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# Jersey Central Power & Light Company

MADISON AVENUE AT PUNCH BOWL ROAD • MORRISTOWN, N. J. 07960 • 201-539-6111

MEMBER OF THE General Public Utilities Corporation SYSTEM

May 17, 1974



Mr. Donald J. Skovholt
Assistant Director for
Operating Reactors
Directorate of Licensing
Office of Regulation
U.S. Atomic Energy Commission
Washington, DC 20545

Dear Mr. Skovholt:

SUBJECT: OYSTER CREEK NUCLEAR GENERATING STATION
DOCKET NO. 50-219
RADIOACTIVE WASTE MODIFICATION

On September 20, 1973, we submitted a report entitled "Preliminary Description and Analyses of Proposed Modifications to the Gaseous, Liquid and Solid Radioactive Waste Treatment Systems for the Oyster Creek Nuclear Generating Station." Your letter dated October 10, 1973 requested additional information in connection with this report. This information was submitted on December 13, 1973.

Subsequent to the Staff review of the above submittals, a meeting was held in your offices on February 21, 1974 to discuss the AEC position. It was acknowledged at this meeting, and later reaffirmed in a March 5, 1974 letter, that the review of the liquid and solid radwaste systems was completed and that the systems, as described, were acceptable.

The Regulatory Staff review of the offgas system found the design unacceptable because the Staff analysis indicated that following a postulated Safe Shutdown Earthquake (SSE), the system would result in a two hour whole body dose at the site boundary in excess of 5 Rem. Since the assumptions for these calculations differed from those which we had used, the Staff calculations resulted in higher dose values. The results of the Staff's calculations indicated that a seismic category I, quality group C system design would be required to comply with Regulatory Guides 1.29 and 1.26, respectively.

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It is our position that the accident dose calculations which we performed to justify the augmented offgas system design were based on very conservative assumptions and that the results presented in our supplementary response of December 13, 1973 do in fact provide reasonable assurance that the dose at the site boundary will not exceed 5 Rem if the plant were subjected to an SSE. We believe that the alternative analysis performed by the Staff is not appropriate since excessively conservative assumptions were used. In particular, the AEC use of semi-infinite cloud geometry for calculating the gamma dose instead of the conservative but more realistic finite cloud geometry, coupled with the beta and gamma surface dose being equated to the whole body dose, leads to calculated values which are more than a factor of 10 higher than would be calculated using more realistic yet still conservative assumptions. In addition, we believe that the assumption that 100% of the total activity contained in the offgas system is released in the first two hours is also excessively conservative and unrealistic. Further, it is our position that the Staff assumptions are not being applied within the content of the Regulatory Guides which are based on the dose "to the whole body or its equivalent to any part of the body" and not on the total beta plus gamma surface dose.

The attached report entitled "Offsite Dose Rates from Offgas System Failure" is submitted for your detailed review and evaluation. This report provides the technical justification for using the finite cloud meteorological model for calculations of gamma dose and for considering the beta dose as contributing to skin dose only. On this basis, the resultant dose calculation provides assurance that the whole body dose or its equivalent to any part of the body at the site boundary will be significantly below 5 Rem, and in fact will be below 0.5 Rem.

Since your March 5, 1974 letter states that the Staff has no further questions on our proposed modifications to the liquid and solid radwaste systems, we will be able to adhere to our present schedule for this work. We estimate that the modifications to these systems will be completed during the summer of 1977 and that a detailed FSAR submittal will be submitted on December 15, 1974.

The augmented offgas system described in our September 20, 1973 report was a quality group D, seismic category II design. We estimate a 12 to 15 month delay in our scheduled in-service date of July 1976 should quality group C and seismic category I design requirements be imposed. In addition to the schedule impact, cost estimates for this redesign show an increase in capital cost from $5.85 million for a quality group D, seismic II to $11.8 million for a quality group C, seismic I system.

As a result of the delays resulting from the ongoing design reviews, an FSAR amendment describing the quality group D, seismic II offgas system, (if acceptable) which was originally scheduled for May 15, 1974, cannot be submitted until August 1, 1974.

