



Office for  
Nuclear Regulation

# NDT of Highest Reliability Components

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Safety

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- NDT in the context of the nuclear safety case
- The basics of highest reliability NDT
- NDT in the avoidance of fracture demonstration
- Some examples



# The Nuclear Safety Case

## The nuclear safety case:

1. Identifies those structures and components that are important for nuclear safety
2. Defines the role and importance (safety function) these have in maintaining nuclear safety - leads to classification
3. Describes the measures that will be taken to assure their integrity through life

## For NDT the safety case defines:

1. The role of the NDT
2. The reliability required from the NDT



# Structural Integrity Safety Case

**DESIGN**  
**(Normal & Upset Conditions)**

Appropriate materials  
Configuration  
Fracture Mechanics  
Environment  
Hazards  
Degradation

**MANUFACTURE**

Forgings, Welds, Castings  
High quality  
Mechanical Testing  
Chemical measurements  
Quality Assurance  
NDT

**COMMISSIONING**

Pressure Test  
Confirming  
NDT

**OPERATION**

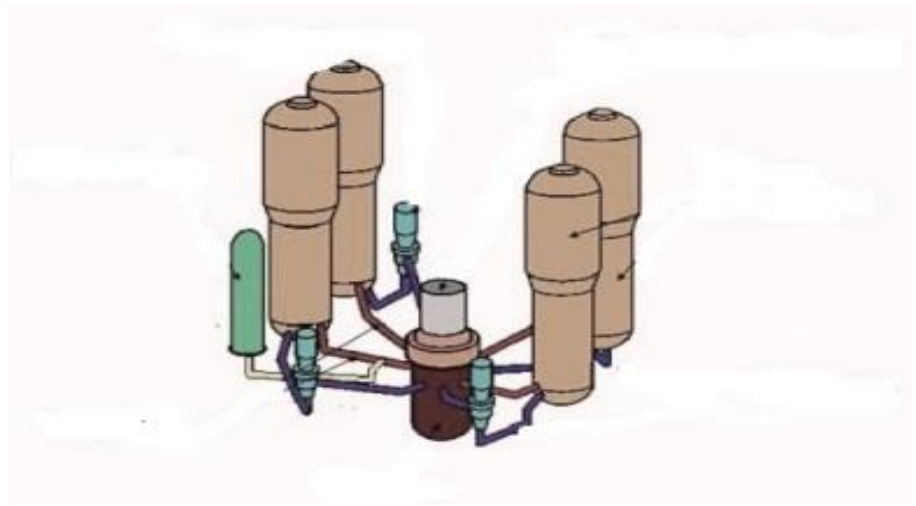
Operating Rules  
Monitoring  
ISI NDT  
Repair



**CONFIRM SAFETY FUNCTION OF THE COMPONENT CAN BE DELIVERED**

# Highest reliability components

- Safety case claims for components and structures the likelihood of gross failure is so low it may be discounted, but if failure did occur the consequences would be extreme
- Additional measures (beyond codes and standards) required to assure the integrity (including NDT)

