Chockie Group International, Inc.

Structural Integrity Associates, Inc.®

The Long Journey in the Development of ISI Rules for CASS Piping

Alan Chockie – Chockie Group International, Inc.
Timothy J. Griesbach – Structural Integrity Associate, Inc.

Presented at:
2013 ASME Pressure Vessel and Piping Division Conference
Paris France

July 14-18, 2013

Presentation Topics

- Background – The Use of CASS in US Plants
- Inservice Inspection Requirements
- The ASME Section XI Code
- CASS Inspection Requirements & Issues
- Plant Strategies for CASS Inspection
- CASS Code Case Actions – 22 Years and Counting

Background

Use of CASS in US Plants

35 BWRs
- GE - 35 units

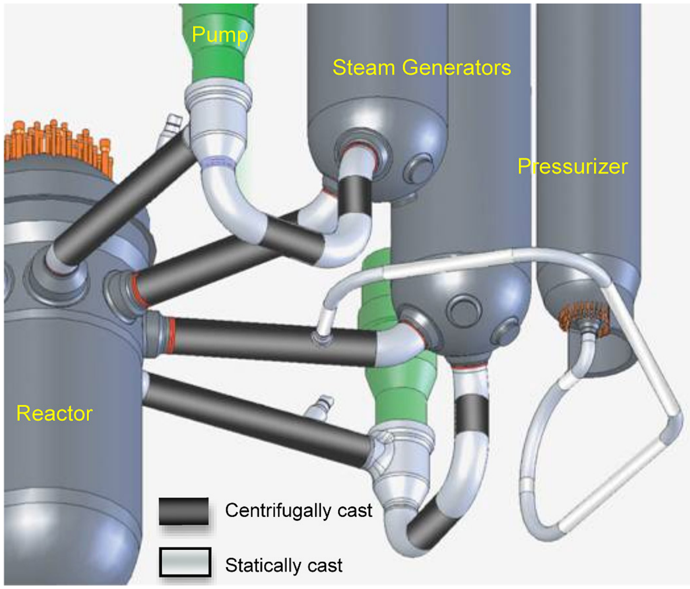
69 PWRs
- Westinghouse - 48 units
- CE - 17 units
- B&W - 7 units

- The primary coolant piping in the 104 US plants is
  - Carbon Steel
  - Austenitic Stainless Steel
    - Wrought Austenitic Stainless Steel
    - Cast Austenitic Stainless Steel (CASS)

Background

Use of CASS in US Plants

- CASS is either centrifugally or statically cast
- Centrifugally cast CASS used in 27 Westinghouse PWRs
  - In reactor coolant system
  - Straight sections of primary pipe systems
- Statically cast CASS is used in other primary coolant system components in all PWRs and BWRs



Background

Importance & Challenges of CASS

- CASS is important due to its use in the Class 1 primary piping systems in a large number of plants
- Increasingly critical to ensure the integrity of aging piping system
- The attributes that make CASS a good candidate for primary piping significantly hamper the ability to reliably detect and to accurately locate and size flaws

US ISI Inspection Requirements

- Plant licensees are responsible for safe plant operation
- Title 10 of the United States Code of Federal Regulations (CFR) is to ensure plants maintain an acceptable level of safety – ISI regulations are in 10 CFR §50.55a
- Federal regulations do not spell out detailed ISI requirements – they invoke Section XI of the ASME Boiler and Pressure Vessel Code

Development of Section XI Code

The Basis for ISI Requirements

- Early 60's – guidelines for nuclear plant inspections based on fossil plant experience
- Little consistency in original ISI programs
- Late 60's – AEC ISI study recommended
    - Inspection of important systems and components
    - 10 years to complete all inspections
    - Random-failure philosophy
    - Preservice exams
    - No guidance on what to do when indications were found

Development of Section XI Code

Inspection Requirements

- 1970 – AEC study formed the basis of 1st edition of ASME Section XI ISI Code
- 1971 – Section XI requirements made mandatory by US Federal Regulation 10 CFR 50.55a
- Quickly realized the need for ISI rules for
  - Accuracy of UT
  - Analysis of flaws
  - Repairs

