COVER SHEET

SUBJECT: Verification of TOXPUFF and TOXEVAP LOTUS 1-2-3 Spreadsheets

PROJECT: Monticello Toxic Chemical Study

CLIENT: Northern States Power

[ ] ECP-2.1 DESIGN
[X] ECP-2.2 CALCULATION
[ ] ECP-2.3 ENG. EVALUATION
[ ] OTHER

CONT. I.D. NO. 1961-2.2-001

NO. OF SHTS. 69 (plus sheet 1A) 1 2

PURPOSE/DESCRIPTION

The purpose of this calculation is to define the methodology for analyzing the buildup of toxic chemical vapors in the Monticello Control Room (CR) as a result of an accidental spill in the area immediately surrounding the plant. Because the methodology is calculation-intensive, as well as being iterative in some aspects, this calculation also describes two LOTUS 1-2-3 (Version 3.1) spreadsheets (called TOXPUFF and TOXEVAP) developed as tools for the analysis process. Manual calculations are performed to verify each of the spreadsheets for an example chemical release.

REVISION 1 INCORPORATES CLIENT COMMENTS. AFFECTED PAGES: ADDITION OF SHEET 1A (PAGE REVISION RECORD) AND REVISED SHEETS 3, 4, 6, 25, 33, 34 and 35. THESE CHANGES ARE FOR CLARITY AND DO NOT IMPACT THE REVISION 0 CONCLUSIONS. REVISION 2 INCORPORATES AN ADDITIONAL REFERENCE. AFFECTED PAGES: 1A, 2C, 9.

REVISION 2 VERIFICATION CONSISTED OF A REVIEW OF THE CHANGES FOR CLARITY AND CONSISTENCY WITH THE REMAINDER OF THE CALCULATION.

DESCRIPTION OF DOCUMENT VERIFICATION

THE VERIFICATION EFFORTS FOR THIS CALCULATION INVOLVED VERIFYING THE ACCURACY OF EACH FORMULA PROVIDED IN THE CALCULATION BACK TO THE ORIGINAL SOURCE DOCUMENT. IN ADDITION, ALL CALCULATED VALUES IN THE MAIN BODY WERE HAND CHECKED FOR ACCURACY. VALIDITY OF THE FORMULAS USED IN THE SPREADSHEET WERE CHECKED. THE METHODOLOGY, ASSUMPTIONS, AND DESIGN INPUTS WERE VERIFIED AS ACCEPTABLE. DESIGN INPUTS TO THE SPREADSHEET WERE CHECKED FOR ACCURACY. TIME STEPS USED IN THE MAIN BODY OF THE CALCULATION WERE COMPARED AGAINST THE PRINTOUTS IN THE APPENDICES FOR ACCURACY. NOT EVERY TIME STEP OF THE PRINTOUTS WAS HAND CHECKED AS THE ACCURACY OF THE INFORMATION WAS VALIDATED THROUGH THE HAND CHECKED CALCULATIONS AT SPECIFIED TIME STEPS. THESE SPECIFIED TIME STEPS ARE THOSE SHOWN IN THE MAIN BODY OF THE CALCULATION. ACCURACY OF THE TEXT AND VALIDITY OF THE CONCLUSIONS WERE ALSO VERIFIED.

REVISION 1 VERIFICATION CONSISTED OF A REVIEW OF THE CHANGES FOR CLARITY AND CONSISTENCY WITH THE REFERENCED

REV. NO.	ORIGINATOR (Signature)	DATE	VERIFIED BY (Signature)	DATE	APPROVED BY (Signature)	DATE
0	[illegible]	3/5/93	[illegible]	3/10/93	[illegible]	3/12/93
1	[illegible]	4/16/93	[illegible]	4/29/93	[illegible] FOR [illegible]	4/29/93
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TENERA

PAGE REVISION RECORD

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SUBJECT Verification of TARIFF and TENERAP Lotus 1-2-3 spreadsheets

CLIENT NORTHERN STATES POWER SHEET 1A

PAGE	REV	PAGE	REV	PAGE	REV	PAGE	REV	PAGE	REV	PAGE	REV
1	2	29	0	58	0						
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5	0	34	1	63	0						
6	1	35	2	64	0						
7	0	36	0	65	0						
8	0	37	0	66	0						
9	0	38	0	67	0						
10	0	39	0	68	0						
11	0	40	0	69	0						
12	0	41	0								
13	0	42	0								
14	0	43	0								
15	0	44	0								
16	0	45	0								
17	0	46	0								
18	0	47	0								
19	0	48	0								
20	2	49	0								
21	0	50	0								
22	0	51	0								
23	0	52	0								
24	0	53	0								
25	1	54	0								
26	0	55	0								
27	0	56	0								
28	0	57	0								

1.0 PURPOSE

The purpose of this calculation is to describe the models, present examples, and verify the correctness of two separate spreadsheets developed using Lotus (Version 3.1) to support the determination of inside control room toxicity levels subsequent to a postulated chemical spill. The technical approach is identical to that implemented in response to NUREG-0737, Requirement III.D.3.4, for determining toxic material release effects on Control Room (CR) Habitability. Major assumptions used in this modeling process, consistent with NUREG-0570, are noted throughout this calculation where appropriate.

Section 6.1 of this calculation verifies the TOXPUFF spreadsheet, which evaluates toxic chemical spill effects on Control Room operators where the spilled material is either a compressed gas or a liquid with a boiling point temperature at atmospheric pressure less than ambient temperature. As an example, a chlorine spill from the Burlington Northern Line is modeled and evaluated. Section 6.2 of this calculation verifies a spreadsheet that is a variation of the TOXPUFF spreadsheet. This modified spreadsheet, called TOXEVAP, models the situation in which there is no initial puff release, which occurs when the spilled chemical has a boiling point temperature (at atmospheric conditions) that exceeds the ambient temperature. In this verification, an example is constructed using a spill from the Burlington Northern Line of Ethyl Alcohol.

1.1 Background

The original CR Habitability Study (Ref. 1) used one of two models, consistent with NUREG-0570 (Ref. 2), to evaluate the rate of toxic chemical buildup in the CR subsequent to an accidental spill outside the CR. The rate of chemical buildup and subsequent CR purging were modeled, in conjunction with the incapacitation models of NUREG/CR-1741 (Ref. 3), to determine how soon after the accidental spill a CR operator might become incapacitated. Model 1 was used for compressed gas or liquid spills whose boiling point is below ambient temperature. Model 2 was used for liquid spills whose boiling point exceeds ambient temperature. Both models are presented in separate sections below. Where identical techniques are implemented, the model is only described once. However, as two separate spreadsheets were developed, examples are provided for both models for the purpose of verification.

2.0 METHODOLOGY

The methodology for performing this study is described in Section 6.0 (ANALYSIS) of this calculation as part of the verification of the TOXPUFF and TOXEVAP spreadsheets. Included in the development in that Section is the referencing to the regulatory documents that establish the bases for the approach used in this study.

3.0 ACCEPTANCE CRITERIA

Regulatory Guide (RG) 1.78 (Reference 9) stipulates that there be at least two minutes from the time of detection of a toxic chemical in the control room (CR) until incapacitation of the operators occurs. Section C.7.B, footnote 6, states that "two minutes is considered sufficient time for a trained operator to put a self-contained breathing apparatus into operation, if these are to be used." One goal of this effort is to evaluate, for the chemicals determined to be applicable, the time operators have available to take appropriate protective actions following an accidental toxic spill occuring in the vicinity of the plant. If the time from detection to incapacitation (as defined and determined using the methodology of this calculation) is in excess of two minutes, then the addition of CR monitors for that chemical to ensure adequate CR isolation need not be considered.

