OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
CALCULATION COVER SHEET

1. QA: QA

2. Calculation Title
Waste Package Misload Probability

3. Document Identifier (including Revision Number)
CAL-WHS-MD-000001 REV 00

4. Total Attachments
1

5. Attachment Numbers - Number of pages in each
I-17

	Print Name	Signature	Date
6. Originator	James K. Knudsen	James K Knudsen	11/16/01
7. Checker	Pierre Macheret	P. Machet	11/19/01
8. Lead	Douglas Brownson	Douglas Brownson	11/20/01

9. Remarks

Revision History

10. Revision No	11. Description of Revision
00	Initial Issue

NMSS07
WM-11

CONTENTS

Page

FIGURES

Page

TABLES

Page

1. PURPOSE

The objective of this calculation is to calculate the probability of occurrence for fuel assembly (FA) misloads (i.e., FA placed in the wrong location) and FA damage during FA movements. The scope of this calculation is provided by the information obtained from the Framatome ANP 2001a report. The first step in this calculation is to categorize each fuel-handling event that occurred at nuclear power plants. The different categories are based on FAs being damaged or misloaded. The next step is to determine the total number of FAs involved in the event. Using the information, a probability of occurrence will be calculated for FA misload and FA damage events. This calculation is an expansion of preliminary work performed by Framatome ANP 2001a.

This calculation is associated with engineering activity and has been developed in accordance with technical work plan, *Technical Work Plan for: Waste Package Design Description for LA* (BSC 2001). The development of this calculation has been performed in accordance with AP-3.12Q, Revision 0, ICN 4, *Calculations*.

2. METHOD

This calculation follows the steps outlined below.

1. Review all licensee event reports (LERs) and other published reference media (e.g., Institute of Nuclear Power Operations (INPO) library database) that pertains to fuel-handling events as documented in Framatome ANP 2001a (Attachment 1). The Framatome ANP 2001a report contains proprietary information; therefore, a summary report (Framatome ANP 2001b) was produced to remove the proprietary information. The events listed in Attachment I of this calculation will be correlated to the events listed in the summary report (Framatome ANP 2001b, Attachment 1).

2. Create an event tree in order to define each fuel-handling category. The fuel-handling categories are specifically noted as end states on the event tree.

3. Categorize each fuel-handling event based upon the specific sequence through the event tree.

4. Obtain the number of FAs involved in each fuel-handling event.

5. Calculate a probability of occurrence for each fuel-handling category and specific groups of fuel-handling categories.

6. Calculate a probability of occurrence for the FA damage events and FA misload events.

3. ASSUMPTIONS

3.1 The total number of FA movements for the study period of 1985 to 1999 is assumed to be 1,198,723. The total number of fuel movements was obtained from the Framatome ANP

2001b report (Attachment 2 [pp. 14-18]). For this calculation, the total number of FA movements will be rounded to 1,199,000. During this study period, the report made some simplifying assumptions to estimate the total number of FA movements for each operating cycle at all nuclear power plants. The report assumed each operating cycle consists of three batches where each batch makes up one third of the reactor core. The simplifying assumptions were necessary since the exact number of FAs for each batch loaded in each operating cycle is unknown. The rationale for this assumption is consistent with industry practices. This assumption is used in Section 6.

The total number of FA movements used in this calculation are associated to reactor core reloads, offloads, and shuffles. FA movements associated with dry cask storage, spent fuel shuffle, and spent fuel re-rack are not included in the total number of FA movements. Therefore, the total number of FA movements used in this calculation is conservative for the estimation of probability of occurrence of fuel-handling events.

3.2 For Event 13 discussed in Attachment I, this reactor core contains 193 FAs. During the event 1/3 of the reactor core was to be replaced with new fuel. It is assumed that the total number of FAs involved in this event is 64. The rationale for using 64 FAs is consistent with the information obtained from the event.

3.3 It is assumed for this calculation that pressurized water reactor (PWR) FAs contain 200 fuel rods (Painter et al. 1994, Table B.1). This assumption is based on a 15 x 15 PWR FA array that contains 225 fuel rods minus approximately 20 fuel rods used for instrumentation. The other manufactured PWR FA arrays are 14 x 14, 16 x 16 and 17 x 17. Each of these arrays contains approximately 164 fuel rods, 224 fuel rods and 264 fuel rods, respectively. The rationale for using 200 fuel rods per FA is consistent with Westinghouse designed nuclear power plants that use 15 x 15 FA array. This assumption is used for Events 28 and 75 in Attachment I to determine the number of FAs involved in the event.

3.4 For Event 77 discussed in Attachment I, this reactor core contains 217 FAs. During the event, 1/3 of the reactor core is going to be replaced with new fuel during the next refueling outage. It is assumed that the total number of FAs involved in this event is 72. The rationale for using 72 FAs is consistent with the information obtained from the event.

4. USE OF COMPUTER SOFTWARE AND MODELS

4.1 SOFTWARE

The Systems Analysis Programs for Hands-on Integrated Reliability Evaluations (SAPHIRE) V6.69 (Software Tracking Number (STN): 10325-6.69-00) was used to construct the misload event tree used to categorize the plant fuel-handling events. The STN was obtained from Software Configuration Management in accordance with appropriate procedures. The software was installed and ran on a Dell Optiplex PC, tag number 111855, with Windows NT version 4. The software was qualified in accordance with AP-SI.1Q. The software is appropriate to the application for this calculation, and it is used within its range as described in the qualification documentation.

4.2 MODELS

No models were used for this calculation.

5. CALCULATION

This section discusses how the fuel-handling events are categorized for evaluation. An event tree has been created and is used for the categorizing process. To illustrate how the fuel-handling events are categorized, an example fuel-handling event will be used. After all of the fuel-handling events are categorized, a probability of occurrence for each category will be calculated.

5.1 EVENT TREE

The event tree shown in Figure 1 is used to categorize the fuel-handling events. The event tree first separates the fuel-handling events into 1) "Misload Events," 2) "Fuel Damage Events," or 3) "No Fuel Damage Events." The event tree then determines what caused the event to occur. There are four causes listed on the event tree. The causes are 1) "Human Error," 2) "Procedure Error," 3) "Equipment Failure," or 4) "Fabrication/Indeterminate Error." Lastly, the event tree addresses whether the event is a violation in plant technical specifications. The top events and their definition are discussed below.

MISLOAD — Was the assembly misplaced? This top event determines if the fuel-handling event was a misload. A misload is defined as an FA being placed in a location other than expected or required.

DAMAGE — Was the assembly damaged? This top event determines if the fuel-handling event caused damage to the FA. This top event is not queried if the event is determined to be a misload (i.e., MISLOAD = YES).

DROP — Was the assembly raised or moved? This top event determines if the FA was raised or moved during the fuel-handling event. This top event is not queried if the event is determined to be a misload (i.e., MISLOAD = YES).

OE — Was there personnel error? This top event determines if the fuel-handling event was caused by personnel error. Personnel error is viewed as deviations from work procedures, miscommunication among personnel, maintenance errors that lead to fuel damage, misload, etc.

EF — Was there an equipment failure or equipment design error? This top event determines if some type of equipment failure or improper equipment design caused the fuel-handling event.

PE — Was there an error in the procedure or procedure deficiencies? This top event determines if errors or deficiencies in the procedures caused the fuel-handling event. Procedure errors or procedure deficiencies for this top event are assumed to be incorrect, incomplete, or missing information about steps required to perform the fuel movement correctly. An example would be no visualization step prior to raising an FA.

FE-OTHER Was there an assembly fabrication error or indeterminate cause? This top event determines if the fuel-handling event was caused by fuel fabrication errors [i.e., incorrect weight percent (wt%) enrichment of Uranium-235 (U-235)] or indeterminate cause. An indeterminate cause event is assumed to be an event that no conclusion could be determined as to the cause of the event.

TSV Was there a technical specification violation? This top determines if any plant technical specifications were violated due to the fuel-handling event.