Very truly yours,

Ivan R. Finfrock, Jr.
Vice President

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## OFFSITE DOSE FROM OFFGAS SYSTEM FAILURE

The site boundary dose resulting from an SSE was calculated assuming the complete failure of the proposed Augmented Offgas (AOG) System and the existing delay pipe with the resulting release of the contained radioactive inventory. In addition, the Condenser Steam Jet Air Ejectors (SJAE) were assumed to continue to operate for 10 minutes, exhausting directly to the atmosphere in the turbine building.

1.0 Assumptions

1) The SJAE activity release rate to the delay pipe was 260,000 μCi/sec (measured at an age of 30 minutes) for a sufficient time interval before the SSE to reach equilibrium activity inventories in the delay pipe and all of the equipment in the AOG system. Operating experience has indicated annual average release rates substantially lower than 100,000 μCi/sec, however, to be conservative this analysis was performed assuming the plant Technical Specification Limit of 260,000 μCi/sec.

2) The SJAE's continued to release activity at the rate of 260,000 μCi/sec (measured at an age of 30 minutes) to the atmosphere, within the turbine building, for 10 minutes after the SSE.

3) The gas flow rate through the delay pipe is:

| | | |
|---|---|---|
| Condenser air inleakage | - | 20 SCFM |
| Radiolytic $H_2$ | - | 85.4 SCFM |
| Radiolytic $O_2$ | - | 42.7 SCFM |
| Water Vapor | - | 22.8 SCFM |
| Total | | 170.9 SCFM |

After the recombiner the total gas flow rate is reduced to the condenser air inleakage of 20SCFM.

4) A conservative estimate of the transport time of the active cloud released from the delay pipe or the SJAE's to the site boundary is a minimum of 5 minutes. Hence, noble gas isotopes with half lives ($T-\frac{1}{2}$) less than 30 seconds are considered not to contribute to the site boundary dose.

5) The proposed AOG building is located 274 meters from the nearest site boundary resulting in a X/Q of $7.0 \times 10^{-3}$ $sec/m^3$ for AOG releases.

6) The delay pipe's closest approach to the site boundary is at the plant 112 meter stack resulting in a X/Q of $4.6 \times 10^{-3}$ $sec/m^3$ for delay pipe releases.

7) The SJAE's release into the turbine building resulting in a X/Q of $2.3 \times 10^{-3}$ $sec/m^3$ for SJAE releases.

8) 100% of the contained activity of all the equipment, except charcoal beds, within the AOG system and the delay pipe were released to the atmosphere at ground level within the first two hours after the SSE. For the charcoal beds, 50% of the contained noble gases were similarly released.

Basis for the above assumptions are given in Appendix I.

## 2.0 Method of Calculation

### 2.1 Source Terms

The standard G.E. isotope mix as given in Table I of G.E. report NEDO-10734 and normalized to 260,000 μCi/sec at T=30 min is used. The isotope mixture at T=0 is assumed to flow from the SJAE's into the delay pipe and then to the AOG system. The gas flow rates through the system are given in assumption No. 3.

A Burns & Roe developed computer code, CORN* (Concentration Of Radioactive Nuclides), is used to calculate the inventories of the radioactive isotopes in each of the pieces of equipment in the AOG system and in the delay pipe. The results of this calculation are given in Table I.

### 2.2 Dose Calculations

#### 2.2.1 Beta Surface Dose (B)

The beta surface dose is calculated using the semi-infinite cloud model given in Regulatory Guide 1.3. A semi-infinite cloud model is justified for betas because of their relatively short range in air.

$$B = 0.23\ \bar{E}_B \left(\frac{X}{Q}\right) Q \qquad (1)$$

Where: B = Beta surface dose - rad

$\bar{E}_B$ = Total beta energy per disintegration - mev/dis

* A brief description of CORN is given in Appendix II.

$X/Q$ = Meteorological dilution factor - $sec/m^3$

$Q$ = Total Curies released (from Table I) - Ci

The value of $\bar{E}_B$ used in the calculation for each nuclide considered is given in Table II. Equation (1) is applied to each isotope and then summed over all isotopes to give the total beta surface dose. The total beta surface dose at the site boundary from each piece of equipment is given in Table 1.

