APPENDIX 15A

SUMMARY OF METHODS USED FOR EVALUATING RADIOLOGICAL EFFECTS OF ACCIDENTS

15A.1 THE ANALYTICAL METHOD FOR CALCULATING DOSES

15A.1.1 Introduction

The analytical techniques used in the original license application to calculate radiological effects from each of the major accidents are described in this Appendix.

The sources of radiation considered in these various accident analyses are: (1) the noble gases and their external whole-body dose effect, (2) the halogens and the resulting thyroid dose from inhalation, (3) volatile solids (cesium, rubidium, selenium, arsenic, antimony, molybdenum and tellurium) resulting in lung dose from inhalation, and (4) bone dose from inhalation of the nonvolatile solids (all others).

Various meteorological conditions have been examined to give a spectrum of radiological effects during the poor diffusion conditions of inversion and the better diffusion conditions of lapse or unstable. Six points in the meteorological spectrum are examined; these are (1) very stable and moderately stable each at a wind speed of 2 mph, (2) neutral conditions at wind speeds of 2 and 10 mph, and (3) unstable conditions at wind speeds of 2 and 10 mph.

Wind direction persistence and variability of direction were considered in radiological effects analysis. Persistence of direction was assumed for 15 hours duration. Various values of the diffusion parameter, the product of standard deviation of wind direction fluctuation, and average wind speed were assumed to exist for the entire 15 hour period of persistent direction.

15A.1.2 General

Radiological effects of the control rod drop, fuel loading, and Loss-of-Coolant Accidents were evaluated at distances of 1/4, 1/2, 1, 2, 5 and 10 miles from the plant. The first distance is approximately the site boundary with other distances given to illustrate the decrease with distance of the various radiological effects.

Since airborne materials are released via the stack, the effects at distances less than 1/4 mile for any diffusion condition are far less for all modes of exposure except that from the passing cloud. At such short distances, the plume has not yet reached ground level so that exposure from inhalation and from deposition is very small. The passing cloud effect, however, remains nearly constant due to essentially line-source geometry of the plume overhead.

Two special cases of radiological effects are also shown for the fuel loading and Loss-of-Coolant Accidents. One is the effect of direct radiation from the airborne fission products contained in the Reactor Building. The effect in this case is shown at the plant site boundary, and involves no meteorological considerations. The main steam line break in the Turbine Building is the second special case evaluated. The steam escaping the Turbine Building would initially rise at a rapid rate due to buoyancy. Even as the steam cloud mixed with the surrounding air, it would remain less dense than the normal atmosphere. Measurements of the altitudes to which hot clouds will rise when released at ground level have been made at Brookhaven National Laboratory.(1) The equation developed in the experiments indicates that the cloud would rise to a centerline height of 4090 feet with a 2 mph (1 m/sec) wind, to 819 feet with a 10 mph (5m/sec) wind and to 164 feet with a 50 mph (22 m/sec) wind. Because of the large change in maximum dose with change in height of release, a 50 mph wind results in the maximum ground level doses for the accident and is assumed for the analysis. The release is assumed to be from a point source, located at the side of the Turbine Building, 25 feet above ground plus 140 feet due to a cloud rise for a total of 165 feet. The diffusion calculations are performed for unstable meteorological conditions, using the analytical techniques described in this section. The doses are also calculated by the methods described in this section.

With the Standby Gas Treatment System designed to provide a negative pressure of 0.25 inch of water in the Reactor Building, a wind of around 40 mph (18 m/sec) is necessary to get exfiltration. Winds of this speed are very infrequent and do not last long. Therefore, the doses which could result during such a wind condition are not included in the accident analyses.

15A.1.3 <u>Meteorological Diffusion Evaluation Methods</u>

The radiological effects of secondary containment leakage via the stack were evaluated at six points in the atmosphere diffusion spectrum, which

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(1) Singer, I.A., Frizzola, J.A., and Smith, M.E., "The Prediction of the Rise of a Hot Cloud From Field Experiments," Journal of the Air Pollution Control Association (November 1964).

