Proposed Revision to VE Acceptance Criteria of ASME Code Case N-729-x (-3140)

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NRC Virtual Public Meeting
May 11, 2022
1:30 to 3:30 pm ET

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Objective of Revision to N-729-x

- The existing VE acceptance criteria of N-729-x (-3140) are somewhat ambiguous and confusing
- NRC issued Regulatory Issue Summary RIS 2018-006 documenting NRC concerns regarding past interpretations and application of N-729-x to investigate relevant conditions
- Under the current situation, leakage from sources unrelated to PWSCC of head Nickel-base alloy penetrations could lead to:
  - need for emergent NRC relief
  - unnecessary, expensive, emergent volumetric or surface examinations
- A revision to the acceptance criteria is needed to define a clear process for evaluating VE relevant conditions and applying a more reasonable standard for weighing the evidence

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Proposed Revisions to -3140 VE Acceptance Criteria

- The current -3140 acceptance criteria include the following concepts:
  - Evaluation for source of relevant conditions
  - Evaluation for degradation of low-alloy steel
  - Supplemental exam or correction of the source
  - Subsequent VE of the previously obscured surfaces before return to service and at the next RFO
- The following extensions are proposed:
  - Explicit consideration of masking deposits from a source other than head pen leakage (including limit on number of masked pens depending on the head category)
    - A statistical evaluation shows that the VE retains substantial value to detect incipient leakage when the number of masked pens is 15 or fewer
  - Explicit recognition that superficial discoloration and superficial deposits do not require evaluation
  - Specification of the information to be collected, to the extent such information is relevant and can reasonably be obtained
  - Establishes an explicit standard of *reasonable confidence* that the relevant condition is not the result of head pen leakage
  - For Alloy 600 heads: Modest extension of requirement for VE in next RFO to entire head if not already scheduled (usually a VE would have been required anyway)
- MRP-060 will be revised to provide guidance in implementing the revised -3140, with a companion technical basis report

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Proposed Personnel Requirement Performing Evaluation of Source of Relevant Conditions

- Proposed Requirement in -3142.1(b)(1):
  "Personnel responsible for the evaluation of relevant conditions should be knowledgeable in the requirements for design and inservice inspection of RVCH penetrations."
- This requirement ensures that personnel with responsibility for the evaluation have the requisite knowledge and background
- Specific knowledge areas / training topics include the following:
  - VE method
  - Appearance and properties of boron deposits and corrosion products
  - Plant RVCH examples spanning range of cases, including head pen leakage and masking deposits
  - Experience that not all apparently leaking RVCH pens have shown VE relevant conditions
  - Procedures for sampling deposits, residue, and debris
  - Techniques for characterizing deposit chemical and isotopic composition and deposit tenacity
  - Special considerations for evaluating potential for head pen leakage at masked pens
  - Best approaches to removing tenacious deposits to facilitate subsequent VE of obscured areas
  - Available guidance for evaluation of collected information to conclude whether reasonable confidence that the relevant condition is not the result of head pen leakage