2.2.2 Gamma Surface Dose ($\gamma$)

The gamma surface dose is calculated using the finite cloud model described in Section 7-5.23 of Meteorology and Atomic Energy - 1968. A semi-infinite cloud model is not justified for gammas with source to site boundary distances less than 5000 meters due to the great range of gamma rays in air. A complete justification for the use of a finite cloud model for the gamma dose is given in Appendix III.

$$\gamma = \gamma_\infty \sum_{j=1}^{3} C_j f_j \qquad (2)$$

Where: $$\gamma_\infty = 0.25\ \bar{E}_\gamma \left(\frac{X}{Q}\right) Q \qquad (3)$$

$\bar{E}_\gamma$ = Total gamma energy emitted per disintegration - mev/dis

$\frac{X}{Q}$ = Meteorological dilution factor - $sec/m^3$

$Q$ = Total Curies released (from Table I) - Ci

$C_j = \gamma/\gamma_\infty$ for gamma energy group j

$f_j$ = Fraction of total gamma energy emitted within energy group j

$\gamma$ = Gamma surface dose from finite cloud - rad

$\gamma_\infty$ = Gamma surface dose from semi-infinite cloud (from Regulatory Guide 1.3) - rad

The values of $\bar{E}_\gamma$ used in this calculation for each nuclide is given in Table II. The values of $C_j$ are a function of the gamma energy and the cloud characteristic dimension $\sigma_y$. Those values are obtained from Fig 7.16 of Meteorology and Atomic Energy - 1968. The values of $C_j$ used in this calculation are given in Table III as a function of X/Q, which defines the cloud dimension $\sigma_y$. The total gamma energy per disintegration for each isotope is divided into three energy groups and the fraction of gammas in each group, $f_j$, determined. The energy group structure used in these calculations was selected to be compatible with the above reference and is as follows:

| Group No. | Energy Range - mev | Assigned Group Energy-mev |
|---|---|---|
| 1 | $\leq .4$ | 0.1 |
| 2 | $0.4 < E < 1.35$ | 0.7 |
| 3 | $\geq 1.35$ | 2.0 |

Equations (2) and (3) are applied to each isotope in the cloud and then summed over all isotopes to give the total gamma surface dose. The total gamma surface dose at the site boundary from each piece of equipment is given in Table I.

## 3.0 Whole Body and Skin Dose at Site Boundary

The Whole Body Dose (WBD) and the Skin Dose (SD) are derived from the beta surface dose (B) and the gamma surface dose ($\gamma$) as follows:

$$SD = 0.78B + 1.0\gamma \qquad (4)$$

$$WBD = \gamma \qquad (5)$$

The justification for using equations (4) and (5) for calculating WBD and SD is given in Appendix IV. Table I lists the whole body dose (WBD) and skin dose (SD) from the postulated SSE releases from the offgas system.

## 4.0 Conclusion

The whole body dose per equation (5) above is 0.189 rem. This whole body dose is less than the 0.5 rem limit for whole body exposures stated in regulatory guide 1.29. This whole body dose is also significantly less than the 5 rem whole body dose limit for backfit plants, as stated in the letter from AEC to JCP&L dated 3/5/74.

The skin dose per equation (4) above is 2.53 rem. This skin dose is less than the 3.0 rem limit for the skin. The dose limit of 3.0 rem is the dose equivalent to the skin of 0.5 rem to the whole body (see Appendix IV). The skin dose is also less than the 5 rem limit stated in the letter from AEC to JCP&L dated 3/5/74.

Since the dose limits of regulatory guide 1.29 for both the whole body and the skin are not exceeded, a seismic category II system is justified.

Similarly, the whole body dose from failure of the first charcoal bed, the component with the highest radioactivity inventory in the AOG system, is 78 mrem. This dose is less than the 500 mrem limit for quality D components as stated in the proposed revision to regulatory guide 1.26. The skin dose from this component is 1.06 rem and is also less than the 3 rem skin dose equivalent of 500 mrem whole body dose.

Hence, we believe that due to the nature of conservative assumptions and the conservative calculational model used, a seismic category II system and quality group D components are justified..

