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2CAN010205

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Nuclear Regulatory Commission
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Subject: Arkansas Nuclear One - Unit 2
Docket No. 50-368
License No. NPF-6
Response to Follow-up Request for Additional Information Concerning SGTR and MHA Dose Assessment Calculations Supporting ANO-2 Power Uprate

Dear Sir or Madam:

Entergy Operations, Inc. submitted an "Application for License Amendment to Increase Authorized Power Level" on December 19, 2000 (2CAN120001). In response to a request from the NRC staff, four calculations were transmitted to the NRC for review in a letter dated July 3, 2001 (2CAN070103). Two of the four calculations submitted were "ANO-2 Maximum Hypothetical Accident Control Room and Offsite Dose Analysis (LOCA)" and "ANO-2 Radiological Dose Analysis for RSG and Power Uprate (includes Steam Generator Tube Rupture and Control Element Assembly Ejection - Secondary Side Release)."

Subsequent to submittal of these calculations, telephone discussions have been held with the NRC on several occasions to discuss various aspects of the calculations. On January 8, 2002, the NRC telexed two written questions regarding the calculations. The first question pertains to the isotopic distribution of iodine in reactor coolant for the steam generator tube rupture (SGTR) calculation. The second question requests additional information regarding the mixing assumptions utilized in the maximum hypothetical accident (MHA). The draft responses were discussed with the NRC via teleconferences on January 14 and 16, 2002. The written response to NRC question 1 is provided in Attachment 1. The response to question 2 is provided in Attachment 2.

In addition, clarification is provided for statements contained in letter dated January 14, 2002 (2CAN010201) regarding planned actions to ensure control room habitability for ANO-2. The last paragraph on page 5 of 6 of Attachment 1 is modified to indicate that ANO-2 will be in compliance with its design basis inleakage value following completions of the committed actions. The last paragraph should read:

> The current limiting tracer gas test case resulted in a maximum inleakage of 134 scfm as discussed in Task 1 above. However, as described below, the

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> successful completion of the specified actions will reduce the maximum unfiltered inleakage to approximately 40 scfm, which is well below the design basis value of 61 scfm.

Entergy is also adding a new commitment to the List of Regulatory Commitments contained in Attachment 2 of the January 14, 2002, letter. Upon NRC approval, Entergy will establish and maintain a control room inleakage limit of ≤ 61 scfm. The modified List of Regulatory Commitments has been included in Attachment 3.

Regarding the committed action to perform seal repair of the VSF-9 ventilation housing, Entergy has expedited purchase of new seals; however, the seal vendor indicates that delivery may not arrive in time to satisfy the original commitment date of February 28, 2002. Based on discussions with Mr. Jack Hayes, of your staff, on January 31, 2002, the timing for completing control room habitability actions should be commensurate with the ANO-2 Power Uprate; no later than startup from the 2R15 Refueling/Power Uprate outage. Therefore, the completion date for the associated control room habitability actions has been revised accordingly in Attachment 3 of this letter.

I declare under penalty of perjury that the foregoing is true and correct. Executed on January 31, 2002.

Sincerely,

Glenn R. Ashley

Glenn R. Ashley
Manager, Licensing

GRA/dwb
Attachments

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NRC Question #1

The steam generator tube rupture (SGTR) calculations are based upon a distribution of iodine isotopes in reactor coolant which is inconsistent with the distribution provided in Table 11.1-3 of the Safety Analysis Report (SAR). The staff believes that the iodine distribution utilized in the licensee's calculations may underestimate the potential consequences of a SGTR or any other accident whose consequences were based upon the core activity distribution of iodine isotopes rather than Table 11.1-3. ANO-2 has experienced a sufficient number of iodine spike events (18 spiking events between the period 1/29/80 and 4/18/89) to assess whether the distribution of iodine isotopes is representative of Table 11.1-3 or the core. The licensee should assess the ANO-2 spiking data to determine whether the reactor coolant activity levels before and after the spike for these events are representative of the distribution of iodine isotopes utilized in the existing SGTR calculations or the reactor coolant distribution of Table 11.1-3. If operating data does not substantiate the distribution utilized in the calculations, the calculations should be updated in future analyses of accidents involving reactor coolant releases or iodine spiking provided such accidents are not the limiting accident with respect to control room operators' doses. However, if such an accident results in the limiting control room operators' doses, then these accidents need to be revised as part of the power uprate amendment request. Additional details on this issue are provided below.

The SGTR calculations provided in the July 3, 2001, submittal based the distribution of iodine isotopes in reactor coolant upon the distribution of such isotopes in the core. That distribution is significantly different from the isotopic distribution of iodine in reactor coolant provided in Table 11.1-3 of SAR Chapter 11 and is not typical of distributions which the staff has seen for other main steam line break accidents. The staff believes that the data presented in Table 11.1-3 may be more indicative of the isotopic distribution that would exist in reactor coolant in the event of a SGTR and an iodine spike than the data based upon core activity. The staff believes that the mechanisms associated with the appearance of these isotopes (e.g., escape rate coefficient, fuel matrix diffusion coefficient, precursor diffusion, the number of defective rods and decay) all affect the appearance in reactor coolant. The staff believes that the delay in short lived isotopes progressing to the fuel pellet gap and then into the reactor coolant shifts the distribution of iodine isotopes away from the core inventory distribution. However, actual measurements of iodine isotopes in reactor coolant following actual spiking events may provide data which resolves this issue. The data may be representative of the core distribution, of Table 11.1-3, or neither.

