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Grout Treatment Facility
Airborne Emissions Proctions

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7. Abstract

The purpose of this document is to provide Grout Treatment Facility airborne emissions information to support the Grout Treatment Facility Safety Anaylsis Report (SAR) and submissions to environmental regulatory agencies with jurisdiction under the *Clean Air Act*.

Airborne emissions of organic chemicals and radionuclides to the environment, from the operation of the Grout Treatment Facility, are projected and compared to regulatory requirements.

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GROUT TREATMENT FACILITY AIRBORNE EMISSIONS PROJECTIONS

1.0 PURPOSE AND SUMMARY

The purpose of this document is to provide Grout Treatment Facility (GTF) airborne emissions information to support the GTF Safety Analysis Report (SAR) and submissions to environmental regulatory agencies with jurisdiction and/or delegation under the *Clean Air Act of 1977*.

The scope of this document includes the calculation of airborne organic chemical and radioactive material emissions from the proposed operation of the GTF while grouting double-shell tank (DST) waste. For the purposes of Subpart H of the National Emission Standards for Hazardous Air Pollutants (NESHAP) (EPA 1985), promulgated pursuant to Section 112 of the *Clean Air Act*, modeling of anticipated and potential radioactive airborne emissions is conducted to determine offsite dose from projected emissions.

Conservative estimates for organic chemical emissions indicate expected releases of approximately 590 kg/yr (1,300 lb/yr) from the Grout Processing Facility (GPF) and 27,320 kg/yr (60,100 lb/yr) from the vault operations at the Grout Disposal Facility (GDF). Anticipated radioactive airborne emission estimates were modeled to result in doses of 3.7×10^{-8} seivert (3.68×10^{-3} mrem/yr) effective dose equivalent (EDE) to the maximally exposed offsite individual. Potential (i.e., uncontrolled during full operation) radioactive airborne emission estimates were modeled to result in doses of 1×10^{-6} seivert (1.04×10^{-1} mrem/yr) EDE to the maximally exposed offsite individual.

Subsequent sections of this review discuss calculation of emissions based upon operational parameters and waste source term, modeling of dose commitment, and resultant emission and dose commitment of proposed operations as compared to specific regulatory standards.

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2.0 CALCULATIONAL METHODS

The approaches to the calculation of radionuclide and organic chemical emissions within this document are similar. Both share common methods for the calculation of constituent concentration in the waste feed and the grout, and use the same effluent vapor temperatures, ventilation rates, and duration of emissions. Differences in calculational methods are a result of the availability, or lack thereof, of representative empirical data on constituent vapor concentrations. Vapor concentrations of radionuclides are based on empirical data while concentrations of organic chemicals are based on accepted predictive methods (AIChE 1983).

2.1 95% CONFIDENCE MEAN WASTE CONCENTRATIONS

Clean Air Act requirements address the determination of average annual emissions. Thus, the use of 95% confidence mean concentrations of organic chemicals and radionuclides present in grouted wastes in these and future calculations is necessary to ensure that the mean concentrations are equal to or less than those represented with a 95% certainty. The 95% "student's t" method of evaluation was applied with two degrees of freedom. A 95% confidence mean concentration of a radionuclide in DST waste is evaluated as:

$$C_i = \text{mean } C_i + (\text{S. Dev.})_i \times [t_{95}(\text{d.f.})/\text{sqrt}(n)] \qquad [1]$$

where:

C_i	=	Constituent concentration, Ci/L or mg/g;[1]
t_{95}(d.f.)	=	The 95% confidence level factor from the "student's t" table for (d.f.) degrees of freedom;
n	=	the number of samples; and,
d.f.	=	n - 1 = 2.

Example: Tritium

$$C_{3_H} = 7.0 \times 10^{-6} + 5.2 \times 10^{-6} \times [2.92/\text{sqrt}(3)]$$
$$= 1.58 \times 10^{-5} = 1.6 \times 10^{-5} \text{ Ci/L}$$

Example: Citric Acid

$$C_i = 1.4 + 2.5 \times [2.92/\text{sqrt}(3)] = 5.615 = 5.6 \text{ mg/g}$$

---

[1]Conversion factors, such as those from curies to the internationally accepted SI units of becquerels, are contained in Appendix Attachment 8. Units used within the text of this document are those of the applicable regulations.

Table 2-1 contains the radionuclide source term data from Hendrickson (1990) as amended by the radioactive daughters (ENDF/B-VI 1989) and calculated 95% confidence mean concentrations of source term constituents. Table 2-2 contains the organic chemical source term data from Hendrickson (1990) and calculated 95% confidence mean concentrations of source term constituents.

2.2 SINGLE CAMPAIGN AND ANNUAL EMISSION RATES

Annual (i.e., chronic) emissions are the basis for evaluation under the *Clean Air Act*. For the purposes of the *Clean Air Act* and this document, annual process emission rates are the emissions from a single campaign times the number of campaigns projected to be conducted annually.

Single campaign emission rates were calculated on the following bases:

- 95% Confidence mean concentrations in the grout
- The effluent concentration of the constituent in terms of
  - Vapor/grout partition fraction for radionuclides
  - Partial vapor pressures for organic constituents
  - Resuspension for organic constituents.
- The vapor temperature
- Ventilation rate
- Decontamination factor
- Duration of emission.

Due to the flexibility of dose modeling, radionuclide process emissions were initially calculated in terms of dose per curie emitted per year. Organic chemical and radionuclide emissions resulting from maintenance were calculated in annual terms.

Three process operations were considered as routine emission contributors: the GPF exhauster stack and both active and stagnant vault ventilation of the GDF. Active vault ventilation is that ventilitation occuring while grout feed is being actively transferred into a vault. Stagnant vault ventilation is that ventilation of a vault which contains curing grouted waste, but which is not actively receiving grout. Radioactive emissions resulting from maintenance are considered as nonroutine emission contributors. Each of these emission calculation bases is discussed below for these operations.

Table 2-1. Grout Treatment Facility Radionuclide Source Term.

Radionuclide	Adjusted mean concentration (Ci/L)	Sample standard deviation (Ci/L)	95% Conf. mean concentration (Ci/L)
^{3}H	7.0 E-06	5.2 E-06	1.6 E-05
^{14}C	8.4 E-07	1.6 E-07	1.1 E-06
^{60}Co	1.1 E-05	9.9 E-06	2.8 E-05
^{79}Se	6.7 E-06	1.1 E-05	2.5 E-05
^{90}Sr	6.6 E-03	2.7 E-03	1.1 E-02
^{90}Y			1.1 E-02
^{94}Nb	1.0 E-05	1.5 E-05	3.5 E-05
^{99}Tc	7.7 E-05	7.3 E-06	8.9 E-05
^{106}Ru	4.3 E-03	7.4 E-03	1.7 E-02
^{106}Rh			1.7 E-02
^{129}I	1.7 E-07	7.9 E-08	3.0 E-07
^{134}Cs	1.2 E-03	2.1 E-03	4.7 E-03
^{137}Cs	3.1 E-01	3.5 E-02	3.7 E-01
^{137m}Ba			3.5 E-01
^{234}U	1.2 E-08	1.2 E-08	3.2 E-08
^{235}U	7.0 E-10	8.2 E-10	2.1 E-09
^{238}U	8.2 E-09	4.6 E-09	1.6 E-08
^{237}Np	5.8 E-08	8.8 E-08	2.1 E-07
^{238}Pu	4.3 E-07	2.2 E-07	8.0 E-07
$^{239/240}Pu$	9.0 E-07	4.9 E-07	1.7 E-06
^{241}Am	1.4 E-06	3.5 E-07	2.0 E-06
^{244}Cm	7.7 E-08	9.9 E-08	2.4 E-07
Total			7.75 E-01

9 1 1 2 0 5 7 0 4 0 6

Table 2-2. Grout Treatment Facility, Organic Chemical Source Term.

Chemical	Adjusted mean concentration (mg/g)	Sample standard deviation (mg/g)	95% Confidence mean conc. (mg/g)
n-$C_{22}H_{46}$ - n-$C_{40}H_{82}$	2.8 E-03	4.8 E-03	1.1 E-02
n-$C_{22}H_{46}$ - n-$C_{34}H_{70}$	1.4 E-03	2.4 E-03	5.4 E-03
Alkyl, hydroxymethylbenzene	1.7 E-04	2.9 E-04	6.6 E-04
Methyltoluidine	3.3 E-04	5.7 E-04	1.3 E-03
n-Dimethyltoluidine	1.1 E-03	1.9 E-03	4.3 E-03
2-Chloromethyl, hydroxymethylbenzene	1.2 E-03	2.0 E-03	4.6 E-03
2-Chloromethyl-o-xylene	6.2 E-04	1.1 E-03	2.5 E-03
Ethylxylene	3.0 E-05	5.2 E-05	1.2 E-04
Ethyl, 2-methyl, hydroxymethylbenzene	4.4 E-03	7.5 E-03	1.7 E-02
2-Methylhydroxymethylbenzene	3.3 E-02	5.7 E-02	1.3 E-01
C_3-alkylbenzene	3.0 E-02	5.2 E-02	1.2 E-01
Propylbenzene	1.7 E-04	2.9 E-04	6.6 E-04
Trimethylbenzene	7.3 E-03	1.3 E-02	2.9 E-02
Ethylbenzaldehyde	6.5 E-02	1.1 E-01	2.5 E-01
Methylbenzaldehyde	6.5 E-02	1.1 E-01	2.5 E-01
Diethylphthalates	9.4 E-04	1.6 E-03	3.6 E-03
Unknown phthalates	2.7 E-03	2.9 E-03	7.6 E-03
Dioctylphthalates	2.5 E-03	3.7 E-03	8.7 E-03
Chloroethyl, 2-hydroxymethylbenzoic acid	1.2 E-03	2.0 E-03	4.6 E-03
2-Hydroxymethylbenzoic acid	2.6 E-03	4.4 E-03	1.0 E-03
2-Methylbenzoic acid	1.7 E-03	2.9 E-03	6.6 E-03

Table 2-2. Grout Treatment Facility, Organic Chemical Source Term.

Chemical	Adjusted mean concentration (mg/g)	Sample standard deviation (mg/g)	95% Confidence mean conc. (mg/g)
Butanedioic acid	3.9 E-02	6.8 E-02	1.5 E-01
n-Dodecane	6.1 E-04	5.7 E-04	1.6 E-03
Dodecanoic acid	1.3 E-04	2.3 E-04	5.2 E-04
EDTA	3.4 E-01	5.7 E-01	1.3 E+00
ED3A	3.0 E-03	4.1 E-03	9.9 E-03
HEDTA	1.3 E+00	2.3 E+00	5.2 E+00
MICEDA	2.9 E-03	4.9 E-03	1.1 E-02
MAIDA	5.4 E-02	9.3 E-02	2.1 E-01
Ethanedioic acid	3.9 E-01	6.8 E-01	1.5 E+00
Hydroxyacetic acid	8.0 E-01	1.4 E+00	3.2 E+00
NTA	1.5 E-03	1.6 E-03	4.2 E-03
Heptadecanoic acid	2.3 E-04	3.9 E-04	8.9 E-04
Heptanedioic acid	2.6 E-03	4.4 E-03	1.0 E-02
Hexadecanoic acid	1.2 E-04	2.0 E-04	4.6 E-04
Hexanedioic acid	7.0 E-03	9.6 E-03	2.3 E-02
Hexanoic acid	4.1 E-03	7.0 E-03	1.6 E-02
Octadecanoic acid	5.8 E-05	1.0 E-04	2.3 E-04
n-Pentadecane	4.6 E-04	5.3 E-04	1.4 E-03
Pentadecanoic acid	3.3 E-03	5.7 E-03	1.3 E-02
Pentanedioic acid	6.6 E-03	1.1 E-02	2.5 E-02
Tri-n-butyl phosphate	5.5 E-03	5.8 E-03	1.5 E-02
[(Tri-n-butyl)di-ol] phosphate	1.1 E-03	1.8 E-03	4.1 E-03

9 1 1 2 0 5 7 0 4 0 8

Table 2-2. Grout Treatment Facility, Organic Chemical Source Term.