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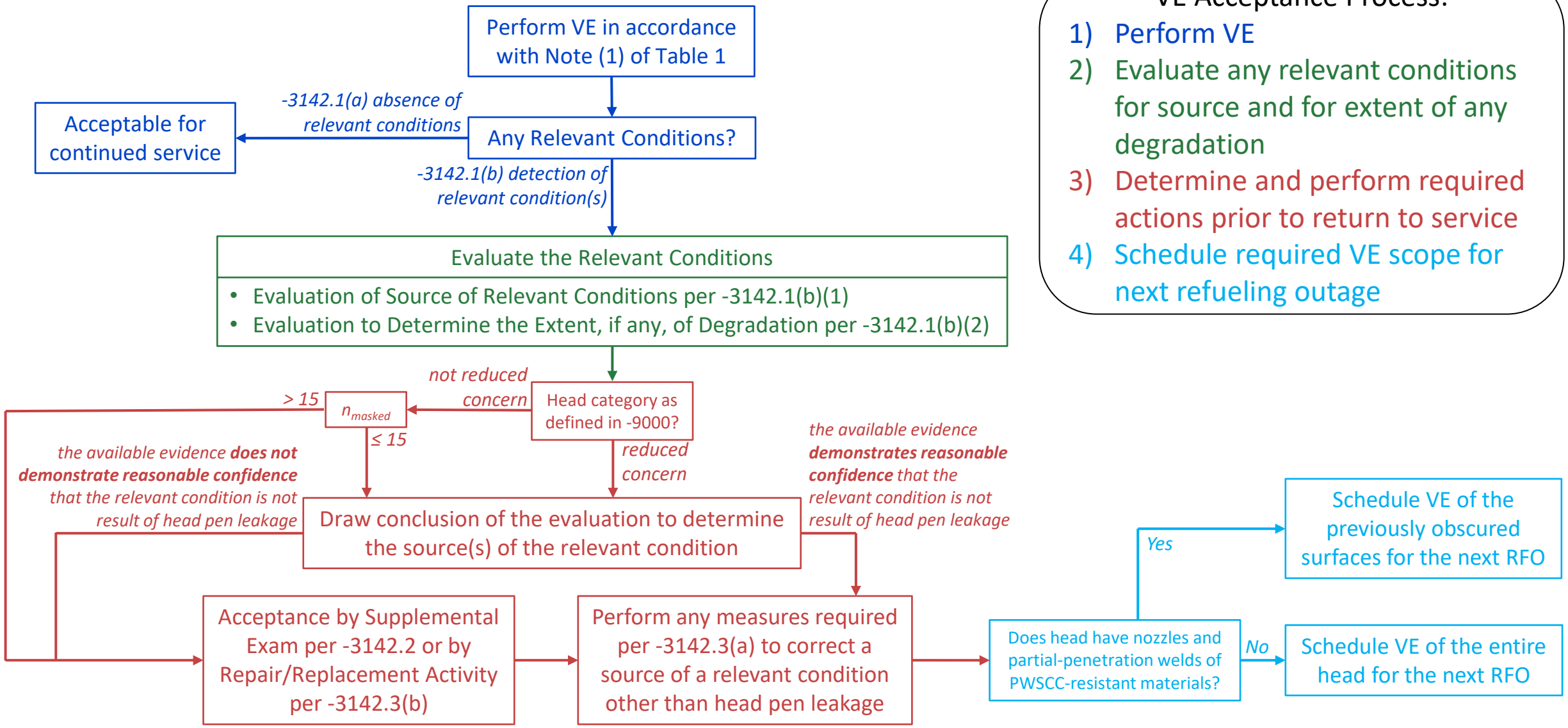
Proposed Revision to -3140 for N-729-10

Proposed Revised VE Acceptance Standards



VE Acceptance Process:

1) Perform VE
2) Evaluate any relevant conditions for source and for extent of any degradation
3) Determine and perform required actions prior to return to service
4) Schedule required VE scope for next refueling outage

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Proposed Revision to -3140 for N-729-10

Proposed Revised VE Acceptance Standards

Additions to Note (1) of Table 1:
The VE shall consist of the following:
(a) …
(b) …
(c) …
(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).

Perform VE in accordance with Note (1) of Table 1

Any Relevant Conditions?

-3142.1(a) absence of relevant conditions

Acceptable for continued service

-3142.1(b) detection of relevant condition(s)

Future Revised MRP-060 Guidance

Evaluate the Relevant Conditions

Evaluation of Source of Relevant Conditions per -3142.1(b)(1)

Components with relevant conditions require evaluation of the potential sources of the relevant condition including head penetration leakage, other sources of leakage of reactor coolant, and refueling water. This evaluation shall include the following:
(-a) an assessment to identify and count the masked head penetrations (number, n_{masked}), 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) 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.

Evaluation to Determine the Extent, if any, of Degradation per -3142.1(b)(2)

- Remove the deposits and residue to the extent necessary to allow adequate exams and evaluation of degradation.
- Perform VE of the previously obscured surfaces.
- Evaluate and resolve any metal loss beyond design limits.

