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Topical Report

Reactor Pressure Vessel Material Surveillance Program

Approved by
Vessels & Components Engineering Group

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0	Apr 28, 2009	Initial issue	K. Matsunaga Apr 28, 2009	K. Matsunaga Apr 28, 2009	Apr 28, 2009

1. Scope
This program defines the requirements for Reactor Pressure Vessel Material Surveillance Program for the US ABWR.

2. Applicable and Reference Laws, Codes and Standards
2.1 Applicable Laws, Codes and Standards
(1) NUREG-0800 Standard Review Plan 5.3.1 Reactor Vessel Material
(2) 10 CFR 50, Appendix H Reactor Vessel Material Surveillance Program Requirements
(3) ASTM E185-82 Standard Practice for Design of Surveillance Programs for Light-Water Moderated Nuclear Power Reactor Vessels
(4) Regulatory Guide 1.99 Rev.2 Radiation Embrittlement of Reactor Vessel Materials
(5) ASTM E23-07a Standard Test Methods for Notched Bar Impact Testing of Metallic Materials

3. Description
The materials surveillance program monitors changes in the fracture toughness properties of ferritic materials in the reactor vessel beltline region resulting from exposure to neutron irradiation and the thermal environment. Part of the specimens which are to be exposed to irradiation will be installed in removable specimen capsules at the inside vessel wall opposite the active core. The remaining unirradiated baseline specimens will be used to establish a material reference data.

4. Requirements
4.1 Type of Specimens
The dimensions of the tension and Charpy V-notch Impact Test Specimen (CV specimen) shall be in accordance with Figures 2 and 3.

4.2 Number of Capsules and Specimens
The number of surveillance capsules and test specimens are shown in Table 1.

4.3 Material
4.3.1 Material Selection
Surveillance test materials shall be full thickness samples taken from each of the actual materials used in fabricating the beltline of the reactor vessel or from weldments fabricated to match the reactor vessel weld. These surveillance test materials shall include a minimum of one heat of the base metal, one weld and one weld heat-affected zone (HAZ).
The base metal, weld metal and heat affected zone materials shall be included in the program.
The base metal and the weld with the highest adjusted reference temperature at end-of-life shall be selected for the surveillance program.

4.3.2 Heat Treatment
The fabrication history (austenitizing, quench and tempering, and post-weld heat treatment) of the test materials shall be fully representative of the fabrication history of the materials in the beltline of the reactor vessel.

4.4 Neutron Dosimeters
The neutron dosimeters shall be capable of providing information about fast neutron fluence, fluence rate, and spectrum. The neutron dosimeters shall be located within each vessel wall capsule. The neutron dosimeters materials should be high purity metals.

4.5 Temperature Monitoring
Temperature monitors shall be installed in the capsule to monitor the temperature of the reactor coolant.

Several types of alloy with melting points lower and higher than the anticipated temperature inside RPV are used for the temperature monitors.

5. Fabrication Requirements

5.1 Tensile Test Specimens

a. Base Metal

Specimens shall be removed from about the quarter-thickness (1/4-T) locations. Material from the mid-thickness of the base metal shall not be used for test specimens. The longitudinal axis of the specimen shall be parallel to the forging surface and perpendicular to the forging direction. (Figure 4)

b. Weld Metal Specimens

The longitudinal axis of the specimen shall be parallel to the welding direction. The specimen shall be taken in the center of the weld and at least 12.7mm away from the final weld surface and the root of the weld. (Figure 5)

c. Heat Affected Zone

The specimen shall be taken from at least 12.7mm away from the final weld surface. The longitudinal axis of the specimen shall be perpendicular to the welding direction and parallel to the surface. (Figure 5)

