Farley Nuclear Plant – Units 1 and 2
Response to Request for Additional Information for TSTF-312

Enclosure 2

Excerpts from Calculation SM-96-1064-001

Attachment 8

PURPOSE:

Via letter dated May 17, 2016, NRC requested plant Farley to address the question of Radioactivity migrating from open containment penetrations to the areas around the control room (See ML16125A411 which contains Requests for Additional Information in response to a SNC License Amendment request to implement TSTF-312). The NRC was specifically concerned with the potential for these areas adjacent to the control room to become contaminated and leak into the control room, increasing operator doses. This attachment attempts to resolve the NRC's concern and show the technical basis.

Attachment 8 re-evaluates the case discussed in Attachment 2, where the personnel airlock and the Containment equipment hatch are both open and a design basis fuel handling accident happens in the containment. Two parameters are changed in this re-evaluation: the unfiltered in-leakage to the control room through the CREFS system is changed to the maximum allowable per the Control Room Integrity Program (43 CFM), and the unfiltered in-leakage due to ingress and egress from the control room is taken from the area around the control room. The dose that is most limiting is the Thyroid Dose, so only the Thyroid dose will be evaluated here. Since the Noble gases have basically no impact on the Thyroid Dose, the Iodine isotopes and their impact on thyroid doses are considered here.

CRITERIA:
As described in the main body of the calculation, the criteria for the control room dose does not change for this re-evaluation, per RG-1.195:

Thyroid – 50 Rem

SUMMARY OF RESULTS:

Location	Thyroid
Control Room	12.3 Rem

These results show that the doses at the respective locations are within the RG-1.195 (ref. 8.12) limits. The doses at the LPZ or EAB do not change. This is as expected as the re-evaluation does not impact any of the assumptions or inputs of the PERLOK1t TACT V runs.

Design Inputs:

8.1 The maximum unfiltered in-leakage to the control room is limited to 43 cfm. This is the technical specification limit per TS 5.5.18 for the CREFS leakage during Pressurization Mode. It is a major reduction from the calculation assumed value of 450 cfm unfiltered in-leakage.

8.2 Flows into the control room are otherwise held to be the same as the case described in Attachment 2 (calculation page 29).

8.3 Control room ingress/egress unfiltered in-leakage is set at 10 CFM, per Reference 4, Section 6.4.

8.4 Dispersion coefficients for release from containment are as shown in the main body calculation.

8.5 The height of the rooms at the 155' elevation is 18'0" (173'0 – 15'0") as shown on references 8.4 and 8.14.

8.6 The doors to the Main Control Room (MCR) are Mark No. 418, 453, and 2480. Per References 8.2 and 8.3, Doors 453 and 2480 are airtight. Door 418, as part of the airtight boundary shown on D176069 (ref. 8.13) is also an airtight door. The rest of the rooms on elevation 155' are not airtight, as confirmed by references 8.5 and 8.6. See assumption 8.5 for further discussion.

8.7 Room Areas for the following rooms are taken from BM-99-1932-001 (Ref. 8.10) or scaled from D176516 (reference 8.11). Note that no reduction in floor areas is made for floor mounted components.

TABLE 8.1 – Unit 1 Auxiliary Building Mixing Volumes

ROOM	Area (ft^2)	Height (ft)	Volume (ft^3)	Source/Comment
409	1958	18	35244	BM-99-1932-001, Sht D579
402	213	18	3834	D176516, V22.0
419	1203	18	21654	BM-99-1932-001, Sht D544
408	1483	18	26694	BM-99-1932-001, Sht D544
405	1181	18	21258	BM-99-1932-001, Sht D544
422	316	18	5688	BM-99-1932-001, Sht D544
423	344	18	6192	BM-99-1932-001, Sht D544
410-A	271	18	4878	BM-99-1932-001, Sht D544
410-B	146	18	2628	BM-99-1932-001, Sht D544
417	243	18	4374	D176516, V22.0
415	217	18	3906	BM-99-1932-001, Sht D569
483	595	18	10710	D176516, V22.0
432	354	18	6372	BM-99-1932-001, Sht D568
446	780	18	14040	BM-99-1932-001 Sht D569
454	251	18	4518	BM-99-1932-001, Sht D569
429	2144	18	38592	like 2429 but less elevator shaft and instrument room (D176516, V22)
Total	11699	18	210582	

8.9 For Unit 2 the follow room floor area data is taken from either calculation BM-99-1932-001 (ref. 8.10) or drawing D206516 (ref 8.11). Similarity of areas (as treated in the calculation), enables the assumption 8.6 on the floor areas. Note that no reduction for floor mounted components is made.

