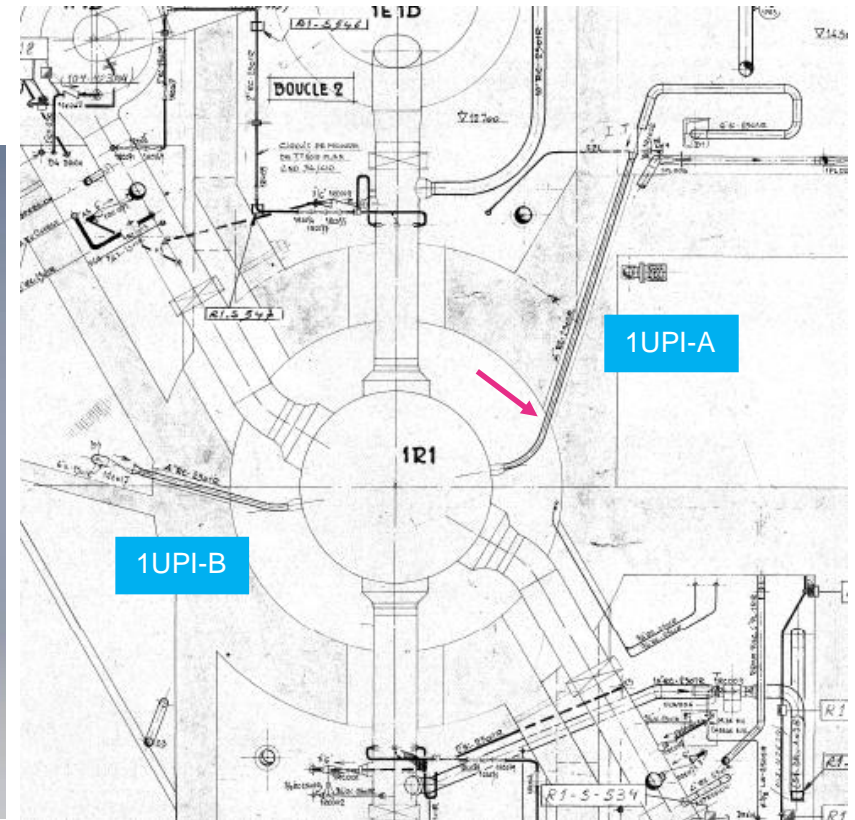
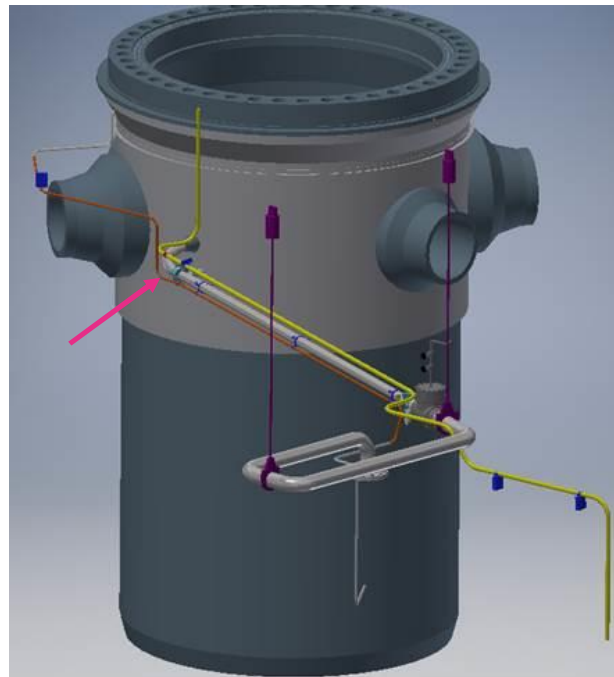

Doel 1&2 Upper Plenum Injection line issue

International Workshop on Age-Related Degradation of Reactor Vessels and Internals, USNRC, Washington, 23-24/5/2019



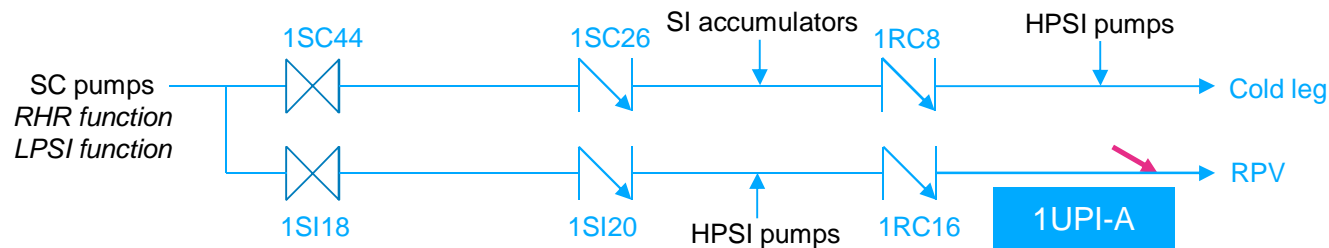
The issue...