ANO Response

Distribution of Iodine Isotopes

The method used in the calculation submitted in the July 3, 2001, letter inappropriately used the distribution of iodine isotopes of the fuel instead of the reactor coolant system (RCS). However, when performing the calculation (as discussed below) using the more appropriate RCS distribution of iodine isotopes, the results showed the July 3, 2001, version of the calculation to be more conservative. Regardless, consistent with the staff's recommendation, future calculations utilizing the methods defined in the

July 3, 2001, submittal will consider incorporation of the RCS distribution of iodine isotopes.

Calculation of RCS Concentration

The purpose of the following calculation is to find the time-dependent dose equivalent I^{131} concentration in the RCS. This concentration should have been used to calculate dose consequences of the steam generator tube rupture event versus the fuel concentrations used in the July 3, 2001, submittal.

Guidance for performing the calculation is given in Standard Review Plan (SRP) 15.6.3 section III.6.b:

> The reactor trip or the primary system depressurization associated with the postulated accident creates an iodine spike in the primary system. The increasing primary coolant iodine concentration is estimated using a spiking model which assumes that the iodine release rate from the fuel rods to the primary coolant – expressed in bequerels (curies) per time unit – increases to a value 500 times greater than the release rate corresponding to the iodine concentration at the equilibrium value stated in the NSSS vendor standard technical specifications or from the plant specific technical specifications (i.e., concurrent iodine spike case).

The calculation follows the method of calculating activity level in the RCS following an iodine spike described in CE Topical Report "Iodine Spiking Radioiodine Behavior in the Reactor Coolant System during Transient Operations" CENPD-180-P, March 1976. The major difference is that the reference assumes that all iodine is released as iodine-131 while the present calculation treats each isotope separately. The more detailed treatment in the calculation results in slightly higher activity following an event-generated iodine spike (GIS).

The following calculation is consistent with the SRP. The iodine release from the fuel is assumed to have proportions present in the fuel gap. The release is multiplied by a factor of 500. The equilibrium iodine distribution is related to the initial release rate in a simple way. The mathematical formula used to calculate the time dependent iodine concentration has made an appropriate substitution by using the initial RCS concentration.

$C_i(t)$ and B_{oi}

The equations for $C_i(t)$ and B_{oi} are unchanged from the previous calculation.

Calculation of $C_{0,i}$

$C_{0,i}$, the equilibrium concentration of iodine isotope i prior to GIS, is related to the release rate by:

$$C_{0,i} = \frac{R_i}{M_{RCS} * B_{0,i}}$$

Here,

$C_{0,i}$ = Equilibrium concentration of iodine isotope i prior to GIS (μCi/g.)
R_i = Release rate from the fuel of isotope i, Ci/sec
M_{RCS} = Total liquid mass of the RCS, gm
$B_{0,i}$ = Removal constant prior to the event (s^{-1})
Ci(t) = RCS iodine activity concentration of iodine isotope i at time t (mCi/g).

R_i and $C_{0,i}$ are found by recognizing that the iodine isotopes are released in the same proportions as are present in the fuel gas gap and that the total concentration is limited to 1.0 μCi/g DEQ I^{131} by the technical specifications. That is:

$R_i = f * Agap_i$ and

$\sum C_{0,i} * DEQ_{I131} = 1\mu Ci/g$ so that

$$\sum \frac{f * Agap_i}{M_{RCS}\ B_{0,i}} * DEQ_i = 1\mu Ci/g$$

$$f = \frac{1\mu Ci/g}{\sum \frac{Agap_i}{M_{RCS}\ B_{0,i}} * DEQ_i}$$

Where,

$Agap_i$ is the gap activity of iodine isotope i in a fuel rod (Ci/rod),
f is the release rate (fraction of one rod gap activity/sec), and
DEQ_i is the I_{131} Dose equivalent of the isotope i,

The normalization factor f determines R_i and $C_{o,i}$

Comparison of initial RCS activity to the updated SAR Chapter 11 data

The initial iodine activities that were found by the calculation described above were reviewed against historical data given in SAR section 11.1. The values cannot be compared directly because the Chapter 11 data imply an RCS activity above the technical specification limit of 1 μCi/gm DEQ I^{131}. The activities were compared by calculating the ratio of the activity of each species to the activity of I^{131}. The only significant difference is for I^{132} which does not contribute significantly to dose.

