History of Nuclear NDT in the UK

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Seminar “NDT for Nuclear Industries”
24th January 2020
Outline of Presentation

- Apology, explanation, change of plan
- Some Milestones in Nuclear NDT
Why you might consider buying the book

- A better understanding of the past may help answer today’s questions
- The future role of nuclear power in the UK remains a controversial topic
- Lessons can be learnt for other large infrastructure projects
- Helps readers to form their own view of nuclear power.
Evolution of Commercial Nuclear Power in UK

1950 Windscale Piles
1962 Magnox Berkeley
1983 AGR Dungeness B
1995 PWR Sizewell B

First Operation

Golden Egg or Poisoned Chalice?
The Story of Nuclear Power in the UK
Milestones in Nuclear NDT and lessons learned

Magnox, AGR and PWR

All three reactor types were initially designed before the importance of NDT was fully understood. There was little consideration of in-service inspection requirements. The main volumetric inspection method during manufacture was radiography, and design for inspection by ultrasonics was not considered.
NDT of Magnox reactors

In the late 1970s, in-service inspection by ultrasonics revealed many cases of manufacturing defects in Magnox gas duct welds – these had only been inspected by MPI during manufacture because the geometry was unsuitable for radiography.

In the 1980s, attempts were made to undertake in-service UT of Magnox RPV welds because manufacture had relied on RT. Ultimately, the inaccessibility of many of the welds for inspection and repair proved to be the life-limiting feature of the Magnox stations with steel RPVs

LESSONS: need design for inspection, need to understand potential value of NDT
NDT of AGRs

AGRs have concrete pressure vessels which also contain the boilers. The boilers and boiler penetrations use austenitic steel – and the coarse-grained nature of the austenitic welds makes them difficult to inspect using UT. *There was originally no intention to perform regular ISI and so no PSI.*

- Pic shows a boiler being lowered into the concrete pressure vessel
- Concrete plug with austenitic steel penetrations
NDT of AGRs

Heysham 1/Hartlepool austenitic welds ~ 1977

- boiler closure MMA weld was an unsuitable geometry for RT in manufacture, and consequently UT was proposed. This led to some ground-breaking R&D in CEGB to understand the propagation of ultrasound in such welds, and also the welds were re-designed to allow good inspection.

- similar methodology was followed by Babcock Power on boiler nozzle to header welds
- in both cases the manufacturing inspection results were invaluable when reheat cracking (a novel, unexpected mechanism) was later found by UT ISI.
• Each reactor at Heysham 1 and Hartlepool has eight boiler units. Within each boiler are tubes assembled in a coil formation around a central vertical pipe called the boiler spine. The boiler spines support whole weight of each boiler.

• In 2014, the four reactors were shut down after the discovery of a crack in a boiler spine at Heysham 1 by Long Range Guided Wave Ultrasound.

• Subsequently the crack in one boiler spine was confirmed by remote conventional NDT and the other 31 boilers were cleared by Guided Wave
NDT of AGRs - mid 80’s

Heysham 2 and Torness

- Lessons were learned from earlier AGRs

- All major boiler penetration austenitic welds were inspected during manufacture by UT
- Narrow Gap TIG welding adopted because of its favourable grain properties for UT
- Design for inspection (counterbores, weld caps ground, space for ISI)

- All AGRs
  - NDT in - service has been/remains a vital component of the Safety Cases for Life Extension and continued operation beyond the original design lives of the plants
NDT of Pressurised Water Reactors

• In the 70’s the key question in the UK was “Can the reactor pressure vessel (and other safety critical vessels) be manufactured with sufficient reliability to ensure their integrity?”

• In the meantime:
  • other countries had built PWRs and were gaining experience in operation and ISI, often finding manufacturing flaws that had not been caught by manufacturing NDT (radiography)
  • Similar problems with submarine fleet PWRs subject to ISI
  • Poor results in round robin trials of code-based UT techniques used for ISI (US-PVRC and PISC1) threatened to undermine the confidence required
  • Poor experience with UT of austenitic pipe welds in USA
  • Mini-computers became available in the mid 1970’s and this spurred the start of developments of automated ultrasonic systems which by the early 1980’s could be used with computer-controlled ultrasonic flaw detectors, such as the Mateval Micropulse and the RTD Sonolog.
**NDT of Pressurised Water Reactors**

- Faced with these challenges and opportunities the UKAEA and CEGB:
  - Organised the UK Defect Detection Trials and the competent participation in these by teams from Harwell, Risley, CEGB/RR+A/Babcock Energy, France and Germany
  - Also organised competent UK participation in the international PISC2 trials which were happening in parallel
- Both initiatives achieved highly successful results with UK teams emerging as the best in the world,
- but there were some below par results from previously favoured teams
NDT of Pressurised Water Reactors

• Faced with these challenges and opportunities (continued):

• On the new generation of submarine PWRs, RR+A and Babcock implemented design for inspection, automated Manufacturing inspection and PSI
• CEGB were able to prepare a body of positive evidence and plans to present at the Sizewell B Public Inquiry
Public Inquiry – Sizewell B

- Structural integrity and the role of NDT was a central issue to the CEGB safety case at the Public Inquiry led by Sir Frank Layfield and by the Nuclear Installations Inspectorate.
- Evidence showed that the poor results in PISC1 had resulted from failure to take proper account of the nature of the defects being sought, while in DDT and PISC2 this was rectified.
- The NDT Inspection Validation Centre was created and charged with the qualification of NDT procedures.
- Additional and repeated inspections were specified for Sizewell B RPV/IOF components during and following manufacture to ensure the absence of significant defects entering service.
NDT of Pressurised Water Reactors

NDT for Sizewell B included:

- RPV subjected to independent auto UT of the forgings and welds during manufacture and pre-service in addition to manual manufacturing inspections by the fabricator
- UT techniques were carefully designed with assistance of modelling for the precise types, orientations and sizes of flaws to be sought (in-manufacture or in-service)
- UT of all welds in the austenitic primary circuit pipework (possible because of design for inspection, use of forged pipes rather than cast and mostly NGTIG welds (benefitting from AGR experience)
- RPV and IOF components (Steam generators, Pressuriser and primary circuit pipework) were also subject to automated UT PSI
- All of the above were subject to independent validation/qualification
NDT of Pressurised Water Reactors

Continued

• Similar inspections methods continue to be used by Doosan Babcock for EDF (France and UK) and Atucha 1 and 2, and by RR+A for submarine PWRs
• Similar requirements for Hinkley Point C
• Design for inspection of the Hinkley Point C primary circuit led to re-design of the cross-over leg to facilitate effective UT
Lessons learned - general

• NDT has proved to be far more important in-service than was expected/foreseen when nuclear plants were being built. NDT in - service has been/remains a vital component of the Safety Cases for Life Extension and continued operation beyond the original design lives of the plants.

• There have been many examples of deterioration that were not predicted in advance and where NDT has proved to be important.

• Importance of design/modelling of inspections to take proper account of the defects to be sought – manufacturing or in-service – and not just following code. Requires material and structural integrity input.

• Importance of design to permit inspection – both during manufacture and in-service.

• Validation/qualification of NDT procedures, equipment and personnel has proved invaluable and has been adopted throughout Europe through ENIQ on all types of nuclear plant.

• Training of personnel for specific inspections has proved to be essential.

• Big lessons in how to achieve technology transfer - the people responsible for the R+D did not just publish it and expect/hope others to follow but they moved with the technology into application. (RCNDE model EngDoc model similar)