Using the top events listed above, the event tree shown in Figure 1 was created in SAPHIRE V6.69 (STN: 10325-6.69-00). SAPHIRE V6.69 is a state-of-the-art computer code for performing probabilistic risk analysis (PRA) evaluations. The top events of the event tree are queried from left to right. The branching below the top events are used to determine the specific path through the event tree. The branching under each top event follows standard event tree convention that requires "success" or "YES" answers to branch up and "failure" or "NO" answers to branch down. After correctly defining the branching under each top event, a total of seventeen fuel-handling end state categories were identified. The various end state categories are listed below along with a brief description as to the type of fuel-handling event they represent.

A – FA misload caused by human error resulting in a technical specification violation

B – FA misload caused by human error but no technical specification violation

C – FA misload caused by procedure error resulting in a technical specification violation

D – FA misload caused by procedure error but no technical specification violation

E – FA misload caused by fabrication/indeterminate error resulting in a technical specification violation

F – FA damage caused by human error

G – FA damage caused by equipment failure or equipment design

H – FA damage caused by fuel-handling procedure error or deficiency

I – No FA movement, but the FA was damaged due to human error

J – No FA movement, but the FA was damaged due to procedure error or deficiency

K – No FA movement, but the FA was damaged due to fuel fabrication/indeterminate error

L – No FA damage, but human error during an FA movement caused a technical specification violation

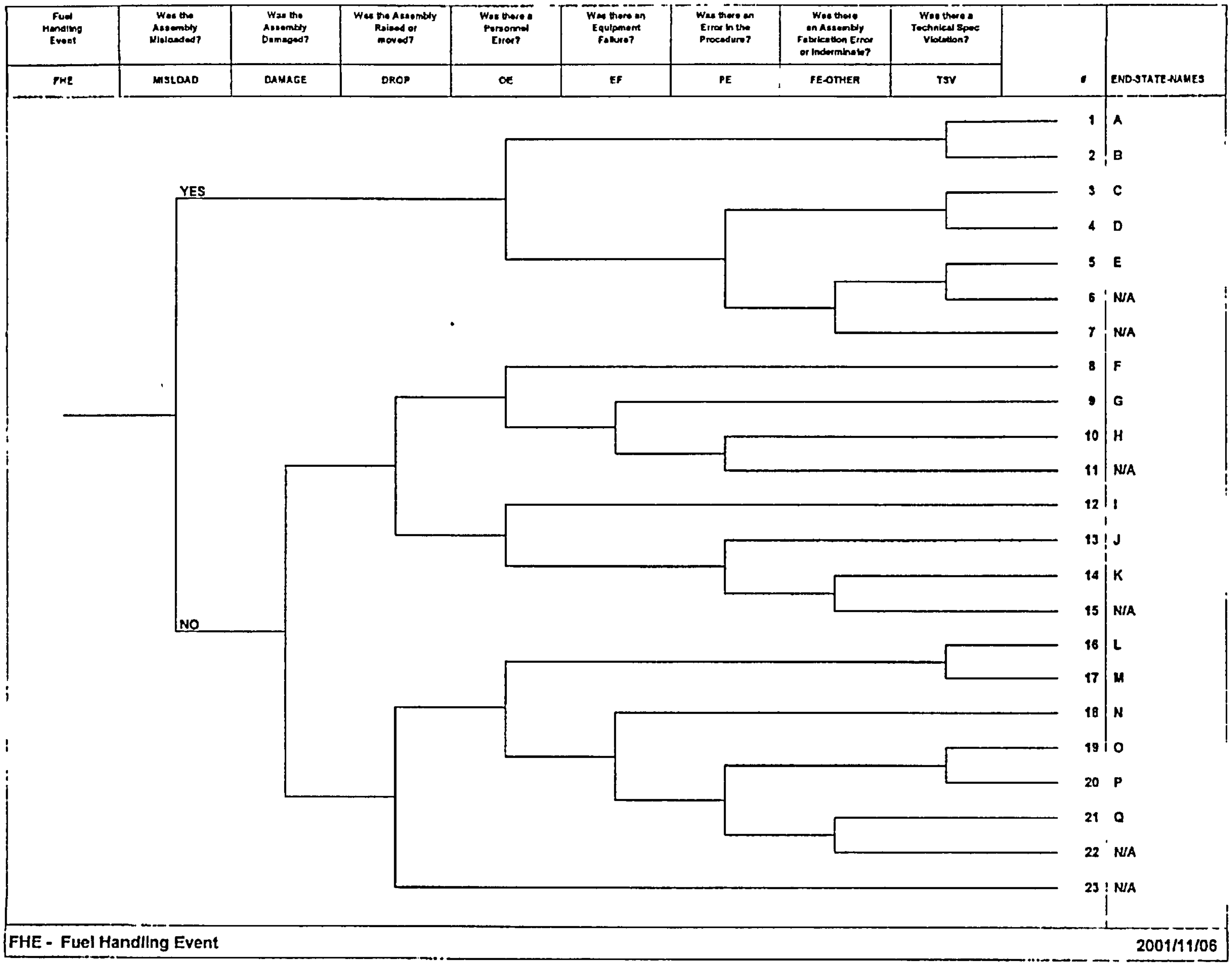

Figure 1. Fuel-Handling Event Tree

M – No FA damage, but human error occurred during an FA movement, though not leading to technical specification violation

N – No FA damage, but equipment failure or design during an FA movement caused the event

O – No FA damage, but fuel-handling procedure error or deficiency during an FA movement caused a technical specification violation

P – No FA damage, but fuel-handling procedure error or deficiency during an FA movement resulted in the event, though no technical specification violation occurred

Q – No FA damage, but fuel fabrication or indeterminate error during an FA movement caused the event

5.2 CATEGORIZING FUEL-HANDLING EVENTS

The Framatome ANP 2001a report used a study period from 1985 to 1999 to identify the fuel-handling events. The reason for this study period is because of inconsistent reporting prior to 1985 and most of the post-Three Mile Island (TMI) rules and regulations had been implemented by operating nuclear power plants. The ending year of 1999 was chosen because this was the most recent complete year of fuel-handling events available when the Framatome ANP 2001a study was completed.

To categorize the events identified in Framatome ANP 2001a (Attachment 1), they will be evaluated using the event tree shown in Figure 1. Each event will be binned into one of the seventeen categories. To illustrate this process, the following fuel-handling event (Event 19 from Attachment I) will be used as an example. A brief description of the fuel-handling event and the process of stepping through the event tree in order to categorize the event will be provided.

The event involves an FA being placed in the wrong location of the spent fuel pool (SFP). Plant technical specifications prohibit FAs with a wt% of U-235 greater than 3.5 be stored in the "A" location of the SFP. Contrary to the technical specifications, an FA with a wt% greater than 3.5 was stored in the "A" location of the SFP. The FA had an enrichment of 3.85 wt% of U-235. The FA was placed in the "A" location because the Fuel/Control moving sheet incorrectly specified this location. SFP location M42 was specified instead of the correct location of M43. The cause of the event was cognitive personnel error for incorrectly specifying the SFP location.

Given the information about the fuel-handling event and the top event definitions provided in Section 5.1, the event tree will be used to categorize this event. The first top event questions whether the event was a MISLOAD. The answer to this top event is "YES." The FA was placed in the wrong location of the SFP. The next top event that is questioned along this path is OE. This top event questions whether the event was caused by human error. Based on the information, plant personnel specified the wrong SFP location. Therefore, the answer to this top event is "YES." The next and last top event to be questioned on this branch path is TSV. This top event questions if a plant technical specification was violated. The answer to this top event is "YES." This specific branch path leads to the end state A. This event is categorized into end state A which is defined in Section 5.1 as an FA misload event caused by human error that violated plant technical specifications.

There are a total of 89 reported fuel-handling events for the study period of 1985-1999. All of the events will be evaluated in the same manner as discussed above. Some of the reported fuel-handling events contained multiple events. Therefore, a total of 91 events need to be evaluated. Each of the 91 events will be binned into one of seventeen fuel-handling categories by tracing the event through the event tree. Table I-1 of Attachment I lists all of the fuel-handling events. The table provides a brief description of the event; a cross-reference to Framatome ANP 2001b, Attachment 1; the answer to each top event queried; and the resultant categorization. The table also lists the number of FAs that are affected in the event. Some of the reported fuel-handling events did not specifically state how many FAs are affected. Therefore, some assumptions are made in order to determine this number. These assumptions are discussed in Section 3.