Chemical	Adjusted mean concentration (mg/g)	Sample standard deviation (mg/g)	95% Confidence mean conc. (mg/g)
Citric acid	1.4 E+00	2.5 E+00	5.6 E+00
n-Tetradecane	1.9 E-03	1.7 E-03	4.8 E-03
n-Tridecane	3.4 E-03	3.1 E-03	8.6 E-03
n-Undecane	5.2 E-04	7.7 E-04	1.8 E-03
Total	4.6 E+00		1.82 E+01

2.2.1 Grouted Waste Concentrations

From the formulation criteria of Hendrickson (1990), grouted waste concentrations will be 1/1.43 that of the 95% confidence mean concentrations. Concentrations of organic chemicals, in terms of mg/g, are converted to units of mass per unit volume through the 95% confidence mean density of 1.406 g/cm^3 resulting in an overall dilution factor of 0.809 for dry materials addition of 1.08 kg/L (9 lb/gal).

2.2.2 Constituent Effluent Concentrations

2.2.2.1 Radionuclides: Vapor/Grout Partition Fraction. Emission rates of radionuclides are dependant upon the distribution of the radionuclide between the vapor space and grout slurry. Conservative partition fractions (PF) for non-tritium radionuclides were derived from the characterization of actively filling, mixed, and stagnant tank vapor space and slurry concentrations (Kimura and Lindsey 1987). Partition fractions for tritium were derived from the assumption that tritium is homogeneously distributed among water molecules and OH^- radicals and that the water content of the exhaust stream is that of air at 100% relative humidity for operating temperatures of 45 and 70 °C (113 and 158 °F).

Tank vapor spaces of nine underground tanks at the U.S. Department of Energy Hanford Site were sampled to characterize airborne radionuclides present as gases and particulate matter (Kimura and Lindsey 1987). Comparable to the operations anticipated in the grouting of DST waste, tanks sampled included: stagnant tanks, tanks undergoing active filling (transfer), and tanks mixed with airlift circulators. Sampling results were expressed as ratios of vapor to liquid concentration (partition fractions) for given radionuclides.

In application, it is deemed that the vapor space concentration of a radionuclide is equal to the grouted concentration of the radionuclide multiplied by the partition fraction appropriate to the operation and radionuclide. Partition fractions used for ^3H (see vapor temperature discussion below and Appendix Attachment 1) are 9.80×10^{-5} for GPF and maintenance operations and 2.94×10^{-4} for vault operations. Non-tritium partition fractions used in the calculations for stagnant and active vault operations are the mean value of empirical partition fractions for that operation. Thus, partition fractions used for other radionuclides during active operation are 1.81×10^{-9}, during stagnant and maintenance operations are 1.72×10^{-11}, and during GPF operation are 2.49×10^{-9} (the highest measured PF from mixed tanks). Conservatively, the resultant vapor space concentration is assumed to remain unaffected by ventilation in each of the three routine operations, and is equivalently replaced hourly in maintenance operations.

Other discussions of release factors for radionuclides, present in NUREG-1320 (NRC 1988), address only accident scenarios in nuclear fuel cycle facilities and are beyond the scope of concern for *Clean Air Act* permitting matters. Calculation of such release factors under the format of NUREG-1320 is not applicable in this address and is not deemed to supersede the empirical data found in Kimura and Lindsey (1987).

2.2.2.2 Organic Chemicals.

2.2.2.2.1 Partial Vapor Pressure. Emission rates of organic chemicals in these operations are dependant upon the partial pressure of the chemical in the vapor space. Conservatively, equilibrium partial pressures are assumed to exist in the vapor space.

2.2.2.2.2 Particle Entrainment. Annual emission calculations of particulate organic material were conducted in the manner of radionuclide calculations, imposing an arbitrary resuspension factor of 50% rather than a partition fraction. These emissions were found to be insignificant in comparison to vapor phase emissions. The table of Appendix Attachment 2 represents the calculations and results of this modeling. The remainder of organic chemical discussions address only vapor phase emissions.

2.2.3 Vapor Temperature

The temperature of the exhausted vapor, in the range considered, is important in the determination of tritium emissions and of organic chemical partial vapor pressure. Tritium is assumed to be emitted in the form of water vapor with a vapor space concentration of 100% relative humidity. Operating temperatures used were based upon GPF operations and upon grout surface temperature modeling. Temperatures assumed for all calculations were 45 °C (113 °F) during GPF and maintenance operations and 70 °C (158 °F) during vault operations. Under these conditions, the tritium partition fractions are those represented above and the organic chemical partial pressures those represented by calculational example in Section 2.2.7.2.

2.2.4 Ventilation Rates

The portable exhauster design calls for exhaust rates of 330 L/s (700 actual ft^3/min [acfm]), with the rated maximum flowrate of 472 L/s (1000 acfm).

A flow of 335 L/s (710 acfm) from the GPF stack is comprised of three streams: (1) 70.8 L/s (150 acfm) from the surge tank, (2) 28.3 L/s (60 acfm) from the liquid collection tank, and (3) 236 L/s (500 acfm) from the module ventilation. As the bulk of the GPF stack emissions are uncontaminated in the absence of a spill in the module, the partition fractions, partial vapor pressures, and flow rate assumed for the GPF stack are considered highly conservative in estimating emissions.

Ventilation rates (VR) are thus applied in emission calculations as 472 L/s from either active or stagnant vault operations and 335 L/s from the GPF stack. Ventilation rates are not explicitly applicable to module maintenance; however, maintenance emissions of radionuclides are conservatively calculated upon the premise that the total volume of the module airspace is lost upon entry, and that an equivalent contaminant loss occurs for every hour that the module remains open (Section 2.2.7.1.2).

2.2.5 Decontamination Factor

A decontamination factor (DF) is the inverse of one minus the efficiency of control of a control device. Thus, a 90% efficiency of control is represented by a DF of 10, and 99.95% by a DF of 2,000. Decontamination factors used in these calculations are 2,000 for a high-efficiency particulate air (HEPA) filter, 200 for a second sequential HEPA filter (LA-5784 1974), and 10 for a fabric filter. The second and third segments of the GPF stack emissions (see above) are controlled, not by a fabric filter, but by routine spraydown of the mixer module such that standing and spray water would acquire at least the DF of a fabric filter. The vaults are controlled by dual HEPA filters with a total DF of 400,000, while the GPF stack is controlled by dual HEPA filters following a fabric filter (or water spray) for a total DF of 4,000,000. It is noted that tritiated water, gaseous organic chemicals, and radioactive maintenance emissions are not controlled by either of these devices, hence these retain a DF of 1 for all operations.

2.2.6 Duration of Emissions

The duration of operating emissions from any given campaign is applied as the time (t) during which that operation exhausts. It is assumed that active vault operations exhaust for 30 d of fill time. Although the GPF stack is in operation at all times, washing of the mixer, surge tank, and liquid collection tank with approximately six volumes of water and decontamination agents reduces the time of operation under contaminated conditions. Thus, operating exhaust duration for air pollutant considerations from the GPF are similarly assumed to last 30 d. It is further assumed that stagnant vault operations will last 180 d until void fill placement. The air partition fractions are assumed constant and independent of time given the operation. Annual emissions are based on the assumption that four campaigns are conducted annually and that maintenance emissions are as described in Section 2.2.7.1.2.

2.2.7 Example Calculations

2.2.7.1 Emission of ^{137}Cs. Emissions of radionuclides are based on single campaign emissions and annual maintenance emissions.

2.2.7.1.1 Single Campaign Emission of ^{137}Cs.

$$E_i\,[\text{Ci/day}] = C_i\,[\text{Ci/L feed}] \times (\text{L feed}/1.43\ \text{L grout}) \times PF \times VR\,[\text{L/s}] \times (60\ \text{s/min}) \times (1{,}440\ \text{min/day}) / DF \qquad [2]$$

GPF Stack

$$E_{^{137}Cs} = 3.7 \times 10^{-1} \times (1/1.43) \times 2.49 \times 10^{-9} \times 335 \times 60 \times 1{,}440 / 4 \times 10^{6} = 4.65 \times 10^{-9}\ \text{Ci/day}$$

Active Vault

$$E_{^{137}Cs} = 3.7 \times 10^{-1} \times (1/1.43) \times 1.89 \times 10^{-9} \times 472 \times 60 \times 1{,}440 / 4 \times 10^{5} = 4.76 \times 10^{-8} \text{ Ci/day}$$

Stagnant Vault

$$E_{^{137}Cs} = 3.7 \times 10^{-1} \times (1/1.43) \times 1.72 \times 10^{-11} \times 472 \times 60 \times 1{,}440 / 4 \times 10^{5} = 4.52 \times 10^{-10} \text{ Ci/day}$$

$$E_{i,tot}\ [\text{Ci}] = (E_i \times t)_{GPF} + (E_i \times t)_{Act} + (E_i \times t)_{Stg}$$
$$= (4.65 \times 10^{-9} \times 30) + (4.76 \times 10^{-8} \times 30) + (4.52 \times 10^{-10} \times 180)$$
$$= 1.65 \times 10^{-6} \text{ Ci } (6.10 \times 10^{4} \text{ Bq}) \qquad [3]$$

Similar calculations for all other radionuclides, by operation, have been conducted for four vaults per year (simple multiplication by the number of vaults). It should be noted that the diluent factor of grouting (the term 1/1.43) has been applied in determining the tritium partition fractions and should not be reapplied in calculating tritium emissions. The results of these calculations have been tabulated in Table 2-3.

2.2.7.1.2 **Annual Maintenance Emission of ^{137}Cs.** Annual maintenance emissions are based on an assumed uncontrolled release from the air space of the Liquid Collection Tank/Mixer Module during two types of maintenance periods. The air space is assumed to be contaminated to the partition fraction of a stagnant vault and instantaneously lost upon removal of module cover blocks, with an equivalent contaminant volume lost every hour that the module remains open. The airspace volume used, 125.5 m^3, is that of the module, neglecting volume occupied by equipment. The durations and frequency of open module maintenance are expected not to exceed: one planned annual 16-h maintenance operation, four planned 16-h maintenance operations, and four unplanned 4-h maintenance operations. Total calculated emissions from these operations would be those of [(1 x (1 + 16)) + (4 x (1 + 16)) + 4 (1 + 4)] = 105 airspace volumes of each constituent. Truncating and modifying Equation 2 from above:

$$E_i\,[\text{Ci/yr}] = C_i\ [\text{Ci/L feed}] \times (\text{L feed}/1.43\ \text{L grout}) \times PF \times (125.5\ m^3) \times (1{,}000\ \text{L}/m^3) \times (105/\text{yr})$$

Example: Maintenance emissions of ^{137}Cs

$$E_{^{137}Cs} = 3.7 \times 10^{-1} \times (1/1.43) \times (1.72 \times 10^{-11}) \times 125.5 \times 1{,}000 \times 105 = 5.85 \times 10^{-5} \text{ Ci/yr}$$

Table 2-3. Grout Treatment Facility, Radionuclide Emissions Basis: Four Campaigns Per Year.

