

**NEI 99-02 FAQ 19-02 - Final Response  
Brunswick RCS Leakage**

Plant: Brunswick Nuclear Power Plant Unit 1

Date of Event: March 28, 2019

Submittal Date: May 22, 2019

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Performance Indicator: BI02 - Reactor Coolant System Leakage

Site-Specific FAQ (see Appendix D)?  Yes or ( ) No

FAQ requested to become effective (X) when approved or (other date) \_\_\_\_\_

**Question Section**

**Nuclear Energy Institute (NEI) 99-02 Guidance needing interpretation (include page and line citation):**

NEI 99-02, Revision 7, Page 42, lines 3 – 6. NEI 99-02 defines the purpose of the performance indicator for Reactor Coolant System (RCS) Leakage as:

*This indicator monitors the integrity of the RCS pressure boundary, the second of the three barriers to prevent the release of fission products. It measures RCS Identified Leakage as a percentage of the technical specification allowable Identified Leakage to provide an indication of RCS integrity.*

**Event or circumstances requiring guidance interpretation:**

This FAQ is being submitted to request an exemption from the NEI 99-02 guidance to report elevated Reactor Coolant System (RCS) Leakage due to plant-specific circumstances or unique conditions. Specifically, Brunswick Unit 1 is requesting an exemption related to the March 2019 RCS Leakage Performance Indicator (PI) data, which crossed the Green/White threshold due to the unique circumstances surrounding failure of a 1-inch instrument line coupling that occurred on March 28, 2019. Brunswick does not have a Technical Specification limit on Identified Leakage and reports RCS Total Leakage for this PI, as discussed on NEI 99-02, page 42, lines 33 and 34. The following describes the basis for this exemption request:

1. The RCS Leakage Performance Indicator is intended to monitor RCS leakage below the Technical Specification limit to ensure that licensees identify and trend leakage early and take timely corrective actions well before the technical specification limit is reached. RCS pressure boundary material is ductile by design and typically exhibits a leak-before-break failure mechanism in which cracks begin small and leakage progresses over time. The RCS Leakage Performance Indicator is intended to monitor licensee behaviors in taking prompt action to address RCS leakage before it reaches the limit in the Technical Specifications.

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Contrary to this, the March 28, 2019, Brunswick event resulted from the immediate circumferential separation of a 1-inch coupling on the steam side sensing line for reactor vessel level indication, as shown in Figures 1 and 2. Based on the material of construction and environmental conditions (i.e., temperature, hydrogen), the post-event metallurgical report determined the coupling showed no evidence of localized plastic deformation. The coupling experienced hydrogen embrittlement and did not exhibit a leak-before-break failure mechanism. There were no precursors to this event and the resulting leakage from the break exceeded the Technical Specification (TS) limit. RCS leakage was stable and well below the TS limit before the event. The steam leak could not be isolated from the reactor vessel. Operations took prompt action to reduce power, commenced a plant shutdown, and depressurized the reactor to stop the leak. The leakage resulted in the declaration of an Unusual Event (UE). Operations completed an uncomplicated reactor shutdown. It was the last reading taken before entering Mode 4 (i.e., the Mode in which the SR is no longer applicable) that caused the PI to transition from Green to White. RCS leakage was stable and was being appropriately managed before the event. Based on these unique circumstances, Brunswick requests an exemption to exclude reporting the leakage from the event in the RCS Leakage PI. This would result in the PI returning to Green for March 2019.

2. As a result of the event, the NRC initiated their event follow-up process (IMC 0309, "Reactive Inspection Decision Basis for Reactors", and IP 71153, "Follow-Up on Events and Notices of Enforcement Discretion") to determine if it was appropriate to enter Management Directive 8.3, "Incident Investigation Program" to initiate a follow-up inspection (Special Inspection). In performing the "plant response and event follow-up checklist" the NRC evaluates control room conduct, the circumstances of the leak, plant conditions, and the associated risk of the event. NRC determined that a Special Inspection was not needed. Since the RCS leakage was low prior to the event with no precursors, the supplemental inspection initiated for a White PI would be redundant, in part, to that which has already been inspected. Based on the fact that Brunswick has already replaced all the susceptible couplings in both Units and given the unique characteristics of this failure, plant-specific circumstances should be considered to exempt recording the leakage from the event as part of the indicator and evaluate under other NRC processes.

