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U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Document Control Desk

Subject: Oconee Nuclear Station
Docket Numbers 50-269, 270, and 287
Supplement to License Amendment Request for Full-Scope Implementation of the Alternate Source Term
Technical Specification Change (TSC) Number 2001-07

Pursuant to Title 10, Code of Federal Regulations, Part 50, Section 90 (10 CFR 50.90), Duke Energy (Duke) proposes to amend Appendix A, Technical Specifications, for Facility Operating Licenses DPR-38, DPR-47 and DPR-55 for Oconee Nuclear Station, Units 1, 2, and 3. The license amendment requests approval of the Alternate Source Term (AST) analysis methodology for Oconee Nuclear Station that will support simplification of Ventilation System testing requirements during core alterations or movement of irradiated fuel. The License Amendment Request (LAR) was submitted to the Nuclear Regulatory Commission (NRC) on October 16, 2001.

Duke received additional questions from the NRC related to the AST LAR. In a meeting with the NRC on March 21, 2002, Duke discussed the additional questions with the staff. A common understanding of the questions and required responses were obtained. Attachment 1 documents Duke's response to the additional questions. Attachment 2 is Duke's Final Report related to Control Room Envelope Inleakage Testing at Oconee Nuclear Station. Attachment 3 is an electronic data file that supports the information contained in Attachment 1.

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Duke has committed to three modifications as a result of the AST LAR. The three modifications include: a dual air intake system to the Control Room; a high pressure/low pressure injection relief valve discharge to the reactor building emergency sump; and a passive caustic addition system. These modifications will be completed on all three units by the end of 2005.

Pursuant to 10 CFR 50.91, a copy of this proposed license amendment is being sent to the State of South Carolina.

If there are any questions regarding this submittal, please contact Reene' Gambrell at (864) 885-3364.

Very truly yours,

W. R. McCollum, Jr., Vice President
Oconee Nuclear Site

cc: w/attachments 1, 2 & 3(two copies)

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W. R. McCollum, Jr., being duly sworn, states that he is Vice President, Oconee Nuclear Site, Duke Energy Corporation, that he is authorized on the part of said Company to sign and file with the U. S. Nuclear Regulatory Commission this revision to the Renewed Facility Operating License Nos. DPR-38, DPR-47, DPR-55; and that all the statements and matters set forth herein are true and correct to the best of his knowledge.

W. R. McCollum, Jr., Vice President
Oconee Nuclear Site

Subscribed and sworn to before me this 20 day of May, 2002

Connie M Breazeale
Notary Public

My Commission Expires:

2/12/03

ATTACHMENT 1

Duke Energy Corporation
Response to Request For Additional Information
Approval of Alternative Source Term Implementation

Duke Energy Corporation
Response to Request For Additional Information
Approval of Alternative Source Term Implementation

Introduction

Duke personnel met with NRC staff on March 21, 2002 to discuss proposed responses to the Request for Additional Information. Based on the discussions at this meeting, both the Loss of Coolant Accident (LOCA) and Fuel Handling Accident (FHA) analyses have been revised to incorporate improvements and conservative simplifications in features and input parameters.

Duke agreed to use a simplified, conservative model for the LOCA analysis by revising the model to credit natural deposition only in the unsprayed region of containment. Duke also agreed to revise the FHA analysis to credit an overall effective Decontamination Factor (DF) of 200, instead of an elemental DF of 500 and organic DF of 1.

LOCADOSE Version 6.0 was used in the revision of these analyses. This version provides improved logic and treatment of a calculation using the ONS model input features. Version 6.0 of the code adds some modeling techniques to Version 5.0 that are especially suited to the ONS Alternative Source Term (AST) application.

The calculated LOCA and FHA doses are shown in the tables below. All calculated doses remain within the regulatory limits prescribed in Regulatory Guide 1.183.

LOCA Calculated Doses			
	Containment Model (rem TEDE)	**RBES Model (rem TEDE)**	**Total TEDE (rem)**
EAB	8.4	0.2	8.6
LPZ	1.5	0.1	1.6
Control Room	2.5	0.6	3.1

Calculated Doses to Control Room Operators due to Fuel Handling Events Spent Fuel Pool (SFP) and Containment					
Case	**Group**	**Source**	**Unit and Release Point**	**Control Room Unit Destination**	**TEDE (rem)**
1	1	Fuel Assembly Accident in SFP	Unit 2 Unit Vent	Unit 1&2	1.8
2	1	Fuel Assembly Accident in SFP	Unit 3 Roll-Up Door	Unit 1&2	0.6
3	1	Fuel Assembly Accident in SFP	Unit 2 Unit Vent	Unit 3	1.2
4	1	Fuel Assembly Accident in SFP	Unit 3 Roll-Up Door	Unit 3	0.4
5	2	Fuel Assembly Accident in Containment	Unit 2 Unit Vent	Unit 1&2	1.0
6	2	Fuel Assembly Accident in Containment	Unit 3 Unit Vent	Unit 3	0.7
7	3	Transport Cask Drop in SFP	Unit 2 Unit Vent	Unit 1&2	2.8
8	3	Transport Cask Drop in SFP	Unit 2 Unit Vent	Unit 3	1.9
9	3	ISFSI Cask Drop in SFP	Unit 2 Unit Vent	Unit 1&2	1.2
10	3	ISFSI Cask Drop in SFP	Unit 2 Unit Vent	Unit 3	0.8
11	3	ISFSI Cask Drop in SFP	Unit 3 Roll-Up Door	Unit 1&2	0.4
12	3	ISFSI Cask Drop in SFP	Unit 3 Roll-Up Door	Unit 3	0.3

Calculated Offsite Doses due to Fuel Handling Events Spent Fuel Pool (SFP) and Containment					
Case	**Group**	**Source**	**Unit and Release Point**	**EAB TEDE (rem)**	**LPZ TEDE (rem)**
1	1	Fuel Assembly Accident in SFP	Unit 2 Unit Vent	1.2	0.1
2	1	Fuel Assembly Accident in SFP	Unit 3 Roll-Up Door	1.2	0.1
5	2	Fuel Assembly Accident in Containment	Unit 2 Unit Vent	0.7	0.1
7	3	Transport Cask Drop in SFP	Unit 2 Unit Vent	1.2	0.2
9	3	ISFSI Cask Drop in SFP	Unit 2 Unit Vent	0.8	0.1
11	3	ISFSI Cask Drop in SFP	Unit 3 Roll-Up Door	0.8	0.1

1. **NRC Request**

In page 12 of Attachment 3, you stated that all radiological consequence calculations for implementing the alternative source term (AST) were performed with the LOCADOSE computer code system. You further stated that the AST using the LOCADOSE computer code have been submitted previously to the NRC for review in licensing submittal for the Surry Nuclear Power Station.

Provide the inputs used and outputs obtained from the LOCADOSE computer code system (similar to those provided to the NRC by Surry) for the postulated design basis loss-of-coolant accident (LOCA) and fuel handling accident (FHA) at Oconee Units 1, 2, and 3. The submittal should contain the fission product transport and removal models used in the computer code.

Response

The LOCADOSE code transport input (*.lti), dose input (*.ldi), library (*.lib), transport output (*.lto) and dose output (*.ldo) electronic files are provided on the enclosed CD. The last page of this response gives a detailed file listing. LOCA files are provided for both the containment model and Reactor Building (RB) sump (ECCS) model. The FHA files are provided for each of the 12 different cases discussed in the LAR submittal. A description of the LOCADOSE input data is given below for each accident.

Loss-of-Coolant Accident (LOCA) LOCADOSE Input Data

Two separate models are used for the LOCA. One computes the releases from the containment atmosphere and the other computes releases from the RB sump. Two models are needed because LOCADOSE automatically creates a "pseudo-sump" for collecting iodine washed out by the RB spray system. This pseudo-sump cannot be simultaneously specified as a node with which to model leakage to the Borated Water Storage Tank (BWST) and Auxiliary Building. These two models are based on Regulatory Guide 1.183 (RG-1.183) source term methodology.

The containment model simulates mixing between the sprayed and unsprayed portions of containment, releases from containment to the penetration room, and containment releases that bypass the penetration room and enter the environment directly.

The RB sump model simulates leakage from the sump into the BWST, and leakage into the Auxiliary Building.

Containment Model

1.1 Flow Paths and Flowrates

The model consists of the following nodes and volumes:

Node #	Description	Volume (ft^3)
1	Outside Atmosphere	N/A
2	Sprayed Containment Volume	8.66E+05
3	Unsprayed Containment Volume	9.17E+05
4	Penetration Room	4.0

The Penetration Room is assumed to have an arbitrarily small volume, which conservatively does not take credit for dilution or hold up in this node.

The fission product transport paths are represented by:

Node 2 ⟶ Node 1

This flow path represents the leakage from the sprayed containment volume to the atmosphere via the Unit Vent bypass.

Filtered Flow = 0.0
Filter Efficiencies = 0.0 for all 12 isotope groups
Unfiltered Flow: 0-24 hrs. = 0.6016 cfm
1-30 days = 0.3008 cfm

Node 2 ⟶ Node 3

This flow path represents the mixing between the sprayed containment volume and the unsprayed containment volume.

Filtered Flow = 0.0
Filter Efficiencies = 0.0 for all 12 isotope groups
Unfiltered Flow = 30,567 cfm

Node 2 ⟶ Node 4

This flow path represents the leakage from the sprayed containment volume to the Penetration Room.

Filtered Flow = 0.0
Filter Efficiencies = 0.0 for all 12 isotope groups
Unfiltered Flow: 0-24 hrs. = 0.6016 cfm
1-30 days = 0.3008 cfm

<u>Node 3 ⟶ Node 1</u>

This flow path represents the leakage from the unsprayed containment volume to the atmosphere via the Unit Vent.

Filtered Flow = 0.0
Filter Efficiencies = 0.0 for all 12 isotope groups
Unfiltered Flow: 0-24 hrs. = 0.6368 cfm
1-30 days = 0.3184 cfm

<u>Node 3 ⟶ Node 2</u>

This flow path represents the mixing between the unsprayed containment volume and the sprayed containment volume.

Filtered Flow = 0.0
Filter Efficiencies = 0.0 for all 12 isotope groups
Unfiltered Flow = 30,567 cfm

<u>Node 3 ⟶ Node 4</u>

This flow path represents the leakage from the unsprayed containment volume to the Penetration Room.

Filtered Flow = 0.0
Filter Efficiencies = 0.0 for all 12 isotope groups
Unfiltered Flow: 0-24 hrs. = 0.6368 cfm
1-30 days = 0.3184 cfm

<u>Node 4 ⟶ Node 1</u>

This flow path represents the normal transfer from the Penetration Room through the Penetration Room Ventilation System to the atmosphere via the Unit Vent.

Filtered Flow = 0.0
Filter Efficiencies = 0.0 for all 12 isotope groups
Unfiltered Flow = 1000 cfm

1.2 Source Terms

The source term methodology used for the containment model follows that presented in RG-1.183. In order to adhere to both RG-1.183 and the LOCADOSE methodology, LOCADOSE libraries were constructed using the LOCADOSE Center that were consistent with the applicable reference.

The RG-1.183 source term input for LOCADOSE are entered as a curie per hour production based on a fraction of the core inventory.

This curie per hour production is calculated by combining the release fractions, the iodine fractions, the specific isotope fractions, the core inventory from the Library file, and the reactor power. The following equations illustrate how the activities for the LOCADOSE groups are calculated:

$$\begin{pmatrix} Production: \\ Groups\,1-3 \end{pmatrix} = \frac{\begin{pmatrix} Group\,Release \\ Fraction \\ \ \end{pmatrix} * \begin{pmatrix} Iodine\,Species \\ Fraction \\ \ \end{pmatrix} * \begin{pmatrix} Isotope \\ Fractions \\ \ \end{pmatrix} * \begin{pmatrix} Source \\ Term \\ \ \end{pmatrix} * \begin{pmatrix} Reactor \\ Power \\ \ \end{pmatrix}}{Time\,Frame\,Production\,Term\,is\,Applied\,Over-in\,Hours}$$

$$\begin{pmatrix} Production: \\ Groups\,4-12 \end{pmatrix} = \frac{\begin{pmatrix} Group\,Release \\ Fraction \\ \ \end{pmatrix} * \begin{pmatrix} Isotope \\ Fractions \\ \ \end{pmatrix} * \begin{pmatrix} Source \\ Term \\ \ \end{pmatrix} * \begin{pmatrix} Reactor \\ Power \\ \ \end{pmatrix}}{Time\,Frame\,Production\,Term\,is\,Applied\,Over-in\,Hours}$$

<u>Group Release Fractions</u>

The containment models include LOCADOSE Groups 1-9 and 11-12 when calculating dose (see Table 2 below). For this reason the release fractions for Groups 1-9 and 11-12 are set to 1.0 in Record 10 of the activity transport input decks. Since Group 10 is not considered within RG-1.183 methodology, its fraction is input as 0.0.

<u>Iodine Species Fractions</u>

The values for iodine species fractions in the LOCADOSE models are as follows:

Elemental = 4.85%
Organic = 0.15%
Particulate = 95%

<u>Isotope Fractions</u>

RG-1.183 presents release times, durations, and core fractions that are used for LOCADOSE modeling. Tables 1 and 2 illustrate the requirements.

Table 1
Alternative Source Term Release Times and Durations

Phase	Onset Time	Duration
Gap Release	30 seconds	30 minutes
Early In-Vessel	30 minutes	1.3 hours

Table 2
RG-1.183 Source Term Core Fraction Releases

Group	Corresponding LOCADOSE Group	Gap Release	Early In-Vessel Phase
Noble Gases	Group 4	0.05	0.95
Halogens	Groups 1-3,11	0.05	0.35
Alkali Metals	Group 5	0.05	0.25
Tellurium Metals	Group 6	0.00	0.05
Ba, Sr	Group 7	0.00	0.02
Noble Metals	Group 8	0.00	0.0025
Cerium Group	Group 12	0.00	0.0005
Lanthanides	Group 9	0.00	0.0002

Source Terms

The source terms for each isotope, in Ci per MW, are entered as part of the Library file.

1.3 Containment Spray

Elemental Iodine

For the modeling of elemental iodine, the DF was set to 1E+14 to avoid spray removal cutoff. The injection phase spray lambda for containment was set to 20 hr^{-1}. For the recirculation phase, the values for spray lambda were varied in order to produce node inventories matching results of Duke calculations modeling iodine washout and re-volatilization.

The values calculated and used for this phase are presented below:

Start Time (hours)	End Time (hours)	Elemental Iodine Spray Lambda (hr^{-1})
2.667E-02	0.4167	20.0
0.4167	1.8	0.0
1.8	8.0	0.06
8.0	13.8	0.09
13.8	24	0.13
24	96	0.071
96	112.8	0.002
112.8	720	0.0

Particulate Iodine and Other LOCADOSE Groups

Due to the physical mechanisms, particulate iodine has no re-volatilization phase associated with it. For this reason, particulate iodine also has no spray cut-off. In order to model this behavior a DF was chosen (1.0E+14) sufficiently high to take full credit for particulate removal. The spray lambdas used for particulate iodine are shown below: In the model, sprays are cut off at the time when elemental iodine reaches equilibrium, so the particulate removal also stops at 112.8 hours.

Start Time (hours)	End Time (hours)	Particulate Iodine Spray Lambda (hr^{-1})
2.667E-2	0.4167	9.70
0.4167	112.8	6.73 initially. Reduces to 0.673 when overall atmospheric concentration falls below 2% of initial

In order to determine the time that the spray lambda is reduced, a sensitivity calculation was performed. An extra time step was added to the activity transport input deck to provide an additional output point within the activity transport output file (.LTO). The extra time step was varied until a specific time was identified such that the overall particulate I-131 atmospheric concentration reported in the LTO file was 2% of the initial amount. For this particular model that time was found to be 3.48 hours and was used as the transition point for the reduction in the particulate iodine spray lambda.

One aspect of the RG-1.183 source term methodology is the allowance of particulate iodine removal constant values for removal by natural processes (designated as λ_{np}) using methodology from NUREG/CR-6189. RG-1.183 also indicates that LOCADOSE Groups 5-12 can be treated the same as the particulate iodine group (Group 3) for the natural process lambdas. Each lambda is entered into the activity transport input deck as a spray lambda, and is applied only to the unsprayed region.

1.4 LOCADOSE Activity Transport Input Data:

For the LOCADOSE modeling, an activity transport input (.LTI) deck for the LOCA accident analysis is created. The input records for this deck are described below.

Records 1-6 Title Information

These records are used to indicate problem title, originator's name, project name, job charge number, calculation number and revision, and the number for the first page of the LOCATRAN output.

Record 7 Problem Limits

Number of nodes = 3
Including sprayed containment volume, unsprayed containment volume, and penetration room.
Control room option = 1 (On)
Daughter product calculation option = 1 (On)
Spray cut-off option = 1 (On)
See Section 1.3

Record 8 Input Data

Core activity source term, curies or fractions = 0 (Curies)
Purge option = 0 (Off)
Reactor power rating = 2568 MWt
Time interval from reactor shutdown = -1 this entry allows no decay of the activity prior to the beginning of the problem considered.
Iodine printed as separate fractions option = 1 (Yes)
Number of sprayed nodes = 2
Number of elements for delay calculations = 0
Delay calculations are excluded due to their insignificant contribution.
Switch to determine if max 2 hour dose is calculated = 1 (On)

Record 8a Maximum 2-Hour Dose

Time interval in hours for calculation of maximum 2-hour dose. TDELTA=0.1
Time in hours until the maximum 2-hour dose is calculated. TMAX=24

Record 9 Units

Flow rate units = CFM
Node volume units = CUFT
Activity units = CURIES

Record 10 Release Fractions

See Section 1.2 for discussion on release fractions.

Record 11 Iodine Fractions

Elemental = 4.85%
Organic = 0.15%
Particulate = 95%

Record 12 Node Names

Node 2: Sprayed
Node 3: Unsprayed
Node 4: PenRoom

Note: LOCADOSE automatically assigns Node 1 as the environment.

Record 13 Sprayed Node Designation

The sprayed containment volume (Node 2) and unsprayed containment volume (Node 3) are selected for the automatic spray cut-off option.

Records 14-25

These records are not needed.

Record 26 Time Steps

Time to begin and end the step = These are listed in the table below.
Print activities option = 1 (On)
Units for activities = 0 (Fractions of core inventories)
Units for production terms = 0 (Fraction of core inventories per hour)
Print interpretive summary option = 1 (On)

Time Steps for Containment Model

Time-step	Start (hr)	End (hr)
1	0.00E+00	8.33E-03
2	8.33E-03	2.667E-02
3	2.667E-02	4.167E-01
4	4.167E-01	5.00E-01
5	5.00E-01	5.0833E-01
6	5.0833E-01	5.17E-01
7	5.17E-01	6.00E-01
8	6.00E-01	6.67E-01
9	6.67E-01	8.17E-01
10	8.17E-01	9.67E-01
11	9.67E-01	1.417E+00
12	1.417E+00	1.80E+00
13	1.80E+00	2.0E+00
14	2.0E+00	2.60E+00
15	2.60E+00	3.48E+00
16	3.48E+00	3.8E+00
17	3.8E+00	4.167E+00
18	4.167E+00	8.0E+00
19	8.0E+00	1.38E+01
20	1.38E+01	2.222E+01
21	2.222E+01	2.4E+01
22	2.4E+01	9.6E+01
23	9.6E+01	1.128E+02
24	1.128E+02	1.2E+02
25	1.2E+02	2.4E+02
26	2.4E+02	4.8E+02
27	4.8E+02	7.2E+02

Record 27 Initial Data

Enter initial activities option = Off
Enter initial production term option = On for timesteps when production term is changed.

Enter node volume option = On for initial time step and Off for remainder of model.
Switch to determine if flow paths are entered = 1 (On) for timesteps when the flow path information is changed, 0 (Off) when there is no change.
Switch to determine if spray removal rates are entered = 1 (On) for timesteps that include spray removal, 0(Off) when there is no spray.
Switch to determine if spray DF information is entered = 1 (On) for timesteps that include DF information, 0(Off) when there is no change.

Record 27a Node Activity Designation

This record is only used when activities change for a given timestep. The change is signaled in the first field of Record 27. For this model, the record will read as follows:

Number of nodes with new activity = 2
Node numbers where activity changes = 2 (Sprayed Node), 3 (Unsprayed Node)

Record 28 Activities

Source terms are entered for each isotope group at the nodes designated in Record 27a. See Section 1.2 for a discussion on the values entered into the models.

Record 29

This record is not needed.

Record 30 Node Volumes

'Sprayed' node = 8.66E+5 cubic feet
'Unsprayed' node = 9.17E+5 cubic feet
'PenRoom' node = 4.0 cubic feet

Records 31-32 Flow Paths and Filter Efficiency

Values entered per Section 1.1.

Records 33-34 Spray Removal Parameters

Values entered per Section 1.3.

Record 35 Control Room Conditions

Parameter change option = 1 (On) for timesteps when Records 36-38 are varied from previous timestep and 0 (Off) when constant. Model only changes conditions at the 30-minute point to accommodate the Control Room (CR) booster fan activation.

Number of χ/Q Values = -1
Flag integer to signify that multiple χ/Q values will be entered in Record 39.

Record 36 Control Room Data:

Data shown is for Units 1&2 Control Room.

Control room volume = 86446 cubic feet
Filtered intake = 0.0 cfm for first 30 minutes, 1215 cfm thereafter
Unfiltered intake = 1150 cfm for first 30 minutes, 150 cfm thereafter
Recirculation rate = 0.0
Exhaust rate = Sum of the filtered and unfiltered rates

Record 37 Intake Filter Efficiencies

The assumed filter efficiencies for the control room intake iodine filters are 99% for particulate, 95% for organic, and 99% for elemental iodine.

Record 38 Recirculation Filter Efficiencies

Efficiencies are entered as 0.0 since the recirculation rate is entered as 0.0 in Record 36

Record 39 Node χ/Q Values

Values are input based on the time step being considered.

Containment Model:

Time (hours)	Node 2 Equipment Hatch (sec/m^3)	Node 3 Equipment Hatch (sec/m^3)	Node 4 Unit Vent (sec/m^3)
0-2	3.18E-4	3.18E-4	4.35E-4
2-8	2.46E-4	2.46E-4	3.09E-4
8-24	1.04E-4	1.04E-4	1.27E-4
24-96	7.80E-5	7.80E-5	9.95E-5
96-720	6.10E-5	6.10E-5	8.05E-5

Sump Model:

Time (hours)	Node 3 Unit Vent (sec/m^3)	Node 4 BWST (sec/m^3)
0-2	4.35E-4	1.94E-4
2-8	3.09E-4	1.47E-4
8-24	1.27E-4	6.05E-5
24-96	9.95E-5	4.72E-5
96-720	8.05E-5	3.70E-5

1.5 LOCADOSE Dose Calculation Input Values

For modeling purposes, a dose calculation input (.LDI) deck for the LOCA accident analysis is produced for calculating dose contributions. The input records for this deck are described below.

Records 1-6 Title Information

These records are used to indicate problem title, originator's name, project name, job charge number, calculation number and revision, and the number for the first page of the LOCATRAN output.

Record 7 Problem Options

For this record the desired calculation and printout options are listed. Those chosen for this calculation are as follows:

DOR = calculate doses within regions
DOF = calculate doses offsite
ISO = print per isotope

Record 7a Problem Options

This record allows selection of those regions for which LOCADOSE will calculate doses.

Number of nodes to print results = 1
Node number for which to print the results = 5 (Control Room)

Record 7b

For this record, the dose point used to calculate dose rates = 1

Record 8 Dose Parameters

Number of offsite dose points = 2 (LPZ and EAB)

Number of χ/Q values = 5
This value allows for an additional dose point at 2 hours.

Number of breathing rates for offsite dose points = 3

Number of occupancy factors = 3

Number of breathing rates for regions = 1

Record 9 Units

Dose calculation = REM
Dose rate calculation = REM/HR

Record 10 Offsite Dose χ/Q values

The 0-2 Hour exclusion area boundary (EAB) atmospheric dispersion factor (χ/Q) for offsite dose calculations is assumed to be 2.2E-4 sec/m^3.

The χ/Q values for the outer boundary of the low population zone (LPZ) are:

Time Period	LPZ χ/Q (sec/m^3)
0 - 8 Hrs	2.35E-5
8 - 24 Hrs	4.70E-6
1 - 4 Days	1.50E-6
4 - 30 Days	3.30E-7

Record 11 Offsite Breathing Rates

Regulatory Guide 1.183 breathing rate values are used in the offsite dose predictions:

0-8 hours:	3.5E-04 m^3/sec
8-24 hours:	1.8E-04 m^3/sec
1-30 days:	2.3E-04 m^3/sec

Note: Records 10 and 11 are repeated for number of offsite dose points specified (2).

Record 12 χ/Q Time Change

Record indicates the time at which the offsite χ/Q values change: 2, 8, 24, 96, 720 hours.

Record 13 Breathing Rate Time Change

Record indicates the time at which the offsite breathing rates change: 8, 24, 720 hours.

Record 14 Gamma Correction Factor

Finite cloud gamma dose correction factor is input as 1.00 for each offsite dose point.

Record 15 Region Occupancy Factors

The occupancy factors for the Control Room operators during the 30-day post-accident period are taken from RG-1.183:

0 to 24 hours = 100%
1 to 4 days = 60%
4 to 30 days = 40%

Record 16 Region Breathing Rates

The breathing rate for control room operators is taken from RG-1.183, and is 3.5E-4 m^3/sec for the duration of the accident

Note: Records 15 and 16 are repeated for the number of regions specified.
Containment model = 5 (3 nodes + control room + pseudo node for spray)

Record 17 Occupancy Time Change

Record indicates the time at which the region occupancy factors change: 24, 96, 720 hours.

Record 18 Breathing Rate Time Change

Record indicates the time at which the CR breathing rates change: 720 hours.

Record 19 Gamma Correction Factor

Finite cloud gamma dose correction factor is input as 1.00 for each region. LOCADOSE automatically applies a finite cloud correction factor to the whole body or DDE dose result for the control room based on 100% of the control room volume input in Record 36 of the corresponding .LTI file.

Records 20-21

These records are not needed since the decay during transit option was turned off in Record 8.

1.6 Library File

The LOCADOSE library input file used for Control Room dose calculations was produced using the LOCADOSE Center. The library was produced by selecting the Federal Guidance Report 11 and 12 Dose Conversion Factors and the isotopes listed in the LOCADOSE Theoretical Manual. The remainder of the library is completed by LOCADOSE when the daughter option is selected.

The following long-lived isotopes were removed from the LOCADOSE Center produced library:

Ce-142	Cm-247	Cm-248
Cs-135	Nd-144	Np-237
Pd-107	Pu-242	Pu-244
Rb-87	Sm-148	Sm-149
Zr-93	Gd-152	U-236
U-234	U-238	Th-232

Since these are all long-lived isotopes, the effect of removing these isotopes from the analysis is negligible.

The code automatically computes the core inventory for each isotope. These core inventories were updated to accurately model the Oconee units. These numbers were divided by a reactor power of 2568 MW and entered into the LOCADOSE produced library. A 2% power uncertainly was included in the calculation of the core inventory.

Sump Model

2.1 Source Terms

Source term input data for this model are identical to those presented in the containment model in Section 1.2, with the following exceptions:

Group Release Fractions

Based on Regulatory Guide 1.183, the control room ECCS models must include 100% of LOCADOSE Groups 1-9 and 11-12 when calculating dose. RG-1.183 states that with the exception of iodine, all radioactive materials in the liquid are assumed to be retained in the liquid phase. In order to accommodate both requirements, the release fractions for Groups 1-2 are input as 1.0 in Record 10 of the activity transport input decks. Since Groups 3-12 are not included in the ECCS liquid that is assumed to flash to steam, these fractions are entered as 0.0.

Iodine Species Fractions

The values are input into the LOCADOSE models as follows:

Elemental = 97%
Organic = 3%
Particulate = 0%

2.2 Containment Spray

There is no containment spray for the ECCS model.

2.3 LOCADOSE Activity Transport Input Data:

Activity transport inputs for this model are identical to those presented in the containment model in Section 1.5, with the following exceptions:

Record 7 Problem Limits

Automatic spray cut-off option = 0 (Off)

Record 10 Release Fractions

See Section 2.1 for discussion on release fractions.

