VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA 23261

November 20, 2000

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Serial No. 00-123B
NLOS/GDM R1
Docket Nos. 50-280, 281
License Nos. DPR-32, 37

Gentlemen:

VIRGINIA ELECTRIC AND POWER COMPANY
SURRY POWER STATION UNITS 1 AND 2
REQUEST FOR ADDITIONAL INFORMATION
ALTERNATE SOURCE TERM - PROPOSED TECHNICAL SPECIFICATION CHANGE

In a letter dated April 11, 2000 (Serial No. 00-123), Virginia Electric and Power Company (Dominion Generation) submitted a license amendment request for implementation of the Alternate Source Term (AST) as the plant design and licensing bases for Surry Power Station Units 1 and 2. We subsequently received a request for additional information from the NRC and responded to the request in a letter dated August 28, 2000 (Serial No. 00-123A). A second request for additional information was received from the Surry NRC Project Manager, Gordon Edison, on September 11, 2000, and included eight questions. Our response to the NRC's questions is provided in the enclosure.

Should you have any questions or require additional information, please contact us.

Very truly yours,

W. R. Matthews
Vice President – Nuclear Operations

Enclosure

Commitments made in this letter: None.

A001
Disk 40 files

cc: U.S. Nuclear Regulatory Commission
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Mr. R. A. Musser
NRC Senior Resident Inspector
Surry Power Station

COMMONWEALTH OF VIRGINIA)
)
COUNTY OF HENRICO)

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by William R. Matthews, who is Vice President - Nuclear Operations, of Virginia Electric and Power Company. He has affirmed before me that he is duly authorized to execute and file the foregoing document in behalf of that Company, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 20TH day of November, 2000.

My Commission Expires: 3/31/04.

Maggie McGuire
Notary Public

(SEAL)

Enclosure

Response to NRC Request for Additional Information
Alternate Source Term

Surry Power Station Units 1 and 2

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION
ALTERNATE SOURCE TERM TECHNICAL SPECIFICATION CHANGES
SURRY POWER STATION, UNITS 1 AND 2

NRC Question No. 1

Provide the radiological dose calculations you performed to estimate radiation doses at exclusion area boundary and low population zone, and in the control room for the postulated loss-of-coolant accident and fuel handling accident.

Dominion Generation Response

Analyses of the radiological consequences of a Loss Of Coolant Accident (LOCA) and a Fuel Handling Accident (FHA) at Surry based on the alternate source term are provided in Attachment 1. These analyses consist of excerpts from calculational notes on the same topics. The pagination from the calculational notes has been retained.

NRC Question No. 2

The staff issued Regulatory Guide 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors" in July 2000. This guide provides, among other things, guidance on the assumptions and methods to be used in the design basis accident radiological consequence analyses in conjunction with new acceptance dose criteria. State if you made any exception or deviation from the guidance provided in this regulatory guide.

Dominion Generation Response

Certain details of the radiological analyses supporting the April 11, 2000 application did incorporate exceptions to the guidance provided in Regulatory Guide 1.183. The exceptions taken are summarized below, along with a reference to the associated section of the analysis report (submitted in the April 11, 2000 letter) in which discussion of each can be found.

LOCA Accident Analysis Exceptions

1. Modeling of containment leakage following a LOCA assumes a leakage rate that is a function of containment pressure, versus assuming a constant leakage equal to the containment design leakage as specified in Regulatory Guide 1.183, Appendix A, Item 3.7. [Report Section 3.1.5.1, p. 29]

Fuel Handling Accident Analysis Exceptions

1. Assumption of a reduced fission product inventory in the fuel assembly, based upon Surry core characteristics, considering achievable rod peaking factor and burnup combinations versus the bounding values for peaking factor and fission product gap content inherent in the values of Table 3 in Regulatory Guide 1.183, Section 3.2. [Report Section 3.2.2, p.36]

2. No time requirement is specified in which to close an open personnel airlock, equipment access hatch or other penetrations. Regulatory Guide 1.183, Appendix B, Item 5.3 (footnote 3) indicates that administrative controls are generally required by which closure can be accomplished in less than 30 minutes. [Report Section 2.2, p.13; Section 4.2, p. 51]

3. Technical Specifications changes & proposed station procedures do not require a dedicated individual to be present at the open airlock or equipment hatch during fuel handling operations. Regulatory Guide 1.183, Appendix B, Item 5.3 (footnote 3) indicates this is a generally required element of the administrative controls. [Report Section 2.2, p.13]

4. The release of radioactive material from the Fuel Building and Containment is modeled by assuming a range of potential flow rates that encompass credible ventilation system performance. Regulatory Guide 1.183, Appendix B, Items 4.1 and 5.3 specify the assumption that the material be removed within a 2 hour timeframe without modeling specific flows. [Report Section 3.2.4.1, p.43]

NRC Question No. 3

In Table 1.3-1 of your submittal, you assumed 10 cfm unfiltered air inleakage into the control room. Discuss your control room habitability design including air inleakage test performed to verify the assumed unfiltered air inleakage into the control room.

Dominion Generation Response

A 10-cfm unfiltered air inleakage was assumed in the Surry Power Station Alternate Source Term analysis. This is reasonable for the design and operation of the Control Room Envelope (CRE) and ventilation systems. As discussed below, the control room is a positive pressure design. No physical inleakage testing has been performed .

The design configuration, maintenance, and operation of the Control Room (CR) ventilation system precludes unfiltered air inleakage into the CR envelope. The upper elevation of the two-story CRE consists of the Unit 1 and Unit 2 control rooms, computer rooms, and CR Air Handling Unit (AHU) rooms. The lower part consists of the Unit 1 and Unit 2 emergency switchgear rooms (ESGR) and relay rooms, and contains the auxiliary shutdown panels. Envelope boundary surfaces (walls, ceiling, and floor) are poured concrete and painted. Cable and conduit/pipe penetrations are sealed with approved sealants. The AHUs for both elevations of the envelope are located within the envelope. Ducting associated with the CR cooling ventilation system is also located within the envelope. Only supply and exhaust ducting penetrates the boundary and includes two isolation dampers in series to protect against single failure. No other ducting traverses the envelope. In response to an SI signal, the normal supply and exhaust ducting is isolated by dampers and the fans trip. Non-safety related fans serving spaces adjacent to the CRE are also tripped on an SI signal. These functions are periodically tested.

Following a DBA, the CRE will be maintained at a pressure differential of at least 0.05" relative to the adjacent spaces. Numerous pressure differential indicators (PDIs) are permanently installed for use by CR operators. Routine testing is performed to verify that bottled air/emergency fan flows are within required limits, and can adequately pressurize the CRE. A bottled air system provides sufficient pressurization air for the first hour following a DBA. Thereafter, four independent emergency fans and HEPA/charcoal filter assemblies provide filtered pressurization air; only one assembly is necessary to provide the required pressurization. Two fan/filter assemblies are located on each elevation of the envelope. These assemblies are located on the outside of the envelope wall, and are separated horizontally by approximately 40 feet and 100 feet for the CR and ESGR fans, respectively. The filter assemblies are of welded construction and bolted directly to the fans. The fans are also of welded construction, and include bellows seals on the shafts to prevent inleakage. The ducting downstream of the emergency fans is very short in length, and will be under a positive pressure when the fan is running.

Since late 1999, representatives from the NRC, NEI, and the industry have been working on a guidance document (NEI 99-03) to resolve generic concerns with Control Room habitability. Dominion Generation has participated in the development of NEI 99-03, and will continue to participate until concerns are resolved to the mutual satisfaction of the NRC and industry. Dominion Generation intends to review the final version of NEI 99-03 and consider recommendations that will improve the Control Room habitability systems performance.

NRC Question No. 4

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. For example, during the periods of data collection did the measurement program meet the guidelines of Regulatory Guide 1.23, "Onsite Meteorological Programs," including factors such as maintaining good siting, instruments within specifications, and adequate data recovery and quality assurance checks? If deviations occurred, describe such deviations from Regulatory Guide 1.23 guidance and why the data are still deemed to be adequate. 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? Were calibrations properly performed and instruments found to be within guideline specifications for the use of the data? What additional checks and at what frequency were the checks performed on the data following collection and prior to input into the atmospheric dispersion calculations to assure identifying any problems in a timely manner and flagging data of questionable quality?

Dominion Generation Response

The data provided for use in the analysis were collected using the guidance of Regulatory Guide 1.23, "Onsite Measurement Programs". Calibrations were performed semi-annually or more frequently, and repairs and recalibrations were performed as required. Subsequent to 1996, a program was established to ensure that the area surrounding the meteorological tower is cleared to provide the best air flow possible. Trees, shrubs, and brush on Dominion Generation property have been cleared in all directions. Our analysis of the data, in which we examined average, maximum, and minimum diurnal values, showed that clearing of this vegetation had no appreciable influence on the wind speed and direction data. However, the quadrant to the south-southeast through southwest of the primary tower - which is not part of the owner controlled property - has 80-foot tall trees less than 250 feet from the tower. The landowner was not willing to harvest those trees, nor would he accept a reasonable offer to purchase a number of acres adjacent to our property to allow us to clear those trees. During the 1992-1996 period, difficulties were encountered with maintaining the Delta T system; however, obviously erroneous data and data recorded during periods of maintenance and repair were deleted from the database and are not included in this dataset.

The data from the meteorological monitoring sites at Surry Power Station are telemetered daily to the corporate office. Each business day, the data from the previous calendar day or days are reviewed by Environmental Policy and Compliance (EP&C) personnel. The data from each tower level and from each site at Surry are compared for consistency. In addition, comparisons are made with data collected at other Dominion Generation meteorological monitoring sites in York County and Chesterfield County, as well as with data from National Weather Service offices in Norfolk, VA and Richmond, VA. If questions arise regarding the validity of any of the data, meteorologists from the EP&C staff are requested to review the suspect data. The data are edited as needed during the month. At the end of each month, the data are merged into a historical database located on the corporate mainframe computer. A program is run that performs more detailed seasonally adjusted statistical checks of the data, and flags any hour of data in which a potential outlier occurs. If necessary, review of the data by staff meteorologists is done and any further editing is performed. A monthly statistical summary of the data is run to insure its overall consistency and representativeness. Data recovery rates for this period are generally in the 95-100% range except when the primary tower was out of service due to Hurricane Fran in 1996.

NRC Question No. 5

A preliminary staff review of the 1992 through 1996 meteorological data and comparison with data from the 1970's and 1980's indicates some apparent inconsistencies with respect to wind speed, wind direction, and atmospheric stability. During the 1992 through 1996 time period, there appear to have been some intermittent measurements of very or extremely unstable lapse rates during the night and very or extremely stable lapse rates during the day when, typically, neutral or stable lapse rates are expected to occur at night and neutral or unstable conditions during the day.

Further, a comparison of wind speed and direction during 1992 through 1996 with the older data indicates a slight shift in wind direction and a general decrease in wind speed during the more recent time period. Do you agree with these observations? If so, to what is this attributed? During the periods 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?

Dominion Generation Response

We agree that there are some slight differences between the 1992 through 1996 meteorological data, which was used in the rebaselining study, and the earlier data from the 1970's and 1980's. These differences were most prevalent in the portion of the meteorological data that affected the calculation of offsite X/Q values with the PAVAN code. However, these differences appeared to have little or no affect on either standard statistical evaluations of the data (see the response to question No. 4 above) or the portion of the meteorological data used to calculate Control Room X/Q values with the ARCON96 computer code.

For the April 11, 2000 amendment request, Dominion Generation has determined offsite X/Q values using meteorological data from 1994 to 1998 and Control Room X/Q values using meteorological data from 1982 through 1986. The PAVAN computer code was used to calculate the offsite X/Q values and the ARCON96 computer code was used to calculate the control room X/Q values. The use of the 1994-1998 meteorological data was originally intended to determine the overall impact of tree growth around the meteorological tower and only a subset of the source-receptor geometries was developed. Comparison of the ARCON96 results for the two sets of meteorological data indicated a negligible difference. However, the PAVAN output indicated a factor of 2 to 3 increase in X/Q in the 1994-1998 based X/Q's relative to the 1982-1986 based X/Q's. Based on these results the X/Q's generated with 1982-1986 data were used for onsite releases and the X/Q's generated with 1994-1998 data were used for offsite releases. Therefore, use of the more recent meteorological data, represents a significant penalty, which has been included in the offsite dose calculations.

As discussed in the response to question 4, it is suspected that trees in the vicinity of the tower may have caused the differences observed between the two sets of meteorological data. The trees, stumps, and brush on Dominion Generation property that may have been affecting the meteorological tower have since been removed. Although the offsite X/Q values have been conservatively determined as discussed above, we intend to further evaluate the impact of the tree removal on the meteorological data and any resultant change in the offsite X/Q values.

NRC Question No. 6

Provide, on the docket, an electronic copy of the meteorological data used to calculate the X/Q values. Data should be provided either in the format specified in Appendix A to

Section 2.7, "Meteorology and Air Quality," of draft 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. If the ARCON96 format is selected when providing data, the atmospheric stability categorization should be based on the delta-T methodology. Any missing data should be designated by completely filling the field for that parameter with 9's.

Dominion Generation Response

The attached diskette contains self-extracting ZIP files of the meteorological data used to calculate X/Q values in the ARCON96 format, as well as the ARCON96 input and output files.

NRC Question No. 7

Which of the X/Qs are new for this amendment request and which have been previously approved by the NRC? Why were different periods of data used for control room and off-site X/Q calculations? Describe the specific inputs and assumptions used, including a list of the inputs used in the PAVAN and ARCON96 calculations. A copy of the computer printout pages showing the inputs is acceptable. If modifications were made to either of the codes when making this assessment, describe the modifications and resultant impact. When making estimates using ARCON96, was the physical height of the vent or other release location assumed? Are distances the shortest distance from the postulated release location to the intake location? Figures showing structures, dimensions, and distances may also be helpful in describing the postulated transport of the effluent. If flow rates were assumed when making X/Q calculations, were they based on Technical Specification values? If more than one release to the environment/transport scenario could occur (e.g., loss of offsite power and non-loss of site power), were comparative X/Q calculations made to ensure consideration of the limiting dose?

Dominion Generation Response

The X/Qs used in this amendment are new and were generated with either the PAVAN code or the ARCON96 code. In general, the set of meteorological data that produced conservative dose consequences was selected for use in the dose calculations. The PAVAN X/Q values for the subset of source-receptor geometries that used the 1994 through 1998 meteorological data were selected for the offsite analysis because the X/Q values were generally 2 to 3 times the values derived with the 1982 through 1986 data. The ARCON96 X/Q values using the 1982 through 1986 data were selected for the Control Room analysis because there were negligible differences between X/Q's calculated with each set of meteorological data and a complete set of source-receptor geometries were available.

The PAVAN and ARCON96 source codes were not modified, however, the PAVAN code was moved from the mainframe platform to the personal computer platform. The

adaptation of the PAVAN code to the personal computer platform included verification, validation and benchmarking in accordance with the quality assurance program of the vendor performing the X/Q calculations. The offsite X/Q values generated with PAVAN took no credit for wake effects due to the distance of the offsite receptors from the release locations exceeding 10 times the building heights. PAVAN input files and joint frequency distribution tables, and a marked up site plan indicating the relative locations of the sources and receptors are attached. A summary of the horizontal and vertical distances and direction from the receptor location to the sources that were used in the ARCON96 input files are also attached. Furthermore, as discussed in the response to question 6, the attached diskette contains self-extracting ZIP files of the meteorological data used to calculate X/Q values in the ARCON96 format, as well as the ARCON96 input and output files.

The following is a list of the assumptions that were used in the development of ARCON96 X/Q's:

a) X/Q's were modeled as ground level releases.
b) Containment X/Q's were modeled as area sources.
c) A factor of 6 was used in estimating the initial dispersion coefficients for the containment area source.
d) Wake effects only considered the portion of the Containment that exceeds the height of the Auxiliary building. Additionally, only one Containment area was considered. The onsite receptors are within the zone influenced by the Containment wake effect.
e) Releases were assumed to travel directly from the release point to the receptors following the "slant range path" calculated by ARCON96.
f) Releases from Ventilation Vent No. 2 were modeled at the elevation of the stack (97.5 feet) with no credit for plume rise.

Additionally, several conservative ventilation flow rates were modeled in the X/Q calculations for Ventilation Vent No. 2; however, since the release was modeled as a ground level release, the inclusion of flow rates had little or no impact on the results. These flow rates are included in the attached ARCON96 input files. Finally, when more than one release to the environment/transport scenario was considered, the transport path and associated X/Q which resulted in the highest dose consequences were generally used. This included consideration of equipment availability during conditions with and without offsite power and was not limited strictly to the X/Q generation in an effort to provide an overall evaluation of dose consequences that was conservative.

NRC Question No. 8

The April 11, 2000 VEPCO letter makes mention of requirements for equipment hatch, personnel airlock and penetrations having a direct release to the environment. Were separate X/Q values calculated for the two cases, closed penetrations and open penetrations? Page 26 of the enclosure to the letter mentions "wake effects" when

using ARCON96. Is this in reference to using the diffuse release option of ARCON96? Also, on page 26 it is stated that the EAB and LPZ X/Q values are modeled assuming releases from the Unit 1 containment building. Are these the most limiting conditions for the site?

Dominion Generation Response

As discussed in the answer to question 7, ARCON96 area source X/Q's with wake effects have been determined for the Containment, which is expected to have closed penetrations for the LOCA. The Equipment Hatch, Personnel Airlock and certain other containment penetrations have been assumed to be open during the Fuel Handling Accident. ARCON96 based point source X/Q's were determined for Ventilation Vent No. 2 and the Auxiliary Building 45-ft elevation east and west louvers. These X/Q's were used to model releases from containment penetrations that may open into the Auxiliary Building lower levels, Safeguards, the open Personnel Airlock, and from containment penetrations that may open into the Auxiliary Building 45-ft elevation. Furthermore, releases modeled with these X/Q's bound releases from the Equipment Hatch due to the Equipment Hatch being located further away and on the opposite side of containment from the receptor points. In addition to selecting conservative X/Q's to model the Fuel Handling Accident release, release flows from the Containment and the Fuel Building were varied from natural circulation rates to twice the technical specification fan flow rate in order to maximize both the offsite and Control Room dose consequences.

As is indicated in the response to question 7, the Unit 1 X/Q's generated with the 1994-1998 meteorological data were a subset of source-receptor geometries modeled with the 1982-1986 meteorological data. These X/Q's were generated to determine the impact of tree growth around the meteorological tower. The PAVAN generated offsite X/Q's based on 1994-1998 meteorological data were 2 to 3 times larger than the X/Q's generated with the 1982-1986 meteorological data. A review of the 1982-1986 data indicates that due to the site arrangement, which has the release points relatively closely grouped, and the fairly large distances to the EAB and LPZ, the offsite X/Q calculations were relatively insensitive to the release point. Therefore, use of the Unit 1 Containment source point in conjunction with the 1994-1998 meteorological data was deemed to be acceptable for calculating the EAB and LPZ doses. The use of these X/Q's in conjunction with other modeling choices produced conservative offsite dose consequences.

ATTACHMENT 1

(QUESTION NO. 1)

Analyses of the radiological consequences of a Loss Of Coolant Accident (LOCA) and a Fuel Handling Accident (FHA) at Surry based on the alternate source term are attached. These analyses consist of excerpts from calculational notes on the same topics. The pagination from the calculational notes has been retained. These analyses are referred to – within the bodies of their text – as papers.

The doses highlighted in the tables in the "Results" sections of the analyses are the basis for the doses provided in the April 11, 2000 submittal. In most cases, these doses have been rounded up to obtain the values reported in the submittal.

Radiological Consequences of a LOCA at Surry Based on the Alternate Source Term

Objective: To document the doses at the control room, EAB and LPZ at Surry Power Station as a consequence of a LOCA using alternate source term methodologies. In conjunction with the use of the alternate term 1) TEDE radiological units and limits were used, 2) ARCON96 was used to calculate the onsite atmospheric dispersion factors 3) NUREG-5966 was used to calculate the containment spray lambdas and 4) Federal Guidance Reports No.11 and 12 dose conversion factors were used.

Conclusions: The LOCA doses based on the alternate source term, TEDE units, ARCON96, NUREG-5966 spray lambdas and Federal Guidance Report 11 and 12 dose conversion factors were lower than the new TEDE limits for the control room, EAB and LPZ. The new control room limit in TEDE REM is 5 REM. The new EAB and LPZ limits are 25 REM TEDE.

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1) OBJECTIVE

The objective of this paper is to document the analysis of the dose consequences of a Loss of Coolant Accident (LOCA) at Surry based on the alternate source term and associated methodology. This paper predicts the doses in the Control Room, at the Exclusion Area Boundary (EAB) and the Low Population Zone Boundary (LPZ) resulting from a LOCA.

Note that this paper was generated to support a Technical Specification Change Request and a change in the design basis source term from TID-14844 to the Alternate Source Term. As such, the requirements of NDCM 3.7 Sections 6.8, which are for calculations not supporting plant changes, do not apply to this paper.

2) BACKGROUND

NUREG-1465 "Accident Source Terms for Light-Water Nuclear Power Plants" compares the old TID-14844 LOCA and FHA source term with a "revised" or "alternate" source term. The primary differences between the TID and alternate source terms are shown in Table 1 below.

Table 1 - Comparison of TID-14844 and NUREG-1465 Source Terms

	TID Source Term	Alternate Source Term
Core fractions released Into containment	Noble gases - 100% Iodine - 50% (with half of this 50% plated out) Solids - 1%	Noble gases - 100% Iodine - 40% Cesium - 30% Tellurium - 5% Barium - 2% Others - 0.02% to 0.2%
Rate of Release	Release Instantaneously	Released over 1.8 hours
Iodine chemical and Physical form	91% inorganic iodine vapor 4% organic vapor 5% aerosol	4.85% inorganic iodine vapor 0.15% organic vapor 95% aerosol
Solids	Ignored in offsite And control room Dose assessment	Treated as an aerosol

NUREG-1465 breaks the core releases into the fuel gap release phase in the first 30 minutes of a LOCA and the early in-vessel release phase in the subsequent 1.3 hours of a LOCA. The other release phases mentioned in NUREG-1465 [Ref 1] are not considered for design basis accidents according to NRC guidance [Ref 25]. Table 2 shows the fractions of the isotope groups assumed to be released in each of the two phases. Table 2 also shows the rate of release or production for each isotope group assuming the releases are linear with respect to time.

Table 2 - NUREG-1465 Release Phases

	Core Release Fractions		Production Rate (Frac/hr)	
Group	Gap	Early In-Vessel	Gap	Early In-Vessel
Noble Gases	0.05	0.95	0.1	7.31E-01
Halogens	0.05	0.35	0.1	2.69E-01
Alkali Metals	0.05	0.25	0.1	1.92E-01
Tellurium	0	0.05	0	3.85E-02
Barium, Strontium	0	0.02	0	1.54E-02
Noble Metals	0	0.0025	0	1.92E-03
Cerium	0	0.0005	0	3.85E-04
Lanthanides	0	0.0002	0	1.54E-04
Duration (hr)	0.5	1.3		

In conjunction with the implementation of the alternate source term, the NRC has stated that the total effective dose equivalent (TEDE) methodology in 10 CFR Part 20 should be adopted. The dose limits using TEDE methodology would be 25 REM TEDE for offsite doses (EAB and LPZ) and 5 REM TEDE for control room doses according the draft rule for the alternate source term - 10CFR50.67(b)(2). The total effective dose equivalent is equal to the sum of the committed effective dose equivalent (CEDE) and the deep dose equivalent (DDE). The CEDE is the sum of the doses received to a select group of organs from radioactive sources inside the body. The DDE is the dose received from external whole body exposure.

Implementation of the alternate source term also requires that the EAB dose be calculated over the worst two hour period.

Preliminary alternate source term dose consequences calculations done by the NRC and it's contractors indicate that there is a possibility for significant reduction in the dose consequences from a LOCA compared to dose consequences based on the old TID source term [Ref 29].

Bechtel Power Corporation was contracted to make a series of scoping calculations to determine the effect of the alternate source term on the dose consequences of a LOCA at Surry. This paper is based on the results of these scoping calculations in the sense that the selection of inputs and methods used in this paper were based on the findings of the scoping calculations.

All the calculations in this paper were done with the computer code system LOCADOSE. The LOCADOSE codes were developed by Bechtel Corporation to analyze doses from transport of radioactive materials through multi-region systems. The LOCADOSE codes were obtained from Bechtel as executable codes for PCs.

The two codes of the LOCADOSE code system used in this analysis are LOCADOSE and LOCATRAN. LOCATRAN calculates the initial core inventory and the transport of this inventory to the Environment, Control Room and regions of the plant specified by the user based on volumes and flow rates provided by the user. The LOCADOSE computer code then calculates the doses resulting from these radioactive releases based on user supplied X/Q, breathing rate, and occupancy factors either offsite or within regions of the plant specified by the user. For each case executed, 3 input files are required: one for LOCATRAN, one for LOCADOSE and a library file which contains isotopic data.

The version of LOCADOSE used in these calculations was 4.1.

3) **DESIGN INPUTS**

1. The NRC used 52 isotopes in their re-baselining LOCA calculations using the alternate source term [Ref 29]. The Bechtel scoping calculations [ ] used 135 isotopes for their LOCA model. The same 135 isotopes used in the Bechtel scoping calculations were used in this paper. ORIGEN2 was used to calculate the activity of each isotope at the end of a fuel cycle [ ]. Table 3 lists the isotopes used in this paper for a LOCA as well as the associated core activities at the end of a fuel cycle. Each activity is divided by the core power of 2605 MWt to yield the activity per megawatt thermal power. Also shown in Table 3 are the dose conversion factors for each of the isotopes used in this paper. These dose conversion factors are for TEDE units of dose and are taken from [Ref 4, 27]. The "Inh" dose conversion factor is the inhalation dose conversion factor and the "Imm" dose conversion factor is the immersion dose conversion factor. To calculate the TEDE using these dose conversion factors the effective inhalation dose would have to be added to the effective immersion dose. The inhalation dose is equivalent to the CEDE dose and the immersion dose is equivalent to the DDE dose.

Table 3 - Core Activity and Dose Conversion Factors by Isotope

Grp	Isotope	Activity		Dose Conversion Factor			
				Inh (Rem/Ci)		Imm (Rem-m^3/Ci-sec)	
		(Ci)	(Ci/MWt)	Thyroid	Effective	Thyroid	Effective
1	I-130	2.45E+06	9.39E+02	7.36E+04	2.64E+03	3.85E-01	3.85E-01
1	I-131	6.64E+07	2.55E+04	1.08E+06	3.29E+04	6.70E-02	6.73E-02
1	I-132	9.54E+07	3.66E+04	6.44E+03	3.81E+02	4.14E-01	4.14E-01
1	I-133	1.35E+08	5.17E+04	1.80E+05	5.85E+03	1.08E-01	1.09E-01
1	I-134	1.48E+08	5.69E+04	1.07E+03	1.31E+02	4.81E-01	4.81E-01
1	I-135	1.26E+08	4.85E+04	3.13E+04	1.23E+03	2.96E-01	2.95E-01
1	I-136	6.01E+07	2.31E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1	I-137	5.87E+07	2.25E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1	I-138	2.90E+07	1.11E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2	I-130	2.45E+06	9.39E+02	7.36E+04	2.64E+03	3.85E-01	3.85E-01
2	I-131	6.64E+07	2.55E+04	1.08E+06	3.29E+04	6.70E-02	6.73E-02
2	I-132	9.54E+07	3.66E+04	6.44E+03	3.81E+02	4.14E-01	4.14E-01
2	I-133	1.35E+08	5.17E+04	1.80E+05	5.85E+03	1.08E-01	1.09E-01
2	I-134	1.48E+08	5.69E+04	1.07E+03	1.31E+02	4.81E-01	4.81E-01
2	I-135	1.26E+08	4.85E+04	3.13E+04	1.23E+03	2.96E-01	2.95E-01
2	I-136	6.01E+07	2.31E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2	I-137	5.87E+07	2.25E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2	I-138	2.90E+07	1.11E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	I-130	2.45E+06	9.39E+02	7.36E+04	2.64E+03	3.85E-01	3.85E-01
3	I-131	6.64E+07	2.55E+04	1.08E+06	3.29E+04	6.70E-02	6.73E-02
3	I-132	9.54E+07	3.66E+04	6.44E+03	3.81E+02	4.14E-01	4.14E-01
3	I-133	1.35E+08	5.17E+04	1.80E+05	5.85E+03	1.08E-01	1.09E-01
3	I-134	1.48E+08	5.69E+04	1.07E+03	1.31E+02	4.81E-01	4.81E-01
3	I-135	1.26E+08	4.85E+04	3.13E+04	1.23E+03	2.96E-01	2.95E-01
3	I-136	6.01E+07	2.31E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	I-137	5.87E+07	2.25E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	I-138	2.90E+07	1.11E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	Kr-85	8.01E+05	3.08E+02	0.00E+00	0.00E+00	4.37E-04	4.40E-04
4	Kr-87	3.27E+07	1.26E+04	0.00E+00	0.00E+00	1.53E-01	1.52E-01
4	Kr-88	4.61E+07	1.77E+04	0.00E+00	0.00E+00	3.81E-01	3.77E-01
4	Kr-89	5.61E+07	2.15E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	Kr-83m	8.12E+06	3.12E+03	0.00E+00	0.00E+00	2.38E-06	5.55E-06
4	Kr-85m	1.71E+07	6.56E+03	0.00E+00	0.00E+00	2.71E-02	2.77E-02
4	Xe-133	1.35E+08	5.18E+04	0.00E+00	0.00E+00	5.59E-03	5.77E-03
4	Xe-135	3.31E+07	1.27E+04	0.00E+00	0.00E+00	4.37E-02	4.40E-02
4	Xe-137	1.18E+08	4.53E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	Xe-138	1.11E+08	4.27E+04	0.00E+00	0.00E+00	2.13E-01	2.13E-01
4	Xe-131m	7.39E+05	2.84E+02	0.00E+00	0.00E+00	1.45E-03	1.44E-03

Table 3 - Core Activity and Dose Conversion Factors by Isotope

Grp	Isotope	Activity		Dose Conversion Factor			
				Inh (Rem/Ci)		Imm (Rem-m^3/Ci-sec)	
		(Ci)	(Ci/MWt)	Thyroid	Effective	Thyroid	Effective
4	Xe-133m	4.21E+06	1.62E+03	0.00E+00	0.00E+00	5.03E-03	5.07E-03
4	Xe-135m	2.65E+07	1.02E+04	0.00E+00	0.00E+00	7.55E-02	7.55E-02
5	Cs-134	1.38E+07	5.31E+03	4.11E+04	4.63E+04	2.80E-01	2.80E-01
5	Cs-136	3.17E+06	1.22E+03	6.40E+03	7.33E+03	3.96E-01	3.92E-01
5	Cs-137	8.88E+06	3.41E+03	2.93E+04	3.19E+04	2.79E-05	2.86E-05
5	Cs-138	1.23E+08	4.74E+04	1.32E+01	1.01E+02	4.48E-01	4.48E-01
5	Cs-139	1.17E+08	4.49E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5	Cs-134m	3.44E+06	1.32E+03	1.24E+01	4.37E+01	3.29E-03	3.35E-03
5	Rb-86	1.38E+05	5.29E+01	4.92E+03	6.62E+03	1.79E-02	1.78E-02
5	Rb-88	4.68E+07	1.80E+04	5.07E+00	8.36E+01	1.25E-01	1.24E-01
5	Rb-89	6.00E+07	2.30E+04	5.96E+00	4.29E+01	3.96E-01	3.92E-01
5	Rb-90	5.82E+07	2.23E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	Sb-124	9.34E+04	3.59E+01	2.49E+03	2.52E+04	3.39E-01	3.39E-01
6	Sb-125	1.47E+03	5.64E-01	1.20E+03	1.22E+04	7.44E-02	7.47E-02
6	Sb-126	3.97E+01	1.52E-02	1.88E+03	1.17E+04	5.07E-01	5.07E-01
6	Sb-127	7.13E+06	2.74E+03	5.55E+02	6.03E+03	1.23E-01	1.23E-01
6	Sb-129	2.13E+07	8.18E+03	7.66E+01	6.44E+02	2.65E-01	2.64E-01
6	Te-127	7.09E+06	2.72E+03	2.39E+01	3.18E+02	8.88E-04	8.95E-04
6	Te-129	2.10E+07	8.06E+03	6.03E+00	8.95E+01	1.01E-02	1.02E-02
6	Te-131	5.88E+07	2.26E+04	9.84E+03	4.77E+02	7.51E-02	7.55E-02
6	Te-132	9.39E+07	3.60E+04	2.32E+05	9.44E+03	3.77E-02	3.81E-02
6	Te-133	7.94E+07	3.05E+04	2.19E+03	9.21E+01	1.70E-01	1.70E-01
6	Te-134	1.12E+08	4.29E+04	2.06E+03	1.27E+02	1.57E-01	1.57E-01
6	Te-125m	3.17E+02	1.22E-01	3.67E+02	7.29E+03	1.72E-03	1.68E-03
6	Te-127m	9.71E+05	3.73E+02	8.84E+02	2.15E+04	5.55E-04	5.44E-04
6	Te-129m	3.14E+06	1.21E+03	1.46E+03	2.39E+04	5.77E-03	5.74E-03
6	Te-131m	9.54E+06	3.66E+03	1.34E+05	6.40E+03	2.60E-01	2.59E-01
6	Te-133m	4.90E+07	1.88E+04	9.73E+03	4.33E+02	4.26E-01	4.22E-01
7	Ba-139	1.21E+08	4.63E+04	8.88E+00	1.72E+02	7.88E-03	8.03E-03
7	Ba-140	1.16E+08	4.44E+04	9.47E+02	3.74E+03	3.16E-02	3.17E-02
7	Ba-141	1.09E+08	4.19E+04	4.92E+00	8.07E+01	1.54E-01	1.54E-01
7	Ba-136m	5.22E+05	2.00E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7	Ba-137m	8.41E+06	3.23E+03	0.00E+00	0.00E+00	1.07E-01	1.07E-01
7	Sr-89	6.44E+07	2.47E+04	1.54E+03	4.14E+04	2.81E-04	2.86E-04
7	Sr-90	6.30E+06	2.42E+03	9.77E+03	1.30E+06	2.71E-05	2.79E-05
7	Sr-91	7.78E+07	2.99E+04	1.51E+02	1.66E+03	1.28E-01	1.28E-01
7	Sr-92	8.45E+07	3.24E+04	8.10E+01	8.07E+02	2.52E-01	2.51E-01
7	Sr-93	9.60E+07	3.68E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 3 - Core Activity and Dose Conversion Factors by Isotope

