FAILED FUEL ACTION PLAN

1. PURPOSE

1.1. This procedure provides instructions to manage the effects of in-core fuel failures in both BWRs and PWRs and for identifying failures for subsequent discharge or repair.

1.2. This procedure also provides guidance in identifying the root cause of fuel failures to prevent recurrence. It is an integral part of Exelon's program to meet and maintain its strategic objective of operating with zero fuel defects.

2. TERMS AND DEFINITIONS

2.1. **Action Level** – the states of fuel integrity expressed in terms of fission product activity in the offgas or coolant. The Action Levels are:

- Normal Operation - **no** fuel failures
- Action Level 1 - one or more failures with little fission product release
- Action Level 2 - one or more failures yielding fission product release substantial enough to pose in-plant radiological issues
- Action Level 3 - characterized by high fission product release potentially jeopardizing continued unit operation.

2.2. **Dose Equivalent Iodine (DEI)** – the concentration of Iodine-131 (usually given in microcuries/gram) that alone would produce the same thyroid dose as the quantity and isotopic mixture of the Iodine-131, Iodine-132, Iodine-133, Iodine-134, and Iodine-135 actually present.

2.3. **Failed/Defective Fuel** – pertains to any fuel rod that has been breached in such a way that fission products can escape into the reactor coolant. A failed or defective fuel assembly may contain one or more failed/defective fuel rods. Such an assembly or rod is often referred to as a "leaker."

2.4. **Failed Fuel Monitoring Team (FFMT)** – a team of on-site and off-site personnel that evaluate and manage a fuel defect. It is normally composed of the Site Reactor Engineering Manager (REM), a Nuclear Fuels Fuel Reliability Engineer (FRE), representatives from Site Chemistry, Operations, Maintenance, and Radiological Protection and, if needed, from Outage Services and the applicable Fuel Supplier. The REM normally chairs the FFMT.

2.5. **Fuel Reliability Indicator (FRI)** – is defined by the World Association of Nuclear Operators (WANO) and has been designed to provide a uniform measure of fuel performance between reactors of similar design. The FRI is one of the parameters used to determine Action Levels within the context of this procedure.

2.6. **Normal Operation** – is defined as plant operation with zero fuel defects. Such operation is generally associated with a WANO Fuel Reliability Indicator (FRI) below 5.0E-4 μCi/g for PWRs and below 300 μCi/sec for BWRs (unsuppressed).

2.7. **Primary Noble Gases** – in the context of this Failed Fuel Action Plan (FFAP), the six primary noble gases in the BWR off-gas are: Xenon-133, Xenon-135, Xenon-138, Krypton-85m, Krypton-87, and Krypton-88.

2.8. **Recoil** – normally refers to coolant or off-gas activity resulting from the fissioning of tramp uranium or plutonium. Since the fissioning is occurring on the surface of core components, there is little or **no** holdup time between the fission event and release of the fission products to the coolant. The reported recoil activity can increase as a result of an open defect. It also increases during a cycle as tramp U-238 is converted into the fissile isotope, Pu-239. It is common to adjust the BWR sum-of-the-six noble gas activity or PWR iodine-131 activity to subtract out the recoil activity and such correction may be particularly useful in analyzing fuel integrity in cores contaminated from past fuel defects.

2.9. **Reconstitution** – the replacement of one or more fuel rods in a nuclear fuel assembly for reasons such as cladding defects or to achieve high exposure for demonstration purposes. Replacement rods may be inert rod(s), new (un-irradiated) fuel rod(s), or irradiated rod(s) from another assembly. The usual purpose of a reconstitution is to achieve a leaker-free assembly suitable for further irradiation. Reconstitution can also refer to replacement of all or part of the fuel assembly skeleton because of handling damage or to the insertion of special fueled or **non**-fueled rods into an irradiated assembly for test purposes.

2.10. **Tramp Uranium** – refers to fissionable uranium that has been deposited on reactor core internals or other surfaces from previous failed fuel or is present on the surface of fuel elements from the manufacturing process.

3. RESPONSIBILITIES

3.1. Failed Fuel Monitoring Team (FFMT) – recommends chemistry sampling, assesses data, recommends actions to prevent additional failures, recommends actions to mitigate consequences of fuel defects and recommends actions to locate and determine the root cause of each fuel failure.

3.2. Nuclear Fuels Fuel Reliability Engineer (FRE) – notifies fuel supplier(s) of a fuel defect, reviews fuel fabrication records, assesses data for mode of fuel failure, provides End-of-Cycle EOC recommendations.

3.3. Reactor Engineering Manager (REM) – notifies Station Management, Vice President – Operations, and Vice President – Nuclear Fuels of fuel defect.

3.4. Site Vice President (SVP) – assigns members to the FFMT.

3.5. Station Radiation Protection Manager – supports FFMT in developing an action plan.

3.6. Station Reactor Engineer (SRE) – makes initial determination of a fuel failure and initiates corrective action process.

4. **MAIN BODY**

4.1. Fuel Failure Determination

4.1.1. **ENTER** the Failed Fuel Action Plan by identifying a fuel defect through: ***(SRE)***

- PWR Fuel Integrity Monitoring (Reference NF-AP-400-1000)
- BWR Fuel Integrity Monitoring (Reference NF-AB-400-1000)
- WANO FRI Calculation for BWRs (Reference NF-AB-400-1700)
- WANO FRI Calculation for PWRs (Reference NF-AP-400-1700)
- An increase in process radiation indication.

NOTE: It is conservative to assume entry into a higher Action Level based upon unexpected increases in coolant, off-gas activity or plant monitoring instrumentation during **non**-steady state power. Should activity levels during subsequent steady state power operation indicate a lower Action Level, the station may downgrade the Action Level after consultation with NF.