**Problem Statement:** The RCS leakage Performance Indicator (PI) monitors leakage that is below the Technical Specification (TS) limit to ensure licensee's take prompt actions to monitor, diagnose, mitigate, and correct RCS leakage to prevent it from progressing into a more significant condition.

At Brunswick Nuclear Plant, Unit 1, RCS leakage was stable, monitored and managed well below the TS Limit with the PI low in the Green performance band prior to this event. On March 28, 2019, a 1-inch instrument line failed without any prior indications, resulting in exceeding the TS limit for RCS total leakage, as shown in Figure 3. A deliberate, controlled shutdown of Unit 1 was undertaken that was commensurate with the risk associated with the leakage. The location of the leak prevented it from being isolated, requiring the depressurization of the RCS to stop the steam leak. There were no precursors for the failure of this instrument line. The last data point taken in Mode 3 was 13.93 gpm as shown in Figure

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4. This was the only data point in March 2019 that exceeded the 50% of the TS Total Leakage Green/White threshold of >12.5 gpm.

NRC Region II implemented their event follow-up procedure and did not raise any concerns with the performance of the Operations crew responding to the leak. Duke Energy's position is that the absence of any precursor to the leakage and the prompt action of the Operations crew in responding to the leak provides special circumstances not addressed in the PI guidance. Duke Energy requests an exemption to exclude reporting leakage from the event in the RCS leakage PI calculation, which would return the indicator to Green for March 2019. While this FAQ is being resolved, the Brunswick Unit 1 first quarter 2019 RCS Leakage PI was reported as White on April 22, 2019, for the PI exceedance on March 28, 2019.

Brunswick, Unit 2 was shut down for a refueling outage during this event.

**Event Description:**

At 1419 on March 28, 2019, while operating at 100% reactor power, the Brunswick Nuclear Plant Unit 1 N004B narrow range reactor water level instrument (1-C32-LI-R606B) failed high. N004B is an instrument tap off the steam space of the reactor vessel. Drywell pressure and drywell floor drain leakage increased. Operators controlled drywell pressure and reduced reactor power per the immediate power reduction instructions. An Unusual Event was declared at 1450 based on elevated drywell leakage and reported to the NRC via Event Notification 53961. A controlled shutdown of Unit 1 was undertaken that was commensurate with the risk associated with the leakage. This timely action by the operators mitigated the leakage while preventing an unnecessary transient on the plant by performing a scram from a high power level. Timeline of event:

- March 28, 2019 – Unit 1 operating at full power
  - 1419 – N004B narrow range Reactor Pressure Vessel level instrument failed high
    - Drywell pressure and floor drain leakage increased
    - Entered TS 3.4.4 RCS Leakage for unidentified floor drain leakage
    - Operators reduced reactor power per the immediate power reduction instructions
  - 1429 – Drywell pressure slowly lowering in response to operator action
  - 1438 – Drywell Floor Drain sump alarm increased above setpoint, automatic actions in progress (sump pump started)
  - 1440 – Drywell Floor Drain sump level lowered below reset point and alarm cleared
  - 1450 – Declared Unusual Event due to elevated drywell leakage
    - Operators continued reducing power in accordance with procedures
  - 1600 – RCS leakage data recorded at 8.3 gpm as shown on Fig. 4
  - 1603 – Operators completed a manual reactor shutdown in accordance with procedures
    - Reactor Pressure Vessel level maintained in established level band
    - Scram recovery and cooldown – no significant problems
  - 2000 - RCS leakage data recorded at 11.51 gpm as shown on Fig. 4

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- March 29, 2019 – Unit 1 shutdown
  - 0000 - RCS leakage data recorded at 13.93 gpm as shown on Fig. 4
  - 0238 – Entered Mode 4

Investigation inside containment determined that a 1-inch coupling on line 1-B21-774 located on the steam side of a reactor level condensing chamber experienced a 360° circumferential separation at the approximate center of the coupling as shown in Figures 1 and 2 below. This opened a path for steam from the reactor to leak into the drywell. Reactor water level was maintained in the established level band, below the level of the sensing line nozzle, throughout the event. The impact from the coupling failure has been analyzed by the Duke Probabilistic Risk Assessment staff and determined to be very low safety significance.