Grp	Isotope	Activity		Dose Conversion Factor			
				Inh (Rem/Ci)		Imm (Rem-m^3/Ci-sec)	
		(Ci)	(Ci/MWt)	Thyroid	Effective	Thyroid	Effective
7	Sr-94	9.09E+07	3.49E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7	Sr-95	8.43E+07	3.24E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
8	Co-58	1.09E+04	4.18E+00	3.23E+03	1.09E+04	1.76E-01	1.76E-01
8	Co-60	7.88E+04	3.03E+01	5.99E+04	2.19E+05	4.70E-01	4.66E-01
8	Mo-99	5.18E+04	1.99E+01	4.33E+02	3.96E+03	2.69E-02	2.69E-02
8	Pd-109	2.22E+07	8.53E+03	2.99E+01	1.10E+03	9.10E-04	9.29E-04
8	Rh-105	6.57E+07	2.52E+04	9.51E+01	9.55E+02	1.36E-02	1.38E-02
8	Rh-106	4.37E+07	1.68E+04	0.00E+00	0.00E+00	3.81E-02	3.85E-02
8	Ru-103	1.04E+08	3.97E+04	2.21E+03	8.95E+03	8.29E-02	8.33E-02
8	Rh-103m	9.32E+07	3.58E+04	3.14E-01	5.11E+00	3.16E-05	3.26E-05
8	Ru-105	7.13E+07	2.74E+04	5.55E+01	4.55E+02	1.41E-01	1.41E-01
8	Ru-106	3.98E+07	1.53E+04	5.07E+04	4.77E+05	0.00E+00	0.00E+00
8	Tc-101	1.30E+04	4.98E+00	2.86E+01	1.79E+01	5.88E-02	5.96E-02
8	Tc-99m	1.06E+08	4.06E+04	1.85E+02	3.26E+01	2.13E-02	2.18E-02
9	Ce-141	1.09E+08	4.20E+04	1.71E+02	8.95E+03	1.24E-02	1.27E-02
9	Ce-143	1.02E+08	3.90E+04	4.48E+01	3.39E+03	4.74E-02	4.77E-02
9	Ce-144	9.10E+07	3.49E+04	6.96E+03	3.74E+05	3.08E-03	3.16E-03
9	Eu-154	5.69E+02	2.18E-01	2.64E+04	2.86E+05	2.28E-01	2.27E-01
9	Eu-155	3.68E+02	1.41E-01	8.88E+02	4.14E+04	8.92E-03	9.21E-03
9	Eu-156	8.29E+03	3.18E+00	7.99E+02	1.41E+04	2.51E-01	2.50E-01
9	La-140	1.19E+08	4.58E+04	4.51E+02	4.85E+03	4.37E-01	4.33E-01
9	La-141	1.10E+08	4.21E+04	3.48E+01	5.81E+02	8.84E-03	8.84E-03
9	La-142	1.06E+08	4.07E+04	3.23E+01	2.53E+02	5.37E-01	5.33E-01
9	La-143	1.01E+08	3.87E+04	2.89E+00	5.99E+01	1.92E-02	1.92E-02
9	Nb-95	1.15E+08	4.41E+04	1.32E+03	5.81E+03	1.39E-01	1.38E-01
9	Nb-97	1.12E+08	4.28E+04	4.96E+00	8.29E+01	1.18E-01	1.18E-01
9	Nb-95m	8.08E+05	3.10E+02	1.43E+02	2.44E+03	1.07E-02	1.08E-02
9	Nd-147	4.39E+07	1.68E+04	7.18E+01	6.85E+03	2.26E-02	2.29E-02
9	Pm-147	9.65E+06	3.70E+03	7.33E-02	3.92E+04	2.50E-06	2.56E-06
9	Pm-148	1.85E+07	7.09E+03	1.58E+02	1.09E+04	1.07E-01	1.07E-01
9	Pm-149	3.03E+07	1.16E+04	1.37E+00	2.93E+03	1.98E-03	2.00E-03
9	Pm-151	1.32E+07	5.07E+03	2.48E+01	1.75E+03	5.55E-02	5.59E-02
9	Pm-148m	2.16E+06	8.31E+02	3.89E+03	2.26E+04	3.58E-01	3.58E-01
9	Pr-143	1.01E+08	3.87E+04	6.22E-06	8.10E+03	7.59E-05	7.77E-05
9	Pr-144	9.17E+07	3.52E+04	3.13E-02	4.33E+01	7.22E-03	7.22E-03
9	Pr-144m	1.09E+06	4.20E+02	0.00E+00	0.00E+00	1.04E-03	1.03E-03
9	Sm-153	1.95E+03	7.47E-01	5.59E+00	1.96E+03	8.21E-03	8.44E-03
9	Y-90	6.55E+06	2.52E+03	3.52E+01	8.44E+03	6.92E-04	7.03E-04

Table 3 - Core Activity and Dose Conversion Factors by Isotope

Grp	Isotope	Activity		Dose Conversion Factor			
				Inh (Rem/Ci)		Imm (Rem-m^3/Ci-sec)	
		(Ci)	(Ci/MWt)	Thyroid	Effective	Thyroid	Effective
9	Y-91	8.38E+07	3.21E+04	4.07E+02	4.88E+04	9.62E-04	9.62E-04
9	Y-92	8.48E+07	3.26E+04	1.37E+01	7.81E+02	4.81E-02	4.81E-02
9	Y-93	9.84E+07	3.78E+04	1.87E+01	2.15E+03	1.77E-02	1.78E-02
9	Y-94	9.95E+07	3.82E+04	2.47E+00	6.99E+01	2.09E-01	2.08E-01
9	Y-95	1.07E+08	4.11E+04	1.28E+00	3.77E+01	1.79E-01	1.77E-01
9	Y-91m	4.52E+07	1.73E+04	2.31E+00	3.63E+01	9.40E-02	9.44E-02
9	Zr-95	1.15E+08	4.40E+04	5.33E+03	2.36E+04	1.34E-01	1.33E-01
9	Zr-97	1.11E+08	4.24E+04	3.54E+02	4.33E+03	3.34E-02	3.34E-02
11	Br-82	3.59E+05	1.38E+02	8.81E+02	1.53E+03	4.81E-01	4.81E-01
11	Br-83	8.10E+06	3.11E+03	1.22E+01	8.92E+01	1.41E-03	1.41E-03
11	Br-84	1.40E+07	5.38E+03	1.15E+01	9.66E+01	3.52E-01	3.48E-01
11	Br-85	1.69E+07	6.47E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
11	Br-87	2.76E+07	1.06E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
11	Br-88	2.94E+07	1.13E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
12	Am-241	1.51E+04	5.80E+00	5.92E+03	4.44E+08	2.90E-03	3.03E-03
12	Am-242	6.27E+06	2.41E+03	9.32E+00	5.85E+04	2.20E-03	2.28E-03
12	Cm-242	3.47E+06	1.33E+03	3.48E+03	1.73E+07	1.82E-05	2.11E-05
12	Cm-244	3.22E+05	1.23E+02	3.74E+03	2.48E+08	1.55E-05	1.82E-05
12	Np-238	2.55E+07	9.77E+03	9.07E+01	3.70E+04	1.01E-01	1.01E-01
12	Np-239	1.29E+09	4.93E+05	2.82E+01	2.51E+03	2.78E-02	2.85E-02
12	Pu-238	2.64E+05	1.01E+02	3.56E+03	3.92E+08	1.48E-05	1.81E-05
12	Pu-239	2.33E+04	8.94E+00	3.34E+03	4.29E+08	1.44E-05	1.57E-05
12	Pu-240	2.64E+04	1.01E+01	3.35E+03	4.29E+08	1.45E-05	1.76E-05
12	Pu-241	1.19E+07	4.58E+03	4.59E+01	8.25E+06	2.58E-07	2.68E-07
12	Pu-243	2.60E+07	9.96E+03	1.78E+00	1.64E+02	3.67E-03	3.81E-03

2. As mentioned before, the reactor power used was 2605 MWt [ ].

3. The chemical form of the iodine released from the fuel is 95% aerosol, 4.85% elemental and 0.15% organic [Ref 1, Sec 3.5].

4. The containment volume is 1.863E6 cubic feet and the cross-sectional area of the containment is 1.25E4 square feet [ ].

5. The fraction of the containment volume that is directly sprayed by the containment spray is 60% [ ].

6. The mixing rate between the sprayed and unsprayed regions of the containment volume is 2 unsprayed volumes per hour [ ].

7. There are seven different spray headers belonging to two different systems inside the Surry containment. The containment spray system has two separate pump trains. Both containment spray pump trains feed one circular dome header each at the top of containment and a common circular crane wall header on top of the crane wall. The recirculation spray system consists of two inside recirculation pump trains with one semi-circular header each at the top of the crane wall and two outside recirculation pump trains with one semi-circular header each at the top of the crane wall. As stated in the assumptions sections, for the LOCA analysis only one train of the containment spray and one train of the inside recirculation and one train of the outside recirculation were modeled as working [ ].

8. The start times of the flows and the flow rates vary with time for each of the spray systems. Table 4 below gives the start times and flow rates used as input for the LOCA dose analysis. The containment spray system stops flowing when the RWST is

empty which occurs at 4100 seconds from the onset of the accident. Also included in Table 4 are the elevations of the headers. The containment operating deck is at elevation 47'-4" [ ].

Table 4
Spray System Characteristics

Containment Spray Dome headers:	Containment Spray Crane Wall Headers:
Elevation - 142'-5" & 143'-9"	Elevation 95' -6"
834 gpm (100 - 700 sec) 958 gpm (700 - 4100 sec)	956 gpm (100 - 700 sec) 1032 gpm (700 - 4100 sec)
Inside Recirculation Spray headers:	Outside Recirculation Spray Headers:
Elevation - 93'-5" & 94'-5"	Elevation - 93' 5" & 94'-5"
2700 gpm (216 sec - 30 days)	3000 gpm (415 sec - 30 days)

9. Aerosol removal rates due to containment sprays are calculated using the methodology of NUREG/CR-5966 [Ref 3], which presents removal equations at 10, 50, and 90 percentile levels. In accordance with NRC guidance, only the 10 percentile (most conservative) equations are used [Ref 25].

10. Elemental iodine removal due to containment sprays is at a rate of 10.0 hr-1 [ ] until a decontamination factor (DF) of 200 [Ref 31] is reached.

11. No credit for iodine plateout is taken.

12. Airborne leakage from the containment to the environment is at a rate of 0.1% volume per day during the first hour of the accident [ ]. After the first hour, two different leak rates are used. One set of LOCADOSE runs models the leak rate as zero based on the containment becoming subatmospheric after one hour. The second set of LOCADOSE runs models the leak rate as 0.021% volume per 24 hour period for hours 1 through 4. After 4 hours this leak rate is also set to zero.

13. For ECCS leakage, it is conservatively modeled that all the iodine that is released to the containment is instantaneously transported to the containment sump at the onset of the accident.

14. The containment sump volume is 1.65E6 liters or 5.83E4 cubic feet [ ].

15. The ECCS leakage from the containment sump to the safeguards building is modeled at a rate of 0.03213 liters per minute (1.135E-03 cfm) or 1928 cc/hr from 415 seconds to 30 days. The ECCS leakage from the containment sump to the auxiliary building starts at 2300 seconds at 7672 cc/hr or 4.516E-03 cfm and continues for 30 days [ ]. The sum of the safeguards and auxiliary building leak rates is 5.65E-03 cfm or 9600 cc/hr.

16. Passive failure is defined as an unfiltered leak of ECCS fluid at 50 gpm for 30 minutes starting at 24 hours after the onset of the accident [Ref 6].

17. 10% of the iodine in the ECCS fluid which leaks becomes airborne while all other elements remain in the water [Ref 25]. Of the iodine that becomes airborne, 97% is modeled as elemental and 3% organic [Ref 25].

18. Leakage of ECCS fluid into the RWST through a leaking check valve is modeled at 38,400 cc/hr.

19. One LOCADOSE run was made which took credit for the auxiliary building filters. The filter efficiencies modeled were 99% for aerosols, 90% for elemental iodine and 70% for organic iodine [Ref 14, 32]. There is a delay of 20 minutes before the auxiliary building filters are lined up to filter air exhausting from the safeguards building and auxiliary building. This is a required operator action that is currently in 1(2)-E-0, Step 17. The ventilation path from the safeguards and auxiliary buildings to vent stack no. 2 via the 1(2)-VS-F-58A(B) fan was modeled as working.

20. The control room volume is 2.23E5 cubic feet [ ].

21. Control room filter efficiency is 99% for aerosols, 90% for elemental iodine, and 70% for organic iodine [Ref 14, 32].

22. The atmospheric dispersion factors used in this analysis were computed in [ ]. In that calculation two sets of meteorological data - one for data from 1982 to 1986 and one for data from 1994 to 1998 - were used to compute two sets of atmospheric dispersion factors for both onsite and offsite releases. The larger of the two sets of atmospheric dispersion factors were conservatively used in this analysis. This means that the onsite atmospheric dispersion factors based on the 1982-1986 data were used and the offsite atmospheric dispersion factors based on the 1994-1998 data were used.

For the first 24 hours of the LOCA, this analysis uses the atmospheric dispersion factors which model the turbine building fresh air louvers as the receptor points for the control room emergency air intakes. As long as the turbine building fans are running, i.e. no LOOP, the shortest path to the control room emergency air intakes would be through the turbine building fresh air louvers. After 24 hours it is assumed that the turbine building fans would be turned off. Thus, after 24 hours the atmospheric dispersion factors which modeled the turbine building fresh air pits and rollup doors as the receptor points for the control room emergency air intakes were used.

The atmospheric dispersion factors used are shown in tabular form below in units of seconds per cubic meter.

Table 5 - Atmospheric Dispersion Factors

Source	Receptor	0-2 hr	0-8 hr	8-24 hr	24-96 hr	96-720 hr
Contain-ment (Unit 1)	TB Fresh Air Intake#1		5.18E-04	2.22E-04	1.66E-04	1.20E-04
	TB Fresh Air Louver#1		1.69E-03	7.19E-04	5.62E-04	4.03E-04
	EAB	3.40E-03	1.85E-03	1.36E-03	7.03E-4	2.72E-04
	LPZ		1.66E-04	9.76E-05	3.06E-05	5.79E-06
Vent Stack No. 2	TB Fresh Air Louver#3		1.60E-03	6.99E-04	5.07E-04	3.60E-04
	TB Fresh Air Pit#2		5.38E-04	2.28E-04	1.71E-04	1.19E-04
	TB Rollup Door#2		5.40E-04	2.30E-04	1.69E-04	1.22E-04

The offsite set of atmospheric dispersion factors calculated based on the 1994-1998 meteorological data did not include all the geometry's found in the set of atmospheric dispersion factors calculated with the 1982-1886 meteorological data. Specifically, there were no atmospheric dispersion factors for the vent stack no.2 to EAB or LPZ geometry's. Therefore, the atmospheric dispersion factors for the unit #1 containment to EAB and LPZ geometry's were used for both the unit #1 containment to the EAB and LPZ geometry's and the vent stack no.2 to EAB and LPZ geometry's. Since the differences between the two geometry's based on the 1982-1986 meteorological data is small, the differences for the 1994-1998 meteorological data should be small as well.

23. For ECCS leakage into the auxiliary building, the vent stack atmospheric dispersion factors are used after 20 min. This is because the ventilation will be aligned to normal and the safeguards and auxiliary building ventilation exhaust flow will go out vent stack no. 2. See assumption no. 8 and design input no. 19.

24. The dose conversion factors are taken from Federal Guidance Reports 11 and 12 [Ref 4, 27] and are shown in Table 3.

25. The control room breathing rate and occupancy factors came from Draft Guide 1081 and Safety Guide 1.4 and were 3.47E-4 cubic meters per second and 100% occupancy for the first 24 hours and 60% occupancy for the next 72 hours and 40% occupancy for the next 624 hours. The offsite breathing rates came from Draft Guide 1081 and were 3.47E-4 cubic meters per second for the first 8 hours and 1.75E-4 cubic meters per second for 8 to 24 hours and 2.32E-4 cubic meters per second for 24 hours to the end of the accident.

4) ASSUMPTIONS:

1. In order to maximize the dose consequences, it was assumed that the LOCA occurs without a concurrent loss of offsite power. This meant that larger atmospheric dispersion factors would be used until the fans causing the increase in atmospheric dispersion factors - the turbine building fresh air louver fans - were turned off. It was assumed that the turbine building fans would be turned off if a LOCA occured without a concurrent loss of offsite power within 24 hours. The fans that are to be secured within 24 hours are listed below in Table 6.

2. It is assumed that the control room operators will turn on the emergency control room fans 60 minutes or more after the accident occurs but not after the bottled air has been depleted [ ].

Table 6 - Turbine Building Supply Fans to be Turned Off Within 24 Hours

	Fan Mark Number
Unit 1	1-VS-F-28A
	1-VS-F-28B
	1-VS-F-28C
Unit 2	2-VS-F-28A
	2-VS-F-28B
	2-VS-F-28C

3. It is assumed that there are no pathways for inter-building transport of airborne radioactive effluents. Specifically, it is assumed that there is no flow of air between the auxiliary building and the turbine building via the pipe tunnel. This can be accomplished by balancing turbine building fans or blocking off the tunnel. After a LOCA it is assumed that the turbine building supply fans listed in Table 6 would be turned off. If the pipe tunnel between the auxiliary building and the turbine building were not blocked off, then the turbine building exhaust fans would have to be turned off at the same time the turbine building supply fans were turned off to prevent air from being pulled out of the auxiliary building by the turbine building exhaust fans.

4. It is assumed that the RWST will only leak 10 cfm air inward. It is also assumed that the non seismic 8" vent pipe will not fail catastrophically in a seismic event. It is conservative to assume that the pipe does not fail. If the pipe were to fail then there would be no suction on the RWST to draw the iodine gas out of the RWST. For more details see the section "RWST Leakage" under "Calculations and Methodology".

5. Unfiltered air leakage into the control room is assumed to be 10 cfm for the duration of the accident [ ]. A set of scoping runs was also done with the unfiltered control room inleakage set at 350 cfm.

6. Control room filtered intake is assumed to be at a rate of 1000 cfm [ ]. This represents the intake of 1 control room emergency fan. This intake starts at 1 hr after the bottled air is depleted. NOTE: Additional LOCADOSE runs were also made with two control room fans running. This was done to determine whether one fan or two fans would produce the highest doses in the control room.

7. With the exception of one scoping run involving RWST leakage, it was assumed that the auxiliary building filters are not in service. However, the ventilation path from the safeguards and auxiliary buildings to vent stack no. 2 via the 1(2)-VS-F-58A(B) fan was modeled as working.

8. It is assumed that the containment shine and cloud shine doses are small enough to ignore because of the thickness of the control room walls [Ref 33, 34] in accordance with Reference no. 20.

9. The 1(2)-VS-F-58A(B) fan is assumed to be lined up initially in refueling mode and to not be switched over to normal alignment until 20 minutes after the onset of the accident. When in refueling mode, an SI signal will not cause automatic realignment of the ventilation. This means that the safeguards and auxiliary building will not

be ventilated for 20 minutes. This is a required operator action that is currently in 1(2)-E-0, Step 17. However, the 20 minute action time is a reduction from the 30 minutes currently assumed.

10. Only one train of the containment spray and one train of the inside recirculation and one train of the outside recirculation were assumed to be working. This was based on single failure criteria.

11. It is assumed that after 24 hours all non-essential personnel are evacuated from the exclusion area. This means that for the passive failure - which is defined to occur at 24 hours - the offsite dose point at the EAB is not considered.

5) CALCULATIONS AND METHODOLOGY:

There are four release or leakage paths modeled in this analysis - containment leakage, ECCS leakage, RWST leakage and passive failure.

CONTAINMENT LEAKAGE

CONTAINMENT LEAKAGE - LOCADOSE Time Steps
The containment leakage consists of the airborne particulates and gases which leak out the containment at the rate of 0.1% of the volume of containment per day. To model this leakage, the airborne contents of the containment must be calculated as a function of time. This is done using LOCADOSE by breaking the event into discreet time steps. The size or duration of the time steps is determined by how quickly the input parameters change. Table 7 shows the changes in LOCADOSE input parameters which determine the time steps.

Table 7 - Timing of Events for Containment Release

Time		Event
	0 hr	Start gap activity release into containment Start containment release to environment Start control room unfiltered inleakage
100 sec	2.78E-2 hr	Start aerosol removal by sprays in containment
216 sec	6.00E-2 hr	Change aerosol spray removal rate in containment
415 sec	0.115 hr	Change aerosol spray removal rate in containment
700 sec	0.194 hr	Change aerosol spray removal rate in containment
30 min	0.5 hr	Stop gap activity release into containment Start release of early in-vessel activity into containment
	1 hr	Stop containment release to environment Start control room filtered intake
4100 sec	1.14 hr	Change aerosol spray removal rate in containment
	1.8 hr	Stop release of early in-vessel activity into containment Change aerosol spray removal rate in containment
	1.9 hr	Change aerosol spray removal rate in containment
	2 hr	Change aerosol spray removal rate in containment
	2.33 hr	Stop spray removal of elemental iodine Change EAB χ/Q to 0
	2.51 hr	Change aerosol spray removal rate in containment
	4.38 hr	Change aerosol spray removal rate in containment
	6.48 hr	Change aerosol spray removal rate in containment
	8 hr	Change control room and offsite χ/Q
1 day	24 hr	Change control room and offsite χ/Q and occupancy factor Change onsite atmospheric dispersion factors to those which use the turbine building fresh air intakes & rollup doors as receptors
4 day	96 hr	Change control room and offsite χ/Q and occupancy factor
30 day	720 hr	End of accident

CONTAINMENT LEAKAGE - Source Term and Dose Conversion Factors

NUREG-1465 breaks the core releases into the fuel gap release phase in the first 30 minutes of a LOCA and the early in-vessel release phase in the subsequent 1.3 hours of a LOCA. The other release phases mentioned in NUREG-1465 [Ref 1] are not considered for design basis accidents according to NRC guidance [Ref 22]. Table 8 shows the core fractions released by LOCADOSE isotope group as well as the elements which are contained in each LOCADOSE isotope group. Table 9 shows the rate of release or production rate in core fractions per hour for each element assuming the releases are linear with respect to time. Table 9 breaks the production rates down into sprayed and unsprayed regions of containment based on the spray coverage being 60% of the containment volume.

LOCADOSE has an interface called the LOCADOSE Center where the user can generate a library file. From the list of available isotopes, the user can select the ones to include in the library. For this calculation the isotopes were limited to those listed in Table 3. The normal LOCADOSE library input file contains the fission yield in Curies per megawatt, the decay constant and the dose conversion factors for each isotope in the library. The fission yields (Ci/MWt) in a standard LOCADOSE library are based on TID-14844 [Ref 2]. The library file used to model the containment airborne leakage was modified such that the TID based Ci/MWt values were replaced with those calculated by ORIGEN2 specifically for Surry. These Surry specific fission yields are shown in Table 3. Since the dose conversion factors in Federal Guidance Reports 11 and 12 were not available in LOCADOSE Center, the library file was also modified to replace the normal RG-1.109 or ICRP-30 dose conversion factors with the Federal Guidance Report 11 and 12 dose conversion factors. These dose conversion factors are also shown in Table 3.

Table 8 - Core Release Fractions

LOCADOSE		NUREG-1465		Core Release Fractions	
Group	Description	Description	Elements	Gap	Early In-Vessel
1	Iodine (Elemental)	Halogens	I	0.05	0.35
2	Iodine (Organic)	Halogens	I	0.05	0.35
3	Iodine (Particulate)	Halogens	I	0.05	0.35
4	Noble Gases	Noble Gases	Kr, Xe	0.05	0.95
5	Cesium & Rubidium	Alkali Metals	Cs, Rb	0.05	0.25
6	Tellurium & Antimony	Tellurium Group	Sb, Se, Te	0	0.05
7	Barium & Strontium	Barium, Strontium	Ba, Sr	0	0.02
8	Noble Metals	Noble Metals	Co, Mo, Pd, Rh, Ru, Tc	0	0.0025
9	Rare Earths	Cerium Group	Ce	0	0.0005
10	Others			0	0
11	Halogens	Halogens	Br	0.05	0.35
12	Transuranics	Cerium Group	Np, Pu	0	0.0005
		Lanthanides	Am, Cm, Eu, La, Nb Nd, Pm, Pr, Y, Zr	0	0.0002
Release Duration (hr)				0.5	1.3

Table 9 - Core Release Rates by Element

	Core Fractions		Core Release Rates (Fraction per Hour)			
		Early	Gap		Early In-Vessel	
Element	Gap	In-Vessel	Sprayed	Unsprayed	Sprayed	Unsprayed
Am	0	0.0002	0.00E+00	0.00E+00	9.23E-05	6.15E-05
Ba	0	0.02	0.00E+00	0.00E+00	9.23E-03	6.15E-03
Br	0.05	0.35	6.00E-02	4.00E-02	1.62E-01	1.08E-01
Ce	0	0.0005	0.00E+00	0.00E+00	2.31E-04	1.54E-04
Cm	0	0.0002	0.00E+00	0.00E+00	9.23E-05	6.15E-05
Co	0	0.0025	0.00E+00	0.00E+00	1.15E-03	7.69E-04
Cs	0.05	0.25	6.00E-02	4.00E-02	1.15E-01	7.69E-02
Eu	0	0.0002	0.00E+00	0.00E+00	9.23E-05	6.15E-05
I	0.05	0.35	6.00E-02	4.00E-02	1.62E-01	1.08E-01
Kr	0.05	0.95	6.00E-02	4.00E-02	4.38E-01	2.92E-01
La	0	0.0002	0.00E+00	0.00E+00	9.23E-05	6.15E-05
Mo	0	0.0025	0.00E+00	0.00E+00	1.15E-03	7.69E-04
Nb	0	0.0002	0.00E+00	0.00E+00	9.23E-05	6.15E-05
Nd	0	0.0002	0.00E+00	0.00E+00	9.23E-05	6.15E-05
Np	0	0.0005	0.00E+00	0.00E+00	2.31E-04	1.54E-04
Pd	0	0.0025	0.00E+00	0.00E+00	1.15E-03	7.69E-04
Pm	0	0.0002	0.00E+00	0.00E+00	9.23E-05	6.15E-05
Pr	0	0.0002	0.00E+00	0.00E+00	9.23E-05	6.15E-05
Pu	0	0.0005	0.00E+00	0.00E+00	2.31E-04	1.54E-04
Rb	0.05	0.25	6.00E-02	4.00E-02	1.15E-01	7.69E-02
Rh	0	0.0025	0.00E+00	0.00E+00	1.15E-03	7.69E-04
Ru	0	0.0025	0.00E+00	0.00E+00	1.15E-03	7.69E-04
Sb	0	0.05	0.00E+00	0.00E+00	2.31E-02	1.54E-02
Se	0	0.05	0.00E+00	0.00E+00	2.31E-02	1.54E-02
Sm	0	0.0002	0.00E+00	0.00E+00	9.23E-05	6.15E-05
Sr	0	0.02	0.00E+00	0.00E+00	9.23E-03	6.15E-03
Tc	0	0.0025	0.00E+00	0.00E+00	1.15E-03	7.69E-04
Te	0	0.05	0.00E+00	0.00E+00	2.31E-02	1.54E-02
Xe	0.05	0.95	6.00E-02	4.00E-02	4.38E-01	2.92E-01
Y	0	0.0002	0.00E+00	0.00E+00	9.23E-05	6.15E-05
Zr	0	0.0002	0.00E+00	0.00E+00	9.23E-05	6.15E-05

Notes:
1. The core fractions are from Table 8.
2. The total core release rate for an element during the gap release phase is obtained by dividing the core fraction by 0.5 hr [Table 8]. This is then multiplied by 60% (spray coverage) and 40% to get the release rates for the sprayed and unsprayed regions, respectively. The release rates for the early in-vessel phase are calculated in the same manner except that the duration is 1.3 hr [Table 8].

The dose resulting from immersion in an airborne cloud of radionuclides is labeled in the LOCADOSE output "Eff-Immer". This corresponds to the DDE part of the TEDE. The dose resulting from inhalation of airborne radionuclides is labeled "Eff-Inhal" in the LOCADOSE output. This dose corresponds to the CEDE part of the TEDE. The TEDE dose is the sum of immersion and inhalation (DDE and CEDE) doses output by LOCADOSE. This summation must be done manually. LOCADOSE does not sum these two doses automatically.

CONTAINMENT LEAKAGE - Spray Lambdas

Unique to this release path was the use of spray lambdas to model the effectiveness of the containment spray and recirculation spray systems in removing airborne radioisotopes. The computation of the effective spray lambdas was carried out according to the methods and equations contained in NUREG/CR-5966 [Ref 3].

To simplify the modeling of the spray headers, both the containment spray dome headers are modeled at the elevation of 142'5" and the 5 remaining headers - 4 recirculation spray headers and containment spray crane wall header - are modeled at the elevation of 93'5".

NUREG/CR-5966 [Ref 3, Page 173] presents the following equations for aerosol removal rate for the 10 percentile level:

$$\ln\left(\lambda_{m_f=0.9}\right) = 5.5750 + (0.94362)\ln Q - (7.327\mathrm{E}-7)QH^2 - (6.9821\mathrm{E}-3)Q^2H + (3.555\mathrm{E}-6)Q^2H^2$$

$$\frac{\lambda_{m_f}}{\lambda_{m_f=0.9}} = [0.1108 - (0.00201)\log_{10} Q]\left[1 - \left(\frac{m_f}{0.9}\right)^{0.8945}\right] + \left(\frac{m_f}{0.9}\right)^{0.8945}$$

where λ is the removal rate, m_f is the mass fraction remaining in the containment, H is the spray drop height, and Q is the spray water flux, calculated by dividing the spray flow rate by the cross-sectional area of the containment. The first equation above is used to calculate the removal rate corresponding to a mass fraction of 0.9. Plugging this value into the second equation yields the removal for a given value of mass fraction. Since the removal rate is dependent on drop height and spray rate, each of the 4 spray headers has a different removal rate. For the dome headers, drop height and spray flux are calculated as follows:

H = (142'5") - (47'4") = 95.1 ft = 2.90E3 cm

Q = (834 gal/min)(0.13368 ft^3/gal)/(1.25E4 ft^2) = 8.92E-3 ft/min = 4.53E-3 cm/sec
(100 - 700 sec)

Q = (958 gal/min)(0.13368 ft^3/gal)/(1.25E4 ft^2) = 1.02E-2 ft/min = 5.20E-3 cm/sec
(700 - 4100 sec)

The following table shows the removal rates, assuming the mass fraction remains at 0.9. The last two columns indicate the time step during which the removal rate is in effect. The 2.78E-02 hours corresponds to 100 seconds and the 1.94E-01 hours corresponds to 700 seconds. The 1.14 hours corresponds to 4100 seconds and is the time at which the containment spray flow is terminated upon emptying the RWST.

Table 10 - Containment Spray Aerosol Lambda's

M_f	Q (cm/sec)	H (cm)	Removal Constant (hr^{-1})			Time (hr)	
			$\lambda_{mf=.9}$	$\lambda_{mf}/\lambda_{mf=.9}$	λ_{mf}	From	To
9.00E-01	4.53E-03	2.90E+03	1.58E+00	1.00E+00	1.58E+00	2.78E-02	1.94E-01
9.00E-01	5.20E-03	2.90E+03	1.79E+00	1.00E+00	1.79E+00	1.94E-01	1.14E+00
9.00E-01	0.00E+00	2.90E+03	0.00E+00	0.00E+00	0.00E+00	1.14E+00	7.20E+02

For the recirculation spray headers and containment spray crane wall headers the fall height is modeled as follows:

H = (93'5") - (47'4") = 46.1 ft = 1.40E3 cm

As with the dome headers above, a time-dependent Q value is calculated for each of these lower headers. Where 2 or more headers are in operation during a time step, the Q values are added, resulting in the following table:

Table 11 - Recirculation Spray Aerosol Lambda's

m_f	Q (cm/sec)	H (cm)	Removal Constant (hr^{-1})			Time (hr)	
			$\lambda_{mf=.9}$	$\lambda_{mf}/\lambda_{mf=.9}$	λ_{mf}	From	To
9.00E-01	5.19E-03	1.40E+03	1.83E+00	1.00E+00	1.83E+00	2.78E-02	6.00E-02
9.00E-01	1.99E-02	1.40E+03	6.34E+00	1.00E+00	6.34E+00	6.00E-02	1.15E-01
9.00E-01	3.62E-02	1.40E+03	1.09E+01	1.00E+00	1.09E+01	1.15E-01	1.94E-01
9.00E-01	3.66E-02	1.40E+03	1.10E+01	1.00E+00	1.10E+01	1.94E-01	1.14E+00
9.00E-01	3.10E-02	1.40E+03	9.47E+00	1.00E+00	9.47E+00	1.14E+00	1.80E+00
5.00E-01	3.10E-02	1.40E+03	9.47E+00	6.38E-01	6.04E+00	1.80E+00	1.90E+00
3.00E-01	3.10E-02	1.40E+03	9.47E+00	4.46E-01	4.22E+00	1.90E+00	2.02E+00
1.00E-01	3.10E-02	1.40E+03	9.47E+00	2.38E-01	2.25E+00	2.02E+00	2.51E+00
1.00E-02	3.10E-02	1.40E+03	9.47E+00	1.30E-01	1.23E+00	2.51E+00	4.38E+00
1.00E-03	3.10E-02	1.40E+03	9.47E+00	1.16E-01	1.10E+00	4.38E+00	6.48E+00
1.00E-04	3.10E-02	1.40E+03	9.47E+00	1.14E-01	1.08E+00	6.48E+00	8.61E+00
1.00E-50	3.10E-02	1.40E+03	9.47E+00	1.14E-01	1.08E+00	8.61E+00	7.20E+02

NUREG/CR-5966 recommends that for a volume with continuing source, the removal constant associated with a mass fraction of 0.9 be used until the time-dependent source terminates [Ref 3, Page 170]. Hence, the mass fraction is assumed to remain at 0.9 from the start of the sprays until the end of the early in-vessel release phase at 1.8 hr. After this phase, the removal rate is adjusted stepwise by varying the mass fraction. The duration of time, t, required to change from a mass fraction m_{f0} to m_{f1} is determined using the following formula:

$$m_{f1} = m_{f0}e^{-\lambda t}$$

$$t = \ln(m_{f0}/m_{f1})/\lambda$$

For example, it is seen in the above table that it takes 0.1 hr (1.80 to 1.90 hr) to reduce the iodine mass fraction from 0.9 to 0.5. During this time step, the removal rate is assumed to be constant at 6.04 hr^{-1}.

The removal rates for the dome headers and the lower headers are combined from the tables above to yield the following effective removal rates for all the sprays:

Table 12 - Combined Containment and Recirculation Spray Aerosol Lambda's

Aerosol Removal Constant Time (hr)		λ_{mf}
From	To	(hr^{-1})
2.78E-02	6.00E-02	3.40E+00
6.00E-02	1.15E-01	7.92E+00
1.15E-01	1.94E-01	1.25E+01
1.94E-01	1.14E+00	1.28E+01
1.14E+00	1.80E+00	9.47E+00
1.80E+00	1.90E+00	6.04E+00
1.90E+00	2.02E+00	4.22E+00
2.02E+00	2.51E+00	2.25E+00
2.51E+00	4.38E+00	1.23E+00
4.38E+00	6.48E+00	1.10E+00
6.48E+00	8.61E+00	1.08E+00
8.61E+00	7.20E+02	1.08E+00

The removal of elemental iodine by sprays continues at a rate of 10 hr^{-1} until a decontamination factor (DF) of 200 is reached [Ref 31]. The DF is reached when the elemental iodine activity in the containment at the end of the early in-vessel release phase is reduced by a factor of 200 [Ref 31]. The time it takes to reduce the activity by 200 is determined as follows:

$$A = A_0e^{-\lambda t}$$

$$DF = A_0/A = e^{\lambda t}$$

$t = \ln(DF)/\lambda = \ln(200)/10 = 0.53$ hr

This is the duration required starting at the end of early in-vessel phase at 1.8 hr. Hence, the post accident time at which elemental iodine removal stops is:

Stop time = 1.80 hr + 0.53 hr = 2.33 hr

Spray removal of organic iodine is not modeled.