	I^{131}	I^{132}	I^{133}	I^{134}	I^{135}
$C_{0,i}$	0.705	0.158	0.916	0.103	0.474
Ratio to I^{131}	1.000	0.224	1.299	0.146	0.672
SAR Table 11.1-4 0.25% failed fuel					
Activity	0.890	0.281	1.250	0.135	0.583
Ratio to I^{131}	1.000	0.316	1.404	0.152	0.655
SAR Table 11.1-3 1.00% failed fuel					
Activity	3.460	1.100	4.890	0.531	2.280
Ratio to I^{131}	1.000	0.318	1.413	0.153	0.659

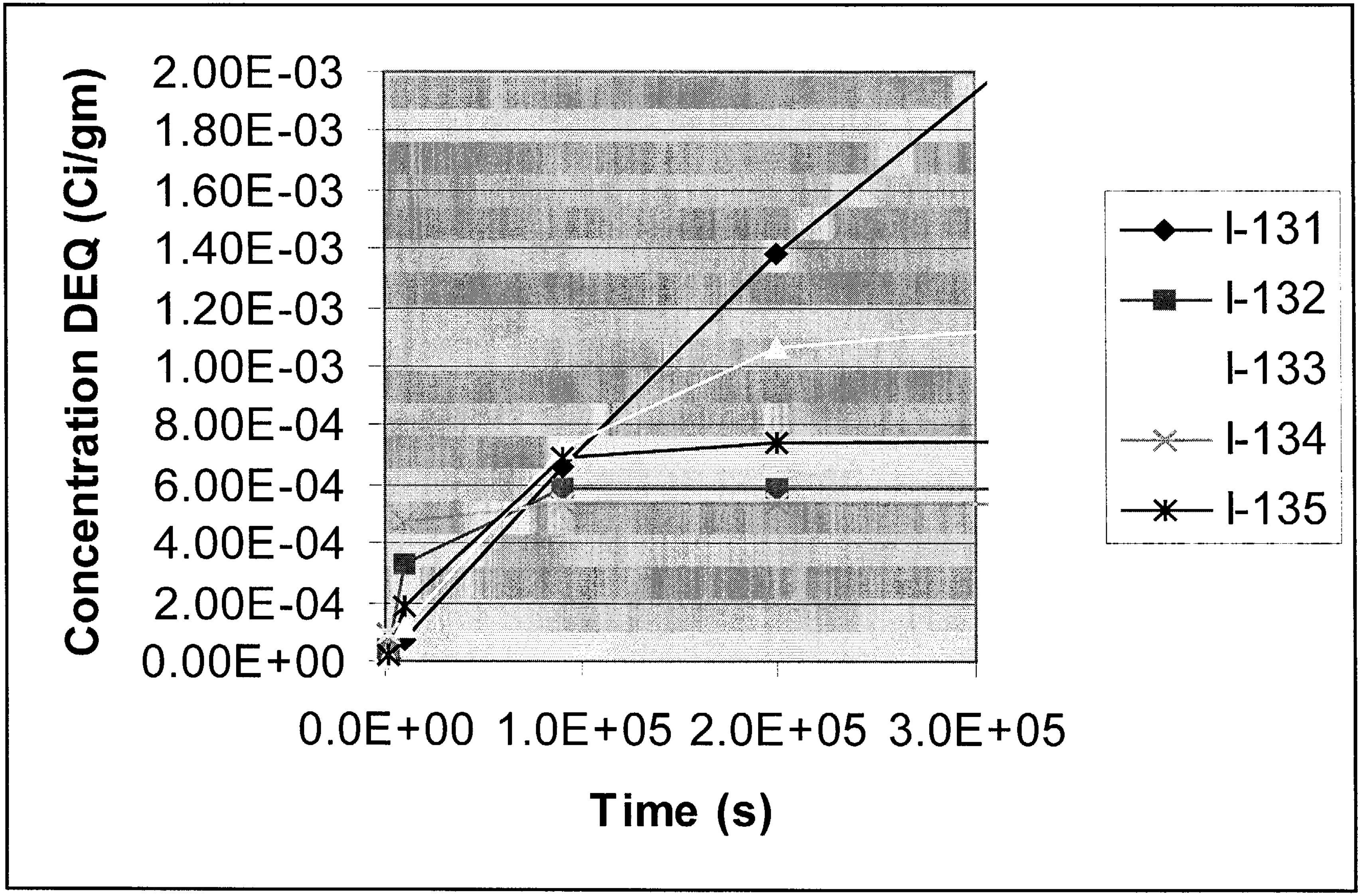
Comparison of initial RCS activity to the activity used in the July 3, 2001, letter

The parameters $C_{0,i}$, $B_{0,i}$, λ_i and DEQ_i were used to solve for C(t) which was then compared to previous results.

The previously calculated GIS results are more conservative at every time point. The previous calculation under-estimated the contribution of I^{131} by about 20% but over-estimated the contribution of the other isotopes by more than 60%. This is because, although the short-lived isotopes have a lower equilibrium concentration, they achieve the equilibrium more quickly following a GIS as depicted in the figure on the following page.