(2) Fuquay, J.J., Simpson, C.L., and Hinds, W.T., "Prediction of Environmental Exposures from Sources Near the Ground, Based on Hanford Experimental Data," Journal of Applied Meteorology, Volume 3, No. 6 (December 1964).

should encompass the conditions encountered at the reactor site. These are the poor diffusion conditions caused by inversion (stable), at a wind speed of about 2 mph, typical of warm weather nights, for both very stable and moderately stable conditions, and the better diffusion conditions, typical of daytime, represented by neutral and unstable (lapse) diffusion, both at wind speeds of 2 and 10 mph. The atmospheric diffusion methods reported in the Journal of Applied Meteorology(2) were used.

15A.1.3.1 Height of Release

Leakage from the Secondary Containment via a 368 foot (112 meter) stack takes optimum advantage of atmospheric dispersion. The effective height of release is the sum of the stack height plus any effluent rise due to momentum and buoyancy. However, momentum and buoyancy are small in this case: thus, the calculations were made by assuming the height of release to be only 368 feet, i.e., the stack height.

15A.1.3.2 Diffusion Conditions

In using the referenced diffusion methods, an important parameter to be chosen is the product of the average wind speed and wind direction variability over the period of interest. This is given as the product of the standard deviation of the horizontal wind direction fluctuations and the average wind velocity. Combined with the stability condition assumed, specification of this diffusion parameter permits calculation of air concentrations at various distances from the source.

A value of 12.8 degree-mph for the diffusion parameter is considered a reasonably pessimistic value of this parameter, and was used to describe the horizontal spreading of the plume for the 2 mph wind cases. A value of 12.8 degree-mph for this parameter was chosen to evaluate the effects during 10 mph conditions.

15A.1.3.3 Wind Direction Persistence

Inherent in the choice of the parameter, is the restriction that wind direction be unvarying within some specific direction increment (for example 22½ degrees). Since the diffusion values chosen are typical for a 1 hour period, and since larger values would be applicable to longer periods, in general, a choice of persistent wind direction (number of continuous hours) must be made during which the diffusion values chosen could be expected to apply. Therefore, for poor diffusion conditions, a wind direction persistence for 15 hours was assumed and is believed to be quite conservative when used with a value of 12.8 degrees-mph and a 2 mph wind speed. The basis for choosing 15 hours of persistent wind can be seen from Table 15A-1-1 which was taken from unpublished work by the U.S. Weather Bureau.[3] As can be seen from the table, persistent wind for as long a period of time as 15 hours occurs only about 1 percent of the time or less at the sites examined. The sites listed include flat terrain, coastal and lake shore sites, and some valley locations. For a 10 mph wind, a value of the diffusion parameter of 128 degree-mph corresponds to a standard deviation of 12.8 degrees which is quite similar to the value of 6.4 degrees for the 2 mph case. Thus, approximately the same amount of wind variability is being considered and the 15 hour persistent assumption appears equally applicable although slightly more conservative. Refer to Table 15A-1-1.

15A.1.3.4 Cloud Dispersion Calculations

The diffusion coefficients were used in calculating cloud dispersion. In these calculations, horizontal cloud growth is expressed by the standard deviation of width as discussed in Reference (4). Vertical cloud growth, as defined by the standard deviation of height, has been calculated in accordance with the methods presented in Reference (4) for the stable case, and in Reference (5) for the neutral and unstable cases.

The diffusion constants which were used for these calculations are presented in Table 15A-1-2. The calculated values of cloud dispersion were used in the Gaussian equation for X/Q to calculate concentrations in air at various down wind distances.(5)

The conventional "reflection" factor of 2 usually applied for releases from ground level was not included. For passing cloud dose, which is primarily a gamma dose, the entire cloud volume was integrated as an

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(3) Pack, D.H., Angell, J.K., vander Hoven, I., and Slade, D.H., Unpublished data discussed in "Recent Developments in the Application of Meteorology to Reactor Safety," Paper A/CONF/28/P/714, Geneva Conference on Peaceful Uses of Atomic Energy (1964).

