Approval Date: ~~July~~ xxx ~~28~~xx, 20xx~~21~~

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Case N-729-~~9~~10
Alternative Examination Requirements for PWR Reactor Vessel Upper Heads With Nozzles Having Pressure-Retaining Partial-Penetration WeldsSection XI, Division 1

Inquiry: What alternative examination requirements to those of Table IWB-2500-1, Examination Category B-P,IWB-2200, IWB-2400, and IWB-3000, may be used for PWR reactor vessel upper heads with nozzles having pressure-retaining partial-penetration welds?

Reply: It is the opinion of the Committee that the following alternatives to the requirements of Table IWB-2500-1, Examination Category B-P, IWB-2200, IWB-2400, and IWB-3000, may be used for PWR reactor vessel upper heads with nozzles having pressure-retaining partial-penetration welds.

-1000 SCOPE AND RESPONSIBILITY

-1100 SCOPE

(a) This Case provides alternative requirements for examination of PWR reactor vessel upper heads with nozzles having pressure-retaining partial-penetration welds.

(b) This Case shall not be used to perform mitigation activities. For the type of mitigation activity identified in -1210(c), this Case provides premitigation examination requirements, configuration requirements, peening mitigation performance criteria, and preservice and inservice examination requirements.

-1200 COMPONENTS SUBJECT TO EXAMINATION

-1210 Examination Requirements

The examination requirements shall apply to the following:

(a) Heads having nozzles fabricated from UNS N06600 material with UNS N06082 or UNS W86182 partial-penetration welds.

(b) Heads having nozzles fabricated from Primary Water Stress Corrosion Cracking (PWSCC) resistant materials, such as UNS N06690 base metal with UNS N06052 or UNS W86152 partial-penetration welds.

(c) Heads with nozzles fabricated from UNS N06600 material with UNS N06082 or UNS W86182 partial-penetration welds and mitigated by application of peening mitigation techniques that meet the criteria of Mandatory Appendix II.

-2000 EXAMINATION AND INSPECTION

-2200 PRESERVICE EXAMINATION

-2210 Baseline Examination

The examinations listed in Table 1 shall be performed completely, once, as a baseline examination. These examinations shall include all nozzles. Examinations performed prior to implementation of this Case that meet the requirements of Table 1, with the exception of the 4 hr of additional training required for VE personnel, may be credited.

-2220 Preservice Examination after Repair/ replacement Activities

Prior to return to service, the applicable volumetric and surface examinations listed in Table 1 shall be performed on items affected by the repair/replacement activity.

-2400 INSPECTION SCHEDULE

-2410 Inspection Program

Inservice examination methods and frequency are specified in Table 1. Reactor vessel head penetration and partial penetration welds mitigated by a peening mitigation technique meeting Mandatory Appendix II shall be examined in accordance with Table 1, Items B4.50 and B4.60. Examination frequencies for heads characterized in -1210(a) shall be determined using the following parameters to characterize the susceptibility to crack initiation and the potential for crack propagation:

(a) Susceptibility to crack initiation is represented by the EDY parameter, calculated as follows:

$$EDY = \sum_{j=1}^{n}\left\{\Delta EFPY_j \exp\left[-\frac{Q_i}{R}\left(\frac{1}{T_{\text{head}j}} - \frac{1}{T_{\text{ref}}}\right)\right]\right\}$$

The Committee's function is to establish rules of safety, relating only to pressure integrity, governing the construction of boilers, pressure vessels, transport tanks and nuclear components, and inservice inspection for pressure integrity of nuclear components and transport tanks, and to interpret these rules when questions arise regarding their intent. This Code does not address other safety issues relating to the construction of boilers, pressure vessels, transport tanks and nuclear components, and the inservice inspection of nuclear components and transport tanks. The user of the Code should refer to other pertinent codes, standards, laws, regulations or other relevant documents.

Table 1
Examination Categories: Class 1 PWR Reactor Vessel Upper Head

Item No.	Parts Examined	Examination Requirements/Fig. No.	Examination Method	Acceptance Standard	Extent and Frequency of Examination	Deferral of Examination to End of Interval
B4.10	Head with UNS N06600 nozzles and UNS N06082 or UNS W86182 partial penetration welds	Figure 1	Visual, VE [Note (1)], [Note (2)]	-3140	Each refueling outage [Note (3)], [Note (4)]	Not permissible
B4.20	UNS N06600 nozzles and UNS N06082 or UNS W86182 partial-penetration welds in head	Figure 2 [Note (5)]	Volumetric ([Note (6)] Surface [Note (6)]	-3130	All nozzles, every 8 calendar years or before RIY=2.25, whichever is less [Note (7)], [Note (8)], [Note (9)]	Not permissible
B4.30	Head with nozzles and partial-penetration welds of PWSCC-resistant materials	Figure 1	Visual, VE [Note (1)], [Note (2)]	-3140	Every third refueling outage or 5 calendar years, whichever is less [Note (3)]	Not permissible
B4.40	Nozzles and partial-penetration welds of PWSCC-resistant materials in head	Figure 2 [Note (5)]	Volumetric [Note (6)] Surface [Note (6)]	-3130	All nozzles, not to exceed two inspection intervals (nominally 20 calendar years) [Note (8)], [Note (9)], [Note (10)]	Not permissible
B4.50	Head with UNS N06600 nozzles and UNS N06082 or UNS W86182 partial-penetration welds mitigated by peening qualified in accordance with Mandatory Appendix II	Figure 1	Visual, VE [Note (1)], [Note (2)]	-3140	Every other refueling outage [Note (3)], [Note (11)], [Note (13)], [Note (14)]	Not permissible
B4.60	UNS N06600 nozzles and UNS N06082 or UNS W86182 partial-penetration welds mitigated by peening qualified in accordance with Mandatory Appendix II	Figure 2 [Note (5)]	Volumetric [Note (6)], Surface [Note (6)]	-3130	All nozzles, not to exceed one inspection interval (nominally 10 calendar years) [Note (9)], [Note (12)], [Note (13)], [Note (14)]	

NOTES:

(1) The VE shall consist of the following:

(a) A direct examination of the bare-metal surface of the entire outer surface of the head, including essentially 100% of the intersection of each nozzle with the head. If welded or bolted obstructions are present (i.e., mirror insulation, insulation support feet, shroud support ring/lug), the examination shall include ≥95% of the area in the region of the nozzles as defined in Figure 1 and the head surface uphill and downhill of any such obstructions. The examination may be performed with insulation in place using remote equipment that provides resolution of the component metal surface equivalent to a bare-metal direct examination.

(b) The examination may be performed with the system depressurized.

(c) The examination shall be performed with an illumination level and a sufficient distance to allow resolution of lower case characters not greater than 0.105 in. (2.7 mm) in height.

(d) The VE personnel may apply pressurized air (with pressure regulated for this purpose) or vacuuming to remove loosely adherent dust or debris for purpose of determining whether they are relevant conditions.

(e) A record of the VE shall be produced, including description of any detected deposits, residues, dust, or debris and the steps taken by the VE personnel to determine whether such deposits, residues, dust, or debris are relevant conditions for the purposes of the VE acceptance standard (-3140).

(2) Personnel performing the VE shall be qualified as a VT-2 visual examiner and shall have completed at least 4 hr of additional training in detection of borated water leakage from UNS N06600, UNS N06082 or UNS W86182 components and the resulting boric acid corrosion of adjacent ferritic steel components.

(3) Examination may be performed with the system depressurized.

(4) If EDY < 8 and no flaws unacceptable for continued service under -3130 or -3140 have been detected, the reexamination frequency may be extended to every third refueling outage or 5 calendar years, whichever is less, provided an IWA-2212 VT-2 visual examination of the head is performed under the insulation through multiple access points in outages that the VE is not completed. This IWA-2212 VT-2 visual examination may be performed with the reactor vessel depressurized.