4.1.2. **NOTIFY** the REM of a potential fuel failure. ***(SRE)***

NOTE: Fission Product activity levels may change subsequent to entry into the original Action Level either due to additional fuel failures or degradation of one or more existing failures. If this occurs, then it is necessary to re-evaluate the appropriate Action Level.

4.1.3. **DETERMINE** an Action Level appropriate for the condition by gathering additional data on the event and evaluating the multiple entry parameters provided in Attachments 1, 2 and 3 for determining an Action Level. ***(SRE)***

1. **If** there are indications that a failure has occurred, **then ENTER** the appropriate Action Level.

2. **If** the fission product activities are showing an increasing trend, **then CONSIDER** placing the unit in the next higher Action Level.

4.1.4. **MONITOR** the unit's fission product activity on a frequent and periodic basis. Additional fuel failures or degradation of the initial failure(s) may warrant a higher action level. Fission product activity, particularly on a PWR, may also decline as the cycle progresses and could warrant a reduction in the action level. ***(SRE)***

4.2. Action Level 1, 2, or 3

4.2.1. **NOTIFY** the appropriate Station Management, Senior Vice President of Operations and Vice President of Nuclear Fuels within twenty-four hours of determination that an Action Level has been entered. ***(REM)***

4.2.2. **INITIATE** a report in the corrective action program identifying the development of the leaker. ***(SRE)***

1. **ENSURE** that a Root Cause investigation is included in the CAP actions.

4.2.3. **INITIATE** an Operational Experience Report to inform others in the industry of the Failed Fuel. ***(SRE)***

NOTE: The FFMT is normally responsible for providing overall evaluation and management of the fuel defect.

4.2.4. **FORM** an FFMT and select a chairperson, normally the REM. ***(SVP)***

4.2.5. **DEVELOP** a meeting schedule to manage on-going FFMT responsibilities.

NOTE: Increasing the frequency of BWR off gas sampling enables close monitoring of the failed fuel performance.

NOTE: Attachment 4 provides a table of principal nuclides, their half-lives, and fission product yields to be used for fuel performance evaluation.

4.2.6. **DETERMINE** needed frequency of coolant or off-gas sampling. Consideration should be given to expanding the scope of monitoring to include isotopes **not** routinely monitored (e.g. Sr-91, Sr-92, and Np-239). ***(FFMT)*** **(CM-3)**

– **CONSIDER** additional sampling on unit shutdowns or load drops to obtain the best cesium data for determining the exposure of the defective fuel.
– **CONSIDER** an Adverse Condition Monitoring and Contingency Planning document for sampling, re-sampling, and communications plan. (Reference OP-AA-108-111)

4.2.7. **If** needed, **then DIRECT** Chemistry to perform needed coolant and off gas sampling to adequately monitor the fuel defect. ***(FFMT)***

CAUTION

The Reactor Coolant System (RCS) activity levels can increase by several orders of magnitude during plant shutdowns or down power maneuvers. Radiochemistry samples should be obtained during the plant maneuvers with special consideration of the Technical Specification Limits and the Emergency Action Levels (EALs) threshold values.

4.2.8. **ASSESS** radiochemistry data including: ***(FFMT)***

1. **ESTIMATE** of the number of failed fuel rods
2. **ESTIMATE** of the exposure of the failure from the cesium ratios (when available)
3. **If** possible, **then IDENTIFY** the type of fuel that has failed
4. **TREND** fission product activity – particularly the Sum-of-the-Six Noble Gas Activity, Xe-138/Xe-133 on the BWRs, Xe-133/Xe-135 and I-131 on PWRs, and Xe-133, DEI, and isotopes for tracking fuel wash out (e.g. Sr-91, Sr-92 and Np-239) on both BWRs and PWRs.
5. **PROJECT** the need to increase the Action Level, the possibility that a Technical Specification and/or the Emergency Action Levels (EALs) will be challenged (see Attachment 3, Footnote 5), or the possibility that a plant shutdown will be required. **(CM-3)**

4.2.9. **NOTIFY** the appropriate fuel supplier(s) of the fuel failure(s) **and**, **if** needed, **then REQUEST** assistance. ***(FRE)***

4.2.10. **EVALUATE** altering plant operation to mitigate the consequences of the existing failure(s) on plant operation and to prevent additional fuel failures. Control Rod motion should be avoided – particularly rod withdrawal - until fuel defects are suppressed (BWRs). ***(FFMT)*** **(CM-5)**

4.2.11. **RECOMMEND** alterations on unit operation using an Operational and Technical Decision Making document, as appropriate. (Reference OP-AA-106-101-1006) ***(FFMT)***

1. **INCREASE** the cleanup of primary coolant water via increased letdown flow (PWRs) or increased number of on-line cleanup demineralizers (BWRs).

2. **INITIATE** Power Suppression Test, as appropriate. (Reference NF-AB-431 for BWRs)

   A. BWRs are to perform the PST as soon as practical after the fuel defect is identified.

   B. Perform the PST prior to maneuvers that change leaker power distribution.

   C. **If** a PST is not planned, scheduled to start more than ten days after a defect was determined to exist, restricted to a specific core region, or planned to stop before all available cells are tested, e.g. after a failure has been detected, **then DOCUMENT** this decision using the Operational and Technical Decision Making Process. (Reference OP-AA-106-101-1006)

3. **REFER** to the procedure for BWR Fuel Conditioning or PWR Fuel Conditioning for fuel conditioning instructions for failed fuel. (Reference 6.1.11 through 6.1.14)

CAUTION
The actions at BWRs to minimize the effects of prolonged operation with high coolant activity shall include reviewing off-gas post-treatment activity and evaluating the need for and amount of induced air added to the off-gas system to ensure off-site releases are minimized. The addition of air may have an adverse impact on radioactive releases. **(CM-1)**

4.2.12. **EVALUATE** the impact of the fuel failure upon plant radiation fields, airborne conditions, area contamination, and effluents. ***(FFMT)***

4.2.13. **IMPLEMENT** any actions determined to be necessary to mitigate impact on plant radiological conditions and effluents. ***(FFMT)***

4.2.14. **COMPLETE** a Failure Modes and Effects Analysis within 90 days from first entering an Action Level. ***(FFMT)***

- Fuel fabrication records to determine if any manufacturing abnormalities exist for the affected fuel
- Radiochemistry, operational and power history data **(CM-4)**
- Nuclear Design
- Mechanical Design
- Foreign Material and Fuel Handling events
- Coolant Chemistry
- Relevant Operating Experience
- Grid-to-Rod Fretting

4.2.15. **RECOMMEND** appropriate actions to prevent recurrence of similar fuel failure(s) in the remainder of the current cycle. ***(FRE)***

4.2.16. **COMMUNICATE**, as appropriate, known details of the fuel failure to other stations in the fleet for determination of applicability to the station.

