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JUN 26 1981

Docket No. 50-341

MEMORANDUM FOR Steve L. Ramos, Chief
Emergency Preparedness Development Branch
Division of Emergency Preparedness, IE

FROM: R. Wayne Houston, Chief
Accident Evaluation Branch
Division of Systems Integration, NRR

SUBJECT: REVIEW OF FERMI-2 AMENDMENT 33 - EMERGENCY METEOROLOGICAL PROGRAM

In response to the June 3, 1981 request for a cursory review of the Fermi-2 emergency preparedness meteorological program, the attached comments have been provided by J. Levine of the Meteorology Section.

Original Signed by
R. Wayne Houston

R. Wayne Houston, Chief
Accident Evaluation Branch
Division of Systems Integration, NRR

Enclosure
As stated

cc:w/o encl:
R. Mattson
W.E. Kreger

cc w/encl:
P. Psomas
L. Kintner
B. Zalcman

8107090079

OFFICE	AEB:DSI	AEB:DSI					
SURNAME	JLevine:ml	RWHouston					
DATE	6/25/81	6/25/81		3			

NRR

FERMI-2 EMERGENCY PLAN METEOROLOGY

The meteorological tower is planned to have redundant (primary and backup) instrumentation separately telemetered to the control room. The instrumentation on this 60 meter tower would be the only onsite data sources and would therefore be subject to loss if there were a tower failure. No information is provided on auxiliary power to the tower.

It is also proposed that meteorological data from Davis Beese, 33 miles southeast of Fermi, would be used to represent diffusion conditions at the Fermi site when onsite data were unavailable. There is no indication that the applicant has analyzed how well the meteorological characteristics at both sites are related on a real-time basis.

No information is provided on the dose assessment meteorological model other than to indicate proposed use of a Gaussian model.

Considering the site proximity to Lake Erie, information on lake breeze circulation at the site, should be considered for the effects on effluent transport and dose determination as a result of gaseous releases.

F-84-552

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

AUG 3 1981

Docket No.: 50-341

not action
team leader
Should be an easy one
BJ

MEMORANDUM FOR: James H. Sniezek, Director, Division of Resident and Regional Inspection, I&E

[redacted]

William E. Kreger, Assistant Director for Radiation Protection, DSI

FROM: Robert L. Tedesco, Assistant Director for Licensing, DL

SUBJECT: PUBLIC HEARING FOR FERMI 2

Have ELD send to FEMA & request testimony

In a pre-hearing conference on July 22, 1981, the ASLB established a hearing schedule and selected three contentions, No. 4, No. 5 and No. 8 (Enclosed). The hearing is scheduled to start December 1, 1981, with testimony to be filed November 9, 1981. An affidavit may be required sooner.

This is not an Urbanik problem BJ

OELD expects that staff testimony and witnesses will be required for Contention No. 4 and Contention No. 8, and that an affidavit will be needed for Contention No. 5. An OELD attorney, C. Woodhead or D. Swanson, will contact you or your staff directly to arrange for preparation of the testimony and affidavit.

Please schedule appropriate man power for preparation and participation in the hearing.

Fema OFF site problem

R Tedesco

Robert. L. Tedesco, Assistant Director for Licensing
Division of Licensing

Enclosure: As stated

cc: D. G. Eisenhut
H. Denton
B. J. Youngblood
L. L. Kintner
B. Little
C. Woodhead

Assigned to RAB by ELD

Work with Ed Williams & Congel on a short answer saying these systems are not required now but are under study. There is some TMI-1 testimony that may be useful — see Chesnut!

~~VAN NIEL~~ 8/7 Paul - please do.

Psomas Action

8108060375

8/7/81 4

ELD Release NRR Release

(4) The following contentions and their factual bases are supported by the direct and indirect knowledge of at least one member of CEE, who is and has been personally involved in the construction of Fermi 2 since work was begun.

(a) There has been an appalling lack of physical security at the construction site since the inception of construction. Given the need for extremely close quality control in the erection of a nuclear plant, this failing could well lead to flaws in the structure, through deliberate sabotage or unintentional injury to components.

(b) The Applicant's Quality Assurance Inspection Program has not been executed in conformance with Criterion X of Appendix B to 10 CFR Part 50. Recent reinspections of various materials and workmanship indicate that quality control was inadequate during construction prior to the 1974 shutdown of construction activities at the site. Specifically, CEE identifies: (1) large and small bore pipe hangers, and (2) welds of safety related components.

(c) The Applicant has not maintained sufficient quality assurance records to furnish evidence of activities affecting quality to comply with Criterion XVII of Appendix B to 10 CFR Part 50 in that records have been destroyed or lost during the course of construction.

(d) Detroit Edison twice replaced the team of supervisors from the first general contractor, Ralph M. Parsons Co., then terminated its contract with Parsons and hired a second firm, because Parsons' employees refused to sacrifice quality control in order to expedite the construction schedule.

(e) Specific flaws in construction can be identified, among them:

(1) Excessive water in the reactor hole which caused the concrete base to crack severely, a problem purportedly remedied by patching.

(2) Hairline cracks in structural steel surrounding the dry well.

* * *

(5) (including 4(c)(3)) The design of the radiation monitoring system is insufficient and incomplete as specified below to adequately monitor radiation releases (a) to demonstrate, during normal operation, conformance with Part 20 and Appendix I to 10 CFR Part 50 and (b) to implement the offsite protective actions following accidents set forth in the Applicant's emergency plan. The deficiencies of the radiation monitoring system are:

(a) There is no continuous monitoring system on the lake (for air and water) that can be read remotely; and ✓ not yet

(b) There is no continuous monitoring system at the site boundary that can be read remotely. ✓ Required

(8) CEE is concerned over whether there is a feasible escape route for the residents of the Stony Pointe area which is adjacent to the Fermi 2 site. The only road leading to and from the area, Pointe Aux Peaux, lies very close to the reactor site. In case of an accident the residents would have to travel towards the accident before they could move away from it.

(2) Hairline cracks in structural steel surrounding the dry well.

* * *

5. (including 4(e)(3)) The design of the radiation monitoring system is insufficient and incomplete as specified below to adequately monitor radiation releases (a) to demonstrate, during normal operation, conformance with Part 20 and Appendix I to 10 CFR Part 50 and (b) to implement the offsite protective actions following accidents set forth in the Applicant's emergency plan. The deficiencies of the radiation monitoring system are:

(a) There is no continuous monitoring system on the lake (for air and water) that can be read remotely; and

(b) There is no continuous monitoring system at the site boundary that can be read remotely.

6. (a) CEE contends that reactor coolant piping installed in Fermi 2 will be susceptible to stress corrosion cracking. CEE contends that Edison has failed to provide adequate procedures for inspection and maintenance of reactor coolant piping.

(b) CEE contends that the Applicant has not addressed the problem of deterioration of electrical cables due to adverse conditions of heat, radiation and oxidation.

(c) CEE contends that the Applicant has not demonstrated that it can comply with the guidelines set forth in Standard Review Plan §9.5.1 relative to the adequate isolation, spacing, and delineation of cable trays.

* * *

FERMI-2

EMERGENCY PLAN CONTENTION

CONTENTION 8: The Intervenor CEE is concerned over whether there is a feasible escape route for the residents of the Stony Pointe area which is adjacent to the Fermi-2 site. The only road leading to and from the area, Pointe Aux Peaux Rd., lies very close to the reactor site. In case of accident the residents would have to travel towards the accident before they could move away from it.

STAFF COUNSEL:COLLEEN WOODHEAD
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MNBB, OELD

SARGENT & LUNDY
ENGINEERS
CHICAGO

ACCIDENT RADIOLOGICAL DOSE ASSESSMENT - MANUAL METHOD FOR THE ENRICO FERMI ATOMIC POWER PLANT - UNIT 2

THE DETROIT EDISON COMPANY
ENRICO FERMI ATOMIC POWER PLANT - UNIT 2

Prepared by: R. S. Hubner
Sargent & Lundy
March 31, 1982

8211240153

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ACCIDENT RADIOLOGICAL DOSE ASSESSMENT - MANUAL METHOD FOR THE ENRICO FERMI ATOMIC POWER PLANT - UNIT 2

1. Introduction

This report documents the assumptions and technical basis for the manual back-up method for Fermi-2 off-site, accident dose assessments and radiological emergency declarations. The method uses the accident classifications of the Environmental Protection Agency Protective Action Guides (PAG), Reference 1, as well as NUREG-0654, Reference 2. Total dose projections offsite are compared to the criteria of Reference 1. Reference 2 site and general emergencies based on radiological considerations at the site boundary are projected.

Accident classifications based on both projected dose rate at the site boundary and projected dose to the general population require a considerable amount of information to be known about the plant performance. In-plant monitor readings may provide an estimation of the amounts of radionuclides released in plant but do not predict the amounts that may be released to the environment without many assumptions. Additional parameters that are required but are not well known are:

(a) the nuclidic composition of the source

(b) the time dependent leakage rate from the primary containment to the secondary containment (reactor building)

(c) the amount of mixing in and the exhaust rate from the reactor building

(d) other releases; e.g. Standby Gas Treatment System (SGTS) bypass leakage, Main Steamline Isolation Valve (MSIV) leakage, and drywell purge

(e) the actual SGTS filter efficiency for iodines

(f) the effective height of the release to the environment
(g) the wind speed and direction
(h) the meteorological stability class

The actual values for these items may be unknown; however, their limiting values may be known. In order to make a manual method for determining accident classifications tractable, these items must be limited in a conservative manner; that is, the values chosen must give the highest doses and dose rates.

2. Model

The model for the manual method uses conservative assumptions similar to those of Reference 3. The accident scenario starts with instantaneous release of noble gases and iodines to the primary containment at reactor shutdown or at discrete times after shutdown. 100% of the core inventory of noble gases and 25% of the core inventory of iodines (both reduced by radiodecay for the time between shutdown and the accident) are airborne and are instantaneously mixed in the primary containment volume. These activities leak to the reactor building at the design basis leak rate where they are exhausted immediately by the SGTS through an iodine filter to the environment at ground level.

The calculated released activities are not necessarily the actual released activities. An estimation of the actual released activities may be made by normalizing the calculated released activities (based on conservative plant parameter assumptions) by the ratio of actual monitor readings to calculated monitor readings.

The estimated actual released activities are then transported instantaneously downwind to the dose point. Dose and dose rate equations used are those for a semi-infinite cloud whose concentration is that for the center of a Gaussian plume. The dispersion parameters are those for the current Pasquill stability class (Reference 4) at the distance downwind from the release point to the dose point; however, in certain applications, the "worst" class (class G) is used.

No iodine depletion by plating, washout, or ground deposition occurs. Thyroid inhalation doses and dose rates are based on the product of breathing rate times dose conversion factor for an awake (active) adult; for a child this product is taken to be two times larger. Parent-daughter relationships are not

considered after the accident; however, during the time between reactor shutdown and the accident, the parent-daughter relationships between I-135 and both Xe-135m and Xe-135 are included.

Noble gas and iodine nuclides with half-lives less than 3 minutes are omitted.

A more general model for off-site dose and dose rate projections including mathematical descriptions and solutions of equations can be found in Appendix A. The manual method is a specific application of this general model. Equations used for the production of tables, graphs, and worksheets for the manual method are developed from the equations of Appendix A using certain specific assumptions and using Fermi-2 data.

Among the potentially useful monitors, two have been chosen - an in-containment and a standby gas treatment system (SGTS) monitor. These monitors provide the idealized readings of Rad (air)/Hr and μci/cc of Xe-133 equivalent respectively. The in-containment monitor is located on the outer wall of the drywell at the 605 ft. elevation. It views a portion of a cylindrical annulus cloud of gamma emitters and is not affected by beta radiation. The SGTS monitor is located in the standby gas treatment effluent stream after the iodine filter. It provides the effective Xe-133 activity concentration, based on γ energy emitted, at that point.

Each of these monitors has its faults for accident classification. Although the SGTS monitor reflects what is being instantaneously released to the environment, it may not be conservative under certain conditions for projections of dose rate and dose as we will see later. The drywell monitor reflects what potentially might be released and may thus be overly conservative.

3. Assumptions

3.1 Nuclidic Composition of the Source

For noble gases the nuclide mix in the reactor core at the time of the accident would be the same as the mix in the core at reactor shutdown reduced by radiodecay for the time between shutdown and the accident. The maximum noble gas activity released to the primary containment would then be 100% of the core inventory at the time of the accident. To be conservative these activities are assumed to be immediately airborne. The ratio of the actual to the calculated monitor readings would be a measure of the fraction of the 100% core activity that was actually released. The exclusion of iodine activity from the monitor readings would result in a conservative estimate of that fraction since the actual monitor reading could be higher due to iodines.

For iodine, the amount of release relative to the noble gas release is unknown. Furthermore, the amounts airborne and available for leakage are unknown. We will rely on Reference 3 to obtain a conservative estimate of the relative amounts of iodine released. This Reference states that 100% of the noble gases and 25% of the iodines in the core inventory are airborne and available for leakage to the environment. We will assume that, for the purpose of determining thyroid inhalation doses, the amounts of iodine released are always in this proportion; that is, the amount of iodine airborne in the primary containment will always be 25% of the iodine core inventory times the fraction of the Reference 3 mixture that is actually airborne. This fraction is the ratio of the actual monitor reading to the calculated reading including both 100% noble gases and 25% iodines. For example, if the ratio of the monitor readings is ½, then we assume that 12-½% of the iodines are airborne.

We must note that in this example, the fraction of the 100% core inventory of noble gases that is airborne would be ½, but this fraction would not be conservative because the actual amounts of iodine present are unknown. So we exclude the iodine contribution to the calculated monitor reading when we determine the fraction of noble gases airborne. Thus, in the example, the fraction of the 100% noble gas core inventory that is airborne would be significantly larger than ½.

In any case the activities are assumed to be completely mixed in the entire primary containment volume.

3.2 Primary Containment Leakage Rate

The primary containment leakage rate is not only unknown but also is probably a complicated function of time. To be conservative the design basis leak rate given in Reference 5 (p. 15B.6-37) is used. This value of 0.5 %/day (2.083×10^{-4} hr^{-1}) is assumed to be constant for the duration of the accident (Reference 3).

3.3 Mixing in and Exhaust Rate from the Reactor Building

Reference 5 (pp. 15B.6-34 and 15B.6-37) states that no credit is taken for mixing and holdup in the reactor building. This is conservative for immediate dose considerations but leads to difficulties for projected dose rates and doses based on Standby Gas Treatment System monitor readings. One would expect that some mixing does occur. Thus an SGTS monitor would give increasing readings with time until a maximum is reached, and then the readings would fall with radiodecay. However, calculated monitor readings based on no mixing would start at a high value and fall monotonically with time. The result is that at early times the fraction of core inventory released would be underestimated. The estimation would improve with time and eventually become conservative. But the

drywell monitor would project overly conservative results at early times because holdup due to mixing was ignored.

Because we lack mixing data, we must assume no mixing, but we must recognize that the dose projections at early times must be closely watched.

The no mixing assumption is equivalent to direct leakage from the primary containment through the SGTS filter to the environment. In other words, the SGTS exhaust rate is infinite.

3.4 Other leakages

Bypass leakage is assumed to be zero. Reference 5 (p. 6.2-10f) states that a conservative estimate of the SGTS bypass leakage is zero for wind speeds less than 20 miles per hour.

MSIV leakage is assumed to be zero. Reference 5 (Section 9A.3.1, p. 9A-1) states that the MSIV leakage control system is designed to operate at a higher pressure than the primary containment. Thus, leakage is inhibited.

A drywell purge is not assumed to occur.

3.5 SGTS Filter Efficiency

Reference 5 (p. 15B.6-37) states that the SGTS filter efficiency for iodine is 99%. This is a conservative value. The actual value may be higher. Since the actual value is unknown, we must use the conservative value which will result in an overestimation of the thyroid inhalation dose consequences.

3.6 Release Height

The Fermi-2 SGTS vent is not at sufficient height to take credit for elevated release. Although some height effects are present, we must be conservative by selecting a ground level release. Although a methodology for partial elevated releases could be formulated (Reference 6), finite cloud considerations would have to be used for whole body dose determinations. In addition, terrain effects would have to be considered. These complications were rejected in favor of the more simple conservative ground release with no plume rise and no terrain effects; however, building wake is included.

3.7 Wind Speed and Direction

Dose rates and doses are inversely proportional to wind speed. To project such quantities over time, the wind speed must be known. It is assumed that the wind speed at the time of the projection is constant over the time period of the projection. Dose projections over large time periods should be avoided because of changes in wind speed and direction. Of course, instantaneous dose rates downwind are independent of wind direction but integrated doses apply only to directions in which the wind was blowing.

3.8 Meteorological Stability Class

The Pasquill stability class (Reference 4) is required to fix the amount of dispersion in the Gaussian plume model (References 7 and 3). The stability class is assumed to be constant over the time period of the projection.

3.9 Monitors

All calculated monitor readings use the following assumptions.

1. for the purpose of determining the actual amount of noble gas released to the primary containment, 100% of the core inventory of noble gases are instantaneously released to the entire primary containment with perfect mixing. Radiodecay from time of reactor shutdown to time of accident is included.
2. for the purpose of determining the actual amount of iodines airborne in the primary containment, 100% of the core inventory of noble gases plus 25% of the core inventory of iodines are instantaneously released to the entire primary containment with perfect mixing. Radiodecay from time of reactor shutdown to time of accident is included.

4. <u>Data</u>

Tables 1 and 2 present the specific Fermi-2 data used in preparing the material for the manual method.

TABLE 1

FERMI-2 PLANT DESIGN BASIS PARAMETERS

Appendix A Variable	Value	Description	Ref.	Location in Ref.
V	2.946×10^5 ft^3	Primary Containment Volume	5	p. 6.2-4
			5	Table 6.2-1
L	2.083×10^{-4} hr^{-1}	Primary Containment Leak Rate	5	p. 15B.6-37
P	0.0	Purge Rate (Primary Containment)	-	-
B	0.0	SGTS Bypass Fraction	5	p. 6.2-10f
V	1.836×10^6 ft^3	Secondary Containment Volume	8	p. 3
M	0.0*	Secondary Containment Mixing Fraction	5	p. 15B.6-34
			5	p. 15B.6-37
E	(1.0 hr^{-1})	SGTS Exhaust Rate (any non-zero value since M = 0.0)	-	-
ε_j	0.99	SGTS Filter Fractional Efficiency for Iodines; $1 \leq j \leq 5$; ($\varepsilon_j \equiv 0.0$ for $6 \leq j \leq 18$)	5	p. 15B.6-37

*Since M $\neq$ 0.0 (See Appendix A), M = 1.0×10^{-10} was used.

TABLE 2

NUCLIDE DATA FOR FERMI-2

Nuclide Index, j	Nuclide	$A_j(0)$, Primary Containment Initial Airborne Activity, Ci	D_{tj}, Thyroid Dose Conv. Factor, Rem/Inhaled Ci	λ_j, Radiodecay Constant, hr^{-1}	$\bar{E}_{\gamma j}$, Average Energy per Disintegration, Mev	H_j, Infinite/Finite Gamma Cloud Dose Ratio
1	I-131	2.20+7	1.49+6	.003593	.381	28.74
2	I-132	3.32+7	5.48+4	.3035	2.26	31.33
3	I-133	4.80+7	3.66+5	.03334	.608	30.20
4	I-134	5.67+7	2.87+4	.792	2.601	32.12
5	I-135	4.41+7	1.17+5	.1051	1.557	34.71
6	Kr-83m	1.41+7	-	.374	.00245	1.173
7	Kr-85m	4.41+7	-	.1548	.158	26.08
8	Kr-85	1.40+6	-	7.38-6	.00221	29.55
9	Kr-87	7.97+7	-	.5472	.7825	36.10
10	Kr-88	1.10+8	-	.2477	1.934	37.92
11	Kr-89	1.37+8	-	13.18	1.713	36.22
12	Xe-131m	8.90+5	-	.002408	.01975	7.245
13	Xe-133m	4.80+6	-	.01296	.04123	11.60
14	Xe-133	1.90+8	-	.00547	.04501	13.73
15	Xe-135m	5.34+7	-	2.718	.4317	28.61
16	Xe-135	1.80+8	-	.0756	.2471	28.39
17	Xe-137	1.80+8	-	10.84	.1968	30.68
18	Xe-138	1.68+8	-	2.93	1.096	35.68

The data in Table 2 were obtained from the following sources:

$A_j(0)$ from Reference 5, Table 15B.6.5-2 but with the 1 minute values in the Table multiplied by $\exp(.01667\lambda_j)$ to obtain values at time = 0.0; λ_j is given in Table 2, and its units are hr^{-1}.

D_{tj} from Reference 9

λ_j from Reference 10

$\overline{E}_{rj}$ from Reference 11 by summing the products of the frequencies times their discrete energies.