***Caution:** Do not remove deposits/ residue prior to* completing -3142.1(b)(1)

Head category as defined in -9000?

not reduced concern

n_{masked}

> 15

≤ 15

reduced concern

*the available evidence **does not demonstrate reasonable confidence** that the relevant condition is not result of head pen leakage*

*the available evidence **demonstrates reasonable confidence** that the relevant condition is not result of head pen leakage*

Draw conclusion of the evaluation to determine the source(s) of the relevant condition

Acceptance by Supplemental Exam per -3142.2 or by Repair/Replacement Activity per -3142.3(b)

Perform any measures required per -3142.3(a) to correct a source of a relevant condition other than head pen leakage

Does head have nozzles and partial-penetration welds of PWSCC-resistant materials?

Yes

No

Schedule VE of the previously obscured surfaces for the next RFO

Schedule VE of the entire head for the next RFO

Modified -3141(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.

New -3141(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.

New -3142.1(b)(1) states in part: 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.

Proposed Associated Additions to -9000 Glossary

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.

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).

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

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.

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Proposed Revision to -3140 for N-729-10

Proposed Revised VE Acceptance Standards

Additions to Note (1) of Table 1:
The VE shall consist of the following:
(a) …
(b) …
(c) …
(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).

Revised Text Excerpts

Perform VE in accordance with Note (1) of Table 1

Presence / Absence of Relevant Conditions

Any Relevant Conditions?

-3142.1(b) detection of relevant condition(s)

no relevant conditions

Acceptable for continued service

Modified -3141(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.

Evaluation of Evidence from Relevant Conditions

Future Revised MRP-060 Guidance

Evaluate the Relevant Conditions

Evaluation of Source of Relevant Conditions per -3142.1(b)(1)

Components with relevant conditions require evaluation of the potential sources of the relevant condition including head penetration leakage, other sources of leakage of reactor coolant, and refueling water. This evaluation shall include the following:
(-a) an assessment to identify and count the masked head penetrations (number, n_{masked}), 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 hemispherical steel head
(-b) 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.

New -3141(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.

Caution: *Do not remove deposits/ residue prior to completing -3142.1(b)(1)*

Evaluation to Determine the Extent, if any, of Degradation per -3142.1(b)(2)

- Remove the deposits and residue to the extent necessary to allow adequate exams and evaluation of degradation.
- Perform VE of the previously obscured surfaces.
- Evaluate and resolve any metal loss beyond design limits.

New -3142.1(b)(1) states in part: 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.

Decision Process to Determine Required Actions

not reduced concern

Head category as defined in -9000?

reduced concern

n_{masked}

> 15

≤ 15

*the available evidence **does not demonstrate reasonable confidence** that the relevant condition is not result of head pen leakage*

*the available evidence **demonstrates reasonable confidence** that the relevant condition is not result of head pen leakage*

Draw conclusion of the evaluation to determine the source(s) of the relevant condition

Acceptance by Supplemental Exam per -3142.2 or by Repair/Replacement Activity per -3142.3(b)

Perform any measures required per -3142.3(a) to correct a source of a relevant condition other than head pen leakage

Does head have nozzles and partial-penetration welds of PWSCC-resistant materials?

Yes

No

Schedule VE of the previously obscured surfaces for the next RFO

Schedule VE of the entire head for the next RFO

Essential Definitions

Proposed Associated Additions to -9000 Glossary

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.

masked penetration: the condition of deposits or corrosion products in the area of the intersection of the nozzle and the upper head surface clearly identified as from a source other than 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).

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

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.

