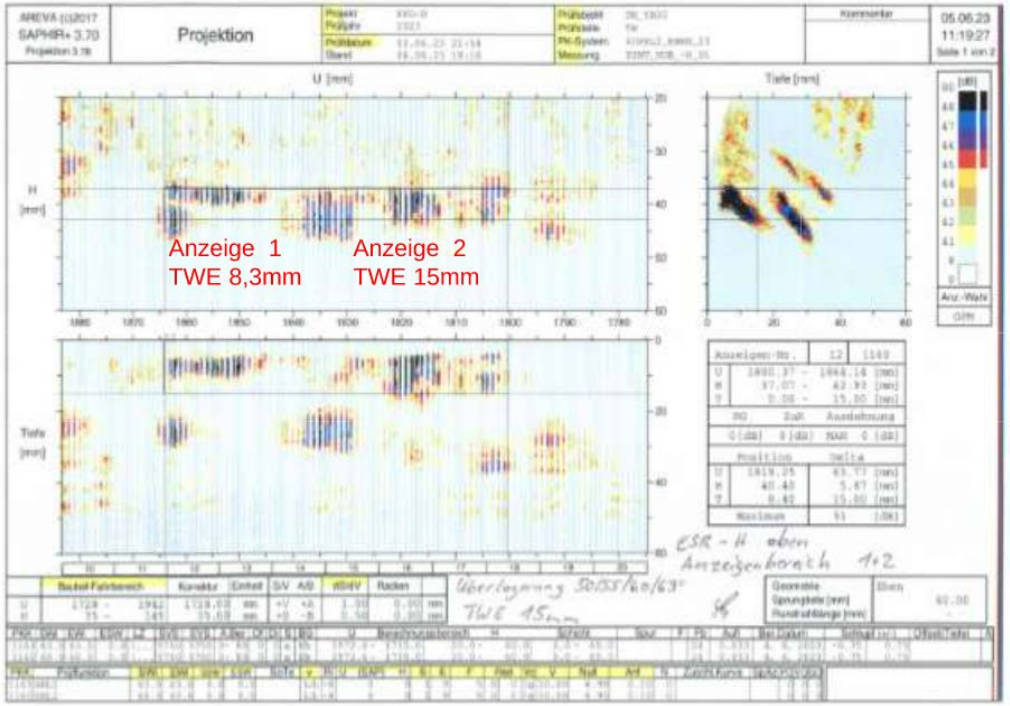


Results: VT-Testing shows no change in crack lengths

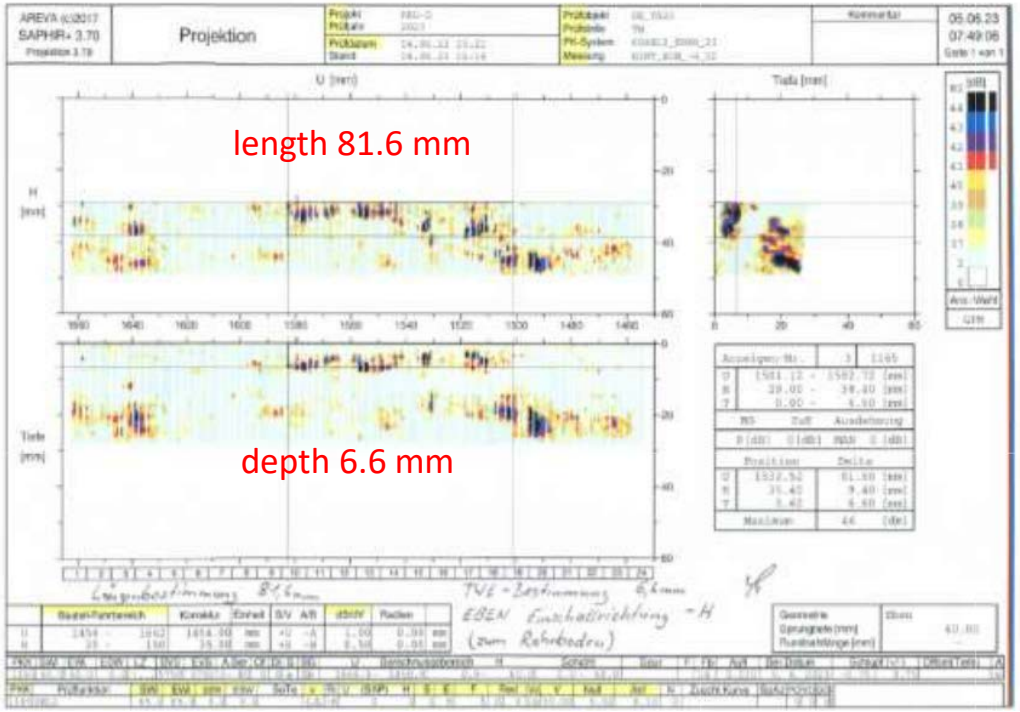
SCC in Steam Generator Divider Plate

Request 01: Detection of the length and depth of the cracks in the outage 2023 - UT-Measurement