(4) Fuquay, J.J., Simpson, C.L., and Hinds, W.T., "Prediction of Environmental Exposures from Sources Near the Ground, Based on Hanford Experimental Data," Journal of Applied Meteorology, Volume 3, No. 6 (December 1964).

(5) Watson, E.C., and Gamertsfelder, C.C., "Environmental Radioactive Contamination as a Factor in Nuclear Plant Siting Criteria," HW-SA-2809 (February 14, 1963).

"infinite" number of point sources to plus and minus infinity in the z-direction, ignoring interception by the ground, so that the entire cloud volume is included. Inhalation doses are a function of concentration at the ground and subject to "reflection" effects if they exist. Since the materials of interest in inhalation effects deposit on the ground, it is doubtful that "perfect" reflection will occur, but rather the cloud will expand distorting the Gaussian mass distribution of the cloud thus resulting in, at most, a small increase in concentration. In addition, no account was taken of the better diffusion at the ground (effective on the portion of the cloud near the ground) compared to the stack exit elevation used. The Manual of Meteorology and Atomic Energy, AECU 3066, shows that compared to an elevation of 200 meters, ground-level diffusion coefficients are larger by about a factor of 2, thus proportionally increasing diffusion. In any event, an increase by a factor of less than 2 but perhaps more than 1 may be a result of this "reflection" effect. A factor of 1.0 was used in this analysis.

No distinction in the choice of the diffusion parameter was made between the first 2 hour period for which doses are calculated, as compared to the period of interest for total accident dose calculations. This is inconsistent because larger values of this parameter are quite obviously appropriate for the longer time period. That is, the values used, as discussed in Subsection 15A.1.3.2, are for 1 hour periods, and thus are somewhat conservative when applied to the 2 hour period dose calculation and are markedly conservative for the total accident (15 hour) calculation.

15A.1.3.5 Cloud Depletion and Ground Deposition

The fallout concentrations of radioactive materials were determined on the basis of particle settling by eddy diffusion only, since settling by gravity is expected to be negligible in this case.

The extent of halogen and solid fission product deposition on the ground is a function of the apparent deposition velocity, which, in turn, is considered to be a function of the diffusion condition and wind speed. Deposition velocities used in this evaluation were based on British results cited in HW-SA-2809 and given in Table 15A-1-3. These values of the deposition velocity are used in the calculation of the cloud depletion term defined as Q/Q_o in Subsection 15A.1.3.4.

15A.1.3.6 Precipitation Washout

Cloud depletion as a result of precipitation washout could cause ground deposition of an otherwise elevated cloud. The dose from this type of fallout on the ground was calculated for each accident. Washout rates commonly used give the same results as from the dry deposition rates used in Subsection 15A.1.3.5 for a ground release in the stable case.

Thus, the calculation of deposited concentrations from washout were made by using the same diffusion conditions as in the other dose calculations, but assuming a ground release. This is not to say that rain occurs during stable conditions or that a ground-level release actually is assumed, but merely that this approach was taken as a way of calculating deposited quantities using the same diffusion model.

15A.1.3.7 Calculated Air Concentrations

The methods described in the previous sections were used to calculate integrated air concentrations (micro-Ci/sec/cc) from a unit release of 1 curie. Tables 15A-1-4 and 15A-1-5 show the values calculated for the six different meteorological conditions assumed for a release height of 368 feet and 0 feet respectively.