CONTAINMENT LEAKAGE - Nodes and Flows

The LOCADOSE computer code model represents the containment airborne to environment leakage with four volumes or nodes: (1) the environment, (2) the portion of the containment covered by the containment spray systems, (3) the portion of the containment not covered by the containment spray systems, and (4) the control room.

Note that the environment is always considered by LOCADOSE to be volume or node number 1 and to have an infinite volume. The diagram below shows how the containment airborne to environment release path was modeled in LOCADOSE.

```
 _____________
|             |            Environment
| Containment |             (Node #1)
|             |
|  Sprayed    |----------\
|   Region    |          |
|  (Node #2)  |          |
|             |          |                          _______________
|     ^       |          |                         |               |
|-----|--|----|          |                         | Control Room  |
|     V       |          |                         |  (Node #4)    |
| Unsprayed   |          `--------------->      ##                |
|   Region    |-------------------------->      ## control room   |
|  (Node #3)  |                                 |    filters    |
|             |                                 |               |
|-------------|~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~|---------------|
```

The transfer of radionuclides is modeled in LOCADOSE by specifying flow rates between the various volumes or nodes modeled. The input for these flow rates is described below.

The mixing rate between the sprayed and unsprayed containment nodes was modeled based on 2 unsprayed volumes per hour. The containment is modeled as 60% sprayed. Thus, the volumes for sprayed and unsprayed regions are as follows:

Sprayed volume (1.863E6 ft^3)(0.6) = 1.118E6 ft^3
Unsprayed volume 1.863E6 ft^3 - 1.118E6 ft^3 = 7.452E5 ft^3

The mixing flow rate between the sprayed and unsprayed regions is 2 X 7.452E5 cubic feet every 60 minutes which equals 2.48E4 cfm.

The leak rate of 0.1% volume per day translates to the following release rates to the environment:

Sprayed region (0.001 /day)(1.12E6 cubic ft^3)/[(24 hr/day)(60 min/hr)] = 0.776 cfm
Unsprayed region (0.001 /day)(7.45E5 cubic ft^3)/[(24 hr/day)(60 min/hr)] = 0.518 cfm

As stated in the design inputs section the volume of the control room is 2.23E5 cubic feet.

As stated in the assumptions section the filtered fan flow into the control room is 1000 cfm and the unfiltered leakage into the control is 10 cfm.

CONTAINMENT LEAKAGE - Atmospheric Dispersion Factors

The control room atmospheric dispersion factors used for the first 24 hours of the LOCA were based on the unit #1 containment as the source point and the turbine building fresh air louver#1 as the receptor point for the control room emergency air intakes. This was because for the first 24 hours of the LOCA it was assumed that the turbine building fans are running. The turbine building fans pull in air through the turbine building fresh air louvers. The atmospheric dispersion factor for fresh air louver#1 was the largest of the atmospheric dispersion factors for the turbine building fresh air louvers. After the turbine building fans are turned off, the turbine building rollup door on the east side of the turbine building was used as the receptor point for the control room emergency air intakes. Without the turbine building fans pulling air in at the fresh air louvers, the east side rollup door has the largest atmospheric dispersion factor of the possible turbine building entry points.

CONTAINMENT LEAKAGE - Breathing Rates and Occupancy Factors

The control room breathing rate and occupancy factors came from Draft Guide 1081 and Safety Guide 1.4 and were 3.47E-4 cubic meters per second and 100% occupancy for the first 24 hours and 60% occupancy for the next 72 hours and 40% occupancy for the next 624 hours. The offsite breathing rates came from Draft Guide 1081 and were 3.47E-4 cubic meters per second for the first 8 hours and 1.75E-4 cubic meters per second for 8 to 24 hours and 2.32E-4 cubic meters per second for 24 hours to the end of the accident.

CONTAINMENT LEAKAGE - LOCADOSE Input Files

The LOCATRAN and LOCADOSE input files used to model the doses from containment leakage are contained in Tables 13 and 14 respectively.

Table 13 - LOCATRAN Input File for Modeling Containment Leakage

```
LOCA EAB0.5hr CR10cfm Containment Leak w/24hr turb fan delay        Prob title
D.L. Gilliatt                                                        Originator
Surry                                                                 Proj name
Alternate Source Term                                                    Proj #
PA-0163, 0                                                          Calc #, Rev
1                                                            First page # of output
2 18 139 1 0 0                 # Nodes, # Time steps, # Iso, CR, Dau, Spr cutoff
1 0 2605 -1 2 0 0      TID, Purge, Pwr, SD time, NPF, # Spr nodes, # Delay calcs
CFM  CUFT CURIES                          Flow unit, Volume unit, Activity unit
1 1 1 1 1 1 1 1 1 1 1 1                          Release frac for iso grps 1-12
.0485 .0015 .95                                    Elem, org, part iodine frac
 Sprayed Unsprayed                                            Names for nodes 2-3
0 2.78E-2 1 0 0 1     Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 1 1                                          Initial act, Prod terms, Volume
 6.00E-02 4.00E-02   Production rate (core frac/hr) in nodes 2-3 for elem I--130
 6.00E-02 4.00E-02                                                   elem I--131
 6.00E-02 4.00E-02                                                   elem I--132
 6.00E-02 4.00E-02                                                   elem I--133
 6.00E-02 4.00E-02                                                   elem I--134
 6.00E-02 4.00E-02                                                   elem I--135
 6.00E-02 4.00E-02                                                   elem I--136
 6.00E-02 4.00E-02                                                   elem I--137
 6.00E-02 4.00E-02                                                   elem I--138
 6.00E-02 4.00E-02                                                    org I--130
 6.00E-02 4.00E-02                                                    org I--131
 6.00E-02 4.00E-02                                                    org I--132
 6.00E-02 4.00E-02                                                    org I--133
 6.00E-02 4.00E-02                                                    org I--134
 6.00E-02 4.00E-02                                                    org I--135
 6.00E-02 4.00E-02                                                    org I--136
 6.00E-02 4.00E-02                                                    org I--137
 6.00E-02 4.00E-02                                                    org I--138
 6.00E-02 4.00E-02                                                   part I--130
 6.00E-02 4.00E-02                                                   part I--131
 6.00E-02 4.00E-02                                                   part I--132
 6.00E-02 4.00E-02                                                   part I--133
 6.00E-02 4.00E-02                                                   part I--134
 6.00E-02 4.00E-02                                                   part I--135
 6.00E-02 4.00E-02                                                   part I--136
 6.00E-02 4.00E-02                                                   part I--137
 6.00E-02 4.00E-02                                                   part I--138
 6.00E-02 4.00E-02                                                        KR--85
 6.00E-02 4.00E-02                                                        KR--87
 6.00E-02 4.00E-02                                                        KR--88
 6.00E-02 4.00E-02                                                        KR--89
 6.00E-02 4.00E-02                                                       KR-83M
 6.00E-02 4.00E-02                                                       KR-85M
 6.00E-02 4.00E-02                                                       XE-133
 6.00E-02 4.00E-02                                                       XE-135
 6.00E-02 4.00E-02                                                       XE-137
 6.00E-02 4.00E-02                                                       XE-138
 6.00E-02 4.00E-02                                                      XE131M
```

6.00E-02	4.00E-02	XE133M
6.00E-02	4.00E-02	XE135M
6.00E-02	4.00E-02	CS-134
6.00E-02	4.00E-02	CS-136
6.00E-02	4.00E-02	CS-137
6.00E-02	4.00E-02	CS-138
6.00E-02	4.00E-02	CS-139
6.00E-02	4.00E-02	CS134M
6.00E-02	4.00E-02	RB--86
6.00E-02	4.00E-02	RB--88
6.00E-02	4.00E-02	RB--89
6.00E-02	4.00E-02	RB--90
0.00E+00	0.00E+00	SB-124
0.00E+00	0.00E+00	SB-125
0.00E+00	0.00E+00	SB-126
0.00E+00	0.00E+00	SB-127
0.00E+00	0.00E+00	SB-129
0.00E+00	0.00E+00	TE-127
0.00E+00	0.00E+00	TE-129
0.00E+00	0.00E+00	TE-131
0.00E+00	0.00E+00	TE-132
0.00E+00	0.00E+00	TE-133
0.00E+00	0.00E+00	TE-134
0.00E+00	0.00E+00	TE125M
0.00E+00	0.00E+00	TE127M
0.00E+00	0.00E+00	TE129M
0.00E+00	0.00E+00	TE131M
0.00E+00	0.00E+00	TE133M
0.00E+00	0.00E+00	BA-139
0.00E+00	0.00E+00	BA-140
0.00E+00	0.00E+00	BA-141
0.00E+00	0.00E+00	BA136M
0.00E+00	0.00E+00	BA137M
0.00E+00	0.00E+00	SR--89
0.00E+00	0.00E+00	SR--90
0.00E+00	0.00E+00	SR--91
0.00E+00	0.00E+00	SR--92
0.00E+00	0.00E+00	SR--93
0.00E+00	0.00E+00	SR--94
0.00E+00	0.00E+00	SR--95
0.00E+00	0.00E+00	CO--58
0.00E+00	0.00E+00	CO--60
0.00E+00	0.00E+00	MO--99
0.00E+00	0.00E+00	PD-109
0.00E+00	0.00E+00	RH-105
0.00E+00	0.00E+00	RH-106
0.00E+00	0.00E+00	RU-103
0.00E+00	0.00E+00	RH103M
0.00E+00	0.00E+00	RU-105
0.00E+00	0.00E+00	RU-106
0.00E+00	0.00E+00	TC-101
0.00E+00	0.00E+00	TC-99M
0.00E+00	0.00E+00	CE-141
0.00E+00	0.00E+00	CE-143

```
0.00E+00 0.00E+00                                                    CE-144
0.00E+00 0.00E+00                                                    EU-154
0.00E+00 0.00E+00                                                    EU-155
0.00E+00 0.00E+00                                                    EU-156
0.00E+00 0.00E+00                                                    LA-140
0.00E+00 0.00E+00                                                    LA-141
0.00E+00 0.00E+00                                                    LA-142
0.00E+00 0.00E+00                                                    LA-143
0.00E+00 0.00E+00                                                    NB--95
0.00E+00 0.00E+00                                                    NB--97
0.00E+00 0.00E+00                                                    NB-95M
0.00E+00 0.00E+00                                                    ND-147
0.00E+00 0.00E+00                                                    PM-147
0.00E+00 0.00E+00                                                    PM-148
0.00E+00 0.00E+00                                                    PM-149
0.00E+00 0.00E+00                                                    PM-151
0.00E+00 0.00E+00                                                    PM148M
0.00E+00 0.00E+00                                                    PR-143
0.00E+00 0.00E+00                                                    PR-144
0.00E+00 0.00E+00                                                    PR144M
0.00E+00 0.00E+00                                                    SM-153
0.00E+00 0.00E+00                                                    Y---90
0.00E+00 0.00E+00                                                    Y---91
0.00E+00 0.00E+00                                                    Y---92
0.00E+00 0.00E+00                                                    Y---93
0.00E+00 0.00E+00                                                    Y---94
0.00E+00 0.00E+00                                                    Y---95
0.00E+00 0.00E+00                                                    Y--91M
0.00E+00 0.00E+00                                                    ZR--95
0.00E+00 0.00E+00                                                    ZR--97
6.00E-02 4.00E-02                                                    BR--82
6.00E-02 4.00E-02                                                    BR--83
6.00E-02 4.00E-02                                                    BR--84
6.00E-02 4.00E-02                                                    BR--85
6.00E-02 4.00E-02                                                    BR--87
6.00E-02 4.00E-02                                                    BR--88
0.00E+00 0.00E+00                                                    AM-241
0.00E+00 0.00E+00                                                    AM-242
0.00E+00 0.00E+00                                                    CM-242
0.00E+00 0.00E+00                                                    CM-244
0.00E+00 0.00E+00                                                    NP-238
0.00E+00 0.00E+00                                                    NP-239
0.00E+00 0.00E+00                                                    PU-238
0.00E+00 0.00E+00                                                    PU-239
0.00E+00 0.00E+00                                                    PU-240
0.00E+00 0.00E+00                                                    PU-241
0.00E+00 0.00E+00                                                    PU-243
1.12E6 7.45E5                                          Volumes for nodes 2-3
2 1 0 .776                       Flow from node, Flow to node, Filt, Unfilt
 0 0 0 0 0 0 0 0 0 0 0 0                       Filter eff for iso grps 1-12
2 3 0 2.48E4                     Flow from node, Flow to node, Filt, Unfilt
 0 0 0 0 0 0 0 0 0 0 0 0                       Filter eff for iso grps 1-12
3 1 0 .518                       Flow from node, Flow to node, Filt, Unfilt
 0 0 0 0 0 0 0 0 0 0 0 0                       Filter eff for iso grps 1-12
```

```
 3 2 0 2.48E4                          Flow from node, Flow to node, Filt, Unfilt
  0 0 0 0 0 0 0 0 0 0 0 0                            Filter eff for iso grps 1-12
 -1 0 0 0                                                          End flow input
 -1 0 0 0                                                        End lambda input
 1 1.69E-3                        CR param chg, CR X/Q containment#1 to louver#1
  2.23E5 0 10 0 10                   CR vol, Filt in, Unfilt in, Recirc, Outleak
  90 70 99 0 99 99 99 99 99 0 99 99        Intake filt eff (%) for iso grps 1-12
  0 0 0 0 0 0 0 0 0 0 0 0                  Recirc filt eff (%) for iso grps 1-12
2.78E-2 6.00E-2 0 0 0 1   Start, Stop, Print act, Act unit, Prod unit, Print sum
 0 0 0                                              Initial act, Prod terms, Volume
 -1 0 0 0                                                          End flow input
 1 2 10.0                                                   Iso group, Node, Lambda
 3 2 3.40                                                   Iso group, Node, Lambda
 5 2 3.40                                                   Iso group, Node, Lambda
 6 2 3.40                                                   Iso group, Node, Lambda
 7 2 3.40                                                   Iso group, Node, Lambda
 8 2 3.40                                                   Iso group, Node, Lambda
 9 2 3.40                                                   Iso group, Node, Lambda
 11 2 3.40                                                  Iso group, Node, Lambda
 12 2 3.40                                                  Iso group, Node, Lambda
 -1 0 0 0                                                        End lambda input
 0 1.69E-3                        CR param chg, CR X/Q containment#1 to louver#1
6.00E-2 .115 0 0 0 1  Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                              Initial act, Prod terms, Volume
 -1 0 0 0                                                          End flow input
 3 2 7.92                                                   Iso group, Node, Lambda
 5 2 7.92                                                   Iso group, Node, Lambda
 6 2 7.92                                                   Iso group, Node, Lambda
 7 2 7.92                                                   Iso group, Node, Lambda
 8 2 7.92                                                   Iso group, Node, Lambda
 9 2 7.92                                                   Iso group, Node, Lambda
 11 2 7.92                                                  Iso group, Node, Lambda
 12 2 7.92                                                  Iso group, Node, Lambda
 -1 0 0 0                                                        End lambda input
 0 1.69E-3                        CR param chg, CR X/Q containment#1 to louver#1
.115 .194 0 0 0 1     Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                              Initial act, Prod terms, Volume
 -1 0 0 0                                                          End flow input
 3 2 12.5                                                   Iso group, Node, Lambda
 5 2 12.5                                                   Iso group, Node, Lambda
 6 2 12.5                                                   Iso group, Node, Lambda
 7 2 12.5                                                   Iso group, Node, Lambda
 8 2 12.5                                                   Iso group, Node, Lambda
 9 2 12.5                                                   Iso group, Node, Lambda
 11 2 12.5                                                  Iso group, Node, Lambda
 12 2 12.5                                                  Iso group, Node, Lambda
 -1 0 0 0                                                        End lambda input
 0 1.69E-3                        CR param chg, CR X/Q containment#1 to louver#1
.194 .5 1 0 0 1       Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                              Initial act, Prod terms, Volume
 -1 0 0 0                                                          End flow input
 3 2 12.8                                                   Iso group, Node, Lambda
 5 2 12.8                                                   Iso group, Node, Lambda
 6 2 12.8                                                   Iso group, Node, Lambda
```

```
 7 2 12.8                                                  Iso group, Node, Lambda
 8 2 12.8                                                  Iso group, Node, Lambda
 9 2 12.8                                                  Iso group, Node, Lambda
 11 2 12.8                                                 Iso group, Node, Lambda
 12 2 12.8                                                 Iso group, Node, Lambda
 -1 0 0 0                                                        End lambda input
 0 1.69E-3                        CR param chg, CR X/Q containment#1 to louver#1
.5 1 1 0 0 1            Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 1 0                                          Initial act, Prod terms, Volume
 1.62E-01 1.08E-01   Production rate (core frac/hr) in nodes 2-3 for elem I--130
 1.62E-01 1.08E-01                                                   elem I--131
 1.62E-01 1.08E-01                                                   elem I--132
 1.62E-01 1.08E-01                                                   elem I--133
 1.62E-01 1.08E-01                                                   elem I--134
 1.62E-01 1.08E-01                                                   elem I--135
 1.62E-01 1.08E-01                                                   elem I--136
 1.62E-01 1.08E-01                                                   elem I--137
 1.62E-01 1.08E-01                                                   elem I--138
 1.62E-01 1.08E-01                                                    org I--130
 1.62E-01 1.08E-01                                                    org I--131
 1.62E-01 1.08E-01                                                    org I--132
 1.62E-01 1.08E-01                                                    org I--133
 1.62E-01 1.08E-01                                                    org I--134
 1.62E-01 1.08E-01                                                    org I--135
 1.62E-01 1.08E-01                                                    org I--136
 1.62E-01 1.08E-01                                                    org I--137
 1.62E-01 1.08E-01                                                    org I--138
 1.62E-01 1.08E-01                                                   part I--130
 1.62E-01 1.08E-01                                                   part I--131
 1.62E-01 1.08E-01                                                   part I--132
 1.62E-01 1.08E-01                                                   part I--133
 1.62E-01 1.08E-01                                                   part I--134
 1.62E-01 1.08E-01                                                   part I--135
 1.62E-01 1.08E-01                                                   part I--136
 1.62E-01 1.08E-01                                                   part I--137
 1.62E-01 1.08E-01                                                   part I--138
 4.38E-01 2.92E-01                                                        KR--85
 4.38E-01 2.92E-01                                                        KR--87
 4.38E-01 2.92E-01                                                        KR--88
 4.38E-01 2.92E-01                                                        KR--89
 4.38E-01 2.92E-01                                                       KR-83M
 4.38E-01 2.92E-01                                                       KR-85M
 4.38E-01 2.92E-01                                                       XE-133
 4.38E-01 2.92E-01                                                       XE-135
 4.38E-01 2.92E-01                                                       XE-137
 4.38E-01 2.92E-01                                                       XE-138
 4.38E-01 2.92E-01                                                      XE131M
 4.38E-01 2.92E-01                                                      XE133M
 4.38E-01 2.92E-01                                                      XE135M
 1.15E-01 7.69E-02                                                       CS-134
 1.15E-01 7.69E-02                                                       CS-136
 1.15E-01 7.69E-02                                                       CS-137
 1.15E-01 7.69E-02                                                       CS-138
 1.15E-01 7.69E-02                                                       CS-139
```

1.15E-01	7.69E-02	CS134M
1.15E-01	7.69E-02	RB--86
1.15E-01	7.69E-02	RB--88
1.15E-01	7.69E-02	RB--89
1.15E-01	7.69E-02	RB--90
2.31E-02	1.54E-02	SB-124
2.31E-02	1.54E-02	SB-125
2.31E-02	1.54E-02	SB-126
2.31E-02	1.54E-02	SB-127
2.31E-02	1.54E-02	SB-129
2.31E-02	1.54E-02	TE-127
2.31E-02	1.54E-02	TE-129
2.31E-02	1.54E-02	TE-131
2.31E-02	1.54E-02	TE-132
2.31E-02	1.54E-02	TE-133
2.31E-02	1.54E-02	TE-134
2.31E-02	1.54E-02	TE125M
2.31E-02	1.54E-02	TE127M
2.31E-02	1.54E-02	TE129M
2.31E-02	1.54E-02	TE131M
2.31E-02	1.54E-02	TE133M
9.23E-03	6.15E-03	BA-139
9.23E-03	6.15E-03	BA-140
9.23E-03	6.15E-03	BA-141
9.23E-03	6.15E-03	BA136M
9.23E-03	6.15E-03	BA137M
9.23E-03	6.15E-03	SR--89
9.23E-03	6.15E-03	SR--90
9.23E-03	6.15E-03	SR--91
9.23E-03	6.15E-03	SR--92
9.23E-03	6.15E-03	SR--93
9.23E-03	6.15E-03	SR--94
9.23E-03	6.15E-03	SR--95
1.15E-03	7.69E-04	CO--58
1.15E-03	7.69E-04	CO--60
1.15E-03	7.69E-04	MO--99
1.15E-03	7.69E-04	PD-109
1.15E-03	7.69E-04	RH-105
1.15E-03	7.69E-04	RH-106
1.15E-03	7.69E-04	RU-103
1.15E-03	7.69E-04	RH103M
1.15E-03	7.69E-04	RU-105
1.15E-03	7.69E-04	RU-106
1.15E-03	7.69E-04	TC-101
1.15E-03	7.69E-04	TC-99M
2.31E-04	1.54E-04	CE-141
2.31E-04	1.54E-04	CE-143
2.31E-04	1.54E-04	CE-144
9.23E-05	6.15E-05	EU-154
9.23E-05	6.15E-05	EU-155
9.23E-05	6.15E-05	EU-156
9.23E-05	6.15E-05	LA-140
9.23E-05	6.15E-05	LA-141
9.23E-05	6.15E-05	LA-142

```
 9.23E-05 6.15E-05                                                    LA-143
 9.23E-05 6.15E-05                                                    NB--95
 9.23E-05 6.15E-05                                                    NB--97
 9.23E-05 6.15E-05                                                    NB-95M
 9.23E-05 6.15E-05                                                    ND-147
 9.23E-05 6.15E-05                                                    PM-147
 9.23E-05 6.15E-05                                                    PM-148
 9.23E-05 6.15E-05                                                    PM-149
 9.23E-05 6.15E-05                                                    PM-151
 9.23E-05 6.15E-05                                                    PM148M
 9.23E-05 6.15E-05                                                    PR-143
 9.23E-05 6.15E-05                                                    PR-144
 9.23E-05 6.15E-05                                                    PR144M
 9.23E-05 6.15E-05                                                    SM-153
 9.23E-05 6.15E-05                                                    Y---90
 9.23E-05 6.15E-05                                                    Y---91
 9.23E-05 6.15E-05                                                    Y---92
 9.23E-05 6.15E-05                                                    Y---93
 9.23E-05 6.15E-05                                                    Y---94
 9.23E-05 6.15E-05                                                    Y---95
 9.23E-05 6.15E-05                                                    Y--91M
 9.23E-05 6.15E-05                                                    ZR--95
 9.23E-05 6.15E-05                                                    ZR--97
 1.62E-01 1.08E-01                                                    BR--82
 1.62E-01 1.08E-01                                                    BR--83
 1.62E-01 1.08E-01                                                    BR--84
 1.62E-01 1.08E-01                                                    BR--85
 1.62E-01 1.08E-01                                                    BR--87
 1.62E-01 1.08E-01                                                    BR--88
 9.23E-05 6.15E-05                                                    AM-241
 9.23E-05 6.15E-05                                                    AM-242
 9.23E-05 6.15E-05                                                    CM-242
 9.23E-05 6.15E-05                                                    CM-244
 2.31E-04 1.54E-04                                                    NP-238
 2.31E-04 1.54E-04                                                    NP-239
 2.31E-04 1.54E-04                                                    PU-238
 2.31E-04 1.54E-04                                                    PU-239
 2.31E-04 1.54E-04                                                    PU-240
 2.31E-04 1.54E-04                                                    PU-241
 2.31E-04 1.54E-04                                                    PU-243
 -1 0 0 0                                                        End flow input
 -1 0 0 0                                                       End lambda input
 0 1.69E-3                        CR param chg, CR X/Q containment#1 to louver#1
1 1.14 0 0 0 1        Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 2 1 0 0                                Flow from node, Flow to node, Filt, Unfilt
  0 0 0 0 0 0 0 0 0 0 0 0                                Filter eff for iso grps 1-12
 3 1 0 0                                Flow from node, Flow to node, Filt, Unfilt
  0 0 0 0 0 0 0 0 0 0 0 0                                Filter eff for iso grps 1-12
 -1 0 0 0                                                        End flow input
 -1 0 0 0                                                       End lambda input
 1 1.69E-3                        CR param chg, CR X/Q containment#1 to louver#1
  2.23E5 1000 10 0 1010                CR vol, Filt in, Unfilt in, Recirc, Outleak
  90 70 99 0 99 99 99 99 99 0 99 99        Intake filt eff (%) for iso grps 1-12
```

```
 0 0 0 0 0 0 0 0 0 0 0 0                    Recirc filt eff (%) for iso grps 1-12
1.14 1.8 1 0 0 1      Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                        Initial act, Prod terms, Volume
 -1 0 0 0                                                     End flow input
 3 2 9.47                                            Iso group, Node, Lambda
 5 2 9.47                                            Iso group, Node, Lambda
 6 2 9.47                                            Iso group, Node, Lambda
 7 2 9.47                                            Iso group, Node, Lambda
 8 2 9.47                                            Iso group, Node, Lambda
 9 2 9.47                                            Iso group, Node, Lambda
 11 2 9.47                                           Iso group, Node, Lambda
 12 2 9.47                                           Iso group, Node, Lambda
 -1 0 0 0                                                   End lambda input
 0 1.69E-3                        CR param chg, CR X/Q containment#1 to louver#1
1.8 1.9 0 0 0 1       Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 1 0                                        Initial act, Prod terms, Volume
 0 0                  Production rate (core frac/hr) in nodes 2-3 for elem I--130
 0 0                                                              elem I--131
 0 0                                                              elem I--132
 0 0                                                              elem I--133
 0 0                                                              elem I--134
 0 0                                                              elem I--135
 0 0                                                              elem I--136
 0 0                                                              elem I--137
 0 0                                                              elem I--138
 0 0                                                               org I--130
 0 0                                                               org I--131
 0 0                                                               org I--132
 0 0                                                               org I--133
 0 0                                                               org I--134
 0 0                                                               org I--135
 0 0                                                               org I--136
 0 0                                                               org I--137
 0 0                                                               org I--138
 0 0                                                              part I--130
 0 0                                                              part I--131
 0 0                                                              part I--132
 0 0                                                              part I--133
 0 0                                                              part I--134
 0 0                                                              part I--135
 0 0                                                              part I--136
 0 0                                                              part I--137
 0 0                                                              part I--138
 0 0                                                                   KR--85
 0 0                                                                   KR--87
 0 0                                                                   KR--88
 0 0                                                                   KR--89
 0 0                                                                   KR-83M
 0 0                                                                   KR-85M
 0 0                                                                   XE-133
 0 0                                                                   XE-135
 0 0                                                                   XE-137
 0 0                                                                   XE-138
 0 0                                                                   XE131M
```

0	0	XE133M
0	0	XE135M
0	0	CS-134
0	0	CS-136
0	0	CS-137
0	0	CS-138
0	0	CS-139
0	0	CS134M
0	0	RB--86
0	0	RB--88
0	0	RB--89
0	0	RB--90
0	0	SB-124
0	0	SB-125
0	0	SB-126
0	0	SB-127
0	0	SB-129
0	0	TE-127
0	0	TE-129
0	0	TE-131
0	0	TE-132
0	0	TE-133
0	0	TE-134
0	0	TE125M
0	0	TE127M
0	0	TE129M
0	0	TE131M
0	0	TE133M
0	0	BA-139
0	0	BA-140
0	0	BA-141
0	0	BA136M
0	0	BA137M
0	0	SR--89
0	0	SR--90
0	0	SR--91
0	0	SR--92
0	0	SR--93
0	0	SR--94
0	0	SR--95
0	0	CO--58
0	0	CO--60
0	0	MO--99
0	0	PD-109
0	0	RH-105
0	0	RH-106
0	0	RU-103
0	0	RH103M
0	0	RU-105
0	0	RU-106
0	0	TC-101
0	0	TC-99M
0	0	CE-141
0	0	CE-143

```
0 0                                                    CE-144
0 0                                                    EU-154
0 0                                                    EU-155
0 0                                                    EU-156
0 0                                                    LA-140
0 0                                                    LA-141
0 0                                                    LA-142
0 0                                                    LA-143
0 0                                                    NB--95
0 0                                                    NB--97
0 0                                                    NB-95M
0 0                                                    ND-147
0 0                                                    PM-147
0 0                                                    PM-148
0 0                                                    PM-149
0 0                                                    PM-151
0 0                                                    PM148M
0 0                                                    PR-143
0 0                                                    PR-144
0 0                                                    PR144M
0 0                                                    SM-153
0 0                                                    Y---90
0 0                                                    Y---91
0 0                                                    Y---92
0 0                                                    Y---93
0 0                                                    Y---94
0 0                                                    Y---95
0 0                                                    Y--91M
0 0                                                    ZR--95
0 0                                                    ZR--97
0 0                                                    BR--82
0 0                                                    BR--83
0 0                                                    BR--84
0 0                                                    BR--85
0 0                                                    BR--87
0 0                                                    BR--88
0 0                                                    AM-241
0 0                                                    AM-242
0 0                                                    CM-242
0 0                                                    CM-244
0 0                                                    NP-238
0 0                                                    NP-239
0 0                                                    PU-238
0 0                                                    PU-239
0 0                                                    PU-240
0 0                                                    PU-241
0 0                                                    PU-243
-1 0 0 0                                         End flow input
3 2 6.04                                Iso group, Node, Lambda
5 2 6.04                                Iso group, Node, Lambda
6 2 6.04                                Iso group, Node, Lambda
7 2 6.04                                Iso group, Node, Lambda
8 2 6.04                                Iso group, Node, Lambda
9 2 6.04                                Iso group, Node, Lambda
```

```
 11 2 6.04                                          Iso group, Node, Lambda
 12 2 6.04                                          Iso group, Node, Lambda
 -1 0 0 0                                                 End lambda input
 0 1.69E-3                        CR param chg, CR X/Q containment#1 to louver#1
1.9 2 1 0 0 1        Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                        Initial act, Prod terms, Volume
 -1 0 0 0                                                   End flow input
 3 2 4.22                                           Iso group, Node, Lambda
 5 2 4.22                                           Iso group, Node, Lambda
 6 2 4.22                                           Iso group, Node, Lambda
 7 2 4.22                                           Iso group, Node, Lambda
 8 2 4.22                                           Iso group, Node, Lambda
 9 2 4.22                                           Iso group, Node, Lambda
 11 2 4.22                                          Iso group, Node, Lambda
 12 2 4.22                                          Iso group, Node, Lambda
 -1 0 0 0                                                 End lambda input
 0 1.69E-3                        CR param chg, CR X/Q containment#1 to louver#1
2 2.33 1 0 0 1        Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                        Initial act, Prod terms, Volume
 -1 0 0 0                                                   End flow input
 3 2 2.25                                           Iso group, Node, Lambda
 5 2 2.25                                           Iso group, Node, Lambda
 6 2 2.25                                           Iso group, Node, Lambda
 7 2 2.25                                           Iso group, Node, Lambda
 8 2 2.25                                           Iso group, Node, Lambda
 9 2 2.25                                           Iso group, Node, Lambda
 11 2 2.25                                          Iso group, Node, Lambda
 12 2 2.25                                          Iso group, Node, Lambda
 -1 0 0 0                                                 End lambda input
 0 1.69E-3                        CR param chg, CR X/Q containment#1 to louver#1
2.33 2.51 0 0 0 1     Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                        Initial act, Prod terms, Volume
 -1 0 0 0                                                   End flow input
 1 2 0                                              Iso group, Node, Lambda
 -1 0 0 0                                                 End lambda input
 0 1.69E-3                        CR param chg, CR X/Q containment#1 to louver#1
2.51 4.38 0 0 0 1     Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                        Initial act, Prod terms, Volume
 -1 0 0 0                                                   End flow input
 3 2 1.23                                           Iso group, Node, Lambda
 5 2 1.23                                           Iso group, Node, Lambda
 6 2 1.23                                           Iso group, Node, Lambda
 7 2 1.23                                           Iso group, Node, Lambda
 8 2 1.23                                           Iso group, Node, Lambda
 9 2 1.23                                           Iso group, Node, Lambda
 11 2 1.23                                          Iso group, Node, Lambda
 12 2 1.23                                          Iso group, Node, Lambda
 -1 0 0 0                                                 End lambda input
 0 1.69E-3                        CR param chg, CR X/Q containment#1 to louver#1
4.38 6.48 0 0 0 1     Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                        Initial act, Prod terms, Volume
 -1 0 0 0                                                   End flow input
 3 2 1.10                                           Iso group, Node, Lambda
 5 2 1.10                                           Iso group, Node, Lambda
```

```
 6 2 1.10                                                Iso group, Node, Lambda
 7 2 1.10                                                Iso group, Node, Lambda
 8 2 1.10                                                Iso group, Node, Lambda
 9 2 1.10                                                Iso group, Node, Lambda
 11 2 1.10                                               Iso group, Node, Lambda
 12 2 1.10                                               Iso group, Node, Lambda
 -1 0 0 0                                                      End lambda input
 0 1.69E-3                        CR param chg, CR X/Q containment#1 to louver#1
6.48 8 1 0 0 1        Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 -1 0 0 0                                                        End flow input
 3 2 1.08                                                Iso group, Node, Lambda
 5 2 1.08                                                Iso group, Node, Lambda
 6 2 1.08                                                Iso group, Node, Lambda
 7 2 1.08                                                Iso group, Node, Lambda
 8 2 1.08                                                Iso group, Node, Lambda
 9 2 1.08                                                Iso group, Node, Lambda
 11 2 1.08                                               Iso group, Node, Lambda
 12 2 1.08                                               Iso group, Node, Lambda
 -1 0 0 0                                                      End lambda input
 0 1.69E-3                        CR param chg, CR X/Q containment#1 to louver#1
8 24 1 0 0 1          Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 -1 0 0 0                                                        End flow input
 -1 0 0 0                                                      End lambda input
 0 7.19E-4                        CR param chg, CR X/Q containment#1 to louver#1
24 96 1 0 0 1         Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 -1 0 0 0                                                        End flow input
 -1 0 0 0                                                      End lambda input
 0 1.66E-4   CR param chg,CR X/Q containment#1 to TurbineBuild freshair intake#1
96 720 1 0 0 1        Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 -1 0 0 0                                                        End flow input
 -1 0 0 0                                                      End lambda input
 0 1.20E-4   CR param chg,CR X/Q containment#1 to TurbineBuild freshair intake#1
```

Table 14 - LOCADOSE Input File for Modeling Containment Leakage

```
LOCA EAB0.5hr CR10cfm Containment Leak w/24hr turb fan delay        Prob title
D.L. Gilliatt                                                        Originator
Surry                                                                 Proj name
Alternate Source Term                                                    Proj #
PA-0163, 0                                                          Calc #, Rev
1                                                        First page # of output
DORDOF                                   calculate DOses in Regions, DOses oFfsite
2 7 3 3 1 0 0     # DP, # X/Q, # BR offsite, # Occ fac, # BR onsite, Decay, File
REM REM/HR                                             Dose unit, Dose rate unit
3.40E-3 3.40E-3 3.40E-3 0 0 0 0                        SB X/Q for time steps 1-7
3.47E-4 0 0                                     SB breath rates for time steps 1-3
1.66E-4 1.66E-4 1.66E-4 1.66E-4 9.76E-5 3.06E-5 5.79E-6   LPZ X/Q time steps 1-7
3.47E-4 1.75E-4 2.32E-4                       LPZ breath rates for time steps 1-3
0.5 2 2.51 8 24 96 720                                   Time step end for X/Qs
8 24 720                                   Time step end for offsite breath rates
1 1                                     Gamma cloud correction factor for SB, LPZ
0 0 0                                              Occupancy factors for node 2
0                                                    Breathing rates for node 2
0 0 0                                              Occupancy factors for node 3
0                                                    Breathing rates for node 3
1 .6 .4                                         Occupancy factors for node 4 (CR)
3.47E-4                                           Breathing rates for node 4 (CR)
24 96 720                                       Time step end for occupancy factor
720                                          Time step end for onsite breathing rate
1 1 1                                   Gamma cloud correction factor for nodes 2-4
```

CONTAINMENT LEAKAGE - Additional LOCADOSE Runs

Four additional LOCADOSE runs were made. These scoping runs examined 1) the potential impact of increasing the unfiltered control room inleakage from 10 cfm to 350 cfm, 2) the impact of running two control room fans instead of one, 3) the impact of extending the containment airborne leakage phase from 1 hour to 4 hours but at the reduced leak rate of 0.021% of the containment volume per 24 hours between the first and fourth hour and 4) the impact of increasing the unfiltered control room inleakage from 10 cfm to 350 cfm in combination with the extended containment airborne leakage phase.