Approximately 1.5 days before the event, the Brunswick, Unit-1 measured an increase in drywell pumping and implementing procedure 0OI-02.3, Drywell Leakage Control. Investigations determined that the cause of the higher measured leakage was a failed vacuum breaker which allowed water to flow back into the sump after it had been pumped out, causing it to be counted twice by the integrator for the RCS Leakage calculation. The integrator was observed to be ‘clicking’ or counting leakage when the pump was not running. This measured leakage was not related to the coupling failure and did not represent an increase in actual RCS leakage. In addition, there was no indication of increased activity on any of the Radiation Monitors, which provides additional assurance that this was unrelated to the coupling failure. The vacuum breaker was repaired during the outage and leakage rates returned to historical normal values.

**Basis for Exemption from guidance:**

Appendix E of NEI 99-02, Revision 7, allows an exemption to be submitted via the FAQ process for plant-specific circumstances such as unique conditions. Duke Energy is requesting this based on the unique conditions of this RCS leak in that it was not a leak-before-break and not indicative of chronic unresolved elevated RCS leakage. The RCS Leakage Performance Indicator is intended to monitor how licensees manage RCS leakage below the TS limit to ensure that timely corrective actions are taken in advance of reaching the TS limit. As stated in Appendix C of SECY 1999-007, Barrier Integrity Key Attributes and Means to Measure:

*Research has determined the RCS pressure boundary has a high probability of experiencing a leak prior to a rupture (i.e. "leak-before-break"). Therefore, the extent of such leaks offers an objective perspective on the probability of a more catastrophic failure.*

A foundational assumption of this Performance Indicator is that the RCS pressure boundary has a high probability of “leak-before-break” and that the PI is intended to monitor these precursor events. Additionally, in NRC Staff White Paper titled, *Objective of the RCS Leakage Performance Indicator*, from the June 26, 2013, ROP Working Group Public Meeting (ML13203A258), the NRC Staff made the following statement on page 20 of 60 regarding an Observation from the Davis-Besse Lessons Learned Task Force (LLTF):

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*As documented in LLTF recommendation 3.3.3(3), the intent of the current RCS Leakage PI is to call attention to those plants that have identified primary systems leaks but have not corrected them in a timely manner.*

The PI is intended to monitor leak-before-break situations that are viewed as precursors of a more catastrophic failure. In the Brunswick event, RCS Total leakage had been steady for the month of March as shown below in Figure 3. There was no advanced indications of degradation or leakage from the coupling and no trend that worsened over time due to operator inaction.

As shown in Figure 3, RCS Leakage trends were stable and low in the Green performance band for the month leading up to the coupling failure. The coupling failure occurred without warning. Drywell leakage and temperature in the vicinity of the coupling did not increase prior to the failure. There was no opportunity for Operations staff to identify this condition in advance of failure. As no precursors were present, no mitigating actions could have been taken in advance of the leak and the actions taken following the leak indicate prompt and conservative response on the part of the licensee. In addition, the location of the leak prevented it from being isolated until the plant was depressurized, which added to the volume of the leakage calculated in the PI. Despite timely operator actions to accomplish this, the volume of leakage calculated in the PI resulted in one calculation data point exceeding the threshold for White. The degradation mechanism of the coupling will be evaluated under other NRC processes.

The leakage measured during the event should not be counted in the RCS Leakage PI because the operators exhibited the behaviors consistent with the intent of the performance indicator. Operations took prompt action to conduct a safe and stable shutdown, minimizing the transient to the plant, in the interest of safety. Including this leakage in the performance indicator and taking the actions associated with a White PI could have the unintended consequence of providing an incentive to licensees to depressurize the plant in a less controlled manner without a commensurate benefit to public health and safety.

A Root Cause Evaluation was initiated following the March 28, 2019. The coupling that failed was a 1" Cryofit (cryogenic) coupling. Cryofit couplings are devices used to connect small bore piping (1-inch nominal pipe size and less) without welding. They are fabricated from a shape memory alloy (SMA) material composed primarily of Nickel-Titanium-Iron (TiNi) which experiences a phase change at cryogenic (extremely low) temperatures. To prepare for installation, the Cryofit coupling is cooled below the transformation temperature. The ends of the coupling are then expanded and the coupling is stored in the cold, expanded state. The pipe ends are inserted into the coupling while it is cold. The phase change causes the coupling to shrink as its temperature rises from its installation temperature of less than -200° F to ambient temperature and above. This results in an interference fit that does not require welding. This unique effect is produced by a phase transformation, i.e., an instantaneous shear transformation between the alloy's body-centered cubic austenite phase and its highly twinned martensite phase. These couplings had been installed at Brunswick for approximately 30 years.