Charging Pump Flow

The iodine spiking analyses was performed based on the normal operating mode of having only one charging pump running. A single charging pump with a flow rate of 46 gallons per minute (gpm) and a maximum heat exchanger efficiency of 100% was assumed in the analyses. The charging pump flow of 46 gpm includes considerations for RCS leakage and letdown since charging pump flow is constant, because the charging pumps are positive displacement pumps. Plant operation with more than one charging pump in operation is a very infrequent mode of operation. In addition to the infrequent time during which more than one charging pump may be operating, procedural guidance also ensures Reactor Engineering Department and management involvement should iodine concentrations approach the technical specification limits or should a second charging pump be required to improve iodine clean-up. This information is consistent with that provided on page 4 of 5 of the attachment to letter 2CAN050006 dated May 17, 2000, and page 4 of letter 2CAN080004 dated August 4, 2000, which responded to NRC staff questions regarding the replacement steam generator effort. The NRC safety evaluation for license amendment #222 dated September 29, 2000 (2CNA090002), for the replacement steam generator effort also discusses this issue on page 9.


Concentration DEQ (Ci/gm)
2.00E-03
1.80E-03
1.60E-03
1.40E-03
1.20E-03
1.00E-03
8.00E-04
6.00E-04
4.00E-04
2.00E-04
0.00E+00
0.0E+00
1.0E+05
2.0E+05
3.0E+05
Time (s)
I-131
I-132
I-133
I-134
I-135

NRC Question #2

The staff has reviewed the Safety Analysis Report (SAR) to determine if the SAR contains additional information to justify assuming that the air taken from the unsprayed region of the containment by the containment air coolers will only be replaced by air entirely drawn from the sprayed region. A review of Chapter 6 and Figure 9.4-4 provides insufficient information for the staff to conclude that the containment air coolers are drawing 78% of their air from the sprayed region and the remainder from the unsprayed region and that the air returned to the unsprayed [region] is entirely from the sprayed. Please provide additional details on the operation of the containment air coolers to justify the mixing assumptions in the maximum hypothetical accident (MHA) calculations.

ANO Response

Attachment 1 to letter 2CAN070103, dated July 3, 2001, transmitted a calculation titled "ANO-2 Maximum Hypothetical Accident Control Room and Offsite Dose Analysis (LOCA)" (the MHA calculation) to the NRC reviewers.

On page 6 of 13 of the MHA calculation, the last sentence of the first paragraph states that "an instantaneous uniform distribution of the core release is assumed in the sprayed and unsprayed regions that consist of 78% and 22% of the containment volume respectively, based on volume ratios." On the same page, starting with the second sentence, the third paragraph states:

> For conservatism, natural convection was neglected and only the containment air cooler flow of 54,000 cfm was assumed. Since the flow is distributed throughout the containment, an exchange flow proportional to the volume fraction was used between the sprayed and unsprayed regions. The unsprayed region consists of 22% of the total containment volume; therefore 22% of the forced flow, 11880 cfm, is exchanged between the sprayed and unsprayed regions.

This response provides additional information supporting the statements in the previous paragraph. Four figures are provided.

Section 5, "Calculation" on page 5 of 13 of the MHA calculation provides the following data:

1.	RB Free Volume	1.778E6 ft^3
2.	Sprayed Volume	1.332E6 ft^3
3.	Unsprayed Volume	3.831E5 ft^3
4.	Initial Fraction	0.22 to unsprayed 0.78 to sprayed
5.	RB Mixing Rates	11,880 cfm between sprayed and unsprayed regions

Finely Divided Containment Spray and Average Volume Changes

SAR section 6.2.2.2.1.B.6, 1st paragraph, section 6.2.2.3.1, 2nd paragraph and section 6.2.3.2.1, 4th paragraph provide information regarding the size of the spray droplets. Containment spray is in the form of a mist composed of finely divided droplets that are less than 1,000 microns in diameter (< 4 hundredths of an inch (0.04)) as they exit the spray nozzles.

A containment air cooler flow rate of 54,000 cfm changes the containment free volume of 1.778E6 ft^3 an average of 1.82 times per hour.

22% Unsprayed Region

An original calculation performed in 1977 by Bechtel titled "Reactor Building Sprayed Volume" derives the 22% unsprayed region. The calculation is still an active, unamended Design Engineering calculation.

Unsprayed volumes are derived by taking the cross-sectional areas of obstructions. These areas are then projected from the elevation of each obstruction downward to the next lower obstruction.

The 22% value is clearly derived in the calculation. The calculation divides the unsprayed regions into two categories: (1) volumes (ft^3) in "good communication" with the containment spray and (2) volumes designated as "not good communication". The "good communication" volumes equal 259,007 ft^3 and the "not good communication" volumes equal 124,083 ft^3 for a total unsprayed volume of 3.831E5 ft^3 as listed above or 21.6% of the total volume, which is rounded to 22%. The "good communication" volumes represent 68% of the unsprayed volume or 14.6% (versus 21.6%) of the total volume.

Good Communication Volumes

"Good communication volumes" are those judged to readily mix with the sprayed regions. For example, the polar crane consists of a trolley and two girders. The trolley, at elevation 506' is approximately 17' by 12' or 204 ft^2. This area is extended downward for 149 feet to elevation 357' for a projected unsprayed volume of 30,396 cubic feet (ft^3). In the same manner, the two girders, which are broken into sections because of several different lower obstructions, form a series of projected areas of rectangular cross-sections extending downward 139', 91', 68', 131' and 134'. The girders form total projected unsprayed volumes of 82,200 ft^3. Therefore, the polar crane and its girders together account for 112,596 ft^3 or over 43% of the "good communication" unsprayed volume. Figure 1 is a simplified sketch that shows dimensions and proportions of the containment building.

