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In the Matter of: Entergy Nuclear Operations, Inc. (Indian Point Nuclear Generating Units 2 and 3)
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Table 3-1
Final disposition of category B and C B&W internals

Component	Material	Initial Category	SCC	IASCC	Wear	Fatigue	TE	IE	VS	ISR and IC	Final Group
Plenum Cover Assembly											
Plenum Cover Weldment Rib Pads	304 SS	C	A	A	P	A	A	A	A	A	P
Plenum Cover Support Flange	304 SS	C	A	A	P	A	A	A	A	A	P
Alloy X-750 Dowels-to-Plenum Cover Bottom Flange Welds	Alloy 82 Weld	B	N	A	A	A	A	A	A	A	N
Control Rod Guide Tube (CRGT) Assembly											
CRGT Spacer Castings	CF3M	B	A	A	A	A	E	A	A	A	E
CRGT Rod Guide Tubes	304L SS	B	A	A	N	A	A	A	A	A	N
CRGT Rod Guide Sectors	304L SS	B	A	A	N	A	A	A	A	A	N
Core Support Shield Assembly											
CSS Top Flange	304 SS	C	A	A	P	A	A	A	A	A	P
UCB Bolts	Alloy A-286 or Alloy X-750	C	P	A	A	A	A	A	A	A	P
CSS Cast Outlet Nozzles (ONS-3, DB)	CF8	B	A	A	A	A	P	A	A	A	P
CSS Vent Valve Top Retaining Ring	15-5PH	B	A	A	A	A	P	A	A	A	P
CSS Vent Valve Bottom Retaining Ring	15-5PH	B	A	A	A	A	P	A	A	A	P
CSS Vent Valve Discs	CF8	B	A	A	A	A	P	A	A	A	P
CSS Vent Valve Disc Shaft or Hinge Pin	431 SS	B	A	A	A	A	P	A	A	A	P

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Table 3-1
Final disposition of category B and C B&W internals (continued)

Component	Material	Initial Category	SCC	IASCC	Wear	Fatigue	TE	IE	VS	ISR and IC	Final Group
Core Barrel Assembly											
Core Barrel Cylinder (Including Vertical and Circumferential Seam Welds)	304 SS, 308L SS Welds	B	A	A	A	A	A	E	A	A	E
Alloy X-750 Core Barrel-to-Former Plate Dowel	Alloy X-750	B	N	A	A	A	A	N	A	A	N
Alloy X-750 Dowel-to-Core Barrel Cylinder Fillet Welds	Alloy 82 Weld	B	N	A	A	A	A	A	A	A	N
Thermal Shield Upper Restraint Cap Screws (Not Exposed)	304 SS	B	A	A	N	N	A	A	A	N	N
Baffle Plates	304 SS	C	A	N	A	A	A	P	N	A	P
Former Plates	304 SS	C	A	N	A	A	A	E	N	A	E
CB Bolts	304 SS	C	A	E	E	E	A	E	N	E	E
FB Bolts (Note 1)	304 SS	C	A	P	P	P	A	P	N	P	P
Internal BB Bolts (Note 1)	304 SS	C	A	N	E	E	A	E	N	E	E
External BB Bolts	304 SS	C	A	E	E	E	A	E	N	E	E
Accessible Locking Device and Locking Weld (FB Bolts and Internal BB Bolts)	304 SS Locking Device, 308L SS Locking Weld	B	A	P	A	A	A	P	A	A	P
Inaccessible Locking Device and Locking Weld (CB Bolts and External BB Bolts)	304 SS Locking Device, 308L SS Locking Weld	B	A	E	A	A	A	E	A	A	E

Table 3-1
Final disposition of category B and C B&W internals (continued)

Component	Material	Initial Category	SCC	IASCC	Wear	Fatigue	TE	IE	VS	ISR and IC	Final Group
LCB Bolts	Alloy A-286 or Alloy X-750	C	P	A	A	A	A	A	A	A	P
UTS Bolts	Alloy A-286 or Alloy X-750	B	E	A	A	A	A	A	A	A	E
SSHT Bolts (CR-3, DB)	Alloy X-750	B	E	A	A	A	A	A	A	A	E
Upper Grid Assembly											
Alloy X-750 Dowel-to-Upper Grid Rib Section Bottom Flange Welds	Alloy 82 Weld	B	N	A	A	A	A	A	A	A	N
Upper Fuel Assembly Support Pads: Alloy X-750 Dowel Locking Weld	Alloy 82 Weld	B	E	A	A	A	A	A	A	A	E
Lower Grid Assembly											
Lower Fuel Assembly Support Pads: Pad, Pad-to-Rib Section Weld, Alloy X-750 Dowel, Cap Screw, Their Locking Welds	304SS with 308L SS Weld, Except Alloy X-750 Dowel with Alloy 69 Weld	B	A or E (Note 2)	A	A	A	A	E	A	A	E
Lower Grid Assembly Alloy X-750 Dowel-to-Guide Block Welds	Alloy 82 Weld	B	P	A	A	A	A	A	A	A	P
Alloy X-750 Bolts for Lower Grid Shock Pads (TMI-1 only)	Alloy X-750	B	E	A	A	A	A	A	A	A	E
Alloy X-750 Dowel-to-Lower Grid Shell Forging Welds	Alloy 82 Weld	B	N	A	A	A	A	A	A	A	N
Alloy X-750 Dowel-to-Lower Grid Rib Section Welds	Alloy 69 Weld	B	N	N	A	A	A	N	A	A	N

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Table 3-1
Final disposition of category B and C B&W internals (continued)

Component	Material	Initial Category	SCC	IASCC	Wear	Fatigue	TE	IE	VS	ISR and IC	Final Group
Lower Grid Rib-to-Shell Forging Cap Screws	304 SS	B	A	A	N	N	A	A	A	N	N
Lower Grid Support Post Pipe Cap Screws	304 SS	B	A	A	N	N	A	A	A	N	N
LTS Bolts	Alloy A-286 or Alloy X-750	B	E	A	A	A	A	A	A	A	E
Flow Distributor Assembly											
FD Bolts	Alloy A-286 or Alloy X-750	C	E	A	A	A	A	A	A	A	E
Alloy X-750 Dowel-to-Flow Distributor Flange Welds	Alloy 82 Weld	B	N	A	A	A	A	A	A	A	N
IMI Guide Tube Assembly											
IMI Guide Tube Spiders and Spider-to-Lower Grid Rib Section Welds	CF8, 308L SS Weld	B	A	A	A	A	P	P	A	A	P

Notes:

1. Bolt overload after hard contact with the baffle and former plates is identified in Reference 13. This mechanism is only applicable to the FB bolts and internal BB bolts; "Primary" for the FB bolts, and "Expansion" for the internal BB bolts.
2. Only the Alloy X-750 dowel locking weld in the listed items for the lower fuel assembly support pads is susceptible to SCC and categorized as Expansion for SCC. Other items are Category A for SCC.

Table 3-2
Final disposition of category B and C CE internals

Component	Material	Initial Category	SCC	IASCC	Wear	Fatigue	TE (Note 1)	IE (Note 1)	VS	ISR and IC	Final Group
Upper Internals Assembly											
Fuel Alignment Plate (Core Shrouds with Full-Height Shroud Plates)	304 SS	B	N	A	N	P	A	A	A	A	P
Lower Support Structure											
Core Support Plate	304 SS 304L SS	C	N	N	N	P	A	P	A	A	P
Fuel Alignment Pins (Core Shrouds with Full-Height Shroud Plates)	A286 SS	C	A	X	X	X	A	X	A	X	X
Core Support Columns	304 SS	B	E	E	A	E	A	E	A	A	E
Core Support Columns	CF8	B	E	E	A	E	E	E	A	A	E
Core Support Deep Beams (Core Shrouds with Full-Height Shroud Plates)	304 SS	C	X	X	A	P	A	P	A	A	P
Core Support Column Bolts	316 SS	B	A	E	N	E	A	E	A	N	E
Control Element Assembly (CEA)-Shroud Assemblies											
Instrument Tubes	304 SS	B	P	A	A	P	A	A	A	A	P
Core Support Barrel Assembly											
Upper Cylinder Welds	304 SS	B	E	A	A	A	A	A	A	A	E
Lower Cylinder Welds	304 SS	C	E	N	A	A	A	E	A	A	E
Upper Core Barrel Flange Weld	304 SS	B	P	A	X	A	A	A	A	A	P
Lower Core Barrel Flange	304 SS	B	E	A	A	E	A	A	A	A	E
Lower Core Barrel Flange Weld	304 SS	B	E	A	A	P	A	A	A	A	P

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Table 3-2
Final disposition of category B and C CE internals (continued)

Component	Material	Initial Category	SCC	IASCC	Wear	Fatigue	TE (Note 1)	IE (Note 1)	VS	ISR and IC	Final Group
Thermal Shield Positioning Pins (Note 2)	UNS S21800	B	A	A	N	N	A	A	A	N	N
Core Shroud Assembly											
Shroud Plates (Bolted) (Entire Assembly)	304 SS	C	N	E	A	A	A	P	P	A	P
Shroud Plates (Welded)	304 SS	C	N	P	A	A	A	P	P	A	P
Former Plates (Bolted) (Entire Assembly)	304 SS	B	N	E	A	A	A	P	P	A	P
Former Plates (Welded)	304 SS	B	N	P	A	A	A	P	P	A	P
Ribs	304 SS	B	N	E	A	A	A	E	N	A	E
Rings (Core Shrouds with Full-Height Shroud Plates)	304 SS	B	N	E	A	A	A	E	N	A	E
Core Shroud Bolts	316 SS	B	A	P	N	N	A	P	P	P	P
Barrel-Core Shroud Bolts	316 SS	B	A	E	N	N	A	E	A	E	E
Core Shroud Tie Rods	348 SS	B	A	A	N	N	A	N	A	N	N
Core Shroud Tie Rod Nuts	316 SS	B	A	A	N	N	A	N	A	N	N
Guide Lug Insert Bolts (Note 3)	A286 SS	B	A	A	X	X	A	A	A	X	X
In-Core Instrumentation (ICI)											
ICI Thimble Tubes-Lower	Zircaloy-4	C	A	A	X	A	A	A	A	A	X

Notes:

1. The significance of thermal and irradiation embrittlement is directly related to the probability of a flaw existing in the component. There are no recommendations for inspection to determine embrittlement level because these mechanisms cannot be directly observed. However, potential embrittlement must be considered in flaw tolerance evaluations.
2. One plant has an existing program for this item.
3. Bolt deterioration may lead to degradation in lug fixtures. Inspection recommendations relate to the entire guide lug fixture.

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Table 3-3
Final disposition of category B and C Westinghouse internals

Component	Material	Initial Category	SCC	IASCC	Wear	Fatigue	TE (Note 1)	IE (Note 1)	VS	ISR and IC	Final Group
Control Rod Guide Tube Assembly											
Lower Flanges	CF8	B	P	A	A	P	P	P	A	A	P
Guide Plates (Cards)	304 SS	C	N	A	P	N	A	A	A	A	P
C-Tubes (Note 2)	304 SS	C	A	A	P	A	A	A	A	A	N
Sheaths (Note 2)	304 SS	C	A	A	P	A	A	A	A	A	N
Guide Tube Support Pins	Alloy X-750	C	X	A	X	X	A	A	A	N	X
Upper Internals Assembly											
Upper Support Ring or Skirt	304 SS	B	E	A	A	X	A	A	A	A	X
Baffle-Former Assembly											
Baffle-Edge Bolts	316 SS, 347 SS	C	A	P	N	P	A	P	P	P	P
Baffle Plates and Former Plates (Note 3)	304 SS	B	A	N	A	A	A	N	P	A	P
Baffle-Former Bolts	316 SS, 347 SS	C	A	P	N	P	A	P	P	P	P
Barrel-Former Bolts	316 SS, 347 SS	C	A	E	N	E	A	E	E	E	E
Bottom Mounted Instrumentation System											
BMI Column Bodies	304 SS	B	N	N	A	E	A	E	N	A	E
BMI Column Collars	304 SS	B	A	N	A	A	A	N	N	A	N
BMI Column Cruciforms	CF8	B	A	N	A	A	N	N	N	A	N
BMI Column Extension Tubes	304 SS	B	N	N	A	A	A	N	N	A	N
Flux Thimble Tube Plugs	304 SS	B	N	N	A	A	A	N	N	A	N
Flux Thimbles (Tubes)	316 SS	C	N	N	X	A	A	N	N	A	X

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Table 3-3
Final disposition of category B and C Westinghouse internals (continued)

Component	Material	Initial Category	SCC	IASCC	Wear	Fatigue	TE (Note 1)	IE (Note 1)	VS	ISR and IC	Final Group
Core Barrel Assembly											
Core Barrel Flange	304 SS	B	E	A	X	A	A	A	A	A	X
Core Barrel Outlet Nozzle Welds	304 SS	B	E	A	A	E	A	A	A	A	E
Core Barrel Axial Welds	304 SS	C	E	E	A	A	A	E	A	A	E
Upper Core Barrel Flange Weld	304 SS	C	P	E	A	A	A	A	A	A	P
Lower Internals Assembly											
Lower Core Plate	304 SS	C	N	X	X	X	A	X	N	A	X
XL Lower Core Plate	304 SS	C	N	X	X	X	A	X	A	A	X
Lower Support Assembly											
Lower Support Column Bodies	CF8	B	A	E	A	A	N	E	N	A	E
Lower Support Column Bodies	304 SS	B	A	E	A	A	A	E	N	A	E
Lower Support Column Bolts	304 SS	B	A	E	N	E	A	E	N	E	E
Thermal Shield Assembly											
Thermal Shield Flexures	304 SS	B	A	N	P	P	A	N	A	N	P
Alignment and Interfacing Components											
Clevis Insert Bolts	Alloy X-750	B	A	A	X	A	A	A	A	A	X
Internals Hold Down Spring (Note 4)	304 SS	B	A	A	P	A	A	A	A	A	P
Upper Core Plate Alignment Pins	304 SS	B	X	A	X	A	A	A	A	A	X

Notes:

1. The significance of thermal and irradiation embrittlement is directly related to the probability of a flaw existing in the component. There are no recommendations for inspection to determine embrittlement level because these mechanisms cannot be directly observed. However, potential embrittlement must be considered in flaw tolerance evaluations.
2. Some of the items in the control rod guide tube (CRGT) assembly, namely the C-tubes and sheaths, have been placed in the No Additional Measures group, because decisions on remediation of wear and degradation in the CRGT assembly will be based only on the conditions detected in the Primary CRGT item, the guide tubes (cards).
3. The concern is a result of the collective interaction of all components that comprise the assembly and not strictly focused on the plates.
4. The hold-down spring does not directly degrade by wear. It first degrades by loss in preload, which leads to wear when an inadequate preload remains.