15A.1.3.8 Application to Radiological Effects Calculation

The diffusion and wind direction persistence conditions determine the method of application to a certain extent. Since 15 hours of wind persistence is considered, and since both the coolant-loss accident and the fuel-loading accident postulate leakage for much longer periods, the 15 hour time increment where the maximum integrated leakage occurs in each case is the period of interest in determining total accident effects (doses). In the case of the 2 hour dose, the first 2 hours of integrated leakage is used to calculate the dose, assuming persistent wind during the entire period.

In the case of the control rod drop accident almost 100 percent of the total noble gases released are released within the first 15 hours (actually all in first 2 hours); approximately 99 percent of the total halogens released are also released in this first 15 hour period. About 55 percent and 25 percent of the total noble gases and halogens, respectively, are released during the first 15 hour period in the fuel-loading accident. This is the maximum quantity of halogens released in any such 15 hour time increment for this accident. The 15 hour period of maximum leakage in the Loss-of-Coolant Accident analysis occurs between 10 hours and 25 hours after onset of the accident. During this time, 14 percent of the noble gases, 15 percent of the halogens, 75 percent of the volatile solids, and 72 percent of the other solids are released.

Thus, the corresponding number of curies released in the maximum 15 hour period in each case is taken as the amount transported in one general direction and the dose therefrom is calculated.

The remaining fraction, in each case, is assumed to be spread around the site rather uniformly in different directions accompanied by the more frequently occurring highly variable wind patterns common to most locations. It is recognized that a portion of this remaining leakage assumed to be widely spread may diffuse in the same direction as that during which the 15 hour persistent wind occurred. However, reduced leakage, increased horizontal and vertical spreading due to stability changes and greater direction variability during the remainder of the leakage period all combine to make any such added incremental transport of material (and dose) small compared to the doses calculated by the methods described.

15A.1.4 Radiological Effects Calculation Methods

The downwind radiological effects (see Tables 15A-1-1 through 15A-1-3), such as ground deposition and inhalation exposure, are a function principally of the integrated air concentration at any point. Calculation of this integrated concentration has been described in preceeding sections. This section describes the conversion of air concentration to radiation dose of the various kinds considered.

15A.1.4.1 Passing Cloud Dose

The ground level whole body gamma dose from an elevated plume of radioactive materials may be considered as the sum of the doses from all points in the plume. The source strength of each point or incremental volume is equal to the product of the integrated air concentration in volume (micro-Ci/sec/cc) times the incremental volume of the cloud which may be considered as a point source (CC), and the total source is the integral of this term over an infinite space.

The flux from a point source considering buildup in the air is a function of the source strength, a buildup factor (which is in turn a function of the total absorption coefficient, the energy absorption coefficient and the distance from the source), the total absorption coefficient and the distance from the source. The gamma dose rate from a flux is a function of the energy, the flux, and the energy absorption coefficient. From these factors, an expression representing a monoenergetic source is developed for the total dose from the plume. This expression is solved by numerical methods.

15A.1.4.2 Inhalation Dose

The dose due to inhalation of the cloud is calculated by first determining the quantity inhaled and then multiplying by the conversion factor of dose per unit amount inhaled. A value of 230 cc/sec is taken as the standard average breathing rate from ICRP.

The dose conversion factor for a unit amount inhaled is calculated from ICRP. In ICRP the permissible body burden which is equivalent to a permissible dose rate (weekly, quarterly, yearly dose rate) for each isotope is given. Considering the effective half-life of the isotope in the critical organ (or any other organ) permits calculation of the lifetime dose to the organ. Since the permissible body burden refers to total quantity in the body, some factor to account for the fraction of total burden which is in an organ of interest must be applied. This factor is also given by ICRP. Additionally, to convert quantity breathed to quantity deposited in the organ of interest, an additional factor from ICRP is used. Thus the dose from inhalation is calculated from an expression which is a function of the quantity inhaled, the organ deposition factors and the mean life of an isotype in the organ.