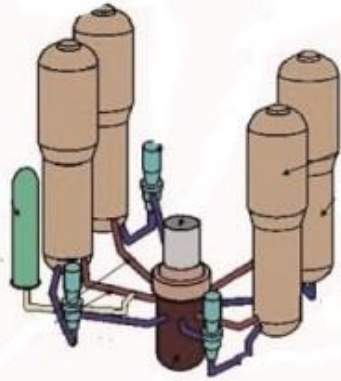




# NDT of Highest Reliability Components

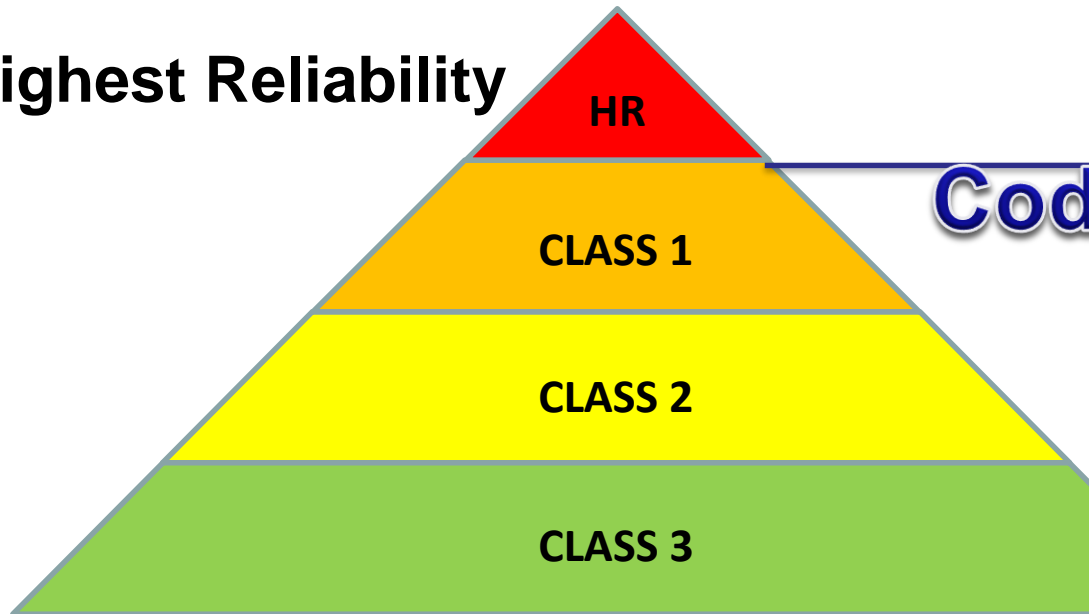
|  |                            |       |
|--|----------------------------|-------|
| <b>Engineering principles: integrity of metal components and structures: highest reliability components and structures</b>   | Safety case and assessment | EMC.1 |
| <p>The safety case should be especially robust and the corresponding assessment suitably demanding, in order that a properly informed engineering judgement can be made that:</p> <ul style="list-style-type: none"><li>(a) the metal component or structure is as defect-free as possible; and</li><li>(b) the metal component or structure is tolerant of defects.</li></ul> |                            |       |

as defect-free as possible

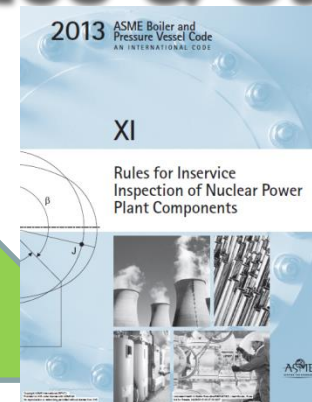


- Objective based manufacturing NDT to meet specific safety case needs
- Design considerations for NDT: ‘Design for inspectability’
- Qualified NDT performed in manufacture.
- Repeat NDT
- Enhanced quality assurance/control

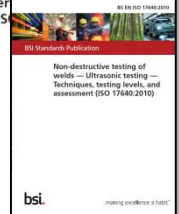
Highest Reliability



## Codes & Standards



Non-destructive testing  
Qualification and certification  
of NDT personnel (ISO  
9712:2012)



bsi.