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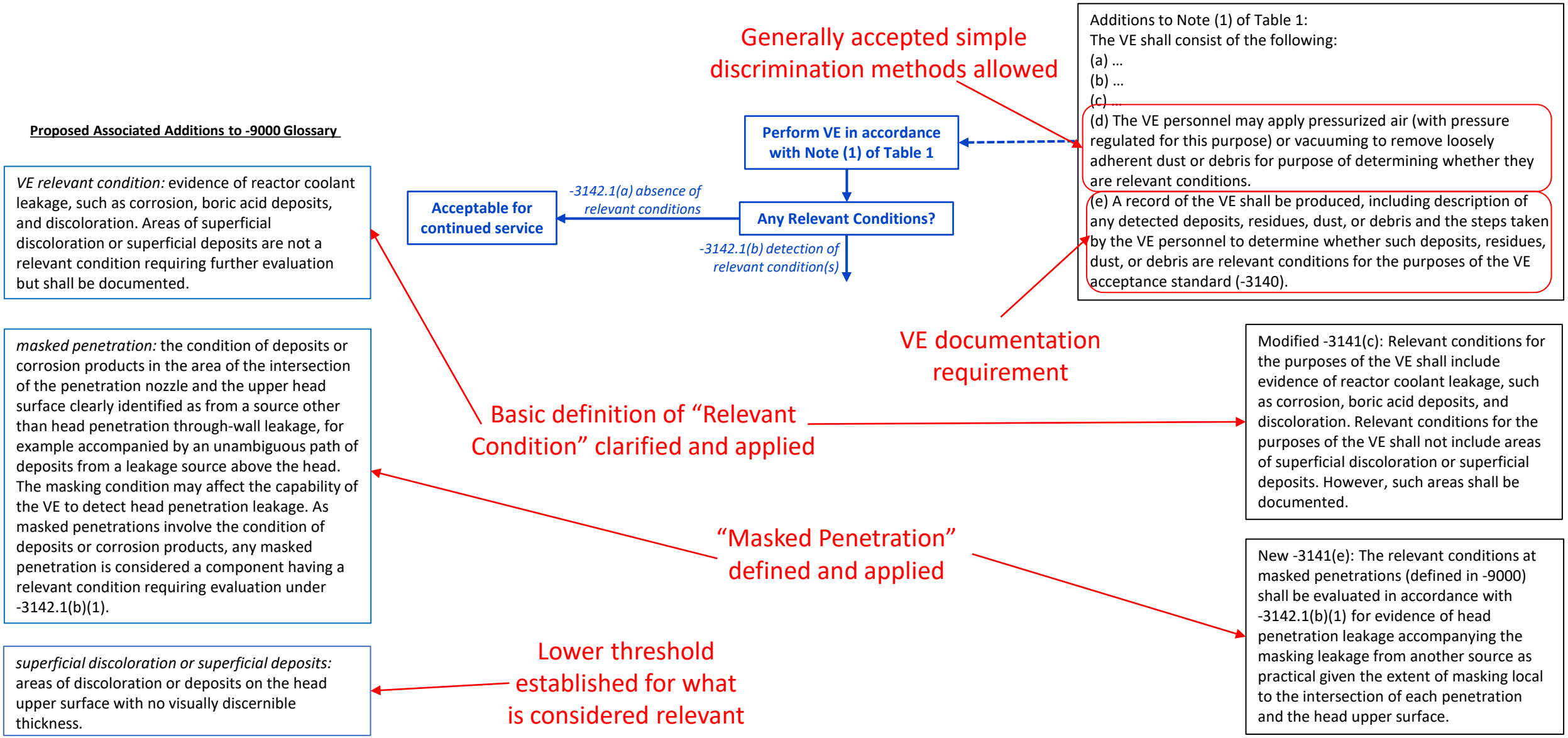
Presence or Absence of Relevant Conditions



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Evaluation of Evidence from Relevant Conditions

Masking Extent Assessment
Complete early, prior to substantial disturbance

Future Revised MRP-060 Guidance

Evaluate the Relevant Conditions

Evaluation of Source of Relevant Conditions per -3142.1(b)(1)

Components with relevant conditions require evaluation of the potential sources of the relevant condition including head penetration leakage, other sources of leakage of reactor coolant, and refueling water. This evaluation shall include the following:

(-a) an assessment to identify and count the masked head penetrations (number, n_{masked}), 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) 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.

Caution: *Do not remove deposits/ residue prior to* completing -3142.1(b)(1)

Evaluation to Determine the Extent, if any, of Degradation per -3142.1(b)(2)

- Remove the deposits and residue to the extent necessary to allow adequate exams and evaluation of degradation.
- Perform VE of the previously obscured surfaces.
- Evaluate and resolve any metal loss beyond design limits.