Table 1
Examination Categories: Class 1 PWR Reactor Vessel Upper Head (Cont'd)

NOTES (CONT'D):

(5) If the examination area or volume requirements of Figure 2 cannot be met, the alternative requirements of Mandatory Appendix I shall be used and the evaluation shall be submittedto the regulatory authority having jurisdiction at the plant site.

(5) Volumetric or surface examinations shall be performed on essentially 100% of the required volume or equivalent surfaces of the nozzle tube, as identified by Figure 2. A demonstrated volumetric or surface leak path assessment through all J-groove welds shall be performed. For leaking penetrations, the meandering fluid stream pattern of the ultrasonic data display represents the leak path of the primary coolant from the pressure vessel to the atmosphere. If a surface examination is being substituted for a volumetric examination on a portion of a penetration nozzle that is below the toe of the J-groove weld, the surface examination shall be performed on the penetration nozzle inside E'-D and outside E-C surfaces of that portion of the nozzle.

(6) If not previously performed, baseline volumetric and surface examinations shall be performed.
(a) for plants with EDY > 12, at the next refueling outage,
(b) for plants with EDY ≥ 8 and EDY ≤ 12, no later than the second refueling outage, or,
(c) for plants with EDY < 8, no later than February 10, 2008.

(7) If flaws are attributed to PWSCC, whether or not acceptable for continued service in accordance with -3130 or -3140, the reinspection interval shall be each refueling outage. For reactor vessel heads with operating temperatures less than 570°F (300°C), the reinspection frequency shall be at least once every 36 months of operating time. Additionally, repaired areas shall be examined during the next refueling outage following the repair.

(8) Includes essentially 100% of surface or volume.

(9) For sister heads with similar operating conditions, the inspection requirements of Item No. B4.40 may be alternated among sister heads.
(a) If no service-induced PWSCC indications are identified during an examination, the sister heads may be considered as having met the examination requirements of B4.40. The initial sister head examination shall be accomplished during the interval in which it is installed. The unexamined sister heads shall be examined during the next required B4.40 inspection interval. If more than two sister heads exist, the examinations of remaining sister heads shall be performed no sooner than two refueling outages following the previous reactor vessel head examination, and no reactor vessel head shall be operated more than 40 yr without examination. The intent is that the sister head examinations are spread over time and are alternated among the sister heads.
(b) If examination results identify a service-induced PWSCC indication, all sister heads shall be examined during the next refueling outage in accordance with the visual examination requirements of Item B4.30, and a volumetric examination shall be performed within two refueling outages.

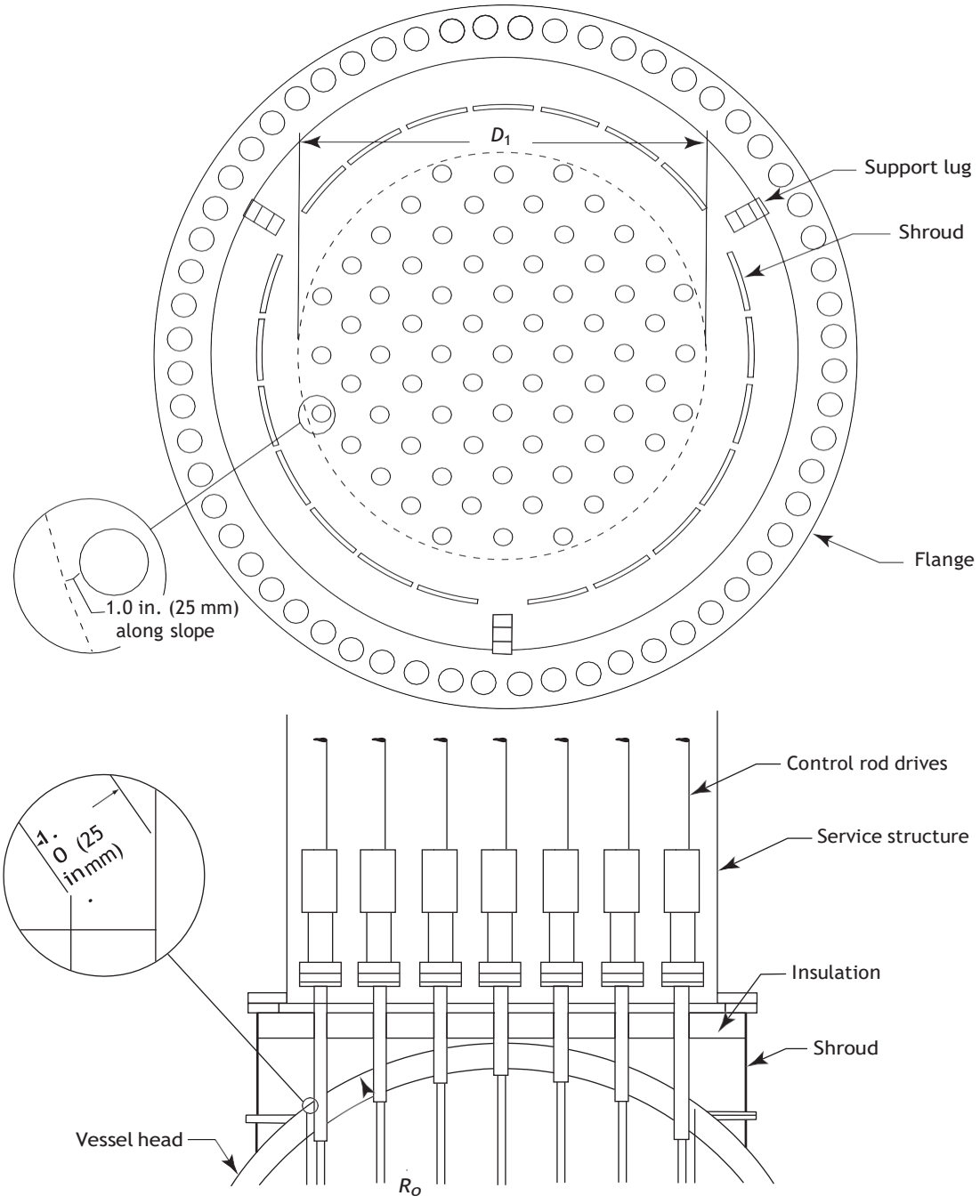
(10) If no flaws unacceptable for continued service under -3130 or -3140 have been detected in the second refueling outage following peening mitigation, the interval for performance of a VE may be extended to every third refueling outage, provided a VT-2 visual examination of the vessel head is performed under the insulation through multiple access points during refueling outages in which the VE is not completed. The VT-2 visual examination may be performed with the reactor vessel depressurized. The VE may be delayed one refueling outage so it can be performed in conjunction with the volumetric examination.

(11) In the second refueling outage following peening mitigation, an examination meeting the inspection requirements of [Note (6)] shall be performed.

(12) If flaws or ~~relevent~~relevant conditions are detected that are unacceptable for continued service in accordance with -3132.3, -3142.1(b), or -3142.1(c), they shall be corrected by repair/ replacement activity of -3132.2 or -3142.3. The head or nozzle shall be identified as Item B4.10 or Item B4.20. If peening mitigation is performed, the head or nozzle may be identifiedas Item B4.50 or Item B4.60.

(13) If peening mitigation techniques qualified in accordance with Mandatory Appendix II are used, the following shall be met:
(a) Volumetric examination of the volume (A-B-C-D) as identified in Figure 2 shall be performed prior to application of peening mitigation techniques. This examination shall be considered the preservice baseline examination.
(b) Prior to peening mitigation, an examination meeting the inspection requirements of [Note (6)] shall be performed of each penetration capable of being examined.
(c) As an alternative to (a) and (b), a surface examination of A-D and C-G may be performed and considered the preservice examination.
(d) A documented evaluation shall be completed demonstrating that the peening mitigation techniques meet the performance criteria in Mandatory Appendix II.
(e) Prior to peening, flaws detected during the pre-mitigation inspection shall be corrected by a repair/replacement activity of -3132.2.
(f) The surfaces to be mitigated shall include the regions of the J-groove weld and penetration tubing (outside and inside) susceptible to PWSCC initiation and growth.