Examination of the failed coupling was conducted at the McGuire Island Metallurgical lab. Microhardness testing, visual microscopy and scanning electron microscopy were used to

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characterize the failed material. Using metallurgical analysis and investigation of the process conditions at the coupling location, the Root Cause Evaluation team determined that the failure was due to hydrogen embrittlement of the Tinel material. This resulted from many years of exposure to high temperature and high levels of hydrogen. This conclusion is supported by the transgranular cleavage, high hardness values in the region exposed to the process fluid, and a hydrogen rich environment, which are all consistent with hydrogen embrittlement.

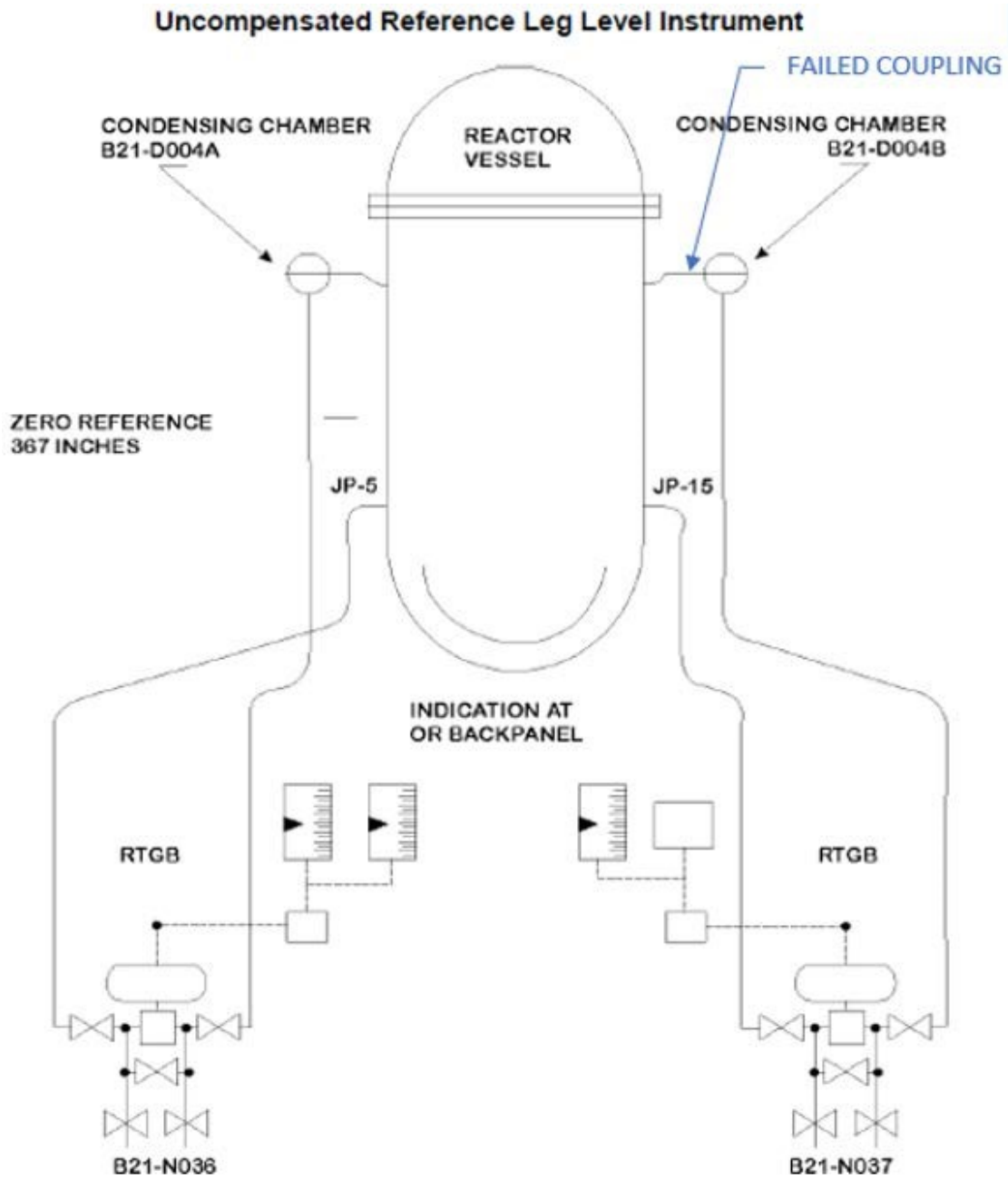
An evaluation was performed to address the couplings installed in both units. All couplings exposed to reactor steam (i.e., potentially susceptible) were removed and replaced with welded fittings prior to startup of Units 1 and 2. In addition, the installation procedure for the couplings was placed on hold pending revision, to prevent any further installation of Cryofit couplings.