Table 8.2 – Unit 2 Auxiliary Building Mixing Volume

Room	Area (ft^2)	Height (ft)	Volume (ft^3)	Source/Comment
2402	213	18	3834	like 402
2410-A	274	18	4932	BM-99-1932-001, Sht D641
2409	2263	18	40734	BM-99-1932-001, Sht D641
2405	747	18	13446	BM-99-1932-001, Sht D641
2419	1191	18	21438	BM-99-1932-001, Sht D662
2406	600	18	10800	BM-99-1932-001, D641
2408	1124	18	20232	BM-99-1932-001, D641
2422	317	18	5706	BM-99-1932-001, D641
2423	344	18	6192	BM-99-1932-001, D641
2429	2345	18	42210	BM-99-1932-001, D661
2452	2441	18	43938	D206516, V20.0 & 206517, Sht 1, V13.0
2446	780	18	14040	BM-99-1932-001, D641
Total	12639	18	227502	

Assumptions:

8.1 In keeping with the rest of the calculation, and in contrast to the implication of RG-1.195 (Ref. 8.12) that the accident is over in two hours, the doses in the MCR will be evaluated for 8 hours. Radioactivity in that enters the control room can linger for much longer than two hours, adding to the operator dose. The results of the evaluation in Attachment 2 showed an approximately 10% increase in operator doses from 2-8 hours. The doses to control room personnel after 8 hours are inconsequential as the intake of radioactivity due to the impact of meteorology (X/Q drops to 7.2E-4) and radioisotope decay.

8.2 Radioactivity released from the containment through the personnel airlock will only disperse on the same level as its release, the level of the control room (the 155' elevation). This is conservative since the control building and auxiliary building stairwells are not protected with airtight doors.

8.3 As discussed in design input 8.6 above, most of the doors on the 155' elevation are not airtight. There are a few pressure tight doors, but they have leakage characteristics that can allow up to 0.5 CFS (see note 4 on references 8.7 and 8.8). Assumption 8.4, below, discusses the mixing of the radioactivity that enters the auxiliary building and control building. Since the doors are not airtight (and are not procedurally closed during refueling operations), the radioactivity can mix in most of the rooms. The mixing volume is assumed to be limited to the rooms shown in Design input 8.7.

8.4 The radioactivity dispersed throughout the auxiliary building and control building will only dilute in 50% of the volume of those buildings on the same floor as the control room. This is in keeping with the spirit of the mixing volume that is allowed by RG-1.195 (ref. 8.12) for the containment. This assumption accounts for potentially dead air spaces (no mixing), walls, and equipment.

A coarse examination of references 8.2 and 8.3 shows that a tortuous path exists from the personnel airlock to the doors for the MCR and the work planning area (in Unit 2 room 2453). Roughly estimated the closest path has 3 90° bends and is about 188 feet long (from Unit 1 PAL to the MCR door mark 418). It is highly likely that non-safety related ventilation systems will be running at the time of the fuel handling accident. These systems will enable the transport of the radioactivity to areas around the control room. However, as a further measure of conservatism, no credit is taken for these non-safety related ventilation systems transporting the dispersed radioactivity out of the auxiliary building.

8.5 No Credit is taken for recirculation filter iodine removal. This assumption is very conservative, leading to higher thyroid doses. Note that the filter efficiencies for the recirculation filters would be calculated as Eff = 1-2*(1-.975)-0.005 = 0.945. The Recirculation system has a normal flow rate of 3000 cfm. Even with a flow reduction of 10%, 94.5% of the iodine passing at 2700 cfm through the filters would be removed.

