ASME

SETTING THE STANDARD

Use of ASME Nuclear Codes and Standards for Design, Construction, and Inservice Inspection and Testing

International Conference on Nuclear Engineering

Early Career Engineer Training

Orlando, Florida

May 12-13, 2008

Outline

- ASME Nuclear Codes and Standards
- ASME Boiler and Pressure Vessel (BPV) Code
- Construction of Nuclear Power Plant Components
- Inservice Inspection and Testing of Nuclear Power Plant Components
- Design Case Study

ASME Nuclear Codes and Standards

- NQA-1 –Quality Assurance
- OM Code – Operation and Maintenance
- N509/510/511 - Air and Gas Treatment
- NOG-1/NUM-1 - Cranes
- QME-1 – Component Qualification
- RA-S – Probabilistic Risk Assessment
- Accreditation

ASME Nuclear Codes and Standards

- Boiler and Pressure Vessel Code
  - Nuclear Sections
    - Section III – Nuclear Construction
    - Section XI – Nuclear Inservice Inspection
  - Service Sections
    - Section II – Materials
    - Section V – Nondestructive Examination
    - Section IX – Welding Qualifications

Brief History of the BPV Code (Why the Code is the way it is)

- ~1660 – 1st confirmed use of steam power
- ~1680 – 1st confirmed boiler explosion, operator killed
- ~1800 – operating pressure increased 10 times (5→50 psi)
- Throughout 1800's, boiler size and operating pressure continued to increase
- Number of explosions tripled between 1879 and 1899 (to more than one per day)
- Typical explosion destroyed factory and killed and injured scores of people
- Steam boat Sultana explosion killed 1500 people

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Brief History of the BPV Code (Why the Code is the way it is)

- 1915 - ASME Boiler and Pressure Vessel (BPV) Code published
- Purpose
  - Safety (pressure boundary integrity)
  - Assure suitability for installation

BPV Code Content and Structure

- Requirements are practical
- Can be empirical (e.g., thickness equations for simple shells predates the hoop stress theory)
- BPV Code is not a Handbook (e.g., allowable materials are listed, selection of the material is the responsibility of the manufacturer)
- Evolve over time to address emerging needs
- Annual revisions

ASME BPV Code Section III Construction of Nuclear Power Plant Components

- Evolved from BPV Code Sections I and VIII and U.S. Department of Defense Naval Reactors development program in 1963

Nuclear Inservice Inspection and Inservice Testing

ASME Boiler and Pressure Vessel Code Section XI

ASME Code for Operation and Maintenance OM Code

Rick Swayne
Reedy Engineering

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ASME BPV Code Section XI
Inservice Inspection of Nuclear Power Plant Components

- ASME BPV Subcommittee on Nuclear Power
  - Now Subcommittee on Nuclear Inservice Inspection
- Published 1970
- Response to U.S. Nuclear Regulatory Commission (NRC)
- Immediately mandated by NRC

USNRC Rules and Regulations

- Code of Federal Regulations
  - Title 10, Part 1, Energy
- 10 CFR 50.55a – Codes & Standards
  - Section III, Section XI, OM Code
- 10 CFR 50 Appendix B
  - Quality Assurance Program
- Technical Specifications
- NRC Generic Communications
- Approved alternatives

Inservice Inspection (ISI) and Inservice Testing (IST)

Why test and inspect?

- Functional degradation
  - Active mechanical equipment
- Structural degradation
  - Active and passive mechanical equipment

Inservice Inspection (ISI) and Inservice Testing (IST)

Why test and inspect?

- Prevent structural failure
- Prevent fluid leakage
- Prevent radiation leakage
- Prevent loss of operability

Inservice Inspection (ISI) and Inservice Testing (IST)

Why test and inspect?

- Aging management
  - Monitor degradation
  - Maintain design margins

Active Functions

- Wear
- Corrosion
- Erosion
- Vibration
- Leakage
- Radiation damage
- Thermal aging
- Unusual or unanticipated loads

Passive Functions

- Corrosion
  - General oxidation
  - Pitting
  - Crevices
  - Microbiological
  - Flow-accelerated
  - Erosion/cavitation

Passive Functions

- Stress corrosion cracking
  - Intergranular
  - Transgranular
  - External Chloride
  - Primary Water

Passive Functions

- Fatigue
  - Mechanical
  - Thermal
  - Corrosion
- Irradiation embrittlement
- Unanticipated events
  - Water hammer
  - Pressurized thermal shock
  - Large seismic event

Detection of Degradation

How do we detect degradation?

- Establish baseline
  - As early as possible
  - Using inservice methods
  - Update after changes
- Monitor changes
  - Performance testing
  - Nondestructive examination
  - Destructive testing

Performance Testing

- Pumps
  - Vibration
  - Flow rate
  - Differential pressure
  - Bearing temperature
- Valves
  - Stroke time
  - Seat leakage for RCS or containment isolation
  - Relieving Pressure
- Snubbers
  - Range of motion
  - Lockup

Destructive Testing

- Tensile testing
- Impact testing

Nondestructive Testing and Examination

- Chemical analysis
- Volumetric examination
  - Radiographic, ultrasonic, eddy current, acoustic emission
- Surface examination
  - Liquid penetrant, magnetic particle, ultrasonic, eddy current
- Visual examination
- Leak testing

Design for ISI & IST

- How are inservice inspection and testing considered in design and construction?
- Who is responsible?

Design for ISI & IST

- Designer responsibilities
  - Identify degradation mechanisms
  - Select resistant materials
  - Understand examination and testing methods capable of detecting degradation
  - Provide access for examination and testing (NDE, chemical, mechanical, functional)

Access Requirements

- Physical space around component, volume, or surface
- Physical or visual access of personnel
- Environmental hazards
- Equipment limitations
- Instrumentation

Questions

Industry Events from a Code and Regulatory Perspective

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Unanticipated Problems

- Lack of accessibility for ISI
- Loss of fracture toughness
- Flow-accelerated corrosion
- Intergranular / primary water stress corrosion cracking (IGSCC/PWSCC)
- Microbiological corrosion (MIC)
- Containment vessel corrosion

Lack of Accessibility

- No automated ISI methods
- ISI needs unknown
- Degradation methods unknown
  - General corrosion
  - Thermal and mechanical fatigue
  - Neutron embrittlement
- 10 CFR 50.55a and Section III & XI revisions have been insufficient
- Designers need to solve

Loss of Fracture Toughness

- Neutron embrittlement hard to predict
- Vessels with low starting toughness
- Section III & XI revisions provide solution

Flow-accelerated Corrosion

- Unanticipated
- Designer selects materials
- Owners don’t want Code or regulatory requirements
- Section XI revisions limited to analytical solutions
- Designers must specify Cr-Mo or PE pipe

Stress-corrosion Cracking

- Unanticipated
- Designer selects materials
- Significant safety issue
  - Challenges leak-before-break assumptions
- Nonlinear propagation rate
- Inadequate NDE
- 10 CFR 50.55a and Section III & XI revisions
- Owners replace or overlay
- Designers must specify resistant materials and configurations

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Microbiological Corrosion

- Unanticipated
- Designer selects materials
- No Code or regulatory requirements
- Designers must specify resistant materials

Containment Vessel Corrosion

- Degree unanticipated
- Design issue more than material issue
- 10 CFR 50.55a and Section XI revisions
- Designers must specify resistant materials or coatings or prevent wetting

Questions

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