Since, as stated above, containment spray is in the form of a mist with <0.04" diameter droplets, classifying these areas as unsprayed is conservative, even if designated "good communication". It is difficult to judge that any object anywhere within these projected unsprayed "good communication" volumes would not be completely wetted (deluged) by the spray.

Similarly, the remaining "good communication" volumes are conservatively derived.

Before the "not good communication" volumes are discussed, information regarding the arrangement of equipment, location of concrete slabs and operation of the containment air coolers during accident conditions is provided.

Containment Arrangement

Figure 1 provides a simplified elevation view of containment. The overall inside height is 208' and the inside diameter is 116'. As indicated on the sketch, the lower 1/3 of containment has three approximately equally spaced elevations composed of a combination of grating walkways and concrete slabs. The upper 2/3 of the structure is largely but not completely open. Most, but not all, of the "good communication" volumes are within the upper two-thirds of containment. All of the "not good communication" volumes are in the bottom one-third. Figure 2 is a plan view of section A-A at elevation 357'-0"; Figure 3 is a plan view of section B-B at elevation 376'-6"; and Figure 4 is a plan view of Section C-C at elevation 405'-6".

As shown on Figures 1 and 3, containment air coolers 2VSF-1B and 2VSF-1D are anchored to the northwest slab at elevation 376'-6". Coolers 2VSF-1A and 2VSF-1C are anchored directly below the upper coolers to the elevation 357'-0" slab. Therefore, the slab in Figure 3 shows that the elevation 405'-6" northwest slab provides roofing over the upper coolers and the elevation 376'-0" slab is a roof to the lower coolers. The Section C-C slab has an area of 800 ft^2. The slab in the Section B-B that is the roofing over 2VSF-1A and 2VSF-1C is also approximately 800 ft^2. The containment air coolers each have a cross-sectional area of 200 ft^2. With two air coolers on an elevation, the cross-sectional area is 400 ft^2 per elevation.

The volumes below these containment air cooler "roofs" are designated as "good communication" volumes in the Bechtel calculation.

Containment Air Cooler Operation During Accident Conditions

A containment cooling actuation system (CCAS) signal releases a bypass damper located immediately upstream of the containment service water cooling coils (CSWCCs) (tag numbers 2VCC-2A/2B/2C/2D). Normally, containment is cooled by containment chilled water cooling coils (CCWCCs) (tag numbers 2VCC-1A/1B/1C/1D), but CCAS initiates flow to the CSWCCs, shuts off chilled water flow to and isolates the CCWCCs and drops the bypass damper. The bypass damper bypasses the supply ductwork to the CCWCCs as well as the CCWCCs themselves.

Containment Air Cooler Discharge Ductwork

As shown schematically on SAR Figure 9.4-4 (P&ID M-2261), containment air cooler discharge ductwork supplies normal air and accident air/steam mixture to registers located throughout the following volumes: (1) between ground floor elevation 336'-6" and elevation 357'-0" (Figure 2); (2) between elevation 357'-0" and elevation 376'-6" (Figure 3); and (3) between elevation 376'-6" and elevation 405'-6" (Figure 4).

Not Good Communication Volumes

"Not good communication" volumes are those judged not to readily mix with the sprayed regions. Five volumes are designated as "not good communication":

1. Under the 424 ft^2 slab shown as Section B-B at elevation 376'-6",
2. Under the 394 ft^2 slab also shown as Section B-B,
3. Under the refueling canal at elevation 361'-6" (not shown in the sketches),
4. The reactor vessel cavity (not shown in the simplified figures), and
5. Under the 2,600 ft^2 slab shown as Section A-A at elevation 357'-0" (Figure 2).

The total of these "not good communication" volumes is 124,083 ft^3 representing 7% of the containment free volume.

While these volumes are correctly judged to be in "not good communication" with the containment spray, they are in good communication with the containment spray by means of the containment air coolers. As stated above, each of these volumes is located in the midst of containment air cooler discharge ducts and registers.

The "good communication" volume above containment air coolers 2VSF-1B and 1-D is 19' high (29' between elevations 405'-6" and 376'-6" minus the 10' height of the coolers) by 800 ft^2 or 15,200 ft^3. At a flow rate of 27,000 cfm minimum for 2VSF-1B and/or 2VSF-1D, the volume change rate in this vicinity is over 1-½ per minute.

Similarly, the good communication" volume above containment air coolers 2VSF-1A and 1-C is 9' high by 800 ft^2 or 7,200 ft^3. At a flow rate of 27,000 cfm minimum for 2VSF-1B and/or 2VSF-1D, the volume change rate in this vicinity is just under 4 per minute.

These swept volumes are forced into the "not good communication" volumes. The air in these "not good communication" volumes is displaced and mixed with the containment spray for recycling back into the containment air coolers.

Conclusion

Approximately 68% of the 22% (14.6/21.6) of the volumes in containment designated as unsprayed are judged to mix readily with the containment spray. Therefore, the conclusion in the calculation is conservative. The unsprayed volumes mix with the sprayed volumes at least at the same rate as containment turn-over, i.e., about 1.82 times per hour.