Figure 1
PWR Reactor Vessel Upper Head Extent of Visual Examination

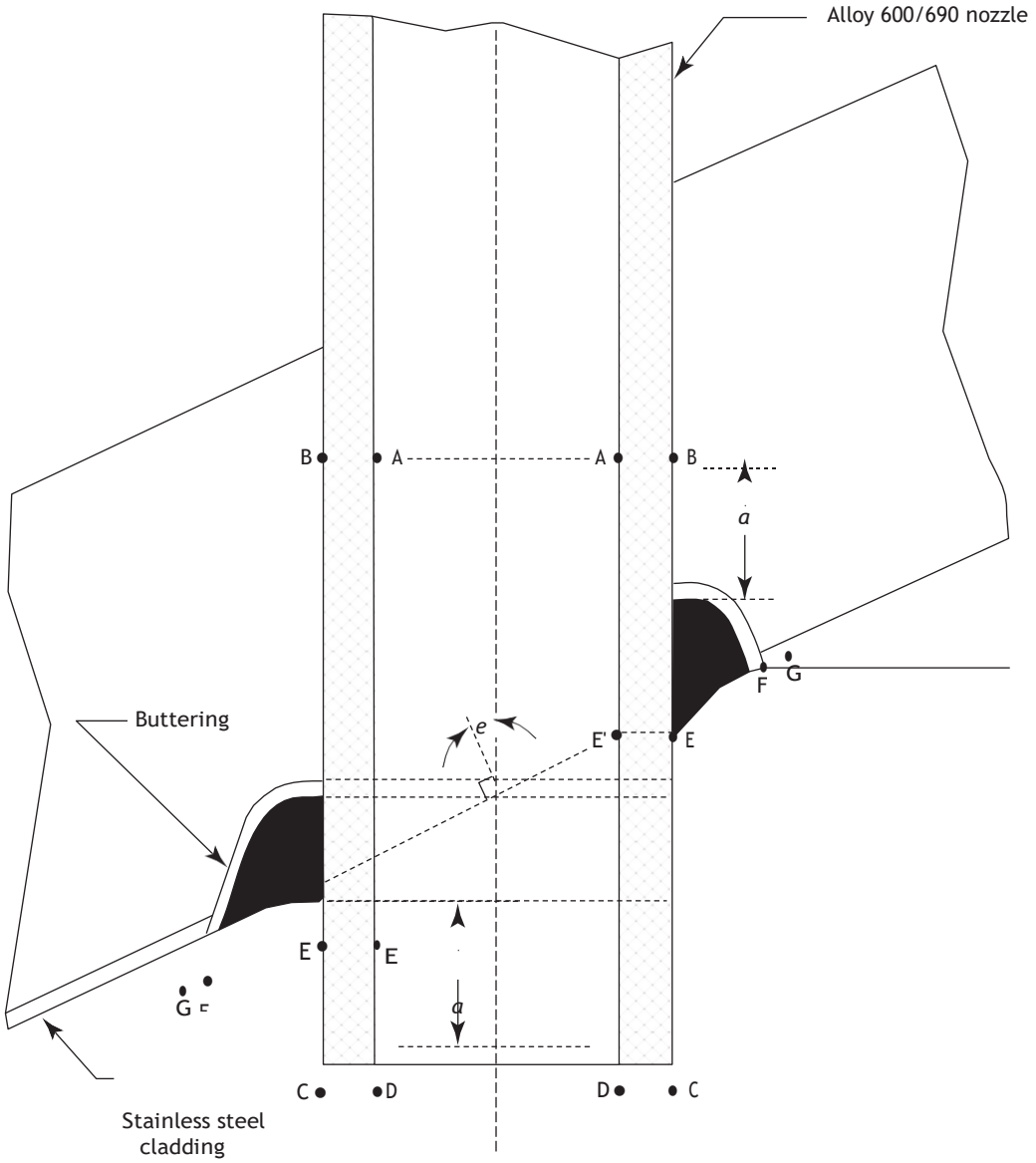


$$A = 2\pi R_o\left[R_o - \sqrt{R_0^2 - \left(D_1/2\right)^2}\right]$$

A_{obstruct} = area on head outer surface obstructed within D_1

$$\frac{A - A_{\text{obstruct}}}{A} \geq 0.95$$

Figure 2
Examination Volume for Nozzle Base Metal and Examination Area for Weld and Nozzle Base Metal



Legend:

a = 1.5 in. (38 mm) for Incidence Angle, ϑ, ≤ 30 deg and for all nozzles ≥ 4.5 in. (115 mm) OD or 1 in. (25 mm) for Incidence Angle, ϑ, > 30 deg; or to the end of the tube, whichever is less

A-B-C-D = extent of volumetric examination for the tube (base metal)

A-D = extent of surface examination for the tube inside surface

G-F = $^1/_4$ in. (6 mm) from the theoretical point "F" in accordance with the design drawings, including tolerances, unless the point "F" can be physically determined.

G-F-E-C = extent of surface examination for the J-groove weld (filler metal and buttering) and tube outside surface below the weld

G-F-E = extent of surface examination zone for the J-groove weld (filler metal and buttering)

(b) Potential for crack propagation is represented by the RIY parameter, calculated as follows:

$$RIY = \sum_{j=n1}^{n2} \left\{ \Delta EFPY_j \exp\left[-\frac{Q_g}{R}\left(\frac{1}{T_{\text{head}j}} - \frac{1}{T_{\text{ref}}} \right) \right] \right\}$$

where

EDY = total effective degradation years, normalized to a reference temperature of 1059.67R (588.71K)

$\Delta EFPY_j$ = effective full power years accumulated during time period j

n = number of time periods with distinct 100% power head temperature[1] since initial headoperation

$n1$ = number of the first time period with distinct 100% power head temperature[1] since time of most recent volumetric or surface NDE

$n2$ = number of the most recent time period with distinct 100% power head temperature[1]

Q_g = activation energy for crack growth
= 31 kcal/mol (130 kJ/mol)

Q_i = activation energy for crack initiation
= 50 kcal/mol (209 kJ/mol)

R = universal gas constant
= 1.103×10^{-3} kcal/mol-R (8.314 J/mol K)

RIY = reinspection years, normalized to a reference temperature of 1059.67R (588.71K)

$T_{\text{head }j}$ = 100% power head temperature during time period j

T_{ref} = reference temperature
= 1059.67R (588.71K)

-2420 Successive Examinations

(a) If a component is accepted by evaluation for continued service in accordance with -3132.3, the areas containing the flaws shall be reexamined prior to the end of the evaluation period used in the flaw evaluation. If the provisions of Table 1 do not require reexamination of the areas containing the flaws at least once per inspection period, a reexamination shall be performed during the next three inspection periods listed in the schedule ofthe inspection program of IWA-2400.

(b) If the reexaminations required by -2420(a) reveal that the flaws remain essentially unchanged for three successive examinations, the component examination schedule may revert to the schedule of examinations identified in Table 1.

-2430 Additional Examinations

If an examination performed in accordance with Table 1 or -2420 reveals a leak or a flaw not acceptable for continued service in accordance with the provisionsof -3132.3, an examination in accordance with Table 1 [Note (6)] shall be performed on all items of that Item Number prior to return to service. Additionally, a visual examination in accordance with Table 1 [Note (1)] (VE throughout this Case), if not already completed during the current outage, shall be performed prior to return to service.

-2500 EXAMINATION REQUIREMENTS

Components shall be examined as specified in Table 1. Surface examinations shall be qualified in accordance with the low rigor requirements of Article 14 of Section V. Volumetric examinations shall be qualified in accordance with (a) through (j). Surface examinations other than eddy current shall be performed in accordance with IWA-2200. If obstructions or limitations prevent examination of the volume or surface required by Figure 2 for one or more nozzles, the analysis procedure of MandatoryAppendix I shall be used to demonstrate the adequacy of the examination volume or surface for each such nozzle. If Mandatory Appendix I is used, the evaluation shall besubmitted to the regulatory authority having jurisdiction at the plant site.