Record 11 Iodine Fractions

Elemental = 97%
Organic = 3%
Particulate = 0%

Record 26 Time Steps

Time to begin and end the step. These are listed in the table below.

Time Steps for Sump Model

Time-step	Start (hr)	End (hr)
1	0.00E+00	8.33E-03
2	8.33E-03	4.167E-01
3	4.167E-01	5.00E-01
4	5.00E-01	5.0833E-01
5	5.0833E-01	6.67E-01
6	6.67E-01	1.70E+00
7	1.70E+00	1.80E+00
8	1.80E+00	2.00E+00
9	2.00E+00	3.70E+00
10	3.70E+00	8.00E+00
11	8.00E+00	2.40E+01
12	2.40E+01	5.056E+01
13	5.056E+01	9.60E+01
14	9.60E+01	7.20E+02

2.4 LOCADOSE Dose Calculation Input Data:

Dose Calculation inputs for this model are identical to those presented in Section 1.5 for the containment model, with the following exceptions:

Records 15 and 16 are only repeated 4 times (as opposed to 5 for containment model). This is based on:

Nodes = 4 = 3 nodes + control room

2.5 Library File

The library file used for the LOCADOSE sump model is was the same one used for the containment case.

Fuel Handling Accident LOCADOSE Input

Model

The accident models simulate releases from containment and the Spent Fuel Pool (SFP) buildings and compute their contribution to control room dose. The difference in the models occurs in the gas transport from either the surface of the SFP or the transfer canal to the exterior environment and subsequently to one of the control rooms.

For accidents in the SFP, the first model considers a release through a unit vent of the SFP building ventilation system during the accident with no filtration of the iodine by the unit vent filters available. In the second model, the gases are considered released through a SFP building roll-up door during the accident (no filtration will occur for this release path).

For accidents in containment, the first model considers a release through a unit vent of the containment building ventilation system during the accident with no filtration of the iodine by the unit vent filters available. In the second model, the gases are considered released through the most limiting pathway of a containment building during the accident.

Model 1: Unit Vent Releases

The first model assumes that the released gases over the SFP or transfer canal are immediately (i.e., released over two hours) transported out a unit vent where they are released to the environment. For groups 1 and 2, releases are through either the Unit 2 unit vent (the Unit 1&2 SFP ventilation exhausts through the Unit 2 unit vent) or through the Unit 3 unit vent. For group 2, the release may be through the Unit 1, 2, or 3 unit vent. The normally continuously running control room ventilation systems are then used to bring air from the environment into the control room. The filtered and unfiltered χ/Q values for the control room are used to determine the radionuclide concentrations in the control room as a result of the intake from the environment.

Model 2: Roll-Up Door and Equipment Hatch Releases

For groups 1 and 3, the second model assumes that the released gases over the SFP are immediately transported out a roll-up door where they are released to the environment. For group 2, this model assumes that the released gases over the transfer canal are immediately transported out an equipment hatch where they are released to the environment. The normally continuously running control room ventilation system is used to bring air from the environment into the control room. The filtered and unfiltered χ/Q values for the control room are used to determine the radionuclide concentrations in the control room as a result of the intake from the environment. No credit is taken for any filtration of iodine in the SFP ventilation system or the reactor building purge system for this model.

χ/Q Release Data

The 0-2 hour χ/Q values for the releases from the containment unit vents and equipment hatches to the two control rooms, as calculated using ARCON96, are reduced by a factor of 2 for dual intake credit. Since the source terms for fuel handling accidents in containment are the same (i.e., the single fuel assembly source term), the maximum dose occurring in a control room can be established from the maximum 0-2 hour χ/Q, which is the unit vent χ/Q.

The 0-2 hour χ/Q values for the releases from the SFP unit vents to the two control rooms for each considered case are reduced by a factor of 2 for dual intake credit. Since the source terms are assumed not to vary with the release point, the maximum calculated dose to a control room can be established from the maximum 0-2 hour χ/Q correlating the release from a SFP unit to a control room.

The table below summarizes the specific fuel handling accidents analyzed in this analysis.

Specifically Analyzed Fuel Handling Accident Cases Examined

Case	Group	Source	Unit and Release Point	Control Room Unit Destination	0-2 hr χ/Q
1	1	Fuel Assembly Accident in SFP	Unit 2 Unit Vent	Unit 1&2	4.35E-04 sec/m^3
2	1	Fuel Assembly Accident in SFP	Unit 3 Roll-Up Door	Unit 1&2	1.44E-04 sec/m^3
3	1	Fuel Assembly Accident in SFP	Unit 2 Unit Vent	Unit 3	4.35E-04 sec/m^3
4	1	Fuel Assembly Accident in SFP	Unit 3 Roll-Up Door	Unit 3	1.44E-04 sec/m^3
5	2	Fuel Assembly Accident in Containment	Unit 2 Unit Vent	Unit 1&2	4.35E-04 sec/m^3
6	2	Fuel Assembly Accident in Containment	Unit 3 Unit Vent	Unit 3	4.35E-04 sec/m^3
7	3	Transport Cask Drop in SFP	Unit 2 Unit Vent	Unit 1&2	4.35E-04 sec/m^3
8	3	Transport Cask Drop in SFP	Unit 2 Unit Vent	Unit 3	4.35E-04 sec/m^3
9	3	ISFSI Cask Drop in SFP	Unit 2 Unit Vent	Unit 1&2	4.35E-04 sec/m^3
10	3	ISFSI Cask Drop in SFP	Unit 2 Unit Vent	Unit 3	4.35E-04 sec/m^3
11	3	ISFSI Cask Drop in SFP	Unit 3 Roll-Up Door	Unit 1&2	1.44E-04 sec/m^3
12	3	ISFSI Cask Drop in SFP	Unit 3 Roll-Up Door	Unit 3	1.44E-04 sec/m^3

Activity Transport Program Input Values

There are two general activity transport input (.LTI) decks for the fuel handling accident analysis: one for releases through a Unit Vent and one for releases through a SFP roll-up door. These two input decks can be applied to releases from either of the Unit 1&2 or Unit 3 SFPs or containments to either of the Unit 1&2 or Unit 3 control rooms. The input records for these decks are described below.

LOCADOSE Inputs Case 1: Releases through Unit Vents

Note that this input case will include cases 1, 3, 5, 6, 7, 8, 9, and 10 from the above table. The input values listed below are applicable for cases 3, 8 and 10. In each of these cases, a fuel handling accident occurs in the Unit 1&2 SFP and doses are calculated to the Unit 3 control room from a release through the Unit 2 unit vent. The differences between these three cases are in their elemental iodine DFs (as entered in Record 28) and source terms: case 3 has a DF for elemental iodine of 137 and a source term for a single fuel assembly, case 8 has a DF for elemental iodine of 301 and a source term related to the dropping of a transport cask, and case 10 has a DF of 301 and a source term related to the dropping of an ISFSI cask into the SFP.

To obtain the inputs necessary to model cases 1, 7, and 9, the control room volume must be changed to 86447 in Record 36, and the control room unfiltered intake and exhaust rates must be changed to 1150 and 1150 for the time steps prior to 0.5-hr and 150 and 2580 for the subsequent time steps in Record 36, respectively. In addition, the appropriate source terms and elemental iodine DFs (as entered in Record 28) must be included with the input values. In each of these cases, a fuel handling accident occurs in the Unit 1&2 SFP and doses are calculated to the Unit 1&2 control room from a release through the Unit 2 unit vent.

To obtain the input values necessary to model cases 5 and 6, the source term for a single fuel assembly is used, along with an elemental iodine DF of 301. The appropriate control room volumes and control room unfiltered intake and exhaust rates are used for each control room. In both of these cases, a fuel handling accident occurs inside containment and doses are calculated to the appropriate control room through the corresponding unit vent.

Records 1-6 Title Information

These records are used to indicate problem title, originator's name, project name, job charge number, calculation number and revision, and the number for the first page of the LOCATRAN output.

Record 7 Problem Limits

Model:
Number of nodes. NODES = 1
 The environment is node 1 (default), the SFP is node 2 (input), and the control room is node 3 (default).
Control room option. ICR = 1
 This parameter sets a flag for the LOCADOSE code to calculate data for the control room.
Daughter product calculation option. CALCDA = 1
 The daughter calculation is turned on.
Spray cut-off option. LSPRAY = 0
 The Reactor Building spray has no bearing on this accident since it occurs in the SFP building. It is turned off with this value.

Record 8 Input Data

Core activity source term, curies or fractions. ITID = 0
 This switch directs LOCADOSE to calculate the activity source term in curies.
Purge option. IPURGE = 0

This switch directs LOCADOSE to ignore the purge option. This is not applicable to this accident.

Reactor power rating. POWER = 2568 MWt

Time interval from reactor shutdown. SDTIME = 0

Iodine printed as separate fractions option. NPF = 1

This switch determines how iodines are to be printed. The 1 indicates they will be printed as elemental, organic, and particulate iodines.

Number of sprayed nodes. NSPN = 0

No spray calculations are executed due to accident occurring in SFP building.

Number of elements for delay calculations. IELEM = 0

No delay calculations are executed due to their insignificant contribution.

Determine if maximum 2 hour dose is calculated. IMAX2=1

Maximum 2-hour dose is desired.

Record 8a Maximum 2-Hour Dose

Time interval in hours for calculation of maximum 2-hour dose. TDELTA=0.5
Time in hours until the maximum 2-hour dose is calculated. TMAX=24

Record 9 Units

Flow rate units. FLUNIT = CFM
Node volume units. VUNIT = CUFT
Activity units. ACUNIT = CURIES

Record 10 Release Fractions

The release fractions for this problem are 1.0 for the elemental iodine (the 1st group), organic iodine (the 2nd group), particulate iodine (the 3rd group), noble gases (the 4th group), and Cesium & Rubidium group (the 5th group), zero for all other groups. The nuclide inventory (per MWt) for each iodine and noble gas are loaded into the Library. All noble gases and iodines are considered released.

Record 11 Iodine Fractions

Elemental = 99.785%

All inorganic iodine is considered to be elemental.

Organic = 0.215%
Particulate = 0%

Note: These fractions are adjusted from the 99.85% and 0.15% listed in Reg Guide 1.183, based on the changes to use an overall effective DF of 200. See response to RAI 18 for details on DF determination.

Record 12 Node Names

Atmospheric Model:

Node 2: SFPDT

Note: LOCADOSE automatically assigns Node 1 as the environment and the last node as the Control Room. Node 2 in this case is the SFP building.

Records 13-25

These records are not needed for the model. Record 13 is only read if the number of sprayed nodes, NSPN, is greater than 0. It is 0 in this case (see Record 8). Record 14 is only read if the number of delay elements, IELEM, is greater than 0. It is 0 in this case (see Record 8). Records 15 – 25 are only read if the local purge option is requested. IPURGE=0 in this case which means it is not requested (see Record 8).

Record 26 Time Steps (repeat Records 26-39 for each time step)

Time to begin and end the step. There are three time steps common to each case: 0 to 0.5-hour, 0.5 to 2-hours, and 2 to 720-hours or 30 days into the accident scenario when the χ/Q and control room occupancy change.

TSTEP1 = 0 TSTEP2 = 0.5
TSTEP1 = 0.5 TSTEP2 = 2.0
TSTEP1 = 2.0 TSTEP2 = 720

Print activities option. IPRTAC = 1

This turns on the print activities.

Units for activities. IAACT = 0

AO is entered in fractions of fuel released, below in Record 28 (curies in the library file).

Units for production terms. IPACT = 0

Fraction of fuel inventories per hour. This is not applicable since production terms are not used.

Print interpretive summary option. IPRINT = 1

This turns on LOCADOSE to print the interpretive summary.

Record 27 Initial Data

Enter initial activities option. LACTIN = 1

Activities are entered (NOTE: for time steps subsequent to the first this value is set to 0).

Enter initial production term option. LPTIN = 0

No production terms are entered.

Enter node volume option. LVOL = 1

Volumes are entered (NOTE: for time steps subsequent to the first this value is set to 0).

Enter flow paths option. LNFLOW=1

Enter spray removal rates option. LNSPRAY=0

Enter spray DF factors option. LNDF=0

Record 27a Nodes with New Activities

One node, Node 2, has new activities entered.
JNODES=1
MNODES=2

Record 28 Activities

Source terms are entered for each isotope at each non-environment and non-control room node. For this problem, the source term is entered into the Library on a Ci per MWt basis uncorrected for pool scrubbing (i.e., using the DFs). The source term in the input deck is entered as 1.00 for each isotope except for the elemental/inorganic iodines whose source terms are corrected for pool water scrubbing by the inclusion of the inverse of DF. For cases 1 through 4, the source terms for elemental/inorganic iodines are set to 0.0073 (=1/137). For cases, 5 through 12, the source terms for elemental/inorganic iodines are set to 0.0033 (=1/301). A record 28 is required for each isotope, therefore 27 source terms are entered (based on NISO, see record 7).

Note: The source term is only entered in the first time step. This is bypassed in subsequent time steps. The release due to a fuel handling accident is exhausted over a two-hour period using the point node established for the SFPDT. A review of the "lto" file demonstrates that by specifying a node volume of 10 ft^3 (see record 30) and a SFPDT node unfiltered release flowrate of 1 CFM (see record 31), the release continues over the two-hour time period to the point where more than 99.99% of the activity is released by the time the analysis reaches two hours in the event.

The A(t) for a volume of air assuming "feed and bleed" phenomena characterized by the equation below. With a volume of 10 ft^3 and flowrate of 1 CFM, 99.99% is removed in two hours.

$$A(t) = A_0 e^{-\left(\frac{F}{V}\right)t}$$

Record 28a

Record 28a is read only if LPTIN = 1, so there is no input for this record.

Record 29

Record 29 is only read if LPTIN = 1. No input since LPTIN = 0 (see record 27).

Record 30 Node Volumes

The volume for the spent fuel pool area is entered as a point node with a volume of 10.0 ft^3 (assures all releases are transported to the control room in two hours).

Records 31-32 Flow Paths and Filter Efficiency

The flow path is from node 2 (SFP Building) to node 1 (environment) with a total flow rate of 1.0 CFM for all time steps. This record has the following values:

From = 2
To = 1
Q1 = 0.0
Q2 = 1.00E+00

The filter efficiency is zero for all 12 groups since unit vent filters are not considered. Thus the entry is 0 0 0 0 0 0 0 0 0 0 0 0

A negative entry for the first value in Record 31 will terminate the cycle of Records 31/32 entries. Hence, -1 0 0 0 is entered after the last entry.

Records 33-34 Spray Removal Parameters

There is no spray, LSPRAY $\neq$ 1 (see Record 7). Hence, Record 33 is entered as -1 0 0 to indicate no spray removal. Record 34 is not read because LSPRAY $\neq$ 1 (see Record 7).

Record 35 Control Room Conditions

Parameter change option flag. LCHG = 1
This switch is used to determine if Control Room parameters change indicating Records 36-38 are to be read. For the final time step, this option can be set to 0 indicating no further changes.

Number of χ/Q values. CRXQ = -1
This field value specifies that multiple χ/Q values will be input for Record 39.

Record 36 Control Room Data:

First Time Step and Time Steps Up to 0.5-hour
Control room volume. CRVOL = 43223 cubic feet for Unit 3
(NOTE: for Unit 1&2 control room volume is 86447).
Filtered intake. CRQ1 = 0
There is no filtered flow considered for the first time step and up to until 0.5 hour.
Unfiltered intake. CRQ2 = 600 for Unit 3
(NOTE: for Unit 1&2 control room intake is 1150).
Recirculation rate. RC = 0.0
Exhaust rate. CRL = 600 for Unit 3
This is the sum of the filtered and unfiltered rates (NOTE: for Unit 1&2 control room rate is 1150).

Time Steps Greater than 0.5-hr

Control room volume. CRVOL = 43223 cubic feet for Unit 3

(NOTE: for Unit 1&2 control room volume is 86447).

Filtered intake. CRQ1 = 1215

The filtered flow rate is 1215 for both Unit 1&2 and Unit 3 control rooms.

Unfiltered intake. CRQ2 = 100 for Unit 3

(NOTE: for Unit 1&2 control room the unfiltered intake flow rate is 150).

Recirculation rate. RC = 0.0

Exhaust rate. CRL = 1315 for Unit 3

This is the sum of the filtered and unfiltered rates (NOTE: for Unit 1&2 control room this rate is 1365).

Final Time Step

This record is no longer input if LCHG = 0 in record 35.

Record 37 Intake Filter Efficiencies

Intake filter efficiencies are entered as 0.0 for the first time step since no filters are considered functional during this time period. For the second through the final time step, the filter efficiencies are 99% for elemental and particulate iodine, 95% for organic iodine, and 0% for all other groups. Thus, the second time step input will appear as: 99 95 99 0 0 0 0 0 0 0 0 0, all subsequent time steps do not require this input if LCHG = 0 in record 35.

Record 38 Recirculation Filter Efficiencies

Efficiencies are entered as 0.0 for all time steps since no recirculation filters are considered present. For time steps subsequent to the second time step this record is no longer input if LCHG = 0 in record 35.

Record 39 Node χ/Q Values

Release origination node. Nodefrom = 2

Release from node 2 (SFP building)

Filtered CR χ/Q. CRXQF = 1.04E-03

The χ/Q values are unaffected by the filtration system, hence the two values are identical.

Unfiltered CR χ/Q. CRXQU = 1.04E-03

The negative entry -1 0 0 ends the record 39 entries.

Record 40 Delay Calculation Parameters

This record is not read since no delay calculations are performed, IELEM = 0 (see Record 8).

LOCADOSE Inputs Case 2: Releases from SFP through Roll-Up Doors

Note that this input case will include cases 2, 4, 11, and 12 from Table 6.7. The input values listed below are applicable for cases 4 and 12. In each of these cases, a fuel handling accident occurs in the Unit 3 SFP and doses are calculated to the Unit 3 control room from a release through the Unit 3 roll-up door. The differences between these two cases are in their decontamination factor (DF) values for elemental iodine (as entered in Record 28) and source terms: case 4 has a DF of 137 and a source term for a single fuel assembly whereas case 12 has a DF of 301 and a source term related to the dropping of an ISFSI cask into the SFP.

To obtain the inputs necessary to model cases 2 and 11, the control room volume must be changed to 86447.6 in Record 36, and the control room unfiltered intake and exhaust rates must be changed to 1150 and 1150, respectively, for the time steps prior to 0.5-hr. These values are then changes to 150 and 2580 for subsequent time steps in Record 36. In addition, the appropriate DFs (as entered in Record 28) must be included with these input values. In each of these cases, a fuel handling accident occurs in the Unit 3 SFP and doses are calculated to the Unit 1&2 control room from a release through the Unit 3 roll-up door.

Records 1-6 Title Information

These records are used to indicate problem title, originator's name, project name, job charge number, calculation number and revision, and the number for the first page of the LOCATRAN output.

Record 7 Problem Limits

Model:

Number of nodes. NODES = 1

The environment is node 1 (default), the SFP is node 2 (input), and the control room is node 3 (default).

Control room option. ICR = 1

This parameter sets a flag for the LOCADOSE code to calculate data for the control room.

Daughter product calculation option. CALCDA = 1

The daughter calculation is turned on.

Spray cut-off option. LSPRAY = 0

The Reactor Building spray has no bearing on this accident since it occurs in the SFP building. It is turned off with this value.

Record 8 Input Data

Core activity source term, curies or fractions. ITID = 0
This switch directs LOCADOSE to calculate the activity source term in curies.
Purge option. IPURGE = 0
This switch directs LOCADOSE to ignore the purge option. This is not applicable to this accident.
Reactor power rating. POWER = 2568 MWt
Time interval from reactor shutdown. SDTIME = 0
Iodine printed as separate fractions option. NPF = 1
This switch determines how iodines are to be printed. The 1 indicates they will be printed as elemental, organic, and particulate iodines.
Number of sprayed nodes. NSPN = 0
No spray calculations are executed due to accident occurring in SFP building.
Number of elements for delay calculations. IELEM = 0
No delay calculations are executed due to their insignificant contribution.
Determine if maximum 2 hour dose is calculated. IMAX2=1
Maximum 2-hour dose is desired.

Record 8a Maximum 2-Hour Dose

Time interval in hours for calculation of maximum 2-hour dose. TDELTA=0.5
Time in hours until the maximum 2-hour dose is calculated. TMAX=24

Record 9 Units

Flow rate units. FLUNIT = CFM
Node volume units. VUNIT = CUFT
Activity units. ACUNIT = CURIES

Record 10 Release Fractions

The release fractions for this problem are 1.0 for the elemental iodine (the 1st group), organic iodine (the 2nd group), particulate iodine (the 3rd group), noble gases (the 4th group), and Cesium & Rubidium group (the 5th group), zero for all other groups. The nuclide inventory (per MWt) for each iodine and noble gas are loaded into the Library (see Attachments 4 and 5). All noble gases and iodines are considered released.

Record 11 Iodine Fractions

Elemental = 99.785%
All inorganic iodine is considered to be elemental.
Organic = 0.215%
Particulate = 0%

Note: These fractions are adjusted from the 99.85% and 0.15% listed in Reg Guide 1.183, based on the changes to use an overall effective DF of 200. See response to RAI 18 for details on DF determination.

Record 12 Node Names

Atmospheric Model:

Node 2: SFPDT

Note: LOCADOSE automatically assigns Node 1 as the environment and the last node as the Control Room. Node 2 in this case is the SFP building.

Records 13-25

These records are not needed for the model. Record 13 is only read if the number of sprayed nodes, NSPN, is greater than 0. It is 0 in this case (see Record 8). Record 14 is only read if the number of delay elements, IELEM, is greater than 0. It is 0 in this case (see Record 8). Records 15 – 25 are only read if the local purge option is requested. IPURGE=0 in this case which means it is not requested (see Record 8).

Record 26 Time Steps (repeat Records 26-39 for each time step)

Time to begin and end the step. There are three time steps common to each case: 0 to 0.5-hour, 0.5 to 2-hours, and 2 to 720-hours or 30 days into the accident scenario when the χ/Q and control room occupancy change.

TSTEP1 = 0 TSTEP2 = 0.5
TSTEP1 = 0.5 TSTEP2 = 2.0
TSTEP1 = 2.0 TSTEP2 = 720

Print activities option. IPRTAC = 1

This turns on the print activities.

Units for activities. IAACT = 0

AO is entered in fractions of fuel released, below in Record 28 (curies in the library file).

Units for production terms. IPACT = 0

Fraction of fuel inventories per hour. This is not applicable since production terms are not used.

Print interpretive summary option. IPRINT = 1

This turns on LOCADOSE to print the interpretive summary.

Record 27 Initial Data

Enter initial activities option. LACTIN = 1

Activities are entered (NOTE: for time steps subsequent to the first this value is set to 0).

Enter initial production term option. LPTIN = 0

No production terms are entered.

Enter node volume option. LVOL = 1

Volumes are entered (NOTE: for time steps subsequent to the first this value is set to 0).

Enter flow paths option. LNFLOW=1

Enter spray removal rates option. LNSPRAY=0

Enter spray DF factors option. LNDF=0

Record 27a Nodes with New Activities

One node, Node 2, has new activities entered.
JNODES=1
MNODES=2

Record 28 Activities

Source terms are entered for each isotope at each non-environment and non-control room node. For this problem, the source term is entered into the Library on a Ci per MWt basis uncorrected for pool scrubbing (i.e., using the DFs). The source term in the input deck is entered as 1.00 for each isotope except for the elemental/inorganic iodines whose source terms are corrected for pool water scrubbing by the inclusion of the inverse of DF. For cases 1 through 4, the source terms for elemental/inorganic iodines are set to 0.0073 (=1/137). For cases, 5 through 12, the source terms for elemental/inorganic iodines are set to 0.0033 (=1/301). A record 28 is required for each isotope, therefore 27 source terms are entered (based on NISO, see record 7).

Note: The source term is only entered in the first time step. This is bypassed in subsequent time steps. The release due to a fuel handling accident is exhausted over a two-hour period using the point node established for the SFPDT. A review of the "lto" file demonstrates that by specifying a node volume of 10 ft^3 (see record 30) and a SFPDT node unfiltered release flowrate of 1 CFM (see record 31), the release continues over the two-hour time period to the point where more than 99.99% of the activity is released by the time the analysis reaches two hours in the event.

The A(t) for a volume of air assuming "feed and bleed" phenomena characterized by the equation below. With a volume of 10 ft^3 and flowrate of 1 CFM, 99.99% is removed in two hours.

$$A(t) = A_0 e^{-\left(\frac{F}{V}\right)t}$$

Record 28a

Record 28a is read only if LPTIN = 1, so there is no input for this record.

Record 29

Record 29 is only read if LPTIN = 1. No input since LPTIN = 0 (see record 27).

Record 30 Node Volumes

The volume for the spent fuel pool area is entered as a point node with a volume of 10.0 ft^3 (assures all releases are transported to the control room in two hours).

Records 31-32 Flow Paths and Filter Efficiency

The flow path is from node 2 (SFP Building) to node 1 (environment) with no filtered flow by the roll-up doors (Assumption 5.12) and an unfiltered flow rate of 1.0 CFM for all time steps.

From = 2
To = 1
Q1 = 0.0
Q2 = 1.00E+00

The filter efficiency is zero for all 12 groups since filters are not considered to have an effect on the gases escaping through the roll-up doors in this analysis (Assumptions 5.3 and 5.12). Thus the entry is 0 0 0 0 0 0 0 0 0 0 0 0

A negative entry for the first value in Record 31 will terminate the cycle of Records 31/32 entries. Hence, -1 0 0 0 is entered after the last entry.

Records 33-34 Spray Removal Parameters

There is no spray, LSPRAY $\neq$ 1 (see Record 7). Hence, Record 33 is entered as -1 0 0 to indicate no spray removal. Record 34 is not read because LSPRAY $\neq$ 1 (see Record 7).

Record 35 Control Room Conditions

Parameter change option flag. LCHG = 1
This switch is used to determine if Control Room parameters change indicating Records 36-38 are to be read. For the final time step, this option can be set to 0 indicating no further changes.

Number of χ/Q values. CRXQ = -1
This field value specifies that multiple χ/Q values will be input for Record 39.

Record 36 Control Room Data:

First Time Step
Control room volume. CRVOL = 43223 cubic feet for Unit 3
(NOTE: for Unit 1&2 control room volume is 86447).
Filtered intake. CRQ1 = 0
There is no filtered flow considered for the first time step (up to 0.5 hour).
Unfiltered intake. CRQ2 = 600 for Unit 3
(NOTE: for Unit 1&2 control room intake is 1150).
Recirculation rate. RC = 0.0
Exhaust rate. CRL = 600 for Unit 3
This is the sum of the filtered and unfiltered rates (NOTE: for Unit 1&2 control room rate is 1150).

Second Time Step

Control room volume. CRVOL = 43223 cubic feet for Unit 3
(NOTE: for Unit 1&2 control room volume is 86447).
Filtered intake. CRQ1 = 1215
The filtered flow rate is 1215 for both Unit 1&2 and 3 control rooms.
Unfiltered intake. CRQ2 = 100 for Unit 3
(NOTE: for Unit 1&2 control room the unfiltered intake flow rate is 150).
Recirculation rate. RC = 0.0
Exhaust rate. CRL = 1315 for Unit 3
This is the sum of the filtered and unfiltered rates (NOTE: for Unit 1&2 control room this rate is 1365).

Final Time Step

These records are no longer input if LCHG = 0 in record 35.

Record 37 Intake Filter Efficiencies

Intake filter efficiencies are entered as 0.0 for the first time step since no filters are considered functional during the first time step. For the second through the final time step, the filter efficiencies are 99% for elemental and particulate iodine, 95% for organic iodine, and 0% for all other groups. Thus, the second time step input will appear as: 99 95 99 0 0 0 0 0 0 0 0 0, all subsequent time steps do not require this input if LCHG = 0 in record 35.

Record 38 Recirculation Filter Efficiencies

Efficiencies are entered as 0.0 for all time steps since no recirculation filters are considered present. Note that for time steps subsequent to the second time step this record is no longer input if LCHG = 0 in record 35.

Record 39 Node χ/Q Values

Release origination node. Nodefrom = 2
Release from node 2 (SFP building)
Filtered CR χ/Q. CRXQF = 3.12E-03
The χ/Q values are unaffected by filtration, and are identical for filtered and unfiltered releases.
Unfiltered CR χ/Q. CRXQU = 3.12E-03
The negative entry -1 0 0 ends the record 39 entries.