Radio-isotopes	Active vaults (Ci/yr)	Stagnant vaults (Ci/yr)	GPF Stack (Ci/yr)	Maintenance (Ci/yr)	Total emissions (Ci/yr)
^{3}H	2.26 E+01	1.36 E+02	5.37 E+00	6.10 E-02	1.64 E+02
^{14}C	1.72 E-11	9.80 E-13	1.68 E-12	1.76 E-10	1.96 E-10
^{60}Co	4.29 E-10	2.44 E-11	4.19 E-11	4.39 E-09	4.88 E-09
^{79}Se	3.91 E-10	2.23 E-11	3.82 E-11	4.00 E-09	4.45 E-09
^{90}Sr	1.73 E-07	9.84 E-09	1.69 E-08	1.77 E-06	1.97 E-06
^{90}Y	1.73 E-07	9.84 E-09	1.69 E-08	1.77 E-06	1.97 E-06
^{94}Nb	5.46 E-10	3.12 E-11	5.34 E-11	5.59 E-09	6.22 E-09
^{99}Tc	1.38 E-09	7.88 E-11	1.35 E-10	1.42 E-08	1.58 E-08
^{106}Ru	2.60 E-07	1.48 E-08	2.54 E-08	2.66 E-06	2.96 E-06
^{106}Rh	2.60 E-07	1.48 E-08	2.54 E-08	2.66 E-06	2.96 E-06
^{129}I	4.69 E-12	2.68 E-13	4.59 E-13	4.81 E-11	5.35 E-11
^{134}Cs	7.34 E-08	4.18 E-09	7.17 E-09	7.51 E-07	8.36 E-07
^{137}Cs	5.71 E-06	3.26 E-07	5.58 E-07	5.85 E-05	6.51 E-05
^{137m}Ba	5.40 E-06	3.08 E-07	5.28 E-07	5.53 E-05	6.16 E-05
^{234}U	4.99 E-13	2.85 E-14	4.87 E-14	5.11 E-12	5.68 E-12
^{235}U	3.22 E-14	1.84 E-15	3.15 E-15	3.30 E-13	3.67 E-13
^{238}U	2.47 E-13	1.41 E-14	2.41 E-14	2.53 E-12	2.81 E-12
^{237}Np	3.20 E-12	1.82 E-13	3.12 E-13	3.27 E-11	3.64 E-11
^{238}Pu	1.24 E-11	7.07 E-13	1.21 E-12	1.27 E-10	1.41 E-10
$^{239/240}Pu$	2.67 E-11	1.52 E-12	2.61 E-12	2.74 E-10	3.04 E-10
^{241}Am	3.08 E-11	1.76 E-12	3.01 E-12	3.15 E-10	3.51 E-10
^{244}Cm	3.78 E-12	2.15 E-13	3.69 E-13	3.87 E-11	4.30 E-11
Total	2.26 E+01	1.36 E+02	5.37 E+00	6.11 E-02	1.64 E+02

Similar calculations for all other radionuclides have been conducted for annual maintenance emissions. It should again be noted that the diluent factor of grouting (the term 1/1.43) has been applied in determining the tritium partition fractions and should not be reapplied in calculating tritium emissions. The results of these calculations have been tabulated in Table 2-3.

2.2.7.1.3 Total Annual Emission of ^{137}Cs. Total annual emissions are the sum of four campaigns and annual maintenance emissions. Thus,

$$E_{^{137}Cs} = 4(1.65 \times 10^{-6}) + 5.85 \times 10^{-5} = 6.5084 \times 10^{-5} = 6.51 \times 10^{-5} \text{ Ci/yr.}$$

Total emissions of process operations and maintenance operations are presented as a summary column in Table 2-3.

2.2.7.2 Annual Vapor Phase Emission of Citric Acid from GPF. Worksheet based calculations for the following discussion are presented in the Appendix as Attachments 3 and 4 (Calculational Equations Set 1 and Calculational Equations Set 2 for the GPF and GDF, respectively) with physical properties listed in Appendix Attachment 5.

Note: Equations numbered and lettered below (e.g., [2A-1]) are cited by the same equation number in AIChE (1983). This reference provides that vapor pressure accuracy is given as 2 to 3% error above 15 KPa.

(1) Critical Temperature

$$T_c = \frac{T_b}{[0.567 + \Sigma\Delta_T - (\Sigma\Delta_T)^2]} \qquad [2A\text{-}1]$$

where:

T_c = Critical temperature, kelvins;
T_b = Normal boiling point, kelvins; and
$\Sigma\Delta_T$ = Summation of contributions from various groups or atoms from Table 2A-1 (AIChE 1983).

$$T_c = (302 = 273.15)/[0.567 + 0.397 - (0.397)^2] = 713.2 \text{ K}$$

(2) Reduced Temperature

$$T_r = T / T_c \qquad [4]$$

where:

T_r = Reduced temperature, dimensionless; and

T = System temperature, kelvins.

$$T_r = (45 + 273.15) / 713.2 = 0.446$$

(3) Reduced Boiling Point

$$T_{rb} = T_b / T_c \qquad [5]$$

where:

T_{rb} = Reduced normal boiling point, dimensionless.

$$T_{rb} = (302 + 273.14)/713.2 = 0.806$$

(4) Critical Pressure

$$P_c = (0.101325 \times M)/(0.34 + \Sigma\Delta_p)^2 \qquad [2D\text{-}1]$$

where:

P_c = Critical pressure, megapascals
M = Molecular weight
$\Sigma\Delta_p$ = Summation of contributions for various groups or atoms from Table 2D-1 (AIChE 1983).

$$P_c = (0.101325 \times 192.14)/(0.34 + 1.941)^2 = 3.742 \text{ megapascal}$$

(5) Reduced Pure Component Vapor Pressure

(a) Correlation factor evaluation

$$S(T_r) = 36/T_r + 96.7 \times \log T_r - 35 - T_r^6 \qquad [3A\text{-}4]$$

$$S(T_r) = 36/0.446 + 96.7 \times \log(0.446) - 35 - (0.446)^6 = 11.8$$

$$S(T_{rb}) = 36/T_{rb} + 96.7 \times \log T_{rb} - 35 - T_{rb}^6 \qquad [6]$$

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$$S(T_{rb}) = 36/0.806 + 96.7 \times \log(0.806) - 35 - (0.806)^6 = 0.331$$

$$\alpha_c = \frac{0.136 \times S(T_{rb}) + \log P_c - 5.01}{0.0364 \times S(T_{rb}) - \log T_{rb}} \qquad [3A\text{-}5]$$

where:

α_c = Reidel's constant
P_c = Critical pressure, pascals.

$$\alpha_c = \frac{0.136 \times 0.331 + \log(3.742 \times 10^6) - 5.01}{0.0364 \times 0.331 - \log(0.806)} = 15.24$$

$$\phi(T_r) = 0.118S(T_r) - 7\log T_r \qquad [3A\text{-}2]$$

$$Psi(T_r) = 0.0364S(T_r) - \log T_r \qquad [3A\text{-}3]$$

where $\phi(T_r)$ and $Psi(T_r)$ are correlation terms.

$$\phi(T_r) = 0.118 \times (11.8) - 7 \times \log(0.446) = 3.85$$

$$Psi(T_r) = 0.0364 \times (11.8) - \log(0.446) = 0.78$$

(b) Log of Reduced Pure Component Vapor Pressure

$$\text{Log } P_r^* = -\phi(T_r) - (\alpha_c - 7) \times Psi(T_r) \qquad [3A\text{-}1]$$

where:

at constant T_r,
P^* = Pure component vapor pressure, pascals
P_r^* = Reduced vapor pressure, P^*/P_c.

$$\text{Log } P_r^* = -(3.85) - (15.24 - 7) \times (0.78) = -10.27$$

(6) Pure Component Vapor Pressure

$$P^* = 10^\wedge(P_r^*) \times P_c \times (14.696 \text{ psi/atm} / 101{,}325 \text{ pascal/atm}) \qquad [7]$$

where:

10^(x) is the antilogarithm of value (x).

$$P^* = 10^\wedge(-10.27) \times (3.742 \times 10^6) \times (14.696/101{,}325) = 2.8 \times 10^{-8} \text{ psi}$$

(7) Component Partial Vapor Pressure

$$p_i = x_i \times P^* \qquad [8]$$

where:

p_i = Partial vapor pressure of component i, psi
x_i = Concentration in slurry of component i, g/g, (molar concentration assumed equal to mass concentration).

$$p_i = (5.6 \times 10^{-3} \times 0.809) \times (2.8 \times 10^{-8}) = 1.27 \times 10^{-10} \text{ psi}$$

(8) Component Gas Concentration

$$y_i = p_i \times M_i / (P \times M_{air}) \qquad [9]$$

where:

y_i = Component concentration in vapor space, g/g_{air}
P = System pressure, psi
M_i = Molecular weight of component i
M_{air} = Molecular weight of air.

$$y_i = 1.27 \times 10^{-10} \times 192.14 / (14.696 \times 29) = 5.7 \times 10^{-11} \text{ } g/g_{air}$$

(9) Annual Emission Rate

$$m_i = VR \times \frac{T_{std}}{T} \times \frac{60s}{min} \times \frac{29g\ air}{22.4L\ air} \times \frac{y_i\ g}{g_{air}} \times \frac{1{,}440\ min}{day} \times \frac{t\ days\ of\ oper.}{campaign} \times n\ \frac{campaign}{yr} \times \frac{lb}{454g} \qquad [10]$$

where:

m_i = Annual emission of component i, lb/yr
VR = Ventilation rate, L/s
T_{std} = Standard temperature, kelvins, to convert to standard cubic feet per minute
T = System temperature, kelvins
t = Days of operation per campaign
n = Campaigns per year.

$$m_i = 335 \times (293.15/318.15) \times (60) \times (29/22.4) \times 5.7 \times 10^{-11} \times 1{,}440 \times 30 \times 4 \times (1/454)$$

$$m_i = 5.22 \times 10^{-4}\ lb/yr \quad (2.37 \times 10^{-4}\ kg/yr)$$

Table 2-4 displays the results of these calculational sets for all components and their sum. It should be noted that worksheet calculations were developed to display the following as a minimum: calculated annual emissions or the total quantity of each waste component present in four grout campaigns. In no case did the calculated annual emissions closely approach that of the total quantity of the component.

Table 2-4. GTF Organic Emissions Basis: Four Campaigns Per Year.

Chemical	GDF (lb/yr)	GPF (lb/yr)	Total (lb/yr)
n-$C_{22}H_{46}$ - n-$C_{40}H_{82}$	0.005	0.000	0.005
n-$C_{22}H_{46}$ - n-$C_{34}H_{70}$	0.001	0.000	0.001
Alkyl, hydroxymethyl benzene	0.472	0.008	0.480
Methyltoluidine	1.549	0.035	1.584
n-Dimethyltoluidine	2.530	0.052	2.581
2-Chloromethyl, hydroxymethylbenzene	1.850	0.029	1.879
2-Chloromethyl-o-xylene	4.853	0.120	4.972
Ethylxylene	0.555	0.015	0.571
Ethyl, 2-methyl, hydroxymethylbenzene	6.691	0.106	6.797
2-Methylhydroxymethyl benzene	93.971	1.649	95.619
C_3-alkylbenzene	2,138.450	72.539	2,210.989
Propylbenzene	9.042	0.292	9.335
Trimethylbenzene	109.071	3.461	112.532
Ethylbenzaldehyde	261.379	5.768	267.147
Methylbenzaldehyde	585.809	14.565	600.375
Diethylphthalates	0.066	0.001	0.067
Unknown phthalates	0.087	0.001	0.088
Dioctylphthalates	0.018	0.000	0.018
Chloroethyl, 2-hydroxymethyl benzoic acid	0.123	0.001	0.124
2-Hydroxymethylbenzoic acid	0.117	0.001	0.118
2-Methylbenzoic acid	0.615	0.009	0.624
Butanedioic acid	10.063	0.114	10.177
n-Dodecane	2.278	0.049	2.327
Dodecanoic acid	0.207	0.003	0.210

Table 2-4. GTF Organic Emissions Basis: Four Campaigns Per Year.

