14.18 FUEL HANDLING INCIDENT

14.18.1 GENERAL

The likelihood of a fuel handling incident is minimized by administrative controls and physical limitations imposed on fuel handling operations. All refueling operations are conducted in accordance with prescribed procedures under direct surveillance of a qualified supervisor. Before any refueling operations begin, verification of complete CEA insertion is obtained by tripping all CEAs to obtain indication that the CEAs are fully in. Boron concentration in the coolant is raised to the refueling boron concentration where the core would be at least 5% subcritical and is verified by chemical analysis.

After the vessel head is removed, the CEA drive shafts are removed from their respective assemblies. A load cell is used to indicate that the drive shaft is free of the CEA as the lifting force is applied.

The maximum elevation to which the fuel assemblies can be raised is limited by the design of the fuel handling hoists and manipulators to assure that the minimum depth of water above the top of a fuel assembly required for shielding is always present (Chapter 9). This constraint applies in fuel handling areas inside containment and in the spent fuel pool area. Supplementing the physical limits on fuel withdrawal, radiation monitors located at the fuel handling areas would provide both audible and visual warning of high radiation levels in the event of a low water level in the refueling cavity and fuel pool. Fuel pool structural integrity is assured by designing the pool and the spent fuel storage racks as Category I structures.

The design of the spent fuel storage racks and handling facilities in both the containment and fuel storage area is such that fuel will always be in a subcritical geometrical array, assuming zero boron concentration in the fuel pool water. The spent fuel pool and refueling pool water are normally at refueling boron concentration. Natural convection of the surrounding water provides adequate cooling of fuel during handling and storage. Adequate cooling of the water is provided by forced circulation in the spent fuel pool cooling system.

Fuel failure during refueling as a result of inadvertent criticality or overheating is not possible. The possibility of damage to a fuel assembly as a consequence of mishandling is minimized by thorough training, detailed procedures, and equipment design. The single-failure-proof design of the Spent Fuel Cask Handling Crane prevents the drop of heavy objects such as shipping/transfer casks on the spent fuel storage racks. Inadvertent disengagement of a fuel assembly from the fuel handling machine is prevented by mechanical interlocks; consequently, the possibility of dropping and damaging of a fuel assembly is remote.

Should a fuel assembly be dropped or otherwise damaged during handling, radioactive release could occur in either the containment or the Auxiliary Building. The air in both of these areas is monitored. The radiation monitors immediately indicate the increased activity level and alarm. The affected area would then be evacuated.

The effects of a Fuel Handling Accident on Control Room habitability are discussed in Section 9.8.2.3, Auxiliary Building Ventilating Systems.

Release of activity through the containment purge system would be prevented by automatic closure of the containment isolation dampers, as described in Chapter 9. With the exception of the personnel airlock doors, the equipment hatch opening, and penetration flow paths providing direct access from the containment atmosphere to the environment unisolated but under administrative controls, automatic containment closure capability is required during movement of irradiated fuel within the containment building.

Both doors of the containment personnel air lock (which leads to the interior of the Auxiliary Building) may be open during fuel movement if at least one door is operable and capable of being closed by a designated individual stationed immediately outside of the airlock. A temporary hatch cover plate may be used in place of an emergency personnel escape door. The equipment hatch opening may be open during fuel movement if the containment outage door is operable and capable of being closed within 30 minutes by a designated individual stationed near the door. Closing the containment outage door includes removal of any grating or truck ramps that are in the opening, with the use of a forklift, followed by door closure. Penetration flow paths providing direct access from the containment atmosphere to the environment may be unisolated under administrative controls. These controls minimize the potential for release of activity to the environment during the time it takes to evacuate the containment structure.

The spent fuel pool ventilation system draws air across the spent fuel pool area; this air is discharged to the atmosphere through the plant vent. If the cask loading hatch and all exterior hatches to the 69' level of the Auxiliary Building are closed, this is the only route for the release of activity from the spent fuel pool area to the environment.