This calculation has two specific acceptance criteria. The first involves the verification of the TOXPUFF and TOXEVAP spreadsheets. Reasonable agreement between the results of manual calculations and the results obtained using these spreadsheets (using the methodology described in this calculation) is necessary in order to consider these spreadsheets to be suitable tools to facilitate

further analysis. The second acceptance criteria invokes the RG 1.78 guidance regarding the two minute operator response time to the results of the example chemicals used in this verification.

4.0 INPUTS

Various plant and chemical compound information are needed to perform the analysis in Section 6. The following is a summary of the inputs used.

- Quantity of Chlorine carried in a typical railroad car is 13,750 gallons (Reference 1).
- Quantity of Ethyl Alcohol carried in a typical railroad car is 29,500 gallons (Reference 12).

5.0 ASSUMPTIONS

The following assumed values are used in the analysis:

- Ambient temperature = 20°C

  Note: This value is reasonable based on a review of USAR Table 2.3-1.

- Wind Speed = 1 m/s

  Note: This value is reasonable based on a review of USAR Table 2.3-12. Also, it is consistent with the value used in NUREG-0570. CHECKER'S NOTE: THIS VALUE IS ALSO CONSISTENT WITH THAT GIVEN IN REG. GUIDE 1.3 FOR EVALUATING THE RADIOLOGICAL CONSEQUENCES OF A LOCA FOR BWRs. JK 4/26/93

6.0 ANALYSIS

The analysis presented here involves two cases. The first looks at the situation in which the chemical compound spilled has a boiling temperature less that ambient; i.e., upon release from its container, the chemical will boil and form a toxic cloud. In this case, the methodology is described and the TOXPUFF spreadsheet that incorporates this methodology is verified for use. The second case looks at the situation in which the spilled chemical has a boiling temperature that is higher than ambient. In this case, the chemical forms a toxic cloud through evaporation. The spreadsheet that incorporate the methodology for this scenario is called TOXEVAP. The analysis for each case is presented in the following two subsections.

6.1 Model 1, $T_a > T_b$, TOXPUFF

This section describes the TOXPUFF model, presents examples, and verifies the LOTUS 1-2-3 spreadsheet. The TOXPUFF model was developed to evaluate toxic chemical spill effects on Control Room operators where the spilled material is either a compressed gas or a liquid whose boiling point temperature (T_b) at atmospheric pressure is less than ambient temperature (T_a). For liquids, the chemical release is modeled as both an instantaneous puff and vaporization of the remaining liquid. Compressed gases are assumed to be released as an instantaneous puff in their entirety provided they are contained at ambient temperature. A step-by-step approach has been developed to describe the complete model. Separate subsections have been developed for this purpose as noted below:

6.1.1 Mass of Instantaneous Puff Release
6.1.2 Concentration of Instantaneous Puff Release at CR Intake
6.1.3 Conversion to PPM
6.1.4 Growth of Spill Area
6.1.5 Vaporization Rate of Remaining Spill
6.1.6 Concentration of Vaporization Release at CR Intake
6.1.7 Buildup Inside Control Room
6.1.8 Incapacitation Model A

The completion of each separate step is identical for both liquid and compressed gas spills, except as noted above. The example chemical used is chlorine. The developed models are identical to those presented in NUREG-0570. TOXPUFF cell locations where a particular formula, value, or output

result is located are noted in brackets next to each parameter. Where a value is shown as an input, it was entered into both the manual calculation shown below and to TOXPUFF as a design input. Where a value is shown as an output, both the hand calculated and TOXPUFF calculated values are shown for verification purposes. A printout which contains selected time steps of the TOXPUFF calculated outputs is included in Appendix 1. A printout of the TOXPUFF formulas, with the first few rows of the time step formulas, is included in Appendix 2. Only a few rows of individual time step formulas were printed as all rows (except the first) are identical.

6.1.1 Mass of Instantaneous Puff Release

As noted in Section 2 of Ref. 2, it is conservatively assumed that the entire container of toxic material ruptures and is available for immediate release. If stored in a container as a liquid at ambient temperature, or stored as a compressed gas at lower storage temperature, a percentage will instantaneously release as a puff. The remainder will vaporize as described in later sections. If the entire shipment is in a gaseous state, it is assumed that the entire mass is released in the form of a puff as described in Sections 6.1.1 through 6.1.3. To calculate the mass of the instantaneous puff, the following equation is solved:

$$m_p = m_l \cdot C_p \cdot (T_a - T_b)/H_v$$

(Ref. 2, eq. 2.1-3)

where: m_p = mass of instantaneous release (grams,g)

m_l = total initial mass of spill (g)

C_p = heat capacity of liquid (cal/g°C)

T_a = ambient temperature (°C)

T_b = normal boiling point of liquid (°C) at 1 atmosphere

H_v = heat of vaporization of liquid (cal/g)

Application of this formula is demonstrated in the following example.

Example 6-1:

Using data from Reference 1 (for a 13,750 gallon (90 ton) Chlorine Spill):

$$V_c = 13{,}750 \text{ (gallons)} \cdot 3.785 \cdot 10^3 \text{ (cm}^3\text{/gallon)}$$

$$= 5.204 \cdot 10^7 \text{ (cm}^3\text{, container volume)}$$

[F10, input]

Note: Conversion coefficient to cm^3 obtained from Table A3 of Reference 4.

$$m_l = V_c \cdot DENS_l$$

$$= 8.17 \cdot 10^7 \text{ g}$$

From TOXPUFF,

$$m_l = 8.17 \cdot 10^7 \text{ g}$$

[F45, output]

where: $DENS_l$ = Density of liquid

$= 1.57$ g/cm^3 ✓

(Ref. 1, Table 2) [F27, input] ✓

Inputs: $m_i = 8.17 \cdot 10^7$ g (computed above)

$C_p = 0.226$ cal/g°C ✓

(Ref. 1, Table 2) [F30, input] ✓

$T_a = 20°C = 293.16°K$ ✓

(assumed) [F17, input] ✓

$T_b = -34.1°C = 239.06°K$ ✓

(Ref. 1, Table 2) [F28, input] ✓

$H_v = 68.8$ cal/g ✓

(Ref. 1, Table 2) [F31, input] ✓

Calc: $m_v = 8.17 \cdot 10^7 \cdot 0.226 \cdot (293.16 - 239.06)/68.8$

$= 1.452 \cdot 10^7$ g ✓

From TOXPUFF,

$m_v = 1.452 \cdot 10^7$ g ✓

[E54, output] ✓

$m_a = m_i - m_v$ (remaining mass after puff release)

$= 8.17 \cdot 10^7 - 1.452 \cdot 10^7$ ✓

$= 6.718 \cdot 10^7$ g ✓

From TOXPUFF,

$m_a = 6.718 \cdot 10^7$ g ✓

[E57, output] ✓

As shown above, excellent agreement between TOXPUFF-generated results and those manually calculated were obtained.

