



Crystal River Nuclear Plant  
Docket No. 50-302  
Operating License No. DPR-72

Ref: 10 CFR 50.90

April 25, 2001  
3F0401-11

U.S. Nuclear Regulatory Commission  
Attn: Document Control Desk  
Washington, DC 20555-0001

Subject: License Amendment Request #267, Revision 1, Supplemental Risk-Informed Information in Support of License Amendment Request #267, Revision 0

- References:
1. FPC to NRC letter, 3F0301-05, dated March 7, 2001, License Amendment Request #267, Revision 0, Revision to Improved Technical Specification 5.6.2.20, "Containment Leakage Rate Testing Program"
  2. 10 CFR 50.54(o) and 10 CFR 50, Appendix J, Primary Reactor Containment Leakage Testing for Water-Cooled Power Reactors, Option B

Dear Sir:

As stated in Reference 1, Florida Power Corporation (FPC) hereby submits License Amendment Request (LAR) # 267, Revision 1, supplemental risk-informed information in support of LAR # 267, Revision 0, to allow a one-time interval extension for the Crystal River – Unit 3 (CR-3) Type A, Integrated Leakage Rate Test (ILRT) for no more than six (6) years. This risk-informed information includes the change in the Large Early Release Frequency (LERF) and the predicted person-rem/year associated with the time interval extension for ILRT performance.

FPC requests NRC approval of LAR #267 by July 31, 2001, with 30 days for implementation. The requested approval date and implementation period will allow sufficient time to reschedule the remaining outage activities to achieve optimum effectiveness of Refueling Outage 12 (R-12), scheduled to begin on September 29, 2001. The reason for this request is to save critical path time in R-12 and move the ILRT to one of the three subsequent refueling outages where it can be performed with minimal impact on critical path.

Attachment A is a summary of FPC Calculation F-01-0001, Evaluation of Risk Significance of ILRT Extension, while Attachment B is the actual FPC Calculation. The conclusion of the FPC Calculation is that the increase in the Type A test interval would result in a net increase in LERF that is less than the value defining risk significance. The net change in population dose results in an increase of about 0.03% or 3.95E-04 man-rem/year. This increased population dose is also considered not to be risk significant.

A017

As stated in the introduction to Attachment B, the calculation utilizes the results of the CR-3 individual plant examination (IPE) (i.e., the most recent Level 2 analysis performed for CR-3) for developing the baseline core damage and plant damage states. It is noted that the CR-3 Level 1 analysis has been updated since the IPE and that update has reduced the overall core damage frequency. Thus, if the current Level 1 analysis was applied to the IPE, the impact of the proposed change should be further decreased.

Attachment C, Generic Level 3 Probabilistic Risk Assessment (PRA) for Crystal River – 3, (BAW-2369) was performed by Framatome Technologies, Inc. (FTI) and Duke Power Company for the Risk-Informed Applications Committee of the B&W Owners Group. This study utilized CR-3 plant-specific site characteristics and CR-3 plant damage state / release category information applied to a generic modeling framework. The man-rem information from this study, which was used in FPC Calculation F-01-0001 (Attachment B), was validated by Attachment D, Engineering Evaluation EEF01-003.

Attachment D is an FPC engineering evaluation which provides an alternate method check of the population dose attributed to containment leakage scenarios in Attachment C, Generic Level 3 PRA for CR-3. This engineering evaluation concluded that there was very good agreement in the calculated population dose estimate with the Generic Level 3 PRA for CR-3.

Attachment E contains an adjustment to the operational Type A test results for CR-3 that were originally presented in Attachment A to Reference 1. The adjustment was previously reported to the NRC and does not change the conclusion that the operational Type A tests were all well under their acceptance criteria.

Attachments F and G are proposed and revised Improved Technical Specifications change pages in strikeout / shadowed and in revision bar format, respectively. The format of these pages conforms to NUREG-1430, Standard Technical Specifications for Babcock & Wilcox Plants, Draft Revision 2, April 2001, and to Industry / TSTF Standard Technical Specification Change Traveler –52 (TSTF-52), Revision 3 for 10 CFR 50, Appendix J, Option B, Containment Leakage Rate Testing Program.

CR-3 has determined that this risk-informed information does not change the conclusion in the Environmental Impact Evaluation and does not change the conclusions reached in the No Significant Hazards Consideration Determination submitted by Reference 1.

The CR-3 Plant Nuclear Safety Committee has reviewed this request and recommended it for approval.

This letter establishes no new regulatory commitments.

The NRC has approved a similar risk-informed submittal relating to a one-time extension of a Type A test interval for Entergy's Indian Point 3 (IP3) nuclear power plant. The IP3 request was submitted on September 6, 2000 (IPN-00-062) and supplemented on January 18, 2001 (IPN-01-007) and on April 2, 2001 (IPN-01-030). The NRC approval was granted on April 17, 2001 (TAC No. MB0178).

If you have any questions regarding this submittal, please contact Mr. Sid Powell, Supervisor, Licensing and Regulatory Programs at (352) 563-4883.

Sincerely,



Dale E. Young  
Vice President, Crystal River Nuclear Plant

DEY/rmb

Attachments:

- A. Summary of FPC Calculation F-01-0001, Evaluation of Risk Significance of ILRT Extension
- B. FPC Calculation F-01-0001, Evaluation of Risk Significance of ILRT Extension
- C. Generic Level 3 PRA for Crystal River 3, B&W Owners Group Risk-Informed Applications Committee, BAW-2369, May 2000
- D. FPC Engineering Evaluation EEF01-003, Level 3 PRA Check – Containment Leakage
- E. Adjusted Operational Type A Test Results for CR-3
- F. Proposed Revised Improved Technical Specifications Change Pages – Strikeout / Shadowed Format
- G. Proposed Revised Improved Technical Specifications Change Pages – Revision Bar Format

xc: NRR Project Manager  
Regional Administrator, Region II  
Senior Resident Inspector

**STATE OF FLORIDA**

**COUNTY OF CITRUS**

Dale E. Young states that he is the Vice President, Crystal River Nuclear Plant for Progress Energy; that he is authorized on the part of said company to sign and file with the Nuclear Regulatory Commission the information attached hereto; and that all such statements made and matters set forth therein are true and correct to the best of his knowledge, information, and belief.

Dale E Young

Dale E. Young  
Vice President  
Crystal River Nuclear Plant

The foregoing document was acknowledged before me this 25<sup>th</sup> day of April, 2001, by Dale E. Young.

Lisa A Morris

Signature of Notary Public  
State of Florida



LISA A. MORRIS  
Notary Public, State of Florida  
My Comm. Exp. Oct. 25, 2003  
Comm. No. CC 879691

LISA A MORRIS

(Print, type, or stamp Commissioned  
Name of Notary Public)

Personally X Produced  
Known \_\_\_\_\_ -OR- Identification \_\_\_\_\_

**FLORIDA POWER CORPORATION**

**CRYSTAL RIVER UNIT - 3**

**DOCKET NUMBER 50-302 / LICENSE NUMBER DPR-72**

**ATTACHMENT A**

**LICENSE AMENDMENT REQUEST #267, REVISION 1  
Containment Leakage Rate Testing Program**

**Summary of FPC Calculation F-01-0001,  
Evaluation of Risk Significance of ILRT Extension**

## SUMMARY

Florida Power – Crystal River – Unit 3 (CR-3) has completed a risk assessment of the proposed one time Technical Specification change of extending the containment Type A test interval from once-per-ten-years to once-per-sixteen-years. The risk assessment was performed following the methodology used in EPRI TR-104285 and NRC Regulatory Guide 1.174 on the use of Probabilistic Risk Assessment (PRA) findings and risk insights in support of a licensee request for changes to a plant's licensing basis. Specifically, the approach combined the use of CR-3's Individual Plant Examination (IPE) results and the findings to the methodology described in EPRI TR-104285 in order to estimate plant risk on specific accident sequences impacted by Type A testing. The calculation used to obtain these numbers is contained in Attachment B.

Revisions to 10 CFR 50, Appendix J allow individual plants to extend Type A surveillance testing requirements from three-in-ten years to at least once per ten years. The revised Type A test frequency is based on an acceptable performance history defined as two consecutive periodic Type A tests at least 24 months apart in which the calculated performance leakage was less than normal containment leakage or 1.0La. CR-3 selected the revised requirements as its testing program. CR-3's current ten-year Type A test is due to be performed during the upcoming Refuel 12 Outage (R-12) currently scheduled for October 2001.

The change in plant risk was evaluated based on the change in the predicted person-rem/year and Large Early Release Frequency (LERF). There is no impact on core melt frequency.

The steps taken to perform this risk assessment evaluation are as follows:

- Define baseline plant damage states and man-rem estimates
- Calculate Type A leakage estimate to define the analysis baseline
- Calculate Type A leakage estimate to address the current inspection frequency
- Modify Type A leakage estimate to address extension of the Type A test frequency
- Compare analysis metrics to estimate the impact and significance of the increase related to those metrics

The conclusions of the plant risk associated with extending the Type A ILRT test frequency are as follows:

The analysis examined the estimated increase in the CR-3 risk profile associated with changing the ILRT testing interval to once per sixteen years. The ILRT involves Type A testing as defined by Appendix J of 10 CFR 50.

A review of the magnitude of the increased release given a Type A failure compared to other early release sequences indicates that the predicted leakage rate based on historical information

is substantially below that defining a LERF. Further, a bounding assessment equating this predicted leakage rate and associated release to a large early release indicates that the net increase in the LERF would be less than the value defining risk significance.

With regard to the change in population dose, as represented by man-rem, relaxing the testing interval for ILRT from once per ten years to once per sixteen years results in an increase in man-rem of  $8.34E-4$  man-rem per year and represents an fractional increase of approximately 0.06%. For the sixteen-year cycle, this equates to an integrated increase in risk of  $1.33E-2$  man-rem. Extension from the current CR-3 interval of once per ten years to once per sixteen years results in an increase of  $3.94E-4$  man-rem per year with an integrated increase in risk of  $6.32E-3$  man-rem. This increase is deemed not risk significant. Table 15 (included below) summarizes the figures of merit for the analysis.

Summary of Analysis Results

Case	LERF <sup>1</sup>	Frequency Increase Relative to Baseline	Frequency Increase Relative to Current CR3 Interval	Man-Rem/yr	Increase Relative to Baseline	Increase Relative to Current CR3 Interval
Three per 10 years (baseline)	1.18E-06			1.42675		
Once per 10-year (current CR-3)	1.21E-06	2.90E-08		1.42719	4.39E-04 (0.03%)	
Once per 16-year	1.23E-06	5.50E-08	2.61E-08	1.42759	8.34E-04 (0.06%)	3.95E-04 (0.03%)
Once per 18-year	1.24E-06	6.37E-08	3.48E-08	1.42772	9.66E-04 (0.07%)	5.27E-04 (0.04%)
Once per 20-year	1.25E-06	7.24E-08	4.35E-08	1.42785	1.10E-03 (0.08%)	6.59E-04 (0.05%)

1. LERF contribution from leakages identified by Type A testing based on bounding estimate. Historical data has identified no leakage events of sufficient size to result in a LERF contribution.

The summary table can be used to examine the increase in fraction of containment failure sequences as compared to the core damage frequency. The change in containment failure in going from one Type A test per ten years to one Type A test per sixteen years is  $2.61E-08$  divided by the core damage frequency (CDF) from Table 6 of Attachment B or 0.2%. The cumulative change in going from three Type A tests in ten years to one Type A test in sixteen years is  $5.50E-08$  divided by the CDF or 0.4%.

**FLORIDA POWER CORPORATION**

**CRYSTAL RIVER UNIT - 3**

**DOCKET NUMBER 50-302 / LICENSE NUMBER DPR-72**

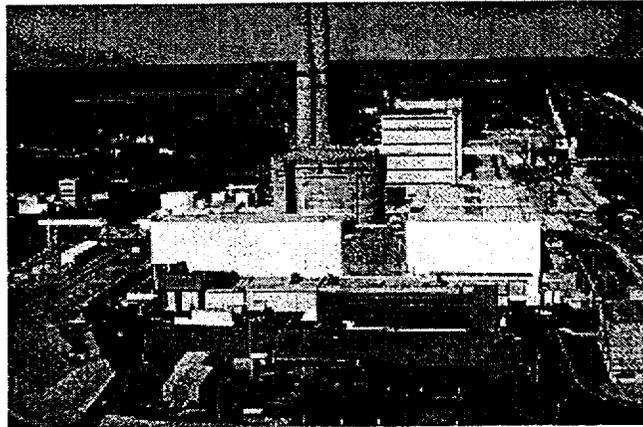
**ATTACHMENT B**

**LICENSE AMENDMENT REQUEST #267, REVISION 1  
Containment Leakage Rate Testing Program**

**FPC Calculation F-01-0001,  
Evaluation of Risk Significance of ILRT Extension**

---

# Crystal River 3 Probabilistic Safety Assessment



## Evaluation of Risk Significance of ILRT Extension

---

Revision 1

April 2001

Principal Analyst

Ricky Summitt

Presented to:

Florida Power

15760 West Power Line Street  
Crystal River, Florida

**RSC Document Configuration Control Form  
FORM NO.: RSC-RPT-STD99-04, Rev. 4**

**Report Number:** RSC 01-10

**Title:** Evaluation of Risk Significance of ILRT Extension

**Revision:** Revision 1

**Author:** Ricky Summitt

Date Completed:	April 19, 2001
Location on Server of Report Files:	\\rscsvr1\RSC_SVR1\RSC_FPC\
Location of Report and Files RSC Site:	Client page
Date of Record for all Models and Analysis	April 19, 2001
Software and Version Used: (bold all that apply)	Word (doc) Version 95, Version 97, <b>Version 2000</b> Excel (xls): Version 95, Version 97, <b>Version 2000</b> Access (mdb): Version 97, Version 2000 Designer (ds4/f): Version 7 CAFTA: Version 3.2b ETA Version 3.2b MAAP BWR Version 3.0B R9, R11, Version 4.0 MAAP PWR Version 18, 19, 20, Version 4.0 RSC Software: PRAMS, SIP, TIFA, BAYESUPDATE



Reviewer Comment	Resolution of Comment
1. The annual man-rem integration should include the period assessed.	Equation modified and recalculated.
2. The >3" isolation faults should be differentiated to produce a split between terminated and further assessed events.	The CR3 IPE combined the two PDSs prior to solving and it is not explicitly separated in the CSET/CET analysis. However, the analysis has split the contributions to RC5xx based on the contributions of the two PDS sequences.
3. The IP3 study adopts a large leakage rate of 35L <sub>a</sub> for class 3B. This study only covers 3 as a combined group. Should the class be split.	The resolution to #2 addresses this concern by expanding the analysis into two isolation failure cases for the PDSs. However, it does not address the issue for Type A faults. The current analysis assumes that only small leakages are possible. This is because the historical data supports only up to 21L <sub>a</sub> . The IP3 study "created" large events to address this issue but failed to include them in the follow-on analysis. The net impact would be small since all leakage is currently placed in the same category and only the man-rem adjusted. The adjustment is based on the observed range. Sensitivity studies of the range to 21L <sub>a</sub> indicate that the results for the 16 year case would not change. It would have no impact on LERF and increase the man-rem by only a factor of two.
4. The analysis should adjust the Class 7 sequences down to account for "earlier" failures due to Type A faults.	Since the Type A faults are not sufficient to preclude further pressurization, they are not removed from the baseline Class 7 sequences. This assumes that subsequent phenomenon-generated faults would result in a significantly higher source term. Early faults are already accounted for in the LERF.
5. Could include a cost-benefit assessment if the cost savings are known.	Currently not required in the scope to match the IP3-type assessment.
6. The man-rem seem substantially below that found in the IP3 study.	The IP3 study addresses the man-rem estimate in parametric fashion by assuming an increase based on that predicted for containment leakage rate given an intact containment. The CR3 study utilizes information that includes plant-specific characteristics including evacuation. The estimate is estimated man-rem and not a "fencepost" dose. It might be useful to do a comparison of the equivalent CR3 estimate to IP3 just to ensure that this inference is correct.
7. The frequency change is from once per 10 years to once per 16, not from 3 per 10. The 3 per 10 should be updated to get 1 for 10 and then go from there.	Documentation corrected to address comments.