Failed fuel rods that have released their active gas gap inventory can be stored in encapsulated fuel tubes. These encapsulated fuel tubes can be stored in the peripheral guide tubes of empty grid cages in the spent fuel pool. A single encapsulation tube containing a damaged fuel rod can be stored in an incore instrumentation (ICI) trash can, can be stored in an empty spent fuel pool (SFP) rack space that is inaccessible to both the spent fuel handling machine and the Auxiliary Building cask handling crane, can be laid temporarily atop the spent fuel pool storage racks with administrative restrictions on fuel movement in the laydown area, or can be placed at the bottom of an upender trench with the associated upender tagged out. Fuel failure resulting from inadvertent criticality is administratively precluded, as described in Section 9.7.2.10. Storage of the encapsulation tubes in the peripheral guide tubes of empty grid cages, in an ICI trash can or empty SFP rack space, will cause a decrease in maximum SFP reactivity due to a decrease in fissile inventory and will not create inadvertent criticality. An encapsulated fuel rod placed temporarily atop the spent fuel pool storage racks or at the bottom of the upender trench will be decoupled in reactivity space from the assemblies stored within the rack.

Undamaged fuel rods can only be stored in the encapsulation tubes in empty grid cages. This will guarantee that the consequences of a fuel handling incident will not be increased. Only damaged fuel rods with no gas gap activity can be stored in encapsulation tubes, in ICI trash cans or empty SFP rack space, temporarily atop the spent fuel pool storage racks, or at the bottom of an upender trench, thus precluding any fission gas release.

14.18.2 METHOD OF ANALYSIS

The analysis assumes that a fuel assembly is dropped during fuel handling in the Containment. Interlocks and procedural and administrative controls make such an event highly unlikely; however, if an assembly were damaged to the extent that one or more fuel rods were broken, the accumulated fission gases and iodines in the fuel element gap would be released to the surrounding water. Release of the solid fission products in the fuel would be negligible because of the low fuel temperature during refueling, which greatly limits their diffusion.

In the spent fuel pool the fuel assemblies are stored within the racks at the bottom of the spent fuel pool. The top of the rack extends above the tops of the stored fuel assemblies. A dropped fuel assembly could not strike more than one fuel assembly in the storage rack. Impact could occur only between the ends of the involved fuel assemblies, the bottom end fitting of the dropped fuel assembly impacting against the top end fitting of the stored fuel assembly. The results of an analysis of the end on energy absorption capability of a fuel assembly indicate that a fuel assembly is capable of absorbing the kinetic energy of the drop with no fuel rod failures.

Reconstitution or inspection of a fuel assembly can take place in individual SFP storage racks with spent fuel assemblies placed on rack spacers and with their upper end fittings removed. In such a configuration, the structural integrity of the fuel assemblies is reduced, and the fuel rods may protrude above the SFP racks. Since fuel damage could occur if a heavy object is dropped on top of an assembly seated on a rack spacer with its upper end fitting or template removed, administrative controls will restrict movement of loads over the affected assemblies on rack spacers plus one storage rack cell on each side of the affected assemblies. Heavy loads may only be moved in this area via the single-failure-proof crane, if assemblies are seated on rack spacers with their upper end fittings or templates removed. Only the single-failure-proof crane or single-failure-proof rigging will be used over the reconstitution area in the SFP for loads other than tools. A knowledgeable and briefed person will be present for the entire time that the upper end fitting or template is removed from an assembly to restrict movement of loads other than tools in this area of the SFP. In addition, after the upper end fittings or templates have been removed, the spent fuel handling machine will be administratively prohibited from nearing the affected assemblies on rack spacers plus one storage rack cell on each side of the affected assemblies.

The analyses for a fuel handling incident in the refueling pool and the spent fuel pool both assume that gas gap activity from 176 fuel rods is released. Because of the high energy absorption required to rupture a fuel rod, this number represents the maximum number of damaged pins expected from any credible fuel handling incident scenario. Undamaged fuel rods can only be stored in the encapsulation tubes in empty grid cages. As with encapsulated failed rods, there can only be four in a grid cage. Only damaged fuel rods with no gas gap activity can be stored in encapsulation tubes, in ICI trash cans or empty SFP rack space, temporarily atop the spent fuel pool storage racks, or at the bottom of an upender trench, thus precluding any fission gas release.