Note: If the released chemical consists completely of a compressed gas stored at some container (or ambient) temperature (T_c), the total mass (using the Ideal Gas Law) is calculated as follows:

$$m_i = (MW \cdot P_c \cdot V_c)/(R \cdot T_c)$$

where: MW = molecular weight of the gas (g/mole)

P_c = container pressure (atmosphere, atm)

R = Universal Gas Constant

$= 8.205 \cdot 10^{-5}$ atm·m^3/mole·°K ✓

(Ref. 6, pg. F-221)

T_c = container temperature (°K)

This formula for calculating compressed gas initial mass is not included in TOXPUFF. If required, the formula in cell F45 would be overwritten with a manually calculated value of m_i. If $T_c=T_s$, the formula in cell E54 would also be overwritten with m_i as m_o would equal m_i.

6.1.2 Concentration of Instantaneous Puff Release at CR Intake

Chemical spill concentration at the CR intake for an instantaneous puff release is calculated as follows:

$$X(x,y,z,h) = [m_o/(2\cdot\pi\cdot 2^{\frac{1}{2}}\cdot\pi^{\frac{1}{2}}\cdot\sigma_{xi}\cdot\sigma_{yi}\cdot\sigma_{zi})]\cdot \exp[-\tfrac{1}{2}\cdot(x^2/\sigma_{xi}^2+y^2/\sigma_{yi}^2)]\cdot (\exp[-\tfrac{1}{2}\cdot(z-h)^2/\sigma_{zi}^2] + \exp[-\tfrac{1}{2}\cdot(z+h)^2/\sigma_{zi}^2])$$

(Ref. 8, eq. 3.1.1.3)

CHECKER'S NOTE: THIS EQUATION SHOULD BE 3.113. THE TERMS OF THE EQUATION SHOWN HERE ARE SLIGHTLY DIFFERENT FROM THOSE IN EQ. 3.113 IN ORDER TO ACCOUNT FOR THE h TERM. THE RESULT IS STILL VALID. GCK 4/16/93

where:

$X(x,y,z,h)$ = puff concentration at point (x,y,z) assuming spill release at point (0,0,0) (g/m³)

σ_{xi}^2 = x dispersion coefficient (m)

(Ref. 2, eq. 2.2-2)

$$\sigma_x^2+\sigma_o^2$$

σ_{yi}^2 = y dispersion coefficient (m)

(Ref. 2, eq. 2.2-3)

$$\sigma_y^2+\sigma_o^2$$

σ_{zi}^2 = z dispersion coefficient (m)

(Ref. 2, eq. 2.2-4)

$$\sigma_z^2+\sigma_o^2$$

σ_{xi}^2 = σ_{yi}^2 (due to spill symmetry)

(Ref. 2, eq. 2.2-5)

Note: σ_o^2 is a correction factor to account for the initial puff volume. It is calculated as follows:

$$\sigma_o = [m_o/(2^{\frac{1}{2}}\cdot\pi\cdot\pi^{\frac{1}{2}}\cdot DENS_v)]^{1/3} \text{ (m)}$$

(Ref. 2, eq. 2.2-7)

where: $DENS_v$ = chemical vapor density (g/m³)

Using the Ideal Gas Law, $DENS_v$ is calculated as follows:

$$DENS_v = MW \cdot P_a / R \cdot T_a \quad (g/m^3)$$

(Ref. 1, App. A, eq. 3.1-8)

where: MW = molecular weight (g/mole)
P_a = atmospheric pressure (=1 atm)

T_a = ambient temperature (°K)

σ_x, σ_y, and σ_z are the atmospheric dispersion coefficients. These values are normally obtained from Figures 1 and 2 of Reg Guide 1.78 (Ref. 9). However, a mathematical representation of the curves shown in Figures 1 and 2 of Ref. 9 was developed in the original study (Ref. 1, pg. A-14). This mathematical model allows computer calculation of dispersion coefficients and provides fairly accurate results when compared to the figures. The values for Class G Stability Category are shown below (as obtained from Ref. 1). Class G was chosen based on Appendix A of Reg. Guide 1.78 (Ref. 9) and Table 2.3-12 of the MNGP USAR (Ref. 10), i.e., the worse case stability category that exists for more than 5% of the time was chosen (Class G).

$$\log_{10}\sigma_y = -1.6212+1.0648\cdot(\log_{10}X_s)-0.014857\ (\log_{10}X_s)^2-$$
$$0.0020555\cdot(\log_{10}X_s)^3$$

(Ref. 1, App. A, eq. 3.3-1)

$$\log_{10}\sigma_z = -1.8981+1.1243\cdot(\log_{10}X_s)-0.036447\cdot(\log_{10}X_s)^2-$$
$$0.0086351\cdot(\log_{10}X_s)^3$$

(Ref. 1, App. A, eq. 3.3-1)

where: X_s = distance from spill to CR intake in meters

Note: Since $\sigma_{x0}^2 = \sigma_{y0}^2$, no separate equation is presented for calculating σ_x above (Ref. 2, eq. 2.2-5).

According to both References 1 and 2, it is normally assumed that the spill locale is aligned on the x-axis with the CR intake. This simplifies the equation for X(x,y,z,h) as y=0. The model outlined in this calculation uses y=0. It is also conservatively assumed that for $DENS_v$ heavier than air density z=h=0 and for $DENS_v$ lighter than air z=h. $DENS_v$ is calculated in TOXPUFF using the Ideal Gas Law as shown previously. Finally, x in the above equation is replace as follows to determine the CR intake concentration buildup and depletion over time:

$$x = x_o - U \cdot t$$

(Ref. 1, pg. A-10)

where: x_o = distance from spill to CR intake (m)

U = wind speed (m/sec)

t = elapsed time since spill (seconds)

$x_o - U \cdot t$ is used to account for the delay time between initial release and transport to the CR intake.

Example 6-2:

Continuing with the chlorine chemical example from above in conjunction with available data from Reference 1:

Inputs: x_e = 3.218 km (=2 miles)

(Ref. 1, Section 2.0, pg. 3) [F11, input]

MW = 70.9 g/mole

(Ref. 1, Table 2) [F29, input]

P_a = 1 atm

(assumed) [F19, input]

R = $8.205 \cdot 10^{-5}$ atm·m³/mole·°K

[F34, input]

U = 1 m/sec

(assumed) [F18, input]

m_p = $1.452 \cdot 10^{7}$ g

(computed above) [E54, output]

T_a = 20°C

(assumed) [F17, input]

Conversion Factors: Adding 273.16 to centigrade temperatures converts °C to °K; a factor of 10^6 is used to convert m^3 to cm^3.

Calc: T_a = 273.16+20

= 293.16°K

[F46, output]

Note: π is stored at cell location F37 in the TOXPUFF spreadsheet. Value input is 3.1415926.

Calc:

$\log_{10}\sigma_y$ = $-1.6212 + 1.0648 \cdot [\log_{10}(3218)] -$

$0.014857 \cdot [\log_{10}(3218)]^2 -$

$0.0020555 \cdot [\log_{10}(3218)]^3$

σ_y = 69.532 m

From TOXPUFF,

σ_y = 69.532 m

[E103, output]

$\log_{10}\sigma_z$ = $-1.8981 + 1.1243 \cdot [\log_{10}(3218)] -$

$0.036447 \cdot [\log_{10}(3218)]^2 -$

$0.0086351 \cdot [\log_{10}(3218)]^3$

σ_z = 16.766 m

From TOXPUFF,

σ_z = 16.766 m

[E111, output]

Note: As an additional confirmation of the σ_y and σ_z values, a comparison was made with the graphs presented in RG 1.78 as Figures 1 and 2. These graphs plot the family of curves for the horizontal and vertical standard deviation of material in the plume for various Pasquill Types. Corresponding to Pasquill G, and using the 3218 meter distance, the above values of σ_y and σ_z compare very well with those calculated above.