TABLE I

DOSE SUMMARY

| No. | Equipment | Inventory (ci) | Surface Dose, (MREM) Gamma | Surface Dose, (MREM) Beta | Skin Dose (MREM) | Whole Body Dose (MREM) |
|---|---|---|---|---|---|---|
| 1 | Delay Pipe | 938.66 | 48.45 | 511.56 | 447.47 | 48.45 |
| 2 | Hepa Filter | 1.73 | 0.22 | 1.28 | 1.22 | 0.22 |
| 3 | Pre-Heater | 0.49 | 0.03 | 0.37 | 0.31 | 0.03 |
| 4 | Re-Combiner | 2.67 | 0.16 | 1.97 | 1.70 | 0.16 |
| 5 | Condenser | 18.39 | 1.09 | 13.63 | 11.72 | 1.09 |
| 6 | Water Separator | 4.53 | 0.28 | 3.32 | 2.87 | 0.28 |
| 7 | Moisture Separator | 1.65 | 0.10 | 1.21 | 1.04 | 0.10 |
| 8 | Dryer | 8.95 | 0.55 | 7.09 | 6.08 | 0.55 |
| 9 | Charcoal Bed-1 | 7320.00 | 77.74* | 1261.93* | 1062.04* | 77.74* |
| 10 | Charcoal Bed-2 | 3217.8 | 20.63* | 355.77* | 298.13* | 20.63* |
| 11 | Charcoal Beds-3 to 8 | 6711.00 | 25.43* | 658.28* | 538.89* | 25.43* |
| Offgas System (1 to 11) | | 18225.87 | 174.68 | 2816.41 | 2371.47 | 174.68 |
| 10 Min. Release from SJAE | | - | 14.81 | 179.15 | 154.55 | 14.81 |
| Total | | - | 189.49 | 2995.56 | 2526.02 | 189.49 |

*These values are based on a release to the environment of 50% of the contained inventory of radioactive gases.

TABLE - II

RADIONUCLIDE ENERGY DATA

| ISOTOPE | $\bar{E}_\beta$ | $\bar{E}_\gamma$ | $f_1$ | $f_2$ | $f_3$ |
|---|---|---|---|---|---|
| KR-83m | 0.0 | 8.400E-04 | 1.0 | 0.0 | 0.0 |
| -85m | 0.208 | 0.163 | 1.0 | 0.0 | 0.0 |
| -85 | 0.226 | 2.200E-03 | 0.0 | 1.0 | 0.0 |
| -87 | 1.067 | 0.696 | 0.0 | 0.775 | 0.225 |
| -88 | 0.331 | 2.070 | 0.331 | 0.166 | 0.503 |
| -89 | 1.049 | 1.05 | 0.168 | 0.512 | 0.32 |
| -90 | 1.07 | 0.786 | 0.348 | 0.451 | 0.201 |
| XE-131m | 0.0 | 5.500E-03 | 1.0 | 0.0 | 0.0 |
| -133m | 0.0 | 3.200E-02 | 1.0 | 0.0 | 0.0 |
| -133 | 0.115 | 3.050E-02 | 1.0 | 0.0 | 0.0 |
| -135m | 0.0 | 0.528 | 0.0 | 1.0 | 0.0 |
| -135 | 0.300 | 0.261 | 0.97 | 0.03 | 0.0 |
| -137 | 1.312 | 0.305 | 0.0 | 1.0 | 0.0 |
| -138 | 0.800 | 0.42 | 0.0 | 1.0 | 0.0 |
| -139 | 0.0 | 0.33 | 0.896 | 0.104 | 0.0 |

TABLE - III

DISPERSION AND CORRECTION FACTORS

| RELEASE FROM | (X/Q) (Sec./$m^3$) | $C_1$ | $C_2$ | $C_3$ |
|---|---|---|---|---|
| AUGMENTED OFFGAS BLDG. | $7.0 \times 10^{-3}$ | 0.063 | 0.054 | 0.038 |
| DELAY PIPE | $4.6 \times 10^{-3}$ | 0.091 | 0.073 | 0.052 |
| STEAM JET AIR EJECTORS | $2.3 \times 10^{-3}$ | 0.118 | 0.104 | 0.073 |

## APPENDIX I

### Basis for the Assumptions Given in Section 1.0

Assumptions 1, 2, 3 and 4 - Radioactive Noble Gas Sources

These assumptions are identical to those used by DOL in its evaluation of the Oyster Creek Gaseous Radwaste System Releases. Assumptions 1, 2 and 3 are from references (a) and (b) and discussions held on February 21, 1974.