The remaining 32% (7/21.6) of the unsprayed volumes are correctly designated as "not good communication" in that the volumes are shielded from direct mixing with the containment spray. However, the forced convection containment air coolers, discharge ductwork and registers mix these volumes with containment spray at a rate that is several times greater than the 1.82 times which represents the average hourly number of containment volume changes.

For both the "good communication" and "not good communication" unsprayed volumes, the assumptions of the ANO-2 MHA calculation regarding mixing of unsprayed volumes with sprayed volumes are quite conservative.

Figure1
Containment Building Looking North

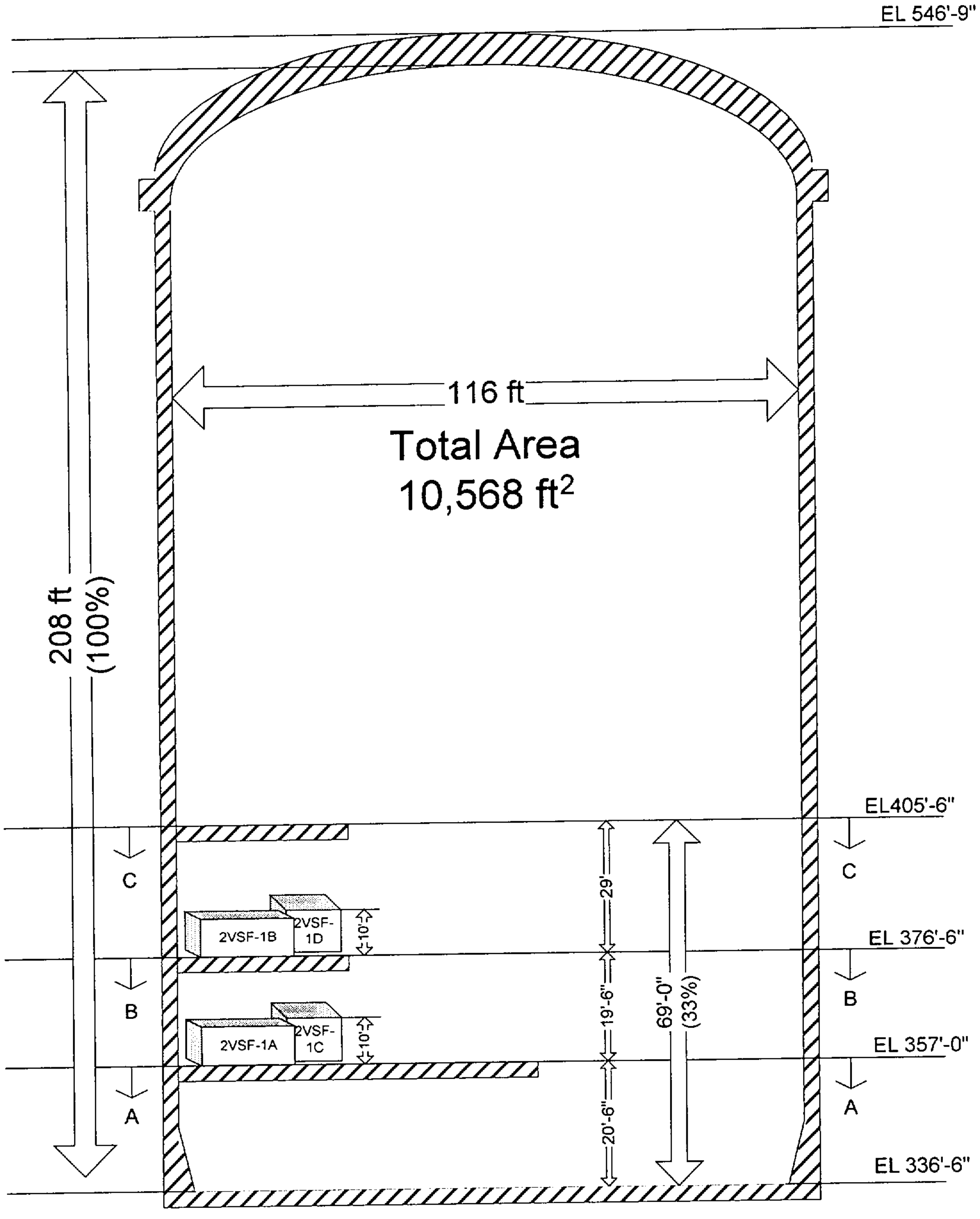
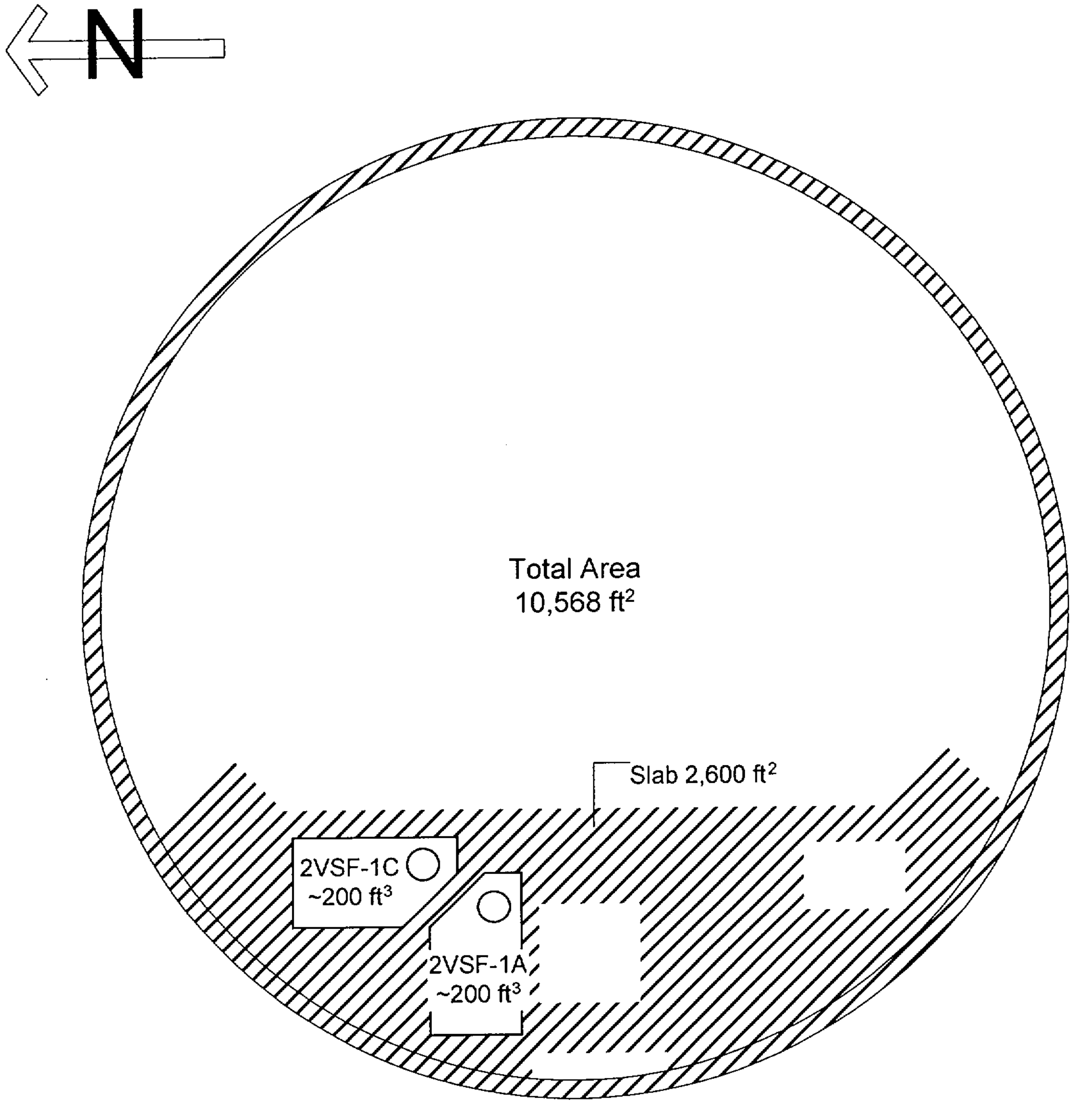
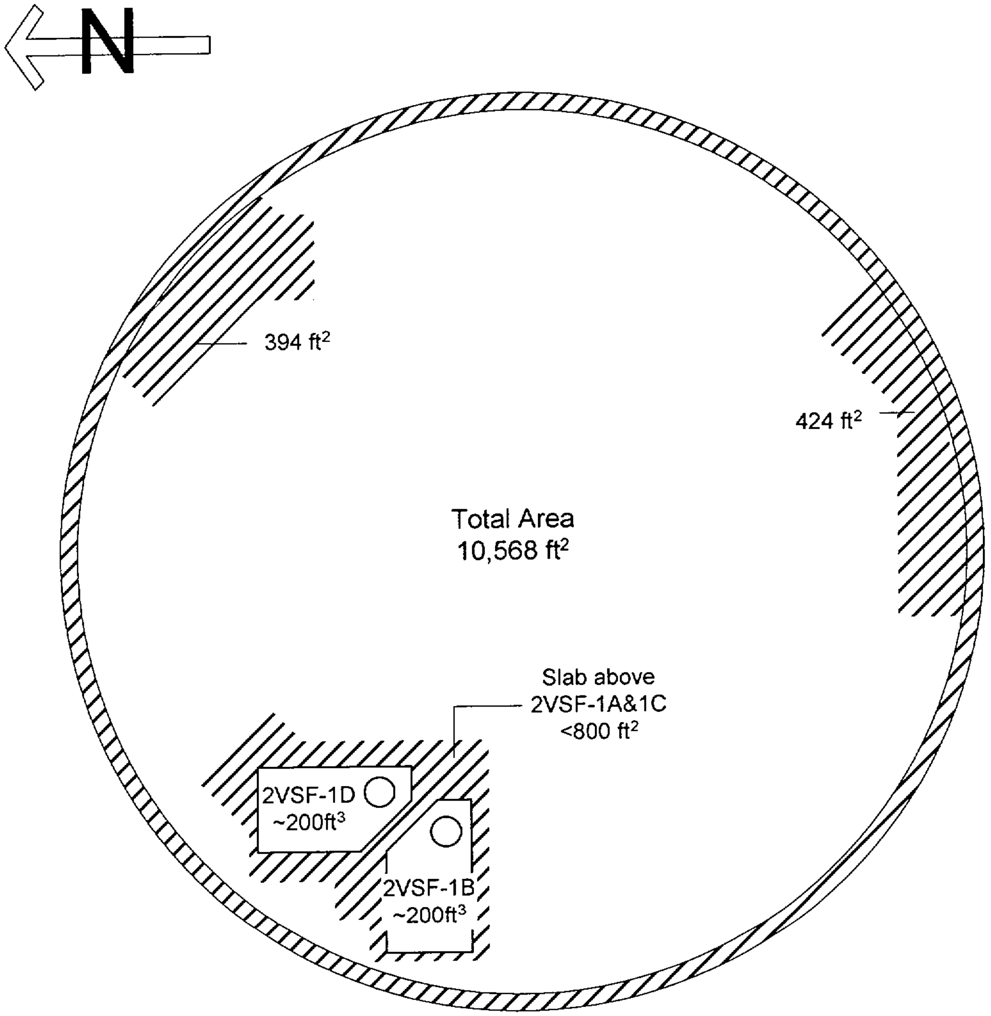