$DENS_v$ = $(70.9 \cdot 1)/(8.205 \cdot 10^{-5} \cdot 293.16 \cdot 1 \cdot 10^6$

= $2.948 \cdot 10^{-3}$ g/cm^3

= $2.948 \cdot 10^3$ g/m^3

From TOXPUFF,

= $2.948 \cdot 10^3$ g/m^3

[E91, output]

σ_x = $[1.452 \cdot 10^7/(2^{\pi} \cdot \pi^{3/2} \cdot 2.948 \cdot 10^3)]^{1/5}$

= 8.552 m

From TOXPUFF,

= 8.552 m

[E95, output]

σ_{y1} = $[(69.532)^2+(8.552)^2]^{\frac{1}{2}}$

= 70.056 m

From TOXPUFF,

= 70.056 m

[E114, output]

σ_{z1} = $[(16.766)^2+(8.552)^2]^{\frac{1}{2}}$

= 18.82 m

From TOXPUFF,

= 18.821 m

[E120, output]

$\sigma_{x1} = \sigma_{y1} =$ 70.056 m

From TOXPUFF,

= 70.056 m

[E117, output]

$DENS_{air} =$ $1.29 \cdot 10^{-3}$ g/cm³

(Ref. 13, Table 3-48)

Note: This value of air density is at 0°C. Correcting it for T_a=20°C only further demonstrates that $DENS_v > DENS_{air}$.

As $DENS_v > DENS_{air}$, z=h=0. In TOXPUFF $DENS_{air}=1.2 \cdot 10^{-3}$ g/cm³ [F36, input]. $DENS_v$ is compared to $DENS_{air}$ at cell location D191 either 0 or F22 (CR intake height) is displayed. Verified run indicates 0 at D191 which is correct (see Appendix 1).

Combining all data points gives:

$$X = [1.452 \cdot 10^7/(2^{3/2} \cdot (\pi)^{3/2} \cdot 70.056 \cdot 70.056 \cdot 18.821)] \cdot$$

$$\exp[-\frac{1}{2} \cdot (3218-t)^2/(70.056)^2] \cdot (\exp[0]+\exp[0])$$

$$= 19.96 \cdot \exp[-(3218-t)^2/9.816 \cdot 10^3] \text{ g/m}^3$$

Note: Results for various time steps using this calc will be compared to the TOXPUFF equation in the next section subsequent to conversion to ppm units.

6.1.3 Conversion to PPM

The following equation, based on the Ideal Gas Law, is used to convert X from g/m³ to parts per million (ppm):

$$X(ppm) = X(g/m^3) \cdot R \cdot T_a \cdot 10^6/MW \cdot P_a$$

(Ref. 1, App. A, eq. 5-3)

Example 6-3

For chlorine using values from above:

$$X(ppm) = X(g/m^3) \cdot 8.205 \cdot 10^{-5} \cdot 293.16 \cdot 10^6/(70.9 \cdot 1)$$

$$= X(g/m^3) \cdot 339.26$$

[value of 339.26 calculated by TOXPUFF, E136, output]

$$= 6.772 \cdot 10^3 \cdot \exp[-(3218-t)^2/9.816 \cdot 10^3] \text{ ppm}$$

In TOXPUFF, the above constant is calculated once and then used with the exponential term at each time step. The constant is calculated at cell location K188 and in this example has a value of $6.772 \cdot 10^3$, which agrees well as shown above.

Calculating X(ppm) values at selected time steps of 3000 and 3200 seconds gives:

$$X(3000) = 6.772 \cdot 10^3 \cdot \exp[-(3218-3000)^2/9.816 \cdot 10^3]$$

$= 53.47$ ppm ✓

$X(3200) = 6.772 \cdot 10^{3} \cdot \exp[-(3218-3200)^{2}/9.816 \cdot 10^{3}]$

$= 6.552 \cdot 10^{3}$ ppm ✓

In TOXPUFF, time steps at 1 second intervals are calculated and displayed in rows A198 through A2598 and represent time steps from t=0 to 2,400 seconds; at 2 second intervals in rows A2599 through A3198 and represent time steps from t=2,402 to 3,600 seconds; and at 100 second intervals in rows A3199 through A3450 and represent time steps from t=3,700 to 28,800 seconds (8 hours). X is calculated in the corresponding rows in Column H (i.e., H198 through H3450). The final concentration outside the CR intake due to the puff is presented in Column B (B198 through B3450). A check is first performed in Column B to ensure the value calculated in the corresponding Column H cell exceeds $1.0 \cdot 10^{-99}$ ppm, otherwise 0 is printed. This check eliminates the potential for error messages due to calculated values less than this amount. Such a roundoff has no effect on the final results. For t=3000 and 3200 seconds, the X values calculated by TOXPUFF are displayed in cell locations B2898 and B2998, respectively. As shown in Appendix 1, these values match identically with those calculated above.

6.1.4 Growth of Spill Area

The remaining spill, which was not released as an instantaneous puff, will be released through vaporization. The rate of vaporization is proportional to the spill area. The spill area changes with time as follows:

$$A(t) = \pi \cdot (r_o^2 + 2 \cdot t \cdot [g \cdot V_o \cdot (DENS_l - DENS_{air})/(\pi \cdot DENS_l)]^{1/2}) \quad \checkmark$$

(Ref. 2, eq. 2.1-1)

$= A_o + A_{CH} \cdot t$

where: V_o = remaining spill volume after release of instantaneous puff

$= m_o/DENS_l$

$= \pi \cdot r_o^2$ cm^3 ✓

Note: Spill assumed initially cylindrical with height equal to radius of base, Ref. 2, Section 2.1.1.

r_o = initial radius of spill (cm)

g = gravitational constant = 981 cm/sec^2 ✓

(Ref. 2, Section 2.1.1)

A_{CH} = area rate of change (cm^2/sec)

$DENS_l$ = density of chemical (g/cm^3)

$DENS_{air} = 1.29 \cdot 10^{-3}$ g/cm^3 $\cdot 273.16/293.16$ ✓

Note: The Ideal Gas Law is used to adjust the value of density cited in Section 6.1.2 above to 20°C from 0°C.

$= 1.20 \cdot 10^{-3}$ g/cm^3 ✓

t = time (sec)

The equation for A(t) above is applicable from time t=0 ($A=A_o=\pi \cdot r_o^2$) until $A = A_{max}$. A_{max} is defined as that point where the spill thickness equals one centimeter. Once A_{max} is reached, the spill area remains constant as the remaining material vaporizes (Ref. 2, Section 2.1.1). A_{max} is calculated as follows:

$$A_{max} = V_p \text{ (cm}^3\text{)}/1 \text{ cm}$$ ✓

The time (t_{max}) at which $A=A_{max}$ can be calculated by solving the following equation for t_{max}:

$$t_{max} = (A_{max} - A_o)/A_{CH}$$ ✓

TOXPUFF uses t_{max} to determine when to start calculating continuous concentration using A_{max} in place of A(t).