Crack 1 + 2 appeared as one crack and had a depth of 15 mm



Crack 3 had a depth of 6.6 mm

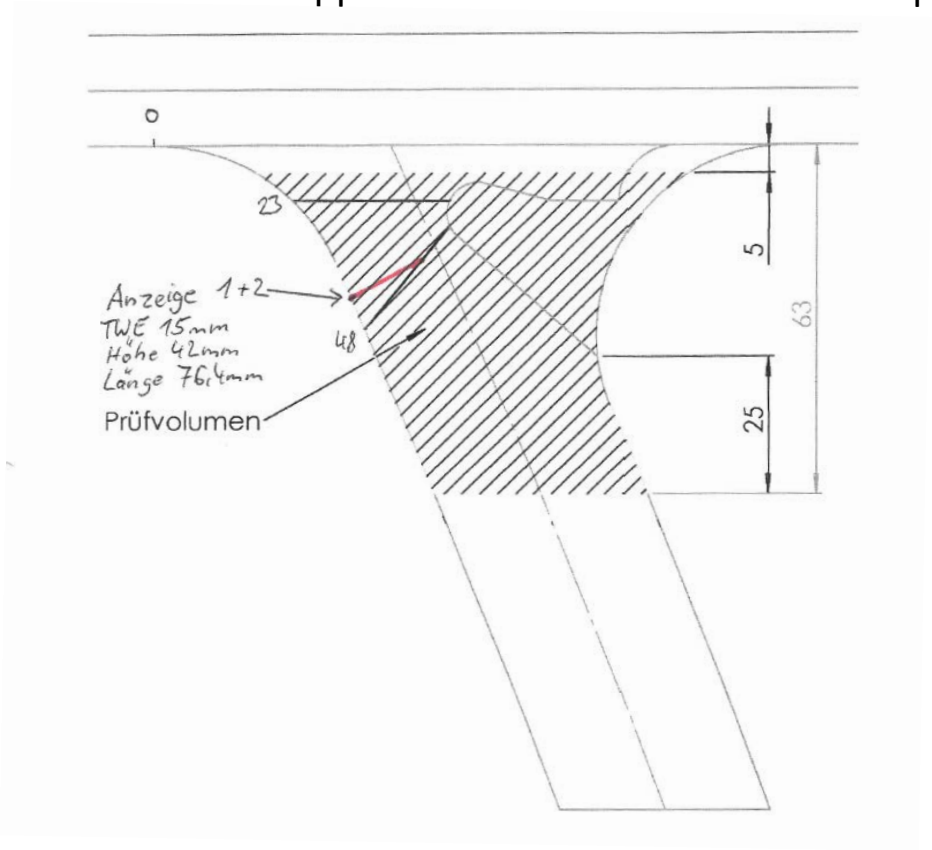


Kernkraftwerk Gösgen

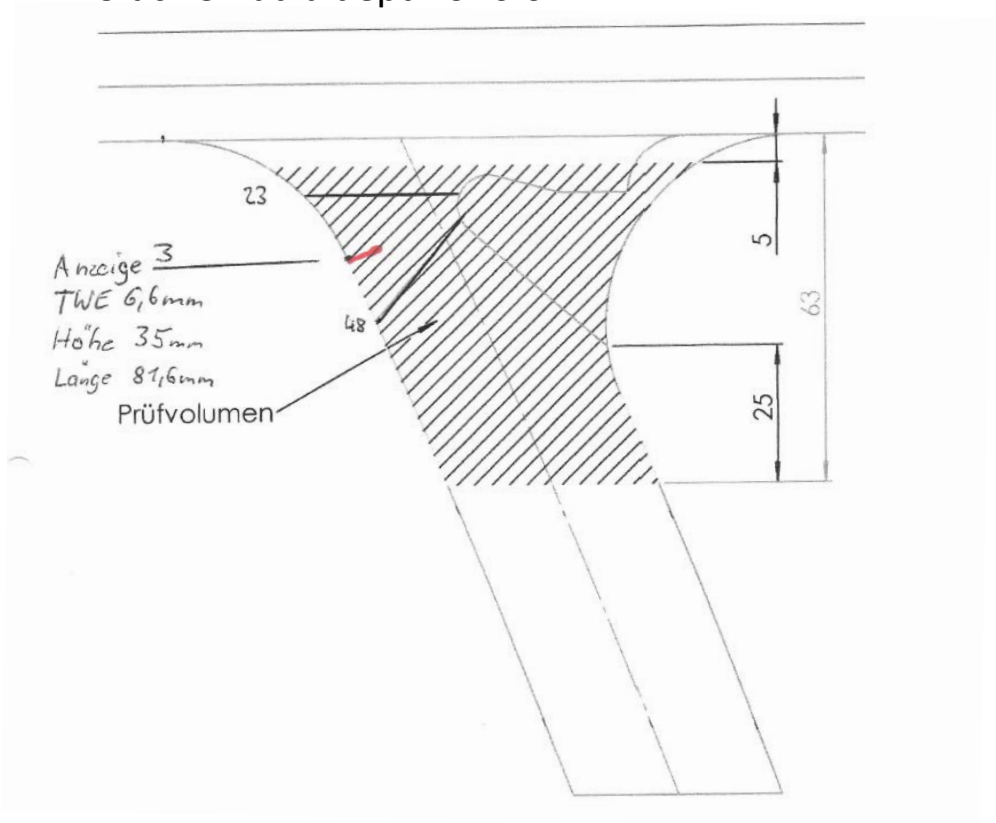
SCC in Steam Generator Divider Plate

Request 01: Detection of the length and depth of the cracks in the outage 2023 - UT-Measurements