Investigation Elements

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

New -3142.1(b)(1) states in part: 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.

Evaluation of Evidence

1) Consider all relevant evidence
2) Logically developed
3) Thoroughly documented

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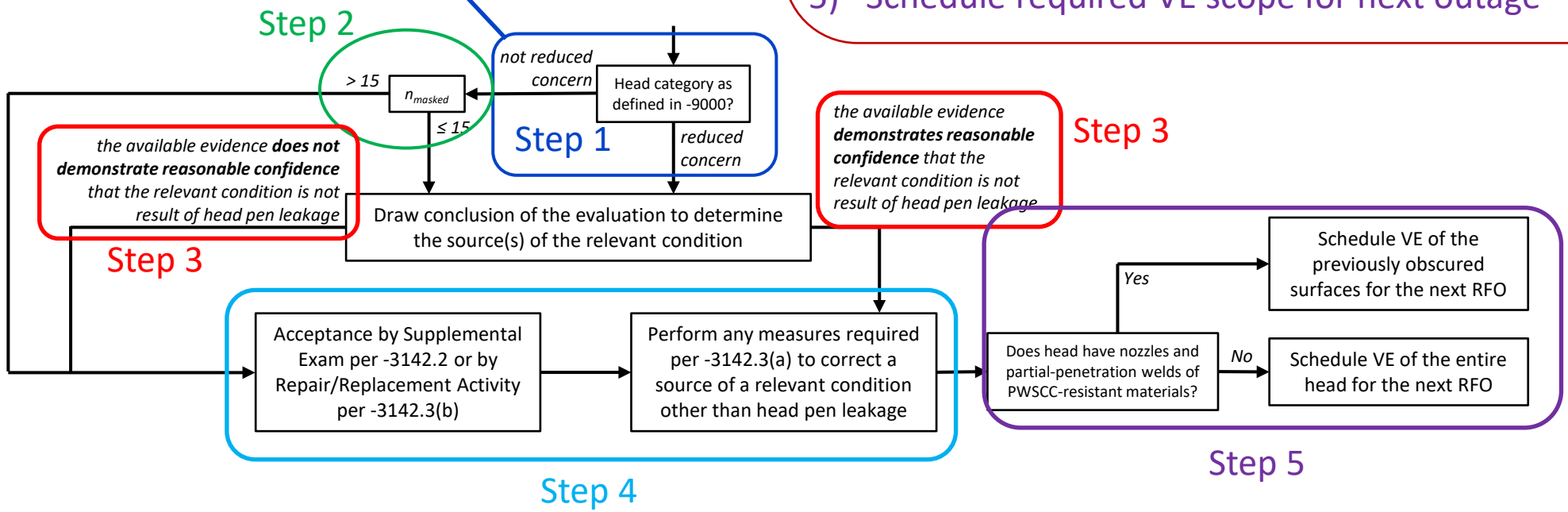
Decision Process to Determine Required Actions

***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.

Decision Process

1) Is this a "head of reduced concern?
2) If not, does it meet the masking threshold?
3) Does the evaluation of evidence demonstrate reasonable confidence the relevant condition is not a result of head pen leakage?
4) Take required actions as indicated
5) Schedule required VE scope for next outage



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Proposed Revision to -3140 for N-729-10