5.2 Charpy V-Notch (CV) Specimens

a. Base Metal

The specimen shall be taken from about the quarter-thickness(1/4-T). The longitudinal axis of the specimen shall be perpendicular to the forging direction. The length of the notch of the specimen shall be perpendicular to the surface. (Figure 4)

b. Weld Metal

The longitudinal axis of the specimen shall be perpendicular to the welding direction and parallel to the forging surface. The root of the notch shall be in the approximate center of the weld metal. The specimens shall be taken from at least 12.7 mm away from the final weld surface and the root of the weld. The length of the notch of the specimen shall be perpendicular to the surface. (Figure 5)

c. Heat Affected Zone

The longitudinal axis of the specimen shall be perpendicular to the welding direction and parallel to the forging surface. The center of the specimen shall be in the heat affected zone adjacent to the edge of the weld metal. The specimens shall be taken from about the quarter-thickness(1/4-T). The length of the notch of the specimen shall be perpendicular to the surface. (Figure 5)

5.3 Encapsulation of Specimens

The specimens shall be maintained in an inert environment with a corrosion-resistant capsule to prevent deterioration of the surface of the specimens during radiation exposure.

5.4 Sampling Process

The test specimen sampling process shall be performed in accordance with Figure 6.

6. Surveillance Capsules

6.1 Numbers and Locations of Capsules

The number of the surveillance capsules is determined based on the suggested number per ASTM E185-82. The surveillance capsules shall be located in Figure 1.

6.2 Expected peak fluence and lead factor

The expected peak fluence at the reactor vessel inside surface in the core regions is approximately 5 x 10^{17} n/cm^2 over a 60 year life. The surveillance capsule lead factor is expected to be approximately 1.1. The peak fluence and the lead factor were evaluated using multi-energy group, two-dimensional discrete ordinates transport computer code DOT3.5.

7. Withdrawal schedule
The withdrawal schedule shall be in accordance with Table 1. The withdrawal schedule is established per ABWR DCD Tier 2 Section 5.3.1.6.1.

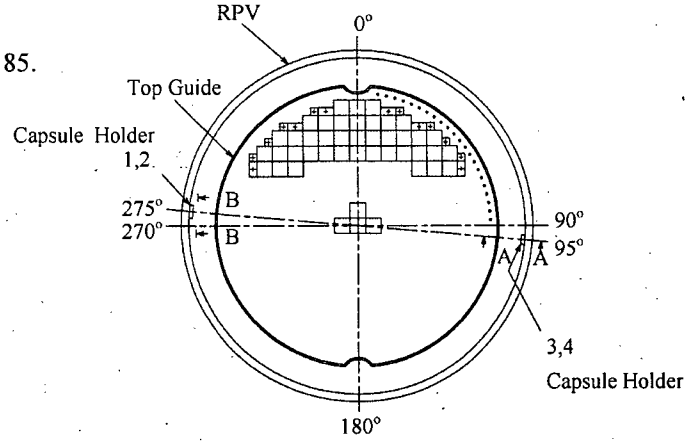
7.1 Irradiation testing
The number of the irradiation testing will be performed in accordance with Table 1.

7.2 Unirradiation testing
The unirradiation testing will be performed at the time of the first irradiated testing , using the same test machines.

Table 1 RPV material surveillance program

No.	Type of specimen	Installation location		Number of test specimens				Withdrawal schedule (EFPY)
		Location	Installed azimuth	Type	Base metal	Weld metal	Heat affected zone	
1	Irradiated specimen	Pressure wall	275°	Tensile specimen	6	6	6	6
				CV specimen	15	15	15	
2		Pressure wall	275°	Tensile specimen	6	6	6	20
				CV specimen	15	15	15	
3		Pressure wall	95°	Tensile specimen	6	6	6	EOL *
				CV specimen	15	15	15	
4		Pressure wall	95°	Tensile specimen	6	6	6	**
				CV specimen	15	15	15	
	Unirradiated specimen	-		Tensile specimen	9	9	9	-
				CV specimen	18	18	18	

Note *:With an exposure not to exceed the peak EOL fluence.
**:Schedule determined based on results of first two capsules per ASTM E185.