Crack 1 + 2 appeared as one crack and had a depth of 15 mm



Crack 3 had a depth of 6.6 mm



Kernkraftwerk Gösgen

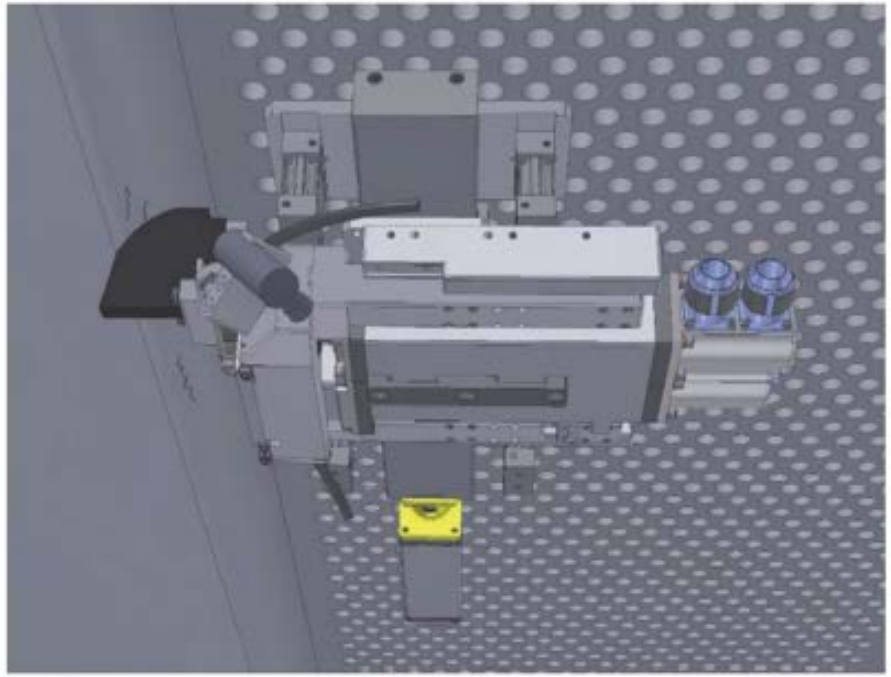
SCC in Steam Generator Divider Plate

Request 02: Repair concept

- Depending on depth and length, the cracks will be removed by means of electrical discharge machining (EDM)
- Developing and qualification of the EMD-tool (Framatome)
- KKG did not qualify a welding process



Positioning



Developed EDM-tool

SCC in Steam Generator Divider Plate

Request 02: Repair concept

Test rig for the electrical discharge machining (EDM)

Removing cracks my means of electrical discharge machining (EDM)



