PRESSURE TUBE TO END FITTING ROLLED JOINTS

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PRESSURE TUBE TO END FITTING ROLLED JOINTS

- Rolled joints are joints between a tube and a hub that are made by cold-working the end of the tube into the hub to produce compressive residual stresses for sealing.
- Such joints are used extensively in CANDU reactors as they are a practical way to join dissimilar metals, eg, zirconium alloys and steels.
- No rules are given in the ASME Code for using roll-expanded joints in Class 1 systems, thus the CSA-N285.2 Standard defines rules for PT/EF joints so they will satisfy the intent of the ASME Code.
- The PT/EF rolled joint design has been developed, optimized and qualified primarily by extensive full-scale testing.
- The PT/EF rolled joint design used to date for all commercial CANDU reactors has a specified reduction (nominal value of 13.5%) in the PT wall thickness, which causes PT material to be extruded into 3 circumferential grooves in the bore of an EF. This produces a strong and leaktight joint.

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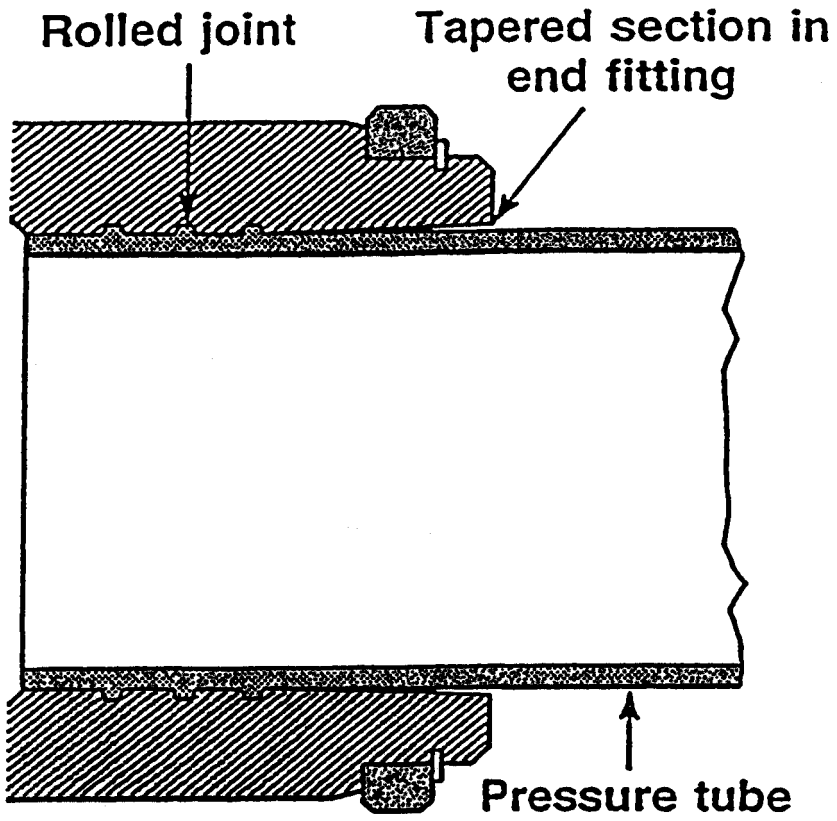

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- No PT/EF rolled joint has been pulled apart by a reactor's coolant pressure.
- Except some early joints, PT/EF rolled joints have performed reliably.
- Some early joints were "over-extended", which resulted in tensile residual stresses in pressure tubes that were large enough to initiate Delayed Hydride Cracking.