*Editorial or illustrative comments are attached to this review sheet to complete the review package.*

Table of Contents

Section	Page
1.0 INTRODUCTION.....	1
2.0 ANALYSIS APPROACH.....	1
3.0 DEFINITION OF ACCIDENT SEQUENCES.....	3
4.0 CALCULATION OF INCREASE IN TYPE-A RELATED LEAKAGE .....	11
5.0 MODIFIED MODEL EVALUATION .....	15
6.0 SUMMARY AND CONCLUSIONS .....	16
7.0 REFERENCES.....	18
A.0 ESTIMATION OF BOUNDING LERF IMPACT .....	A.2
A.1 ESTIMATION OF TYPE A CONTRIBUTION TO LERF .....	A.2
A.2 ESTIMATION OF BASELINE LERF .....	A.3
A.3 ESTIMATION OF IMPACT ON LERF.....	A.5

List of Tables

Table	Page
Table 1 CR3 Core Damage Bin Sequences (from Reference 5).....	4
Table 2 CR3 Plant Damage State Sequences (from Reference 5).....	5
Table 3 CR3 Key Plant Damage States.....	6
Table 4 Contributions of CR3 Key Plant Damage States to Release Categories.....	7
Table 5 Containment Failure Classifications (from Reference 2).....	8
Table 6 CR3 RC Grouping.....	9
Table 7 CR3 Whole-Body Man-Rem by RC Grouping.....	10
Table 8 CR3 RC Baseline Man-Rem and Frequency Information.....	11
Table 9 Probability of Type A Leakage Given a Testing Interval.....	12
Table 10 Type A Leakage Frequency.....	13
Table 11 Comparison of Release Class Doses.....	14
Table 12 Bounding Estimate for Change in LERF.....	14
Table 13 Man-Rem Comparisons.....	15
Table 14 Integrated Man-Rem Estimates.....	16
Table A.1 CR3 PDS Defined LERF Sequences.....	A.3
Table A.2 CR3 RC Grouping.....	A.4
Table A.3 CR3 Baseline LERF.....	A.5
Table A.4 Type A LERF Contribution.....	A.5
Table A.5 Calculation in the Change in LERF.....	A.6

## 1.0 INTRODUCTION

10 CFR 50, Appendix J allows individual plants to extend Type A surveillance testing requirements and to provide for performance-based leak testing. This report documents a risk-based evaluation of the proposed change of the integrated leak rate test (ILRT) test interval for the Crystal River 3 Nuclear Plant (CR3). The proposed change would impact testing associated with the current surveillance test for Type A leakage (procedure SP-178)<sup>1</sup>. No change to Type B or Type C testing is proposed at this time.

The change will increase the frequency of this test from once per ten years to once per sixteen years. This case as well as a case involving a change from three times per ten years to once per sixteen years is provided. As a sensitivity study, frequencies of eighteen and twenty years are also presented. The analysis approach is consistent with guidance provided in EPRI TR-104285<sup>2</sup> and the process identified in NUREG 1493<sup>3</sup>. In addition, the guidance provided in Reg. Guide 1.174<sup>4</sup> is also applied with regard to the use of the risk-based findings in support of a licensing basis change request.

The analysis concentrates on the impact the extended testing interval will have on the risk profile as defined by the change in annual man-rem population dose. Changes in core damage frequency and/or large early release frequency (LERF) are also considered.

The analysis utilizes the results of the CR3 individual plant examination (IPE)<sup>5</sup> for developing the baseline core damage and plant damage states. Although the CR3 level 1 analysis has been updated since the IPE, these updates have not included an update to the level 2 information. Therefore, this document encompasses the most recent level 2 analysis performed for CR3. The level 1 updates have reduced the overall core damage frequency and should decrease the impact of the proposed change.

The man-rem information is based on a study utilizing plant-specific site characteristics and plant damage state/release category information applied to a generic modeling framework<sup>6</sup> using the MACCS2 computer code. Although the referenced work was performed as a pilot project, the results are reasonable and based on actual CR3 information.

Section 2.0 of the document presents a summary of the analysis steps. Section 3.0 presents the CR3 baseline analysis. Sections 4.0 and 5.0 develop the impact of the increased testing interval on the analysis metrics. Section 6.0 summarizes the overall results and conclusions.

## 2.0 ANALYSIS APPROACH

The analysis is based on guidance provided in Reference 2 and uses risk metrics presented in Reference 3 to evaluate the impact of a proposed change on plant risk. Finally, Reference 4 suggests two measures be utilized in the assessment, core damage frequency and LERF. It is these two metrics that are assessed first.

These measures are considered in the determination of the impact of testing extension. CR3 is currently considering an extension from 10 years to 16 years. This period is addressed along with two other periods (18 and 20 years).

Since the testing addresses the ability of the containment to maintain its function, the proposed change has no measurable impact on core damage frequency. Therefore, this attribute remains constant and has no risk significance.

The change in testing interval could impact the ability of the containment to perform its function and this could impact the LERF attribute. Therefore, the estimated change in LERF is addressed.

The change in risk, as defined by the change in annual population man-rem dose is calculated. This metric provides a means to identify the increased risk posed by the change in testing interval.

The basic analysis steps are outlined below:

- Define baseline plant damage states and man-rem estimates
- Calculate Type A leakage estimate to define the analysis baseline
- Calculate Type A leakage estimate to address the current inspection frequency
- Modify Type A leakage estimate to address extension of the Type A test frequency
- Compare analysis metrics to estimate the impact and significance of the increase related to those metrics

The first step in the analysis is to define the baseline plant damage states and man-rem dose measures. Plant damage state information is developed using the CR3 individual plant examination (IPE)<sup>5</sup> results. The plant damage state information and the results of the containment analysis are used to define the sequences. The population man-rem dose estimates for each key plant damage states are based on the information contained in Reference 6.

The information in Reference 6 is based on a more recent solution of the CR3 model. Therefore, the frequency information cannot be used directly. To maintain consistency, the key plant damage state contributions are rebaselined to those found in the CR3 IPE. This process is performed by multiplying each contribution to each release category frequency by the ratio of the values provided in Reference 6 by the values found in the CR3 IPE for each associated key plant damage state. This approach is based on the assumption that the changes in the analysis since the IPE have no impact on the level 2 response such that the release category binning is not impacted. Given that the changes have been associated with the level 1 response modeling, this assumption is reasonable.

The combination of the man-rem for the key plant damage states by the frequency of the key plant damage state estimates the annual man-rem estimate for the plant damage state. Summing these estimates produces the annual man-rem dose based on the sequences defined in the IPE.

The IPE plant damage state definitions include isolation failures due to Type B and Type C faults and examine containment challenges occurring after core damage and/or reactor vessel failure. These sequences are grouped into key plant damage states. Using the plant damage state information, bypass, isolation failures and phenomena-related containment failures are identified.

Once identified, the sequence was then classified by release category definitions specified in Reference 6. With this information developed, the IPE baseline model is completed.

The second step expands the baseline model to address Type A leakage. The CR3 IPE does not explicitly include Type A (liner-related) faults and this contribution must be added to provide a complete baseline. In order to define leakage that can be linked directly to the Type A testing, it is important that only failures that would be identified by Type A testing exclusively be included.

Reference 3 provides the estimate for the probability of a leakage contribution that could only be identified by Type A testing based on industry experience. This probability is then used to adjust the intact containment category of the CR3 IPE to develop a baseline model including Type A faults.

The release, in terms of man-rem, is developed based on information contained in Reference 3. It is estimated as the leakage increase relative to allowable release  $L_a$  (0.25%/day).

The predicted probability of Type A leakage is then modified to address the expanded time between testing. This is accomplished by a ratio of the existing testing interval and the proposed test interval. This assumes a constant failure rate and that the failures are randomly dispersed during the interval between the test.

The change due to the expanded interval is calculated and reported in terms of the change in population man-rem. In addition, the change in large early release frequency is predicted and compared to the acceptance criteria presented in Reference 3.

From these comparisons, a conclusion is drawn as to the risk significance of the proposed change.

### 3.0 DEFINITION OF ACCIDENT SEQUENCES

The CR3 IPE (Reference 5) provides the baseline core damage bin frequency information for the contributing accident sequences. The assessment includes internal initiating events and the total core damage frequency is estimated to be  $1.39E-5$ /yr. Table 1 presents a summary of this information.

Table 1  
CR3 Core Damage Bin Sequences (from Reference 5)

Sequence	Accident Sequence Description	Frequency (/yr)
TBL1U	Transient with failure of secondary-side cooling and HPI cooling	3.35E-6
TBL1L2X	Transient, failure of secondary cooling, successful HPI cooling and failure of HPR cooling	1.47E-7
TQX	Transient with loss of RCS integrity, successful high pressure injection and failure of high pressure recirculation	2.91E-7
TBQX	Transient, loss of secondary cooling, recovery of secondary cooling, loss of RCS integrity, successful HPI and failure of HPR	4.37E-7
SU	Small LOCA with failure of HPI	1.24E-8
SX	Small LOCA with failure of HPR	7.20E-6
MX	Medium LOCA with failure of HPR	1.66E-6
AU	Large LOCA with failure of LPI	1.22E-8
AX	Large LOCA with failure of LPR	1.06E-7
RU	Steam generator tube rupture with secondary-side cooling and failure of HPI	2.95E-7
RXZ	SGTR with secondary-side cooling and HPI, failure to implement DHR cooling, isolate the leakage or refill the BWST	3.07E-7
RBX	SGTR with failure of secondary-side cooling, successful HPI and failure to implement DHR cooling, isolate the leakage or refill the BWST	6.69E-8
	Total:	1.39E-5

These core damage bins in the CR3 IPE were combined with the containment safeguards model to arrive at the plant damage states reported in Reference 5 and summarized in Table 2 below.

Table 2  
CR3 Plant Damage State Sequences (from Reference 5)

Plant Damage State	Accident Sequence Description	Frequency (/yr)
3A	RCS pressure <600 psia at vessel breach, BWST injected into the reactor building prior to vessel failure, containment isolated, containment heat removal available	6.66E-7
3B	RCS pressure <600 psia at vessel breach, BWST injected into RB before vessel breach, containment isolated, CHR only available.	1.12E-6
4B	RCS pressure at vessel breach between 600 psia and 1500 psia, no BWST injection into RB, containment isolated, CHR only available	1.24E-8
4K	RCS pressure at vessel breach between 600 psia and 1500 psia, no BWST injection into RB, small containment bypass, FPS available.	6.69E-7
4L	RCS pressure at vessel breach between 600 psia and 1500 psia, no BWST injection into RB, small containment bypass, FPS not available.	4.57E-9
6A	RCS pressure at vessel breach between 600 psia and 1500 psia, BWST injected into RB, small containment bypass, FPS not available.	3.30E-6
6B	RCS pressure at vessel breach between 600 psia and 1500 psia, BWST injected into RB before vessel breach, containment isolated, CHR only available	4.63E-6
6D	RCS pressure at vessel breach between 600 psia and 1500psia, BWST injected into RB before vessel breach, containment isolated, CHR and FPS not available	4.83E-8
7D	RCS pressure at vessel breach above 1500 psia, no BWST injection into RB, containment isolated, CHR and FPS not available	3.35E-6
7H	RCS pressure at vessel breach above 1500 psia, no BWST injection into RB, containment isolation failure (< 3 in), CHR and FPS not available	6.16E-8
7J	RCS pressure at vessel breach above 1500 psia, no BWST injection into RB, containment isolation failure (> 3 in.), CHR and FPS not available.	3.08E-8
9A	RCS pressure at vessel breach above 1500 psia, BWST injected before vessel breach, containment isolated, CHR and FPS available	7.54E-8
9B	RCS pressure at vessel breach above 1500 psia, BWST injected before vessel breach, containment isolated, CHR only available	7.17E-8

The CR3 IPE groups the PDSs defined in Table 2 into key PDSs (KPDSs). These KPDSs are then propagated through the level 2 analysis to define release categories. The key PDSs are listed below in Table 3.

Table 3  
CR3 Key Plant Damage States

Key Plant Damage State	Frequency (/yr)	Member PDS
K3BA	1.78E-6	3A and 3B
K4K	6.69E-7	4K
K6BA	7.93E-6	6A and 6B
K7D	3.35E-6	7D
K7JH	9.24E-8	7H and 7J

The remaining PDSs were truncated due to their probability being less than one-tenth the frequencies identified in Reference 5. The CR3 IPE identifies release categories for these key PDSs, however, it does not propagate the information to the development of whole-body man-rem. To define this measure, the information contained in the level 3 assessment for CR3 (Reference 6) is utilized.

Reference 6 provides an assessment of offsite consequences based on the key CR3 PDSs. The assessment is based on more recent CR3 results and the total frequency does not match that provided in the IPE. To maintain consistency, the frequencies for the PDSs are adjusted to match those found in the IPE. The contributions to each release category from a particular PDS is defined by the frequency contribution found in Reference 6 multiplied by the ratio of the KPDS value found in Reference 6 and CR3 IPE KPDS value. As shown below:

$$f_{RCxxx | KPDS(i)} = f_{RCxxx(i)} \cdot \frac{f_{KPDS(i)} (Ref 6)}{f_{KPDS(i)} (IPE)}$$

Where:  $f_{RCxxx | KPDS(i)}$  is the rebaselined release category frequency for the analysis,  $f_{RCxxx(i)}$  is the frequency contribution to release category RCxxx as stated in Reference 6 attributed to KPDS(i),  $f_{KPDS(i)}$  is the frequency of KPDS(i) from either Reference 6 (REF6) and the CR3 IPE (IPE).

This approach assumes that the changes in the CR3 model since the IPE have not impacted the distribution of the KPDS amongst the release categories. Since the changes have all related to the core damage (level 1) model, this assumption is reasonable. After the adjustment, the contribution of each PDS to the various release categories is generated and summarized below in Table 4. The release categories (RCs) are described below.

Table 4  
Contributions of CR3 Key Plant Damage States to Release Categories

Release Category	K3BA	K4K	K6BA	K7D	K7JH	Total
RC101	0.00E+00	6.62E-07	0.00E+00	0.00E+00	0.00E+00	6.62E-07
RC102	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RC103	0.00E+00	7.36E-09	0.00E+00	0.00E+00	0.00E+00	7.36E-09
RC501	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RC502	5.35E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.35E-09
RC503	0.00E+00	0.00E+00	5.55E-08	0.00E+00	0.00E+00	5.55E-08
RC504	7.12E-09	0.00E+00	7.93E-09	0.00E+00	0.00E+00	1.50E-08
RC505	0.00E+00	0.00E+00	7.93E-08	0.00E+00	0.00E+00	7.93E-08
RC506	1.42E-08	0.00E+00	7.93E-09	0.00E+00	4.62E-09	2.68E-08
RC507	0.00E+00	0.00E+00	7.93E-09	2.18E-07	8.78E-08	3.14E-07
RC601	4.64E-08	0.00E+00	7.77E-07	0.00E+00	0.00E+00	8.23E-07
RC602	2.50E-08	0.00E+00	5.62E-07	0.00E+00	0.00E+00	5.87E-07
RC603	1.48E-07	0.00E+00	1.66E-07	3.13E-06	0.00E+00	3.45E-06
RC801	2.56E-07	0.00E+00	1.85E-06	0.00E+00	0.00E+00	2.10E-06
RC802	8.95E-07	0.00E+00	8.00E-07	0.00E+00	0.00E+00	1.69E-06
RC901	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RC902	3.84E-07	0.00E+00	3.62E-06	0.00E+00	0.00E+00	4.00E-06

RC1xx represents the SGTR sequences. RC5xx involves early containment faults given containment isolation and are phenomena related faults. RC6xx identifies the catastrophic containment failures late in the accident sequence. RC8xx indicates basemat meltthrough and RC9xx identifies those sequences without failure of the containment throughout the event.

Reference 2 defines eight classifications of containment failures. Type 3 failures, for example, are associated with Type A testing. To define the sequences impacted by the relaxation of Type A testing, the release categories are categorized using the failure classifications. These classifications and an interpretation of each class are provided in Table 5.