Development of Section XI Code

Random-Failure Philosophy

- Operational experience showed service-induced failures were not due to
  - random causes
  - at random times
  - at random locations

- Failures were from high stresses, fatigue, incorrect materials, and operational errors

- Many could have been predicted with proper analysis or material selection criteria

Development of Section XI Code

Revision of Initial ISI Requirements

- Initial Section XI Code revised to
  - Target high stress areas
  - Address high cumulative usage factors (fatigue)
  - Incorporate requirements for
    - UT criteria
    - flaw acceptance standards
    - fracture mechanics analysis
    - repair and replacement rules
    - other piping & components in Class 2 & 3 systems

Development of Section XI Code

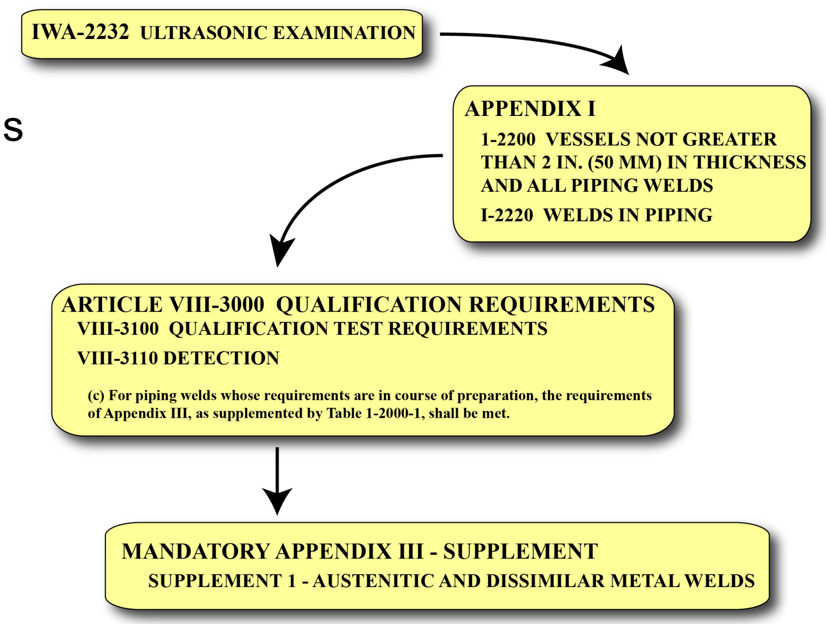
The Current ISI Requirements

- 1978 – Current ISI requirements were established
  - 100% of B-F Class 1 welds
  - 25% of B-J Class 1 welds
  - 7 ½% of Class 2 welds
- There are currently no qualified performance demonstration Code requirements for procedures, equipment, or personnel for the ultrasonic (UT) exams of CASS pressure-retaining welds

CASS Inspection Requirements

Roadmap to Current CASS Inspection Requirements

- IWA-2232 – CASS inspections in accordance with Appendix 1
- Appendix 1 – UT piping weld exams use procedures, equipment, and personnel qualified by Appendix VIII
- Appendix VIII – Supplement 9 is where CASS inspection qualification requirements should exist
- Appendix III, Supplement 1 – Rules for inspections of CASS



CASS Inspection Requirements

Appendix III

- Appendix III has prescriptive requirements for performing nonqualified UT inspections of vessel and piping welds
- The techniques in Appendix III are not considered the best available UT methods for successful CASS inspections
- Licensees are to use Appendix III rules for CASS inspections until Appendix VIII Supplement 9 CASS qualification requirements are developed

CASS Inspection Issues

- Objectives of UT inspections are to reliably detect and accurately locate and size defects

- UT inspections of CASS are challenged due to
  - Coarse grain structure
  - Anisotropic crystal properties of the CASS material
    - Affecting direction and propagation velocity of the ultrasound
  - False indications
  - Incorrect information on the location of the indications
  - Missed signals from actual defects

CASS Inspection Issues

NRC Concerns

- CASS is extremely robust material
  - No known failure of CASS piping
  - Service loads are relatively low
  - Used in conservatively designed Class 1 systems
- NRC remains concerned due to
  - Possible thermal aging embrittlement of CASS components
  - NDE is part of the NRC's defense-in-depth approach to regulating
  - No currently qualified NDE techniques for CASS
  - Need to ensure structural integrity of aging systems and components

