Accelerator Safety Workshop

Pressure Safety Issues at Accelerators

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August 7-9, 2007

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10CFR851 Pressure Safety Requirements

- Contractors must establish safety policies and procedures to ensure that pressure systems are designed, fabricated, tested, inspected, maintained, repaired, and operated by trained and qualified personnel in accordance with applicable and sound engineering principles
- Contractors must ensure that all pressure vessels, boilers, air receivers, and supporting piping systems conform to:
  - The applicable American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (2004); sections I through section XII including applicable Code Cases
  - The applicable ASME B31 (Code for Pressure Piping) standards
  - The strictest applicable state and local codes

ASME Code History

- Boiler explosions common in early 1900s
- From 1899 to 1905, 1300 people killed in 1600 explosions
- First rules by Committee, 3 pages
- Today's rules, 6 feet stacked high
- Rules adopted by a number of legal jurisdictions (states)
- DOE adopted rules via 10CFR851 in 2007
- Authorized Inspectors enforce Codes via National Board of Boiler and Pressure Vessel Inspectors (1919 to today)

Pressure Safety Codes Referenced in 10CFR851

- Twelve Sections of Boiler and Pressure Vessel Code
  - I. Power Boilers
  - II. Materials Specifications
  - III. Nuclear Components
  - IV. Heating Boilers
  - V. Nondestructive Examination
  - VI. Rules for Care and Operation of Power Boilers
  - VII. Guidelines for Care of Power Boilers
  - VIII. Pressure Vessels
  - IX. Welding and Brazing Qualifications
  - X. Fiber-Reinforced Plastic Pressure Vessels
  - XI. Rules for In-Service Inspection of Nuclear Power Plant Components
  - XII. Construction and Continued Service of Transport Tanks
- Addenda / Interpretations / Code Cases
- ASME B31 (ASME Code for Pressure Piping)
- Strictest Applicable State And Local Codes

General Issues

- Date of ASME B&PV standard in 10CFR851 is 2004
  - Code is updated every three years
  - Code indicates one has NO CHOICE but to use the latest version
  - 6 months grace period from contract to build
  - 2007 versions are starting to ship
  - New materials dictate most updates
  - Cannot predict other changes but major rules do change
  - 2007 Section VIII Division 2 saves money and has modern methods
- Design to ASME Code is easy but rules for fabrication and testing apply
  - E.g., ASME Authorized Inspector (AI), usually an insurance company
  - DOE's past savings were due to not using an AI
- Once built, you can use whatever Code applied when built for any modification at any time in the future, if you wish
  - Again problematic 2004 date in 10CFR851

ASME Section VIII Pressure Vessels

- Design and Fabrication of Pressure Vessels
  - 3 Divisions to choose from, all equally safe
    - Trading QA and testing for thickness
  - Code does not dictate which Division is applicable
    - Division 1, 90 years old, semi-empirical models, conservative (fat)
    - Division 2, brand new 2007 update, better models allowed
      - Less materials costs (less thickness allowed)
      - More fabrication QA and testing costs involved
      - Studies show Division 2 usually saves money over Division 1
    - Division 3, usually high-pressure vessels (e.g., 350,000 psi)
      - Very great amount of QA and testing
    - All Divisions can be used for any vessel
      - Most owners go with most economical
  - Code Cases carry same weight as Code

Some Section VIII Exclusions

- Integral parts such as pumps and compressors
- Vessels containing water up to a certain temperature and pressure
- Vessels having internal or external operating pressure not exceeding 15 psi
- Vessels having inside diameter not exceeding 6 inches

10CFR851 Rule Definition

- *Pressure systems* means all pressure vessels, and pressure sources including cryogenics, pneumatic, hydraulic, and vacuum. Vacuum systems should be considered pressure systems due to their potential for catastrophic failure due to backfill pressurization. Associated hardware (*e.g.*, gauges and regulators), fittings, piping, pumps, and pressure relief devices are also integral parts of the pressure system.