Table 5  
Containment Failure Classifications (from Reference 2)

Failure Classification	Description	Interpretation for Assigning CR3 Release Category
1	Containment remains intact with containment initially isolated	Intact containment bins
2	Dependent failure modes or common cause failures	Isolation faults that are related to a loss of power or other isolation failure mode that is not a direct failure of an isolation component
3	Independent containment isolation failures due to Type A related failures	Isolation failures identified by Type A testing
4	Independent containment isolation failures due to Type B related failures	Isolation failures identified by Type B testing
5	Independent containment isolation failures due to Type C related failures	Isolation failures identified by Type C testing
6	Other penetration failures	Other faults not previously identified
7	Induced by severe accident phenomena	Early containment failure sequences as a result of hydrogen burn or other early phenomena
8	Bypass	Bypass sequence or SGTR

The RC frequencies grouped by major RC definition and assigned to Reference 2 classes are presented in Table 6 below.

Table 6  
CR3 RC Grouping

Release Category	Failure Classification	Frequency (/yr)	Comments
RC1xx	Class 8	6.69E-7	SGTR sequences
RC5xx	Class 2/7 <sup>1</sup>	4.96E-7	Early failure due to phenomena or isolation failure
RC6xx	Class 7	4.86E-6	Late failure due to phenomena
RC8xx	Class 7	3.80E-6	Late failure due to phenomena
RC9xx	Class 1	4.00E-6	No containment fault
	Reported Total	1.38E-5	

1. Isolation faults in excess of 3" classified as type 2 due to dependent failure mode.

The release categories are distributed between three classes. Class 1 represents an initially intact containment. Class 8 is a bypass sequence and is associated with SGTR initiating events.

The RC5xx sequences are split. Containment failure sequences are placed in class 7. The isolation failures are placed into Class 2. Based on the core damage bin cutsets supporting these sequences, the most likely cause for a failure of isolation is related to a lack of power and these PDSs are therefore assigned to Class 2 instead of Class 4.

Reference 6 provides a measure of the annual whole-body man-rem for each release category. This information is provided below for the release categories of interest for CR3. Many of the RCs can be combined into more global grouping since the estimated man-rem is essentially the same. This grouping matches that in Table 7.

Table 7  
CR3 Whole-Body Man-Rem by RC Grouping

Release Category	Whole-Body Man-Rem
RC101	2.02E+5
RC103	2.02E+5
RC502	6.57E+5
RC503	6.58E+5
RC504	6.57E+5
RC505	6.58E+5
RC506	6.57E+5
RC507	6.58E+5
RC601	3.79E+4
RC602	1.97E+5
RC603	1.97E+5
RC801	1.21E+3
RC802	1.21E+3
RC902	9.87E+2

Combining the RC frequency information and the man-rem estimates generates the man-rem estimate for CR3. This is presented below in Table 8.

Table 8  
CR3 RC Baseline Man-Rem and Frequency Information

Release Category	Failure Classification	Frequency (/yr)	Whole-Body Man-Rem <sup>1</sup>	Man-Rem/yr
RC1XX	Class 2	6.69E-7	202,000	1.35E-1
RC5XX	Class 2/7	4.96E-7	658,000	3.26E-1
RC6XX	Class 7	4.86E-6	197,000	9.57E-1
RC8XX	Class 7	3.80E-6	1,210	4.59E-3
RC9XX	Class 1	4.00E-6	987	3.95E-3
			Total	1.427E+0

1. Based on the conditions outlined in Reference 5. Includes site-specific population distribution and evacuation.

The information in Table 8 provides the baseline risk profile based on the CR3 IPE. The next section calculates the increased likelihood of a containment leakage being undetected due to the extension of the testing interval for Type A testing. The risk profile for this sequence is also developed.

#### 4.0 CALCULATION OF INCREASE IN TYPE-A RELATED LEAKAGE

In order to determine the impact of the change in testing interval, it is first necessary to define a baseline probability for Type A leakage events and then to adjust this probability to account for the proposed change in testing interval.

Reference 3 states that a review of experience data finds that Type A testing identified only 5 leakage events of the 180 events. Thus about 3% (0.028) of containment leakage events are identified by the ILRT and that the remaining events are identified by the LLRT that is not being evaluated for change. This probability is based on a testing frequency of three tests over a 10-year period and is used to define the baseline for the analysis. A once per ten-year frequency is currently employed at CR3 (Reference 1). Therefore, the first step is to adjust the baseline probability (0.028) to reflect this testing interval.

The impact of relaxing the Type A penetration test interval will increase the average time that a leak that could only be detected by the Type A test would possibly be present. The increase in risk is proportional to the increase in the duration between containment tests. The historical data is based on testing three times per 10 years (120 months). This equates to a mean time between tests of 3.3 years or 40 months. The CR3 testing interval is once per 10 years (120 months). The increase in the exposure time will influence the probability of leakage.

To calculate this impact, two assumptions are made consistent with standard practice and are listed below:

- A constant rate for Type A leakage events;
- The potential for leakage is equally distributed across the period of interest such that the exposure time is reduced by one-half the period.

With these assumptions, the increase can be determined by a ratio of the proposed to the prior exposure times multiplied by the known rate for the prior probability of failure. The equation is shown below:

$$P_{10/1} = P_{10/3} \cdot \frac{0.5 \cdot Exp_{10/1}}{0.5 \cdot Exp_{10/3}}$$

Substituting the values for  $p_{10/3}$  (0.028) and the exposure times ( $Exp_{10/1} = 120$ ,  $Exp_{10/3} = 40$ ) yields a value for the probability of leakage of 0.0833. This value represents the increased likelihood of Type A leakage given the CR3 current testing interval.

The proposed CR3 frequency extension would increase the duration between tests by increasing the time between tests from 10 years to 16 years. Therefore, the total time between Type A testing will increase from 10 years (120 months) to 16 years (192 months). The same equation is again utilized with the variables altered to reflect the specific bounds as shown below:

$$P_{16} = P_{10} \cdot \frac{0.5 \cdot Exp_{16}}{0.5 \cdot Exp_{10}}$$

Substituting yields a value of 0.133 for the probability of Type A (ILRT) detectible leakage events for the relaxed testing interval of 16 years. This probability represents the probability of a leakage path that could only be identified by a Type A test. Similar calculations are generated for the 18- and the 20-year testing intervals. The results are summarized below in Table 9.

Table 9  
Probability of Type A Leakage Given a Testing Interval

Case	Probability of Leakage
Three per 10 years (baseline)	0.028
10 year testing (current CR3 frequency)	0.083
16 year testing	0.133
18 year testing	0.150
20 year testing	0.167

The baseline analysis must include the consideration being assessed in order to preclude biasing the results. The existing analysis does not account for Type A faults. The model is expanded to encompass Type A faults. The intact containment cases are adjusted to include these isolation failures. Since other sequences represent failure they are not adjusted.

The intact containment frequency from the CR3 IPE (4.00E-6) is multiplied by the potential for Type A leakage (0.028) for the baseline case to generate the frequency contribution associated with Type A leakage (1.11E-7/yr). The intact containment contribution is then reduced by this value to maintain the overall frequency (3.89E-6). Each extended case is addressed in a similar manner. Table 10 summarizes the results for each case.

Table 10  
Type A Leakage Frequency

Variable	3 per 10 year case (baseline)	Once per 10 year case	Once per 16 year case	Once per 18 year case	Once per 20 year case
Testing Interval (years)	3	10	16	18	20
Intact Containment Frequency (class 1)	4.00E-06	4.00E-06	4.00E-06	4.00E-06	4.00E-06
Baseline Probability Type A Fault	2.8%	2.8%	2.8%	2.8%	2.8%
Extension (years/test)	0	3	6	8	10
Modified Probability of Type A Faults	2.8% <sup>1</sup>	8.33%	13.3%	15.0%	16.7%
Contribution from Type A faults	1.11E-07	3.33E-07	5.33E-07	6.00E-07	6.67E-07
Revised Intact Containment Freq (class 1)	3.89E-06	3.67E-06	3.47E-06	3.40E-06	3.34E-06

1. No modification since baseline value.

In order to develop the estimate for man-rem, it is necessary to determine the magnitude of the expected release for Type A leakage. Information in Reference 3 indicates that the typical leakage from a Type A failure is on the order of  $2L_a$  where  $L_a$  represents the allowable leakage rate.

Release category RC9xx represents the intact containment case for CR3 and is the best representation of the man-rem estimate for this leakage rate. The expected population dose for this release category is 987 man-rem. The dose rate from this release category is selected and then doubled to define the expected release for the Type A leakage of 1974 man-rem (987\*2).

This new release category must be compared to other sequences to determine if it represents an increase in LERF. In order to be a LERF sequence, it must be both early in time and large in population dose. The first condition is met since the failure represents an existing isolation failure. However, the dose is small compared to other early sequences. Table 11 compares the doses for this and several other cases.

Table 11  
Comparisons of Release Class Doses

Release Class	Population Dose (Man-Rem)
RC5xx	657,000
RC1xx	202,000
RC0 (Type A leakage)	1,974

The Type A man-rem estimate is shown to be substantially (less than 1%) of the other early releases. Therefore, the potential consequence is not a LERF sequence and the proposed change has no impact on LERF.

No examples of Type A leakage sufficient to be considered LERF are identified in the historical data. However, an estimate for LERF is calculated for comparison using the Reg. Guide 1.174 risk criterion for change in LERF and is documented in Appendix A. The approach utilizes a chi-square distribution to generate a 95%-tile value for the probability that a Type A failure will be of sufficient size to contribute to LERF. This value is then applied to the probability of Type A leakage to estimate the Type A LERF fraction. Multiplying this value by the intact containment frequency yields a bounding estimate for Type A LERF. The net increase between the baseline and 16-year case is then calculated. The results are summarized in Table 12.

Table 12  
Bounding Estimate for Change in LERF

Case	Three per Ten Year (Baseline)	Once per Ten Year (Current CR3)	Once per 16 year case
Total LERF	1.18E-6	1.21E-6	1.23E-6
Delta LERF (3 per 10 to once per 16 years)			5.50E-8
Delta LERF (once per 10 to once per 16 years)			2.61E-8

The results indicate a small increase in LERF. The increase is less than the frequency increase that defines a risk significant change (Reference 4) and the relaxed testing interval does not represent a significant risk impact based on a change in LERF.

**5.0 MODIFIED MODEL EVALUATION**

The information provided in Section 4.0 develops an estimate of the increase in the likelihood of a containment isolation failure given that the Type A ILRT testing interval is extended. An increase in the testing interval from once per 10 to once per 16 years increases the probability of a Type A detectible leakage by 0.05. This increase is used to adjust the baseline model defined in Section 4.0 to determine the estimated man-rem.

The baseline model results must be adjusted to address this increase likelihood of increased containment leakage. Only certain sequences would be impacted by this increase since many sequences already involve an impaired containment or isolation failure. Basically only intact containment scenarios need be addressed.

PDS Sequences that already represent release sequences are excluded. The intact containment sequences are combined with the increased probability of leakage (0.05) to define a new contribution to increased leakage. The resulting change in man-rem is summarized below in Table 13.

Table 13  
Man-Rem Comparisons

Case	Man-Rem/yr	Delta Man-Rem Relative to Baseline <sup>1</sup>	Percent Man-Rem Increase Relative to Baseline	Delta Man-Rem Relative to Current CR3 Interval <sup>1</sup>	Percent Man-Rem Increase Relative to Current CR3 Interval
Three per 10 years (baseline)	1.42675				
Once per 10-year (current CR3)	1.42719	0.00043909	0.03%		
Once per 16-year	1.42759	0.00083427	0.06%	0.00039518	0.03%
Once per 18-year	1.42772	0.00083427	0.07%	0.00052690	0.04%
Once per 20-year	1.42785	0.00109772	0.08%	0.00065863	0.05%

1. Significant digits only provided to ensure change is presented.

The net increase in man-rem per year between the 3 tests per 10-year baseline and the one test per 16-year case is estimated to be 0.06% (0.0006). The increase reflects an integrated man-rem increase of approximately 0.0133 man-rem if the 16-year interval is adopted. Extending the testing interval from the current once per 10 years to once per 16 years results in a 0.03% increase and an integrated man-rem increase of 0.00632. The integrated results are presented for all cases in Table 14.

Table 14  
Integrated Man-Rem Estimates

Case	Man-Rem/yr	Delta Man-Rem Relative to Baseline	Integrated Man-Rem Increase Relative to Baseline	Delta Man-Rem Relative to Current CR3 Interval	Integrated Man-Rem Increase Relative to Current CR3 Interval
Three per 10 years (baseline)	1.42675				
Once per 10-year (current CR3)	1.42719	0.00043909	4.39E-03		
Once per 16-year	1.42759	0.00083427	1.33E-02	0.00039518	6.32E-03
Once per 18-year	1.42772	0.00083427	1.74E-02	0.00052690	9.48E-03
Once per 20-year	1.42785	0.00109772	2.20E-02	0.00065863	1.32E-02

1. Net increase relative to the period being assessed for extension (10, 16, 18 or 20 years).

## 6.0 SUMMARY AND CONCLUSIONS

The analysis examined the estimated increase in the CR3 risk profile associated with changing the ILRT testing interval from the current once per ten years to once per 16 years. A testing frequency of three tests per 10 years is also assessed in addition to the current CR3 testing interval. Sensitivity studies were also provided for 18- and 20-year periods.

The analysis utilizes the approach similar to that defined in Reference 2 with consideration of the guidance provided in Reference 4 with regard to the performance of risk-based assessments. Reference 4 defines two measures, core damage and LERF, to be addressed. Since the proposed extension has no impact on core damage, this measure is not considered relevant and is not addressed.

The ILRT involves Type A testing as defined by Appendix J of 10CFR50. Generic analyses have indicated that this test only identifies a limited number of isolation failure modes and that many failure modes are more easily identified during Type B and C testing.

The existing CR3 IPE analysis (Reference 5) is used to define the CR3 current risk profile. Documentation contained in this analysis is used to define the plant damage state frequency and release category frequency. This information is then used to define the LERF and man-rem risk measures. The man-rem risk measure was calculated using the release category information and information contained in Reference 6.

A likelihood of failing to identify a containment isolation failure due to the extension of the ILRT testing interval was determined based in information contained in Reference 2. This reference provides an estimate of isolation faults identified by ILRT testing relative to other isolation test activities (LLRT) based on reported industry experience. The net change identifies

the increase in the likelihood of containment isolation failure. The increased value was then incorporated into the analysis and a modified release category distribution calculated.

A comparison of the magnitude of the Type A failure release, in terms of man-rem, to other early release sequences indicates that the predicted leakage rate based on historical information is substantially below that defining LERF and the change has no impact on LERF.

Further, a bounding assessment based on the premise that such a leakage rate is possible indicates that the net increase in the LERF would be less than the value defining possible risk significance (Reference 4).

With regard to the change in population dose, as represented by man-rem, relaxing the testing interval for ILRT from three per 10 years to once per 16 years results in an increase in man-rem of  $8.34\text{E-}4$  man-rem per year and represents an fractional increase of approximately 0.06%. For the 16-year cycle, this equates to an integrated increase in risk of  $1.33\text{E-}2$  man-rem.

Extension from the current CR3 interval of once per 10 years to once per 16 years results in an increase of  $3.94\text{E-}4$  man-rem per year with an integrated increase in risk of  $6.32\text{E-}3$  man-rem. This increase is deemed not risk significant. Table 15 summarizes the figures of merit for the analysis.

Table 15  
Summary of Analysis Results

Case	LERF <sup>1</sup>	Frequency Increase Relative to Baseline	Frequency Increase Relative to Current CR3 Interval	Man-Rem/yr	Increase Relative to Baseline	Increase Relative to Current CR3 Interval
Three per 10 years (baseline)	1.18E-06			1.42675		
Once per 10-year (current CR3)	1.21E-06	2.90E-08		1.42719	4.39E-04 (0.03%)	
Once per 16-year	1.23E-06	5.50E-08	2.61E-08	1.42759	8.34E-04 (0.06%)	3.95E-04 (0.03%)
Once per 18-year	1.24E-06	6.37E-08	3.48E-08	1.42772	9.66E-04 (0.07%)	5.27E-04 (0.04%)
Once per 20-year	1.25E-06	7.24E-08	4.35E-08	1.42785	1.10E-03 (0.08%)	6.59E-04 (0.05%)

1. LERF contribution from leakages identified by Type A testing based on bounding estimate. Historical data has identified no leakage events of sufficient size to result in a LERF contribution.

As shown, similarly small increases were identified for the 18 and 20-year cases. From these results it is concluded that a cost-benefit assessment would favor the cost reduction posed by extending the testing interval for the ILRT over the increase in risk.