(a) Demonstration Specimen Set

(1) At least 20% of the flaws shall be in the depth range 10% to 30% through-wall.

(2) At least 20% of the flaws shall be in the depth range 30% to 50% through-wall.

(3) At least 20% of the flaws shall be connected tothe nozzle inside surface.

(4) At least 20% of the flaws shall be connected tothe nozzle outside surface.

(5) At least 20% and no more than 60% of the total number of flaws shall be axially oriented.

(6) The demonstration specimen set shall include geometric and material conditions that normally require discrimination from primary stress corrosion cracking. Unflawed area is considered to be the entire surface area within the examination volume that is susceptible to crack initiation, minus the combine area of all the demonstration flaws and their associated location tolerances (defined below). The demonstration specimen set contains a minimum number of unflawed grading units that are typically at least 1.5 times the number of flawed grading units.

(b) Procedure Demonstration. Procedure qualification shall include the equivalent of at least three personnel performance demonstration test sets (30 flaws). Successful personnel performance demonstrations may be

[1] Head temperature at 100% power may have been changed during the life of the plant due to design changes, power uprates, etc., and the summation is over the number of distinct periods, either since initial head operation for EDY or since the last volumetric or surface NDE for RIY.

combined to satisfy these requirements. All flaws shall be detected and the number of false calls shall be less than or equal to 20% of the number of flaws in the demonstration test sets. At least one successful personnel performance demonstration shall be performed. Procedures are qualified with appropriate flaws to the applicable thickness qualification ranges of +25% to −40%. Procedures are qualified to examine nozzles within the minimum and maximum nominal inside diameters of the demonstration mockups. The procedure to perform the volumetric or surface examination for leak path assessment shall be qualified in accordance with the low rigor requirements of Section V, Article 14, without the requirements of Mandatory Appendix II.

(c) Personnel Demonstration. Personnel demonstrationtest sets shall include at least 10 flaws in the tube material. The demonstration test shall meet the detection test acceptance criteria of Table VIII-S10-1 of Section XI, Appendix VIII, Supplement 10. At least two areas of leak paths will be included in the personnel detection demonstration set to evaluate the leak path assessment ability. All leak path indications shall be detected with no false calls. In any part of a reported leak path area falls within the location of a demonstration flaw, the leak path area shall be considered detected. Any part of the reported leak path area that falls outside the location of the demonstrated flaw shall be considered a false call. Sizing is not required. To effectively evaluate the leak path assessmentcapabilities, for example, 2.0 in. (50 mm) above the weld, scanning access above the weld shall be restricted to the minimum limitations identified in the examination procedure.

(d) Detection and False Calls. In any part of a reported flaw indication falls within the location tolerance of a demonstration flaw shall be considered detected. However, any portion of the flaw that is reported outside the location tolerance shall be considered a false call as well. Ifa reported indication does not intersect any of the demonstration flaw's location tolerances, the reported flaw indication shall be considered a false call.

(e) Location Tolerance. For the purpose of determining a detection, each demonstration flaw has a location tolerance of ±0.5 in. (±13 mm) in the axial direction and
±25 deg in the circumferential direction for control rod drive mechanisms (CRDMs) and control element drive mechanisms (CEDMs), and ±18 deg for in core instrumentation nozzles in the circumferential direction. For a CRDM example, an axial flaw 0.75 in. (19 mm) long hasa location tolerance of 1.75 in. (44 mm) in the axial direction with a circumferential tolerance of 50 deg. A circumferential flaw 30 deg long has a location tolerance area of 1 in. (25 mm) in the axial direction with a circumferential tolerance of 25 deg in either circumferential direction.

(f) Length Sizing. The RMS value of length sizing errors from ultrasonic data shall be less than or equal to 0.375 in. (10 mm). At least 10 flaws shall be included in the test set. RMS error shall be calculated as follows:

$$\text{RMS} = \left[\frac{\sum_{i=1}^{n} (m_i - t_i)^2}{n} \right]^{1/2}$$

where

m_i = measured flaw size
n = number of flaws measured
t_i = true flaw size

(g) Depth Sizing. In an acceptable demonstration, the RMS value of depth sizing errors from ultrasonic datashall be less than or equal to 0.125 in. (3 mm). At least 10 flaws shall be included in the test set. RMS error shall be calculated as follows:

$$\text{RMS} = \left[\frac{\sum_{i=1}^{n} (m_i - t_i)^2}{n} \right]^{1/2}$$

(h) Orientation Limitations. The reported orientation ofa recorded flaw is not considered essential when determining flaw detection capabilities.

(i) Essential Variable Changes. Qualification of new values of essential variables requires at least one successful personnel qualification in accordance with the applicable requirements of -2500*(c)* through *(g)*. Procedures shall include clearly identified essential variables. The examination procedure shall identify parameters for the essential variables listed in VIII-3130 and meet the minimum requirements outlined in Appendix VIII. An essential variable describes parameters that directly affect the capability of the system to detect and size flaws. Any changes outside the established range of an essential variable shallmeet the requirements of VIII-4000, or the procedure shall be requalified.

(j) Retest. Retesting for procedure qualification may be done as many times as necessary to qualify the procedure. Before any retesting, the procedure shall be reviewed to determine changes needed to improve the procedure performance. Retesting test sets shall contain at least 50% flaws different from those used in the previous test set. Any candidate that is unsuccessful in passing the initial personnel qualification test may immediately take one retest. They shall have been given feedback from the performance demonstration administrator (PDA) before retesting. After two consecutive unsuccessful personnel qualification attempts, within 12 months, a waiting period of at least 48 hr is required prior to a third test being attempted. The intent of this waiting period is to allow the candidate time to practice or receive additional training

on the procedure for which performance demonstration qualification is being sought. This practice or retrainingis suggested, but is not mandatory. The candidate shallbe eligible for one additional attempt, the failure of whichshall result in the candidate's ineligibility to retest for 12 months. Retesting test sets shall contain at least 50% flaws different from those used in the previous test set.

-3000 ACCEPTANCE STANDARDS

-3100 EVALUATION OF EXAMINATION RESULTS

-3130 Inservice Volumetric and Surface Examinations

-3131 General

(a) The volumetric and surface examinations required by -2500 shall be evaluated by comparing the examination results with the acceptance standards in -3132.1, except where (b) is applicable.

(b) When flaws are detected by a required volumetric or surface examination, the component is acceptable for continued service provided the requirements of IWB-3112(b) are met.

(c) Volumetric and surface examination results shall be compared with recorded results of the preservice examination and prior inservice examinations. Acceptance of components for continued service shall be in accordance with -3132.

(d) The surface and volumetric examination acceptance standards for Item B4.60 of Table 1 are as follows.

(1) For examinations performed prior to the application of peening mitigation, flaws exceeding the criteria of-3132 shall be considered defects and shall be corrected in accordance with IWA-4000 prior to the application of peening mitigation.

(2) For examinations performed following the application of peening mitigation, flaws exceeding the criteria of -3132 shall be considered defects and shall be corrected in accordance with IWA-4000. If an acceptable flawis found, the nozzle shall be identified as Item B4.20 until the flaw has been corrected in accordance with IWA-4000. Following repair/replacement activities, the corrected area of the nozzle, plus 0.5 in. (12.7 mm) beyond the corrected area may be re-peened and reexamined. If no relevant indications are identified, the nozzle may be identified as Item B4.60.

-3132 Acceptance

-3132.1 Acceptance by Volumetric or Surface Examination.

(a) A component whose volumetric or surface examination confirms the absence of flaws shall be acceptable for continued service.

(b) A component whose surface examination detects linear indications of any size, or rounded indications if other relevant conditions indicate ~~nozzle~~ head penetration leakage exists on the partial-penetration weld shall be corrected in accordance with the provisions of -3132.2.