...making excellence a habit™



# Beyond Code NDT

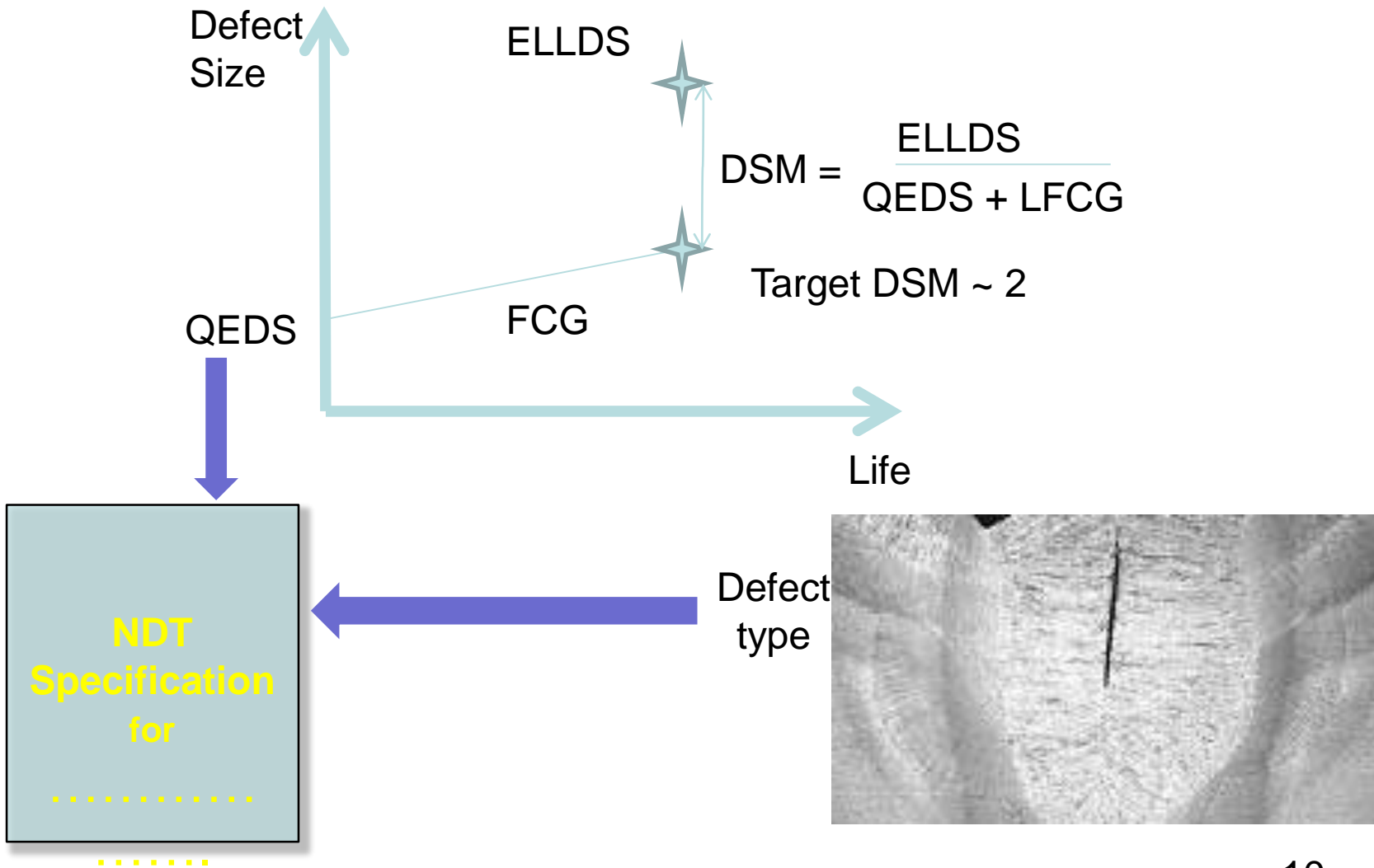
- Objective based manufacturing NDT to meet specific safety case needs
  - Code specified techniques and sensitivities may not be sufficient
- Design considerations for NDT: ‘Design for inspectability’
- Qualified NDT performed in manufacture.
  - procedures
  - personnel
- Repeat NDT
- Enhanced quality assurance/control



## Basic principles for high reliability NDT

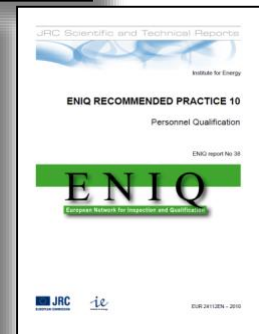
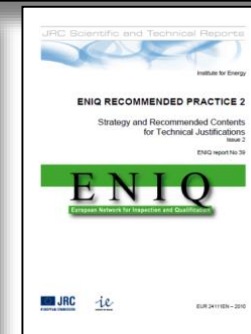
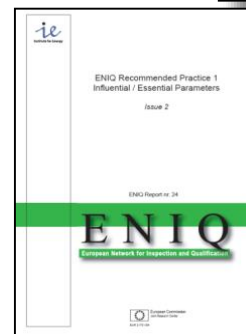
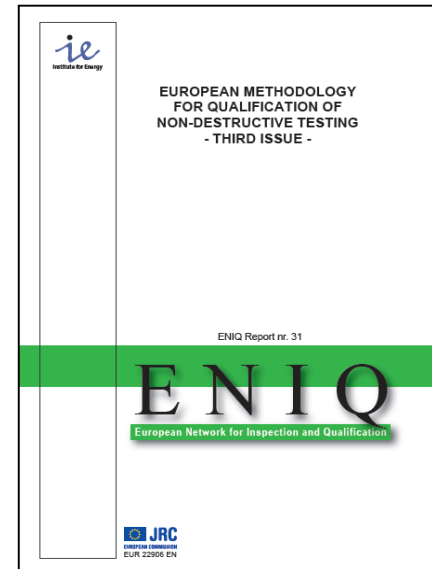
- Mature methods and techniques with a sound physical basis
  - Use of ultrasonic inspection over radiography
- Good margins
- Good inspection conditions
- Well constructed NDT procedures
- NDT training
- Attention to human factors
- Reporting and decision making