Test rig



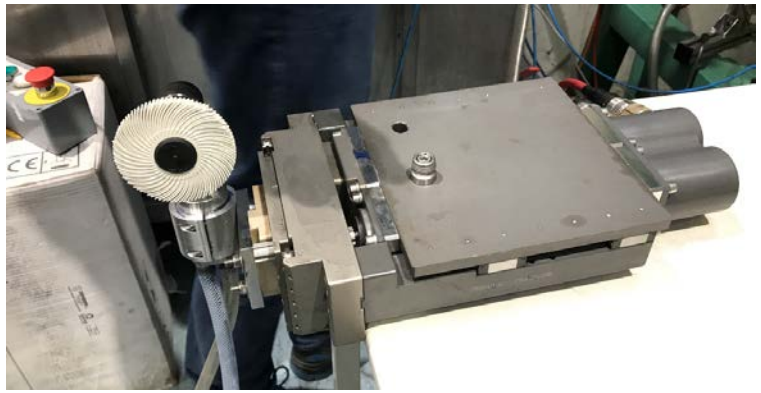
Machined surface

SCC in Steam Generator Divider Plate

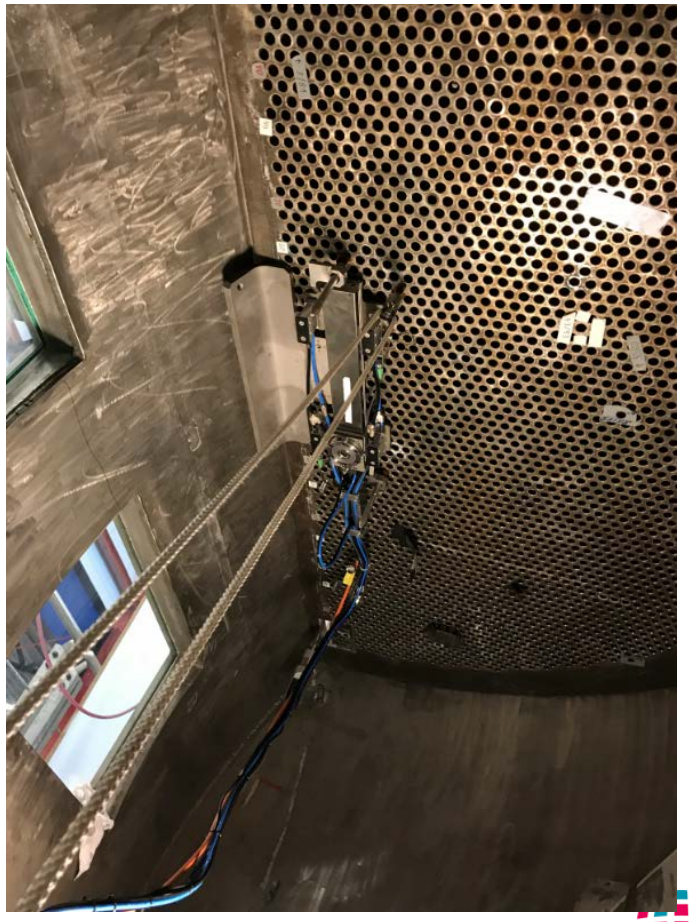
Request 02: Repair concept

Developing and qualification of the electrical discharge machining (EDM)