Values for the dose conversion factor for a unit amount inhaled are given in Tables 15A-1-6 through 15A-1-8 for the halogen, volatile solid, and nonvolatile solid mixtures. In the case of the halogens and nonvolatile solids, the isotopes are assumed to be soluble so that the thyroid and bone are the critical organs, respectively. The volatile solids are assumed insoluble so that the lung is the critical organ.

15A.1.4.3 Fallout Dose

The fallout dose is almost entirely due to the halogens because of their larger assumed release fraction and the larger deposition velocity assigned to them. Fallout dose is calculated by determining the deposition in (Ci/m^2) and multiplying by the dose rate conversion factor (R xRad/h/curie/m^2) and integrating over the decay during the time of dose received.

Values of the dose rate conversion factor (R) are given in Table 15A-1-2 for various gamma energies. Since these values are for an infinite plane source and the cloud size and deposition pattern is not infinite, a correction factor must be applied. The correction factor is given in Table 15A-1-3.

TABLE 15A-1-1
(Sheet 1 of 1)

DOSE COMPUTATIONAL METHODS WIND DIRECTION PERSISTENCE
(ONE SECTOR - 22-1/2°)

Station	Direction	Frequency of Duration Equaled or Exceeded in Hours[a] 50%	10%	1%	0.1%	Most Hours	Most Hours[b] In Any Direction	
Augusta, Georgia	W	2	3	8	13	18	W	18
Birmingham, Alabama	S	2	4	9	16	16	SSE	20
Chicago, Illinois	SSW	2	5	12	21	22	NNE	25
Little Rock, Arkansas	SSW	2	4	9	17	28	SSE	28
Phoenix, Arizona	E	2	3	6	9	12	E	12
Rochester, New York	WSW	2	6	13	23	28	WSW	28
Salt Lake City, Utah	SSE	2	4	7	13	15	S	17
San Diego, California	NW	2	6	12	16	17	WNW	33
Tampa, Florida	ENE	2	3	7	13	14	SSW	18
Yakima, Washington	W	2	5	8	14	17	WNW	19
Rochester, Minnosota	WNW	2	6	15	25	33	E	37

(a) Direction examined is the one showing greatest frequency of persistent winds.

(b) Most hours observed may not be same direction as direction showing most frequency of persistent winds.

TABLE 15A-1-2
(Sheet 1 of 1)

DOSE COMPUTATIONAL METHODS
DIFFUSION CONSTANTS USED

Stability	Wind Speed (m/sec)	a (m^2)	b (m^2/sec)	k^2 (sec^{-2})	C_z ($m^{n/2}$)	n
Very stable	1	34	0.025	$8.8x10^{-4}$	-	-
Moderately stable	1	97	0.33	$2.5x10^{-4}$	-	-
Neutral	1	-	-	-	0.15	0.25
Neutral	5	-	-	-	0.12	0.25
Unstable	1	-	-	-	0.30	0.20
Unstable	5	-	-	-	0.26	0.20

TABLE 15A-1-3
(Sheet 1 of 1)

DOSE COMPUTATIONAL METHODS
DEPOSITION VELOCITIES

Meteorology	Wind Velocity (m/sec)	Ratio of Deposition Velocity to Wind Velocity: Particles	Ratio of Deposition Velocity to Wind Velocity: Halogens	Deposition Velocity (cm/sec): Particles	Deposition Velocity (cm/sec): Halogens
Very stable	1	1.5×10^{-4}	2.4×10^{-3}	0.015	0.24
Moderately stable	1	2.2×10^{-4}	3.4×10^{-3}	0.022	0.34
Neutral	1	3.0×10^{-4}	4.6×10^{-3}	0.03	0.46
Neutral	5	3.0×10^{-4}	4.6×10^{-3}	0.15	2.3
Unstable	1	6.0×10^{-4}	8.0×10^{-3}	0.06	0.8
Unstable	5	6.0×10^{-4}	8.0×10^{-3}	0.3	4.0