The Fuel Handling Incident (FHI) analysis assumes a total iodine decontamination factor of 200 based on a minimum water depth of 23’ per Reference 13. In the refueling pool this assumption is preserved by the Technical Specification requirement of 23’ of water above fuel assemblies seated in the reactor core. In the SFP, the Technical Specifications only require 21.5’ of water above fuel assemblies seated in the SFP storage racks. This Technical Specification was deemed sufficient to preserve the required 23’ of water because a FHI was assumed to occur as a fuel assembly strikes the bottom of the SFP. When assemblies are placed on rack spacers and their upper end fittings are removed, a FHI from a dropped heavy object would require a lower decontamination factor based on reduced water coverage. A revised decontamination factor of 120 for a FHI during reconstitution/inspection with 20.4’ of water between the top of the pin and the surface of the water was computed for a 20.5” rack spacer. Note that this is very conservative, since normal level control will result in at least 21.5’ of water above exposed fuel pins. An FHI with 55 days of decay time post-shutdown and no Spent Fuel Pool Exhaust Ventilation System (SFPEVS) credit is less severe radiologically than an FHI with 72 hours of decay time post-shutdown, a reconstitution decontamination factor of 120, and SFPEVS credit. Thus after 55 days of decay, the SFPEVS operability requirements and the requirement of negative pressure in the SFP area are no longer necessary during irradiated fuel movement or reconstitution in the Auxiliary Building.

Fission product activity in the fuel rod gap has been determined for the highest power fuel assembly in the core for the design basis accident. The rod gap activity is computed as a function of total core inventory for the following isotopes: 20% of Kr-85, 10% of all other noble gases, 16% of I-131, and 10% of all other iodines. These gas gap activities have been validated for assembly average burnup of up to 62,000 MWD/MTU. Such a value bounds Calvert Cliffs current peak pin burnup limit of 62,000 MWD/MTU. Total core inventory is calculated using the methodology described in References 13 and 14. Fuel assemblies will not be removed from the core within 72 hours after shutdown. Therefore, many of the short lived isotopes will have decayed significantly.

14.18.3 RESULTS

14.18.3.1 Fuel Handling Incident in Containment

Table 14.18-1 shows the activity that would be released from the failure of all 176 fuel rods. In the highest power fuel assembly, the activities tabulated are those released to the water in the fuel pool, and those released to the containment atmosphere.

Because iodine is readily absorbed by water and the fuel being handled is under water, much of the iodine released from the damaged rods would be retained in the refueling pool water. To account for this preferential retention of iodine by the pool water, a decontamination factor of 200 is assumed, which corresponds to the value suggested in Reference 13. No additional credit is taken for plate-out of iodines on surfaces within the containment.

The 0-2 hour dose at the exclusion boundary was calculated based on the following assumptions:

a. Gap activity releases from the damaged fuel rods to the refueling pool water and to the containment air are listed in Table 14.18-1.
b. An overall refueling pool iodine decontamination factor of 200 is assumed. This is based upon a decontamination factor of 285 for inorganic iodine and 1 for organic iodine. The iodine in the fuel rod gas gap is composed of 99.85% inorganic species and 0.15% organic species. After applying the appropriate decontamination factors for each species, the refueling pool is 70% inorganic species and 30% organic species. No credit is taken for noble gas retention by the pool water.
c. The site boundary atmospheric dispersion factor is $1.44x10^{-4}$ sec/m^3 (Chapter 2).
d. A breathing rate of $3.5x10^{-4}$ m^3/sec is assumed.
e. The gap activity from the damaged fuel rods is released to the environment over a two hour time period.
f. Because both doors of the containment personnel air lock, unisolated but administratively controlled penetration flow paths from the containment atmosphere to the environment, and the containment outage door may be open during the early stages of a fuel handling incident, all activity released from the containment is assumed to be unfiltered.
g. Doses were computed using the dose conversion factors and methodology described in References 15 and 16.

The results are tabulated in Table 14.18-2.

14.18.3.2 Fuel Handling Incident in the Spent Fuel Pool Area

If a fuel handling incident were to occur while handling fuel in the spent fuel pool area, the following assumptions would apply:

a. The activity release to the spent fuel pool water is identical to that assumed in the case of a fuel handling incident in containment. The overall spent fuel pool decontamination factor for iodine is 120. This is based upon a water level of at least 20.4' covering a ruptured fuel assembly. This activity is tabulated in Table 14.18-1.