## 7.0 REFERENCES

1. Containment Leakage Test-Type "A", Including Liner Plate, Rev. 24, Florida Power Corporation, SP-178, March 14, 2000.
2. Gisclon, J. M., et al, Risk Impact Assessment of Revised Containment Leak Rate Testing Intervals, Electric Power Research Institute, TR-104285, August 1994.
3. Performance-Based Containment Leak-Test Program, USNRC, NUREG-1493, July 1995.
4. An Approach for Using Probabilistic Risk Assessment in Risk-Informed decisions on Plant-Specific Changes to the Licensing Basis, U.S. Nuclear Regulatory Commission (USNRC), Regulatory Guide 1.174, July 1998.
5. Crystal River 3 Individual Plant Examination, Florida Power Corporation, March 1993.
6. Generic Level 3 PRA for Crystal River 3, B&W Owners Group Risk-Informed Applications Committee, BAW-2369, May 2000.
7. PRA Procedures Guide - A Guide to the Performance of Probabilistic Risk Assessments for Nuclear Power Plants, American Nuclear Society and the National Institute of Electrical and Electronic Engineers, NUREG/CR-2300, January 1983.

Appendix A  
Estimation of Early Release Frequency

## A.0 ESTIMATION OF BOUNDING LERF IMPACT

The information provided in References 2 and 3 indicate that the historical leakage rates are not sufficient to result in a situation defined as large-early release. Therefore, the current data supports the supposition that the relaxed testing interval will not have a measurable impact on large early release fraction (LERF).

However, the data does not preclude events that may occur at a lower probability than would be supported by the data collected to date. As a sensitivity study, the probability of larger leakage rates is conservatively estimated. Using the estimated probability and the plant damage state information presented in the CR3 IPE an estimate of LERF is defined for both the baseline model and the 16-year frequency.

### A.1 ESTIMATION OF TYPE A CONTRIBUTION TO LERF

The LERF contribution is based on estimation of the frequency through the use of a chi-square distribution to develop an upper estimate as defined by Reference 7. The chi-square distribution can provide an upper bound given no events. The general equation is presented below:

$$p(\alpha) = \frac{\chi(2F + 2, \alpha)}{2N}$$

where: N is the number of events, F is the number of events of interest,  $\alpha$  is the percentile distribution (assumed to be the 95%-tile).

This equation is used to estimate the probability that, given a leak, it will be sufficiently large to represent a LERF contributor. For this estimate, the following is supplied: N=23 events, F=0 LERF events.

Substitution yields the following:

$$p(\alpha) = \frac{\chi(2, 0.05)}{46}$$

Solving for the probability yields a value of 0.13 (5.99/46). This probability represents a probability that given a leak event, it will be sufficiently large to contribute to LERF. The probability of a Type A failure sufficient to contribute to LERF is found by multiplying the probability of a Type A leak (0.028) and the probability that the leak will be sufficiently large to generate a LERF contributor (0.13). This equates to a probability of a Type A LERF contributor of 3.6E-3 for the case involving three tests per 10 years (baseline). The same process is applied for the current CR3 interval of once per 10 years given that the probability of leakage increases to 0.0833. Solution yields the probability of a Type A LERF contributor of 1.085E-2 for this case. For the case involving a 16-year interval, the probability of a leak increases to 0.133. Thus, the probability of a Type A LERF contributor is estimated as 1.74E-2 for the 16-year case.

With the LERF contributor estimated, the next section defines the baseline LERF.

## A.2 ESTIMATION OF BASELINE LERF

The baseline LERF is defined by collecting any frequency for KPDSs that:

- Involve an early containment isolation failure
- Involve a bypass failure
- Involve early containment failure at or near reactor vessel failure.

Since the potential for containment challenges is addressed in the containment event tree (CET) the last item must be addressed later in the definition of release categories. However, the LERF attributed to the first two conditions can be defined by the PDSs.

Isolation failures must be sufficiently large to preclude any future challenges. For example, an isolation failure must be of sufficient size to mitigate pressure challenges that could occur at reactor vessel failure, e.g., loads from high pressure melt ejection. If this condition is not met, the failure is not sufficient large to meet the definition of a LERF contributor. Table A.1 presents the assessment of the plant damage states to define the LERF fraction for the first two conditions.

Table A.1  
CR3 PDS Defined LERF Sequences

Plant Damage State	LERF Screening	Frequency (/yr)
3A	Containment isolated so not meet the LERF criterion 1 or 2	
3B	Containment isolated so not meet the LERF criterion 1 or 2	
4B	Containment isolated so not meet the LERF criterion 1 or 2	
4K	Small containment bypass. Meets criterion 2.	6.69E-7
4L	Small containment bypass, Meets criterion 2.	4.57E-9
6A	Small containment bypass, Meets criterion 2, however, the size is not sufficient to preclude later loads	
6B	Containment isolated so not meet the LERF criterion 1 or 2	
6D	Containment isolated so not meet the LERF criterion 1 or 2	
7D	Containment isolated so not meet the LERF criterion 1 or 2	
7H	Containment isolation failure (< 3 in). Meets criterion 1, however, the size is not sufficient to preclude later loads	
7J	Containment isolation failure (> 3 in.). Meets criterion 1	3.08E-8

Plant Damage State	LERF Screening	Frequency (/yr)
9A	Containment isolated so not meet the LERF criterion 1 or 2	
9B	Containment isolated so not meet the LERF criterion 1 or 2	
	LERF Contribution (criterion 1 or criterion 2)	7.04E-7

The PDSs are propagated through the containment event tree (CET) to define the frequency of release categories. The release categories define the final accident state with regard to radionuclide contribution, release timing and containment state.

The CET propagation encompasses the containment phenomena and the potential for containment failure given a pressure or temperature challenge of the containment. The RC frequencies grouped by major RC definition and assigned to Reference 2 classes are presented in Table A.2 below.

Table A.2  
CR3 RC Grouping

Release Category	Failure Classification	Frequency (/yr)	Comments
RC1xx	Class 8	6.69E-7	SGTR sequences
RC5xx	Class 2/7 <sup>1</sup>	4.65E-7 <sup>2</sup>	Early failure due to phenomena
RC6xx	Class 7	4.86E-6	Late failure due to phenomena
RC8xx	Class 7	3.80E-6	Late failure due to phenomena
RC9xx	Class 1	4.00E-6	No containment fault
	Reported Total	1.38E-5	

1. Isolation faults in excess of 3" classified as type 2 due to dependent failure mode. For this assessment, however, the difference is not important since both are LERF sequences.
2. Value adjusted to reflect PDS-defined LERF contributions.

RC1xx represents the SGTR sequences. RC5xx involves early containment faults given containment isolation and are phenomena related faults. RC6xx identifies the catastrophic containment failures late in the accident sequence. RC8xx indicates basemat meltthrough and RC9xx identifies those sequences without failure of the containment throughout the event.

The RC5xx RCs represent early failures and are defined as being applicable for criterion 3 associated with the definition of LERF. Therefore, the frequency attributed to RC5xx (4.65E-7/yr) is included in the baseline LERF. The total baseline LERF is defined below in Table A.3.

Table A.3  
CR3 Baseline LERF

Contribution	Frequency (/yr)
LERF Criterion 1 and Criterion 2 (from PDS)	7.00E-7 <sup>1</sup>
LERF Criterion 3	4.65E-7
Total Baseline LERF	1.16E-6

1. Due to rounding and truncation in the CET quantification the sum does not equal that presented for the PDSs.

### A.3 ESTIMATION OF IMPACT ON LERF

The LERF contribution defined in Table 9 does not include the impact of Type A leakage events. This contribution is developed in Section A.1 and must be added to provide a basis comparison.

The Type A LERF contribution is determined by multiplying the probability of a LERF sequence defined in Section A.1 by the intact containment contribution in the same manner as the Type A sequence contribution was developed. Table A.4 summarizes the calculations for three cases, 3 tests per 10 years, the current CR3 testing frequency and the proposed testing frequency.

Table A.4  
Type A LERF Contribution

Variable	Three per Ten Year (Baseline)	One per Ten Year (Current CR3)	16 year period case
Testing Interval (years)	3	10	16
Intact Containment Frequency (class 1)	4.00E-06	4.00E-06	4.00E-06
Probability Type A LERF Fault	0.13	0.13	0.13
Probability of Type A LERF Contributor Given Fault	0.028	0.083	0.133
LERF Fraction	0.0036	0.0108	0.0174
Type A LERF	1.45E-08	4.35E-08	6.95E-08

The calculated Type A LERF is added for three cases and the difference calculated for the baseline frequency to 16 years and for the current CR3 frequency to 16 years. The results represent the increase in LERF due to the relaxation of the testing interval. The results are presented in Table A.5.

Table A.5  
Calculation in the Change in LERF

Variable	Three per Ten Year (Baseline)	Once per Ten Year (Current CR3)	Once per 16 year case
Baseline LERF	1.16E-6	1.16E-6	1.16E-6
Type A LERF	1.45E-8	4.35E-8	6.95E-8
Total LERF	1.18E-6	1.21E-6	1.23E-6
Delta LERF (3 per 10 to once per 16 years)			5.50E-8
Delta LERF (once per 10 to once per 16 years)			2.61E-8

Reference 3 defines a set of risk significance criteria. The following summarizes the criteria:

- If the calculated increase is very small, which is taken as being less than  $10^{-7}$  per reactor year, the change is typically considered to be an insignificant increase in risk.
- If the increase is in the range of  $10^{-7}$  per reactor year to  $10^{-6}$  per reactor year, proposed change will be considered only if it can be reasonably shown that the total LERF is less than  $10^{-5}$  per reactor year.
- If the result shows an increase above  $10^{-6}$  per reactor year, the proposed change would not normally be considered

A comparison of the results to these criteria indicate that the change in LERF is below the level differentiating risk significance and the net change is not risk significant. This result is based on assuming a conservative estimate for the potential for a Type A failure resulting in a LERF sequence. A more realistic value would most likely result in a further reduction in the change in LERF and further support this conclusion.

**FLORIDA POWER CORPORATION**

**CRYSTAL RIVER UNIT - 3**

**DOCKET NUMBER 50-302 / LICENSE NUMBER DPR-72**

**ATTACHMENT C**

**LICENSE AMENDMENT REQUEST #267, REVISION 1  
Containment Leakage Rate Testing Program**

**Generic Level 3 PRA for Crystal River 3, B&W Owners Group  
Risk-Informed Applications Committee, BAW-2369, May 2000**

*THE  
B&W*

# *OWNERS GROUP*

**Risk-Informed Applications Committee**

**Generic Level 3 PRA  
for  
Crystal River-3**



June 19, 2000  
FTI-00-1568

Mr. D. N. Miskiewicz  
Florida Power Corporation  
Crystal River Energy Complex  
15760 W. Power Line Street  
Crystal River, FL 34428-6708

Subject: FPC Contract N01497AD, FTI No. 7807  
FTI Job 4110171 – Generic Level 3 PSA (EB-96-06)

Dear Mr. Miskiewicz:

The enclosed report, BAW 2369 "Generic Level 3 PRA for Crystal River-3," FTI Document 47-2369-00, dated May 2000 is the deliverable for the subject job. Delivery of this report combined with the on-site technology transfer that occurred on February 9, 2000 constitutes FTI contract fulfillment for this project. This report is only being distributed to Florida Power Corporation since it is a plant-specific report. If additional information or assistance is required, please feel free to contact me at 804/832-2684.

Sincerely,

A handwritten signature in black ink that reads "Michael W. Epling".

Michael W Epling  
Project Manager  
B&W Owners Group Services

MWE\kab

c: without enclosure  
S. L. Bernhoft  
C. J. Hudson/FL77

**BAW- 2369**

**Generic Level 3 PRA for Crystal River-3**

prepared by

Framatome Technologies, Inc.

and

Duke Power Company

for the B&W Owners Group  
Risk-Informed Applications Committee

May 2000

## Table of Contents

Table of Contents .....	iii
List of Tables .....	iii
1. Introduction.....	1
2. Development of the MACCS2 input files.....	2
2.1 Meteorological File (cr3met.inp).....	3
2.2 Site File (cr3site.inp) .....	4
2.3 ATMOS File (cr3atmos.inp) .....	5
2.4 EARLY File (cr3early.inp).....	12
2.5 CHRONC File (cr3chrnc.inp) .....	13
3. Execution of MACCS2 .....	14
4. Output of MACCS2 .....	14
5. Risk Spreadsheet.....	16
5.1 Introduction .....	16
5.2 Using the Risk Calculation Spreadsheet.....	16
5.2.1 Run a Calculation .....	17
5.2.2 Review Results .....	19
5.2.3 End.....	19
References.....	24
List of Attachments.....	25

## List of Tables

Table 1 -- Changes to Supplied CR-3 Meteorological File.....	3
Table 2 -- Comparison of Base Case with Modified Watershed Index Case.....	5
Table 3 -- Mapping of CR-3 Release Categories to Oconee Release Categories .....	5
Table 4 -- Assignment of RCxxx Release Categories to CR-3 Release Categories .....	6
Table 5A -- Oconee Release Category Parameter Values Used for CR-3 .....	8
Table 5B -- Oconee Release Category Parameter Values Used for CR-3 .....	8
Table 6 -- "Tweaked" Values of Sr Release Category to Handle Identical Change Records.....	9
Table 7 -- CR-3 Source Term Input in Curies and Bequerels.....	10
Table 8 -- CR-3 Parameter Values used to Develop the ATMOS File.....	11
Table 9 -- CR-3 Parameter Values used to Develop the EARLY File.....	12
Table 10 -- Spreadsheet Options Defined by Task .....	18

## 1. Introduction

This document details the development of the inputs needed to perform a (generic) level 3 probabilistic risk assessment (PRA) for Crystal River-3 (CR-3) and discusses the results of the calculation. The *generic* analysis is based on the level 3 analysis that Duke Power Co. originally performed for Oconee with CRAC2. The CRAC2 input files have been converted to MACCS2 input files producing reasonable and consistent results. Since this is a generic analysis, many of the assumptions used by Duke are also incorporated into the CR-3 analysis, most notably the use of many default MACCS2 input parameters. Thus, all the capabilities of MACCS2 have not been exercised in the generic analysis, however, sensitivity runs can be easily set up and run to investigate the effects of changing the input parameters.

Two additional areas of specificity driven by the Oconee analysis are the use of Duke's syntax for release categories (see Section 2.3) and the layout and format of output reports created by the risk spreadsheet (see Section 5). The choice of output variables selected were the same as Duke's analysis (i.e., early fatality risk, early injury risk, latent fatality risk, thyroid nodule risk, and whole-body person Rem); these, however, can be changes, as described in Section 5.

There are two general areas for which input is required from all the utilities participating in the B&W Owners Group's Generic Level 3 PRA, sponsored by the Risk-Informed Applications Committee (RIAC). The first area is the input required to execute the MACCS2 code (Version 1.12), which is used to calculate the health and economic consequences of accidental releases of radioactive material to the atmosphere. The principal phenomena considered in MACCS (the immediate predecessor of MACCS2) are atmospheric transport, short-term and long-term mitigative actions and pathways, deterministic and stochastic health effects, and economic costs. [1]

The second area is the input necessary for the Risk Calculation Spreadsheet (risk spreadsheet) developed by Duke Power Company that provides a linkage between the Level 1 PRA and Level 2 PRA results, and the Level 3 PRA analysis. Using the risk spreadsheet facilitates the ability to update the Level 3 PRA results when there are changes in the Level 1 and Level 2 analysis through the course of normal updates due to model changes, new data, plant modifications, etc.

The input requested of CR-3 to perform a generic level 3 PRA has been split into two requests, one focusing on the results of the Level 2 PRA (for both MACCS2 input and risk spreadsheet input). The second part of the request is for additional plant-specific inputs for MACCS2. These requests are provided in Attachments A and B. The analysts have made judgements about which MACCS2 inputs can be treated generically. For each plant-specific run of MACCS2, these inputs should be reviewed by the participating utility for their validity.

To confirm execution of the MACCS2 code, Sample Problem A, whose output is presented in Appendix C of Reference [1], was run. The input files (in1a.inp, in1b.inp, in1c.inp, metsur.inp, and sursit.inp) were loaded from the MACCS2 installation CD (into subdirectory MACCS2). Upon successfully execution, the output file (lista\_n.out), also loaded from the installation CD, was compared to the new output file. The only differences in the two output files related to header lines that contained dates and/or times, and output lines that reported the CPU time

required for MACCS2 execution. Accordingly, it was concluded that the executable MACCS2 files generated results consistent with the documentation [1] provided.