(c) A component with planar flaws in the nozzle base metal shall be corrected in accordance with the provisions of -3132.2 or -3132.3. Linear indications detected by surface examination of the nozzle base material shall be considered planar. Prior to evaluation, the depth of linear indications shall be further characterized by volumetric examination. If volumetric examination cannot be performed, the linear indication shall be assumed to be planar and through-wall.

-3132.2 Acceptance by Repair/Replacement Activity. A component whose volumetric or surface examination reveals a leak or flaw not acceptable for continued service in accordance with the provisions of -3132.3 is unacceptable for continued service until the additional exams of -2430 are satisfied and the component is corrected by a repair/replacement activity to the extent necessary to meet the acceptance standards of -3000.

-3132.3 Acceptance by Analytical Evaluation. A component whose volumetric examination detects planar flaws or whose surface examination detects linear indications which are assumed to be planar, is acceptable for continued service without repair/replacement activity if an analytical evaluation meets the requirements of IWB-3660. The area containing the flaw shall be reexamined in accordance with -2420(a) and -2420(b).

-3140 Inservice Visual Examinations (VE)

-3141 General

(a) The VE required by -2500 and performed in accordance with IWA-2200 and the additional requirements of this Case shall be evaluated by comparing the examination results with the acceptance standards specified in -3142.1.

(b) Acceptance of components for continued service shall be in accordance with -3142.

(c) Relevant conditions for the purposes of the VE shall include evidence of reactor coolant leakage, such as corrosion, boric acid deposits, and discoloration. Relevant conditions for the purposes of the VE shall not include areas of superficial discoloration or superficial deposits. However, such areas shall be documented.

(d) The visual examination acceptance standards for Item B4.50 of Table 1 are as follows.

(1) For examinations performed prior to application of peening mitigation, flaws exceeding the criteria of -3142 shall be considered defects and shall be corrected in accordance with IWA-4000 prior to the application of peening mitigation.

(2) For examinations performed following application of peening mitigation, indications exceeding the acceptance criteria of -3142 are unacceptable. If an indication is identified, the indication shall be evaluated under -3142 and the nozzle shall be identified as Item B4.10 until the indication has been corrected in accordance with IWA-4000. Following repair/replacement activities, the corrected

area of the nozzle, plus 0.5 in. (12.7 mm) beyond the corrected area, may be re-peened and reexamined. If no relevant indications are identified, the nozzle may be returned to Examination Category Item B4.50.

(e) The relevant conditions at masked penetrations (defined in -9000) shall be evaluated in accordance with -3142.1(b)(1) for evidence of head penetration leakage accompanying the masking leakage from another source as practical given the extent of masking local to the intersection of each penetration and the head upper surface.

-3142 Acceptance

-3142.1 Acceptance by VE.

(a) A component whose VE confirms the absence of relevant conditions shall be acceptable for continued service.

(b) A component whose VE detects a relevant condition shall be unacceptable for continued service until the requirements of (1)~~,(~~), (2), (3), (c), and (~~c~~d) below are met.

(1) Components with relevant conditions require ~~further~~ evaluation~~.~~ of the potential sources of the relevant condition including head penetration leakage, other sources of leakage of reactor coolant, and refueling water. The methods and findings of the evaluation shall be documented in an engineering record. Personnel responsible for the evaluation of relevant conditions should be knowledgeable in the requirements for design and inservice inspection of RVCH penetrations. This evaluation shall include ~~determi- nation of the source of the leakage~~the following:

(-a) an assessment to identify and ~~correction~~count the masked head penetrations, if any. In counting the number of masked penetrations, partially masked penetrations may be counted on the basis of the fraction of each respective nozzle circumference that is masked in the area of the intersection of the nozzle and the upper surface of the head low-alloy steel material.

(-b) ~~of the source of leakage in accordance with~~an investigation assessing the following types of information, to the extent such information is relevant and can reasonably be obtained:

(-*1*) deposit location,

(-*2*) deposit morphology and color,

(-*3*) deposit chemical and isotopic composition,

(-*4*) deposit tenacity, and

(-*5*) the location and extent of any visually discernible metal loss at the upper head surface subsequent to removal of deposits and residue as required by -3142.~~3.~~1(b)(2).

~~(1)~~(2) All components having relevant conditions shall be evaluated to determine the extent, if any, of degradation. The ~~boric acid crystals~~deposits and residue shall be removed to the extent necessary to allow adequate examinations and evaluation of degradation, and a subsequent VE of the previously obscured surfaces shall be performed, prior to return to ~~ser- vice, and again in the subsequent refueling outage~~service. Any degradation detected shall be evaluated to determine if any corrosion has impacted the structural integrity of the component. Corrosion that has reduced component wall thickness below design limits shall be resolved through repair/replacement activity in accordance with IWA-4000.

(3) ~~A nozzle whose VE indicates relevant conditions~~ A visual examination (VE) in~~- dicative~~ accordance with Table 1 [Note (1)] shall be scheduled for the subsequent refueling outage:

(-a) if the head contains nozzles and partial-penetration welds of ~~possible nozzle~~PWSCC-resistant materials, the VE during the subsequent refueling outage may be limited to the previously obscured surfaces unless a full VE is otherwise required.

(-b) otherwise a full VE in accordance with Table 1 [Note (1)] shall be scheduled for the subsequent refueling outage if not otherwise already required.

(c) To disposition the possibility of head penetration leakage as a source contributing to the relevant condition, a component whose VE detects a relevant condition shall be unacceptable for continued service ~~unless~~until it meets the requirements of -3142.2 or -3142.3~~.~~(b), unless the evaluation of available evidence per -3142.1(b)(1) demonstrates both (1) and (2):

(1) reasonable confidence that the relevant condition is not the result of head penetration leakage.

(2) the head is either of a category of reduced concern as defined in -9000 or the number of masked penetrations is ≤15.

(d) To disposition sources other than head penetration leakage contributing to the relevant condition, a component whose evaluation of the relevant conditions per -3142.1(b)(1) indicates a source other than head penetration leakage shall be unacceptable for continued service until it meets the requirements of -3142.3(a).

-3142.2 Acceptance by Supplemental Examination. A nozzle ~~with~~whose evaluation of the relevant conditions ~~indicative of possible nozzle leakage~~per -3142.1(b)(1) does not satisfy the criteria of -3142.1(c) shall be acceptable for continued service if the results of supplemental examinations [-3200(b)] meet the requirements of -3130.

-3142.3 Acceptance by Corrective Measures or Repair/Replacement Activity.

(a) A component with relevant conditions ~~not indica- tive~~indicative of ~~possible nozzle~~a source other than head penetration leakage per -3142.1(d) is acceptable for continued service if the source of the relevant condition is corrected by a repair/replacement activity or by corrective measures necessary to preclude degradation.

(b) A component ~~with~~ whose evaluation of the relevant conditions ~~indicative of possible nozzle leakage~~per -3142.1(b)(1) does not satisfy the criteria of -3142.1(c) shall be acceptable for continued service if a repair/replacement activity corrects the ~~de- fect~~affected component in accordance with IWA-4000.

-3200 SUPPLEMENTAL EXAMINATIONS

(a) Volumetric or surface examinations that detect flaws which require evaluation in accordance with -3130 may be supplemented by other techniques to characterize the flaw (i.e., size, shape, and orientation).

(b) The supplemental examination performed to satisfy -3142.2 shall include volumetric examination of the nozzle tube and surface examination of the partial-penetration weld, or surface examination of the nozzle tube inside surface, the partial penetration weld, and nozzle tube outside surface below the weld, in accordance with Figure 2, or the alternative examination area or volume shall be analyzed to be acceptable in accordance with Mandatory Appendix I. The supplemental examinations shall be used to determine the extent of the unacceptable conditions and the need for corrective measures, analytical evaluation, or repair/replacement activity.