H_j from Appendix A.4

5. Manual Method Theory

5.1 Projected Effective Activity Release

Projected effective Xe-133 and effective I-131 activity releases are given by Eqns. A17, A18, A21, and A22 in Appendix A.3.3. In each case an effective activity released during a time period is given by an actual monitor reading times the ratio of the design basis effective activity released to the design basis calculated monitor reading; e.g., from Eqn. A17 of Appendix A.3.3,

$$_{AD}Q_{eff\,Xe\text{-}133}(t_A, t_B) = R_{AD}(t) \left\{ \frac{Q_{eff\,Xe\text{-}133}(t_A, t_B)}{R_{CD}(t)} \right\}$$

This ratio (that in the curly brackets) will be called Q/R and may be tabulated for various combinations of release time period (t_A to t_B) and time (t) of the monitor reading. Such Q/R tabulations can be made for both effective Xe-133 and effective I-131 as well as for both drywell monitor and SGTS monitor. To obtain the actual effective activity released during a time period, the actual monitor reading at time t is multiplied by the appropriate Q/R. Since the actual drywell monitor reading units are mrad/hr, that reading must be multiplied by 1.0×10^{-3} to convert the units to rad/hr.

Such Q/R tables were prepared for the accident occurring 0, 2, 4, 6, and 8 hours after the reactor shutdown. Consecutive 8 hour release time periods were used.

Worksheets were prepared which provided a record of

(a) time after shutdown of release to primary containment

(b) time of monitor reading

(c) 8 hr period desired for activity release

(d) Q/R as obtained from the appropriate table

(e) the monitor reading

(f) the calculation of the activity, Q, released.

For the drywell monitor:

$$Q = [Q/R]\ [\text{monitor reading (mrad/hr)}]\ [1.0 \times 10^{-3}]$$

For the SGTS monitor:

$$Q = [Q/R]\ [\text{monitor reading } (\mu\text{ci/cc})]$$

5.2 PAG Emergency Classification - Worst EAB Conditions

Projected downwind doses for the time period t_A to t_B are given by Eqns. A67 through A70 in Appendix A.3.8.2. These equations may be solved for actual released activity required to obtain the PAG dose limit, $D_{k\gamma}$ or $D_{k\,Thyroid}$ (See Appendix A, Section A.3.8.3). The subscripts D and S may be dropped because the actual release activity found in this manner is independent of plant parameters. Thus, from either Eqn. A67 or Eqn. A68,

$$_{kA}Q_{eff\,Xe\text{-}133}(t_A, t_B) = \frac{D_{k\gamma}\,\bar{u}}{K\,\bar{E}_{\gamma Xe\text{-}133}\left[\bar{u}(\chi/Q')_{id}\right]} \qquad \text{Eqn. 1}$$

where $\left[\bar{u}\,(\chi/Q')_{id}\right]$ equations are found in Appendix A.3.7.2.

And, from either Eqn. A69 or Eqn. A70,

$$_{kA}Q_{eff\,I\text{-}131}(t_A, t_B) = \frac{D_{k\,Thyroid}\,\bar{u}}{D_{e\,I\text{-}131}\,B_R\left[\bar{u}(\chi/Q')_{id}\right]} \qquad \text{Eqn. 2}$$

Eqns. 1 and 2, may be evaluated for the worst conditions (conditions giving the smallest activity release). These conditions are:

(a) Pasquill class G, $i = 7$

and (b) shortest downwind distance of importance, d = 915m (EAB distance Ref. 5, P. 15B.6-37, Table 15B.6.5-1).

Any time period t_A to t_B may be assumed. When this is done the effective activity released to obtain the k^{th} PAG dose limit becomes a linear function of the wind speed $\bar{u}$.

A graph of Eqn. 1 and a graph of Eqn. 2 with wind speed in units of miles per hour and with worst conditions were prepared. Each graph consisted of 3 curves, one for each value of k . Any known or projected (Section 5.1) effective activity release and the current wind speed are coordinates of a point that may be plotted on each of the graphs. If the point lies above the $k = 1$ curve, there is a red emergency; if the point lies between the $k = 1$ and $k = 2$ curves, there is a yellow emergency; if the point lies between the $k = 2$ and $k = 3$ curves, there is a white emergency; and, if the point lies below the $k = 3$ curve, there is no emergency.

A worksheet was prepared which provides a record of

(a) wind speed
(b) effective Xe-133 activity released
(c) whole body dose emergency classification from graph
(d) effective I-131 activity released
(e) thyroid inhalation dose emergency classification from graph

5.3 PAG Emergency Classification

5.3.1 Whole Body Dose Emergency

Equation 1 may be rewritten

$$Q_{k\,eff\,Xe\text{-}133} = \frac{0.447\, D_{kr}\, \bar{u}'}{K\, \bar{E}_{rXe\text{-}133}\left[\bar{u}\left(\chi/Q'\right)_{1d}\right]} \qquad \text{Eqn. 3}$$

where $Q_{k\,eff\,Xe-133}$ is the effective Xe-133 activity released over any time period to obtain the k^{th} PAG whole body dose limit, and the wind speed $\bar{u}'$ in the numerator is expressed in units of miles per hour.

The activity $Q_{k\,eff\,Xe-133}$ may be normalized such that the normalized value ${}_{N}Q_{k\,eff\,Xe-133}$ equals 1 for $k = 3$ and $\bar{u}' = 1$ mph; since $D_{3\gamma} = 0.05$ Rem (Appendix A.3.8.3 and Table A4) and $\bar{E}_{\gamma\,Xe-133} = 0.04501$ Mev (Table 2),

$${}_{N}Q_{3\,eff\,Xe-133} = K_{id\gamma} \frac{0.447 \times 0.05 \times 1}{0.253 \times 0.04501 \left[\bar{u}(\chi/Q')_{id}\right]}$$

where $K_{id\gamma}$ is the normalization constant.
Since ${}_{N}Q_{3\,eff\,Xe-133} = 1$,

$$K_{id\gamma} = 0.5095 \left[\bar{u}(\chi/Q')_{id}\right] \qquad \underline{\text{Eqn. 4}}$$

where $\left[\bar{u}(\chi/Q')_{id}\right]$ is found in Appendix A.3.7.2. Applying the normalization factor $K_{id\gamma}$ to Eqn. 3 gives

$${}_{N}Q_{3\,eff\,Xe-133} = \left(1 \frac{ci}{mph}\right)\bar{u}' \qquad \underline{\text{Eqn. 5}}$$

for $k = 3$. For $k = 2$, since $D_{2\gamma} = 1.0$ Rem (Appendix A.3.8.3 and Table A4) and, thus, $D_{2\gamma}/D_{3\gamma} = 20$,

$${}_{N}Q_{2\,eff\,Xe-133} = \left(20 \frac{ci}{mph}\right)\bar{u}' \qquad \underline{\text{Eqn. 6}}$$

For $k = 1$, since $D_{1\gamma} = 5$ Rem (Appendix A.3.8.3 and Table A4) and, thus, $D_{1\gamma}/D_{3\gamma} = 100$,

$${}_{N}Q_{1\,eff\,Xe-133} = \left(100 \frac{ci}{mph}\right)\bar{u}' \qquad \underline{\text{Eqn. 7}}$$

A graph of Eqns. 5 through 7 (3 curves) was prepared. On this graph, titled PAG Emergency Classification - Normalized Curves Including Stability Class and Distance, the ordinate is the normalized effective Xe-133 activity released. Any known or projected (Section 5.1) effective Xe-133 activity release can be multiplied by the normalization factor $K_{id\delta}$ evaluated by Eqn. 4 for a particular downwind distance and Pasquill stability class to produce the normalized effective Xe-133 activity release. Any normalized effective Xe-133 activity release and the current wind speed $\bar{u}'$ are coordinates of a point that may be plotted on the graph. If the point lies above the k = 1 (Eqn. 7) curve, there is a red whole body dose emergency; if the point lies between the k = 1 and k = 2 (Eqn. 6) curves, there is a yellow whole body dose emergency; if the point lies between the k = 2 and k = 3 (Eqn. 5) curves, there is a white whole body dose emergency; and, if the point lies below the k = 3 curve, there is no whole body dose emergency.

A table of normalization factors titled Multiplying Factors For Xe-133 Activity (ci) Released was prepared. The entries in this table resulted from the evaluation of Eqn. 4 for all seven Pasquill stability classes at the distances 915m and the integral miles from 1 through 10.

5.3.2 Thyroid Inhalation Dose Emergency

Equation 2 may be rewritten

$$Q_{k\,eff\,I\text{-}131} = \frac{0.447\, D_{k\,Thyroid}\, \bar{u}'}{D_{c\,I\text{-}131}\, B_R \left[\bar{u}(\chi/Q')_{id}\right]} \qquad \text{Eqn. 8}$$

where $Q_{k\,eff\,I-131}$ is the effective I-131 activity released over any time period to obtain the k^{th} PAG thyroid inhalation dose limit, and the wind speed $\bar{u}'$ in the numerator is expressed in units of miles per hour.

The activity $Q_{k\,eff\,I-131}$ may be normalized such that the normalized value $\underset{\sim}{Q}_{k\,eff\,I-131}$ equals 1 for $k = 3$ and $\bar{u}' = 1$ mph; since

$D_{3\,Thyroid}$ = 0.3 Rem (Appendix A.3.8.3 and Table A4)

$D_{c\,I-131}$ = 1.49×10^{6} Rem/(inhaled ci) (Table 2)

and B_R = 3.47×10^{-4} m^3/sec (Ref. 3),

$$\underset{\sim}{Q}_{3\,eff\,I-131} = K_{id\,Thyroid} \frac{0.447 \times 0.3 \times 1}{1.49 \times 10^{6} \times 3.47 \times 10^{-4} \left[\bar{u}(\chi/Q')_{id}\right]}$$

where $K_{id\,Thyroid}$ is the normalization constant. Since $\underset{\sim}{Q}_{3\,eff\,I-131}$ = 1,

$$K_{id\,Thyroid} = 3.856 \times 10^{3} \left[\bar{u}(\chi/Q')_{id}\right] \qquad \text{Eqn. 9}$$

where $\left[\bar{u}(\chi/Q')_{id}\right]$ is found in Appendix A.3.7.2. Applying the normalization factor $K_{id\,Thyroid}$ to Eqn. 8 gives

$$\underset{\sim}{Q}_{3\,eff\,I-131} = \left(1 \frac{ci}{mph}\right)\bar{u}' \qquad \text{Eqn. 10}$$

for $k = 3$. For $k = 2$, since $D_{2\,Thyroid}$ = 5 Rem (Appendix A.3.8.3 and Table A4) and, thus

$D_{2\,Thyroid} / D_{3\,Thyroid}$ = 16.667,

$$\underset{\sim}{Q}_{2\,eff\,I-131} = \left(16.667 \frac{ci}{mph}\right)\bar{u}' \qquad \text{Eqn. 11}$$

For $k = 1$, since $D_{1\,Thyroid}$ = 25 Rem (Appendix A.3.8.3 and Table A4) and, thus, $D_{1\,Thyroid} / D_{3\,Thyroid}$ = 83.33,

$$_{N}Q_{1\,eff\,I\text{-}131} = \left(83.33 \frac{ci}{mph}\right)\bar{u}' \qquad \underline{\text{Eqn. 12}}$$

A graph of Eqns. 10 through 12 (3 curves) was prepared. On this graph, titled PAG Emergency Classification - Normalized Curves Including Stability Class and Distance, the ordinate is the normalized effective I-131 activity released. Any known or projected (Section 5.1) effective I-131 activity release can be multiplied by the normalization factor $K_{id\,Thyroid}$ evaluted by Eqn. 9 for a particular downwind distance and Pasquill stability class to produce the normalized effective I-131 activity release. Any normalized effective I-131 activity release and the current wind speed $\bar{u}'$ are coordinates of a point that may be plotted on the graph. If the point lies above the $k = 1$ (Eqn. 12) curve, there is a red thyroid inhalation dose emergency; if the point lies between the $k = 1$ and $k = 2$ (Eqn. 11) curves, there is a yellow thyroid inhalation dose emergency; if the point lies between the $k = 2$ and $k = 3$ (Eqn. 10) curves, there is a white thyroid inhalation dose emergency; and, if the point lies below the $k = 3$ curve, there is no thyroid inhalation dose emergency.

A table of normalization factors titled Multiplying Factors For I-131 Activity (ci) Released was prepared. The entries in this table resulted from the evaluation of Eqn. 9 for all seven Pasquill stability classes at the distances 915m and the integral miles from 1 to 10.

5.3.3 Worksheet

A worksheet titled Emergency Classification Calculation was prepared which provides a record of

(a) Pasquill stability class
(b) downwind distance
(c) type of dose (whole body or thyroid inhalation)
(d) multiplying factor from appropriate table
(e) effective activity release (effective Xe-133 or effective I-131)
(f) normalized effective activity released (the product of item (d) and item (e))
(g) wind speed

The coordinates of the point as itemized in (f) and (g) are then plotted on the appropriate graph; the location of the point on the graph determines the emergency classification.

5.4 Dose Calculation at 10 Miles or Less

5.4.1 Whole Body Dose

From Appendix A.3.8.2 Eqn. A67, the whole body dose $D_{id\gamma}$ due to an effective Xe-133 activity release $Q_{eff\,Xe-133}$ over any time period at a distance d downwind and for Pasquill class i is

$$D_{id\gamma} = 0.253\, Q_{eff\,Xe-133}\, \overline{E}_{\gamma\,Xe-133} \left[\overline{u}\left(\chi/Q'\right)_{id}\right] / \overline{u}$$

Rewriting this equation, using the data of Section 5.3.1 for $\overline{E}_{\gamma Xe-133}$, and expressing the wind speed as $\overline{u}'$ in units of miles per hour,

$$D_{id\gamma} = 0.025475\, Q_{eff\,Xe-133} \left[\overline{u}\left(\chi/Q'\right)_{id}\right] / \overline{u}' \qquad \text{Eqn. 13}$$

Rearranging Eqn. 13,

$$\frac{D_{idr}\bar{u}'}{Q_{eff\,Xe\text{-}133}} = 0.025475\left[\bar{u}\left(\chi/Q'\right)_{id}\right]$$ Eqn. 14

Eqn. 14 says that for a particular distance downwind and Pasquill stability class the quantity $D_{idr}\bar{u}'/Q_{eff\,Xe\text{-}133}$ is a constant; let C_{idr} be that constant.

Thus,

$$C_{idr} = 0.025475\left[\bar{u}\left(\chi/Q'\right)_{id}\right]$$ Eqn. 15

From Eqn. 14, the units of C_{idr} are Rem·mph/ci. Using Eqn. 15, Eqn. 13 can be rewritten

$$D_{idr} = C_{idr}\,Q_{eff\,Xe\text{-}133}\,/\bar{u}'$$ Eqn. 16

A table of the C_{idr} factors titled Dose Calculation Table, Xe-133 Whole Body Gamma Dose, Rem·mph/ci was prepared. The entries in this table resulted from the evaluation of Eqn. 15 for all seven Pasquill stability classes at the distances 915m and the integral miles from 1 to 10. These data were also prepared in graphical form. The graph title was Whole Body Dose · MPH Per Curie Released vs. Distance For Indicated Pasquill Stability Classes.

Given the effective Xe-133 activity released over any time period and given the wind speed $\bar{u}'$, the downwind whole body dose may be calculated using Eqn. 16 with a value of C_{idr} from the table or graph.

5.4.2 Thyroid Inhalation Dose

From Appendix A.3.8.2 Eqn. A69, the thyroid inhalation dose $D_{idThyroid}$ due to an effective I-131 activity release $Q_{eff\,I\text{-}131}$ over any time period at a distance d downwind and for Pasquill class i is

$$D_{idThyroid} = D_{C\,I\text{-}131}\, B_R\, Q_{eff\,I\text{-}131} \left[\bar{u}\left(\chi/Q'\right)_{id}\right] / \bar{u}$$

Rewriting this equation, using the data of Section 5.3.2 for $D_{C\,I\text{-}131}$ and B_R, and expressing the wind speed as $\bar{u}'$ in units of miles per hour,

$$D_{idThyroid} = 1156.67\, Q_{eff\,I\text{-}131} \left[\bar{u}\left(\chi/Q'\right)_{id}\right] / \bar{u}' \qquad \text{Eqn. 17}$$

Rearranging Eqn. 17,

$$\frac{D_{idThyroid}\,\bar{u}'}{Q_{eff\,I\text{-}131}} = 1156.67 \left[\bar{u}\left(\chi/Q'\right)_{id}\right] \qquad \text{Eqn. 18}$$

Eqn. 18 says that for a particular distance downwind and Pasquill stability class the quantity $D_{idThyroid}\,\bar{u}'/Q_{eff\,I\text{-}131}$ is a constant; let $C_{idThyroid}$ be that constant. Thus,

$$C_{idThyroid} = 1156.67 \left[\bar{u}\left(\chi/Q'\right)_{id}\right] \qquad \text{Eqn. 19}$$

From Eqn. 18, the units of $C_{idThyroid}$ are Rem·mph/ci. Using Eqn. 19, Eqn. 17 can be rewritten

$$D_{idThyroid} = C_{idThyroid}\, Q_{eff\,I\text{-}131} / \bar{u}' \qquad \text{Eqn. 20}$$

A table of the $C_{id\ Thyroid}$ factors titled Dose Calculation Table, I-131 Thyroid Inhalation Dose, Rem·mph/ci was prepared. The entries in this table resulted from the evaluation of Eqn. 19 for all seven Pasquill stability classes at the distances 915m and the intergral miles from 1 to 10. These data were also prepared in graphical form. The graph title was Thyroid Inhalation Dose·MPH Per Curie Released vs. Distance For Indicated Pasquill Stability Classes.

Given the effective I-131 activity released over any time period and given the wind speed $\bar{u}'$, the downwind thyroid inhalation dose may be calculated using Eqn. 20 with a value of $C_{id\ Thyroid}$ from the table or graph.

5.4.3 Worksheet

A worksheet titled Dose Calculation was prepared which provides a record of

(a) Pasquill stability class
(b) downwind distance
(c) type of dose (whole body or thyroid inhalation)
(d) value from $C_{id\gamma}$ or $C_{id\ Thyroid}$ table or graph
(e) effective activity released (effective Xe-133 or effective I-131)
(f) wind speed
(g) calculation of item (e) divided by item (f)
(h) calculation of dose: item (d) times item (g)

5.5 Area Affected Calculation for PAG Classification

5.5.1 $\left[\bar{u}(\chi/Q')_{id}\right]$ Curves

A graph of $\left[\bar{u}(\chi/Q')_{id}\right]$ vs. distance was prepared. The graph contained a curve for each of the seven Pasquill stability classes. The plotted values were obtained from the evaluation of equations given in Appendix A.3.7.2. Note that this is for a ground level release with building wake included.

5.5.2 Outer Boundary of PAG Whole Body Dose Emergency Condition

Rearranging Eqn. 3,

$$\left[\bar{u}(\chi/Q')_{id}\right]_k = \left(\frac{0.447\, D_{k\gamma}}{K\,\bar{E}_{\gamma Xe\text{-}133}}\right)\left(\frac{\bar{u}'}{Q_{eff\,Xe\text{-}133}}\right) \qquad \text{Eqn. 21}$$

where the subscript k was removed from the $Q_{eff\,Xe\text{-}133}$ in order to denote any effective Xe-133 activity released over any time period and the subscript k was added to the $\left[\bar{u}(\chi/Q')_{id}\right]_k$ to denote that this quantity is that required to obtain the dose $D_{k\gamma}$. Using the values of K and $\bar{E}_{\gamma Xe\text{-}133}$ from Section 5.3.1, Eqn. 21 becomes

$$\left[\bar{u}(\chi/Q')_{id}\right]_k = \left(39.25346\, D_{k\gamma}\right)\left(\frac{\bar{u}'}{Q_{eff\,Xe\text{-}133}}\right) \qquad \text{Eqn. 22}$$

For $k = 1$, $D_{1\gamma}$ = 5.0 Rem and Eqn. 22 becomes

$$\left[\bar{u}(\chi/Q')_{id}\right]_1 = 196.27\,\bar{u}'/Q_{eff\,Xe\text{-}133} \qquad \text{Eqn. 23}$$

For $k = 2$, $D_{2\gamma}$ = 1.0 Rem and Eqn. 22 becomes

$$\left[\bar{u}(\chi/Q')_{id}\right]_2 = 39.25\,\bar{u}'/Q_{eff\,Xe\text{-}133} \qquad \text{Eqn. 24}$$

For $k = 3$, $D_{3\gamma} = 0.05$ Rem and Eqn. 22 becomes

$$\left[\bar{u}(\chi/Q')_{id}\right] = 1.9627\,\bar{u}'/Q_{eff\ Xe-133} \qquad \text{Eqn. 25}$$

Eqns. 23 through 25 provide the means of calculating the wind speed times the atmospheric relative concentration at the outer boundary of the PAG whole body dose emergency condition k for any effective Xe-133 activity release over any time period. The value obtained along with the current Pasquill stability class can be used to obtain the outer boundary distance from the curves developed in Section 5.5.1; let this distance be $d_{k\gamma}$. Then, for any distance, d

$0.57 \text{ miles} \leq d \leq d_{1\gamma}$	, Red Emergency
$d_{1\gamma} < d \leq d_{2\gamma}$	, Yellow Emergency
$d_{2\gamma} < d \leq d_{3\gamma}$	, White Emergency
$d_{3\gamma} < d$	, No Emergency

The curves of Section 5.5.1 are not defined for distances less than 0.57 miles (915m). If any of the upper boundaries $d_{k\gamma}$ are apparently less than 0.57 miles because the associated $\left[\bar{u}(\chi/Q')_{id}\right]_k$ is greater than any value on the appropriate curve, then the corresponding emergency condition is not required. The curves of Section 5.5.1 are also not defined for distances greater than 50 miles because emergency condition evaluations are not required beyond that distance.

