ANALYSIS OF HABITABILITY OF THE SHEARON HARRIS NUCLEAR POWER PLANT EMERGENCY OPERATIONS FACILITY

Prepared for

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1.0 INTRODUCTION

The Emergency Operations Facility (EOF) will be operated by Carolina Power and Light Company for the management of overall licensee emergency response, coordination of radiological and environmental assessment, development of recommendations for public protective actions and coordination of emergency response activities with Federal, State and Local supporting agencies. The EOF for the Shearon Harris Nuclear Power Plant is located 3,429 meters from the plant site.

The Nuclear Regulatory Commission has provided guidance on acceptable design features for EOFs. Supplement 1 to NUREG-0737 indicates that an EOF should have a protection factor of 5, ventilation isolation and HEPA filters. Habitability requirements are only for the part of the EOF in which dose assessments, communications and decision making take place.

This habitability study consists of an assessment of exposures to individuals in the EOF from radionuclides airborne inside the facility and an analysis of the building protection factors for outside contamination.

2.0 EXPOSURES TO RADIONUCLIDES AIRBORNE INSIDE FACILITY

The EOF ventilation system is designed to draw in 720 CFM outside air. In the event of an incident at SHNPP, the outside air whether drawn in by the air handling unit or injected into the system by the emergency fan serves to pressurize the system and will leave the system by enfiltration. (See Figure 1)

The 30-day thyroid, whole body and skin doses to individuals inside the EOF were evaluated for a design basis loss-of-coolant accident (LOCA).

2.1 Methodology

A design basis LOCA provides the radionuclide release rate from the containment using the guidance given in Regulatory Guide 1.4. Atmospheric dispersion factors at the EOF were calculated in accordance with Regulatory Guide 1.145. The detailed description of the activity release and dose evaluation models are given in Appendix 15.0.A of the SHNPP FSAR.

2.2 Assumptions and Parameters

The following lists the assumptions and parameters used in the analysis of inhalation and submersion doses:

1) design basis assumptions presented in FSAR 15.6.5.4.1 are applied,
2) accident duration is assumed to be 30 days,
3) the net free volume of EOF is estimated to be 31,716 ft^3 (898 M^3), allowing 10% of the volume for equipment and furniture. This volume represents the first floor of the EOF where management and coordination of emergency activities, dose assessment, communications and decision making takes place (See Figure 2),
4) radionuclides are uniformly distributed throughout the EOF net free volume,
5) EOF atmospheric dispersion factors are:

Time Period	X/Q in sec/m^3
0 - 8 hrs	1.1×10^{-4}
8 - 24 hrs	8.1×10^{-5}
1 - 4 days	2.9×10^{-5}
4 - 30 days	7.1×10^{-6}

6) occupancy of the EOF is based on the following:

Time Period	Occupancy Factor
0 - 24 hours	1.0
1 - 4 days	0.6
4 - 30 days	0.4

7) a finite cloud correction is used,
8) filter efficiency of EOF emergency cleanup system for iodine is 99%,
9) a breathing rate of the occupants of 3.47×10^{-4} cubic meters per second for the duration of the accident,
10) the EOF air intake flow rate is 720 CFM (with no recirculation), and
11) the assumed unfiltered in-leakage into the pressurized EOF is 3 CFM with air locks as a result of opening and closing of doors.

2.3 Results

The doses to an EOF occupant are presented in Table 1. These doses are well within the GDC-19 limit of 5 rems to the whole body and the corresponding SRP 6.4 limits of 30 rem to the skin and thyroid.

3.0 PROTECTION FACTORS ESTIMATE

An individual in the EOF would also receive exposure from outdoor contamination which is 1) airborne and 2) deposited on the ground and roof. Building protection factors have been calculated separately for each type of contamination.

3.1 Methodology

The models used in the calculation of protection factors for outdoor airborne contamination are included in Appendix A. Methodology included in Reference 1 was used in the calculation of protection factors for outdoor ground and roof contamination.

The analysis has been performed by dividing the first and second floors into six azimuthal sectors as indicated in Figure 2. Figure 3 indicates that the contribution to exposure through walls in sectors E and F is small due to presence of the building complex and therefore has been ignored in the analysis. The parameters used in the evaluation and results for outdoor surface contamination are included on the PFE solution forms. The chart numbers refer to those included in Reference 1.