-9000 GLOSSARY

bounding loss of coolant accident conditional core damage probability (CCDP): the plant-specific conditional core damage probability for the loss of coolant accident (e.g., medium, small, or small-small break) that bounds the consequences of the head nozzle-ejection event.

effective degradation years (EDY): the lifetime accumulated effective time at temperature, normalized to 1059.67R (588.71K), with an activation energy characteristic of initiation of Primary Water Stress Corrosion Cracking in UNS N06600, 50 kcal/mol (209 kJ/mol).

head category of reduced concern: a head categorized as Item No. B4.10 with operating temperatures less than 570°F (300°C) and without previous detections of flaws attributed to PWSCC, Item No. B4.30, or Item No. B4.50.

masked penetration: the condition of deposits or corrosion products in the area of the intersection of the penetration nozzle and the upper head surface clearly identified as from a source other than head penetration through-wall leakage, for example accompanied by an unambiguous path of deposits from a leakage source above the head. The masking condition may affect the capability of the VE to detect head penetration leakage. As masked penetrations involve the condition of deposits or corrosion products, any masked penetration is considered a component having a relevant condition requiring evaluation under -3142.1(b)(1).

peening mitigation: a process that produces sufficiently low stress conditions on the surface of interest to mitigate initiation and propagation of primary water stress corrosion cracking. Peening mitigation is not a repair/replacement activity.

reinspection years (RIY): the accumulated effective time at temperature between examinations normalized to 1059.67R (588.71K), with an activation energy characteristic of growth of Primary Water Stress Corrosion Cracking in UNS N06600, 31 kcal/mol (130 kJ/mol).

VE relevant condition: evidence of reactor coolant leakage, such as corrosion, boric acid deposits, and discoloration. Areas of superficial discoloration or superficial deposits are not a relevant condition requiring further evaluation but shall be documented.

sister heads: reactor vessel heads owned by the same owner that have a similar or identical design, fabricated by the same manufacturer, and containing nozzles fabricated from materials of the same material specification supplied by the same material supplier.

superficial discoloration or superficial deposits: areas of discoloration or deposits on the head upper surface with no visually discernible thickness.

MANDATORY APPENDIX I
ANALYSIS PROCEDURE FOR ALTERNATIVE EXAMINATION AREA OR VOLUME DEFINITION

I-1000 SCOPE

This Mandatory Appendix provides an analysis procedure that shall be used to define an alternative examination area or volume (zone) to that defined in Figure 2 if impediments (such as physical obstructions, threads on the nozzle end, or an ultrasonic examination corner shadow zone) prevent examination of the complete zone. In such cases, analyses shall be performed to demonstrate that there is an extremely low probability of PWSCC existing wholly in the unexamined zones, and that the potential undetected PWSCC will not lead to a safety concernor an unacceptable probability of leakage in the time interval until the next examination.

For alternative examination zones that eliminate portions of Figure 2 examination zone above the J-groove weld (Figure I-1), the analyses shall be performed usingat least two of the three techniques below to demonstratethat the applicable criteria are satisfied. For alternative examination zones that eliminate portions of Figure 2 examination zone below the J-groove weld (Figure I-2), the analyses shall be performed using at least the stress analysis method (I-2000) or the deterministic fracture mechanics analysis method (I-3000) to demonstrate that the applicable criteria are satisfied.

All other examination requirements of Table 1 shall be met.

I-2000 STRESS ANALYSIS

This analysis shall be used to determine a reduced examination zone. Plant-specific analysis shall demonstrate that the hoop and axial stresses on the nozzle inside and outside surfaces remain below 20 ksi (140 MPa) (tensile) over the entire region outside the alternative examination zone but within the examination zone defined in Figure 2. The analysis shall be performed using either design or as-built weld dimensions for the specific nozzles for which a portion of Figure 2 examination zone is being eliminated, or for nozzles shown to bound the stresses in those specific nozzles.

I-3000 DETERMINISTIC FRACTURE MECHANICS ANALYSES

The analyses described in I-3100 or I-3200 shall be used to determine a reduced examination zone.

I-3100 ZONES ABOVE THE J-GROOVE WELD

For alternative examination zones above the J-groove weld, the analysis shall demonstrate that a potential circumferential crack in the unexamined zone will not grow to a size that exceeds the acceptance criteria for austenitic piping in IWB-3640 prior to the next scheduled examination.

The crack growth calculation shall be performed based on the following:

(a) The assumed initial flaw size shall be a through-wall, circumferentially-oriented crack equal to 30 deg of the nozzle circumference, at the outermost edge of the alternative examination zone (Figure I-1).

(b) Alternatively, the flaw shall be assumed to exist in a plane closer to the J-groove weld (i.e., within the inspected region), if such location can be shown to conservatively bound flaws at the outermost edge of the alternative examination zone.

(c) The flaw shall be assumed to be at either the uphill or the downhill location of the nozzle, whichever results in the higher applied stress intensity factor (Figure I-1).

(d) The average of inside and outside surface axial stress shall be applied along the entire length of the assumed through-wall crack.

(e) The stress intensity factor for a circumferential, through-wall crack in a cylinder shall be used.

(f) Crack growth rate determination shall be in accordance with Appendix O of Section XI, in the 2004 Edition.

I-3200 ZONES BELOW THE J-GROOVE WELD

For alternative examination zones below the J-groove weld, the analysis shall demonstrate that a potential axial crack in the unexamined zone will not grow to the toe of the J-groove weld prior to the next scheduled examination.

(a) Method 1. Using stress analysis results for the as-designed J-groove weld configuration, demonstrate that the upper extremity of an axial through-wall crack would not propagate to the toe of the J-groove weld prior to the next scheduled examination.

The crack growth calculation shall be performed based on the following:

(1) The initial axial through-wall crack size shall be determined by assuming its upper extremity to be initially located at the bottom edge of the alternative examination zone and the lower extremity to be located where either the inside or the outside surface hoop stress becomes compressive (Figure I-2).

(2) If the hoop stress remains tensile for the entire portion of the nozzle below the weld, an axial through-wall crack shall be postulated from the bottom edge ofthe alternative examination zone to the bottom of the nozzle (Figure I-3).

(3) The average of inside and outside surface hoop stresses shall be applied along the entire length of the assumed through-wall crack.

(4) The postulated axial flaw shall be located in the unexamined zone at the azimuthal location that results in the shortest time to reexamination.

(5) The stress intensity factor for an axial through-wall crack in a cylinder shall be used.

(6) Crack growth rate determination shall be in accordance with Appendix O of Section XI, in the 2004 Edition.

(b) Method 2. If acceptability cannot be demonstrated using Method 1, the following shall be performed.

(1) Review the available UT examination data and demonstrate that the as-built J-groove weld depth is larger than the as-designed weld depth.

(2) Determine the hoop stress distribution in the portion of the nozzle below the weld by performing a stress analysis based on the as-built J-groove weld configuration.

(3) Perform the crack growth calculation of Method 1, using the hoop stress distribution for the as-built configuration.

I-4000 PROBABILISTIC FRACTURE MECHANICS ANALYSIS

These provisions shall not be applied to heads having prior PWSCC in nozzles or J-groove welds that required repair/replacement activity. Calculate the percentage of the total required examination zone defined in Figure 2, for all nozzles in the head, that will be eliminated. Demonstrate, using a probabilistic fracture mechanics method, that the total eliminated examination zone in all nozzles does not lead to unacceptable probabilities of leakage and nozzle ejection prior to the next required examination. A probability of leakage no greater than 5% per vessel per year and a probability of core damage associated with the potential for nozzle ejection no greater than 1×10^{-6} per vessel per year are acceptable.

