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Application of Risk-Based Inspection for Cryogenic Equipment

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Equipment Integrity

- Operating units need to be able to demonstrate proper management of pressure equipment integrity
  - Legal and moral requirement
    - "*Our assets are safe, and we know it*"
    - Continued safe operation is 'good business'

Equipment Integrity

- Starts with sound designs, materials selection, adequate quality assurance and quality control during manufacture, appropriate consideration of safety aspects, correct commissioning, operating within design limits…
- …and continued verification that the equipment is still safe to operate

Why use Risk-Based Inspection?

- An RBI approach can be a significant part of pressure equipment integrity management
- Periodic inspection conditions and requirements vary between countries
  - Inspection periods are often a legal requirement
  - In some countries exclusions or extensions based on RBI are possible
  - Other countries fully recognise RBI as the inspection basis in pressure equipment integrity management
- Potential cost savings
  - Allows inspection effort to be focused on critical items, and using appropriate inspection techniques
  - Assists in achieving lowest lifecycle costs by avoiding unnecessary inspection

What is Risk-Based Inspection?

- RBI focus is on maintaining mechanical integrity of pressure equipment items and minimising loss of containment due to deterioration
  - Complementary technique to PHA, HAZOP, etc.
- Inspection periods and inspection techniques are set according to the probability of failure and consequence of failure of the equipment (i.e. set according to the risk)
  - Usually involving a facilitated multidisciplinary team
- Systematic evaluation of each potential degradation mechanism and estimation of probability of failure (PoF)
  - In RBI, this is not only a function of time but also of 'knowledge' of the equipment and inspection effectiveness
- Determination of possible and credible consequences (harm to people, environment, asset losses) in case of equipment failure (CoF) resulting from the degradation mechanism
- The combination of PoF and CoF defines the risk, typically depicted on a risk matrix, and from which an inspection interval factor is set
- Based on the inspection interval factor and the remnant life (or design life for new facilities), the next inspection date is determined
- The appropriate inspection technique and inspection coverage for the degradation mechanism is determined

RBI Challenge with Cryogenics

- RBI assessments are usually done per degradation mechanism
  - General thinning, local thinning, pitting, environmental cracking,…
- Cryogenic equipment operating at cold effectively have no degradation mechanisms
  - Provided that original materials selection and mechanical design were fit-for-purpose
  - Provided operated as per original design intent, within design temperature and pressure operating window
  - Provided not subject to unexpected upsets or external influences
- However, because the consequences of failure can be very high, some operating units want to do “something” in terms of inspection
  - For example, defaulting to an intrusive inspection at the maximum inspection interval generated by RBI (e.g. 80%) as a proportion of the original unit design life
  - But must be balanced against risk of doing the inspection itself and associated safety aspects
    - For example, controlling moisture ingress and ice formation on cooldown

A Risk-Based Approach

- Elements of RBI can be used nevertheless in the integrity management of cryogenic equipment
  - Multidisciplinary assessment of risk
    - Documented, traceable and defendable
  - Control of management of change
  - Ensuring that residual risk factors for loss of containment are understood and mitigated, including consequential effects from/on neighbouring equipment
    - Assists to put appropriate compensatory measures in place
  - API RP 581 *Risk-Based Inspection* defines standard “release hole diameters” for assessing PoF and CoF
    - “Small” – d=6.4 mm up to “Rupture” d = min [D, 406] mm
      - Such an approach can be used to standardise and compare release scenarios

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- 2302 pressure vessels, of which 1286 are considered cryogenic
- In accordance with its intergovernmental status, CERN establishes and updates Safety Rules to implement its Safety Policy
- Inspection and testing requirements for cryogenic equipment given by Safety Rule GSI-M-4
- Inspection intervals pushed out compared to previous rules, based on assessment of experience and risk

CERN Inspection Requirements

- Fixed cryogenic pressure equipment
  - External visual inspection, including safety accessories, at 5 year interval
  - No additional requalification tests, unless under management of change
- Transportable cryogenic pressure equipment
  - External visual inspection, including safety accessories, at 5 year interval
  - Pressure and leak-tightness test at 90% maximum allowable pressure (PS), at 10 year interval
- Cryogenic pressure equipment liable to have major safety implications
  - External visual inspection, including safety accessories, at 3 year interval
  - No additional requalification tests, unless under management of change

CERN Inspection Requirements

- Safety Valves
  - Functional test 5 year interval
    - Inert fluids in ‘non-fouling’ situations
  - Functional test 3 year interval
    - ‘Fouling’ situations
    - Flammable or oxidising cryogenic fluids
    - Pilot-operated valves
    - Valves protecting cryogenic equipment liable to have major safety implications
- Rupture discs
  - Replaced at manufacturer-defined intervals
  - Replaced if any signs of damage
  - Replaced after 10 years at the latest

Summary

- RBI, done properly, can be considered a robust component of pressure equipment integrity management
- Despite the issue of determining degradation mechanisms, elements of the RBI process can be applied with validity to ensuring integrity of cryogenic equipment by evaluating and documenting risk, and assisting in promoting and maintaining safety in operation.

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