8.6 As discussed in design input 8.6 above, most of the doors on the 155' elevation are not airtight. There are a few pressure tight doors, but they have leakage characteristics that can allow up to 0.5 CFS (see note 4 on references 8.7 and 8.8). Assumption 8.3, above discusses the mixing of the radioactivity that enters the auxiliary building and control building. Since the doors are not airtight (and are not procedurally closed during refueling operations), the radioactivity can mix in most of the rooms. The mixing volume is assumed to be limited to the rooms shown in Design input 8.7.

8.7 Reference 8.9 contains an assumption that Unit 2 rooms have similar floor areas as Unit 1 rooms (cf. room 2402, 2409, 2408, etc. as shown above in Design Input 8.8, above). As the Unit 2 mixing area is not going to be used in the ongoing calculations of the impact of flow in the MCR doors, this assumption is preserved for the ongoing discussions.

8.8 Radioactivity released from containment through the personnel airlock is conservatively assumed to dilute in the auxiliary building volume in 1 second. This assumption ignores dilution and transit time for the radioactivity and makes the radioactivity immediately available for import into the control room.

References:

8.1 Joseph P. Farley Technical Specification Section 5.5.18, Revision 198/194
8.2 Farley Drawing D176006, Version 39.0
8.3 Farley Drawing D206006, Version 38.0
8.4 Farley Drawing D176012, Version 2.0
8.5 Farley Drawing D176027, Sheet 2, Version 8.0
8.6 Farley Drawing D206027, Sheet 2, Version 6.0
8.7 Farley Drawing D176026, Sheet 1, Version 37.0
8.8 Farley Drawing D206026, Sheet 1, Version 35.0
8.9 Farley Drawing D176145, Version 3.0
8.10 Farley Calculation BM-99-1932-001, Version 6.0
8.11 Farley Drawings D176156 Version 22.0
8.12 Regulatory Guide 1.195, May 2003
8.13 Farley Drawing D176069, Version 23.0
8.14 Drawing D206012, Version 2.0
8.15 NRC letter dated May 17, 2016, "Joseph M. Farley Nuclear Plant, Units 1 and 2, and Vogtle Electric Generating Plant, Units 1 and 2 – Request for Additional Information (ADAMS Accession Number ML16125A411).

Methodology:

The doses in the Main control room are calculated with the methodology described in Attachment 2.

The doses are calculated in two parts. The first involves unfiltered, but dispersed, in-leakage entering the control room from the CREFS system. This unfiltered in-leakage is set to 43 cfm, per the Technical Specification for the Control Room Integrity Program. The second involves unfiltered, but diluted, in-leakage entering from the control building through the opening of the control room envelope doors. The ingress/egress leakage is set to 10 cfm, per industry standards.

PART 1 – RADIOACTIVITY IMPORTED TO THE CONTROL ROOM FROM THE CONTROL ROOM EMERGENCY FILTRATION SYSTEM (CREFS)

Two important effects occur as a result of lowering the unfiltered in-leakage to 43 cfm from 450 cfm, while moving the location of the ingress/egress leakage to the part of the Auxiliary Building outside the control room doors. The first effect alters the direct transfer rates calculated in the case discussed on page 29 of this calculation. The second effect causes a change to the "effective filter efficiency" for iodine isotopes.

Since TACT5 does not allow transfer from the environment back into a node and allows only one transfer path for both filtered and unfiltered in-leakage, an equivalent direct transfer from the containment via the environment to the control room needs to be modelled.

(Release Rate) x (X/Q) x (unit conversion factors) x (intake rate) = direct transfer rate.

The effective flow rates of isotopes are adjusted as shown in the table below:

Table 8.3 - FLOW RATES OF NUCLIDES TO THE CONTROL ROOM:FROM THE OPEN EQUIPMENT HATCH

Time Start HR	TIME End HR	RELEASE FLOW CFM	X/Q (s/m^3)	I1min/ 60 sec) min/s	$(1\ m^3)/(35.3\ ft^3)$ m^3/ft^3	Intake FLOW CFM	Direct Transfer/ Intake Flow CFM
0.0000	0.0125	53500	5.06E-03	0.01667	0.02832861	2340	299.08
0.0125	0.1667	53500	1.66E-03	0.01667	0.02832861	600	25.16
0.1667	2.0000	53500	1.66E-03	0.01667	0.02832861	493	20.67
2.0000	8.0000	53500	1.38E-03	0.01667	0.02832861	493	17.19