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4
AGING MANAGEMENT REQUIREMENTS

The ultimate goal of an aging management program (AMP) is to monitor the condition of the internals to maintain appropriate levels of plant safety and reliability. Properly managed, the plants will fulfill their license renewal commitments. Appendix A identifies the elements of a complete AMP that these guidelines support.

Inspection and evaluation in support of aging management requirements typically consists of the following:

- selection of items for aging management;
- selection of the type of examination or other methodologies appropriate for each applicable degradation mechanism;
- specification of the required level of examination qualification;
- schedule of first and frequency of any subsequent examinations;
- sampling and coverage;
- expansion of scope if sufficient evidence of degradation is observed;
- examination acceptance criteria;
- methods for evaluating examination results not meeting the examination acceptance criteria;
- updating the program based on industry-wide results; and
- contingency measure to repair, replace, or mitigate.

The listed elements of inspection and evaluation interrelate. For example, the particulars of the examination acceptance criteria may affect the rules for sampling or frequency of examination.

This section of the guidelines specifies aging management requirements that are appropriate to detect the expected effects of the degradation mechanisms, and are considered acceptable for the development of an AMP. The criterion for acceptability of an aging management requirement is that it accomplishes the AMP goal, namely, ensuring the continued achievement of safety related and economically important functions of the internals. The technical bases used to develop these aging management requirements are documented [13, 14].

Some of the aging management requirements listed, for example, examination acceptance criteria, deserve greater elaboration and are therefore discussed in Section 5.

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Section 4.1 describes the overall aging management approach. Then, Section 4.2 describes the various examination methodologies, ranging from general condition visual examinations to more rigorous visual, surface, and volumetric examinations, with a final sub-section that describes physical measurement. Section 4.3 summarizes the examination requirements that are recommended for two groups of PWR internals – Primary and Expansion.

The requirements stated within this section may revert to those required by ASME Code Section XI [2] if components are repaired, modified or replaced such that the effects of aging are fully mitigated. Demonstration of the adequacy of repair, replacement, or modification activities to fully mitigate the effect of aging is the responsibility of the owner. In addition, repair, replacement or modification activities may also warrant revision to the scope and/or frequency of the generic requirements stated in these guidelines. This includes re-establishing the technical basis for the replaced components (if not fully mitigated) and the technical basis for examination of any linked Expansion components, which was developed on the basis of expert panel solicitation [15]. Individual utilities will be responsible for the technical justification of such activities to demonstrate their acceptability for different requirements than those stated in these guidelines.

The requirements for the PWR internals in the Existing Programs group are described in Section 4.4. As described in Section 4.5, those PWR internals in the No Additional Measures group require no further actions with respect to management of aging degradation, other than to continue any existing requirements that affect these components.

4.1 Aging Management Approach

The aging management approach for PWR internals consists of four major elements: (1) component categorization and aging management strategy development; (2) selection of aging management methodologies for PWR internals that are both appropriate and based on an adequate level of applicable experience; (3) qualification of the recommended methodologies that is based on adequate technical justification; and (4) implementation of the recommendations based on the Industry Initiative for the Management of Materials Issues [1]. Each element in the approach is described in greater detail in the following paragraphs.

4.1.1 PWR Internals Categorization and Aging Management Strategy Development

The PWR internals categorization and aging management strategy development were summarized in Section 3.

4.1.2 Selection of Established Aging Management Methodologies

The second part of the aging management approach involved the selection of aging management methodologies for the PWR internals. The criteria for selection were based on:

- the methodologies should be appropriate for the characterization of particular age-related degradation effects; and
- the aging management methodologies should concentrate on techniques that have been subject to widespread application.

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For these two reasons, the selected aging management methodologies emphasize existing, well-proven techniques that have been subject to widespread, relevant application. These methodologies are described in Section 4.2.

4.1.3 Aging Management Methodology Qualification

An extensive experience base for the aging management methodologies described in this section of the I&E guidelines permits selection of known aging management methodologies. Some of these methodologies already have well established procedural qualifications, such as volumetric examination of bolting. For those requiring additional procedural qualification, Article 14 of Section 5 of the ASME Code [16] provides the criteria for the possible levels of rigor that can be selected for the qualification of examination methodologies. For example, the level of procedural qualification for volumetric (UT) examination of bolting is limited to technical justification. This level of qualification is appropriate. Failures of internals do not result in pressure boundary failures. Internals are either of robust design resulting in flaw tolerance well above the detection level that can be established via technical justification or consist of assemblies for which a single component item failure does not prevent the assembly from performing its function.

The Inspection Standard [3] provides detailed guidance for conducting and justifying the selected examination techniques and the technical justifications required for different examination methodologies and component configurations.

4.1.4 Implementation of Aging Management Requirements

Information on the implementation of the aging management requirements is provided in Section 7 of these I&E guidelines.

4.2 Aging Management Methodologies

The aging management methodologies described in these guidelines include visual examinations, surface examinations, volumetric examinations, and physical measurements. Each of these methodologies is suitable for managing the effects of one or more aging degradation mechanisms for PWR internals, depending upon:

- tolerance of the component functionality to the progression of particular effects;
- accessibility of the component by the equipment needed for the examination; and
- suitability of the equipment for detecting the particular effect.

Where appropriate the examination methodologies selected for use in these guidelines are as specified in the latest U.S. Nuclear Regulatory Commission (NRC) approved edition and addenda of ASME Code Section XI [2], including those discussed in 4.2.1 and 4.2.2.

These methodologies are described in the following sub-sections.

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4.2.1 Visual (VT-3) Examination

One examination methodology selected for use in these guidelines, which has an extensive history of use for PWR internals, is visual (VT-3) examination. Such visual examinations are exclusively relied upon for detection of general degradation of PWR internals subject to IWB-2500 B-N-3 [2] requirements. Visual (VT-3) examinations are conducted to determine the general mechanical and structural condition of components by detecting discontinuities and imperfections, such as loss of integrity at bolted or welded connections, loose or missing parts, debris, corrosion, wear, or erosion; and by identifying conditions that could affect operational or functional adequacy of components. This type of examination has been determined to be acceptable for the continued monitoring of many of the internals within the scope of these guidelines.

When specified in these guidelines, a visual (VT-3) examination is conducted in accordance with the requirements of the Inspection Standard [3]. Visual (VT-3) examinations of internals are conducted using remote examination techniques, because of personnel radiation exposure issues.

A large amount of industry experience is available relative to the application of visual (VT-3) examination procedures for examining PWR internals; however, implementation of character height requirements for VT-3 is relatively new. Thus the VT-3 required by these guidelines has greater detection capability than most of the IWB-2500 B-N-3 [2] examinations previously conducted.

4.2.2 Visual (VT-1 and EVT-1) Examinations

Other examination methodologies selected for use in these guidelines are visual (VT-1 and EVT-1) examinations. The visual (VT-1) examination and the enhanced visual (EVT-1) examination were selected where a greater degree of detection capability than visual (VT-3) examination was needed to manage the aging effect. Unlike the detection of general degradation conditions by visual (VT-3) examination, visual (VT-1) and enhanced visual (EVT-1) examinations are conducted to detect discontinuities and imperfections on the surface of components, including such conditions as cracks, wear, corrosion, or erosion. Specifically, VT-1 is used for the detection of surface discontinuities such as gaps, while EVT-1 is used for the detection of surface breaking flaws.

When specified in these guidelines, a visual (VT-1) examination is conducted in accordance with the requirements of the Inspection Standard [3]. Enhanced visual (EVT-1) examination is also conducted in accordance with the requirements described for visual (VT-1) examination with additional requirements (such as camera scanning speed) as specified in the Inspection Standard [3].

As with visual (VT-3) examination, the current ASME Code [2] requirements for visual (VT-1) examination became more rigorous than the previous ASME Code versions. Many previous VT-1 examinations were only required to discern a 1/32" black line on a gray background. These limitations led the NRC and industry to adopt modified visual examinations for use in detecting flaws discovered in boiling water reactor (BWR) internals. The most recent research conducted by the EPRI Non-Destructive Examination (NDE) Center established the VT-1 character heights specified in Reference 2 as equally or better able to detect the degradation effects than the modified visual examination requirements developed previously [17].

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4.2.3 Surface Examination

In order to further characterize discontinuities on the surface of components, surface examination can supplement either visual (VT-3) or (VT-1/EVT-1) examinations specified in these guidelines. This supplemental examination may thus be used to reject or accept relevant indications. A surface examination is an examination that indicates the presence of surface discontinuities, and the ASME Code [2] lists magnetic particle, liquid penetrant, eddy current, and ultrasonic examination methods as surface examination alternatives. Here, only the electromagnetic testing (ET), also called eddy current surface examination method, is covered.

When selected for use as a supplemental examination to examinations performed in these guidelines, an ET examination is conducted in accordance with the requirements of the Inspection Standard [3].

ET examination is widely used for heat exchanger tubing inspections. Eddy currents are induced in the inspected object by electromagnetic coils, with disruptions in the eddy current flow caused by surface or near-surface anomalies detected by suitable instrumentation. Industry experience with ET examination is relatively robust, especially in the aerospace and petroleum refinery industries. The experience base for PWR nuclear systems is moderately robust, in particular for examination of steam generator, flux thimble, and heat exchanger tubing.

4.2.4 Volumetric Examination

Another methodology selected for use in these guidelines is volumetric examination. An ultrasonic examination (UT) was selected where visual or surface examination is unable to detect the effect of the age-related degradation for some PWR internals. For example, irradiation-assisted stress corrosion cracking (IASCC) in baffle/former bolts may occur under the bolt head – in the shank or threaded region – and will be undetectable by visual or surface examination unless the bolt is removed and subject to examination over its entire length.

When specified in these guidelines, an ultrasonic examination (UT) is conducted in accordance with the requirements of the Inspection Standard [3].

While UT has only been selected for use in these guidelines for detection of aging effects in bolting, UT is also permissible as an alternative or supplement to the specified visual examinations for other configurations such as plates and welds. This is consistent with Reference 2.

The industry has had extensive experience with the application of ultrasonic examination (UT) to PWR internals bolts, pins, and fasteners, in particular with baffle/former bolting examinations. The industry also has extensive experience in applying UT to BWR internals to detect intergranular stress corrosion cracking (IGSCC) in stainless steel and nickel-base welded plates, stainless steel internals piping, and nickel-base forgings and bolting.

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4.2.5 Physical Measurements

The effects of loss of material caused by wear, the loss of pre-load or clamping force caused by such mechanisms as thermal and irradiation-enhanced stress relaxation, and excessive distortion or deflection caused by void swelling can be managed in some cases by physical measurements. Satisfaction of prescribed limits on these physical measurements (see Section 5.2) is intended to demonstrate that the affected components remain functional and can continue in service for a determined period until the next set of physical measurements. If the prescribed limits are exceeded, corrective action or evaluation for continued service is required.

In some cases, these effects may involve changes in clearances, settings, and physical displacements that can be monitored by visual means, supplemented by physical measurements that characterize the magnitude of the effects. This methodology may be used in conjunction with visual (VT-3) examination, which includes "verifying parameters, such as clearances, settings, and physical displacements." The measurement of these parameters and their comparison to prescribed limits extends beyond visual (VT-3) examination, and will be referred to as "physical measurement of the effects of degradation."

4.3 Primary and Expansion Component Requirements

The aging management requirements for Primary and Expansion PWR internals are covered in this section. As described in Section 3.3, Primary components are those for which the effects of at least one of the eight aging mechanisms is above the screening criteria, and for which additional aging management is needed to manage those effects. The particular additional aging management methodologies were selected from the methodologies described in Section 4.2. The implementation schedule for the Expansion components will depend on the findings from the application of the additional aging management methodologies to the Primary components. The expansion criteria are defined in Section 5.

Sections 4.3.1, 4.3.2, and 4.3.3 identify and discuss the aging management methodologies for the Primary and Expansion components for B&W, CE, and Westinghouse plants, respectively. The requirements for these components are listed in Tables 4-1 through 4-6. For example, the Primary and Expansion requirements for Westinghouse internals are listed in Tables 4-3 and 4-6. These tables contain columns describing the component; any particular applicability requirement for that component; the degradation effect to be detected; the examination method; the examination coverage; and any linkage between the Primary and Expansion components. The technical bases for the examination requirements are contained in the aging management strategy reports [13, 14].

There are no specified examinations where inadequate coverage is anticipated to be an issue. However if a utility determines that the examination coverage is questionable with respect to meeting the intent of the guidelines, the condition should be entered in the utility's corrective action program for disposition.

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The term "accessible" as used in Tables 4-1 through 4-6 is defined as a component surface or volume for which an examination is specified in accordance with MRP-228 that can be examined with the technologies specified in MRP-228. This accessibility is consistent with current ASME Section XI practices.

4.3.1 B&W Components

Tables 4-1 and 4-4 describe the examination requirements for PWR internals Primary and Expansion components for B&W plants.

The following is a list of the B&W Primary and Expansion components by examination technique.

- ***Visual (VT-3) Examination***

  Primary (applicable to all plants):

  – Baffle plates

    Expand to:

    - Core barrel cylinder (including vertical and circumferential seam welds)
    - Former plates

Since the regions around flow or bolt holes are preferential crack initiation sites, the surface area within one inch of the flow and bolt hole edges represents the required examination coverage.

Note that even though the core barrel cylinder and the former plates are Expansion components, they require an evaluation and not an inspection.

  Primary (applicable to all plants):

  – Locking devices, including locking welds, of baffle-to-former bolts and internal baffle-to-baffle bolts

    Expand to:

    - Locking devices for the external baffle-to-baffle bolts and barrel-to-former bolts

Note that even though the locking devices for the external baffle-to-baffle bolts and barrel-to-former bolts are Expansion components, they require an evaluation and not an inspection.