TABLE 15A-1-4
(Sheet 1 of 1)

DOSE COMPUTATIONAL METHOD
UNIT INTEGRATED AIR CONCENTRATION

Distance, Miles		Air Concentration, Micro curies/cc per curie/sec released					
		VS-2*	MS-2	N-2	N-10	U-2	U-10
1/4	Noble Gases	(1)	$3.5x10^{-16}$	$3.5x10^{-11}$	$7.3x10^{-16}$	$4.9x10^{-6}$	$2.3x10^{-7}$
	Particles	(1)	$3.5x10^{-16}$	$3.5x10^{-11}$	$7.3x10^{-16}$	$4.9x10^{-6}$	$2.3x10^{-7}$
	Halogens	(1)	$3.5x10^{-16}$	$3.5x10^{-11}$	$7.3x10^{-16}$	$4.9x10^{-6}$	$2.3x10^{-7}$
1/2	Noble Gases	(1)	$3.2x10^{-12}$	$3.6x10^{-7}$	$5.9x10^{-9}$	$1.1x10^{-5}$	$1.1x10^{-6}$
	Particles	(1)	$3.2x10^{-12}$	$3.6x10^{-7}$	$5.9x10^{-9}$	$1.1x10^{-5}$	$1.1x10^{-6}$
	Halogens	(1)	$3.2x10^{-12}$	$3.6x10^{-7}$	$5.9x10^{-9}$	$1.1x10^{-5}$	$1.1x10^{-6}$
1	Noble Gases	(1)	$2.0x10^{-9}$	$4.3x10^{-6}$	$3.0x10^{-7}$	$5.5x10^{-6}$	$7.3x10^{-7}$
	Particles	(1)	$2.0x10^{-9}$	$4.3x10^{-6}$	$3.0x10^{-7}$	$5.5x10^{-6}$	$7.3x10^{-7}$
	Halogens	(1)	$2.0x10^{-9}$	$4.2x10^{-6}$	$3.0x10^{-7}$	$5.4x10^{-6}$	$7.1x10^{-7}$
2	Noble Gases	(1)	$8.2x10^{-8}$	$3.4x10^{-6}$	$4.8x10^{-7}$	$2.0x10^{-6}$	$3.1x10^{-7}$
	Particles	(1)	$8.2x10^{-8}$	$3.4x10^{-6}$	$4.8x10^{-7}$	$2.0x10^{-6}$	$3.1x10^{-7}$
	Halogens	(1)	$8.2x10^{-8}$	$3.4x10^{-6}$	$4.7x10^{-7}$	$1.9x10^{-6}$	$2.9x10^{-7}$
5	Noble Gases	$5.0x10^{-17}$	$6.5x10^{-7}$	$1.1x10^{-6}$	$2.1x10^{-7}$	$4.8x10^{-7}$	$8.7x10^{-8}$
	Particles	$5.0x10^{-17}$	$6.5x10^{-7}$	$1.1x10^{-6}$	$2.1x10^{-7}$	$4.8x10^{-7}$	$8.6x10^{-8}$
	Halogens	$5.9x10^{-17}$	$6.4x10^{-7}$	$1.1x10^{-6}$	$2.0x10^{-7}$	$4.4x10^{-7}$	$7.9x10^{-8}$
10	Noble Gases	$5.6x10^{-12}$	$9.4x10^{-7}$	$4.3x10^{-7}$	$8.7x10^{-8}$	$1.7x10^{-7}$	$3.3x10^{-8}$
	Particles	$5.6x10^{-12}$	$9.4x10^{-7}$	$4.2x10^{-7}$	$8.7x10^{-8}$	$1.7x10^{-7}$	$3.2x10^{-8}$
	Halogens	$5.6x10^{-12}$	$9.0x10^{-7}$	$3.9x10^{-7}$	$7.9x10^{-8}$	$1.5x10^{-7}$	$2.9x10^{-8}$