Example 6-4:

Inputs:

$m_p = 6.718 \cdot 10^7$ g [from above calculation]

From TOXPUFF,

$= 6.718 \cdot 10^7$ g ✓ [E57, output] ✓

$DENS_l = 1.57$ g/cm^3 ✓ [F27, input] ✓

$DENS_{air} = 1.2 \cdot 10^{-3}$ g/cm^3 ✓ [F36, input] ✓

$g = 981$ cm/sec^2 ✓ [F38, input] ✓

Calc: $r_o = [m_p/(DENS_l \cdot \pi)]^{1/2}$ ✓

$= [6.718 \cdot 10^7/(1.57 \cdot \pi)]^{1/2}$ ✓

$= 238.8$ cm ✓

From TOXPUFF,

$= 238.8$ cm ✓ [E62, output] ✓

$A_o = \pi \cdot (238.8)^2$ ✓

$= 1.792 \cdot 10^5$ cm^2 ✓

From TOXPUFF,

$= 1.792 \cdot 10^5$ cm^2 ✓ [E65, output] ✓

$A_{CH} = 2 \cdot \pi \cdot [981 \cdot (6.718 \cdot 10^7/1.57) \cdot (1.57 \cdot 1.2 \cdot 10^{-3})/(\pi \cdot 1.57)]^{1/2}$ ✓

$= 7.260 \cdot 10^6$ cm²/sec ✓

From TOXPUFF,

$= 7.260 \cdot 10^6$ cm²/sec ✓

[E69, output] ✓

$A_{max} = 6.718 \cdot 10^7/1.57 \cdot 1$ ✓

$= 4.279 \cdot 10^7$ cm² ✓

From TOXPUFF,

$= 4.279 \cdot 10^7$ cm² ✓

[E72, output] ✓

$t_{max} = (4.279 \cdot 10^7 \cdot 1.792 \cdot 10^5)/7.260 \cdot 10^6$ ✓

$= 58.69$ sec ✓

From TOXPUFF,

$= 58.69$ sec ✓

[E75, output] ✓

As shown above, the spreadsheet values are in agreement with manual calculations.

6.1.5 Vaporization Rate of Remaining Spill

The remaining chemical will be released through vaporization over time as follows:

$dm/dt_v = A(t) \cdot [V_a + V_{CH}/t_v^n]$ ✓

(Ref. 2, eq. 2.1-12)

$V_a = [q_s + h_c \cdot (T_a - T_b)]/H_v$ ✓

$V_{CH} = 197 \cdot (T_i - T_b)/H_v$ ✓

where: dm/dt_v = rate of vaporization (g/sec)

q_s = atmospheric and solar heat flux

= 212 cal/m²·sec ✓

(Ref. 2, Section 2.1.2.1, pg. 7)

Note: Reference 2, Section 2.4.2, recommends the use of 275 cal/m²·sec when q_s is unknown. Consistent with Reference 1, 212 cal/m²·sec is used in this calculation. 212 is the highest value measured in the south western region between 27°N and 40°N latitudes (Ref. 2). As the latitude of MNGP is closer to 50°N, the value of 212 is conservative.

h_c = forced convection heat transfer

$= 1.6$ cal/m²·sec·°C

(for U=1 m/sec and T_a=20°C from Ref. 2, Sec. 2.1.2.2)

T_g = ground (earth) temperature (°C)

(typically assumed equal to T_a)

$t_v = t - x_o/U$

Vaporization effects do not reach the CR intake instantaneously but over time as wind transports the spill, therefore:

$dm/dt_v = 0$ for $t \leq x_o/U$

Also, $dm/dt_v = 0$ once the spill is completely released and has passed by the CR intake. This time (t_{gone}) is determined by solving the following equation for t_{gone}:

$$m_t = \int_0^{t_{gone}} dm/dt_v \cdot dt_v = \int_0^{t_{gone}} A(t_v) \cdot [V_o + V_{CH}/(t_v)^N] \cdot dt_v$$

$A(t_v)$ is replaced by A_{max} for times when $t_v > t_{max}$. This modifies the above equation as follows:

$$m_t = \int_0^{t_{max}} (A_o + A_{CH} \cdot t_v) \cdot [V_o + V_{CH}/(t_v)^N] \cdot dt_v +$$

$$\int_{t_{max}}^{t_{gone}} A_{max} \cdot [V_o + V_{CH}/(t_v)^N] \cdot dt_v$$

If $t_{max} > t_{gone}$ then the A_{max} term (second integral) as shown below will not exist as the entire spill would have vaporized prior to reaching its maximum area. Such a situation is not typically anticipated and would require manual calculation and entry into TOXPUFF. Solving the above integrals gives:

$$m_t = (A_o \cdot V_o \cdot t_v + \tfrac{1}{2} \cdot A_{CH} \cdot V_o \cdot t_v^2 + 2 \cdot A_o \cdot V_{CH} \cdot t_v^{1/2} + (2/3) \cdot A_{CH} \cdot V_{CH} \cdot t_v^{3/2}) \Big|_0^{t_{max}} +$$

$$(A_{max} \cdot V_o \cdot t_v + 2 \cdot A_{max} \cdot V_{CH} \cdot t_v^{1/2}) \Big|_{t_{max}}^{t_{gone}}$$

The above equation is stored as a macro (\m) at cell location I180. It obtains a value of t_{gone} entered at cell location E180 and computes and outputs a value of m_t at cell location G179. Values of t_{gone} are entered at E180 manually on an iterative basis until m_t is reached.

Example 6-5:

Inputs: $h_t = 1.6$ cal/m²·sec·°C

[F40, input]

T_t = 20°C = 293.16°K ✓

(assumed) [F46, input] ✓

q_s = 212 cal/m²·sec ✓

[F41, input] ✓

T_a = 20°C ✓

[F17, input] ✓

T_b = -34.1°C = 239.06°K ✓

[F28, input] ✓

H_v = 68.8 cal/g ✓

[F31, input] ✓

x_p/U = 3218 sec ✓

m_p = 6.718·10⁷ g ✓

A_{max} = 4.279·10³ m² ✓

A_o = 17.92 m² ✓

A_{CH} = 72.6 m²/sec ✓

t_{max} = 58.69 sec ✓

Calc: V_o = [212 + 1.6·(293.16-239.06)]/68.8 ✓

= 4.34 g/m²·sec ✓

From TOXPUFF,

= 4.34·10⁻⁴ g/cm²·sec ✓

[E83, output] ✓

V_{CH} = 197·(20 - -34.1)/68.8 ✓

= 154.9 g/m²·sec$^{\frac{1}{2}}$ ✓

From TOXPUFF,

= 1.549·10⁻² g/cm²·sec$^{\frac{1}{2}}$ ✓

[E86, output] ✓

Calc: solving for t_{pave}!

$$6.715 \cdot 10^7 = [(17.92 \cdot 4.34 \cdot t_v) + ((1/2) \cdot 72.6 \cdot 4.34 \cdot t_v^2) + (2 \cdot 7.92 \cdot 154.9 \cdot t_v^{1/2}) + ((2/3) \cdot 72.6 \cdot 154.9 \cdot t_v^{3/2})]\Big|_0^{58.69} + [(4.279 \cdot 10^3 \cdot 4.34 \cdot t_v) + (2 \cdot 4.279 \cdot 10^3 \cdot 154.9 \cdot t_v^{1/2})]\Big|_{58.69}^{t_{pave}}$$

$$= 3.961 \cdot 10^6 + (1.857 \cdot 10^4 \cdot t_{pave} + 1.326 \cdot 10^6 \cdot t_{pave}^{1/2} - 1.125 \cdot 10^7)$$

Solving iteratively gives t_{pave} = 1369 seconds.