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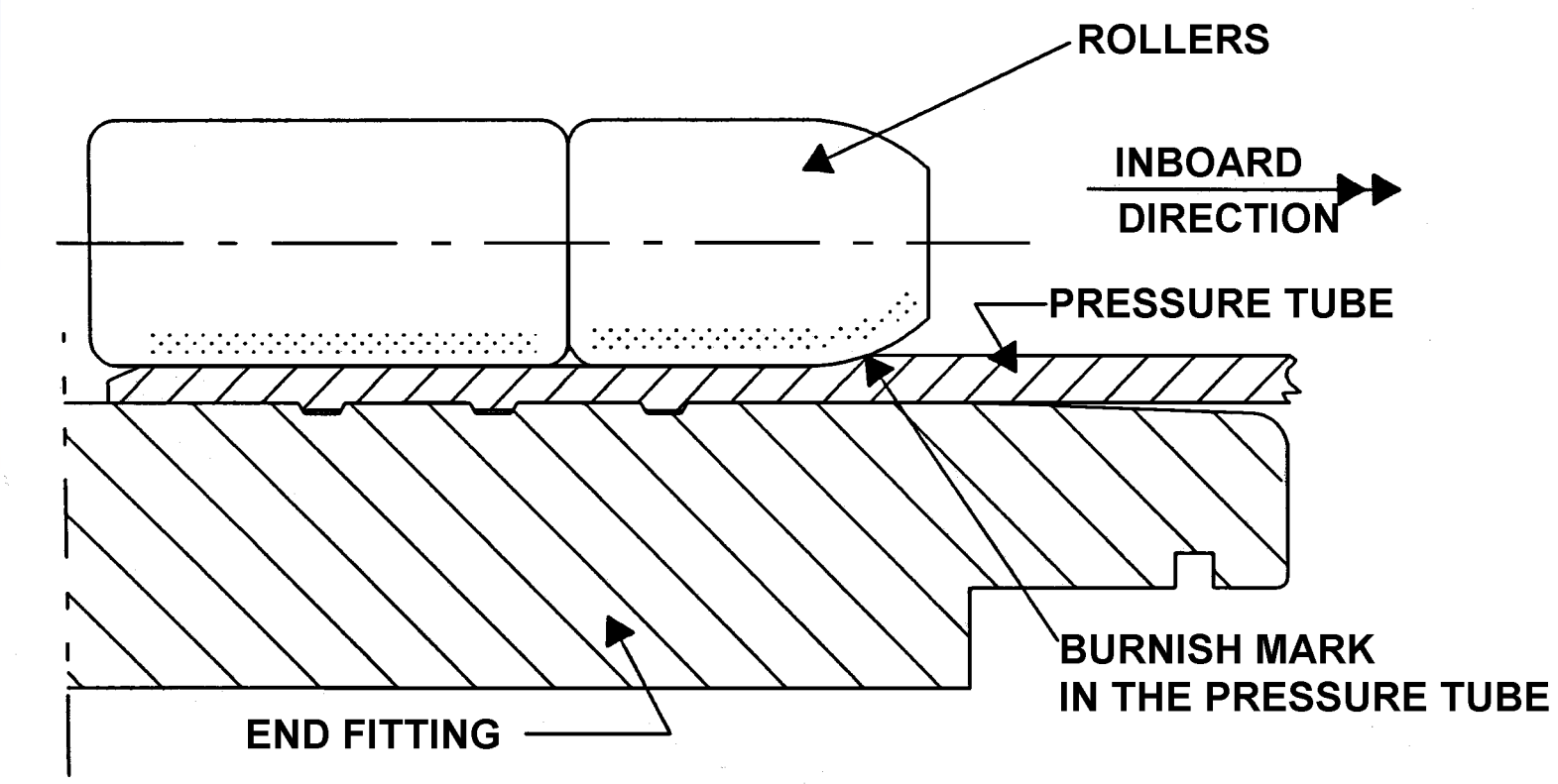

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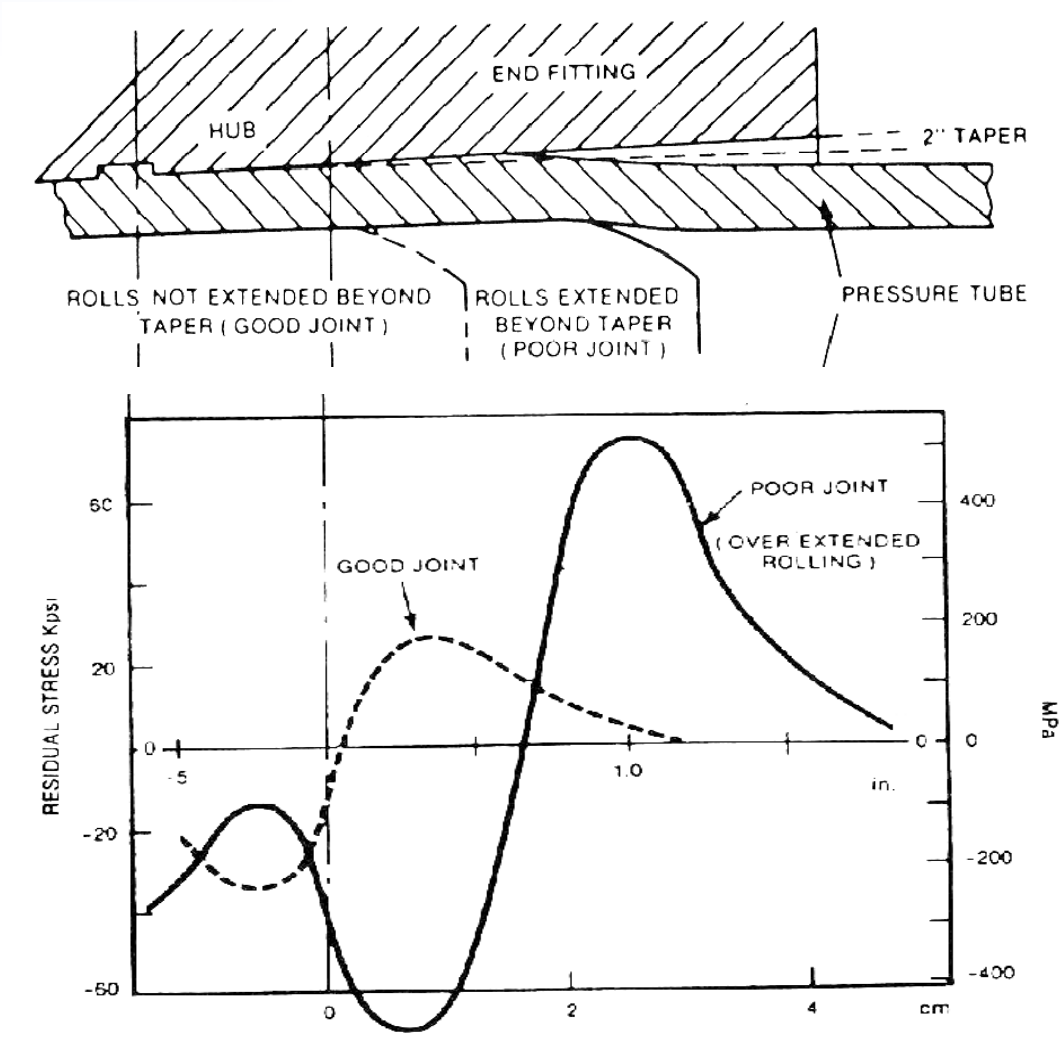