# Avoidance of Fracture Demonstration



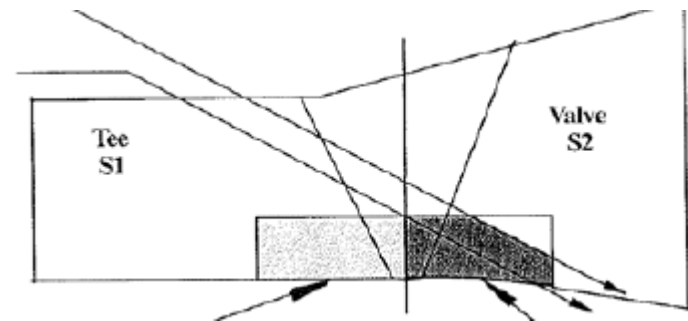
# High Reliability NDT: Inspection Qualification

- The elements of the inspection qualification process that ONR is seeking are:
  - Objective Based
    - Pre-defined inspection objectives
    - Defect specification
    - Performance criteria
  - Procedure qualified using technical justification and practical trials
  - Personnel qualified against a specific NDT procedure using blind trials
- These elements are found in the ENIQ Methodology



# Design for inspectability

- Components designed to ASME III often cannot meet the ASME XI NDE requirements
  - Component geometry
  - Physical access
  - Materials (cast stainless steel)
- ASME Code Case N-711-1
  - Revision of inspection volume to consider degradation effects.





# Design for inspectability

|  |                           |       |
|--|---------------------------|-------|
| Engineering principles: integrity of metal components and structures: design     | Providing for examination | EMC.8 |
| Geometry and access arrangements should have regard to the need for examination. |                           |       |

|   |           |        |
|---|-----------|--------|
| Engineering principles: integrity of metal components and structures: manufacture and installation  | Materials | EMC.13 |
| Materials employed in manufacture and installation should be shown to be suitable for the purpose of enabling an adequate design to be manufactured, operated, examined and maintained throughout the life of the facility. |           |        |

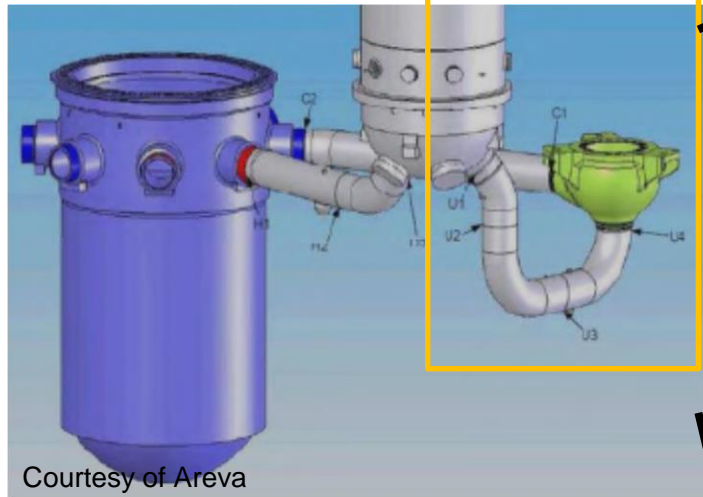
- Component design
  - Position of counterbores
  - Change of section
  - Materials
- Manufacture
  - Welding process
  - Surface preparation (machined)
  - Weld root removal
- Good man/machine access