Chemical	GDF (lb/yr)	GPF (lb/yr)	Total (lb/yr)
EDTA	0.465	0.002	0.467
ED3A	0.004	0.000	0.004
HEDTA	0.681	0.002	0.683
MICEDA	2.119	0.020	2.139
MAIDA	0.136	0.001	0.137
Ethanedioic acid	4,669.245	85.201	4,754.446
Hydroxyacetic acid	51,919.241	1,109.748	53,028.990
NTA	0.019	0.000	0.019
Heptadecanoic acid	0.351	0.005	0.356
Heptanedioic acid	0.098	0.001	0.099
Hexadecanoic acid	0.000	0.000	0.000
Hexanedioic acid	0.328	0.003	0.331
Hexanoic acid	15.657	0.308	15.965
Octadecanoic acid	0.000	0.000	0.000
n-Pentadecane	0.146	0.002	0.148
Pentadecanoic acid	0.961	0.011	0.971
Pentanedioic acid	0.039	0.000	0.039
Tri-n-butyl phosphate	0.183	0.002	0.185
[(Tri-n-butyl)di-ol] phosphate	1.712	0.037	1.748
Citric acid	0.212	0.001	0.213
n-Tetradecane	4.335	0.101	4.436
n-Tridecane	5.284	0.099	5.384
n-Undecane	6.215	0.153	6.368
Total	59,857.	1,295.	61,152.

3.0 DOSE MODELING AND CALCULATIONS

An application for modification of the GTF under the NESHAP, Subpart H, was submitted to the Environmental Protection Agency (EPA) on December 13, 1989. At that time, airborne radionuclide dose commitment modeling for *Clean Air Act* considerations specifically required the application of AIRDOS-EPA and RADRISK codes for evaluation of dispersion and dose equivalents (based upon pathway and impacted organs) (EPA 1985). Since that time, EPA has promulgated revisions to these standards (EPA 1989) which incorporated more stringent offsite dose limitations, requirements to address nonroutine emissions, compliance assessment based upon a slightly differing dose model code, and continuous monitoring requirements based on uncontrolled emissions calculated at full operation. In compliance with the recent promulgations, emission stream data were modeled (Appendix Attachment 6) with the currently applicable EPA model CAP-88. The Hanford Environmental Dose Overview Panel (HEDOP) has approved the model results (Appendix Attachment 9).

The CAP-88 model yields doses linear with respect to emission rate. As such, the model was run assuming that one curie (3.7×10^{10} Bq) of each radionuclide was emitted per year. Dose commitments for all operations are calculated for each operation by multiplying the model resultant dose with the ratio of emissions anticipated to emissions modeled, e.g.,:

$$\text{Dose} = \text{SUM}\ (\text{Dose}_{i(\text{model})} \times E_i/E_{i(\text{model})}) \quad [\text{mrem}] \qquad [11]$$

These modeled doses are presented, in terms of mrem/yr, EDE, in Appendix Attachment 7 and evaluated to be 3.68×10^{-3} mrem/yr EDE. It should be noted that as maintenance emissions are not chronic emissions and therefore not strictly capable of being modeled by CAP-88, a dose assessment for maintenance emissions was conservatively evaluated based on stack height and plume temperature of a stagnant vault.

Monitoring considerations of recent EPA promulgations require that continuous monitoring be conducted on any stream which, uncontrolled at full operation, may exceed 1% of the offsite dose limit of 10 mrem/yr EDE (i.e., 0.1 mrem/yr). In order to address this issue, emission streams of Table 2-3 were scaled to reduce all decontamination factors (see Equation 2) to unity. Thus, potential emissions, other than tritium, are 4×10^5 times higher than anticipated vault emissions and 4×10^6 times higher than anticipated GPF emissions. Scaled modeling, as discussed above, was conducted and is present, in parallel with anticipated emissions and doses, in Appendix Attachment 7 to yield a potential offsite dose impact of 0.104 mrem/yr EDE.

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4.0 RESULTS

4.1 RADIONUCLIDE EMISSIONS AND DOSE

Conservatively calculated emissions and modeled dose commitments resulted in dose commitments of 3.68×10^{-3} mrem/yr EDE to the maximally exposed offsite individual. Calculated potential emissions were found to be 1.04×10^{-1} mrem/yr EDE. Stated emission limitations under the NESHAP (EPA 1985) are 10 mrem/yr EDE.

In comparison to the federal emission standards, the dose commitments projected from the grouting of DST waste are approximately one-three thousandth of the standard while uncontrolled potential emissions do not exceed one-half of the trigger level for continuous monitoring for any stack.

Inclusion of these estimated emissions and dose commitments within the GTF SAR as routine emissions is considered appropriate.

4.2 ORGANIC CHEMICAL EMISSIONS

Conservative calculations of vapor phase organic chemical emissions from the grouting of DST wastes indicate the expectation of 590 kg/yr (1,300 lb/yr) of these constituents would be released from the GPF, and that 27,320 kg/yr (60,100 lb/yr) would be released from the GDF (vaults). Particulate organic chemical emissions were determined to be negligible from these operations.

Emission estimates of this range are not impacted by *Clean Air Act* requirements delineated by the Prevention of Significant Deterioration (EPA 1978 and Ecology 1988). Inclusion of these estimated emissions within the Grout Facility Safety Analysis Report as routine emissions is considered appropriate.

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5.0 REFERENCES

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APPENDIX

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ATTACHMENT 1

TRITIUM PARTITION FRACTION CALCULATION

Purpose

Determine the partition fraction (PF) of tritium (^3H) between exhausted gases and grouted wastes for DST waste processing.

Define:

$$PF = Ci\,^3H/L\ air\ /\ Ci\,^3H/L\ grouted\ waste$$

A. **Mean Feed Source Term and Grouted Source Term--**

1. **Mean Feed Source Term--**The mean feed source term calculation has been described in Section 2.1, above, and tabulated in Table 2-1 as 1.6×10^{-5} Ci/L waste (1.5766×10^{-5}).

2. **Grouted Source Term--**The grouted source term is 1/1.43 that of the mean feed source term and is 1.10×10^{-5} Ci/L grout (1.1025×10^{-5}).

B. **Tritium Concentration in Water Molecules**[1]--Tritium is assumed to be uniformally distributed among inorganic molecules containing hydrogen. Tritiated water is assumed to be the volatile fraction in this case. Thus, the concentration of tritium among all hydrogen atoms in water is reduced by that fraction which would be contained in hydroxyls.

$$\frac{Ci\,^3H}{g\ H_2O} =$$

$$\frac{\left(\frac{1.6 \times 10^{-5}\ Ci\,^3H}{L\ waste}\right) \times \left(\frac{949\ g\ H_2O}{L\ waste} \times \frac{2\ g\ H}{18\ g\ H_2O}\right) \times \left(\frac{L\ waste}{949\ g\ H_2O}\right)}{\left(\frac{949\ g\ H_2O}{L\ waste} \times \frac{2\ g\ H}{18\ g\ H_2O} + \frac{35.1\ g\ OH^-}{L\ waste} \times \frac{g\ H}{17\ g\ OH^-}\right)}$$

$$= 1.6294 \times 10^{-8} \quad = \frac{1.63 \times 10^{-8}\ Ci\,^3H}{g\ H_2O}$$

[1]Mean H_2O and OH^- multiplied by 1.3 from WHC-SD-WM-TI-355, Rev. 1 (Hendrickson 1990) for correction to specific gravity of waste.

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C. **Water Vapor Concentration of Exhaust Air**--Conditions chosen for review were those of 45 and 70 °C and 100% relative humidity.

Given: H is humidity, v is specific volume.[2]

$$H = 6.61 \times 10^{-2}\ g\ H_2O\ /\ g\ dry\ air\ at\ 45\ °C\quad (113\ °F)$$
$$= 2.79 \times 10^{-1}\ g\ H_2O\ /\ g\ dry\ air\ at\ 70\ °C\quad (158\ °F)$$

$$v = 0.99645\ L/g\ dry\ air\ at\ 45\ °C$$
$$= 1.40415\ L/g\ dry\ air\ at\ 70\ °C$$

then, at 45°C:

$$\frac{g\ H_2O}{L\ moist\ air} = \frac{H}{v} = \frac{\left(\frac{6.61 \times 10^{-2}\ g\ H_2O}{g\ dry\ air}\right)}{\left(\frac{0.99645\ L}{g\ dry\ air}\right)}$$

$$\frac{g\ H_2O}{L\ moist\ air} = \frac{6.6335 \times 10^{-1}\ g\ H_2O}{L\ moist\ air}$$

similarly, at 70°C

$$\frac{g\ H_2O}{L\ moist\ air} = \frac{1.9855 \times 10^{-1}\ g\ H_2O}{L\ moist\ air}$$

D. **Partition Fraction**--

$$PF_{45} = \frac{\left(\frac{6.63 \times 10^{-2}\ g\ H_2O}{L\ moist\ air}\right) \times \left(\frac{1.63 \times 10^{-8}\ Ci\,^3H}{g\ H_2O}\right)}{\left(\frac{1.10 \times 10^{-5}\ Ci\,^3H}{L\ grout}\right)}$$

$$= \frac{\frac{9.80 \times 10^{-5}\ Ci\,^3H}{L\ moist\ air}}{\frac{Ci\,^3H}{L\ grout}}$$

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[2]Reference: R. H. Perry, ed., Perry's Chemical Engineers Handbook, Sixth Edition, McGraw-Hill Book Co., New York, NY, 1984. Converted to SI units.

$$PF_{70} = \frac{\left(\frac{1.99 \times 10^{-1}\ g\ H_2O}{L\ moist\ air}\right) \times \left(\frac{1.63 \times 10^{-8} Ci\ ^3H}{g\ H_2O}\right)}{\left(\frac{1.10 \times 10^{-5}\ Ci\ ^3H}{L\ grout}\right)}$$

$$= \frac{\frac{2.94 \times 10^{-4}\ Ci\ ^3H}{L\ moist\ air}}{\frac{Ci\ ^3H}{L\ grout}}$$

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ATTACHMENT 2

Grout Treatment Facility Particulate Organic Emissions
Basis: 50% resuspension, 4 campaigns/yr, no stagnant emissions