The third and fourth additional LOCADOSE run examined the radiological impact of extending the time before the containment returns to atmospheric pressure. In these cases the containment is modeled with a volumetric leak rate of 0.1% per day for the first hour and 0.021% per day for the next three hours. The flow rate of 0.021% per day was based on the requirement that the maximum containment pressure would be 0.5 psig for hours 1 through 4. To determine that a containment pressure of 0.5 psig would yield a flow rate of 0.021% per day, calculations were done using equations and tables from References no. 40 and 41. From Reference no. 40 the equation for compressible flow through an orifice is

$$q = YCA\sqrt{2g(144)\Delta P / \rho}$$

where q is the volumetric flow rate through the orifice, Y is the expansion factor, C is the flow coefficient, A is the area of the orifice, g is the acceleration of gravity, ΔP is the difference in pressure between the inlet and outlet sides of the orifice and ρ is the density of the air entering the orifice. Using the above equation, the area of an orifice which would leak 0.1% of the containment volume per day at a pressure of 45 psig was computed using a spreadsheet. In this spreadsheet the containment volume was set to 1.863E6 cubic feet, the containment temperature was set to 280 degrees Fahrenheit and the equation below from Reference no. 41 was used to compute the air density in containment.

$$\rho = 0.0709\left[(P + 14.7)/14.7\right]\left[560/(T + 460)\right]$$

This temperature and pressure bound the conditions expected in the containment during the first hour. The value of the product of Y and C was set to 1. The resulting orifice area was used to compute containment leak rates corresponding to containment pressures from 44 psig through 1 psig in 1 psig increments and from 0.9 psig through 0.1 psig in 0.1 psig increments. Based on the tables in Reference no. 40, the product of Y and C would be almost constant across the range of pressures considered. If YC is treated as a constant, then the containment leak rate for any pressure between 45 psig and 0.1 psig can be expressed in terms of the leak rate at 45 psig as shown below

$$q2 = q1\frac{\sqrt{\Delta P2 / \rho 2}}{\sqrt{\Delta P1 / \rho 1}}$$

where q2 is the volumetric containment leak rate for any pressure between 45 psig and 0.1 psig, q1 is the volumetric leak rate at 45 psig (0.1 % of the containment volume every 24 hours), ΔP2 is the selected pressure, ρ2 is the density of the air in the containment at the selected pressure, ΔP1 is 45 psig and ρ1 is the density of the air in the containment at 45 psig. From the above equation it can be seen that if the product of Y and C is constant, then setting the value of their product arbitrarily to one does not effect the accuracy of the calculations for volumetric leak rates at pressures other than 45 psig. The results of the calculated containment leak rates are presented in Table 15. At 45 psig the leak rate is forced to equal the Technical Specification maximum containment leak rate and therefore is not dependent upon product of Y and C.

Table 15 - Calculated Containment Leak Rates

P, psig	Rho,air	V, Ft/sec	Q,CFM
0	0.053654	0	0
0.1	0.054019	131.024	0.12249
0.2	0.054384	184.673	0.172645
0.3	0.054749	225.4221	0.21074
0.4	0.055114	259.4317	0.242534
0.5	0.055479	289.0978	0.270268
0.6	0.055844	315.6541	0.295095
0.7	0.056209	339.8367	0.317702
0.8	0.056574	362.1268	0.33854
0.9	0.056939	382.8605	0.357924
1	0.057304	402.2831	0.376081
2	0.060954	551.6179	0.515689
3	0.064604	656.2292	0.613487
4	0.068254	737.2092	0.689192
5	0.071904	803.0331	0.750729
6	0.075554	858.1674	0.802272
7	0.079204	905.3171	0.846351
8	0.082854	946.2669	0.884633
9	0.086503	982.265	0.918287
10	0.090153	1014.222	0.948163
11	0.093803	1042.825	0.974902
12	0.097453	1068.603	0.999002
13	0.101103	1091.977	1.020853
14	0.104753	1113.281	1.040769
15	0.108403	1132.789	1.059007
16	0.112053	1150.727	1.075777
17	0.115703	1167.284	1.091255
18	0.119353	1182.617	1.105589
19	0.123003	1196.86	1.118905
20	0.126653	1210.129	1.13131
21	0.130303	1222.523	1.142896
22	0.133953	1234.127	1.153744
23	0.137603	1245.016	1.163924
24	0.141253	1255.254	1.173495
25	0.144902	1264.9	1.182513
26	0.148552	1274.005	1.191025
27	0.152202	1282.612	1.199072
28	0.155852	1290.763	1.206692
29	0.159502	1298.494	1.213919
30	0.163152	1305.835	1.220782
31	0.166802	1312.817	1.227309
32	0.170452	1319.466	1.233525
33	0.174102	1325.804	1.23945
34	0.177752	1331.854	1.245106
35	0.181402	1337.634	1.25051
36	0.185052	1343.163	1.255679
37	0.188702	1348.457	1.260628
38	0.192352	1353.531	1.265371
39	0.196002	1358.397	1.26992
40	0.199651	1363.069	1.274288
41	0.203301	1367.558	1.278485
42	0.206951	1371.875	1.282521
43	0.210601	1376.03	1.286405
44	0.214251	1380.031	1.290145
45	0.217901	1383.887	1.29375

The spreadsheet used to produce Table 15 estimated the speed of sound in containment at each pressure. This allowed a check to ensure there were no choked flow conditions. The temperature used in the spreadsheet was held at 280 degrees Fahrenheit even though the predicted temperature in the containment for hours 1 through 4 is about 120 degrees Fahrenheit. Using the higher temperature of 280 degrees should be conservative since the density goes down with a higher temperature and a lower density produces choked flow at a lower velocity.

The LOCATRAN input file for the third additional LOCADOSE run made somewhat extensive changes to the input file shown in Table 13. First, the title line was changed. The new title line is shown below. Next the input line with the number of nodes and time steps was changed to designate 19 time steps instead of 18. This is the second line shown below. In the 1 to 1.14 hour time step the flow rates from node 2 (the sprayed portion of the containment) to the environment and node 3 (the unsprayed portion of the containment) to the environment were changed from 0.000 cfm to 0.1622 cfm and 0.000 cfm to 0.1081 cfm respectively. This is shown in lines three and four below. Finally, the time step for 2.51 to 4.38 hours was broken into two time steps - 2.51 to 4.00 hours and 4.00 to 4.38 hours. These two time steps in their entirety are shown below in lines five through thirty four inclusive.

```
LOCA EAB0.5hr CR10cfm ContLeak 1-4hr/0.021%leak w/24hrtbfandel        Prob title

2 19 139 1 0 0                 # Nodes, # Time steps, # Iso, CR, Dau, Spr cutoff

2 1 0 .1622                          Flow from node, Flow to node, Filt, Unfilt
3 1 0 .1081                          Flow from node, Flow to node, Filt, Unfilt


2.51 4.00 0 0 0 1     Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 -1 0 0 0                                                        End flow input
 3 2 1.23                                                Iso group, Node, Lambda
 5 2 1.23                                                Iso group, Node, Lambda
 6 2 1.23                                                Iso group, Node, Lambda
 7 2 1.23                                                Iso group, Node, Lambda
 8 2 1.23                                                Iso group, Node, Lambda
 9 2 1.23                                                Iso group, Node, Lambda
 11 2 1.23                                               Iso group, Node, Lambda
 12 2 1.23                                               Iso group, Node, Lambda
 -1 0 0 0                                                          End lambda input
 0 1.69E-3                        CR param chg, CR X/Q containment#1 to louver#1
4.00 4.38 0 0 0 1     Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 2 1 0 0                              Flow from node, Flow to node, Filt, Unfilt
  0 0 0 0 0 0 0 0 0 0 0 0                                Filter eff for iso grps 1-12
 3 1 0 0                              Flow from node, Flow to node, Filt, Unfilt
  0 0 0 0 0 0 0 0 0 0 0 0                                Filter eff for iso grps 1-12
 -1 0 0 0                                                        End flow input
 3 2 1.23                                                Iso group, Node, Lambda
 5 2 1.23                                                Iso group, Node, Lambda
 6 2 1.23                                                Iso group, Node, Lambda
 7 2 1.23                                                Iso group, Node, Lambda
 8 2 1.23                                                Iso group, Node, Lambda
 9 2 1.23                                                Iso group, Node, Lambda
```

```
 11 2 1.23                                          Iso group, Node, Lambda
 12 2 1.23                                          Iso group, Node, Lambda
 -1 0 0 0                                                  End lambda input
 0 1.69E-3                      CR param chg, CR X/Q containment#1 to louver#1
```

The LOCADOSE input file was identical to the LOCADOSE input file in Table 14 except for the title line which is shown below.

```
LOCA EAB0.5hr CR10cfm ContLeak 1-4hr/0.021%leak w/24hrtbfandel        Prob title
```

ECCS LEAKAGE

The ECCS fluid consists of the contaminated water in the sump of the containment. This water contains - according to the alternate source term methodology - 40% of the core inventory of iodine isotopes and most of the released core isotopes which are assumed to be in particulate form. This makes the ECCS fluid highly radioactive. During a LOCA the ECCS fluid is pumped from the containment sump to the recirculation spray headers and sprayed back into the containment sump. This is done to keep the containment cool after a LOCA. The outside recirculation spray pumps which are located in the Safeguards building pump ECCS fluid after a LOCA. This means that there is a potential for ECCS fluid leakage in the Safeguards building after a LOCA. Also, when a LOCA occurs, the high head charging pumps located in the auxiliary building are used to supplement the low head safety injection pumps. Thus, the high head charging pumps would be pumping ECCS fluid and would be another potential source of ECCS fluid leakage.

When modeling the radiological effects of the ECCS leakage, it is assumed that 10% of the iodine isotopes in the ECCS fluid come out of solution and become airborne gas. It is assumed that all other isotopes in the ECCS fluid remain either in solution or suspension in accordance with DG-1081 [Ref 25].

ECCS LEAKAGE - LOCADOSE Time Steps

The pumping of the ECCS fluid by the outside recirculation spray pumps starts at 415 seconds after the LOCA. The charging pumps start flowing ECCS fluid at 2300 seconds after the LOCA. These pump start times and other input parameters which determine the time steps used in LOCADOSE are shown in Table 17.

Table 17 - Timing of Events for ECCS Leakage

Time		Event
	0 hr	Instantaneously transport iodine into containment sump Start control room unfiltered inleakage of 10 cfm
415 sec	0.115 hr	Outside recirculation spray pumps start flowing ECCS fluid - start ECCS leakage into Safeguards For control room χ/Q use Unit 1 containment to fresh air louver #1
1200 sec	0.333 hr	Primary ventilation aligned to normal Change control room χ/Q to vent stack #2 to fresh air louver #3
2300 sec	0.639 hr	Charging pumps start flowing ECCS fluid - start ECCS leakage into auxiliary building - same χ/Q
3600 sec	1 hr	Start control room filtered intake of 1000 cfm
	8 hr	Change control room and offsite χ/Q to 8-24 hours
1 day	24 hr	Turn off turbine building fans Change control room χ/Q to vent stack #2 to rollup door #2 Change offsite χ/Q and occupancy factor
4 day	96 hr	Change control room and offsite χ/Q and occupancy factor to 4-30 days
30 day	720 hr	End of accident

ECCS LEAKAGE - Source Term and Dose Conversion Factors

The LOCADOSE source term used to model the ECCS leakage contains only the iodine isotopes. This is because iodine is the only element in the containment sump water which is modeled as coming out of solution and becoming airborne. The iodine isotopes are conservatively modeled as being instantaneously transported from the core to the containment sump. Forty percent of the core inventory of iodine isotopes are modeled as being transported into the containment sump. The iodine isotopes are input into LOCADOSE as initial activities. The containment sump volume is 1.65E6 liters or 5.83E4 cubic feet [ ].

The library file includes only iodines and was modified to contain the Federal Guidance Report 11 and 12 dose conversion factors instead of the RG 1.109 and ICRP-30 dose conversion factors. The library file also was modified to contain the fission yields specific to Surry as calculated in the ORIGEN2 run. The LOCADOSE inputs specifiy that 40% of the core inventory of iodine is in the ECCS liquid at the start of the LOCA.

The LOCADOSE inputs specify that 10% of the iodine in the ECCS leakage into the safeguards building and auxiliary building becomes airborne. Furthermore, of the iodine which becomes airborne, 97% is modeled as being elemental and 3% is modeled as being organic [Ref 25].

ECCS LEAKAGE - Nodes and Flows

The LOCADOSE computer code model represents the ECCS leakage to the environment with three volumes or nodes: (1) the environment, (2) the containment sump, and (3) the control room.

Note that the environment is always considered by LOCADOSE to be volume or node number 1 and to have an infinite volume. The diagram below shows how the ECCS leakage to environment was modeled in LOCADOSE.

```
                    ,------>   Environment (Node #1)
                    |      |
                  |--|     |
             vent|  |     |
            stack|  |     |
             no.2|  |     |
                 |  |     |
                 |  |     |
              |---|  |--|  |
              |Auxiliary|  |
              | Building|  |
       ,------>|         |  |
       |      |~~~~/\~~~|  |
       |          |       |                    _____________
       |          |       |                   |             |
|-----|-------|    |___    |                   | Control Room |
|            |         |   |                   |  (Node #3)  |
| Containment |         |   `------------>     ##           |
|    Sump    |      __|_______   ,----->      ## control room |
|  (Node #2)  |     |         | |              |   filters   |
|            |---->|Safeguards|--/              |             |
|-------------|~~~~~|~~~~~~~~~~|~~~~~~~~~~~~~~~~|-------------|
```

The transfer of radionuclides is modeled in LOCADOSE by specifying flow rates between the various volumes or nodes modeled. The flow rates input into LOCADOSE are described below along with a more detailed development of the ECCS leakage scenario.

The ECCS liquid leaks into the Safeguards building from the outside recirculation pumps and into the auxiliary building from the charging pumps. The leakage into the Safeguards building is modeled as starting at 415 seconds when the outside recirculation pumps start taking suction on the containment sump. The 1(2)-VS-F-58A(B)fan is assumed to be lined up in the refueling alignment and to not switchover for 20 minutes. Thus, for 20 minutes the iodine evolving from the ECCS leakage into the safeguards will vent to the environment directly from safeguards. The leakage into safeguards from the containment sump is modeled at a rate of 1928 cc/hour or 1.14E-3 cfm with roundoff. The allowed leak rate from Safeguards is 964 cc/hour. After 20 minutes, the iodine from the safeguards building will be drawn by the 1(2)-VS-F-58A(B)fan into the auxiliary building and up the vent stack. Thus, explaining the need for the two release paths shown above as coming from the safeguards building. No credit is taken for holdup in the Safeguards building.

According to SWEC calculations [ ], the earliest switchover of the SI system suction occurs at 2300 seconds. At switchover the SI system switches suction from the RWST to the containment sump. This means that the SI piping starts to contain ECCS liquid instead of RWST water. At switchover the ECCS liquid starts to leak into the charging pump pits in the auxiliary building. The airborne iodine from the ECCS leakage would be drawn into the intake hoods in the charging pump pits. There must be forced air ventilation of the charging pump pits because of the need to cool the motors on the charging pumps. The rate of auxiliary building ECCS leakage modeled was 7672 cc/hr. The allowed leak rate from the auxiliary building is 3836 cc/hour. When this is added to the ECCS from the Safeguards building the total ECCS leakage modeled was 9600 cc/hr or 5.65E-3 cfm which is double the total allowed ECCS leak rate. No credit was taken for filtration or holdup in the auxiliary building. The Safeguards building and auxiliary building are therefore not modeled as nodes.

The dose resulting from immersion in an airborne cloud of radionuclides is labeled in the LOCADOSE output "Eff-Immer". This corresponds to the DDE part of the TEDE. The dose resulting from inhalation of airborne radionuclides is labeled "Eff-Inhal" in the LOCADOSE output. This dose corresponds to the CEDE part of the TEDE. The TEDE dose is the sum of immersion and inhalation (DDE and CEDE) doses output by LOCADOSE. This summation must be done manually. LOCADOSE does not sum these two doses automatically.

ECCS LEAKAGE - Atmospheric Dispersion Factors

The initial ECCS leakage comes from the Safeguards building and lasts for about 13 minutes until the primary ventilation is re-aligned. Once the primary ventilation system is re-aligned the iodine which evolves from the ECCS leakage in the Safeguards building is drawn by the 1(2)-VS-F-58A(B) fan out of the Safeguards building and blown out of vent stack no 2. Since no control room atmospheric dispersion factor was computed specifically for the Safeguards building as a source point, the control room atmospheric dispersion factor for the unit #1 containment building being the source point was used for the ECCS leakage from the Safeguards building for the 13 minutes before the primary ventilation re-alignment. The receptor point used for these 13 minutes was the turbine building fresh air louver #1. This is the largest atmospheric dispersion factor among the potential receptor points for the control room emergency air intakes with the turbine building fans operating. If the turbine building fans were turned off - as is assumed at 24 hours - then the fresh air

louvers close and are no longer viable receptors for the control room emergency intakes.

After 20 minutes the primary ventilation system is re-aligned and the control room atmospheric dispersion factor for the no. 2 vent stack as source point and the turbine building fresh air louver #3 as receptor was used. This is the largest atmospheric dispersion factor for the no. 2 vent stack being the source point with the turbine building fans running.

After 24 hours the turbine building fans are turned off and the control room atmospheric dispersion factor used was for the geometry from the vent stack no. 2 to the turbine building rollup doors or fresh air intake pits - whichever was larger.

The offsite atmospheric dispersion factors were based on 1994-1998 meteorological data.

In summary, the LOCADOSE input files contained the initial iodine activities in each node. The LOCADOSE input files also contains the occupancy factors, the atmospheric dispersion factors, the filter efficiencies, node volumes and the flow rates between nodes. The library file has been modified to contain Surry specific fission yields and the Federal Guidance Report 11 and 12 dose conversion factors. The resulting doses computed by LOCADOSE are labeled "Eff-Immer" and "Eff-Inhal" and must be summed to attain the TEDE dose.

ECCS LEAKAGE - Breathing Rates and Occupancy Factors

The control room breathing rate and occupancy factors came from Draft Guide 1081 and Safety Guide 1.4 and were 3.47E-4 cubic meters per second and 100% occupancy for the first 24 hours and 60% occupancy for the next 72 hours and 40% occupancy for the next 624 hours. The offsite breathing rates came from Draft Guide 1081 and were 3.47E-4 cubic meters per second for the first 8 hours and 1.75E-4 cubic meters per second for 8 to 24 hours and 2.32E-4 cubic meters per second for 24 hours to the end of the accident.

ECCS LEAKAGE - LOCADOSE Input Files

The LOCATRAN and LOCADOSE input files used to model the doses from ECCS leakage are contained in Tables 18 and 19 respectively. The atmospheric dispersion factor used for the EAB in Table 19 for 2-2.5 hours is 3.40E-3 and it could arguably be 1.85E-3 instead. However, this produces a slightly conservative dose and was left as is.

Table 18 - LOCATRAN Input for Modeling ECCS Leakage

```
LOCA CR10cfm in ECCS nofilt noholdup 24hrTBfandelay EABslide          Prob title
D. Gilliatt                                                           Originator
Surry                                                                  Proj name
Alternate Source Term                                                     Proj #
PA-0163, 0                                                            Calc #, Rev
1                                                            First page # of output
1 11 27 1 0 0                  # Nodes, # Time steps, # Iso, CR, Dau, Spr cutoff
1 0 2605 -1 2 0 0      TID, Purge, Pwr, SD time, NPF, # Spr nodes, # Delay calcs
CFM  CUFT CURIES                          Flow unit, Volume unit, Activity unit
1 1 1 1 1 1 1 1 1 1 1 1                          Release frac for iso grps 1-12
.97 .03 0                                          Elem, org, part iodine frac
  Sump                                                        Names for nodes 2-3
0 .115 1 0 0 1        Start, Stop, Print act, Act unit, Prod unit, Print summary
 1 0 1                                            Initial act, Prod terms, Volume
 .4                       Initial activity (core frac) in node 2 for elem I--130
 .4                                                                  elem I--131
 .4                                                                  elem I--132
 .4                                                                  elem I--133
 .4                                                                  elem I--134
 .4                                                                  elem I--135
 .4                                                                  elem I--136
 .4                                                                  elem I--137
 .4                                                                  elem I--138
 .4                                                                   org I--130
 .4                                                                   org I--131
 .4                                                                   org I--132
 .4                                                                   org I--133
 .4                                                                   org I--134
 .4                                                                   org I--135
 .4                                                                   org I--136
 .4                                                                   org I--137
 .4                                                                   org I--138
 .4                                                                  part I--130
 .4                                                                  part I--131
 .4                                                                  part I--132
 .4                                                                  part I--133
 .4                                                                  part I--134
 .4                                                                  part I--135
 .4                                                                  part I--136
 .4                                                                  part I--137
 .4                                                                  part I--138
 5.83E4                                                     Volume for nodes 2-3
 -1 0 0 0                                                         End flow input
 -1 0 0 0                                                       End lambda input
 1 1.69E-3                        CR param chg, CR X/Q containment#1 to louver#1
  2.23E5 0 10 0 10                   CR vol, Filt in, Unfilt in, Recirc, Outleak
  90 70 99 0 99 99 99 99 99 0 0 99         Intake filt eff (%) for iso grps 1-12
  0 0 0 0 0 0 0 0 0 0 0 0                  Recirc filt eff (%) for iso grps 1-12
.115 .333 1 0 0 1     Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                            Initial act, Prod terms, Volume
 2 1 1.14E-3 0                        Flow from node, Flow to node, Filt, Unfilt
```

```
 90 90  0 0 0 0 0 0 0 0 0 0                          Filter eff for iso grps 1-12
-1 0 0 0                                                                End flow input
-1 0 0 0                                                            End lambda input
0 1.69E-3                                                     CR param chg, CR X/Q
.333 .500 1 0 0 1     Start, Stop, Print act, Act unit, Prod unit, Print summary
0 0 0                                                Initial act, Prod terms, Volume
-1 0 0 0                                                                End flow input
-1 0 0 0                                                            End lambda input
0 1.60E-3                          CR param chg, CR X/Q ventstack#2 to TB louver#3
.500 .639 1 0 0 1     Start, Stop, Print act, Act unit, Prod unit, Print summary
0 0 0                                                Initial act, Prod terms, Volume
-1 0 0 0                                                                End flow input
-1 0 0 0                                                            End lambda input
0 1.60E-3                            CR param chg, CR X/Q ventstack#2 to louver#3
.639 1 1 0 0 1        Start, Stop, Print act, Act unit, Prod unit, Print summary
0 0 0                                                Initial act, Prod terms, Volume
2 1 5.65E-3 0                          Flow from node, Flow to node, Filt, Unfilt
 90 90  0 0 0 0 0 0 0 0 0 0                          Filter eff for iso grps 1-12
-1 0 0 0                                                                End flow input
-1 0 0 0                                                            End lambda input
0 1.60E-3                            CR param chg, CR X/Q ventstack#2 to louver#3
1 2 1 0 0 1           Start, Stop, Print act, Act unit, Prod unit, Print summary
0 0 0                                                Initial act, Prod terms, Volume
-1 0 0 0                                                                End flow input
-1 0 0 0                                                            End lambda input
1 1.60E-3                            CR param chg, CR X/Q ventstack#2 to louver#3
 2.23E5 1000 10 0 1010                CR vol, Filt in, Unfilt in, Recirc, Outleak
 90 70 99 0 99 99 99 99 99 0 0 99          Intake filt eff (%) for iso grps 1-12
 0 0 0 0 0 0 0 0 0 0 0 0                   Recirc filt eff (%) for iso grps 1-12
2 2.5 1 0 0 1         Start, Stop, Print act, Act unit, Prod unit, Print summary
0 0 0                                                Initial act, Prod terms, Volume
-1 0 0 0                                                                End flow input
-1 0 0 0                                                            End lambda input
0 1.60E-3                          CR param chg, CR X/Q ventstack#2 to TB louver#3
2.5 8 1 0 0 1         Start, Stop, Print act, Act unit, Prod unit, Print summary
0 0 0                                                Initial act, Prod terms, Volume
-1 0 0 0                                                                End flow input
-1 0 0 0                                                            End lambda input
0 1.60E-3                            CR param chg, CR X/Q ventstack#2 to louver#3
8 24 1 0 0 1          Start, Stop, Print act, Act unit, Prod unit, Print summary
0 0 0                                                Initial act, Prod terms, Volume
-1 0 0 0                                                                End flow input
-1 0 0 0                                                            End lambda input
0 6.99E-4                            CR param chg, CR X/Q ventstack#2 to louver#3
24 26 1 0 0 1         Start, Stop, Print act, Act unit, Prod unit, Print summary
0 0 0                                                Initial act, Prod terms, Volume
-1 0 0 0                                                                End flow input
-1 0 0 0                                                            End lambda input
0 1.71E-4                    CR param chg, CR X/Q ventstack#2 to TB intake pit#2
26 96 1 0 0 1         Start, Stop, Print act, Act unit, Prod unit, Print summary
0 0 0                                                Initial act, Prod terms, Volume
-1 0 0 0                                                                End flow input
-1 0 0 0                                                            End lambda input
0 1.71E-4                    CR param chg, CR X/Q ventstack#2 to TB intake pit#2
```

```
96 720 1 0 0 1        Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                   Initial act, Prod terms, Volume
 -1 0 0 0                                                   End flow input
 -1 0 0 0                                                 End lambda input
 0 1.22E-4                  CR param chg, CR X/Q ventstack#2 to TB rollupdoor#2
```

Table 19 - LOCATRAN Input for Modeling ECCS Leakage

```
LOCA CR10cfm in ECCS nofilt noholdup 24hrTBfandelay EABslide          Prob title
D. Gilliatt                                                           Originator
Surry                                                                  Proj name
Alternate Source Term                                                     Proj #
PA-0163, 0                                                            Calc #, Rev
1                                                          First page # of output
DORDOF                                   calculate DOses in Regions, DOses oFfsite
2 9 3 3 1 0 0     # DP, # X/Q, # BR offsite, # Occ fac, # BR onsite, Decay, File
REM REM/HR                                              Dose unit, Dose rate unit
3.40E-3 3.40E-3 3.40E-3 3.40E-3 1.85E-3 1.36E-3 7.03E-4 7.03E-4 2.72E-4   SB X/Q
3.47E-4 1.75E-4 2.32E-4                          SB breath rates for time steps 1-3
1.66E-4 1.66E-4 1.66E-4 1.66E-4 1.66E-4 9.76E-5 3.06E-5 3.06E-5 5.79E-6  LPZ X/Q
3.47E-4 1.75E-4 2.32E-4                        LPZ breath rates for time steps 1-3
0.333 0.5 2.0 2.5 8 24 26 96 720                           Time step end for X/Qs
8 24 720                                   Time step end for offsite breath rates
1 1                                      Gamma cloud correction factor for SB, LPZ
0 0 0                                                Occupancy factors for node 2
0                                                      Breathing rates for node 2
1 .6 .4                                           Occupancy factors for node 4 (CR)
3.47E-4                                             Breathing rates for node 4 (CR)
24 96 720                                        Time step end for occupancy factor
720                                          Time step end for onsite breathing rate
1 1 1                                    Gamma cloud correction factor for nodes 2-4
```

RWST LEAKAGE

The reactor water storage tank (RWST) provides water to the recirculation spray headers and the containment spray dome and crane wall headers in the event of a LOCA. After the RWST has been pumped down to empty, the containment spray pumps turn off and the recirculation spray pumps switch suction from the RWST to the containment sump which contains ECCS fluid. There are still 6400 gallons of water in the RWST when pump down stops and switchover occurs [ ]. The switchover takes place at the earliest at 2300 seconds or about 38 minutes from the beginning of the LOCA [ ]. Once the recirculation spray system starts to flow ECCS fluid from the containment sump, a check valve in the safety injection system leaks ECCS fluid into the RWST. The leak rate modeled in this paper is 38,400 cc/hr of ECCS fluid flowing through the check valve into the RWST, which corresponds to a total allowed leak rate of 19,200 cc/hr.

The RWST is vented via an 8" pipe which goes from near the top of the RWST to the Safeguards building sump [Ref 39]. The Safeguards building sump would see a partial vacuum during a LOCA of about 0.3" of water [ ]. This is caused by one of the 1(2)-VS-F-58A(B) fans aligned to draw air from the Auxiliary building central area and the Safeguards building and blow it out vent stack no. 2. This ventilation alignment would occur within 20 minutes of the onset of a LOCA. The ECCS backleakage into the RWST would not occur before switchover at 38 minutes. So by the time ECCS fluid starting to leak into the RWST through the check valve, the Safeguards sump is already seeing 0.3" of partial vacuum.

RWST LEAKAGE - LOCADOSE Time Steps

The pumping of the ECCS fluid by the outside recirculation spray pumps starts at 415 seconds after the LOCA. The charging pumps start flowing ECCS fluid at 2300 seconds after the LOCA. The charging pump start time and other input parameters which determine the time steps used in LOCADOSE to model the RWST leakage are shown in Table 22.

Table 22 - Timing of Events for RWST Leakage

Time		Event
	0 hr	Instantaneously transport iodine into containment sump Start control room unfiltered inleakage of 10 cfm
2300 sec	0.639 hr	Start ECCS leakage from SI system into RWST For control room χ/Q use vent stack #2 to fresh air louver #3
3600 sec	1 hr	Start control room filtered intake of 1000 cfm
	8 hr	Change control room and offsite χ/Q to 8-24 hours
1 day	24 hr	Turn off turbine building fans Change control room χ/Q to vent stack #2 to rollup door #2 Change offsite χ/Q and occupancy factor
4 day	96 hr	Change control room and offsite χ/Q and occupancy factor to 4-30 days
30 day	720 hr	End of accident

RWST LEAKAGE - Source Term and Dose Conversion Factors

The LOCADOSE source term used to model the ECCS fluid which leaks into the RWST contains only the iodine isotopes. This is because iodine is the only element in the containment sump water - ECCS fluid - which is modeled as coming out of solution and becoming airborne. The iodine isotopes are modeled as being instantaneously transported from the core to the containment sump. Forty percent of the core inventory of iodine isotopes are modeled as being transported into the containment sump. The iodine isotopes are input into LOCADOSE as initial activities. The containment sump volume is 1.65E6 liters or 5.83E4 cubic feet [ ].

The library file includes only iodines and was modified to contain the Federal Guidance Report 11 and 12 dose conversion factors instead of the RG 1.109 and ICRP-30 dose conversion factors. The library file also was modified to contain the fission yields specific to Surry as calculated in the ORIGEN2 run. The LOCADOSE inputs specifiy that 40% of the core inventory of iodine is in the ECCS liquid at the start of the LOCA.

The LOCADOSE inputs specify that 10% of the iodine in the ECCS leakage into the safeguards building and auxiliary building becomes airborne. Furthermore, of the iodine which becomes airborne, 97% is modeled as being elemental and 3% is modeled as being organic [Ref 25].

RWST LEAKAGE - Nodes and Flows

The LOCADOSE computer code model represents the RWST leakage to the environment with four volumes or nodes: (1) the environment, (2) the containment sump, (3) the RWST, and (4) control room.

Note that the environment is always considered by LOCADOSE to be volume or node number 1 and to have an infinite volume. The diagram below shows how the RWST leakage to the environment was modeled in LOCADOSE.

The RWST contains about 399,025 gallons of water when it is indicating 100% full [Ref 36]. When the water level in the RWST is indicating 100% there is still an air space at the top of the RWST which is not included in the gauged volume of the RWST. For the purposes of this paper, it was assumed that the volume of the space above 100% full was approximately equal in volume to the 6400 gallons remaining in the bottom of the RWST after pumpdown. Thus, the air space available in the RWST after pumpdown was modeled as being 399,025 gallons. This equates to about 53,350 cubic feet of volume.

As can be seen in the diagram, no holdup was modeled for the Safeguards building. This was because the volume of the air pulled out the Safeguards building is so large that the residence time for any airborne gases in the Safeguards building would be relatively short. The flow from the containment sump into the RWST was set at 38,400 cc/hr or 0.0226 cfm. 10% of the iodine in the ECCS fluid which leaks into the RWST was modeled as becoming airborne in the RWST. The RWST was modeled as a node with a volume of 53,350 cubic feet. Thus, holdup credit was taken for the RWST.

As stated in the assumptions section, it was assumed that after the RWST has been pumped down that it is basically air tight. This is based on the RWST being water tight and the results of the mainframe database PASSPORT which reported that all the pipes connected directly to the RWST are seismically qualified - except for the 8" vent line to Safeguards. If the pipes connected to the RWST are seismically qualified, then they wouldn't break and create an complete flow path from the

atmosphere into the RWST and back out as a result of a seismic event. Preliminary discussions with a ventilation specialist showed that if the 8" vent pipe were to break in a seismic event, then the dose consequences would be less severe than if the 8" vent pipe remained intact. This is because the 8" vent pipe - while intact - provides a pathway for one of the 1(2)-VS-F-58A(B) fans to pull airborne iodine from the RWST and into the environment. If the 8" vent pipe were to break and create a single open pipe connecting the RWST to the atmosphere, then the RWST would "breath" through the 8" pipe and much less of the airborne iodine would reach the atmosphere than a 1(2)-VS-F-58A(B) fan would pull out of the RWST. Therefore, it was assumed that the 8" vent pipe would remain undamaged during a seismic event to maximize the resulting dose. Furthermore, in order to evaluate a bounding case, the assumption was made that 10 cfm of air would be pulled into the RWST from the atmosphere and that therefore 10 cfm of the gaseous contents of the RWST would flow out the 8" vent pipe into Safeguards. Once the gaseous effluent from the RWST reached Safeguards, a 1(2)-VS-F-58A(B) fan would pull it out of Safeguards and push it out vent stack no. 2 to the environment.