3.2 Assumptions and Parameters

The following assumptions and parameters are used in the evaluation of the protection factors for the EOF:

1) interior walls of the building, in which the EOF is located, are 8.0 inches thick.
2) walls enclosing the EOF are 8.0 inches thick.
3) each floor thickness is 8.0 inches.
4) the ceiling heights of the first floor, second floor and mezzanine are 9.7 ft., 8.2 ft. and 8 ft., respectively.
5) density of concrete is 140 lbs/cu. ft.

3.3 Results

Protection factors calculated for the first and second floors of the EOF are included in Table-2. The values for both outdoor surface and airborne contaminations are above 5 and hence exceed the requirements of NUREG-0737.

4.0 CONCLUSIONS

The analysis of the inhalation and submersion (skin, whole body and thyroid) doses to an EOF occupant has shown that the 30-day exposures will be well within the GDC-19 and SRP 6.4 limits. Consequently, the EOF location and design of its emergency air filtration system have been demonstrated to be appropriately chosen to ensure more than adequate protection of personnel during relatively long periods of occupancy following even the most severe design-basis accident.

In addition, the structural aspects of the EOF have been analyzed with regards to the protection level it affords against outside airborne and deposited radioactive contaminants. The resultant protection factors, prove that there is sufficient shielding between the critical areas of the EOF to be occupied and the outside contamination carried in and deposited by a radioactive plume.

TABLE 1

30-Day Inhalation and Submersion Doses
At The Emergency Operations Facility
(Rem)

	Dose
Whole Body	0.02
Skin	0.60
Thyroid	1.60

TABLE 2

Emergency Operations Facility
Protection Factors for Outdoor Contamination

	Protection Factors	
	Radioactive Plume	Surface Contamination
First Floor	18.5	50
Second Floor	5.1	33

Project SHNPP - EMERGENCY OPERATIONS FACILITY - FIRST FLOOR

Parameters	Factor	SECTOR OR BUILDING SIDE				Chart
		A	B	C	D	
0		66	40	70	70	

- W = 52.7
- L = 90.5
- A = 4769
- Z = 22.83
- H = 3
- A_p = 0
- W_c =
- X_o = 187.2
- X_e = 93.6
- X_i = A 0, B 93.6, C 93.6, D 0
- X_f = 187.2
- X_r = 0
- X_c =
- y =
- h =
- $E_x = \frac{y}{h}$ =

ROOF MASS THICKNESS:

Factor	A	B	C	D	Chart
$X'_o(A,ZX_o)$ =					Chart 1
$C_o(A,ZX_o)$ =				.0018	Chart 1

WALL MASS THICKNESS:

Factor	A	B	C	D	Chart
$X'_e(X_e,A_p)$ =	93.6	93.6	93.6	93.6	Chart 2
X_i =	0	93.6	93.6	0	–
$\Delta X_w(H,W_c)$ =					Chart 3
$\Delta X_w(A)$ =					
$\Delta X_w(E_x)$ =					
$\Delta X_w(X_c)$ =	6.7	6.7	6.7	6.7	WALL HEIGHT RULE
X'_w =	100.3	193.9	193.9	100.3	

WALL-BY-WALL ANALYSIS:

Factor	A	B	C	D	Chart
X'_w =	100.3	193.9	193.9	100.3	Leave out $\Delta X_w(A)$
r =	32	48	130	42.5	–
$C'_g(X'_w,r)$	012	0012	0005	0098	Chart 8

PROTECTION FACTOR:

Factor	A	B	C	D	
$C_g(X'_w,r)$ =	.009	.0005	.0004	.008	.018
$RF = C_o + C_g$ =					.02
PF =					~50

PFE SOLUTION FORM

Project: SHNPP - EMERGENCY OPERATIONS FACILITY - SECOND FLOOR

Parameters	Factor	SECTOR OR BUILDING SIDE A	B	C	D	Chart
W = 52.7		66	40	70	70	

Parameters:

- W = 52.7
- L = 90.5
- A = 4769
- Z = 13.17
- H = 12.66
- A_p = 0
- W_c =
- X_o = 93.6
- X_e = 93.6
- X_i = 0, 93.6, 93.6, 0 (A, B, C, D)
- X_f = 93.6
- X_r = 0
- X_c =
- y =
- h =
- $E_x = \frac{y}{h}$ =

ROOF MASS THICKNESS:

Factor	A	B	C	D	Chart
$X'_o(A,ZX_o)$ =					Chart 1
$C_o(A,ZX_o)$ =				.018	Chart 1