The total number of FAs for each fuel-handling category listed in Table I-1 will be used to calculate the probability of occurrence for each category. However, some of the fuel-handling events listed in Table I-1 are not representative of operations that will be performed at a monitored geological repository (MGR). These types of fuel-handling events will not be considered in this calculation. Some examples of fuel-handling events not considered are FA damage due to debris in the reactor coolant, FA damage due to water chemistry, and FA orientation (i.e., rotated 90 degrees). These events are noted in Table I-1 of Attachment I as not considered for this calculation. The reason for discarding these events is due to how the FAs will be handled and stored at the MGR. The FAs loaded into the waste packages will not be cooled using forced coolant and therefore, not susceptible to this type of damage. The FA orientation has no impact on the loaded waste packages; therefore, these events are also removed from the calculation.

The probability of occurrence for each fuel-handling category will use only the estimated number of FAs that are representative of MGR operations. Table 1 provides a list of each fuel-handling category and the total number of FAs affected by an event representative of MGR operations.

Table 1. Number of Fuel Assemblies Affected in Each Fuel-Handling Category

Fuel-handling Category	Estimated Number of FAs used in Calculation
A	205
B	20
C	11
D	0
E	91
F	22
G	23
H	3
I	9
J	0
K	0
L	3,131
M	6
N	2
O	4
P	1
Q	3

6. RESULTS

The probability of occurrence is calculated for the seventeen unique fuel-handling categories. To calculate these probabilities, the total number of FA movements is divided into the total number of FAs involved in each category. No uncertainty parameters or probability distributions will be determined at this time. The estimated number of FA movements used for this calculation is 1,199,000 (see Assumption 3.1). This estimated number of moved FAs is based on the study period of 1985-1999 (Framatome ANP 2001b, Attachment 2 pp. 14-18). Table 1 provides a list of the total number of FAs involved in each fuel-handling category.

The probability of occurrence for each fuel-handling category is calculated using only the number of FAs representative of MGR operations. This total is listed in Table 1. Table 2 lists the total number of FAs affected for each fuel-handling category and their probability of occurrence. This probability of occurrence is calculated only for reference purposes. The objective of this calculation, however, is to obtain the probability of occurrence for FA misload events and FA damage events.

Table 2. Probability of Occurrence for Each Fuel-Handling Category

Fuel-handling Category	Number of FAs Affected	Probability of Occurrence
A	205	1.7×10^{-4}
B	20	1.7×10^{-5}
C	11	9.2×10^{-6}
D	0	0.0
E	91	7.6×10^{-5}
F	22	1.8×10^{-5}
G	23	1.9×10^{-5}
H	3	2.5×10^{-6}
I	9	7.5×10^{-6}
J	0	0.0
K	0	0 0
L	3,131	2.6×10^{-3}
M	6	$5\ 0 \times 10^{-6}$
N	2	1.7×10^{-6}
O	4	3.3×10^{-6}
P	1	8.3×10^{-7}
Q	3	2.5×10^{-6}

Now that the fuel-handling events are categorized, the probability of occurrence for the FA misload and FA damage events can be calculated. To calculate the probability of occurrence for the FA misload and FA damage events, the fuel-handling event categories will be collated into three different FA misload groups and four different FA damage groups. The different FA misload groups and FA damage groups are based on what caused the event. The three different causes identified for FA misload events are human errors, procedure errors, or fuel fabrication/indeterminate errors. The four different causes identified for FA damage events are human errors, procedure errors, equipment failures, or fuel fabrication/indeterminate errors.

The probability of occurrence for the three FA misload groups is calculated by summing up the number of FAs affected in each group and dividing it by the total number of FA movements (Framatome ANP 2001b, Attachment 2). The number of FAs affected in each group is obtained from grouping similar end states together. The following end states are gathered together in order to make up the three different FA misload groups. End states A and B are gathered together to represent FA misload events due to human error. FA misload events due to procedure errors gathered end states C and D together. Lastly, FA misload events due to fabrication/indeterminate errors is represented by end state E. Table 3 lists the three different FA misload groups along with the collated end states that make up the FA misload groups. The probability of occurrence and the total number of FAs affected in each FA misload group is also listed in Table 3.

Table 3. Probability of Occurrence for Specific FA Misload Events

FA Misload Group	End States	Number of FAs Affected	Probability of Occurrence
FA Misload due to human error	A & B	225	$1.9x10^{-4}$
FA Misload due to procedure errors	C & D	11	$9.2x10^{-6}$
FA Misload due to fabrication/indeterminate errors	E	91	$7.6x10^{-5}$

The probability of occurrence for the four different FA damage groups is obtained by grouping similar end states together as discussed above. The following end states are gathered together in order to make up the four different FA damage groups. FA damage due to human error gathered end states F and I together. End state G represents FA damage due to equipment failure and end state K represents FA damage due to fabrication/indeterminate errors. The last FA damage group, fuel damage due to procedure errors, gathers end states H and J together. The results of these groupings are listed in Table 4. Table 4 lists the FA damage groups, end states grouped together, number of FAs affected in each group, and the probability of occurrence for each group.

Table 4. Probability of Occurrence for Specific FA Damage Events

FA Damage Group	End States	Number of FAs Affected	Probability of Occurrence
Fuel damage due to human error	F & I	31	$2.6x10^{-5}$
Fuel damage due to procedure errors	H & J	3	$2.5x10^{-6}$
Fuel damage due to equipment failure	G	23	$1.9x10^{-5}$
Fuel damage due to fabrication/indeterminate errors	K	0	0.0

Lastly, the overall probability of occurrence for all FA misload events and FA damage events is calculated. For this calculation, the three FA misload groups in Table 3 are gathered together and the four FA damage groups in Table 4 are gathered together. Table 5 provides the results of these groupings. The total number of FAs affected for both FA misload events and FA damage events along with their probability of occurrence is listed in Table 5.

Table 5. Probability of Occurrence for FA Misload and FA Damage Events

Category	Number of FAs Affected	Probability of Occurrence
FA misloads	327	$2.7x10^{-4}$
FA damages	57	$4.8x10^{-5}$

This calculation is a preliminary calculation that will be evaluated further and used in the post-closure evaluation. Since this is a preliminary calculation, the probability of occurrence is only an estimate. No uncertainty information is determined for this calculation. Also, the information is not fit to a probability distribution.

7. REFERENCES

7.1 DOCUMENTS CITED

BSC (Bechtel SAIC Company) 2001. *Technical Work Plan for: Waste Package Design Description for LA.* TWP-EBS-MD-000004 REV 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20011106.0177.

CRWMS M&O 2001. *Software Code: SAPHIRE.* V6.69. PC. 10325-6.69-00.

Framatome ANP (Advanced Nuclear Power) 2001a. *Commercial Nuclear Fuel Assembly Damage/Misload Study - 1985-1999.* 51-5011061-01. Lynchburg, Virginia: Framatome Advanced Nuclear Power. ACC: MOL.20011016.0046.

Framatome ANP 2001b. *Summary, Commercial Nuclear Fuel Assembly Damage/Misload Study - 1985-1999.* [Lynchburg, Virginia]: Framatome Advanced Nuclear Power. ACC: MOL.20011018.0158.

Painter, C.L.; Alvis, J.M.; Beyer, C.E.; Marian, A.L.; Payne, G.A.; and Kendrick, E.D. 1994. *Fuel Performance Report for 1991.* NUREG/CR-3950. Volume 9. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 248924.

7.2 PROCEDURES

AP-3.12Q, Revision 0, ICN 4. *Calculations.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010404.0008.

AP-SI.1Q, Rev 3, ICN 2, ECN 1. *Software Management.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20011030.0598.

8. ATTACHMENTS

Attachment I lists all of the events used for this calculation. The events are tabulated in Table I-1. The table provides a summary of each event, the answers to the queried top events on the fuel-handling event tree shown in Figure 1, the resultant end state category, and the total number of FAs affected by the event.