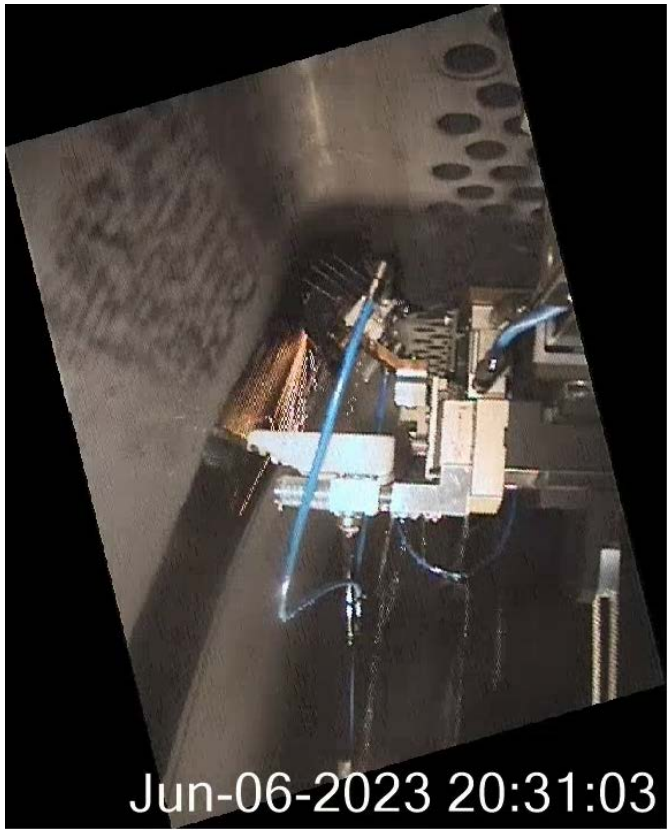


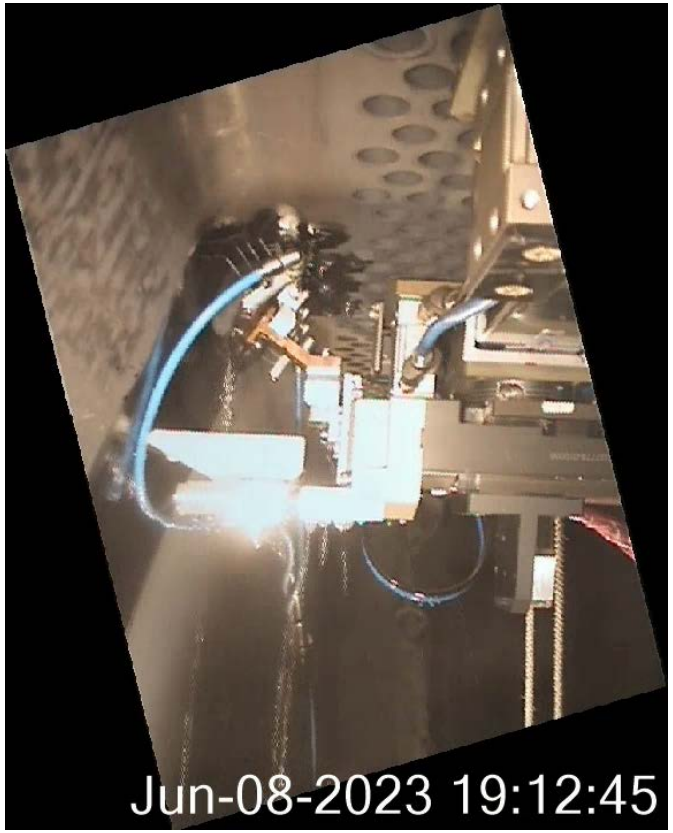


SCC in Steam Generator Divider Plate

Request 02: Repair concept

Removing cracks by means of electronic discharge machining (EDM) in the outage 2023







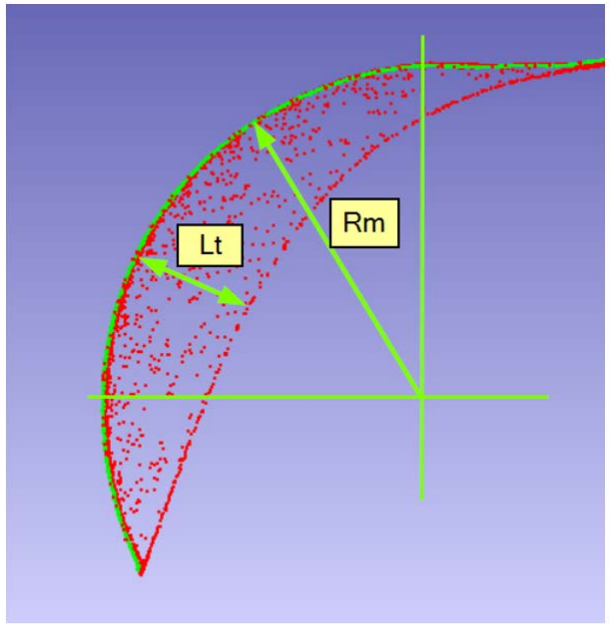