A worksheet titled Area Affected Calculation - Xe-133 was prepared which provides a record of

(a) effective Xe-133 activity released

(b) wind speed

(c) Eqn. 25 evaluation

(d) Eqn. 24 evaluation
(e) Eqn. 23 evaluation
(f) Pasquill stability class
(g) white emergency outer boundary
(h) Yellow emergency outer boundary
(i) red emergency outer boundary

5.5.3 Outer Boundary of PAG Thyroid Inhalation Dose Emergency Condition

Rearranging Eqn. 8,

$$\left[\bar{u}\left(\chi/Q'\right)_{id}\right]_k = \left(\frac{0.447\, D_{k\,Thyroid}}{D_{c\,I\text{-}131}\, B_R}\right)\left(\frac{\bar{u}'}{Q_{eff\,I\text{-}131}}\right)$$ Eqn. 26

where the subscript k was removed from the $Q_{eff\,I\text{-}131}$ in order to denote any effective I-131 activity released over any time period and the subscript k was added to the $\left[\bar{u}\left(\chi/Q'\right)_{id}\right]_k$ to denote that this quantity is that required to obtain the dose $D_{k\,Thyroid}$. Using the values of $D_{c\,I\text{-}131}$ and B_R from Section 5.3.2, Eqn. 26 becomes

$$\left[\bar{u}\left(\chi/Q'\right)_{id}\right]_k = \left(8.64553\times10^{-4} D_{k\,Thyroid}\right)\left(\frac{\bar{u}'}{Q_{eff\,I\text{-}131}}\right)$$ Eqn. 27

For $k = 1$, $D_{1\,Thyroid}$ = 25.0 Rem and Eqn. 27 becomes

$$\left[\bar{u}\left(\chi/Q'\right)_{id}\right]_1 = 2.1614\times10^{-2}\, \bar{u}'/Q_{eff\,I\text{-}131}$$ Eqn. 28

For $k = 2$, $D_{2\,Thyroid}$ = 5.0 Rem and Eqn. 27 becomes

$$\left[\bar{u}\left(\chi/Q\right)_{id}\right]_2 = 4.3228\times10^{-3}\, \bar{u}'/Q_{eff\,I\text{-}131}$$ Eqn. 29

For $k = 3$, $D_{3\,Thyroid}$ = 0.3 Rem and Eqn. 27 becomes

$$\left[\bar{u}(\chi/Q')_{id}\right]_3 = 2.5937\times10^{-4}\,\bar{u}'/Q_{eff\,I\text{-}131} \qquad \text{Eqn. 30}$$

Eqns. 28 through 30 provide the means of calculating the wind speed times the atmospheric relative concentration at the outer boundary of the PAG thyroid inhalation dose emergency condition k for any effective I-131 activity release over any time period. The value obtained along with the current Pasquill stability class can be used to obtain the outer boundary distance from the curves developed in Section 5.5.1; let this distance be $d_{k\,Thyroid}$. Then, for any distance d,

$0.57 \text{ miles} \le d \le d_{1\,Thyroid}$, Red Emergency
$d_{1\,Thyroid} < d \le d_{2\,Thyroid}$, Yellow Emergency
$d_{2\,Thyroid} < d \le d_{3\,Thyroid}$, White Emergency
$d_{3\,Thyroid} < d$, No Emergency

The curves of 5.5.1 are not defined for distances less than 0.57 miles (915m). If any of the upper boundaries $d_{k\,Thyroid}$ are apparently less than 0.57 miles because the associated $\left[\bar{u}(\chi/Q')_{id}\right]_k$ is greater than any value on the appropriate curve, then the corresponding emergency condition is not required. The curves of Section 5.5.1 are also not defined for distances greater than 50 miles because emergency condition evaluations are not required beyond that distance.

A worksheet titled Area Affected Calculation - I-131 was prepared which provides a record of

(a) effective I-131 activity released
(b) wind speed
(c) Eqn. 30 evaluation

(d) Eqn. 29 evaluation
(e) Eqn. 28 evaluation
(f) Pasquill stability class
(g) white emergency outer boundary
(h) yellow emergency outer boundary
(i) red emergency outer boundary

5.6 Doses at Distances Between 0.57 and 50 Miles

5.6.1 Whole Body Dose

Eqn. 13 enables the calculation of the downwind whole body dose for any effective Xe-133 activity release over any time period. The value of $\left[\bar{u}(\chi/Q')_{id}\right]$ for a given distance and Pasquill stability class may be found from the appropriate curve developed in Section 5.5.1.

A worksheet titled Calculation of Dose at Distances Between 0.57 and 50 Miles - Xe-133 was prepared which provides a record of

(a) downwind distance
(b) Pasquill stability class
(c) wind speed times atmospheric relative concentration from the appropriate curve developed in Section 5.5.1
(d) wind speed
(e) effective Xe-133 activity released
(f) Eqn. 13 evaluation for whole body dose

5.6.2 Thyroid Inhalation Dose

Eqn. 17 enables the calculation of the downwind thyroid inhalation dose for any effective I-131 activity release over any time period. The value of $\left[\bar{u}(\chi/Q')_{id}\right]$ for a given distance and Pasquill stability class may be found from the appropriate curve developed in Section 5.5.1.

A worksheet titled Calculation of Dose at Distances Between 0.57 and 50 Miles - I-131 was prepared which provides a record of

(a) down wind distance
(b) Pasquill stability class
(c) wind speed times atmospheric relative concentration from the appropriate curve developed in Section 5.5.1
(d) wind speed
(e) effective I-131 activity released
(f) Eqn. 17 evaluation for thyroid inhalation dose

5.7 NUREG-0654 Emergency Classification

In the following development, the theory of Appendix A.3.9.2 leading to Eqns. A82 and A83 will be used. These two equations are now rewritten.

$$\frac{F_\ell}{\bar{u}} = \frac{\dot{D}_\ell}{K_1 \bar{u} (\chi/Q)_i \dot{Q}_{eff}} \qquad \text{Eqn. 31}$$

and

$$R_\ell = \frac{F_\ell}{\bar{u}} R_{1c} \bar{u} \qquad \text{Eqn. 32}$$

See Appendix A.2 for definitions of the variables.

These equations are now made more explicit by elaborations for monitor type, downwind dose rate type, time dependence, and Pasquill stability class. Thus, Eqn. 31 becomes

$$\frac{F_{i\ell\gamma}}{\bar{u}} = \frac{\dot{D}_{\ell\gamma}}{0.253 \, \bar{E}_{\gamma Xe\text{-}133} \left[\bar{u}(\chi/Q)_i\right] \dot{Q}_{eff\,Xe\text{-}133}(T_{max\,Xe\text{-}133})} \qquad \text{Eqn. 33}$$

and

$$\frac{F_{i\ell\,Thyroid}}{\bar{u}} = \frac{D_{\ell\,Thyroid}}{D_{c\,I\text{-}131} B_R \left[\bar{u}(\chi/Q)_i\right] \dot{Q}_{eff\,I\text{-}131}(T_{max\,I\text{-}131})} \qquad \text{Eqn. 34}$$

Also, after dividing Eqn. 32 by $\bar{u}$, that equation becomes

$$\frac{R_{ADi\ell\gamma}(t)}{\bar{u}} = \left(\frac{F_{i\ell\gamma}}{\bar{u}}\right) R_{CD}(t) \qquad \text{Eqn. 35}$$

$$\frac{R_{ASi\ell\gamma}(t)}{\bar{u}} = \left(\frac{F_{i\ell\gamma}}{\bar{u}}\right) R_{CS}(t) \qquad \text{Eqn. 36}$$

$$\frac{R_{ADi\ell\,Thyroid}}{\bar{u}} = \left(\frac{F_{i\ell\,Thyroid}}{\bar{u}}\right) R_{CD}(t) \qquad \text{Eqn. 37}$$

$$\frac{R_{ASi\ell\,Thyroid}}{\bar{u}} = \left(\frac{F_{i\ell\,Thyroid}}{\bar{u}}\right) R_{CS}(t) \qquad \text{Eqn. 38}$$

The following definitions apply.

$F_{i\ell\gamma}$ = fraction of the design basis accident release with iodines excluded that is actually released to the primary containment and will result in the NUREG-0654 whole body dose rate limit ℓ at the site boundary for Pasquill stability class i .

$F_{i\ell\,Thyroid}$ = fraction of the design basis accident release including 25% of the core inventory of iodines that is actually released to the primary containment and will result in the NUREG-0654 thyroid inhalation dose rate limit ℓ at the site boundary for Pasquill stability class i .

$R_{ADil\gamma}(t)$ = actual drywell monitor reading at time t for the NUREG-0654 whole body dose rate limit ℓ at the site boundary for Pasquill stability class i .

$R_{ASil\gamma}(t)$ = same as $R_{ADil\gamma}(t)$ except for SGTS monitor.

$R_{ADil\,Thyroid}(t)$ = same as $R_{ADil\gamma}(t)$ except for resulting in the NUREG-0654 thyroid inhalation dose rate limit ℓ .

$R_{ASil\,Thyroid}(t)$ = same as $R_{ADil\,Thyroid}(t)$ except for SGTS monitor.

5.7.1 Calculated Monitor Readings

Calculated monitor readings, $R_{CD}(t)$ and $R_{CS}(t)$, were tabulated at several times, t , after the accident from 0.167 hr through 24.0 hr. Tabulations were made for both 0% and 25% iodine core inventory airborne in the primary containment; in both cases, 100% of the noble gas core inventory was airborne. Drywell monitor readings, $R_{CD}(t)$, were evaluated from Eqn. A13 in Appendix A.3.2.1. SGTS monitor readings, $R_{CS}(t)$, were evaluated from Eqn. A14 in Appendix A.3.2.2.

These tabulations were done for the accident occurring 0, 2, 4, 6, and 8 hrs after reactor shutdown.

5.7.2 General Emergency

Eqns. 33 and 34 were evaluated with ℓ = 1 for each of the seven Pasquill stability classes, $1 \leq i \leq 7$. Results of Eqn. 33 were tabulated. There was a table for each time interval between reactor shutdown and the accident. The title of each table was

Fractions of 100% Noble Gases Plus N% Iodines Released And Wind Speed Ranges to Give Gamma Whole Body Emergency Condition (NUREG-0654) For Release to Primary Containment at X. Hours After Shutdown Without I-135 As Parent

where X was the appropriate time 0, 2, 4, 6, or 8.

Four tables containing minimum monitor readings divided by wind speed, at times t and for all Pasquill stability classes, at which general emergencies exist were prepared. There was a table for evaluations of each of Eqns. 35 through 38 with ℓ = 1. The titles of the tables were

(a) for Eqn. 35 evaluation
Drywell Monitor Readings - General Emergency
For Release at X. Hr After Shutdown
Whole Body Gamma Dose Rate Emergency

(b) for Eqn. 36 evaluation
SGTS Monitor Readings - General Emergency
For Release at X. Hr After Shutdown
Whole Body Gamma Dose Rate Emergency

(c) for Eqn. 37 evaluation
Drywell Monitor Readings - General Emergency
For Release at X. Hr After Shutdown
Thyroid Inhalation Dose Rate Emergency

(d) for Eqn. 38 evaluation
SGTS Monitor Readings - General Emergency
For Release at X. Hr After Shutdown
Thyroid Inhalation Dose Rate Emergency

where X was the appropriate time 0, 2, 4, 6, or 8.

Worksheets titled
General Energency Determination For Drywell Monitor
and
General Emergency Determination For SGTS Monitor
were prepared which provide a record of

(a) Pasquill stability class

(b) type of dose rate - whole body or thyroid inhalation

(c) time of monitor reading

(d) value of monitor reading divided by wind speed from the general emergency table

(e) wind speed (mph)

(f) calculation of monitor reading for general emergency

Drywell monitor: 447.0 x item (d) x item (e), mrad/hr

SGTS monitor: 0.447 x item (d) x item (e), μci/cc

(g) actual monitor reading

(h) comparison of item (g) with item (f) for emergency determination

If item (g) $\geq$ item (f) then general emergency.

If item (g) $<$ item (f) then no emergency.

5.7.3 Site Emergency

Table A5 in Appendix A.3.9.1 lists two criteria for determining a site emergency. One states that a given dose rate limit (ℓ = 3) at the site boundary for Pasquill stability class G (i = 7) and for a 1.0 m/sec wind speed must be equalled or exceeded for a period of ½ hour. The other is similar except the dose rate limit (ℓ = 2) is ten times larger and the duration is 2 minutes. For the types of accidents considered, a large dose rate for a period of 2 minutes is not possible without a similar large dose rate for a period of ½ hr. The largest possible time rate of change of dose rate is that for the whole body during the first 30 minutes of the accident

assuming the accident occurs at reactor shutdown; however, this decrease in dose rate is considerably less than a factor of 10. Thus, all ℓ = 2 site emergencies are a subset of the ℓ = 3 site emergencies. In site emergency determination only the ℓ = 3 criterion will be used.

Since both $T_{max\ Xe-133}$ and $T_{max\ I-131}$ are always zero because there is no reactor building mixing and since the activity release rates are monotonically decreasing, the times $T_{max\ Xe-133}$ and $T_{max\ I-131}$ should both be set to ½ hour for ℓ = 3 calculations.

Eqns. 33 and 34 were evaluated with ℓ = 3 for Pasquill class G (i = 7). The results were included in the tables described in the first paragraph of Section 5.7.2.

Two tables containing minimum monitor readings, at times t and Pasquill stability class G (i = 7), at which site emergencies exist were prepared. One table was for the drywell monitor and contained the evaluations of Eqns. 37 and 35. The other table was for the SGTS monitor and contained the evaluations of Eqns. 38 and 36. The titles of the tables were

(a) for Eqns. 37 and 35 evaluations
Drywell Monitor Readings - Site Emergency
Release at X. Hr After Shutdown
Pasquill Stability Class G
Wind Speed = 1.0 M/Sec

(b) for Eqns. 38 and 36 evalautions
SGTS Monitor Readings - Site Emergency
Release at X. Hrs After Shutdown
Pasquill Stability Class G
Wind Speed = 1.0 M/Sec

where X was the appropriate time 0, 2, 4, 6, or 8.

Worksheets titled

Site Emergency Determination For Drywell Monitor

and

Site Emergency Determination For SGTS Monitor

were prepared which provide a record of

(a) type of dose rate - whole body or thyroid inhalation

(b) time of monitor reading

(c) value of monitor reading from the site emergency table. For the drywell monitor multiply this value by 1000 to convert to mrad/hr

(d) actual monitor reading

(e) comparison of item (d) with item (c) for emergency determination

If item (d) $\geq$ item (c) then site emergency

If item (d) $<$ item (c) then no emergency.

5.8 Adjustment for Infant Thyroid Inhalation Dose Assessment

In Section 5.2 through 5.7 thyroid inhalation dose assessment methods were based on the response of an awake, active adult. From Reference 1, the response of an infant is conservatively twice that for an adult. This factor of 2 will now be used to extend the manual method to include infant dose assessments.

The thyroid inhalation dose response is the breathing rate times the thyroid inhalation dose conversion factor, $D_{cI-131} B_R$. In Section 5.2 through 5.7, $D_{cI-131} B_R$ is evaluated for an awake, active adult. For an infant response the factor should be multiplied by two. However, this is equivalent to recording on the worksheets of Section 5.2 through 5.6 two times the projected effective I-131 activity release found in Section 5.1. If two times the projected effective I-131 activity release is used, no other change is required to effect an infant thyroid inhalation dose assessment for Section 5.2 through 5.6.

For Section 5.7, an increase in $D_{cI-131} B_R$ would cause a decrease in the quantity calculated in Eqn. 34; a corresponding decrease in the tables generated by Eqns. 37 and 38 would occur. Thus, when using the worksheet in Section 5.7.2, item (d) (the value from the general emergency table) should be divided by 2 when doing thyroid inhalation dose rate evaluations. Similarly, when using the worksheet in Section 5.7.3, item (c) (the value from the site emergency table) should be divided by 2 when doing thyroid inhalation dose rate evaluations. No other change is required to effect an infant thyroid inhalation dose emergency assessment for Section 5.7.

6. References

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13. Nuclear Regulatory Commission, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants", U.S.N.R.C. Regulatory Guide 1.145, August 1979.
14. R. S. Hubner, "User's Manual for POSTDBA - Supplement for Modification No. 1", S&L Program No. 09.8.085-1.1, August 25, 1980.

*Thyroid inhalation dose conversion factors were selected from this draft because they were more conservative than the values which were used in U.S.N.R.C. Regulatory Guide 1.109, Rev. 1, Oct. 1977, and they agreed better with values from TID-14844 and values in a letter from J. C. Golden, "AEC Standard Assumptions", Jan. 10, 1973.

APPENDIX A

A.1 Method of Solution

A.1.1 Solution Models

Figure A1 shows a simple model of a Boiling Water Reactor (BWR) power plant building structure and shows nuclide activity transport paths. In this model the accident occurs at time t equal to zero. The activity $A_j(0)$ for nuclide j is instantaneously mixed in the drywell plus wetwell (primary containment) volume. The airborne activity $A_j(t)$ is assumed to leak at a constant rate L to the reactor building (secondary containment) volume; a fraction B of this leakage is immediately released, unfiltered, to the environment (bypass leakage), and a fraction $1-B$ of this leakage is instantaneously mixed in the reactor building volume. Airborne activity $C_j(t)$ in the reactor building is exhausted to the environment by the standby Gas Treatment System (SGTS); the iodine portion of this effluent may be filtered. Mixing in the reactor building volume can include any percentage of that volume; e.g. 0% would be no mixing and 100% would be complete mixing. In addition, a filtered purge of the primary containment volume is possible. These three modes of release - SGTS, purge, and bypass leakage - then contribute to the total activity release rate $\dot{Q}_j(t)$ for nuclide j.