4.3. <u>Action Level 2 or 3</u>

NOTE: Fission product activity levels may be high enough in Action Level 2 to significantly alter the plant radiological conditions.

4.3.1. **DEVELOP and IMPLEMENT** an action plan to minimize the effects of prolonged operation with high coolant or off-gas activity on plant operation, maintenance, and effluents considering actions in Attachment 5 using OP-AA-106-101-1006, Operational and Technical Decision Making as appropriate. The on-site Radiation Protection Supervisor and Chemistry Supervisor will support the FFMT in developing this action plan. ***(FFMT)*** **(CM-5)**

– Guidance to plant workers to minimize radiation exposure should include consideration of the potential for exposure to highly radioactive fuel particles.

4.4. <u>Action Level 3</u>

CAUTION

Continued operation in Action Level 3 for greater than fourteen (14) days is permitted only if approved by the Plant Operations Review Committee (PORC).

WARNING

Operation in Action Level 3 can result in significantly elevated in-plant dose rates, elevated plant effluents and long-term plant contamination.

4.4.1. **OBTAIN** PORC direction within fourteen days for continued plant operation in Action Level 3. This review by PORC shall address as a minimum the issues identified in Attachment 8. ***(FFMT)***

4.4.2. **If** necessary, **then RECOMMEND** restricting Unit operation to control impact of fission product activity. ***(FFMT)*** **(CM-5)**

1. **If** it is anticipated that Technical Specification limits could be challenged **or** plant dose rates or effluent levels could become significant problems, **then TERMINATE** load following the unit. Load following can result in more frequent iodine spiking.

2. **If** it is anticipated that Technical Specification limits could be approached **or** plant dose rates or effluent levels could challenge continued operation, **then DERATE** the unit. **(CM-3)**

4.4.3. **If** needed, **then SCHEDULE** periodic PORC reviews during the remainder of the cycle. The need for and frequency of these reviews will depend on the actual activity levels and their impact on reactor and site operations safety. ***(FFMT)***

4.4.4. **RECOMMEND** to the SVP and Vice President Nuclear Fuels conditions at which a mid-cycle outage may be necessary. ***(FFMT)*** **(CM-3)**

4.5. Failed Fuel Identification Campaign

NOTE: Fuel reliability recommendations should normally be issued at least six (6) months **prior** to the end of cycle to allow adequate time to plan outage activities related to fuel failures.

4.5.1. **DEVELOP** Outage fuel reliability recommendations in accordance with Attachment 6. ***(FRE)***

1. **REVIEW** operating reactor fuel failure data with the FFMT and determine nature of fuel failure(s). This information will provide guidance regarding the scope and technology required for locating the failed fuel.

2. **INCLUDE** recommendations on method(s) for identifying the failed fuel assembly(s) and failed fuel rod(s) (see Attachment 6, Table 1).

3. **If** needed during the rest of the cycle, **then ISSUE** updates.

4.5.2. **ENSURE** Station and Nuclear Fuels planning for the next refueling contains a project to remove the fuel failure(s) from the core. ***(FRE, FFMT)***

4.5.3. **SUPPORT** the site and Vendor efforts to identify the fuel failure(s). ***(FRE)***

CAUTION
<u>Neither</u> BWR **<u>nor</u>** PWR failed fuel shall be intentionally re-inserted for continued operation. Guidance is provided for scenarios in which failed fuel **<u>cannot</u>** be identified and may carry over into the follow-on cycle.

NOTE: It is particularly important to avoid re-insertion of failed BWR fuel due to secondary degradation issues.

4.5.4. **If** a fuel failure **<u>cannot</u>** be located during EOC fuel inspections and the possibility exists for a failure to carry over into the follow-on cycle, **then PROVIDE** a detailed technical and operability analyses to justify any use of Defective Fuel in a Technical Evaluation. This justification is required for each operating cycle the defective fuel is to be used. (Reference CC-AA-309-101) **(CM-2)** ***(FRE)***

1. **USE** Attachment 7 guidance in developing the Technical Evaluation for possible re-insertion of failed fuel.

4.5.5. **DOCUMENT** the failed fuel identification campaign in the appropriate assignment from the IR generated for the fuel failure. ***(FRE)***

1. **PROVIDE** detailed information on the methods used, number of assemblies inspected, failure(s) identified, problems identified and other pertinent data. ***(FRE)***

4.5.6. **PREDICT** off-gas and coolant fission product activity levels in the follow-on fuel cycle from recoil trends. ***(FRE)***

4.5.7. **RECOMMEND** appropriate actions to prevent recurrence of similar fuel failure(s) in subsequent cycles. ***(FRE)***

4.5.8. **ENSURE** that a fuel failure root cause inspection campaign is planned. (Reference NF-AA-412) ***(FRE, FFMT)***

5. DOCUMENTATION

5.1. Nuclear Fuels Letter documenting the results of the failed fuel identification campaign.

6. REFERENCES

6.1. User's References

6.1.1. Electric Power Research Institute (EPRI) Special Report NR-5521-SR, "Failed Fuel Action Plan Guidelines," November 1987.