ATTACHMENT I

FUEL-HANDLING EVENTS

(17 pages)

Table I-1. Fuel-Handling Events used to Calculate Probability of Occurrence for Misloads and Fuel Damage Events

Event Number	Event Description[a]	Event Reference[b]	Top Events								End State[c]	Assemblies Affected
			MISLOAD	DAMAGE	DROP	OE	EF	PE	FE-OTHER	TSV		
1	An FA was being moved from the fuel storage rack to its position in the core when the lower end scraped across the top of the core barrel The cause was improper setting of the fuel mast grapple up limit switch and failure to verify that the fuel assembly was fully withdrawn.	Attachment 1, p. 12, plant #31, 1993	NO	NO	YES	YES	N/A	N/A	N/A	NO	M	1
2	FA damage due to misalignment of one of the upenders and the fuel transfer carriage/basket. The upender did not perform its intended function due to incorrect design The carriage lifting guide supports made it physically impossible to achieve a full vertical position	Attachment 1, p 13 plant #8 1996	NO	YES	YES	NO	YES	N/A	N/A	N/A	G	14
3	An FA was misplaced due to misread serial number. The cause was attributed to written communications and design deficiency (use of alphanumeric serial numbers that could be mistaken for numbers.)	Attachment 1, p 12, plant #31 1997	YES	N/A	N/A	YES	N/A	N/A	N/A	NO	B	1
4	A fuel bundle was being lowered into a fuel rack cell when the fuel bundle contacted the top of the cell and de-grappled from the fuel handling equipment The event may be attributed to design of the new grapple, and since this task is not performed routinely, the degree of acquired skill is not the same between operators	Attachment 1, p 11 plant #20 & Attachment 1, p. 9 plant #10 1991	NO	YES	YES	NO	YES	N/A	N/A	N/A	G	1
5	Technical specifications (TS) require fuel assemblies (FAs) not meeting the minimum burnup criteria to be stored in a checkerboard pattern An FA meeting the required burnup criteria was moved into the spent fuel pool and stored next to FAs that did not meet the minimum burnup criteria violating TS The cause was attributed to personnel error	Attachment 1, p 12 plant #30 1996 (1)	YES	N/A	N/A	YES	N/A	N/A	N/A	YES	A	1
6	TS require FAs not meeting the minimum burnup criteria to be stored in a checkerboard pattern. An FA meeting the required burnup criteria was moved into the spent fuel pool and stored next to FAs that did not meet the minimum burnup criteria violating TS The cause was attributed to personnel error.	Attachment 1, p 12 plant #30 1996 (2)	YES	N/A	N/A	YES	N/A	N/A	N/A	YES	A	1

Table I-1 (continued)

Event Number	Event Description[a]	Event Reference[b]	Top Events								End State[c]	Assemblies Affected
			MISLOAD	DAMAGE	DROP	OE	EF	PE	FE-OTHER	TSV		
7	Fuel sipping identified two leaking FAs due to pieces of metal The cause of the debris was attributed to maintenance activities performed during recirculation pipe replacement. The cleanliness procedures used did not adequately enforce a detailed inspection and debris removal work plan.	Attachment 1, p 9 plant #15 1993	NO	YES	NO	NO	N/A	YES	N/A	N/A	J	N/A[d]
8	A fuel bundle was dropped when a loss of power to the grapple occurred simultaneously as the bundle encountered resistance as it was being lowered. The cause was attributed to the grappling assembly air lines being reversed and causing the grapple to open on a loss of power.	Attachment 1, p. 13 plant #3 & Attachment 1, p. 9 plant #15 1991	NO	YES	YES	NO	NO	YES	N/A	N/A	H	1
9	During control rod drive shaft latching activities, difficulty was experienced. The upper internals were investigated and found that the guide pins had not been seated correctly. This caused damage to 3 FAs. The cause was attributed to 1) loss of available clearance between FA top nozzle and baffle wall (sufficient loss can occur after the 8th inserted FA), 2) FA assembly bow/twist, and 3) improper core loading sequence.	Attachment 1, p. 9 Plant #12 1993	NO	YES	YES	NO	YES	N/A	N/A	N/A	G	3
10	TS require FAs not meeting the minimum burnup criteria to be stored in a checkerboard pattern. An FA meeting the required burnup criteria was moved into the spent fuel pool and stored next to FAs that did not meet the minimum burnup criteria violating TS. The cause was attributed to personnel error.	Attachment 1, p 11 plant #25 1994	YES	N/A	N/A	YES	N/A	N/A	N/A	YES	A	1
11	TS require FAs not meeting the minimum burnup criteria to be stored in a checkerboard pattern. An FA meeting the required burnup criteria was moved into the spent fuel pool and stored next to FAs that did not meet the minimum burnup criteria violating TS. The cause was attributed to personnel error.	Attachment 1, p. 11 plant #25 1996	YES	N/A	N/A	YES	N/A	N/A	N/A	YES	A	3
12	An FA was in the reconstitution basket and slipped out of the basket during rotation testing The lid on the basket was not fully closed thus allowing the lid pins to not lock the lid. The test failed because it yielded a false indication and fuel handling operators failed to perform a dual confirmation of the basket top and bottom lid hold down pins being latched.	Attachment 1, p 9 plant #8 1990	NO	YES	YES	NO	NO	YES	N/A	N/A	H	1

Table I-1 (continued)

Event Number	Event Description[a]	Event Reference[b]	Top Events: MISLOAD	DAMAGE	DROP	OE	EF	PE	FE-OTHER	TSV	End State[c]	Assemblies Affected
13	TS require operability checks for cask handling and spent fuel pool cranes prior to and during operation. This check was not performed prior to fuel handling. The cause was attributed to personnel oversight	Attachment 1, p. 11 plant #11 1987	NO	NO	YES	YES	N/A	N/A	N/A	YES	L	64[e]
14	TS require operability checks of radiation monitors in the new fuel storage area prior to placing new fuel in the area. This check was not performed prior to moving two FAs into the new fuel storage area. The cause was attributed to lack of adequate procedural mechanism to assure performance of these tests.	Attachment 1, p. 11 plant #11 1987	NO	NO	YES	NO	NO	YES	N/A	YES	O	2
15	Communication breakdown between the Fuel Building Upender Operator, Control Room Communicator, and Containment Operator caused 4 assemblies to be placed in wrong locations in the core The cause was attributed to overconfidence, lack of 3-way communication and poor attention to detail.	Attachment 1, p. 12 plant #34 1999	YES	N/A	N/A	YES	N/A	N/A	N/A	NO	B	4
16	FA was being lowered into the rack and the operator though it had entered the rack so the speed was increased. The FA contacted to the top edge of the rack and the lowering immediately stopped and began to raise the FA but there was some slack in the cable and caused the assembly to be jerked, pulling the upper nozzle block away. The cause of the event was due to the operator not following procedures on setting the speed and lack of independent verification to ensure the FA was inserted properly.	Attachment 1, p 9 plant #19 1997	NO	YES	YES	YES	N/A	N/A	N/A	N/A	F	1
17	Plant procedures control the proper handling of FAs; however, an FA was improperly engaged and raised about 10 ft before being noticed. The cause of the event was attributed to procedural deficiency.	Attachment 1, p 11 plant #5 1985	NO	NO	YES	NO	NO	YES	N/A	NO	P	1
18	Two FAs were loaded into the core without all control rods fully inserted, in violation of TS. Previously, 4 FAs had been removed as instructed, however, the instructions were revised to remove the additional 2 FAs. The work was performed without verifying the TS to insert the control rod. The cause was attributed to personnel error in not recognizing the requirements of the TS	Attachment 1, p. 11 plant #5 1993	NO	NO	YES	NO	NO	YES	N/A	YES	O	2

Table I-1 (continued)