The activities $A_j(t)$ and $C_j(t)$ and the activity release rates $\dot{Q}_j(t)$ are calculated using design basis accident plant parameters or, if possible, known parameters at the time of the accident. Such activities and activity release rates are referred to as design basis accident or just design basis values. By suitable input the design basis accident may be changed; however, the actual activities and activity release rates are not necessarily the design basis values. To calculate the actual values, the design basis values are normalized to actual radiation monitor readings

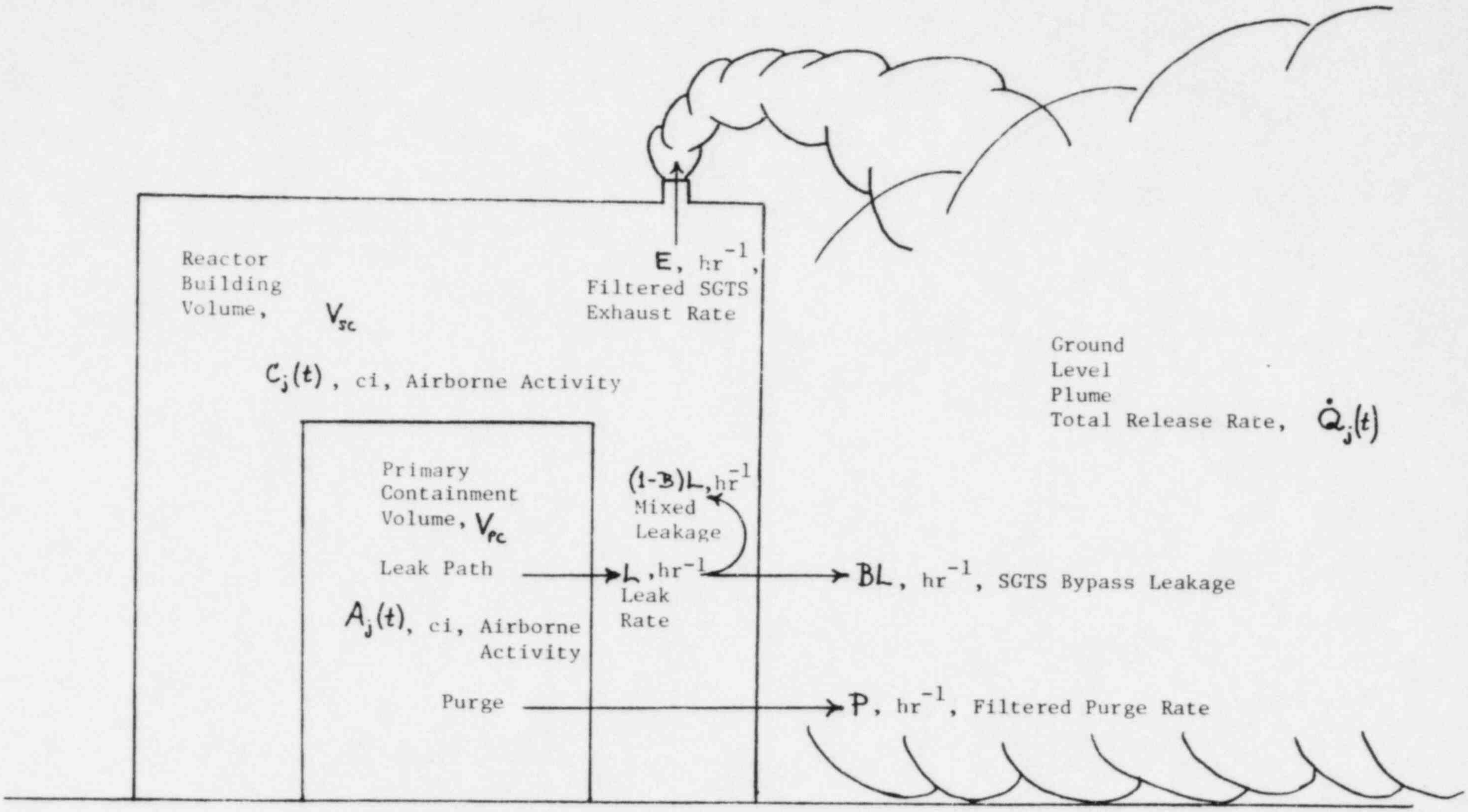

Figure A1. Activity Transport Model

in the drywell or in the SGTS effluent. The normalization requires a calculation of the monitor readings using the design basis activities.

The drywell (in-containment) monitor calculated reading is the actual air dose rate due to gamma radiation at a specific point in the drywell.* The calculational model is that for a semi-infinite cloud (Ref. 3) of activities $A_j(t)$ but with a finite cloud correction (see Section A.4). The SGTS monitor calculated reading is the actual effective Xe-133 activity concentration in the SGTS effluent; a definition of effective Xe-133 activity is given at the beginning of Section A.3.2.2 of this report. The SGTS monitor is placed downstream from the SGTS iodine filter.

In order to be conservative and in view of the fact that the iodine releases to the primary containment may be considerably smaller then the design basis values, the calculated monitor readings should not include contributions from iodines when normalizing the activity releases for the purpose of determining downwind whole body doses and dose rates. However, if the amount of iodine present is known, suitable input will effect the inclusion of iodine in the monitor calculations. For the purpose of determining downwind thyroid inhalation doses and dose rates, the contribution from the design basis iodine or the actual iodine, if known, is always included in the calculation of the monitor readings.

Both the SGTS and purge effluents are assumed to be released near the top of the highest structure and, thus, will be completely mixed in the building wake resulting in a ground level release (Ref. 3). Although the exhaust velocities may be sufficient to

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*For the Enrico Fermi Atomic Power Plant - Unit 2, this monitor is located on the outer wall of the drywell at the 605 ft. elevation. It views a portion of a cylindrical annulus cloud of gamma emmitters. See Section A.4 for a discussion of the finite cloud correction.

claim partial elevated release (Ref. 6), this effect is conservatively ignored. A partial elevated release would require the consideration of finite plume models as well as terrain effects which would greatly increase the complexity of the problem.

Any bypass leakage effluent would probably be of a diffuse nature over the reactor building structure. Such effluent must then be a ground level release.

The transport of the effluent is modelled by a straight line Gaussian plume with a building wake correction using current site meteorological data. Such data include the average wind speed and the Pasquill stability class (Ref. 4); wind direction is not required. The centerline concentrations of nuclide activities as predicted by this model at a given downwind distance is assumed to exist at all points in space - the semi-infinite cloud model. The transport of activities from the release point to the dose point is instantaneous; there is no radiodecay in transit. This conservative modelling is used to reduce the complexity of the problem.

Downwind whole body doses and dose rates use the semi-infinite cloud immersion tissue dose model of Reference 3; body depth shielding is conservatively ignored. Downwind thyroid inhalation doses and dose rates are for an awake adult, but this may be modified by suitable input.

Emergency classifications based on radiological dose and dose rate considerations are obtained from the criteria given in both the Environmental Protection Agency Portective Action Guides, Appendix D, (Ref. 1) and NUREG-0654, Appendix 1, (Ref. 2).

A.1.2 Assumptions

The assumptions are:

1. The accidental release of radioactive nuclides is to the primary containment
2. For the two types of releases -
   (a) If the release is at or after reactor shutdown, the release is instantaneous at time equal zero hours.
   (b) If the release is during reactor operation, the release is continuous and the reactor is not shutdown during the time period of interest; that time period should start at zero hours.
3. The release consists of noble gases and iodines - the noble gases in proportion to their core inventory and the iodines in proportion to 25% of their core inventory (Ref. 3). Optionally, the iodines may be in proportion to any amount of their core inventory. Optionally, the core inventory may be changed to any desired values.
4. The release is instantaneously mixed in the entire primary containment volume.
5. The primary containment leaks to the reactor building at a constant rate.
6. The leakage into the reactor building is instantaneously mixed into any desired fraction of the reactor building volume.
7. The reactor building is exhausted to the environment at a constant rate through an iodine filter of constant efficiency.
8. The primary containment may be purged to the environment with a constant purge rate through an iodine filter of constant efficiency.
9. Bypass leakage is direct and instantaneous from the primary containment to the environment and is unfiltered.
10. All exhausts are released as a ground level Gaussian plume with no plume rise and no terrain effects; however, building wake is included.

11. Whole body doses and dose rates can be conservatively calculated with a semi-infinite gamma cloud model.
12. No iodine depletion by plating, washout, or ground deposition occurs.
13. Radioactive decay in transit may be conservatively excluded.
14. Parent-daughter relationships need not be considered in the release calculations (Reference 3 stipulates only 100% noble gases and 25% iodines in the reactor core are released). However, optionally, the contribution of I-135 to Xe-135m and Xe-135 may be included; this relationship is the only one of importance.
15. The drywell monitor views a portion of an easily modelled (simple geometry) finite cloud of thoroughly mixed gamma emitters and is not affected by beta radiation; also, this monitor is not affected by plated out activities.
16. The SGTS monitor is placed in the SGTS exhaust after the iodine filter. It measures the effective Xe-133 activity concentration in the SGTS exhaust.
17. All monitors respond to gamma radiation only.
18. The ratio of the actual monitor reading to the calculated reading for that monitor is the fraction of the design basis accident release that has actually occurred.
19. For the purpose of determining downwind whole body doses and dose rates, no iodine is present when calculating the monitor readings. However, iodine may optionally be included.
20. For the purpose of determining downwind thyroid inhalation doses and dose rates, contributions of both noble gases and iodines (design basis accident amounts) are included in the calculated monitor readings.
21. Thyroid inhalation dose and dose rate criteria for determination of emergency classifications are for an awake adult. Optional input can adjust this for any person.

22. The wind direction is assumed to be constant over the dose accumulation time period.
23. The average wind speed for the dose accumulation time period is appropriate for use during the entire time period.
24. The Pasquill stability class is constant over the dose accumulation time period.
25. Nuclides with half-lives less than 3 minutes may be excluded.

A.2 Definitions of Variables

A_{iy}	Parameter in the algorithm for $\sigma_{iy}(d)$
A_{iz}	Parameter in the algorithm for $\sigma_{iz}(d)$
$A_j(t)$	Time dependent airborne activity, ci, in the primary containment. For $1 \leq j \leq 5$, $A_j(o)$ is the desired fraction of the core inventory of iodines at reactor shutdown. For $j > 5$, $A_j(o)$ is all of the core inventory of noble gases.
$A_p(t)$	Same as $A_j(t)$ but for a parent nuclide (I-135).
A_R	Smallest vertical plane cross-sectional area, m^2, of the reactor building.
B	Standby Gas Treatment System bypass fraction; fraction of primary containment leakage that goes directly to the environment (unfiltered).
B_{iy}	Parameter in the algorithm for $\sigma_{iy}(d)$
B_{iz}	Parameter in the algorithm for $\sigma_{iz}(d)$
B_R	Awake, adult breathing rate, m^3/sec.
b_j	Branching ratio from parent nuclide (I-135) to daughter nuclide j; $j=15$ for Xe-135m and $j=16$ for Xe-135.
C_{iz}	Parameter in the algorithm for $\sigma_{iz}(d)$
$C_j(t)$	Time dependent airborne activity, ci, in the secondary containment (Reactor Building). $C_j(o) \equiv 0.0$ ci. $C_j(t)$ is a meaningful quantity only if M does not equal its equivalent of zero, i.e., 1.0×10^{-10}.
$C_p(t)$	Same as $C_j(t)$ but for a parent nuclide (I-135).
D_{cj}	Thyroid inhalation dose conversion factor, Rem/(inhaled ci), for iodine nuclide j, $1 \leq j \leq 5$.
$D_{c\,I\text{-}131}$	Same as D_{cj} but for I-131, $j=1$.
D_{kr}	Whole body dose, rem, for PAG (Reference 1) lower dose limit k. (See definition of k).

$D_{k\,Thyroid}$ Thyroid inhalation dose, rem, for PAG (Reference 1) lower dose limit k. (See definition of k).

${}_{D}D_{id\gamma}(t_A, t_B)$ Drywell monitor projected downwind whole body dose, Rem, at distance d for Pasquill class i for the time period t_A to t_B. This quantity is also dependent on windspeed $\bar{u}$.

${}_{D}D_{id\,Thyroid}(t_A, t_B)$ Drywell monitor projected downwind thyroid inhalation dose, Rem, at distance d for Pasquill class i for the time period t_A to t_B. This quantity is also dependent on windspeed $\bar{u}$.

${}_{S}D_{id\gamma}(t_A, t_B)$ Same as ${}_{D}D_{id\gamma}(t_A, t_B)$ except SGTS monitor projected.

${}_{S}D_{id\,Thyroid}(t_A, t_B)$ Same as ${}_{D}D_{id\,Thyroid}(t_A, t_B)$ except SGTS monitor projected.

${}_{D}\dot{D}_{id\gamma}(T_{Max\,Xe\text{-}133})$ Drywell monitor projected downwind maximum whole body dose rate, Rem/hr, at distance d for Pasquill class i. This quantity is also dependent on windspeed $\bar{u}$.

${}_{D}\dot{D}_{id\,Thyroid}(T_{Max\,I\text{-}131})$ Drywell monitor projected downwind maximum thyroid inhalation dose rate, Rem/hr, at distance d for Pasquill class i. This quantity is also dependent on windspeed $\bar{u}$.

${}_{S}\dot{D}_{id\gamma}(T_{Max\,Xe\text{-}133})$ Same as ${}_{D}\dot{D}_{id\gamma}(T_{Max\,Xe\text{-}133})$ except SGTS monitor projected.

${}_{S}\dot{D}_{id\,Thyroid}(T_{Max\,I\text{-}131})$ Same as ${}_{D}\dot{D}_{id\,Thyroid}(T_{Max\,I\text{-}131})$ except SGTS monitor projected.

$\dot{D}_{\ell}$ A NUREG-0654 (Ref. 2) dose rate, Rem/hr, limit at the site boundary for emergency classification ℓ (see definition of ℓ).

$\dot{D}_{\ell\gamma}$ The NUREG-0654 (Ref. 2) whole body dose rate, Rem/hr, limit at the site boundary for emergency classification ℓ. (See definition of ℓ).

$\dot{D}_{\ell Thyroid}$	Same as $\dot{D}_{\ell\gamma}$ except for thyroid inhalation dose rate.
d	Downwind distance, m, between activity release point and dose point.
${}_{D}d_{k\gamma}$	Maximum distance, m, to which the PAG (Ref. 1) whole body dose emergency condition k extends (See definition of k) as projected by the drywell monitor. This quantity is also dependent on windspeed $\bar{u}$.
${}_{D}d_{k Thyroid}$	Maximum distance, m, to which the PAG (Ref. 1) thyroid inhalation dose emergency condition k extends (See definition of k) as projected by the drywell monitor. This quantity is also dependent on windspeed $\bar{u}$.
${}_{S}d_{k\gamma}$	Same as ${}_{D}d_{k\gamma}$ except as projected by the SGTS monitor.
${}_{S}d_{k Thyroid}$	Same as ${}_{D}d_{k Thyroid}$ except as projected by the SGTS monitor.
${}_{D}d_{\ell\gamma}$	Distance, m, at which NUREG-0654 (Ref. 2) whole body dose rate limit for emergency classification ℓ (see definition of ℓ) occurs as projected by the drywell monitor. This quantity is also dependent on windspeed $\bar{u}$.
${}_{D}d_{\ell Thyroid}$	Distance, m, at which NUREG-0654 (Ref. 2) thyroid inhalation dose rate limit for emergency classification ℓ (see definition of ℓ) occurs as projected by the drywell monitor. This quantity is also dependent on windspeed $\bar{u}$.
${}_{S}d_{\ell\gamma}$	Same as ${}_{D}d_{\ell\gamma}$ except as projected by the SGTS monitor.
${}_{S}d_{\ell Thyroid}$	Same as ${}_{D}d_{\ell Thyroid}$ except as projected by the SGTS monitor.
E	SGTS exhaust rate, hr^{-1}. This is defined as the SGTS actual exhaust rate, cfm, times 60 $\frac{min.}{hr}$ divided by the entire volume, ft^3, being exhausted without regard to mixing fraction.

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$\overline{E}_{\gamma j}$	Average energy, Mev, per disintegration for nuclide j; see, also, the definition of j.
$\overline{E}_{\gamma Xe-133}$	Same as $\overline{E}_{\gamma j}$ but for j corresponding to Xe-133.
ε_j	Fractional efficiency of SGTS filter for nuclide j. $1 \leq j \leq 5$ are iodine nuclides. For $j > 5$, $\varepsilon_j \equiv 0.0$.
F_{id}	The building wake correction factor as defined by Eqn. A62 for a point at a distance d downwind and for Pasquill class i.
F_ℓ	The fraction of the design basis accident activity release that is actually released to the primary containment and that will result in the NUREG-0654 (Ref. 2) dose rate limit at the site boundary for emergency classification ℓ (see definition of ℓ).
f_j	Fraction of nuclide j that contributes to a monitor reading for the purpose of projecting downwind whole body dose and dose rate. $1 \leq j \leq 5$ are iodine nuclides. For $j > 5$, $f_j \equiv 1.0$.
H_j	Ratio of a semi-infinite gamma cloud dose rate to that for a finite cloud for nuclide j. See Section A.4 for theory.
i	Pasquill Stability Class index for atmospheric dispersion (Ref. 4).

Index i	Class
1	A (least stable)
2	B
3	C
4	D
5	E
6	F
7	G (most stable)

j Nuclide index

index j	nuclide	index j	nuclide
1	I-131	10	Kr-88
2	I-132	11	Kr-89
3	I-133	12	Xe-131m
4	I-134	13	Xe-133m
5	I-135	14	Xe-133
6	Kr-83m	15	Xe-135m
7	Kr-85m	16	Xe-135
8	Kr-85	17	Xe-137
9	Kr-87	18	Xe-138

K Dose conversion factor for semi-infinite cloud whole body immersion dose rate (Ref. 3); $K = 0.253$ Rem·m^3/(ci·Mev·sec).

K' Same as K except for air dose rate; $K' = K/1.11$ (Ref. 7).

K_c Defined in Eqn. A61; $K_c = A_R/(2\pi)$; see definition of A_R .

K_1 Constant of proportionality between activity release rate and dose rate.

k An index denoting the PAG (Ref. 1) emergency condition dose limit.

$k = 1$, Red emergency; whole body and thyroid dose limits are 5.0 and 25.0 Rem respectively.

$k = 2$, Yellow emergency; whole body and thyroid dose limits are 1.0 and 5.0 Rem respectively.

$k = 3$, White emergency; whole body and thyroid dose limits are 0.05 and 0.3 Rem respectively.

L Primary containment leak rate, hr^{-1}.

ℓ — An index denoting the NUREG-0654 (Ref. 2) dose rate limit for the emergency classifications in Table A5: thus,

- ℓ = 1 for General Emergency
- ℓ = 2 for Site Emergency with duration 2 minutes.
- ℓ = 3 for Site Emergency with duration ½ hour.

M — That fraction of the secondary containment volume in which the primary containment leaked activity is instantaneously and completely mixed before being exhausted by the SGTS. M cannot be zero. The flag $M = 1.0 \times 10^{-10}$ effects no mixing; i.e., direct leakage from the primary containment through the SGTS.

P — Primary containment purge rate, hr^{-1}. A purge is assumed to be filtered by a filter whose iodine efficiency is the same as that for the SGTS filter.

p — A subscript which denotes a parent nuclide.

$Q_{eff\,Xe\text{-}133}(t_A, t_B)$ — Effective Xe-133 activity, ci, (as defined by Eqn. A11) released to the environment during the time period t_A to t_B for a design basis accident; note that this quantity is not the actual effective Xe-133 activity released because it has not been normalized by the monitor readings. Note, also, that this quantity contains the gamma energy importance of all nuclides including iodines.

$Q_{eff\,I\text{-}131}(t_A, t_B)$ — Effective I-131 activity, ci, (as defined by Eqn. A12) released to the environment during the time period t_A to t_B for a design basis accident; note that this quantity is not the actual effective I-131 activity released because it has not been normalized by the monitor readings. Note, also, that this quantity contains the thyroid inhalation dose conversion importance of all the iodines.

$Q_j(t_A, t_B)$ — The activity, ci, for nuclide j released to the environment during the time period t_A to t_B for a design basis accident; note that this quantity is not the actual activity released because it has not been normalized by the monitor readings.

$Q_{T\,Nobles}(t_A, t_B)$ — The total noble gas activity, ci, (as defined by Eqn. A9) released to the environment during the time period t_A to t_B for a design basis accident; note that this quantity is not the actual total noble gas activity released because it has not been normalized by the monitor readings.

$Q_{T\,Iodines}(t_A, t_B)$ — The total Iodine activity, ci, (as defined by Eqn. A10) released to the environment during the time period t_A to t_B for a design basis accident; note that this quantity is not the actual total iodine activity released because it has not been normalized by the monitor readings.

${}_{AD}Q_{eff\,Xe\text{-}133}(t_A, t_B)$ — Same as $Q_{eff\,Xe\text{-}133}(t_A, t_B)$ except this quantity has been normalized by the drywell monitor and is the projected actual effective Xe-133 activity released to the environment.

${}_{AD}Q_{eff\,I\text{-}131}(t_A, t_B)$ — Same as $Q_{eff\,I\text{-}131}(t_A, t_B)$ except this quantity has been normalized by the drywell monitor and is the projected actual effective I-131 activity released to the environment.

${}_{AD}Q_{T\,Nobles}(t_A, t_B)$ — Same as $Q_{T\,Nobles}(t_A, t_B)$ except this quantity has been normalized by the drywell monitor and is the projected total noble gas activity released to the environment.

$_{AD}Q_{T\,Iodines}(t_A, t_B)$ Same as $Q_{T\,Iodines}(t_A, t_B)$ except this quantity has been normalized by the drywell monitor and is the projected total iodine activity released to the environment.

$_{AS}Q_{eff\,Xe\text{-}133}(t_A, t_B)$ Same as $_{AD}Q_{eff\,Xe\text{-}133}(t_A, t_B)$ but normalized by the SGTS monitor.

$_{AS}Q_{eff\,I\text{-}131}(t_A, t_B)$ Same as $_{AD}Q_{eff\,I\text{-}131}(t_A, t_B)$ but normalized by the SGTS monitor.

$_{AS}Q_{T\,Nobles}(t_A, t_B)$ Same as $_{AD}Q_{T\,Nobles}(t_A, t_B)$ but normalized by the SGTS monitor.

$_{AS}Q_{T\,Iodines}(t_A, t_B)$ Same as $_{AD}Q_{T\,Iodines}(t_A, t_B)$ but normalized by the SGTS monitor.

$\dot{Q}_j(t)$ Nuclide j activity release rate, ci/hr, to the environment at time t for a design basis accident; note that this quantity is not the actual activity release rate because it has not been normalized by the monitor readings.