  Primary (applicable to all plants):

  – Alloy X-750 dowel-to-guide block welds

    Expand to:

    - Alloy X-750 dowel locking welds to the upper and lower fuel assembly support pads

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The locking welds may be susceptible to cracking as a result of stress corrosion cracking (i.e., primary water stress corrosion cracking (PWSCC)). The recommended program to manage cracking of the locking welds is in conjunction with the existing Examination Category B-N-3 of the ASME Section XI [2] ISI program. The guide block area is accessible when the core support assembly is removed from the vessel. The 10-year interval is considered adequate due to the low consequences of failure. Due to weld residual stresses and the constrained geometry, it is anticipated that significant cracks will be accompanied by locking device/weld separation and therefore be detectable by the visual (VT-3) examination method.

Primary (applicable to all plants):

- IMI guide tube spiders
- IMI guide tube spider-to-lower grid rib section welds

  Expand to:

  - CRGT spacer castings
  - Lower fuel assembly support pad items: pad, pad-to-rib section welds, Alloy X-750 dowel, cap screw, and their locking welds

The IMI guide tube spiders and their associated welds, the CSS cast outlet nozzles, the CSS vent valve discs, the control rod guide tube (CRGT) spacer castings, and the lower grid fuel assembly support pads and their associated welds may have degradation by thermal or irradiation embrittlement. The effects of thermal and irradiation embrittlement can be detected by inspection to detect fracture in the items.

The CRGT spacer castings (Figure 4-5) are an expansion item for thermal embrittlement. The primary items are the IMI guide tube spiders, the CSS cast outlet nozzles, and the CSS vent valve discs (see following primary item sub-section). The spacer castings are a part of the CRGT structure. The spacer castings do have limited accessibility from the top or bottom of the CRGT through a center free path. This of course presumes that the plenum assembly is removed from the vessel. Remote video can be used to perform a visual (VT-3) examination at the quarter points where the threaded connections are present. These lanes are not blocked by the rod guide tubes. The examination would look for fracture of the spacer surface or evidence that the spacer is not approximately centered. The threaded fasteners are welded to the OD of the pipe column, so it is possible that a degraded threaded location would not be detected. In this case, it is assumed that the redundant support is acceptable for continued operation.

The lower fuel assembly support pad items (Figure 4-6) consist of the stainless steel block, Alloy X-750 dowels, and stainless steel cap screws, all susceptible to irradiation embrittlement. The primary item is the IMI guide tube spider and associated fillet welds. Cracking of the dowel or cap screw tack weld may be observed, but more likely, the aging mechanism will be detected by the grid pad not being properly located.

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Primary:

- CSS cast outlet nozzles (applicable to Oconee Nuclear Station Unit 3 (ONS-3) and Davis-Besse (DB) only)
- CSS vent valve discs (applicable to all plants)

  Expand to:

  - CRGT spacer castings

The CSS outlet nozzles are currently inspected by the existing ASME Section XI [2] 10-year ISI program, while the CSS vent valve discs are inspected every refueling outage as part of the existing vent valve inspection program defined in BAW-2248A, Page 4.3 and Table 4-1 [18]. The lower grid fuel pads and their associated welds are already part of the ASME Section XI [2] 10-year ISI program and are inspected via visual (VT-3) examination.

The expansion item is covered in the previous primary component sub-section.

Primary (applicable to all plants):

- CSS vent valve top retaining ring
- CSS vent valve bottom retaining ring
- CSS vent valve disc shaft or hinge pin

There are no expansion items for these components.

The vent valves are contained in the core support shield assembly where the plenum assembly resides. These valves are check valves meant to relieve pressure in the interior of the core support assembly during a large break LOCA, preventing backpressure from reversing coolant flow through the core. These vent valves can be damaged due to mishandling when inserting and removing the plenum. The vent valve components listed above were identified as being susceptible to thermal aging embrittlement, which may lead to cracking. An existing program is in place at each of the B&W-designed units that requires testing and inspection of the vent valve assemblies each refueling outage. The aging management measures provided in these requirements include a provision to visually inspect the valve body and disc seating surfaces. Continuation of the existing vent valve testing and inspection requirements will manage cracking of the vent valve component items that could cause loss of the vent valve function.

Primary (applicable to all plants):

- Plenum cover weldment rib pads
- Plenum cover support flange
- CSS top flange

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There are no expansion items for these components.

The potential age-related degradation mechanism for the core clamp region is wear. The purpose of the clamping is to stabilize and significantly restrict rigid body pendulum motion of the core support assembly. Wear at these locations will progress from motions generated by fluid flow once the loss of core clamping is initiated. Note that a one-time physical measurement is to be performed prior to subsequent visual (VT-3) examination.

Primary:

- Upper core barrel (UCB) bolt locking devices (applicable to all plants)

  Expand to:

  - Lower core barrel (LCB) bolt locking devices (Expansion to LCB applies if the required Primary examination of LCB bolt locking devices has not been performed as scheduled in Table 4-1)
  - Upper thermal shield (UTS) bolt locking devices (applicable to all plants)
  - Lower thermal shield (LTS) bolt locking devices (applicable to all plants)
  - Flow distributor (FD) bolt locking devices (applicable to all plants)
  - Surveillance specimen holder tube (SSHT) bolt locking devices (Crystal River Unit 3 (CR-3) and Davis-Besse (DB) only)
  - Lower grid shock pad bolt locking devices (TMI-1 only)
- Lower core barrel (LCB) bolt locking devices (applicable to all plants)

  Expand to:

  - Upper thermal shield (UTS) bolt locking devices (applicable to all plants)
  - Lower thermal shield (LTS) bolt locking devices (applicable to all plants)
  - Flow distributor (FD) bolt locking devices (applicable to all plants)
  - Surveillance specimen holder tube (SSHT) bolt locking devices (Crystal River Unit 3 (CR-3) and Davis-Besse (DB) only)
  - Lower grid shock pad bolt locking devices (TMI-1 only)

Note that these bolts are also examined by volumetric (UT) examination.

- ***Volumetric (UT) Examination***

  Primary:

  - Upper core barrel (UCB) bolts (applicable to all plants)

    Expand to:

    - Lower Core Barrel (LCB) bolts (Expansion to LCB applies if the required Primary examination of LCB bolts has not been performed as scheduled in Table 4-1)

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- Upper thermal shield (UTS) bolts (applicable to all plants)
- Lower thermal shield (LTS) bolts (applicable to all plants)
- Flow distributor (FD) bolts (applicable to all plants)
- Surveillance specimen holder tube (SSHT) bolts (Crystal River Unit 3 (CR-3) and Davis-Besse (DB) only)
- Lower grid shock pad bolts (TMI-1 only)

– Lower core barrel (LCB) bolts (applicable to all plants)

Expand to:

- Upper thermal shield (UTS) bolts (applicable to all plants)
- Lower thermal shield (LTS) bolts (applicable to all plants)
- Flow distributor (FD) bolts (applicable to all plants)
- Surveillance specimen holder tube (SSHT) bolts (Crystal River Unit 3 (CR-3) and Davis-Besse (DB) only)
- Lower grid shock pad bolts (TMI-1 only)

Note that the locking devices of these bolts are also examined by visual (VT-3) examination.

The potential degradation mechanism for the structural bolting rings is stress corrosion cracking. For bolting, this mechanism is best detected using ultrasonic examination techniques.

The upper core barrel bolts are accessible for ultrasonic examination while the core support shield assembly is in the reactor vessel and the plenum is removed. Ultrasonic examination of the upper core barrel bolts can be performed during a normal refueling outage. The lower core barrel bolts are only accessible when the core support shield assembly is removed from the reactor vessel. Some lower core barrel bolts are more difficult to examine and are inaccessible for replacement due to the presence of the core guide blocks mounted on the side of the lower grid assembly.

Primary (applicable to all plants):

– Baffle-to-former (FB) bolts

Expand to:

- Baffle-to-baffle (BB) bolts
- Core barrel-to-former (CBF) bolts

Note that the locking devices of these bolts are also examined by visual (VT-3) examination.

Note that even though the baffle-to-baffle (BB) bolts and core barrel-to-former (CBF) bolts are Expansion components, they require an evaluation and not an inspection.

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- ***Physical Measurement***

  Primary (applicable to all plants):

  - Plenum cover weldment rib pads
  - Plenum cover support flange
  - CSS top flange

There are no expansion items for these components.

Note: the measurement is performed to determine the differential height of top of the plenum rib pads to the reactor vessel seating surface with all three items inside the reactor vessel, but with the fuel assemblies removed.

Note that these components are subsequently examined by visual (VT-3) examination.

4.3.2 CE Components

Tables 4-2 and 4-5 describe the examination requirements for the PWR internals Primary and Expansion components for CE plants.

The following is a list of the CE Primary and Expansion components by examination technique.

- ***Visual (VT-3) Examination***

  Primary (applicable to bolted plant designs):

  - Core shroud assembly (bolted)

There are no expansion items for this component.

Note that the core shroud assembly (bolted) is examined in order to detect void swelling effects as evidenced by abnormal interaction with fuel assemblies, gaps along high fluence shroud plate joints, vertical displacement of shroud plates near high fluence joint.

Primary (applicable to all plants with instrument guide tubes in the control element assembly (CEA) shroud assembly):

- Instrument guide tubes (peripheral)

  Expand to:

  - Remaining instrument guide tubes within the CEA shroud assemblies

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- ***Visual (VT-1 and EVT-1) Examinations***

Primary (applicable to plant designs with core shrouds assembled in two vertical sections):

- Core shroud assembly (welded)

There are no expansion items for this component.

Note that the core shroud assembly (welded) is examined in order to detect void swelling effects as evidenced by separation between the upper and lower core shroud segments.

Primary (applicable to plant designs with core shrouds assembled in two vertical sections):

- Core shroud plate-former plate weld

  Expands to:

  - Remaining axial welds

Primary (applicable to plant designs with core shrouds assembled with full-height shroud plates)

- Shroud plates

  Expand to:

  - Remaining axial welds
  - Ribs and rings

Primary (applicable to all plants):

- Upper (core support barrel) flange weld

  Expands to:

  - Remaining core barrel assembly welds, starting with the lower core barrel flange weld
  - Core support column welds (these components receive a visual (VT-3) examination)

Primary (applicable to all plants with core shrouds assembled with full-height shroud plates):

- Deep beams

There are no expansion items for this component.

Primary (depends on time-limited aging analysis [TLAA]):

- Core support barrel assembly lower flange weld (applicable to all plants)
- Core support plate (applicable to all plants with a core support plate)
- Fuel alignment plate (applicable to all plants with core shrouds assembled with full-height shroud plates)

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There are no expansion items for these components.

- ***Volumetric (UT) Examination***

  Primary (applicable to bolted plant designs):

  - Core shroud bolts

    Expand to:

    - Core support column bolts
    - Barrel-shroud bolts

4.3.3 Westinghouse Components

Tables 4-3 and 4-6 describe the examination requirements for the PWR internals Primary and Expansion components for Westinghouse plants.

The following is a list of the Westinghouse Primary and Expansion components by examination technique.

- ***Visual (VT-3) Examination***

  Primary:

  - Baffle-former assembly (applicable to all plants)
  - Thermal shield flexures (applicable to all plants with thermal shields)
  - Guide plates (cards) (applicable to all plants)

There are no expansion items for these components.

Note that the baffle-former assembly is examined in order to detect void swelling effects as evidenced by abnormal interaction with fuel assemblies, gaps along high fluence baffle joint, vertical displacement of baffle plates near high fluence joint, or broken or damaged edge bolt locking systems along high fluence baffle joint.
Also note that the PWROG is conducting a guide card wear project.

Primary:

- Baffle-edge bolts (applicable to all plants with baffle-edge bolts)

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There are no expansion items for these components.

Note that the baffle-edge bolts are examined in order to detect lost or broken locking devices, failed or missing bolts, or protrusion of bolt heads.

- ***Visual (VT-1 and EVT-1) Examinations***

  Primary (applicable to all plants):

  - Upper core barrel flange weld

    Expands to:

    - Remaining core barrel welds
    - Lower support column bodies (non cast)

  Primary (applicable to all plants):

  - Control rod guide tube (CRGT) assembly lower flange welds

    Expand to:

    - Bottom-mounted instrumentation (BMI) column bodies (these components receive a visual (VT-3) examination)
    - Lower support column bodies (cast)

Note that the examination coverage is 100% of outer (accessible) CRGT lower flange weld surfaces and adjacent base metal.

- ***Volumetric (UT) Examination***

  Primary (applicable to all plants):

  - Baffle-former bolts

    Expand to:

    - Lower support column bolts
    - Barrel-former bolts

- ***Physical Measurement***

  Primary (applicable to all plants with 304 stainless steel hold down springs):

  - Internals hold down spring

There are no expansion items for this component.

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Table 4-1
B&W plants Primary components

Item	Applicability	Effect (Mechanism)	Expansion Link (Note 2)	Examination Method/Frequency (Note 2)	Examination Coverage
Plenum Cover Assembly & Core Support Shield Assembly Plenum cover weldment rib pads Plenum cover support flange CSS top flange	All plants	Loss of material and associated loss of core clamping pre-load (Wear)	None	One-time physical measurement no later than two refueling outages from the beginning of the license renewal period. Perform subsequent visual (VT-3) examination on the 10-year ISI interval.	Determination of differential height of top of plenum rib pads to reactor vessel seating surface, with plenum in reactor vessel. See Figure 4-1.
Core Support Shield Assembly CSS cast outlet nozzles	ONS-3, DB	Cracking (TE), including the detection of surface irregularities, such as damaged or fractured material	CRGT spacer castings	Visual (VT-3) examination during the next 10-year ISI. Subsequent examinations on the 10-year ISI interval.	100% of accessible surfaces. See Figure 4-9.
Core Support Shield Assembly CSS vent valve discs (Note 1)	All plants				100% of accessible surfaces (see BAW-2248A, page 4.3 and Table 4-1). See Figures 4-10 and 4-11.
Core Support Shield Assembly CSS vent valve top retaining ring CSS vent valve bottom retaining ring CSS vent valve disc shaft or hinge pin (Note 1)	All plants	Cracking (TE), including the detection of surface irregularities, such as damaged, fractured material, or missing items	None	Visual (VT-3) examination during the next 10-year ISI. Subsequent examinations on the 10-year ISI interval.	100% of accessible surfaces (see BAW-2248A, page 4.3 and Table 4-1). See Figures 4-10 and 4-11.