Event Number	Event Description[a]	Event Reference[b]	Top Events								End State[c]	Assemblies Affected
			MISLOAD	DAMAGE	DROP	OE	EF	PE	FE-OTHER	TSV		
19	TS prohibit the storage of FAs with greater than 3 01wt% of U-235 in the "A" location of the spent fuel pool (SFP), however, an FA with 3 85 wt% was stored in the "A" location of SFP. The FA move sheet specified M42 instead of M43. The cause was attributed to personnel error.	Attachment 1, p 11 plant #13 1987	YES	N/A	N/A	YES	N/A	N/A	N/A	YES	A	1
20	Six fuel rods were found damaged because of fuel fretting that was attributed to Flexitallic gasket material. The cause was attributed to installation of incorrect gasket, the Flexitallic gasket being incompatible with the particular valve design	Attachment 1, p. 9 plant #16 1997	NO	YES	NO	YES	N/A	N/A	N/A	N/A	I	N/A[d]
21	FA inspection was in progress when the reactor operator wrote down AM43, but the fuel crane operator grabbed FA BM43 instead. The error was recognized when there was an attempt to place the FA back into AM43 and an assembly was still in that position. The cause was attributed to fuel handler not receiving positive verification before fuel latching and movement and failure to establish direct communications.	Attachment 1, p. 12 plant #37 1995	YES	N/A	N/A	YES	N/A	N/A	N/A	NO	B	1
22	During fuel shuffle activities, the FA in R-8 was moved instead of FA in O-8. The cause was attributed to personnel error - self verification less than adequate, independent verification error.	Attachment 1, p. 12 plant #36 1994	YES	N/A	N/A	YES	N/A	N/A	N/A	NO	B	1
23	During inspection, plant personnel damaged nine FAs. A long metal rod was manually inserted into the center instrument tube to check for free travel. The personnel used excessive force when the rod came in contact of the plug at the upper nozzle block The cause was attributed to lack of awareness on the part of plant personnel	Attachment 1, p 9 plant #5 1995	NO	YES	NO	YES	N/A	N/A	N/A	N/A	I	9
24	FA tipped against the core baffle, damaging the corner of the assembly grid strap. The FA had been raised slightly to allow the fuel manipulator crane load switch to reset. The FA was set back down and unlatched, however, the FA did not align because of fuel rod bow. The visual inspection prior to unlatching failed to detect this condition. Cause was attributed to bowed fuel rods and lighting conditions causing the operators' failure to detect the FA was not aligned.	Attachment 1, p. 9 plant #5 1986	NO	YES	YES	YES	N/A	N/A	N/A	N/A	F	1

Table I-1 (continued)

Event Number	Event Description[a]	Event Reference[b]	Top Events								End State[c]	Assemblies Affected
			MISLOAD	DAMAGE	DROP	OE	EF	PE	FE-OTHER	TSV		
25	An FA was placed in the wrong location in the SFP storage racks The cause was attributed to informality of communications, fuel movement sheets not readily available, and operator inexperience	Attachment 1, p. 12 plant #39 1995	YES	N/A	N/A	YES	N/A	N/A	N/A	NO	B	1
26	During core offload, the wrong FA was removed and transferred to the SFP twice. The cause was attributed to personnel error due to inattention to detail and lack of self checking on the part of grapple operators and independent verifiers	Attachment 1, p. 12 plant #35 1990	YES	N/A	N/A	YES	N/A	N/A	N/A	NO	B	2
27	An FA was being lowered into the SFP rack when a minor interference was encountered, the fuel handler tried to rotate the grapple to free the FA but caused the FA to be partially inserted and cocked at a small angle. The cause can be attributed to the grapple cable, which provides vertical motion control had fallen off of its rotating bail The slack cable switch allowed enough slack cable (by not stopping the bail) so the cable jumped the grooves.	Attachment 1, p. 13 plant #5 1990	NO	NO	YES	NO	YES	N/A	N/A	N/A	N	1
28	Fuel rods loaded into the core exceeded the weight limit for Uranium, which was a violation of plant TS. The information from the vendor came after the fuel was loaded into the core. The utility checked and found that 289 fuel rods exceeded the limit. The vendor also notified the utility that the previous cycle contained 248 fuel rods that exceeded the limit. No discrete cause was given for the event The cause could be attributed to design error on the manufacture without providing the information to the utility.	Attachment 1, p 11 plant #7 1986	YES	N/A	N/A	NO	N/A	NO	YES	YES	E	3[f]
29	An FA was damaged when being removed from the shipping container because the top clamp had been mistakenly loosened which allowed the FA to fall. The cause was attributed to the fact that the supervisor in charge had visually inspected the clamp but did not perform an adequate verification.	Attachment 1, p. 9 plant #1 1985	NO	YES	YES	YES	N/A	N/A	N/A	N/A	F	1
30	During control rod drive maintenance, an FA was raised instead of the fuel support piece. The cause was attributed to grapple being lowered and visualization of the grapple was lost due to air bubbles from the grapple air hose The grapple was being lifted to determine the source when it was observed that the FA was caught on the grapple	Attachment 1, p 11 plant #3 1985	NO	NO	YES	YES	N/A	N/A	N/A	NO	M	1

Table I-1 (continued)

Event Number	Event Description[a]	Event Reference[b]	Top Events								End State[c]	Assemblies Affected
			MISLOAD	DAMAGE	DROP	OE	EF	PE	FE-OTHER	TSV		
31	TS restrict hot channel thermal limit value, however, this criteria was exceeded The fuel vendor notified the licensee that 6 FAs were misfabricated. Cause of event was attributed to management deficiency, in that they failed to ensure the FAs were fabricated to meet design requirements	Attachment 1, p 11 plant #24 1993	YES	N/A	N/A	NO	N/A	NO	YES	YES	E	6
32	An FA was stuck in the upper internals and was inadvertently raised when the upper internals were moved. The FA subsequently fell from the upper internals and landed on two other FAs. All three FAs were moved to the SFP. The cause was determined to be fuel alignment pin on the upper internals being bent during a previous outage.	Attachment 1, p. 9 plant #2 1986	NO	YES	YES	YES	N/A	N/A	N/A	N/A	F	1
33	Ultrasonic testing revealed a significant number of failed fuel rods There were a total of 233 fuel rods damaged in 88 of the 109 fuel assemblies. The failures were attributed to debris lodged in the region between the FA lower nozzle and spacer grid The debris matched the by-product from thermal shield support system repairs	Attachment 1, p. 9 plant #2 1989	NO	YES	NO	YES	N/A	N/A	N/A	N/A	I	N/A[d]
34	An FA dropped into the fuel pool while being moved from dry storage. The rigging used in the move failed where the mail threads of an eyebolt mated with the female threads The cause was attributed to a mismatch in thread sizes between the male and female threads	Attachment 1, p. 13 plant #4 1985	NO	YES	YES	YES	N/A	N/A	N/A	N/A	F	1
35	Fuel sipping identified three leaking FAs due to machining debris and fretting induced clad failure. The cause of the debris was attributed to machining activities in which housekeeping procedures for the activity were inadequate.	Attachment 1, p. 9 plant #11 1992	NO	YES	NO	NO	N/A	YES	N/A	N/A	J	N/A[d]
36	An FA was found out of position by 180 degrees. The FA was misoriented during last refueling outage. Cause of the event was attributed to personnel error.	Attachment 1, p 11 plant #26 1995	YES	N/A	N/A	YES	N/A	N/A	N/A	NO	B	N/A[d]
37	TS limit the number of FA in a single work location, however, during decontaminating FAs for shipment more than one FA was present in the work area. The cause of the event was attributed to insufficient attention to TS by the personnel involved.	Attachment 1, p 11 plant #1 1985	YES	N/A	N/A	YES	N/A	N/A	N/A	YES	A	1

Table I-1 (continued)