**ALARP Principles  
important here**

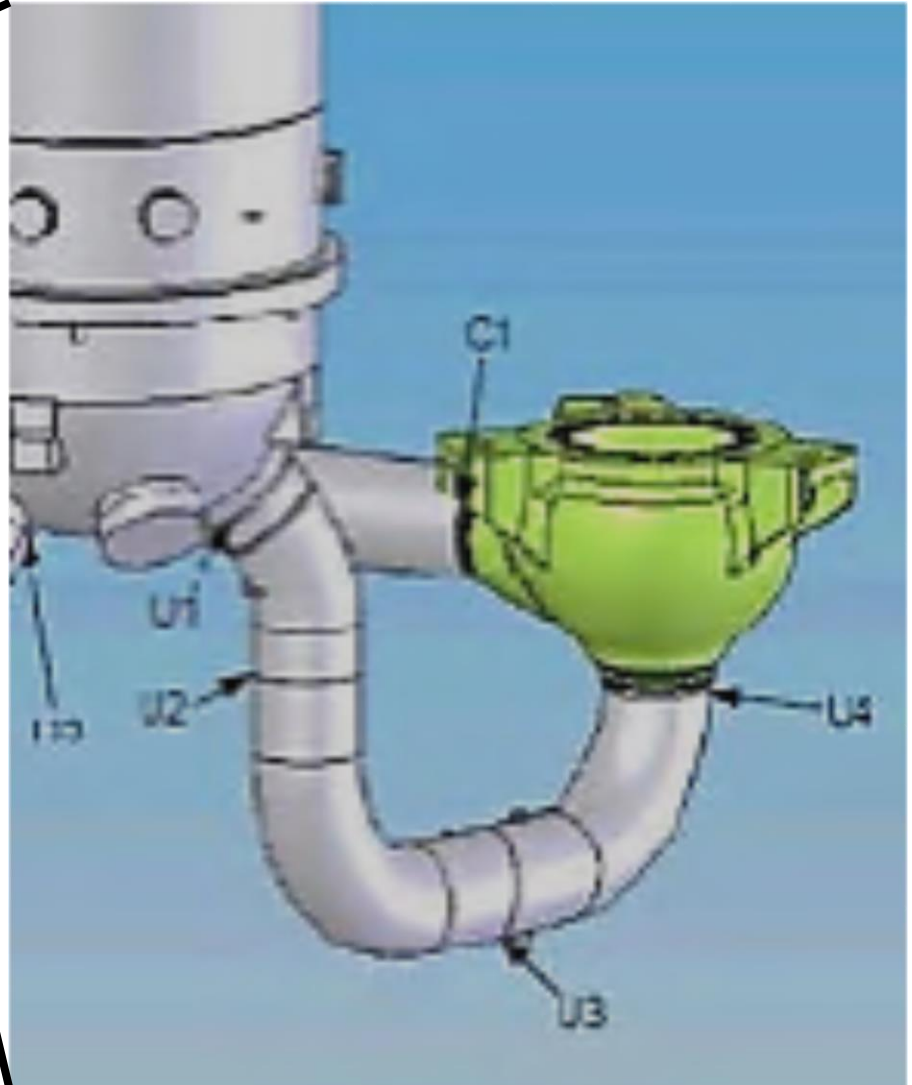


# Design for inspectability



Initial design not optimised for ultrasonic inspection.  
Design modified to provide a 250mm straight section on the ends of the bends.

UK EPR Main Coolant Lines



## Doel 3/Tihange 2 Hydrogen Flakes

- Around 10,000 defects identified in the RPV forgings in 2012, understood to be present at manufacture.
- Significant NDT failure applying ASME based procedures – difficult to establish the root cause.
- The Sizewell B RPV forgings were subject to several qualified mechanised inspections.
- EDF were able to provide good evidence that hydrogen flakes were not present in Sizewell B RPV



Courtesy of EDF



# Conclusions

- Licensee's safety cases are the basis of defining the NDT requirements for nuclear safety and the associated reliability
- Codes and standards are generally not sufficient for providing the reliability for 'Highest Reliability' components and structures
- Design for inspectability is important for new build





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Thank you