## 2. Development of the MACCS2 input files

Five input files are developed to run the MACCS2 code. These are:

- Meteorological file  
This file contains one year of site-specific meteorological data consisting of hourly readings of the wind direction, wind speed, atmospheric stability, and accumulated precipitation. Details, including file format, for the meteorological file can be found in Appendix A, Section A.1, of Ref. [1].
- Site file  
This file contains site-specific population and land usage data. Included in the site file are: site spatial intervals, population distribution, fraction of the area that is land, watershed data, information on agricultural use, and regional economic information. Details, including file format, for the site file can be found in Appendix A, Section A.3, of Ref. [1].
- EARLY file  
In the EARLY module, MACCS2 models the time period immediately following a radioactive release. The EARLY file contains parameters that specify emergency response scenarios that include evacuation, sheltering, and dose-dependent relocation. Other inputs include organ definition data, shielding and exposure data, early fatality and injury data, and cancer models. Details, including file format, for the EARLY file can be found in Section 6 of Ref. [1].
- ATMOS file  
In the ATMOS module, MACCS2 calculates the dispersion and deposition of material released to the atmosphere as a function of downwind distance. The ATMOS file contains radioisotope data, wet and dry deposition data, dispersion parameter data, plume and wake effects data, release description data (e.g., height of release, energy of release, etc.), and meteorological modeling parameters. Details, including file format, for the ATMOS file can be found in Section 5 of Ref. [1].
- CHRONC file  
The CHRONC module simulates the events that occur following the emergency-phase time modeled by the EARLY module. This module calculates the individual health effects that result from both direct exposure and indirect health effects. CHRONC also can calculate economic costs.

## 2.1 Meteorological File (cr3met.inp)

Raymond A. Crandall (raymond.a.crandall@fpc.com) of Florida Power Co. (FPC) (352-795-6486 x-3865) provided a meteorological (met) file, **CR3Met\_data98.txt**. This file is over 150 pages, and is only provided in as an electronic file. The file was examined and a series of observations were made, leading to some file changes that are discussed below in Table 1. The resulting file (formatted for use as an input file to MACCS2) is named **cr3met.inp**; it is provided, in its entirety, in Attachment C. The items in Table 1 were discussed with Ray Crandall, at which time he agreed to the proposed changes.

**Table 1 -- Changes to Supplied CR-3 Meteorological File**

Meteorological File Identifier		Value		Comment
Day	Hour	Original	New	
-----	-----	<b>Stability Category</b>		-----
29	23	0	5	Value of "0" is not a valid stability class. Each value was changed to "5" as indicated by values that come before and after the "0" value.
47	13	0	5	
47	14	0	5	
-----	-----	<b>Precipitation</b>		-----
47	14	700	0	These unreasonable high values were identified to R. Crandall who confirmed them to be erroneous mostly due to equipment calibration.
55	10	996	0	
222	20	9521	0	
-----	-----	<b>Wind Speed</b>		-----
47	13	0	15	New value of "15" are based on values that are observed before and after the "0" values.
47	14	0	15	
78	12	0	39	New value of "39" is the average of the value observed immediately before (51) and after (27) the string of "0" values.
through		0	39	
92	16	0	39	
93	8	0	47	New value of "47" is the average of the value observed immediately before (17) and after (76) the string of "0" values.
through		0	47	
93	15	0	47	
94	8	0	59	New value of "59" is the average of the value observed immediately before (63) and after (55) the string of "0" values.
through		0	59	
94	13	0	59	
222	18	0	152	New value of "152" is the average of the value observed immediately before (296) and after (7) the string of "0" values.
222	19	0	152	
222	20	0	152	
-----	-----	<b>Wind Speed</b>		-----
97	14	306	300	Wind speed exceed upper limit of MACCS2 input range. All values adjusted to upper limit (300).
97	17	315	300	
222	16	330	300	
-----	-----	<b>Wind Direction</b>		-----
47	13	9	4	Replace apparent default "9" with a "4," direction with max. population (conservative).
47	14	9	4	

Meteorological File Identifier		Value		Comment
Day	Hour	Original	New	
78	12	9	4	Replace apparent default "9" with a "4," direction with max. population (conservative).
through		9	4	
92	16	9	4	Replace apparent default "9" with a "4," direction with max. population (conservative).
93	8	9	4	
through		9	4	
93	15	9	4	Replace apparent default "9" with a "4," direction with max. population (conservative).
94	8	9	4	
through		9	4	
94	13	9	4	

Note that the wind direction for day 222, hours 18 through 20 were not changed to "4" since the original wind directions were not the apparent default value (when wind speed was recorded as 0) of "9." Accordingly, the original values were left unchanged.

## 2.2 Site File (cr3site.inp)

The site file was prepared with the estimated year 2000 population data taken from the CR-3 FSAR (Rev. 25.5) [Ref. 2, Figure 2-6]. The population data for each spatial element is also included as a table in the Excel file **CR3 Population Data.xls**, provided only electronically. The population data was copied (from tab *Site Data*) onto a new worksheet (tab *Population*). The format was changed to accommodate the fixed format for the site file (i.e., 8E10.0). After the first eight values, it was necessary to continue the data on a new line. This is also shown in the *Population* tab. This information is then saved as a formatted text (space delimited) \*.prn file in a temporary file, where it was copied and pasted into the site file. This process was repeated for the other inputs to the site file, as indicated by the tab names: *Land Fraction*, *Region Index*, and *Watershed*. The site file, named **cr3site.inp** (formatted for use as an input file to MACCS2), is provided in Attachment D.

The spatial grid provided by CR-3 consisted of spatial intervals (e.g., concentric rings) with radii of 1, 2, 3, 4, 5, 10, 20, 30, 40, 50 miles and 16 wind directions.

The input provided by R. Crandall indicated that the land fraction should be assigned a "1" wherever there was population, and a "0" where there was no population. However, a review of a map in the CR-3 FSAR (Rev. 25.5) [Ref. 2, Figure 2-5] showed that there were some areas of zero population that were land (not water); these were evident at a radius of 3 miles (and less) from the site, as well as at some spatial cells at 4 miles and 5 miles. Accordingly, for the first three entire spatial intervals and for part of the fourth and fifth spatial interval, the "no population" rule was not used; land was assumed from the NNW sector sweeping clockwise to (and including) the S sector.

Similar logic was used to assign the region index, which was either "8" for Florida or "50" for ocean. For the watershed index, since a spatial region was assumed to be either land or ocean

(i.e., no rivers or lakes considered within the 50 mile radius), an index value of “2” was used for all spatial elements. (Note that this is contrary to the original direction provided by R. Crandall, who indicated the use of “1” for spatial elements with population and “2” for spatial elements with no population. The distinction is not by population, but rather “river or lake” versus “ocean or land.” The watershed index value of “1” is only used when a spatial grid element contributes to any drinking water. Subsequent discussions with D. Miskiewicz and R. Crandall indicated that there was a large number of small rivers located with the 50-mile radius of the plant, in which deposition could contribute to drinking water and should have an index of “1.” Accordingly, a sensitivity case was performed using a modification of Crandall’s original guidance, that is, using a “1” for every sector that is not ocean. Population is not the proper discriminator, since there are land sectors with rivers, but no population. The two runs were compared using the RiskIntegrator, see Section 5, comparing in particular early fatalities/year, early injuries/year, latent fatalities/year, thyroid cancers/year, and whole body dose, in person-rem/year. The results, shown in Table 2, for the first three parameters were identical, the fourth and fifth showed an increase of 0.2% and 0.4%, respectively. With such a small difference, the base case input was not modified.)

**Table 2 -- Comparison of Base Case with Modified Watershed Index Case**

	<i>Base Case</i>	<i>Modified Watershed Index</i>
<i>Early Fatalities/yr</i>	<i>9.9e-11</i>	<i>9.9e-11</i>
<i>Early Injuries/yr</i>	<i>1.43e-9</i>	<i>1.43e-9</i>
<i>Latent Fatalities/yr</i>	<i>2.81e-4</i>	<i>2.81e-4</i>
<i>Thyroid Cancers/yr</i>	<i>4.58e-6</i>	<i>4.59e-6 (0.2% increase)</i>
<i>Whole Body (person-rem/yr)</i>	<i>5.69e-1</i>	<i>5.71e-1 (0.4% increase)</i>

### 2.3 ATMOS File (cr3atmos.inp)

To use Duke’s risk spreadsheet, it is convenient to use the same major release category definitions as Oconee. However, the RC### syntax must be used. The CR-3 release categories were first mapped to the existing definitions of the Oconee release categories (see Attachment H for a complete list of Oconee release categories), as shown in the table below:

**Table 3 -- Mapping of CR-3 Release Categories to Oconee Release Categories**

CR-3 Release Category Identifier	Oconee Release Category Identifier	Oconee Release Category Description
IN	RC902	No Containment Failure, <i>without</i> Ex-Vessel Fission Product Release, <i>without</i> Fission Product Scrubbing
IE	RC501	Early Containment Failure, <i>without</i> Ex-Vessel Fission Product Release
XN	RC904	No Containment Failure, <i>with</i> Ex-Vessel Fission Product Release, <i>without</i> Fission Product Scrubbing

CR-3 Release Category Identifier	Oconee Release Category Identifier	Oconee Release Category Description
XDAQ	RC606	Late Overpressurization, with Catastrophic Containment Failure, <i>with</i> Ex-Vessel Release of Fission Products, <i>without</i> Revaporization, <i>without</i> Fission Product Scrubbing
XDAS	RC605	Late Overpressurization, with Catastrophic Containment Failure, <i>with</i> Ex-Vessel Release of Fission Products, <i>without</i> Revaporization, <i>with</i> Fission Product Scrubbing
XDAU	RC606	See XDAQ
XDMS	RC802	Containment Failure from Basemat Melt-Through, <i>with</i> Ex-Vessel Release of Fission Products
XDMU	RC802	See XDMS
XEQL	RC502	Early Containment Failure, <i>with</i> Ex-Vessel Fission Product Release
XEQH	RC502	See XEQL
XESL	RC502	See XEQL
XESH	RC502	See XEQL
XEUL	RC502	See XEQL
XEUH	RC502	See XEQL
BXDAU	RC104	Containment Bypass (SGTR), which also bypasses the Auxiliary Building, <i>with</i> an Ex-Vessel Release of Fission Products, <i>without</i> Fission Product Scrubbing
BXEUL	RC104	See BXDAU
BXEUH	RC104	See BXDAU

Since there are multiple CR-3 release categories that map into a single Oconee release category, a new assignment of RC### identifiers needs to be made to the CR-3 release. These new assignments (as well as the original identifiers) are provided in the table below:

**Table 4 -- Assignment of RCxxx Release Categories to CR-3 Release Categories**

Oconee Release Category Identifier (Original)	CR-3 Release Category Identifier	CR-3 Release Category Identifier (New)
RC104	BXDAU	<b>RC101</b>
RC104	BXEUL	<b>RC102</b>
RC104	BXEUH	<b>RC103</b>
RC501	IE	<b>RC501</b>
RC502	XEQL	<b>RC502</b>
RC502	XEQH	<b>RC503</b>
RC502	XESL	<b>RC504</b>
RC502	XESH	<b>RC505</b>
RC502	XEUL	<b>RC506</b>
RC502	XEUH	<b>RC507</b>
RC605	XDAS	<b>RC601</b>

Oconee Release Category Identifier (Original)	CR-3 Release Category Identifier	CR-3 Release Category Identifier (New)
RC606	XDAQ	<b>RC602</b>
RC606	XDAU	<b>RC603</b>
RC802	XDMS	<b>RC801</b>
RC802	XDMU	<b>RC802</b>
RC902	IN	<b>RC901</b>
RC904	XN	<b>RC902</b>

Note that the new CR-3 release categories all “align” with the Oconee major release category definitions, that is, the RCx is the same for both plants. For Oconee, the major classifications for these release categories are:

- RC1xx = Containment Bypass with Auxiliary Building Bypass
- RC2xx = Interfacing-Systems LOCA
- RC3xx = Large Isolation Failures
- RC4xx = Small Isolation Failures
- RC5xx = Early Containment Failure
- RC6xx = Late Containment Failure (Catastrophic)
- RC7xx = Late Containment Failure (Benign)
- RC8xx = Basemat Melt-Through
- RC9xx = No Containment Failure

The substructure (i.e., the “xx” sequence number on the major release sequence category) is different for the two plants, as shown above in Table 3. When establishing the release category substructure, the user can use up to 99 sub-release categories for each major category (e.g., from RCy01 to RCy99).

From the original mapping of the release categories (see Table 3), the Oconee values of the following parameters:

- Time of release (seconds)
- Duration of release (seconds)
- Energy of release (watts)
- Warning time for evacuation (seconds)
- Elevation of release (meters)
- Isotopic fractions released to the environment

are used to characterize the CR-3 release categories. For example, the parameter values for RC802 (original) are used to characterize both **RC801** (new) and **RC802** (new). By convention, the new release category identifiers will always be in **bold** type. The release category parameter values taken from the Oconee analysis are provided in Tables 5A and 5B. The MACCS2 variable name is shown below the parameter name.

**Table 5A -- Oconee Release Category Parameter Values Used for CR-3**

CR-3 RCs	Oconee RCs	Time of Release	Dur. Of Release	Warning Time	Energy of Release	Elev. Of Release
		(seconds) [RDPDELAY]	(seconds) [RDPLUDUR]	(seconds) [RD0ALARM]	W/(cal/sec) [RDPLHEAT]	(meters) [RDPLHITE]
IN	RC902	13500	36000	11700	0.0E+00	0
IE	RC501	9900	1800	8100	8.4E+07	10
XN	RC904	18000	36000	16200	0.0E+00	0
XDAQ	RC606	99000	1800	97200	4.2E+07	10
XDAS	RC605	93600	1800	91800	4.2E+07	10
XDAU	RC606	99000	1800	97200	4.2E+07	10
XDMS	RC802	104400	36000	102600	0.0E+00	0
XDMU	RC802	104400	36000	102600	0.0E+00	0
XEQL	RC502	15300	1800	13500	8.4E+07	10
XEQH	RC502	15300	1800	13500	8.4E+07	10
XESL	RC502	15300	1800	13500	8.4E+07	10
XESH	RC502	15300	1800	13500	8.4E+07	10
XEUL	RC502	15300	1800	13500	8.4E+07	10
XEUH	RC502	15300	1800	13500	8.4E+07	10
BXDAU	RC104	21600	3600	19800	4.2E+04	10
BXEUL	RC104	21600	3600	19800	4.2E+04	10
BXEUH	RC104	21600	3600	19800	4.2E+04	10

**Table 5B -- Oconee Release Category Parameter Values Used for CR-3**

CR-3 RCs	Oconee RCs	Release Fraction								
		Xe/Kr	I	Cs	Te	Sr	Ru	La	Ce	Ba
IN	RC902	7.3E-04	8.7E-06	8.2E-06	6.3E-06	1.4E-08	6.8E-07	2.3E-09	2.3E-09	1.7E-07
IE	RC501	1.0E+00	1.4E-01	1.4E-01	2.0E-01	8.0E-04	3.1E-02	1.5E-04	1.5E-04	1.2E-02
XN	RC904	9.0E-04	7.8E-06	1.1E-05	2.0E-05	2.2E-07	1.7E-06	1.3E-08	1.3E-08	5.4E-07
XDAQ	RC606	1.0E+00	8.4E-03	9.0E-03	1.9E-02	5.9E-05	1.4E-04	1.8E-06	1.8E-06	7.9E-05
XDAS	RC605	1.0E+00	4.2E-04	4.5E-04	1.9E-02	5.9E-05	1.4E-04	1.8E-06	1.8E-06	7.9E-05
XDAU	RC606	1.0E+00	8.4E-03	9.0E-03	1.9E-02	5.9E-05	1.4E-04	1.8E-06	1.8E-06	7.9E-05
XDMS	RC802	1.0E+00	7.7E-06	1.2E-05	2.1E-05	2.2E-07	1.7E-06	1.3E-08	1.3E-08	5.4E-07
XDMU	RC802	1.0E+00	7.7E-06	1.2E-05	2.1E-05	2.2E-07	1.7E-06	1.3E-08	1.3E-08	5.4E-07
XEQL	RC502	1.0E+00	7.2E-02	7.9E-02	8.4E-02	1.4E-03	6.1E-02	6.8E-03	6.8E-03	7.9E-02
XEQH	RC502	1.0E+00	7.2E-02	7.9E-02	8.4E-02	1.4E-03	6.1E-02	6.8E-03	6.8E-03	7.9E-02
XESL	RC502	1.0E+00	7.2E-02	7.9E-02	8.4E-02	1.4E-03	6.1E-02	6.8E-03	6.8E-03	7.9E-02
XESH	RC502	1.0E+00	7.2E-02	7.9E-02	8.4E-02	1.4E-03	6.1E-02	6.8E-03	6.8E-03	7.9E-02
XEUL	RC502	1.0E+00	7.2E-02	7.9E-02	8.4E-02	1.4E-03	6.1E-02	6.8E-03	6.8E-03	7.9E-02
XEUH	RC502	1.0E+00	7.2E-02	7.9E-02	8.4E-02	1.4E-03	6.1E-02	6.8E-03	6.8E-03	7.9E-02
BXDAU	RC104	4.3E-01	1.2E-02	1.0E-02	4.4E-03	7.0E-06	1.9E-04	1.5E-06	1.5E-06	6.7E-05
BXEUL	RC104	4.3E-01	1.2E-02	1.0E-02	4.4E-03	7.0E-06	1.9E-04	1.5E-06	1.5E-06	6.7E-05
BXEUH	RC104	4.3E-01	1.2E-02	1.0E-02	4.4E-03	7.0E-06	1.9E-04	1.5E-06	1.5E-06	6.7E-05

In the ATMOS file (**cr3atmos.inp**), shown in Attachment D, all of the release category identifiers are defined as a change record. Because many of the CR-3 release categories map into a single Oconee release category, the values of the parameters for the change records (characterizing each release category) are identical (being derived from the same Oconee release category). (When FPC evaluates the individual release categories, this will not be the case.) When two sequential change records are identical, MACCS2 will abort; accordingly, the isotopic release fraction of Sr was “tweaked” back and forth to provide at least one difference for these change records. When there was more than two change records of identical parameter values, the isotopic release fraction of Sr was increased by “0.1” (in the context of a number expressed in scientific notation) and then restored to its original value for the next change record. The element Sr was selected since it typically has one of the lowest isotopic release fractions (for a given release category). Table 6 below shows specifically for which release category a “tweaked” value was used.

