



# **Pressure Boundary Codes and Standards Applicable to CANDU Fuel Channels**



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## **PRESSURE BOUNDARY CODES AND STANDARDS APPLICABLE TO CANDU FUEL CHANNELS**

- **The ASME Code design and material requirements are used for CANDU pressure boundary components whenever it is practical to do this.**
- **Thus most CANDU pressure boundary components fully comply with the ASME material requirements (fabrication specifications and allowable properties) and the ASME design/analysis rules.**
- **However, not all of the unique pressure boundary components/requirements for a pressure tube reactor are adequately addressed by ASME, e.g., cold-worked Zr-2.5%Nb (R60901) material has been developed as a practical pressure tube material.**



## **PRESSURE BOUNDARY CODES AND STANDARDS APPLICABLE TO CANDU FUEL CHANNELS**

The Canadian Standards Association (CSA) has published “rules to complement those of ASME”. Its N285 series of Standards provides appropriate requirements for the unique features of a pressure tube reactor with on-power refuelling. For example:

- |                               |  |
|-------------------------------|--|
| <b>CSA-N285.0</b>             | <b>General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants</b>              |
| <b>CSA-N285.2</b>             | <b>Requirements for Class 1C, 2C and 3C Pressure-Retaining Components and Supports in CANDU Nuclear Power Plants</b> |
| <b>CSA-N285.4</b>             | <b>Periodic Inspection of CANDU Nuclear Power Plant Components</b>   |
| <b>CSA-N285.6</b>             | <b>Material Standards for Reactor Components for CANDU Nuclear Power Plants</b>                                      |
| <b>CSA-N285.8<br/>(draft)</b> | <b>Technical Requirements for In-Service Evaluation of Zirconium Alloy Pressure Tubes in CANDU Reactors</b>          |



# **CSA-N285.0: GENERAL REQUIREMENTS**

- **Scope**
- **Reference Publications and Definitions**
- **General Requirements**
- **Responsibilities**
- **Classification**
- **Registration**
- **Design**
- **Materials**
- **Fabrication and Installation**
- **Quality Assurance**
- **Inspection, Examination and Testing**
- **Records, Identification and Reports**
- **In-Service Requirements**
- **Supports**



## **CSA-N285.0: GENERAL REQUIREMENTS**

- **Clause 7 on Design**
  - “Class 1 systems and components shall be designed to comply with the requirements of Section III, Division 1, NB-3000.”
  - “In addition to the requirements of clause 7, components classified as Class 1C, 2C, 3C shall be designed to comply with the requirements of CSA Standard CAN/CSA-N285.2.”
  
- **Clause 8 on Materials**
  - “Material for pressure-retention in Class 1 systems and components shall comply with the requirements of Section III, Division 1, NB-2000 or CSA CAN/CSA-N285.6.”



## **CSA-N285.2: TECHNICAL RULES TO COMPLEMENT THOSE OF ASME**

- **Scope**
- **Definitions, Reference Publications and Abbreviations**
- **General Requirements**
- **Specific Requirements**
- **Fuel Channel Assemblies**
- **Calandria Assembly**
- **Reactivity Control Units**
- **Joints Between Tubular Components**
- **Fuel-Handling Equipment**