WALL MASS THICKNESS:

Factor	A	B	C	D	Chart
$X'_e(X_e,A_p)$ =	93.6	93.6	93.6	93.6	Chart 2
X_i =	0	93.6	93.6	0	–
$\Delta X_w(H,W_c)$ =	17	17	17	17	Chart 3
$\Delta X_w(A)$ =					
$\Delta X_w(E_x)$ =					
$\Delta X_w(X_c)$ =	9.7	9.7	9.7	9.7	Wall Height Rule
X'_w =	120.3	213.9	213.9	120.3	

WALL-BY-WALL ANALYSIS:

Factor	A	B	C	D	Chart
X'_w =	120.3	213.9	213.9	120.3	Leave out $\Delta X_w(A)$
r =	32	48	130	42.5	–
$C'_g(X'_w,r)$	.008	.0008	.00033	.005	Chart 8

PROTECTION FACTOR:

Factor	A	B	C	D	Total
$\frac{0}{90}$ $C'_g(X'_w,r)$ =	.006	.0004	.0003	.004	0.11
$RF = C_o + C_g$ =					.03
PF =					33

P F E SOLUTION FORM

LIST OF SYMBOLS

θ = Azimuthal Angle, ^{o}

W = Width, ft

L = Length, ft

A = The Plan Area of the Building or the Contributing Roof Area, sq ft

Z = Distance from Detector Location to Roof, ft

H = Height of Detector Location Above Ground Contamination, ft

A_p = Percent of Apertures in Exterior Wall.

W_c = Width of Ground Contaminated Field, ft

X_o = Total Mass Thickness between a Detector Location and Roof, psf = $X_f + X_r$

X_e = Exterior Wall Mass Thickness, psf

X_i = Interior Partition Mass Thickness, psf

X_f = Floor Mass Thickness, psf

X_r = Roof Mass Thickness, psf

X_c = Basement Ceiling Mass Thickness, psf

y = The Exposed Portion of a Partially Exposed Basement Wall, ft

h = The Ceiling Height of an Exposed Basement, ft

E_x = y/h the Exposed Fraction of a Basement Wall

X'_e = Adjusted Wall Mass Thickness (Corrected for Apertures) psf

C_o = Total Overhead Contribution

X'_o = Equivalent Overhead Mass Thickness, psf

ΔX_w = An Incremental Increase (or Decrease) in the Exterior Wall Mass Thickness Used to Equate the Real Building to an Equivalent Building, psf

X'_w = Equivalent Wall Mass Thickness, psf

C_g = Total Ground Contribution

PF = Protection Factor

<u>References</u>:

1. "Shelter Design And Analysis", TR-20 (Vol. 2), February 1976, Defense Civil Preparedness Agency.

2. Meteorology and Atomic Energy, 1968. U.S. Atomic Energy Commission.

3. "The Effectiveness of Sheltering as a Protective Action Against Nuclear Accidents Involving Gaseous Releases", Protective Action Evaluation Part 1, April 1978. George H. Anno and Michael A. Dore, U. S. Environmental Protection Agency.