Record 40 Delay Calculation Parameters

This record is not read since no delay calculations are performed, IELEM = 0 (see Record 8).

6.2.3 Dose Calculation Program Inputs

The input records for the Dose Calculation Program deck (*.LDI file) are described below. These inputs are applicable for each of the Activity Transport Program Inputs described above.

Records 1-6 Title Information

These records are used to indicate problem title, originator's name, project name, job charge number, calculation number and revision, and the number for the first page of the LOCATRAN output.

Record 7 Problem Options

For this record the desired calculation and printout options are listed. Those chosen for this calculation are as follows:

DOR = calculate doses within regions
DOF = calculate doses offsite

Record 7a is read if DOR or DRR is selected in Record 7. Prints results for one node, Node 3.

JNODES = 1
MNODES = 3

Record 8 Dose Parameters

Number of Offsite Dose Points = 2
Number of Atmospheric Dispersion Factors = 5
Number of Offsite Breathing Rates = 3
Number of occupancy factors = 4
The 0-0.5hr and the 0.5-24hr factors are the same, but are entered separately.
Number of breathing rates for regions = 1
Evacuation dose option = Off
No evacuation dose calculations.
Save output as a file option = Off
No postprocessor output files are needed.

Record 9 Units

Dose calculation = REM
Dose rate calculation = REM/HR

Record 10 Offsite Atmospheric Dispersion Factor

Atmospheric Dispersion Factor = 2.20E-04 for EAB
Atmospheric Dispersion Factor = 2.35E-05, 4.7E-06, 1.5E-06, 3.3E-07 for LPZ

Record 11 Offsite Breathing Rate

Offsite Breathing Rate = 3.5E-04, 1.8E-04, 2.3E-04

Record 12 Time Change for Offsite Atmospheric Dispersion Factors

Time Offsite Atmospheric Dispersion Factor Changes = 2, 8, 24, 96, and 720 hours

> The offsite atmospheric dispersion factor input values in Record 10 correspond to these times, hence the atmospheric dispersion factor will change at these intervals.

Record 13 Time Change for Breathing Rate

Time Breathing Rate Changes = 2, 24 and 720 hours

Record 14 Finite Cloud Gamma Dose Correction Factor

Correction Factor = 1.00

Record 15 Region Occupancy Factors (Records 15-16 are Repeated for Each Node - SFPDT and Control Room)

Control Room Occupancies are:

0 - 24 hours	100%
1 - 4 days	60%
4 - 30 days	40%

with the value for 0-0.5 hour and 0.5-24 hours set to the 0-24 hour value. These values are entered for both the spent fuel pool area and the control room.

Record 16 Region Breathing Rates

The breathing rate of control room operators is assumed to be 3.5E-04 m^3/sec for the duration of a fuel handling accident.

Record 17 Occupancy Time Change

Record indicates the time at which the region occupancy factors change: 0.5, 24, 96, and 720 hours.

Record 18 Breathing Rate Time Change

Record indicates the time at which the spent fuel pool area and the control room breathing rates change: 720 hours.

Record 19 Gamma Correction Factor

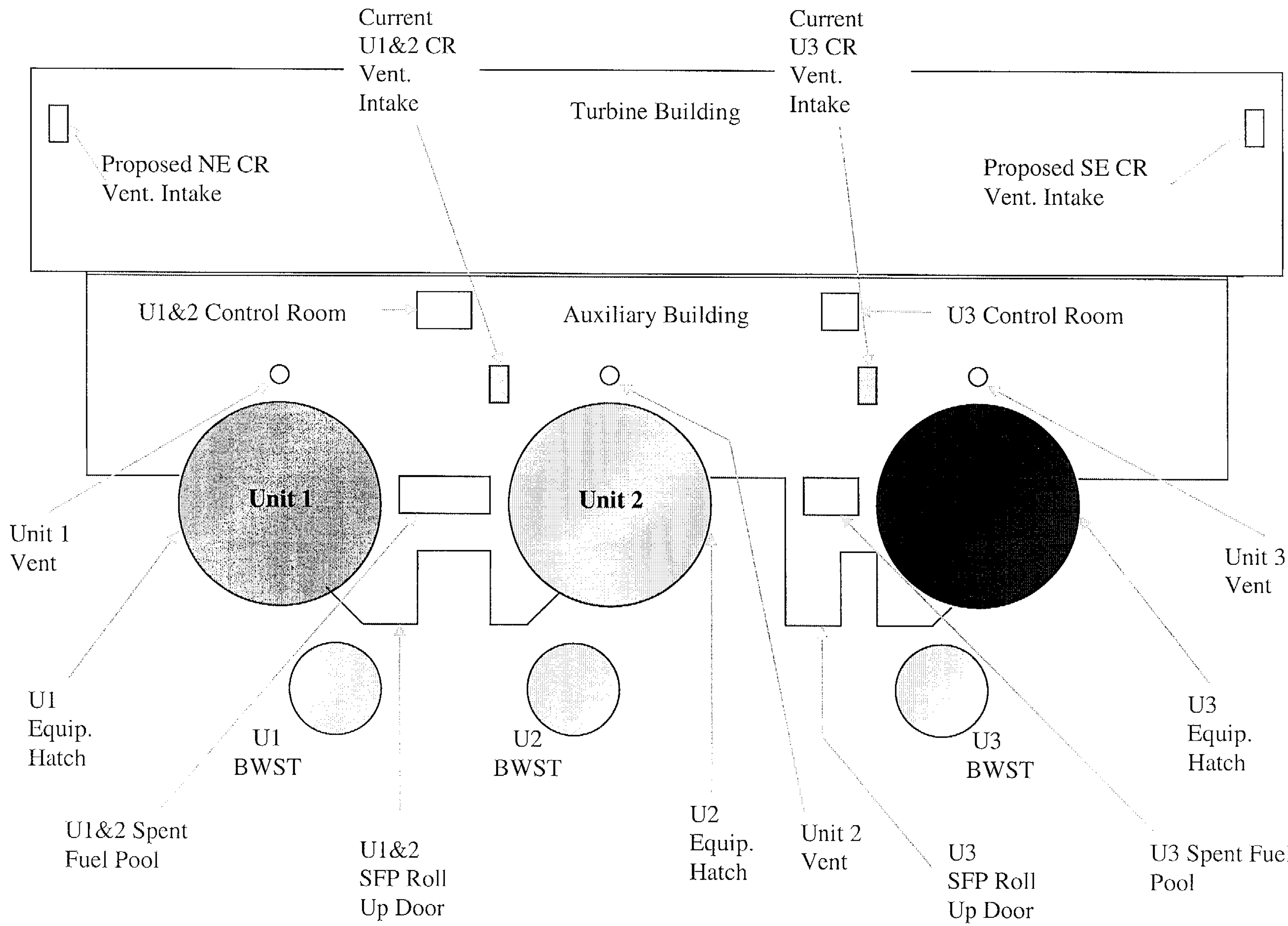
Finite cloud gamma dose correction factor is input as 1.00 for each region.

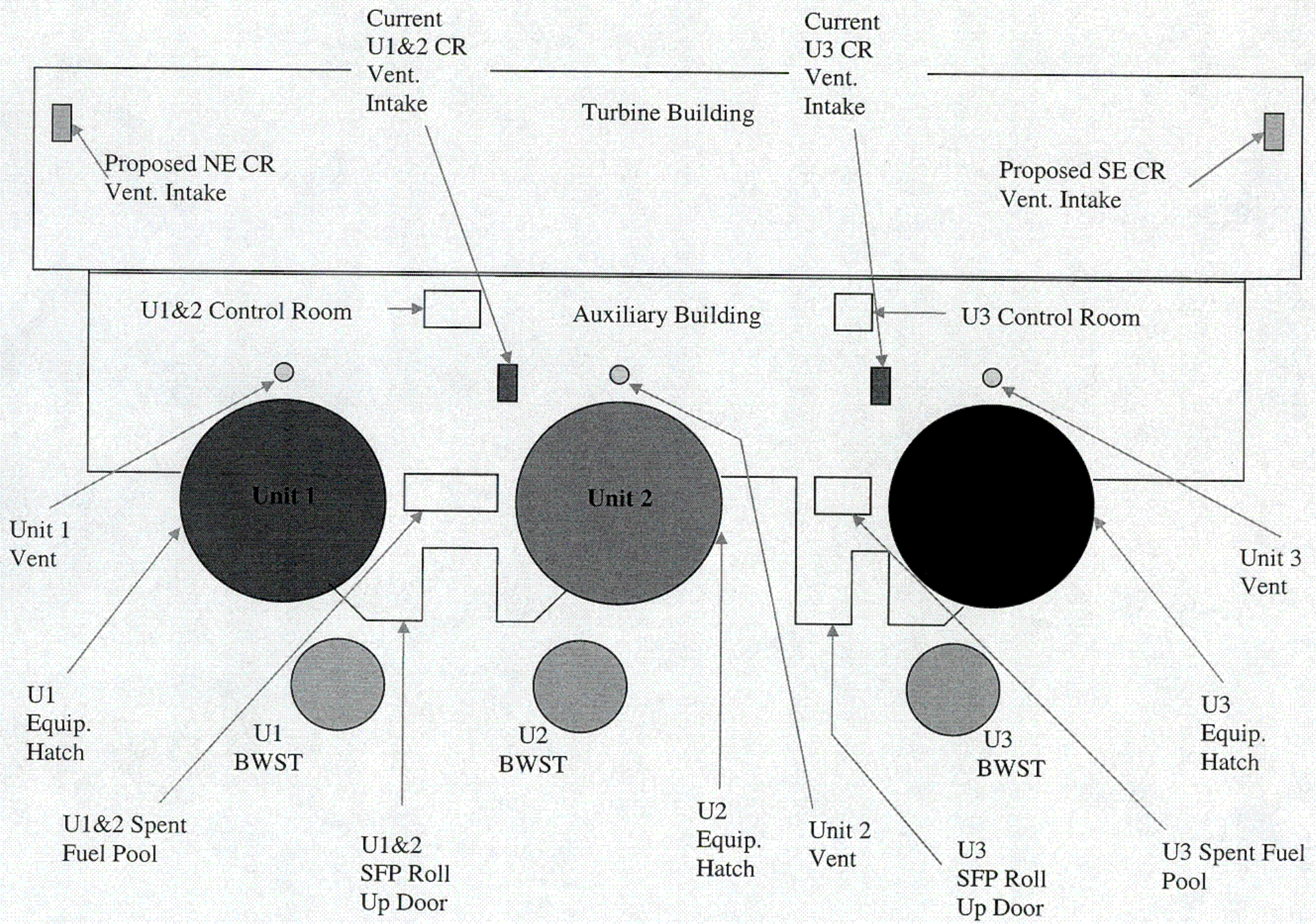
2. NRC Request

Provide drawings (or sketches) showing containment, turbine building, auxiliary building, fuel building, control room, fuel pool, containment equipment hatch, containment personal air locks, spent fuel pool roll-up door, unit vent, borated water storage tank, current control room air intake, proposed future dual control room air intakes, and source term release points for all 3 units.

Response

The following page contains a sketch which shows layout of site buildings, location of current control room air intakes, proposed future dual control room air intakes, and source term release points for all 3 units. Note that this figure is not to scale.


Current
U1&2 CR
Vent.
Intake
Current
U3 CR
Vent.
Intake
Turbine Building
Proposed NE CR
Vent. Intake
Proposed SE CR
Vent. Intake
U1&2 Control Room
Auxiliary Building
U3 Control Room
Unit 1
Unit 2
Unit 1
Vent
Unit 3
Vent
U1
Equip.
Hatch
U1
BWST
U2
BWST
U3
BWST
U3
Equip.
Hatch
U1&2 Spent
Fuel Pool
U1&2
SFP Roll
Up Door
U2
Equip.
Hatch
Unit 2
Vent
U3
SFP Roll
Up Door
U3 Spent Fuel
Pool


Current
U1&2 CR
Vent.
Intake
Turbine Building
Current
U3 CR
Vent.
Intake
Proposed NE CR
Vent. Intake
Proposed SE CR
Vent. Intake
U1&2 Control Room
Auxiliary Building
U3 Control Room
Unit 1
Unit 2
Unit 1
Vent
Unit 3
Vent
U1
Equip.
Hatch
U1
BWST
U2
BWST
U3
BWST
U3
Equip.
Hatch
U1&2 Spent
Fuel Pool
U1&2
SFP Roll
Up Door
U2
Equip.
Hatch
Unit 2
Vent
U3
SFP Roll
Up Door
U3 Spent Fuel
Pool

3. NRC Request

You proposed to delete the penetration room ventilation system and the spent fuel pool ventilation system from the Oconee technical specifications. In Section 1.1.2, "Defense in Depth," of Regulatory Guide 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," the staff provided the following guidance:

> "Proposed modifications that seek to downgrade or remove required engineered safeguards equipment should be evaluated to be sure the modification does not invalidate assumptions made in facility PRAs and does not adversely impact the facility's severe accident management program."

Discuss your proposed deletions in accordance with the staff's guidance stated above.

Response

The ONS PRA is a full scope level 3 PRA. It includes both internal and external events. The ONS PRA does not credit the PRVS or the SFPVS for the mitigation of the onsite or offsite consequences following a severe core damage accident. Therefore, removal of the PRVS and SFPVS from the ONS Technical Specifications will not invalidate any assumptions in the ONS PRA.

The Oconee Severe Accident Guideline does not credit either the PRVS or the SFPVS. Therefore, removal of PRVS and SFPVS from T.S. will not adversely impact the severe accident management program.

4. NRC Request

Provide piping and instrument diagrams (P&ID) and/or layout drawings for the proposed dual air intake system to the control room. The dilution effects associated with a dual air inlet configuration should be based upon the dilution derived from drawing in equal amounts of clean and contaminated air through two open inlets. Evaluate and state the dilution effects. Provide the schedule for this plant modification as a license commitment.

Response

The design of this system is being finalized. The sketch provided in response to RAI 2 shows the relative location of the new intakes. The proposed dual Control Room air intakes will be designed to achieve equal flowrates. Post-modification testing will be performed to set the flowrates equal. Any flow imbalance will be included in the dose analyses.

The implementation schedule for this modification is currently planned as follows:

Units 1 & 2 Control Room intakes: Unit 1 EOC21 refueling outage (fall 2003)

Unit 3 Control Room intakes: Unit 3 EOC21 refueling outage (fall 2004)

However, given that design and procurement activities are ongoing, some potential exists for changes in the above schedule. Therefore, Duke's commitment is to have these modifications completed on all three units by the end of 2005.

5. NRC Request

Provide P&ID for the proposed the high pressure/low pressure injection relief valve discharge to the reactor building emergency sump. Provide the schedule for this plant modification as a license commitment.

Response

As stated in our October 16, 2001, submittal, the Letdown Storage Tank (LDST) relief valve, HP-79, currently relieves to the RC Bleed Hold-up tank, which is located in the Auxiliary Building. A modification is being implemented to route the LDST relief valve discharge to the Reactor Building Emergency Sump (RBES). The engineering design work is still in progress. The attached drawing illustrates the conceptual design. Relief valve HP-79 can be pressurized due to leakage through the following valves:

LP-15 and LP-16 (LPI pump discharge to HPI pump suction)
HP-23 (LDST outlet header isolation valve)
HP-97 (LDST outlet header check valve)

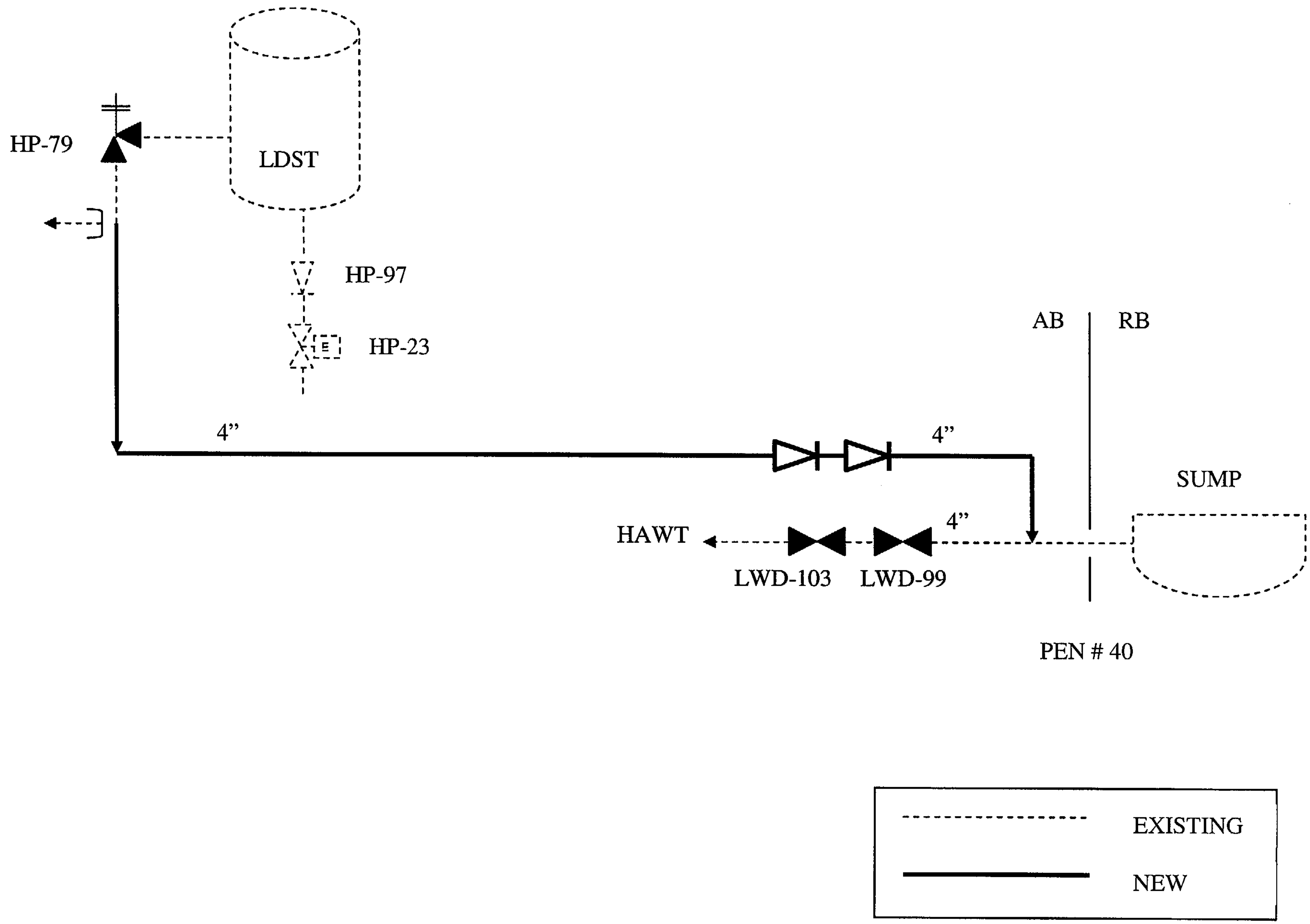
Operator actions in the Emergency Operating Procedure currently prevent overpressurization of the LDST. However, Duke believes it is prudent to improve the design such that it is passive in nature. This will simplify operator actions and ensure that any leakage to the LDST is prevented from creating an offsite dose concern in that it will be routed back into the Reactor Building. This design change improves defense in depth in terms of eliminating a potential dose release pathway.

The implementation schedule for this modification is currently planned as follows:

Unit 1 EOC21 refueling outage (fall 2003)
Unit 2 EOC20 refueling outage (spring 2004)
Unit 3 EOC21 refueling outage (fall 2004)

However, given that design and procurement activities are ongoing, some potential exists for changes in the above schedule. Therefore, Duke's commitment is to have these modifications completed on all three units by the end of 2005.

RE-ROUTE LDST RELIEF VALVE TO THE REACTOR BUILDING EMERGENCY SUMP



6. NRC Request

In page 10 of Attachment 3, you stated that the new passive caustic addition system will contain solid caustic or trisodium phosphate. Provide reactor building sump water pH transient calculation for the entire duration of the postulated LOCA addressing the amounts of chemical to be used, initial water pH value, water volume, chloride-bearing cable inventory, acid generation rates, radiation dose profiles, and iodine re-evolution. Provide the schedule for this plant modification as a license commitment.

Response

The reactor building sump water pH transient calculation determines a pH profile based on 300 cubic feet of trisodium phosphate dodecahydrate (TSP-C), to be located in 5 wire screen baskets. Solid caustic will not be used. The initial water pH value is calculated to be 5.21 at actual sump temperatures (or 5.25 normalized to 25 deg. C). A graph of the time dependent pH profile is shown on the following page.

Total sump water inventory is a time dependent variable which increases from 6.8E+05 lbm at accident initiation, when the Core Flood Tanks and Reactor Coolant System inventory is assumed to be instantaneously introduced, to 3.1E+06 lbm at the beginning of sump recirculation (25 minutes post-accident), when the entire BWST inventory has been emptied into the sump.

Nitric acid generation is based on NUREG/CR-5950 (Reference 1) methodology, and is calculated to be 7.3×10^{-9} mol HNO_3 per g H_2O per Mrad. Hydrochloric acid generation due to the presence of chlorinated polymers found in electrical cable insulation inside containment is also based on Reference 1 methodology. The inventory of chloride-bearing cable is 45,700 lbm. The generation rate for PVC cable insulation is 33.12×10^{-4} mol of HCL per lbm of PVC insulation per Mrad.

The containment dose in the Reactor Building following an accident is based on data in the ONS post-accident shielding calculation. An equation representing this time dependent dose for the first 24 hours after an accident is:

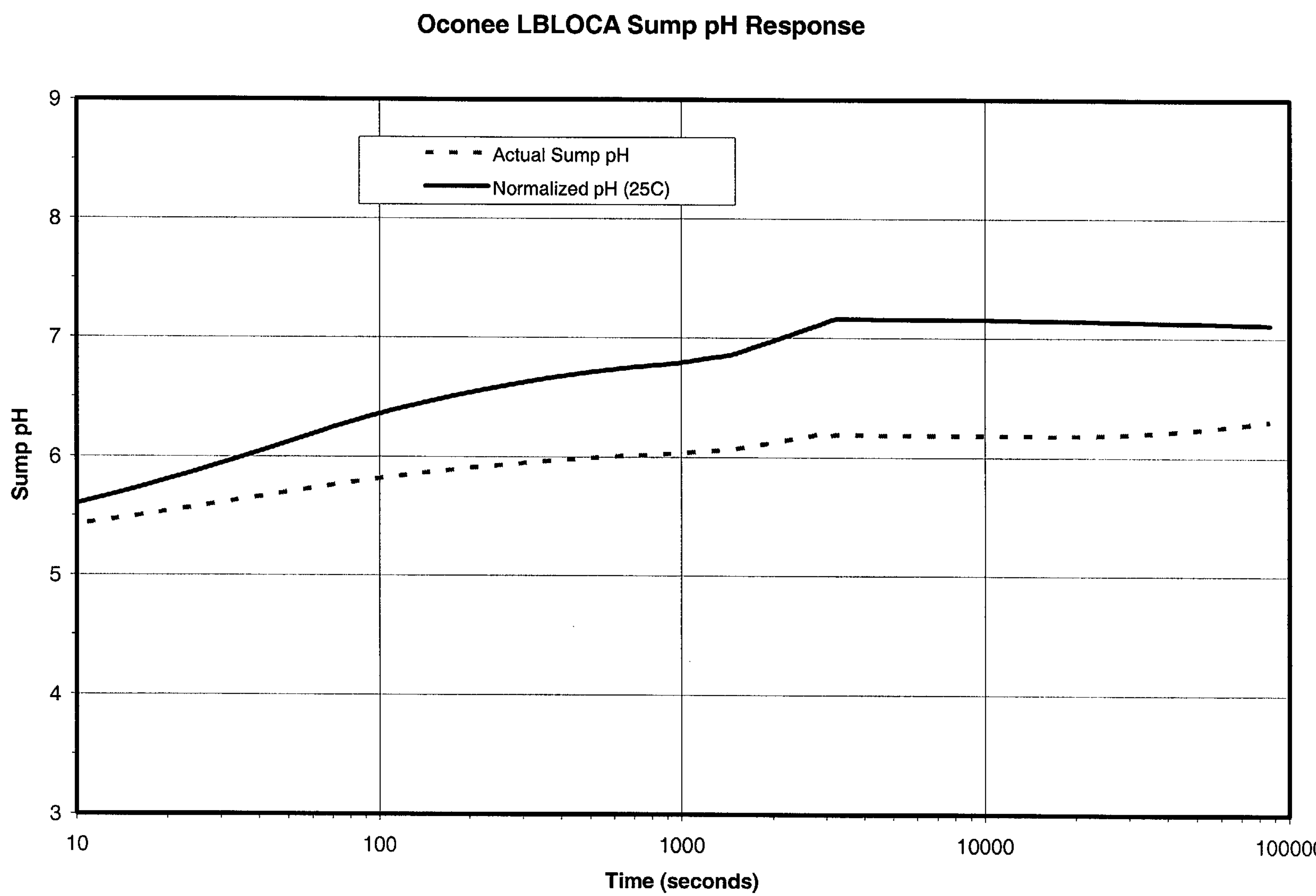
$$D(t) = (3.89 \times 10^{-14})*t^3 - (7.026 \times 10^{-9})*t^2 + (5.34 \times 10^{-4})*t + 6.01 \times 10^{-1} \text{ [Mrads]}$$

Details of Duke's iodine re-evolution calculation are provided as part of the answer to RAI 8 below.

The implementation schedule for this modification is currently planned as follows:

Unit 1 EOC21 refueling outage (fall 2003)
Unit 2 EOC20 refueling outage (spring 2004)
Unit 3 EOC21 refueling outage (fall 2004)

However, given that design and procurement activities are ongoing, some potential exists for changes in the above schedule. Therefore, Duke's commitment is to have these modifications completed on all three units by the end of 2005.


Oconee LBLOCA Sump pH Response
Actual Sump pH
Normalized pH (25C)
Sump pH
9
8
7
6
5
4
3
10
100
1000
10000
100000
Time (seconds)

7. NRC Request

In pages 15 and 16 of Attachment 3, you describe fission product release model from the containment. Provide the following additional information:

- Values and calculation of aerosol deposition (natural processes) rates in reactor building
- Calculation of particulate removal coefficients by containment spray and the bases for 25 minute turnover of the rate
- Time for reaching a particulate decontamination factor of 50 by containment spray
- Time for reaching an elemental iodine decontamination factor of 200 by containment spray
- Duration of the worst 2 hour period used in Exclusion Area Boundary (EAB) dose calculation

Response

- The particulate iodine removal constant values for removal by natural processes are calculated using methodology from NUREG/CR-6189 (Reference 2). The DF values in NUREG/CR-6189 are calculated as cumulative values, in the sense that they give the amount of iodine remaining in the atmosphere at a given time from the start of the accident. For use in LOCADOSE modeling, DF values are needed for each specific time interval independently (non-cumulative), in order to calculate a separate λ_{np} value for each time interval. These DF values are calculated for each time interval and for each phase (i.e., gap and in-vessel releases). For use in LOCADOSE modeling, a single λ_{np} value is needed for each time interval that accounts for both gap and in-vessel releases. During only one time interval, 1800-6480 seconds, the λ_{np} values for gap and in-vessel releases differ. For this time interval, an effective λ_{np} is calculated by weighting the λ_{np} values for each phase using the amount of iodine in the atmosphere from each source (gap and in-vessel). For all other time intervals post-accident, the gap and in-vessel particulate iodine removal constants are equal, and this value can be used directly. The table below provides the values of deposition rates used.

  These aerosol deposition lambdas are only applied to the unsprayed region of containment. They are not credited in addition to building spray for the sprayed region.

Radiological Design Basis Accidents Estimations (assumes no ex-vessel or late in-vessel release source terms)									
	Gap Release						In-vessel Release		
Time Interval (seconds)	0-1800	1800-6480	6480-13680	13680-49680	49680-80000		1800-6480	6480-13680	13680-49680
Length of time interval (hrs)	0.5	1.3	2	10	8.422		1.3	2	10
Lambda (50) (hr^-1) "best estimate"	3.57E-02	7.78E-02	1.82E-01	1.56E-01	9.12E-02		4.01E-02	1.82E-01	1.56E-01
DF "best estimate"	1.018	1.106	1.440	4.749	2.156		1.053	1.440	4.749

Using the median or "best estimate" numbers from Radiological Design Basis Accident calculations above, the following lambdas can be used as "effective" lambdas over each time period. These lambdas are a weighted average, which takes into account both Gap and In-vessel releases.

