

Doel 3 & Tihange 2 Reactor Pressure Vessel Flaw Indications



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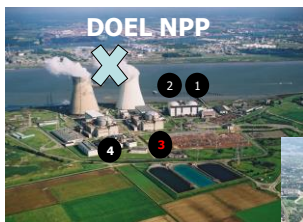
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Overview

1. Introduction & Safety Concern
2. Safety assessment process: actors, timing
3. Manufacturing of RPV
4. In-service inspections
5. Metallurgical origin and evolution of indications
6. Material properties
7. Structural integrity of RPV
8. FANC Conclusions - Current Status

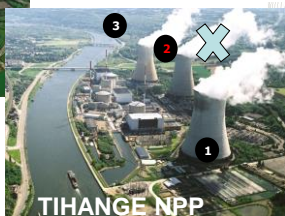


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1. Doel 1 - 433 MW (1975)
2. Doel 2 - 433 MW (1975)
3. Doel 3 - 1006 MW (1982)
4. Doel 4 - 1040 MW (1985)

1. Tihange 1 – 962 MW (1975)
2. Tihange 2 – 1008 MW (1983)
3. Tihange 3 – 1054 MW (1985)



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1. Introduction & Safety Concern

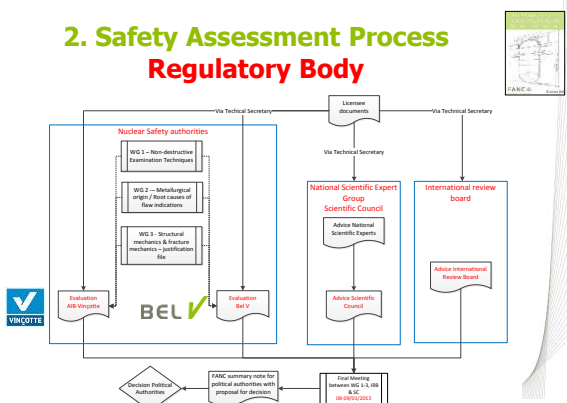
- Flaw Indications found during 2012 RPV In-service inspections at Doel 3 & Tihange 2
- Safety concern: Is structural integrity of the reactor pressure vessel still maintained at all times and in all circumstances?



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2. Safety Assessment Process Regulatory Body



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2. Safety Assessment Process Timing

- June-July 2012: Flaw Indications found at Doel 3 RPV
- September 2012: Flaw Indications found at Tihange 2 RPV
- 05/12/2012: **Electrabel Safety Cases**
- End of December: Evaluation reports of Bel V, AIB Vinçotte, International Review Board & Scientific Council → input for FANC
- 30/01/2013: Publication of **FANC Provisional Evaluation Report**: additional analysis and tests are necessary
- 04/02/2013: **Licensee action plan** to fulfill FANC requirements (approved by FANC on 06/02/2013)



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6. Material properties

FANC CONCLUSIONS

- Some uncertainty on representativeness of material testing program
- More experimental data on tensile and toughness properties of the materials are needed to validate the approach followed in the structural integrity assessment.

FANC REQUIREMENTS (Prerequisite to restart of units)

- The licensee shall **complete material testing program** using samples with macro-segregations containing hydrogen flakes: **small-scale specimen tests** (local toughness tests at hydrogen flake crack tip, local tensile tests on ligament material near the flakes) + large scale tests (see § 9)
- The licensee shall perform additional **measurements of the current residual hydrogen content** in specimens with hydrogen flakes

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7. Structural integrity assessment

FANC CONCLUSIONS

- Deterministic flaw evaluation of each indication performed (modelling of flaws, grouping criteria,...)
- Screening criterion showed that very large majority of indications has no safety impact
- ASME III primary stress limits satisfied
- Fatigue crack growth is very small

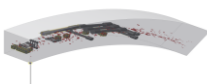
FANC REQUIREMENTS (Prerequisite to restart of units)

- The licensee shall evaluate the impact of the possible non-reporting of flaws with **higher tilts** on the results of the structural integrity assessment
 - LICENSEE ACTION: If needed, additional sensitivity study for higher tilt flaws

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7. Structural integrity assessment



FANC REQUIREMENTS (Prerequisite to restart of units)

- The licensee shall complete the on-going material testing program by **testing larger specimens** containing hydrogen flakes, with the following 2 objectives:
 - **Objective 1**: Tensile tests on samples with (inclined) multiple hydrogen flake defects, which shall in particular demonstrate that the material has sufficient ductility and load bearing capacity, and that there is no premature brittle fracture.
 - LICENSEE ACTION: On-going test program at SCK.CEN : Large tensile specimens containing flakes parallel and with 20° tilt angle to axis (2 tests at room temperature, 2 tests at -80° C)

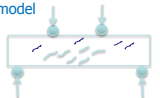
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7. Structural integrity assessment

FANC REQUIREMENTS (Prerequisite to restart of units)

- The licensee shall complete the on-going material testing program by **testing larger specimens** containing hydrogen flakes, with the following 2 objectives:
 - **Objective 2**: An experimental confirmation of the suitability and conservatism of the 3D finite elements analysis.
 - **LICENSEE ACTION**: Bending test on samples with hydrogen flakes
 - The objective is to show that the experimental load of first brittle initiation of a flake in a large specimens with flakes is larger than the initiation load by 3D finite element model



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7. Structural integrity assessment "Load test"

FANC REQUIREMENTS (Prerequisite to restart of units)

- Some uncertainty in structural integrity assessment needs to be dealt with additional experimental validation
- The licensee shall perform a **load test** of both reactor pressure vessels, accompanied with acoustic emission testing (during) and ultrasonic inspections (before & after).
- The acceptance criterion will be that no crack initiation and no crack propagation are recorded under the pressure loading.

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8. FANC Conclusions – Current situation

- Some open issues remaining
 - Do not represent conditions requiring a definitive shutdown of Doel 3 and Tihange 2
 - Requirements formulated which need to be fulfilled by licensee before restart
- **Licensee action plan** to be elaborated and submitted to regulatory body for approval (DONE: 06/02/2013)
- Licensee actions ongoing
- Once licensee has implemented action plan, FANC – Bel V – AIB-Vinçotte will evaluate results (end of march?)
- FANC will motivate decision on restart of Doel 3 & Tihange 2 in subsequent **final evaluation report**

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Implications for other RPVs in the world Need for inspections - investigations?

- Belgian reactors
 - ✓ Other Belgian Reactors (different manufacturers)
 - Tihange 1 (LTO): april 2013
 - Tihange 3: end of 2013
 - ...
- Foreign (RDM) reactors
 - ✓ Muhleberg (Switzerland): no indications found
 - ✓ Ringhals 2 (Sweden): no indications found
 - ✓ Borssele (Netherlands): inspections planned 2013
 - ✓ ...

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More information
FANC-website

Questions?

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