Kernkraftwerk Gösgen

SCC in Steam Generator Divider Plate

Request 02: Repair concept - Laser scan of moulds

Erosion mould 1/2:

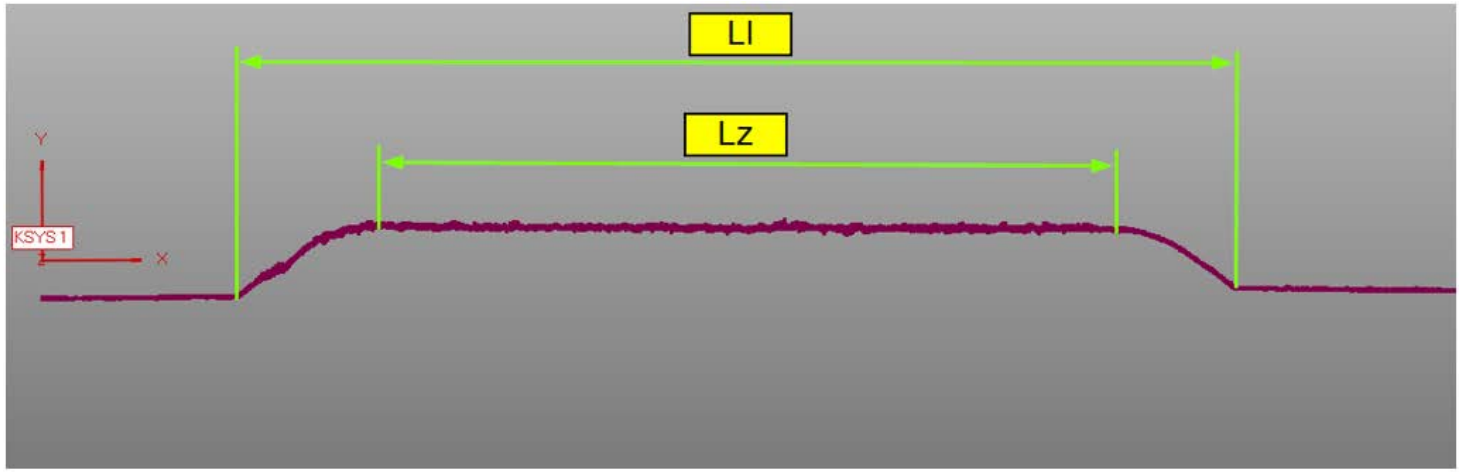
- Depth: Lt = 17.9 mm
- Radius: Rm = 28.8 mm
- Length: Lz = 110 mm
- Total length: LI = 165.1 mm