Proposed Revised VE Acceptance Standards

Proposed Associated Additions to -9000 Glossary

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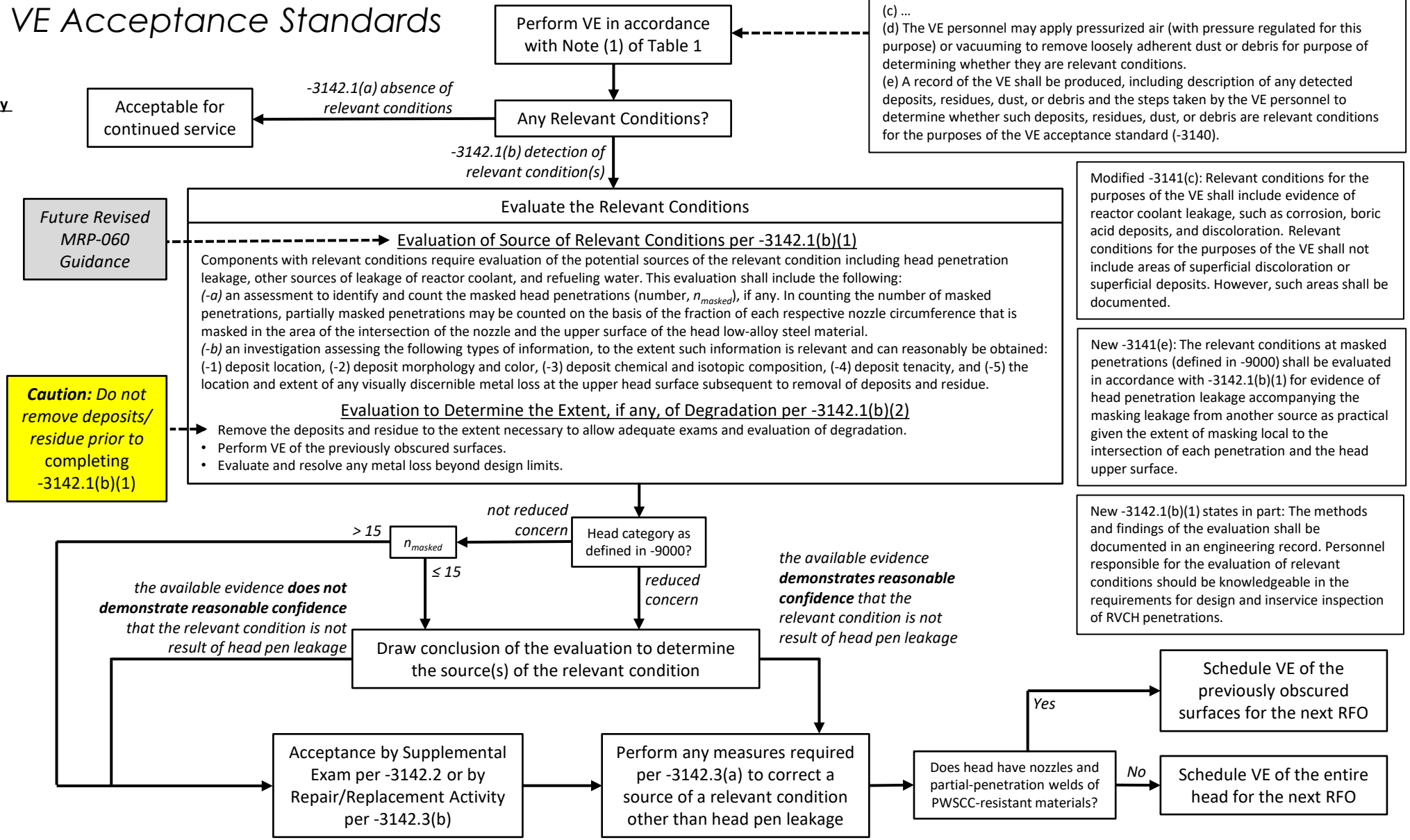
masked penetration: the condition of deposits or corrosion products in the area of the intersection of the penetration nozzle and the upper head surface clearly identified as from a source other than head penetration through-wall leakage, for example accompanied by an unambiguous path of deposits from 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).

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

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.

Additions to Note (1) of Table 1:
The VE shall consist of the following:
(a) …
(b) …
(c) …
(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).



Modified -3141(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.

New -3141(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.

New -3142.1(b)(1) states in part: 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.