Time Interval (seconds)	0-1800	1800-6480	6480-13680	13680-49680	49680-80000
Effective Lambda (hr^-1)	3.57E-02	4.46E-02	1.82E-01	1.56E-01	9.12E-02
Effective DF	1.018	1.060	1.440	4.749	2.156

- Particulate fission products, including aerosol particle forms of iodine, are effectively removed by containment sprays through several mechanisms including Brownian diffusion, diffusiophoresis, interception, and inertial impaction. Estimates of particulate washout are obtained using NUREG/CR-0009 (Reference 3) and SRP 6.5.2 (Reference 4) methodology as follows:

  $$\lambda_{sp} = \frac{3hF_t}{2V}(3.048 \quad ft^{-1}) \text{ for } 0.02 \leq C/C_O \leq 1.0$$

  $$\lambda_{sp} = \frac{3hF_t}{2V}(0.3048 \quad ft^{-1}) \text{ for } C/C_O < 0.02$$

  where:

  C/C_O = Ratio of particulate concentration at time t to the initial concentration at time zero.
  h = Drop fall height, ft.
  F_t = Spray flow rate during time step t, ft^3/hr.
  V = Volume of contained gas phase, ft^3

  The particulate iodine spray removal rate constant, λ_{sp}, early in the recirculation phase is calculated corresponding to the higher removal efficiency presented above. The lower removal efficiency is applied in the later stages of the recirculation phase.

  At 25 minutes post-accident, the recirculation phase begins, and a new lambda is calculated based on the recirculation spray flowrate.

- The time for reaching a particulate decontamination factor of 50 by containment spray is approximately 3.5 hours post-accident.

- The elemental iodine decontamination factor does not reach 200 by containment spray in the calculation based on NUREG/CR-5950 methodology. See RAI 8 for description of calculations. The elemental iodine DF reached is approximately 82 when equilibrium elemental iodine concentration is reached. Spray removal is terminated at 4.7 days post-accident, once equilibrium is reached.

- The maximum 2 hour dose for the EAB occurs during the time period from 0.6 to 2.6 hours following accident initiation.

8. NRC Request

In page 16 of Attachment 3, you stated that

"the modeling of containment spray is based on Oconee Nuclear Station calculations for Post-Accident Iodine Re-volatilization Analysis and for Post-Accident Containment Atmosphere Iodine Spray Removal Analysis." Provide a copy of these analyses.

Response

A description of Duke calculations modeling containment spray iodine removal and re-volatilization are given below.

Containment Atmosphere Iodine Spray Removal Analysis

This analysis determines the elemental and particulate iodine spray removal constants. The major steps of this analysis are listed below.

1. Reactor Building Spray flow rates and timing considerations are established for four cases by varying ECCS configuration of one or two train operation, and maximum or minimum BWST inventory to determine the limiting case.

2. The conditions required to apply SRP 6.5.2 guidance for the containment spray coverage is established.

3. The spray flow rate correction due to the spray interaction with the containment wall is validated.

4. The elemental iodine spray removal constant is determined. The method used to calculate elemental iodine spray removal constants (i.e., λ_{se}) for sprayed regions of the Oconee Nuclear Station (ONS) containment is based on guidance provided in Section 6.5.2, Revision 2 of the Standard Review Plan (SRP) and NUREG/CR-0009 (References 4 and 3, respectively).

5. The particulate iodine spray removal constant is determined by using the guidelines of Section 5.3.1 of Reference 3 and Section III.4.c(4) of Reference 4.

6. An iodine washout model is developed using the removal process given in ANSI/ANS-56.5 (Reference 5).

Post-Accident Iodine Re-volatilization Analysis

Following an accident, fission products collected in the containment sump aqueous solution produce by-products as a result of irradiation of water. These by-products can transform iodine initially present in the non-volatile form to a volatile form in low pH solutions. As a result, the potential exists for iodine to re-volatize back into the containment atmosphere as the containment sump aqueous solution is recirculated through the containment atmosphere as spray solution.

To evaluate the extent of re-volatilization of iodine during the recirculation mode of operation, this analysis:

- predicts the extent to which iodine is transformed from the non-volatile (particulate iodine or I^-) to the volatile form (elemental iodine or I_2) when exposed to an ionizing radiation field, and
- determines and quantifies the mass transfer process by which elemental iodine re-volatizes back into the containment atmosphere.

Iodine Radiolysis

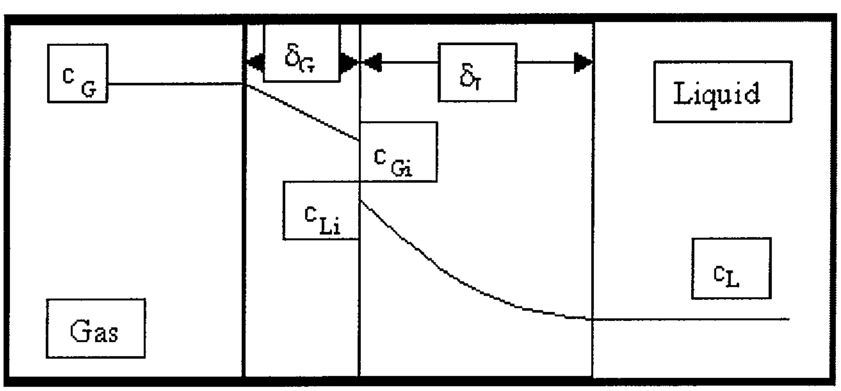
The extent to which iodine is transformed from the non-volatile to volatile form is determined by a simplified approach presented in NUREG/CR-5950 (Ref. 1) for determining post-accident iodine formation based on steady-state decomposition of hydrogen peroxide.

The partitioning of elemental iodine between the gas and liquid phases is given by the following equation:

$$PC(I_2) = [I_2]_{aq} / [I_2]_{gas} = 10^{(6.29-0.0149T[K])}$$

Mass Transport Theory

The generally-accepted theory for momentum, heat and mass transfer from a continuous phase to a boundary system postulates a turbulent core, which is assumed to be completely mixed, and a laminar boundary layer in which shear, temperature, and concentration gradients exist (Reference 6).



The Stagnant Film model described Reference 5 considers both the liquid and gas film resistances and provides an equation for determining the spray drop liquid film mass transfer coefficient.

Correlations for determining the gas film mass transfer equation for a falling sphere are given by equations provided in References 5, and 7.

Reference 8 describes the mass transfer analogy for parallel flow over a flat plate, which is used to evaluate direct mass transfer from the sump liquid to the containment atmosphere.

9. NRC Request

In page 16 of Attachment 3, you also stated that

"Elemental iodine spray lambdas were selected in order to produce sprayed and unsprayed iodine inventories that match the stated reference." Provide a copy of spray lambda calculation.

Response

A description of Duke calculations documenting elemental iodine spray lambdas is given in response to RAI 8.

10. NRC Request

In pages 16 and 17 of Attachment 3, you describe fission product release from the ECCS model. Provide the following additional information:

- ECCS leakage start time and its basis
- Duration of the worst 2 hour period used in EAB dose calculation
- Calculated EAB, low population zone (LPZ), and control room doses

Response

- ECCS leakage to the Auxiliary Building is assumed to begin at the earliest time that the recirculation mode is initiated. The earliest calculated time for recirculation is 25 minutes post-accident.

  Selected Licensee Commitment (SLC) 16.6.4 ensures that leakage does not exceed 2 gph. This SLC requires leakage to be verified by testing and inspection on an 18 month frequency.

- The maximum 2 hour dose for the EAB occurs during the time period from 1.7 to 3.7 hours following accident initiation.

- The doses from the ECCS leakage to the auxiliary building in the RBES model are calculated to be:

EAB	2.5E-01 rem TEDE
LPZ	1.4E-01 rem TEDE
Control Room	6.4E-01 rem TEDE

11. <u>NRC Request</u>

In page 17 of Attachment 3, you describe fission product release model from the BWST. Provide the following additional information:

- BWST back-leakage start time and its basis
- Bases for 5 gpm back-leakage from the sump
- Iodine partition factor used in the BWST
- BWST volume
- Release rate from BWST to the environment
- Duration of the worst 2 hour period used in EAB dose calculation
- Calculated EAB, LPZ, and control room doses

<u>Response</u>

- The back-leakage from the ECCS system to the Borated Water Storage Tank (BWST) is modeled to begin at the earliest time of swapover to recirculation, which is 25 minutes following accident initiation.

- The back-leakage from the sump to the BWST is tested and monitored against the assumption of 5 gpm every outage by Duke procedures. The analysis value of 5 gpm bounds actual testing results.

- The NUREG/CR-5950 model is applied to the BWST. The inherent assumption is that other fission products also leak back into the BWST, which in turn creates the water radiolysis by-products which transform the iodine into the elemental form. Since the radiation levels in the BWST are not expected to be nearly as high as the radiation levels in the containment sump, the equilibrium concentrations determined by the NUREG/CR-5950 methodology are not expected to be reached in short periods of time. Although using this approach is very conservative, the conservatism is acceptable since the release amounts from the BWST are not a significant contributor to the total calculated offsite or onsite doses. The calculated elemental iodine partition coefficient is a temperature dependent (and therefore time dependent) variable that varies from a value of 34 at back-leakage initiation to a value of 9 at the end of leakage.

- BWST volume is also a time dependent variable that varies with ECCS back-leakage into the BWST. The initial volume of the BWST at the end of the spray injection period is approximately 4,000 gallons. This increases to a value of 219,000 gallons at the end of ECCS back-leakage.

- The release rate from the BWST to the environment is calculated on a time dependent basis, and averaged over a range of timesteps for input into the dose model. The release rate of iodine from the BWST ranges from 4.4E-13 gram/second at initiation of back-leakage to 4.2E-08 gram/second at the end of back-leakage. The increase in release rate is due to the increasing concentration of iodine in the BWST liquid as ECCS back-leakage occurs.

- The maximum 2 hour dose for the EAB occurs during the time period from 1.7 to 3.7 hours following accident initiation.

- The doses from the BWST portion of the RBES model are calculated to be:

EAB	1.6E-04 rem TEDE
LPZ	7.2E-04 rem TEDE
Control Room	3.4E-03 rem TEDE

12. NRC Request

In pages 14 and 21 of Attachment 3, you provided the control room unfiltered air inleakage values used based on the results obtained from a tracer gas testing performed in 1998. Discuss uncertainty associated with these values and provide a copy of tracer gas test report prepared by your contractor.

Response

Tracer gas testing was conducted 1998 and 2001 at ONS. Both test programs were performed by NCS Corporation and Lagus Applied Technology, Inc. System improvements and sealing work were performed between the 1998 and 2001 tests. The purpose of the testing work in August 2001 was to demonstrate the effectiveness of this Control Room Ventilation System sealing program.

Additionally, reviews of the test data from the 1998 campaign suggested improvements that could be made in the testing setup and protocol to improve the accuracy of the results. In particular, the following features were added to the 2001 testing approach:

- Tracer gas mixing was augmented by incorporating advanced flow sparger designs for tracer gas injection and mixing fans in the flow stream to assure more accurate and repeatable sample measurement in the flow stream.
- Injection and sampling locations for flow measurements were modified to obtain more uniform tracer gas mixing in the flow stream at the sampling points.
- Calculation of measured values and uncertainties was augmented to evaluate uncertainty associated with data sets with data values clustered about a zero inleakage value.

Results from the 2001 test demonstrate that the sealing program had a significant improvement in system performance. The changes in testing protocol, combined with the sealing program improvements, resulted in data sets that exhibited lower deviation in testing measurement within each test and between comparable tests.

A copy of the tracer gas test report for the 2001 Control Room testing campaign, prepared by NCS Corporation and Lagus Applied Technology, Inc is provided as an Attachment to this submittal.

The measurement results from the 2001 test set were not available when this License Amendment Request was submitted to the NRC for review. Therefore, the data sets for unfiltered Control Room inleakage used in the submittal analyses were derived from the 1998 tests. The comparisons of the data obtained in the 1998 and 2001 test campaigns are presented in the tables below. The impacts of these improvements in testing results on the Control Room dose evaluation are then discussed.

The measured inleakage values, with uncertainty, obtained from 1998 tracer gas testing are shown in the following table. The unfiltered inleakage values used in the current analyses are also included:

Control Room	Ventilation Mode	Measured Inleakage Values	Analyses Inleakage Values
U1/U2	Normal	1065 +/- 61 ACFM	1150 CFM
U1/U2	Emergency 1 Fan	80 +/- 55 SCFM*	150 CFM
U3	Normal	534 +/- 30 ACFM	600 CFM
U3	Emergency 1 Fan	73 +/- 25 SCFM*	100 CFM
* Referenced to 70 Deg F and 14.7 psia			

The measured inleakage values, with uncertainty, obtained from 2001 tracer gas testing are shown in the following table. The unfiltered inleakage values used in the current analyses are also included:

Control Room	Ventilation Mode	Measured Inleakage Values	Analyses Inleakage Values
U1/U2	Normal	869 +/- 31 ACFM	1150 CFM
U1/U2	Emergency 1 Fan	0 +/- 18 SCFM*	150 CFM
U3	Normal	467 +/- 16 ACFM	600 CFM
U3	Emergency 1 Fan	0 +/- 13 SCFM*	100 CFM
* Referenced to 70 Deg F and 14.7 psia			

The methodology used in the testing and analyses follows that described in References 9 and 10. The referenced ASTM Standard E 741-95 was in process of development and review at the time of the1998 testing. However, the protocol outlined in Reference 9 was followed. This protocol served as part of the basis for the guidance developed in the Standard, and the test method used is consistent with it. Except for the improvements noted above, there were no fundamental differences in the performance of the 1998 and 2001 ONS tests.

For the 1998 test results, the total uncertainty of each CRE air inleakage measurement is calculated using the prescription provided in ANSI/ASME Standard PTC 19.1-1985 "Measurement Uncertainty" and represents 95% confidence limits. The same method was applicable to the measurement of inleakage for the configuration in the “Normal” ventilation mode in the 2001 test data evaluation. For the analyses of the “Emergency” ventilation mode the uncertainty values were determined using a different application of the statistical *T*-test (Students t or Fisher's “*t* test of significance for differences between sample means”). First, the statistical test is used to ascertain if the test data demonstrate that the testing result is different than zero inleakage. If it does not satisfy this statistical test condition, then the measured response is zero inleakage. The uncertainty value is then calculated as that value of the mean difference that satisfies the statistical test condition with the corresponding degree-of-freedom (7 or 8) and confidence level (95%).

As shown in the tables of results, the Control Room unfiltered inleakage values chosen for the analyses presented in the October 31, 2001 LAR submittal bound the nominal test values plus the upper bound value of the uncertainty range for both the 1998 and 2001 tests. For each test the values chosen also bound the sum of (1) the nominal test results and (2) a 10 CFM allowance for unfiltered inflow due to Control Room ingress and egress during the course of an accident.

Duke has concluded that the appropriate input values for unfiltered inleakage as derived from these test results should correspond to the nominal values determined from each of the testing programs. This conclusion is valid because the uncertainty values derived from the experimental results are within a reasonable range, as seen in the data set measurement results shown above. For the 2001 test results the range of calculated uncertainty is between 13 and 31 CFM, so that the nominal measured values of inleakage (0 CFM) should be used. This value to be used for analyses will be augmented by a 10 CFM allowance for unfiltered inflow due to Control Room ingress and egress throughout the course of an accident.

The selection of bounding values for the analyses as described above provides Duke with margin to accommodate changes in input assumptions that could be required to account for possible plant operational changes, such as increases in ECCS system leakage flow, imbalances in ventilation system flowrates, or reductions in filtration efficiencies. When these analyses are required, Duke will include additional margin in the input value for unfiltered inleakage of 15 CFM in the Emergency mode to account for potential unfiltered inleakage performance degradation. Therefore, the unfiltered inleakage values used for these analyses, based upon the modified 2001 results, will be no less than 880 CFM for normal ventilation operation and 25 CFM for the Emergency – 1 Fan operation.

The following table demonstrates the sensitivity of the results for the Control Room dose for representative sets of unfiltered inleakage values. Results are shown for the limiting evaluation using the input parameters for the Unit 1&2 Control Room for the LOCA analyses. The margin of the base case to the 5 rem TEDE limit is evident. The "Augmented Bounding Case" demonstrates that the input set predicts dose values within limits with inleakage values 50% greater than the "Bounding Case" and more than 10 times the Emergency mode inleakage value for the "Base Case". Additional sensitivity studies demonstrate that the dose prediction is most sensitive to this post-booster fan value (after 30 minutes into the accident). For example, doubling the value of the inleakage during the period before booster fan operation for the "Bounding Case" (to 2300 CFM), while holding the Emergency Ventilation mode value at 150 CFM, results in an increase in total dose of only 0.2 rem TEDE. This result is expected because of the relative amounts of radioactivity available for intake before and after the 30 minute switchover time.

Sensitivity of Control Room LOCA Dose to Unfiltered Inleakage Input Parameters				
Case Description:	**Base Case 2001 Test Basis**	**Bounding Case 1998 Test Basis**	**Augmented Bounding Case**	**Ventilation Mode Sensitivity**
Inleakage Ventilation Mode Normal	880 CFM	1150 CFM	1725 CFM	2300 CFM
Inleakage Ventilation Mode Emergency 1-Fan	25 CFM	150 CFM	225 CFM	150 CFM
Containment Dose (rem)	0.9	2.5	3.4	2.7
ECCS Dose (rem)	0.2	0.6	1.0	0.6
Total Control Room Dose (rem TEDE)	**1.1**	**3.1**	**4.4**	**3.3**

13. NRC Request

You stated in page 20 of Attachment 3 that you assumed a peak rod average burnup of 62,000 MWD/MTU, with an axial peaking factor of 1.65 for the fuel-cladding gap source term for single assembly fuel handling accident.

- What is the corresponding maximum linear heat generation rate?
- Provide fission product inventory assumed in the reactor core for noble gases and halogens
- Noble gas and halogen activity assumed in the fuel rod gap available for release to the water surrounding the failed fuel assembly
- Fraction of fission product inventory in fuel gap
- Fission product decay time prior to moving fuel assemblies
- Total amounts of fission products released (in curies) to the environment following the postulated fuel handling accident

Response

- The corresponding maximum linear heat generation rate is 6.0 kW per foot, based on a 418.6 effective full power days (EFPDs), 3 cycles, MTU loading per fuel assembly of 0.4946, an active fuel height of 11.86 feet, and 208 pins per assembly.

- The fission product inventory assumed in the reactor core for noble gases and halogens is shown in the table below.

Isotope	Total Curies in Core
Kr-83m	8.952+6
Kr-85m	1.901+7
Kr-85	8.301+5
Kr-87	3.657+7
Kr-88	5.149+7
Xe-131m	7.885+5
Xe-133m	4.506+6
Xe-133	1.385+8
Xe-135m	2.820+7
Xe-135	4.171+7
Xe-138	1.194+8
I-131	7.158+7
I-132	1.031+8
I-133	1.486+8
I-134	1.731+8
I-135	1.347+8

- The noble gas and halogen activity assumed in the fuel rod gap available for release to the water surrounding the failed fuel assembly is shown in the table below. These activities reflect a decay time of 72 hours as described below.

Isotope	**Total Curies per Fuel Assembly (Gap Activity)**
	72-Hour Decayed
Kr-83m	1.77E-05
Kr-85m	2.92E-01
Kr-85	6.65E+02
Kr-87	1.77E-13
Kr-88	6.35E-04
Xe-131m	3.82E+02
Xe-133m	1.20E+03
Xe-133	5.31E+04
Xe-135m	5.34E+00
Xe-135	6.74E+02
I-129	1.50E-03
I-131	4.38E+04
I-132	2.62E+04
I-133	6.31E+03
I-135	3.33E+01

- The fraction of fission product inventory in the fuel gap is taken in accordance with Regulatory Guide 1.183 Appendix B and Regulatory Position 3.2 of that guide. All the gap activity in the damaged rod is assumed to be instantaneously released. The fraction of fission product inventory in the gap is assumed to be:

  I-131 0.08

  Kr-85 0.10

  Other Noble Gases 0.05

  Other Halogens 0.05

- For fuel assembly events taking place in a spent fuel pool or a transfer canal, the fuel assembly is decayed for 72 hours, since the Oconee Technical Specifications prohibit fuel movement until 72 hours after shutdown (subcritical).

- The total amounts of fission products released (in curies) to the environment following the postulated fuel handling accident is given below by isotope, for the bounding single assembly fuel handling accident.

Isotope	Curies
Kr-83M	1.67E-05
Kr--85	6.65E+02
Kr-85M	2.85E-01
Kr--87	1.62E-13
Kr--88	6.10E-04
Rb--88	1.71E-04
I--129 Elem	1.09E-05
I--131 Elem	3.19E+02
I--132 Elem	1.82E+02
I--133 Elem	4.57E+01
I--135 Elem	2.38E-01
I--129 Org	3.22E-06
I--131 Org	9.40E+01
I--132 Org	5.36E+01
I--133 Org	1.35E+01
I--135 Org	7.04E-02
I--129 Part	0.00E+00
I--131 Part	0.00E+00
I--132 Part	0.00E+00
I--133 Part	0.00E+00
I--135 Part	0.00E+00
Xe131M	3.82E+02
Xe-133	5.30E+04
Xe133M	1.20E+03
Xe-135	6.65E+02
Xe135M	3.68E+00
Cs-135	3.81E-09

14. NRC Request

You also stated in page 20 of Attachment 3 that you assumed a power peaking factor of 1.2 and a core average inventory for multiple assembly fuel handling accident.

- What is the corresponding maximum linear heat generation rate?
- Provide fission product inventory assumed in the reactor core for noble gases and halogens
- Noble gas and halogen activity assumed in the fuel rod gap available for release to the water surrounding the failed fuel assembly
- Fraction of fission product inventory in fuel gap
- Fission product decay time prior to moving fuel assemblies
- Total amounts of fission products released (in curies) to the environment following the postulated fuel handling accident

Response

- The corresponding maximum linear heat generation rate is 3.8 kW per foot, based on 500 EFPDs, 3 cycles, MTU loading per fuel assembly of 0.4946, an active fuel height of 11.86 feet, and 208 pins per assembly.

- The fission product inventory assumed in the reactor core for noble gases and halogens is identical to the inventory shown in response to RAI 13.

- The noble gas and halogen activity assumed in the fuel rod gap available for release to the water surrounding the failed fuel assembly is shown in the table below. This inventory reflects various decay times for the multiple assemblies postulated to fail.

Isotope	Total Curies per Fuel Assembly (Gap Activity)				
	55-Day Decayed	57-Day Decayed	65-Day Decayed	70-Day Decayed	1-Year Decayed
Kr-83m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85	5.57E+02	5.57E+02	5.57E+02	5.56E+02	5.28E+02
Kr-87	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-131m	2.95E+01	2.65E+01	1.72E+01	1.30E+01	4.96E-07
Xe-133m	6.82E-05	3.62E-05	2.88E-06	5.91E-07	0.00E+00
Xe-133	4.06E+01	3.12E+01	1.08E+01	5.59E+00	6.57E-17
Xe-135m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-135	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	9.52E-04	9.52E-04	9.52E-04	9.52E-04	9.54E-04
I-131	3.49E+02	2.94E+02	1.47E+02	9.58E+01	8.66E-10
I-132	2.93E-01	1.92E-01	3.50E-02	1.21E-02	0.00E+00
I-133	3.95E-15	7.97E-16	1.33E-18	2.11E-20	0.00E+00
I-135	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

- The fraction of fission product inventory in the fuel gap is taken in accordance with Regulatory Guide 1.183 Appendix B and Regulatory Position 3.2 of that guide. All the gap activity in any damaged rod is assumed to be instantaneously released. The fraction of fission product inventory in the gap is assumed to be:

I-131	0.08
Kr-85	0.10
Other Noble Gases	0.05
Other Halogens	0.05

- The number of fuel assemblies involved in these multiple assembly fuel handling events varies depending on the location of the cask drop (i.e., the Unit 1&2 or Unit 3 spent fuel pool) and the type of cask dropped (i.e., transport cask or ISFSI cask). The table below summarizes the number of fuel assemblies involved with each cask drop event in each Spent Fuel Pool. Since the number of fuel assemblies involved in these events is greater than the amount of fuel freshly discharged from a core(s) (i.e., 177 fuel assemblies per core), two different decay times are assumed for each event: one for the fuel freshly discharged from the core and one for the other fuel involved in the event. The decay times for the freshly discharged fuel vary depending on cask type and fuel pool. All other fuel is conservatively assumed decayed for only one year.

Number of Fuel Assemblies Involved with Cask Drops

Cask Type	**# of Fuel Assemblies per Spent Fuel Pool Unit**	
	1 & 2	**3**
Transport Cask	576 - 354 decayed over 55-days - 222 decayed over 1-year	518 - 177 decayed over 70-days - 341 decayed over 1-year
ISFSI Cask	1024 - 354 decayed over 65-days - 670 decayed over 1-year	825 - 177 decayed over 57-days - 648 decayed over 1-year

Thus, to obtain the total source terms for each fuel handling accident, the activity per fuel assembly is multiplied by the number of assemblies decayed over the specified period. The table below summarizes the total source terms (gap inventory) which is used as input into LOCADOSE.

Gap Source Terms for Fuel Handling Accidents

Isotope	Gap Inventory (Curies)			
	Transport Cask Drop into Unit 1&2 SFP	**ISFSI Cask Drop into Unit 1&2 SFP**	**Transport Cask Drop into Unit 3 SFP**	**ISFSI Cask Drop into Unit 3 SFP**
Kr-83m	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85m	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85	3.14E+05	5.51E+05	2.78E+05	4.41E+05
Kr-87	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-131m	1.04E+04	6.07E+03	2.31E+03	4.69E+03
Xe-133m	2.41E-02	1.02E-03	1.05E-04	6.41E-03
Xe-133	1.44E+04	3.83E+03	9.89E+02	5.51E+03
Xe-135m	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-135	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	5.49E-01	9.76E-01	4.94E-01	7.86E-01
I-131	1.24E+05	5.22E+04	1.70E+04	5.20E+04
I-132	1.04E+02	1.24E+01	2.13E+00	3.39E+01
I-133	1.40E-12	4.70E-16	3.74E-18	1.41E-13
I-135	0.00E+00	0.00E+00	0.00E+00	0.00E+00

- The total amounts of fission products released (in curies) to the environment following the postulated fuel handling accident are given below by isotope for the bounding cask drop accident.

Isotope	Curies
Kr-83M	0.00E+00
Kr--85	3.15E+05
Kr-85M	0.00E+00
Kr--87	0.00E+00
Kr--88	0.00E+00
Rb--88	0.00E+00
I--129 Elem	1.81E-03
I--131 Elem	4.07E+02
I--132 Elem	3.26E-01
I--133 Elem	4.58E-15
I--135 Elem	0.00E+00
I--129 Org	1.18E-03
I--131 Org	2.66E+02
I--132 Org	2.13E-01
I--133 Org	2.99E-15
I--135 Org	0.00E+00
I--129 Part	0.00E+00
I--131 Part	0.00E+00
I--132 Part	0.00E+00
I--133 Part	0.00E+00
I--135 Part	0.00E+00
Xe131M	1.04E+04
Xe-133	1.44E+04
Xe133M	2.41E-02
Xe-135	0.00E+00
Xe135M	0.00E+00
Cs-135	0.00E+00

15. NRC Request

The tables in pages 24 and 25 of Attachment 3 include the radiological consequences resulting from the transportation and ISFSI cask drop accidents. Provide the following additional information:

- What is ISFSI cask?
- Number of fuel assemblies in each cask
- Noble gas and halogen activity assumed in each cask available for release to the water surrounding the failed fuel cask
- Fraction of fission product inventory in each cask
- Fission product decay time used
- Total amounts of fission products released to the environment following the postulated each fuel cask accidents

Response

- It is postulated that a transportation cask or an Independent Spent Fuel Storage Installation (ISFSI) transfer cask is dropped onto the spent fuel pool racks. Fuel contained inside the cask is not postulated to be released due to the robustness of the cask. The dropped cask is postulated to impact and damage numerous assemblies stored in the SFP racks. The entire gap activity of the impacted assemblies is released. Fractions of fission products in the fuel gap follow Regulatory Guide 1.183 Position 3.2.