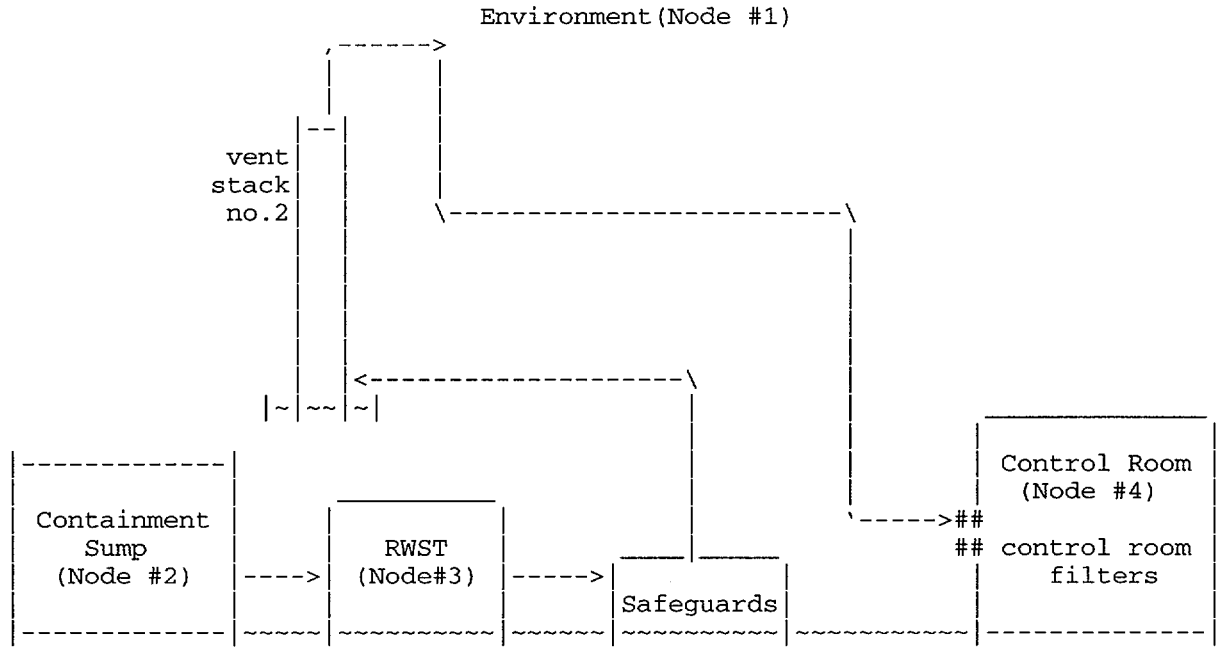
A preliminary calculation showed that the RWST air volume displaced by the volume of the iodine gas evolving out of the ECCS fluid and the rise of the RWST water level is negligible compared to the 10 cfm of air assumed to be entering the RWST from the environment.

No credit was taken for the auxiliary building filters.

The control room unfiltered inleakage was modeled at 10 cfm. As stated in the design inputs section the volume of the control room is 2.23E5 cubic feet.

As stated in the assumptions section the filtered fan flow into the control room is 1000 cfm.

The containment sump volume is 1.65E6 liters or 5.83E4 cubic feet [ ].



RWST LEAKAGE - Atmospheric Dispersion Factors

The iodine which evolves from the ECCS leakage into the RWST is ventilated out of vent stack no. 2. The control room atmospheric dispersion factor used for vent stack no. 2 as the source point is the turbine building fresh air louver#3 as the receptor point. This is because the turbine building fans draw air into the turbine building via the fresh air louvers and direct the air down toward the control room emergency air intakes and of the fresh air louvers, the atmospheric dispersion factor for louver #3 was the largest. However, the turbine building fans are assumed to be turned off by 24 hours. The only paths which are then available for the iodine from vent stack no. 2 to reach the control room emergency air intakes are through the turbine building fresh air pits or rollup doors. Therefore, from 24 hours to 30 days the atmospheric dispersion factors for vent stack no. 2 as the source point and the turbine building fresh air intake pit no. 2 and rollup door no. 2 as the receptor points were used.

The offsite atmospheric dispersion factors were based on 1994-1998 meteorological data.

RWST LEAKAGE - Breathing Rates and Occupancy Factors

The control room breathing rate and occupancy factors came from Draft Guide 1081 and Safety Guide 1.4 and were 3.47E-4 cubic meters per second and 100% occupancy for the first 24 hours and 60% occupancy for the next 72 hours and 40% occupancy for the next 624 hours. The offsite breathing rates came from Draft Guide 1081 and were 3.47E-4 cubic meters per second for the first 8 hours and 1.75E-4 cubic meters per second for 8 to 24 hours and 2.32E-4 cubic meters per second for 24 hours to the end of the accident.

RWST LEAKAGE - LOCADOSE Input Files

The LOCATRAN and LOCADOSE input files used to model the doses from RWST leakage are contained in Tables 23 and 24 respectively.

Table 23 - LOCATRAN Input for Modeling RWST Leakage

```
LOCA CR10cfmRWST38l/hr nofil 10%air holdup24hrFD 10cfmoutEABslide     Prob title
D. Gilliatt                                                           Originator
Surry                                                                  Proj name
Alternate Source                                                          Proj #
PA-0163, 0                                                            Calc #, Rev
1                                                                 First page # of output
2 10 27 1 0 0                  # Nodes, # Time steps, # Iso, CR, Dau, Spr cutoff
1 0 2605 -1 2 0 0      TID, Purge, Pwr, SD time, NPF, # Spr nodes, # Delay calcs
CFM  CUFT CURIES                           Flow unit, Volume unit, Activity unit
1 1 1 1 1 1 1 1 1 1 1 1                          Release frac for iso grps 1-12
.97 .03 0                                          Elem, org, part iodine frac
  Sump   RWSTank                                                 Name for node 2
0 .500 1 0 0 1        Start, Stop, Print act, Act unit, Prod unit, Print summary
 1 0 1                                          Initial act, Prod terms, Volume
 .4  0.0                 Init act (core frac) node 2 .4 x PF 10  for elem I--130
 .4  0.0                                                          elem I--131
 .4  0.0                                                          elem I--132
 .4  0.0                                                          elem I--133
 .4  0.0                                                          elem I--134
 .4  0.0                                                          elem I--135
 .4  0.0                                                          elem I--136
 .4  0.0                                                          elem I--137
 .4  0.0                                                          elem I--138
 .4  0.0                                                           org I--130
 .4  0.0                                                           org I--131
 .4  0.0                                                           org I--132
 .4  0.0                                                           org I--133
 .4  0.0                                                           org I--134
 .4  0.0                                                           org I--135
 .4  0.0                                                           org I--136
 .4  0.0                                                           org I--137
 .4  0.0                                                           org I--138
 .4  0.0                                                          part I--130
 .4  0.0                                                          part I--131
 .4  0.0                                                          part I--132
 .4  0.0                                                          part I--133
 .4  0.0                                                          part I--134
 .4  0.0                                                          part I--135
 .4  0.0                                                          part I--136
 .4  0.0                                                          part I--137
 .4  0.0                                                          part I--138
 5.83E4 5.335E4                                                Volume for node 2
 -1 0 0 0                                                         End flow input
 -1 0 0 0                                                       End lambda input
 1 1.69E-3                        CR param chg, CR X/Q containment#1 to louver#1
  2.23E5 0 10 0 10                   CR vol, Filt in, Unfilt in, Recirc, Outleak
  90 70 99 0 99 99 99 99 99 0 0 99          Intake filt eff (%) for iso grps 1-12
  0 0 0 0 0 0 0 0 0 0 0 0                   Recirc filt eff (%) for iso grps 1-12
.5 .639 1 0 0 1       Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 -1 0 0 0                                                         End flow input
```

```
 -1 0 0 0                                                    End lambda input
 0 1.69E-3                       CR param chg, CR X/Q containment#1 to louver#1
.639 1 1 0 0 1         Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 2 3 2.26E-2 0                        Flow from node, Flow to node, Filt, Unfilt
  90 90 0 0 0 0 0 0 0 0 0 0                          Filter eff for iso grps 1-12
 3 1 0 1.00E01
  90 70 99 0 0 0 0 0 0 0 0 0
 -1 0 0 0                                                      End flow input
 -1 0 0 0                                                    End lambda input
 0 1.60E-3                        CR param chg, CR X/Q ventstack#2 to louver#3
1 2 1 0 0 1            Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 -1 0 0 0                                                      End flow input
 -1 0 0 0                                                    End lambda input
 1 1.60E-3                        CR param chg, CR X/Q ventstack#2 to louver#3
  2.23E5 1000 10 0 1010            CR vol, Filt in, Unfilt in, Recirc, Outleak
  90 70 99 0 99 99 99 99 99 0 0 99          Intake filt eff (%) for iso grps 1-12
  0 0 0 0 0 0 0 0 0 0 0 0                   Recirc filt eff (%) for iso grps 1-12
2 2.5 1 0 0 1          Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 -1 0 0 0                                                      End flow input
 -1 0 0 0                                                    End lambda input
 0 1.60E-3                        CR param chg, CR X/Q ventstack#2 to louver#3
2.5 8 1 0 0 1          Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 -1 0 0 0                                                      End flow input
 -1 0 0 0                                                    End lambda input
 0 1.60E-3                        CR param chg, CR X/Q ventstack#2 to louver#3
8 24 1 0 0 1           Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 -1 0 0 0                                                      End flow input
 -1 0 0 0                                                    End lambda input
 0 6.99E-4                        CR param chg, CR X/Q ventstack#2 to louver#3
24 26 1 0 0 1          Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 -1 0 0 0                                                      End flow input
 -1 0 0 0                                                    End lambda input
 0 1.71E-4                  CR param chg, CR X/Q ventstack#2 to freshair intake#2
26 96 1 0 0 1          Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 -1 0 0 0                                                      End flow input
 -1 0 0 0                                                    End lambda input
 0 1.71E-4                  CR param chg, CR X/Q ventstack#2 to freshair intake#2
96 720 1 0 0 1         Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 -1 0 0 0                                                      End flow input
 -1 0 0 0                                                    End lambda input
 0 1.22E-4                       CR param chg, CR X/Q ventstack#2 to rollupdoor#2
```

Table 24 - LOCADOSE Input for Modeling RWST Leakage

```
LOCA CR10cfmRWST38l/hr nofil 10%air holdup24hrFD 10cfmoutEABslide     Prob title
D. Gilliatt                                                           Originator
Surry                                                                  Proj name
Alternate Source                                                          Proj #
PA-0163, 0                                                          Calc #, Rev
1                                                                 First page # of output
DORDOF                                   calculate DOses in Regions, DOses oFfsite
2 8 3 3 1 0 0     # DP, # X/Q, # BR offsite, # Occ fac, # BR onsite, Decay, File
REM REM/HR                                                  Dose unit, Dose rate unit
3.40E-3 3.40E-3 1.85E-3 1.85E-3 1.36E-3 7.03E-4 7.03E-4 2.72E-4  SB X/Q steps1-8
3.47E-4 1.75E-4 2.32E-4                          SB breath rates for time steps 1-3
1.66E-4 1.66E-4 1.66E-4 1.66E-4 9.76E-5 3.06E-5 3.06E-5 5.79E-6  LPZ X/Qsteps1-8
3.47E-4 1.75E-4 2.32E-4                         LPZ breath rates for time steps 1-3
0.5 2 2.5 8 24 26 96 720                                  Time step end for X/Qs
8 24 720                                     Time step end for offsite breath rates
1 1                                        Gamma cloud correction factor for SB, LPZ
0 0 0                                                 Occupancy factors for node 2
0                                                       Breathing rates for node 2
0 0 0                                                 Occupancy factors for node 3
0                                                       Breathing rates for node 3
1 .6 .4                                            Occupancy factors for node 4 (CR)
3.47E-4                                              Breathing rates for node 4 (CR)
24 96 720                                         Time step end for occupancy factor
720                                            Time step end for onsite breathing rate
1 1 1                                    Gamma cloud correction factor for nodes 2-4
```

PASSIVE FAILURE

The passive failure is defined in the SRP as a leak of ECCS fluid in an area which is not ventilated by a filtered system. The specified leak rate is 50 gallons per minute for a duration of 30 minutes. The passive failure starts at 24 hours after the onset of the LOCA.

The current position of Virginia Power is that within the systems which carry the ECCS fluid after a LOCA, the only credible location which could sustain a leak of the magnitude of 50 gallons per minute is the flanges of the charging pumps [ ]. The charging pumps are located in pits in the auxiliary building. During a LOCA, the charging pump pits are ventilated to the auxiliary building filters and therefore if the flanges leaked, the leakage would not constitute a passive failure. Thus, no passive failure is credible according to the current Virginia Power position. However, for completeness, the passive failure scenario is examined in this paper. That is, a 50 gpm leak is modeled for 30 minutes at the charging pump flanges, but without credit for the effluent being filtered by the auxiliary building filters.

PASSIVE FAILURE - LOCADOSE Time Steps

The charging pumps are assumed to start flowing ECCS fluid at 2300 seconds after the LOCA. The charging pump flanges start to leak at 24 hours and stop at 24.5 hours. These times and other input parameters which determine the time steps used in LOCADOSE to model the passive failure are shown in Table 28.

Table 28 - Timing of Events for Passive Failure

Time		Event
	0 hr	Instantaneously transport iodine into containment sump Start control room unfiltered inleakage of 10 cfm
2300 sec	0.639 hr	Start ECCS fluid flowing through the charging pumps For control room χ/Q use vent stack #2 to fresh air louver #3
3600 sec	1 hr	Start control room filtered intake of 1000 cfm
	8 hr	Change control room and offsite χ/Q to 8-24 hours
1 day	24 hr	Start 50gpm leak of ECCS fluid at charging pump flange Turn off turbine building fans Change control room χ/Q to vent stack #2 to rollup door #2 Change offsite χ/Q and occupancy factor
	24.5 hr	Stop 50gpm leak of ECCS fluid at charging pump
4 day	96 hr	Change control room and offsite χ/Q and occupancy factor to 4-30 days
30 day	720 hr	End of accident

6) RESULTS

RESULTS - Doses

The results of the LOCADOSE runs based on 10cfm unfiltered control room inleakage, no credit for the auxiliary building filters, one control room fan and containment leakage for one hour at 0.1% are shown below in tabular form. It was assumed that at the Exclusion Area Boundary all personnel would be excluded/evacuated by the time a passive failure occurs, i.e. 24 hours.

	CR DOSE (REM TEDE)	EAB DOSE (REM TEDE) 0.0-2.0 HR	EAB DOSE (REM TEDE) 0.5-2.5 HR	LPZ DOSE (REM TEDE)
CONTAINMENT LEAK				
ECCS LEAKAGE	**0.827**		**1.748**	**0.836**
RWST LEAKAGE	**1.042**		**0.056**	**1.014**
Total Dose in REM				
PASSIVE FAILURE				

Additional LOCADOSE runs were made to evaluate the radiological effects of extending the containment leakage beyond 1 hour to 4 hours at a reduced leak rate of 0.021%. The table below shows the dose contribution from containment leakage based on a rate

of leakage of 0.1% for 0-1 hour and 0.021% for 1-4 hours. The unfiltered control room inleakage was set at 350cfm with no credit for the auxiliary building filters, one control room fan.

			EAB DOSE REM TEDE 0.5-2.5HR				LPZ DOSE REM TEDE
CONTAIN LEAK			**14.598**				**0.949**

The table below shows the radiological impact of the extended containment leakage with an unfiltered control room inleakage of 10 cfm instead of 350 cfm. The EAB dose at the time interval of 0-2.0 hours is identical to the EAB dose for 350 cfm unfiltered control room inleakage. The EAB doses at the other time intervals would be identical to the EAB doses for 350 cfm unfiltered control room inleakage since the unfiltered control room inleakage has no effect on offsite doses.

	CR DOSE REM TEDE		LPZ DOSE REM TEDE
CONTAIN LEAK	**0.153**		**0.949**

This calculation contains several areas where conservatisms are believed to exist. The control room bottled air system when activated would have a purging effect on any unfiltered inleakage into the control room. No credit was taken for this effect. Surry is licensed under the leak before break methodology and is therefore entitled to a 10 minute delay of the gap release. The turbine building fresh air louver fans are assumed to be on for the first 24 hours of the LOCA which requires a non-LOOP LOCA. The containment and recirculation spray systems were modeled with only one train each as functioning and this required the assumption of a LOOP LOCA. The occupancy factors expected at Surry are more likely to be 70% for the first 24 hours and 40% thereafter.

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13)

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24)

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26)

27) Federal Guidance Report No. 12, "External Exposures to Radionuclides in Air, Water and Soil", EPA 420-r-93-081, Environmental Protection Agency.

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Radiological Consequences of a Fuel Handling Accident at Surry Based on the Alternate Source Term

Objective: To document the doses at the control room , EAB and LPZ at Surry Power Station as a consequence of a fuel handling accident using alternate source term methologies. In conjunction with the use of the alternate source term methodologies 1) TEDE radiological units and limits were used, 2) ARCON96 was used to calculate the onsite atmospheric dispersion factors, 3) Federal Guidance Reports No.11 and 12 dose conversion factors were used and 4) Westinghouse based gap fractions were used.

Conclusion: The fuel handling accident doses based on the alternate source term methodologies, the TEDE units, ARCON96, Federal Guidance Report 11 and 12 dose conversion factors and Westinghouse gap fractions were lower than the new TEDE limits for the control room, EAB and LPZ. The new control room limit in TEDE REM is 5 REM. The new EAB and LPZ limit is 6.25 REM TEDE.

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1) OBJECTIVE

The objective of this paper is to document the analysis of the dose consequences of a fuel handling accident (FHA) at Surry based on the alternate source term and associated methodologies. This paper estimates the doses in the Control Room, at the Exclusion Area Boundary (EAB) and at the Low Population Zone (LPZ) boundary.

This paper also uses fuel assembly gap fractions based on Westinghouse reports and these gap fractions do not agree with the Draft Guide 1081 gap fractions.

Note that this paper was generated to support a Technical Specification Change Request and a change in the design basis source term from TID-14844 to the Alternate Source Term. As such, the requirements of NDCM 3.7 Section 6.8, which are for calculations not supporting plant changes, do not apply to this calculation note.

2) BACKGROUND

In general, this paper is based on the guidance of Draft Regulatory Guide DG-1081. Appendix B of Draft Regulatory Guide-1081 contains the recommended assumptions for evaluating the radiological consequences of a fuel handling accident. Items to which this paper does not conform are discussed at the end of this section with additional details provided in Section 5. The following paragraphs are quotes or paraphrases of the assumptions contained in Appendix B of Draft Regulatory Guide-1081:

1. Source Term

Assumptions regarding core inventory and the release of radionuclides from the fuel are provided in Regulatory Position 3 of this guide. The following assumptions also apply.

The following paragraph is from Regulatory Position 3.1 of Draft Regulatory Guide DG-1081:

3.1 ***Core Inventory***

The inventory of fission products in the reactor core and available for release to the containment should be based on the maximum full power operation of the core with, as a minimum, current licensed values for fuel enrichment, fuel burnup, and 1.02 times the current licensed rated thermal power. The period of irradiation should be of sufficient duration to allow the activity of dose-significant radionuclides to reach equilibrium or to reach maximum values. For non-LOCA events, the appropriate radial peaking factor from the facility's core operating limits report (COLR) should be applied. No adjustment to the core inventory should be made for events postulated to occur during power operations at less than full rated power or those postulated to occur at the beginning of core life. For events postulated to occur while the facility is shutdown, e.g., a fuel handling accident, radioactive decay from the time of shutdown may be modeled.

1.1 The number of fuel rods damaged during the accident should be based on conservative analysis that considers the most limiting case.

1.2 The gap activity fractions of Table 3 in Regulatory Position 3 of Draft Regulatory Guide DG-1081 should be assumed. All the gap activity in the damaged rods is assumed to be instantaneously released. Radionuclides that

should be considered include xenons, krytons, halogens, cesiums, and rubidiums.

Table 3 of Regulatory Position 3 of DG-1081 lists the fraction of the core inventory assumed to be in the fuel gap for I-131, Kr-85 and other noble gases and halogens and alkali metals. The gap fraction specified for I-131 is 0.12. The gap fraction specified for Kr-85 is 0.15. The gap fractions specified for the other noble gases and halogens and the alkali metals are all 0.10.

1.3 Of the radioiodine released from the fuel, 99.75% of the released iodine should be assumed to be in the form of elemental iodine and 0.25% in organic species.

2. Water Depth

If the depth of water above the damaged fuel is 23 feet or greater, the decontamination factors for the elemental and organic species are 500 and 1, respectively, giving an overall effective decontamination of 200 (i.e., 99.5% of the total iodine released from the damaged rods is retained by the water). This difference in decontamination factors for elemental and organic iodine species results in the iodine above that water being composed of 44% elemental and 55% organic species. If the depth of water is not 23 feet the decontamination factor will have to be determined on a case-by-case method.

3. Noble Gases

The retention of noble gases in the water in the fuel pool or reactor cavity is negligible (i.e., decontamination factor of 1). Particulate radionuclides are assumed to be retained by the water in the fuel pool or reactor cavity (i.e., infinite decontamination factor).

4. Fuel Handling Accidents Within the Fuel Building

For fuel handling accidents postulated to occur within the fuel building, the following assumptions should be made.

4.1 The radioactive material that escapes from the fuel pool to the fuel building is assumed to be released to the environment over a 2-hour time period.

4.2 A reduction in the amount of radioactive materiel released from the fuel pool by engineered safety feature (ESF) filter systems may be taken into account provided these systems meet the guidance of Regulatory Guide 1.52 and Generic Letter 99-02. Delays in radiation detection, actuation of the ESF filtration system, or diversion of ventilation flow to the ESF filtration system should be determined and accounted for in the release analyses.

4.3 The radioactivity release from the fuel pool should be assumed to be drawn into the ESF filtration system without mixing or dilution in the fuel building.

5. Fuel Handling Accident Within Containment

For fuel handling accidents postulated to occur within the containment, the following assumptions should be made:

5.1 If the containment is isolated during fuel handling operations, no radiological consequences need to be analyzed.

5.2 If the containment is open during fuel handing operations, but designed to automatically isolate in the event of a fuel handling accident, the release duration should be based on delays in radiation detection and completion of containment isolation. If it can be shown that containment isolation occurs before radioactivity is released to the environment, no radiological consequences need to be analyzed.

5.3 If the containment is open during fuel handling operations (e.g., personnel air lock or equipment hatch is open), the radioactive material that escapes from the reactor cavity pool to the containment is released to the environment over a 2 hour time period.

5.4 A reduction in the amount of radioactive material released from the containment by ESF filter systems may be taken into account provided that these systems meet the guidance of Regulatory Guide 1.52 and Generic Letter 99-02. Delays in radiation detection, actuation of the ESF filtration system or diversion of ventilation flow to the ESF filtration system should be determined and accounted for in the radioactivity release analyses.

5.5 Credit for dilution or mixing of the activity released from the reactor cavity by natural or forced convection inside the containment may be considered on a case-by-case basis. Such credit is generally limited to 50% of the containment free volume.

The above regulatory guidelines were followed in this paper with the exception of 1.1, 1.2 and 4.3. As stated in assumption number 1, all the fuel pins in one assembly are assumed to fail. This is consistent with the details of the fuel handling accident analysis described in Chapter 14 of the Surry FSAR. The fuel gap fractions used were based on NUREG-1465 values that were justified by an evaluation of high burnup fuel performed by Westinghouse. This is discussed in detail in the Section 5 Calculations. Also, since no credit for filtration was taken in the fuel building release, dilution and holdup were modeled. However, the effect of the dilution and holdup on the dose is very small since the exhaust flow out of the fuel building is so high that the radioactive release is purged from the fuel building in much less than two hours. See Section 5 Calculations for further details.

In conjunction with the implementation of the alternate source term, the NRC has stated that the total effective dose equivalent (TEDE) methodology in 10 CFR Part 20 should be adopted. The dose limits using TEDE methodology would be 6.25 REM TEDE for offsite doses (EAB and LPZ) and 5 REM TEDE for control room doses. The total effective dose equivalent is equal to the sum of the committed effective dose equivalent (CEDE) and the deep dose equivalent (DDE). The CEDE is the sum of the doses received to a select group of organs from radioactive sources inside the body. The DDE is the dose received from external whole body exposure.

Also in conjunction with the implementation of the alternate source term, the dose conversion factors in Federal Guidance Reports 11 and 12 are now used.

DG-1081 says to use the radial peaking factor from the COLR for the core being modeled. For a Surry core the COLR value of the radial peaking factor is 1.56. However, the appropriate peaking factor, including uncertainties for events that do not employ the Statistical DNBR Evaluation Methodology (e.g. FHA) is 1.62. [Ref 25, Section 2.3.1]

All the calculations in this paper were done with the computer code system LOCADOSE. The LOCADOSE codes were developed by Bechtel Corporation to analyze doses from transport of radioactive materials through multi-region systems. The LOCADOSE codes were obtained from Bechtel as executable codes for PCs.

The two codes of the LOCADOSE code system used in this analysis are LOCADOSE and LOCATRAN. LOCATRAN calculates the transport of the fuel assembly gap inventory to the Environment, Control Room and regions of the plant specified by the user based on volumes and flow rates provided by the user. The LOCADOSE computer code then calculates the doses resulting from these radioactive releases based on user supplied X/Q, breathing rate, and occupancy factors either offsite or within regions of the plant specified by the user. For each case executed, 3 input files are required: one for LOCATRAN, one for LOCADOSE and a library file, which contains isotopic data. The version of LOCADOSE used in these calculations was 4.1.

3) DESIGN INPUTS

Fourteen isotopes are used in this evaluation of the dose consequences of a fuel handling accident. These isotopes are listed in Table 1 below.

Table 1 - Isotopes Used in the Analysis of the Fuel Handling Accident

I-130	I-133	Kr-83m	Kr-88	Xe-131m	Xe-135
I-131	I-135	Kr-85		Xe-133	Xe-135m
I-132		Kr-85m		Xe-133m	

Table 2 lists the dose conversion factors for each of the isotopes used in this paper. These dose conversion factors are for TEDE units of dose and are taken from [ ]. To calculate the TEDE using these dose conversion factors the effective inhalation dose would have to be added to the effective immersion dose. The inhalation dose is equivalent to the CEDE dose and the immersion dose is equivalent to the DDE dose.

Table 2 - Dose Conversion Factors by Isotope

Group	Isotope	Dose Conversion Factors			
		Inhalation (Rem/Ci)		Immersion (Rem-m^3/Ci-sec)	
		Thyroid	Effective	Thyroid	Effective
1	I-130	7.36E+04	2.64E+03	3.85E-01	3.85E-01
1	I-131	1.08E+06	3.29E+04	6.70E-02	6.73E-02
1	I-132	6.44E+03	3.81E+02	4.14E-01	4.14E-01
1	I-133	1.80E+05	5.85E+03	1.08E-01	1.09E-01
1	I-135	3.13E+04	1.23E+03	2.96E-01	2.95E-01
2	I-130	7.36E+04	2.64E+03	3.85E-01	3.85E-01
2	I-131	1.08E+06	3.29E+04	6.70E-02	6.73E-02
2	I-132	6.44E+03	3.81E+02	4.14E-01	4.14E-01
2	I-133	1.80E+05	5.85E+03	1.08E-01	1.09E-01
2	I-135	3.13E+04	1.23E+03	2.96E-01	2.95E-01
4	Kr-85	0.00E+00	0.00E+00	4.37E-04	4.40E-04
4	Kr-88	0.00E+00	0.00E+00	3.81E-01	3.77E-01
4	Kr-83m	0.00E+00	0.00E+00	2.38E-06	5.55E-06
4	Kr-85m	0.00E+00	0.00E+00	2.71E-02	2.77E-02
4	Xe-133	0.00E+00	0.00E+00	5.59E-03	5.77E-03
4	Xe-135	0.00E+00	0.00E+00	4.37E-02	4.40E-02
4	Xe-131m	0.00E+00	0.00E+00	1.45E-03	1.44E-03
4	Xe-133m	0.00E+00	0.00E+00	5.03E-03	5.07E-03
4	Xe-135m	0.00E+00	0.00E+00	7.55E-02	7.55E-02

The following is a list of design inputs:

1. Reactor power is 2605 MWt [ ].
2. Handling of fuel does not commence until 100 hr after shutdown [Ref 29], the earliest time an accident can occur.
3. The following fraction of the gap activity within damaged fuel rods is released into the spent fuel pool instantaneously at the start of the accident: 3% or 5%. Runs were made with both gap fractions [Ref 1].
4. Iodine form is 99.75% elemental and 0.25% organic [Ref 18].

5. The Surry COLR radial peaking factor value is 1.56. However, the appropriate peaking factor, including uncertainties, for events that do not employ the Statistical DNBR Evaluation Methodology (e.g. FHA) is 1.62 [Ref 25, Section 2.3.1].
6. The minimum depth of water in the spent fuel pool and reactor refueling water cavity is 23 ft [Ref 18].
7. For a water depth of 23 feet or more the pool decontamination factors are 1 for organic iodine and noble gases, 500 for elemental iodine, and infinity for particulates [Ref 18]. The last value indicates that alkali metals are not released from the pool.
8. Holdup credit is taken for the fuel building, whose volume is 1.11E5 ft^3 [ ].
9. Release rate from the fuel building is modeled at a rate of 3.6E4 cfm. This is the maximum flow rate out of a 58 fan [Ref 30]. One run is made with the exhaust flow from the fuel building set at 8.0E4cfm to bound 2 58 fans running.
10. Some Fuel Building cases take credit for the auxiliary building filters, which have filter efficiencies of 99% for aerosols, 90% for elemental iodine, and 70% for organic iodine [Ref 9].
11. For the cases modeling the containment release, the flow out of the containment is modeled at 4000 cfm, 6000 cfm, 16,000 cfm and 36,000 cfm. See assumptions.
12. The duration of the release is 2 hr [Ref 18]. For the 4000 cfm, 6000 cfm and 16,000 cfm containment exhaust flow rates, a portion of the release is still in the containment after two hours. These containment exhaust flow rates were modeled because they result in larger control room doses.
13. Holdup credit is taken for the containment, whose volume is 1.863E6 ft^3. However, for modeling purposes, only half the volume of the containment - 9.315E5 cubic feet - is used.[Ref 9].
14. Control room volume is 2.23E5 ft^3 [ ].
15. Control room unfiltered inleakage is modeled at a rate of 10 cfm for some runs [ ] and at 350 cfm for other runs to determine sensitivity of dose consequences to unfiltered control room inleakage.
16. Control room filtered intake is at a rate of 1000 cfm [Ref 11, 12] for one control room emergency fan and 2000 cfm for two control room emergency fans. This intake starts at 1 hr for all cases. Credit is taken for bottled air during the first hour.
17. Control room intake filter efficiency is 99% for aerosols, 90% for elemental iodine, and 70% for organic iodine [Ref 9].
18. The atmospheric dispersion factors (sec/m^3) are as follows [ ]:

Table 3 - Atmospheric Dispersion Factors

Source	Receptor	0-2 hr	0-8 hr	8-24 hr	24-96 hr	96-720 hr
Contain-ment (Unit 1)	TB Fresh Air Intake#1		5.18E-04	2.22E-04	1.66E-04	1.20E-04
	TB Fresh Air Louver#1		1.69E-03	7.19E-04	5.62E-04	4.03E-04
	EAB	3.40E-03	1.85E-03	1.36E-03	7.03E-04	2.72E-04
	LPZ		1.66E-04	9.76E-05	3.06E-05	5.79E-06
Vent Stack No. 2	TB Fresh Air Louver#3		1.60E-03	6.99E-04	5.07E-04	3.60E-04
	TB Fresh Air Pit#2		5.38E-04	2.28E-04	1.71E-04	1.19E-04
	TB Rollup Door #2		5.40E-04	2.30E-04	1.69E-04	1.22E-04
Aux Bldg 45' Lvl E. Louver	TB Fresh Air Louver#3		3.87E-03	1.65E-03	1.14E-03	7.96E-04

19. Dose conversion factors are taken from Federal Guidance Reports 11 and 12 [Ref 3, 20] and are shown in Table 2.
20. The activities calculated in the ORIGEN2 run [ ] for the once burned batch after 100 hours of decay were as follows:

Table 4 - Once Burned Batch Activity After 100 Hours of Decay

Isotope	Batch Activity (Curies)	Isotope	Batch Activity (Curies)
I-130	2.67E+03	Kr-85m	1.83E+00
I-131	2.34E+07	Kr-88	6.46E-04
I-132	1.97E+07	Xe-131m	3.50E+05
I-133	2.47E+06	Xe-133	4.68E+07
I-135	1.77E+03	Xe-133m	8.63E+05
Kr-83m	5.10E-06	Xe-135	8.51E+04
Kr-85	2.09E+05	Xe-135m	2.83E+02

For an explanation of the use of the once burned batch activities as design input instead of the thrice-burned batch, see the "Calculations" section.

21. The control room personnel will be in communication with the containment personnel when fuel is being moved in containment [Ref. 31].

4) Assumptions

1. It is assumed that all the fuel rods within a single assembly are damaged such that the gap inventory in all the fuel rods is released [Ref 37].

2. It is assumed that the control room operators will turn on the emergency control room fans 60 minutes or more after the accident occurs but not after the bottled air has been depleted [ ].

3. It is assumed that communications will be established between the control room and the location where fuel is being moved - either the fuel building or containment [Ref 31, 33, 34, 35, 36].

4. It is assumed - based on radiation monitor readings/alarms and communications with the location where fuel is being moved - that the control room operators will take action to isolate the control room and dump air bottles prior to any control room ventilation intake of radionuclides [Ref 31, 33, 34, 35, 36].

5. It is assumed that all exhaust flow out of the containment exits via either the equipment hatch or personnel hatch instead of the containment purge system to vent stack no. 2. This is conservative since the atmospheric dispersion factors used for the equipment hatch (containment area source) and personnel hatch (auxiliary building louver point source) are larger than the atmospheric dispersion factors for vent stack no. 2.

6. The flow out of the containment equipment hatch, the containment personnel hatch and the fuel building are modeled at various rates to determine the maximum offsite and control room doses. The maximum containment exhaust flow modeled out of either hatch is 36,000 cfm - the maximum capacity of one 58 fan. An containment exhaust flow of 36,000 cfm was assumed to bound any credible sustained flow out of the equipment hatch and personnel hatch combined. The flow out of the fuel building was modeled at two levels - 36,000 cfm and 80,000 cfm. The 80,000 cfm flow exceeds the capacity of two 58 fans and it is modeled to ensure that operation with two 58 fans is not excluded. Similarly, the modeled 36,000 cfm containment exhaust flow is far greater than the expected purge flow out of the containment with two 58 fans in operation.

7. & 8. ARCON96 was used to calculate the atmospheric dispersion factors for the onsite geometries where the containment building was the source and the turbine building fresh air louvers, turbine building fresh air intake pits and turbine building rollup doors were receptor points. In these ARCON96 runs the containment building was treated as an area source and not a point source. This treatment meant that radioactive effluent from the containment structure was modeled as being diffuse or exiting from the surface of the containment instead of a point on the containment. This effectively reduced the onsite atmospheric dispersion factors associated with the containment structure.

It is assumed that the onsite atmospheric dispersion factors based on the containment area source would be acceptable for use when calculating the FHA doses caused by radioactive effluent exhausting the containment from the equipment hatch. The equipment hatch is on the north side of the containment structure and the onsite receptor points are all south of the containment structure. Therefore, any effluent exiting the equipment hatch would have to flow around the containment structure and be subject to the wake effects of the containment structure before making it's way to any of the receptor points. This would effectively diffuse any plume from the equipment hatch before it reached the southern side of the containment structure. Thus, the fact that the equipment hatch is not a large area source like the containment structure will not matter when applying the containment area source atmospheric dispersion factors.