DOE Area Office Response

- …The ASME B&PV Code does NOT consider *vacuum* systems to be "pressure vessels" because their internal nor external operating pressures do not exceed 15 psi. Therefore, the ASME code is NOT applicable to vacuum systems. *DOE HSS has also vaguely acknowledged that ASME Code is not applicable to vacuum systems (see attached HSS Response to Frequently Asked Questions from their 10 CFR 851 Guide).*
- … Appendix A provides specific measures to be taken if ASME Code is not applicable *(i.e., design by a PE, qualified personnel used to perform examinations and inspections, documentation and accountability for each pressure vessel).*

Scope Statement in ASME Pressure Vessel Code

- "Laws or regulations issued by municipality, state, provinces, federal, or other enforcement or regulatory bodies having jurisdiction at the location of an installation establish the mandatory applicability of the Code rules, in whole or in part, within their jurisdiction. Those laws or regulations may require the use of this Division of the Code for vessels or components not considered to be within its Scope. These laws or regulations should be reviewed to determine size or service limitations of the coverage which may be different or more restrictive than those given here."

Issues

- B&PV Code allows one to draw pressure boundary around gauges, regulators, windows, etc.
  - ASME calls these items 'proprietary items'
  - Exempt from the vessel Code
- Any pressure vessel that meets Code may be stamped
  - Many companies stamp vacuum vessels due to liability
  - Code Case 2286 deals with externally pressurized vessel design and buckling
- Internal pressure ala 10CFR851 'backfill pressurization' scenario is confusing wording
- B&PV Code would cover vacuum vessel if internal or external pressure can go above 15 psi
- ASME says owner, not Code, decides how much failure risk to take where appropriate
  - LNG facility in Abu Dhabi versus one in Ohio – one is designed for grenade overpressure
  - Owners add earthquake and wind loads when applicable for safety or for local compliance
  - Even if failed vessel presents no risk, any pressure scenario over 15 psi is inclusive ala 851
  - Stored energy may be safety issue for vacuum vessel as opposed to backfill pressure
  - Should we use threshold value of 100,000 joules (515 psi-ft^3) for stored energy issue?
- Code does not address all aspects
  - ASME says what is not addressed should not be considered prohibited
  - ASME Code says you are on your own to make it safe
  - 10CFR851 says you must meet ASME level of protection or better

Issues

- ASME Codes deal with design fabrication, inspection and testing of NEW CONSTRUCTION only
- Maintenance, in-service inspection and repair rules can be found in National Board Inspection Code (NBIC)
  - Not referenced in 10CFR851
  - Not referenced in ASME Code
- BUT most state and local codes contain maintenance, repair and operation standards for pressure systems
  - Do we adopt NBIC if no state or local code?

Materials Issues

- ASME allows a piece of paper for similar material
  - Material not listed in ASME Code
  - However, material with similar chemical, mechanical and thermal properties is listed
  - Owner or manufacturer can write paper
  - Creating piece of paper for similar material is ‘re-certifying’
- If you want new material listed, then contact ASME
  - ASME B&PV Code Appendix 16 describes this process

Issues

- What ‘paper’ do we use to ‘re-certify’ a similar material?
- Who takes the lead to request new materials (e.g., niobium) be listed by ASME?

Impact Tests at Low Temperatures

- ASME toughness requirements – impact testing is mandatory for materials less than -425 ^{o}F
  - Concern is brittle fracture
  - Impact tests cannot be performed at LHe and LH temperatures because ambient heating from impact raises temperature of test specimen above design metal temperature
  - ASME Codes have appendices (UCS, UNF, UHA) that appear to address this issue

10CFR851 Equivalent or Better Protection

- "When national consensus codes are not applicable (because of pressure range, vessel geometry, use of special materials, etc.), contractors must implement measures to provide equivalent protection and **ensure a level of safety greater than or equal to the level of protection afforded by the ASME** or applicable state or local code"

Issue

- What is equivalent or better protection?

- Something that reduces risk (frequency and severity)?
- Something that reduces severity only?
- A mechanical engineering mechanism such as a relief valve?
- An interlock system?
- An administrative procedure?

10CFR51 Equivalence or Better Process

- Measures must include the following:
  - (1) Design drawings, sketches, and calculations must be reviewed and approved by a qualified independent design professional (*i.e.*, professional engineer). Documented organizational peer review is acceptable
  - (2) Qualified personnel must be used to perform examinations and inspections of materials, in-process fabrications, nondestructive tests, and acceptance test
  - (3) Documentation, traceability, and accountability must be maintained for each pressure vessel or system, including descriptions of design, pressure conditions, testing, inspection, operation, repair, and maintenance

Issues

- What are qualifications of peer reviewers?
  - (1) Design drawings, sketches, and calculations must be reviewed and approved by a qualified independent design professional (*i.e.*, professional engineer). Documented organizational peer review is acceptable
    - Trained in Codes?
    - Education?
    - Experience?
    - Certifications?