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Table 4-1
B&W plants Primary components (continued)

Item	Applicability	Effect (Mechanism)	Expansion Link (Note 2)	Examination Method/Frequency (Note 2)	Examination Coverage
Core Support Shield Assembly Upper core barrel (UCB) bolts and their locking devices	All plants	Cracking (SCC)	LCB bolts (Note 3) UTS, LTS, and FD bolts SSHT bolts (CR-3 and DB only) Lower grid shock pad bolts (TMI-1 only)	Volumetric examination (UT) of the bolts within two refueling outages from 1/1/2006 or next 10-year ISI interval, whichever is first. Subsequent examination to be determined after evaluating the baseline results. Visual (VT-3) examination of bolt locking devices on the 10-year ISI interval.	100% of accessible bolts. See Figure 4-7.
Core Barrel Assembly Lower core barrel (LCB) bolts and their locking devices	All plants	Cracking (SCC)	UTS, LTS, and FD bolts SSHT bolts (CR-3 and DB only) Lower grid shock pad bolts (TMI-1 only)	Volumetric examination (UT) of the bolts during the next 10-year ISI interval from 1/1/2006. Subsequent examination to be determined after evaluating the baseline results. Visual (VT-3) examination of bolt locking devices on the 10-year ISI interval.	100% of accessible bolts. See Figure 4-8.

Table 4-1
B&W plants Primary components (continued)

Item	Applicability	Effect (Mechanism)	Expansion Link (Note 2)	Examination Method/Frequency (Note 2)	Examination Coverage
Core Barrel Assembly Baffle-to-former bolts	All plants	Cracking (IASCC, IE, IC/ISR/Fatigue/Wear, Overload)	Baffle-to-baffle bolts, Core barrel-to-former bolts	Baseline volumetric examination (UT) no later than two refueling outages from the beginning of the license renewal period with subsequent examination after 10 to 15 additional years.	100% of accessible bolts. See Figure 4-2.
Core Barrel Assembly Baffle plates	All plants	Cracking (IE), including the detection of readily detectable cracking in the baffle plates	Core barrel cylinder (including vertical and circumferential seam welds), Former plates	Visual (VT-3) examination during the next 10-year ISI. Subsequent examinations on the 10-year ISI interval.	100% of the accessible surface within 1 inch around each flow and bolt hole. See Figure 4-2.
Core Barrel Assembly Locking devices, including locking welds, of baffle-to-former bolts and internal baffle-to-baffle bolts	All plants	Cracking (IASCC, IE, Overload), including the detection of missing, non-functional, or removed locking devices or welds	Locking devices for the external baffle-to-baffle bolts and Barrel-to-former bolts	Visual (VT-3) examination during the next 10-year ISI. Subsequent examinations on the 10-year ISI interval.	100% of accessible baffle-to-former and internal baffle-to-baffle bolt locking devices. See Figure 4-2.
Lower Grid Assembly Alloy X-750 dowel-to-guide block welds	All plants	Cracking (SCC), including the detection of separated or missing locking welds, or missing dowels	Alloy X-750 dowel locking welds to the upper and lower fuel assembly support pads	Initial visual (VT-3) examination no later than two refueling outages from the beginning of the license renewal period. Subsequent examinations on ten-year interval.	100% of accessible locking welds of the 24 dowel-to-guide block welds. See Figure 4-4.

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Table 4-1
B&W plants Primary components (continued)

Item	Applicability	Effect (Mechanism)	Expansion Link (Note 2)	Examination Method/Frequency (Note 2)	Examination Coverage
Incore Monitoring Instrumentation (IMI) Guide Tube Assembly IMI guide tube spiders IMI guide tube spider-to-lower grid rib section welds	All plants	Cracking (TE/IE), including the detection of fractured or missing spider arms or separation of spider arms from the lower grid rib section at the weld	CRGT spacer castings Lower fuel assembly support pad items: pad, pad-to-rib section welds, Alloy X-750 dowel, cap screw, and their locking welds (Note: the pads, dowels, and cap screws are included because of TE/IE of the welds)	Initial visual (VT-3) examination no later than two refueling outages from the beginning of the license renewal period. Subsequent examinations on ten-year interval.	100% of accessible top surfaces of 52 spider castings and welds to the adjacent lower grid rib section. See Figures 4-3 and 4-6.

Notes:

1. A verification of the operation of each vent valve shall also be performed through manual actuation of the valve. Verify that the valves are not stuck in the open position and that no abnormal degradation has occurred. Examine the valves for evidence of scratches, pitting, embedded particles, variation in coloration of the seating surfaces, cracking of lock welds and locking cups, jack screws for proper position, and wear. The frequency is defined in each unit's technical specifications or in their pump and valve inservice test programs (see BAW-2248A, page 4.3 and Table 4-1[18]).
2. Examination acceptance criteria and expansion criteria for the B&W components are in Table 5-1.
3. Expansion to LCB applies if the required Primary examination of LCB has not been performed as scheduled in this table.

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Table 4-2
CE plants Primary components

Item	Applicability	Effect (Mechanism)	Expansion Link (Note 1)	Examination Method/Frequency (Note 1)	Examination Coverage
Core Shroud Assembly (Bolted) Core shroud bolts	Bolted plant designs	Cracking (IASCC, Fatigue)	Core support column bolts, Barrel-shroud bolts	Baseline volumetric (UT) examination between 25 and 35 EFPY, with subsequent examination after 10 to 15 additional EFPY to confirm stability of bolting pattern. Re-examination for high-leakage core designs requires continuing inspections on a ten-year interval.	100% of accessible bolts, or as supported by plant-specific justification. Heads are accessible from the core side. UT accessibility may be affected by complexity of head and locking device designs. See Figure 4-24.
Core Shroud Assembly (Welded) Core shroud plate-former plate weld	Plant designs with core shrouds assembled in two vertical sections	Cracking (IASCC)	Remaining axial welds	Enhanced visual (EVT-1) examination no later than 2 refueling outages from the beginning of the license renewal period and subsequent examination on a ten-year interval.	Axial and horizontal weld seams at the core shroud re-entrant corners as visible from the core side of the shroud, within six inches of central flange and horizontal stiffeners. See Figures 4-12 and 4-14.
Core Shroud Assembly (Welded) Shroud plates	Plant designs with core shrouds assembled with full-height shroud plates	Cracking (IASCC)	Remaining axial welds, Ribs and rings	Enhanced visual (EVT-1) examination no later than 2 refueling outages from the beginning of the license renewal period and subsequent examination on a ten-year interval.	Axial weld seams at the core shroud re-entrant corners, at the core mid-plane (± three feet in height) as visible from the core side of the shroud. See Figure 4-13.

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Table 4-2
CE plants Primary components (continued)

Item	Applicability	Effect (Mechanism)	Expansion Link (Note 1)	Examination Method/Frequency (Note 1)	Examination Coverage
Core Shroud Assembly (Bolted) Assembly	Bolted plant designs	Distortion (Void Swelling), including: • Abnormal interaction with fuel assemblies • Gaps along high fluence shroud plate joints • Vertical displacement of shroud plates near high fluence joint	None	Visual (VT-3) examination no later than 2 refueling outages from the beginning of the license renewal period. Subsequent examinations on a ten-year interval.	Core side surfaces as indicated. See Figures 4-25 and 4-26.
Core Shroud Assembly (Welded) Assembly	Plant designs with core shrouds assembled in two vertical sections	Distortion (Void Swelling), as evidenced by separation between the upper and lower core shroud segments	None	Visual (VT-1) examination no later than 2 refueling outages from the beginning of the license renewal period. Subsequent examinations on a ten-year interval.	If a gap exists, make three to five measurements of gap opening from the core side at the core shroud re-entrant corners. Then, evaluate the swelling on a plant-specific basis to determine frequency and method for additional examinations. See Figures 4-12 and 4-14.

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Table 4-2
CE plants Primary components (continued)

Item	Applicability	Effect (Mechanism)	Expansion Link (Note 1)	Examination Method/Frequency (Note 1)	Examination Coverage
Core Support Barrel Assembly Upper (core support barrel) flange weld	All plants	Cracking (SCC)	Remaining core barrel assembly welds, Core support column welds	Enhanced visual (EVT-1) examination no later than 2 refueling outages from the beginning of the license renewal period. Subsequent examinations on a ten-year interval.	100% of the accessible surfaces of the upper flange weld. See Figure 4-15.
Core Support Barrel Assembly Lower flange weld	All plants	Cracking (Fatigue)	None	If fatigue life cannot be demonstrated by time-limited aging analysis (TLAA), enhanced visual (EVT-1) examination, no later than 2 refueling outages from the beginning of the license renewal period. Subsequent examination on a ten-year interval.	Examination coverage to be defined by plant-specific fatigue analysis. See Figure 4-15.
Lower Support Structure Core support plate	All plants with a core support plate	Cracking (Fatigue)	None	If fatigue life cannot be demonstrated by time-limited aging analysis (TLAA), enhanced visual (EVT-1) examination, no later than 2 refueling outages from the beginning of the license renewal period. Subsequent examination on a ten-year interval.	Examination coverage to be defined by plant-specific fatigue analysis. See Figure 4-16.

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Table 4-2
CE plants Primary components (continued)

Item	Applicability	Effect (Mechanism)	Expansion Link (Note 1)	Examination Method/Frequency (Note 1)	Examination Coverage
Upper Internals Assembly Fuel alignment plate	All plants with core shrouds assembled with full-height shroud plates	Cracking (Fatigue)	None	If fatigue life cannot be demonstrated by time-limited aging analysis (TLAA), enhanced visual (EVT-1) examination, no later than 2 refueling outages from the beginning of the license renewal period. Subsequent examination on a ten-year interval.	Examination coverage to be defined by plant-specific fatigue analysis. See Figure 4-17.
Control Element Assembly Instrument guide tubes	All plants with instrument guide tubes in the CEA shroud assembly	Cracking (SCC, Fatigue) that results in missing supports or separation at the welded joint between the tubes and supports	Remaining instrument guide tubes within the CEA shroud assemblies	Visual (VT-3) examination, no later than 2 refueling outages from the beginning of the license renewal period. Subsequent examination on a ten-year interval. Plant-specific component integrity assessments may be required if degradation is detected and remedial action is needed.	100% of tubes in peripheral CEA shroud assemblies (i.e., those adjacent to the perimeter of the fuel alignment plate). See Figure 4-18.
Lower Support Structure Deep beams	All plants with core shrouds assembled with full-height shroud plates	Cracking (Fatigue) that results in a detectable surface-breaking indication in the welds or beams	None	Enhanced visual (EVT-1) examination, no later than 2 refueling outages from the beginning of the license renewal period. Subsequent examination on a ten-year interval, if adequacy of remaining fatigue life cannot be demonstrated.	Examine beam-to-beam welds, in the axial elevation from the beam top surface to four inches below. See Figure 4-19.

Note:

1. Examination acceptance criteria and expansion criteria for the CE components are in Table 5-2.

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Table 4-3
Westinghouse plants Primary components

Item	Applicability	Effect (Mechanism)	Expansion Link (Note 1)	Examination Method/Frequency (Note 1)	Examination Coverage
Control Rod Guide Tube Assembly Guide plates (cards)	All plants	Loss of Material (Wear)	None	Visual (VT-3) examination no later than 2 refueling outages from the beginning of the license renewal period, and no earlier than two refueling outages prior to the start of the license renewal period. Subsequent examinations are required on a ten-year interval.	20% examination of the number of CRGT assemblies, with all guide cards within each selected CRGT assembly examined. See Figure 4-20
Control Rod Guide Tube Assembly Lower flange welds	All plants	Cracking (SCC, Fatigue)	Bottom-mounted instrumentation (BMI) column bodies, Lower support column bodies (cast)	Enhanced visual (EVT-1) examination to determine the presence of crack-like surface flaws in flange welds no later than 2 refueling outages from the beginning of the license renewal period and subsequent examination on a ten-year interval.	100% of outer (accessible) CRGT lower flange weld surfaces and adjacent base metal. See Figure 4-21.
Core Barrel Assembly Upper core barrel flange weld	All plants	Cracking (SCC)	Remaining core barrel welds, Lower support column bodies (non cast)	Periodic enhanced visual (EVT-1) examination, no later than 2 refueling outages from the beginning of the license renewal period and subsequent examination on a ten-year interval.	100% of one side of the accessible surfaces of the selected weld and adjacent base metal. See Figure 4-22.
Baffle-Former Assembly Baffle-edge bolts	All plants with baffle-edge bolts	Cracking (IASCC, Fatigue) that results in • Lost or broken locking devices • Failed or missing bolts • Protrusion of bolt heads	None	Visual (VT-3) examination, with baseline examination between 20 and 40 EFPY and subsequent examinations on a ten-year interval.	Bolts and locking devices on high fluence seams. 100% of components accessible from core side. See Figure 4-23.

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Table 4-3
Westinghouse plants Primary components (continued)

Item	Applicability	Effect (Mechanism)	Expansion Link (Note 1)	Examination Method/Frequency (Note 1)	Examination Coverage
Baffle-Former Assembly Baffle-former bolts	All plants	Cracking (IASCC, Fatigue)	Lower support column bolts, Barrel-former bolts	Baseline volumetric (UT) examination between 25 and 35 EFPY, with subsequent examination after 10 to 15 additional EFPY to confirm stability of bolting pattern. Re-examination for high-leakage core designs requires continuing examinations on a ten-year interval.	100% of accessible bolts or as supported by plant-specific justification. Heads accessible from the core side. UT accessibility may be affected by complexity of head and locking device designs. See Figures 4-23 and 4-24.
Baffle-Former Assembly Assembly	All plants	Distortion (Void Swelling), or Cracking (IASCC) that results in • Abnormal interaction with fuel assemblies • Gaps along high fluence baffle joint • Vertical displacement of baffle plates near high fluence joint • Broken or damaged edge bolt locking systems along high fluence baffle joint	None	Visual (VT-3) examination to check for evidence of distortion, with baseline examination between 20 and 40 EFPY and subsequent examinations on a ten-year interval.	Core side surface as indicated. See Figures 4-24, 4-25, 4-26 and 4-27.