The personnel hatch is inside the 45' elevation of the auxiliary building. Therefore, any effluent exiting the personnel hatch from the containment will actually enter the 45' elevation of the auxiliary building - not the environment. For the effluent to make it's way to the environment and hence to the onsite receptor points, it would have to exit the auxiliary building. The closest exit points are the partially closed louvers on the east and west sides of the auxiliary building at the 45' elevation. The atmospheric dispersion factors for the auxiliary building east louver at the 45' elevation are the largest and were therefore the ones used to model the radiological effects of containment exhaust flow out of the personnel hatch. The volume of the 45' elevation of the auxiliary building was assumed to be only 100,000 cubic feet because of the volume occupied by fan housings, filter housings, interior walls and ventilation ducts [Refs 38, 39]. Holdup and dilution of the containment exhaust flow in the 45' elevation of the auxiliary building were modeled.

9. The LOCADOSE runs modeling the radiological effects of exhaust flow from fuel building or the containment equipment hatch were setup based on the assumption that the turbine building fans would be turned off within 24 hours of the fuel handling accident. This was a mistake since the timing of a FHA release means that the control room dose consequences are only very slightly sensitive to the turbine building fans being turned off after 24 hours. Therefore, control room doses resulting from the fuel building and containment equipment hatch LOCADOSE runs were adjusted - where necessary - to remove any benefit afforded by the turbine building supply fans being turned off at 24 hours. The doses were unchanged for all but three runs. The three control room doses that were slightly changed are highlighted in Table 25 at the end of the results section.

10. A loss of offsite power of a short duration with a starting time other than the beginning of the accident was considered but not modeled because of the extremely low risk potential of such a scenario. Based on a scoping case that was not documented this scenario produces doses that are enveloped by the reported results.

5) Calculations

5.1 Determination of Limiting Batch

An ORIGEN2 run calculated the activities in each batch of fuel in a representative core after 100 hours of decay [ ]. A representative core contains a once burned batch, a twice burned batch and a thrice burned batch. Inherent physical phenomena associated with fuel depletion dictate that fuel assembly peaking factors decrease as burnup increases. This behavior is typical of all Virginia Power core designs. The relative power distribution (RPD) factors assigned to each of these three batches in the ORIGEN2 run were 1.35, 1.17 and 0.345 for the once, twice and thrice burned batches respectively [ ]. These RPD's are representative of the expected RPD's in a Surry core.

Fourteen isotopes are used to model the dose consequences of a fuel handling accident. This selection of isotopes was arrived at by starting with the 135 isotopes used in the alternate source term LOCA analysis [ ] as shown in Table 5 below. Of the 135 isotopes, only isotopes which would be gaseous and not soluble in water could possibly leave the water after escaping the failed fuel assembly and become airborne in either the fuel building or the containment. The 22 isotopes which meet these criteria are listed in Table 6 below. Table 6 also includes the activities (from the ORIGEN2 run once burned assembly) after 100 hours of decay and the dose conversion factors for inhalation and immersion for the 22 isotopes. Examination of Table 6 shows that of the 22 isotopes that are gaseous and not soluble in water, 8 have no activity after 100 hours of decay. This leaves 14 isotopes to contribute to the fuel handling accident. These are isotopes of iodine, krypton and xenon and are listed in the first column of Table 7 below.

When modeling the dose consequences of a fuel handling accident, it was assumed that all fuel rods in one fuel assembly fail. That is, it was assumed that every fuel rod in the failed fuel assembly would release its gap inventory. To determine which of the three batches of fuel should be selected to yield the highest doses in a fuel handling accident, the activity per fuel assembly for each isotope used to model the dose consequences was tabulated by fuel batch in Table 7. The isotopic batch activities used to calculate the activity per fuel assembly for each batch in Table 7 were taken from the ORIGEN2 run [ ]. These values represent the total inventory in a fuel assembly, and are further adjusted to account for the amount of the inventory that migrates into the fuel/cladding gap. The development of a conservative, burnup-independent gap fraction is discussed in the next section.

Table 5 - 135 Isotopes Used In LOCA Analysis

I-130	Cs-136	Rh-105	Br-83
I-131	Cs-137	Rh-106	Br-84
I-132	Cs-138	Ru-103	Br-85
I-133	Cs-139	Rh-103m	Br-87
I-134	Cs-134m	Ru-105	Br-88
I-135	Rb-86	Ru-106	Am-241
I-136	Rb-88	Tc-101	Am-242
I-137	Rb-89	Tc-99m	Cm-242
I-138	Rb-90	Ce-141	Cm-244
I-130	Sb-124	Ce-143	Np-238
I-131	Sb-125	Ce-144	Np-239
I-132	Sb-126	Eu-154	Pu-238
I-133	Sb-127	Eu-155	Pu-239
I-134	Sb-129	Eu-156	Pu-240
I-135	Te-127	La-140	Pu-241
I-136	Te-129	La-141	Pu-243
I-137	Te-131	La-142	
I-138	Te-132	La-143	
I-130	Te-133	Nb-95	
I-131	Te-134	Nb-97	
I-132	Te-125m	Nb-95m	
I-133	Te-127m	Nd-147	
I-134	Te-129m	Pm-147	
I-135	Te-131m	Pm-148	
I-136	Te-133m	Pm-149	
I-137	Ba-139	Pm-151	
I-138	Ba-140	Pm-148m	
Kr-85	Ba-141	Pr-143	
Kr-87	Ba-136m	Pr-144	
Kr-88	Ba-137m	Pr-144m	
Kr-89	Sr-89	Sm-153	
Kr-83m	Sr-90	Y-90	
Kr-85m	Sr-91	Y-91	
Xe-133	Sr-92	Y-92	
Xe-135	Sr-93	Y-93	
Xe-137	Sr-94	Y-94	
Xe-138	Sr-95	Y-95	
Xe-131m	Co-58	Y-91m	
Xe-133m	Co-60	Zr-95	
Xe-135m	Mo-99	Zr-97	
Cs-134	Pd-109	Br-82	

Table 6 - Activities and Dose Conversion Factors of the Isotopes Which Are Gaseous and Not Water Soluble

Isotope	Activity after 100 hours of Decay	Dose Conversion Factor			
		Inh (Rem/Ci)		Imm (Rem-m^3/Ci-sec)	
	(Ci)	Thyroid	Effective	Thyroid	Effective
I-130	2.670E+03	7.36E+04	2.64E+03	3.85E-01	3.85E-01
I-131	2.336E+07	1.08E+06	3.29E+04	6.70E-02	6.73E-02
I-132	1.973E+07	6.44E+03	3.81E+02	4.14E-01	4.14E-01
I-133	2.474E+06	1.80E+05	5.85E+03	1.08E-01	1.09E-01
I-134	0.0E+00	1.07E+03	1.31E+02	4.81E-01	4.81E-01
I-135	1.767E+03	3.13E+04	1.23E+03	2.96E-01	2.95E-01
I-136	0.0E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-137	0.0E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-138	0.0E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85	2.085E+05	0.00E+00	0.00E+00	4.37E-04	4.40E-04
Kr-87	0.0E+00	0.00E+00	0.00E+00	1.53E-01	1.52E-01
Kr-88	6.457E-04	0.00E+00	0.00E+00	3.81E-01	3.77E-01
Kr-89	0.0+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-83m	5.100E-06	0.00E+00	0.00E+00	2.38E-06	5.55E-06
Kr-85m	1.831E+00	0.00E+00	0.00E+00	2.71E-02	2.77E-02
Xe-133	4.678E+07	0.00E+00	0.00E+00	5.59E-03	5.77E-03
Xe-135	8.513E+04	0.00E+00	0.00E+00	4.37E-02	4.40E-02
Xe-137	0.0E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-138	0.0E+00	0.00E+00	0.00E+00	2.13E-01	2.13E-01
Xe-131m	3.504E+05	0.00E+00	0.00E+00	1.45E-03	1.44E-03
Xe-133m	8.626E+05	0.00E+00	0.00E+00	5.03E-03	5.07E-03
Xe-135m	2.831E+02	0.00E+00	0.00E+00	7.55E-02	7.55E-02

Table 7 - Activities per Fuel Assembly by Batch

Isotopes Considered	Once Burned Act per FA in Ci	Twice Burned Act per FA in Ci	Thrice Burned Act per FA in Ci
I-130	4.77E+01	8.64E+01	3.35E+01
I-131	4.17E+05	3.44E+05	1.11E+05
I-132	3.52E+05	2.86E+05	9.18E+04
I-133	4.42E+04	3.49E+04	1.11E+04
I-135	3.16E+01	2.51E+01	8.01E+00
Kr-85	3.72E+03	5.79E+03	5.96E+03
Kr-88	1.15E-05	7.24E-06	2.16E-06
Kr-83m	9.11E-08	6.26E-08	1.92E-08
Kr-85m	3.27E-02	2.12E-02	6.40E-03
Xe-133	8.35E+05	6.62E+05	2.11E+05
Xe-135	1.52E+03	1.21E+03	4.23E+02
Xe-131m	6.26E+03	5.16E+03	1.66E+03
Xe-133m	1.54E+04	1.23E+04	3.93E+03
Xe-135m	5.06E+00	4.03E+00	1.28E+00

The radial peaking factor limit in the COLR is 1.56 as stated in Section 2. The appropriate peaking factor, including uncertainties, for events that do not employ the Statistical DNBR Evaluation Methodology (e.g. FHA) is 1.62 [Ref 25, Section 2.3.1]. However, only a small fraction of the fuel assemblies in the once burned and twice burned fuel batches even contain individual rods that may reach radial peaking factors approaching 1.62 based on the fuel management scheme and the quantity of fissile material in the assemblies. In the case of the thrice burned batch, it could not physically achieve a radial peaking factor of 1.62. In fact, the highest radial peaking factor that is reasonably expected to be achieved by a thrice burned fuel assembly is about 1.296 including uncertainties of 8%. As stated previously, the RPD's (relative power distributions) for each fuel batch are 1.35, 1.17 and 0.345 for the once burned batch, twice burned batch and thrice burned batch respectively. To determine which batch would yield the worst dose, the activities per fuel assembly for each batch must first be normalized to the maximum radial peaking factor applicable to the batch. This is shown in Table 8 below.

Table 8 - Activities Normalized to the Batch Radial Peaking Factor

Isotopes	Once Burned Activities Normalized to a Radial Peaking Factor of - 1.62	Twice Burned Activities Normalized to a Radial Peaking Factor of - 1.62	Thrice Burned Activities Normalized to a Radial Peaking Factor of – 1.296
I-130	5.72E+01	1.20E+02	1.26E+02
I-131	5.00E+05	4.76E+05	4.17E+05
I-132	4.22E+05	3.96E+05	3.45E+05
I-133	5.30E+04	4.83E+04	4.17E+04
I-135	3.79E+01	3.48E+01	3.01E+01
Kr-85	4.46E+03	8.02E+03	2.24E+04
Kr-88	1.38E-05	1.00E-05	8.12E-06
Kr-83m	1.09E-07	8.67E-08	7.21E-08
Kr-85m	3.92E-02	2.94E-02	2.40E-02
Xe-133	1.00E+06	9.17E+05	7.93E+05
Xe-135	1.82E+03	1.68E+03	1.59E+03
Xe-131m	7.51E+03	7.15E+03	6.24E+03
Xe-133m	1.85E+04	1.70E+04	1.48E+04
Xe-135m	6.07E+00	5.58E+00	4.81E+00

For the once burned batch, each activity is multiplied by 1.2 to produce the normalized activities shown in Table 8 above. This is (1.62/1.35) which is the limiting radial peaking factor for the batch divided by the RPD for the batch. For the twice burned batch each activity is multiplied by (1.62/1.17) or 1.385. For the thrice burned batch each activity is multiplied by (1.296/0.345) or 3.757. Except for krypton-85 and iodine-130, all the isotopes considered have the highest activity in the once burned batch. Krypton-85 has a half-life of 10 years which means that the krypton-85 will increase with burnup. Looking at Table 6 it can be seen that krypton-85 has an inhalation dose conversion factor of zero and a very low dose conversion factor for immersion. Furthermore, krypton-85 has much lower activity levels than iodine-131, iodine-132, iodine-133, xenon-133 and xenon-133m. Iodine-130 has negligible activity levels compared to iodine-131, iodine-133, iodine-134, xenon-131m, xenon-133, xenon-133m, and xenon135. Therefore, the small increase in the activity of iodine-130 between the once burned batch and the thrice burned batch and the small increase in the activity of krypton-85 between the once burned batch and the thrice burned batch are not radiological significant. The once burned batch would produce the largest doses in a fuel handling accident.

5.2 Determination of Gap Activity

Regulatory Guide 1.25 specifies fuel gap fractions for the fuel handling accident of 0.10 for all isotopes except for krypton-85 which has a gap fraction of 0.30. The fuel gap fractions specified in DG-1081 are 0.10 for all isotopes except for krypton-85 and iodine-131. The gap fraction for krypton-85 is 0.15 and the gap fraction for iodine-131 is 0.12. The gap fractions in DG-1081 are based on NUREG/CR-5009 [Ref 27]. NUREG/CR-5009 verifies the validity of using the Reg Guide 1.25 gap fractions when analyzing a fuel handling accident with extended burnup fuel of up to 60,000 MWD/MTU. However, NUREG/CR-5009 bases this conclusion on calculations that are meant to bound the possible releases from a fuel handling accident based on the single peak fuel rod. NUREG/CR-5009 states that the calculations are based on "the release from the peak operating rod in a fuel batch of a fuel design with high operating powers." Section 2.2 of NUREG/CR-5009 makes the following statement about the fuel gap

fraction of the peak fuel rod versus the fuel gap fractions of the rest of the fuel rods in the core.

"It should be noted that the fission-product release from the peak operating rod in any given reactor core will be substantially greater than those from 95 to 99% of the fuel rods in a fuel batch at extended burnup. For example, 95 to 99% of the rods in any given fuel batch at a batch average burnup of 50 GWd/t have fission-gas (noble) release fractions between 0.015 and 0.025 (Pati and Garde 1985), whereas the calculated peak rod in the batch may have release fractions two to five times this amount. At the current batch average burnup of 33 GWd/t the majority of the rods (95% or more) in a fuel batch with an extended burnup fuel design will have release fractions less than or equal to 0.01, with the calculated peak rod having release fractions three to five times this amount."

The fuel handling accident that is considered in this paper is for an entire fuel assembly - not the peak fuel rod. Therefore, the gap fractions that would be appropriate for this paper would be in the neighborhood of 3% and not 10%. This is further substantiated by the results of a Westinghouse study discussed in the following paragraphs.

Westinghouse has evaluated the behavior of isotope migration to the fuel rod/clad gap for irradiated fuel. This is documented in WCAP-10125-P-A, "Extended Burnup Evaluation of Westinghouse Fuel" which used the ANS 5.4 Standard Fission Product Release Model to compute the gap fraction for a typical fuel assembly at a 60,000 MWD/MTU burnup. This analysis considered 17 isotopes of iodine, krypton and xenon. Data for temperature and specific power as a function of burnup was based on data collected from an actual fuel assembly with representative temperature and power histories. The results of this analysis show that, for isotopes with half-lives of less than a year, the gap fraction is more sensitive to fuel temperature than to burnup. All isotopes of radiological significance for a fuel handling accident have half-lives less than one year and are correctly characterized by this conclusion. Thus, the lower fuel temperatures associated with lower achievable peaking factors tend to decrease the gap fraction, when inherent physical features are accounted for.

The Westinghouse calculated peak gap fractions for a typical fuel assembly at a 60,000 MWD/MTU burnup are given in Table 9 where they are compared with the Regulatory Guide 1.25 gap fractions. The Regulatory Guide 1.25 gap fractions are identical to the DG-1081 gap fractions except for krypton-85 and iodine-131. Looking at Table 9, except for krypton-85 the peak gap fraction for each isotope would be bounded by an assumed value of approximately 1%. Krypton-85 has a ten year half-life and continues to increase with increasing burnup. The peak gap fraction for krypton-85 was 26%. Based upon the Westinghouse analysis and the discussion presented in NUREG/CR-5009, except for krypton-85, the 3% gap fraction recommended for the FHA in NUREG-1465 is conservative. The Westinghouse values represent expected behavior for fuel and conditions typical of Virginia Power cores. The values used in the fuel handling accident analysis should bound these calculated values.

The gap fractions found in Appendix B of Draft Guide DG-1081 are presented for use in all non-LOCA accident analyses, including events that have accident-induced phenomena that increase the isotope migration into the gap. This situation does not apply to fuel handling accident, for which the gap content is established by the inherent phenomena of fuel depletion in a typical core. It is inappropriate to use these gap fractions for a fuel handling accident. DG-1081 specifies gap fractions of 10% to 15% for a fuel handling accident. The gap fractions specified in DG-1081 are considered excessively conservative, inconsistent with documented behavior of Virginia Power cores and not applicable to an event such as fuel handling accident

for which there is no accident-induced release of isotopes. By comparison, NUREG-1465 specifies the use of a 3% gap fraction for a fuel handling accident. This is found in the following paragraph excerpted from Section 3.6 of NUREG-1465:

"1. Accidents where long-term fuel cooling is maintained despite fuel failure. Examples include the design basis LOCA where ECCS functions and a postulated spent fuel handling accident. For this category, fuel failure is taken to result in an immediate release, based upon Reference 5 and 16, of 3 percent of the volatile fission products (noble gases, iodine, and cesium) which are in the gap between the fuel pellet and the cladding. No subsequent appreciable release from the fuel pellet occurs, since the fuel does not experience prolonged high temperatures."

The 3% gap fraction recommended in NUREG-1465 is considered sufficiently conservative relative to the expected gap fractions documented by the Westinghouse calculations in WCAP-10125-P-A. Therefore, for these calculations, a conservative gap fraction of 3% is used except for krypton-85. For krypton-85 a gap fraction of 26% is used.

The gap activity per fuel assembly for each of the 14 isotopes is calculated for the once burned batch. This calculation is shown in the Table 11 below. As can be seen from the table, a fuel assemble gap fraction of 3% was used except for krypton-85. for which a gap fraction of 26% was used.

Table 9 - Westinghouse Calculated Peak Gap Fractions
From Table 2.3 of Ref #26 - *Westinghouse Proprietary Data*

Fuel Rod Gap Release Fractions for Fuel Rod Burnups to [60000] MWD/MTU

Isotope	Regulatory Guide 1.25	Peak Release* Fraction
I-131	0.10	[ ]
I-132	0.10	[ ]
I-133	0.10	[ ]
I-134	0.10	[ ]
I-135	0.10	[ ]
Xe-131m	0.10	[ ]
Xe-133m	0.10	[ ]
Xe-133	0.10	[ ]
Xe-135m	0.10	[ ]
Xe-135	0.10	[ ]
Xe-138	0.10	[ ]
Kr-83m	0.10	[ ]
Kr-85m	0.10	[ ]
Kr-85	0.30	[ ]
Kr-87	0.10	[ ]
Kr-88	0.10	[ ]
Kr-89	0.10	[ ]

*The gap release fractions for all the listed nuclides except Kr-85 reach peak values at the end of the second fuel cycle with a rod average burnup of [ ] MWD/MTU. For Kr-85 the release fraction does not peak but increases with fuel burnup. The release fraction of [ ] is associated with a rod average burnup of [ ] MWD/MTU which is the upper value used in the analysis. For nuclides that have a peak gap release fraction, the release fraction decreases from the peak value as burnup increases.

NOTE FOR NRC REVIEWER:
In the above table the bracketed spaces contained Westinghouse proprietary data which has been removed. All of these values for the radiological significant isotopes were significantly less than 3%.

Table 11 -Calculation of Gap Activity Released from One 3% Gap Fraction Fuel Assembly

Isotope	Batch Activity (Curies)	No. of Fuel Assemblies (FA)	Activity per FA (Curies)	Batch RPD	Peaking Factor	Peaking Factor/ RPD	Activity per FA X PF/RPD (Curies)	Gap Release Fraction	Adjusted FA Activity X Gap Release (Curies)
I-130	2.67E+03	56	4.77E+01	1.35	1.62	1.200	5.72E+01	0.03	1.716E+00
I-131	2.34E+07	56	4.17E+05	1.35	1.62	1.200	5.01E+05	0.03	1.502E+04
I-132	1.97E+07	56	3.52E+05	1.35	1.62	1.200	4.23E+05	0.03	1.268E+04
I-133	2.47E+06	56	4.42E+04	1.35	1.62	1.200	5.30E+04	0.03	1.590E+03
I-135	1.77E+03	56	3.16E+01	1.35	1.62	1.200	3.79E+01	0.03	1.136E+00
Kr-85	2.09E+05	56	3.72E+03	1.35	1.62	1.200	4.47E+03	0.26	1.162E+03
Kr-88	6.46E-04	56	1.15E-05	1.35	1.62	1.200	1.38E-05	0.03	4.151E-07
Kr-83m	5.10E-06	56	9.11E-08	1.35	1.62	1.200	1.09E-07	0.03	3.279E-09
Kr-85m	1.83E+00	56	3.27E-02	1.35	1.62	1.200	3.92E-02	0.03	1.177E-03
Xe-133	4.68E+07	56	8.35E+05	1.35	1.62	1.200	1.00E+06	0.03	3.007E+04
Xe-135	8.51E+04	56	1.52E+03	1.35	1.62	1.200	1.82E+03	0.03	5.473E+01
Xe-131m	3.50E+05	56	6.26E+03	1.35	1.62	1.200	7.51E+03	0.03	2.253E+02
Xe-133m	8.63E+05	56	1.54E+04	1.35	1.62	1.200	1.85E+04	0.03	5.545E+02
Xe-135m	2.83E+02	56	5.06E+00	1.35	1.62	1.200	6.07E+00	0.03	1.820E-01

5.3 Determination of Activity Released to Atmosphere

The adjusted fuel assembly activities in the last column on the right of Tables 11 represent the activities, which would be released from the fuel assembly assumed to be damaged in either the fuel building or the containment. These isotopes would

be in a gaseous form and would bubble up through either the spent fuel pool water or the reactor refueling cavity pool water. The appendices of Draft Guide DG-1081 state that the assumed decontamination factor which should be used for the elemental iodine is 500. That is, the water is assumed to remove all but 0.2% of the elemental iodine. None of the noble gases or organic iodine isotopes are assumed to be removed by the water. Therefore, the activity which would reach the atmosphere of either the fuel building or the containment would be 0.2% of the elemental iodine released from the fuel and 100% of the noble gases and organic iodine released from the fuel. Thus, the initial activities entered into LOCADOSE for the noble gases and organic iodine will be the adjusted fuel assembly activities. For the elemental iodines, the initial activities entered into LOCADOSE will be the adjusted fuel assembly activities divided by 500 because of the scrubbing effects of the water. The initial activities entered into LOCADOSE are shown in Table 12 below for both the 3% gap fraction.

Table 12 - Initial Activities Entered in LOCADOSE for a Fuel Assembly with a 3% Gap Fraction and a Fuel Assembly with a 5% Gap Fraction

Isotope	3% Gap Fraction Fuel Assembly Activity Released To the Atmosphere (Curies)
Elemental I-130	3.433E-03
Elemental I-131	3.003E+01
Elemental I-132	2.537E+01
Elemental I-133	3.181E+00
Elemental I-135	2.272E-03
Organic I-130	1.716E+00
Organic I-131	1.502E+04
Organic I-132	1.268E+04
Organic I-133	1.590E+03
Organic I-135	1.136E+00
Kr-85	1.162E+03
Kr-88	4.151E-07
Kr-83m	3.279E-09
Kr-85m	1.177E-03
Xe-133	3.007E+04
Xe-135	5.473E+01
Xe-131m	2.253E+02
Xe-133m	5.545E+02
Xe-135m	1.820E-01

5.4 Discussion of Cases

The results of 31 LOCADOSE runs modeling the fuel handling accident are presented in this paper. These runs modeled a fuel handling accident in the fuel building and in the containment. Table 13 shows the various values of the major input parameters used in the 31 LOCADOSE runs as well as the file names used in each LOCADOSE run. The runs with a location of "Containment-E" are modeling a release from the containment equipment hatch. The runs with a location of "Containment-P" are modeling a release from the containment personnel hatch. Varying the values of the major input parameters was done to determine the sensitivity of the dose consequences to the value of the unfiltered control room inleakage, the fuel rod gap fraction, the number of control room emergency fans operating and the containment exhaust flow where applicable. Runs were also made with and without credit for the auxiliary building filters to determine their impact on the doses.

Finally, runs were made to determine the peak control room dose with an unfiltered inleakage of 10 cfm. For an unfiltered inleakage of 10 cfm the containment equipment hatch exhaust flow of 4000 cfm produced the maximum control room dose from the containment equipment hatch. Similarly, for an unfiltered inleakage of 10 cfm the containment personnel hatch exhaust flow of 4000 cfm produced the maximum control room dose from the containment personnel hatch. The LOCADOSE sensitivity runs made to determine these maximum doses are not included in this paper but could easily be reproduced.

All but one of the fuel building runs were made at an exhaust flow rate of 36,000 cfm. This is the maximum flow of one 58 fan. One run was made with an exhaust flow rate of 80,000 cfm which exceeds the rated flow of both 58 fans. The resulting offsite doses were insensitive to the increase in exhaust flow from 36,000 cfm to 80,000 cfm.

Table 13 - LOCADOSE Runs and Input Parameters

Location Of FHA	Unfiltered Control Room Inleakage	Credit Aux Build Filters	Fuel Rod Gap Fraction	Fuel Bldg or Containment Exhaust flow	No. of CR Emergency Fans	LOCADOSE File Name
Fuel Building	10 cfm	No	3%	36,000 cfm	1	F3BNH010
Containment-P	10 cfm	No	3%	4,000 cfm	1	F3CP0104

5.6 Fuel Building FHA LOCATRAN Input Files

All runs modeling a FHA in the fuel building take credit for holdup in the fuel building. The draft Regulatory Guide DG-1081 says not to take credit for dilution and holdup by the fuel building when filtering the release from the fuel handling accident in the fuel building. DG-1081 also says that the activity released from the failed fuel assembly should be evacuated to the environment within 2 hours. The flow rate out of the fuel building is set at the maximum flow of the 58 fan that would be exhausting the fuel building. This flow rate - 36,000 cfm - is sufficient to move one third of the fuel building volume every minute. Thus, the activity released by the failed fuel assembly would be exhausted to the environment in far less than 2 hours. Thus, the effects of modeling dilution and hold up by the fuel building are minimal.

Table 15 - LOCATRAN Input File for FHA in the Fuel Building with 3% Gap Fraction, 10 cfm Unfiltered CR Inleakage and Credit for the Aux Building Filters (F3BFH010)

```
FHA inFB CR10cfm inleak auxfilt 24hrTBfan delay FBhold 3%Gap          Prob title
D. L. Gilliatt                                                        Originator
Surry                                                                  Proj name
Aternate Source Term                                                       Proj #
PA-0165, Rev. 0                                                       Calc #, Rev
1                                                          First page # of output
1 6 19 1 0 0                  # Nodes, # Time steps, # Iso, CR, Dau, Spr cutoff
0 0 2605 -1 2 0 0      TID, Purge, Pwr, SD time, NPF, # Spr nodes, # Delay calcs
CFM  CUFT CURIES                          Flow unit, Volume unit, Activity unit
1 1 1 1 1 1 1 1 1 1 1 1                          Release frac for iso grps 1-12
.9975 .0025 0                                      Elem, org, part iodine frac
Fuel Bldg                                                     Name for node 2
0 1 1 1 0 1           Start, Stop, Print act, Act unit, Prod unit, Print summary
```

```
 1 0 1                                          Initial act, Prod terms, Volume
 3.433E-03      Initial Activity after DF of 500 applied Elemental I-130
 3.003E+01      Initial Activity after DF of 500 applied Elemental I-131
 2.537E+01      Initial Activity after DF of 500 applied Elemental I-132
 3.181E+00      Initial Activity after DF of 500 applied Elemental I-133
 2.272E-03      Initial Activity after DF of 500 applied Elemental I-135
 1.716E+00      Initial Activity                         Organic   I-130
 1.502E+04      Initial Activity                         Organic   I-131
 1.268E+04      Initial Activity                         Organic   I-132
 1.590E+03      Initial Activity                         Organic   I-133
 1.136E+00      Initial Activity                         Organic   I-135
 1.162E+03      Initial Activity                                  Kr-85
 4.151E-07      Initial Activity                                  Kr-88
 3.279E-09      Initial Activity                                  Kr-83m
 1.177E-03      Initial Activity                                  Kr-85m
 3.007E+04      Initial Activity                                  Xe-133
 5.473E+01      Initial Activity                                  Xe-135
 2.253E+02      Initial Activity                                  Xe-131m
 5.545E+02      Initial Activity                                  Xe-133m
 1.820E-01      Initial Activity                                  Xe-135m
 1.11E5                                                       Volume for node 2
 2 1 3.6E4 0                          Flow from node, Flow to node, Filt, Unfilt
90 70 0 0 0 0 0 0 0 0 0 0                        Filter eff for iso grps 1-12
 -1 0 0 0                                                      End flow input
 -1 0 0 0                                                    End lambda input
 1 1.60E-3    CR param chg, ventstack no.2 to turb build fresh air louver #3 X/Q
  2.23E5 0 10 0 10                   CR vol, Filt in, Unfilt in, Recirc, Outleak
  90 70 99 0 99 99 99 99 99 0 0 99         Intake filt eff (%) for iso grps 1-12
  0 0 0 0 0 0 0 0 0 0 0 0                  Recirc filt eff (%) for iso grps 1-12
1 2 1 0 0 1           Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 -1 0 0 0                                                      End flow input
 -1 0 0 0                                                    End lambda input
 1 1.60E-3    CR param chg, ventstack no.2 to turb build fresh air louver #3 X/Q
  2.23E5 1000 10 0 1010              CR vol, Filt in, Unfilt in, Recirc, Outleak
  90 70 99 0 99 99 99 99 99 0 0 99         Intake filt eff (%) for iso grps 1-12
  0 0 0 0 0 0 0 0 0 0 0 0                  Recirc filt eff (%) for iso grps 1-12
2 8 1 0 0 1           Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 2 1 3.6E4 0                          Flow from node, Flow to node, Filt, Unfilt
  90 70 0 0 0 0 0 0 0 0 0 0                        Filter eff for iso grps 1-12
 -1 0 0 0                                                      End flow input
 -1 0 0 0                                                    End lambda input
 0 1.60E-3    CR param chg, ventstack no.2 to turb build fresh air louver #3 X/Q
8 24 1 0 0 1          Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 -1 0 0 0                                                      End flow input
 -1 0 0 0                                                    End lambda input
 0 6.99E-4    CR param chg, ventstack no.2 to turb build fresh air louver #3 X/Q
24 96 1 0 0 1         Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 -1 0 0 0                                                      End flow input
 -1 0 0 0                                                    End lambda input
 0 1.71E-4    CR param chg, ventstack no.2 to turb build freshair intake #2  X/Q
96 720 1 0 0 1        Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
```

```
-1 0 0 0                                                    End flow input
-1 0 0 0                                                    End lambda input
0 1.22E-4          CR param chg, ventstack no.2 to turb build rollup door #2 X/Q
```

The LOCATRAN input file used to model the FHA in the fuel building with a 3% gap fraction, a 10 cfm unfiltered control room inleakage and no auxiliary building filters (F3BNH010) differs from Table 15 in only two lines. These lines are shown below. The first line is the flow from node 2 to node 1 - from the fuel building to the environment - for the initial 0-1 hour time step. The second line is the flow from node 2 to node 1 - from the fuel building to the environment - for the 2-8 hour time step. In these two lines the 3.6E4 cfm flow to the environment has been changed from the filtered flow column to the unfiltered flow column.

```
2 1 0 3.6E4                          Flow from node, Flow to node, Filt, Unfilt

2 1 0 3.6E4                          Flow from node, Flow to node, Filt, Unfilt
```

5.7 Containment FHA LOCATRAN Input Files

All runs modeling a FHA in the containment take credit for holdup in the containment. All runs modeling a FHA in the containment take no credit for the auxiliary building filters. In accordance with draft Regulatory Guide DG-1081, only 50% of the free containment volume is modeled as being available for dilution and holdup in the LOCADOSE runs.

Current practice is that during fuel movement the containment purge system exhausts containment air into the intake of a 58 fan which in turn exhausts to vent stack no.2. Upon receiving a high radiation signal - which would occur with a FHA - the containment purge system isolates the containment exhaust flow. For this accident it is conservatively assumed that either the containment purge system was not in use or it successfully isolates the exhaust flow to vent stack no.2 and all flow out of the containment is assumed to go out of the equipment hatch and/or the personnel hatch. This is conservative because the modeled atmospheric dispersion factor is greater if the exhaust flow goes out the equipment hatch or the personnel hatch. The equipment hatch and/or personnel hatch are/is assumed to be open when the FHA occurs and to remain open for the duration of the accident, i.e. 30 days. The above discussion does not require the operability of the containment purge and isolation system nor does it preclude leaving other containment penetrations that terminate in either the auxiliary building or safeguards building open during refueling. This will be discussed further in Section 5.9.

The exhaust flow out of the containment equipment hatch was modeled at 4000 cfm, 6,000 cfm, 16,000 cfm and 36,000 cfm. The 36,000 cfm exhaust flow yields the most complete evacuation of the radioactive gases to the environment within the 2 hours specified in DG-1081 as well as the largest doses at the EAB and LPZ. The 36,000 cfm exhaust flow is equal to the maximum flow capacity of one 58 fan and is assumed to be greater than any credible sustained containment exhaust flow out the equipment hatch and the personnel hatch combined.