Assumptions 5, 6 and 7 - Meteorology and Dilution Factors

The (X/Q) values or meteorological dilution factors for this gaseous radwaste system is significantly (about 1.5 to 3 times) more conservative than the meteorology considered for a loss of coolant accident in Regulatory Guide 1.3.

The X/Q value listed in assumptions 6 and 7 are those calculated by the Regulatory Staff and given to JCP&L during the discussions held on February 21, 1974. The X/Q value in assumption 5 is higher than the Regulatory Staff value due to the relocation of the AOG system building to a position slightly closer to the site boundary than the Regulatory Staff used in their calculations.

Assumption 8 - Percentage Release of Activity

The theoretical and experimental studies by First and Underhill, et. al.[2] show small percentages of release of noble gases. For example, assuming a break at the front end of the adsorber, theoretical studies at higher pressures on the order of 10 atmospheres accounted for only 15% of total activity release. Experimental observations

showed lower release rates than predicted by the studies. For operation at lower pressures, on the order of 1.2 atmospheres, significantly lower release rates are predicted.

Another extremely conservative theoretical approach is to consider a charcoal bed failure resulting in the release of Kr and Xe gases due to the instantaneous increase in charcoal bed temperature from 40°F, its lowest operating temperature, to 100°F, the highest expected ambient temperature. Based on the change in $K_D$ caused by the temperature change indicated, a percentage release rate of 50% to 67% can be calculated as the hypothetical maximum release. However, to obtain this high release percentage, infinite concentration and temperature gradients are necessary. Since these gradients are not infinite, it would be realistic to choose a small fraction of the above percentages to estimate releases during the first two hours following the postulated failure. In the interest of conservatism, a 50% release rate for noble gases is assumed.

Release of noble gases due to burning of the charcoal in the adsorber is not considered due to:

1. high ignition temperature of charcoal (320°F),
2. low ignition sensitivity (0.1),
3. limited diffusion of oxygen to limited surface area and,
4. lack of explosive or flammable mixtures needed for initiation of another event.

Ref. 1 - Underhill, D.W., "Effect of Rupture in a Fission.Gas Holdup Bed", Proceedings of the Twelfth AEC Air Cleaning Conference (Conf. 720823, Vol. 1) page 60.

Ref. 2 - First, M.W., Underhill, D.W., et. al., "Semi-Annual Progress Report - Issued April 1972", COO-3019-1, Harvard Air Cleaning Laboratory, Harvard University, Mass., page 31

## APPENDIX II

### Description of CORN Program

The program CORN evaluates the concentration of radioactive nuclides in the effluents of equipment such as the recombiner, charcoal adsorber, etc., in which exists a steady state continuous flow. This program also evaluates the inventories of the radioactive nuclides, energy release rates and radiation source strengths in each piece of equipment.

The inputs to the program consist of two sets of data. The first set which is generally common to many problems is the nuclear data which consists of the half life of each nuclide, radioactive decay chain data and energy release rates during radioactive decay. The second set of data which varies from problem to problem consists of process and equipment data such as flow rates, residence times, input concentrations, equipment volume, etc.

### THEORY

Consider a typical continuous plug flow system with or without processing in an equipment, as shown in Figure 1.1.