RCS Leakage Data Collection:

The BNP Technical Specifications defines the frequency of Surveillance Requirement (SR) 3.4.4.1, RCS Operational Leakage, in accordance with the Surveillance Frequency Control Program (SFCP). The Brunswick SFCP has an 8-hour frequency for this SR. This is consistent with NUREG-1433, Revision 4, General Electric BWR/4 Standard Technical Specifications, which lists an RCS Operational Leakage Surveillance Requirement frequency of 8 hours, or in accordance with the SFCP. As a normal practice, Brunswick performs this surveillance every 4 hours in Modes 1 through 3 as a conservative approach to ensure the completeness of the required surveillance. It was the last data point collected before entering Mode 4 that caused the PI to transition from Green to White.

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Figure 1, RCS Leak location



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Figure 2, Picture of failed 1-inch coupling:

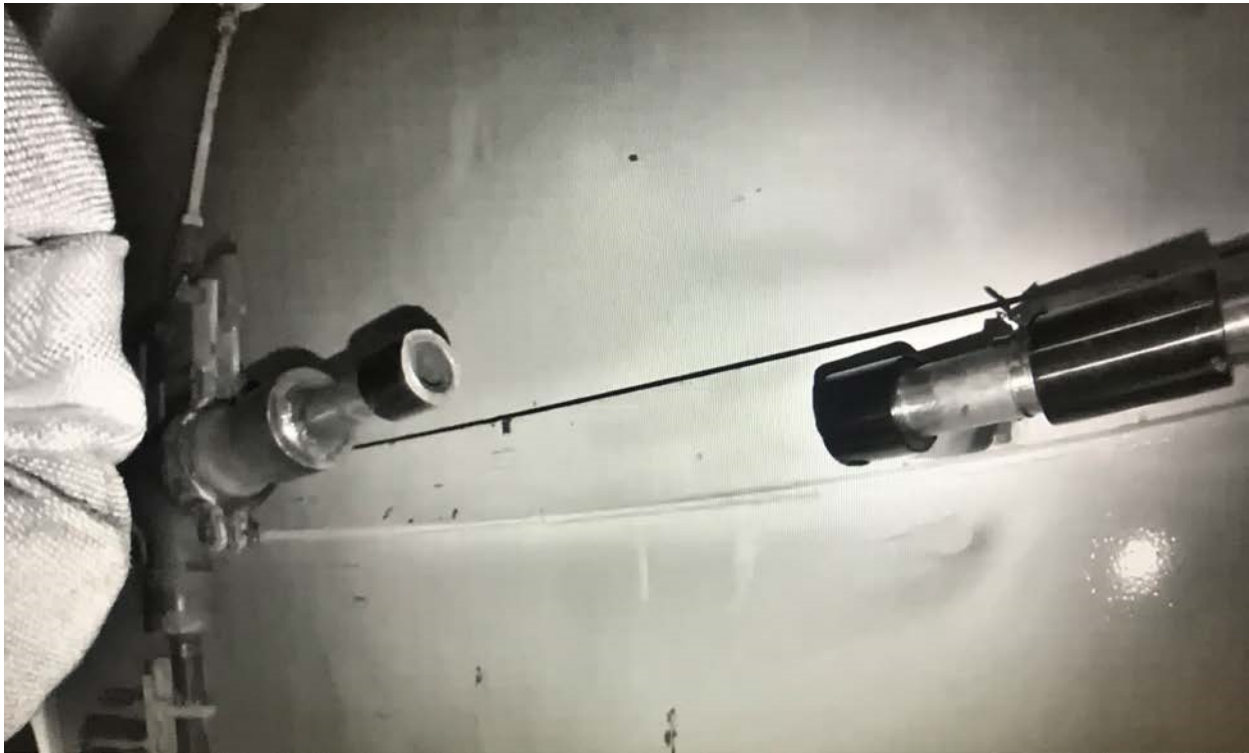
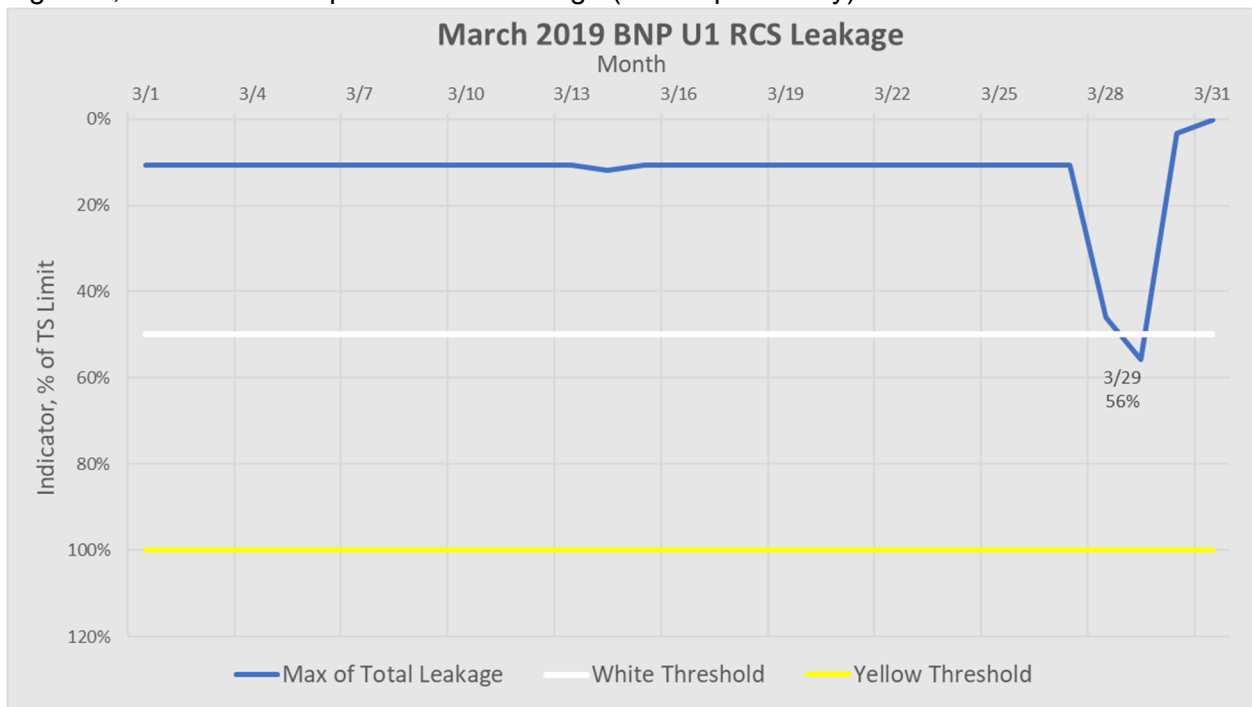


Figure 3, March 2019 Reported RCS Leakage (4-hour periodicity)





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Figure 4, Brunswick Unit 1 total RCS Leakage CDE data reported:

### U1 Total Leakage CDE Data

Max of Tot_Lkg Row Labels	Column Labels						Grand Total
	00:00	04:00	08:00	12:00	16:00	20:00	(blank)
(blank)							
3/1/2019	2.64	2.65	2.65	2.65	2.65	2.65	2.65
3/2/2019	2.65	2.65	2.65	2.65	2.65	2.65	2.65
3/3/2019	2.67	2.67	2.65	2.67	2.65	2.65	2.67
3/4/2019	2.64	2.64	2.66	2.63	2.65	2.66	2.66
3/5/2019	2.65	2.65	2.65	2.65	2.66	2.66	2.66
3/6/2019	2.66	2.66	2.66	2.67	2.67	2.67	2.67
3/7/2019	2.68	2.68	2.68	2.68	2.68	2.68	2.68
3/8/2019	2.67	2.67	2.66	2.65	2.66	2.67	2.67
3/9/2019	2.67	2.67	2.68	2.68	2.67	2.66	2.68
3/10/2019	2.67	2.66	2.66	2.67	2.67	2.66	2.67
3/11/2019	2.68	2.68	2.67	2.67	2.67	2.7	2.7
3/12/2019	2.69	2.66	2.66	2.66	2.67	2.66	2.69
3/13/2019	2.67	2.67	2.66	2.67	2.67	2.65	2.67
3/14/2019	2.66	2.66	2.69	2.69	2.67	2.69	2.69
3/15/2019	2.68	2.68	2.69	2.67	2.68	2.67	2.69
3/16/2019	2.68	2.67	2.67	2.69	2.68	2.68	2.69
3/17/2019	2.68	2.67	2.67	2.66	2.66	2.65	2.68
3/18/2019	2.64	2.66	2.66	2.67	2.65	2.67	2.67
3/19/2019	2.65	2.66	2.67	2.69	2.69	2.68	2.69
3/20/2019	2.7	2.7	2.69	2.68	2.68	2.68	2.7
3/21/2019	2.68	2.69	2.69	2.69	2.67	2.69	2.69
3/22/2019	2.67	2.66	2.65	2.63	2.64	2.62	2.67
3/23/2019	2.64	2.65	2.64	2.65	2.66	2.68	2.68
3/24/2019	2.68	2.67	2.69	2.68	2.67	2.67	2.69
3/25/2019	2.67	2.67	2.67	2.68	2.67	2.67	2.68
3/26/2019	2.67	2.67	2.66	2.66	2.66	2.66	2.67
3/27/2019	2.65	2.65	2.67	2.67	2.68	2.68	2.68
3/28/2019	2.69	2.69	2.68	2.68	8.3	11.51	11.51
3/29/2019	13.93						13.93
3/30/2019	0.83						0.83
3/31/2019	0.03						0.03
<b>Grand Total</b>	<b>13.93</b>	<b>2.7</b>	<b>2.69</b>	<b>2.69</b>	<b>8.3</b>	<b>11.51</b>	<b>13.93</b>

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**If licensee and NRC resident/region do not agree on the facts and circumstances, explain:**

The Brunswick Senior Resident Inspector reviewed this FAQ, said it appears to be factually correct and had no comments.

Potentially relevant FAQs:

N/A

**Response Section**

**Proposed Resolution of FAQ:**

This FAQ is proposed as a plant-specific exemption for the subject event and the RCS leakage data immediately following the transient initiated by the instrument line coupling failure. The RCS leakage associated with this event should not be counted, due to the unique circumstances of the event. RCS Leakage was stable and well below Technical Specification limits before the event, the identified couplings were replaced prior to plant startup and there would be negligible benefit in transitioning the plant to Column 2 of the Action Matrix and performing IP 95001.

PRA update required to implement this FAQ?

No

MSPI Basis Document update required to implement this FAQ?

No

**NRC Response:**

The NRC staff reviewed this FAQ and the details of the March 28, 2019 event at Brunswick Unit 1. The licensee is requesting an exemption from the NEI 99-02 guidance to report elevated Reactor Coolant System (RCS) Leakage due to plant-specific circumstances or unique conditions. Specifically, Brunswick Unit 1 is requesting an exemption related to the March 2019 RCS Leakage Performance Indicator (PI) data, which crossed the Green/White threshold due to the failure of a 1-inch instrument line coupling on March 28, 2019.

The licensee provided the following points (in part) to support their basis for their request:

1. The RCS Leakage Performance Indicator is intended to monitor RCS leakage below the Technical Specification limit to ensure that licensees identify and trend leakage early and take timely corrective actions well before the technical specification limit is reached.
2. Since Brunswick has already replaced all the susceptible couplings in both Units and given the unique characteristics of this failure, plant-specific circumstances should be

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considered to exempt recording the leakage from the event as part of the indicator and evaluate under other NRC processes.