- | Doel 1
- | April 23, 2018
- | Leak on 1UPI-A
- | In reactor cavity (10 mSv/hr)
- | 4"sch160
- | Type 316 SS
- | ASME III Cl.1



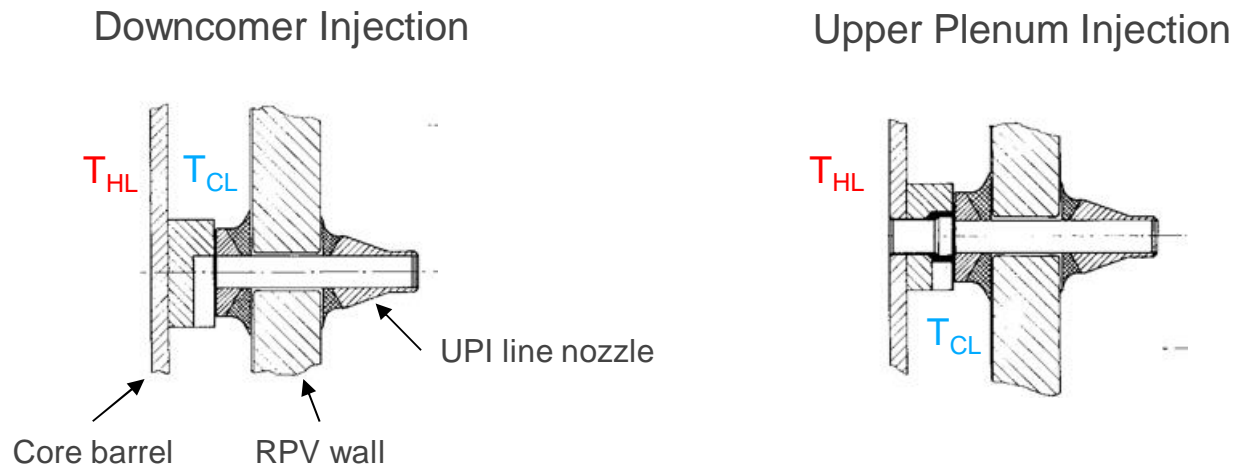
Doel 1&2 Upper Plenum Injection lines

- | Typical for Westinghouse 2-loop PWR
- | Part of Safety Injection (SI) system
- | RPV UPI nozzles are at the same level as I/O nozzles
- | Direct injection into Upper Plenum
- | 2 UPI lines per reactor



Doel 1&2 Upper Plenum Injection lines

- Inside the RPV, conversion from Downcomer Injection to UPI in 1992



Non-destructive examinations

- | Mechanized VT, ET, UT, UT-TOFD (FRAMATOME GmbH Erlangen) of all 4 UPI lines
 - From inside, access through check-valve
 - Dry (pneumatic plug in RPV nozzle)
 - Several carriers
- | Manual UT of welds
 - From outside



Destructive examinations

- | Doel 1 UPI-A ► SCK•CEN (Mol, Belgium) ►► THERMAL FATIGUE
- | Doel 2 UPI-A ► FRAMATOME GmbH (Erlangen, Germany) ►► THERMAL FATIGUE



Overview observed degradation

	UPI-A straight pipe	UPI-A weld	UPI-A elbow
Doel 1	Cracks Leak	Circumferential crack	-
Doel 2	Cracks	Circumferential crack	-

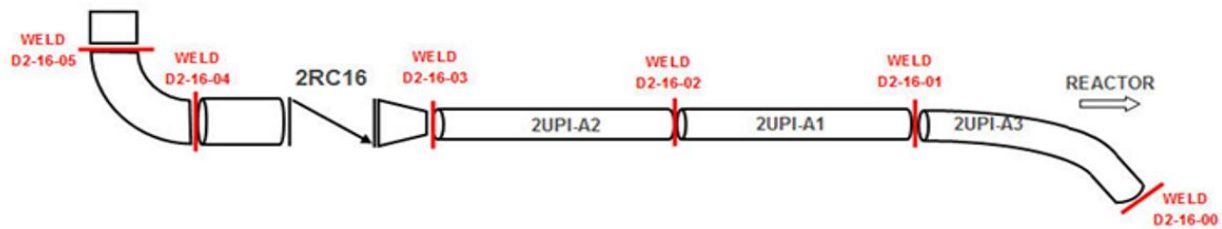
Susceptibility for fatigue

- | Screening of non-isolable RCS branches, including UPI lines (RPV branches), in the framework of Periodic Safety Review
- | No in-leakage ►► no inspection necessary ?
(*EPR1 MRP-146 Rev2 excludes Horizontal RCS branch lines without in-leakage from further evaluation*)
- | UPI-A considered to be more susceptible than UPI-B based on its:
 - Length (8m, versus 4m for UPI-B)
 - Slope (upward to RPV)
- | Recommended inspection location difficult to access and with high dosimetry

Repair

- | Affected straight pipes of Doel 1&2 A-lines were replaced by new A2 and A1 parts

2UPI-A (2RC16):