6.1.2. EPRI Report TR-100659, "Fuel Reliability Improvement Guidelines," April 1992.

6.1.3. EPRI Report TR-102799, "Severe Degradation of BWR Fuel Failures: Coolant Activity Analysis," Interim Report, November 1993.

6.1.4. General Electric SIL 379, Revision 1, Power Suppression Testing

6.1.5. INPO Significant Operating Experience Report (SOER), 90-02, "Nuclear Fuel Defects," July 16, 1990.

6.1.6. INPO SOER, 96-02, "Design and Operating Considerations for Reactor Cores," November 1996.

6.1.7. Nuclear Operations Directive NOD-OP.26, "Significant Changes to Reactor Core Design or Core Operating Strategy."

6.1.8. NF-AP-400-1000 PWR Fuel Integrity Monitoring

6.1.9. NF-AB-400-1700 WANO FRI Calculation for BWRs

6.1.10. NF-AB-431 BWR Power Suppression Testing

6.1.11. NF-AB-440-1001, Fuel Conditioning for 3-D MONICORE Plants

6.1.12. NF-AB-440-1002, Fuel Conditioning for POWERPLEX Plants

6.1.13. NF-AB-440-1003, Fuel Conditioning for CMS Plants

6.1.14. NF-AP-440 PWR Fuel Conditioning

6.1.15. NF-AP-400-1700 WANO FRI Calculation for PWRs

6.1.16. OP-AA-106-101-1006, Operational and Technical Decision Making Process

6.1.17. OP-AA-108-111, Adverse Conditioning Monitoring and Contingency Planning

6.1.18. EPRI Technical Report 1003407, Fuel Integrity Monitoring and Failure Evaluation Handbook, Revision 1

6.1.19. NF-AB-400-1000 BWR Fuel Integrity Monitoring

6.1.20. EPRI Guideline No. 1015032, "Fuel Reliability Guidelines – Fuel Surveillance and Inspection, March 2008

6.2. <u>Commitments</u>

6.2.1. LaSalle County Station

1. **CM-1** INPO Evaluation Report, 1992, related to induced air in-leakage in a BWR offgas system. (Caution for Step 4.2.11 and Attachment 5)

6.2.2. Limerick Generating Station and Peach Bottom Atomic Power Station

1. **CM-2** INPO SOER 90-2, Nuclear Fuel Defects, Recommendation 2a (T01809) guidance to technically and operationally justify any reuse of defective fuel (Section 4.5.4 and Attachment 7)

2. **CM-3** INPO SOER 90-2, Nuclear Fuel Defects, Recommendation 2e (T01134) description of action levels and responsibilities for responding to indications of fuel defects including the need for increased chemistry monitoring and selection of radiochemistry activity levels to determine desirability of a plant derate and the need for setting admin limits above which reactor operations will not be allowed (Sections 4.2.5, 4.2.7.5, 4.4.2.2 and 4.4.4.)

3. **CM-4** INPO SOER 90-2, Nuclear Fuel Defects, Recommendation 2f (T01135) identify the causes and contributing factors of fuel defects and appropriate corrective actions (Sections 4.2.13)

4. **CM-5** INPO SOER 90-2, Nuclear Fuel Defects, Recommendation 2g (T01136) identify methods to minimize the impact of existing defects and reduce the probability of causing similar addition defects (Sections 4.2.9, 4.3.1, 4.4.2.)

7. ATTACHMENTS

7.1. Attachment 1, BWR Failed Fuel Action Levels

7.2. Attachment 2, PWR Failed Fuel Action Levels

7.3. Attachment 3, Footnotes and Instructions on Failed Fuel Action Level Criteria

7.4. Attachment 4, Table of Nuclides Typically Used for Fuel Performance Evaluation

7.5. Attachment 5, Actions to Minimize Effects of Long Term Operation with High Fission Product Activity

7.6. Attachment 6, Guidance for Developing Outage Fuel Reliability Recommendations

7.7. Attachment 7, Guidance on Re-insertion of Defective Fuel

7.8. Attachment 8, Items for Review if in Action Level 3

ATTACHMENT 1
BWR Failed Fuel Action Levels
Page 1 of 1

BWR ACTION LEVELS

Parameter	**Normal Operation**	**Level 1**	**Level 2**	**Level 3**
Spiking (1) **I^{131} and/or Xe^{133}**	< 2 times the steady state full power activity (2)	> 2 times the steady state full power activity (2)	N/A	N/A
Xe^{138} / Xe^{133} (7)	≥ 300	≤ 100	N/A	N/A
∑ 6 (µCi/s) (3)	≤ 1000	> 1000	> 10,000	> 50,000
FRI (µCi/s) (4)	≤ 300	> 300	N/A	N/A
DEI (µCi/g) (5)	N/A	N/A	>0.001	> 20% of Tech Spec Limit
Noble Gases (µCi/s/MWth) (6)	N/A	N/A	N/A	> 20% of Tech Spec Limit

Footnote numbers () refer to Attachment 3.

ATTACHMENT 2
PWR Failed Fuel Action Levels
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BYRON AND BRAIDWOOD ACTION LEVELS

Parameter	**Normal Operation**	**Level 1**	**Level 2**	**Level 3**
Spiking or Step Change (1) **I^{131} and/or Xe^{133}**	< 2 times the steady state full power activity (2)	> 2 times the steady state full power activity (2)	N/A	N/A
I^{131} Activity (μCi/g) (8)	≤0.0005	> 0.0005	> 0.005	> 0.05
Xe^{133} Activity (μCi/g) (8)	≤ 0.01	> 0.01	>0.5	>5.0
Xe^{133} / Xe^{135} (7)	≤ 1.5*	≥ 2.0	N/A	N/A
FRI (μCi/g) (4)	≤ 0.0005	> 0.0005	> 0.01	> 0.1
DEI (5)	N/A	N/A	N/A	> 20% TS

*If the Xe133/Xe135 ratio is greater than 1.5 and less than 2 then review the values of the other criteria listed above for the possible presence of a fuel failure.