Figure 2 (Section A-A)
Containment Building Floorplan Elevation 357'-0"



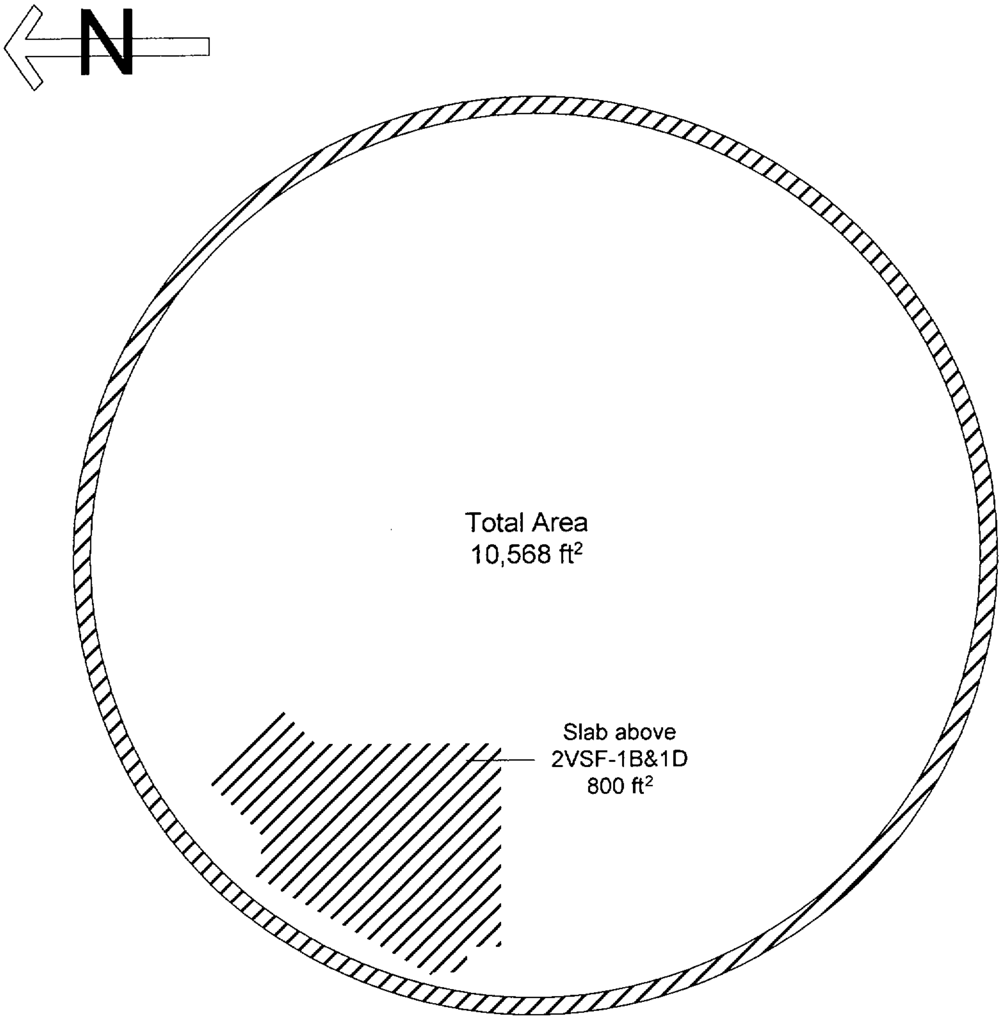
Elevation 357'-0"

Figure 3 (Section B-B)
Containment Building Floorplan Elevation 376'-6"



Elevation 376'-6"

Figure 4 (Section C-C)
Containment Building Floorplan Elevation 405'-6"



Elevation 405'-6"