Figure I-1
Circumferential Flaw Assumption for Elimination of Portions of the Required Examination Zone Above J-Groove Weld

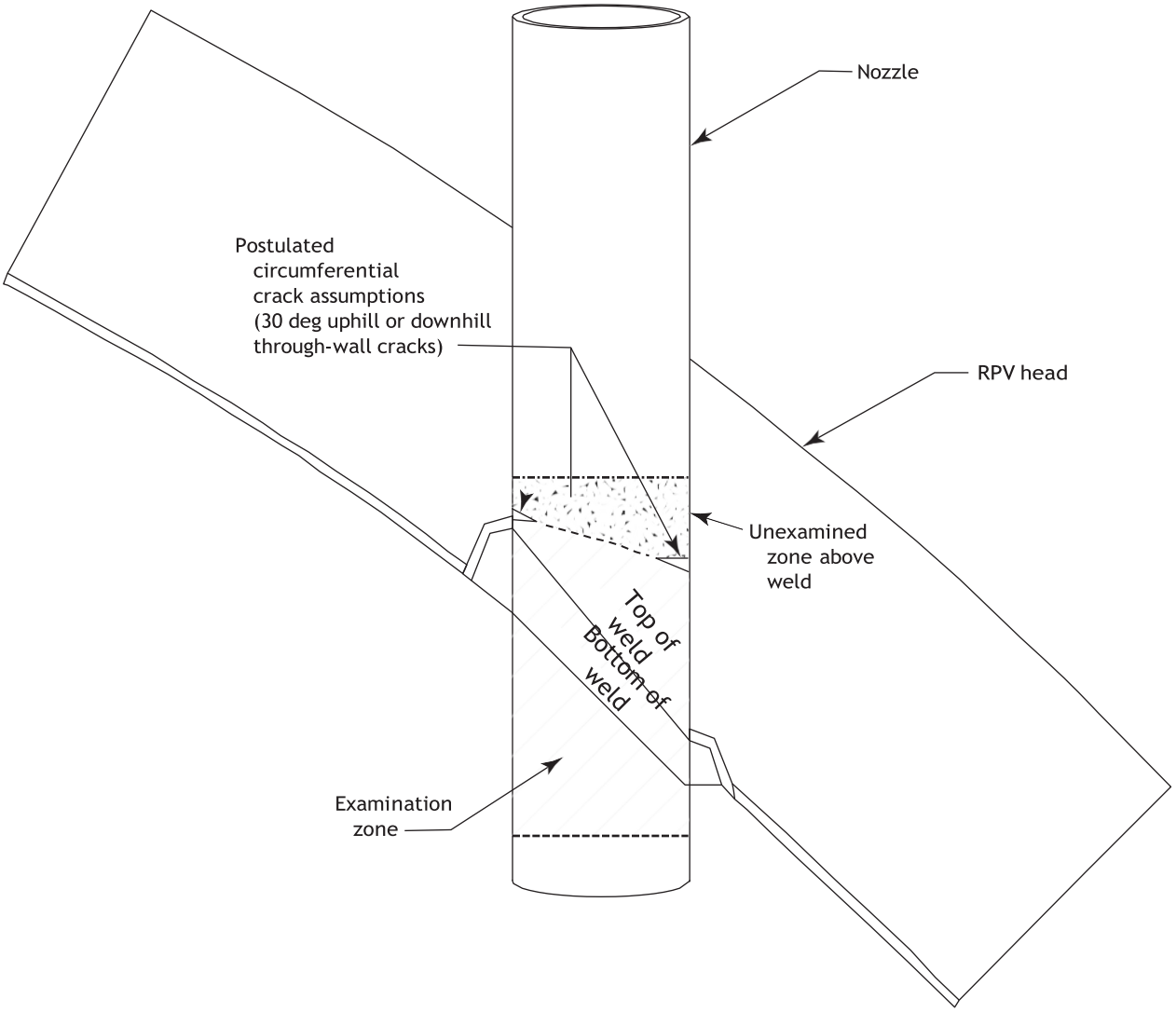


Figure I-2
Axial Flaw Assumption for Elimination of Portions of the Required Examination Zone Below J-Groove Weld

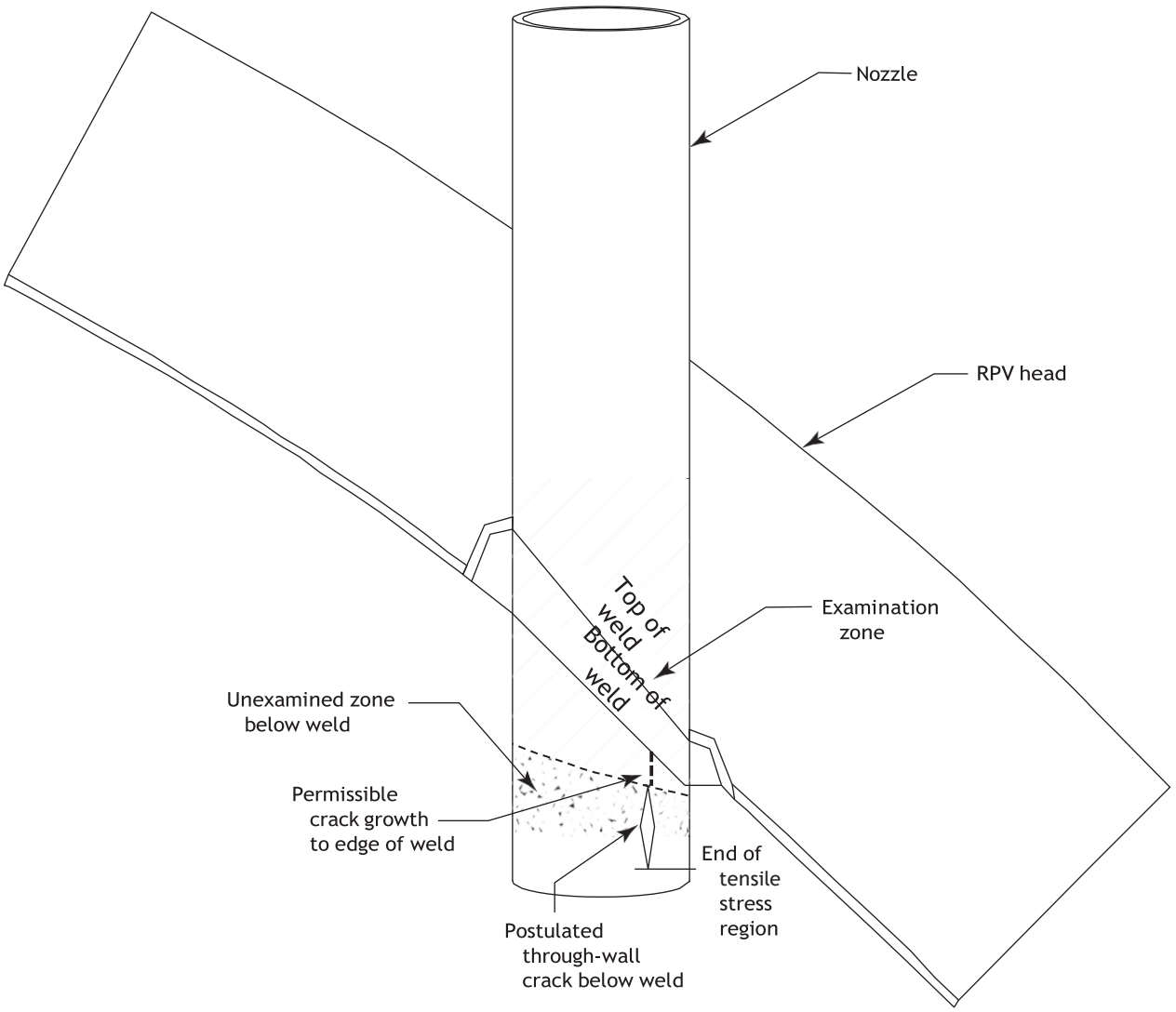
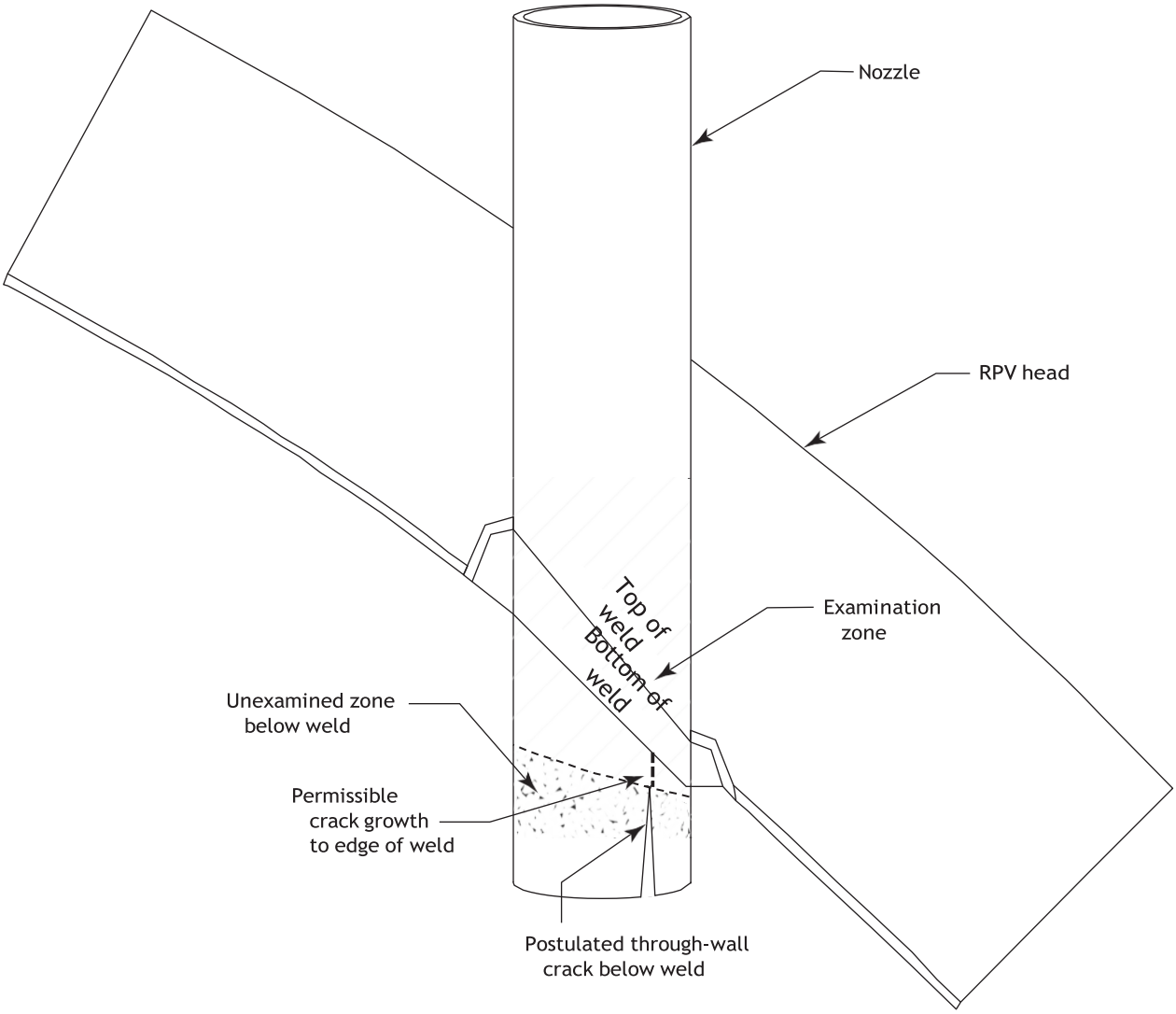