- The noble gas and halogen activity available for release in each cask drop accident is described in RAI 14 for both the transportation cask and ISFSI cask drops. The fraction of fission product inventory in the gap of damaged fuel assemblies is also described in RAI 14.

- Since the number of fuel assemblies involved in these events is greater than the amount of fuel freshly discharged from a core(s) (i.e., 177 fuel assemblies per core), different decay times are assumed for each event. Freshly discharged fuel is decayed from 55 to 70 days. All other fuel is conservatively assumed decayed for one year. See response to RAI 14 for further details.

- Amounts of fission products released to the environment following a cask drop event are given for the bounding cask drop case in response to RAI 14.

16. NRC Request

In Appendix B to Regulatory guide, the staff provided a guidance to close the containment air locks, equipment hatch, or open penetrations within 30 minutes following fuel handling accident. State your position.

Response

The equipment hatch closure process at Oconee, which presents the limiting timeline for these actions, is achievable within 30 minutes. Station training and testing is performed during each refueling outage (a frequency of every six months at the Oconee Nuclear Station) to demonstrate actual equipment hatch closure times. Based on the cumulative results of this testing program, equipment hatch closure time is consistently less than 25 minutes. For a fuel handling accident event the allowance for notifications and evacuation actions is assumed to be five minutes based upon training and testing. Therefore, the total time for all anticipated and planned actions is less than 30 minutes.

As recommended in Appendix B of Regulatory Guide 1.183, the analyses take no credit for any isolation actions in demonstrating that calculated doses are within regulatory limits. Rather, these features are in place to assure additional defense in depth in the unlikely event of an accident.

Duke has received approval of a License Amendment for the Catawba Nuclear Station (CNS) that allows the equipment hatch to be open during fuel movement, based upon the offsite and control room dose evaluations and system performance guidance in accordance with Regulatory Guide 1.183. As part of the amendment implementation process designed by Duke, worker exposure analyses have been performed to provide bounding estimates for workers that would be exposed to radioactivity release while implementing equipment hatch closure actions. These evaluations have conservatively assumed that the maximum activity releases from the DBA analyses do occur. That is, the evaluations postulate that all fuel rods in an assembly fail catastrophically in a fuel assembly drop event and immediately release the design basis fission product gap activity to the pool. With these conservative assumptions and with additional bounding assumptions on the distribution of radioactivity in the local environment, the projected 30 minute dose to a worker closing the equipment hatch in this environment would exceed Duke's administrative guidelines. As a result, Duke is carefully examining this evaluation to determine appropriate programmatic controls on the closure process at CNS in the 2002/2003 timeframe and before fuel movement is performed when the equipment hatch is open (Spring 2003 outage). Results of this examination, including the procedural guidance that is derived, will be applicable to Oconee. Since implementation at Oconee is scheduled in the 2003/2004 timeframe, the results of this work will be available for application in the site implementation process

17. NRC Request

In pages 15, 23 and 31 of Attachment 3, you have listed various atmospheric dispersion factors (χ/Q values) for the control room air intakes. State specifically which χ/Q values were used for:

Containment leak
ECCS leak
BWST release
Fuel handling accident release from the containment
Fuel handling accident release from the spent fuel pool

Response

χ/Q values were calculated for each release point by analyzing the corresponding release from each unit (1, 2 and 3) to each control room intake location. Maximum bounding χ/Q values are applied, so that the calculation is bounding for all 3 Oconee units. The following χ/Q values were used for the specified release points.

- Containment leak - The containment leakage that bypasses the Penetration Room Ventilation System (PRVS) is assumed to be 50%. The portion of containment leakage that bypasses PRVS is assumed to leak out of the Equipment Hatch to the atmosphere, and uses the Equipment Hatch χ/Q. While 50% of the leakage travels through the Penetration Room Ventilation System, no credit is taken for filtration. This portion of the leakage uses the Unit Vent χ/Q.

- ECCS leak - For ECCS leakage (other than BWST back-leakage), the bounding χ/Q is represented by the Unit Vent release point.

- BWST release - A specific χ/Q value has been calculated for the BWST release point and is used for this portion of ECCS leakage. Note that the LAR submittal contained a typographical error in the χ/Q value for the 8 to 24 hr timeframe. The correct value is 6.05E-5 sec/m^3.

- Fuel handling accident release from the containment - While a release from the containment with the equipment hatch open could be dispersed via this pathway, the Unit Vent χ/Q value is higher. Therefore, the Unit Vent χ/Q is used as a bounding value for all containment releases following an FHA.

- Fuel handling accident release from the spent fuel pool - Models for an FHA in the SFP are analyzed using both the Unit Vent release (for the SFP ventilation system pathway, without filtration credit) and the SFP roll-up doors. Both models are analyzed to ensure the limiting dose is evaluated. A table listing the χ/Q value used for each of the 12 FHA cases is provided in the response to RAI 1 in the section titled "Fuel Handling Accident LOCADOSE Input".

18. NRC Request

In page 22 of Attachment 3, you describe decontamination factors (DFs) used for organic and elemental iodine. State overall effective DF used with the fuel transfer canal water level of greater than or equal to 21.34 feet above the top of the reactor vessel flange. The staff stated in Appendix B to Regulatory guide 1.183 an overall DF of 200 if the depth of water above the damaged fuel is 23 feet or greater is acceptable to the staff.

Response

The individual iodine DFs given in Regulatory Guide 1.183 are an elemental DF of 500 and an organic DF of 1 for a water level greater than or equal to 23 feet. These DFs for iodine species, in combination with the Regulatory Guide 1.183 specified composition fractions for iodine species entering the pool (99.85% inorganic, 0.15% organic) and iodine species leaving the pool (57% inorganic, 43% organic) are inconsistent with the stated overall effective DF of 200. These parameters are consistent with an overall effective DF of 286.

Since the NRC preferred parameter for use in accident analysis is the overall effective DF of 200, the fuel gap iodine species composition and the pool-retention factors for the individual iodine species were redefined, and are as follows, for water depth of 23 feet.

Overall iodine airborne fraction	= (1/200)	= 0.005
Fraction of inorganic airborne iodines	= 0.005 * 0.57	= 0.00285
Fraction of organic airborne iodines	= 0.005 * 0.43	= 0.00215
Pool DF for organic iodine		= 1.0
Fuel gap organic iodine fraction (same as the airborne)		= 0.00215
Fuel gap inorganic iodine fraction	= 1 - 0.00215	= 0.99785
Pool DF for inorganic iodine	= 0.99785 / 0.00285	= 350.1

The ratio of calculated DFs for 23' and 21.34' of water depth from Duke calculations is 0.860. For the Oconee pool 21.34 feet of water depth, a comparatively conservative DF for inorganic iodine is determined as follows:

$$350.1 * 0.860 = 301$$

The resulting overall effective DF, for 21.34' of water depth, is then:

$$[\,(301)^{-1} * .99785 + (1.0)^{-1} * 0.00215\,]^{-1} = 183$$

The Oconee Fuel Handling Accident cases have been re-analyzed using these revised DFs. The resulting doses are still within the limits prescribed in Regulatory Guide 1.183, as shown in the tables below.

Calculated Doses to Control Room Operators due to Fuel Handling Events Spent Fuel Pool (SFP) and Containment					
Case	**Group**	**Source**	**Unit and Release Point**	**Control Room Unit Destination**	**TEDE (rem)**
1	1	Fuel Assembly Accident in SFP	Unit 2 Unit Vent	Unit 1&2	1.8
2	1	Fuel Assembly Accident in SFP	Unit 3 Roll-Up Door	Unit 1&2	0.6
3	1	Fuel Assembly Accident in SFP	Unit 2 Unit Vent	Unit 3	1.2
4	1	Fuel Assembly Accident in SFP	Unit 3 Roll-Up Door	Unit 3	0.4
5	2	Fuel Assembly Accident in Containment	Unit 2 Unit Vent	Unit 1&2	1.0
6	2	Fuel Assembly Accident in Containment	Unit 3 Unit Vent	Unit 3	0.7
7	3	Transport Cask Drop in SFP	Unit 2 Unit Vent	Unit 1&2	2.8
8	3	Transport Cask Drop in SFP	Unit 2 Unit Vent	Unit 3	1.9
9	3	ISFSI Cask Drop in SFP	Unit 2 Unit Vent	Unit 1&2	1.2
10	3	ISFSI Cask Drop in SFP	Unit 2 Unit Vent	Unit 3	0.8
11	3	ISFSI Cask Drop in SFP	Unit 3 Roll-Up Door	Unit 1&2	0.4
12	3	ISFSI Cask Drop in SFP	Unit 3 Roll-Up Door	Unit 3	0.3

Calculated Offsite Doses due to Fuel Handling Events Spent Fuel Pool (SFP) and Containment					
Case	**Group**	**Source**	**Unit and Release Point**	**EAB TEDE (rem)**	**LPZ TEDE (rem)**
1	1	Fuel Assembly Accident in SFP	Unit 2 Unit Vent	1.2	0.1
2	1	Fuel Assembly Accident in SFP	Unit 3 Roll-Up Door	1.2	0.1
5	2	Fuel Assembly Accident in Containment	Unit 2 Unit Vent	0.7	0.1
7	3	Transport Cask Drop in SFP	Unit 2 Unit Vent	1.2	0.2
9	3	ISFSI Cask Drop in SFP	Unit 2 Unit Vent	0.8	0.1
11	3	ISFSI Cask Drop in SFP	Unit 3 Roll-Up Door	0.8	0.1

References:

1. NUREG/CR-5950, "Iodine Evolution and pH Control", December 1992.

2. D. A. Powers, et al., A Simplified Model of Aerosol Removal by Natural Processes in Reactor Containments, NUREG/CR-6189, Sandia National Laboratories.

3. A. K. Postma, et al., Technological Bases for Models of Spray Washout of Airborne Contaminants in Containment Vessels, NUREG/CR-0009, Benton City Technology, October 1978.

4. U.S. Nuclear Regulatory Commission, *Standard Review Plan*, NUREG-0800, Section 6.5.2, Rev. 2, December, 1988. [Note that although information from this document is being used as input to this analysis, it is guidance beyond the licensing basis for ONS]

5. American National Standard, *PWR and BWR Containment Spray System Design Criteria*, ANSI/ANS-56.5-1979, 1980.

6. ORNL-TM-1911, "Removal of Elemental Iodine from Steam-Air Atmospheres By Reactive Sprays," October 1967.

7. WASH-1329, "A Review of Mathematical Models for Predicting Spray Removal of Fission Products in Reactor Containment Vessel," June 1974.

8. Incropera and DeWitt, "Fundamentals of Heat Transfer," 1981.

9. P. L. Lagus ad R. A. Grot, "Control Room Inleakage Testing", NRC Contractor Report of Contract Work Performed 7/1/94 to 1/31/95 under Contract NRC-04-94-070, January 1995.

10. American Society for Testing and Materials, "Standard Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution", ASTM Standard Designation: E 741-95, December 1999.

Response to comments received via email from Leta Brown (USNRC):

1. *Confirm that, overall, the meteorological data used in the assessment are of high quality and suitable for use in the assessment of atmospheric dispersion to which it was applied.*

   (a) During the period of data collection, was the tower base area on the natural surface (e.g., short natural vegetation) and tower free from obstructions (e.g., trees, structures) and micro-scale influences to ensure that the data were representative of the overall site area?

   Meteorological data (1991-1995) from the primary Northwest tower site was used in the assessment. The area around the 60m tall Northwest meteorological tower has been maintained free of obstructions. Trees and scrub plants were last cleared from the area around the outside of the fenced tower sites (primary Northwest site and supplemental river site) between October 2000 – March 2001, to ensure good exposure in the future.

   The original meteorological system, located on the microwave tower (40m tall), was in use through 1988 and was replaced with the new primary tower (60m tall), which began operation on 23 April 1988 at 1800 hours. The current tower is located in a clearing to the west of the plant and offers the best siting available. A supplemental tower also operates in the Keowee River Valley, located to the E/SE of the station.

   (b) Did the measurement program meet the guidelines of Regulatory Guide 1.23, "Onsite Meteorological Programs."

   The Oconee Nuclear Station meteorological system is maintained to comply with Regulatory Guide 1.23. All collected meteorological data are reviewed, validated, edited and archived. Prior to the archival process, the meteorological data is reviewed and approved by the in-house Certified Consulting Meteorologist.

   (c) Were good data collection practices followed including factors such as maintaining good siting, instruments within specifications, and obtaining adequate data recovery and proper performing quality assurance checks?

   The meteorological equipment in use is of high quality and is maintained within operating specifications to ensure accurate data collection and the tower sensor instruments are free of obstructions. Annual meteorological data recoveries for the Northwest tower during the period 1991 through 1995 were approximately 96.5, 96.3%, 96.3%, 93.0%, and 92.5% respectively (i.e. average of recoveries from both instrument levels). Data recoveries increased to 93.9% and 96.8% in 1996 and 1997. Weekly meteorological system checks were performed to ensure all data channels were operating within tolerance. Semi-annual meteorological system calibrations are performed, during which all tower-mounted sensors are replaced with newly certified sensors. The precipitation gauge is located at the Keowee River tower site and is calibrated in place, without replacement.

(d) If deviations occurred, describe the deviations and why the data are still deemed to be adequate.

During the meteorological data quality assurance process, if meteorological system performance does not satisfy the accuracies and specifications of Regulatory Guide 1.23, then the meteorological data would be deleted. Missing data values (e.g. 999s) would be inserted in the historical/archive database. No data values were maintained that did not satisfy regulatory criteria.

(e) What types of quality assurance checks were performed on the meteorological measurement systems prior to and during the periods of collection to assure that the data are of high quality?

Weekly meteorological system checks were performed to ensure all data channels were operating within tolerance. Semi-annual meteorological system calibrations were performed during which all tower-mounted sensors were replaced with newly certified sensors. The precipitation gauge, located at the Keowee River site, is calibrated in place without replacement. All collected meteorological data were reviewed, validated, edited and archived. Prior to the archival process, the meteorological data was reviewed and approved by the in-house Certified Consulting Meteorologist.

(f) Were calibrations properly performed and systems found to be within guideline specifications for the use of the data?

Yes. Weekly checks and semi-annuals calibrations assured that instruments were operating within tolerance. Any out-of-tolerance conditions would prompt data deletion.

(g) What additional checks and at what frequency were the checks performed on the raw data following collection and during processing prior to input into the atmospheric dispersion calculations to assure identifying any problems in a timely manner and flagging data of questionable quality?

Routine quality assurance checks were performed on the meteorological system and collected data as described above. Meteorological data were retrieved from the quality assured archive and provided for use in the air dispersion calculations. The format of the hourly data files and missing data values were considered in the calculation, when the data was converted to the required format for input into ARCON96.

Hourly stability classes were calculated based on the vertical temperature gradient (i.e. delta-T) measurements. Input to ARCON96 treated missing data as blanks. The data is being provided to NRC with this document, on the enclosed CD, in Arcon96 format with missing data fields now filled in with 9's.

A representative ARCON96 run was performed to ensure the validity of the original data files which used blanks for missing data. With the reformatted meteorological data files, insignificant differences in χ/Q values occurred beginning in the 8 to 24 hour timeframe (less than 1% difference). Based on this review, the reformatted MET files are expected to have a negligible effect on final dose results, and the calculated χ/Q values presented in the LAR submittal are not revised.

(h) *Were the data compared with other site historical or regional data and, if so, what were the findings? The intent of these questions is to assess the overall quality of the meteorological data. A detailed response for each individual data point is not expected.*

During the quality assurance process, data is flagged for further review if it falls outside its expected ranges. The data reviewers and meteorologist also look for unusual behavior in the variables and investigate the validity of the data with any such occurrences. In such cases, data is compared with MET data from other Duke nuclear sites for the same time period, to verify similar trends.

The only routine comparison of MET data to the site's historical data occurs during the annual modeling of χ/Q values and D/Q values for routine releases, supporting the compilation of the Annual Effluent Release Reports submitted to NRC. The preceding year's 10m level MET data is compared to the 1988-1992 MET dataset at the 10m level, which used in the ODCM. Frequencies of wind speeds, wind directions, delta-T and stability classes are compared, as well as max, min, and mean values of wind speed and delta-T. For the 60m level, wind directions are compared with previous years' data, as well as stability classes.

Attached Tables 1 through 5 provide meteorological data summaries from these analyses. Stability classes D and E occur most frequently, along with 10m wind speeds in the 1.5 – 3 m/s range (i.e. 3.4 - 6.7 mph). The prevailing wind directions at the 10m-level are generally southwesterly and ENE. Prevailing winds at the 60m-level are also southwesterly, in general, and from the ENE.

Table 1 Oconee Stability Class Frequency - NW MET Tower (Based on 60-10m Delta-T)

Stability Class	**ONS-5yr (1988-1992)**	1995 Frequency (%)	1996 Frequency (%)	1997 Frequency (%)	1998 Frequency (%)	1999 Frequency (%)	2000 Frequency (%)	2001 Frequency (%)
A-very unstable	**9**	9	8	4	10	9	11	7
B-unstable	**5**	6	5	3	4	4	5	5
C-slightly unstable	**6**	6	6	5	5	5	6	6
D-neutral	**40**	**39**	**44**	**49**	**39**	**37**	**40**	**41**
E-slightly neutral	**33**	**34**	**30**	**33**	**37**	**38**	**31**	**33**
F-stable	**6**	4	5	5	5	6	6	6
G-very stable	**2**	1	1	2	1	1	1	1
Total Percentage	100	100	100	100	100	100	100	100

Table 2 Oconee 10m-level Wind Speed

Wind Speed Class (mph)	Wind Speed Class (m/s)	ONS-5yr (1988-1992)	ONS-1998 (%)	ONS-1999 (%)	ONS-2000 (%)	ONS-2001 (%)
1.01 - 1.67 mph	0.45 - 0.74 m/s	4.7	3.3	2.3	3.4	3.84
1.68 - 2.23 mph	0.75 - 0.99 m/s	9.4	**13.5**	13.4	13.4	13.44
2.24 - 2.78 mph	1.00 - 1.24 m/s	10	**13.6**	**14**	**12.6**	13.01
2.78 - 3.35 mph	1.25 - 1.49 m/s	**12.3**	**13.5**	13.5	13.5	**13.5**
3.36 - 4.47 mph	**1.50 - 1.99 m/s**	**16.8**	**19.4**	**19**	**19.3**	**19.42**
4.48 - 6.71 mph	**2.00 - 2.99 m/s**	**20.4**	**21.2**	**21.6**	**21.9**	**20.55**
6.72 - 8.95 mph	**3.00 - 3.99 m/s**	9.6	7.6	8.9	8.8	9.2
8.96 - 11.18 mph	4.00 - 4.99 m/s	4.5	4.1	4.1	4.1	4.29
11.19 - 13.42 mph	5.00 - 5.99 m/s	1.8	2	1.5	1.7	1.48
13.43 - 17.91 mph	6.00 - 7.99 m/s	1.3	1.7	1.4	1.2	1.05
17.92 - 22.38 mph	8.00 - 9.99 m/s	0.3	0.7	0.2	0.1	0.17
	CALMS (%)	1	0.18	0	0.071	0.23
	CALMS (hours)	390 hours/5yrs or average 78hrs/yr	14 hours	0 hours	6	20

Table 3 Oconee Delta-T and 10m-level Wind Speed

Oconee	MAX Delta-T (°C)	MEAN Delta-T (°C)	MIN Delta-T (°C)	MAX 10m Wind Speed (m/s)	MEAN 10m Wind Speed (m/s)	MIN 10m Wind Speed (m/s)
1988-1992	6	-0.25	-3.83	12.8	4.7	0 & 0.045
1998	4.39	-0.26	-2.4	9.585	1.999	0.045
1999	5.35	-0.209	-2.05	10.485	2.011	0.45
2000	5.00	-0.28	-3.30	9.77	2.00	0.27
2001	4.77	-0.23	-2.54	12.47	1.99	0.09

Table 4 Oconee 10m-level Wind Direction Frequency

Wind Direction Sector (from which wind is blowing)	**ONS-10m (1988-1992) (%)**	ONS-1998 (%)	ONS-1999 (%)	ONS-2000 (%)	ONS 2001 (%)
N	**5.1**	5	4.4	3.9	5.2
NNE	**5.2**	5	5.4	4.2	4.3
NE	**9**	**7.2**	8.4	6.7	7.0
ENE	**8.3**	**8.7**	**9.6**	**8.6**	7.7
E	**5.2**	5.5	4.8	5.3	4.6
ESE	**3.1**	3.6	3.2	3.4	2.8
SE	**3**	3.7	3.1	2.9	2.8
SSE	**3.5**	4.2	3.5	3.5	3.1
S	**3.6**	3.6	3.1	3.6	3.0
SSW	**8.5**	**8.7**	8	9.5	**9.3**
SW	**11.7**	**12.3**	**11.8**	**13**	**14.0**
WSW	**7.4**	8.9	**9**	**9.5**	**8.6**
W	**5.1**	5.3	6	6.7	6.0
WNW	**6.9**	6.5	7.8	7.7	8.9
NW	**7.2**	6	6.4	7	7.2
NNW	**6.3**	5.7	5.6	4.5	5.6

Table 5 Oconee Nuclear Station - 60m Meteorology from NW Tower

Wind Direction Sector (from which wind is blowing)	1995 Frequency (%)	1996 Frequency (%)	1997 Frequency (%)	1998 Frequency (%)	1999 Frequency (%)	2000 Frequency (%)	2001 Frequency (%)
N	8.17	7.31	8.97	**8.75**	**8.60**	3.82	**9.57**
NNE	**9.67**	7.86	**9.13**	8.09	**8.64**	4.11	**8.93**
NE	7.43	7.37	8.59	7.25	8.37	6.60	7.03
ENE	8.63	8.21	8.47	8.10	8.09	**8.61**	6.95
E	6.11	4.89	4.32	4.84	4.32	5.26	4.28
ESE	2.79	2.51	2.49	2.92	2.96	3.37	2.64
SE	1.91	2.42	1.63	2.23	2.05	2.86	1.87
SSE	2.02	2.48	2.73	3.39	2.94	3.50	2.44
S	2.78	3.86	3.43	3.82	3.71	3.59	3.23
SSW	7.70	**9.19**	8.73	8.66	**9.13**	**9.55**	**9.78**
SW	**13.05**	**12.78**	**12.86**	**12.64**	**11.36**	**13.16**	**13.72**
WSW	8.12	8.90	7.60	7.77	8.05	**9.56**	8.51
W	4.92	5.57	4.49	4.68	4.92	6.75	4.74
WNW	5.99	5.85	5.87	5.07	5.41	7.74	5.49
NW	5.07	5.50	5.27	5.14	5.00	7.00	4.90
NNW	5.57	5.27	5.43	6.63	6.46	4.46	5.85
Calm	0.09	0.01	0.00	0.02	0.00	0.07	0.07
Total Percentage	100	100	100	100	100	100	100

2. *(a) What period(s) of meteorological data was used to perform the relative concentration calculations?*

The meteorological data used to perform the relative concentration calculations is from the Northwest tower site, for the period of 1991 through 1995.

(b) Have these data been provided in on an electronic media on the docket to the NRC? If not, data should be provided either in the format specified in Appendix A to Section 2.7, "Meteorology and Air Quality," of NUREG-1555, "Environmental Standard Review Plan," or in the ARCON96 format described in NUREG/CR-6331, "Atmospheric Relative Concentrations in Building Wakes." Data may be provided in a compressed form, but a method to decompress the data should be provided. Any missing data should be designated by completely filling the field for that parameter with 9's. Atmospheric stability should be determined by the delta-T method.

The original meteorological data input to Arcon96 were provided in files "ONS91.MET" through "ONS95.MET". Reformatted files (i.e. *Ons91_nb.met* through *Ons95_nb.met*) are being provided with invalid data designated by filling data fields with 9's. Both the original and reformatted files used stability class determined by the delta-T method with a vertical separation distance of 50 m (upper level at 60m and lower level at 10m). The wind speed units are in mph.

(c) If the meteorological data have been provided, are they the "Ons91.met" and sequential files for the period of 1991 through 1995? If so, are all invalid data designated as blanks?

Yes, in the original meteorological data input files for Arcon96, invalid data was designated as blanks. Refer to item (b) above.

(d) There appear to be a number of cases of wind data values remaining the same for two or more consecutive hours.

Some of these occurrences may have been due to continuous hours of missing data (i.e. blanks within the original Arcon96 MET input files) being treated as zeros in wind speed or wind direction data. Reformatted input files, with missing MET data filled with 9's, are being supplied with this document.

Hourly averaged wind speeds can be constant for several hours, especially under lower wind speeds (e.g. 2-6 mph) and neutral conditions, which occur more frequently. General wind directions might also remain unchanged for up to 8-hours or more, based on how fast a dominating synoptic pattern is changing over a region.

(e) There appear to be relatively few occurrences (only about one percent) of extremely stable conditions while historic data in the SAR and comparison of data from some other sites would suggest a higher frequency.

UFSAR 2.3.3.1 cites a 24% frequency for temperature inversions (October 1966-October 1967), based on temperature gradients "...determined by thermographs located...[in shelters]...stationed on the site at varying terrain elevations." In June 1967, a "...temperature gradient measuring system ...[was]... mounted on the 46 meter...[microwave]...tower" with a ground-level sheltered thermograph and mercury thermometer for comparison. This study gave an inversion frequency of 40% (June 1967 – May 1968).

With respect to the SAR, the 40m tall microwave tower at ONS was located at the top a hill to the west overlooking the plant, with likely impacts from surrounding trees and terrain, as well as structural and thermal influences from the station. The lower level temperature sensor was initially located at 1.5 m above ground and later moved to the 10m level (refer to dates in Table 6). The upper level temperature sensor was located at 46 m above ground.

Old aspirators also had no flow sensors, so there would be no indication of mechanical aspirator failure for immediate repairs to be made. This could produce a warm bias in the temperature sensor and lead to large positive or negative delta-T values, depending on which sensor level was impacted.

Delta-T ranges listed in Table 6 indicate accuracies of 1 to 2 decimal digits would be required to accurately categorize the stability class, based on delta-T measurement. However, equipment accuracies have varied over time, ranging from +/- 0.5F to +/- 1.0F in the 1960s and 1970s. Temperature sensors with 4-lead RTDs were installed in February 1979, allowing measurement accuracies of +/-0.1F. Prior to 1984, delta-T data were reduced from stripcharts or thermographs. Starting in 1984, real-time digital values were available through the station's Operator Aid Computers (OACs). All of these potential sources of error would affect stability calculations based on the early vintage data.

It is concluded that the occurrence of stability class G, based on 1960s-1970s meteorological data, is overestimated. More recent measurements from the 60m tall meteorological tower support a typical stability class distribution and result in an annual frequency of stability G only 1-2% of the time (refer to Table 1; 1988-1992 and 1995-2001). Recent data is captured digitally, to the second decimal digit, with a temperature sensor accuracy of +/- 0.1C. Thus, even current observations of delta-T can only provide stability class estimates to within 1-2 classes.

Table 6 ONS Delta-T Ranges for Determining Stability Class

Stability Class	ONS 40m Tower 44.5m Delta-T (C) (6/23/1967 – 2/23/1977)	ONS 40m Tower 36m Delta-T (C) (2/23/1977 – 4/22/1988)	ONS 60m Tower 50m Delta-T (C) (4/22/1988-Present)
A = 1; Extremely Unstable	**dT < - 0.85**	**dT < - 0.68**	**dT < - 0.97**
B = 2; Moderately Unstable	**- 0.85 < dT < - 0.76**	**- 0.68 < dT < - 0.61**	**- 0.97 < dT < - 0.87**
C = 3; Slightly Unstable	**- 0.76 < dT < - 0.67**	**- 0.61 < dT < - 0.54**	**- 0.87 < dT < - 0.76**
D = 4; Neutral	**- 0.67 < dT < - 0.22**	**- 0.54 < dT < - 0.18**	**- 0.76 < dT < - 0.25**
E = 5; Slightly Stable	**- 0.22 < dT < 0.67**	**- 0.18 < dT < 0.54**	**- 0.25 < dT < 0.76**
F = 6; Moderately Stable	**0.67 < dT < 1.78**	**0.54 < dT < 1.44**	**0.76 < dT < 2.04**
G = 7; Extremely Stable	**1.78 < dT**	**1.44 < dT**	**2.04 < dT**

(f)There appears to be more than, at most, a few occurrences of extremely unstable measurements at night, and infrequently recorded occurrences of extremely unstable conditions occurring for much of a day or more. If these observations are valid, to what are they attributed?