Notes

(1) Less than 1×10^{-20}

Legend

*VS-2 very stable, 2-mph wind
MS-2 moderately stable, 2-mph wind
N-2 neutral, 2-mph wind
N-10 neutral, 10-mph wind
U-2 unstable, 2-mph wind
U-10 unstable, 10-mph wind

TABLE 15A-1-5
(Sheet 1 of 1)

DOSE COMPUTATIONAL METHOD
INTEGRATED AIR CONCENTRATION - GROUND SOURCE*

Distance, Miles	Air Concentration, microcuries/cc per curie/sec released	
	Halogens	Particulates
1/4	$5.1x10^{-4}$	$5.4x10^{-4}$
1/2	$2.0x10^{-4}$	$2.2x10^{-4}$
1	$7.3x10^{-5}$	$9.0x10^{-5}$
2	$2.7x10^{-5}$	$3.7x10^{-5}$
5	$7.1x10^{-6}$	$1.2x10^{-5}$
10	$2.5x10^{-6}$	$5.7x10^{-6}$

* Used to calculate fallout doses from precipitation without case. Moderately stable 2 mph used with a diffusion parameter of 12.8 degree-mph. This does not mean that a ground source is assumed, but rather that this is used to obtain ground deposition values from washout.

TABLE 15A-1-6
(Sheet 1 of 1)

RADIOBIOLOGICAL FACTORS FOR HALOGENS

Isotope	Half Life(1)	Effective Half Life(2)	E (gamma) (Mev)	E (beta) (Mev)	E_{eff} (Mev)(3)	k (Rem/microcurie)(4)
I-131	8.05d	7.0d	0.39	0.191	0.23	1.48
I-132	2.3h	2.3h	1.992	0.434	0.65	5.35×10^{-2}
I-133	21h	21h	0.444	0.45	0.14	4.0×10^{-1}
I-134	53m	53m	1.27	0.6	-	2.5×10^{-2}
I-135	6.7h	6.7h	1.54	0.308	0.066	1.24×10^{-1}

(1) Radioactive half-life
(2) Effective half-life in the thyroid from ICRP
(3) Effective energy in the thyroid from ICRP
(4) Dose per Microcurie inhaled

TABLE 15A-1-7
(Sheet 1 of 1)

RADIOBIOLOGICAL FACTORS FOR
VOLATILE SOLID RADIOISOTOPES

Isotope	Half Life[1]	Effective Half Life[2]	E (gamma) (Mev)	E (beta) (Mev)	E_{eff} (Mev)[3]	k (Rem/microcurie)[4]
Mo-99	66h	66h	0.24	0.376	0.45	8.7×10^{-3}
Te-127m	105h	105h	0.0885	0	0.083	6.0×10^{-2}
Te-127	9.3h	9.3h	-	0.23	0.24	6.4×10^{-4}
Te-131	25m	25m	0.475	0.577	0.73	8.5×10^{-5}
Te-132	78h	78h	0.231	0.073	0.13	2.9×10^{-3}
Cs-134	2.1y	120d	1.41	0.52	0.074	6.1×10^{-2}
Cs-137	30y	138d	0	0.192	0.192	1.8×10^{-1}

(1) Radioactive half-life
(2) Effective half-life in the lung from ICRP
(3) Effective energy in the lung from ICRP
(4) Dose per Microcurie inhaled

TABLE 15A-1-8
(Sheet 1 of 1)