$\dot{Q}_{eff\,\ell}(t)$ The actual effective Xe-133 or I-131 activity release rate, ci/hr, to the environment at time t to obtain the NUREG-0654 (Ref. 2) dose rate limit at the site boundary for emergency classification ℓ ; see definition of ℓ .

$\dot{Q}_{eff\,Xe\text{-}133}(t)$ Effective Xe-133 activity release rate, ci/hr, (as defined by Eqn. A23) to the environment at time t for a design basis accident; note that this quantity is not the actual effective Xe-133 activity release rate because it has not been normalized by the monitor readings. Note, also, that this quantity contains the gamma energy importance of all nuclides including iodines.

$\dot{Q}_{eff\,I\text{-}131}(t)$ — Effective I-131 activity release rate, ci/hr, (as defined by Eqn. A24) to the environment at time t for a design basis accident; note that this quantity is not the actual effective I-131 activity release rate because it has not been normalized by the monitor readings. Note, also, that this quantity contains the thyroid inhalation dose conversion importance of all the iodines.

$\dot{Q}_{eff}(t)$ — Same as $\dot{Q}_{eff\,Xe\text{-}133}(t)$ or $\dot{Q}_{eff\,I\text{-}131}(t)$.

${}_{AD}\dot{Q}_{eff\,Xe\text{-}133}(t)$ — Same as $\dot{Q}_{eff\,Xe\text{-}133}(t)$ except this quantity has been normalized by the drywell monitor and is the projected actual effective Xe-133 activity release rate to the environment.

${}_{AD}\dot{Q}_{eff\,I\text{-}131}(t)$ — Same as $\dot{Q}_{eff\,I\text{-}131}(t)$ except this quantity has been normalized by the drywell monitor and is the projected actual effective I-131 activity release rate to the environment.

${}_{AS}\dot{Q}_{eff\,Xe\text{-}133}(t)$ — Same as ${}_{AD}\dot{Q}_{eff\,Xe\text{-}133}(t)$ but normalized by the SGTS monitor.

${}_{AS}\dot{Q}_{eff\,I\text{-}131}(t)$ — Same as ${}_{AS}\dot{Q}_{eff\,I\text{-}131}(t)$ but normalized by the SGTS monitor.

${}_{AS}\hat{\dot{Q}}_{eff\,Xe\text{-}133}(T_A, T_B)$ — Same as ${}_{AS}\dot{Q}_{eff\,Xe\text{-}133}(t)$ except this is an average value over the time interval T_A to T_B.

${}_{AS}\hat{\dot{Q}}_{eff\,I\text{-}131}(T_A, T_B)$ — Same as ${}_{AS}\dot{Q}_{eff\,I\text{-}131}(t)$ except this is an average value over the time interval T_A to T_B.

$\ddot{Q}_{eff\,Xe\text{-}133}(t)$ — Time derivative of $\dot{Q}_{eff\,Xe\text{-}133}(t)$.

$\ddot{Q}_{eff\,I\text{-}131}(t)$ — Time derivative of $\dot{Q}_{eff\,I\text{-}131}(t)$.

$\ddot{Q}_j(t)$ — Time derivative of $\dot{Q}_j(t)$.

$R_{AD}(t)$ — Actual time dependent drywell monitor reading, Rad/hr.

$R_{CD}(t)$ — Calculated time dependent drywell monitor reading, Rad/hr, for the design basis accident.

$R_{AS}(t)$ — Actual time dependent SGTS monitor reading, μci/cc.

$R_{cs}(t)$	Calculated time dependent SGTS monitor reading, μci/cc, for the design basis accident.
R_c	Calculated monitor reading for the design basis accident at the time of the maximum release rate (either the drywell or the SGTS monitor).
R_ℓ	The monitor reading (either drywell or SGTS) which would result in the NUREG-0654 (Ref. 2) dose rate limit at the site boundary for emergency classification ℓ; see definition of ℓ.
T_A	The lower time, hr, limit of the time period T_A to T_B .
T_B	The upper time, hr, limit of the time period T_A to T_B .
$T_{Max\ Xe-133}$	The time, hr, of the maximum release rate for effective Xe-133 activity; thus, the time of the maximum whole body dose rate downwind.
$T_{Max\ I-131}$	The time, hr, of the maximum release rate for effective I-131 activity; thus, the time of the maximum thyroid inhalation dose rate downwind.
t	Time, hr, after the accident.
t_A	The lower time, hr, of the time period t_A to t_B .
t_B	The upper time, hr, of the time period t_A to t_B .
t_1	The lower time, hr, of the time period t_1 to t_2 .
t_2	The upper time, hr, of the time period t_1 to t_2 .
$\overline{u}$	The average wind speed, m/sec, over a time period for a given direction at ground level.
V_{PC}	The volume, ft^3, of the primary containment, both wetwell and drywell.
V	The volume, ft^3, of the secondary containment - reactor building - serviced by the SGTS.
α	A collection of constants defined by Eqn. A41.
β	A collection of constants defined by Eqn. A42.

γ	A collection of constants defined by Eqn. A43.
δ	A collection of constants defined by Eqn. A47
λ_j	Radiodecay constant, hr^{-1}, for nuclide j.
λ_p	Radiodecay constant, hr^{-1}, for a parent nuclide.
μ	A collection of constants defined by Eqn. A45.
ν	A collection of constants defined by Eqn. A46.
ν_{2j}, ν_{1j}, ν_{3j}	Collections of constants defined in Section A.3.4 preceding Eqn. A23.
ξ_p	The ratio of the fraction of the core inventory of the parent nuclide contributing to the airborne daughter in the primary containment to the fraction of the core inventory of the parent nuclide that is airborne in the primary containment.
$\sigma_{iy}(d)$	The lateral (crosswind) standard deviation, m, of a Gaussian plume a distance d downwind from the release point for Pasquill class i.
$\sigma_{iz}(d)$	The vertical standard deviation, m, of a Gaussian plume a distance d downwind from the release point for Pasquill class i.
$(\chi/Q')_{id}$	The atmospheric relative concentration, sec/m^3, for Pasquill class i at a distance d downwind from the release point. It is the ratio of the activity concentration, ci/m^3, at the downwind location to the activity release rate, ci/sec, at the release point. As used in this report, the value is on the centerline of a ground released Gaussian plume with a possible building wake correction.

A.3 Development of Equations

A.3.1 Activities and Activity Releases Based on Design Basis Assumptions

The differential equations describing the time dependent activities in the primary and secondary containments without parent contributions are:

$$\dot{A}_j(t) = -(\lambda_j + L + P)\,A_j(t) \qquad \text{Eqn. A1}$$

$$\dot{C}_j(t) = -(\lambda_j + \tfrac{E}{M})\,C_j(t) + (1-B)\,L\,A_j(t) \qquad \text{Eqn. A2}$$

The quantity $\frac{E}{M}$ is the effective SGTS exhaust rate. A value of M equal to zero is not allowed in the above differential equations. Such a value would imply direct leakage from the primary containment through the SGTS; thus, $C_j(t)$ would be identically zero. However, the use of a very small value for M, e.g. 1.0×10^{-10}, gives the same results as direct leakage. The above differential equations can then be used for both no mixing and mixing.

The solutions to the above differential equations are:

$$A_j(t) = A_j(t_A)\,e^{-(\lambda_j + L + P)(t - t_A)} \qquad \text{Eqn. A3}$$

$$C_j(t) = \left[C_j(t_A) - \frac{(1-B)\,L\,A_j(t_A)}{(\frac{E}{M} - L - P)}\right] e^{-(\lambda_j + \frac{E}{M})(t - t_A)} + \frac{(1-B)\,L\,A_j(t_A)}{(\frac{E}{M} - L - P)}\,e^{-(\lambda_j + L + P)(t - t_A)} \qquad \text{Eqn. A4}$$

The initial conditions are, when $t_A = 0.0$, $A_j(0)$ is the initial airborne activity in the primary containment and $C_j(0) = 0.0$.

The release rate to the environment for nuclide j is then

$$\dot{Q}_j(t) = \left[BL + (1-\varepsilon_j)P\right] A_j(t) + (1-\varepsilon_j)\frac{E}{M}\,C_j(t) \qquad \text{Eqn. A5}$$

Substituting Eqns. A3 and A4 into Eqn. A5,

$$\dot{Q}_j(t) = \left[BL + (1-\mathcal{E}_j)P + \frac{(1-\mathcal{E}_j)(1-B)L\frac{E}{M}}{(\frac{E}{M} - L - P)}\right] A_j(t_A)\, e^{-(\lambda_j + L + P)(t - t_A)}$$

$$+ \left[C_j(t_A) - \frac{(1-B)L A_j(t_A)}{(\frac{E}{M} - L - P)}\right](1-\mathcal{E}_j)\frac{E}{M}\, e^{-(\lambda_j + \frac{E}{M})(t - t_A)}$$

Eqn. A6

The total release to the environment during the time period t_A to t_B is then

$$Q_j(t_A, t_B) = \int_{t_A}^{t_B} \dot{Q}_j(t)\, dt$$

Eqn. A7

$$Q_j(t_A, t_B) = \left[BL + (1-\mathcal{E}_j)P + \frac{(1-\mathcal{E}_j)(1-B)L\frac{E}{M}}{(\frac{E}{M} - L - P)}\right] \frac{A_j(t_A)}{(\lambda_j + L + P)}\left[1 - e^{-(\lambda_j + L + P)(t_B - t_A)}\right]$$

$$+ \left[C_j(t_A) - \frac{(1-B)L A_j(t_A)}{(\frac{E}{M} - L - P)}\right]\frac{(1-\mathcal{E}_j)\frac{E}{M}}{(\lambda_j + \frac{E}{M})}\left[1 - e^{-(\lambda_j + \frac{E}{M})(t_B - t_A)}\right]$$

Eqn. A8

The total and the effective activities released to the environment for the time period are

$$Q_{T\,Nobles}(t_A, t_B) = \sum_{j=6}^{18} Q_j(t_A, t_B)$$

with exclusions*

Eqn. A9

$$Q_{T\,Iodines}(t_A, t_B) = \sum_{j=1}^{5} Q_j(t_A, t_B)$$

Eqn. A10

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*The sum over all noble gas nuclides must exclude Kr-83m, Kr-89, Xe-131m, Xe-137, and Xe-138 for subsequent use in the methods of Appendix D in Reference 1.

$$Q_{eff\,Xe-133}(t_A,t_B) = \sum_{j=1}^{18} \frac{\bar{E}_{\gamma j}}{\bar{E}_{\gamma Xe-133}} Q_j(t_A,t_B)$$ Eqn. A11

(includes all nuclides, even iodines)

$$Q_{eff\,I-131}(t_A,t_B) = \sum_{j=1}^{5} \frac{D_{cj}}{D_{c\,I-131}} Q_j(t_A,t_B)$$ Eqn. A12

Note that the above total and effective activities released are not the actual activities released. They are the result of a design basis accident and have not been modified by actual monitor readings.

$$Q_{eff\,Xe\text{-}133}(t_A, t_B) = \sum_{j=1}^{18} \frac{\bar{E}_{\gamma j}}{\bar{E}_{\gamma\,Xe\text{-}133}} Q_j(t_A, t_B)$$ Eqn. A11

(includes all nuclides, even iodines)

$$Q_{eff\,I\text{-}131}(t_A, t_B) = \sum_{j=1}^{5} \frac{D_{tj}}{D_{t\,I\text{-}131}} Q_j(t_A, t_B)$$ Eqn. A12

Note that the above total and effective activities released are not the actual activities released. They are the result of a design basis accident and have not been modified by actual monitor readings.

A.3.2 Calculated Monitor Readings

A.3.2.1 Calculated Drywell Monitor Readings

The drywell monitor is assumed to be unshielded and to read the air dose rate due to a finite cloud of gamma emitting nuclides. The finite cloud is approximated by a cylindrical annulus. Cloud geometry, monitor location, and calculated ratio, H_j , of semi-infinite to finite gamma cloud dose rates for each nuclide as well as the theory for the ratios are given in Section A.4. The calculation of these ratios is not a part of the Accident Radiological Dose Assessment Program.

The drywell monitor response is assumed to be independent of energy. However, a response function can be incorporated in the H_j's if needed.

The calculated drywell monitor reading as a function of time is for the design basis accident

$$R_{CD}(t) = \frac{K' \; 3600 \left(\frac{sec}{hr}\right)}{V_{PC} \left(0.3048 \; \frac{m}{ft}\right)^3} \sum_{j=1}^{18} \left[f_j \bar{E}_{\gamma j} A_j(t) / H_j \right]$$

where $A_j(t)$ is obtained from Eqn. A3.

Thus

$$R_{CD}(t) = \frac{2.8986 \times 10^4}{V_{PC}} \sum_{j=1}^{18} \left[\frac{f_j \bar{E}_{\gamma j}}{H_j} A_j(t_A) e^{-(\lambda_j + L + P)(t - t_A)} \right] \qquad \text{Eqn. A13}$$

A.3.2.2 Calculated SGTS Monitor Readings

The SGTS monitor is assumed to measure the effective Xe-133 activity concentration in the SGTS effluent at a point after the iodine filter. The effective Xe-133 activity concentration is the sum of all nuclide activity concentrations each weighted by the ratio of their gamma energy emitted per disintegration to that for Xe-133.

The calculated SGTS monitor reading as a function of time is for the design basis accident

$$R_{cs}(t) = \frac{1}{(0.3048\,\frac{m}{ft})^3 M V_{sc}} \sum_{j=1}^{18} \frac{f_j \overline{E}_{\gamma j}\, C_j(t)}{\overline{E}_{\gamma Xe-133}}$$

where $C_j(t)$ is obtained from Eqn. A4.

Thus

$$R_{cs}(t) = \frac{35.3147}{M V_{sc}} \sum_{j=1}^{18} \frac{f_j \overline{E}_{\gamma j}}{\overline{E}_{\gamma Xe-133}} \left\{ \left[C_j(t_A) - \frac{(1-B) L A_j(t_A)}{(\frac{E}{M} - L - P)} \right] e^{-(\lambda_j + \frac{E}{M})(t - t_A)} + \frac{(1-B) L A_j(t_A)}{(\frac{E}{M} - L - P)} e^{-(\lambda_j + L + P)(t - t_A)} \right\}$$

Eqn. A14

A.3.3 Activity Releases Normalized to Actual Monitor Readings

The ratio of an actual monitor reading $R_{AD}(t)$ or $R_{AS}(t)$ to the calculated monitor reading for the design basis accident is assumed to be a measure of the ratio of the actual activity released (or the actual activity release rate) to the calculated activity released (or the calculated activity release rate) based on the design basis accident. This is a good assumption if the accident is according to the design basis and departs from design basis only in the percentage of core inventory activities that are released to the primary containment. However, if $\frac{E}{M}$ is large the assumption is also good for other values of L that are not too large.

Using this assumption with the drywell monitor read and calculated at the same time t, (see also Eqns. A9 through A12), the actual activity releases are

$${}_{AD}Q_{T\,Nobles}(t_A, t_B) = \frac{R_{AD}(t)}{R_{CD}(t)} Q_{T\,Nobles}(t_A, t_B) \qquad \text{Eqn. A15}$$

$${}_{AD}Q_{T\,Iodines}(t_A, t_B) = \frac{R_{AD}(t)}{R_{CD}(t)} Q_{T\,Iodines}(t_A, t_B) \qquad \text{Eqn. A16}$$

$${}_{AD}Q_{eff\,Xe\text{-}133}(t_A, t_B) = \frac{R_{AD}(t)}{R_{CD}(t)} Q_{eff\,Xe\text{-}133}(t_A, t_B) \qquad \text{Eqn. A17}$$

$${}_{AD}Q_{eff\,I\text{-}131}(t_A, t_B) = \frac{R_{AD}(t)}{R_{CD}(t)} Q_{eff\,I\text{-}131}(t_A, t_B) \qquad \text{Eqn. A18}$$

Similarly for the SGTS monitor,

$${}_{AS}Q_{T\,Nobles}(t_A, t_B) = \frac{R_{AS}(t)}{R_{CS}(t)} Q_{T\,Nobles}(t_A, t_B) \qquad \text{Eqn. A19}$$

$${}_{AS}Q_{T\,Iodine}(t_A, t_B) = \frac{R_{AS}(t)}{R_{CS}(t)} Q_{T\,Iodines}(t_A, t_B) \qquad \text{Eqn. A20}$$

$${}_{AS}Q_{eff\,Xe\text{-}133}(t_A,t_B) = \frac{R_{AS}(t)}{R_{CS}(t)}\,Q_{eff\,Xe\text{-}133}(t_A,t_B)$$ Eqn. A21

$${}_{AS}Q_{eff\,I\text{-}131}(t_A,t_B) = \frac{R_{AS}(t)}{R_{CS}(t)}\,Q_{eff\,I\text{-}131}(t_A,t_B)$$ Eqn. A22

A.3.4 Time of Maximum Effective Activity Release Rate

This section presents equations for the time of maximum effective activity release rate (for a design basis accident) on a specific time interval. This section does not apply if the value of M is 1.0×10^{-10} ($M = 1.0 \times 10^{-10}$ is a flag for the desired value of M equal to zero).

If M does not equal zero, the effective activity release rate should increase with time until the activity buildup in the secondary containment reaches a level at which the removal through the SGTS equals the addition through the primary containment leakage. After this point the effective activity release rate should decrease because of radiodecay. If the specific time interval includes the time of maximum effective activity release rate, then this section presents equations for the time at which that release rate occurs. If that time interval does not include the time of maximum effective activity release then, for that time interval, the time of maximum effective activity release is that interval end point time which has the larger effective activity release rate.

Substituting

$$\nu_{2j} = \frac{(1-B)(1-\epsilon_j)L\frac{E}{M}}{\left(\frac{E}{M} - L - P\right)}$$

$$\nu_{1j} = \nu_{2j} + (1-\epsilon_j)P + BL$$

$$\nu_{3j} = (1-\epsilon_j)\frac{E}{M}$$

and $t_1 = t_A$

into Eqn. A6, employing the definitions of effective activity, and summing over appropriate nuclides, the effective activity release rates are

$$\dot{Q}_{eff\,Xe\text{-}133}(t) = \sum_{j=1}^{18} \frac{\bar{E}_{\gamma j}}{\bar{E}_{\gamma Xe\text{-}133}} \left\{ \nu_{1j} A_j(t_1)\, e^{-(\lambda_j + L + P)(t - t_1)} - \left[\nu_{2j} A_j(t_1) - \nu_{3j} C_j(t_1)\right] e^{-(\lambda_j + \frac{E}{M})(t - t_1)} \right\} \quad \text{Eqn. A23}$$

$$\dot{Q}_{eff\ I-131}(t) = \sum_{j=1}^{5} \frac{D_{cj}}{D_{c\ I-131}} \Big\{ \nu_{1j} A_j(t_1) e^{-(\lambda_j+L+P)(t-t_1)} - \left[\nu_{2j} A_j(t_1) - \nu_{3j} C_j(t_1)\right] e^{-(\lambda_j+\frac{E}{m})(t-t_1)} \Big\} \quad \text{Eqn. A24}$$

To find the time of maximum $\dot{Q}_{eff\ Xe-133}(t)$ and $\dot{Q}_{eff\ I-131}(t)$, the derivatives of Eqns. A23 and A24 must be set equal to zero and the result solved for the time. The derivatives of Eqns. A23 and A24 are

$$\ddot{Q}_{eff\ Xe-133}(t) = \sum_{j=1}^{18} \frac{\bar{E}_{\gamma j}}{\bar{E}_{\gamma Xe-133}} \Big\{ -(\lambda_j+L+P)\nu_{1j} A_j(t_1) e^{-(\lambda_j+L+P)(t-t_1)} + (\lambda_j+\frac{E}{m})\left[\nu_{2j} A_j(t_1) - \nu_{3j} C_j(t_1)\right] e^{-(\lambda_j+\frac{E}{m})(t-t_1)} \Big\} \quad \text{Eqn. A25}$$

$$\ddot{Q}_{eff\ I-131}(t) = \sum_{j=1}^{5} \frac{D_{cj}}{D_{c\ I-131}} \Big\{ -(\lambda_j+L+P)\nu_{1j} A_j(t_1) e^{-(\lambda_j+L+P)(t-t_1)} + (\lambda_j+\frac{E}{m})\left[\nu_{2j} A_j(t_1) - \nu_{3j} C_j(t_1)\right] e^{-(\lambda_j+\frac{E}{m})(t-t_1)} \Big\} \quad \text{Eqn. A26}$$

The desired times of maximum effective activity release rates $T_{max\ Xe-133}$ and $T_{max\ I-131}$ on the interval t_1 to t_2 are then given by

$$\ddot{Q}_{eff\ Xe-133}(T_{max\ Xe-133}) = 0.0 \quad \text{Eqn. A27}$$

$$\ddot{Q}_{eff\ I-131}(T_{max\ I-131}) = 0.0 \quad \text{Eqn. A28}$$

with the conditions $\ddot{Q}_{eff\ Xe-133}(t_1)$ and $\ddot{Q}_{eff\ I-131}(t_1)$ must be positive; if they are negative then the time of maximum effective activity release rate is t_1.