Issues

- What is meant by qualified personnel?
  - (2) Qualified personnel must be used to perform examinations and inspections of materials, in-process fabrications, nondestructive tests, and acceptance test
    - Independent 3rd party examiners and inspectors?
    - Authorized Inspector?
    - ASME qualified welding procedures?
    - Welders qualified to those procedures?
    - ASME qualified QA program for fabrication facility (B&PV Code Appendix 10, which is mandatory)?

Issues

- Do we file ASME Data Report forms?
  - (3) Documentation, traceability, and accountability must be maintained for each pressure vessel or system, including descriptions of design, pressure conditions, testing, inspection, operation, repair, and maintenance
    - Do we create our own repository for these forms?
    - Normally Data Reports go to NBIC
    - Do we use our own stamp (U, R, L …)?

Issues

- Fabrication
  - Duties of Authorized Inspector (AI) spelled out in Code
  - AI must check fabricators compliance with Code and Code's QA requirements
  - AI must make all inspections specified by the Code
  - AI must verify calculations have been made
  - AI must sign the data report
  - Defects in materials may be repaired only by prior approval of an AI
- Tolerance Requirements
  - How many locations to be checked for out-of-tolerance is at discretion of AI
  - Measuring deviations from true form in a knuckle must be worked out with an AI

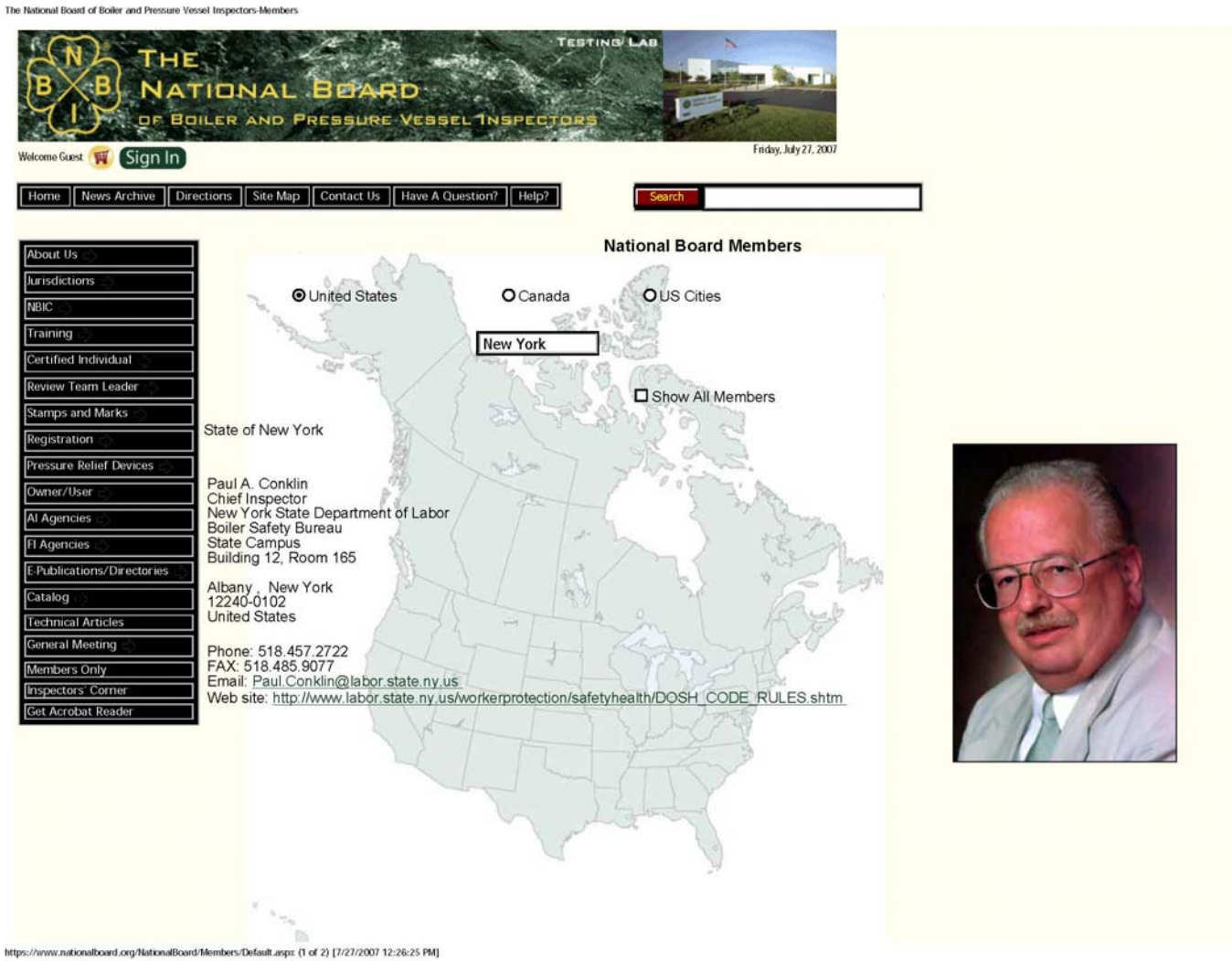
Issues

- Overpressure Test
  - Duration of overpressure test not specified in ASME Code, 1 hour is standard, but NBIC says 10 minutes
  - Should accelerators standardize on 1 hour?
- Stamping Requirements
  - L Mark (concern is release of unhealthy substance from vessel; e.g., Hg, SF6, etc.)
  - Minimum plate requirements, what do we adopt?
- New 2007 Division 2 Section VIII addresses records
  - Do we follow 2007 since 2004 version is in 10CFR851?

Maintenance, In-Service Inspection, Repair

- National Board of B and PV Inspectors founded in 1919 (all states belong):
