Safety of Suprises

Perspective of a Former Nuclear Regulator

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Overview of Safety Lessons from Tihange 2 & Doel 3

Two major elements in the analysis – once 1 is done go to 2

1. What are the flaws?
    - Assumptions are dominant
    - No corrective action is taking to deal with the failure to find the flaws originally.
    - Shows significant issues with the fabrication and UT inspection process
    - What other issues were missed?
2. What affect could they have?
    - Through wall crack of reactor Pressure Vessel is catastrophic
    - Justification is based on risk, do we know enough to make that claim?
    - Fix the vessel or at least improve brittleness

History

- This is not the first time that actual material performance has differed from predictions
- US Experience
  - Steam generator and pressurize longevity
  - Vessel head integrity
  - Stress corrosion cracking in Alloy 600 materials
  - San Onofre and Indian Point Steam Generator Tube Ruptures

  - These incidents lead to shutdown, significant new inspections, or equipment replacements or several of these factors
- Tihange 2/Doer 3 experience has primarily focused on analytical justification for continued operation

Luck of the Inspection

- Doel 3 and Tihange 2 were undergoing an inspection of the inner diameter shell of the pressure vessel *for an unrelated issue*
- ASME codes do not require non-destructive testing of base metal areas of the pressure vessel
- In a surprising result unexpected indications of flaw were found in both vessels
  - ➔ Inspection of the full through wall thickness of the pressure vessel

What Are the Flaws

- Consensus view of industry and most regulators is that the flaws are hydrogen flakes
  - No other explanation appears to demonstrate the same characteristic as the flaws
- This is a crucial question, because many assumptions about future behavior come from the belief that flaws existed from initial fabrication and have not changed over thirty years of operation

Were They There are Not?

“Electrabel reviewed all available fabrication records and determined that fabrication met all applicable codes and standards. However, no explanation was given for failure of the manufacturing examinations to report the indications. *An expert working group reviewed the RDM fabrication UT procedures and concluded that the flaws found in 2012 should have been detected and reported during manufacture of the vessels.”*

“A retrospective evaluation suggests that the flaking in Doel 3 and Tihange 2 would have been detectable and recordable, but acceptable... If the Doel 3 / Tihange 2 indications had been properly reported in the fabrication records, the operational impact may have been minor…*It is considered highly unlikely that a component with such imperfections would, have been accepted by any owner had the indications been properly recorded and reported, even if they were not rejectable under ASME III acceptance criteria.”*

US Nuclear Regulatory Commission, October 2013

Were They There or Not?

"The discrepancy between the indications reported in the acceptance reports of the rings from the 1970s and in the 2012 inspection in the core shells of the two plants remains unresolved, since the UT technology available at that time should have had the capacity to detect the indications found."

International Expert Review Board, Final Report, 2013

Results

1. Hydrogen flakes are the industry/regulator consensus source of the flaws, but…they should have been identified and the vessels rejected.
    - This inconsistency continues to be ignored.
        - Could mean hydrogen flakes are NOT the cause
        - Could mean flake indications were identified and ignored
        - Could mean flake indications were present and not identified
    - None of this is an acceptable outcome.

2. There should be a discussion of the need for base metal inspection in many reactors. The specific standards for much of the reactors in operation are simply inadequate.
    - Base metal inspections will take time and likely lengthen outages
    - Analytical calculations of unknown phenomenon are NOT a replacement for physical inspectios

Approach to Findings

- Root cause analysis
  - There are two main issues:
    1. What caused the flaws?
       There is an answer but it has internal inconsistencies
    2. Why weren't the flaws identified earlier?
       This question remains unresolved.

Impacts

- Regardless of the initial cause, the existing condition can be analyzed and the impacts assessed
- Two approaches to consider the uncertainties in the scientific and technical issues
    1. Risk Analysis
    2. Shutdown with further analysis

- The overwhelming pressure is to restart the units for financial and energy needs

Primary Impact

- Concern is for through wall crack in the pressure vessel
  - Means a very difficult to cool core
  - Severe accident which existing plants have no ability to address

- Basis for acceptance of the existing vessel is based in part on an analysis of the performance during pressurized thermals shock which could lead to crack growth and through wall cracks

Thermal Shock Analysis

- Is a probabilistic approach
  - 95% Confidence of through wall crack < 10^{-6} per reactor operation years
  - NRC analysis of similar situation showed 10^{-7} for US plants.
- Problems with this approach is that it does not show that through wall cracks are impossible just unlikely
  - 10^{-6} versus 10^{-7} is largely meaningless
  - Both are small and there are sufficient uncertainties through the assessment that could shift

Alternative

- Consider the impacts of a severe accident and address issues appropriately
  - That means repairing the vessel or
  - Shutting the plant
- This is how comparable issues have been addressed in US in the past