The overall SFP decontamination factor for iodine is 120 for a FHI during reconstitution with 20.4' of water between the tops of the pins and the surface of the water.

b. The same breathing rates and atmospheric dispersion factor assumptions apply for the spent fuel pool as for the refueling pool case.

c. The iodine in the fuel rod gas gap is composed of 99.85% inorganic species and 0.15% organic species. After applying the appropriate decontamination factors for each species (146 for inorganic and 1 for organic), the iodine in the air above the spent fuel pool is 82% inorganic species and 18% organic.

d. For a FHI in the SFP, all of the activity released to the air above the spent fuel pool is assumed to be discharged to the outside atmosphere through the SFPEVS. An FHI with 55 days of decay time post-shutdown and no SFPEVS credit is less severe radiologically than an FHI with 72 hours of decay time post-shutdown, a reconstitution decontamination factor of 120, and SFPEVS credit. Thus after 55 days of decay, the SFPEVS operability requirements and the requirement of negative pressure in the SFP area are no longer necessary during irradiated fuel movement or reconstitution in the Auxiliary Building.

The results are tabulated in Table 14.18-2.

14.18.4 CONCLUSION

The 0-2 hour exclusion boundary doses resulting from a fuel handling incident are within the guidelines of 10 CFR 50.67. This is true even if all the rods of the highest power fuel assembly fail when the fuel assembly is dropped into the refueling pool or when a fuel assembly is damaged on a rack spacer during reconstitution or inspection with its upper end fitting removed in the SFP.

This event includes the transition to Advanced CE-14 HTP™ fuel (with Gd_2O_3 burnable poison irradiated to a maximum burnup of 62 GWd/MTU).

14.18.5 REFERENCES

1. Deleted
2. Deleted
3. Deleted
4. Deleted
5. Deleted
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7. Deleted
8. Deleted
9. Deleted
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12. Deleted

13. Regulatory Guide 1.183, “Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors,” July 2000

14. Letter from D. V. Pickett (NRC) to J. A. Spina (CCNPP), “Calvert Cliffs Nuclear Power Plant, Unit Nos. 1 and 2 - Amendment Re: Implementation of Alternative Radiological Source Term (TAC Nos. MC8845 and MC8846),” dated August 29, 2007

15. Federal Guidance Report (FGR) 11, “Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion,” September 1988

16. Federal Guidance Report (FGR) 12, “External Exposure to Radionuclides in Air, Water, and Soil,” September 1993

TABLE 14.18-1

SOURCE TERM FOR FUEL HANDLING ACCIDENT IN CONTAINMENT OR SPENT FUEL POOL BASED UPON ALTERNATIVE SOURCE TERM METHODOLOGY

Isotope	Decay Constant (1/sec)	Ci/MWt	Ci Released to Water	Ci Released to Cntmt Air	Ci Released to SFP Air
Kr-85	2.049E-09	3.718E+02	1.603E+03	1.603E+03	1.603E+03
Kr-85m	4.298E-05	7.968E+03	2.496E-01	2.496E-01	2.496E-01
Kr-87	1.514E-04	1.621E+04	3.161E-13	3.161E-13	3.161E-13
Kr-88	6.780E-05	2.266E+04	1.141E-03	1.141E-03	1.141E-03
I-131	9.978E-07	2.756E+04	7.346E+04	3.673E+02	6.122E+02
I-132	8.371E-05	3.946E+04	3.211E-05	1.605E-07	2.676E-07
I-133	9.257E-06	5.572E+04	1.091E+04	5.456E+01	9.093E+01
I-134	2.196E-04	6.286E+04	2.564E-20	1.282E-22	2.137E-22
I-135	2.913E-05	5.296E+04	6.011E+01	3.005E-01	5.009E-01
Xe-133	1.530E-06	5.571E+04	8.085E+04	8.085E+04	8.085E+04
Xe-135	2.118E-05	1.771E+04	1.577E+02	1.577E+02	1.577E+02
Xe-133m	3.663E-06	1.735E+03	1.449E+03	1.449E+03	1.449E+03
Xe-135m	7.551E-04	1.164E+04	2.530E-81	2.530E-81	2.530E-81
Xe138	8.193E-04	4.933E+04	6.261E-88	6.261E-88	6.261E-88

TABLE 14.18-2

OFFSITE AND CONTROL ROOM DOSES FOR A FUEL HANDLING ACCIDENT IN CONTAINMENT OR SPENT FUEL POOL BASED UPON ALTERNATIVE SOURCE TERM METHODOLOGY

	TEDE Dose (Rems)		
	FHI in Containment	**FHI in SFP**	**Regulatory Limit**
Exclusion Area Boundary	0.6958	1.1136	6.3
Low Population Zone	0.1638	0.2622	6.3
Control Room	2.3314	3.8538	5.0