  - Promotes increased safety in the industry
  - Allows efficient use of inspectors and their time
  - Allows sales between multiple states
  - Provides the only central repository for manufacturers' data reports
- Some changes have occurred over the years, including:
  - The inspectors engaged in new fabrication inspections are referred to as "Authorized Inspectors"
  - Authorized Inspectors must receive additional training and obtain an endorsement on their commission relative to the type of equipment they inspect
  - National Board registration was allowed for pressure vessels, piping, and nuclear components as the ASME Code grew to include those items
  - National Board registration has expanded to include pressure retaining items constructed in accordance with multiple international standards meeting specific criteria and accepted by the National Board
  - An "NB" symbol stamp has been implemented for manufacturers to stamp adjacent to the National Board number

National Board



Example Piece of NY State Code

... (mm) Unfired pressure vessel means a container for the containment of internal or external pressure which may be obtained from an external source or by the application of heat from a direct or indirect source, or any combination thereof, but excluding:

(1) a pressure vessel meeting the requirements of the United States department of transportation for the shipment of liquids or gases under pressure;

(2) an air tank used on a vehicle used for carrying passengers or freight or used directly in the operation of trains;

(3) a pressure vessel having a volume of five cubic feet or less or having an inside diameter not exceeding six inches;

(4) a pressure vessel designed for pressures of less than 15 psi;

(5) a hot water supply storage tank, provided none of the following limitations is exceeded:

(i) a heat input of 200,000 BTU's per hour;

(ii) a water temperature of 210° Fahrenheit; or

(iii) a nominal water containing capacity of 120 gallons;

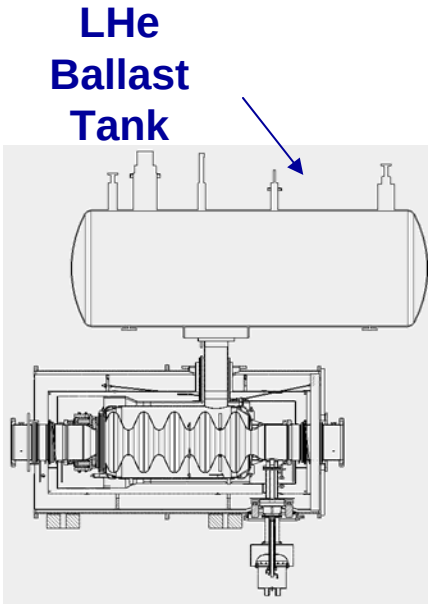
(6) a pressure vessel under Federal control or regulation;