The hours of A & B stability at night are true observations, based on valid measurements of the vertical temperature gradient between upper and lower 10m level temperature sensors, regardless of upper level height (i.e. 40m or 60m).

Occurrences of unstable hours at night or unstable conditions existing for a day or more are due to (a) cold air advection aloft, and (b) post-frontal air mass changes. Concurrent northerly winds would be indicative of cold air advection within this geographical area, which is subject to "cold-air damming" events as winds trap cool air against the eastern slopes of the Appalachian Mountains. Hours of instability are often associated with precipitation events and good mixing conditions.

Unstable conditions at night are not "unexpected" in the Carolinas. Occurrences of A and B stability classes at night or for extended periods are considered valid.

3. *Attachment 3 to the October 16, 2001 submittal provides inputs common to all of the calculations using the ARCON96 methodology for control room relative concentrations (χ/Qs). Provide figures and/or tables showing structures, assumed paths of air flow, dimensions, heights and distances used as input in estimating the postulated transport of effluent from each of the release locations to the intakes. Are all directional inputs defined in terms of true north? If the figures are drawn to plant or magnetic north, what is the relationship to true north? If more than one release to the environment/transport scenario could occur (e.g., loss of offsite power and non-loss of site power, single failure), were comparative χ/Q calculations made to ensure consideration of the limiting dose? Confirm that each of the control room intakes meet applicable qualifications such as single failure criterion for active components and seismic and missile criteria to merit the factor of two reduction credit as dual intakes. Are flow rates into the control room intakes the same for all intakes? If any of this information has been provided previously on the docket, a reference to the appropriate document(s) is acceptable.*

Response

Structure and Release Point Elevations

Elevation of plant grade, EL_{GRADE} = 796.5 feet

Elevation of top of Auxiliary Building roof, EL_{ROOF} = 858' 0" feet

Elevation of unit vent exit, EL_{VENT} = 995' 0"

Elevation of top of RB Dome, EL_{RB} = 986' 9"

Height of Unit Vent Exit above Grade, H_{VENT} = EL_{VENT} - EL_{GRADE}
= 198.5 feet
= 60.5 meters

Height of Top of RB Roof above Grade, H_{RB} = EL_{RB} - EL_{GRADE}
= 190.25 feet
= 58.0 meters

Height of Air Intake Centerline above Grade, H_{INTAKE}:

H_{INTAKE} = 25.9 meters

Elevation of horizontal centerline of ADV release, EL_{ADV}:

EL_{ADV} = 839'0"

Average elevation of MSSV releases, EL_{MSSV} :

The portion of the main steam (MS) line to which the MSSVs are attached gradually slopes downward, towards the Auxiliary Building. The average elevation of the pipe centerline in the vicinity of the MSSVs is approximated by:

EL_{MS}(Avg) = Avg(827'4 3/8" , ~ 827' 1")
= 827.22 feet.

The MSSVs discharge to the atmosphere 6 feet above the MS line centerline elevation. The average MSSV discharge elevation is:

EL_{MSSV} = EL_{MS}(Avg) + 2'6" + 12" + 2'6"
= 833.22 feet.

Elevation of MSLB Releases, EL_{MSLB}:

Control room χ/Qs for MSLBs are maximized by assuming that the break occurs at the closest point on the horizontal run of piping containing the MSSVs (based on piping and structural configurations). Discharge from the MSLB is assumed to occur near the top of the MS line steam volume:

EL_{MSLB} = EL_{MS}(Avg) + 0.5*(MS line inner diameter)
= 827.22 feet + 0.5*(34")
= 828.64 feet.

Elevation of Fuel Handling Building Releases (FHB), EL_{FHB}:

Elevation of the top of the Fuel Handling Building roll-up doors is 830 feet.

Centerline Elevation of MS Penetration above grade
= 853.75 feet – 796.5 feet
= 57.25 feet
= 17.4 meters

Release Elevation of Top of Equipment Hatch above Grade:
= 815.0 feet - 796.5 feet
= 18.5 feet
= 5.64 meters

Height of ADV Release above Grade, H_{ADV} = EL_{ADV} - EL_{GRADE}
= 42.50 feet
= 13.0 meters

Height of MSSV Release above Grade, H_{MSSV} = EL_{MSSV} - EL_{GRADE}
= 36.72 feet
= 11.2 meters

Height of MSLB Release above Grade, H_{MSLB} = EL_{MSLB} - EL_{GRADE}
= 32.14 feet
= 9.8 meters

Height of FHB roll-up door above Grade, H_{FHB} = EL_{FHB} - EL_{GRADE}
= 830 feet - 796.5 feet
= 33.5 feet
= 10.2 meters

Height of BWST release above Grade: = 855 feet – 796.5 feet
= 58.5 feet
= 17.8 meters

Horizontal Distance from Control Room Intakes to Release Points

The horizontal distance from the centerline of each control room intake (NE and SE) to each release point on Units 1, 2, and 3 are summarized in the table below. All distances between release points and intake locations are calculated as straight-line distances, conservatively not taking credit for air flow paths around structures.

Wind Directions

For the various cases considered, the wind direction from the receptor point (centerline of the air intake) to the release point is measured relative to true north. The plant north direction is 18° 49' counter clockwise from true north. The ARCON96 direction coordinate system is used (i.e. East = 90°, South = 180°, West = 270°, true North = 360°). The wind directions are listed in the table below.

Source-Receptor Pairs Distance and Direction Data

Source	Receptor	Direction from Receptor to Source (degrees)	Horizontal Distance, s (meters)
Unit 1 Vent	NE CR Intake	215.5	75.8
Unit 2 Vent	NE CR Intake	189.5	129.9
Unit 3 Vent	NE CR Intake	178.2	209.9
Unit 1 Vent	SE CR Intake	323.3	200.2
Unit 2 Vent	SE CR Intake	314.1	135.2
Unit 3 Vent	SE CR Intake	280.2	70.4
Unit 1 MS Line	NE CR Intake	232.4	104.3
Unit 2 MS Line	NE CR Intake	199.6	158.9
Unit 3 MS Line	NE CR Intake	186.3	232.7
Unit 1 MS Line	SE CR Intake	315.0	223.5
Unit 2 MS Line	SE CR Intake	299.2	147.6

Source	Receptor	Direction from Receptor to Source (degrees)	Horizontal Distance, s (meters)
Unit 3 MS Line	SE CR Intake	264.5	101.5
Unit 1 Eqpt. Hatch	NE CR Intake	232.2	87.7
Unit 2 Eqpt. Hatch	NE CR Intake	194.5	150.8
Unit 3 Eqpt. Hatch	NE CR Intake	182.5	227.8
Unit 1 Eqpt. Hatch	SE CR Intake	318.9	218.4
Unit 2 Eqpt. Hatch	SE CR Intake	302.8	133.5
Unit 3 Eqpt. Hatch	SE CR Intake	263.7	85.0
Unit 1 ADV	NE CR Intake	227.2	57.9
Unit 2 ADV	NE CR Intake	182.5	145.7
Unit 3 ADV	NE CR Intake	174.6	228.2
Unit 1 ADV	SE CR Intake	327.1	218.3
Unit 2 ADV	SE CR Intake	313.2	112.8
Unit 3 ADV	SE CR Intake	265.4	54.6
Unit 1 MSSV	NE CR Intake	225.6	61.5
Unit 2 MSSV	NE CR Intake	184.1	142.7
Unit 3 MSSV	NE CR Intake	175.5	224.6
Unit 1 MSSV	SE CR Intake	326.2	214.8
Unit 2 MSSV	SE CR Intake	312.8	116.7
Unit 3 MSSV	SE CR Intake	267.7	57.9
Unit 1 MSLB	NE CR Intake	230.2	70.0
Unit 2 MSLB	NE CR Intake	187.5	147.4
Unit 3 MSLB	NE CR Intake	177.8	227.9
Unit 1 MSLB	SE CR Intake	323.8	218.2
Unit 2 MSLB	SE CR Intake	308.3	120.4
Unit 3 MSLB	SE CR Intake	264.1	67.0
Unit 1&2 FHB roll-up door	NE CR Intake	217.2	126.2
Unit 3 FHB roll-up door	NE CR Intake	193.3	196.9
Unit 1&2 FHB roll-up door	SE CR Intake	309.1	197.0
Unit 3 FHB roll-up door	SE CR Intake	285.2	126.2
Unit 1 BWST	NE CR Intake	223.8	125.6
Unit 2 BWST	NE CR Intake	209.2	149.9
Unit 3 BWST	NE CR Intake	192.0	217.3
Unit 1 BWST	SE CR Intake	308.9	208.6
Unit 2 BWST	SE CR Intake	301.4	174.2
Unit 3 BWST	SE CR Intake	274.3	121.2

Control Room Intake Qualifications

The Control Room Ventilation System (CRVS) was not designed as seismic or designed for tornado missiles. The proposed modification to relocate the intakes maintains this design basis. Since a large source term would not occur during a seismic event or tornado, Duke believes this design basis is adequate. With respect to single failure, the CRVS was not designed to meet the single failure criterion. The current Technical Specifications support this in that operability is based on two 50% booster fans maintaining a positive pressure in the control room. However, the dose calculations are more conservative than the TS requirements in that credit is given for operation of only one booster fan.

4. *Are the EAB and LPZ χ/Q values used in the dose assessment previously approved values? If so, provide a reference documenting the approval.*

Response

EAB and LPZ χ/Q values used in ONS dose assessments were previously approved by the NRC in Oconee Nuclear Station Units 2 and 3 Safety Evaluation Report, "Safety Evaluation by the Directorate of Licensing, U.S. Atomic Energy Commission, In the Matter of Duke Power Company Oconee Nuclear Station Units 2 and 3 Docket Nos. 50-270/287," Section 11.2 and Tables 11-1, 11-2, dated 7/6/1973, and Supplements.

CD attachment

LOCADOSE file nomenclature:

*.lti	Transport Input File
*.ldi	Dose Input File
*.lib	Library file
*.lto	Transport Output File
*.ldo	Dose Output File

The enclosed CD contains the following electronic files:

LOCA Containment Model LOCADOSE 6.0 files

mhacont.lti
mhacont.lib
mhacont.ldi
mhacont.lto
mhacont.ldo

LOCA RBES Model LOCADOSE 6.0 files

mhaeccs.lti
mhaeccs.lib
mhaeccs.ldi
mhaeccs.lto
mhaeccs.ldo

FHA LOCADOSE 6.0 files for all 12 cases (e.g., for Case 1, files are named "fha1.*)

fha1.lti
fha1.lib
fha1.ldi
fha1.lto
fha1.ldo

Other files include the corresponding LOCADOSE input and output files for Cases 2 through 12 (i.e., files named fha2.* through fha12.*)

Meteorological data files in ARCON96 format

ONS91_NB.MET	contains 1991 data
ONS92_NB.MET	contains 1992 data
ONS93_NB.MET	contains 1993 data
ONS94_NB.MET	contains 1994 data
ONS95_NB.MET	contains 1995 data

ATTACHMENT 2

Duke Energy Corporation
Control Room Envelope Inleakage Testing
At Oconee Nuclear Station
Final Report

NCS CORPORATION

CONTROL ROOM ENVELOPE INLEAKAGE TESTING AT OCONEE NUCLEAR STATION 2001

FINAL REPORT

DUKE ENERGY
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CONTROL ROOM ENVELOPE INLEAKAGE TESTING AT OCONEE NUCLEAR STATION

2001

DUKE ENERGY
PO ON46050

FINAL REPORT
(LAT w/o 3272)

September 30, 2001

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NOTICE

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SECTION 1

1.0 EXECUTIVE SUMMARY

In order to assess the amount of air inleakage into the Control Room Envelope (CRE) at the Oconee Nuclear Generating Station, tracer gas air inleakage tests were performed during August 2001. For the purposes of air inleakage testing, the Control Room Envelope consisted either of the Unit 3 Main Control Room or the Unit 1 & 2 Main Control Room and the ductwork associated with their respective ventilation systems.

Air inleakage into the Control Room Envelope was measured with the Control Room Ventilation System (CRVS) operating in the Pressurization Mode or in the Normal Mode. Measured air inleakage rates are summarized in Table 1 presented below.

Sulfur hexafluoride (SF6) was used as the tracer gas. In all of the testing performed at Oconee Generating Station, sulfur hexafluoride concentrations were determined using measurement specific analyzers optimized for detection of SF6.

Air inleakage rates into the Control Room Envelope (CRE) with the Control Room Ventilation System (CRVS) in the Pressurization Mode were inferred using NCS/LAT Procedure 1204A Rev. 4 dated 4/3/01 "Constant Injection Tracer Ventilation Test". Air inleakage rates into the Control Room Envelope (CRE) with the Control Room Ventilation System in the Normal Mode were inferred using NCS/LAT Procedure 1204 Rev. 2 "Tracer Concentration Decay Ventilation Test". These procedures are based on the methodology described in ASTM Standard E741-95 "Standard Test Method for Determining Air Change Rate in a Single Zone by Means of a Tracer Gas Dilution".

Tracer gas flowrate measurements of makeup airflow rates were performed using NCS/LAT Procedure 1215 Rev. 3 dated 1/25/01 "Tracer Gas Flowrate Determination Test". This procedure is based on the methodology described in ASTM Standard E2029-00 "Standard Test Method for Volumetric and Mass Flow Rate Measurement using Tracer Gas Dilution".

Table 1

Measured Inleakage Values

Control Room	Ventilation Mode	Inleakage
U1/U2	NORMAL	869 +/- 31 (ACFM)
U1/U2	EMERGENCY-1 FAN	0 +/- 18 (SCFM)*
U1/U2	EMERGENCY-2 FAN	0 +/- 30 (SCFM)*
U3	NORMAL	467 +/- 16 (ACFM)
U3	EMERGENCY-1 FAN	0 +/- 13 (SCFM)*
U3	EMERGENCY-2 FAN	0 +/- 42 (SCFM)*

* Referred to 70 Deg F and 14.7 psia

SECTION 2

2.0 INTRODUCTION AND SUMMARY

Tracer gas air inleakage tests were performed on the two Control Room Envelopes (CRE's) at the Oconee Nuclear Generating Station (NGS) during August 2001 by a team of test engineers from NCS Corporation (NCS) and Lagus Applied Technology, Inc. (LAT). Air inleakage into each Control Room Envelope was measured with the ventilation system operating in either the Emergency or the Normal Mode. For the purposes of air inleakage testing, the Control Room Envelope consisted either of the Unit 3 Main Control Room (MCR) or the Unit 1 & 2 Main Control Room (MCR) with their associated ventilation ductwork.

Air inleakage rates into the Control Room Envelope (CRE) with the Control Room Ventilation System (CRVS) in the Pressurization Mode were inferred using NCS/LAT Procedure 1204A Rev. 4 dated 4/3/01 "Constant Injection Tracer Ventilation Test". Air inleakage rates into the Control Room Envelope (CRE) with the Control Room Ventilation System in the Normal Mode were inferred using NCS/LAT Procedure 1204 Rev. 2 "Tracer Concentration Decay Ventilation Test". These procedures are based on the methodology described in ASTM Standard E741-95 "Standard Test Method for Determining Air Change Rate in a Single Zone by Means of a Tracer Gas Dilution".

In a concentration buildup/steady state test, tracer gas is continuously injected into the makeup air stream at a constant rate and is dispersed throughout the CRE. After waiting a sufficient period of time for concentration equilibrium to occur, measurement of the tracer gas concentration at the most downstream negative static pressure point in the CRVS allows inference of the Total Air Inflow to the CRE.

In a concentration decay test, a quantity of tracer gas is dispersed throughout the CRE in an approximately homogeneous fashion over a short period of time (typically 30 minutes to one hour). Tracer concentration decay within the CRE is then measured as a function of time. The logarithmic decay rate of tracer concentration yields the air exchange rate. The air exchange rate is the volume normalized air leakage rate. Knowledge of the volume of the CRE allows calculation of the air inleakage rate. At

Oconee, the volume of the U3 CRE was taken as 54,000 Cubic Feet. The volume of the U1/U2 CRE was taken as 108,000 Cubic Feet.

For the air inleakage tests with the CRVS in the Pressurization Mode, simultaneous tracer gas flowrate measurements of makeup airflow rates were performed using NCS/LAT Procedure 1215 Rev. 3 dated 1/25/01 "Tracer Gas Flowrate Determination Test". This procedure is based on the methodology described in ASTM Standard E2029-00 "Standard Test Method for Volumetric and Mass Flow Rate Measurement using Tracer Gas Dilution". Measurement of the Makeup Flowrate allows calculation of the amount of air inleakage into the CRE (by differencing Total Air Inflow and Makeup Flow) that is not provided by makeup flow.

The electronegative gas, sulfur hexafluoride (SF6), was used as a tracer in the Concentration Buildup/Steady State Tests as well as in the Concentration Decay Tests, and the Flowrate Tests. This gas is generally recognized as non-toxic and non-reactive. Since it is easily detectable in minute quantities by means of electron capture gas chromatography, SF6 is an ideal tracer gas for ventilation system performance investigations.

In the testing at the Oconee Nuclear Generating Station, all SF6 tracer gas measurements were performed by means of chromatographic instrumentation manufactured for field use by LAT. On site calibration using certified calibration standards was performed daily prior to initiation of each test to ensure that instrument drift and any sensitivity variations would be minimized. Daily calibrations were performed using NCS/LAT Procedure 1308 Rev. 1, dated 4/27/99 "Field Calibration of AUTOTRAC™ Automated SF6 Gas Chromatograph". Analytical sensitivity to SF6 ranged from 20 parts per billion to approximately 5000 parts per billion.

Due to existence of a variable, yet measurable, CRE background concentration of SF6 (in the range of 0.2 ppb to approximately 8 ppb) the tracer gas tests were undertaken using a target CRE concentration of approximately 0.9 ppm to 3 ppm (a factor of 20 to 60 times greater than usually generated for such a test). Utilizing a target concentration of this magnitude, any measurable background SF6 concentration would amount to, at most, 1 % of the equilibrium tracer gas values measured, and hence a 1% uncertainty in the final measured inleakage values. Concentration measurement uncertainty of this magnitude is not detectable by the test techniques used. Therefore the existence of background SF6 concentrations, while measured before each test, was ignored in subsequent data reduction.

Air samples were obtained using disposable polypropylene syringes. Within the Main Control Room, air samples were taken directly as grab samples. Air samples from a number of locations within the CRE HVAC System ductwork were obtained using a pump/manifold sampling system.

Each pump/manifold sampling system consisted of a diaphragm pump connected to a multi-position sampling valve. A Swagelok ™ tee and septum fitting was affixed to the sample pump exhaust. This allowed remotely located air samples (such as those taken from within ductwork of the CRVS) to be obtained using polypropylene syringes. Lengths of polyethylene tubing were connected to the multi-position valve and were routed to the appropriate locations for sampling.

During each of the tests in which the CRVS was operating in an Emergency Mode, differential pressure measurements between the MCR and surrounding areas were obtained by Oconee personnel using an Inclined Manometer System mounted within the MCR for the specific purpose of monitoring MCR differential pressures.

Tracer gas injection rates were controlled by a Matheson Model 8270 Mass Flow Controller. Tracer gas injection rates were measured using a Sierra Model 821 Top Trak Thermal Mass Flowmeter. The tracer gas injection source was a high-pressure cylinder containing a dilute mixture of SF6 in nitrogen. The SF6 injection concentration was analyzed and certified to +/- 1% (traceable to NIST) of the measured concentration by an independent laboratory. The procedures and test equipment of this laboratory are periodically audited by NCS as part of the NCS QA program.

In Section 3 of this report, technical background is provided in which the theory behind ventilation testing using tracer gases and the operating characteristics of the tracer gas measurement instrumentation and the mass flowmeters are described. Section 4 discusses the experimental techniques and summarizes measured tracer concentration data and the calculated air inleakage rates. Section 5 contains a summary of the measured air inleakage rates as well as conclusions, observations and recommendations regarding the testing and the conditions extant within the respective CRE's.

Four appendices are provided which contain tracer data spread sheets, ANSI/ASME PTC 19.1 uncertainty calculation spreadsheets, spreadsheets providing statistical tests on the measured mean values of tracer concentration data, and the measured CRE differential pressures. Copies of filled-out Test Procedures and Calibration Certificates for all injection and calibration gases, as well as for the flow meters used in the testing were provided to Oconee personnel at the conclusion of each test and are part of the file for Duke Energy Contract ON46050. Accordingly, to limit the size of this document they are not included in this report.

SECTION 3

3.0 MEASURING BUILDING AIR FLOWS USING TRACER GASES

There are three principal tracer gas techniques for quantifying airflow rates within a structure; namely, the tracer concentration decay method, the constant injection method, and the constant concentration method. All three of these techniques are incorporated in the most recent revision of ASTM Standard E741-93 "Standard Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution".

In all three methods, a gaseous or vapor tracer is introduced into a test volume and the resulting concentration of tracer is measured as a function of time. Conservation of mass equations then allow one to deduce mass flow properties within the test volume.

3.1 TRACER GAS CONCENTRATION DECAY METHOD

To interpret data resulting from a tracer gas test, one employs a mass balance of a tracer gas released within the volume under test. Assuming that the tracer gas mixes thoroughly within the structure, the mass balance equation is,

$$V \; dC(t)/dt = S(t) - L(t)C(t) \qquad (1)$$

where V is the test volume, C(t) is the tracer gas concentration (dimensionless), dC(t)/dt is the time derivative of concentration, L(t) is the volumetric airflow rate out of the test volume, S(t) is the volumetric tracer gas injection rate, and t is time.

With the CRE ventilation system operating in the Normal Mode, the air inleakage testing at Oconee Nuclear Generating Station used the tracer concentration decay method. This method measures the decay in tracer concentration at a number of spatially distinct locations within the CRE as a function of time. The logarithmic decay rate in tracer concentration determines the air exchange rate. The essentials of the test method are illustrated schematically in Figure 1.

After an initial tracer injection into the test volume, there is no source of tracer gas, hence S(t) = 0 and assuming A is constant, a solution to equation (1) is;

$$C = C_0 \exp(-A \cdot t) \qquad (2)$$

where C_0 is the concentration at time t=0.

This method requires only the measurement of relative tracer gas concentrations, as opposed to absolute concentrations, and the analysis required to determine A is straightforward. In use, equation (2) is often recast to the following form;

$$\ln C = \ln C_0 - A \cdot t \qquad (3)$$

In practice one obtains a series of concentration versus time data points and then performs regression analysis on the logarithm of concentration versus time to find the best straight line fit to the form of the equation given by equation (3). The slope of this straight line is A, the air exchange rate.

The air exchange or infiltration rate, A, is given by A(t) = L(t)/V. The units of A are air changes per hour (h^{-1} or ACH). The value of A represents the volume normalized flowrate of "dilution air" entering the volume during the test interval. Note that this "dilution air" can be actual outside fresh air or, more generally, it can be air whose origin is not within the test volume.

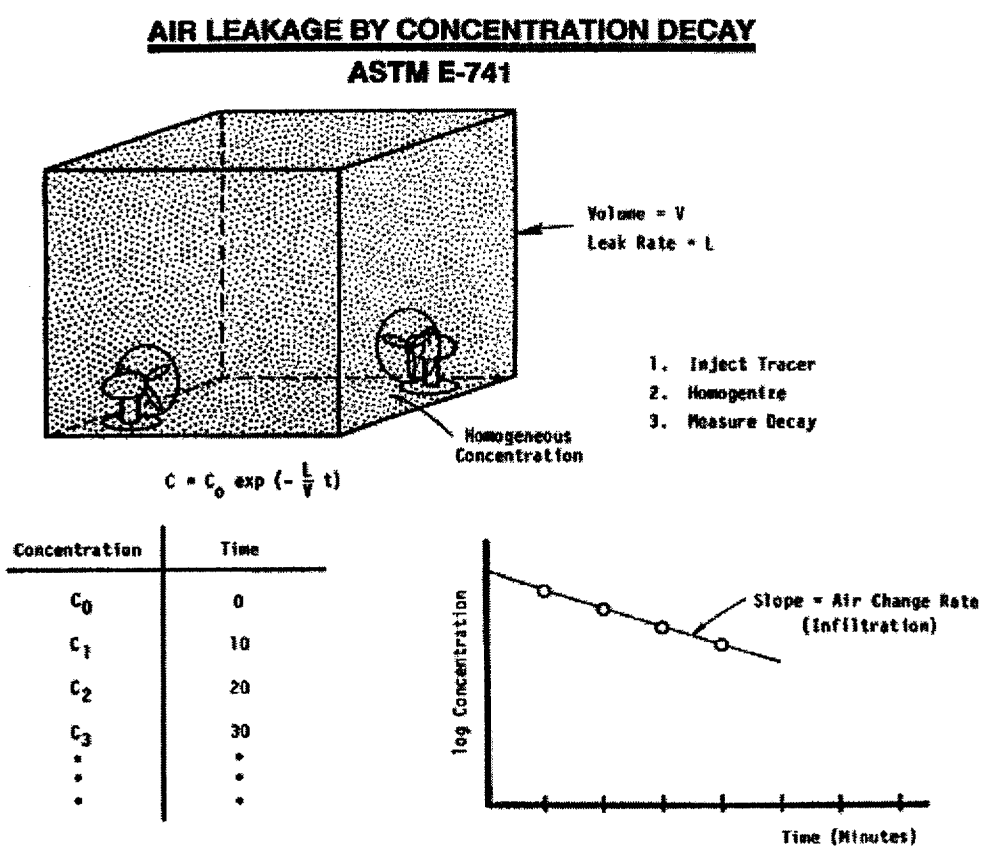

Figure 1. Concentration decay test.

As depicted in Figure 1, the natural logarithm of the tracer concentration decreases linearly with time. The slope of this line is A, the air exchange rate. To calculate the air inleakage rate, one must have independent knowledge of the CRE volume from which,

$$L = A \cdot V \qquad (4)$$

The results obtained with this technique are exact only for a well mixed volume, (i.e. concentration at a given time is the same throughout the test volume). Otherwise, the results will be subject to errors, with the magnitude of these errors depending on the extent of the departure from homogeneity. The tracer concentration data obtained within both of the Oconee CRE's and used in the calculation of the air exchange rates demonstrate that the tracer gas was well mixed, hence equation (2) could be applied.

3.2 CONCENTRATION BUILDUP/STEADY STATE TECHNIQUE

With the CRVS operating in the Emergency Mode, the air inleakage testing at Oconee NGS used the constant injection method. This method measures the equilibrium tracer concentration within a ventilated area. This equilibrium concentration can be related to the air flow rate into the test volume if the tracer release rate is known. It is possible to solve equation (1) assuming a constant tracer gas injection.

For the constant injection technique S(t) = constant. If A is also assumed to be constant, a solution to equation (1) is,

$$C(t) = (S/L) + (C_0 - S/L) \exp(-A \cdot t) \qquad (5)$$

A schematic representation of this technique is provided in Figure 2.