Footnote numbers () refer to Attachment 3.

ATTACHMENT 2
PWR Failed Fuel Action Levels
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TMI ACTION LEVELS

Parameter	Normal Operation	Level 1	Level 2	Level 3
Spiking or Step Change (1) **I^{131} and/or Xe^{133}**	< 2 times the steady state full power activity (2)	2 times the steady state full power activity (2)	N/A	N/A
I^{131} Activity (µCi/g) (8)	≤ 0.005	> 0.005	> 0.05	> 0.5
Xe^{133} Activity (µCi/g) (8)	≤ 0.1	> 0.1	>1.0	>10.0
Xe^{133} / Xe^{135} (7)	< 1.0	≥ 1.0	N/A	N/A
FRI (µCi/g) (4)	≤ 0.0005	> 0.0005	> 0.01	> 0.1
DEI (5)	N/A	N/A	N/A	> 20% TS

Footnote numbers () refer to Attachment 3.

ATTACHMENT 3
Footnotes and Instructions on Failed Fuel Action Level Criteria
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Footnotes for Attachments 1 and 2

1. Spiking refers to a short-duration increase in the activity. A large increase in fission product activity (either coolant or noble gas) could come from rapid changes in reactor power or pressure resulting in increased communication between an existing defective fuel rod and the coolant or from the initial inventory ejection when a defect first appears.

   A step change refers to a noticeable and sustained jump in the steady state activity that is not necessarily associated with a change in reactor power.

2. Significant fission product spiking in the reactor coolant or off-gas is indicative of the presence of defective fuel. A significant spike is an activity level increase greater than approximately a factor of 2 above the steady state activity level band of activity. For low levels of fission product activity – particularly near the lower level of detection, substantial fluctuations in the activity levels are expected. The spiking referred to here is a meaningful increase of at least a factor of 2 above what can be explained by normal fluctuations in activity levels. Neither the number of defects nor the size of the defect(s) can be accurately determined from spiking. Iodine-131 and Xenon-133 are two principal fission products that can exhibit significant spiking from failed fuel. Note that isotopic data analysis has now shown that post Noble Metals, NMs, application in a BWR can result in significant iodine spiking as a result of iodine return. This can occur in a core with no fuel defects; hence, spiking information must be carefully interpreted to determine if a fuel failure is the cause or if NMs is driving the spike on a BWR.

   Significant spiking (e.g. a factor of 2 or more increase) in coolant or off-gas activity following a unit shutdown or depressurization should be reported and evaluated. Significant spiking usually results from an increased release of fission products from defective fuel during rapid changes in reactor power or pressure. Activity level spikes believed to be from defective fuel should not be used to determine Action Levels except to move a unit from the Normal Operations category into Action Level 1 per the Tables. Some fuel defects of a "tight" nature or in low powered fuel may be detected only through spiking. Spiking could also arise from changes in reactor operation such as the loss of a coolant demineralizer, which effectively eliminates a major removal path for fission products.

   For PWRs, any step increase in Xe-133 activity in excess of 0.025 µCi/gm (AREVA fleet PWRs conservatively use a change of 0.01 µCi/gm), especially if the increase is sustained for more than about a week, suggests the possibility of the existence of a fuel failure. In practice, the ability to observe a Xe-133 spike may be greatly influenced by the presence of tramp fuel on the core surface.

ATTACHMENT 3
Footnotes and Instructions on Failed Fuel Action Level Criteria
Page 2 of 4

3. The activity level of the sum-of-the-six noble gases, ∑ 6, has long been a BWR standard monitoring parameter. Defect-free cores can run less than 100 µCi/s if not contaminated from past failures. Although a small, tight failure may only produce an activity level of several hundred µCi/s or less, a typical BWR single-rod failure on BWRs has resulted in an initial increase of 1500 to 2000 µCi/s or more, which may later drop to 500 µCi/s or lower. Local power suppression can further reduce this value. Single rod defects may also result in very high offgas release exceeding 1 E5 µCi/s. Should the core be contaminated with uranium plate-out from past failures (tramp uranium), the ∑ 6 can be significantly elevated with no present failures. Such contamination can also make detection of new defects difficult. If most of the activity is from tramp uranium (termed recoil), the FRI may be a more appropriate parameter upon which to base the initial Action Level of the unit. **Alternatively**, the sum-of-the-six noble gas activity may be recoil corrected to subtract out background activity from previous cycle failures **in a defect free core**. If a failure occurs in the present cycle, caution must be applied when recoil correcting to assure that activity from an "open" defect that develops is not reduced i.e. it is not appropriate to subtract out recoil like activity from an ongoing defect. Do not subtract more activity than existed prior to identification of the current cycle's defect. Adjust the recoil correction by fraction of rated power. Introduction of NMs may result in an increase in the ∑ 6 characterized by all six of the isotopes increasing in a proportional amount. This is very much plant specific and will require careful interpretation of alternate indicators such as the Xe ratio to determine if a fuel failure exists.

4. The FRI is a WANO indicator of fuel performance, which is normalized to a reference linear heat generation rate, full power adjusted, and corrected for tramp uranium. In certain fuel failure scenarios in which the pellets are exposed to the coolant, the tramp uranium correction term in the FRI may dominate and drive the FRI to misleadingly low or negative values. This can occur for the normal BWR FRI indicator but not for the alternate, full power adjusted sum-of-the-six equation. Should this situation occur when fuel degradation is obviously occurring as determined by increasing fission product activity rates, the Action Levels should be conservatively determined by using one or more of the other parameters. In other scenarios, when fuel failures may not be present but coolant or off-gas activities are elevated from past failures, the FRI may be the appropriate parameter by which to establish an Action Level (see note “c” below). Because the FRI is a full power adjusted parameter, it may show significantly elevated values when calculated at reduced power. Caution should be used in applying FRI values calculated at reduced power.