RADIOBIOLOGICAL FACTORS DOSE COMPUTATIONAL METHODS NONVOLATILE SOLID RADIOISOTOPES

Isotope	Half Life(1)	Effective Half Life(2)	E (gamma) (Mev)	E (beta) (Mev)	E_{eff} (Mev)(3)	k (Rem/ Microcurie)(4)
Sr-89	50.4d	50.4d	0	0.487	0.49	$5.5x10^{-2}$
Sr-90	28y	17.53y	0	0.2	1.1	6.65
Sr-91	9.7h	9.7h	0.845	0.533	3.3	$2.9x10^{-3}$
Y-90	64.2h	64.2h	-	0.73	4.4	$1.7x10^{-2}$
Y-91	59d	59d	0.551	0	2.9	$2.5x10^{-1}$
Zr-95	65d	59.5d	0.733	0.127	0.57	$6.7x10^{-2}$
Nb-95m	90h	59.5d	0.235	0	3.8	$1.8x10^{-1}$
Nb-95	35d	33.8d	0.745	0.053	0.36	$9.5x10^{-3}$
Ru-103	40d	2.4d	0.473	0.08	0.43	$1.6x10^{-4}$
Ru-106	1.0y	15d	-	0.013	0.013	$3.0x10^{-5}$
Rh-105	36h	1.39d	0.032	0.183	0.86	$1.9x10^{-4}$
Ba-140	12.8d	10.7d	0.237	0.268	1.5	$2.4x10^{-2}$
La-140	40.2m	1.68d	2.11	0.495	2.7	$3.5x10^{-3}$
Ce-141	32.5d	31d	0.097	0.163	0.17	$3.1x10^{-3}$
Ce-143	33h	1.33d	0.344	0.355	2.2	$1.7x10^{-3}$
Ce-144	285d	243d	0.043	0.087	1.3	$1.9x10^{-1}$
Pr-143	13.7d	13.7d	0	0.311	1.6	$1.7x10^{-2}$
Nd-147	11.1d	11.1d	0.286	0.228	1.2	$9.5x10^{-3}$
Pm-147	2.7y	570d	-	0.074	0.22	$8.9x10^{-2}$
Pm-149	53h	2.2d	0.285	0.35	1.9	$2.9x10^{-3}$
Np-239	2.35d	2.35d	0.72	0.395	0.63	$1.3x10^{-3}$
Pu-240	$6.76x10^{3}y$	$1.95x10^{3}y$	0.011	0	0.88	$9.88x10^{1}$

(1) Radioactive half-life
(2) Effective half-life in the bone from ICRP
(3) Effective energy in the bone from ICRP
(4) Dose per Microcurie inhaled

APPENDIX 15B

DOSES AT THE SITE BOUNDARY FROM A WASTE GAS SYSTEM RUPTURE ACCIDENT

APPENDIX 15B

DOSES AT THE SITE BOUNDARY FROM A WASTE GAS SYSTEM RUPTURE ACCIDENT

15B.1 DOSE CALCULATION

a. Using the assumed source terms and SJAE discharge rate, the CORN computer code was used to calculate the inventory of radionuclides in each component of the Gaseous Waste System (GWS). Each components inventory was then considered as an individual release with the appropriate assumed X/Q. (See Table 15.7-1)

b. The beta surface dose for a semi-infinite cloud was calculated using the Regulatory Guide 1.3 model.

c. The Gamma surface dose was calculated by a three energy group summation (see Section 15.9).

   These relations were applied to each isotope for each GWS component, and then summed. The results are presented in Table 15.7-1.

d. The Skin Dose (SD) was calculated from Gamma and Beta by the relation:

   SD = (1.0) Gamma + (.78) Beta*

e. The Whole Body Dose (WBD) is set equal to Gamma. Section 15.9 defines the WBD as that fraction of Gamma & Beta that penetrate 5 cm of tissue. At these energies 5 cm of tissue effectively absorbs all the Betas and a negligible amount of Gammas.

15B.2 CONCLUSION

The final doses (as tabulated in Table 15.7-1) are below the 0.5 rem limit for WBD, and the 3.0 rem limit for SD, stated in Regulatory Guide 1.29.

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*From page 332 of "Meteorology and Atomic Energy", which states that only 78 percent of all Betas penetrate the dead skin layer, wheras 100 percent of all Gammas do so.