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Table 4-3
Westinghouse plants Primary components (continued)

Item	Applicability	Effect (Mechanism)	Expansion Link (Note 1)	Examination Method/Frequency (Note 1)	Examination Coverage
Alignment and Interfacing Components Internals hold down spring	All plants with 304 stainless steel hold down springs	Distortion (Loss of Load) Note: This mechanism was not strictly identified in the original list of age-related degradation mechanisms [7].	None	Direct measurement of spring height within three cycles of the beginning of the license renewal period. If the first set of measurements is not sufficient to determine life, spring height measurements must be taken during the next two outages, in order to extrapolate the expected spring height to 60 years.	Measurements should be taken at several points around the circumference of the spring, with a statistically adequate number of measurements at each point to minimize uncertainty. Replacement of 304 springs by 403 springs is required when the spring stiffness is determined to relax beyond design tolerance. See Figure 4-28.
Thermal Shield Assembly Thermal shield flexures	All plants with thermal shields	Cracking (Fatigue) or Loss of Material (Wear) that results in thermal shield flexures excessive wear, fracture, or complete separation	None	Visual (VT-3) no later than 2 refueling outages from the beginning of the license renewal period. Subsequent examinations on a ten-year interval.	100% of thermal shield flexures. See Figures 4-29 and 4-36.

Notes:

1. Examination acceptance criteria and expansion criteria for the Westinghouse components are in Table 5-3.

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Table 4-4
B&W plants Expansion components

Item	Applicability	Effect (Mechanism)	Primary Link (Note 1)	Examination Method (Note 1)	Examination Coverage
Upper Grid Assembly Alloy X-750 dowel-to-upper fuel assembly support pad welds	All plants (except DB)	Cracking (SCC), including the detection of separated or missing locking welds, or missing dowels	Alloy X-750 dowel-to-guide block welds	Visual (VT-3) examination.	100% of accessible dowel locking welds. See Figure 4-6 (i.e., these are similar to the lower fuel assembly support pads).
Control Rod Guide Tube Assembly CRGT spacer castings	All plants	Cracking (TE), including the detection of fractured spacers or missing screws	CSS cast outlet nozzle, CSS vent valve disks, or IMI guide tube spiders	Visual (VT-3) examination.	100% of accessible surfaces at the 4 screw locations (at every 90°) (limited accessibility). See Figure 4-5.
Core Barrel Assembly Upper thermal shield bolts (UTS)	All plants	Cracking (SCC)	UCB and LCB bolts	Volumetric examination (UT).	100% of accessible bolts. See Figure 4-7.
Core Barrel Assembly Surveillance specimen holder tube (SSHT) studs/nuts (CR-3) or bolts (DB)	CR-3, DB				
Core Barrel Assembly Core barrel cylinder (including vertical and circumferential seam welds) Former plates	All plants	Cracking (IE), including readily detectable cracking	Baffle plates	Justify by evaluation or by replacement.	Inaccessible. See Figure 4-2.

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Table 4-4
B&W plants Expansion components (continued)

Item	Applicability	Effect (Mechanism)	Primary Link (Note 1)	Examination Method (Note 1)	Examination Coverage
Core Barrel Assembly Baffle-to-baffle bolts Core barrel-to-former bolts	All plants	Cracking (IASCC, IE, IC/ISR/Fatigue/ Wear, Overload)	Baffle-to-former bolts	Internal baffle-to-baffle bolts: No examination requirements, Justify by evaluation or by replacement.	N/A. See Figure 4-2.
				External baffle-to-baffle bolts, Barrel-to-former bolts: No examination requirements, Justify by evaluation or by replacement.	Inaccessible. See Figure 4-2.
Core Barrel Assembly Locking devices, including locking welds, for the external baffle-to-baffle bolts and core barrel-to-former bolts	All plants	Cracking (IASCC, IE)	Locking devices, including locking welds, of baffle-to-former bolts or internal baffle-to-baffle bolts	Justify by evaluation or by replacement.	Inaccessible. See Figure 4-2.
Lower Grid Assembly Lower fuel assembly support pad items: pad, pad-to-rib section welds, Alloy X-750 dowel, cap screw, and their locking welds (Note: the pads, dowels, and cap screws are included because of TE/IE of the welds)	All plants	Cracking (IE), including the detection of separated or missing welds, missing support pads, dowels, cap screws and locking welds, or misalignment of the support pads	IMI guide tube spiders and spider-to-lower grid rib section welds	Visual (VT-3) examination.	100% of accessible pads, dowels, and cap screws, and associated welds. See Figure 4-6.

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Table 4-4
B&W plants Expansion components (continued)

Item	Applicability	Effect (Mechanism)	Primary Link (Note 1)	Examination Method (Note 1)	Examination Coverage
Lower Grid Assembly Alloy X-750 dowel-to-lower fuel assembly support pad welds	All plants	Cracking (SCC), including the detection of separated or missing locking welds, or missing dowels	Alloy X-750 dowel-to-guide block welds	Visual (VT-3) examination.	100% of accessible dowels welds. See Figure 4-6.
Lower Grid Assembly Lower grid shock pad bolts	TMI-1	Cracking (SCC)	UCB and LCB bolts	Volumetric examination (UT).	100% of accessible bolts. See Figure 4-4.
Lower Grid Assembly Lower thermal shield (LTS) bolts	All plants	Cracking (SCC)	UCB and LCB bolts	Volumetric examination (UT).	100% of accessible bolts. See Figure 4-8.
Flow Distributor Assembly Flow distributor (FD) bolts					

Note:
1. Examination acceptance criteria and expansion criteria for the B&W components are in Table 5-1.

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Table 4-5
CE plants Expansion components

Item	Applicability	Effect (Mechanism)	Primary Link (Note 1)	Examination Method (Note 1)	Examination Coverage
Core Shroud Assembly (Bolted) Barrel-shroud bolts	Bolted plant designs	Cracking (IASCC, Fatigue)	Core shroud bolts	Volumetric (UT) examination, with initial and subsequent examination frequencies dependent on the results of core shroud bolt examinations.	100% (or as supported by plant-specific justification) of barrel-shroud and guide lug insert bolts with neutron fluence exposures > 3 displacements per atom (dpa). See Westinghouse design Figure 4-23.
Core Support Barrel Assembly Lower core barrel flange	All plants	Cracking (SCC, Fatigue)	Upper (core support barrel) flange weld	Enhanced visual (EVT-1) examination, with initial and subsequent examinations dependent on the results of the upper (core support barrel) flange weld examinations.	100% of accessible welds and adjacent base metal. See Figure 4-15.
Core Support Barrel Assembly Remaining core barrel assembly welds	All plants	Cracking (SCC)	Upper (core support barrel) flange weld	Enhanced visual (EVT-1) examination, with initial and subsequent examinations dependent on the results of core barrel assembly upper flange weld examinations.	100% of one side of the accessible weld and adjacent base metal surfaces for the weld with the highest calculated operating stress. See Figure 4-15.

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Table 4-5
CE plants Expansion components (continued)

Item	Applicability	Effect (Mechanism)	Primary Link (Note 1)	Examination Method (Note 1)	Examination Coverage
Lower Support Structure Core support column welds	All plants except those with core shrouds assembled with full-height shroud plates	Cracking (SCC, IASCC, Fatigue) including damaged or fractured material	Upper (core support barrel) flange weld	Visual (VT-3) examination, with initial and subsequent examinations based on plant evaluation of SCC susceptibility and demonstration of remaining fatigue life.	Examination coverage determined by plant-specific analysis. See Figures 4-16 and 4-31.
Core Shroud Assembly (Bolted) Core support column bolts	Bolted plant designs	Cracking (IASCC, Fatigue)	Core shroud bolts	Ultrasonic (UT) examination, with initial and subsequent examination frequencies dependent on the results of core shroud bolt examinations.	100% (or as supported by plant-specific analysis) of core support column bolts with neutron fluence exposures > 3 dpa. See Figures 4-16 and 4-33.
Core Shroud Assembly (Welded) Remaining axial welds	Plant designs with core shrouds assembled in two vertical sections	Cracking (IASCC)	Core shroud plate-former plate weld	Enhanced visual (EVT-1) examination, with initial and subsequent examination frequencies dependent on the results of the core shroud weld examinations.	Axial weld seams other than the core shroud re-entrant corner welds at the core mid-plane. See Figure 4-12.

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Table 4-5
CE plants Expansion components (continued)

Item	Applicability	Effect (Mechanism)	Primary Link (Note 1)	Examination Method (Note 1)	Examination Coverage
Core Shroud Assembly (Welded) Remaining axial welds, Ribs and rings	Plant designs with core shrouds assembled with full-height shroud plates	Cracking (IASCC)	Shroud plates of welded core shroud assemblies	Enhanced visual (EVT-1) examination, with initial and subsequent examination frequencies dependent on the results of the core shroud weld examinations.	Axial weld seams other than the core shroud re-entrant corner welds at the core mid-plane, plus ribs and rings. See Figure 4-13.
Control Element Assembly Remaining instrument guide tubes	All plants with instrument guide tubes in the CEA shroud assembly	Cracking (SCC, Fatigue) that results in missing supports or separation at the welded joint between the tubes and supports.	Peripheral instrument guide tubes within the CEA shroud assemblies	Visual (VT-3) examination, with initial and subsequent examinations dependent on the results of the instrument guide tubes examinations.	100% of tubes in CEA shroud assemblies. See Figure 4-18.

Note:

1. Examination acceptance criteria and expansion criteria for the CE components are in Table 5-2.

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Table 4-6
Westinghouse plants Expansion components

Item	Applicability	Effect (Mechanism)	Primary Link (Note 1)	Examination Method (Note 1)	Examination Coverage
Core Barrel Assembly Barrel-former bolts	All plants	Cracking (IASCC, Fatigue)	Baffle-former bolts	Volumetric (UT) examination, with initial and subsequent examinations dependent on results of baffle-former bolt examinations.	100% of accessible bolts. Accessibility may be limited by presence of thermal shields or neutron pads. See Figure 4-23.
Lower Support Assembly Lower support column bolts	All plants	Cracking (IASCC, Fatigue)	Baffle-former bolts	Volumetric (UT) examination, with initial and subsequent examinations dependent on results of baffle-former bolt examinations.	100% of accessible bolts or as supported by plant-specific justification. See Figures 4-32 and 4-33.
Core Barrel Assembly Core barrel flange, Core barrel outlet nozzles, Lower core barrel flange weld	All plants	Cracking (SCC, Fatigue)	Upper core barrel flange weld	Enhanced visual (EVT-1) examination, with initial examination and re-examination frequency dependent on the examination results for upper core barrel flange.	100% of one side of the accessible surfaces of the selected weld and adjacent base metal. See Figure 4-22.
Lower Support Assembly Lower support column bodies (non cast)	All plants	Cracking (IASCC)	Upper core barrel flange weld	Enhanced visual (EVT-1) examination, with initial examination and re-examination frequency dependent on the examination results for upper core barrel flange weld.	100% of accessible surfaces. See Figure 4-34.

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Table 4-6
Westinghouse plants Expansion components (continued)

Item	Applicability	Effect (Mechanism)	Primary Link (Note 1)	Examination Method (Note 1)	Examination Coverage
Lower Support Assembly Lower support column bodies (cast)	All plants	Cracking (IASCC) including the detection of fractured support columns	Control rod guide tube (CRGT) lower flanges	Visual (EVT-1) examination.	100% of accessible support columns. See Figure 4-34.
Bottom Mounted Instrumentation System Bottom-mounted instrumentation (BMI) column bodies	All plants	Cracking (Fatigue) including the detection of completely fractured column bodies	Control rod guide tube (CRGT) lower flanges	Visual (VT-3) examination of BMI column bodies as indicated by difficulty of insertion/withdrawal of flux thimbles. Flux thimble insertion/withdrawal to be monitored at each inspection interval.	100% of BMI column bodies for which difficulty is detected during flux thimble insertion/withdrawal. See Figure 4-35.

Note:

1. Examination acceptance criteria and expansion criteria for the Westinghouse components are in Table 5-3.

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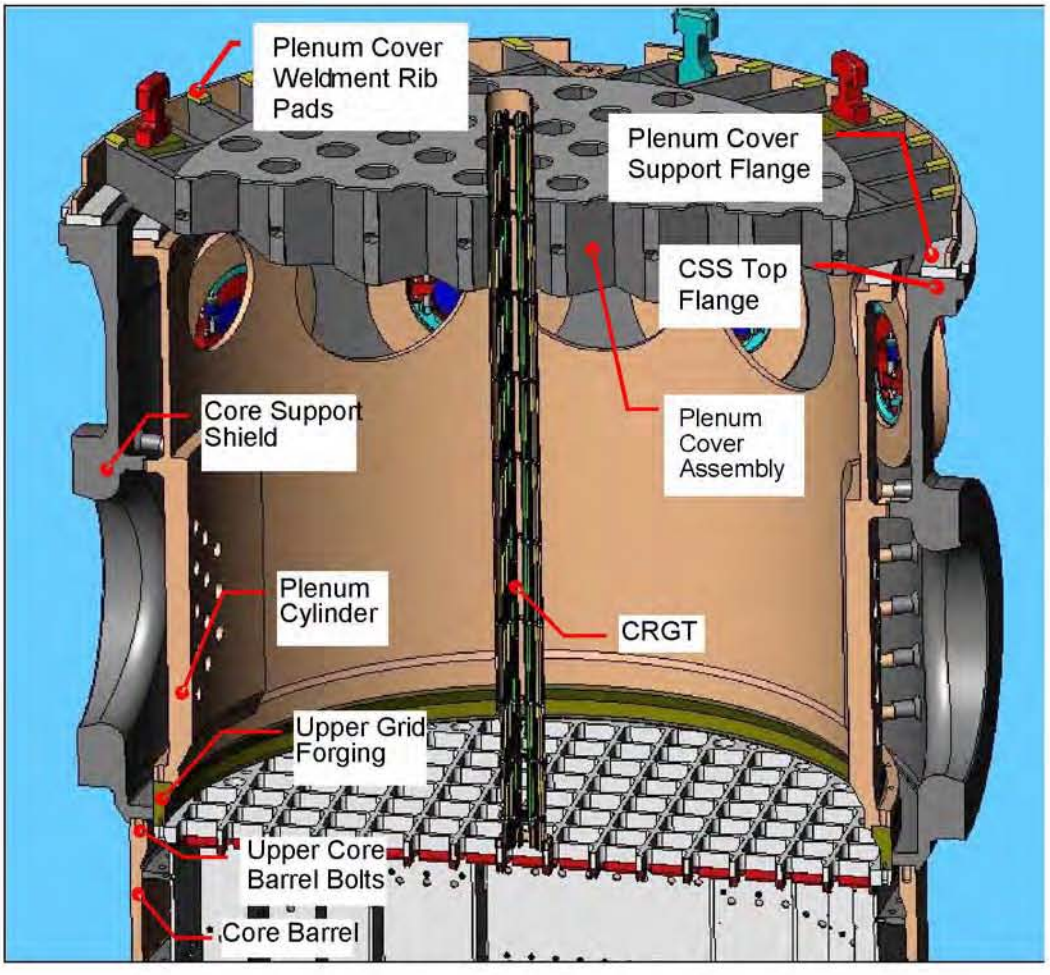