**Table 6 -- “Tweaked” Values of Sr Release Category to Handle Identical Change Records**

CR-3 Release Category	Original Sr Release Fraction (from Oconee Release Category)	“Tweaked” Value to Prevent Duplicate Change Records
<b>RC102</b>	7.0e-6	7.1e-6
<b>RC503</b>	1.4e-3	1.5e-3
<b>RC505</b>	1.4e-3	1.5e-3
<b>RC507</b>	1.4e-3	1.5e-3
<b>RC603</b>	5.9e-5	6.0e-5
<b>RC802</b>	2.2e-7	2.3e-7

R. A. Crandall provided a source term file (see Table 7) in the unit of *curies*. MACCS2 input (variable CORINV) requires the source term to be in units of *bequerels*. Table 6 shows both the provided input and its conversion to *bequerels*. The following conversion factor was used:

$$1 \text{ bequerel (bq)} = 1 \text{ curies (ci)} / 2.703 \times 10^{-11}$$

The list of radioisotopes is the same as suggested in the example MACCS2 problem and used in the Oconee analysis.

**Table 7 -- CR-3 Source Term Input in Curies and Bequerels**

Radioisotope	Core Inventory (curies)	Core Inventory (bequerels)	Radioisotope	Core Inventory (curies)	Core Inventory (bequerels)
CO-58	4.00E+05	1.480E+16	I-132	1.01E+08	3.737E+18
CO-60	4.80E+05	1.776E+16	I-133	1.48E+08	5.475E+18
KR-85	1.10E+06	4.070E+16	I-134	1.64E+08	6.067E+18
KR-85M	2.24E+07	8.287E+17	I-135	1.19E+08	4.403E+18
KR-87	4.09E+07	1.513E+18	XE-133	1.47E+08	5.438E+18
KR-88	5.68E+07	2.101E+18	XE-135	4.00E+07	1.480E+18
RB-86	3.46E+05	1.280E+16	CS-134	1.48E+07	5.475E+17
SR-89	7.58E+07	2.804E+18	CS-136	4.23E+06	1.565E+17
SR-90	8.30E+06	3.071E+17	CS-137	1.10E+07	4.070E+17
SR-91	9.84E+07	3.640E+18	BA-140	1.28E+08	4.735E+18
Y-90	8.27E+06	3.060E+17	LA-140	1.30E+08	4.809E+18
Y-91	1.01E+08	3.737E+18	CE-141	1.15E+08	4.255E+18
ZR-95	1.00E+08	3.700E+18	CE-143	9.30E+07	3.441E+18
ZR-97	1.10E+08	4.070E+18	CE-144	9.70E+07	3.589E+18
NB-95	1.00E+08	3.700E+18	PR-143	9.08E+07	3.359E+18
MO-99	1.32E+08	4.883E+18	ND-147	4.54E+07	1.680E+18
TC-99M	1.12E+08	4.144E+18	NP-239	2.17E+09	8.028E+19
RU-103	1.41E+08	5.216E+18	PU-238	7.25E+04	2.682E+15
RU-105	1.06E+08	3.922E+18	PU-239	3.22E+05	1.191E+16
RU-106	3.50E+07	1.295E+18	PU-240	1.89E+05	6.992E+15
RH-105	4.80E+07	1.776E+18	PU-241	9.90E+06	3.663E+17
SB-127	1.18E+07	4.366E+17	AM-241	4.11E+04	1.521E+15
SB-129	2.11E+07	7.806E+17	CM-242	2.36E+06	8.731E+16
TE-127	1.18E+07	4.366E+17	CM-244	3.90E+03	1.443E+14
TE-127M	1.60E+06	5.919E+16	Sr-92	9.65E+07	3.570E+18
TE-129	2.91E+07	1.077E+18	Y-92	6.64E+07	2.457E+18
TE-129M	4.37E+06	1.617E+17	Y-93	8.28E+07	3.063E+18
TE-131M	1.26E+07	4.661E+17	Ba-139	1.29E+08	4.772E+18
TE-132	1.08E+08	3.996E+18	La-141	1.14E+08	4.218E+18
I-131	7.59E+07	2.808E+18	La-142	1.02E+08	3.774E+18

The parameters and their values in Table 8 (below) were requested of CR-3 (and provided by R. A. Crandall) and used to develop the ATMOS input file. (Other parameter values in the ATMOS file were taken from the Oconee analysis.) One value supplied by CR-3 was incompatible with MACCS2 input and was modified. This parameter was the number of rain distance intervals for binning ... the minimum number of intervals is "4." Accordingly, the value "4" was used with the endpoints shown in Table 8.

**Table 8 -- CR-3 Parameter Values used to Develop the ATMOS File**

Parameter	MACCS2 Variable	Value Used	Comments
<b>Geometric (GE) Data (5.3)</b>			
Number of spatial radial elements	NUMRAD	10	Same as used in SITE
Spatial endpoints distances (kilometers)	SPAEND	1, 2, 3, 4, 5, 10, 20, 30, 40, 50	Value provided in miles, converted to kilometers, same as used in SITE
<b>Wake Effects (WE) Data (5.10)</b>			
Reactor building height (m)	BUILDH	53	
Reactor building width (m)	n/a	44	Used to calculate other input values
<b>Release Description (RD) Data (5.11)</b>			
Number of plume segments that are released	NUMREL	1	
Representative time point for dispersion and radioactive decay	REFTIM	leading edge	
Particle size distribution of each element group	PSDIST	one size assumed for all 9 elements groups	
Scaling factor to adjust the core inventory	CORSCA	1.0	
<b>Boundary Weather (M2) Data (5.14)</b>			
Boundary weather mixing layer height (m)	BNDMXH	1400	
Boundary weather stability class index	IBDSTB	4	
Boundary weather rain rate (millimeter/sec)	BNDRAN	0.0	
Boundary weather wind speed (meters/sec)	BNDWND	2.5	
<b>Meteorological Bin Sampling (M4) Data (5.16)</b>			
Number of rain distance intervals for binning	NRNINT	4	Requested value of "2" below MACCS2 minimum value of "4"
Endpoints of the rain distance interval (kilometers)	RNDSTS	16.10, 32.21, 48.31, 80.52	Based on minimum required values, 10, 20, 30, 50 miles were used.
Number of rain intensity breakpoints	NRINTN	2	
Rain intensity breakpoints (millimeters/hours)	NRRATE	99.9, 100.	

Parameter	MACCS2 Variable	Value Used	Comments
Number of samples per bin	NSMPLS	8	

#### 2.4 EARLY File (cr3early.inp)

The parameters and their values in Table 8 (below) were requested from CR-3 (and provided by R. A. Crandall) and used to develop the EARLY input file, **cr3early.inp**, which is provided in Attachment F. (Other parameter values in the EARLY file were taken from the Oconee analysis or default MACCS2 values.) One of the inputs provided by CR-3 had to be adjusted based on an assumption made for another parameter; see NUMEVA in Table 9 below.

**Table 9 -- CR-3 Parameter Values used to Develop the EARLY File**

Parameter	MACCS2 Variable	Value Used	Comments
<b>Shielding and Exposure (SE) Data (6.5)</b>			
Cloudshine shielding factor	CSFACT	1.0, 0.75, 0.6	The three values are for the following activities: evacuation, normal activity, and sheltering.
Ground shielding factor	GSHFAC	0.5, 0.33, 0.2	The three values are for the following activities: evacuation, normal activity, and sheltering.
<b>Evacuation Zone (EZ) Data (6.6)/Evacuation Data Block Input Parameters (6.6.8)</b>			
Weighting fraction to be applied to the results from the emergency response scenario	WTFRAC	0.95	Specifies the fraction of the population evacuated within a specified amount of time.
Identifies whether evacuees are presumed to move from a spatial element when they cross the boundary dividing the two elements or when they reach the centerpoint of the destination element	TRAVEL-POINT	BOUNDARY	“CENTERPOINT” is used if the centerpoint model is to be selected.
Evacuation speed (meters/second)	ESPEED	2.0, 2.0, 2.0	Evacuation speed provides for the three phases of the evacuation, e.g., initial, middle, and late.

Parameter	MACCS2 Variable	Value Used	Comments
Reference time for actions in the evacuation and sheltering zone	REFPNT	ALARM	ALARM indicates the clock starts when the off-site alarm occurs (versus ARRIVAL, when the plume arrives at the first spatial element.
The duration of the initial phase of the evacuation (seconds)	DURBEG	3600.0	
The duration of the middle phase of the evacuation (seconds)	BURMID	20000.0	
Number of radial spatial elements (i.e., contiguous rings) comprising the sheltering and evacuation region	NUMEVA	8	CR-3 specified all ten radial spatial elements (i.e., out to 50 miles); however, the parameter LASMOV (the outermost spatial interval of the evacuation movement zone, i.e., the distance at which evacuees are assumed to disappear from the early health effects model and receive no further dose) was set at 8 (or 30 miles), and NUMEVA must be less and or equal to LASMOV. Accordingly, NUMEVA was set to 8.
Delay that elapses from reference time point to when individuals take shelter (seconds)	DLTSHL	0.0	This value is used for each of the NUMEVA radial spatial elements. (Assumes no delay time to take shelter.)
Delay that elapses from the beginning of the shelter period to when the individuals begin their evacuation	DLTEVA	600.0	This value is used for each of the NUMEVA radial spatial elements.

## 2.5 CHRONC File (cr3chrnc.inp)

No plant-specific input was requested from CR-3 for this input file. The CHRONC file used was the same as used in the Oconee analysis, which was taken from the MACCS2 example case. The input file, **cr3chrnc.inp**, is provided in Attachment G. If MACCS2-based output derived

specifically from the CHRONC file were to be used, the input in this file should be reviewed for applicability.

### 3. Execution of MACCS2

The execution of MACCS2 is facilitated by use of a batch file (**runcr3.bat**) that involves another batch file (**runmax2.bat**) and provides the necessary input file names. For example, runcr3.bat may contain the following command line:

```
call runmax2 cr3atmos cr3early cr3chrnc cr3met cr3site cr3pra
```

where cr3atmos is the "ATMOS" input file for CR-3  
cr3early is the "EARLY" input file for CR-3  
cr3chrnc is the "CHRONC" input file for CR-3  
cr3met is the meteorological input file for CR-3  
cr3site is the "SITE" input file for CR-3  
cr3pra is the output file of the MACCS2 execution

Note that for each of the input files, the proper file name is the name provided in the command line plus the suffix "inp," e.g., the SITE file name is: cr3site.inp. The single output file name has the suffix "out," e.g., in this case, the filename would be: cr3pra.out. Also note that the root file name for all the inputs and the output file are limited to eight characters.

To execute MACCS2 in a directory other than the one in which the program was loaded, the following files are required in addition to the above stated input files (and batch file):

```
maccs2.exe  
runmax2.bat  
indexr.dat  
dosdata.inp  
samp_a.bin
```

### 4. Output of MACCS2

The output file that resulted from the execution of MACCS2 with the above referenced input files for CR-3 is quite lengthy. This is due primarily to the output generated for each of the release categories. Accordingly, Attachment I shows the output file, **cr3pra.out** with only release category RC101 and none of the input echoing. Partial results for the other release categories can be ascertained from running Duke Power Co.'s risk spreadsheet (see Section 5).

The entire MACCS2 output files (for the CR-3 execution) can be broken down as follows:

- identifies the input files used
- echoes the ATMOS input file
- provides decay chain information

- gives released inventory from all plumes (only one plume modeled)
- provides meteorological summary: percent of time across all 16 wind directions for each meteorological bin, number of days (per year) across all 16 wind directions for each meteorological bin, and windrose by percent of time across all 16 wind directions
- processing of input for subsequent cases/release inventory (remaining 16 release categories)
- echoes the EARLY input file
- lists defined organs
- acknowledges reading from the DOSDATA.INP file ( dose conversion factor file)
- echoes the SITE input file
- processing of input for subsequent evaluation model inputs (for remaining five percent of the population)
- echoes the CHRONC input file
- acknowledges reading from the COMIDA-2 file (food-chain model)
- echoes more input parameters
- provides windrose probability by wind direction and meteorological bin
- echoes summary of output types selected
- shows the meteorological trials (8 samples x 20 bins = 160 trials)
- shows output results, repeated 17 times, one for each release category; output results for release category RC101 is provided in Attachment I

Attachment I shows the outputs as selected by the user via the MACCS2 variables TYPE1OUT, TYPE2OUT, etc. The first portion shows the output parameters selected in the EARLY input file for the combination of evacuation model (identified as COHORT 1 and COHORT 2), as well as results for each cohort separately. This is followed by the output parameters selected in the CHRONC input file.

The same five output parameters used in the Oconee analysis to evaluate public health consequences were also used in the generic analysis for CR-3. These parameters are selected by the user in the MACCS2 “coded comments” (see Section 5.2.3) and are subsequently displayed by the risk spreadsheet. These are, as adapted from Reference [3]:

*Early Fatalities* – This risk is characterized by fatalities that occur within one year of exposure, and are estimated on the basis of exposure to the bone marrow, lungs, and gastrointestinal tract.

*Early Injuries* – This risk is defined as non-fatal, non-carcinogenic illness that appears with one year of the exposure and requires medical attention or hospital treatment.

*Latent Fatalities* – This risk is defined as latent cancer fatalities occurring due to both initial and chronic exposure. This includes the early exposure to the radioactive cloud, chronic exposure to ground contamination, inhalation, and ingestion.

*Thyroid Nodules* – This risk is defined as any thyroid effects incurred from both initial and chronic exposure.

*Whole-Body Person Rem* – This is defined as the sum of the whole-body dose received by the population within 50 miles of the Crystal River-3 site.

At the user's discretion, different output parameters can be selected and displayed via the risk spreadsheet.

## 5. Risk Spreadsheet

### 5.1 Introduction

The risk calculation spreadsheet was developed by Duke Power Co. to import, calculate, and analyze data for the purpose of producing accurate risk results. The risk spreadsheet combines the results of a level 1 PRA, level 2 PRA, and a level 3 PRA. In particular, the effects of changes in the level 1 and 2 PRAs can be propagated to overall risk measures without rerunning the MACCS2 code (for a level 3 PRA).