Plant Strategies for CASS Inspection

- US plants have used 3 strategies for the inspection of CASS pressure-retaining welds
  - ASME Section XI Appendix III, Supplement 1 Requirements
  - Risk-Informed ISI (RI-ISI)
    - use risk-informing methodology to modify the existing ISI program and thereby reduce the number of required CASS welds to be examined
  - Weld Overlays
    - use weld overlays to modify or eliminate the need future inspections of the CASS piping weld

CASS Code Case Actions

22 Years and Counting

- Appendix VIII published in 1989
  - Included Supplements with qualified performance demonstration requirements for each type of inspection
  - Supplement 9 was to deal with the inspection of CASS
  - Supplement 9 has remained, *"…in course of preparation"*

- 1990 first CASS-related Code Case was prepared
  - Code Case ISI 90-03, "*Approve changes to Appendix I, Appendix III, and Appendix VIII for Cast Austenitic Weld Inspection*"
  - Code Case has been under development for over 22 years

CASS Code Case Actions

Task Group on CASS Inspection

- 1997 – ASME Section XI Task Group on CASS Inspection was formed
  - To resolve the issues with CASS inspection
  - To propose Code actions to complete Appendix VIII Supplement 9

- 2000 – Task Group proposed to abandon the effort until improved inspection systems were developed
  - Group concluded that UT exams from the outside surface of CASS components have a lower POD and a higher false call rate than the Appendix VIII criteria – and well below the desired performance levels

CASS Code Case Actions

2002 Draft CASS Code Case

- ASME Section XI Subcommittee ISI rejected Task Group request – directed them to continue their efforts

- 2002 – Task Group prepared a draft CASS Code Case
  - Based on an existing Code Case for pump casing welds
    - VT-2 visual exam during Class I system pressure test performed after each refueling
    - Engineering evaluation to demonstrate the safety and serviceability of the system
    - Surface examination for selected welds involving CASS components
    - Volumetric exam of wrought components welded to CASS components

CASS Code Case Actions

Recent Influencing Factors

- ASME did not approve Code Case due to various concerns
- Over last 7 to 8 years – Significant developments and rethinking related to the inspection of CASS
  - Improvements in the ability to inspect CASS using UT from the outer surface (OD)
  - Flaw tolerance evaluation of CASS components
  - Systematic approach to management of aging CASS

CASS Code Case Actions

Improvements in Inspection

- Improved ability to inspect CASS using UT from the outer surface due to NRC-funded PNNL and EPRI-funded efforts

- 2009 – Proposed CASS Code Case prepared
  - Code Case, *Qualification Requirements for Cast Austenitic Piping Welds Less than 2.0-inch in Thickness*
  - Based on PNNL's successful inspection of vintage 1.6-inch thick CASS pressurizer surge lines
  - Would allow Supplement 10 qualification techniques to apply to thinner CASS
  - Task Group continues to refine the Code Case

CASS Code Case Actions

Improvements in Inspection

- 2010 – CASS Code Case (N-824) introduced
  - Based on concern that existing Appendix III prescriptive requirements for performing nonqualified UT exams of vessel and piping welds are not considered the most appropriate for CASS exams
  - Code Case objective – Guidance on the best and most reliable equipment and exam parameters currently available for the exam of CASS from the OD
- 2012 – Approved for incorporation into the Section XI Code

CASS Code Case Actions

Flaw Tolerance of CASS

- Important to understand critical flaw size in CASS – EPRI funded work at Structural Integrity Associates to establish methodology for determining acceptable flaw sizes for CASS piping using a probabilistic fracture mechanics approach

- 2012 – Code Case, *Alternative Flaw Tolerance Analyses for Acceptance of Cast Austenitic Stainless Steel (CASS) Components,* was introduced to determine
  - allowable flaw sizes in CASS components
  - target flaw sizes for NDE that will ensure safe operation taking into account possible flaw growth