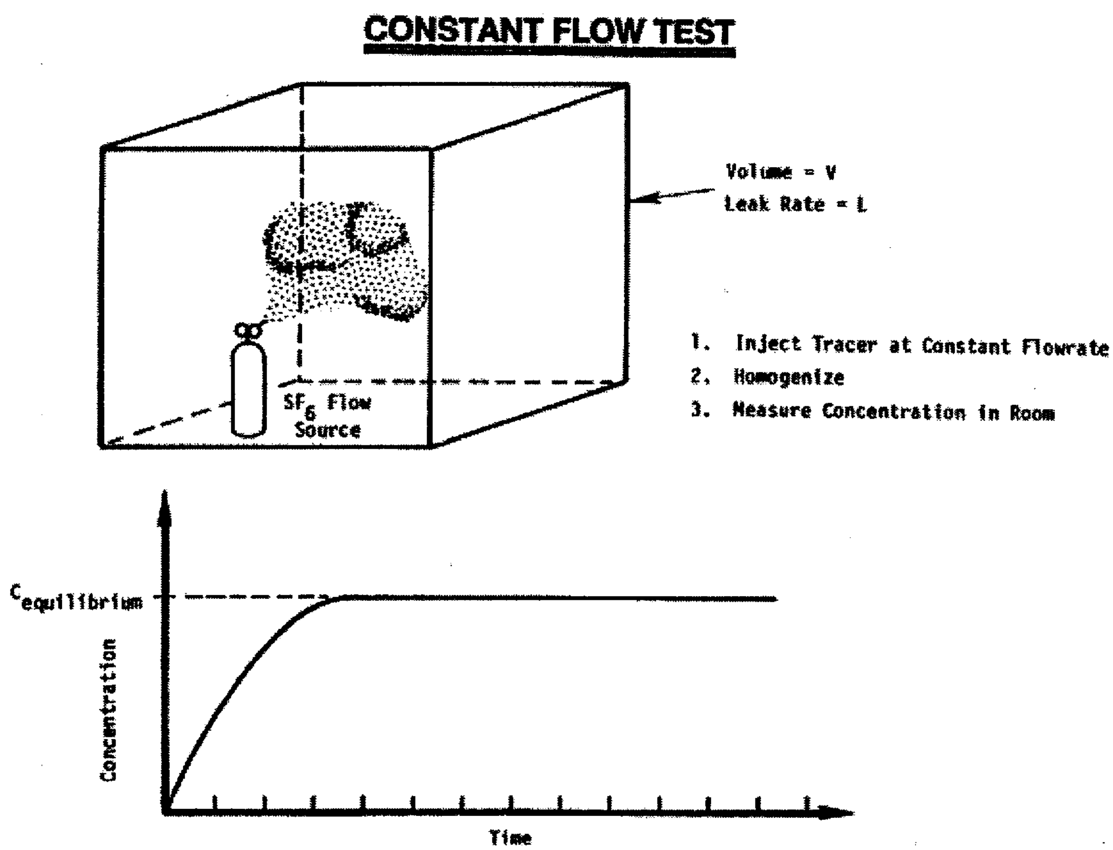

Figure 2. Concentration buildup in test volume as function of time

As depicted in Figure 2, the tracer concentration initially increases with time but eventually reaches a plateau. After waiting a sufficient time (at least equal to approximately 3/A), the transient dies out and concentration equilibrium occurs. Equation (5) then becomes the simple constant injection equation,

$$C = S/L \qquad (6)$$

The results obtained with this technique are exact only when the system is in equilibrium, (i.e. concentration is not changing as a function of time). Otherwise, the results will be subject to errors, with the magnitude of these errors depending on the extent of the departure from equilibrium. All tracer concentration data used in the calculation of inleakage values were equilibrium values. Hence equation (6) could be applied.

For Concentration Buildup/Steady State tests, the total air inflow rate into each CRE was measured using equation (6). This technique is described in Section 3.3. A constant flowrate of tracer gas was injected into the supply side of the respective CRE ventilation system and, after waiting for concentration equilibrium to occur, a number of measurements of the resulting concentration at the most downstream portion of the CRE system were obtained. Recasting equation (6) yields the following:

$$L_{tot} = S / C_{av} \qquad (7)$$

Where L_{tot} now represents the total air inflow into either the CRE. L_{tot} is made up of two components, namely, the amount of makeup air, $L_{m/u}$ and the amount of air inleakage, L_{inleak} . C_{av} is the average concentration measured at the downstream point after concentration equilibrium has been obtained.

Making use of these quantities, we can write an expression for the total air inflow to the CRE as;

$$L_{tot} = L_{m/u} + L_{inleak} \qquad (8)$$

Rearranging equation (8) to put the known quantities on the same side of the equation results in;

$$L_{inleak} = L_{tot} - L_{m/u} \qquad (9)$$

Since $L_{m/u}$ can be measured independently either by means of a Pitot or hot wire traverse or by using a tracer flow measurement technique, it is possible to calculate the total air inleakage into the CRE using equation (9). For the testing at Oconee $L_{m/u}$ was measured by a tracer gas technique in both U3 and U1/U2.

3.3 TRACER GAS FLOWRATE MEASUREMENT

For many years it has been known that a method to measure duct flowrates exists other than Pitot tube or hot wire anemometer traverses. It entails the use of a tracer gas dilution method. This method is a *volumetric* as opposed to a point measurement. To undertake such a measurement, a tracer gas is continuously metered into a flowing duct at a known rate. After allowing for mixing, air samples are collected at a point downstream of the injection point and the concentration of tracer gas is measured. Assuming that the tracer gas is well mixed within the duct, the rate of flow is readily calculated from the ratio of the tracer injection flowrate to the diluted concentration--in symbols:

$$L = S / C_{av} \qquad (10)$$

The tracer gas method relies on the use of a tracer gas to infer flowrate through a section of duct. An individual flowrate test is performed by injecting a tracer gas at a known rate into a section of duct upstream of a point and then measuring the equilibrium tracer gas concentration downstream of that point. The basic test setup is shown in Figure 3.

This equilibrium concentration in the duct is inversely proportional to the flowrate through the duct (as given by equation (10)). Thus, the measured concentration allows calculation of the flowrate since the injection flowrate is known.

One can rewrite equation (10) to explicitly reflect this measurement as equation (11),

$$L_{m/u} = S / C_{m/u} \qquad (11)$$

where, $L_{m/u}$, is now the fresh air makeup flowrate.

For the Oconee testing, tracer was injected through two sets of three 1/4 inch OD stainless steel tubes each of which possessed 0.08 inch in diameter holes spaced equally along the tubing length. These tubes were inserted into the makeup duct at the outside air entrance location on the roof of the respective mechanical equipment rooms (Doghouse). Three tubes were inserted parallel to and equally spaced along the long axis of the duct. Three tubes were inserted parallel to and equally spaced along the short axis of the duct.

The stainless steel injection tubes were connected to the mass flow meter via a manifold of polyethylene tubing. Further, flows to each individual injection tube could be controlled by use of a 0-1 SLPM rotameter inserted into each length of polyethylene tubing immediately prior to the connection with the stainless steel injection tube.

In addition, to enhance mixing of tracer gas during actual testing, two 12 inch in diameter circulating fans were lowered into the makeup duct and were positioned on the turning vanes pointed generally in a direction against the incoming flow. Experience has shown that pointing the mixing fans against the predominant flow provides better mixing than when fans are pointed either along the flow or perpendicular to it.

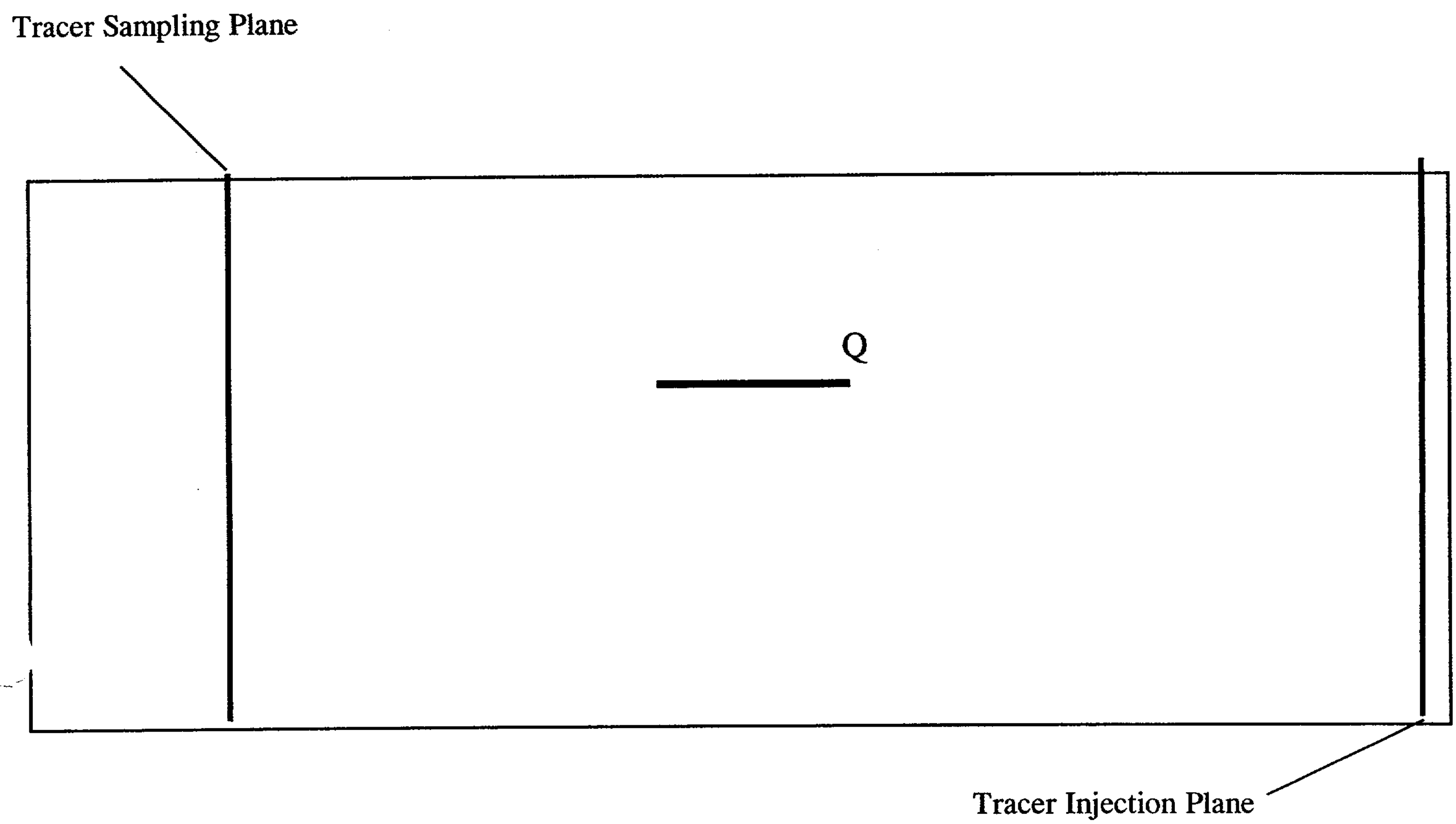

Figure 3. Schematic representation of tracer gas flowrate test.

3.4 UNCERTAINTY CALCULATIONS

For the purposes of the uncertainty analysis, equation (9) is re-written as equation (14) below using equations (7) and (11) to explicitly include all measured quantities for the two tests in which tracer gas flowrate measurements could be successfully used.

$$L_{inleak} = S \times C_{inj} \times [\ (1/C_{DS}) - (1/C_{m/u})\ ] \qquad (14)$$

Equation (14) is used in all uncertainty value calculations relating to Pressurization Mode testing where both the Total Air Inflow Rate and the Makeup Flow Rate are measured simultaneously using a constant injection tracer gas technique.

In this report, the total uncertainty of each CRE air inleakage measurement or duct flowrate measurement is calculated using the prescription provided in ANSI/ASME Standard PTC 19.1-1985 (Reaffirmed 1990) "Measurement Uncertainty" and represent 95% confidence limits. This analysis is based upon either equation (14) for the concentration buildup/steady state test, equation (3) for the concentration decay tests, or equation (8) for flowrates. Uncertainties for all derived and measured quantities are incorporated into the analysis.

To use PTC 19.1 we assume that the data are distributed normally. Statistical tests can be used to verify this assumption but have not been performed on the data in this report since only a small number data points are obtained for each inleakage value. The calculations are provided for each inleakage test in Appendix B.

Referring to the calculation spreadsheets in Appendix B, note that for the inleakage calculation at least some of the calculated values are negative. This behavior of measured data (i.e. exhibiting both positive and negative values as if oscillating around a zero value) can sometimes be observed for CRE's that exhibit inleakage values close to zero. If the means values of C_{DS} and $C_{m/u}$ are statistically the same value, then according to equation (14) the inleakage is equal to zero.

As is apparent from the PTC 19.1 analyses presented in Appendix B, conventional analysis breaks down when confronted with negative values of inleakage. In this report we will use a different statistical test to infer a statistically defensible value for inleakage. If we assume that the measured data are normally distributed about their mean values then it is possible to use a statistical test to determine whether the means of C_{DS} and $C_{m/u}$ are indistinguishable.

To proceed define:

$$S_p = \left(\frac{(n_{m/u} - 1)S_{m/u}^2 + (n_{DS} - 1)S_{DS}^2}{n_{m/u} + n_{DS} - 2} \right)^{0.5} \qquad (15)$$

and,

$$t = \frac{\bar{x}_{m/u} - \bar{x}_{DS}}{\left(S_p \left[\left(\frac{1}{n_{m/u}} \right) + \left(\frac{1}{n_{DS}} \right) \right]^{0.5} \right)} \qquad (16)$$

where: Sp = pooled standard deviation
Sm/u = standard deviation of makeup flow mean concentration
S_{DS} = standard deviation of DS point (total flowrate) mean concentration
t = Student's t statistic
$n_{m/u}$ = number of observations in makeup concentration data set
n_{DS} = number of observations in DS concentration data set
df = degrees of freedom (equal to $n_{m/u} + n_{DS} - 2$)
$\bar{x}_{m/u}$ = mean of makeup flowrate concentration values
$\bar{x}_{DS}$ = mean of total flowrate concentration values

To proceed, calculate the t statistic using equation (16). If the value of the t statistic exceeds the 95% confidence value for the appropriate degrees of freedom, the difference in the means is statistically significant at the 95% confidence value. Stated another way, if the t value calculated using equation (16) is less than the 95% Student t value for the number of degrees of freedom, the mean values are indistinguishable. In this case, equation (14) then implies that the inleakage value is equal to zero.

Due to the existence of negative values of calculated inleakage the conventional PTC 19.1 analysis also does not allow a calculation of the uncertainty inherent in each inleakage value. It is possible to use the equations (15) and (16) to estimate a value for the uncertainty in the zero inleakage values.

To achieve this we numerically increase one of the concentration values (for either the makeup measurements or the total inleakage measurements) until the mean concentration values become statistically distinct. These values are then used in equation (14) to arrive at a value of inleakage that would be "just barely" statistically significant. For the Oconee data, the value of makeup concentration was increased for each data set until the calculated t statistic just exceeded the Student t value. Calculations using the data obtained at Oconee are presented in Section 4.7

3.5 TRACER GAS MONITOR

Testing of air samples for the presence of tracer gas in this study was performed by means of several channels of electron-capture gas chromatograph manufactured for field use by LAT. Operating characteristics of the LAT monitor are provided in Table 2. All output from each analyzer channel is displayed on an LCD display as well outputted to a HP Desk Jet Printer. The output is also manually recorded in a data log.

The electron-capture gas chromatograph utilizes the high electron affinity of gases with halogen group elements to provide a measurable signal. In the units utilized in the study, all samples are injected by means of disposable polypropylene syringes. Injection is through a rubber septum located on an external sample fitting. This septum prevents spurious contaminants from diffusing into the chromatograph and producing anomalous signals.

The gas chromatographic column, in simplest terms, operates to separate the various gaseous components of a sample by selectively slowing down some gases relative to others. The column can be thought of as a device to output the distinct components of a gas sample in a definite order. The Model 101 AUTOTRAC uses a 5 Angstrom molecular sieve chromatographic column to separate SF6 from other constituents of air.

The detector portion of the chromatograph consists of a tritiated titanium foil encased within an electrically-conductive housing. Specific pulse generator circuitry energizes the detector, initiating a flow of electrons. A collector wand within the detector receives the electrons and establishes a current flow, which is amplified through an electrometer circuit. Should an electronegative gas flow through this stream of electrons, the number of electrons being collected, and hence the current, is decreased in proportion to the concentration of the gas resulting in a measurable signal. This signal response can be quantitated by measuring the response to known concentrations of tracer gas. The resulting calibration curve can then be used to provide concentration outputs for a given response to an injection of tracer gas.

In order to ensure the greatest possible measurement accuracy from the chromatographs, each channel of analyzer was individually calibrated immediately prior to a test. Calibration was effected by injecting three aliquots of different standard mixtures into each analyzer and recording the response. These response data are then used to calculate a specific calibration curve for each analyzer. Note that daily individual calibration is standard analytical chemistry laboratory practice used for precision analyses of chemical constituents.

TABLE 2

Specifications for Model 101 AUTOTRAC™ Automated Tracer Gas Monitor

Measurement Technology:	*Electron Capture Gas Chromatograph with heated column and automatic back-flush.*
Detection Limit:	*To 5 x 10 $^{-12}$ parts SF_6 in air.*
Linear Dynamic Range:	*100:1 typical in range of 0.05 - 100 ppb.*
Precision:	*±3% of reading within linear dynamic range.*
Stability:	*Drift is negligible under typical operation with automatic calibration feature.*
Sample Method:	*Front panel syringe injection and rear panel remote (>300 ft.) sampling with built-in pump.*
Measurement Cycle Time:	*Minimum 60 seconds. 180 is normal operating condition.*
Set-up:	*Menu supported via 16-keypad with storage diskette for recall.*
Remote Interface:	*Capability to monitor AUTOTRAC functions from PC via an RS232C interface.*
Modes:	*Automatic or manual operation.*
Output:	*32-character LCD panel display, RS232C to PC, PC compatible 3.5" diskette and 0-1V DC for strip chart recorder.*
Carrier Gas:	*P-5 (5% methane in argon gas).*
Power:	*115V, 50/60 Hz., 3 Amp.; 220V optional.*
Size/Weight:	*8.75" H x 17" W x 18.5" D. 35 Lb.*

3.6 MASS FLOW METER

The mass flow meter directly monitors the mass flow rate of gas passing through it. Gas enters the flow meter body and divides into two flow paths. Most of the flow goes through a laminar flow bypass. This creates a pressure drop that forces a small fraction of the flow through a sensor tube. Two resistance temperature detector coils surrounding the sensor tube direct a constant amount of heat into the gas stream. In operation, the mass of gas flowing through the flowmeter carries heat from one of the coils to the other. The resulting temperature difference is detected and is directly proportional to the gas mass flow.

Operating characteristics of the mass flow meter are summarized in Table 3.

TABLE 3

Specifications for Sierra Model 821 Top Trak Mass Flow Meter

Display:	*3 1/2 digit LCD-removable for remote mounting.*
Output Signal:	*Linear 0-5 VDC standard, 1000 Ohms minimum load resistance.*
Power Reqmnts:	*12-15 VDC nominal; 100 mA max.*
Accuracy:	*±2% of full scale including linearity over 15 to 25 Deg C and 5 to 60 psia; with special calibration ±1%.*
Repeatability:	*± 0.5 % of full scale.*
Temperature Coefficient:	*0.15 % of full scale per Deg C, or better.*
Pressure Coefficient:	*0.01 % of full scale per psi or better.*
Gas and Ambient Temperature:	*0 to 50 Deg C.*
Gas Pressure:	*150 psi gauge max.; 20 psi gauge optimum.*
Weight:	*2 Lb.*

3.7 MATHEMATICAL SYMBOLS

The mathematical symbols used throughout this report are defined below.

C = Tracer Gas Concentration

C_{av} = Mean of Individual Tracer Gas Concentration Values

$C_{m/u}$ = Tracer Concentration in makeup duct

C_{DS} = Tracer Concentration at downstream measurement point

C_{inj} = Tracer Injection Gas Concentration

s = Standard Deviation of C_{av}

t = Time

A = Infiltration or Air Exchange Rate

L_{tot} = Total Air Inflow rate to CRE

$L_{m/u}$ = Makeup Airflow rate to CRE

L_{inleak} = Air inleakage rate to CRE

S = Tracer Gas Injection rate

Q = Duct Flowrate

V = Volume of CRE

SECTION 4

4.0 EXPERIMENTAL TECHNIQUES AND MEASURED DATA

In order to investigate air inleakage into the Oconee NGS Control Room Envelope (CRE), an extensive series of tracer gas tests was performed during August 2001. These tests consisted of:

Test G: U3 CRE Inleakage-HVAC in Normal Mode

Test H: U3 CRE Inleakage-HVAC In Emergency Mode, 1 Booster Fan

Test I: U3 CRE Inleakage-HVAC In Emergency Mode, 2 Booster Fan

Test J: U1/U2 CRE Inleakage-HVAC in Normal Mode

Test K: U1/U2 CRE Inleakage-HVAC In Emergency Mode, 1 Booster Fan

Test L: U1/U2 CRE Inleakage-HVAC In Emergency Mode, 2 Booster Fans

Note that the test designators are alphabetically identified and continue the designation sequence used for the tests performed in 1998. This is done to eliminate the possibility of confusion when discussing tests performed over different time periods. A schematic diagram for the Unit 3 CRVS is shown in Figure 4. The corresponding diagram for the Unit 1 & 2 CRVS is shown in Figure 5.

The experimental details and relevant data for each test will be described in the following sections of this report. The actual sample and tracer gas injection locations for each test are also provided. Differential pressure data were obtained by Oconee test personnel for each test with the CRVS in an Emergency Mode and are summarized in Appendix D.

Section 4.7 presents inleakage data and discusses measurement uncertainties for each test.

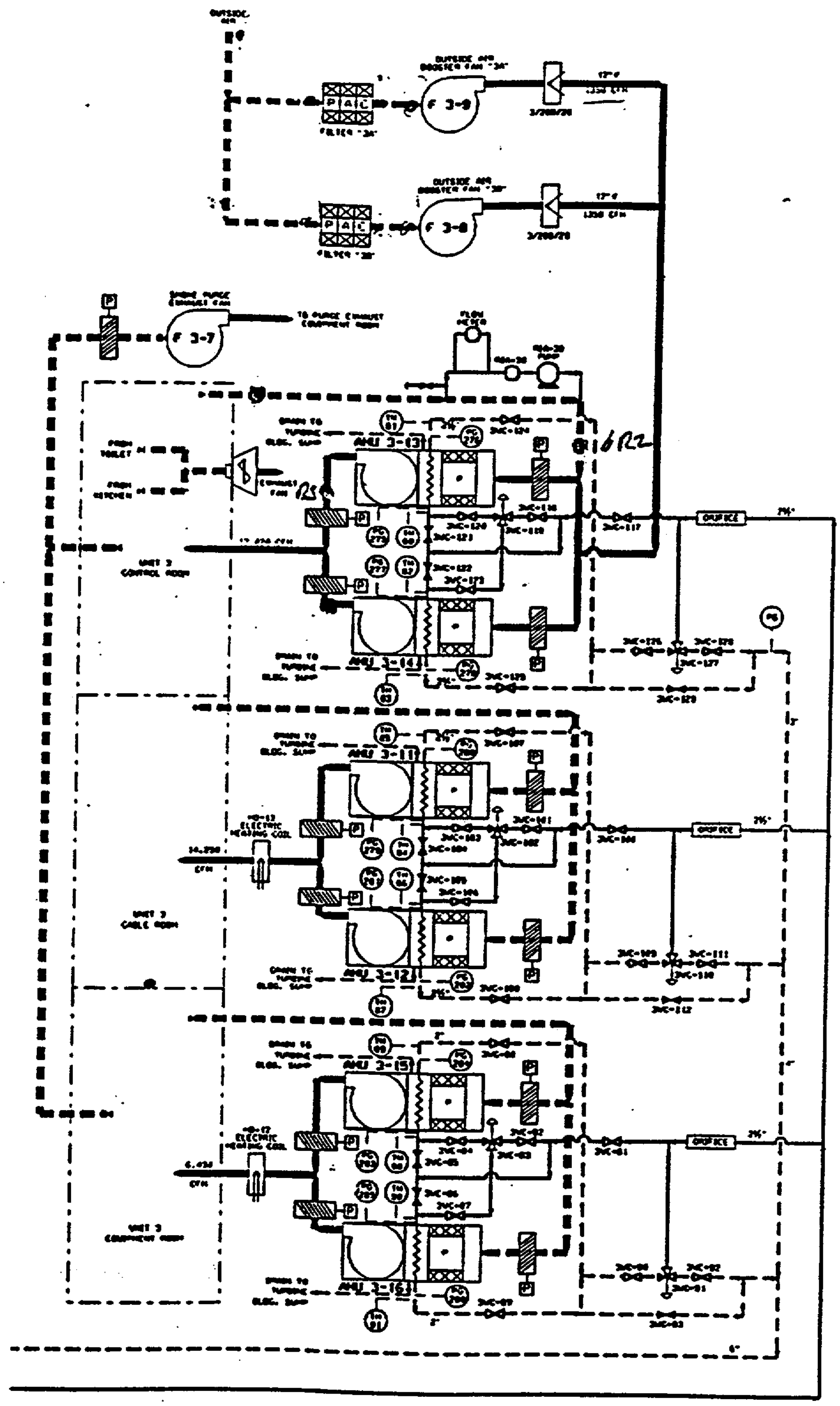

Figure 4. Schematic drawing of Unit 3 CRVS.

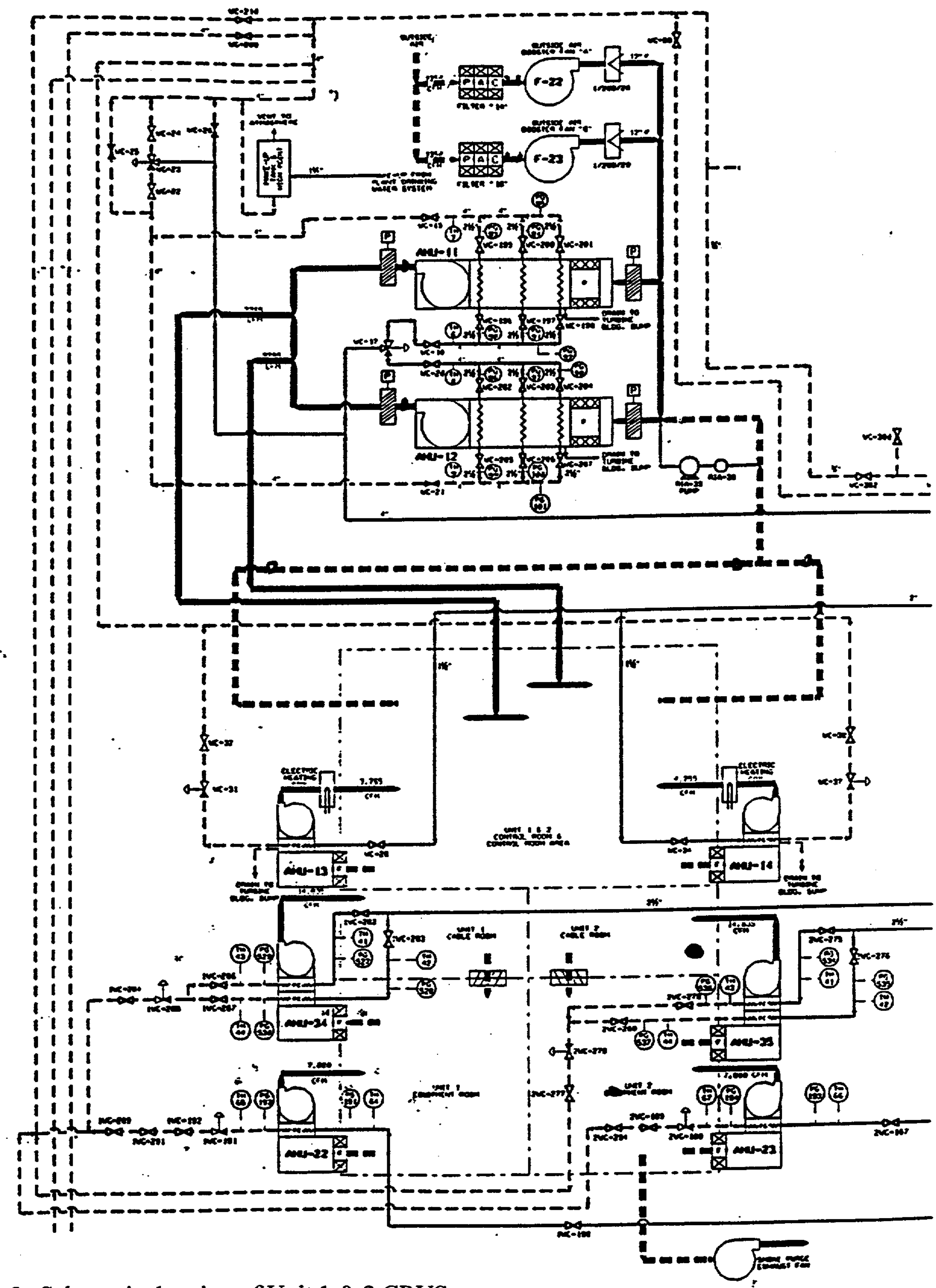

Figure 5. Schematic drawing of Unit 1 & 2 CRVS.