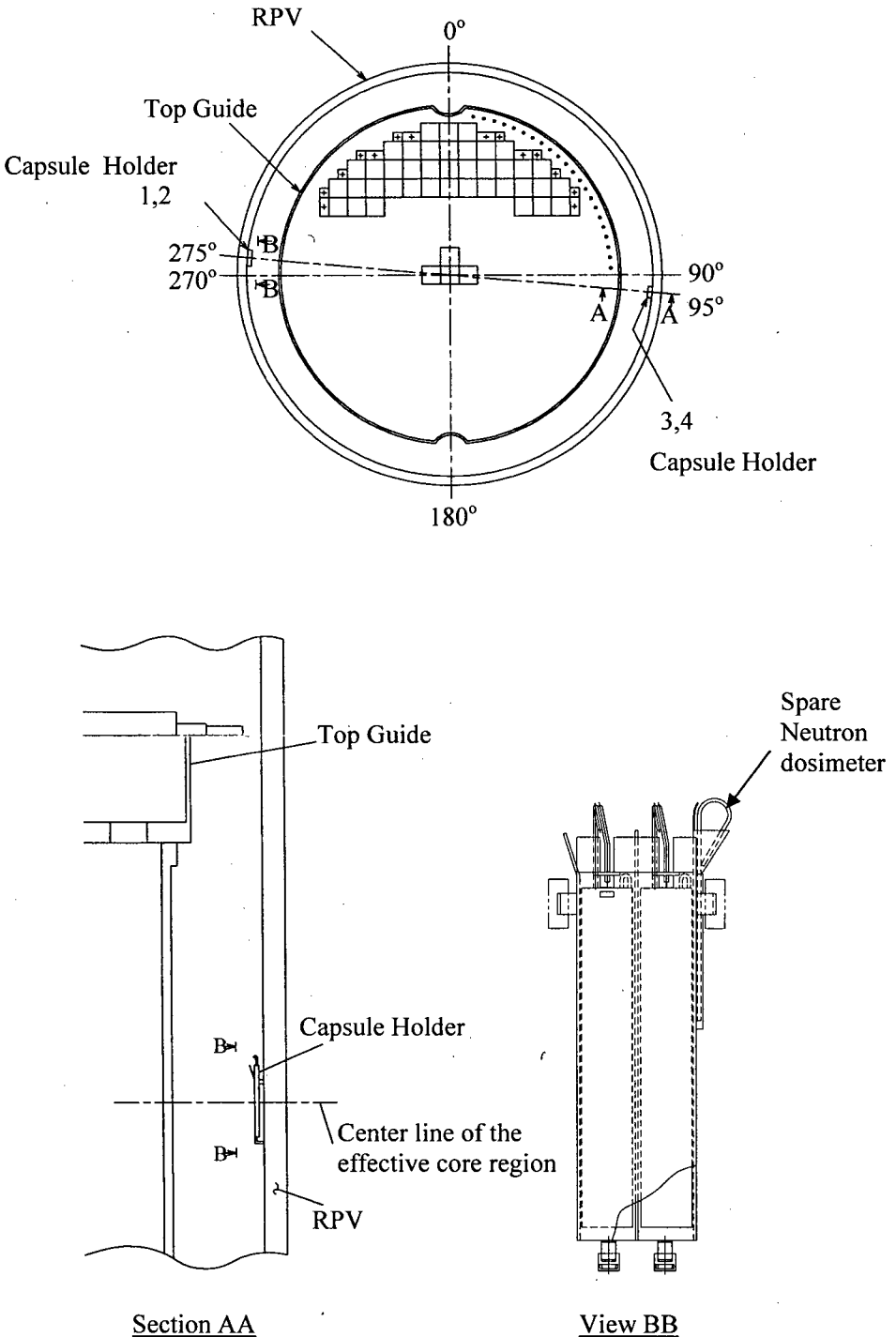
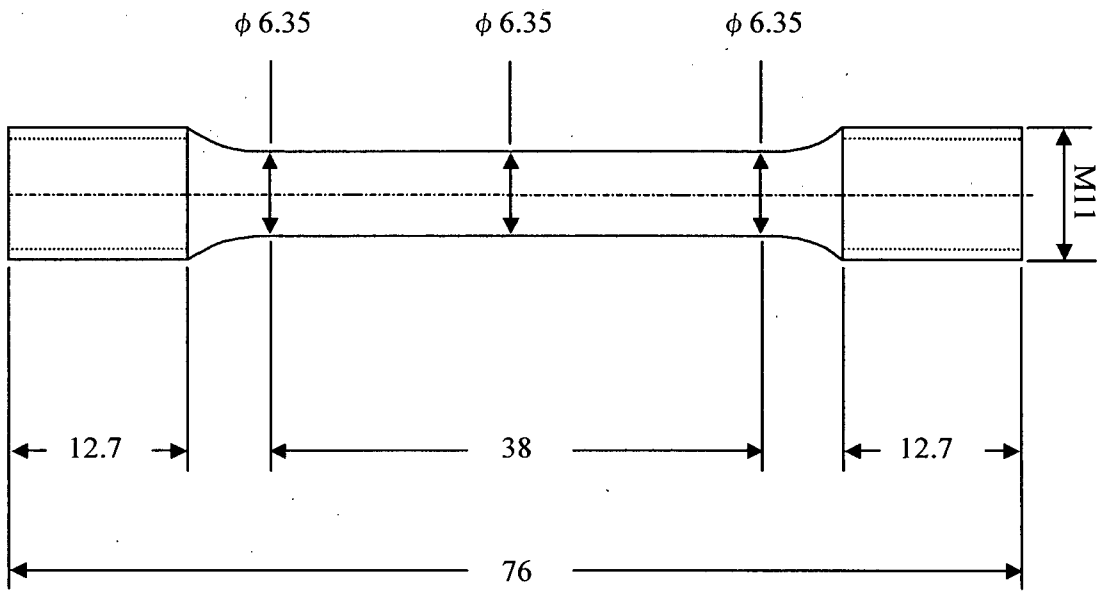
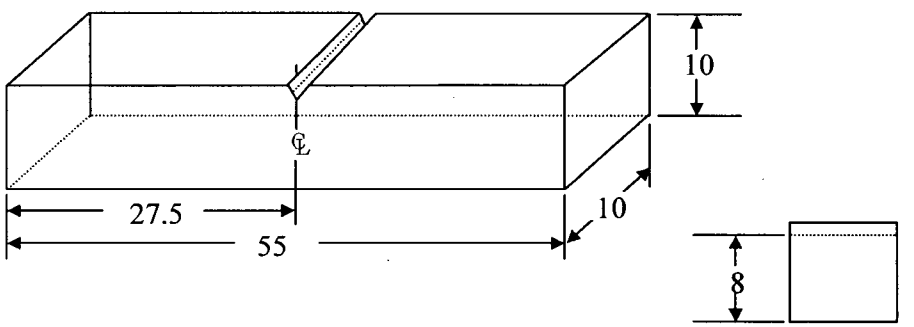