The risk spreadsheet requires three input files:

- Conditional Probability Matrix (\*.cpm) [from level 1 PRA]
- Release Category Matrix (\*.rcm) [from level 2 PRA]
- MACCS2 output file (\*.out)

Additional information in the form of an initiating event lookup table, which is used to label initiating events, break them into sub-categories, and specify whether a particular initiating event is an internal or external event. The information in the initiating event lookup table is integrated into the risk calculation spreadsheet file (and not used as an independent, free-standing file). The generation and description of the MACCS2 output file is discussed in Section 4. The CPM and RCM files, as well as the initiating event lookup table, are more completely described in Attachment A. Examples of these files are in Attachments J, K, and L.

### 5.2 Using the Risk Calculation Spreadsheet

The Risk Calculation Spreadsheet (Version 1.00) is a Microsoft Excel spreadsheet augmented with Visual Basic programming to facilitate the user's ability to load files, select options, run calculations, view files, and generate output tables and figures. To start the spreadsheet, either double click on the file (RiskIntegrator.xls) or open the file as an Excel spreadsheet. Upon opening the spreadsheet file, the user will be informed about the use of macros within the spreadsheet. The "Enable Macros" option must be selected.

The splash screen (a window entitled Risk Calculation Spreadsheet) identifies the program name and version number, and provides the user with the high level options to:

- *Run a Calculation* (load input files, extract data, and format into tables and figures)
- *Review Results* (view any of the input files, or output tables or figures)
- *End* (remove the window and permit selection of Excel options and/or data tabs)

### 5.2.1 Run a Calculation

When this option is selected, the RiskIntegrator will test for the existence of the default directory. If the directory is not found, a warning message is displayed. Syntax for the default directory name is discussed below.

This option permits the user to select a nuclear power plant, a revision number, and a method of calculation. The selection of a nuclear power plant creates a link to the initiating event lookup table, and sets the default file names for the CPM, RCM, and MACCS2 output files. The revision number creates a link to the default subdirectory, named rev#, where “#” is the revision number, and the default file names for the CPM, RCM, and MACCS2 output files. If the revision subdirectory structure is not used (see option discussed in Section 5.2.3 under Run Data), then the current directory is considered the default (i.e., where the program will look for the input files).

There are two choices for the syntax of the default subdirectory and input file names: (1) abbreviation and (2) full plant name. The options are selected within the Run Data (see Section 5.2.3.) The *abbreviation* default syntax for the CPM and RCM files is as follows: the first letter of the plant name (e.g., “C” from CR3) is followed by an “r” (for revision), and then the revision number specified by the user. The suffix “.cpm” or “.rcm” completes the file name, depending on which file name is being formed. For example, the *abbreviation* default CPM file name for CR3, Revision 1 would be: cr1.cpm. The *full plant name* syntax for these files is as follows: the full plant name (e.g., cr3) is followed by a “-r” (for revision), and then the revision number specified by the user. The full plant names have been used for this CR-3 analysis, i.e., **cr3-r1.cpm** and **cr3-r1.rcm**. These input files can always have a non-default file name that can be selected using the *Browse* option.

The default MACCS2 output file, for this example, would be either be **cr1MACCS.out** (*abbreviation* default) or **cr3-r1.out** (*full file name* default). The non-default MACCS2 output file name used for CR-3 analysis is **cr3pra.out**, which must be selected using the *Browse* option. The MACCS2 output file name is specified in the batch file **cr3run.bat**, discussed above in Section 3.

The user has six choices for importing and processing data. There are three basic tasks performed by the spreadsheet:

- A – import (or read in) all the files, namely, \*.cpm, \*.rcm, and \*.out
- B – perform validity checks on PDS names, RC names, and initiator names across files
- C – perform the calculation, namely, the creation of pre-defined tables and figures

The six options can be described in terms of the above tasks. Note that task A\* is defined as importing/reading one or more of the files. The task parentheses for option 6 indicate that each step is optional. The options are listed in the spreadsheet for the user’s selection, but are not identified by the option numbers used in Table 10.

**Table 10 -- Spreadsheet Options Defined by Task**

<b>Option Number</b>	<b>Option Name</b>	<b>Task Sequence</b>
1	Import all the files and run a complete calculation	A – B – C
2	Import all files and compare PDS, RC, and Initiator names	A – B
3	Import only selected files and run a complete calculation	A* – B – C
4	Import only selected files and compare PDS, RC, and Initiator names	A* – B
5	Run calculation only	C
6	Perform this process step by step	(A) – (B) – (C)

For options 1 and 2, the user must specify all three input files by choosing the default name, selecting a non-default file name using the Browse button, or typing a file name in the file name dialog box. After each file name is selected, the Next button must be selected so that the next file name can be specified. For options 3 and 4, a menu appears on the right-hand side of the window, allowing the user to check which file names are to be imported. If the user chooses to import a file, the program automatically permits the user to select a file from the default “rev#” directory. (As the file names are requested, blue text describing the file’s contents and origins appear; some information display is Ocone-specific.)

For options 1 through 4, once the file names are specified, the user is presented with two additional buttons: *Initiator Codes*, *LERF Criteria*, and *Change Report Names*. Initiator Codes permits the user to check the current initiator codes and change them, if desired.

LERF Criteria permits the user to select from one of two methods to determine LERF. The first method allows the user to set an Early Fatality threshold – for each release category that exceeds the threshold, that release category will be included in the LERF calculation. The second method will allow the user to select specific release categories to be included in the LERF calculation.

Change Report Names allows the user to rename the pre-determined report names (as used by Duke). This option is intended to permit the user to change the Table and Figure tabs (and corresponding titles). While it is possible within this option to change other tabs, only the Table and Figure tabs should be changed.

When task B is invoked, the program will check that the plant damage state (PDS) names in the CPM and RCM files are consistent, i.e., identical. Similarly, a check is made between the release category (RC) names in the RCM and MACCS2 output files. Finally, the initiator codes in the CPM file are checked against the information in the Initiator Code tab, whose source can be found in Attachment L.

The Begin Calculation button will perform a comparison only (task B) or a comparison and calculation (tasks A and C). After the calculation is finished, the Cancel button will take the user back to the “splash” window, which, with the selection of Review Results (see Section 5.2.2), the input files, calculations, figures, and tables can be viewed. When complete, the spreadsheet can

be saved with all the imported data, and the generated tables and figures. When one of the input files is modified, the file needs to be imported again and the calculation rerun.

### 5.2.2 Review Results

After selecting the Review Results button, the user can view the input files, calculated data, and reports (figures and tables). Select the item to be viewed, and then press the Go To Item button. This essentially takes the user to the appropriate tab. The tabs (or worksheets) are described in Section 5.2.3. While viewing a specified item, a six-icon menu bar will also appear. The “arrows” will allow the user to view the tab to the immediate right or left of the current tab. The “red-x” will return the user to the Review Results window. The printer icon will print the display page in a pre-set format. The binocular icon will permit the user to select a different range (if available), e.g., results at 10 miles versus 50 miles. This is the same function of the ReCalc Range option in the *Run Data* worksheet; see discussion in Section 5.3. The paper icon will display a brief description of the information displayed on the screen.

In addition to the Go To Item button in the Review Results window, there are three other options available to the user; these are:

- What is It? – this option will provide a description of the selected item (if available)
- Print – this option will display a list of print options, i.e., select items to print
- Done – this option will return the user to the “splash” window.

### 5.2.3 End

When this option is selected, the “splash” window is deleted, and the user has access to the conventional Excel options. In particular, the user can use the tabs to see the contents of each worksheet. A brief description of each worksheet (or each set of worksheets) is provided below. The “splash” window can be restored with a single mouse click on the blank *StartUp* worksheet.

#### **StartUp**

This is where the program begins and displays the “splash” window with the first menu of user options. After selecting the End button, the user can redisplay the “splash” window with a single mouse click on the empty *StartUp* worksheet.

#### **Run Data**

This worksheet contains a variety of user-supplied and spreadsheet-retrieved information. Items include:

- Date that a specific input file (i.e., \*.cpm, \*.rcm, or \*.out) was last imported
- List of full plant names (e.g., Oconee, CR3) [Note that CR3 is used as the full plant name, as opposed to the abbreviation of “C.”]
- Default file name options: user can select between the *abbreviation* default or the *full plant name* default, as well as choose to not use the default revision subdirectory syntax
- LERF release categories (if selected for use)

- LERF criteria (if selected for use)
- Figure 6.1-1 data (Figure 6.1-1 is a pie chart showing the CDF contribution from all of the initiating events; this information can be changed manually and the pie chart updated by using the Reproduce Chart option)
- Release Category (RC) designators (using the Duke RC lexicon) and number of RCs
- Two sets of pull-down menu options for results' tables
- Report names and descriptions
- MACCS2 names of TYPE1 and TYPE5 output parameters (with alternate names to be used in results tables) to be extracted from MACCS2 output file
- Number of CCDF data to be extracted from MACCS2 output file
- The ReCalc Range button will permit the user to select output variables from another range, if available (e.g., 50 miles versus 10 miles); see the discuss on MACCS Mean for other the parameters are selected

Care should be exercised when manually changing any information on this worksheet; most items can be changed from within the program. The one exception is that the default file name option/use of default directory structure options can **only** be changed in the Run Data worksheet. Though, usually once these options are selected, they will not be changed.

### Initiator Codes

For each plant that is using the spreadsheet program, there must be a tab with the label **{plant name} Initiator Code**; further, the plant name must match the name in the pull-down menu in *Run a Calculation* window. This list is also stored in the *Run Data* worksheet. The information on this worksheet comes from the information requested in Attachment A, with an example give in Attachment L. Basically, the information includes an initiating event code, identification of internal or external event, what group the initiating event is in, and a description of the initiating event. The group name is used to determine the display format for the pie chart (Figure 6.1-1); for an initiating event to be displayed individually on the pie chart, there should be no "group" designation, otherwise, the groups are consolidated on the pie chart.

### Name Check

This worksheet shows the results of the three name checks: PDS, RC, and Initiator Event codes.

### RCFM by Initiator

The worksheet contains a release category frequency matrix by initiating events. Each cell of the matrix contains the core damage frequency for each release category for each initiating event. A vector product (matrix multiplication) of the CPM and RCM is used to generate this worksheet. The initiating event codes are pulled from the CPM file; the corresponding "internal" (in blue) and "external" (in red) designation is pulled from the *CR-3 Initiator Code* worksheet. Accordingly, the initiating events list in the CPM can be a subset of what is included in the CR-3 Initiator Code list.

## RCFM by PDF

The worksheet contains a release category frequency matrix by plant damage states. Each cell of the matrix contains the core damage frequency for each release category for each plant damage state. The release category frequency is multiplied by the core damage frequency of the plant damage state, which is computed by added the CDF contribution for the plant damage state for each initiating event (in the CPM).

## MACCS MEAN

This worksheet contains the mean values for five parameters from the MACCS2 output file. For the first four parameters (e.g., early fatalities, early injuries, latent fatalities, and thyroid cancers), the units are the expected number of people affected within the stated radius (of a plant following a release) for each release category. The fifth parameter, whole body, is in units of person-rem. These values are pulled from the *RCxyy* worksheets by searching for the MACCS2 output parameter type code (e.g., TYPE1OUT1) that are read from the yellow range in the *Run Data* worksheet (AK27..AR29). The yellow region contains the first four TYPE1OUT parameters and the first TYPE5OUT at the specified range. The range can be changed by using the ReCalc Range button on the *Run Data* worksheet. When selecting the TYPE1OUT and TYPE5OUT parameters, it is important to remember that there are at least four TYPE1OUT parameter specified for the same range (e.g., 50 miles) and one TYPE5OUT parameter specified for the same range. It is also important to note that for each range satisfying this condition, *only the first four TYPE1OUT parameters and the first TYPE5OUT parameters will be available to the RiskIntegrator*. For the LERF determination (see LERF below), one of the TYPE1OUT parameters *must* be “Early Fatalities.”

The available parameters in the TYPE1 and TYPE5 output parameter tables are extracted from the MACCS2 input file as specified by the user with specially coded comment statements. There are four “comment codes” that can be placed in the MACCS2 input file (EARLY) that will be “processed” by the RiskIntegrator, with the results placed in the *Run Data* worksheet; these are:

- \*\* TYPE1DISP – specifies the index of theTYPE1OUT parameters that are to be available to the spreadsheet
- \*\* TYPE1CCDF – specifies the number of the TYPE1OUT parameters for which CCDFs are to be calculated (as specified in the EARLY input file)
- \*\* TYPE5DISP – specifies the index of theTYPE5OUT parameters that are to be available to the spreadsheet
- \*\* TYPE5CCDF – specifies the number of the TYPE5OUT parameters for which CCDFs are to be calculated (as specified in the EARLY input file)

The syntax for “comments” following TYPE?DISP is:

- \*\* {Index of desired parameter from TYPE?OUT list} {User-friendly name for parameter}
- [Note: the user-friendly name is limited to four words.]

The syntax for the single “comment” following TYPE?CCDF is:  
\*\* {Number of specified CCDF requests from TYPE?OUT list}

## LERF

The worksheet contains a large early release frequency (LERF) matrix by initiating events. Each cell of the matrix contains the portion of the core damage frequency that contributes to LERF for each release category for each initiating event. The LERF release categories are determined by (1) keeping those release categories where the number of early fatalities (per release category) exceeded the specified threshold or (2) simply the number of early fatalities for those release categories specified by the user as being LERF release categories. (See MACCS MEAN above for selection of the Early Fatalities parameter needed to determine LERF.) For CR-3, there is no LERF contribution (by threshold value) from any release category, so just the total (of zero) is shown for each initiating event. The initiating event codes and corresponding “internal” (in blue) and “external” (in red) designation are pulled from the *RCFM by Initiator* worksheet.

## RC Results

This worksheet contains the frequency of MACCS2 output results (i.e., the five parameters summarized in the *MACCS MEAN* worksheet) organized by internal and external initiating event frequency and by release category (detailed release category structure). The initiating event frequencies are pulled from the *RCFM by Initiator* worksheet and then multiplied by the parameter values (pulled from the *MACCS MEAN* worksheet). The units for these parameters are the same as discussed for the *MACCS MEAN* worksheet per year.

## RC Results (%)

This worksheet contains the same information as presented in the *RC Results* worksheet, except instead of presenting the results in the parameter units, the results are expressed as percentages.

## RC Result (Summary)

This worksheet contains the same information as presented in the *RC Results* worksheet, except that the results are for each major release category, that is, the sub-release categories have been summed.

## Table 6.1-1 (CDF by Initiator)

This worksheet provides a report-ready table containing the core damage frequency organized by initiating events and groups of initiating events as defined by the Initiator Code tab. Note a small pull-down menu provides the user with some choices of how this table is ultimately displayed. The available options are:

- **Show Zero Values** – Display all the initiating events, even those with zero contribution to CDF.

- **Hide Zero Values** – Display only the initiating events with a non-zero contribution to CDF.

**Figure 6.1-1** (% CDF by Initiator)

This worksheet provides a report-ready graphic with the same information as Table 6.1-1 for major initiating event groups in the form of a pie chart. In the *Run Data* worksheet, the user can make manual changes to the “raw” data and redisplay the pie chart. See discussion in *Run Data* above. As discussed above (Initiator Code), the sectors of the pie chart are determined by the Group designation in the Initiator Code tab; to display an individual initiating event in the pie chart, either delete the group designation or place the initiating event in a group of its own.

**Figure 6.2-1** (CDF by PDF)

This worksheet provides a report-ready table containing core damage frequency (contribution and percent contribution) results by plant damage state.

**Figure 6.3-1** (Internal Risk Results)

This worksheet provides a report-ready table containing a summary of risk results (the frequency of the five MACCS2 parameters) for release categories identified by “user-friendly” name as opposed to the RCxy lexicon used by Duke. Nonetheless the results in this (and other 6.3-x tables) are based on Duke’s method of categorizing release categories; these figures are intended for inclusion in a report and accordingly the “cryptic” designator has been replaced a more easily interpreted one. Note a small pull-down menu provides the user with some choices of how this table is ultimately displayed. The available options are:

- **View Summary Data** – Data are displayed in a roll-up of seven release categories.
- **View Detailed Data** – Data are displayed breaking up “Isolation Failure” into “Large” and “Small” categories, and breaking up “Late Containment Failure” into “Catastrophic” and “Benign” categories.
- **View All Data** – Data are displayed with both categories and subcategories.