Thus if

$$\ddot{Q}_{eff\,Xe\text{-}133}(t_1) \leq 0.0 \quad \text{then} \quad T_{max\,Xe\text{-}133} = t_1$$ Eqn. A29

or if

$$\ddot{Q}_{eff\,I\text{-}131}(t_1) \leq 0.0 \quad \text{then} \quad T_{max\,I\text{-}131} = t_1$$ Eqn. A30

Eqns. A27 and A28 may be solved for $T_{max\,Xe\text{-}133}$ and $T_{max\,I\text{-}131}$ respectively by a method of interpolation (regula falsi). The first guess should be t_1 and Eqns. A29 and A30 tested. The second guess may be any value between t_1 and t_2. If the solution to either Eqns. A27 or A28 exceed t_2 then the solution is set equal to t_2.

In the following steps describing the method of interpolation, the subscripts Xe-133 and I-131 have been dropped because the method applies either quantities denoted by those subscripts.

Step 1: Let first guess for the maximum time be T_1 and calculate $\ddot{Q}_{eff}(T_1)$ using either Eqn. A25 or Eqn. A26 whichever is appropriate.

Step 2: Let the second guess for the maximum time be T_2.

Step 3: Increment the loop counter.

Step 4: Calculate $\ddot{Q}_{eff}(T_2)$ using either Eqn. A25 or Eqn. A26 whichever is appropriate.

Step 5: Calculate new maximum time T by linear interpolation; thus, $T = T_1 - (T_2 - T_1)\ddot{Q}_{eff}(T_1)/[\ddot{Q}_{eff}(T_2) - \ddot{Q}_{eff}(T_1)]$

Step 6: If $|T_2 - T_1|/T < 0.0001$ then $T_{max} = T$; finished

Step 7: If loop counter exceeds 30 then finished.

Step 8: If $|\ddot{Q}_{eff}(T_1)| > |\ddot{Q}_{eff}(T_2)|$ then go to Step 10.

Step 9: Set $T_2 = T$ and go to Step 3.

Step 10: Set $\ddot{Q}_{eff}(T_1) = \ddot{Q}_{eff}(T_2)$; set $T_1 = T_2$; set $T_2 = T$; then go to Step 3.

A.3.5 Effective Activity Release Rates Normalized to Actual Monitor Readings

With the assumptions of Section A.3.3, and Eqns. A23 and A24, the actual activity releases are for the drywell monitor

$$_{AD}\dot{Q}_{eff\,Xe\text{-}133}(t) = \frac{R_{AD}(t)}{R_{cD}(t)}\,\dot{Q}_{eff\,Xe\text{-}133}(t)$$ Eqn. A31

$$_{AD}\dot{Q}_{eff\,I\text{-}131}(t) = \frac{R_{AD}(t)}{R_{cD}(t)}\,\dot{Q}_{eff\,I\text{-}131}(t)$$ Eqn. A32

Similarly for the SGTS monitor,

$$_{AS}\dot{Q}_{eff\,Xe\text{-}133}(t) = \frac{R_{AS}(t)}{R_{cS}(t)}\,\dot{Q}_{eff\,Xe\text{-}133}(t)$$ Eqn. A33

$$_{AS}\dot{Q}_{eff\,I\text{-}131}(t) = \frac{R_{AS}(t)}{R_{cS}(t)}\,\dot{Q}_{eff\,I\text{-}131}(t)$$ Eqn. A34

A.3.6 Parent Contributions

Section A.3.1 developed equations excluding parent effects. For most of the required nuclides parent effects are negligible. Only the parent I-135 is of any consequence in its production of Xe-135. This section develops the equations which include the effects of one parent. Note that the subscript p denotes parent and the subscript j denotes daughter.

The differential equations describing the time dependent activities of the parent in the primary and secondary containments (without contributions from its parent) are the same as Eqns. A1 and A2 with subscript j replaced by subscript p. The solutions are then similar to Eqns. A3 and A4; thus

$$A_p(t) = A_p(t_A)\, e^{-(\lambda_p + L + P)(t - t_A)}$$ Eqn. A35

$$C_p(t) = \left[C_p(t_A) - \frac{(1-B)L\,A_p(t_A)}{\left(\frac{E}{M} - L - P\right)}\right] e^{-\left(\lambda_p + \frac{E}{M}\right)(t - t_A)} + \frac{(1-B)L\,A_p(t_A)}{\left(\frac{E}{M} - L - P\right)} e^{-(\lambda_p + L + P)(t - t_A)}$$ Eqn. A36

Let ζ_p be the ratio of the fraction of the core inventory of the parent contributing to the airborne daughter in the primary containment to the fraction of the core inventory of the parent that is airborne on the primary containment. Then the differential equations describing the time dependent daughter activities in the primary and secondary containments are

$$\dot{A}_j(t) = -(\lambda_j + L + P)A_j(t) + b_j \lambda_j \zeta_p A_p(t)$$ Eqn. A37

$$\dot{C}_j(t) = -\left(\lambda_j + \frac{E}{M}\right)C_j(t) + (1-B)L\,A_j(t) + b_j \lambda_j C_p(t)$$ Eqn. A38

Note that the absence of λ_p in Eqns. A37 and A38 is correct.

After substituting Eqns. A35 and A36 into Eqns. A37 and A38, the solutions are

$$A_j(t) = A_j(t_A)\, e^{-(\lambda_j + L + P)(t - t_A)} + \frac{b_j \lambda_j \xi_p A_p(t_A)}{(\lambda_j - \lambda_p)} \left[e^{-(\lambda_p + L + P)(t - t_A)} - e^{-(\lambda_j + L + P)(t - t_A)} \right] \quad \text{Eqn. A39}$$

$$C_j(t) = \left[C_j(t_A) + \alpha - \beta - \gamma \right] e^{-(\lambda_j + \frac{E}{M})(t - t_A)} + \left[\gamma - \alpha \right] e^{-(\lambda_p + \frac{E}{M})(t - t_A)} + \left[\beta - \alpha \right] e^{-(\lambda_j + L + P)(t - t_A)} + \alpha\, e^{-(\lambda_p + L + P)(t - t_A)} \quad \text{Eqn. A40}$$

where

$$\alpha = b_j (1 - B) \lambda_j L \xi_p A_p(t) \Big/ \left[\left(\frac{E}{M} - L - P\right)(\lambda_j - \lambda_p) \right] \quad \text{Eqn. A41}$$

$$\beta = (1 - B) L A_j(t_A) \Big/ \left(\frac{E}{M} - L - P\right) \quad \text{Eqn. A42}$$

$$\gamma = b_j \lambda_j C_p(t_A) \Big/ (\lambda_j - \lambda_p) \quad \text{Eqn. A43}$$

The initial conditions are, when $t_A = 0.0$, $A_j(0)$ is the initial airborne daughter activity in the primary containment, $A_p(0)$ is the initial airborne parent activity in the primary containment, and both $C_j(0)$ and $C_p(0)$ are zero.

The release rate to the environment for the daughter nuclide is then

$$\dot{Q}_j(t) = \left[(1 - \varepsilon_j) P + BL \right] A_j(t) + (1 - \varepsilon_j) \frac{E}{M} C_j(t) \quad \text{Eqn. A44}$$

Let $\mu = \left[(1 - \varepsilon_j) P + BL \right]$ Eqn. A45

$\nu = (1 - \varepsilon_j) \frac{E}{M}$ Eqn. A46

and $\delta = b_j \lambda_j \xi_p A_p(t_A) / (\lambda_j - \lambda_p)$ Eqn. A47

Substituting Eqns. A39, A40, A45, A46, and A47 into Eqn. A44,

$$\dot{Q}_j(t) = \mu \left\{ A_j(t_A) e^{-(\lambda_j+L+P)(t-t_A)} - \delta e^{-(\lambda_j+L+P)(t-t_A)} + \delta e^{-(\lambda_p+L+P)(t-t_A)} \right\}$$
$$+ \nu \left\{ \left[C_j(t_A) + \alpha - \beta - \gamma \right] e^{-(\lambda_j + \frac{E}{m})(t-t_A)} + \left[\gamma - \alpha \right] e^{-(\lambda_p + \frac{E}{m})(t-t_A)} + \left[\beta - \alpha \right] e^{-(\lambda_j+L+P)(t-t_A)} + \alpha e^{-(\lambda_p+L+P)(t-t_A)} \right\}$$ Eqn. A48

The total release to the environment during the time period t_A to t_B is

$$Q_j(t_A, t_B) = \int_{t_A}^{t_B} \dot{Q}_j(t)\, dt$$ Eqn. A49

$$Q_j(t_A,t_B) = \mu \left\{ \left[A_j(t_A) - \delta \right] \left[1 - e^{-(\lambda_j+L+P)(t-t_A)} \right] \Big/ \left[\lambda_j + L + P \right] + \delta \left[1 - e^{-(\lambda_p+L+P)(t-t_A)} \right] \Big/ \left[\lambda_p + L + P \right] \right\}$$
$$+ \nu \left\{ \left[C_j(t_A) + \alpha - \beta - \gamma \right] \left[1 - e^{-(\lambda_j + \frac{E}{m})(t-t_A)} \right] \Big/ \left[\lambda_j + \frac{E}{m} \right] \right.$$
$$+ \left[\gamma - \alpha \right] \left[1 - e^{-(\lambda_p + \frac{E}{m})(t-t_A)} \right] \Big/ \left[\lambda_p + \frac{E}{m} \right] + \left[\beta - \alpha \right] \left[1 - e^{-(\lambda_j+L+P)(t-t_A)} \right] \Big/ \left[\lambda_j + L + P \right]$$
$$\left. + \alpha \left[1 - e^{-(\lambda_p+L+P)(t-t_A)} \right] \Big/ \left[\lambda_p + L + P \right] \right\}$$ Eqn. A50

Eqn. A50 should replace Eqn. A8 when parent effects are to be considered for nuclide j .

Rearranging Eqn. A48, the activity release rate,

$$\dot{Q}_j(t) = \left\{\nu\left[\beta-\alpha\right] + \mu\left[A_j(t_A)-\delta\right]\right\} e^{-(\lambda_j+L+P)(t-t_A)}$$
$$+\left\{\nu\alpha+\mu\delta\right\} e^{-(\lambda_p+L+P)(t-t_A)} + \left\{\nu\left[C_j(t_A)+\alpha-\beta-\gamma\right]\right\} e^{-(\lambda_j+\frac{E}{M})(t-t_A)}$$
$$+\left\{\nu\left[\gamma-\alpha\right]\right\} e^{-(\lambda_p+\frac{E}{M})(t-t_A)}$$

Eqn. A51

Eqn. A51 should replace Eqn. A6 when parent effects are to be considered for nuclide j .

The derivative of $\dot{Q}_j(t)$ (Eqn. A51) is

$$\ddot{Q}_j(t) = \left\{\lambda_j+L+P\right\}\left\{\nu\left[\alpha-\beta\right] \mu\left[\delta-A_j(t_A)\right]\right\} e^{-(\lambda_j+L+P)(t-t_A)}$$
$$-\left\{\lambda_p+L+P\right\}\left\{\nu\alpha+\mu\delta\right\} e^{-(\lambda_p+L+P)(t-t_A)}$$
$$+\left\{\lambda_j+\frac{E}{M}\right\}\left\{\nu\left[\beta+\gamma-\alpha-C_j(t_A)\right]\right\} e^{-(\lambda_j+\frac{E}{M})(t-t_A)}$$
$$+\left\{\lambda_p+\frac{E}{M}\right\}\left\{\nu\left[\alpha-\gamma\right]\right\} e^{-(\lambda_p+\frac{E}{M})(t-t_A)}$$

Eqn. A52

Eqn. A52 should replace the quantity within the braces in Eqn. A25 when j in the summation corresponds to a nuclide for which parent effects are to be considered.

A.3.7 Atmospheric Relative Concentration, $(\chi/Q')_{id}$

The atmospheric disperison model used is that for a semi-infinite cloud whose concentration is that for the center of a Gaussian plume a distance d meters downwind from the ground level release point. The lateral and the vertical plume spreads, m meters, are termed $\sigma_{iy}(d)$ and $\sigma_{iz}(d)$ respectively and are functions of the Pasquill stability class i and the downwind distance d.

The atmospheric relative concentration times the wind speed $\bar{u}$ in meters/second for the desired model, excluding a building wake correction and excluding plume rise is (Ref. 1)

$$\bar{u}\left(\chi/Q'\right)_{id} = \frac{1}{\pi\,\sigma_{iy}(d)\,\sigma_{iz}(d)} \qquad \text{Eqn. A53}$$

The next subsections will describe the determination of

(a) $\sigma_{iy}(d)$ and $\sigma_{iz}(d)$
(b) $\bar{u}\left(\chi/Q'\right)_{id}$ with building wake correction
(c) d when given a value of $\bar{u}\left(\chi/Q'\right)_{id}$

A.3.7.1 Determination of $\sigma_{iy}(d)$ and $\sigma_{iz}(d)$

The algorithms, Reference 12, for determining $\sigma_{iy}(d)$ and $\sigma_{iz}(d)$ were

$$\sigma_{iy}(d) = A_{iy} d^{B_{iy}} \quad \text{Eqn. A54}$$

$$\sigma_{iz}(d) = A_{iz} d^{B_{iz}} + C_{iz} \quad \text{if} \quad \sigma_{iz}(d) \leq 1000.0\text{m} \quad \text{Eqn. A55}$$

$$\sigma_{iz}(d) = 1000.0\text{m if Eqn. A55 fails} \quad \text{Eqn. A56}$$

The inequality test for Eqn. A55 results from the assumption of 1000.0 meters for the planetary boundary layer thickness (maximum mixing depth). The parameters for these equations are given in Table A1 and Table A2. All parameters for Pasquill class G (i = 7) were calculated from the parameters for Pasquill class F (i = 6) using the following equations from Reference 13.

$$\sigma_{7y}(d) = 0.667\, \sigma_{6y}(d) \quad \text{Eqn. A57}$$

$$\sigma_{7z}(d) = 0.6\, \sigma_{6z}(d) \quad \text{Eqn. A58}$$

TABLE A1

Parameters for $\sigma_{iy}(d)$ Algorithm

(From Reference 12 and Eqn. A57)

Pasquill Class	Class Index i	A_{iy}	B_{iy}
A	1	.3658	.9031
B	2	.2751	.9031
C	3	.2089	.9031
D	4	.1471	.9031
E	5	.1046	.9031
F	6	.0722	.9031
G	7	.0481	.9031

TABLE A2

Parameters for $\sigma_{iz}(d)$ Algorithm

(From Reference 12 and Eqn. A58)

Pasquill Class	Class Index i	d < 100m A_{iz}	B_{iz}	C_{iz}	100≤ d < 1000m A_{iz}	B_{iz}	C_{iz}	d ≥1000 m A_{iz}	B_{iz}	C_{iz}
A	1	.192	.936	0	.00066	1.941	9.27	.00024	2.094	-9.6
B	2	.156	.922	0	.0382	1.149	3.3	.0055	1.098	2.0
C	3	.116	.905	0	.113	.911	0	.113	.911	0
D	4	.079	.881	0	.222	.725	-1.7	1.26	.516	-13.0
E	5	.063	.871	0	.211	.678	-1.3	6.73	.305	-33.8*
F	6	.053	.814	0	.086	.74	- .35	18.05	.18	-48.6
G	7	.032	.814	0	.052	.74	- .21	10.83	.18	-29.13*

*Adjusted values to give a better match at the interval boundary, z = 1000m

A.3.7.2 Determination of $\bar{u}(\chi/Q')_{id}$ With Building Wake Correction

Let A_R = smallest vertical plane cross-sectional area, m^2, of the reactor building.*

Then from Reference 13, conservatively assuming no plume meander,

$$\bar{u}(\chi/Q')_{id} = \frac{1}{[\pi \sigma_{iy}(d)\sigma_{iz}(d) + A_R/2]} \quad \text{Eqn. A59}$$

or

$$\bar{u}(\chi/Q')_{id} = \frac{1}{3\pi \sigma_{iy}(d)\sigma_{iz}(d)} \quad \text{Eqn. A60}$$

whichever is the larger.

Define $K_c \equiv \frac{A_R}{2\pi}$ Eqn. A61

Define $F_{id} \equiv 1 + \frac{K_c}{\sigma_{iy}(d)\sigma_{iz}(d)}$ Eqn. A62

which is the building wake correction factor.

Then, if $F_{id} \geq 3$,

$$\bar{u}(\chi/Q')_{id} = \frac{1}{3\pi \sigma_{iy}(d)\sigma_{iz}(d)} \quad \text{Eqn. A63}$$

or if $F_{id} < 3$,

$$\bar{u}(\chi/Q')_{id} = \frac{1}{\pi[\sigma_{iy}(d)\sigma_{iz}(d) + K_c]} \quad \text{Eqn. A64}$$

---

*For the Enrico Fermi Atomic Power Plant - Unit 2, the value of A_R was found to be 160 (ft.) x 152.5 (ft) x $(.3048)^2$ $(m/ft)^2$ from The Detroit Edison Co. Architectural Drawings #7A721-2001 and #7A721-2003. Thus, A_R = 2266.83 m^2 and K_c = 360.78 m^2.

A.3.7.3 Determination of Distance When Given a Value of $\bar{u}\left(\chi/Q'\right)_{id}$

Solving for the product $\sigma_{iy}(d)\sigma_{iz}(d)$ in both Eqns. A63 and A64,

$$\sigma(d)\sigma(d) = \frac{1}{3\pi\bar{u}\left(\chi/Q'\right)_{id}}$$ Eqn. A65

to be used if $\sigma_{iy}(d)\sigma_{iz}(d) \leq K_c/2$

and

$$\sigma(d)\sigma(d) = \frac{1}{\pi\bar{u}\left(\chi/Q'\right)_{id}} - K_c$$ Eqn. A66

to be used if $\sigma_{iy}(d)\sigma_{iz}(d) > K_c/2$

The appropriate equation (Eqn. A65 or Eqn. A66) may be solved for the distance, d, by a method of interpolation (regula falsi) when given a value of $(\chi/Q')_{id}$. The following steps are used.

Step 1: Evaluate $S = \sigma_{iy}(d)\sigma_{iz}(d)$ using both Eqn. A65 and Eqn. A66, and select the appropriate value according to the inequalities associated with each of these equations.

Step 2: Select the range $100 \leq d < 1000$ m. for the parameters to be used in Eqns. A54 through A56.

Step 3: Let the first guess for the distance be $d_1 = 200$ m.

Step 4: Let the second guess for the distance be $d_2 = 800$ m.

Step 5: Set the iteration counter equal to zero.

Step 6: Calculate $S_1 = \sigma_{iy}(d_1)\sigma_{iz}(d_1)$ from Eqns. A54 through A56.

Step 7: Increment the iteration counter by 1.

Step 8: Calculate $S_2 = \sigma_{iy}(d_2)\sigma_{iz}(d_2)$ from Eqns. A54 through A56.

Step 9: Calculate new distance d by log-log interpolation; thus, $d = \exp\left\{\ln(d_1) + \ln\left(\frac{d_2}{d_1}\right)\ln\left(\frac{S}{S_1}\right)/\ln\left(\frac{S_2}{S_1}\right)\right\}$

Step 10: If $|d-d_2|/d <$ 0.0001 then go to Step 15.

Step 11: If iteration counter exceeds 30 then go to Step 15.

Step 12: If $|S_1-S| > |S_2-S|$, then go to Step 14.

Step 13: Set $d_2 = d$; then go to Step 7.

Step 14: Set $S_1 = S_2$; set $d_1 = d_2$; set $d_2 = d$; then go to Step 7.

Step 15: If $d \geq 1000$ m. and the parameters in use for Eqns. A54 through A56 are not for the range $d \geq 1000$ m., go to Step 18.

Step 16: If $d < 100$ m. and the parameters in use for Eqns. A54 through A56 are not for the range $d < 100$ m., go to Step 19.

Step 17: Finished.

Step 18: Select the range $d \geq 1000$ m. for the parameters to be used in Eqns. A54 through A56; Set d_1 = 2000 m.; Set d_2= 8000 m.; go to Step 5.

Step 19: Select the range $d < 100$ m. for the parameters to be used in Eqns. A54 through A56; Set d_1 = 10 m.; Set d_2 = 90 m.; go to Step 5.

A.3.8 Total Downwind Doses

A.3.8.1 Environmental Protection Agency Protective Action Guide Limits

In Reference 1, Protective Action Guides (PAG), recommended protective actions to reduce whole body and thyroid dose from exposure to a gaseous plume are given based on projected whole body and thyroid inhalation doses to the population (see Table 5.1 in Reference 1). Table A3 summarizes these actions. Table A4 condenses the limits of Table A3 into Red, Yellow, White, and No emergency conditions. The White energency condition does not exist in Reference 1.