ATTACHMENT 3
Footnotes and Instructions on Failed Fuel Action Level Criteria
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5. DEI is a Technical Specification-based parameter and Emergency Action Level (EAL) High Reactor Coolant Activity Threshold Value in which several of the iodines present in the coolant are evaluated in terms of the corresponding activity level of Iodine-131 necessary to produce the same thyroid dose (see Section 2.0, Definitions). DEI may meet the Emergency Action Level (EAL) Threshold Value for Reactor Coolant System (RCS) Coolant Activity that needs to be considered and checked when a reactor shutdown or significant power level change occurs with failed/defective fuel. Although it is unlikely that the DEI would be the defining parameter for establishing an Action Level, it is included to verify that a Technical Specification limit is not violated by fuel defects. Similarly the EAL Threshold Value for High Reactor Coolant Activity may not be met by failed/defective fuel. However, if a PWR Core is operating with failed/defective fuel in Level 1, Level 2, or Level 3 then it is necessary that the Failed Fuel Monitoring Team Plan contain direction requiring Operation’s review of EALs for meeting High RCS Coolant Activity Threshold Value when a reactor shutdown or significant power level change occurs with failed/defective fuel. The Technical Specification DEI limit may vary somewhat from unit to unit. For BWRs where most activity monitoring centers around noble gases, Level 2 and 3 entry points are provided based upon DEI activity to provide additional evaluation of this parameter. The Action Level 3 value may be corrected for tramp uranium plated out in the core.

6. The BWRs have a Technical Specification limit on gross noble gas activity, which is usually specified in µCi/s/MWth. This value is not expected to be the defining parameter for establishing an Action Level, but is included to protect against violating a Technical Specification limit. The Technical Specification limit may vary somewhat from unit to unit.

7. There are numerous fission product ratios, which can be of assistance in interpreting fuel integrity. The ratio of short lived Xe-138 to long lived Xe-133 is particularly good for use on BWRs. A defect free core generally has a high ratio of 300 to 400 or higher. While a fuel failure generally results in this ratio dropping to less than 100. Intermediate values would require additional interpretation. In some instances in the industry the inverse ratio is reported so care must be exercised in reviewing the ratio to assure whether the short or long-lived isotope is in the numerator.

   For PWRs, a sustained ratio of Xe-133/Xe-135 greater than 1.0 (TMI) or 2.0 (Byron / Braidwood) is an indicator of a fuel failure (having this ratio without any concurrent iodine indicators is an indication of a low-power peripheral leaker). In addition, for Byron and Braidwood, a Xe-133/Xe-135 ratio between 1.5 and 2 is reason to evaluate other parameters for the possible presence of a defect. Additionally, divergence in the trends of Xe-133/Xe-135 and Kr-88/Xe-133 ratios indicates potential fuel failure.

ATTACHMENT 3
Footnotes and Instructions on Failed Fuel Action Level Criteria
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8. The iodine-131 and/or Xenon-133 activity in a PWR coolant system may be elevated from fuel defects in previous cycles. The I-131 and /or Xenon-133 activity may be recoil corrected to subtract out background activity from previous cycle failures **in a defect free core**. If a failure occurs in the present cycle, caution must be applied when recoil correcting to assure that activity from an "open" defect that develops is not reduced i.e. it is not appropriate to subtract out recoil like activity from an ongoing defect. Do not subtract more activity than existed prior to identification of the current cycle's defect. Adjust the recoil correction by fraction of rated power.

General Comments on Use of Action Level Tables

a) The relationship between fuel defects and the magnitude of fission products released to the coolant is complex, being dependent upon numerous operating parameters and defect characteristics. Therefore, several parameters are provided to assist station and Corporate personnel in determining the appropriate Action Level and resulting response to the defect(s). The final Action Level should correspond to the most reasonable actions for the particular plant conditions assuring conservative reactor operations.

b) On BWRs, the Off-gas Pretreatment Radiation Monitor and/or charcoal vault area radiation monitors can provide an early indication of a significant change in fission product activity and may be the first indication of a fuel defect. On PWRs, the Gross Fuel Failure Monitor may provide an early indication of a fuel defect. The Operations Department or the Reactor Engineers who routinely monitor these instruments should request additional radiochemistry samples to confirm any significant increase in readings.

Note that fission product activity from past fuel failures can result in significantly elevated plant dose rates and impact effluent release rates even if no fuel failure presently exists. Although it may not be appropriate to be in an elevated Action Level all cycle for a core with no fuel failures but elevated activity from past failures, it is appropriate to fully evaluate actions to assure safe radiological and effluent controls.

ATTACHMENT 4
Table of Nuclides Typically Used for Fuel Performance Evaluation
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Nuclide	**Half-life**	**Fission Yield (%)**	
Primary Noble Gas Nuclides		U-235	Pu-239
Xenon-138	14.1 min	6.2	4.9
Krypton-87	76 min	2.5	1.0
Krypton-88	2.8 h	3.5	1.3
Krypton-85m	4.5 h	1.3	0.6
Xenon-135	9.1 h	6.6	7.5
Xenon-133	5.2 d	6.8	7.0
Iodine Nuclides in Coolant Samples			
Iodine-134	52.6 min	7.8	7.3
Iodine-132	2.3 h	4.3	5.4
Iodine-135	6.6 h	6.3	6.4
Iodine-133	20.8 h	6.7	6.9
Iodine-131	8.0 d	2.9	3.9
Other Nuclides			
Cesium-134	2.1 y	0.000045	0.00032
Cesium-137	30.2 y	6.2	6.7
Neptunium-239	2.4 d	N/A	N/A

ATTACHMENT 5
Actions to Minimize the Effects of Long Term Operation with High Fission Product Activity
Page 1 of 1

1. Minimize plant contamination from uranium washout and transuranic isotopes such as Np-239, if possible, by maintaining or increasing hydrogen injection (BWR only for both Noble Metals and Hydrogen Water Chemistry only plants). This may reduce fuel pellet oxidation.