Figure 1 Locations and Outline of Installed Surveillance Holders



(Unit: mm)

Figure 2. Tensile Test Specimen



(Unit: mm)

Figure 3. Charpy V notch impact Test Specimen

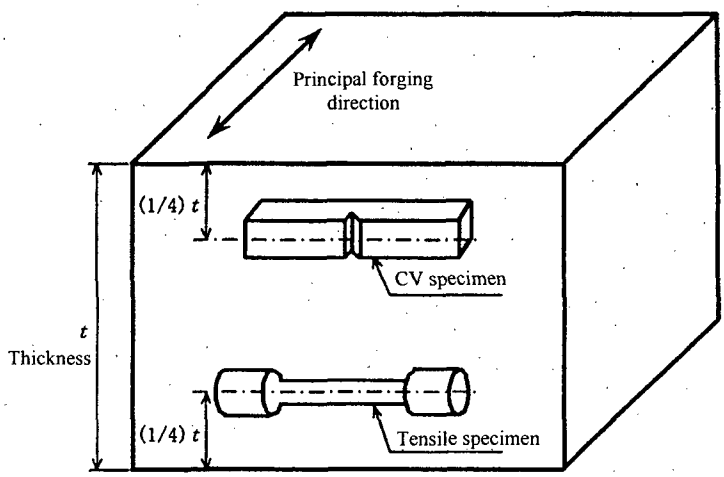


Figure 4. Base Metal Block

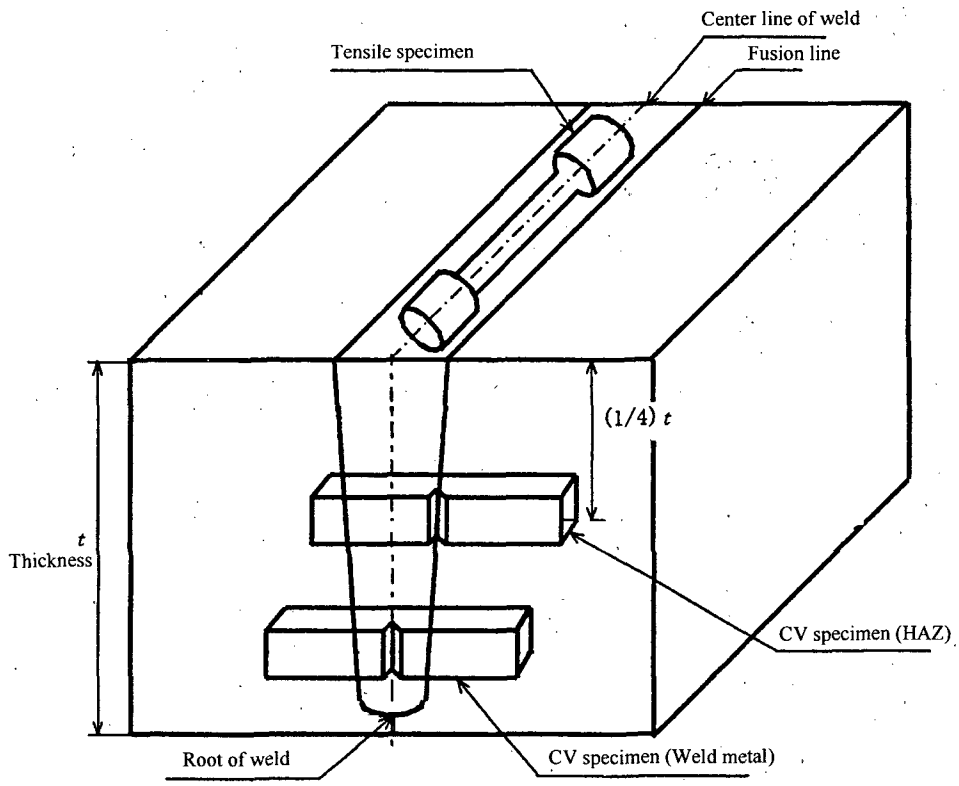
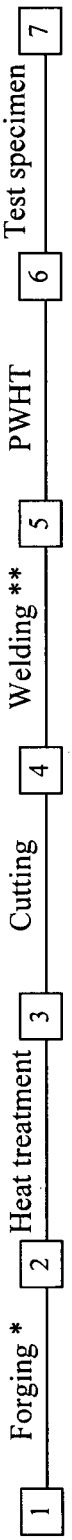


Figure 5. Weld Metal Block



Note
*: Base metal shall be used in the beltline.
**: Weld metal shall be made with the same heat of weld wire and lot of flux and by the same welding procedure.

Figure 6. Process to take test specimens from RPV material