Event Number	Event Description[a]	Event Reference[b]	Top Events								End State[c]	Assemblies Affected
			MISLOAD	DAMAGE	DROP	OE	EF	PE	FE-OTHER	TSV		
38	While moving new fuel from the dry storage racks to the SFP, an FA was incorrectly placed in the SFP. The cause was attributed to the fuel handler not paying attention and failing to verify the FA identification and insert number, prior to lowering the FA	Attachment 1, p. 12 plant #38 1997	YES	N/A	N/A	YES	N/A	N/A	N/A	NO	B	1
39	While moving an FA, the technicians noticed an FA was already stored in the location for the FA. The FA was supposed to be placed into the next position. The cause was attributed to inattention to detail, poor self-checking practices, and failure to follow procedures	Attachment 1, p. 11 plant #10 1999	YES	N/A	N/A	YES	N/A	N/A	N/A	NO	B	1
40	A new FA was damaged when it rubbed against a deformed identification number on the lead-in of its fuel storage rack. The weight of the FA and fuel handling tool caused the metal at the bottom of the number to deform and stick out. Therefore, when the FA was withdrawn, the deformed metal contacted the FA resulting in damage.	Attachment 1, p 13 plant #2 1992	NO	YES	YES	NO	YES	N/A	N/A	N/A	G	1
41	TS require FAs that do not meet a certain initial enrichment and burn-up to be stored in a checkerboard arrangement. Contrary to this, an FA was loaded in the wrong location. The cause was attributed to personnel error.	Attachment 1, p. 11 plant #10 1987	YES	N/A	N/A	YES	N/A	N/A	N/A	YES	A	1
42	Two FAs were inadvertently withdrawn from the core due to being connected to the upper core plate by misaligned guide pins. The guide pins were damaged on the last outage when the upper internals package was not lifted sufficiently. The cause was attributed to procedural violation (the upper internal package was not raised to a sufficient height prior to lateral movement).	Attachment 1, p 11 plant #10, Attachment 1, p. 9 plant #9, & Attachment 1, p 13 plant #2 1990	NO	YES	YES	YES	N/A	N/A	N/A	N/A	F	2
43	An FA could not be grappled because the center of the FA was bowed down 1/2-inch. The High Pressure Core Spray (HPSC) bundle bent the FA handle when it was re-installed. The HPCS encountered the FA handle since it was higher than normal. Eventually the HPCS nozzle forced the center of the FA handle down The cause was attributed to human error	Attachment 1, p. 9 plant #3 1986	NO	YES	YES	YES	N/A	N/A	N/A	N/A	F	1

Table I-1 (continued)

Event Number	Event Description[a]	Event Reference[b]	Top Events								End State[c]	Assemblies Affected
			MISLOAD	DAMAGE	DROP	OE	EF	PE	FE-OTHER	TSV		
44	During the uprighting of a metal shipping container, a fuel bundle restraint clip disengaged allowing a fuel bundle to fall out The cause was attributed to failure of the metal restraint clip	Attachment 1, p 13 plant #9 1989	NO	YES	YES	NO	YES	N/A	N/A	N/A	G	1
45	A chemical transient early in the fuel cycle caused fuel cladding degradation The cause was attributed to crud-induced localized corrosion The plant's main feedwater concentration of copper was greater than the Boiling Water Reactor Owners Group (BWROG) recommendation.	Attachment 1, p. 9 plant #6 1988	NO	YES	NO	YES	N/A	N/A	N/A	N/A	I	N/A[d]
46	During FA movement, the wrong FA was selected, grappled, and lifted above the reactor vessel flange before the error was identified The cause was attributed to the fuel handling supervisors and fuel handlers were not adequately trained in proper communications.	Attachment 1, p. 11 plant #19 (1) 1991	YES	N/A	N/A	YES	N/A	N/A	N/A	NO	B	1
47	During FA movement, the wrong FA was selected, grappled, and moved. The error was recognized when the FA was to be placed in the core and another FA was already in its place. The cause was attributed to the inadequate verification of the fuel bundle core location.	Attachment 1, p. 11 plant #19 (2) 1991	YES	N/A	N/A	YES	N/A	N/A	N/A	NO	B	1
48	The day shift upender operator loaded a fuel bundle into the upender and then turned over the work to the night shift operator with the fuel bundle still in the upender The night shift operator assumed the upender was empty and sent it back to the SFP, at which time they discovered a fuel bundle was still in the upender. The cause was attributed to miscommunication between the operators during shift turnover. The procedures were weak in defining the chain of command and communications during fuel movement	Attachment 1, p. 12 plant #40 1995	NO	NO	YES	YES	N/A	N/A	N/A	NO	M	1
49	TS require FAs that do not meet a certain initial enrichment and burn-up to be stored in a checkerboard arrangement. Contrary to this, seven FAs were loaded in the wrong location. The cause was attributed to personnel error.	Attachment 1, p. 11 plant #6 1985	YES	N/A	N/A	YES	N/A	N/A	N/A	YES	A	7

Table I-1 (continued)

Event Number	Event Description[a]	Event Reference[b]	Top Events								End State[c]	Assemblies Affected
			MISLOAD	DAMAGE	DROP	OE	EF	PE	FE-OTHER	TSV		
50	TS require FAs that do not meet a certain initial enrichment and burn-up to be stored in a checkerboard arrangement. Contrary to this, 11 FAs were loaded in the wrong location. The cause was attributed to personnel error	Attachment 1, p 11 plant #6 1991	YES	N/A	N/A	NO	N/A	YES	N/A	YES	C	11
51	An FA was found out of position by 90 degrees The FA was misoriented during last refueling outage Cause of the event was contributed to personnel error.	Attachment 1, p. 11 plant #12 1987	YES	N/A	N/A	YES	N/A	N/A	N/A	NO	B	N/A[d]
52	An independent contractor informed the utility that the effective neutron multiplication factor (k-eff) in the SFP was higher than originally calculated The error was traced to 2 approximations. The new calculation verified that the reactivity condition in the SFP was in compliance of the TS The cause was attributed to 2 approximations used in the original calculation that were incorrect.	Attachment 1, p. 11 plant #23 1992	YES	N/A	N/A	YES	N/A	N/A	N/A	NO	B	N/A[d]
53	Two fuel bundles were dropped during fuel receipt activities. The fuel bundles fell from the metal shipping containers because the restraints and safety belt had not been installed. The cause was attributed to the operators failing to install the fuel bundle restraints and safety belt restraint.	Attachment 1, p. 11 plant #28 1991	NO	NO	YES	YES	N/A	N/A	N/A	NO	M	2
54	A fuel loading error occurred during a fuel movement. A fuel bundle was in a core location where there should not have been a fuel bundle. The cause was attributed to work practices when operators failed to verify the grapple engaged the correct bundle prior to movement	Attachment 1, p. 11 plant #28 1996	YES	N/A	N/A	YES	N/A	N/A	N/A	NO	B	1
55	An FA was left unattended and suspended in the SFP fuel handling bridge mast. Although this event was not contrary to TS, the intent of the TS was not met The cause was attributed to inadequate self checking and lack of management expectations.	Attachment 1, p. 11 plant #27 1996	NO	NO	YES	YES	N/A	N/A	N/A	YES	L	1
56	An FA experienced structural failure, while operators were attempting to lower the FA into its new location The lower tie plate and most of the fuel pins separated from the bundle. The cause was attributed to over-rotation of the unchanneled fuel by the operators The check is done to ensure the fuel grapple is firmly engaged.	Attachment 1, p. 9 plant #4 1995	NO	YES	YES	YES	N/A	N/A	N/A	N/A	F	1

Table I-1 (continued)