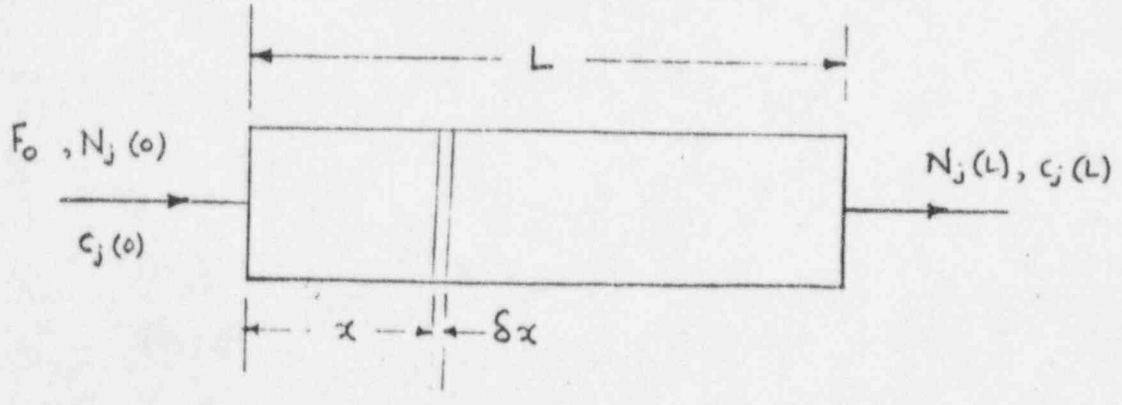


Figure 1.1

Applying an isotopic balance across a small section $\delta x$ for an isotope; entering the section at a distance x and time t and simplifying, we got the partial differential equation for the concentration of j as

$$\frac{\partial c_j}{\partial t} + \frac{F_o}{A}\frac{\partial c_j}{\partial x} - \lambda_j\left(\sum_{K=1}^{\gamma} c_K B_K - c_j\right) = o \qquad (1)$$

with $\frac{\partial c_j}{\partial t} = o$ for all x

and

$c_j = c_j(o)$ for all t at $x = o$

where

$c_j$ is the concentration of isotope j in $\mu$Ci/cc

t is time in secs

$F_o$ is the flow rate in ccs/sec

A is the area of cross section for flow, $cm^2$

x is the distance transported, cm

$\lambda_j$ is the decay constant of isotope j

$B_K$ is the branching ratio for isotope j from the parent isotope K of $\gamma$ parent isotopes.

Equation (1) was simplified to the form of a set of n ordinary differential equations for n isotopes in a decay chain as

$$\frac{dN_j}{d\tau} = \sum_{K=1}^{\gamma} \lambda_K N_K B_K - \lambda_j N_j \quad , j = 1, \cdots, n \qquad (2)$$

with

$$N_j = N_j(o) \quad \text{at} \quad \tau = o \qquad (3)$$

where

$$N_j = \frac{C_j a}{\lambda_j} \text{ is the concentration in atoms/cc} \quad (4)$$

$$\tau = (V/F_o) \text{ is the residence time in secs} \quad (5)$$

and $a$ is the conversion factor from $\mu$Ci to disintegrations/sec

Using equations (1) to (5) the CORN program calculates the concentrations. To account for the increased residence times for isotopes like Kr, Xe and Iodine in a charcoal adsorption bed, $\theta$ is used instead of $\tau$ as

$$\theta = d_f \tau \quad (6)$$

where

$$d_f = \frac{\text{Actual Residence Time of the Isotope}}{\text{Bulk Flow Residence Time}} \quad (7)$$

For equipment like charcoal adsorbers and filters, equations (6) and (7) were also used in evaluating the effluent concentrations.

To obtain the inventory in each equipment, the following equations are used. For parent isotope i, the inventory in $\mu$Ci is given by

$$I_i = \frac{F_o(C_{oi} - C_{ei})}{\lambda_i} \quad (8)$$

and for any daughter isotope i from its parent isotope $(i - 1)$, the inventory is evaluated from

$$I_i = \frac{F_o(C_{oi} - C_{ei})}{\lambda_i} + I_{(i-1)} B_{(i-1)} \quad (9)$$

where I is the inventory in $\mu$Ci and the subscripts o and e indicate the conditions of the inlet and effluent streams.

