# Pressurized Water Reactor Pressure Vessels

Material from
*"Aging and Life Extension of Major Light Water Reactor Components"*
*edited by V. N. Shah and P. E. MacDonald*
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## Introduction

- **"In terms of plant safety, the reactor pressure vessel (RPV) is the most critical pressure boundary component in a PWR"**

- **The RPV ;**

  **1.) Vital safety barrier to fission product release**
  **2.) Supports and guides control rods**
  **3.) Supports vessel internals**
  **4.) Provides coolant around the reactor core**
  **5.) Directs reactor coolant to steam generator**

- **2 Major concerns for the RPV.**

  **1.) Radiation embrittlement**
  **2.) Fatigue**

# <u>Design and Materials</u>

- **Major US Vendors for RPV's**

  *Combustion Engineering (Now part of a European conglomerate)*
  *Babcock & Wilcox*
  *Westinghouse (via CE and B&W, Chicago Bridge & Iron, Rotterdam Dockyard)*

- **Different design specifications depending on date of fabrication**

  *Before 1963-ASME Boiler & Pressure Vessel Code, Sections I and III.*
  *After 1963-ASME Boiler & Pressure Vessel Code, Section III.*

- **Materials**

  *Earliest RPV's used SA302B steel (Table 3-1)*
  *Most vessels are made from SA533B (Table 3-1)*
  *Latest RPV's used low Cu/P contents*
  *Inside RPV is lined with stainless steel (types 304(early), 308 & 309) to reduced corrosion*

- **Heat Treatments**

  *All vessel welds were post heat treated at ≈ 610 ± 14 °C for 40-50 hr's (early) and ≈ 25 hr's in the newer RPV's.*

- **Diameters**

  *Westinghouse-3.35 to 4.11 meters*
  *Babcock & Wilcox-4.34 meters*
  *Combustion Engineering-3.99 to 4.37 meters*
  *Combustion Engineering System 80- 4.62 meters*

- **See Figure 3-1**

## Stressors

- **Primary Stressors**

  *Mechanical pressure loads during operation*
  *Periodic thermal transients*
  *Dead weight loads*
  *Pressurized thermal shock*

- **Other Important Parameters**

  *Temperature*
  *Water Chemistry*
  *Mechanical Contact*

- **Ductility is an important measure of performance**

  *Charpy V-notch---(CVN)*
  *Ductile to brittle transition temperatures (DBTT)*
  *Upper shelf energies (USE) (see figure 3-2)*

## Pressure-Temperature (P-T) Limits

- **PWR vessels typically experience pressures of 15.5 MPa (2250 psi) and temperatures of nearly 288 °C (550 °F) during normal steady state operation.**

- **Perturbations to these conditions are what set the limits to RPV performance.**

- **P-T limits require that plants operate above certain minimum and below certain maximum limits**

  *Minimum T to be above DBTT*
  *The reactor coolant pump characteristics govern the maximum T*

- **See Figure 3-3**
  *Note: if a critical size defect had been present at a critical site and the degree of radiation embrittlement had been severe*

*enough, this transient might have resulted in the rupture of the pressure vessel.*

- **Primary Transients Leading to Fatigue**

  **1.) Plant heatup/cooldown**
  **2.) Plant loading/unloading**
  **3.) Reactor trips**
  **4.) Loss of flow**
  **5.) Abnormal loss of load**

  **See Table 3-2**

## Degradation Sites

- **Beltline region (embrittlement)**

  ***Welds may be weakest link because early welding materials used Cu coated filler rods***

- **Geometric discontinuities (fatigue)**

  ***Closure studs***
  ***Outlet nozzles***
  ***Inlet nozzles***
  ***Instrumentation nozzles***
  ***Control rod drive nozzles***

## Degradation Mechanisms

- ***Generally corrosion and stress corrosion cracking are not a problem in PWR RPV's because water contains low $O_2$***

- ***Erosion and cavitation not a problem***
- ***High T creep not a problem***

## Radiation Embrittlement

- **Neutron fluence range-**

  ***$10^{18}$ to $10^{19}$ n/cm$^2$ (E> 1 MeV)***

- **Result for Charpy V-notch (CVN) specimens:**

  ***Increase in reference DBTT ($RT_{NDT}$) (usually measured at 41 J [30 ft-lb] energy, or, $T_{30}$)***

  ***Drop in upper shelf energy (USE)***