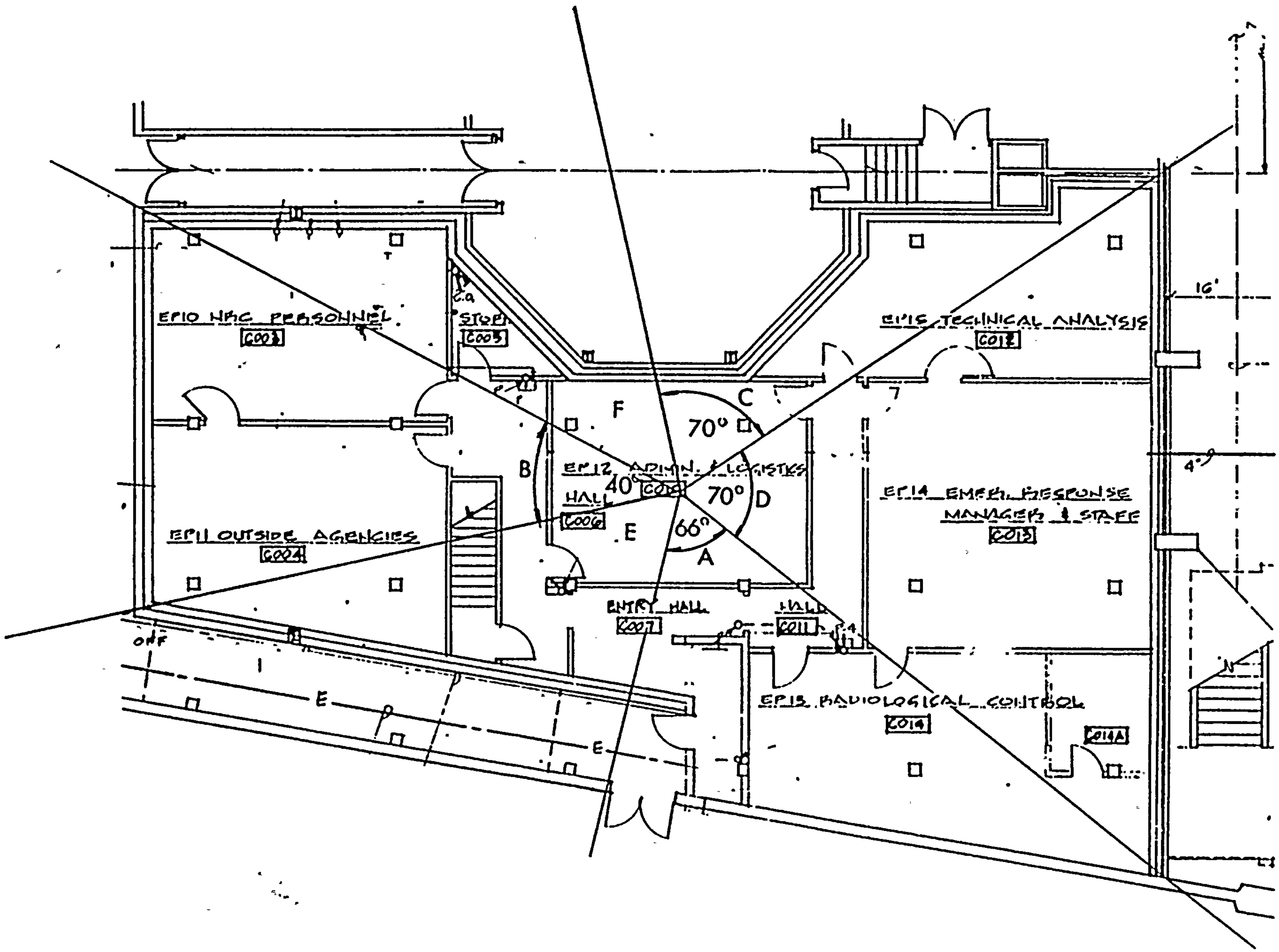

FIGURE 2

EMERGENCY OPERATIONS FACILITY

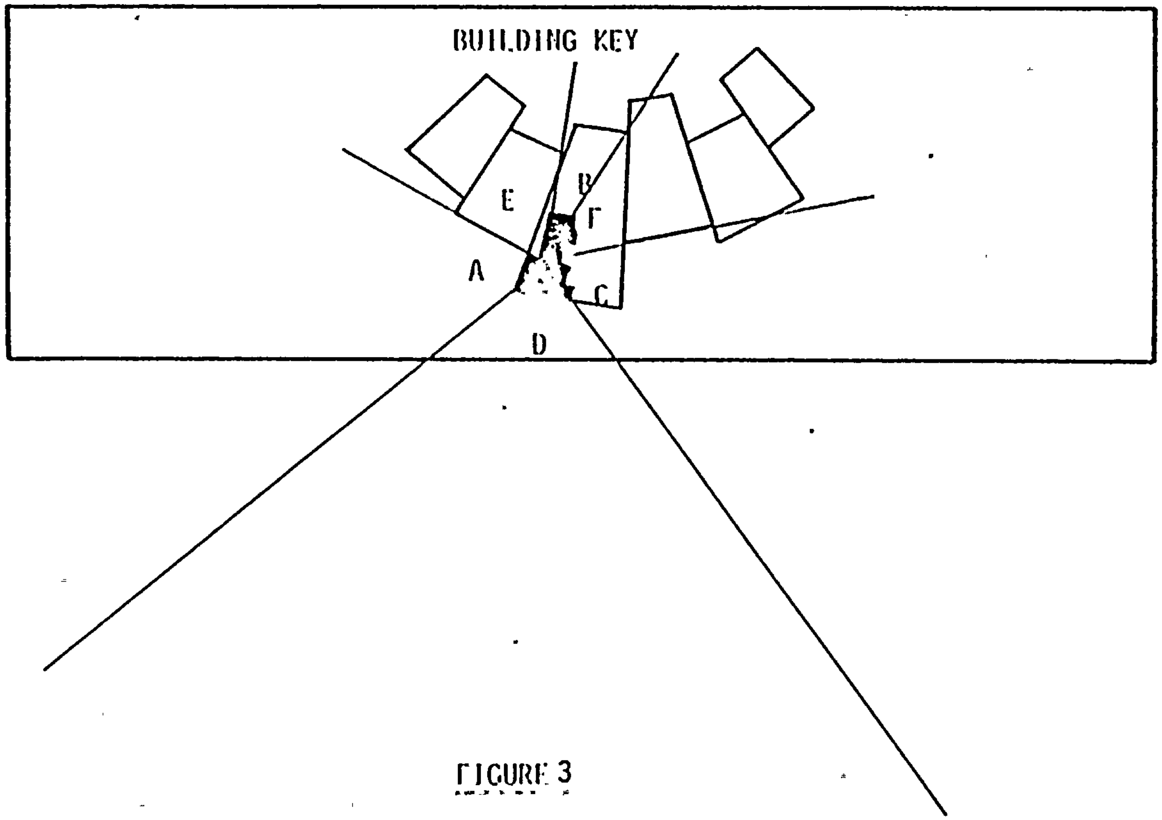

FIGURE 3

EMERGENCY OPERATIONS FACILITY
BUILDING KEY

APPENDIX A

PROTECTION FACTOR CALCULATION MODELS

Protection Factors (PF) for the buildings due to outdoor ground and roof contaminations were calculated using the methodology presented in Ref. 1 , which should be referred to for this purpose.

PF for outdoor plume were calculated using the models presented as follows:

A structure provides protection by the geometrical effect of limiting the distance of approach of the cloud and by shielding afforded by walls. PF is obtained by assuming the plume to be hemispherical in shape and applying equation 7.77 of Ref. 2 .

$$PF = (1+Kx.Ux.W)\exp(-Ux.W) \times \Big\{ [\exp(-u.a) - \exp(-u.r1) - K(1+u.r1) \times \exp(-u.r1) + K(1+u.a)\exp(-u.a)] \times [1-\exp(-u.r1) - K(1+u.r1)\exp(-u.r1) + K]^{-1} \Big\}$$

Where,

- Ux = total absorption coefficient for building material; cm^2/g or cm^{-1}
- u = total absorption coefficient for air; cm^2/g or cm^{-1}
- u = Ua + Us
- Ua = energy absorption coefficient; cm^2/g or cm^{-1}
- Us = scattering absorption coefficient; cm^2/g or cm^{-1}
- W = thickness of shield afforded by building material; g/cm^2
- Kx = component in the buildup factor = (Ux - Ua)/Ua