# APPENDIX III

## Justification for Finite Cloud Model

The gamma dose from immersion in a hemispherical cloud of uniform gamma activity can be expressed by the following equation:

$$D = \frac{KS}{2\mu}(1-e^{-\mu R}) \qquad (1)$$

where: D= Dose rate - mr/hr

K= Flux to dose conversion factor - mr/hr per mev/$m^2$- sec

$\mu$= Attenuation coefficient of gamma ray in air - $m^{-1}$

S= Volumetric source - mev/$m^3$

R= Cloud dimension - m

For a semi-infinite cloud, R = $\infty$ and equation (1) becomes:

$$D_\infty = \frac{KS}{2\mu} \qquad (2)$$

The ratio of the dose from a finite cloud to semi-infinite cloud is:

$$\frac{D}{D_\infty} = \frac{\frac{KS}{2\mu}(1-e^{-\mu R})}{\frac{KS}{2\mu}} = 1-e^{-\mu R} \qquad (3)$$

For the dose from a finite cloud to be within 10% of the dose for a semi-infinite cloud:

$$\frac{D}{D_\infty} = 0.9 = 1-e^{-\mu R}$$

and $e^{-\mu R} = 0.1$

When $e^{-\mu R} = .1$, $\mu R = 2.303$

Taking a very conservative low value for the average gamma energy of only .4mev gives a value of $\mu = 1.22 \times 10^{-2}\ m^{-1}$ for air. Therefore the cloud dimension required for the finite cloud dose to be within 10% of the semi-infinite cloud dose is $R = \frac{2.303}{1.22\times10^{-2}} = 189m$. For this cloud dimension, the distance from the source to the site boundary would have to exceed 5000 meters. The AOG building is 274 meters from the nearest site boundary. This results in a X/Q of $7\times10^{-3}$ sec/$m^3$ and an average cloud radius, R, of 10.2 meters. Using this value for R in equation (3) gives:

$$\frac{D}{D_\infty} = 1-e^{-(1.22\times10^{-2})(10.2)}$$

$$= 0.12$$

or the semi-infinite dose model would over estimate the gamma dose by a factor of 8.

To be conservative, equation (1) was derived assuming air attenuation without buildup and a uniform source strength throughout the cloud. A more rigorous treatment including air buildup and the correct source strength distribution is described in Section 7 - 5.2.3 of Meteorology and Atomic Energy - 1968. Fig. 7.16 in that section gives values of $\frac{D}{D_\infty}$ as a function of $\bar{\sigma}y$, the cloud characteristic radius, for several gamma energies. At an energy of .4 mev, $D/D_\infty$ does not reach 0.9 until the cloud radius exceeds 430 meters. Thus the more rigorous treatment results in a larger value of required cloud radius for the finite cloud model dose to be within 10% of the dose from the semi-infinite cloud model than does the simpler treatment based on equation (1).

## APPENDIX IV

Definition of Whole Body and Skin Dose

The whole body and skin dose to a person immersed in a cloud of beta and gamma activity is defined in WASH-1258- Final Environmental Statement - ALAP Vol. 2 pages F-16 and F-17 as follows:

Skin Dose - The fraction of the $\beta + \gamma$ surface dose that penetrates the dead skin surface layer equivalent to 7 mg/cm$^2$.

Whole Body Dose - The fraction of the $\beta + \gamma$ surface dose that penetrates through a 5 cm depth in tissue.

The fraction of the beta dose that penetrates 7 mg/cm$^2$ is 0.78, (obtained from Fig. 7.5 on page 332 of Meteorology and Atomic Energy - 1968). The attenuation of 7 mg/cm$^2$ for gamma rays is negligible and therefore the skin dose is $0.78\beta + 1.0\gamma$, where $\beta$ and $\gamma$ are the calculated beta and gamma surface doses respectively.

The beta surface dose is fully attenuated by 5 cm of tissue. The whole body dose can therefore be conservatively assumed equal to the gamma surface dose, no credit being taken for the small amount of attenuation expected through the 5 cm tissue depth.

Regulatory Guides 1.26 and 1.29 dose limits are stated as "dose to the whole body or the equivalent to any part of the body." The equivalency factor between skin dose and whole body dose is 6. This factor is from paragraph 20.101 of 10CFR20. Therefore, the .5 rem dose limit to the whole body in Regulatory Guides 1.26 and 1.29 leads to an equivalent skin dose of 3 rem.