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VE at Masked Penetrations

- A new paragraph -3141(e) is proposed: “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.”
- This paragraph makes clear that the evaluation for the source of the relevant condition must consider the possibility of head penetration leakage occurring at a penetration that is masked with deposits from a source other than head penetration leakage
- This evaluation shall consider the information that is relevant and that can be reasonably obtained for the relevant condition in the area of a masked penetration
- However, the chance of detecting head penetration leakage (if it is in fact present) is reduced compared to the situation if there was no masking, and the extent to which the capability is affected depends on the extent of masking deposits that are present

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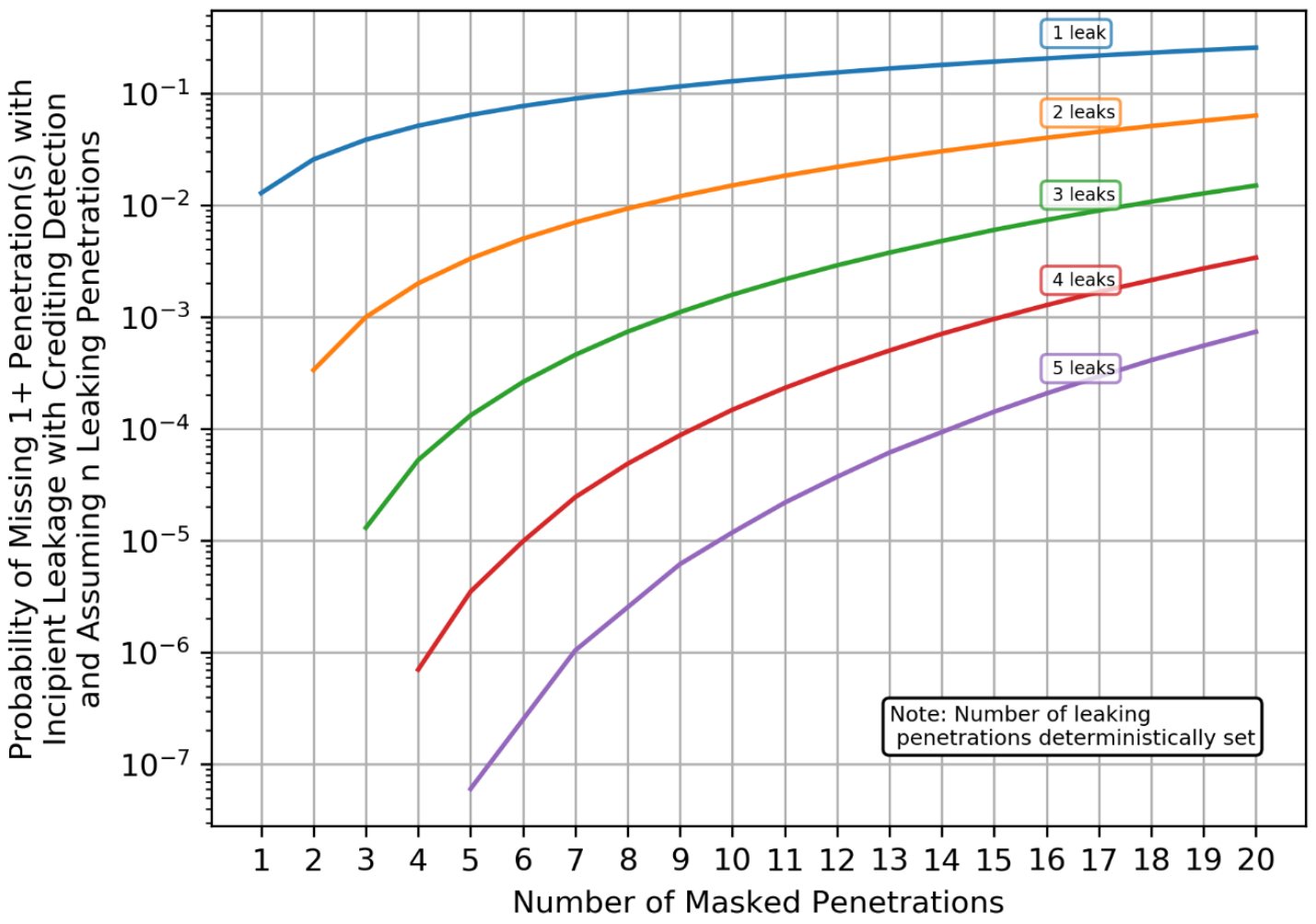
Basis for Threshold of 15 Masked Penetrations