**Figure 6.3-2** (External Risk Results)

This worksheet provides the same information in the same format as Figure 6.3-1 for the external risk results.

**Figure 6.3-3** (All Risk Results)

This worksheet provides the same information in the same format as Figure 6.3-1 for the sum of the internal and the external risk results.

## **CPM**

This worksheet contains the conditional probability matrix as read in (imported) from the input CPM file.

## **RCM**

This worksheet contains the release category matrix as read in (imported) from the input RCM file.

## **BlankRC**

This worksheet contains a template (blank) release category worksheet.

## **RCxyy**

These worksheets contain information extracted from the MACCS2 output for all the TYPE1 and TYPE5 output parameters for each of the release categories. In addition, the complementary cumulative distribution functions (CCDFs) specified by the user are contained in these worksheets.

## References

- [1] D. Chanin and M. L. Young, *Code Manual for MACCS2*, NUREG/CR-6613, Vol. 1, SAND97-0594, prepared by Technadyne Engineering Consultants and Sandia National Laboratories, prepared for the U. S. Nuclear Regulatory Commission and U. S. Department of Energy, May 1998.
- [2] Final Safety Analysis Report, Florida Power Corp., Crystal River Unit-3, Revision 25.5.
- [3] Oconee Nuclear Station, PRA Revision 2 Summary Report, Duke Power Company, December 1996.

## List of Attachments

- Attachment A -- Input Required to Perform "Generic Level 3 PRA," Part 1
- Attachment B -- Input Required to Perform "Generic Level 3 PRA," Part 2
- Attachment C -- MACCS2 Meteorological Input File for CR-3 (cr3met.inp)
- Attachment D -- MACCS2 Site Input File for CR-3 (cr3site.inp)
- Attachment E -- MACCS2 ATMOS Input File for CR-3 (cr3atmos.inp)
- Attachment F -- MACCS2 EARLY Input File for CR-3 (cr3early.inp)
- Attachment G -- MACCS2 CHRONC Input File for CR-3 (cr3chrnc.inp)
- Attachment H -- Description of Major/Minor Released Category Definitions used by Oconee Nuclear Station
- Attachment I -- Output File for CR-3 MACCS2 Base Case (cr3pra.out)
- Attachment J -- CR-3 Conditional Probability Matrix File (cr3-r1.cpm)
- Attachment K -- CR-3 Release Category Matrix File (cr3-r1.rcm)
- Attachment L -- CR-3 Initiating Event Lookup Table (cr3\_init.xls)

# **Attachment A**

## **Input Required to Perform “Generic Level 3 PRA,” Part 1**

## **INPUT REQUIRED TO PERFORM “GENERIC LEVEL 3 PRA”**

### **(Part 1)**

-- B&WOG Project --

There are two general areas for which input will be required from the utilities participating in the B&W Owners Group’s Generic Level 3 PRA, sponsored by the Risk-Informed Applications Committee (RIAC). The first area is the input required to run the MACCS2 code, which is used to calculate the health and economic consequences of accidental releases of radioactive material to the atmosphere. The principal phenomena considered in MACCS (the immediate predecessor of MACCS2) are atmospheric transport, short-term and long-term mitigative actions and pathways, deterministic and stochastic health effects, and economic costs. [1]

The second area is the input necessary for the risk spreadsheet applications developed by Duke Power Company to provide a linkage between the Level 1 PRA and Level 2 PRA results, and the Level 3 PRA analysis. Using the risk spreadsheet will facilitate the ability to update the Level 3 PRA results when there are changes in the Level 1 and Level 2 analysis through the course of normal updates due to model changes, new data, plant modifications, etc. This B&WOG project will provide the participating utilities with the technology transfer necessary to run MACCS2, as well as use the risk spreadsheets.

#### Inputs Required for the Risk Spreadsheet Application

The inputs required for the risk spreadsheet application consist of three files:

- Conditional Probability Matrix (\*.cpm) [from Level 1 Analysis]
- Release Category Matrix (\*.rcm) [from Level 2 Analysis]
- Initiating Event Lookup Table

In addition, the risk spreadsheet application requires MACCS2 outputs.

The CPM and RCM files contain plant damage states (PDSs), release categories (RCs), and initiating events (IEs). All PDSs, RCs, and IEs must conform to certain naming conventions:

- No names may contain a space.
- The use of an “underscore” ( \_ ) is permitted.
- The RC names should be of the format: RCxyy, where the x identifies the applied RC group, and yy corresponds to a sequence number, e.g., RC101, RC102, RC103, etc. are all in Group 1, which for Oconee is the Steam Generator Tube Rupture endstate).

Other conditions for the files include:

- Both the CPM and RCM files are read in as space-delimited files and should be prepared in matrix format. (WordPad can be used to create these files.) Two examples are provided as electronic attachments (cr2.cpm and cr2.rcm); currently, the inputs need be in the exact format shown in these files. (Plans are in place to provide a more flexible input method.)

- The file name for the CPM should have the suffix “.cpm”
- The file name for the RCM should have the suffix “.rcm”

### *Conditional Probability Matrix*

The two dimensions of the Conditional Probability Matrix (CPM) are (1) Initiating Events (IEs) across the top, and (2) Plant Damage States (PDSs) along the left-hand edge. The “number” in the matrix is the core damage frequency (CDF) contribution for  $IE_i$  by  $PDS_j$ . Note in the example provided in file cr2.cpm that there are many zero entries where there was no contribution to CDF. Further note that the sum of a column would yield the CDF contribution of  $IE_i$ , while the sum of a row would yield the CDF contribution of  $PDS_j$ . The sum of all the matrix elements yields the total CDF; for the file cr2.cpm (Catawba), the total CDF can be found to be  $4.7 \times 10^{-5}$ . The information for this file should be able to be produced automatically using CAFTA.

### *Release Category Matrix*

The two dimensions of the Release Category Matrix (RCM) are (1) Release Categories (RCs) across the top, and (2) Plant Damage States (PDSs) along the left-hand edge. The “number” in the matrix is the fractional contribution of  $PDS_i$  to each  $RC_j$ . Note, therefore, that the sum of a row is equal to 1.0 (the sum of the fractional contributions must sum to unity). The sum of the columns has no interpretable meaning. The information for this matrix should come from the Containment Event Tree solution (using GTPROB with CAFTA) in the Level 2 analysis.

### *Initiating Event Lookup Table*

This table is used as a look-up table to correctly sort the matrix table by Initiator Code. The left-most column containing the initiating event “code” must be in all upper case. The second column must contain either an “i” or “x” to indicate whether it is an internal or external event. The third column is for grouping (e.g., small break LOCA, SL, is in the LOCAS group). The last column is for a textual description.

### Inputs Required for MACCS2 (Execution)

While many of the parameters required as input to MACCS2 will be taken from the existing Oconee input deck, there are some that should be provided as plant-specific. These fall into several categories, e.g., level 2 results, meteorological, population, etc. For this request, the MACCS2 input parameter will be limited to the level 2 results. Other needed parameters will follow shortly in a Part 2 request.

The input data required from the level 2 analysis (for MACCS2) includes *for each release category*:

- warning time [time after accident initiation that off-site alarm is sounded] (seconds)
- energy of release (watts)

- height of plume segment at release (meters)
- duration of release (seconds)
- time of release (seconds)
- release fraction for nine groups of isotopes (Xe/Kr, I, Cs, Te, Sr, Ru, La, Ce, Ba)

At Duke, the information for each release category is obtained from MAAP runs. For each release category, a MAAP run is made based on the dominant accident sequence (i.e., plant damage state) for that particular release category.

#### Attached Files

- cr2.cpm - an example of a conditional probability matrix file (for Catawba)
- cr2.rcm - an example of a release category matrix file (for Catawba)
- Sample Initiator Database.xls - an example of an initiating event look-up table (for Catawba)

---

[1] D. Chanin and M. L. Young, *Code Manual for MACCS2*, NUREG/CR-6613, Vol. 1, SAND97-0594, prepared by Technadyne Engineering Consultants and Sandia National Laboratories, prepared for the U. S. Nuclear Regulatory Commission and U. S. Department of Energy, May 1998.

# **Attachment B**

## **Input Required to Perform “Generic Level 3 PRA,” Part 2**

## INPUT REQUIRED TO PERFORM “GENERIC LEVEL 3 PRA”

### (Part 2)

-- B&WOG Project --

There are two general areas for which input will be required from the utilities participating in the B&W Owners Group’s Generic Level 3 PRA, sponsored by the Risk-Informed Applications Committee (RIAC). The first area is the input required to run the MACCS2 code, which is used to calculate the health and economic consequences of accidental releases of radioactive material to the atmosphere. The principal phenomena considered in MACCS (the immediate predecessor of MACCS2) are atmospheric transport, short-term and long-term mitigative actions and pathways, deterministic and stochastic health effects, and economic costs. [1]

The second area is the input necessary for the risk spreadsheet applications developed by Duke Power Company to provide a linkage between the Level 1 PRA and Level 2 PRA results, and the Level 3 PRA analysis. Using the risk spreadsheet will facilitate the ability to update the Level 3 PRA results when there are changes in the Level 1 and Level 2 analysis through the course of normal updates due to model changes, new data, plant modifications, etc. This B&WOG project will provide the participating utilities with the technology transfer necessary to run MACCS2, as well as use the risk spreadsheets.

#### Inputs Required for the Risk Spreadsheet Application

The inputs required for the risk spreadsheet application consists of three files:

- Conditional Probability Matrix (\*.cpm) [from Level 1 Analysis]
- Release Category Matrix (\*.rcm) [from Level 2 Analysis]
- Initiating Event Lookup Table

These items are discussed in Part 1 (previously sent).

#### Inputs Required for MACCS2 (Execution)

While many of the parameters required as input to MACCS2 will be taken from the existing Oconee input file, there are some plant-specific parameters that should be provided . These fall into several categories, e.g., level 2 results, meteorological, population, etc. The input data required from the level 2 analysis (for MACCS2) was addressed in Part 1 (previously sent). The additional information can be grouped into the four input files (or models) that are required by MACCS2, e.g., EARLY, CHRONIC, SITE, and ATMOS. There is also a meteorological file required. Assumed default values will be shown in bold brackets (e.g., [default]).

---

---

*Inputs required for EARLY*

Shielding and Exposure (SE) Data (6.5)

- Cloud shielding factor for evacuation, normal activity and sheltering  
(Duke used      Evacuees - 1.0  
                         Normal - 0.74  
                         Shelter - 0.71)
- Ground shielding factor for evacuation, normal activity and sheltering  
(Duke used      Evacuees - 0.5  
                         Normal - 0.31  
                         Shelter - 0.28)

Evacuation Zone (EZ) Data (6.6)

- Weighting fraction to be applied to the results from the emergency response scenario (Duke used 0.52) -- this value specifies the fraction of the population evacuates within a specified amount of time. For Ocone, the assumption is that 52% of the population evacuates in 3960 seconds (based on evacuation time estimate studies for Ocone).
- Define whether evacuees are presumed to move from a spatial element when they cross the boundary dividing two elements (BOUNDARY) or when they reach the CENTERPOINT of the destination (Duke used CENTERPOINT)
- Evacuation speeds during three phases: initial, middle, late (meters/sec) (Duke used 2.7 for all three phases)
- Define reference time point for actions in the evacuation and sheltering zone (Duke used when the evacuation alarm occurs)
- Define duration of early evacuation phase (seconds) (Duke used 3600.0)
- Define duration of middle evacuation phase (seconds) (Duke used 7200.0)
- Number of rings in the shelter and evacuation region (Duke used 15, 10 miles around the site)
- Define delay that elapses from reference time point to when individuals take shelter (seconds) (Duke used 0.0 for all 15 rings)
- Define the delay for individuals to begin evacuation (seconds) (Duke used 3960.0 for all 15 rings)

---

---

*Inputs required for CHRONIC*

*[Duke used all MACCS defaults for this file.]*

---

---

*Inputs required for SITE*

Duke used 34 spatial intervals and 16 wind directions.

Spatial Distances Data Block (A.3.1)

- spacing of spatial rings (kilometers) (Duke used 34 rings out to 3218.6 km (2000 miles))

Population Data Block (A.3.2)

- population for each element in the spatial grid: 34 rings x 16 wind directions

Land Fraction Data Block (A.3.3)

- fraction of each spatial element in the spatial grid that is land (versus lakes, oceans, rivers, etc.)

Region Index Data Block (A.3.4)

- state code for each spatial element in the spatial grid

Watershed Index Data Block (A.3.5)

- watershed index for each spatial element in the spatial grid ... the watershed index assignment for each of the spatial intervals in the grid can be made by reviewing a site map and determining whether the spatial grid interval contributes to any drinking water. The following assignments can be made: use "1" if part of the spatial grid interval is a river or lake; use "2" if the spatial grid interval is an ocean or land.

---

---

*Inputs required for ATMOS*

Geometric (GE) Data (5.3)

- number of spatial radial elements
- spatial endpoint distances in kilometers

Wake Effects (WE) Data (5.10)

- reactor building height (meters)
- reactor building width (meters)

Release Description (RD) Data (5.11)

- Warning time (seconds) [from Part 1 request]
- Number of plume segments that are released [**1**]
- Representative time point for dispersion and radioactive decay [**leading edge**]
- Heat content of release segment (W) [from Part 1 request]
- Height of plume (meters) [from Part 1 request]

- Duration of plume (seconds) [from Part 1 request]
- Time of release (seconds) [from Part 1 request]
- Particle size distribution of each element group [**one size assumed for all 9 element groups**]
- Core inventory of each radionuclide at time of accident initiation (becquerels) (Duke listed 60 isotopes)
- Scaling factor to adjust the core inventory (may be used to account for different power level) [**1.0**]
- Release fraction [from Part 1 request]

#### Boundary Weather (M2) Data (5.14)

- Boundary weather mixing layer height (meters) (Duke used 1000., approximate average of the eight mixing heights supplied in the ONS MACCS2 meteorological file)
- Boundary weather stability class index (Duke used "4" since approximately half of the hourly data had a value of "4.")
- Boundary weather rain rate (millimeters/hour) (Duke assumed a value of 0.0)
- Boundary weather wind speed (meters/second) (Duke used 2.5 as the approximate average wind speed)

#### Meteorological Bin Sampling Data (5.16)

- Number of rain distance intervals for binning (Duke used six)
- Endpoints of the rain distance interval (kilometers) (Duke used 8.05, 16.09, 24.14, 32.19, 40.23, and 48.28)
- Number of rain intensity breakpoints [**2**] (minimum permitted)
- Rain intensity breakpoints (millimeters/hours) (Duke used 99.9 100 .0, set arbitrary high to force all rain intensities into a single group)
- Number of samples per bin (Duke used 4)

#### Meteorological Input File

8760 lines of data contain hourly meteorological data for one year:

The first column of data (1 to 365) denotes the day of the year:

```
1 1 40176 0
1 2 20156 0
1 3 40306 0
```

The next column of data (1 to 24) denotes the hour of the day:

```
1 1 40176 0
1 2 20156 0
1 3 40306 0
```

The third column of data may contain either 5 or 6 digits formatted as follows: The first set of data (first or first two numbers) is the direction the wind is blowing *toward* represented by sector numbers 1 through 16, e.g., N – sector 1, NNE – sector 2, NE – sector 3, ENE – sector 4, etc.

```
1 1 40176 0
1 2 20156 0
1 3 40306 0
1 4 50156 0
1 5 40156 0
1 6 130106 0
```

The second set of data in the next three numbers is the wind speed in units of 10ths of meters per second:

```
1 1 40176 0
1 2 20156 0
1 3 40306 0
```

The third set of data in the last digit is the stability category (1 to 7 - Pasquill A through G):

```
1 1 40176 0
1 2 20156 0
1 3 40306 0
```

The last column of data, up to three digits, is the accumulated precipitation in units of 100ths of inches. Some meteorological data files use “-1” to indicate a trace of precipitation during the hour. MACCS2 assumes these values to be 0.

```
1 1 40176 0
1 2 20156 0
1 3 40306 0
```

The last line of data in the meteorological file contains eight values of mixing layer height. Two values of mixing height are supplied for each of the four seasons of the year. The first of these two values corresponds to the morning mixing height and the second to the afternoon height.

```
8.0 12.0 11.0 9.0 10.0 12.0 11.0 9.
```