- | Challenging environmental conditions: radiation level and limited space, difficult to access
 - Shielding
 - Training on full-scale mock-up

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Repair – Mock-up
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Justification for safe restart – Defence-In-Depth principle

Level 1

- Repaired UPI lines are free of indications
- Degradation is confirmed to be due to fatigue
- Validation of phenomenon at the origin of fatigue

Level 2

- Monitoring of UPI lines
- Future inspection programme of UPI lines to timely detect damage

Level 3

- Definition of conservative undetected flaw in UPI line
- Stability of postulated flaw under all possible operating conditions
- Management of UPI line ruptures

Monitoring & future inspections

- | Monitoring of 4 UPI lines
 - Temperatures (FAMOSi)
 - Displacements (LABORELEC)
 - Accelerations (LABORELEC)
- | Inspection of 4 UPI lines at next outage
 - Base metal
 - Welds
 - Combination of VT, ET, UT, RT

First observations from monitoring

MS09

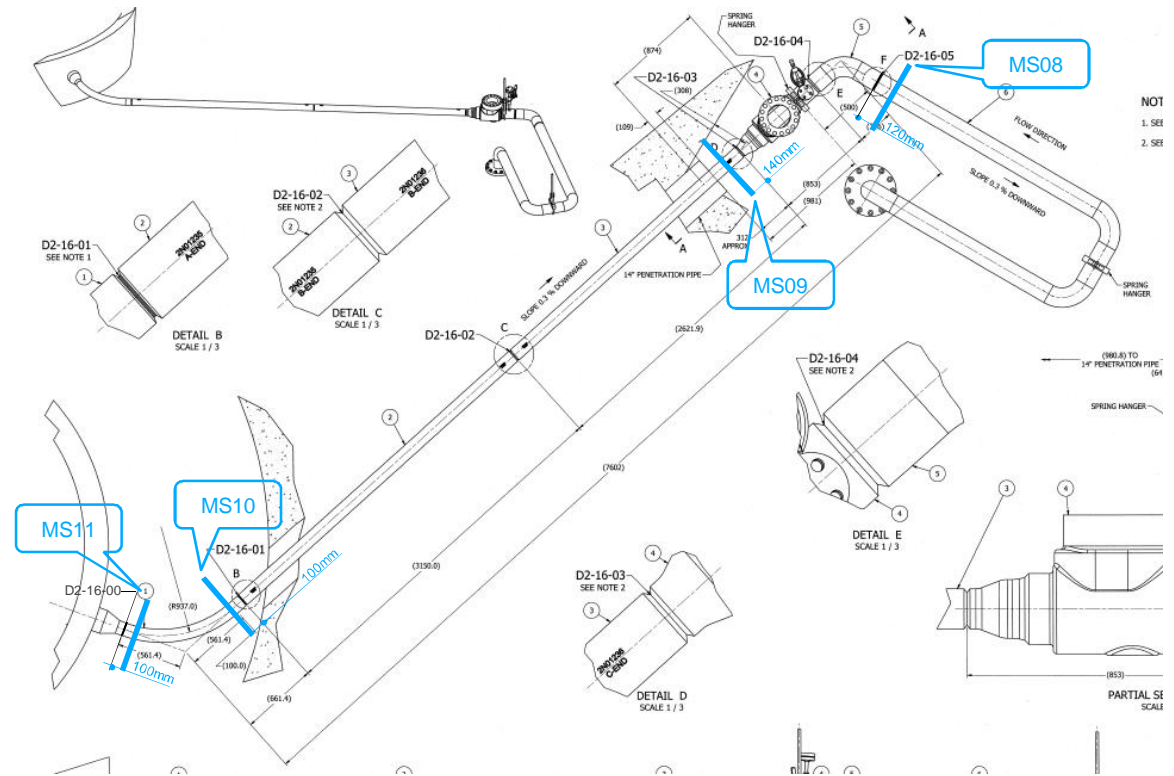
DT_{top-bottom} ~40°C (A,B)
 Range: 120°C – 160°C (A)
 Range: 200°C – 240°C (B)

MS10

DT_{top-bottom} <10°C (A)
 DT_{top-bottom} <30°C (B)
 Fluctuations in range: 210°C – 250°C

MS11

DT_{top-bottom} ~0°C
 Small fluctuations as a function of time



Summary

- | A leak occurred in the UPI-A line of Doel 1 in April 2018
- | NDE revealed degradation in the UPI-A lines of Doel 1&2:
 - Cracking in the bottom part of the straight pipe, upstream of the weld between straight pipe and elbow
 - Circumferential cracking in the weld between straight pipe and elbow
 - No cracking was found in the UPI-B lines.
- | Destructive examination confirmed degradation was due to thermal fatigue
- | The straight parts of the UPI-A lines were replaced
- | Safety demonstration relies on repair, monitoring and future inspections
- | Monitoring confirms the presence of thermal cycles in UPI lines at full power
- | Structural integrity evaluations (stress, fatigue, fatigue crack growth) are on-going

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Thank you for your attention...
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Any questions ?

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