Figure 4-1
Typical upper internals arrangement for B&W-designed PWRs

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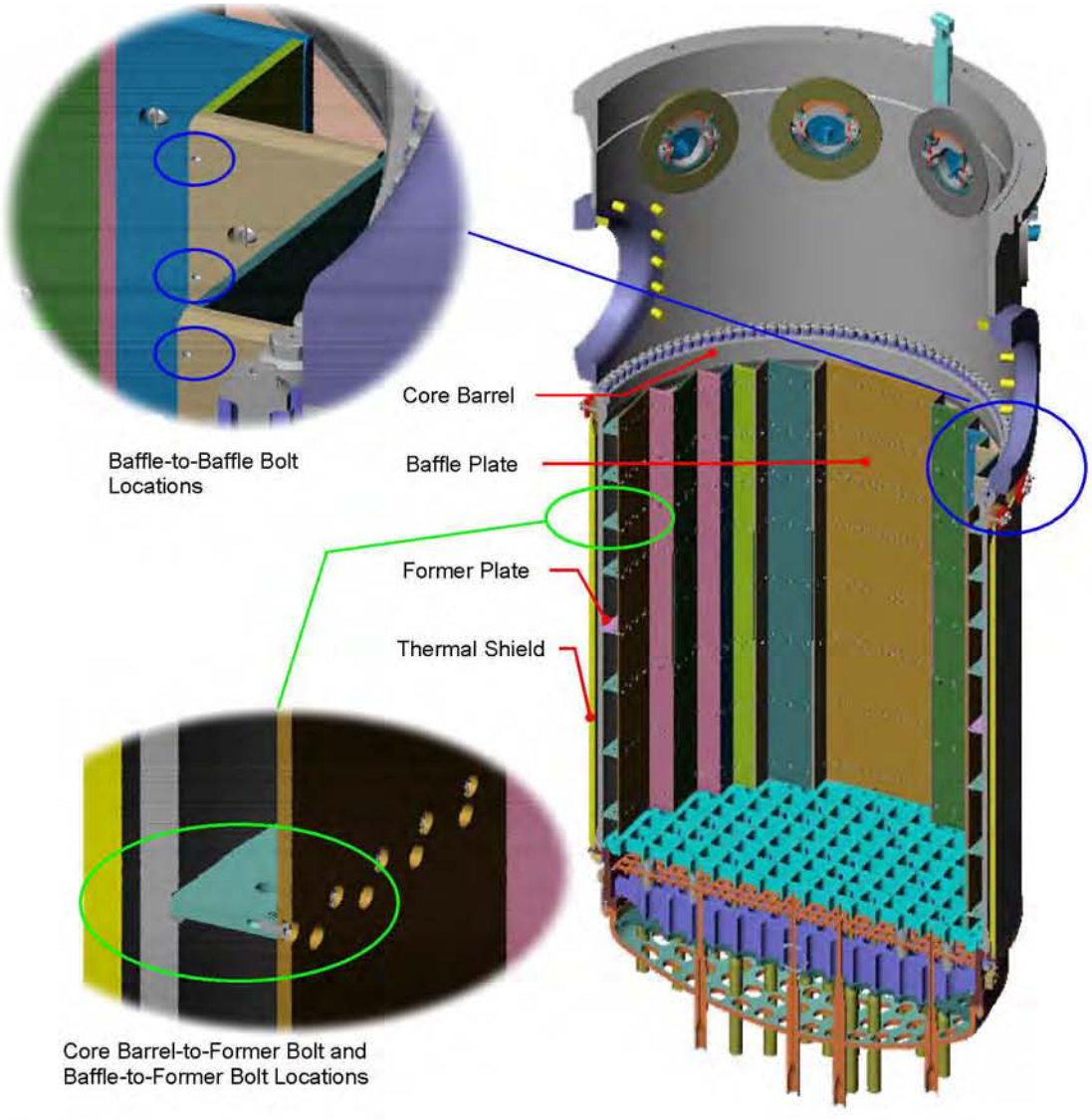

Figure 4-2
Typical internals core barrel assembly for B&W-designed PWRs

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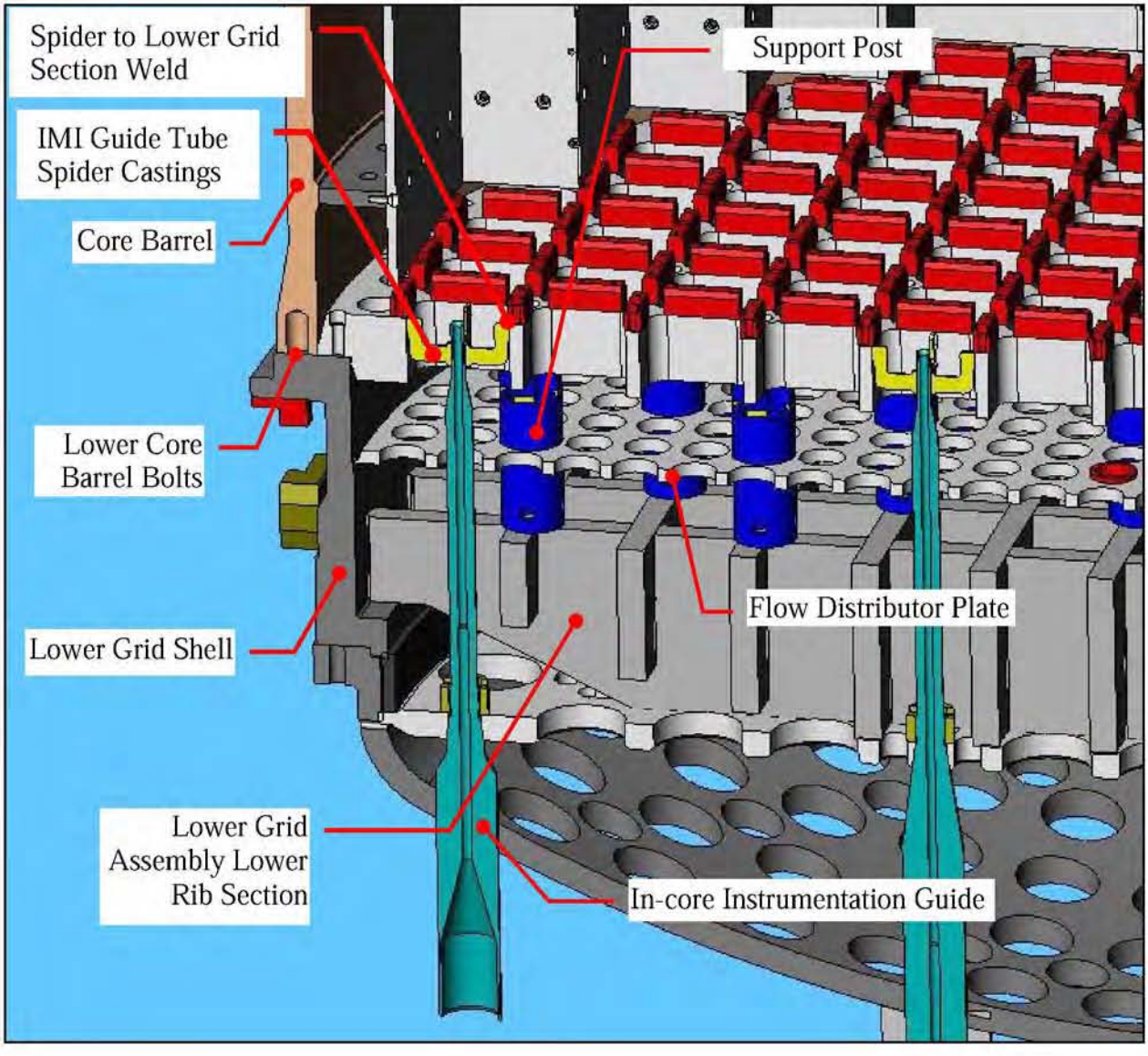