TABLE A3

Recommended Protective Actions to Reduce Whole Body and Thyroid Dose From Exposure to a Gaseous Plume (Ref. 1)

Projected Dose (Rem) to the Population	Recommended Actions[a]	Comments
Whole body, <1 Thyroid, <5	No planned protective actions.[b] State may issue an advisory to seek shelter and await further instructions. Monitor environmental radiation levels.	Previously recommended protective actions may be reconsidered or terminated.
Whole body, 1 to < 5 Thyroid, 5 to < 25	Seek shelter as a minimum. Consider evacuation. Evacuate unless constraints make it impractical. Monitor environmental radiation levels. Control access.	If constraints exist, special consideration should be given for children and pregnant women.
Whole body, 5 and above Thyroid, 25 and above	Conduct mandatory evacuation. Monitor environmental radiation levels and adjust area for mandatory evacuation based on these levels. Control access.	Seeking shelter would be an alternative if evacuation were not immediately possible.

(a) These actions are recommended for planning purposes. Protective action decision at the time of the incident must take existing conditions into consideration.

(b) At the time of the incident, officials may implement low impact protective actions in keeping with the principle of maintaining radiation exposure as low as reasonably achievable.

TABLE A4

Protective Action Guide Dose Limits

Projected Dose (Rem) to the Population	Emergency Condition	Relation to Table A3
Whole Body < 0.05	No	Corresponds to the
Thyroid < 0.3	No	first set of entries.
0.05 ≤ Whole Body < 1.0	White	Corresponds to the
0.3 ≤ Thyroid < 5.0	White	first set of entries.
1.0 ≤ Whole Body < 5.0	Yellow	Corresponds to the
5.0 ≤ Thyroid < 25.0	Yellow	second set of entries.
5.0 ≤ Whole Body	Red	Corresponds to the
25.0 ≤ Thyroid	Red	third set of entries.

A.3.8.2 Dose Calculations

The projected whole body (γ) dose for the time period t_A to t_B at a distance d for Pasquill class i as determined by the drywell monitor reading is

$$ {}_{D}D_{id\gamma}(t_A,t_B) = K\left[{}_{AD}Q_{eff\,Xe\text{-}133}(t_A,t_B)\right]\overline{E}_{\gamma Xe\text{-}133}\left[\bar{u}\left(\chi/Q'\right)_{id}\right]/\bar{u} \qquad \text{Eqn. A67} $$

where $K = 0.253\ (\text{Rem}\cdot\text{m}^3)/(\text{ci}\cdot\text{Mev}\cdot\text{sec})$,

$\left[{}_{AD}Q_{eff\,Xe\text{-}133}(t_A,t_B)\right]$ is found from Eqn. A17,

and $\left[\bar{u}\left(\chi/Q'\right)_{id}\right]$ is found from Eqns. A62 through A64.

As determined by the SGTS monitor reading, it is

$$ {}_{S}D_{id\gamma}(t_A,t_B) = K\left[{}_{AS}Q_{eff\,Xe\text{-}133}(t_A,t_B)\right]\overline{E}_{\gamma Xe\text{-}133}\left[\bar{u}\left(\chi/Q'\right)_{id}\right]/\bar{u} \qquad \text{Eqn. A68} $$

where $\left[{}_{AS}Q_{eff\,Xe\text{-}133}(t_A,t_B)\right]$ is found from Eqn. A21.

The projected thyroid inhalation dose for the time period t_A to t_B at a distance d for Pasquill class i as determined by the drywell monitor reading is

$$ {}_{D}D_{id\,Thyroid}(t_A,t_B) = D_{C\,I\text{-}131}\,B_R\left[{}_{AD}Q_{eff\,I\text{-}131}(t_A,t_B)\right]\left[\bar{u}\left(\chi/Q'\right)_{id}\right]/\bar{u} \qquad \text{Eqn. A69} $$

where $\left[{}_{AD}Q_{eff\,I\text{-}131}(t_A,t_B)\right]$ is found from Eqn. A18.

As determined by the SGTS monitor reading, it is

$$ {}_{S}D_{id\,Thyroid}(t_A,t_B) = D_{C\,I\text{-}131}\,B_R\left[{}_{AS}Q_{eff\,I\text{-}131}(t_A,t_B)\right]\left[\bar{u}\left(\chi/Q'\right)_{id}\right]/\bar{u} \qquad \text{Eqn. A70} $$

where $\left[{}_{AS}Q_{eff\,I\text{-}131}(t_A,t_B)\right]$ is found from Eqn. A22.

The doses as calculated by Eqns. A67 through A70 can be compared to the PAG dose limits in Table A4, and the associated Emergency Condition can be assigned.

A.3.8.3 Distances to Protective Action Guides Dose Limits

Let k be an index denoting the lower PAG dose limit for the PAG emergency conditions in Table A4 excluding the no emergency condition; thus,

k = 1 for lower dose limit of Red emergency condition,

k = 2 for lower dose limit of Yellow emergency condition,

and k = 3 for lower dose limit of White emergency condition.

Let $D_{k\gamma}$ be the whole body dose for lower dose limit k and $D_{k\,Thyroid}$ be the thyroid inhalation dose for lower dose limit k.

As determined by the drywell monitor reading let ${}_Dd_{k\gamma}$ be the maximum distance to which the whole body emergency condition k extends; thus,

from 0 to ${}_Dd_{1\gamma}$ the Red emergency condition exists,

from ${}_Dd_{1\gamma}$ to ${}_Dd_{2\gamma}$ the Yellow emergency condition exists,

and from ${}_Dd_{2\gamma}$ to ${}_Dd_{3\gamma}$ the White emergency condition exists.

Similarly let ${}_Dd_{k\,Thyroid}$ be the maximum distance to which the thyroid inhalation emergency condition k extends.

As determined by the SGTS monitor reading define ${}_Sd_{k\gamma}$ and ${}_Sd_{k\,Thyroid}$ in a similar manner.

The distances to the Protective Action Guide dose limits are found by substituting $D_{k\gamma}$ or $D_{k\,Thyroid}$ into the appropriate Eqn. A67, A68, A69, or A70 and solving for $\bar{u}(\chi/Q')_{ix}$ where x is the appropriate distance designation ${}_Dd_{k\gamma}$, ${}_Sd_{k\gamma}$, ${}_Dd_{k\,Thyroid}$, or ${}_Sd_{k\,Thyroid}$.

Solving Eqn. A67,

$$\bar{u}(\chi/Q')_{ix} = \frac{\bar{u}\,D_{k\gamma}}{K\left[{}_{AD}Q_{eff\,Xe\text{-}133}(t_A,t_B)\right]\bar{E}_{\gamma Xe\text{-}133}} \qquad \text{Eqn. A71}$$

where $X = {}_{D}d_{k\gamma}$ which may be found from the procedure in Section A.3.7.3.

Solving Eqn. A68,

$$\bar{u}\left(\chi/Q'\right)_{ix} = \frac{\bar{u}\, D_{k\gamma}}{K\left[{}_{AS}Q_{eff\,Xe-133}(t_A, t_B)\right]\bar{E}_{\gamma\,Xe-133}}$$ Eqn. A72

where $X = {}_{S}d_{k\gamma}$ which may be found from the procedures in Section A.3.7.3.

Solving Eqn. A69,

$$\bar{u}\left(\chi/Q'\right)_{ix} = \frac{\bar{u}\, D_{k\,Thyroid}}{\left[{}_{AD}Q_{eff\,I-131}(t_A, t_B)\right] D_{c\,I-131}\, B_R}$$ Eqn. A73

where $X = {}_{D}d_{k\,Thyroid}$ which may be found from the procedures in Section A.3.7.3.

Solving Eqn. A70,

$$\bar{u}\left(\chi/Q'\right)_{ix} = \frac{\bar{u}\, D_{k\,Thyroid}}{\left[{}_{AS}Q_{eff\,I-131}(t_A, t_B)\right] D_{c\,I-131}\, B_R}$$ Eqn. A74

where $X = {}_{S}d_{k\,Thyroid}$ which may be found from the procedures in Section A.3.7.3.

A.3.9 Total Downwind Dose Rates

A.3.9.1 NUREG-0654 Emergency Dose Rate Limits

In Reference 2, (NUREG-0654), Licensee and State and/or Local Offsite Authority actions are given for several emergency classifications. One method of defining these classifications is by specifying dose rate limits at the site boundary. Table A5 summarizes these dose rate limits.

TABLE A5

NUREG-0654, Rev. 1, Appendix 1, (Ref. 2)

Emergency Dose Rate Limits

Projected Dose Rate Limit, Rem/hr, at the Site Boundary	Minimum Duration	Pasquill Class	Wind Speed, m/sec	Emergency Classification
Whole Body = 0.05 Thyroid = 0.25	½ hour	G*	1.0*	Site
Whole Body = 0.5 Thyroid = 2.5	2 minutes	G*	1.0*	Site
Whole Body = 1.0 Thyroid = 5.0	N/A	Actual**	Actual**	General

*Values assumed to be "adverse meteorology"

**Actual site meteorology

A.3.9.2 Dose Rate Calculations

The projected whole body (γ) dose rate at the time of maximum release rate at a distance d for Pasquill class i as determined by the drywell monitor reading is

$${}_{D}\dot{D}_{id\gamma}(T_{max\,Xe\text{-}133}) = K\left[{}_{AD}\dot{Q}_{eff\,Xe\text{-}133}(T_{max\,Xe\text{-}133})\right]\overline{E}_{\gamma Xe\text{-}133}\left[\bar{u}\left(\chi/Q'\right)_{id}\right]/\bar{u}$$ Eqn. A75

where K = 0.253 $(\text{Rem}\cdot\text{m}^3)/(\text{ci}\cdot\text{Mev}\cdot\text{sec})$,

$\left[{}_{AD}\dot{Q}_{eff\,Xe\text{-}133}(T_{max\,Xe\text{-}133})\right]$ is found from Eqn. A31

$T_{max\,Xe\text{-}133}$ is found by the methods of Section A.3.4,

and $\left[\bar{u}\left(\chi/Q'\right)_{id}\right]$ is found from Eqns. A62 through A64.

As determined by the SGTS monitor reading, it is

$${}_{S}\dot{D}_{id\gamma}(T_{max\,Xe\text{-}133}) = K\left[{}_{AS}\dot{Q}_{eff\,Xe\text{-}133}(T_{max\,Xe\text{-}133})\right]\overline{E}_{\gamma Xe\text{-}133}\left[\bar{u}\left(\chi/Q'\right)_{id}\right]/\bar{u}$$ Eqn. A76

where $\left[{}_{AS}\dot{Q}_{eff\,Xe\text{-}133}(T_{max\,Xe\text{-}133})\right]$ is found from Eqn. A33.

The projected thyroid inhalation dose rate at the time of maximum release rate at a distance d for Pasquill class i as determined by the drywell monitor reading is

$${}_{D}\dot{D}_{id\,Thyroid}(T_{max\,I\text{-}131}) = D_{C\,I\text{-}131}B_R\left[{}_{AD}\dot{Q}_{eff\,I\text{-}131}(T_{max\,I\text{-}131})\right]\left[\bar{u}\left(\chi/Q'\right)_{id}\right]/\bar{u}$$ Eqn. A77

where $\left[{}_{AD}\dot{Q}_{eff\,I\text{-}131}(T_{max\,I\text{-}131})\right]$ is found from Eqn. A32 and

$T_{max\,I\text{-}131}$ is found by the methods of Section A.3.4.

As determined by the SGTS monitor reading, it is

$${}_{S}\dot{D}_{id\,Thyroid}(T_{max\,I\text{-}131}) = D_{C\,I\text{-}131}B_R\left[{}_{AS}\dot{Q}_{eff\,I\text{-}131}(T_{max\,I\text{-}131})\right]\left[\bar{u}\left(\chi/Q'\right)_{id}\right]/\bar{u}$$ Eqn. A78

where $\left[{}_{AS}\dot{Q}_{eff\,I\text{-}131}(T_{max\,I\text{-}131})\right]$ is found from Eqn. A34.

The dose rates at the site boundary as calculated by Eqns. A75 through A78 can be compared to the NUREG-0654 dose rate limits and the associated Emergency Classification can be assigned. Another approach would be to calculate the monitor reading which would result in the dose rate limit at the site boundary. This approach is now described; however, the subscript Xe-133 or I-131 will be dropped because this description applies to both Xe-133 and I-131.

Eqn. A23 or Eqn. A24 can be interpreted to be the calculation of the effective activity release rate to achieve the dose rate limit at the site boundary $\dot{Q}_{eff\,\ell}(t)$ divided by the fraction of the design basis accident release that is actually released to the primary containment F_ℓ ; thus,

$$\frac{\dot{Q}_{eff\,\ell}(t)}{F_\ell} = \dot{Q}_{eff}(t) \qquad \text{Eqn. A79}$$

For simplicity the functional dependence on time will no longer be indicated; all time dependent quantities will be understood to be evaluated at the time of the maximum release rate. Also, the distinction between whole body and thyroid inhalation dose rates will be dropped as well as the indication of the monitor location. Distance d will be the distance to the site boundary; the subscript d will be dropped.

Let $\dot{D}_\ell$ be the dose rate limit at the site boundary. Then

$$\dot{D}_\ell = K_1 \dot{Q}_{eff\,\ell} \left[\bar{u} \left(\chi/Q'\right)_i\right] / \bar{u} \qquad \text{Eqn. A80}$$

where K_1 is a constant.

Solving Eqn. A80 for $\frac{\dot{Q}_{eff\,\ell}}{\bar{u}}$,

$$\frac{\dot{Q}_{eff\,\ell}}{\bar{u}} = \frac{\dot{D}_\ell}{K_1\left[\bar{u}\left(\chi/Q'\right)_i\right]} \qquad \text{Eqn. A81}$$

Dividing Eqn. A81 by Eqn. A79,

$$\frac{F_l}{\bar{u}} = \frac{\dot{D}_l}{K_1\left[\bar{u}(\chi/Q')_i\right]\dot{Q}_{eff}}$$ Eqn. A82

The monitor reading R_l which would result in the dose rate limit at the site boundary is

$$R_l = \frac{F_l}{\bar{u}} R_c \bar{u}$$ Eqn. A83

where the R_c is obtained from Eqn. A13 or Eqn. A14.

Substituting Eqn. A82 into Eqn. A83,

$$R_l = \frac{\dot{D}_l R_c \bar{u}}{K_1\left[\bar{u}(\chi/Q')_i\right]\dot{Q}_{eff}}$$ Eqn. A84

The actual monitor reading can be compared to R_l to determine the emergency classification.

Eqn. A84 should now be recognized as the design basis accident calculated monitor reading times the ratio of the dose rate limit to the design basis accident dose rate.

A.3.9.3 Distances to NUREG-0654 Emergency Dose Rate Limits

Let ℓ be an index denoting the NUREG-0654 (Ref. 2) dose rate limit for the emergency classifications in Table A5; thus,

ℓ = 1 for General Emergency

ℓ = 2 for Site Emergency with duration 2 minutes

ℓ = 3 for Site Emergency with duration ½ hour.

Let $\dot{D}_{\ell\gamma}$ be the whole body dose rate for classification ℓ and $\dot{D}_{\ell\,Thyroid}$ be the thyroid inhalation dose rate for classification ℓ.

As determined by the drywell monitor reading, let ${}_{D}d_{\ell\gamma}$ be the distance at which classification ℓ for the whole body emergency occurs. Similarly let ${}_{D}d_{\ell\,Thyroid}$ be the distance at which classification ℓ for the thyroid inhalation emergency occurs.

As determined by the SGTS monitor reading define ${}_{S}d_{\ell\gamma}$ and ${}_{S}d_{\ell\,Thyroid}$ in a similar manner.

The distances to the NUREG-0654 dose rate limits are found by substituting $\dot{D}_{\ell\gamma}$ and $\dot{D}_{\ell\,Thyroid}$ into the appropriate Eqn. A75, A76, A77, or A78 and solving for $\bar{u}(\chi/Q')_{ix}$ where x is the appropriate distance designation ${}_{D}d_{\ell\gamma}$, ${}_{S}d_{\ell\gamma}$, ${}_{D}d_{\ell\,Thyroid}$, or ${}_{S}d_{\ell\,Thyroid}$.

Solving Eqn. A75,

$$\bar{u}\left(\chi/Q'\right)_{ix} = \frac{\bar{u}\,\dot{D}_{\ell\gamma}}{K\left[{}_{AD}\dot{Q}_{eff\,Xe-133}(T_{max\,Xe-133})\right]\bar{E}_{\gamma\,Xe-133}} \qquad \text{Eqn. A85}$$

where $x = {}_{D}d_{\ell\gamma}$ which may be found from the procedures in Section A.3.7.3.

Solving Eqn. A76,

$$\bar{u}\left(\chi/Q'\right)_{ix} = \frac{\bar{u}\,\dot{D}_{\ell\gamma}}{K\left[{}_{AS}\dot{Q}_{eff\,Xe-133}(T_{max\,Xe-133})\right]\bar{E}_{\gamma\,Xe-133}} \qquad \text{Eqn. A86}$$

where $x = {}_{S}d_{\ell\gamma}$ which may be found from the procedures in Section A.3.7.3.

Solving Eqn. A77,

$$\bar{u}\left(\chi/Q'\right)_{ix} = \frac{\bar{u}\,\dot{D}_{\ell\,Thyroid}}{\left[{}_{AD}\dot{Q}_{eff\ I\text{-}131}\left(T_{max\ I\text{-}131}\right)\right] D_{c\ I\text{-}131}\, B_R} \qquad \text{Eqn. A87}$$

where $x = {}_{D}d_{\ell\,Thyroid}$ which may be found from the procedures in Section A.3.7.3.

Solving Eqn. A78,

$$\bar{u}\left(\chi/Q'\right)_{ix} = \frac{\bar{u}\,\dot{D}_{\ell\,Thyroid}}{\left[{}_{AS}\dot{Q}_{eff\ I\text{-}131}\left(T_{max\ I\text{-}131}\right)\right] D_{c\ I\text{-}131}\, B_R} \qquad \text{Eqn. A88}$$

where $x = {}_{S}d_{\ell\,Thyroid}$ which may be found from the procedures in Section A.3.7.3.

A.3.10 Projections Based on Constant SGTS Monitor Reading with No Shutdown

This section deals with the special case of a constant SGTS monitor reading. The special assumptions of no reactor shutdown and no reactor building mixing will apply.

Let R_{AS} = the actual SGTS monitor reading, ci/m^3, (effective Xe-133); since R_{AS} is assumed to be constant, the functional dependence on t will be dropped.

Then the effective Xe-133 activity, ci, released during the time period T_A to T_B is

$$ {}_{AS}Q_{eff\,Xe\text{-}133}(T_A, T_B) = R_{AS} V_{SC}\, E \left[T_B - T_A\right] \left[0.3048 \frac{m}{ft}\right]^3 $$ Eqn. A89

The total noble gas activity, ci, released during the time period is

$$ {}_{AS}Q_{T\,Nobles}(T_A, T_B) = {}_{AS}Q_{eff\,Xe\text{-}133}(T_A, T_B)\, \overline{E}_{\gamma Xe\text{-}133} \left\{ \frac{\sum_{j=6}^{18} A_j}{\sum_{j=1}^{18} \overline{E}_{\gamma j}(1-\varepsilon_j) f_j A_j} \right\}^* $$ Eqn. A90

where A_j is independent of time because no reactor shutdown was assumed. (Eqn. A90 becomes obvious if the definition of $Q_{eff\,Xe\text{-}133}$ is recalled).

Similarly the total iodine activity, ci, released during the time period is

$$ {}_{AS}Q_{T\,Iodine}(T_A, T_B) = {}_{AS}Q_{eff\,Xe\text{-}133}(T_A, T_B)\, \overline{E}_{\gamma Xe\text{-}133} \left\{ \frac{\sum_{j=1}^{5} (1-\varepsilon_j) A_j}{\sum_{j=1}^{18} \overline{E}_{\gamma j}(1-\varepsilon_j) A_j} \right\} $$ Eqn. A91

*When using the results of this section as input to the methodology of Reference 1, all summations including values of $j \geq 6$ should use only those nuclides in Table 3.1, Appendix D, page D-25 of Reference 1.