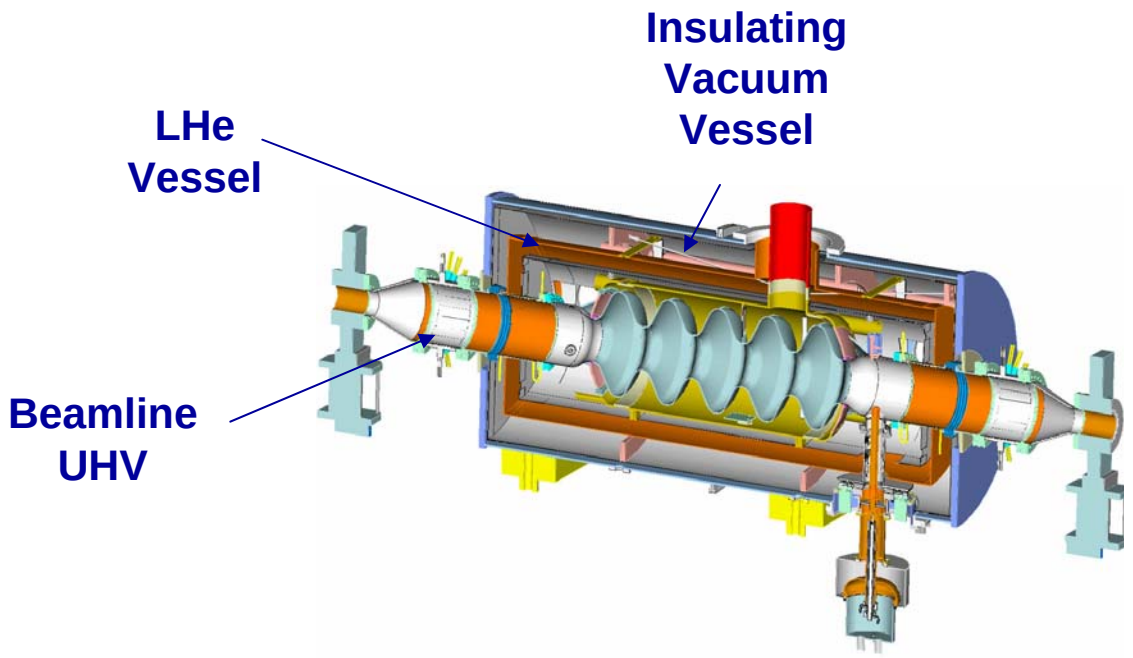
...

Status at BNL

- BNL has a Laboratory ESH Committee
  - Equivalence authority delegated to Pressure and Cryogenic Safety Subcommittee (PCSS)
- PCSS reviews compliance with pressure rules in 10CFR851
- PCSS has started training members in ASME Codes
- For external pressure and internal pressure on vacuum systems, PCSS has 100,000 joule (515 psi-ft^3) stored-energy threshold
- BNL does not have an AI or U, R or L stamp capability
- BNL has AWS certification for welding
- Majority of cryogenic systems are not code stamped
- A system for retention of materials certifications and welding inspection records is being developed
- We are procuring new software for design calculations
- We are investigating NBIC, state and local codes

Example PCSS Problem: ERL SCRF Cavity





Three Closed Volumes with safety implications:

- Beam Line vacuum – internal to the SCRF Cavity and upstream and downstream of cavity
- LHe/cryogenic system volume – external to the RF Cavities
- Insulating Vacuum – external to the LHe system volume

Example Summary of PCSS Issues

- Cavities have materials and processes not covered by ASME code
  - Niobium internal vacuum vessel – thin walls needed for tuning, no fat
  - No niobium materials listed in ASME Code
- Cryogenic designs used for cavities have been successful in past
- Cleanliness requirement makes pressure testing of completed assembly cost prohibitive
- External insulating vacuum vessel has 5 psig pressure relief
  - Not stamped but made in ASME fabricator's shop
- He vessel has welding certifications, pressure tests, materials certification, shop QA
- Niobium vessel is treated as separate pressure vessel due to backfill pressurization from He
- Low pressure results in relief system that is not in code compliant range
- Can add 8 psig burst disks on niobium cavity to deal with internal pressure
  - Cavity was internally pressure tested to 22 psia, which changed its tune about 10 MHz
- Due to off-normal operation of LHe system, external pressure on niobium cavity >15 psi
- We can design out ODH problems; no risk to personnel if it implodes

Summary of 10CFR851 Issues

- **Date of Codes referenced in 10CFR851**
- **Unclear language in 10CFR851 'pressure' definition**
  - **Can we use a risk? Risk is implied in 10CFR851 'pressure' definition**
    - 'Vacuum systems should be considered pressure systems due to their potential for catastrophic failure due to backfill pressurization'
- **What is equivalent or better protection?**
  - **Qualifications of peer reviewers and welders?**
  - **Do we use Authorized Inspector? What is equivalent?**
  - **Documentation (e.g., equivalent stamp, Data Record)?**
  - **Equivalent fabrication facility QA?**
- **Listing new materials, who?**
- **Re-certifying similar materials, what 'paper' should we all use?**
- **Maintenance, in-service inspection, repair rules; do we use NBIC?**