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- To reduce the PT tensile residual stresses and eliminate PT cracking, two actions were taken:
  - Ensure that PT/EF rolled joints would not be “over-extended” and
  - Reduce the PT/EF diametral clearance.
- A “zero-clearance” PT/EF rolled joint was developed then used in the construction of the current generation of CANDU reactors (diametral fit of 0.002 inch clearance to 0.007 inch interference)
- This “zero-clearance” joint has been very reliable, strong and leaktight, ie, it fully satisfies the 3 primary performance requirements for a PT/EF rolled joint:
  - Low PT tensile residual stress,
  - High pull-out strength and
  - Low leakage.

LOW PT TENSILE RESIDUAL STRESS

- Residual stresses in the rolled portion of a PT are compressive, which is not a concern.
- Tensile residual stresses may exist in a PT slightly inboard of the rolled portion of the PT.
- The CSA-N285.2 Standard requires that the maximum PT tensile stress due to operating/upset loads, plus the maximum tensile residual stress, not “exceed 67% of the tensile stress required to initiate delayed hydride cracking as determined in the laboratory by tests on unnotched specimens.”
- PT/EF rolled joints used during the construction of the current generation of CANDU reactors easily satisfy this requirement.

LOW PT TENSILE RESIDUAL STRESS

Testing has demonstrated that pressure tube residual stresses relax during reactor operation.

HIGH PULL-OUT STRENGTH

- The strength of a PT/EF rolled joint is determined in a pull-out test during which an axial load pulls the PT out of the EF bore.
- The CSA-N285.2 Standard requires that the pull-out strength of PT/EF rolled joints “exceed three times the design condition axial load, including pressure, when the test is performed at design temperature”.
- PT/EF rolled joints used to date in the construction of CANDU reactors easily satisfy this requirement.

HIGH PULL-OUT STRENGTH

- Since the pull-out strength of a PT/EF rolled joint is primarily due to the PT material extruded into the EF grooves, it is not affected by the stress relaxation that occurs during reactor operation.
- Testing has demonstrated that the pull-out strength of a PT/EF rolled joint increases with reactor operation.

LOW LEAKAGE

- PT/EF rolled joints need to be very water leaktight.
- Every PT/EF rolled joint made during the construction of a CANDU reactor has been helium leak tested and shown to have very low helium leakage.

LOW LEAKAGE

Testing (and reactor operation) has demonstrated that stress relaxation (time at temperature) and temperature/pressure cycling during reactor startups/shutdowns have a minimal effect on leaktightness.

REACTOR CONSTRUCTION

- Before any PT/EF rolled joints are made during reactor construction, personnel, procedures and tooling are qualified by making joints in a full-scale fuel channel mock-up.
- Each PT/EF rolled joint made during reactor construction is inspected to verify its structural integrity before reactor start-up, which includes measuring:
  - Burnish mark location
  - PT wall reduction
  - Helium leaktightness

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Summary

- There are about 20,000 PT/EF rolled joints of the current design in operating CANDU reactors and all of them have operated reliably.
- No PT/EF rolled joint has been pulled apart by a reactor's coolant pressure.


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