However, it will be noted that the f_j in the denominator of Eqn. A90 was omitted from the denominator of Eqn. A91. This is because the definition of $Q_{eff\ Xe-133}$ is different when determining iodine releases; in this case all of the design basis accident iodine is assumed to be present and, therefore, $f_j \equiv 1.0$. The effective I-131 activity, ci, release during the time period is

$$_{AS}Q_{eff\ I-131}(T_A,T_B) = {}_{AS}Q_{T\ Iodines}(T_A,T_B)\left\{\frac{\sum_{j=1}^{5} D_{cj}(1-\mathcal{E}_j)A_j}{\sum_{j=1}^{5}(1-\mathcal{E}_j)A_j}\right\} \Big/ D_{c\ I-131}$$ Eqn. A92

The average effective activity release rates for the time period are

$$_{AS}\hat{\dot{Q}}_{eff\ Xe-133}(T_A,T_B) = {}_{AS}Q_{eff\ Xe-133}(T_A,T_B) \Big/ \left[T_B - T_A\right]$$ Eqn. A93

and

$$_{AS}\hat{\dot{Q}}_{eff\ I-131}(T_A,T_B) = {}_{AS}Q_{eff\ I-131}(T_A,T_B) \Big/ \left[T_B - T_A\right]$$ Eqn. A94

The results of Eqns. A89 and A92 can be used in Eqns. A68 and A70 to obtain downwind doses. The results of Eqns. A93 and A94 can be used in Eqns. A76 and A78 to obtain downwind dose rates. The results of Eqns. A89 and A92 can be used in Eqns. A72 and A74 to obtain the distances to the Protective Action Guides (Ref. 1) dose limits.

A.4 Drywell Finite Gamma Cloud Corrections

Since the drywell monitor calculated readings, Eqn. A13, are based on the semi-infinite cloud equation, the division by a correction factor K_j was required to effect a finite cloud. This correction factor is the ratio of the semi-infinite gamma cloud dose rate to that for a finite cloud. This ratio is dependent only on the nuclide j and the geometry of the finite cloud; thus, for a given monitor location, ratios need to be calculated only once.

For a BWR drywell monitor located on the outer wall of the drywell, a simple model of the geometry of the finite cloud will be a cylindrical annulus. This section provides a reference for the theory of infinite to finite gamma cloud dose rate ratios as well as documentation for extending the theory to a cylindrical annulus cloud. Calculation of the ratios are done by an independent computer program; the ratios are then available as default values in the Accident Radiological Dose Assessment Program. Any input values may override the default ratios.

Reference 14, Section 2.1 provides the theory of infinite to finite gamma cloud dose rate ratios. The equations developed in Ref. 14, Section 2.1.3.4 (Finite Rectangular Parallelopiped Cloud Dose) can be modified in order to apply to a cylindrical annulus cloud by replacing the function $R(\theta)$ by a function $r(\alpha)$ to be derived in this Section.

Let R_1 be the radius of the outer cylinder.
Let R_2 be the radius of the inner cylinder.
Define r to be the distance from a point on the outer cylinder to the outer or inner cylinder whichever is shorter in a direction whose angle is α from the tangent to the point on the outer cylinder (see Figure A2). Also, define

$\alpha_0 = \cos^{-1}(R_2/R_1)$,

the angle of the direction of r when r is tangent to the inner cylinder.

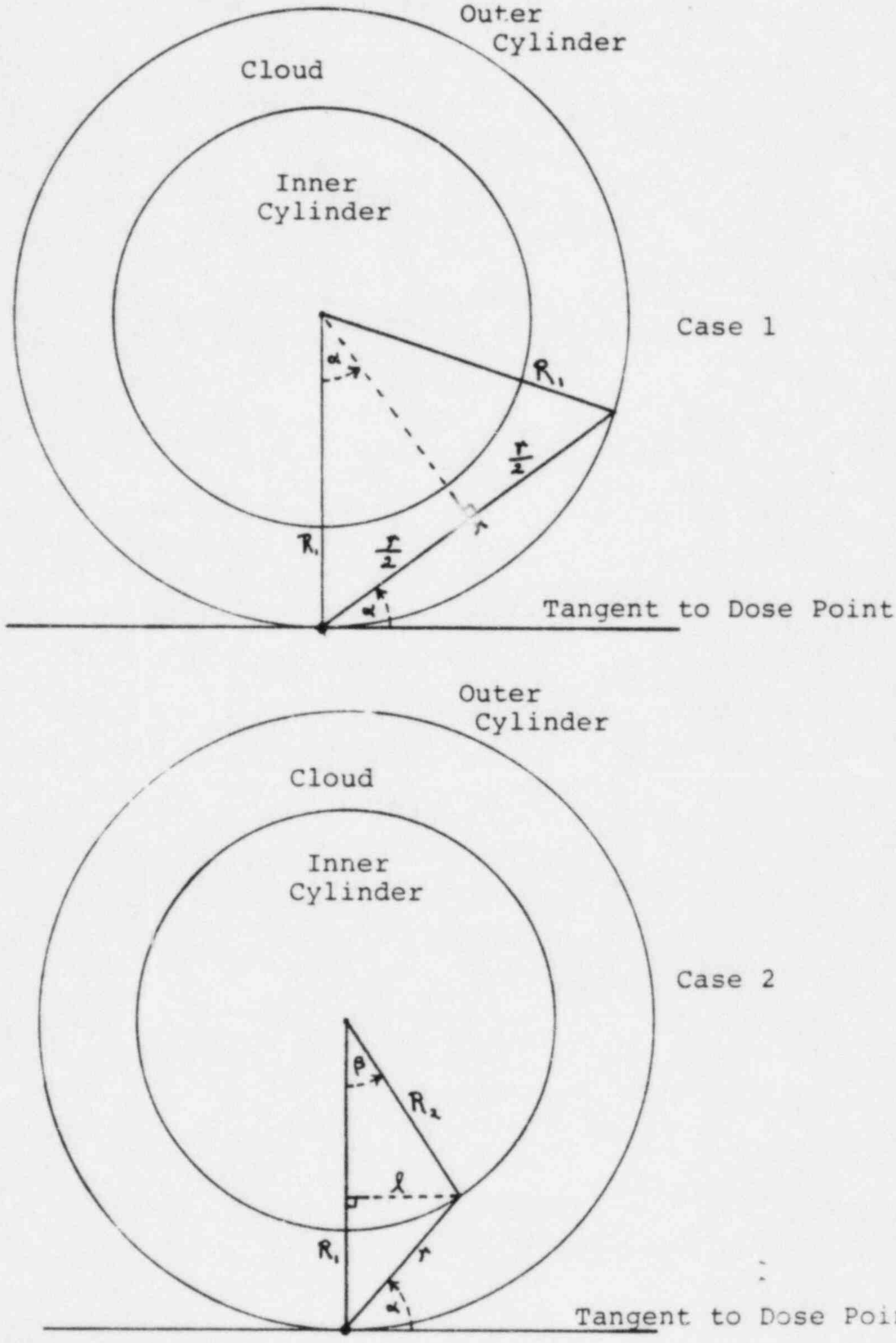

Figure A2. Cylindrical Annulus Cloud Geometry

Two cases must be considered. Case 1 applies when the distance r is from the point on the outer cylinder to another point on the outer cylinder. From Figure A2, Case 1,

$$0 \leq \alpha < \alpha_0$$

$$\sin\alpha = (r/2)/R_1$$

Therefore, $r = 2R_1 \sin\alpha$ Eqn. A95

Case 2 applies when the distance r is from the point on the outer cylinder to a point on the inner cylinder. From Figure A2, Case 2,

$$\alpha_0 \leq \alpha \leq \pi/2$$

$$R_1 = r\sin\alpha + R_2\cos\beta$$

where β is defined in Figure A2, Case 2. Therefore,

$$R_2^2\cos^2\beta = R_1^2 - 2R_1 r\sin\alpha + r^2\sin^2\alpha$$ Eqn. A96

But $\sin\beta = \ell/R_2$ and $\cos\alpha = \ell/r$ where ℓ is defined in Figure A2, Case 2. Solving for ℓ and equating the two results,

$$r\cos\alpha = R_2\sin\beta$$

$$r^2\cos^2\alpha = R_2^2\left[1 - \cos^2\beta\right]$$

$$R_2^2\cos^2\beta = R_2^2 - r^2\cos^2\alpha$$ Eqn. A97

Substituting Eqn. A96 into Eqn. A97

$$R_1^2 - 2R_1 r\sin\alpha + r^2\sin^2\alpha = R_2^2 - r^2\cos^2\alpha$$

$$R_1^2 - 2R_1 r\sin\alpha + r^2 = R_2^2$$

Dividing by R_1^2 and applying the definition of α_0

$$1 - \frac{2r}{R_1}\sin\alpha + \frac{r^2}{R_1^2} = \cos^2\alpha_0$$

$$1 - \frac{2r}{R_1}\sin\alpha + \frac{r^2}{R_1^2} = 1 - \sin^2\alpha_0$$

Multiplying by R_1^2 and rearranging,

$$r^2 - 2rR_1\sin\alpha + R_1^2\sin^2\alpha_0 = 0$$

Applying the quadratic formula,

$$r = \left[2R_1\sin\alpha \pm \sqrt{4R_1^2\sin^2\alpha - 4R_1^2\sin^2\alpha_0}\right]/2$$

$$r = R_1\left[\sin\alpha - \sqrt{\sin^2\alpha - \sin^2\alpha_0}\right]$$ Eqn. A98

where the negative sign was chosen because the shortest distance to the inner cylinder is wanted.

From Eqns. A95 and A98, the function $r(\alpha)$ is

$$r(\alpha) = 2R_1 \sin\alpha \qquad \text{for } 0 \le \alpha < \alpha_0$$

$$r(\alpha) = R_1\left[\sin\alpha - \sqrt{\sin^2\alpha - \sin^2\alpha_0}\right] \qquad \text{for } \alpha_0 \le \alpha \le \pi/2$$

The function $r(\alpha)$ replaces the function $R(\theta)$ in Section 2.1.3.4 of Ref. 14. The integration over θ in that Reference is replaced by an integration over α for $0 \le \alpha \le \pi/2$; the result is multiplied by two to account for the interval $\pi/2 \le \alpha \le \pi$. For the interval $\pi \le \alpha \le 2\pi$, the integral is zero.

BOARD OF COMMISSIONERS

MONROE COUNTY, MICHIGAN

August 27, 1982

Mr. Jon Eckert, Director
Office of Civil Preparedness

Dear Jon:

At a Regular Meeting of the Monroe County Board of Commissioners held on August 24, 1982, the Board referred the enclosed communication to your office for incorporation with the balance of the comments regarding the evacuation plan. You are also instructed to provide copies of the communication, at no charge, to citizens who would like them.

Sincerely,

Warren J. LaBeau

Warren J. LaBeau, Clerk
MONROE COUNTY BOARD OF COMMISSIONERS

WJL/jp

84-552

6

Release

BOARD OF COMMISSIONERS

MONROE COUNTY, MICHIGAN

August 31, 1982

Mr. Jon Eckert, Director
Office of Civil Preparedness

Dear Jon:

At a Regular Meeting of the Monroe County Board of Commissioners held on August 24, 1982, the Board approved the request of Michael Barret and Joan Mumaw to make copies of the following documents available for public inspection: a transcript of the June 16, 1982 public hearing, results of the FEMA informal review, and all pertinent Standard Operating Procedures of all agencies involved in the evacuation process. This will allow them to continue their efforts to research and articulate the serious failings of the evacuation plan.

Sincerely,

Warren J. LaBeau

Warren J. LaBeau, Clerk
MONROE COUNTY BOARD OF COMMISSIONERS

WJL/jp

94-552

Release IE

To: Monroe County Board of Commissioners

Re: Citizens' concerns regarding the Proposed Radiological Emergency Response Plan

1. An evacuation of the residential areas surrounding FermiII would be extraordinarily difficult because of the unique geography of the beach communities, particularly Stoney Point and Estral Beach. These communities are directly on Lake Erie. Therefore, any escape to the east is impossible. The residents of this area would have few roads available to them. In most cases, they would have to travel north or south before being able to escape to the west. This could mean travelling extremely close to the plant itself. The roads have an hourly capacity of 1200 vehicles and would have to be the main arteries of emergency vehicles going to the plant itself. Therefore, movement out of the beach area will be very slow.
These difficulties are compounded by meteorological factors. As last winter demonstrated, this area can be paralyzed by heavy snowfall and is susceptible to flooding. Sheltering in lieu of evacuation is unacceptable because of the proximity to the plant. Another feature of the area is that it is a relatively short distance across the lake to the Davis-Bessie nuclear facility in Ohio.

2. The evacuation process outlined in Monroe County's Radiological Emergency Response Plan (RERP) is dependent upon the Governor of the State of Michigan declaring a State of Disaster according to Public Act 390. This will necessitate a lapse of time which will further endanger those in close proximity to the plant. It also leaves the decision to evacuate in the hahds of the Governor.

3. A full county-wide response to a nuclear emergency is dependent upon the activation of the Emergency Operating Center (EOC) and the establishment of the decontamination/reception centers. This process as well and the mobilization of the county's forces will take a great deal of time. This time will be available only if an unusual event progresses slowly to a general emergency. The county can not respond with full force to an incident which immediately threatens lives and property.

4. The facilities for the EOC at 106 East First in Monroe may be insufficient for the staff it must accommodate. This facility also may not adequately protect the Eoc staff since it is inside the ten-mile Emergency Preparedness Zone (EPZ).

5. Throughout the plan the authorities are dependent upon the plant operator to determine when a nuclear incident has occurred. Although there is periodic monitoring by the Michigan Department of Public Health, there is not a moment by moment independent monitoring of the plants perimeter or the intake for the City of Monroe's water system.

6. The RERP states,"It is the responsibility of each agency committed to a nuclear power incident response to initially and annually train and maintain the capability of its own staff to respond to an incident." Since this training responsibility rests within each agency, there is no guarantee that the training is sufficient and is fully coordinated with other agencies. This is particualarly true of volunteer organizations. The drills called for in the plan do not test the adequacy of training programs because the actual moving of people, decontaminating of vehicles, and protecting of property are never part of the drills. There is never a realistic evaluation of the training of emergency workers since a mock evacuation is impossible due to the liabilities it imposes on local government.

7. The plan states, "If possible contaminates are involved, the evacuees may require processing through decontamination centers." The plan proposes five possible centers:-Monroe High School

Monroe Intermediate School District

Airport Community Schools

Ida Community Schools

Mason High School

The Monroe County Department of Social Services is responsible for staffing these centers.

Federal criteria states that sufficient resources shall be available for registering and monitoring evacuees in a 12 hour period. If the entire EPZ was forced to evacuate, these centers would have to process well over 1000 people per hour. Creating additional centers is virtually impossible because the Department of Social Services has only approximately 100 employees available for administering the centers. It is even questionable if the five centers can be properly staffed given the size of the DSS staff even with the assistance from the Red Cross. This problem is compounded by the fact that the majority of the DSS employees reside outside the confines of Monroe County. If an emergency occurred other than between 8:00 to 5:00 on a weekday, the DSS would have great difficulty in meeting its responsibility.

The physical location of three of these facilities may present a problem since Monroe High School, Monroe ISD, and Ida High School are in a line southwest of the plant. A movement of a plume southwest could render all three centers useless. Other facilities exist that could replace these, but a shift of 60% of the decontamination/reception centers at the last moment could create tremendous confusion.

8. Although the RERP establishes decontamination centers and a decontamination process, there are not provisions to monitor cars leaving the EPZ for decontamination. Therefore, participation in the monitoring for radioactivity and decontamination is voluntary. To monitor vehicles within the EPZ would disrupt and retard the traffic within the areas being evacuated. This would increase the risk of exposure to radiation.

9. The process available to the county for the decontamination of vehicles may be inadequate and may create additional problems. This process calls for a decontamination center to be established at a school where vehicles and emergency equipment will be hosed off by the local fire department. The plan states, "The water pressure attained will serve to decontaminate vehicles."
It is questionable is this method will be effective. The effect of running contaminated water into a field has not been studied. This also raises the possibility of contaminating the water table beneath the field by the run-off. This is an important question since the schools available for the proposed centers are very close to residential areas dependent upon well-water.
Another questionable aspect of the decontamination procedure is the reliance on the local fire departments within the district of the center to perform the decontamination. In many cases, this means relying on volunteer fire departments for the personnel and equipment. Since these persons will be volunteers, they are placed in a legal position that prevents them from having liability coverage. This might effect their willingness to actively participate in this dangerous operation. Since the selection of decontamination centers will be dependent on the wind direction, all fire department personnel must be trained and willing to participate in the decontamination procedure.

10. Local fire departments have many responsibilities in addition to the decontamination process. These include:
    a. The Frenchtown Fire Department (a volunteer unit) will provide on-site fire and rescue service at the Fermi plant.

b. Fire department will provide notification to residents not provided with siren coverage.

c. Fire personnel will assist immobilized and institutionalized persons leaving their homes or facility if evacuation is ordered.

d. Each fire department will perform re-entry and recovery tasks as necessary.

The majority of these fire departments are volunteer organizations. Because of the limitations of P.A. 390 and insurance policies, volunteers have no liability coverage. Therefore, it is inadvisable to depend upon volunteers for these vital functions.

11. Local law enforcement agencies have substantial duties during an evacuation in addition to their normal responsibilities. Yet these agencies have rather limited personnel to meet these duties. This limitation is compounded by the fact that law enforcement personnel will be working in areas where they will be exposed to radiation. As each officer is exposed to maximum levels of radiation, the local law enforcement agencies will be dramatically depleted. Depending upon the National Guard troops to supplement local agencies means turning very fundamental emergency procedures over to people unfamiliar with not only the locality, but also the coordinated effort of all agencies in the radiological emergency response.

12. It has been widely accepted that the ingestion of potassium iodide (KI) can significantly reduce the dangers of exposure to certain radiation by its thyroid blocking properties. It is also widely understood that KI must be ingested immediately to have its full impact. The RERP states that the Michigan Department of Public Health maintains a quantity of KI at its central office. When an incident occurs this supply will be transported to the local area. The plan calls for the Director of the Monroe County Health Department to distribute the drugs. The plan even has a sample press to instruct persons living in designated areas where to pick up a supply of potassium iodide.
This procedure will take several hours. This delay will render potassium iodide unavailable and useless to evacuees. The delay will also minimize its value for emergency workers.

13. The RERP places the responsibility for the recovery of and re-entry into areas evacuated and /or contaminated due to an off-site release on local government. During this period, local government is assigned numerous tasks including: decontamination of people, property, and food; health and medical services for evacuees; mass care and welfare; and radioactive waste disposal.

The cost to fulfill this list of tasks in addition to the other requirements placed upon local government is astronomical. The cost of decontamination of private houses and property could destroy the local government financially. Especially the cost of decontamination of farms in the rural area surrounding the plant could be devastating. The environmental impact statement states, "where the material becomes relatively fixed in its location as an environmental contaminant (for example, in soil), the hazard can continue to exist for a relatively long period of time - months, years or even decades." It is doubtful if homes and property could ever be decontaminated fully if the cost is beyond the resources and expertise of the local government responsible for it.

Health and medical services that would be necessary following a nuclear emergency could become very costly. This is a cost local government can not assume.

Mass care and welfare could place the county in a position of long term care for the people whose homes and farms are uninhabitable because of contamination.

It is obvious that the county can never accept responsibility for radioactive waste disposal.

The entire process of re-entry and recovery could destroy the county financially but the real danger is that a full and proper response is beyond the ability of the local government.

14. The first priority during a response to a radiological emergency will be the transportation of children, the sick and the elderly. This means a complete evacuation of the Monroe Public Schools, Airport Community Schools, Jefferson Schools, all parochial schools, all private schools, pre-schools, Mercy-Memorial Hospital, and all nursing care facilities. A minimal estimate of the school children involved is 15,500, and 1100 people will need evacuation from nursing homes and hospitals. The combined capacity of the buses of Monroe Public Schools, Jefferson Schools, Airport Community Schools and Lake Erie Transportation Commission is 9685. In addition, roughly 2800 people will need public transportation to leave the area. In rough figures, 20,000 people must be transported by vehicles which can carry only 10,000.

Help from out county schools will be very limited since Bedford, Milan, Mason, Dundee and Ida will be transporting their children home.

Reliance on buses and trucks coming from a distance away from the EPZ creates increased hazard to children, the sick and elderly.

15. It is unfortunate that the county's two hospitals are within the EPZ. As stated previously, it will be very difficult to use buses to transport patients. There is also an alarming lack of ambulances available. In addition to the transportation problem, no thorough evaluation of the availability of hospital beds to relocate the very ill have been done. This need is compounded by the possibility of illness and accidents occurring during the evacuation.

16. The proposed plan never addresses the protection and care of farm livestock and other animals.

17. Numerous agencies and volunteer organizations are involved in the evacuation. A partial listing includes:

a. Law Enforcement Agencies
b. Fire Departments
c. Health Department
d. Hospital staffs
e. Department of Social Services
f. School Personnel
g. Red Cross
h. Salvation Army
i. Road Commission
j. Planning Department

This means a tremendous number of individuals are involved in the evacuation process. Unfortunately many of these people have families living inside the EPZ which they will want to care for during an emergency. This, combined with a general reluctance to enter a radioactive area, places these emergency workers under a great deal of pressure.