To illustrate the calculations in the above table, the Direct Transfer flow from 0.1667 hours (10 minutes) to 2 hours is determined assuming that we have 450 cfm filtered intake and 43 cfm unfiltered intake from the CREFs system (450 + 43 = 493)

(Release Flow)*(X/Q)*(1/60)*(1/35.3)*(Intake Flow) = Direct Transfer Flow

(53500)*(1.66E-3)*(1/60)*(1/35.3)*(493) = 20.67 cfm

By way of comparison, the flow rate at that time step for the case evaluated in Attachment 2 would have been:

(53500)*(1.66E-3)*(1/60)*(1/35.3)*(910) = 38.16 cfm

The impact factor would be 20.67/38.16 = 0.5417, effectively lowering the transfer flow to 54.17% of the amount used in the case described on page 29.

So, for all isotopes a smaller amount of radioactivity will be "directly' transferred to the control room. The change in direct transfer flow lowers the amount of radioactivity transferred from the containment node to the control room.

Table 8.5 - IMPACT FACTOR FOR DIRECT TRANSFER FLOW RATE CHANGE:

Start Time (Hr)	End Time (HR)	Old Direct transfer Flow Rate (cfm)	New Direct transfer Flow Rate (cfm)	Transfer Flow Impact Factor
0.0000	0.0125	300.4	299.08	0.9956
0.0125	0.1667	25.58	25.16	0.9836
0.1667	2.0000	38.16	20.67	0.5417
2.0000	8.0000	31.72	17.19	0.5419

Note that in the Table 8.4 above, the flow rate at time zero is now 2340 cfm, not 2350 cfm, as the 10 cfm from ingress/egress comes from a different in-leakage location. 2340/2350 = 0.9956. Similarly the flow rate during isolation mode (from 45 seconds to 10 minutes) is 600 cfm, not 610 cfm. 600/610 = 0.9836.

Under a similar logic, the radioactivity from iodine isotopes would also be reduced slightly due to the reduction of intake flow. This reduction is applied only to the time before the pressurization flow is initiated, 10 minutes by assumption.

FILTRATION IMPACT FACTORS:

To address the reduction in the "direct" transfer of iodine isotope radioactivity from the containment ot the control room, one must consider the change in the effective filtration rate:

The effective filtration would also change, given that the unfiltered in-leakage would change (from 450 + 10 = 460 to 43 CFM).

The effective filtration was calculated from Attachment 2 (page 29) as:

(1-450*(1-.985) + 450 + 10)/910 = 0.4871

Here the filtered in-leakage (450 cfm) is multiplied by a factor that represents the amount of nuclides that get past the filter (1-0.985), where 0.985 is the filter efficiency, calculated on page 17. This flow of nuclides is then added to the unfiltered in-leakage of 450 cfm (assumed) and 10 cfm (ingress/egress). The resultant sum is then divided by the total intake flow (450+450+10 = 910) to get the effective filtration efficiency.

It is obvious that when the unfiltered intake flow is lowered to 43 cfm, the effective filtration efficiency will go up, and it does. Note in the example below, the amount of ingress/egress flow is not included, as it will come from a different source, shown later:

(1-450*(1-0.985) + 43)/493 = 0.8991

So the filtration impact factor after pressurization (10 minutes to 8 hours) is:
(1-0.8991)/(1-.4871) = 0.1967448

Note that this new filtration impact factor accounts for the reduction of direct transfer of radioactivity from iodine isotopes only. The filtration factor applies to the Iodine isotopes, whether elemental or organic. The filtration factor is, of course, not applicable to noble gases.

The table below addresses the impact factors:

Table 8.6 – Impact Factors

Start Time (hr)	End Time (hr)	Direct Transfer Impact factor (NG)	Filtration Impact Factor (iodine)
0.0000	0.0125	0.9956	1.0000
0.0125	0.1667	0.9835	1.0000
0.1667	2.0000	0.5417	0.1967
2.0000	8.0000	0.5417	0.1967

These impact factors must be applied to the results of the PERLOK1t model TACT V run to lower the intake to the control room and therefore lower the dose to the control room operators.