The value of the first integral above (evaluated from 0 to 58.69 seconds) is calculated by TOXPUFF at cell location E163. In TOXPUFF this value equals $3.961 \cdot 10^6$ which agrees with the manually calculated value of $3.961 \cdot 10^6$. A value of 1369 seconds for t_{pave} is indicated in TOXPUFF cell location E180 and calculates the value shown in cell G179 which equals m_0 minus $3.961 \cdot 10^6$.

1368.9 - O.K. [illegible] 3/10/93

In conclusion, dm/dt, is calculated as follows over the various time intervals:

$dm/dt_v = 0$, for $t_v \leq x_o/U$

$dm/dt_v = A(t) \cdot (V_o + V_{CH}/t_v^{1/2})$,

for $x_o/U < t_v \leq x_o/U + t_{max}$

$dm/dt_v = A_{max} \cdot (V_o + V_{CH}/t_v^{1/2})$,

for $x_o/U + t_{max} < t_v \leq x_o/U + t_{max} + t_{pave}$

$dm/dt_v = 0$,

for $t_v > x_o/U + t_{max} + t_{pave}$

6.1.6 Concentration of Vaporization Release at CR Intake

Chemical spill concentration at the CR intake for a vaporization release is calculated as follows:

$$X(x,y,z,h) = (dm/dt_v) \cdot (1/(2 \cdot \pi \cdot U \cdot \sigma_{yv} \cdot \sigma_{zv})) \cdot \exp[-\tfrac{1}{2} \cdot (y^2/\sigma_{yv}^2)] \cdot (\exp[-\tfrac{1}{2} \cdot (z-h)^2/\sigma_{zv}^2] + \exp[-\tfrac{1}{2} \cdot (z+h)^2/\sigma_{zv}^2])$$

(Ref. 2, eq. 2.2-9)

where: z = calculated as described in Section 6.1.2

h = calculated as described in Section 6.1.2

y = calculated as described in Section 6.1.2

dm/dt_y = calculated as described in Section 6.1.5

$\sigma_{yv}' = \sigma_y' + \sigma_{ye}'$ (Ref. 2, Section 2.2.2) ✓

$\sigma_{zv}' = \sigma_z' + \sigma_{ze}'$ (Ref. 2, Section 2.2.2) ✓

σ_y' = calculated as described in Section 6.1.2

σ_z' = calculated as described in Section 6.1.2

$\sigma_{ye}' = \pi \cdot r'/4.3'$ (Ref. 2, eq. 2.2-10) ✓

$\sigma_{ze}' = 0$ (Ref. 2, Section 2.2.2) ✓

The σ_{ze} term above was assumed to be zero as suggested by Reference 2 since it is a small value.

The σ_{ye} correction term is to account for spill area which resides perpendicular to the CR intake (in the y direction). For circular spills (spill shape assumed in all calculations), r equals the radius of the spill. As r may change with time, σ_{ye} may also change with time. This is accounted for as follows:

$$\sigma_{ye}(t) = \pi^{*} \cdot r(t)/4.3$$ ✓

As the effect at the CR intake is delayed by x_o/U seconds, $\sigma_{ye}(t)$ is calculated as follows:

$$\sigma_{ye}(t) = [A_o + A_{CH} \cdot (t - x_o/U)]^{*}/4.3$$ ✓

for $x_o/U \leq t < t_{max} + x_o/U$

$$= A_{max}^{*}/4.3$$ ✓

for $t_{max} + x_o/U \leq t$

Finally, the conversion of final calculated concentrations from g/m^3 to ppm is performed in the same fashion as shown in Section 6.1.3.

Example 6-6:

Inputs: h = 0

z = 11.28 m ✓

[F22, input] ✓

Note: z=0 is used in the concentration calculation as $DENS_y > DENS_{air}$. The value of z used in this examples comes from the location of the Monticello CR intake; i.e., intake at elevation 967'-0" (Reference 15) and grade elevation is at 930'-0" (Reference 10, Section 2.4.1), the difference being 37', which corresponds to 11.28 meters.

y = 0 ✓

U = 1 m/sec ✓

[F18, input]

σ_y = 69.532 m (see Section 6.1.2)

σ_z = 16.766 m (see Section 6.1.2)

$\sigma_{zo}' = 0$

$\sigma_{zv} = 16.766$

From TOXPUFF,

= 16.766 m

[E123, output]

$\sigma_{yy}(t) = [(69.532)^2 + \sigma_{yo}(t)^2]^{.5}$

$\sigma_{yo}(t)^2 = [17.92 + 72.6 \cdot (t-3218)]/4.3^2$

for $3218 \le t < 3277$

$= 4.279 \cdot 10^3/4.3^2 = 231.4$ for $3277 \le t$

$X = (dm/dt_v) \cdot (1/(2 \cdot \pi \cdot 16.766 \cdot \sigma_{yy}(t) \cdot 1)) \cdot$

$\exp(0) \cdot (\exp[0] + \exp[0]) \cdot 339.26$

$= (dm/dt_v) \cdot [1/\sigma_{y}(\quad)] \cdot 6.441$

Example values of X (ppm) will now be calculated for each of the various time intervals:

$t \le 3218$ sec ($t \le x_o/U$):

$dm/dt_v = 0$ g/sec

X = 0 ppm

From TOXPUFF,

= 0 ppm

[C198 to C3007, t=0 to 3218, output]

$t = 3220$ sec ($x_o/U < t \le x_o/U + t_{max}$):

$dm/dt = A(t-3218) \cdot V(t-3218)$

$= [17.92 + 72.6 \cdot (3220 - 3218)] \cdot [4.34 + 154.9/(3220 - 3218)^{1/2}]$

$= 1.857 \cdot 10^4$ g/sec

$\sigma_{yy}(t) = (69.532^2 + [17.92 + 72.6 \cdot (3220 - 3218)]/4.3^2)^{.5}$

= 69.60 m

From TOXPUFF,

= 69.60 m

[C3008, output]

$$X = 1.857 \cdot 10^{4} \cdot (1/69.60) \cdot 6.441$$

$$= 1.719 \cdot 10^{3} \text{ ppm}$$

From TOXPUFF,

$$= 1.719 \cdot 10^{3} \text{ ppm}$$

[C3008, output]

$t = 3500$ sec $(x_o/U + t_{max} < t < x_o/U + t_{max} + t_{gone})$:

$$dm/dt_v = A_{max} \cdot V(t-3218)$$

$$= 4.279 \cdot 10^{3} \cdot [4.34 + 154.9/(3500 - 3218)^{1/2}]$$

$$= 5.804 \cdot 10^{4} \text{ g/sec}$$

$$\sigma_{vv}(t) = 71.18 \text{ m}$$

$$X = 5.804 \cdot 10^{4} \cdot (1/71.18) \cdot 6.441$$

$$= 5.252 \cdot 10^{3} \text{ ppm}$$

From TOXPUFF,

$$= 5.253 \cdot 10^{3} \text{ ppm}$$

[C3148, output]