Querschnitt Erodiermulde Seitenansicht

Erosion mould 3:

- Depth: Lt = 10.85 mm
- Radius : Rm = 32.5 mm
- Length: Lz = 110 mm
- Total length: LI = 150.8 mm



Querschnitt Erodiermulde Draufsicht

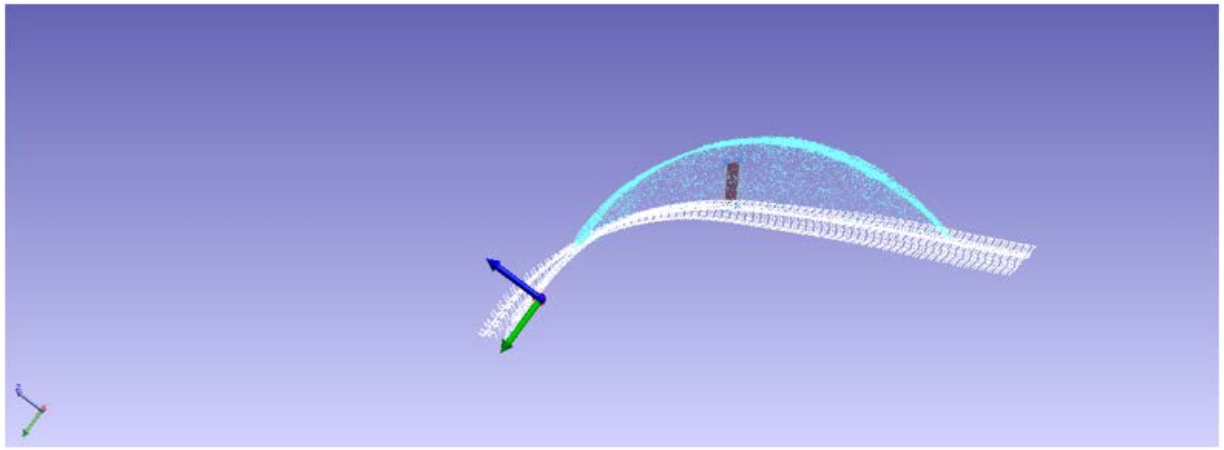
Kernkraftwerk Gösgen

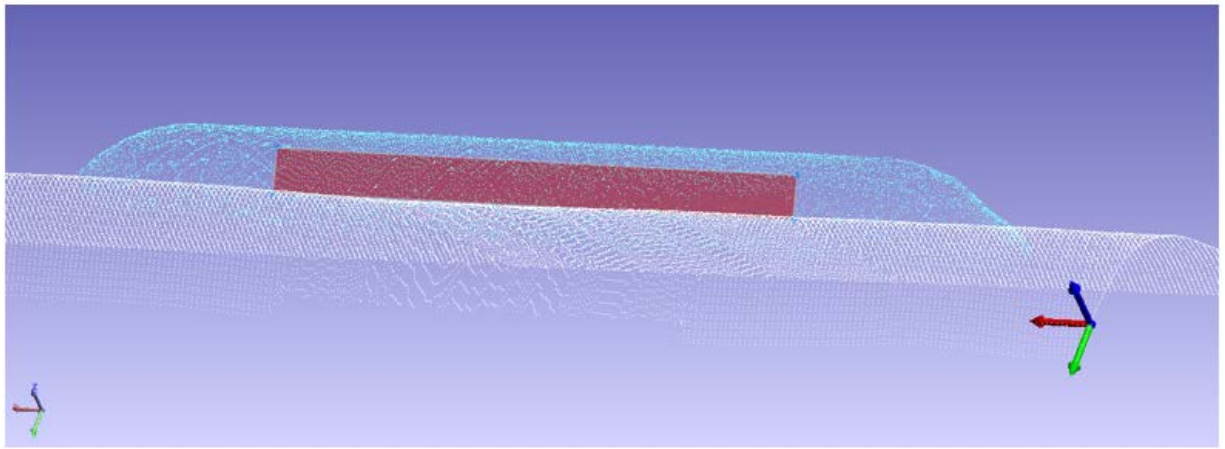
SCC in Steam Generator Divider Plate

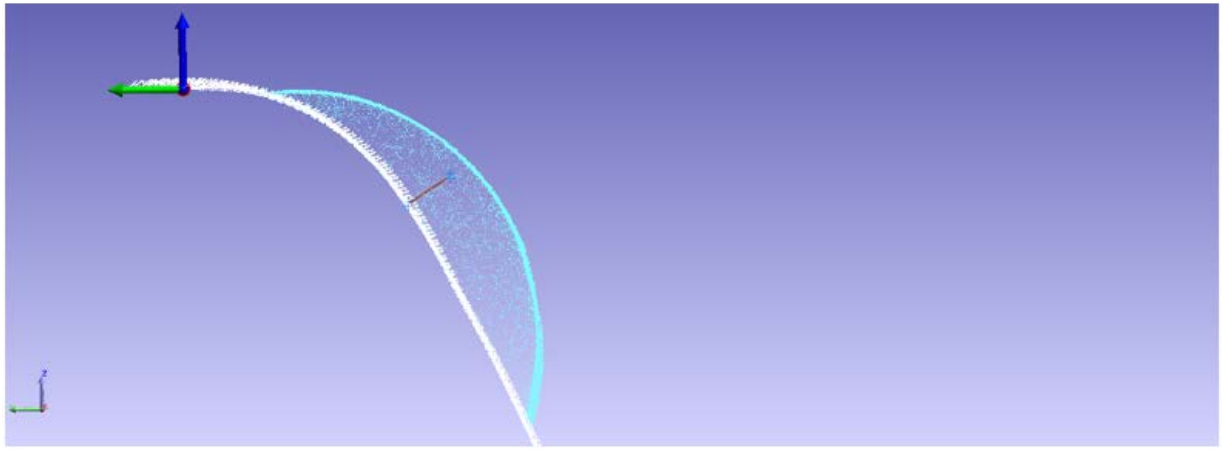
Request 02: Repair concept - Laser scan of moulds

- Performed to determine the exact depth of mould
- Crack (red bar) is enveloped by point cloud of laser scan
- Additionally, the moulds were inspected visually (camera: 10x magnification)

➔ confirmation, that crack is removed completely







Kernkraftwerk Gösgen

SCC in Steam Generator Divider Plate

Conclusion:

- Outage 2022: 3 cracks found in weld between divider plate and tube sheet
- Ageing mechanism: PWSCC
- Development and qualification of new UT-System and repair-system by means of EDM
- Outage 2023:
  - No crack growth
  - Removal of cracks by means of EDM
- Complete revision of all stress analysis (primary and secondary stresses)
- Next visual inspection: outage 2026

Visual Inspection 2026

- In the outage 2026 the weld of the divider plate of all 3 steam generators was inspected visually
- No new cracks were found in Steam generator DE20
- 3 new cracks were found in steam generator DE10



Bild 4: Riss 1, Position



Bild 8: Riss 2, Position



Bild 12: Riss 3, Position



Questions





Kernkraftwerk Gösgen