Chemical	Active vaults (lb/yr)	GPF (lb/yr)	Total (lb/yr)
n-$C_{22}H_{46}$ - n-$C_{40}H_{82}$	7.7 E-08	5.5 E-09	8.2 E-08
n-$C_{22}H_{46}$ - n-$C_{34}H_{70}$	3.8 E-08	2.7 E-09	4.1 E-08
Alkyl, hydroxymethyl benzene	4.7 E-09	3.3 E-10	5.0 E-09
Methyltoluidine	9.1 E-09	6.5 E-10	9.8 E-09
n-Dimethyltoluidine	3.0 E-08	2.2 E-09	3.3 E-08
2-Chloromethyl,hydroxymethylbenzene	3.2 E-08	2.3 E-09	3.5 E-08
2-Chloromethyl-o-xylene	1.7 E-08	1.2 E-09	1.9 E-08
Ethylxylene	8.3 E-10	5.9 E-11	8.9 E-10
Ethyl, 2-methyl hydroxymethylbenzene	1.2 E-07	8.6 E-09	1.3 E-07
2-Methylhydroxymethyl benzene	9.1 E-07	6.5 E-08	9.8 E-07
C3-alkylbenzene	8.3 E-07	5.9 E-08	8.9 E-07
Propylbenzene	4.7 E-09	3.3 E-10	5.0 E-09
Trimethylbenzene	2.1 E-07	1.5 E-08	2.2 E-07
Ethylbenzaldehyde	1.8 E-06	1.3 E-07	1.9 E-06
Methylbenzaldehyde	1.8 E-06	1.3 E-07	1.9 E-06
Diethylphthalates	2.6 E-08	1.8 E-09	2.8 E-08
Unknown phthalates	5.4 E-08	3.8 E-09	5.7 E-08
Dioctylphthalate	6.2 E-08	4.4 E-09	6.6 E-08
Chloroethyl, 2-hydroxymethyl Benzoic acid	3.2 E-08	2.3 E-09	3.5 E-08
2-Hydroxymethylbenzoic acid	7.1 E-08	5.0 E-09	7.6 E-08
2-Methylbenzoic acid	4.7 E-08	3.3 E-09	5.0 E-08
Butanedioic acid	1.1 E-06	7.7 E-08	1.2 E-06

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Grout Treatment Facility Particulate Organic Emissions
Basis: 50% resuspension, 4 campaigns/yr, no stagnant emissions

Chemical	Active vaults (lb/yr)	GPF (lb/yr)	Total (lb/yr)
n-Dodecane	1.1 E-08	7.9 E-10	1.2 E-08
Dodecanoic acid	3.7 E-09	2.6 E-10	3.9 E-09
EDTA	9.2 E-06	6.5 E-07	9.8 E-06
ED3A	7.0 E-08	5.0 E-09	7.5 E-08
HEDTA	3.7 E-05	2.6 E-06	3.9 E-05
MICEDA	7.9 E-08	5.6 E-09	8.4 E-08
MAIDA	1.5 E-06	1.1 E-07	1.6 E-06
Ethanedioic acid	1.1 E-05	7.7 E-07	1.2 E-05
Hydroxyacetic acid	2.2 E-05	1.6 E-06	2.4 E-05
NTA [nitriloacetic acid]	3.0 E-08	2.1 E-09	3.2 E-08
Heptadecanoic acid	6.3 E-09	4.5 E-10	6.7 E-09
Heptanedioic acid	7.1 E-08	5.0 E-09	7.6 E-08
Hexadecanoic acid	3.2 E-09	2.3 E-10	3.5 E-09
Hexanedioic acid	1.6 E-07	1.2 E-08	1.8 E-07
Hexanoic acid	1.1 E-07	8.0 E-09	1.2 E-07
Octadecanoic acid	1.6 E-09	1.1 E-10	1.7 E-09
n-Pentadecane	9.6 E-09	6.8 E-10	1.0 E-08
Pentadecanoic acid	9.1 E-08	6.5 E-09	9.8 E-08
Pentanedioic acid	1.8 E-07	1.3 E-08	1.9 E-07
Tri-n-butyl phosphate	1.1 E-07	7.7 E-09	1.2 E-07
[(Tri-n-butyl)di-ol] phosphate	2.9 E-08	2.1 E-09	3.1 E-08
Citric acid	4.0 E-05	2.8 E-06	4.2 E-05
n-Tetradecane	3.4 E-08	2.4 E-09	3.6 E-08

9 1 1 2 0 5 7 0 4 3 5

Grout Treatment Facility Particulate Organic Emissions
Basis: 50% resuspension, 4 campaigns/yr, no stagnant emissions

Chemical	Active vaults (lb/yr)	GPF (lb/yr)	Total (lb/yr)
n-Tridecane	6.1 E-08	4.3 E-09	6.5 E-08
n-Undecane	1.3 E-08	9.1 E-10	1.4 E-08
Total	1.3 E-04	9.1 E-06	1.4 E-04

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ATTACHMENT 3

CALCULATIONAL EQUATIONS SET 1
GROUT PROCESSING FACILITY EMISSIONS CALCULATION

This set of calculations constitutes those calculations required to evaluate the GPF emissions of one organic constituent in the waste slurry. Work was conducted on a Symphony™[3] worksheet.

```
A66: 1
B66: 'n-C22H46 - n-C40H82
C66: 'Alkanes [paraffins] assume C31
D66: (S1) 0.0028
E66: (S1) 0.0048
F66: (S4) (D66+(E66*2.92)/(@SQRT(3)))*$E$62 [where $E$62 = 0.809 dil. factor]
G66: 436.86
H66: 67.9
J66: 458
L66: 1
M66: 273.15+45
N66: (F3) 0.62
O66: (F3) 7.037
P66: +J66+273.14
Q66: (F2) +P66/(0.567+N66-(N66)^2)
R66: (F4) +M66/Q66
S66: (F4) +P66/Q66
T66: (S3) +G66*101325/(0.34+O66)^2
U66: (F4) 36/R66+96.7*(@LOG(R66))-35-(R66^6)
V66: (F4) 36/S66+96.7*(@LOG(S66))-35-(S66^6)
W66: (F4) (0.136*V66+(@LOG(T66))-5.01)/(0.0364*V66-(@LOG(S66)))
X66: (F4) 0.118*U66-7*(@LOG(R66))
Y66: (F4) 0.0364*U66-(@LOG(R66))
Z66: (F4) -X66-(W66-7)*Y66
AA66: (S2) 10^Z66
AB66: 1
AC66: 'n-C22H46 - N-C40H82
AD66: (S2) +AA66*T66
AE66: (S2) +AD66*14.696/101325
AF66: 14.696
AG66: (S2) +AE66*F66/1000
AH66: (S2) +AG66/AF66*(G66/29)
AI66:
@MIN((710*(293.15/M66)*(28.316*29/22.4)*AH66*1440*30*4/454),(F66*19.227*4000))
```

[3]Symphony is a trademark of Lotus Development Corporation, Cambridge, Massachusetts.

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9 1 1 2 0 5 7 0 4 3 9

ATTACHMENT 4

CALCULATIONAL EQUATIONS SET 2
GROUT DISPOSAL FACILITY EMISSIONS CALCULATION

This set of calculations constitutes those calculations required to evaluate the GDF emissions of one organic constituent in the waste slurry. Work was conducted on a Symphony™ worksheet.

```
A6: 1
B6: 'n-C22H46 - n-C40H82
C6: 'Alkanes [paraffins] assume C31
D6: (S1) 0.0028
E6: (S1) 0.0048
F6: (S4) (D6+(E6*2.92)/(@SQRT(3)))*$E$2  [where $E$2 = 0.809 dil. factor]
G6: 436.86
H6: 67.9
J6: 458
L6: 1
M6: 273.15+70
N6: (F3) 0.62
O6: (F3) 7.037
P6: +J6+273.14
Q6: (F2) +P6/(0.567+N6-(N6)^2)
R6: (F4) +M6/Q6
S6: (F4) +P6/Q6
T6: (S3) +G6*101325/(0.34+O6)^2
U6: (F4) 36/R6+96.7*(@LOG(R6))-35-(R6^6)
V6: (F4) 36/S6+96.7*(@LOG(S6))-35-(S6^6)
W6: (F4) (0.136*V6+(@LOG(T6))-5.01)/(0.0364*V6-(@LOG(S6)))
X6: (F4) 0.118*U6-7*(@LOG(R6))
Y6: (F4) 0.0364*U6-(@LOG(R6))
Z6: (F4) -X6-(W6-7)*Y6
AA6: (S2) 10^Z6
AB6: 1
AC6: 'n-C22H46 - N-C40H82
AD6: (S2) +AA6*T6
AE6: (S2) +AD6*14.696/101325
AF6: 14.696
AG6: (S2) +AE6*F6/1000
AH6: (S2) +AG6/AF6*(G6/29)
AI6:
@MIN((1000*(293.15/M6)*(28.316*29/22.4)*AH6*1440*210*4/454),(F6*19.227*4000))
```

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9 1 1 2 0 5 7 0 4 1 1

ATTACHMENT 5

Organic Constituent Physical Property Data.

Chemical Name	IUPAC Name
n-$C_{22}H_{46}$ - n-$C_{40}H_{82}$	Alkanes [paraffins] assume C_{31}
n-$C_{22}H_{46}$ - n-$C_{34}H_{70}$	Alkanes [paraffins] assume C_{28}
Alkyl,hydroxymethyl benzene	Alkyl,hydroxymethyl benzene [assume butyl-]
Methyltoluidine [Xylidine]	x-amino-(1,y-dimethyl)benzene
n-Dimethyltoluidine [Methylxylidine]	x-amino-(1,y,z-trimethyl)benzene
2-Chloromethyl,hydroxymethylbenzene	ß-chloro-,α-hydroxy-1, 2-dimethylbenzene
2-Chloromethyl-o-xylene	2-Chloromethyl-1,2-dimethylbenzene
Ethylxylene	1,2-dimethyl-,4-ethylbenzene
Ethyl, 2-methyl hydroxymethylbenzene	ethyl,α-hydroxymethyl benzene
2-Methylhydroxymethyl benzene	1-hydroxymethyl,2-methylbenzene [α-hydroxy-o-xylene]
C_3-alkylbenzene	assume isopropylbenzene
Propylbenzene	Propylbenzene
Trimethylbenzene	1,(2,3, or 2,4, or 3,5)-trimethyl benzene
Ethylbenzaldehyde	Ethylbenzenecarbonal
Methylbenzaldehyde	2-Methylbenzenecarbonal
Diethylphthalates	1,2-benzenedicarboxylic acid, diethyl ester
Unknown phthalates	1,2-benzenedicarboxylic acid, di-R esters
Dioctylphthalate	1,2-benzenedicarboxylic acid, dioctyl ester
Chloroethyl, 2-hydroxymethyl Benzioc Acid	4-Chloroethyl, 2-hydroxymethyl Benzioc Acid
2-Hydroxymethylbenzoic acid	2-Hydroxymethylbenzoic acid

9 1 1 2 0 5 7 0 4 1 2

Organic Constituent Physical Property Data.

Chemical Name	IUPAC Name
2-Methylbenzioc acid	2-Methylbenzioc acid [o-toluic acid]
Butanedioic acid	Butanedioic Acid [Succinic acid]
n-Dodecane	n-Dodecane
Dodecanoic acid	Dodecanoic acid [Lauric Acid]

Organic Constituent Physical Property Data.