2. Installing temporary shielding in plant auxiliary system areas or other appropriate areas whenever workers are present;

3. Repairing steam or radioactive liquid leaks to minimize airborne conditions and plant contamination;

4. Minimize operation without turbine and reactor building ventilation to reduce airborne conditions within the plant.

5. Providing special instructions to plant operators, health physics personnel, chemists, maintenance and other workers regarding personnel exposure from elevated dose rates and possible airborne, surface contamination or hot particles in the plant;

6. Using portable or permanent iodine filters in the containment to begin removing airborne activity prior to a refueling or maintenance outage (PWRs only);

7. Using containment purge systems not normally used to lower airborne activity prior to a refueling or maintenance outage (PWRs only);

8. Replacing Demineralizer resin (if dose rates are a problem);

9. Reviewing off-gas post-treatment activity and evaluating the need for and amount of induced air added to the off-gas system to ensure off-site releases are minimized. The addition of air may have an adverse impact on radioactive releases. (BWRs only). **(CM-1)**

10. At Oyster Creek, reduce offsite gaseous fission product release through use of the augmented off-gas system.

ATTACHMENT 6
Guidance for Developing Outage Fuel Reliability Recommendations
Page 1 of 4

Determine how to identify and remove defective fuel from the reactor

1. **ASSESS** the confidence that the number and location of defective fuel is known based on the topics listed below.
    - Radiochemistry history/trend analysis. Increases may reveal new leaks or existing leaks degrading. Radiochemistry activity spiking or increases must be reviewed in context with other radiochemistry parameters (for example Xe-133 with I-131 and Sr-92) to determine if new leakers had emerged during the cycle or existing leaker(s) have degraded.
    - The effect of radiochemistry background levels on the ability to detect small leaks. The level of radiochemistry activity uncertainty (error) can be greater than the expected indication of a primary defect. The longer the core operates with a defect, the greater is the risk that a new defect was masked by the existing defect
    - Cs ratio can indicate exposure of a defective bundle and therefore its likely batch and for BWRs, its location when used in conjunction with the power suppression test results.
    - During subsequent reactor maneuvers and as reactor power shape changes over the cycle, radiochemistry data can indicate potential location of defects.
    - Ambiguity of PST results (BWR).
    - PST extent. If less than the whole core was tested, large uncertainty exists (BWR).
    - Validation of defect location by decrease in radiochemistry after suppression (BWR).
    - Validation of PST results by confirmatory radiochemistry indications such as Cs ratio data (BWR).
    - Input from the investigation of the cause of the defect. A chemistry excursion or debris intrusion infers the potential of core-wide vulnerability. Defects that occur after a power maneuver may infer specific control cells.
    - Overall fuel reliability. A global issue such as FME, manufacturing defects in a reload batch or coolant chemistry would adversely affect overall fuel reliability.

ATTACHMENT 6
Guidance for Developing Outage Fuel Reliability Recommendations

2. **DECIDE** on the extent of the core that will be examined.

   - Testing the whole core is expected. Examining the whole core yields the lowest risk of starting the follow-on cycle with a defective bundle and identifies the failed fuel for detailed inspection. In certain circumstances, the number and location of defective fuel assemblies is highly certain and if overall fuel reliability (corrosion, mechanical design) is not a concern, limited sipping may be utilized if thoroughly reviewed and approved through OP-AA-106-101-1006, Operational and Technical Decision Making.
   - For BWRs, situations for which location and number are certain, testing the fuel in the 16 bundle matrix centered on a suppression rod has been successful. In this case, a contingency population of the next row of fuel outside the 16-bundle matrix (36 bundle matrix) may be appropriate. If the defective fuel is not found after testing the 36-bundle matrix or the location of defective fuel is unknown, then other core locations may be prioritized by topics listed in 1.1 above.
   - For PWRs, identification may be prioritized by topics listed in 1.1 above.

3. **SELECT** a method of identifying the defective fuel.
   - The preferred method of identifying defective fuel is in-mast or telescope sipping. This is based on speed and accuracy of the system.
   - Alternate methods should be considered if the in-mast or telescope sipper is not available, there is an interface problem with the facility, the leaker source term is very low, or other relevant experience. Vacuum can sipping, although slow, is generally the most accurate method of identifying a defective fuel assembly.
   - The BWR telescope sipper should be functionally tested on known leakers stored in a Spent Fuel Pool and successfully confirm a leaker.
   - Table I provides a summary of known methods.

4. A visual inspection during the outage is recommended to assess any generic concerns such as FME or corrosion and to assess any obvious mode of failure. **DETERMINE** if the pool-side post irradiation examination of the defective fuel should be within the outage scope using guidance in NF-AA-412, “Inspection of Irradiated Fuel”.

5. **EVALUATE** corrective actions to prevent recurrence such as debris removal, fuel cleaning, reactor water chemistry changes, or component replacement. This should be based on the understanding of the failure mode of the defect.