K , = component in the buildup factor for air = 1.25 @ 1.0 MeV.*

a = effective building radius, cm

$= \sqrt[3]{V \times \frac{3}{2\pi}}$

V = volume of building; cm^3

r1 = radioactive plume radius, cm

Assuming the plume size is very large and substituting infinity for r1 in the above equation;

$$PF = (1+Kx.Ux.W)\ \exp(-Ux.W)\ X \left\{ \frac{[1+K\ (1+u.a)]\ \exp(-u.a)}{1+K} \right\}$$

$$= \quad A \quad X \quad B \text{ —— (i)}$$

The term represented by B expresses the PF from the geometrical considerations, whereas that represented by A expresses the shielding factor.

The shielding provided through the roof is different from that provided by walls. Also, walls have windows and doors which do not provide any protection. Therefore, the above equation has been modified as follows:

$$PF = B\ X \left[Fw \left\{ Ap + (1-Ap) \times Aw \right\} + Fr \times Ar \right] \text{ \_\_\_\_ (ii)}$$

Where, Fr** = fraction of gamma radiation through roof

Fw = fraction of gamma radiation through walls

Ap = fraction representing aperture (windows, doors, etc.) in walls.

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* 1.0 MEV gamma energy used in the calculation is close to the value indicated in Ref.3 .

** Fr is obtained by using Figure 7.33 of Ref. 2 or hand calculation.

Aw = shielding factor for walls

Ar = shielding factor for roof