Figure I-3
Axial Flaw Assumption for Elimination of Portions of the Required Examination Zone Below J-Groove Weld (Tensile Stress to Bottom of Nozzle)



MANDATORY APPENDIX II
PERFORMANCE CRITERIA AND MEASUREMENT OR QUANTIFICATION CRITERIA FOR MITIGATION BY SURFACE STRESS IMPROVEMENT (PEENING) OF THE REACTOR VESSEL UPPER HEAD PENETRATIONS AND ATTACHMENT WELDS

II-1000 PERFORMANCE CRITERIA

To minimize the likelihood of crack initiation, the process shall have resulted in a compressive stress in the full area of the susceptible material prior to consideration of operating stresses. Material is considered susceptible if residual plus normal operating stresses on the surface in contact with the reactor coolant fluid exceeds +20 ksi (+140 MPa). Susceptible material locations include the attachment weld, butter, and nozzle base material, including the inside surface region of nozzle penetrations in areas adjacent to the attachment weld, as applicable. The residual stress plus normal operating stress on peened surfaces shall be included in the evaluation and shall not exceed +20 ksi (+140 MPa) in the area of interest.

II-1100 PROCESS QUALIFICATION CRITERIA

An analysis and demonstration test shall be performed to demonstrate the required capability of the peening method to produce the required stress state. The testing shall quantify the post-mitigation stress state exclusive of normal operating stresses. The testing shall be used to demonstrate the critical process parameters and define acceptable ranges of the parameters needed to ensure that the required residual stress field (exclusive of operating stresses) has been produced on the mitigated surface. The analysis shall combine the normal operating stresses with residual stresses obtained from the testing. The combined stress shall not exceed +20 ksi (+140 MPa) on the application surface. In the analysis to determine the surface stress, including the operating and residual stresses, the uncertainty in measurement of the surface residual stress shall be considered.

II-1200 COMPRESSIVE STRESS FIELD CRITERIA

The nominal compressive surface residual stress field shall be demonstrated by testing.

(a) The nominal compressive residual stress field shall extend to a minimum depth of 0.04 in. (1.0 mm) on the outside surface of the nozzle and attachment weld surface area susceptible to PWSCC initiation as defined in II-1000.

(b) The nominal compressive residual stress field on the nozzle inside surface shall extend to a minimum depth of 0.01 in. (0.25 mm) on surfaces susceptible to PWSCC initiation as defined in II-1000.

II-2000 MITIGATION PROCESS CRITERIA

The effect produced by the mitigation process shall result in a peened surface with a stress state no greater than +20 ksi (+140 MPa) including residual and operating stresses.

II-2100 MITIGATION PROCESS QUALIFICATION

An analysis or demonstration test shall be performed to confirm that the mitigation process is permanent or at least effective for the remaining service life of the component. The analysis or demonstration test plan shall include startup and shutdown stresses, normal operating pressure stress, thermal cyclic stresses, transient stresses, and residual stresses. The analysis or demonstration test shall account for

(a) load combinations that could relieve stress due to shakedown and

(b) any material properties related to stress relaxation over time.

II-3000 EXAMINATION CRITERIA

The capability to perform ultrasonic examination of the relevant volume of the component shall not be adversely affected.

II-3100 ULTRASONIC EXAMINATION QUALIFICATION CRITERIA

Ultrasonic examinations shall be performed using personnel, procedures, and equipment qualified by blind demonstration on representative mockups that meet the requirements of -2500. Testing shall be performed to demonstrate that the examination volume of the mitigated component can be examined subsequent to mitigation, including changes to component geometry, material properties, or other factors.

II-4000 ADVERSE EFFECTS CRITERIA

The mitigation process, including vibration effects during application, shall not degrade the component or adversely affect other components in the system.

II-4100 MITIGATION PROCESS GEOMETRY EFFECTS CRITERIA

An analysis or testing shall be performed to verify that the mitigation process does not result in changes to the component geometry.

II-4200 SURFACE EFFECT CRITERIA

Analysis or testing shall be performed to verify that peening does not cause undesirable hardness at the peened surface, erosion of surfaces, undesirable surface roughening, or detrimental effects in the transition regions adjacent to the peened regions.

II-5000 INSPECTABILITY CRITERIA

The relevant volume or surface shall be inspectable using a qualified process.

II-5100 EXAMINATION COVERAGE CRITERIA

An evaluation shall be performed to confirm that the required examination volume and surfaces of the mitigated configuration are within the scope of the examinations identified in Table 1 of this Case.