Table 19 - LOCATRAN Input File for FHA in the Containment with 6,000 cfm Exhaust Flow Out the Personnel Hatch, 3% Gap Fraction and 350 cfm Unfiltered CR Inleakage (F3CP3506)

```
FHACont/2 CR350cfm nofilt 6000cfmex 3%Gap Personnel hatch            Prob title
D. L. Gilliatt                                                       Originator
Surry                                                                 Proj name
Aternate Source Term                                                     Proj #
PA-0165, Rev. 0                                                      Calc #, Rev
1                                                          First page # of output
2 6 19 1 0 0                  # Nodes, # Time steps, # Iso, CR, Dau, Spr cutoff
0 0 2605 -1 2 0 0      TID, Purge, Pwr, SD time, NPF, # Spr nodes, # Delay calcs
CFM  CUFT CURIES                          Flow unit, Volume unit, Activity unit
1 1 1 1 1 1 1 1 1 1 1 1                          Release frac for iso grps 1-12
.9975 .0025 0                                      Elem, org, part iodine frac
  Ctmt   Auxlv4                                                Name for node 2
0 1 1 1 0 1           Start, Stop, Print act, Act unit, Prod unit, Print summary
 1 0 1                                          Initial act, Prod terms, Volume
 3.433E-03 0      Initial Activity after DF of 500 applied Elemental I-130
 3.003E+01 0      Initial Activity after DF of 500 applied Elemental I-131
 2.537E+01 0      Initial Activity after DF of 500 applied Elemental I-132
 3.181E+00 0      Initial Activity after DF of 500 applied Elemental I-133
 2.272E-03 0      Initial Activity after DF of 500 applied Elemental I-135
 1.716E+00 0                                                Organic   I-130
 1.502E+04 0                                                Organic   I-131
 1.268E+04 0                                                Organic   I-132
 1.590E+03 0                                                Organic   I-133
 1.136E+00 0                                                Organic   I-135
 1.162E+03 0                                                         Kr-85
 4.151E-07 0                                                         Kr-88
 3.279E-09 0                                                         Kr-83m
 1.177E-03 0                                                         Kr-85m
 3.007E+04 0                                                         Xe-133
 5.473E+01 0                                                         Xe-135
 2.253E+02 0                                                         Xe-131m
 5.545E+02 0                                                         Xe-133m
 1.820E-01 0                                                         Xe-135m
 9.315E5  1.0E5    Per DG-1081 half containment volume of 1.863E6 used for node2
 2 3 0 6.0E3                          Flow from node, Flow to node, Filt, Unfilt
  90 0 0 0 0 0 0 0 0 0 0 0                          Filter eff for iso grps 1-12
 3 1 0 6.0E3                          Flow from node, Flow to node, Filt, Unfilt
  90 0 0 0 0 0 0 0 0 0 0 0                          Filter eff for iso grps 1-12
 -1 0 0 0                                                        End flow input
 -1 0 0 0                                                      End lambda input
 1 3.87E-3   CR param chg,CR X/Q aux bldg east louver to turbine build louver#3
  2.23E5 0 350 0 350                 CR vol, Filt in, Unfilt in, Recirc, Outleak
  90 70 99 0 99 99 99 99 99 0 0 99          Intake filt eff (%) for iso grps 1-12
  0 0 0 0 0 0 0 0 0 0 0 0                   Recirc filt eff (%) for iso grps 1-12
1 2 1 0 0 1           Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 -1 0 0 0                                                        End flow input
 -1 0 0 0                                                      End lambda input
 1 3.87E-3   CR param chg,CR X/Q aux bldg east louver to turbine build louver#3
 2.23E5 1000 350 0 1350              CR vol, Filt in, Unfilt in, Recirc, Outleak
  90 70 99 0 99 99 99 99 99 0 0 99          Intake filt eff (%) for iso grps 1-12
  0 0 0 0 0 0 0 0 0 0 0 0                   Recirc filt eff (%) for iso grps 1-12
2 8 1 0 0 1           Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 -1 0 0 0                                                        End flow input
 -1 0 0 0                                                      End lambda input
 0 3.87E-3   CR param chg,CR X/Q aux bldg east louver to turbine build louver#3
8 24 1 0 0 1          Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
```

```
 -1 0 0 0                                                    End flow input
 -1 0 0 0                                                  End lambda input
 0 1.65E-3   CR param chg,CR X/Q aux bldg east louver to turbine build louver#3
24 96 1 0 0 1         Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 -1 0 0 0                                                    End flow input
 -1 0 0 0                                                  End lambda input
 0 1.14E-3   CR param chg,CR X/Q aux bldg east louver to turbine build louver#3
96 720 1 0 0 1        Start, Stop, Print act, Act unit, Prod unit, Print summary
 0 0 0                                          Initial act, Prod terms, Volume
 -1 0 0 0                                                    End flow input
 -1 0 0 0                                                  End lambda input
 0 7.96E-4   CR param chg,CR X/Q aux bldg east louver to turbine build louver#3
```

The LOCATRAN input file used to model the FHA in the containment with a 3% gap fraction, a 10 cfm unfiltered control room inleakage and a containment personnel hatch exhaust flow of 4,000 cfm (F3CP0104) differs from Table 19 in only four lines. These lines are shown below. The first line contains the control room volume, control room filtered inflow, control room unfiltered inflow, control room recirculation flow and total control room exhaust flow for the 0-1 hour time step. The second line

contains the control room volume, control room filtered inflow, control room unfiltered inflow, control room recirculation flow and total control room exhaust flow for the 1-2 hour time step. The unfiltered inflow has been changed from 350 cfm to 10 cfm in the 0-1 hour time step and the total exhaust flow has been changed from 350 cfm to 10 cfm in the 0-1 hour time step and from 1350 cfm to 1010 cfm in the 1-2 hour time step. The third line is the flow from node 2 to node 3 - from the containment to the auxiliary building - for the initial 0-1 hour time step. The fourth line is the flow from node 3 to node 1 - from the auxiliary building to the environment - for the 0-1 hour time step. In these last two lines the flow has been changed from 6.0E3 to 4.0E3.

```
2.23E5 0 10 0 10                CR vol, Filt in, Unfilt in, Recirc, Outleak

2.23E5 1000 10 0 1010           CR vol, Filt in, Unfilt in, Recirc, Outleak

2 3 0 4.0E3                       Flow from node, Flow to node, Filt, Unfilt

3 1 0 4.0E3                       Flow from node, Flow to node, Filt, Unfilt
```

5.8 FHA LOCADOSE Input Files

The LOCADOSE input file for the fuel building FHA with a 5% gap fraction, an unfiltered control room inleakage of 10cfm and credit for auxiliary building filters is shown in Table 20 below.

Table 20 - LOCADOSE Input File for FHA in the Fuel Building with 5% Gap Fraction, 10 cfm Unfiltered CR Inleakage and Credit for Auxiliary Building Filters

```
FHAinFB CR10cfminleak auxfilter 24hrTBfandelay FBholdup 5%Gap         Prob title
D. L. Gilliatt                                                        Originator
Surry                                                                  Proj name
Aternate Source Term                                                      Proj #
PA-0165, Rev. 0                                                        Calc #, Rev
1                                                          First page # of output
DORDOF                                   calculate DOses in Regions, DOses oFfsite
2 5 3 3 1 0 0     # DP, # X/Q, # BR offsite, # Occ fac, # BR onsite, Decay, File
REM REM/HR                                            Dose unit, Dose rate unit
3.40E-3 0 0 0 0                                       SB X/Q for time steps 1-5
3.47E-4 0 0                                   SB breath rates for time steps 1-3
1.66E-4 1.66E-4 9.76E-5 3.06E-5 5.79E-6               LPZ X/Q for time steps 1-5
3.47E-4 1.75E-4 2.32E-4                       LPZ breath rates for time steps 1-3
2 8 24 96 720                                              Time step end for X/Qs
8 24 720                                 Time step end for offsite breath rates
1 1                                    Gamma cloud correction factor for SB, LPZ
0 0 0                                            Occupancy factors for node 2
0                                                  Breathing rates for node 2
1 .6 .4                                     Occupancy factors for node 3 (CR)
3.47E-4                                       Breathing rates for node 3 (CR)
24 96 720                                   Time step end for occupancy factor
720                                       Time step end for onsite breathing rate
1 1                                     Gamma cloud correction factor for nodes 2-3
```

The 21 LOCADOSE input files for the fuel building and containment equipment hatch runs are all identical except for their title lines which contain abbreviated descriptions of the input parameters used in the LOCATRAN portion of their LOCATRAN/LOCADOSE runs. The 10 remaining LOCADOSE input files for the containment personnel hatch runs are identical to Table 21 except for the title lines. The title lines contain abbreviated descriptions of the input parameters used in the LOCATRAN portion of their LOCATRAN/LOCADOSE runs.

Table 21 - LOCADOSE Input File for FHA in the Containment with a Personnel Hatch Exhaust Flow of 36,000 cfm, a 5% Gap Fraction and 350 cfm Unfiltered CR Inleakage

```
FHACont/2 CR350cfm nofilt 36000cfmex 5%Gap Personnel hatch            Prob title
D. L. Gilliatt                                                        Originator
Surry                                                                  Proj name
Aternate Source Term                                                      Proj #
PA-0165, Rev. 0                                                        Calc #, Rev
1                                                          First page # of output
DORDOF                                   calculate DOses in Regions, DOses oFfsite
2 5 3 3 1 0 0     # DP, # X/Q, # BR offsite, # Occ fac, # BR onsite, Decay, File
REM REM/HR                                            Dose unit, Dose rate unit
3.40E-3 0 0 0 0                                       SB X/Q for time steps 1-5
3.47E-4 0 0                                   SB breath rates for time steps 1-3
1.66E-4 1.66E-4 9.76E-5 3.06E-5 5.79E-6               LPZ X/Q for time steps 1-5
```

```
3.47E-4 1.75E-4 2.32E-4                    LPZ breath rates for time steps 1-3
2 8 24 96 720                                              Time step end for X/Qs
8 24 720                                  Time step end for offsite breath rates
1 1                                     Gamma cloud correction factor for SB, LPZ
0 0 0                                                Occupancy factors for node 2
0                                                      Breathing rates for node 2
0 0 0                                                Occupancy factors for node 3
0                                                      Breathing rates for node 3
1 .6 .4                                       Occupancy factors for node 4 (CR)
3.47E-4                                         Breathing rates for node 4 (CR)
24 96 720                                     Time step end for occupancy factor
720                                         Time step end for onsite breathing rate
1 1 1                                     Gamma cloud correction factor for nodes 2-4
```

5.9 Exhaust Flow and Atmospheric Dispersion Factor Considerations

The containment exhaust flow was varied from 1000cfm to 36,000cfm to find the flows that produce the maximum control room dose and the maximum offsite doses.

Between the exhaust flow range of 1000 - 36,000cfm inclusive, the highest offsite doses were produced by a containment exhaust flow of 36,000cfm. This result was dependent on whether the source of the exhaust was the equipment hatch or the personnel hatch. The containment exhaust flow which exits the containment via the personnel hatch is subject to holdup and dilution in the 45' elevation of the auxiliary building and therefore produces EAB doses slightly smaller than those for the exhaust flow from the equipment hatch. See the results in the next section.

The exhaust of the fuel building was modeled at 36,000cfm and 80,000cfm. There was essentially no difference in the results for both the control room and offsite doses at these two flow rates. The offsite doses produced by the FHA in the fuel building were slightly higher than those produced by the most limiting 36,000cfm exhaust release from the containment. The fuel building volume was modeled at 1.11E5 cubic feet and the volume of the containment was modeled at 9.315E5 cubic feet. Because the modeled volume of the fuel building was so much smaller than the modeled volume of the containment, the time required to remove the entire FHA release from the fuel building was much less than the time to remove the entire FHA release from the containment. Thus, the offsite doses for the fuel building with a 36,000cfm exhaust flow bound any offsite doses that could be produced by any credible sustained exhaust flow from the containment. The offsite doses are relatively insensitive to release flows in excess of 36,000 cfm.

The conclusion of the preceding paragraph means that the combined exhaust flow from the containment equipment hatch, personnel hatch and penetrations terminating in the auxiliary building or the safeguards building would produce offsite doses smaller than the fuel building offsite doses at an exhaust flow of 80,000cfm. Only penetrations terminating in the auxiliary building or the safeguards are included in the above statement because ventilation considerations have only been made for the auxiliary building and safeguards building.

The equipment hatch exhaust flow that produced the largest control room dose at 10cfm of unfiltered control room inleakage was 4000cfm. The personnel hatch exhaust flow that produced the largest control room dose at 10cfm of unfiltered control room inleakage was also 4000cfm. However, because of the much larger atmospheric factors applied to the personnel hatch exhaust flow the maximum control room dose from the personnel hatch was about 2.5 times larger than the maximum control room dose from the equipment hatch exhaust flow. (See results in the next section.)

Airborne releases from penetrations in the auxiliary building on other than the 45′ elevation are considered to be part of personnel hatch exhaust release. This is because airborne releases on other auxiliary building elevations would either migrate up to the 45′ elevation and go out the 45′ louvers like the personnel hatch exhaust flow or be captured by the auxiliary building ventilation and go up vent stack no.2. Since vent stack no.2 has smaller atmospheric dispersion factors than the 45′ elevation louvers, it is conservative to lump any auxiliary building penetration releases in with the personnel hatch releases.

Airborne releases from penetrations in the safeguards are also considered to be part of the personnel hatch exhaust flow. This is because airborne releases in the safeguards building would either be captured by the safeguards ventilation system and go up vent stack no.2 or - if there is no safeguards ventilation working - collect in the safeguards building and gradually leak out to the environment. In either case the atmospheric dispersion factor applied to the personnel hatch would be conservative.

6) Results

Table 22 shows the doses for a FHA in the fuel building. Table 24 shows the doses for a FHA in the containment with exhaust flow out the personnel hatch respectively. The doses shown in Tables 22 and 24 are the sum of the columns labeled "Eff-Immer" and "Eff-Inhal" in the LOCADOSE output. The control room and offsite dose limits are 5 and 6.25 REM TEDE respectively.

Table 22 - LOCADOSE Results for a Fuel Handling Accident in the Fuel Building (/ 3% Gap Fraction Dose in REM TEDE)

Ventilation / Filtration Assumptions	Control Room	EAB	LPZ
10 cfm CR inleakage w/36000exh no aux filters		**/ 3.400**	**/ 0.166**

Table 24 - LOCADOSE Results for a Fuel Handling Accident in the Containment With Exhaust Flow Out of the Personnel Hatch (/ 3% Gap Fraction Dose in REM TEDE)

Ventilation / Filtration Assumptions	Control Room	EAB	LPZ
+10 cfm CR inleakage w/4000 cfm contain exh	**/ 0.530**		

+ 4000 cfm containment exhaust flow produced the peak control room dose with a 10 cfm unfiltered control room inleakage. The LOCADOSE runs made to determine this are not included in this paper but could easily be reproduced.

It should be noted that all the runs except those for the containment personnel hatch, assumed that the turbine building fans were turned off by 24 hours after the release. Upon examination of the dose consequences, the dose contributions to the control room are so small from 24-720 hours that whether the turbine building fans are turned off or left running makes no significant difference. The atmospheric dispersion factors that should be used if the turbine building fans were left running after 24 hours are about 3 times larger than the atmospheric dispersion factors used in the LOCADOSE runs for the time steps from 24-720 hours. This translates directly into dose contributions three times higher for the time steps after 24 hours. The dose contributions to the control room for the time steps after 24 hours are shown below in Table 25.

Table 25 - Total Control Room Doses and Control Room Doses from 24-720 Hours

Location Of FHA	Unfiltered CR Inleakage	Credit Aux Filters	Fuel Rod Gap Fract	Containment Exhaust flow	No. of CR Fans	24-720 Hr CR Dose	Previous CR Dose	Adjusted CR Dose	LOCADOSE File Name
Fuel Building	350 cfm	No	5%	N/A	1	6E-5	0.680	0.680	FBNFH350
Fuel Building	350 cfm	Yes	5%	N/A	1	1E-5	0.150	0.150	FBFHU350
Fuel Building	10 cfm	No	5%	N/A	1	2E-5	0.026	0.026	FBNFHU10
Fuel Building	10 cfm	Yes	5%	N/A	1	5E-5	0.006	0.006	FBFIHU10
Fuel Building	10 cfm	No	3%	N/A	1	0	0.016	0.016	F3B80000
Fuel Building	350 cfm	Yes	3%	N/A	1	9E-6	0.090	0.090	F3BFH350
Fuel Building	350 cfm	No	3%	N/A	1	4E-5	0.408	0.408	F3BNH350
Fuel Building	10 cfm	Yes	3%	N/A	1	3E-6	0.004	0.004	F3BFH010
Fuel Building	10 cfm	No	3%	N/A	1	1E-5	0.016	0.016	F3BNH010
Fuel Building	10 cfm	No	5%	N/A	2	2E-8	0.016	0.016	FB2FN010
Fuel Building	350 cfm	No	5%	N/A	2	8E-8	0.470	0.470	FB2FN350
Containment-E	10 cfm	No	5%	36,000 cfm	1	8E-5	0.073	0.073	FCT01036
Containment-E	10 cfm	No	5%	4,000 cfm	1	1.7E-3	0.352	0.355*	FCT01004
Containment-E	350 cfm	No	5%	6,000 cfm	1	8E-5	0.815	0.815	FCT35006
Containment-E	350 cfm	No	5%	16,000 cfm	1	1E-4	0.759	0.759	FCT35016
Containment-E	350 cfm	No	5%	36,000 cfm	1	4E-4	0.703	0.704*	FCT35036
Containment-E	10 cfm	No	3%	4,000 cfm	1	1.1E-3	0.211	0.213*	F3C01004
Containment-E	10 cfm	No	3%	36,000 cfm	1	5E-5	0.044	0.044	F3C01036
Containment-E	350 cfm	No	3%	6,000 cfm	1	5E-5	0.489	0.489	F3C35006
Containment-E	350 cfm	No	3%	36,000 cfm	1	7E-5	0.422	0.422	F3C35036
Containment-E	350 cfm	No	3%	16,000 cfm	1	2E-4	0.456	0.456	F3C35016

The control room doses received from 24-720 hours are multiplied by a factor of 2 and added to the total control room doses to account for the increase in atmospheric dispersion factors. The resulting control room doses are unchanged except for the FCT01004, F3C01004 and FCT35036 cases. In the FCT01004 case the total dose would increase by 0.003 Rem, in the F3C01004 case the total dose would increase 0.002 Rem and in the FCT35036 case the total dose would increase by 0.001 Rem. Therefore, for the purposes of this paper, whether the turbine building fans are turned off or not by 24 hours makes no appreciable difference to the control room doses. The turbine building fans do not effect the offsite doses.

Finally, it should also be noted that node number 2 in the LOCADOSE runs F3C01036, F3C35006, F3C35016 and F3C35036 is labeled "Fuel Bldg" instead of "Ctmt". The doses calculated by these runs are correct. This is only a labeling error.

8) REFERENCES

1) NUREG-1465, "Accident Source Terms for Light-Water Nuclear Power Plants", L. Soffer et al., February 1995.

2) U.S. Atomic Energy Commission Technical Information Document (TID)-14844, "Calculation of Distance Factors for Power and Test Reactor Sites", J.J. DiNunno et al., 1962.

3) Federal Guidance Report No. 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion", EPA 520/1-88-020, Environment Protection Agency, Washington, D.C., 1988.

4)

5)

6)

7)

8)

9) Regulatory Guide 1.52, "Design, Testing and Maintenance Criteria for Engineered Safety Feature Atmosphere Cleanup System Air Filtration and Adsorption Units of Light Water Cooled Nuclear Power Plants," Rev. 2, March 1978.

10) Regulatory Guide 1.109, Revision 1, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I," October 1977.

11) LOCADOSE NE319, "A Computer Code System for Multi-Region Radioactive Transport and Dose Calculation," User's Manual, Revision 4A, August 1995, Bechtel Power Corporation, San Francisco, CA.

12) Computer Code LOCADOSE, Version 4.1, 05/26/95. LOCATRAN, Version 4.1, 05/26/95.

13) LOCADOSE NE319, "A Computer Code System for Multi-Region Radioactive Transport and Dose Calculation," Theoretical Manual, Revision 4, June 1995, Bechtel Power Corporation, San Francisco, CA.

14) K. G. Murphy and K. M. Campe, "Nuclear Power Plant Control Room Ventilation System Design for Meeting General Design Criterion 19," 13th AEC Air Cleaning Conference, August 1974.

15) Regulatory Guide 1.145, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants," Rev. 1, November 1982.

16) Regulatory Guide 1.49, "Power Levels of Nuclear Plants", December 1973.

17)

18) U.S. Nuclear Regulatory Commission Draft Guide DG-1081 (preliminary).

19)

20) Federal Guidance Report No. 12, "External Exposures to Radionuclides in Air, Water and Soil", EPA 420-r-93-081, Environmental Protection Agency.

21) AEB-98-01, "Detailed Modeling and Analysis of Phase III of the Revised (NUREG-1465) Source Term Rebaselining for Operating Reactors", Chester Gingrich, Jason Schaperow, Office of Nuclear Regulatory Commission, September 23, 1998.

22)

23) Virginia Power Surry Power Station Technical Specifications 4.12 Auxiliary Ventilation Exhaust Filter Trains, Basis, 1-17-1984.

24)

25) Letter, Bart C. Buckley (NRC) to W. L. Stewart, "Surry Units 1 and 2 - Issuance of Amendments Re: F Delta H Limit and Statistical DNBR Methodology (TAC Nos. M81271 and M82168)," June 1, 1992.

26) WCAP-10125-P-A, "Extended Burnup Evaluation of Westinghouse Fuel", December 1985, Edited by S.L.Davidson and W.R.Kramer.

27) NUREG/CR-5009, PNL-6258, "Assessment of the Use of Extended Burnup Fuel in Light Water Power Reactors", February, 1988.

28)

29) Surry Technical Specification 3.10 - REFUELING, condition 11., "No movement of irradiated fuel in the reactor core shall be accomplished until the reactor has been subcritical for a period of at least 100 hours."

30) NCRODP-47, Surry Power Station Primary Ventilation, page 53, CAT I and CAT II Filtration, "The capacity of each CAT I filter train and fan is rated at 36,000 cfm ….", 12-21-98.

31) Surry Technical Specification 3.10.

32)

33) Virginia Power Surry Power Station Operating Procedure 0-OP-4.8, Revision 12, "Spent Fuel Assembly Handling Tool (Long Handling Tool)", Initial Conditions and Precautions and Limitations.

34) Virginia Power Surry Power Station Operating Procedure 1-OP-FH-015, Revision 2, "Manipulator Crane", Initial Conditions and Precautions and Limitations.

35) Virginia Power Surry Power Station Operating Procedure 1-OP-FH-001, Revision 9, "Controlling Procedure for Refueling", Precautions and Limitations.

36) Virginia Power Surry Power Station Operating Procedure 0-OP-4.13, Revision 5-P1, "Fuel Transfer System", Initial Conditions.

37) Virginia Power Surry Power Station UFSAR Chapter 14, Section 4.1, "General Station Accident Analysis - Fuel Handling Accidents", Revision 31, 11/16/99.

38) Virginia Power drawings 11448-FMA, 11448-FMB, 11448-FMC, 11448FMD.

39) Virginia Power drawing 11448-FA-24B.

ATTACHMENT 2

(QUESTION NO. 6)

1. Diskette containing:

   Self-extracting ZIP files of the meteorological data used to calculate X/Q values in the ARCON96 format

   ARCON96 input and output files

2. Listing of source and receptor geometries and the corresponding ARCON96 output files

ARCON96 OUTPUT FILES

Source	Receptor	File Name
Unit 1 Reactor	D1	SuU1D1.26o
	D2	SuU1D2.26o
	L1	SuU1L1.26o
	L1	SuU1L1.48o
	L2	SuU1L2.26o
	L3	SuU1L3.26o
	R1	SuU1R1.26o
	R2	SuU1R2.26o
	R3	SuU1R3.26o
	R4	SuU1R4.26o
	R5	SuU1R5.26o
	R6	SuU1R6.26o
	R7	SuU1R7.26o
Vent Stack #2	D1	SuV2D1F.26o
	D1	SuV2D1L.26o
	D2	SuV2D2F.26o
	D2	SuV2D2L.26o
	L1	SuV2L1F.26o
	L2	SuV2L2F.26o
	L3	SuV2L3F.26o
	L3	SuV2L3F.48o
	R1	SuV2R1F.26o
	R2	SuV2R2F.26o
	R3	SuV2R3F.26o
	R4	SuV2R4F.26o
	R5	SuV2R5F.26o
	R6	SuV2R6F.26o
	R7	SuV2R7F.26o
	R6	SuV2R6L.26o
	R7	SuV2R7L.26o
East Aux Bldg	D1	SuEaxD1.26o
	D2	SuEaxD2.26o
	L1	SuEaxL1.26o
	L2	SuEaxL2.26o
	L3	SuEaxL3.26o
	L3	SuEaxL3.48o
	R1	SuEaxR1.26o
	R2	SuEaxR2.26o
	R3	SuEaxR3.26o
	R4	SuEaxR4.26o
	R5	SuEaxR5.26o
	R6	SuEaxR6.26o
	R7	SuEaxR7.26o

Source	Receptor	File Name
Unit 2 Reactor	D2	SuU2D2.26o
	L3	SuU2L3.26o
	L3	~~SuU1L1.48o~~ SuU2L3.48o
	R5	SuU2R5.26o
West Aux Bldg	D1	SuWaxD1.26o
	D2	SuWaxD2.26o
	L1	SuWaxL1.26o
	L2	SuWaxL2.26o
	L3	SuWaxL3.26o
	R1	SuWaxR1.26o
	R2	SuWaxR2.26o
	R3	SuWaxR3.26o
	R4	SuWaxR4.26o
	R5	SuWaxR5.26o
	R6	SuWaxR6.26o
	R7	SuWaxR7.26o
	R3	SuWAXR3.48o

File extensions ".26o" and ".48o" denote years1982-86 and 1994-98, respectively.

(A marked-up site plan indicating the relative locations of the sources and receptors is provided in Attachment 3.)

ATTACHMENT 3

(QUESTION NO. 7)

1. PAVAN input files and joint frequency distribution tables
2. Marked up site plan indicating the relative locations of the sources and receptors
3. Summary of the horizontal and vertical distances and direction from the receptor location to the sources that were used in the ARCON96 input files

TABLE 3. PAVAN Input File – Unit 1 Rector Release

```
0100 00001
Surry (VA Power)      1982-86 JFD          Ground-Level Release
  9.6 m               9.6 m - 44.9 m
Onsite
Unit 1 Ractor Release
    6     0
 960. 35.5  10.  9.6
    0     0     0     0     0     0     0
    5     3     2     3     3     2     4     3     2     2     1     8     4     3     7     5
  150   248   234   209   350   478   341   280   256   206   239   569   498   456   579   180
   50   312   456   233   149   349   300   303   315   254   199   311   217    20    60    20
    4    47    90    26    30    52    58    41    40     5     8     5     6     0     0     2
    0     1     2     4     9     5     5     1     0     0     0     2     0     0     0     0
    0     0     1     0     2     0     1     0     0     0     0     0     0     0     0     0
    1     0     2     1     1     0     0     0     0     2     0     1     1     2     3     0
   28    42    55    54    61    68    50    42    60    37    34    61    64    45    61    24
   12    33    49    38    17    31    22    25    62    42    32    35    22     2     5     6
    1    10     8     7    10     2     9     3     3     0     3     1     1     0     0     0
    0     1     1     0     0     2     0     0     0     0     0     2     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
    1     1     1     1     0     1     0     0     0     1     1     0     2     0     4     1
   25    52    67    48    48    44    57    45    71    46    43    57    80    59    50    29
   13    42    62    42    27    25    20    40    52    47    44    32    18     1     1     6
    2     7    11     2     7     3     9    11     3     1     0     2     2     0     0     0
    0     1     0     0     1     0     1     1     1     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
   26    23    16    16    16     8    13     9    15    15     6    12    14    27    38    30
  161   274   283   257   234   237   239   393   397   359   441   343   459   350   229   175
   71   220   213   135   121   117   161   346   434   364   301   309   186    29    34    34
   20    52    48    24    33    33    91    79    85    38    34    56    14     6     1     4
    1     6     1     1     6     4     6     1     7     3     7    17     4     1     0     0
    0     1     0     0     0     0     0     0     0     0     0     1     0     0     0     0
   86    58    31    24    27    22    17    18    22    15    21    20    32    61    94    99
  649   769   638   526   363   277   271   467   614   466   455   283   544   719   350   484
  227   660   365   217   152   122   219   302   257   150   137    56    70    23    56    53
   14    38    32    18    27    22    27    15    19     1     8    10     7     5     1     3
    0     1     4     1     7     0     1     0    11     3     6     3     9     0     0     0
    0     0     1     0     0     0     0     0     0     0     0     0     0     0     0     0
  100    83    52    29    26    24    25    37    26    17    23    28    38    83   156   169
  565   593   443   292   239   153   140   183   223   111    60    64    68   140   167   335
   10    27    16     3     4     1     2     4     9     2     0     0     0     0     0     4
    0     0     0     0     1     0     0     0     1     0     0     0     0     0     0     1
    0     0     0     0     1     0     0     0     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
  383   335   216   157   113    98    79    68    55    34    37    40    68    94   202   318
  477   566   252   111   100    82    78    77    56    36    22    24    18    28    96   256
    0     1     2     1     3     1     0     3     0     0     0     0     0     0     0     0
    0     0     0     1     0     0     0     1     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
   -1. 0.99   2.9   4.9   6.9   8.9  11.9
  503. 503. 503. 503. 503. 503. 503. 503. 503. 503. 503. 503. 503. 503. 503. 503.
 4827.4827.4827.4827.4827.4827.4827.4827.4827.4827.4827.4827.4827.4827.4827.4827.
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TABLE 3. (Cont'd) PAVAN Input File - Unit 2 Rector Release

```
0100 00001
Surry (VA Power)      1982-86 JFD          Ground-Level Release
  9.6 m               9.6 m - 44.9 m
Onsite
Unit 2 Ractor Release
    6     0
  960.  35.5   10.   9.6
    0     0     0     0     0     0     0
    5     3     2     3     3     2     4     3     2     2     1     8     4     3     7     5
  150   248   234   209   350   478   341   280   256   206   239   569   498   456   579   180
   50   312   456   233   149   349   300   303   315   254   199   311   217    20    60    20
    4    47    90    26    30    52    58    41    40     5     8     5     6     0     0     2
    0     1     2     4     9     5     5     1     0     0     0     2     0     0     0     0
    0     0     1     0     2     0     1     0     0     0     0     0     0     0     0     0
    1     0     2     1     1     0     0     0     0     2     0     1     1     2     3     0
   28    42    55    54    61    68    50    42    60    37    34    61    64    45    61    24
   12    33    49    38    17    31    22    25    62    42    32    35    22     2     5     6
    1    10     8     7    10     2     9     3     3     0     3     1     1     0     0     0
    0     1     1     0     0     2     0     0     0     0     0     2     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
    1     1     1     1     0     1     0     0     0     1     1     0     2     0     4     1
   25    52    67    48    48    44    57    45    71    46    43    57    80    59    50    29
   13    42    62    42    27    25    20    40    52    47    44    32    18     1     1     6
    2     7    11     2     7     3     9    11     3     1     0     2     2     0     0     0
    0     1     0     0     1     0     1     1     1     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
   26    23    16    16    16     8    13     9    15    15     6    12    14    27    38    30
  161   274   283   257   234   237   239   393   397   359   441   343   459   350   229   175
   71   220   213   135   121   117   161   346   434   364   301   309   186    29    34    34
   20    52    48    24    33    33    91    79    85    38    34    56    14     6     1     4
    1     6     1     1     6     4     6     1     7     3     7    17     4     1     0     0
    0     1     0     0     0     0     0     0     0     0     0     1     0     0     0     0
   86    58    31    24    27    22    17    18    22    15    21    20    32    61    94    99
  649   769   638   526   363   277   271   467   614   466   455   283   544   719   350   484
  227   660   365   217   152   122   219   302   257   150   137    56    70    23    56    53
   14    38    32    18    27    22    27    15    19     1     8    10     7     5     1     3
    0     1     4     1     7     0     1     0    11     3     6     3     9     0     0     0
    0     0     1     0     0     0     0     0     0     0     0     0     0     0     0     0
  100    83    52    29    26    24    25    37    26    17    23    28    38    83   156   169
  565   593   443   292   239   153   140   183   223   111    60    64    68   140   167   335
   10    27    16     3     4     1     2     4     9     2     0     0     0     0     0     4
    0     0     0     0     1     0     0     0     1     0     0     0     0     0     0     1
    0     0     0     0     1     0     0     0     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
  383   335   216   157   113    98    79    68    55    34    37    40    68    94   202   318
  477   566   252   111   100    82    78    77    56    36    22    24    18    28    96   256
    0     1     2     1     3     1     0     3     0     0     0     0     0     0     0     0
    0     0     0     1     0     0     0     1     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
   -1.  0.99   2.9   4.9   6.9   8.9  11.9
  511.  483.  455.  433.  423.  423.  427.  434.  453.  485.  517.  545.  572.  587.  575.  547.
 4744. 4744. 4744. 4744. 4744. 4744. 4744. 4744. 4744. 4744. 4744. 4744. 4744. 4744. 4744. 4744.
```

TABLE 3. (Cont'd) PAVAN Input File - Vent Stack #2 Release

```
0100 00001
Surry (VA Power)     1982-86 JFD          Ground-Level Release
  9.6 m              9.6 m - 44.9 m
Onsite
Vent Release (no plume rise)
    6     0
  960. 35.5  10.   9.6
    0     0     0     0     0     0     0
    5     3     2     3     3     2     4     3     2     2     1     8     4     3     7     5
  150   248   234   209   350   478   341   280   256   206   239   569   498   456   579   180
   50   312   456   233   149   349   300   303   315   254   199   311   217    20    60    20
    4    47    90    26    30    52    58    41    40     5     8     5     6     0     0     2
    0     1     2     4     9     5     5     1     0     0     0     2     0     0     0     0
    0     0     1     0     2     0     1     0     0     0     0     0     0     0     0     0
    1     0     2     1     1     0     0     0     0     2     0     1     1     2     3     0
   28    42    55    54    61    68    50    42    60    37    34    61    64    45    61    24
   12    33    49    38    17    31    22    25    62    42    32    35    22     2     5     6
    1    10     8     7    10     2     9     3     3     0     3     1     1     0     0     0
    0     1     1     0     0     2     0     0     0     0     0     2     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
    1     1     1     1     0     1     0     0     0     1     1     0     2     0     4     1
   25    52    67    48    48    44    57    45    71    46    43    57    80    59    50    29
   13    42    62    42    27    25    20    40    52    47    44    32    18     1     1     6
    2     7    11     2     7     3     9    11     3     1     0     2     2     0     0     0
    0     1     0     0     1     0     1     1     1     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
   26    23    16    16    16     8    13     9    15    15     6    12    14    27    38    30
  161   274   283   257   234   237   239   393   397   359   441   343   459   350   229   175
   71   220   213   135   121   117   161   346   434   364   301   309   186    29    34    34
   20    52    48    24    33    33    91    79    85    38    34    56    14     6     1     4
    1     6     1     1     6     4     6     1     7     3     7    17     4     1     0     0
    0     1     0     0     0     0     0     0     0     0     0     1     0     0     0     0
   86    58    31    24    27    22    17    18    22    15    21    20    32    61    94    99
  649   769   638   526   363   277   271   467   614   466   455   283   544   719   350   484
  227   660   365   217   152   122   219   302   257   150   137    56    70    23    56    53
   14    38    32    18    27    22    27    15    19     1     8    10     7     5     1     3
    0     1     4     1     7     0     1     0    11     3     6     3     9     0     0     0
    0     0     1     0     0     0     0     0     0     0     0     0     0     0     0     0
  100    83    52    29    26    24    25    37    26    17    23    28    38    83   156   169
  565   593   443   292   239   153   140   183   223   111    60    64    68   140   167   335
   10    27    16     3     4     1     2     4     9     2     0     0     0     0     0     4
    0     0     0     0     1     0     0     0     1     0     0     0     0     0     0     1
    0     0     0     0     1     0     0     0     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
  383   335   216   157   113    98    79    68    55    34    37    40    68    94   202   318
  477   566   252   111   100    82    78    77    56    36    22    24    18    28    96   256
    0     1     2     1     3     1     0     3     0     0     0     0     0     0     0     0
    0     0     0     1     0     0     0     1     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
   -1.  0.99   2.9   4.9   6.9   8.9  11.9
  523.  494.  476.  455.  447.  446.  444.  451.  468.  485.  513.  532.  551.  564.  561.  545.
 4721. 4721. 4721. 4721. 4721. 4721. 4721. 4721. 4721. 4721. 4721. 4721. 4721. 4721. 4721. 4721.
```

TABLE 3. (Cont'd) PAVAN Input File - Aux. Bldg. West Louver Release