Chemical Name	MW	melt. point (°C)	boil. point (°C)	Comments	Sum of (DELt)	Sum of (DELp)	Tb (K)	Tc (K)	Pc (Pa)
n-$C_{22}H_{46}$ - n-$C_{40}H_{82}$	436.86	67.9	458		0.620	7.037	731.14	910.96	8.134 E+05
n-$C_{22}H_{46}$ - n-$C_{34}H_{70}$	394.78	64.5	431.6		0.560	6.356	704.74	866.41	8.922 E+05
Alkyl,hydroxymethyl benzene	164.12		>208		0.248	2.119	481.14	638.54	2.750 E+06
Methyltoluidine [Xylidine]	121.18		214	214-226	0.137	1.473	487.14	710.91	3.736 E+06
n-Dimethyltoluidine [Methylxylidine]	135.21		232	185-212	0.157	1.700	505.14	722.30	3.292 E+06
2-Chloromethyl,hydroxymethylbenzene	156.44		>220		0.205	1.758	493.14	675.56	3.601 E+06
2-Chloromethyl-o-xylene	155.64		~215		0.143	1.925	488.14	707.91	3.074 E+06
Ethylxylene	134.22	-67	189.7		0.146	1.832	462.84	669.15	2.883 E+06
Ethyl, 2-methyl hydroxymethylbenzene	136.09		>219		0.208	1.665	492.14	672.56	3.430 E+06
2-Methylhydroxymethyl benzene	122.07		>205	~	0.188	1.438	478.14	664.40	3.913 E+06
C_3-alkylbenzene	120.2	-96	152.4		0.118	1.588	425.54	634.12	3.276 E+06
Propylbenzene	120.2	-99.	159		0.126	1.605	432.14	638.20	3.219 E+06
Trimethylbenzene	120.2		164	164-171	0.126	1.605	437.14	645.58	3.219 E+06
Ethylbenzaldehyde	134.17		~220		0.154	1.708	493.14	707.23	3.241 E+06
Methylbenzaldehyde	120.16		199	199-205	0.134	1.481	472.14	691.23	3.672 E+06
Diethylphthalates	222.24	-40.	302		0.240	2.772	575.14	767.47	2.325 E+06
Unknown phthalates	278.35		>302	?dibutyl	0.320	3.680	575.14	733.04	1.745 E+06
Dioctylphthalate	390.62		>340		0.480	5.496	613.14	750.84	1.162 E+06
Chloroethyl, 2-hydroxymethyl Benzioc Acid	214.62		>250		0.310	2.385	523.14	669.92	2.929 E+06
2-Hydroxymethylbenzoic acid	152.16	128	>260	~	0.253	1.611	533.14	705.22	4.050 E+06
2-Methylbenzioc acid	136.16	107	258		0.171	1.551	531.14	749.39	3.858 E+06
Butanedioic acid	118.09	188	235	decomp	0.210	1.254	508.14	693.33	4.709 E+06
n-Dodecane	170.34	-9.6	216.3		0.240	2.724	489.44	653.11	1.838 E+06
Dodecanoic acid	200.33	44	225	100mmHg	0.305	2.897	498.14	639.48	1.937 E+06

ATTACHMENT 5

Organic Constituent Physical Property Data.

Chemical Name	IUPAC Name
EDTA	1,2-diamino-N,N,N',N'-tetra(ethanoic acid)ethane
ED3A	1,2-diamino-N,N,N'-tris(ethanoic acid)ethane
HEDTA	1,2-diamino-N-hydroxy-N,N',N'-tris(ethanoic acid)ethane
MICEDA	1,2-diamino,N-(Methyliminocarboxy)-,N-(ethanoic acid)ethane
MAIDA	N-(Methylamine)iminodiethanoic Acid
Ethanedioic Acid	Ethanedioic Acid [Oxalic acid]
Hydroxyacetic acid	Hydroxyethanoic acid [Glycolic acid]
NTA [nitriloacetic acid]	Nitrilotriethanoic acid
Heptadecanoic acid	Heptadecanoic acid
Heptanedioic acid	Heptanedioic acid
Hexadecanoic acid	Hexadecanoic acid
Hexanedioic acid	Hexanedioic acid
Hexanoic acid	Hexanoic acid
Octadecanoic acid	Octadecanoic acid
n-Pentadecane	n-Pentadecane
Pentadecanoic acid	Pentadecanoic acid
Pentanedioic (acid)	Pentanedioic acid
Tri-n-butyl phosphate	Tri-n-butyl phosphate
[(Tri-n-butyl)di-ol] phosphate	Tris-(n-butyldiol) phosphate
Citric acid	2-Hydroxy-1,2,3-propanetricarboxylic acid

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Organic Constituent Physical Property Data.

Chemical Name	IUPAC Name
n-Tetradecane	n-Tetradecane
n-Tridecane	n-Tridecane
n-Undecane	n-Undecane

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ATTACHMENT 5

Organic Constituent Physical Property Data.

Chemical Name	MW	melt. point (°C)	boil. point (°C)	Comments	Sum of (DELt)	Sum of (DELp)	Tb (K)	Tc (K)	Pc (Pa)
EDTA	292.28	240	>302	decomp	0.480	3.302	575.14	704.31	2.233 E+06
ED3A	234.28	~240	>302		0.383	2.675	575.14	715.96	2.611 E+06
HEDTA	246.28	>240	>302		0.465	2.735	575.14	705.02	2.639 E+06
MICEDA	188.4		>205		0.343	2.113	478.14	603.44	3.173 E+06
MAIDA	162.07	>240	>302		0.275	1.746	575.14	750.47	3.774 E+06
Ethanedioic Acid	90.04	189	157	subl.	0.170	0.800	430.14	607.46	7.020 E+06
Hydroxyacetic acid	76.05	80	>118	decomp	0.187	0.687	391.14	543.98	7.306 E+06
NTA [nitriloacetic acid]	191.16	262	>262	decomp	0.329	2.051	535.14	679.32	3.388 E+06
Heptadecanoic acid	270.46	62	227		0.405	4.032	500.14	619.00	1.434 E+06
Heptanedioic acid	160.17	106	272		0.270	1.935	545.14	713.44	3.136 E+06
Hexadecanoic acid	286.42	126	390		0.385	3.805	663.14	825.03	1.689 E+06
Hexanedioic acid	146.14	153	265		0.250	1.708	538.14	713.24	3.530 E+06
Hexanoic acid	116.16	-2	205		0.185	1.535	478.14	666.14	3.348 E+06
Octadecanoic acid	284.5	71.5	360	decomp	0.425	4.259	633.14	780.33	1.363 E+06
n-Pentadecane	212.42	10	270.6		0.300	3.405	543.74	699.79	1.535 E+06
Pentadecanoic acid	242.41	53	257		0.365	3.578	530.14	663.69	1.600 E+06
Pentanedioic (acid)	132.13	99	302		0.230	1.481	575.14	772.93	4.037 E+06
Tri-n-butyl phosphate	266.36	-80	289	decomp	0.324	3.364	562.14	715.17	1.967 E+06
[(Tri-n-butyl)di-ol] phosphate	298.36		>289		0.816	3.724	562.14	783.86	1.830 E+06
Citric acid	192.14	153	302	decomp	0.397	1.941	575.14	713.23	3.742 E+06
n-Tetradecane	198.4	5.9	253.7		0.280	3.920	526.84	685.45	1.108 E+06
n-Tridecane	184.37	-5.5	235.4		0.260	2.951	508.54	669.66	1.725 E+06
n-Undecane	156.32	-25.	195.9		0.220	2.497	469.04	635.04	1.968 E+06

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Battelle
Pacific Northwest Laboratories

ATTACHMENT 6

Project Number _____

Internal Distribution

R. G. Schreckhise
File/LB

Date November 27, 1990

To Doug Hendrickson

From Kathy Rhoads K Rhoads

Subject Review of Grout Treatment Facility Dose Calculations

The results of Clean Air Act Compliance dose calculations for the Grout Treatment Facility have been reviewed by Bruce Napier, and the attached check-off sheet documents his concurrence. He made one comment regarding presentation of results for ingrowth of daughter radionuclides, and minor revisions were made to the previous letter report as a result. A copy of the revised report containing minor changes to the text is attached; the numerical results are the same as those reported to you previously. If you have questions regarding methods or interpretation of results, please contact me at 375-6832.

9112170418

UNIT RELEASE DOSE CALCULATIONS FOR THE GROUT TREATMENT FACILITY

K. Rhoads, Pacific Northwest Laboratory 11/1/90

The potential radiological consequences of emissions from the Grout Treatment Facility were evaluated to demonstrate compliance with the Clean Air Act (40 CFR 61, USEPA 1989). The facility will be located outside the Southeast corner of the 200 East Area on the Hanford Site. Calculations were based on unit releases of all radionuclides expected in facility airborne effluents in order to provide results that could be adjusted for different emission levels as the facility design is finalized. Dose estimates were made using both the CAP-88 code package (RSIC 1990), as required by the Clean Air Act, and the GENII code system (Napier et al 1988), as required by the Hanford Environmental Dose Overview Panel.

Standard parameters for Hanford dose calculations were used in this assessment (McCormack et al 1984), including site-specific meteorological data and population distributions (Sommer et al 1981). Meteorological data were collected at the 200 Area tower and represent the 5-year average of data from 1983-1987. The maximally exposed individual was located 15,700 m East of the facility based on previous analyses; this is the offsite location having the greatest radionuclide air concentration under average atmospheric conditions. The doses were calculated as 70-year committed effective dose equivalents for all airborne pathways using the EPA model specified in 40 CFR 61.

Results of the evaluation are presented in Table 1. Because the CAP-88 code does not handle ingrowth of long-lived radioactive daughter products following release of the parent nuclide, doses due to daughter ingrowth for some isotopes are estimated using the parent/daughter ratio from GENII results. The doses in Table 1 are for release of 1 Ci of each radionuclide. The total dose expected from actual plant emissions can be obtained by multiplying the release for each nuclide by the corresponding value in Table 1 and summing the contributions for all nuclides in the effluent stream.

Table 1. Dose Estimates for Unit Release (1 Ci) of Radionuclides from Grout Treatment Facility Stacks

	Exhauster Stack: Dose Equivalent (mrem)		Process Facility Stack: Dose Equivalent (mrem)	
	CAP-88	GENII	CAP-88	GENII
H-3	2.25E-05	1.8E-05	2.11E-05	2.1E-05
C-14	2.70E-03	6.4E-03	1.17E-03	7.6E-03
CO-60	2.97E-02	9.3E-03	2.79E-02	1.1E-02
SE-79	0.00E+00	6.4E-02	0.00E+00	7.6E-02
SR-90	4.53E-02	3.3E-02	1.95E-02	3.9E-02
Y-90 *	2.88E-03*	2.1E-03	1.20E-03*	2.4E-03
Y-90 **	3.86E-04	2.6E-04	1.96E-04	3.1E-04
NB-94	2.75E-02	1.1E-02	3.93E-02	1.3E-02
TC-99	1.11E-03	4.8E-03	7.48E-04	5.7E-03
RU-106	1.79E-02	1.4E-02	1.24E-02	1.7E-02
RH-106*	1.74E-03*	***	1.69E-03*	***
I-129	2.87E-01	8.7E-01	2.85E-01	1.0E+00
CS-134	3.21E-02	3.1E-02	3.09E-02	3.7E-02
CS-137	1.47E-02	2.2E-02	1.48E-02	2.6E-02
BA-137M*	4.79E-03*	***	4.65E-03*	***
U-234	3.64E+00	2.9E+00	3.16E+00	3.5E+00
U-235	3.38E+00	2.7E+00	2.93E+00	3.2E+00
U-238	3.24E+00	2.6E+00	2.81E+00	3.1E+00
PU-238	9.70E+00	6.3E+00	8.12E+00	7.5E+00
NP-237	1.57E+01	1.5E+01	1.35E+01	1.8E+01
CM-244	7.55E+00	5.5E+00	6.51E+00	6.6E+00
AM-241	1.71E+01	1.0E+01	1.48E+01	1.2E+01
PU-239	1.11E+01	6.7E+00	9.24E+00	7.9E+00

* Contribution due to ingrowth from 1 Ci release of parent nuclide with daughter in equilibrium. CAP-88 Estimate for Y-90 is derived from GENII results by parent/daughter ratio; ingrowth is not calculated by CAP-88.