Note that the dose from the ingress/egress is being addressed separately later.

<u>THYROID DOSE:</u>

As explained on page 18 of the main body of the calculation, the thyroid doses will be calculated by the following equation for teach time step (using the PERLOK1t TACT V run).

[(Average Ci-hr) * (3600 s/hr) *(35.3 Ft^3/m^3) / (MCR Volume ft^3)] * (Inhalation Rate m^3/s) = Inhaled curies for that time step.

Then the inhaled curies are summed for the period from 0-2 hours and the period from 2-8 hours. Those two sums are then multiplied by the Thyroid Dose Conversion Factor (DCF REM/Ci) for that Iodine Isotope. The Doses for the two time periods are then summed and a total thyroid dose is achieved.

Using the PERLOK1t TACT V (input file on page 31) results and manipulating them as described above, accounting for the Direct Transfer Flow Impact Factor and the Filtration Impact Factor (for Iodine) provides the following Thyroid Dose results:

Table 8.7 – Inhaled Curies and Thyroid Doses

Isotope	Curies Inhaled from 0 to 2 Hours	Curies Inhaled from 2 to 8 hours	Thyroid DCF (Rem/Ci)	Thyroid Dose from 0 to 2 hours (rem)	Thyroid Dose from 2 to 8 hours (Rem)	Total Thyroid Dose (Rem)
I-131	1.08E-05	2.60E-07	1.10E+06	11.8321	0.2861	12.1182
I-132	1.49E-18	1.94E-20	6.30E+03	0.0000	0.0000	0.0000
I-133	7.34E-07	1.67E-08	1.80E+05	0.1321	0.0030	0.1351
I-135	6.16E-10	2.28E-11	3.10E+04	0.0000	0.0000	0.0000

The total Thyroid dose is therefore **12.2533 Rem.**

Note that the curies transferred to the control room are diluted in the control room volume (114,000 cubic feet or 3229.5 cubic meters) and multiplied by the inhalation rate (3.47E-04 m^3/sec) to obtain the inhaled curies.

PART 2: RADIOACTIVITY IMPORTED TO THE CONTROL ROOM FROM THE CONTROL BUILDING:

As described on page 29, this case involves the personnel air lock being open and a large flow rate (2340 cfm) pushing contaminated air from the containment through the personnel airlock into the auxiliary building and the area around the control room envelope. The schematic of this situation is shown on Drawings D176006 and D206006 (see references 8.2 and 8.3). The flow from containment will disperse into the auxiliary building and control building. Per Assumptions 8.2 and 8.3, the radioactivity will dilute in only the volume of these buildings that is on the same floor as the control room and only 50% of the volume is used for dilution.

Examining the activity imported through the open and closing of the control room doors follows the following reasoning:

1. At 100 hours after shutdown, the fuel handling accident occurs in the containment building.
2. All of the rods of one fuel assembly break resulting in gap releases as described in case1.
3. The overlying pool acts as a filter (creating a DF of 200, as described in RG-1.195).
4. The activity escaping the pool is instantaneously diluted in a portion of the containment (the Case 1 assumption is the volume above the operating deck, which is less than one half of the total containment volume).
5. The resultant concentration is exported through the personnel airlock at a rate of 2350 CFM, contaminating the auxiliary building and the control building.
6. The activity passing through the personnel airlock is instantaneously (within 1 second) diluted in 50% of the volume of the rooms of the floor containing the control room.
7. The resulting concentration of activity is imported to the control room at a rate of 10 CFM.
8. The transport of activity out of the control room by either the recirculation filters or the normal CREFS exhaust is neglected. This is a very conservative feature of this analysis.

Since TACT5 does not allow transfer from the environment back into a node and allows only one transfer path for both filtered and unfiltered in-leakage, an equivalent direct transfer from the containment via the auxiliary building to the control room needs to be modelled.

Release Rate x dilution factor x unit conversion factors x intake rate = direct transfer rate.