```
0100 00001
Surry (VA Power)      1982-86 JFD          Ground-Level Release
  9.6 m               9.6 m - 44.9 m
Onsite
Aux Bldg West Louver Release
    6    0
 960. 35.5  10.   9.6
    0    0    0    0    0    0    0
    5    3    2    3    3    2    4    3    2    2    1    8    4    3    7    5
  150  248  234  209  350  478  341  280  256  206  239  569  498  456  579  180
   50  312  456  233  149  349  300  303  315  254  199  311  217   20   60   20
    4   47   90   26   30   52   58   41   40    5    8    5    6    0    0    2
    0    1    2    4    9    5    5    1    0    0    0    2    0    0    0    0
    0    0    1    0    2    0    1    0    0    0    0    0    0    0    0    0
    1    0    2    1    1    0    0    0    0    2    0    1    1    2    3    0
   28   42   55   54   61   68   50   42   60   37   34   61   64   45   61   24
   12   33   49   38   17   31   22   25   62   42   32   35   22    2    5    6
    1   10    8    7   10    2    9    3    3    0    3    1    1    0    0    0
    0    1    1    0    0    2    0    0    0    0    0    2    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    1    1    1    1    0    1    0    0    0    1    1    0    2    0    4    1
   25   52   67   48   48   44   57   45   71   46   43   57   80   59   50   29
   13   42   62   42   27   25   20   40   52   47   44   32   18    1    1    6
    2    7   11    2    7    3    9   11    3    1    0    2    2    0    0    0
    0    1    0    0    1    0    1    1    1    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   26   23   16   16   16    8   13    9   15   15    6   12   14   27   38   30
  161  274  283  257  234  237  239  393  397  359  441  343  459  350  229  175
   71  220  213  135  121  117  161  346  434  364  301  309  186   29   34   34
   20   52   48   24   33   33   91   79   85   38   34   56   14    6    1    4
    1    6    1    1    6    4    6    1    7    3    7   17    4    1    0    0
    0    1    0    0    0    0    0    0    0    0    0    1    0    0    0    0
   86   58   31   24   27   22   17   18   22   15   21   20   32   61   94   99
  649  769  638  526  363  277  271  467  614  466  455  283  544  719  350  484
  227  660  365  217  152  122  219  302  257  150  137   56   70   23   56   53
   14   38   32   18   27   22   27   15   19    1    8   10    7    5    1    3
    0    1    4    1    7    0    1    0   11    3    6    3    9    0    0    0
    0    0    1    0    0    0    0    0    0    0    0    0    0    0    0    0
  100   83   52   29   26   24   25   37   26   17   23   28   38   83  156  169
  565  593  443  292  239  153  140  183  223  111   60   64   68  140  167  335
   10   27   16    3    4    1    2    4    9    2    0    0    0    0    0    4
    0    0    0    0    1    0    0    0    1    0    0    0    0    0    0    1
    0    0    0    0    1    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  383  335  216  157  113   98   79   68   55   34   37   40   68   94  202  318
  477  566  252  111  100   82   78   77   56   36   22   24   18   28   96  256
    0    1    2    1    3    1    0    3    0    0    0    0    0    0    0    0
    0    0    0    1    0    0    0    1    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   -1. 0.99  2.9  4.9  6.9  8.9 11.9
  532. 523. 519. 498. 489. 470. 474. 472. 474. 479. 487. 498. 513. 526. 536. 538.
 4793.4793.4793.4793.4793.4793.4793.4793.4793.4793.4793.4793.4793.4793.4793.4793.
```

TABLE 3. (Cont'd) PAVAN Input File - Aux. Bldg. East Louver Release

```
0100 00001
Surry (VA Power)      1982-86 JFD          Ground-Level Release
  9.6 m               9.6 m - 44.9 m
Onsite
Aux Bldg East Louver Release
    6    0
 960. 35.5  10.   9.6
    0    0    0    0    0    0    0
    5    3    2    3    3    2    4    3    2    2    1    8    4    3    7    5
  150  248  234  209  350  478  341  280  256  206  239  569  498  456  579  180
   50  312  456  233  149  349  300  303  315  254  199  311  217   20   60   20
    4   47   90   26   30   52   58   41   40    5    8    5    6    0    0    2
    0    1    2    4    9    5    5    1    0    0    0    2    0    0    0    0
    0    0    1    0    2    0    1    0    0    0    0    0    0    0    0    0
    1    0    2    1    1    0    0    0    0    2    0    1    1    2    3    0
   28   42   55   54   61   68   50   42   60   37   34   61   64   45   61   24
   12   33   49   38   17   31   22   25   62   42   32   35   22    2    5    6
    1   10    8    7   10    2    9    3    3    0    3    1    1    0    0    0
    0    1    1    0    0    2    0    0    0    0    0    2    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    1    1    1    1    0    1    0    0    0    1    1    0    2    0    4    1
   25   52   67   48   48   44   57   45   71   46   43   57   80   59   50   29
   13   42   62   42   27   25   20   40   52   47   44   32   18    1    1    6
    2    7   11    2    7    3    9   11    3    1    0    2    2    0    0    0
    0    1    0    0    1    0    1    1    1    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   26   23   16   16   16    8   13    9   15   15    6   12   14   27   38   30
  161  274  283  257  234  237  239  393  397  359  441  343  459  350  229  175
   71  220  213  135  121  117  161  346  434  364  301  309  186   29   34   34
   20   52   48   24   33   33   91   79   85   38   34   56   14    6    1    4
    1    6    1    1    6    4    6    1    7    3    7   17    4    1    0    0
    0    1    0    0    0    0    0    0    0    0    0    1    0    0    0    0
   86   58   31   24   27   22   17   18   22   15   21   20   32   61   94   99
  649  769  638  526  363  277  271  467  614  466  455  283  544  719  350  484
  227  660  365  217  152  122  219  302  257  150  137   56   70   23   56   53
   14   38   32   18   27   22   27   15   19    1    8   10    7    5    1    3
    0    1    4    1    7    0    1    0   11    3    6    3    9    0    0    0
    0    0    1    0    0    0    0    0    0    0    0    0    0    0    0    0
  100   83   52   29   26   24   25   37   26   17   23   28   38   83  156  169
  565  593  443  292  239  153  140  183  223  111   60   64   68  140  167  335
   10   27   16    3    4    1    2    4    9    2    0    0    0    0    0    4
    0    0    0    0    1    0    0    0    1    0    0    0    0    0    0    1
    0    0    0    0    1    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  383  335  216  157  113   98   79   68   55   34   37   40   68   94  202  318
  477  566  252  111  100   82   78   77   56   36   22   24   18   28   96  256
    0    1    2    1    3    1    0    3    0    0    0    0    0    0    0    0
    0    0    0    1    0    0    0    1    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   -1. 0.99  2.9  4.9  6.9  8.9 11.9
  539. 515. 493. 470. 461. 444. 444. 444. 455. 470. 474. 513. 539. 557. 566. 558.
 4765.4765.4765.4765.4765.4765.4765.4765.4765.4765.4765.4765.4765.4765.4765.4765.
```

TABLE 3. (Cont'd) PAVAN Input File - Unit 1 Reactor Release
(1994-98 meteorological data)

```
0100 00001
Surry (VA Power)      1994-98 JFD          Ground-Level Release
  9.6 m               9.6 m - 44.9 m
Onsite
Unit 1 Reactor Release
    7    0
 960. 35.5  10.   9.6
    0    0    0    0    0    0    0
    1    0    0    1    0    0    0    0    0    1    0    0    2    0    1    3
   98  181  268  185  370  585  438  181  160  207  232  293  503  585  364   93
    8   83  403  184  122  245  344  217   85  104   72  111  351   26    6    1
    1    1   24    8    8    1   51   15    0    0    3    3   27    0    0    0
    0    0    0    0    0    0    2    3    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    1    0    1    0    0    0    0    0    1    0    0    1    1    2    5    0
   22   45   82   57   72   83   72   66   51   61   72   71  144  113   52   19
    3   20   70   45   16   10   31   45   17   13   12   18   62    4    0    3
    0    0    4    3    4    0   13    3    0    0    0    0    2    0    0    0
    0    0    0    0    0    0    1    0    0    0    0    0    2    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    3    1    2    1    7    1    1    0    2    2    1    1    0    3    4    4
   16   42   80   72   70   83   89   72   96   68   77   96  140  104   54   26
    7   14   68   46   19   13   37   56   26   17   29   20   70    0    0    2
    0    1    6    8    3    1    9    8    0    1    0    1    7    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    1    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   28   38   37   37   39   32   26   24   22   26   31   21   21   39   58   44
  167  271  492  439  325  295  386  629  679  520  491  445  658  403  306  121
   36  135  292  230   83   53  295  539  225  131  125  138  478   13   13   21
    1    0   20   18    3    6   77   59    1    3    6   14   59    0    0    2
    0    0    0    1    0    0    5    0    0    0    0    0    4    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    1    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  132   91  110  129   73   46   41   51   67   50   68   55   77  168  259  199
  502  839 1336 1075  466  202  362  743  618  299  410  343  513  735  625  431
   65  180  281  214   74   47  179  190   65   29   19   22  159   12   20   15
    1    2    8   11    4    3   15   14    1    1   11    9   23    1    0    0
    0    0    0    0    0    0    0    0    0    0    0    1    8    1    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    3    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    2    0    0    0
  191  150  130  109  106   79   62   78   61   62   72   63   89  222  411  269
  104  240  353  315  101   44   82   90   73   38   36   14   61  111  116   74
    0    0    2    4    0    0    0    0    1    0    0    0    1    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  391  393  398  314  385  444  473  277  219   96   97   97  183  231  391  332
   18  116  193   97   17   14   16   13   16    4    2    6    6   10    7    4
    0    0    0    0    0    0    0    1    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   -1. 0.99  2.9  4.9  6.9  8.9 11.9 14.0
  503. 503. 503. 503. 503. 503. 503. 503. 503. 503. 503. 503. 503. 503. 503. 503.
 4827.4827.4827.4827.4827.4827.4827.4827.4827.4827.4827.4827.4827.4827.4827.4827.
```

TABLE 2

JOINT FREQUENCY DISTRIBUTION TABLES FOR 1982-1986 DATA

1982-86 SURRY MET DATA 16:41

1 FRIDAY, APRIL 23, 1999 1

STABILITY CLASS A

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	SECTOR E	ENE	ESE	N	NE	NNE	NNW	NW	TOTAL
0.0-0.99	3	3	2	5	2	3	5	7	57
1-2.9	350	209	478	150	234	248	180	579	5273
3.0-4.9	149	233	349	50	456	312	20	60	3548
5.0-6.9	30	26	52	4	90	47	2	0	414
7.0-8.9	9	4	5	0	2	1	0	0	29
9.0-11.9	2	0	0	0	1	0	0	0	4
TOTAL	543	475	886	209	785	611	207	646	9325

(CONTINUED)

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	SECTOR S	SE	SSE	SSW	SW	W	WNW	WSW	TOTAL
0.0-0.99	2	4	3	2	1	4	3	8	57
1-2.9	256	341	280	206	239	498	456	569	5273
3.0-4.9	315	300	303	254	199	217	20	311	3548
5.0-6.9	40	58	41	5	8	6	0	5	414
7.0-8.9	0	5	1	0	0	0	0	2	29
9.0-11.9	0	1	0	0	0	0	0	0	4
TOTAL	613	709	628	467	447	725	479	895	9325

TABLE 2 (Continued)

JOINT FREQUENCY DISTRIBUTION TABLES FOR 1982-1986 DATA

1982-86 SURRY MET DATA 16:41

1
FRIDAY, APRIL 23, 1999 2

STABILITY CLASS B

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	SECTOR E	ENE	ESE	N	NE	NNE	NNW	NW	TOTAL
0.0-0.99	1	1	0	1	2	0	0	3	14
1-2.9	61	54	68	28	55	42	24	61	786
3.0-4.9	17	38	31	12	49	33	6	5	433
5.0-6.9	10	7	2	1	8	10	0	0	58
7.0-8.9	0	0	2	0	1	1	0	0	6
TOTAL	89	100	103	42	115	86	30	69	1297

(CONTINUED)

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	SECTOR S	SE	SSE	SSW	SW	W	WNW	WSW	TOTAL
0.0-0.99	0	0	0	2	0	1	2	1	14
1-2.9	60	50	42	37	34	64	45	61	786
3.0-4.9	62	22	25	42	32	22	2	35	433
5.0-6.9	3	9	3	0	3	1	0	1	58
7.0-8.9	0	0	0	0	0	0	0	2	6
TOTAL	125	81	70	81	69	88	49	100	1297

TABLE 2 (Continued)

JOINT FREQUENCY DISTRIBUTION TABLES FOR 1982-1986 DATA

1982-86 SURRY MET DATA 16:41

1 FRIDAY, APRIL 23, 1999 3

STABILITY CLASS C

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	SECTOR E	ENE	ESE	N	NE	NNE	NNW	NW	TOTAL
0.0-0.99	0	1	1	1	1	1	1	4	14
1-2.9	48	48	44	25	67	52	29	50	821
3.0-4.9	27	42	25	13	62	42	6	1	472
5.0-6.9	7	2	3	2	11	7	0	0	60
7.0-8.9	1	0	0	0	0	1	0	0	5
TOTAL	83	93	73	41	141	103	36	55	1372

(CONTINUED)

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	SECTOR S	SE	SSE	SSW	SW	W	WNW	WSW	TOTAL
0.0-0.99	0	0	0	1	1	2	0	0	14
1-2.9	71	57	45	46	43	80	59	57	821
3.0-4.9	52	20	40	47	44	18	1	32	472
5.0-6.9	3	9	11	1	0	2	0	2	60
7.0-8.9	1	1	1	0	0	0	0	0	5
TOTAL	127	87	97	95	88	102	60	91	1372

TABLE 2 (Continued)

JOINT FREQUENCY DISTRIBUTION TABLES FOR 1982-1986 DATA

1 FRIDAY, APRIL 23, 1999 4

1982-86 SURRY MET DATA 16:41

STABILITY CLASS D

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	E	ENE	ESE	N	NE	NNE	NNW	NW	TOTAL
0.0-0.99	16	16	8	26	16	23	30	38	284
1-2.9	234	257	237	161	283	274	175	229	4831
3.0-4.9	121	135	117	71	213	220	34	34	3075
5.0-6.9	33	24	33	20	48	52	4	1	618
7.0-8.9	6	1	4	1	1	6	0	0	65
9.0-11.9	0	0	0	0	0	1	0	0	2
TOTAL	410	433	399	279	561	576	243	302	8875

(CONTINUED)

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	S	SE	SSE	SSW	SW	W	WNW	WSW	TOTAL
0.0-0.99	15	13	9	15	6	14	27	12	284
1-2.9	397	239	393	359	441	459	350	343	4831
3.0-4.9	434	161	346	364	301	186	29	309	3075
5.0-6.9	85	91	79	38	34	14	6	56	618
7.0-8.9	7	6	1	3	7	4	1	17	65
9.0-11.9	0	0	0	0	0	0	0	1	2
TOTAL	938	510	828	779	789	677	413	738	8875

TABLE 2 (Continued)

JOINT FREQUENCY DISTRIBUTION TABLES FOR 1982-1986 DATA

1 1982-86 SURRY MET DATA 16:41
FRIDAY, APRIL 23, 1999 5

STABILITY CLASS E

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	E	ENE	ESE	N	NE	NNE	NNW	NW	TOTAL
0.0-0.99	27	24	22	86	31	58	99	94	647
1-2.9	363	526	277	649	638	769	484	350	7875
3.0-4.9	152	217	122	227	365	660	53	56	3066
5.0-6.9	27	18	22	14	32	38	3	1	247
7.0-8.9	7	1	0	0	4	1	0	0	46
9.0-11.9	0	0	0	0	1	0	0	0	1
TOTAL	576	786	443	976	1071	1526	639	501	11882

(CONTINUED)

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	S	SE	SSE	SSW	SW	W	WNW	WSW	TOTAL
0.0-0.99	22	17	18	15	21	32	61	20	647
1-2.9	614	271	467	466	455	544	719	283	7875
3.0-4.9	257	219	302	150	137	70	23	56	3066
5.0-6.9	19	27	15	1	8	7	5	10	247
7.0-8.9	11	1	0	3	6	9	0	3	46
9.0-11.9	0	0	0	0	0	0	0	0	1
TOTAL	923	535	802	635	627	662	808	372	11882

ENGINEERING WORK SHEET

Calc Number PA-0157	Rev. 0	Add. A	Sheet: 12 of 20
Prepared By: D. L. Gilliatt	DLG		Date: 5-25-99
Reviewed By: D. C. Featherston	DCF		Date: 5-25-99
Other (If Applicable):			Date:

TABLE 2 (Continued)

JOINT FREQUENCY DISTRIBUTION TABLES FOR 1982-1986 DATA

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STABILITY CLASS F

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	E	ENE	ESE	N	NE	NNE	NNW	NW	TOTAL
0.0-0.99	26	29	24	100	52	83	169	156	916
1-2.9	239	292	153	565	443	593	335	167	3776
3.0-4.9	4	3	1	10	16	27	4	0	82
5.0-6.9	1	0	0	0	0	0	1	0	3
7.0-8.9	1	0	0	0	0	0	0	0	1
TOTAL	271	324	178	675	511	703	509	323	4778

(CONTINUED)

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	S	SE	SSE	SSW	SW	W	WNW	WSW	TOTAL
0.0-0.99	26	25	37	17	23	38	83	28	916
1-2.9	223	140	183	111	60	68	140	64	3776
3.0-4.9	9	2	4	2	0	0	0	0	82
5.0-6.9	1	0	0	0	0	0	0	0	3
7.0-8.9	0	0	0	0	0	0	0	0	1
TOTAL	259	167	224	130	83	106	223	92	4778

TABLE 2 (Continued)

JOINT FREQUENCY DISTRIBUTION TABLES FOR 1982-1986 DATA

1 1982-86 SURRY MET DATA 16:41
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STABILITY CLASS G

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	E	ENE	ESE	N	NE	NNE	NNW	NW	TOTAL
0.0-0.99	113	157	98	383	216	335	318	202	2297
1-2.9	100	111	82	477	252	566	256	96	2279
3.0-4.9	3	1	1	0	2	1	0	0	11
5.0-6.9	0	1	0	0	0	0	0	0	2
TOTAL	216	270	181	860	470	902	574	298	4589

(CONTINUED)

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	S	SE	SSE	SSW	SW	W	WNW	WSW	TOTAL
0.0-0.99	55	79	68	34	37	68	94	40	2297
1-2.9	56	78	77	36	22	18	28	24	2279
3.0-4.9	0	0	3	0	0	0	0	0	11
5.0-6.9	0	0	1	0	0	0	0	0	2
TOTAL	111	157	149	70	59	86	122	64	4589

1994-98 SURRY MET DATA
STABILITY CLASS A

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	SECTOR E	ENE	ESE	N	NE	NNE	NNW	NW	TOTAL
0.0-0.99	0	1	0	1	0	0	3	1	9
1-2.9	370	185	585	98	268	181	93	364	4743
3.0-4.9	122	184	245	8	403	83	1	6	2362
5.0-6.9	8	8	1	1	24	1	0	0	142
7.0-8.9	0	0	0	0	0	0	0	0	5
TOTAL	500	378	831	108	695	265	97	371	7261

(CONTINUED)

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	SECTOR S	SE	SSE	SSW	SW	W	WNW	WSW	TOTAL
0.0-0.99	0	0	0	1	0	2	0	0	9
1-2.9	160	438	181	207	232	503	585	293	4743
3.0-4.9	85	344	217	104	72	351	26	111	2362
5.0-6.9	0	51	15	0	3	27	0	3	142
7.0-8.9	0	2	3	0	0	0	0	0	5
TOTAL	245	835	416	312	307	883	611	407	7261

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1994-98 SURRY MET DATA
STABILITY CLASS B

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	SECTOR E	ENE	ESE	N	NE	NNE	NNW	NW	TOTAL
0.0-0.99	0	0	0	1	1	0	0	5	12
1-2.9	72	57	83	22	82	45	19	52	1082
3.0-4.9	16	45	10	3	70	20	3	0	369
5.0-6.9	4	3	0	0	4	0	0	0	29
7.0-8.9	0	0	0	0	0	0	0	0	3
TOTAL	92	105	93	26	157	65	22	57	1495

(CONTINUED)

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	SECTOR S	SE	SSE	SSW	SW	W	WNW	WSW	TOTAL
0.0-0.99	1	0	0	0	0	1	2	1	12
1-2.9	51	72	66	61	72	144	113	71	1082
3.0-4.9	17	31	45	13	12	62	4	18	369
5.0-6.9	0	13	3	0	0	2	0	0	29
7.0-8.9	0	1	0	0	0	2	0	0	3
TOTAL	69	117	114	74	84	211	119	90	1495

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TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	SECTOR E	ENE	ESE	N	NE	NNE	NNW	NW	TOTAL
0.0-0.99	7	1	1	3	2	1	4	4	33
1-2.9	70	72	83	16	80	42	26	54	1185
3.0-4.9	19	46	13	7	68	14	2	0	424
5.0-6.9	3	8	1	0	6	1	0	0	45
7.0-8.9	0	0	0	0	0	0	0	0	1
TOTAL	99	127	98	26	156	58	32	58	1688

(CONTINUED)

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	SECTOR S	SE	SSE	SSW	SW	W	WNW	WSW	TOTAL
0.0-0.99	2	1	0	2	1	0	3	1	33
1-2.9	96	89	72	68	77	140	104	96	1185
3.0-4.9	26	37	56	17	29	70	0	20	424
5.0-6.9	0	9	8	1	0	7	0	1	45
7.0-8.9	0	0	0	0	0	1	0	0	1
TOTAL	124	136	136	88	107	218	107	118	1688

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TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	SECTOR E	ENE	ESE	N	NE	NNE	NNW	NW	TOTAL
0.0-0.99	39	37	32	28	37	38	44	58	523
1-2.9	325	439	295	167	492	271	121	306	6627
3.0-4.9	83	230	53	36	292	135	21	13	2807
5.0-6.9	3	18	6	1	20	0	2	0	269
7.0-8.9	0	1	0	0	0	0	0	0	10
9.0-11.9	0	0	0	0	0	0	0	0	1
TOTAL	450	725	386	232	841	444	188	377	10237

(CONTINUED)

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	SECTOR S	SE	SSE	SSW	SW	W	WNW	WSW	TOTAL
0.0-0.99	22	26	24	26	31	21	39	21	523
1-2.9	679	386	629	520	491	658	403	445	6627
3.0-4.9	225	295	539	131	125	478	13	138	2807
5.0-6.9	1	77	59	3	6	59	0	14	269
7.0-8.9	0	5	0	0	0	4	0	0	10
9.0-11.9	0	0	0	0	0	1	0	0	1
TOTAL	927	789	1251	680	653	1221	455	618	10237

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STABILITY CLASS E

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	E	ENE	ESE	N	NE	NNE	NNW	NW	TOTAL
0.0-0.99	73	129	46	132	110	91	199	259	1616
1-2.9	466	1075	202	502	1336	839	431	625	9499
12.0-14.	0	0	0	0	0	0	0	0	2
3.0-4.9	74	214	47	65	281	180	15	20	1571
5.0-6.9	4	11	3	1	8	2	0	0	104
7.0-8.9	0	0	0	0	0	0	0	0	10
9.0-11.9	0	0	0	0	0	0	0	0	3
TOTAL	617	1429	298	700	1735	1112	645	904	12805

(CONTINUED)

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	S	SE	SSE	SSW	SW	W	WNW	WSW	TOTAL
0.0-0.99	67	41	51	50	68	77	168	55	1616
1-2.9	618	362	743	299	410	513	735	343	9499
12.0-14.	0	0	0	0	0	2	0	0	2
3.0-4.9	65	179	190	29	19	159	12	22	1571
5.0-6.9	1	15	14	1	11	23	1	9	104
7.0-8.9	0	0	0	0	0	8	1	1	10
9.0-11.9	0	0	0	0	0	3	0	0	3
TOTAL	751	597	998	379	508	785	917	430	12805

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TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	SECTOR E	ENE	ESE	N	NE	NNE	NNW	NW	TOTAL
0.0-0.99	106	109	79	191	130	150	269	411	2154
1-2.9	101	315	44	104	353	240	74	116	1857
3.0-4.9	0	4	0	0	2	0	0	0	8
TOTAL	207	428	123	295	485	390	343	527	4019

(CONTINUED)

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	SECTOR S	SE	SSE	SSW	SW	W	WNW	WSW	TOTAL
0.0-0.99	61	62	78	62	72	89	222	63	2154
1-2.9	73	82	90	38	36	61	111	14	1857
3.0-4.9	1	0	0	0	0	1	0	0	8
TOTAL	140	144	168	100	108	151	333	77	4019

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1994-98 SURRY MET DATA
STABILITY CLASS G

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	E	ENE	ESE	N	NE	NNE	NNW	NW	TOTAL
0.0-0.99	385	314	444	391	398	393	332	391	4721
1-2.9	17	97	14	18	193	116	4	7	539
3.0-4.9	0	0	0	0	0	0	0	0	1
TOTAL	402	411	458	409	591	509	336	398	5261

(CONTINUED)

TABLE OF WINSPEED BY SECTOR

WINSPEED FREQUENCY	S	SE	SSE	SSW	SW	W	WNW	WSW	TOTAL
0.0-0.99	219	473	277	96	97	183	231	97	4721
1-2.9	16	16	13	4	2	6	10	6	539
3.0-4.9	0	0	1	0	0	0	0	0	1
TOTAL	235	489	291	100	99	189	241	103	5261

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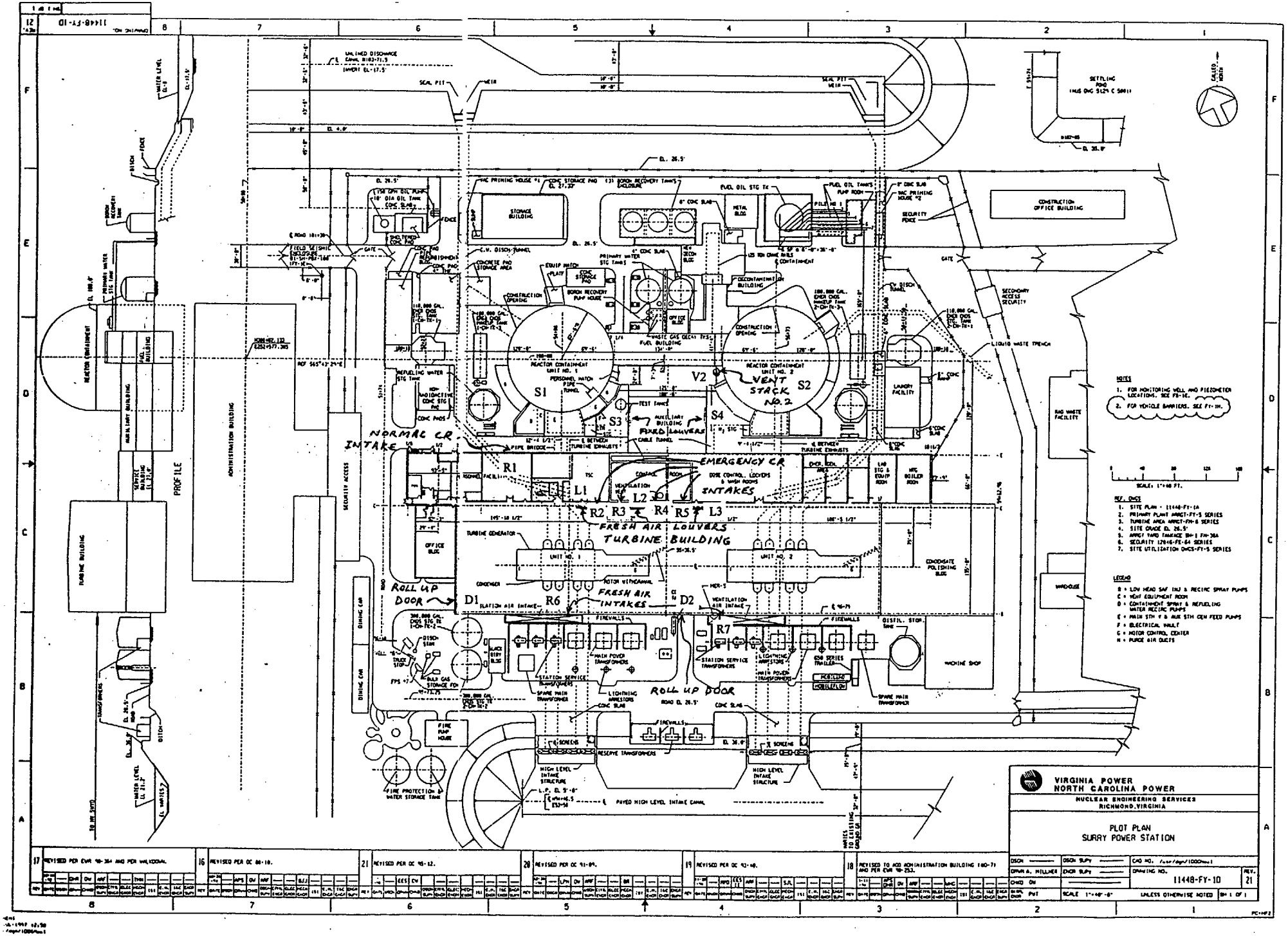

PRIOR TO USING FOR DESIGN WORK CHECK DWGS FOR WORK PENDING

Source-Receptor Distances and Elevations

Source	Elev (ft)	Elev (m)	Drawing	Receptor	LOCA	FHA	Dist (ft)	Dist (m)	Elev (ft)	Elev (m)	Dir. To Source	Drawing
Unit 1 Reactor	125	38.1	11448-FP-13D	CR Normal Air Intake (R1)	x		63	19.2	44.3	13.5	45	11448-FB-25F
(S1)				CR Emer Air Intake (R2)		x	125	38.1	21	6.4	8	11448-FB-25E
				CR Emer Air Intake (R3)		x	137	41.8	37.5	11.4	359	11448-FB-25C
				CR Emer Air Intake (R4)		x	157	47.9	37.5	11.4	349	11448-FB-25C
				CR Emer Air Intake (R5)		x	176	53.6	21	6.4	341	11448-FB-25E
				TB Fresh Air Intake (R6)	x		260	79.2	18	5.5	23	11448-FB-18A
				TB Fresh Air Intake (R7)	x		323	98.5	18	5.5	348	11448-FB-18A
				TB Fresh Air Louver (L1)		x	123	37.5	85.4	26.0	12	11448-FA-2A
				TB Fresh Air Louver (L2)		x	147	44.8	85.4	26.0	354	11448-FA-2A
				TB Fresh Air Louver (L3)		x	190	57.9	85.4	26.0	337	11448-FA-2A
				West Roll Up Door (D1)		x	270	82.3	37.7	11.5	45	11448-FA-2C
				South Roll Up Door (D2)		x	290	88.4	37.7	11.5	357	11448-FA-2B
Unit 2 Reactor	125	38.1		CR Emer Air Intake (R5)		x	152	46.3	21	6.4	54	11448-FB-25E
(S2)				TB Fresh Air Louver (L3)		x	140	42.7	85.4	26.0	47	11448-FA-2A
				South Roll Up Door (D2)		x	273	83.2	37.7	11.5	43	11448-FA-2B
Vent #2	97.5	29.7	11448-FA-24B	CR Normal Air Intake (R1)		61000	276	84.1	44.3	13.5	90	11448-FB-25F
(V2)				CR Emer Air Intake (R2)		61000	230	70.1	21	6.4	67	11448-FB-25E
				CR Emer Air Intake (R3)		61000	206	62.8	37.5	11.4	58	11448-FB-25C
				CR Emer Air Intake (R4)		61000	185	56.4	37.5	11.4	46	11448-FB-25C
				CR Emer Air Intake (R5)		61000	173	52.7	21	6.4	35	11448-FB-25E
				TB Fresh Air Intake (R6)	38400	20000	353	107.6	18	5.5	51	11448-FB-18A
				TB Fresh Air Intake (R7)	38400	20000	310	94.5	18	5.5	19	11448-FB-18A
				TB Fresh Air Louver (L1)		61000	240	73.2	85.4	26.0	68	11448-FA-2A
				TB Fresh Air Louver (L2)		61000	200	61.0	85.4	26.0	52	11448-FA-2A
				TB Fresh Air Louver (L3)		61000	173	52.7	85.4	26.0	28	11448-FA-2A
				West Roll Up Door (D1)	38400	20000	446	135.9	37.7	11.5	70	11448-FA-2C
				South Roll Up Door (D2)	38400	20000	310	94.5	37.7	11.5	28	11448-FA-2B

Source-Receptor Distances and Elevations

Source	Elev (ft)	Elev (m)	Drawing	Receptor	LOCA	FHA	Dist (ft)	Dist (m)	Elev (ft)	Elev (m)	Dir. To Source	Drawing
Aux Bldg (S3) W. manual louver	52	15.8	11448-FA-24B	CR Normal Air Intake (R1)		x	150	45.7	44.3	13.5	95	11448-FB-25F
				CR Emer Air Intake (R2)		x	120	36.6	21	6.4	42	11448-FB-25E
				CR Emer Air Intake (R3)		x	110	33.5	37.5	11.4	27	11448-FB-25C
				CR Emer Air Intake (R4)		x	117	35.7	37.5	11.4	3	11448-FB-25C
				CR Emer Air Intake (R5)		x	133	40.5	21	6.4	349	11448-FB-25E
				TB Fresh Air Intake (R6)	x		256	78.0	18	5.5	36	11448-FB-18A
				TB Fresh Air Intake (R7)	x		277	84.4	18	5.5	355	11448-FB-18A
				TB Fresh Air Louver (L1)		x	130	39.6	85.4	26.0	42	11448-FA-2A
				TB Fresh Air Louver (L2)		x	117	35.7	85.4	26.0	15	11448-FA-2A
				TB Fresh Air Louver (L3)		x	153	46.6	85.4	26.0	343	11448-FA-2A
				West Roll Up Door (D1)		x	327	99.7	37.7	11.5	66	11448-FA-2C
				South Roll Up Door (D2)		x	256	78.0	37.7	11.5	7	11448-FA-2B
Aux Bldg (S4) E. manual louver	52	15.8	11448-FA-24B	CR Normal Air Intake (R1)		x	243	74.1	44.3	13.5	103	11448-FB-25F
				CR Emer Air Intake (R2)		x	173	52.7	21	6.4	75	11448-FB-25E
				CR Emer Air Intake (R3)		x	150	45.7	37.5	11.4	68	11448-FB-25C
				CR Emer Air Intake (R4)		x	120	36.6	37.5	11.4	54	11448-FB-25C
				CR Emer Air Intake (R5)		x	107	32.6	21	6.4	39	11448-FB-25E
				TB Fresh Air Intake (R6)	x		293	89.3	18	5.5	56	11448-FB-18A
				TB Fresh Air Intake (R7)	x		243	74.1	18	5.5	16	11448-FB-18A
				TB Fresh Air Louver (L1)		x	190	57.9	85.4	26.0	77	11448-FA-2A
				TB Fresh Air Louver (L2)		x	137	41.8	85.4	26.0	61	11448-FA-2A
				TB Fresh Air Louver (L3)		x	107	32.6	85.4	26.0	24	11448-FA-2A
				West Roll Up Door (D1)		x	396	120.7	37.7	11.5	76	11448-FA-2C
				South Roll Up Door (D2)		x	240	73.2	37.7	11.5	29	11448-FA-2B