4.1 TEST G:U3 CRE INLEAKAGE-HVAC IN NORMAL MODE

On August 7, 2001 an inleakage test was performed on the U3 CRE with the CRVS in Normal Mode and AHU 3-13 operating. At 20:15, an SF6 in nitrogen mixture possessing a concentration of 1.0 % was injected at a flowrate of 30 SLPM into the AHU 3-13 system return duct in the U3 Mechanical Equipment Room. Injection continued for 23 minutes.

Tracer gas samples were collected from twelve different locations throughout the CRE at 30 minute intervals beginning at 23:45 and ending at 03:15 on August 8, 2001. The tracer sample locations for Test G are described in Table 4. Within the CRE grab samples were taken using individual 60 cc polypropylene syringes. During the testing, CRE ingress and egress was minimized and occurred through only a single door.

Air samples from a location above the drop ceiling within the MCR were obtained using a pump/manifold sampling system. Each pump/manifold sampling system consisted of a diaphragm pump connected to a multi-position sampling valve. A Swagelok™ tee and septum fitting was affixed to the sample pump exhaust. This allowed remotely located air samples to be obtained using polypropylene syringes. Lengths of polyethylene tubing were connected to the multi-position valve and were routed to the appropriate locations for sampling.

The measured air inleakage results for Test G are given in Table 5. Equation (3) was used with regression analysis to determine the air exchange rate. Equation (4) was then used to calculate an actual air inleakage rate. Actual measured tracer concentration data are provided in Appendix A denoted as Test G. Calculation of measurement uncertainty associated with the measured inleakage value in Table 5 is provided in Appendix B denoted as Test G: 8/7/01.

Only a limited number of mixing fans were used in the CRE as previous experience in other nuclear power plant Control Room Envelopes has shown that ventilation flows into well ventilated rooms are sufficient to mix tracer over the time interval that elapsed prior to initiation of sampling. Portable box fans were placed in the doorways to the Restroom, the locked computer room and the northwest vestibule to assist mixing in these areas.

Measured tracer concentration data provided in Appendix A and tabulated as Test G confirm that the tracer gas was well mixed within the CRE. Mean tracer concentration values for each sampling interval also are provided in Appendix A. The standard deviation of all tracer measurements during a given measurement interval expressed as a percentage of the mean is also shown.

The standard deviation is a statistical measure of how much a collection of measurements differs from the mean of the collection. The smaller the standard deviation, the closer individual values in the collection are to the mean. Inspection of concentration data in Appendix A for Test G discloses that at each sample time, the standard deviation of the mean concentration ranges from +/- 2.4 % to +/- 3.2 %, thereby confirming that tracer was well mixed throughout the CRE.

Table 4

Sample Locations for Test G

Location	Description
CR1	Corridor by South Entry Door
CR2	Center of Restroom
CR3	In front of U3 control panel
CR4	Center of MCR east of SRO Desk
CR5	Aisle between Inst. Cab. #7 and ES Logic Channel 1 & 3
CR6	Doorway between lunchroom and copier room
CR7	Center of OSC Room
CR8	Center of Rad Room
CR9	Center of OAC Room
CR10	Center of Computer Room
CR11	Outside doorway to Shift Office
CR12	Above drop ceiling adjacent to Storage Room

Table 5

Air Inleakage Value for Test G

Description	Value
AIR EXCHANGE RATE (ACH)	0.5188
CRE VOLUME (Cu. Ft.)	54000
AIR INLEAKAGE RATE (ACFM)	467+/- 16

4.2 TEST H:U3 CRE INLEAKAGE-BOOSTER FAN 3A OPERATING

On August 8, 2001 an inleakage test was performed on the U3 CRE with the CRVS in Emergency Mode and AHU 3-13 as well as booster fan 3A operating. At 19:45, an SF6 in nitrogen mixture possessing a concentration of 1.027 % was injected at a flowrate of 7 SLPM for approximately 60 minutes after which the injection flowrate was reduced to 3.87 SLPM for the remainder of the test. Tracer gas injection occurred at the entrance to the U3 CRVS makeup air duct as described in Section 3.3. Note that 28.3 SLPM is equal to 1.0 SCFM.

Duct concentration measurements at the makeup flowrate location were obtained using a pump/manifold system attached to a length of polyethylene tubing and a stainless steel probe. The probe was moved to various locations within the duct in a plane perpendicular to the duct axis after which a sample was drawn by the pump/manifold system to individual polypropylene syringes for subsequent analysis. Three samples at 0.25, 0.5 and 0.75 the width of the duct were taken along each of three lines perpendicular to the duct axis located at 0.25, 0.5 and 0.75 of the height of the duct. This resulted in a total of nine samples.

Tracer gas samples for the measurement of Total Air Inflow were obtained through a polyethylene tube inserted into the return duct as it entered the Mechanical Equipment Room. This sample location was designated RET.

Makeup air flowrate results for Test H using the tracer gas technique are given in Table 6. Equation (11) was used to calculate the makeup flowrate for data point. Actual measured tracer concentration data are provided in Appendix A denoted as Test H. Calculation of the makeup flowrates during the actual air inleakage test is provided in Appendix B denoted as Test HF4 through HF10. The mean of these seven measurements is provided in the next spreadsheet in Appendix B denoted "7 Test Average".

Table 6

Makeup Flowrate measured by Tracer Gas for Test H

PRESSURIZATION FAN	FLOWRATE (SCFM)
3A	955 +/- 32

Tracer gas samples were collected from eleven different locations throughout the CRE as well as from sample locations within the ductwork. The tracer sample locations for Test H are described in Table 7.

Within the CRE grab samples were taken using individual 60 cc polypropylene syringes. During the testing, CRE ingress and egress were minimized and occurred through only a single door at any one time.

Air samples from a location above the drop ceiling within the CRE were obtained using a pump/manifold sampling system. Each pump/manifold sampling system consisted of a diaphragm pump connected to a multi-position sampling valve. A Swagelok™ tee and septum fitting was affixed to the sample pump exhaust. This allowed remotely located air samples to be obtained using polypropylene syringes. Lengths of polyethylene tubing were connected to the multi-position valve and were routed to the appropriate locations for sampling.

Equation (12) was used to calculate the air inleakage into the CRE for Test H. Actual measured tracer concentration data are provided in Appendix A denoted as Test H. Calculation of measurement uncertainty associated with the measured tracer concentration values is provided in Appendix A denoted as Test H: 8/8/01. Note that the mean concentrations measured at the makeup duct sample location and at the return duct sample location are statistically indistinct. Thus for this test the inleakage is zero. Further discussion is provided in Section 4.7.

Only a limited number of mixing fans were used in the CRE as previous experience in other nuclear power plant Control Room Envelopes has shown that ventilation flows into well ventilated rooms are sufficient to mix tracer over the time interval that elapsed prior to initiation of sampling. Portable box fans were placed in the doorways to the Restroom, the locked computer room and the northwest vestibule to assist mixing in these areas.

Measured tracer concentration data are provided in Appendix A and are tabulated as Test H. From these data it is clear that the tracer concentration within the CRE was both well mixed and at equilibrium. The standard deviation of all tracer measurements expressed as a percentage of the mean is also shown.

The standard deviation is a statistical measure of how much a collection of measurements differs from the mean of the collection. The smaller the standard deviation, the closer individual values in the collection are to the mean. Inspection of concentration data in Appendix A discloses that the standard deviation of the mean concentration is 0.9 %, thereby confirming that tracer concentration was well mixed throughout the CRE and an equilibrium value.

Table 7

Sample Locations for Test H

Location	Description
RET	Return duct at entry to Mechanical Equipment Room
CR1	Corridor by South Entry Door
CR2	Center of Restroom
CR3	In front of U3 control panel
CR4	Center of MCR east of SRO Desk
CR5	Aisle between Inst. Cab. #7 and ES Logic Channel 1 & 3
CR6	Doorway between lunchroom and copier room
CR7	Center of OSC Room
CR8	Center of Rad Room
CR9	Center of OAC Room
CR10	Center of Computer Room
CR11	Outside doorway to Shift Office
CR12	Above drop ceiling adjacent to Storage Room

4.3 TEST I:U3 CRE INLEAKAGE-BOOSTER FANS 3A & 3B OPERATING

On August 9, 2001 an inleakage test was performed on the U3 CRE with the CRVS in Emergency Mode and AHU 3-13 as well as booster fans 3A and 3B operating. At 17:16, an SF6 in nitrogen mixture possessing a concentration of 1.021 % was injected at a flowrate of 7.5 SLPM for approximately 60 minutes after which the injection flowrate was reduced to 4.73 SLPM for the remainder of the test. Tracer gas injection occurred at the entrance to the U3 CRVS makeup air duct as described in Section 3.3. Note that 28.3 SLPM is equal to 1.0 SCFM.

Duct concentration measurements at the makeup flowrate location were obtained using a pump/manifold system attached to a length of polyethylene tubing and a stainless steel probe. The probe was moved to various locations within the duct in a plane perpendicular to the duct axis after which a sample was drawn by the pump/manifold system to individual polypropylene syringes for subsequent analysis. Three samples at 0.25, 0.5 and 0.75 the width of the duct were taken along each of three lines perpendicular to the duct axis located at 0.25, 0.5 and 0.75 of the height of the duct. This resulted in a total of nine samples.

Tracer gas samples for the measurement of Total Air Inflow were obtained through a polyethylene tube inserted into the return duct as it entered the Mechanical Equipment Room. This sample location was designated RET.

Makeup air flowrate results for Test I using the tracer gas technique are given in Table 8. Equation (11) was used to calculate the makeup flowrate for data point. Actual measured tracer concentration data are provided in Appendix A denoted as Test I. Calculation of the makeup flowrates during the actual air inleakage test is provided in Appendix B denoted as Test IF4 through IF10. The mean of these seven measurements is provided in the next spreadsheet in Appendix B denoted “7 Test Average”.

Table 8

Makeup Flowrate measured by Tracer Gas for Test I

PRESSURIZATION FAN	FLOWRATE (SCFM)
3A& 3B	1799+/- 99

Tracer gas samples were collected from eleven different locations throughout the CRE as well as from sample locations within the ductwork. The tracer sample locations for Test I are described in Table 9.

Within the CRE grab samples were taken using individual 60 cc polypropylene syringes. During the testing, CRE ingress and egress were minimized and occurred through only a single door at any one time.

Air samples from a location above the drop ceiling within the CRE were obtained using a pump/manifold sampling system. Each pump/manifold sampling system consisted of a diaphragm pump connected to a multi-position sampling valve. A Swagelok^{TM} tee and septum fitting was affixed to the sample pump exhaust. This allowed remotely located air samples to be obtained using polypropylene syringes. Lengths of polyethylene tubing were connected to the multi-position valve and were routed to the appropriate locations for sampling.

Equation (12) was used to calculate the air inleakage into the CRE for Test I. Actual measured tracer concentration data are provided in Appendix A denoted as Test I. Calculation of measurement uncertainty associated with the measured tracer concentration values is provided in Appendix A denoted as Test I: 8/9/01. Note that the mean concentrations measured at the makeup duct sample location and at the return duct sample location are statistically indistinct. Thus for this test the inleakage is zero. Further discussion is provided in Section 4.7.

Only a limited number of mixing fans were used in the CRE as previous experience in other nuclear power plant Control Room Envelopes has shown that ventilation flows into well ventilated rooms are sufficient to mix tracer over the time interval that elapsed prior to initiation of sampling. Portable box fans were placed in the doorways to the Restroom, the locked computer room and the northwest vestibule to assist mixing in these areas.

Measured tracer concentration data are provided in Appendix A and are tabulated as Test H. From these data it is clear that the tracer concentration within the CRE was both well mixed and at equilibrium. The standard deviation of all tracer measurements expressed as a percentage of the mean is also shown.

The standard deviation is a statistical measure of how much a collection of measurements differs from the mean of the collection. The smaller the standard deviation, the closer individual values in the collection are to the mean. Inspection of concentration data in Appendix A discloses that the standard deviation of the mean concentration is 1.0 %, thereby confirming that tracer concentration was well mixed throughout the CRE and an equilibrium value.

Table 9

Sample Locations for Test I

Location	Description
RET	Return duct at entry to Mechanical Equipment Room
CR1	Corridor by South Entry Door
CR2	Center of Restroom
CR3	In front of U3 control panel
CR4	Center of MCR east of SRO Desk
CR5	Aisle between Inst. Cab. #7 and ES Logic Channel 1 & 3
CR6	Doorway between lunchroom and copier room
CR7	Center of OSC Room
CR8	Center of Rad Room
CR9	Center of OAC Room
CR10	Center of Computer Room
CR11	Outside doorway to Shift Office
CR12	Above drop ceiling adjacent to Storage Room

4.4 TEST J:U1/U2 CRE INLEAKAGE-HVAC IN NORMAL MODE

On August 7, 2001 an inleakage test was performed on the U3 CRE with the CRVS in Normal Mode and AHU 1-11 operating. At 17:55, an SF6 in nitrogen mixture possessing a concentration of 1.021 % was injected at a flowrate of 30 SLPM into the AHU 1-11 system return duct in the U3 Mechanical Equipment Room. Injection continued for 60 minutes.

Tracer gas samples were collected from eleven different locations throughout the CRE at 30 minute intervals beginning at 19:55 and ending at 22:55. The tracer sample locations for Test J are described in Table 10. Within the MCR grab samples were taken using individual 60 cc polypropylene syringes. During the testing, MCR ingress and egress was minimized and occurred through only a single door.

Air samples from a location above the drop ceiling within the MCR were obtained using a pump/manifold sampling system. Each pump/manifold sampling system consisted of a diaphragm pump connected to a multi-position sampling valve. A Swagelok^{TM} tee and septum fitting was affixed to the sample pump exhaust. This allowed remotely located air samples to be obtained using polypropylene syringes. Lengths of polyethylene tubing were connected to the multi-position valve and were routed to the appropriate locations for sampling.

The measured air inleakage results for Test J are given in Table 11. Equation (3) was used with regression analysis to determine the air exchange rate. Equation (4) was then used to calculate an actual air inleakage rate. Actual measured tracer concentration data are provided in Appendix A denoted as Test J. Calculation of measurement uncertainty associated with the measured inleakage value in Table 11 is provided in Appendix B denoted as Test J: 8/10/01.

Only a limited number of mixing fans were used in the CRE as previous experience in other nuclear power plant Control Room Envelopes has shown that ventilation flows into well ventilated rooms are sufficient to mix tracer over the time interval that elapsed prior to initiation of sampling. Portable box fans were placed in the doorways to the Restroom, the locked computer room and the northwest vestibule to assist mixing in these areas.

Measured tracer concentration data provided in Appendix A and tabulated as Test J confirm that the tracer gas was well mixed within the CRE. Mean tracer concentration values for each sampling interval also are provided in Appendix A. The standard deviation of all tracer measurements at a given measurement interval expressed as a percentage of the mean is also shown.

The standard deviation is a statistical measure of how much a collection of measurements differs from the mean of the collection. The smaller the standard deviation, the closer individual values in the collection are to the mean. Inspection of concentration data in Appendix A for Test J discloses that at each sample time, the standard deviation of the mean concentration ranges from +/- 1.8 % to +/- 2.9 %, thereby confirming that tracer was well mixed throughout the CRE.

Table 10

Sample Locations for Test J

Location	Description
CR1	Old U2 Shift Office
CR2	Center of Restroom
CR3	Center front of U1/U2 control panel
CR4	Center of MCR east of SRO Desk
CR5	Aisle between U1 ES Analog Ch. A Cab. and U1 ICS Cab. No. 4
CR6	Center of TSC
CR7	Center of Locked Computer Room
CR8	Outside doorway to U1 Shift Office
CR9	Center of Corridor Outside Doorway to Shift Manager Office
CR10	Center of Computer Room
CR11	Above drop ceiling between U1 shift office and shift mgr office

Table 11

Air Inleakage Value for Test J

Description	Value
AIR EXCHANGE RATE (ACH)	0.4827
CRE VOLUME (Cu. Ft.)	108000
AIR INLEAKAGE RATE (ACFM)	869+/- 31

4.5 TEST K:U1/U2 CRE INLEAKAGE-BOOSTER FAN 1B OPERATING

On August 11, 2001 an inleakage test was performed on the U1/U2 CRE with the CRVS in Emergency Mode and AHU 1-11 as well as booster fan 1B operating. At 17:33, an SF6 in nitrogen mixture possessing a concentration of 1.013 % was injected at a flowrate of 15 SLPM for approximately 60 minutes after which the injection flowrate was reduced to 4.72 SLPM for the remainder of the test. Tracer gas injection occurred at the entrance to the U1/U2 CRVS makeup air duct as described in Section 3.3. Note that 28.3 SLPM is equal to 1.0 SCFM.

Duct concentration measurements at the makeup flowrate location were obtained using a pump/manifold system attached to a length of polyethylene tubing and a stainless steel probe. The probe was moved to various locations within the duct in a plane perpendicular to the duct axis after which a sample was drawn by the pump/manifold system to individual polypropylene syringes for subsequent analysis. Three samples at 0.25, 0.5 and 0.75 the width of the duct were taken along each of three lines perpendicular to the duct axis located at 0.25, 0.5 and 0.75 of the height of the duct. This resulted in a total of nine samples.

Tracer gas samples for the measurement of Total Air Inflow were obtained through a polyethylene tube inserted into the return duct as it entered the Mechanical Equipment Room. This sample location was designated RET.

Makeup air flowrate results for Test K using the tracer gas technique are given in Table 12. Equation (11) was used to calculate the makeup flowrate for data point. Actual measured tracer concentration data are provided in Appendix A denoted as Test K. Calculation of the makeup flowrates during the actual air inleakage test is provided in Appendix B denoted as Test KF4 through KF10. The mean of these seven measurements is provided in the next spreadsheet in Appendix B denoted "7 Test Average".

Table 12

Makeup Flowrate measured by Tracer Gas for Test K

PRESSURIZATION FAN	FLOWRATE (SCFM)
1B	1099 +/- 40

Tracer gas samples were collected from eleven different locations throughout the CRE as well as from sample locations within the ductwork. The tracer sample locations for Test K are described in Table 13.

Within the CRE grab samples were taken using individual 60 cc polypropylene syringes. During the testing, CRE ingress and egress were minimized and occurred through only a single door at any one time.

Air samples from a location above the drop ceiling within the CRE were obtained using a pump/manifold sampling system. Each pump/manifold sampling system consisted of a diaphragm pump connected to a multi-position sampling valve. A Swagelok™ tee and septum fitting was affixed to the sample pump exhaust. This allowed remotely located air samples to be obtained using polypropylene syringes. Lengths of polyethylene tubing were connected to the multi-position valve and were routed to the appropriate locations for sampling.

Equation (12) was used to calculate the air inleakage into the CRE for Test K. Actual measured tracer concentration data are provided in Appendix A denoted as Test K. Calculation of measurement uncertainty associated with the measured tracer concentration values is provided in Appendix A denoted as Test K: 8/11/01. Note that the mean concentrations measured at the makeup duct sample location and at the return duct sample location are statistically indistinct. Thus for this test the inleakage is zero. Further discussion is provided in Section 4.7.

Only a limited number of mixing fans were used in the CRE as previous experience in other nuclear power plant Control Room Envelopes has shown that ventilation flows into well ventilated rooms are sufficient to mix tracer over the time interval that elapsed prior to initiation of sampling. Portable box fans were placed in the doorways to the Restroom, the locked computer room and the northwest vestibule to assist mixing in these areas.

Measured tracer concentration data are provided in Appendix A and are tabulated as Test K. From these data it is clear that the tracer concentration within the CRE was both well mixed and at equilibrium. The standard deviation of all tracer measurements expressed as a percentage of the mean is also shown.

The standard deviation is a statistical measure of how much a collection of measurements differs from the mean of the collection. The smaller the standard deviation, the closer individual values in the collection are to the mean. Inspection of concentration data in Appendix A discloses that the standard deviation of the mean concentration is 0.9 %, thereby confirming that tracer concentration was well mixed throughout the CRE and an equilibrium value.

Table 13

Sample Locations for Test K

Location	Description
RET	Return duct at entry to Mechanical Equipment Room
CR1	Old U2 Shift Office
CR2	Center of Restroom
CR3	Center front of U1/U2 control panel
CR4	Center of MCR east of SRO Desk
CR5	Aisle between U1 ES Analog Ch. A Cab. and U1 ICS Cab. No. 4
CR6	Center of TSC
CR7	Center of Locked Computer Room
CR8	Outside doorway to U1 Shift Office
CR9	Center of Corridor Outside Doorway to Shift Manager Office
CR10	Center of Computer Room
CR11	Above drop ceiling between U1 shift office and shift mgr office

4.6 TEST L:U1/U2 CRE INLEAKAGE-BOOSTER FANS 1A & 1B OPERATING

On August 9, 2001 an inleakage test was performed on the U1/U2 CRE with the CRVS in Emergency Mode and AHU 1-11 as well as booster fans 1A and 1B operating. At 17:16, an SF6 in nitrogen mixture possessing a concentration of 0.998 % was injected at a flowrate of 10 SLPM for approximately 45 minutes after which the injection flowrate was reduced to 4.84 SLPM for the remainder of the test. Tracer gas injection occurred at the entrance to the U1/U2 CRVS makeup air duct as described in Section 3.3. Note that 28.3 SLPM is equal to 1.0 SCFM.

Duct concentration measurements at the makeup flowrate location were obtained using a pump/manifold system attached to a length of polyethylene tubing and a stainless steel probe. The probe was moved to various locations within the duct in a plane perpendicular to the duct axis after which a sample was drawn by the pump/manifold system to individual polypropylene syringes for subsequent analysis. Three samples at 0.25, 0.5 and 0.75 the width of the duct were taken along each of three lines perpendicular to the duct axis located at 0.25, 0.5 and 0.75 of the height of the duct. This resulted in a total of nine samples.

Tracer gas samples for the measurement of Total Air Inflow were obtained through a polyethylene tube inserted into the return duct as it entered the Mechanical Equipment Room. This sample location was designated RET.

Makeup air flowrate results for Test L using the tracer gas technique are given in Table 14. Equation (11) was used to calculate the makeup flowrate for data point. Actual measured tracer concentration data are provided in Appendix A denoted as Test L. Calculation of the makeup flowrates during the actual air inleakage test is provided in Appendix B denoted as Test LF4 through LF10. The mean of these seven measurements is provided in the next spreadsheet in Appendix B denoted "7 Test Average".

Table 14

Makeup Flowrate measured by Tracer Gas for Test L

PRESSURIZATION FAN	FLOWRATE (SCFM)
1A& 1B	2090+/- 75

Tracer gas samples were collected from eleven different locations throughout the CRE as well as from sample locations within the ductwork. The tracer sample locations for Test L are described in Table 15.

Within the CRE grab samples were taken using individual 60 cc polypropylene syringes. During the testing, CRE ingress and egress were minimized and occurred through only a single door at any one time.

Air samples from a location above the drop ceiling within the CRE were obtained using a pump/manifold sampling system. Each pump/manifold sampling system consisted of a diaphragm pump connected to a multi-position sampling valve. A Swagelok^{TM} tee and septum fitting was affixed to the sample pump exhaust. This allowed remotely located air samples to be obtained using polypropylene syringes. Lengths of polyethylene tubing were connected to the multi-position valve and were routed to the appropriate locations for sampling.

Equation (12) was used to calculate the air inleakage into the CRE for Test L. Actual measured tracer concentration data are provided in Appendix A denoted as Test L. Calculation of measurement uncertainty associated with the measured tracer concentration values is provided in Appendix A denoted as Test L: 8/11/01. Note that the mean concentrations measured at the makeup duct sample location and at the return duct sample location are statistically indistinct. Thus for this test the inleakage is zero. Further discussion is provided in Section 4.7.

Only a limited number of mixing fans were used in the CRE as previous experience in other nuclear power plant Control Room Envelopes has shown that ventilation flows into well ventilated rooms are sufficient to mix tracer over the time interval that elapsed prior to initiation of sampling. Portable box fans were placed in the doorways to the Restroom, the locked computer room and the northwest vestibule to assist mixing in these areas.

Measured tracer concentration data are provided in Appendix A and are tabulated as Test L. From these data it is clear that the tracer concentration within the CRE was both well mixed and at equilibrium. The standard deviation of all tracer measurements expressed as a percentage of the mean is also shown.

The standard deviation is a statistical measure of how much a collection of measurements differs from the mean of the collection. The smaller the standard deviation, the closer individual values in the collection are to the mean. Inspection of concentration data in Appendix A discloses that the standard deviation of the mean concentration is 0.7 %, thereby confirming that tracer concentration was well mixed throughout the CRE and an equilibrium value.

Table 15

Sample Locations for Test L

Location	Description
RET	Return duct at entry to Mechanical Equipment Room
CR1	Old U2 Shift Office
CR2	Center of Restroom
CR3	Center front of U1/U2 control panel
CR4	Center of MCR east of SRO Desk
CR5	Aisle between U1 ES Analog Ch. A Cab. and U1 ICS Cab. No. 4
CR6	Center of TSC
CR7	Center of Locked Computer Room
CR8	Outside doorway to U1 Shift Office
CR9	Center of Corridor Outside Doorway to Shift Manager Office
CR10	Center of Computer Room
CR11	Above drop ceiling between U1 shift office and shift mgr office

4.7 INLEAKAGE VALUES AND MEASUREMENT UNCERTAINTY

Using equations (15) and (16) from Section 3.4, one can calculate a t value for each of the tracer gas test with the CRVS in the Pressurization Mode (Tests H, I, K, and L). These values can be compared with the Students t value to determine if the mean concentration at the makeup duct sample location is statistically distinct from the mean concentration at the return duct sample location. Recall that if $\mathbf{t_{CALC}}$ is greater that $\mathbf{t_{STATISTIC}}$, then the means are different at the 95 % confidence level. If the values are *not* distinct then the measured inleakage using equation (14) is zero. These calculations are provided in Appendix C and are summarized in Table 16.

Table 16

Inleakage Values for Pressurization Mode Tests August 2001

Test	Mean Makeup Conc (ppm)	Mean Return Conc (ppm)	t Calc	t Statistic	Distinct?
H	1.4671	1.4571	1.098	2.179	No
I	0.9434	0.9450	0.157	2.179	No
K	1.5371	1.5314	0.615	2.179	No
L	0.8130	0.8221	1.831	2.179	No

Examination of the spreadsheet calculations of measurement uncertainty in Appendix B reveals that for the Pressurization Mode tests some of the calculated inleakage values are negative. This is an artifact of the measurement process due to the fact that the measured inleakage value is oscillating around a value of zero. Thus the conventional PTC 19.1

uncertainty analysis is unsatisfactory. To estimate the uncertainty inherent in these zero values, we undertake a numerical experiment in which we increase the mean value of the makeup concentration until the means become "just barely" distinct at the 95 % confidence level. We then calculate an inleakage using equation (14) and use this value as an upper (and lower) bound on the uncertainty in the measured inleakage value. The actual calculations are provided on spreadsheets in Appendix C. The results are summarized in Table 17 presented below.

Table 17

Statistical Uncertainty in Inleakage Values

Test	Incremented Makeup Conc (ppm)	Mean Return Conc (ppm)	Calculated Value from Equation (14) (SCFM)
H	1.4771	1.4571	13
I	0.9674	0.9450	42
K	1.5571	1.5314	18
L	0.8340	0.8221	30

SECTION 5

5.0 CONCLUSIONS AND OBSERVATIONS

In order to assess the amount of air leakage into both the Unit 3 and the Unit 1 & 2 Control Room Envelopes at the Oconee Nuclear Generating Station, tracer gas air inleakage tests were performed during August 2001. Measured air inleakage rates are summarized in Table 18 below.

Table 18

Oconee CRE Inleakage Rates

Control Room	Ventilation Mode	Inleakage
U1/U2	NORMAL	869 +/- 31 (ACFM)
U1/U2	EMERGENCY-1 FAN	0 +/- 18 (SCFM)*
U1/U2	EMERGENCY-2 FAN	0 +/- 30 (SCFM)*
U3	NORMAL	467 +/- 16 (ACFM)
U3	EMERGENCY-1 FAN	0 +/- 13 (SCFM)*
U3	EMERGENCY-2 FAN	0 +/- 42 (SCFM)*

* Referred to 70 Deg F and 14.7 psia

The additional sealing effort on the Unit 3 CRE and the repair of duct seams on the U1/U2 CRVS since the prior testing in 1998 has apparently succeeded in eliminating inleakage into both the U3 and the U1/U2 CRE's.