- Statistical and probabilistic Monte Carlo modeling were used to investigate the effect of the number of masked penetrations
- The modeling evaluated the benefit of the VE when a set number of penetrations are masked
- Conservatively assumed no chance of finding leaker at masked location
- Either a set number of leaking penetrations was assumed or the probability of a penetration leaking was sampled from a distribution (with possibility that probability is correlated between the nozzles in a head)
- Some cases credited leakage detection through finding another leaker at an unmasked location
- The results show how most of the benefit of the VE is retained when the number of masked penetrations is as high as about 15



Example Probabilistic Results

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Basis for Treatment of Areas of Superficial Discoloration or Superficial Deposits

- ***Superficial discoloration or superficial deposits*** are defined as areas of discoloration or deposits on the head upper surface with no visually discernible thickness
- Plant experience shows that areas of superficial discoloration or superficial deposits are unlikely to be associated with head penetration leakage
- Furthermore, areas of superficial discoloration or superficial deposits are not amenable to sampling for chemical and isotopic characterization or other characterization
- In the unlikely case that head penetration leakage is occurring, defense in depth is still maintained
- The proposed code case markup would not require evaluation of the source of the superficial discoloration or superficial deposits, but it would require their documentation

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Basis for Standard of Reasonable Confidence

- The proposed code case revision would establish an explicit standard of *reasonable confidence* that the relevant condition is not the result of head penetration leakage
- This standard recognizes that defense in depth is maintained in the unlikely case that head penetration leakage is in fact occurring and a supplemental volumetric or surface examination is not triggered:
  - A VE of at least the previously obscured surfaces is required at the next refueling outage
  - Lack of discernible loss of low-alloy steel metal at the head upper surface shows that any existing head penetration leakage is not currently causing significant boric acid corrosion, with significant damage to the head very unlikely by the time of the next refueling outage
  - Enhanced leakage detection capabilities provide another method to detect leakage
  - The required periodic volumetric or surface examinations of all penetrations address the potential concern for circumferential nozzle cracking leading to nozzle ejection, even if leakage is occurring

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Consideration of Heads with Reduced Susceptibility

- ***Head category of reduced concern*** is defined as follows:
  - 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
- The threshold on the number of masked penetrations that *automatically* triggers a supplemental volumetric or surface examination is applied for heads that are not in a category of reduced concern
- This is a risk-informed approach in that the probability of head penetration leakage occurring in heads of reduced concern is lower than that for other heads

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Proposed Revised MRP-60 – *Outline*

1. Introduction
2. VE Examination Requirements
3. Summary of Operating Experience
4. Guidance for Performing VEs for Effective Detection of Relevant Conditions
5. Guidance for Investigation of Relevant Conditions
6. Conclusions
7. References

A. Inspection Results and Operating Experience
B. Sampling and Analysis Guidance for Deposits Found on Reactor Pressure Vessels at Various Locations
C. Examples of Investigation of Relevant Conditions

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Proposed Technical Basis Report – *Outline*

1. Introduction
2. Knowledge of Range of Deposits Affecting Upper Surface of PWR Reactor Vessel Closure Heads
3. Basis for the Effectiveness of the VE to Detect Relevant Conditions
4. Basis for the Guidance on How to Investigate and Disposition Relevant Conditions
5. Basis for Treatment of Masked Penetrations
6. Basis for Consideration of Head Category
7. Basis for Guidance for Head Cleaning and Visual Examination for Discernible Metal Loss or Corrosion Products Prior to Return to Service
8. Conclusions
9. References

A. Assessment of Utility of Hyperspectral Imaging to Identify Head Deposits

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Next Steps

- Initiate Code Action within TGHSNAI to revise Code Case N-729-9
- Technical basis document now in preparation will be finalized with consideration of feedback from
  - New Orleans TGHSNAI meeting
  - This NRC public meeting
- Distribute technical basis document to TGHSNAI members
- Support Code Action as required

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