Event Number	Event Description[a]	Event Reference[b]	Top Events								End State[c]	Assemblies Affected
			MISLOAD	DAMAGE	DROP	OE	EF	PE	FE-OTHER	TSV		
57	During fuel sipping operations, 47 FAs were found to have cladding failures The cladding failures appeared to be the result of pellet/clad interaction. The pellet/clad interaction appears to result from inability of power shape monitoring system and improper operational guidance, which caused "power shocks."	Attachment 1, p. 13 plant #1 1986	NO	YES	NO	NO	N/A	YES	N/A	N/A	J	N/A[d]
58	TS prohibit the storage of FAs with greater than 3 01wt% of U-235 in the SFP, however, 184 FAs with a planar enrichment of 3.19 wt% were stored in the SFP. The cause was attributed to personnel error not performing a thorough safety analysis for storage of new fuel and not recognizing a conflict with the TS.	Attachment 1, p. 11 plant #9 1987	YES	N/A	N/A	YES	N/A	N/A	N/A	YES	A	184
59	The fuel handling grapple engaged indication light was being repaired After the repairs, an FA was raised from its fully seated position to ensure the problem was corrected. A senior reactor operator was not present which is a TS violation. The cause was attributed to personnel error in decision making.	Attachment 1, p 11 plant #9 1995	NO	NO	YES	YES	N/A	N/A	N/A	YES	L	1
60	An FA was found hanging from the upper guide structure (UGS) when it was being removed for routine refueling practices. The cause of the event was indeterminate	Attachment 1, p. 11 plant #15 1993	NO	NO	YES	NO	NO	NO	YES	N/A	Q	1
61	An FA was found inadvertently raised when the UGS was being removed for routine refueling practices. The cause of the event was indeterminate.	Attachment 1, p. 11 plant #15 1988	NO	NO	YES	NO	NO	NO	YES	N/A	Q	1
62	An FA was found hanging from the UGS when it was being removed for routine refueling practices. The cause of the event was indeterminate, however, the UGS fuel pins located at the FA location were found to be bent	Attachment 1, p. 11 plant #15 1992	NO	NO	YES	NO	NO	NO	YES	N/A	Q	1
63	During a refueling outage, video camera inspection indicated that an FA was damaged with 7 fuel rods protruding from the bottom. Preliminary analysis indicated that the upper guide structure transmitted a load to the fuel assembly during core reassembly. The cause was attributed to deficient design and insufficient knowledge of the design limitations.	Attachment 1, p 9 plant #22 1996	NO	YES	YES	NO	YES	N/A	N/A	N/A	G	1

Table I-1 (continued)

Event Number	Event Description[a]	Event Reference[b]	Top Events								End State[c]	Assemblies Affected
			MISLOAD	DAMAGE	DROP	OE	EF	PE	FE-OTHER	TSV		
64	TS require FAs that do not meet a certain initial enrichment and burn-up to be stored in a checkerboard arrangement. Contrary to this, an FA was loaded in the wrong location. The cause was attributed to personnel error.	Attachment 1, p. 12 plant #32 1999	YES	N/A	N/A	YES	N/A	N/A	N/A	YES	A	1
65	During FA movement, the wrong FA was selected, grappled, and was moved. The error was recognized 20 hours later. The cause was attributed to the inadequate verification of the fuel bundle core location.	Attachment 1, p. 11 plant #21 (1) 1991	YES	N/A	N/A	YES	N/A	N/A	N/A	NO	B	1
66	During FA movement, three incorrect FAs were selected, grappled, and moved. The errors all involved mistakes made in moving FAs in fuel pool rows OO and QQ. The cause was attributed to the core component transfer sheet and inadequate verification by operators.	Attachment 1, p. 11 plant #21 (2) 1991	YES	N/A	N/A	YES	N/A	N/A	N/A	NO	B	3
67	TS require an operable Source Range Monitor (SRM) in intermediate arrays of fuel during unloading and reloading of fuel, however; a fuel bundle was isolated from the SRM. The cause was attributed to operator error.	Attachment 1, p. 11 plant #4 1985	NO	NO	YES	YES	N/A	N/A	N/A	YES	L	1
68	During a refueling outage, an FA was almost fully inserted into the SFP rack when it hung up momentarily (reported as a minor "bump") When the FA was examined, it was observed to be damaged The cause of the damage was the design of the SFP storage rack. Design clearances of the racks resulted in the exposure of some rack component edges.	Attachment 1, p 13 plant #6 1990	NO	YES	YES	NO	YES	N/A	N/A	N/A	G	1
69	TS prohibit FAs that have been subcritical for less than 1 year to be stored against the wall, however, 3 FAs were found to be stored against the wall The cause was attributed to operator error.	Attachment 1, p. 11 plant #2 1985	YES	N/A	N/A	YES	N/A	N/A	N/A	YES	A	3
70	An FA was damaged when it caught the edge of the control rod blade guide during fuel loading. The FA began leaning about 45 to 60 degrees from vertical, which resulted in the damage. The cause was attributed to lack of self-verification during the insertion of the FA	Attachment 1, p 9 plant #7 1994	NO	YES	YES	YES	N/A	N/A	N/A	N/A	F	1

Table I-1 (continued)

Event Number	Event Description[a]	Event Reference[b]	Top Events MISLOAD	DAMAGE	DROP	OE	EF	PE	FE-OTHER	TSV	End State[c]	Assemblies Affected
71	An FA was released from the grapple and fell onto the SFP rack. The control switch for the grapple was inadvertently left in the "release" position after attempting to unlatch the FA When the FA would not release, the FA was raised again, rotated 90 degrees and lowered back but it got caught on the top of the fuel rack and the grapple hook then released the FA. The cause was attributed to personnel error and procedural deficiency.	Attachment 1, p. 11 plant #18 1989	NO	YES	YES	NO	NO	YES	N/A	N/A	H	1
72	An operator lowered the reactor building overhead crane hoist until the hook contacted and then partially laid over onto a fuel bundle which was laying horizontal in the metal shipping container. The cause was attributed to personnel error involving an inadvertent action due to inattention.	Attachment 1, p. 9 plant #7 1989	NO	YES	YES	YES	N/A	N/A	N/A	N/A	F	1
73	Three fuel rods were found to be damaged in an FA. The damage was debris related even though no debris could be found. After further investigation, debris was found and was attributed to machining of the RCS piping conducted during a steam generator replacement outage.	Attachment 1, p 9 plant #18 1997	NO	YES	NO	YES	N/A	N/A	N/A	N/A	I	N/A[d]
74	Permanently defueled TS require that a certified fuel handler is in the fuel storage building during all fuel handling operations, however, one was not available during fuel handling operations. The cause was attributed to human error.	Attachment 1, p. 11 plant #29 1996	NO	NO	YES	YES	N/A	N/A	N/A	YES	L	1
75	TS identify a maximum total fuel weight of 1,766 grams of Uranium/fuel rod. Contrary to this, the fuel vendor informed the utility that this limit had been exceeded for Unit-1, cycle-3 (1,396 rods), cycle-4 (132 rods), and Unit-2, cycle-3 (377 rods). The utility was submitting changes to the TS to delete the maximum total fuel weight limit The event was attributed to recent improvements to fuel design and nominal density increase	Attachment 1, p. 11 plant #8 1986	YES	N/A	N/A	NO	N/A	NO	YES	YES	E	10[g]
76	During fuel loading activities, an FA titled over (18 degrees from vertical) after being released. The cause was attributed to the fuel handling instruction not being completely followed when the FA was inappropriately unlatched from the manipulator crane.	Attachment 1, p. 9 plant #13 1993	NO	YES	YES	YES	N/A	N/A	N/A	N/A	F	1

Table I-1 (continued)

Event Number	Event Description[a]	Event Reference[b]	Top Events								End State[c]	Assemblies Affected
			MISLOAD	DAMAGE	DROP	OE	EF	PE	FE-OTHER	TSV		
77	TS identify a maximum total fuel weight of 2,250 grams of Uranium/fuel rod Contrary to this, the utility verified the actual nominal weight of the fuel rods were 2,273 grams The reason for this condition was the design process failed to identify the TS. The utility was submitting changes to the TS to delete the maximum total fuel weight limit The event was attributed to design error in that the engineering review did not include the TS	Attachment 1, p 11 plant #22 1992	YES	N/A	N/A	NO	N/A	NO	YES	YES	E	72[h]
78	TS require FAs that do not meet a certain initial enrichment and burn-up not to be stored in Region 1 of the SFP. Contrary to this, an FA was loaded in the wrong location The cause was attributed to deficiencies in the methods.	Attachment 1, p. 11 plant #16 1988	YES	N/A	N/A	YES	N/A	N/A	N/A	YES	A	1
79	Misalignment of FAs with the upper internal fuel alignment pins, caused damage to the top nozzles on six FAs The misalignment was caused from stacking FA tolerances (gaps) that an excessive gap was created at one end of the core. The gap verification process incorrectly determined the gap was acceptable. The cause was attributed to human performance	Attachment 1, p. 9 plant #23 1999	NO	YES	YES	YES	N/A	N/A	N/A	N/A	F	6
80	A new FA was damaged when it was dropped 2-3 inches in the inspection stand. The cause was attributed to deficient hardware and human performance error.	Attachment 1, p 9 plant #21 1992	NO	YES	YES	YES	N/A	N/A	N/A	N/A	F	1
81	An incorrect FA was grappled and removed from the core, then returned to its original position. Plant practices would have required the FA to be placed in a special location in the SFP. The cause was attributed to operator error and communications breakdown.	Attachment 1, p 12 plant #41 1993	YES	N/A	N/A	YES	N/A	N/A	N/A	NO	B	1
82	TS restrict loads containing fuel carried over the SFP racks to less than 240,000 inch-pounds, however, 7 FAs were moved over spent FAs stored in the SFP. The cause was attributed to failure of refueling crew to comply with plant procedures.	Attachment 1, p 11 plant #14 1988	NO	NO	YES	YES	N/A	N/A	N/A	YES	L	7