The NRC staff reviewed IMC 0608, IMC 0308 Attachment 1, and the applicable implementing guidance in NEI 99-02, Revision 7, for the RCS Leakage PI, which is defined as:

*The maximum RCS Identified Leakage in gallons per minute each month per the technical specifications and expressed as a percentage of the technical specification limit.*

The RCS Leakage PI thresholds are established as:

*Green  $\leq$  50% TS limit  
White  $>$  50% TS limit  
Yellow  $>$  100% TS limit*

During this event RCS Leakage crossed the Green/White PI threshold. The maximum RCS Leakage data point recorded was 13.93gpm, which is 56% of the technical specification threshold of 25gpm. This RCS Leakage data point exceeded 50% of the Technical Specification RCS Total Leakage and crossed the Green/White threshold.

Guidance in NEI 99-02, Rev 7 further states that “*any RCS leakage determination made in accordance with plant Technical Specifications methodology is included in the performance indicator calculation.*” There are no exemptions in the NEI guidance for the RCS Leakage PI that would apply to this event. As a result, review of NEI 99-02 guidance makes it clear that the event would count in the RCS Leakage PI.

The staff also reviewed the basis for the RCS Leakage performance indicator documented in IMC 0308, Attachment 1, “Technical Basis for Performance Indicators.” The objective of the indicator is stated as:

*This indicator monitors the integrity of the RCS pressure boundary, the second of the three barriers to prevent the release of fission products. It measures RCS Identified Leakage as a percentage of the technical specification allowable Identified Leakage to provide an indication of RCS integrity.*

The documented objective of the performance indicator is to monitor the integrity of the RCS. Consideration of the effectiveness or timeliness of licensee corrective actions or the value of inspection follow-up is not factored into the PI basis.

In the FAQ the licensee referenced a portion of SECY 99-07, Barrier Integrity Key Attributes, which states, in part:

*RCS leakage is the most direct measure of RCS barrier performance. All other key attributes under RCS integrity are aimed at measuring or inspecting areas that are known to contribute to the increased probability that RCS integrity could fail. An actual RCS leak is, by definition, a breach of RCS integrity and a direct indicator of the performance of the RCS pressure boundary. Research sponsored by the industry and NRC has determined that the RCS pressure boundary passive components have a high probability of experiencing a leak prior to a rupture (i.e., "leak-before-break" analysis).*

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*Therefore, two performance indicators have been identified that can offer an objective perspective on the probability of more catastrophic failure potential: the rate of occurrence and magnitude of small RCS pressure boundary leaks.*

The staff does not dispute research showing a high probability of leak before break of RCS pressure boundary passive components, even though that did not occur in this case. The staff also acknowledges that the RCS leakage PI can provide RCS leakage insights such that it can be identified prior to a break. Nevertheless, the PI is defined in IMC 0608 with supporting guidance in NEI 99-02 and the objective of the PI is discussed in IMC 0308, Attachment 1. The objective of the PI is to monitor the integrity of the RCS pressure boundary. Also, the referenced SECY 99-07 above states that “*An actual RCS leak is, by definition, a breach of RCS integrity and a direct indicator of the performance of the RCS pressure boundary*” which is consistent with the PI objective. In conclusion, to discount an actual RCS leak or break because it was sudden rather than gradual, or because corrective actions were timely and effective, is wholly inconsistent with the stated objective of the PI.

Because the FAQ and related comments about it at a recent public meeting discussed aspects of the agency’s assessment process, it appears necessary to address herein the agency’s assessment process documented in IMC 0305. The assessment process consists of both performance indicators and inspection results. It was and is known that some issues affect both the inspection and performance indicator aspects of the assessment process. Section 11.03 of IMC 0305 discusses that some issues may result in both a safety-significant PI and a safety-significant inspection finding and goes on to discuss circumstances under which such issues would not be “double counted” in the assessment process. Once a safety-significant PI or inspection finding occurs, the staff can assess whether the resulting regulatory response is appropriate and pursue an Action Matrix deviation, if appropriate. Such consideration would not impact whether a PI or inspection finding was safety significant in the first place. In other words, the PI FAQ process is not the appropriate place to consider whether the prescribed inspection follow-up to a White PI would be a reasonable regulatory response or whether a potential safety significant finding might be double-counted with the PI. These are appropriate considerations that the staff will address at the proper point in the assessment process, if necessary.

In conclusion, the NRC staff reviewed the points raised by the licensee as to why a plant-specific RCS Leakage performance indicator exemption is appropriate and justified in this instance. The staff determined that the event subject to this FAQ was within the definition and objective of the RCS Leakage PI. The exemption requested in this FAQ for this event is not approved.