$t > 4646$ sec $(t > x_o/U + t_{max} + t_{gone})$

$$dm/dt_v = 0 \text{ g/sec}$$

$$X = 0 \text{ ppm}$$

From TOXPUFF,

$$= 0 \text{ ppm}$$

[C3209 to C3450, t=4700 to 28,800, output]

As noted above, the values compare very well with TOXPUFF results. For each time step (A198 to A3450) TOXPUFF calculates the outside control room concentration due to the vaporization release and displays the results in cell locations C198 to C3450. Cell locations C198 through C3450 select one of these values to print depending on the corresponding time values in columns A198 through A3450, respectively. If $t > x_o/U + t_{max} + t_{gone}$, a value of zero is displayed. If $t - x_o/u < t_{max}$, the value in the corresponding I column location is displayed, else the corresponding value in the J column. The I column first checks if $t \leq x_o/U$ and displays zero if it is. Otherwise, the value of X is computed and displayed by using $A(t-x_o/u)$, $V(t-x_o/U)$, and $\sigma_{vv}(t-x_o/U)$ in the computation. Column I obtains the value of $\sigma_{vv}(t)$ from the corresponding row of column N. If J column is selected it implies that $t_{max} + x_o/U \leq t \leq t_{gone} + t_{max} + x_o/U$. For this case, X is calculated by using $A(t) = A_{max}$, $V(t-x_o/U)$, and $\sigma_{vv}(t) = \sigma_{vv}(t_{max})$.

6.1.7 Buildup Inside Control Room

Once the concentration outside the CR is known, the concentration inside can be calculated as follows:

$$C_{CR}(t_i) = C_{CR}(t_{i-1}) + [X(t_i) - C_{CR}(t_{i-1})] \cdot [1 - \exp(-1 \cdot (t_i - t_{i-1}) \cdot W/60 \cdot V_{CR})]$$

(Ref. 2, eq. 2.4-2)

where: $C_{CR}(t_i)$ = control room concentration at time $t=t_i$ (ppm)

$C_{CR}(t_{i-1})$ = control room concentration at time $t=t_{i-1}$ (ppm)

$X(t_i)$ = outside CR intake concentration at time $t=t_i$ (ppm)

V_{CR} = control room volume (ft^3)

W = intake air flow rate (ft^3/min, cfm)

60 = minutes to seconds conversion

The above equation is used when no isolation is employed and the exhaust flow rate exiting the control room equals the air intake flow rate (W). This equation can be developed from Equation 4-5 of Reference 1 for small time intervals ($t_i - t_{i-1}$) with the assumption that $X(t_i)$ is constant with respect to time over the interval. An example of this approach is provided below which utilizes results from Appendix 1. The buildup and depletion between various time steps were verified to ensure the above equation was correctly incorporated into TOXPUFF. Three time intervals which cover different areas of $X_{vap}(t)$ were selected.

Example 6-7:

Inputs: W = 7440 cfm (Ref. 5, 16) [F24, input]

Note: It is conservatively assumed that the entire design flow rate of 7440 cfm enters the control room even though, by design, some flow is diverted to other areas of the EFT Building.

V_{CR} = 27,000 ft^3 (Ref. 11,16) [F23, input]

Note: As noted in Reference 16, the use of the above is reasonable based on physical measurement of the control room volume.

$C_{CR}(t_i,1)$ = obtained from Appendix 1

$X(t_i)$ = obtained from Appendix 1

At t = 3200 seconds:

$X_{vap}(3200)$ = 0 ppm [C2998, output]

$C_{CR+vap}(3198)$ = 0 ppm [F2997, output]

$$C_{CR+vap}(3200) = 0 + [0 - 0] \cdot [1 - \exp(-1 \cdot (3200 - 3198) \cdot 7440/(60 \cdot 27000))]$$

$$= 0 \text{ ppm}$$

From TOXPUFF,

= 0 ppm ✓

[F2998, output] ✓

$X_{puff}(3200) = 6.552 \cdot 10^{-1}$ ppm ✓

[B2998, output] ✓

$C_{CRpuff}(3198) = 1.736 \cdot 10^{3}$ ppm ✓

[E2997, output] ✓

$C_{CRpuff}(3200) = 1.736 \cdot 10^{3} + [6.552 \cdot 10^{-1} - 1.736 \cdot 10^{3}] \cdot$
$[1 - \exp(-1 \cdot (3200 - 3198) \cdot 7440/(60 \cdot 27000))]$
$= 1.780 \cdot 10^{3}$ ppm ✓

From TOXPUFF,

$= 1.780 \cdot 10^{3}$ ✓

[E2998, output] ✓

At t = 3500 seconds:

$X_{vap}(3500) = 5.253 \cdot 10^{3}$ ppm ✓

[C3148, output] ✓

$C_{CRvap}(3498) = 4.567 \cdot 10^{3}$ ppm ✓

[F3147, output] ✓

$C_{CRvap}(3500) = 4.567 \cdot 10^{3} + [5.253 \cdot 10^{3} - 4.567 \cdot 10^{3}] \cdot [1 -$
$\exp(-1 \cdot (3500 - 3498) \cdot 7440/(60 \cdot 27000))]$
$= 4.573 \cdot 10^{3}$ ppm ✓

From TOXPUFF,

$= 4.573 \cdot 10^{3}$ ppm ✓

[F3148, output] ✓

$X_{puff}(3500) = 2.052$ ppm ✓

[B3148, output] ✓

$C_{CRpuff}(3498) = 1.582 \cdot 10^{3}$ ppm ✓

[E3147, output] ✓

$C_{CRpuff}(3500) = 1.582 \cdot 10^{3} + [2.052 - 1.582 \cdot 10^{3}] [1$
$- \exp(-1 \cdot (3500 - 3498) \cdot 7440/(60 \cdot 27000))]$

$= 1.568 \cdot 10^3$ ppm ✓

From TOXPUFF,

$= 1.568 \cdot 10^3$ ppm ✓

[E3148, output] ✓

At t = 4800 seconds:

$X_{vap}(4800) = 0$ ppm ✓

[C3210, output] ✓

$C_{CRvap}(4700) = 2.160 \cdot 10^3$ ppm ✓

[F3209, output] ✓

$C_{CRvap}(4800) = 2.160 \cdot 10^3 + [0 - 2.168 \cdot 10^3] \cdot [1 -$

$\exp(-1 \cdot (4800 - 4700) \cdot 7440 / (60 \cdot 27000))]$

$= 1.370 \cdot 10^3$ ppm ✓

From TOXPUFF,

$= 1.370 \cdot 10^3$ ppm ✓

[F3210, output] ✓

$X_{puff}(4800) = 0$ ppm ✓

[B3210, output] ✓

$C_{CRpuff}(4700) = 6.337$ ppm ✓

[E3209, output] ✓

$C_{CRpuff}(4800) = 6.337 + [0 - 6.337] \cdot [1 -$

$\exp(-1 \cdot (4800 - 4700) \cdot 7440 / (60 \cdot 27000))]$

$= 4.003$ ppm ✓

From TOXPUFF,

$= 4.003$ ppm ✓

[E3210, output] ✓

As the above example demonstrates, the equation that models chemical buildup and subsequent depletion in the control room was correctly incorporated into TOXPUFF.