Figure 4-3
Typical lower internals arrangement for B&W-designed PWRs

IPEC_PA_OAG0000093

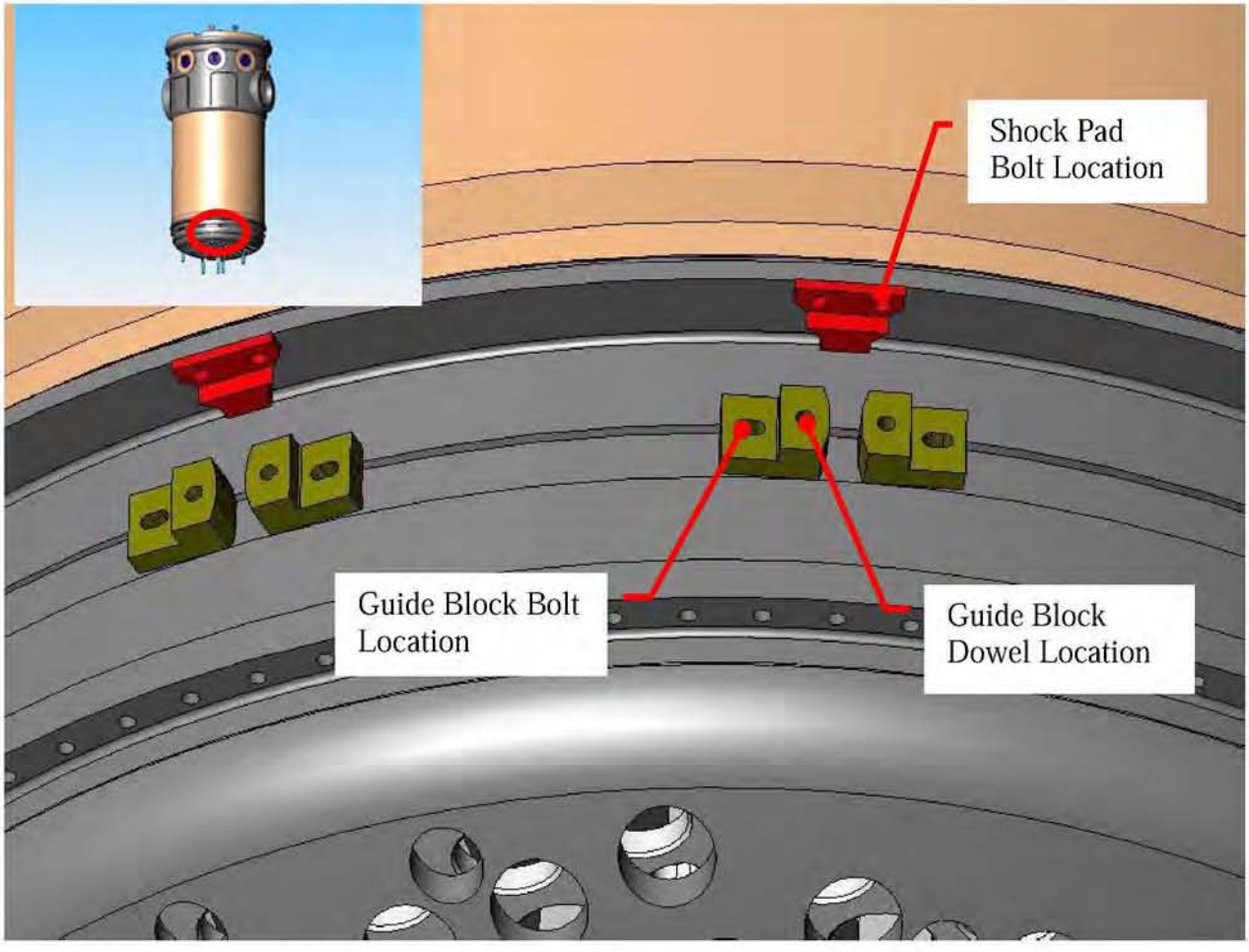

Figure 4-4
Typical guide block and shock pad locations for B&W-designed PWRs

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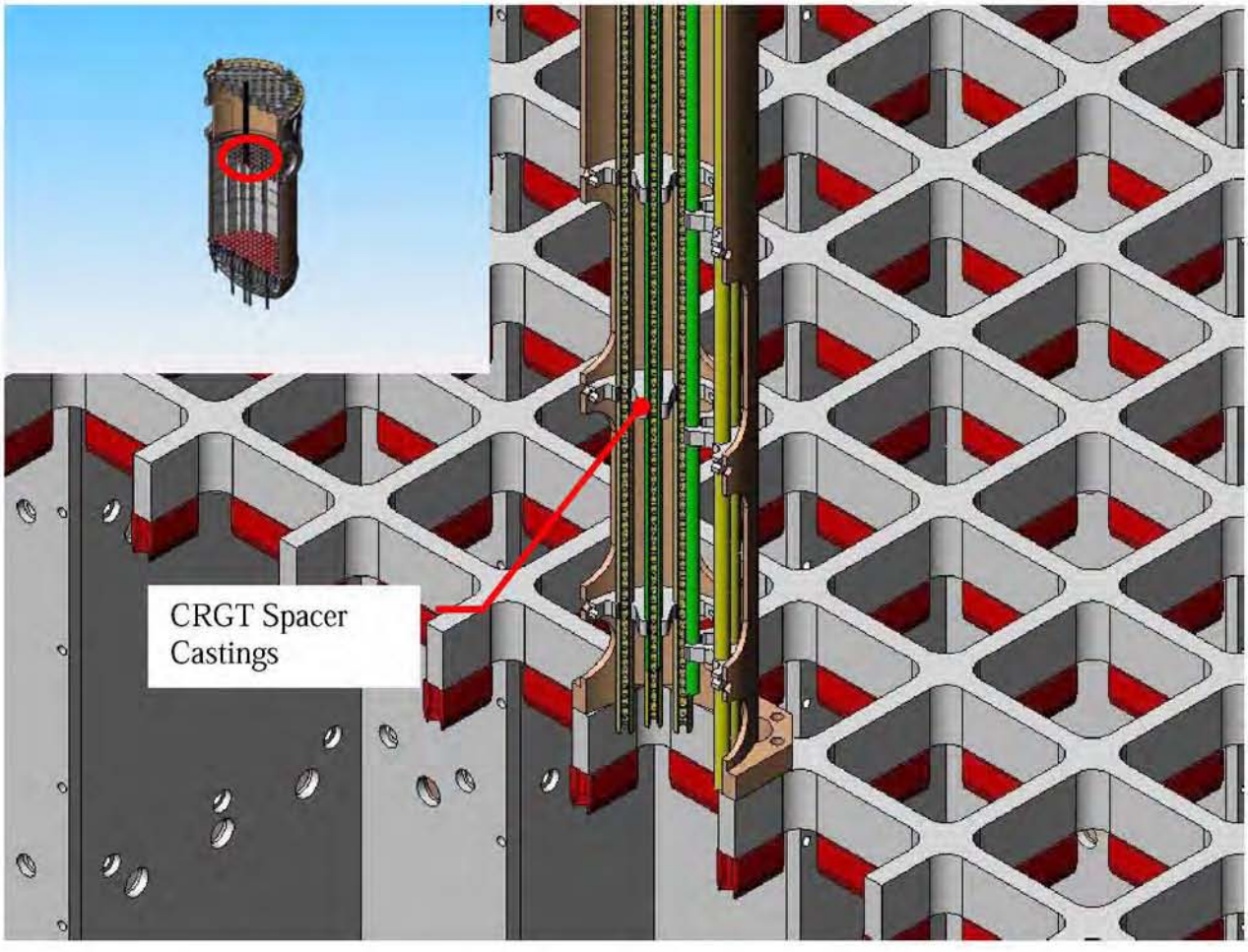

Figure 4-5
Typical control rod guide tube (CRGT) for B&W-designed PWRs (one of 69 CRGTs shown)

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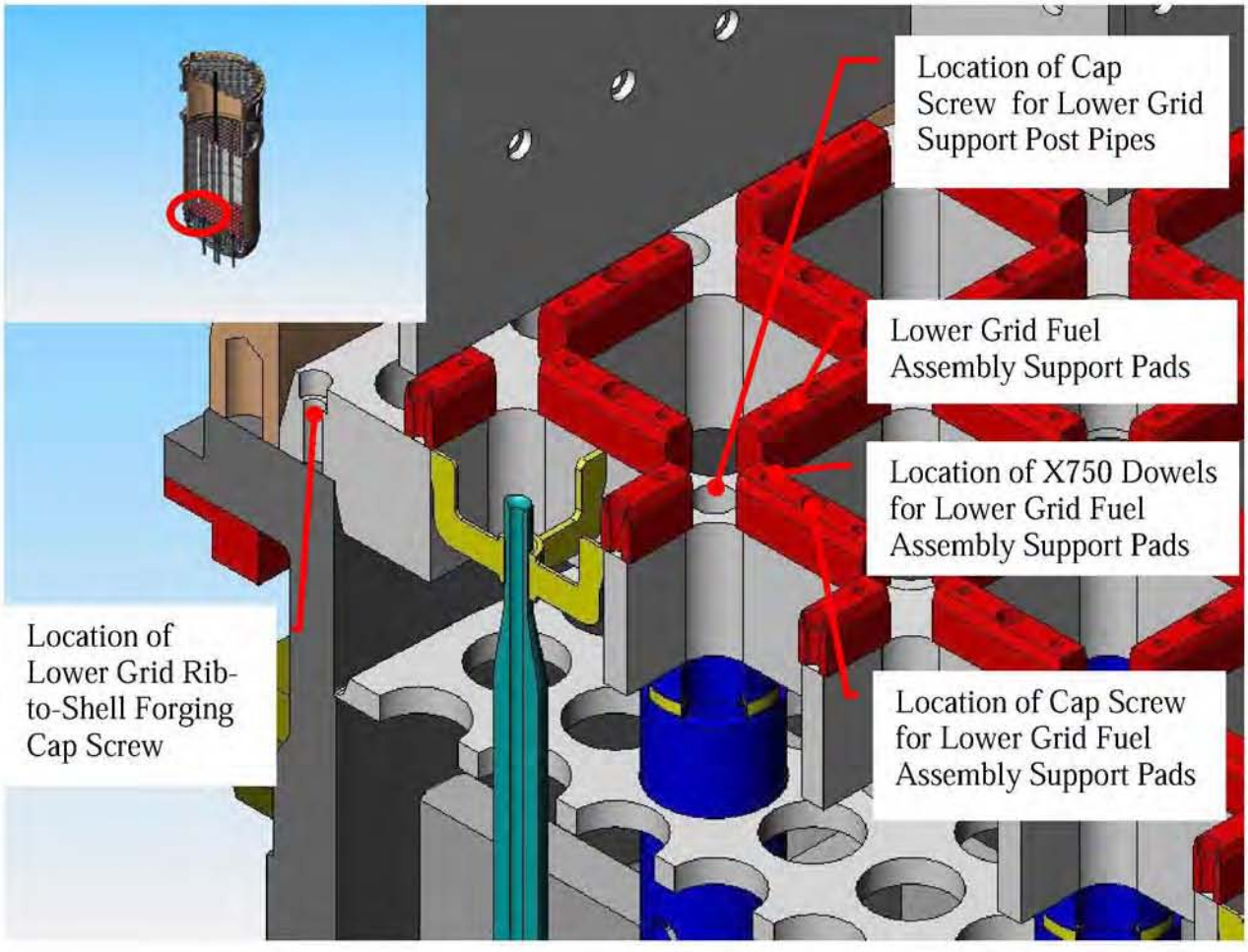

Figure 4-6
Typical lower grid assembly and fuel assembly support pads for B&W-designed PWRs

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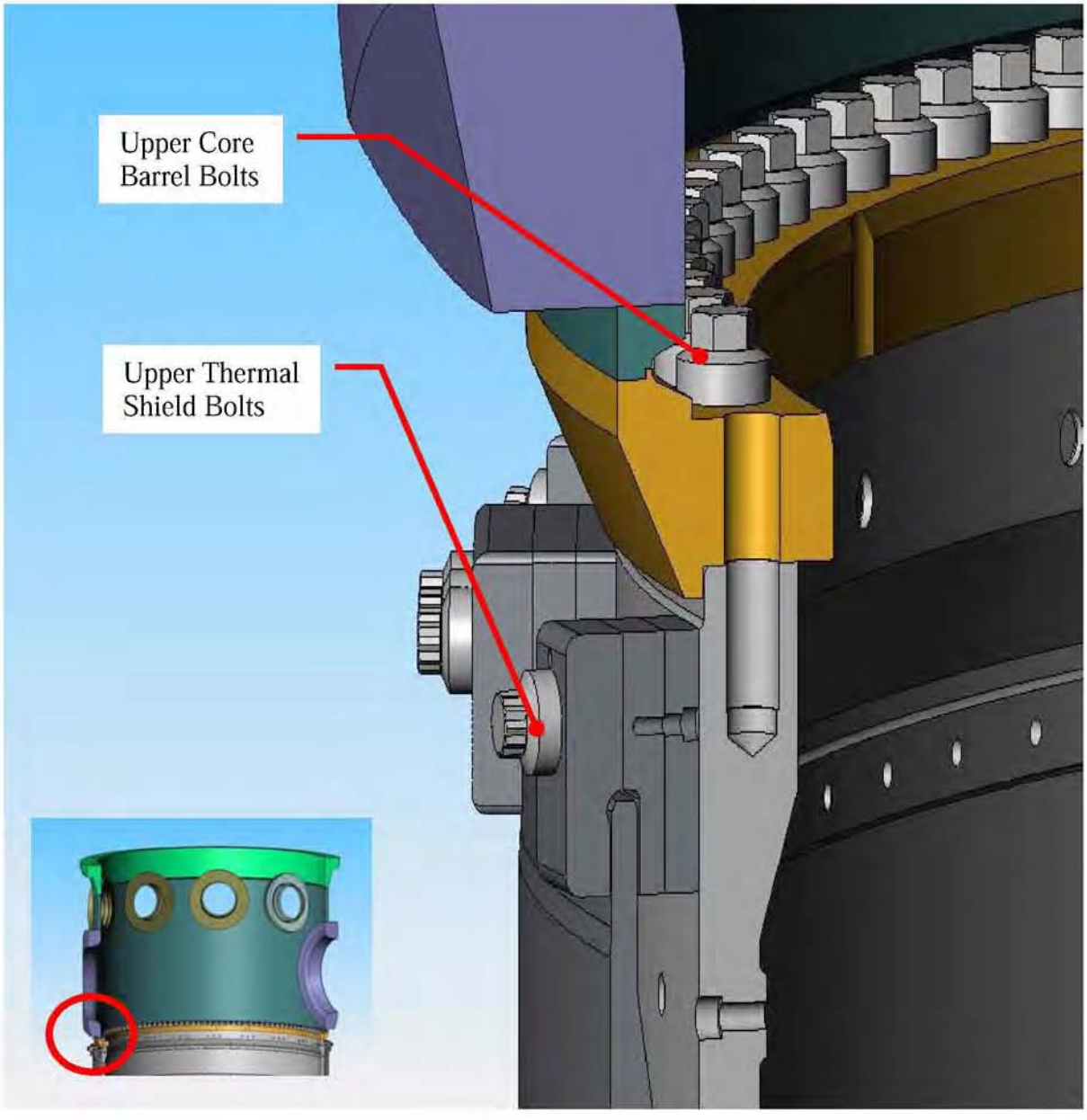

Figure 4-7
Typical upper thermal shield bolts and upper core barrel bolts for B&W-designed PWRs

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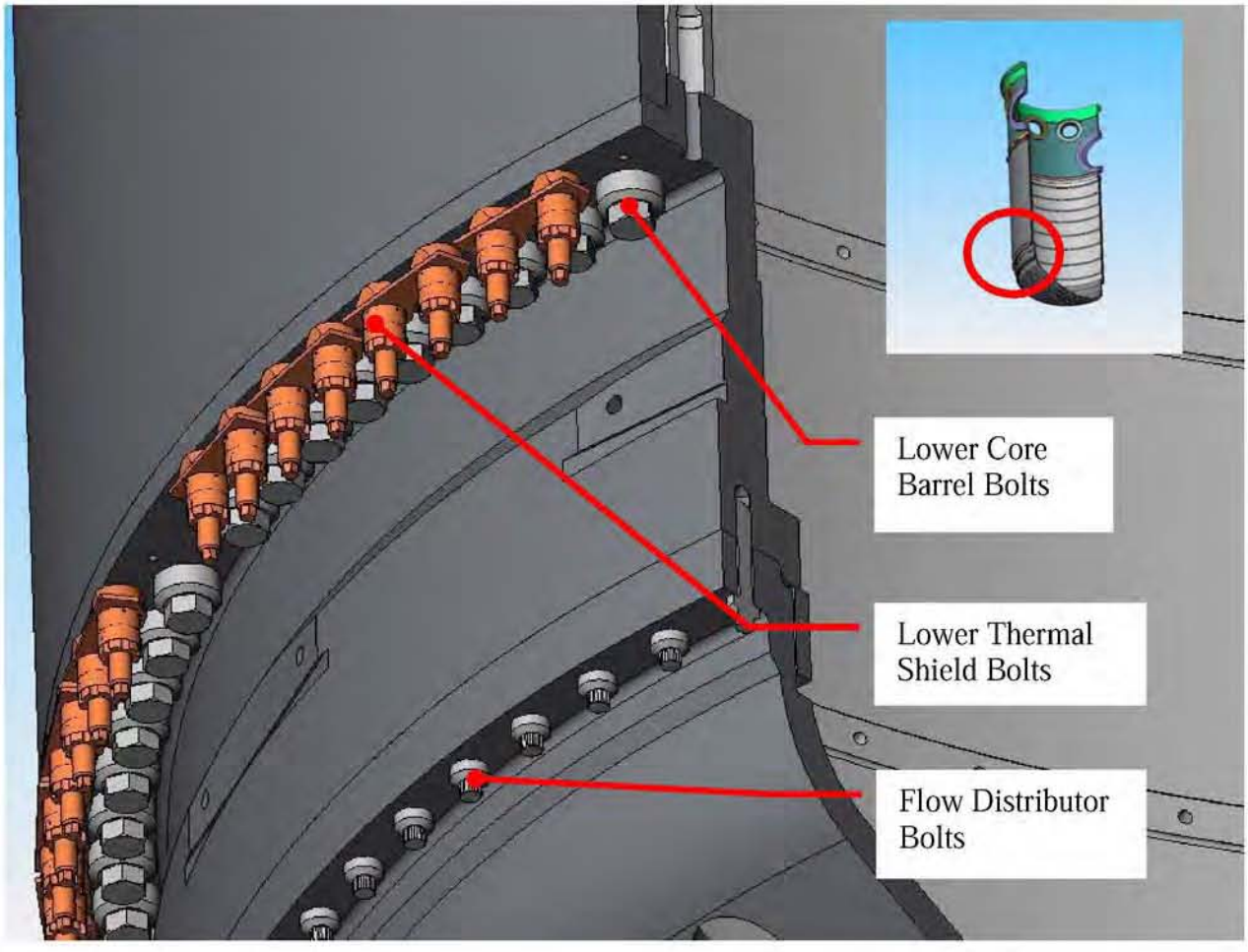

Figure 4-8
Typical lower thermal shield bolts, lower core barrel bolts, and flow distributor bolts for the B&W-designed PWRs