Table I-1 (continued)

Event Number	Event Description[a]	Event Reference[b]	Top Events								End State[c]	Assemblies Affected
			MISLOAD	DAMAGE	DROP	OE	EF	PE	FE-OTHER	TSV		
83	An FA was dropped while it was being removed from the reactor. During the move a minor vibration was noted and the instruments indicated that the crane was no longer loaded The FA separated from the grapple. There is no determination for the cause of this event except that the grapple mating jaws were found in the closed position. The personnel only did a visual verification of grapple connection.	Attachment 1, p. 13 plant #7 1993	NO	YES	YES	YES	N/A	N/A	N/A	N/A	F	1
84	In accordance with the fuel movement sheet, a peripheral FA was mispositioned 90 degrees from its correct orientation in the core. The fuel movement sheet was incorrect. The cause was attributed to manual entry of bundle orientation data	Attachment 1, p. 12 plant #42 1998	YES	N/A	N/A	NO	N/A	YES	N/A	NO	D	N/A[d]
85	During a fuel movement, a power supply disturbance led to a memory loss of the refueling machine computer, resulting in the FA to be suspended over the core location that it had been removed from. The bundle was manually lowered but when it was unlatched it leaned sideways and came to rest against the core baffle. The root cause was inability to detect the exact position of the FA while the refueling machine was under manual control	Attachment 1, p. 11 plant #17 1988	NO	NO	YES	NO	YES	N/A	N/A	N/A	N	1
86	During a refueling outage shuffle, an FA disengaged from the spent fuel handling tool and dropped 5 inches The spent fuel-handling tool was found to be 75% open and locked. The fuel-handling tool was inadvertently mispositioned. The cause was attributed to human error.	Attachment 1, p. 9 plant #17 1997	NO	YES	YES	YES	N/A	N/A	N/A	N/A	F	1
87	An FA was lowered onto another FA that was in the upender. An operator left an FA in the upender during shift turnover and the oncoming operator did not recognize the FA was in the upender until an attempt was performed to load an FA into the upender The cause was attributed to failure to follow procedures.	Attachment 1, p 12 plant #43 1999	NO	NO	YES	YES	N/A	N/A	N/A	NO	M	1
88	FA damage was noted during ultrasonic testing of all FAs. The corner of the bottom grid strap of an FA was found severed and the corner fuel rod had a fretting failure. Dent marks are visible on the bottom nozzle plate on the adjacent FA. The FA damage was attributed to being hit by an adjacent assembly during a previous refueling	Attachment 1, p. 9 plant #20 1995	NO	YES	YES	YES	N/A	N/A	N/A	N/A	F	1

Table I-1 (continued)

Event Number	Event Description[a]	Event Reference[b]	Top Events								End State[c]	Assemblies Affected
			MISLOAD	DAMAGE	DROP	OE	EF	PE	FE-OTHER	TSV		
89	While attempting to load an FA, one corner of the bottom grid strap was torn off. Contact between adjacent FAs is inevitable when loading such assemblies, particularly when loading such assemblies between two other assemblies The cause was attributed to bow and twist of the fuel FA.	Attachment 1, p. 13 plant #10 1990	NO	YES	YES	NO	YES	N/A	N/A	N/A	G	1
90	TS require the establishment of a refueling area secondary containment during fuel shipping cask manipulation Additionally, the updated final safety analysis report requires redundant lifting devices for this activity. Both criteria were violated. Cause was attributed to deficiencies in the controlling procedures	Attachment 1, p 12 plant #33 1999	NO	NO	YES	NO	NO	YES	N/A	YES	O	N/A[i]
91	The utilities refueling practice has been to offload the full core to the SFP. This practice is not consistent with "normal" refueling analyzed in the updated safety analysis report (USAR). More specifically, the redundant SFP cooling requirements of the USAR were not maintained during the September 1990, March 1992, October 1993, and April 1995 refueling outages. Cause was attributed to an inadequate safety review. The reactor core for this plant contains 764 fuel assemblies	Attachment 1, p. 11 plant #28 1996	NO	NO	YES	YES	N/A	N/A	N/A	YES	L	3,056[j]

Notes:

a. The description provided is an abstract of the event. A review of the full report may be required in order to verify the answers to the top events and the final categorization of the event.

b. See Framatome ANP 2001b.

c. End States:

A - MISLOAD/HUMAN ERROR/TSV
B - MISLOAD/HUMAN ERROR/NO TSV
C - MISLOAD/PROCEDURE ERROR/TSV
D - MISLOAD/PROCEDURE ERROR/NO TSV
E - MISLOAD/OTHER/TSV
F - FA DAMAGE/FA MOVE/HUMAN ERROR
G - FA DAMAGE/FA MOVE/EQUIPMENT FAILURE
H - FA DAMAGE/FA MOVE/PROCEDURE ERROR

I - FA DAMAGE/NO FA MOVE/HUMAN ERROR
J - FA DAMAGE/NO FA MOVE/PROCEDURE ERROR
K - FA DAMAGE/NO FA MOVE/OTHER
L - NO FA DAMAGE/FA MOVE/HUMAN ERROR/TSV
M - NO FA DAMAGE/FA MOVE/HUMAN ERROR/NO TSV
N - NO FA DAMAGE/FA MOVE/EQUIPMENT FAILURE
O - NO FA DAMAGE/FA MOVE/PROCEDURE ERROR/TSV
P - NO FA DAMAGE/FA MOVE/PROCEDURE ERROR/NO TSV
Q - NO FA DAMAGE/FA MOVE/OTHER

d. Events are not representative of monitored geological repository operations.

e. The plant's reactor core contains a total of 193 FAs. It is assumed that 1/3 of the core is to be replaced with new fuel during the next refueling outage. Therefore, it is assumed that 1/3 of the core will be affected by the event. This gives the total number of FAs affected as 193 FAs / 3 = 64. (See assumption 3.2)

f. It is assumed there are 200 fuel rods per FA (see Assumption 3.3). The total number of fuel rods affected by this event is obtained from 289 from new cycle + 248 from previous cycle = 537 fuel rods. By using 200 fuel rods per FA, the total number of FAs is 537 fuel rods / 200 fuel rods per FA ≅ 3 FAs.

g. It is assumed there are 200 fuel rods per FA (see Assumption 3.3). The total number of fuel rods affected by this event is obtained from 1,309 fuel rods + 132 fuel rods + 377 fuel rods = 1,905 fuel rods. By using 200 fuel rods per FA, the total number of FAs is 1,905 fuel rods / 200 fuel rods per FA ≅ 10 FAs.

h. This core contains a total of 217 FAs. It is assumed that 1/3 is to be replaced with new fuel during the refueling outage. The total number of FAs affected by the event is calculated as 217 FAs / 3 = 72 FAs. This is considered conservative since new cycle fuel batches typically consist of several enrichment sub-batches. Only the higher enrichment sub-batch would likely exceed the U-235 weight restrictions (see Assumption 3.4).

i. This event is not representative of waste package loading or MGR, since the facility will be designed with the appropriate containment configuration required to receive, move, and load spent nuclear fuel

j. The total number of FAs listed for this event represents four different refueling outages. The total number of FAs affected per refueling outage is the total number of FAs loaded into the reactor core. The plant's reactor core contains 764 FAs. Therefore, the total number of FAs affected is 4 * 764 = 3,056.