ATTACHMENT 6
Guidance on Developing Outage Fuel Reliability Recommendations

6. **DETERMINE** if defective fuel will be reconstituted or replaced. Fuel reconstitution is generally favored if the defect is a once burned assembly. However, outage critical path time may dictate discharging an assembly and repairing it prior to the next outage. The decision regarding fuel reconstitution or discharge should address:
   - Availability of replacement fuel rods, skeletons and tie plates or top nozzles as applicable.
   - Fuel warranty cost recovery.
   - Impact on outage critical path.
   - Cost/benefit of inert rods verses replacement fuel rods.
   - Contingency plan with decision criteria if a defective rod cannot be removed from the assembly because of degradation or stuck tie rod.
   - Availability of replacement fuel.
   - Impact of re-introducing older fuel designs. For example, an old clad type may involve penalties in core design to maintain the clad design limits or the design may have reduced debris mitigating features.
   - Impact on the next cycle's energy loading and licensing basis.
   - Asymmetry in the core, or increase the number of assemblies to attain symmetry.
   - Determine source of replacement fuel based on the parameters listed below.
   - Availability of replacement fuel from the scheduled discharge batch, previously discharged batches, reconstituted fuel, or a new, matched reactivity bundle. Re-insertion of failed BWR liner fuel is specifically avoided due to the increased potential for severe secondary degradation.
   - Impact of introducing older fuel designs, e.g. design limits and mechanical compatibility.
   - Impact on the subsequent cycle's energy loading. Determine if the pool-side post irradiation examination of the defective fuel should be within the outage scope using guidance in NF-AA-412, "Inspection of Irradiated Fuel".
   - Impact on the core design or licensing basis.
   - Cost of alternatives.
   - Outage impact.
   - Risk associated with alternatives, e.g. reconstitution may not be possible on a severely degraded rod.

7. **REVIEW** operating experience for all the above items.

8. **DOCUMENT** recommendations in an Engineering Technical Evaluation.

ATTACHMENT 6
Guidance for Developing Outage Fuel Reliability Recommendations
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Table I

Summary of Methods of Identifying Failed Fuel

Method	**Reliability**	**Duration (min/assy)**	**Supplier**	**Comments**
Telescope Sipping (BWR)	High	5 for fuel remaining in place 2 for fuel moves	Westinghouse (ABB)	Used in parallel with fuel shuffles.
In-mast sipping (PWR)	High	2	Westinghouse (ABB), Areva	Used in parallel with fuel shuffles
Vacuum can sipping	High	15-30	Areva, GENE, Westinghouse	Adds fuel move to SFP and back to reactor. Two chambers used in parallel
Vacuum can – single rod sipping	High	720	Westinghouse	Use if UT or EC is indeterminate. Time assumes 60 min/rod. Limited experience.
Hood sipping	Limited domestic experience	3	Areva	Requires securing core cooling, delays onset of core alterations
Ultrasound – whole bundle	Med	180 (BWR) 30-60 (PWR)	Fuel supplier	Ineffective for short duration for high exposure fuel failures.
Eddy Current	High	500 (BWR) 1000 (PWR)	Fuel Supplier	Single rod process while rod is outside of bundle.
Visual Inspection	Low	120	Fuel supplier or in-house	Fraction of rod surface available for inspection.

ATTACHMENT 7
Guidance on Re-insertion of Defective Fuel (CM-2)
Page 1 of 2

NOTE: This attachment complies with a commitment to address SOER 90-2, "Nuclear Fuel Defects" Recommendation 2.A, "Procedures for preventing or responding to indications of fuel defects should include the following: a. guidance on the analysis and review required to technically and operationally justify any re-use of defective fuel each operating cycle."

NOTE: Any re-insertion of a failed fuel assembly can lead to a forced outage in the follow-on cycle should secondary degradation release in unacceptable fission product release. This is particularly true for BWR liner / barrier fuel.

1. In limited circumstances, when a failed fuel assembly cannot be located, it may be necessary to consider the possible re-insertion of a BWR or a PWR defective fuel assembly. This is not routine and should only be done after a thorough evaluation which shall include a review of the following issues, as a minimum:
   - Applicable industry experience
   - Estimated number of failed fuel rods
   - Estimated exposure of the failed fuel rod(s)
   - Probable failure mechanism
   - Type of fuel that has failed
   - A cost-benefit analysis of the reinsertion versus discharge or repair
   - Present cycle radiological impact of the defect, including
     - Plant dose rates
     - Airborne conditions within the plant
     - Gaseous and liquid effluents
     - Personnel access to equipment and areas of the plant
     - Chemistry sampling frequency
     - Dose rates from demineralizer contamination
     - Resin disposal cost
     - Load following impact on fission product release rates from spiking and possible accelerated fuel degradation
     - Fission product spiking from periodic load reductions or shutdowns.

ATTACHMENT 7
Guidance on Re-insertion of Defective Fuel
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2. The evaluation should include an estimate of the next cycle conditions for the following scenarios:
   - Failure to achieve the Corporate goal of defect-free operation.
   - Continued operation at present activity levels.
   - Operation with additional defects.
   - Degradation of existing defects.
   - Plant radiological dose rates and effluents for items 2, 3 and 4 above.
   - Consideration of possible long-term plant contamination from uranium washout and transuranics such as Np-239.
   - Potential for a mid-cycle outage to replace the defective fuel should it degrade necessitating its removal

ATTACHMENT 8
Items for Review if in Action Level 3
Page 1 of 1

If the unit has entered Action Level 3, the fission product activity is of sufficient magnitude to be of concern for elevated plant dose rates and elevated effluent levels that may jeopardize continued unit operation. This requires a multi-disciplined review (PORC) of the situation to determine if continued reactor operation is acceptable, and if so, under what circumstances. Items for consideration by PORC are as follows:

CONSIDER:

1. Gross magnitude of coolant or offgas fission product activity
2. The rate of change of fission product activity levels and projected future activity levels
3. The estimated number of failed fuel rods
4. The probable failure mechanism and whether or not additional failures can be expected
5. The impact of the fission product activity level on in-plant radiological conditions and what impact this will have on plant operations and maintenance
6. The impact of the fission product activity level on both liquid and gaseous effluents
7. Reducing plant power changes or the rate of changes to minimize spiking and the added potential for secondary degradation
8. A reduction in power to reduce fission product activity levels
9. Long term plant contamination and source term impact

DETERMINE if continued reactor operation is justified and if so, what actions may be needed to minimize the impact of the fuel failure(s). Update the radiological action plan developed in Action Level 2 to address the higher fission product activity level in Action Level 3. See Attachment 5 for guidance.