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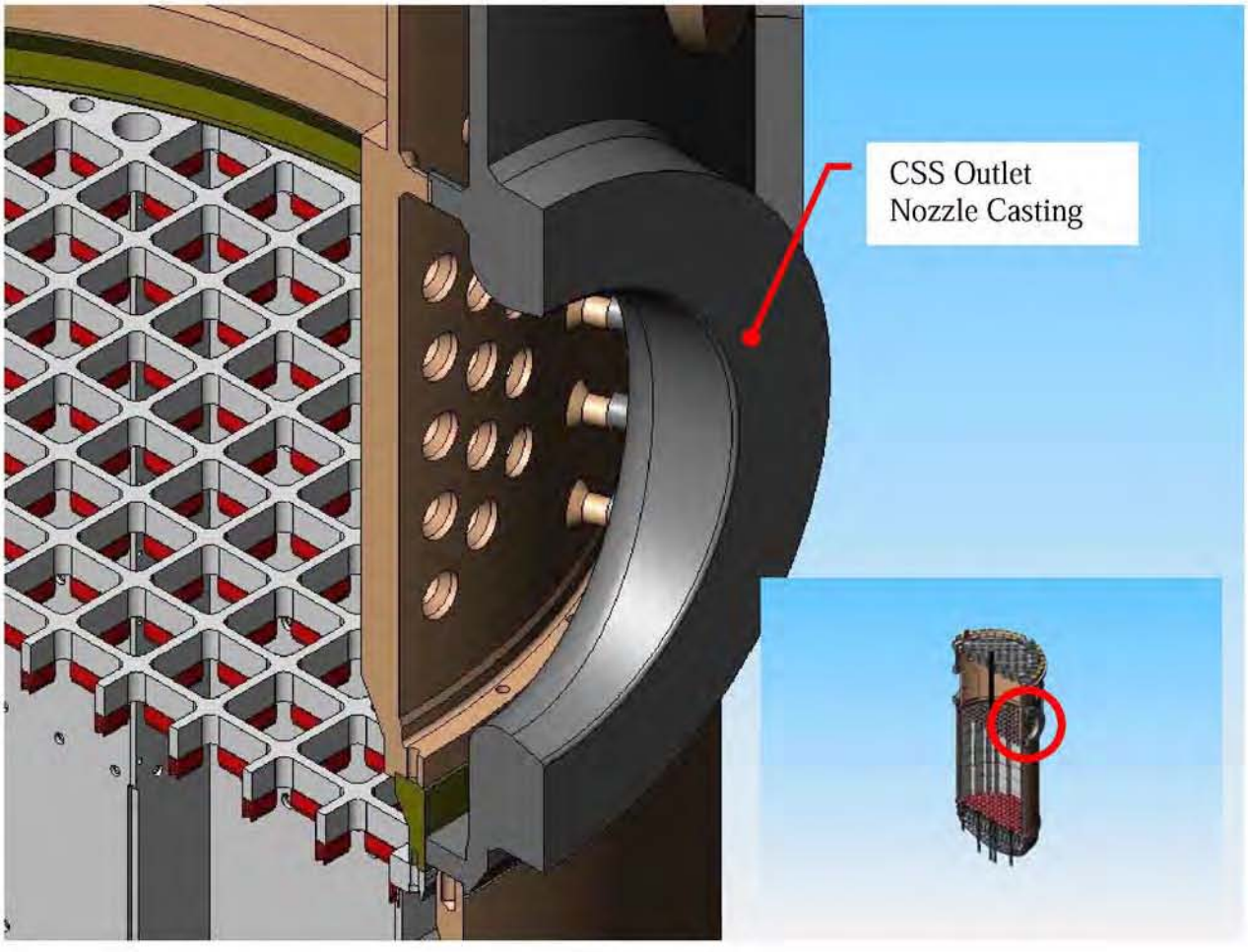

Figure 4-9
Typical core support shield (CSS) outlet nozzle for the B&W-designed PWRs

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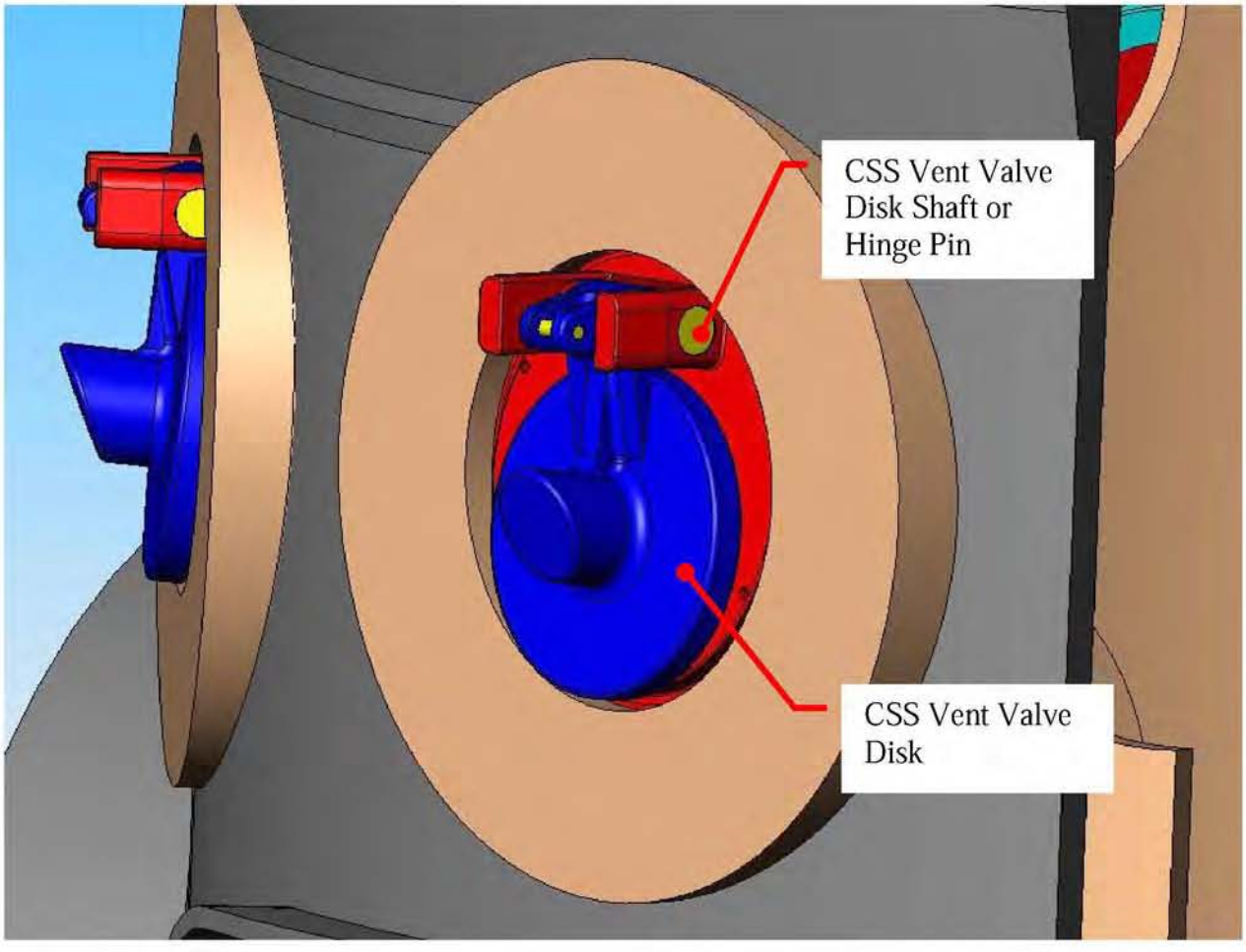

Figure 4-10
Typical core support shield (CSS) vent valve – outside view – for the B&W-designed PWRs

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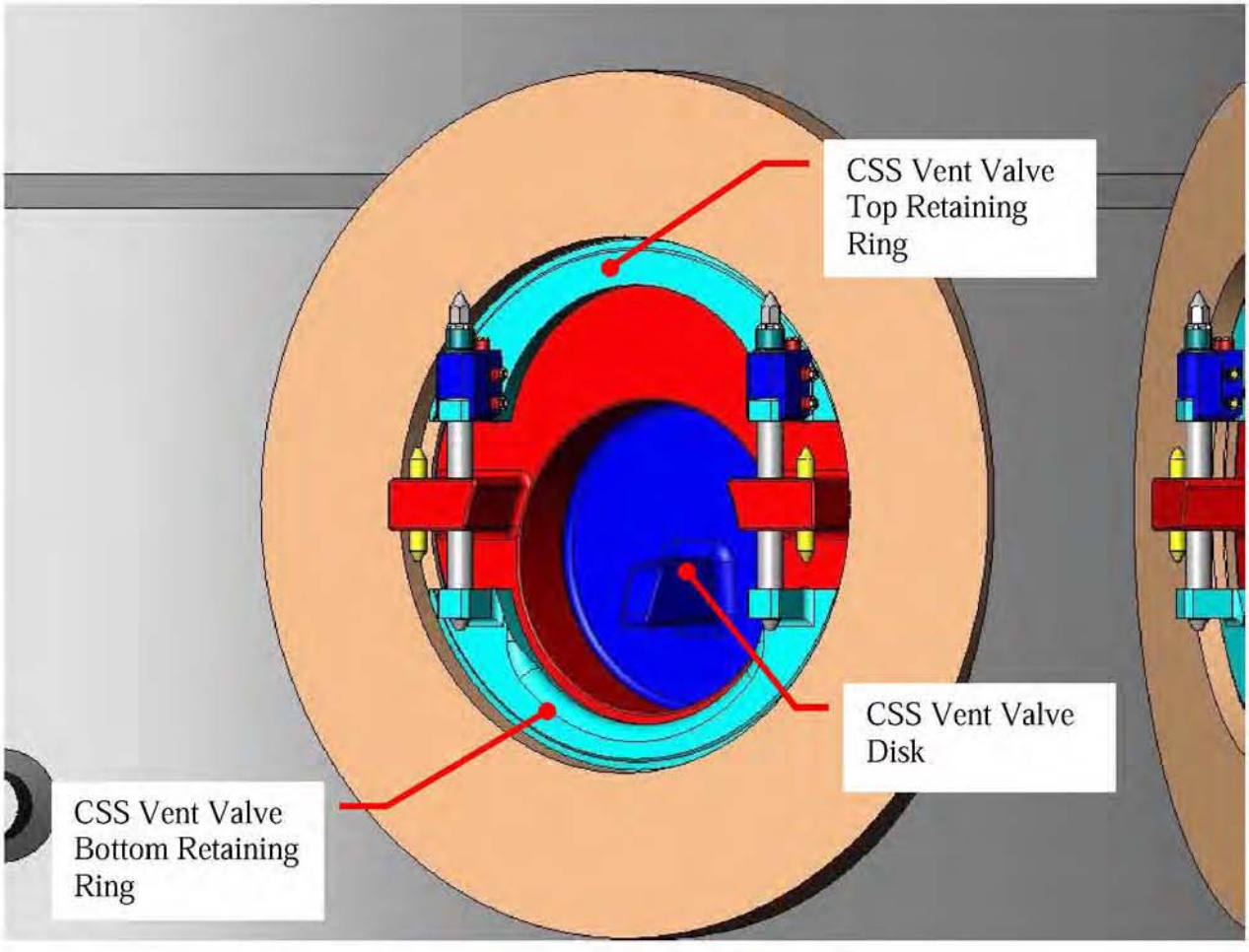

Figure 4-11
Typical core support shield (CSS) vent valve – inside view – for the B&W-designed PWRs

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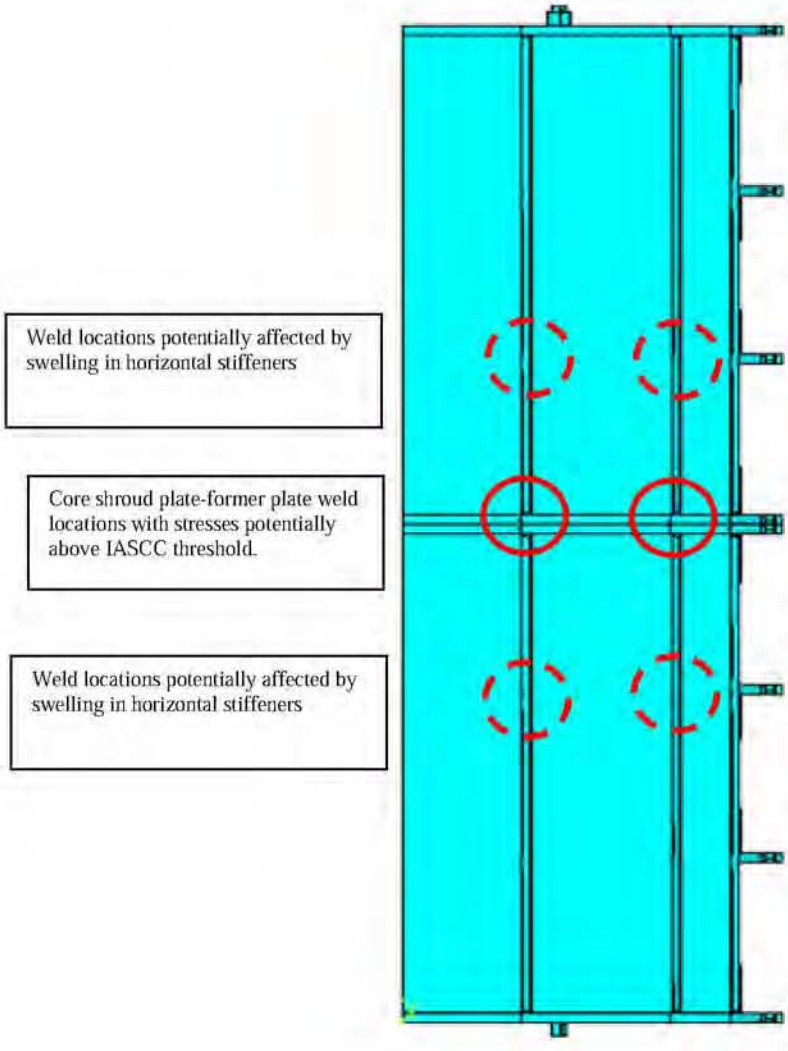

Figure 4-12
Potential crack locations for CE welded core shroud assembled in stacked sections

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