CASS Code Case Actions

Flaw Tolerance of CASS

- Allows use of a flaw tolerance approach – allowable flaw sizes developed based on allowable probabilities of failure
  - Intended to cover a range CASS materials with ferrite content ≥ 20%, including CF-8M

- Evaluation of CASS components would include
  - Screening to determine susceptible CASS components
  - Demonstrate that a ¼-thickness reference flaw with a length 6 times its depth is a conservative assumption
  - Establish appropriate fatigue crack growth law for calculating the final end-of-interval flaw size

CASS Code Case Actions

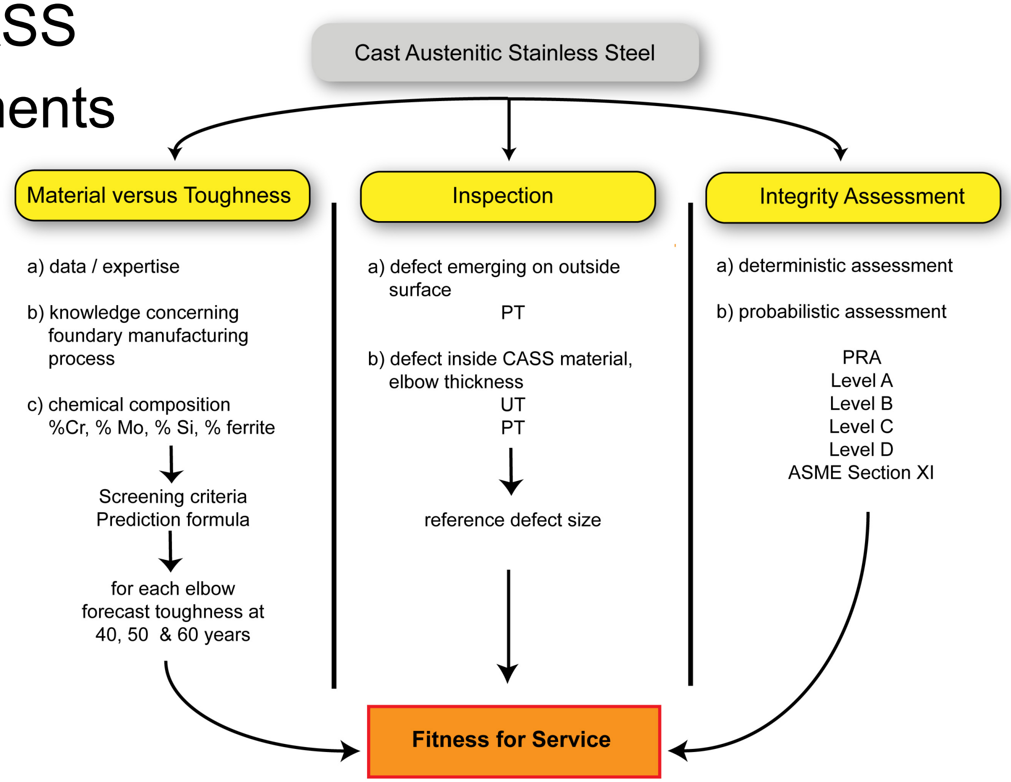
Flaw Tolerance of CASS

- Evaluation of CASS components would include *(continued)*
  - Determine revised flaw acceptance standards for high delta ferrite CASS components (using probabilistic fracture mechanics methodology and defined failure probability)
  - Define acceptable inspection program for susceptible CASS component locations using the flaw tolerance analysis approach
- Code Case intended to be used to demonstrate flaw tolerance and not for evaluation of detected flaws
- Currently being reviewed and refined

CASS Code Case Actions

Systematic Management of Aging CASS

- Ability to determine the fitness for service of aging CASS depends on three elements
  - Material versus toughness
  - Inspections
  - Integrity Assessment



Conclusions

- Significant developments and rethinking related to inspection of CASS in recent years
  - ASME Section XI Task Group on CASS Inspection has been tracking these developments and incorporated many of the findings into a number of CASS-related Code actions
- After 22 years Code Case ISI 90-03 for Appendix VIII, Supplement 9 CASS qualification requirements may finally be completed in the near future
- Due to the nature of CASS, it is likely that the Code Case will be quite different from other Appendix VIII Supplements