** Dose estimate for release of 1 Ci (does not include parent contribution).

*** Dose included in estimate for parent nuclide.

CHECKLIST FOR CALCULATION REVIEW

Document Reviewed: Unit Dose Calculations for the Grout Treatment Facility. K. Rhoads. 11/1/96

Scope of Review:

Yes	No	N/A	
[ ]	[ ]	[X]	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
[X]	[ ]	[ ]	Problem completely defined.
[X]	[ ]	[ ]	Necessary assumptions explicitly stated and supported.
[X]	[ ]	[ ]	Computer codes and data files documented.
[X]	[ ]	[ ]	Data used in calculations explicitly stated in document.
[ ]	[ ]	[X]	Data checked for consistency with original source information as applicable.
[X]	[ ]	[ ]	Mathematical derivations checked including dimensional consistency of results.
[X]	[ ]	[ ]	Models appropriate and used within range of validity or use outside range of established validity justified.
[X]	[ ]	[ ]	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
[X]	[ ]	[ ]	Code runstreams correct and consistent with analysis documentation.
[X]	[ ]	[ ]	Code output consistent with input and with results reported in analysis documentation.
[ ]	[ ]	[X]	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
[ ]	[ ]	[X]	Safety margins consistent with good engineering practices.
[ ]	[ ]	[X]	Conclusions consistent with analytical results and applicable limits.
[X]	[ ]	[ ]	Results and conclusions address all points required in the problem statement.
[ ]		[X]	* Review calculations, comments, and/or notes are attached.

BA Napier [signature] 27 Nov 90

Reviewer Approval (Printed Name and Signature) Date

HEDOP Review (Radiological and Toxicological Release Calculations)

[X]	[ ]	[ ]	GENII (current version) used for radiological calculations / Also AIRDOS CAP-88
[X]	[ ]	[ ]	Appropriate receptor locations evaluated.
[X]	[ ]	[ ]	Appropriate models (finite plume vs. semi-infinite cloud, building wake, etc.) used.
[X]	[ ]	[ ]	Appropriate pathways evaluated for each receptor.
[X]	[ ]	[ ]	Analysis consistent with HEDOP Recommendations.
[ ]		[X]	* Review calculations, comments, and/or notes are attached.

BA Napier [signature] 27 Nov 90

HEDOP Reviewer Approval (Printed Name and Signature) Date

* Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.

ATTACHMENT 7

Radionuclide Dose Assessments

A: Grout Treatment Facility, Annual Doses for Active Vault Emissions.

Radioisotopes	Model emission Ci/yr	Model dose mrem EDE	Actual emission Ci/yr	Actual dose mrem EDE	Potential emission Ci/yr	Potential dose mrem EDE
^{3}H	1	2.25 E-05	2.26 E+01	5.09 E-04	2.26 E+01	5.09 E-04
^{14}C	1	2.70 E-03	1.72 E-11	4.64 E-14	6.87 E-06	1.86 E-08
^{60}Co	1	2.97 E-02	4.29 E-10	1.27 E-11	1.71 E-04	5.09 E-06
^{79}Se*	1	8.33 E-02	3.91 E-10	3.26 E-11	1.56 E-04	1.30 E-05
^{90}Sr	1	4.53 E-02	1.73 E-07	7.82 E-09	6.91 E-02	3.13 E-03
^{90}Y	1	2.88 E-03	1.73 E-07	4.97 E-10	6.91 E-02	1.99 E-04
^{94}Nb	1	2.75 E-02	5.46 E-10	1.50 E-11	2.19 E-04	6.01 E-06
^{99}Tc	1	1.11 E-03	1.38 E-09	1.53 E-12	5.53 E-04	6.14 E-07
^{106}Ru	1	1.79 E-02	2.60 E-07	4.65 E-09	1.04 E-01	1.86 E-03
^{106}Rh	1	1.74 E-03	2.60 E-07	4.52 E-10	1.04 E-01	1.81 E-04
^{129}I	1	2.87 E-01	4.69 E-12	1.35 E-12	1.88 E-06	5.39 E-07
^{134}Cs	1	3.21 E-02	7.34 E-08	2.36 E-09	2.94 E-02	9.42 E-04
^{137}Cs	1	1.47 E-02	5.71 E-06	8.40 E-08	2.29 E+00	3.36 E-02
^{137m}Ba	1	4.79 E-03	5.40 E-06	2.59 E-08	2.16 E+00	1.04 E-02
^{234}U	1	3.64 E+00	4.99 E-13	1.82 E-12	2.00 E-07	7.27 E-07
^{235}U	1	3.38 E+00	3.22 E-14	1.09 E-13	1.29 E-08	4.36 E-08
^{238}U	1	3.24 E+00	2.47 E-13	8.00 E-13	9.88 E-08	3.20 E-07
^{237}Np	1	1.57 E+01	3.20 E-12	5.02 E-11	1.28 E-06	2.01 E-05
^{238}Pu	1	9.70 E+00	1.24 E-11	1.20 E-10	4.96 E-06	4.81 E-05
$^{239,240}Pu$	1	1.11 E+01	2.67 E-11	2.97 E-10	1.07 E-05	1.19 E-04
^{241}Am	1	1.71 E+01	3.08 E-11	5.27 E-10	1.23 E-05	2.11 E-04
^{244}Cm	1	7.55 E+00	3.78 E-12	2.85 E-11	1.51 E-06	1.14 E-05
Total			2.26 E+01	5.09 E-04	2.75 E+01	5.12 E-02

Selenium has no dose factors within the CAP-88 model. As the AIRDOS and RADRISK and GENII models contain dose factors for selenium, the selenium factor used herein was conservatively selected to be the GENII dose times the mean ratio of the CAP-88 dose to GENII dose of other radionuclides modeled (e.g., 6.4×10^{-2} 1.3017).

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B: Grout Treatment Facility, Annual Doses from Stagnant Vault Emissions.

Radioisotopes	Model emission Ci/yr	Model dose mrem EDE	Actual emission Ci/yr	Actual dose mrem EDE	Potential emission Ci/yr	Potential dose mrem EDE
^{3}H	1	2.25 E-05	1.36 E+02	3.06 E-03	1.36 E+02	3.06 E-03
^{14}C	1	2.70 E-03	9.80 E-13	2.65 E-15	3.92 E-07	1.06 E-09
^{60}Co	1	2.97 E-02	2.44 E-11	7.26 E-13	9.78 E-06	2.90 E-07
^{79}Se	1	8.33 E-02	2.23 E-11	1.86 E-12	8.91 E-06	7.43 E-07
^{90}Sr	1	4.53 E-02	9.84 E-09	4.46 E-10	3.94 E-03	1.78 E-04
^{90}Y	1	2.88 E-03	9.84 E-09	2.84 E-11	3.94 E-03	1.13 E-05
^{94}Nb	1	2.75 E-02	3.12 E-11	8.57 E-13	1.25 E-05	3.43 E-07
^{99}Tc	1	1.11 E-03	7.88 E-11	8.75 E-14	3.15 E-05	3.50 E-08
^{106}Ru	1	1.79 E-02	1.48 E-08	2.65 E-10	5.92 E-03	1.06 E-04
^{106}Rh	1	1.74 E-03	1.48 E-08	2.58 E-11	5.92 E-03	1.03 E-05
^{129}I	1	2.87 E-01	2.68 E-13	7.68 E-14	1.07 E-07	3.07 E-08
^{134}Cs	1	3.21 E-02	4.18 E-09	1.34 E-10	1.67 E-03	5.37 E-05
^{137}Cs	1	1.47 E-02	3.26 E-07	4.79 E-09	1.30 E-01	1.92 E-03
^{137m}Ba	1	4.79 E-03	3.08 E-07	1.48 E-09	1.23 E-01	5.90 E-04
^{234}U	1	3.64 E+00	2.85 E-14	1.04 E-13	1.14 E-08	4.14 E-08
^{235}U	1	3.38 E+00	1.84 E-15	6.21 E-15	7.35 E-10	2.49 E-09
^{238}U	1	3.24 E+00	1.41 E-14	4.56 E-14	5.63 E-09	1.83 E-08
^{237}Np	1	1.57 E+01	1.82 E-13	2.86 E-12	7.29 E-08	1.14 E-06
^{238}Pu	1	9.70 E+00	7.07 E-13	6.86 E-12	2.83 E-07	2.74 E-06
$^{239,240}Pu$	1	1.11 E+01	1.52 E-12	1.69 E-11	6.10 E-07	6.77 E-06
^{214}Am	1	1.71 E+01	1.76 E-12	3.00 E-11	7.03 E-07	1.20 E-05
^{244}Cm	1	7.55 E+00	2.15 E-13	1.63 E-12	8.61 E-08	6.50 E-07
Total			1.36 E+02	3.06 E-03	1.36 E+02	5.95 E-03

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C: Grout Treatment Facility, Annual Dose from GPF Stack Emissions.

Radioisotopes	Model emission Ci/yr	Model dose mrem EDE	Actual emission Ci/yr	Actual dose mrem EDE	Potential emission Ci/yr	Potential dose mrem EDE
^{3}H	1	2.11 E-05	5.37 E+00	1.13 E-04	5.37 E+00	1.13 E-04
^{14}C	1	1.17 E-03	1.68 E-12	1.96 E-15	6.71 E-06	7.85 E-09
^{60}Co	1	2.79 E-02	4.19 E-11	1.17 E-12	1.68 E-04	4.67 E-06
^{79}Se	1	9.89 E-02	3.82 E-11	3.78 E-12	1.53 E-04	1.51 E-05
^{90}Sr	1	1.95 E-02	1.69 E-08	3.29 E-10	6.75 E-02	1.32 E-03
^{90}Y	1	1.20 E-03	1.69 E-08	2.02 E-11	6.75 E-02	8.10 E-05
^{94}Nb	1	3.93 E-02	5.34 E-11	2.10 E-12	2.13 E-04	8.39 E-06
^{99}Tc	1	7.48 E-04	1.35 E-10	1.01 E-13	5.40 E-04	4.04 E-07
^{106}Ru	1	1.24 E-02	2.54 E-08	3.15 E-10	1.01 E-01	1.26 E-03
^{106}Rh	1	1.69 E-03	2.54 E-08	4.29 E-11	1.01 E-01	1.71 E-04
^{129}I	1	2.85 E-01	4.59 E-13	1.31 E-13	1.83 E-06	5.23 E-07
^{134}Cs	1	3.09 E-02	7.17 E-09	2.22 E-10	2.87 E-02	8.86 E-04
^{137}Cs	1	1.48 E-02	5.58 E-07	8.26 E-09	2.23 E+00	3.30 E-02
^{137m}Ba	1	4.65 E-03	5.28 E-07	2.45 E-09	2.11 E+00	9.82 E-03
^{234}U	1	3.16 E+00	4.87 E-14	1.54 E-13	1.95 E-07	6.16 E-07
^{235}U	1	2.93 E+00	3.15 E-15	9.23 E-15	1.26 E-08	3.69 E-08
^{238}U	1	2.81 E+00	2.41 E-14	6.78 E-14	9.65 E-08	2.71 E-07
^{237}Np	1	1.35 E+01	3.12 E-13	4.21 E-12	1.25 E-06	1.69 E-05
^{238}Pu	1	8.12 E+00	1.21 E-12	9.83 E-12	4.84 E-06	3.93 E-05
$^{239,240}Pu$	1	9.24 E+00	2.61 E-12	2.41 E-11	1.04 E-05	9.65 E-05
^{241}Am	1	1.48 E+01	3.01 E-12	4.45 E-11	1.20 E-05	1.78 E-04
^{244}Cm	1	6.51 E+00	3.69 E-13	2.40 E-12	1.48 E-06	9.60 E-06
Total			5.37 E+00	1.13 E-04	1.01 E+01	4.71 E-02

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D: Grout Treatment Facility, Annual Module Maintenance Emissions Doses.