To calculate the impact of this situation on the operators, we once again modify the Case 1 TACT5 output to account for the change in export flow from containment, mixing in the auxiliary building, and unfiltered import flow to the control room. Filtration Impact Factors and Flow impact Factors need to be calculated:

MIXING AND FLOW IMPACT FACTOR:

Flow that enters the Auxiliary Building from the personnel airlock will mix in the building. From an examination of Design Inputs 8.7 and 8.8, above, the smallest mixing volume is for Unit 1, 176307 cubic feet. We will take the conservative assumption that the mixing volume is further reduced by 50% to

210582 ft^3 * 0.50 = 105291 ft^3.

Converting to cubic meters:

105291 ft^3 * $(0.3048\ m/ft)^3$ = 2980.75 m^3

Since the mixing is accomplished in 1 second the dilution factor is therefore the inverse of this = 1/2982.75 = 3.35E-04 s/m^3.

Table 8.8 - FLOW RATES OF NUCLIDES TO THE CONTROL ROOM THROUGH MCR DOOR:

Time Start HR	TIME End HR	PERSONNEL AIRLOCK RELEASE FLOW CFM	DILUTION in the Auxiliary Building Elev. 155' (s/m^3)	min/s	m^3/ft^3	Intake FLOW CFM	Direct Transfer/ Intake Flow CFM
0.0000	0.0125	2350	3.35E-04	0.01667	0.02832861	10	3.72E-03
0.0125	0.1667	2350	3.35E-04	0.01667	0.02832861	10	3.72E-03
0.1667	2.0000	2350	3.35E-04	0.01667	0.02832861	10	3.72E-03
2.0000	8.0000	2350	3.35E-04	0.01667	0.02832861	10	3.72E-03

Example:

(2350 CFM) * (1min/60sec) * (1 m^3 / 35.3 ft^3) * (3.35E-04 s/m^3) * (10 cfm) = 0.00372 cfm directly transferred.

So the Flow Impact Factor is, as described above, just the new direct flow transfer rate divided by the old direct flow transfer rate. For example, 0.00372/300.4 = 1.24E-05.

TABLE 8.9 - IMPACT FACTOR FOR DIRECT TRANSFER FLOW RATE CHANGE:

Start Time (Hr)	End Time (HR)	Old Direct transfer Flow Rate (cfm)	New Direct transfer Flow Rate (cfm)	Transfer Flow Impact Factor
0.0000	0.0125	300.4	3.72E-03	1.24E-05
0.0125	0.1667	25.58	3.72E-03	1.45E-04
0.1667	2.0000	38.16	3.72E-03	9.75E-05
2.0000	8.0000	31.72	3.72E-03	1.17E-04

The above factor applies to all the iodine isotopes “directly” transferred from the containment to the control room.

Since the flow is 100% unfiltered, the effective filter efficiency is 0%, and the Efficiency factor is 1.0. The direct flow is then used to determine the doses.

THYROID DOSE:

Using the same TACT V runs and manipulating them as described above, accounting for the Direct Transfer Flow Impact Factor and the Filtration Impact Factor (for Iodine) provides the following Thyroid Dose results:

Isotope	Curies Inhaled from 0 to 2 Hours	Curies Inhaled from 2 to 8 hours	Thyroid DCF (Rem/Ci)	Thyroid Dose from 0 to 2 hours (rem)	Thyroid Dose from 2 to 8 hours (Rem)	Total Thyroid Dose (Rem)
I-131	3.56E-09	1.55E-10	1.10E+06	3.92E-03	1.71E-04	4.09E-03
I-132	4.71E-22	1.16E-23	6.30E+03	2.97E-18	7.29E-20	3.04E-18
I-133	2.42E-10	9.94E-12	1.80E+05	4.36E-05	1.79E-06	4.54E-05
I-135	2.01E-13	1.36E-14	3.10E+04	6.23E-09	4.21E-10	6.65E-09

The total Thyroid dose is therefore **0.0041 Rem.**

Adding this dose to the dose received from intake through the CREFs gives a total thyroid dose of 12.2574 REM, reported as 12.3 REM. This is a significant reduction from the results reported in Case 1 of Attachment 2.

Farley Nuclear Plant – Units 1 and 2
Response to Request for Additional Information for TSTF-312

Enclosure 3

Supplemental Drawings – CD Format