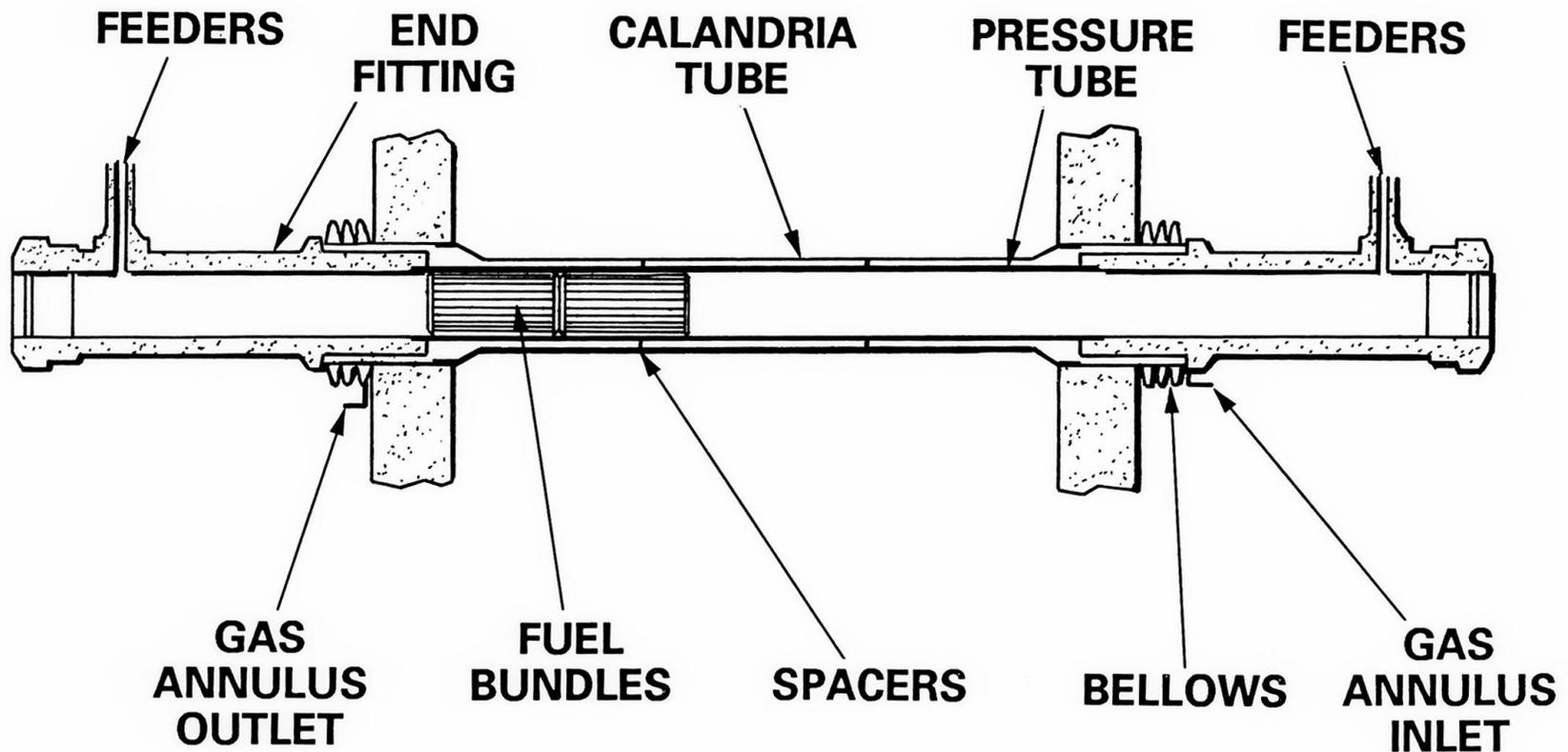
# **CSA-N285.2: TECHNICAL RULES TO COMPLEMENT THOSE OF ASME**

## **Clause 5 on Fuel Channel Assemblies**

- **General**
- **Pressure tube to end fitting joints**
- **Pressure tubes**
- **Channel closure**



# SCHEMATIC FOR A CANDU FUEL CHANNEL





## **CSA-N285.2: TECHNICAL RULES TO COMPLEMENT THOSE OF ASME**

### **Section 5.2 on Pressure Tube to End Fitting Joints**

- **“joints shall be designed in accordance with the rules of Section 3, paragraph NB3200 (design by analysis) of the ASME Boiler and Pressure Vessel Code”.**
- **“prototype joints shall be subjected to performance tests to determine the structural integrity of the joints under simulated service conditions”.**
- **the rolled joint “pullout load shall exceed three times the design condition axial load, including pressure, when the test is performed at design temperature”.**
- **all production rolled joints must be inspected to confirm that the key “parameters determined from the prototypes (eg, pressure tube wall thickness reduction) have been achieved”.**



## **CSA-N285.2: TECHNICAL RULES TO COMPLEMENT THOSE OF ASME**

### **Section 5.3 on Pressure Tubes**

**In addition to satisfying the ASME class 1 design/analysis rules, pressure tubes must also satisfy additional requirements which include:**

- The maximum pressure tube tensile stress due to applied loadings, plus the maximum tensile residual stress, must not “exceed 67% of the tensile stress required to initiate delayed hydride cracking as determined in the laboratory by tests on unnotched specimens.”**
- A pressure tube must “not contact the calandria tube” surrounding it (so hydride will not accumulate and form blisters at the cool spot in the pressure tube).**
- There must be a “system capable of detecting leaks (from pressure tubes) before through-wall cracks grow to unstable lengths”; Leak-Before-Break (LBB).**



## **CSA-N285.2: TECHNICAL RULES TO COMPLEMENT THOSE OF ASME**

### **Section 5.4 on Channel Closure**

**Channel closures are a removeable pressure boundary component at the outboard end of an end fitting to permit on-power refuelling. In addition to satisfying the ASME class 1 design/analysis rules, channel closures must also satisfy additional requirements which include that they:**

- “shall be locked in place by closure safety locks”.**
- “shall be tested for leakage each time they are installed and prior to removal of the fuelling machine.”**



## **CSA-N285.6: MATERIAL STANDARDS**

- **Pressure tubes**
- **Reactivity control rods**
- **Liquid injection shutdown system nozzles**
- **Calandria tubes**
- **Wire for fuel channel spacers**
- **Inspection criteria for zirconium alloys**
- **Zirconium alloy design data**
- **Fuel channel end fittings**
- **Supports**



## **MATERIAL REQUIREMENTS FOR PRESSURE TUBES**

- **CSA-N285.6.1 gives “requirements for the fabrication and properties of seamless zirconium alloy tubing suitable for use as the in-core portions of fuel channels”, ie, pressure tubes.**
- **ASTM-B353 now also specifies similar fabrication and properties requirements for zirconium alloy pressure tubes.**
- **CSA-N285.6.7 defines the peak allowable design stress in the same way as ASME (the lowest of two-thirds YS or one-third UTS).**
- **In addition, AECL has Technical Specifications that define additional requirements for pressure tubes.**



# **MATERIAL REQUIREMENTS FOR END FITTINGS**

**(the out-of-core extensions of a pressure tube)**

- **CSA-N285.6.8 defines the requirements for a modified type 403 stainless steel, including its inspection and design data.**
- **The modifications are restrictions in the chemical composition limits to ensure good corrosion resistance at seal faces and high strength where a pressure tube is rolled into the end fitting bore.**



# **PRESSURE BOUNDARY CODES AND STANDARDS APPLICABLE TO CANDU FUEL CHANNELS**

## **Summary**

**The CSA Standards define “rules that complement those of ASME”. Its additional design and material requirements ensure that the unique features of a pressure tube reactor with on-power refuelling satisfy the intent of the ASME Code.**



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