Radioisotopes	Model emission Ci/yr	Model dose mrem EDE	Actual emission Ci/yr	Actual dose mrem EDE	Potential emission Ci/yr	Potential dose mrem EDE
^{3}H	1	2.25 E-05	6.10 E-02	1.37 E-06	6.10 E-02	1.37 E-06
^{14}C	1	2.70 E-03	1.76 E-10	4.75 E-13	1.76 E-10	4.75 E-13
^{60}Co	1	2.97 E-02	4.39 E-09	1.30 E-10	4.39 E-09	1.30 E-10
^{79}Se	1	8.33 E-02	4.00 E-09	3.33 E-10	4.00 E-09	3.33 E-10
^{90}Sr	1	4.53 E-02	1.77 E-06	8.01 E-08	1.77 E-06	8.01 E-08
^{90}Y	1	2.88 E-03	1.77 E-06	5.09 E-09	1.77 E-06	5.09 E-09
^{94}Nb	1	2.75 E-02	5.59 E-09	1.54 E-10	5.59 E-09	1.54 E-10
^{99}Tc	1	1.11 E-03	1.42 E-08	1.57 E-11	1.42 E-08	1.57 E-11
^{106}Ru	1	1.79 E-02	2.66 E-06	4.76 E-08	2.66 E-06	4.76 E-08
^{106}Rh	1	1.74 E-03	2.66 E-06	4.63 E-09	2.66 E-06	4.63 E-09
^{129}I	1	2.87 E-01	4.81 E-11	1.38 E-11	4.81 E-11	1.38 E-11
^{134}Cs	1	3.21 E-02	7.51 E-07	2.41 E-08	7.51 E-07	2.41 E-08
^{137}Cs	1	1.47 E-02	5.85 E-05	8.60 E-07	5.85 E-05	8.60 E-07
^{137m}Ba	1	4.79 E-03	5.53 E-05	2.65 E-07	5.53 E-05	2.65 E-07
^{234}U	1	3.64 E+00	5.11 E-12	1.86 E-11	5.11 E-12	1.86 E-11
^{235}U	1	3.38 E+00	3.30 E-13	1.12 E-12	3.30 E-13	1.12 E-12
^{238}U	1	3.24 E+00	2.53 E-12	8.19 E-12	2.53 E-12	8.19 E-12
^{237}Np	1	1.57 E+01	3.27 E-11	5.14 E-10	3.27 E-11	5.14 E-10
^{238}Pu	1	9.70 E+00	1.27 E-10	1.23 E-09	1.27 E-10	1.23 E-09
$^{239,240}Pu$	1	1.11 E+01	2.74 E-10	3.04 E-09	2.74 E-10	3.04 E-09
^{241}Am	1	1.71 E+01	3.15 E-10	5.39 E-09	3.15 E-10	5.39 E-09
^{244}Cm	1	7.55 E+00	3.87 E-11	2.92 E-10	3.87 E-11	2.92 E-10
Total			6.11 E-02	2.67 E-06	6.11 E-02	2.67 E-06

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E: Grout Treatment Facility, Summary Annual Doses of Emissions.

Radioisotopes	Actual Emission Ci/yr	Actual Dose mrem EDE	Potential Emission Ci/yr	Potential Dose mrem EDE
^{3}H	1.64 E+02	3.68 E-03	1.64 E+02	3.68 E-03
^{14}C	1.96 E-10	5.26 E-13	1.40 E-05	2.75 E-08
^{60}Co	4.88 E-09	1.45 E-10	3.49 E-04	1.01 E-05
^{79}Se	4.45 E-09	3.71 E-10	3.18 E-04	2.89 E-05
^{90}Sr	1.97 E-06	8.87 E-08	1.40 E-01	4.62 E-03
^{90}Y	1.97 E-06	5.64 E-09	1.40 E-01	2.91 E-04
^{94}Nb	6.22 E-09	1.72 E-10	4.44 E-04	1.47 E-05
^{99}Tc	1.58 E-08	1.74 E-11	1.12 E-03	1.05 E-06
^{106}Ru	2.96 E-06	5.28 E-08	2.11 E-01	3.22 E-03
^{106}Rh	2.96 E-06	5.15 E-09	2.11 E-01	3.63 E-04
^{129}I	5.35 E-11	1.53 E-11	3.82 E-06	1.09 E-06
^{134}Cs	8.36 E-07	2.68 E-08	5.97 E-02	1.88 E-03
^{137}Cs	6.51 E-05	9.57 E-07	4.65 E+00	6.85 E-02
^{137m}Ba	6.16 E-05	2.95 E-07	4.40 E+00	2.08 E-02
^{234}U	5.68 E-12	2.07 E-11	4.06 E-07	1.38 E-06
^{235}U	3.67 E-13	1.24 E-12	2.62 E-08	8.30 E-08
^{238}U	2.81 E-12	9.11 E-12	2.01 E-07	6.10 E-07
^{237}Np	3.64 E-11	5.71 E-10	2.60 E-06	3.81 E-05
^{238}Pu	1.41 E-10	1.37 E-09	1.01 E-05	9.02 E-05
$^{239,240}Pu$	3.04 E-10	3.37 E-09	2.17 E-05	2.22 E-04
^{241}Am	3.51 E-10	6.00 E-09	2.51 E-05	4.01 E-04
^{244}Cm	4.30 E-11	3.24 E-10	3.07 E-06	2.17 E-05
Total	1.64 E+02	3.68 E-03	1.74 E+02	1.04 E-01

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Attachment 8

Conversion Factors

atmosphere (atm)	=	14.696 pounds per square inch (psi)
atmosphere (atm)	=	101,325 pascals (Pa)
curie (Ci)	=	3.7 E+10 becquerels (Bq)
gallon (gal)	=	3.78533 liter (L)
kilogram (kg)	=	2.2 pounds (lb)
liter/second (L/s)	=	2.11894 cubic foot per minute (ft^3/min)
seivert (S)	=	100 rem

ATTACHMENT 9

Hanford Environmental Dose Overview Panel Review

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CHECKLIST FOR CALCULATION REVIEW

Document Reviewed: Draft WHC-SD-WM-TI-427, "Grout Treatment Facility Airborne Emissions Projections," Revison C, authored by D. W. Hendrickson.

Scope of Review: Entire document.

Yes	No	N/A		
[X]	[ ]	[ ]	*	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
[X]	[ ]	[ ]		Problem completely defined.
[X]	[ ]	[ ]		Necessary assumptions explicitly stated and supported.
[X]	[ ]	[ ]		Computer codes and data files documented.
[X]	[ ]	[ ]		Data used in calculations explicitly stated in document.
[X]	[ ]	[ ]		Data checked for consistency with original source information as applicable.
[X]	[ ]	[ ]		Mathematical derivations checked including dimensional consistency of results.
[X]	[ ]	[ ]		Models appropriate and used within range of validity or use outside range of established validity justified.
[X]	[ ]	[ ]		Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
[X]	[ ]	[ ]		Code runstreams correct and consistent with analysis documentation.
[X]	[ ]	[ ]		Code output consistent with input and with results reported in analysis documentation.
[X]	[ ]	[ ]		Acceptability limits on analytical results applicable and supported. Limits checked against sources.
[X]	[ ]	[ ]		Safety margins consistent with good engineering practices.
[X]	[ ]	[ ]		Conclusions consistent with analytical results and applicable limits.
[X]	[ ]	[ ]		Results and conclusions address all points required in the problem statement.
[ ]		[X]	*	Review calculations, comments, and/or notes are attached.
[ ]	[X]			Database form completed or analysis entered into database.

RICK J. VAN VLEET Rick J. Van Vleet 11/13/1990

Reviewer Approval (Printed Name and Signature) Date

* Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.

1. The independent reviewer should have the expertise necessary to have performed the original analysis within the scope of the review. The total scope of all reviews should cover the entire analysis with no gaps.

2. The problem should be completely and explicitly defined in detail. Physical arrangements important to the analysis should be completely described.

3. All assumptions required for the analysis should be explicitly stated and supported. Assumptions should be consistent, valid, and reasonable. Question any assumptions made because "it's always been done that way".

4. Information and background needed for the analysis should be included or referenced. Hard to obtain references (such as memos) should be supplied to the reviewer. Data entering into the calculations should be explicitly stated so that the independent reviewer can duplicate all or any part of the analysis given only the analysis documentation. Detailed sample calculations should be included where appropriate for clarity.

5. Computer codes should be documented as to revision or date run with a list of all data files addressed (including revision dates). Published code documentation (e.g., the User's Manual) should be referenced if the code is not already well known to the reviewer. Note that, since they are not QA qualified, spreadsheets cannot be cited in a document.

6. Computer code runstreams and output should be supplied to the reviewer in whatever form is mutually convenient. Code input in the runstreams should be checked in detail and compared to input parameter listings in the output section. Results in the output section should be carefully checked against results presented in the documentation. If warranted by volume of material, the reviewer may limit the review to spot checks as appropriate.

7. Mathematical derivations and dimensional consistency of the resulting formulas should be checked in detail. Mathematical models used should be checked for consistency with each other and for applicability to the analysis. Carefully ensure that models are not being used outside their range of validity without explicit justification.

8. Hand calculations should be duplicated to check for arithmetic errors. If the volume of the analysis makes this impractical, calculations should be spot checked with special emphasis on results which have the greatest effect on the outcome of the analysis. Spreadsheet results should be treated exactly the same as hand calculations.

9. Any limits applied to the analytical results to determine acceptability should be supported. The acceptability of analytical results relative to applicable limits should be consistent with good engineering practice, i.e., are margins adequate?

10. Conclusions should be carefully checked to ensure consistency with analytical results and applicable limits. Conclusions should also be checked against the problem statement to see if all concerns and issues have been addressed.

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CHECKLIST FOR HEDOP REVIEW

Document Reviewed: Draft WHC-SD-WM-TI-427, "Grout Treatment Facility Airborne Emissions Projections," Revison C, authored by D. W. Hendrickson.

Scope of Review: Entire document.

Yes	No	N/A	
[X]	[ ]	[ ]	HEDOP approved code(s) or appropriate calculation methodology used.
[X]	[ ]	[ ]	Appropriate receptor locations evaluated.
[X]	[ ]	[ ]	Appropriate models (finite plume vs. semi-infinite cloud, building wake, etc.) used.
[X]	[ ]	[ ]	Appropriate pathways evaluated for each receptor.
[X]	[ ]	[ ]	Analysis consistent with HEDOP recommendations.
[ ]		[X] *	Review calculations, comments, and/or notes are attached.

RICK J. VAN VLEET, Dr. Rick J. Van Vleet 11/13/1990

HEDOP Reviewer Approval (Printed Name and Signature) Date

* Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.