6.1.8 Incapacitation Model A

Incapacitation models are not included in TOXPUFF, although the results can be used to assess incapacitation potential. Model A as described in NUREG/CR-1741 (Reference 3) is applicable for chlorine releases (immediate sensory irritant). To determine incapacitation

time, the following equation is solved to determine the total number (N) of time intervals required to make the equation reach a value greater than one:

$$\sum_{i=1}^{N} t_i/TI_i > 1 \qquad \text{[Ref. 3, eq. (3)]}$$

where: $TI_i = 665 \cdot (RD_{50}/C_i)^{0.9}$ (sec) [Ref. 3, eq. (2)]

t_i = time interval (sec)

C_i = total inside CR concentration at $t=t_i$

For chlorine:

RD_{50} = 9.34 ppm [Ref. 3, Table 1]

Note: The above equations are first used when the inside CR concentration reaches the TLV. For chlorine, a conservative TLV of 1 ppm is used (Ref. 3, Table 1).

Incapacitation models, in accordance with Reference 3, will be invoked only as needed in actual toxic chemical calculations. Such modeling will be performed manually and clearly outlined whenever used.

Example 6-8:

In this example, the concentration values (C_i) from the TOXPUFF example constructed through the previous examples will be utilized. The values in column G (Total Inside CR Conc. - ppm) are scanned to locate the time at which the concentration reaches the TLV for chlorine, which is conservatively taken to be a value of 1 ppm. The above equation is then applied to determine the time at which incapacitation occurs. In the following, the time vs concentration values are extracted from the TOXPUFF spreadsheet and incorporated into the following table.

Incapacitation Analysis

TOXPUFF Time	Time Interval	Ci	TIi	ti/TIi	Σ ti/TIi
2968	0	9.576E-01	N/A	N/A	N/A
2970	2	1.066E+00	4.688E+03	4.266E-04	4.266E-04
2972	4	1.187E+00	4.258E+03	4.697E-04	8.963E-04
2974	6	1.320E+00	3.870E+03	5.168E-04	1.413E-03
2976	8	1.466E+00	3.520E+03	5.682E-04	1.981E-03
2978	10	1.628E+00	3.203E+03	6.243E-04	2.606E-03
2980	12	1.806E+00	2.918E+03	6.855E-04	3.291E-03
2982	14	2.002E+00	2.659E+03	7.521E-04	4.043E-03
2984	16	2.218E+00	2.425E+03	8.246E-04	4.868E-03
2986	18	2.455E+00	2.214E+03	9.035E-04	5.771E-03
2988	20	2.715E+00	2.022E+03	9.893E-04	6.761E-03
2990	22	3.001E+00	1.848E+03	1.082E-03	7.843E-03
2992	24	3.314E+00	1.690E+03	1.183E-03	9.027E-03
2994	26	3.656E+00	1.547E+03	1.293E-03	1.032E-02
2996	28	4.032E+00	1.416E+03	1.412E-03	1.173E-02
2998	30	4.442E+00	1.298E+03	1.541E-03	1.327E-02
3000	32	4.890E+00	1.191E+03	1.680E-03	1.495E-02
3002	34	5.379E+00	1.093E+03	1.830E-03	1.678E-02
3004	36	5.913E+00	1.003E+03	1.993E-03	1.878E-02
3006	38	6.495E+00	9.222E+02	2.169E-03	2.094E-02

CHECK @ 2970:

$TI_i = 665\left(9.34/1.066\right)^{0.9}$

$= 4.690 \times 10^3$

$t_i/TI_i = \frac{2}{4.688 \times 10^3}$

$= 4.266 \times 10^{-4}$

CHECK @ 3002:

$TI_i = 665\left(9.34/5.379\right)^{0.9}$

$= 1.693 \times 10^3$

$t_i/TI_i = \frac{2}{1.693 \times 10^3} = 1.830 \times 10^{-3}$

$\sum t_i/TI_i = (4.266 + 4.697 + 5.168 + 5.682 + 6.243 + 6.855 + 7.521 + 9.246 + 9.035 + 9.893 + 10.82 + 11.83 + 12.93 + 14.12 + 15.41 + 16.80 + 14.30) \times 10^{-4}$

$= 1.678 \times 10^{-2}$

3008	40	7.128E+00	8.481E+02	2.358E-03	2.330E-02
3010	42	7.817E+00	7.805E+02	2.562E-03	2.586E-02
3012	44	8.567E+00	7.188E+02	2.782E-03	2.865E-02
3014	46	9.381E+00	6.624E+02	3.019E-03	3.167E-02
3016	48	1.026E+01	6.109E+02	3.274E-03	3.494E-02
3018	50	1.122E+01	5.637E+02	3.548E-03	3.849E-02
3020	52	1.226E+01	5.206E+02	3.842E-03	4.233E-02
3022	54	1.338E+01	4.810E+02	4.158E-03	4.649E-02
3024	56	1.460E+01	4.448E+02	4.496E-03	5.098E-02
3026	58	1.592E+01	4.116E+02	4.859E-03	5.584E-02
3028	60	1.733E+01	3.812E+02	5.247E-03	6.109E-02
3030	62	1.887E+01	3.532E+02	5.663E-03	6.675E-02
3032	64	2.052E+01	3.275E+02	6.107E-03	7.286E-02
3034	66	2.230E+01	3.039E+02	6.582E-03	7.944E-02
3036	68	2.421E+01	2.821E+02	7.089E-03	8.653E-02
3038	70	2.627E+01	2.622E+02	7.629E-03	9.416E-02
3040	72	2.849E+01	2.437E+02	8.205E-03	1.024E-01
3042	74	3.087E+01	2.268E+02	8.819E-03	1.112E-01
3044	76	3.342E+01	2.111E+02	9.473E-03	1.207E-01
3046	78	3.615E+01	1.967E+02	1.017E-02	1.308E-01
3048	80	3.908E+01	1.834E+02	1.091E-02	1.417E-01
3050	82	4.221E+01	1.711E+02	1.169E-02	1.534E-01
3052	84	4.557E+01	1.597E+02	1.252E-02	1.659E-01
3054	86	4.915E+01	1.492E+02	1.340E-02	1.793E-01
3056	88	5.297E+01	1.395E+02	1.434E-02	1.937E-01
3058	90	5.705E+01	1.305E+02	1.533E-02	2.090E-01
3060	92	6.139E+01	1.221E+02	1.638E-02	2.254E-01
3062	94	6.602E+01	1.144E+02	1.748E-02	2.429E-01
3064	96	7.094E+01	1.072E+02	1.865E-02	2.615E-01
3066	98	7.618E+01	1.006E+02	1.989E-02	2.814E-01
3068	100	8.174E+01	9.440E+01	2.119E-02	3.026E-01
3070	102	8.764E+01	8.866E+01	2.256E-02	3.252E-01
3072	104	9.390E+01	8.332E+01	2.400E-02	3.492E-01
3074	106	1.005E+02	7.836E+01	2.552E-02	3.747E-01
3076	108	1.075E+02	7.374E+01	2.712E-02	4.018E-01
3078	110	1.150E+02	6.944E+01	2.880E-02	4.306E-01
3080	112	1.228E+02	6.544E+01	3.056E-02	4.612E-01
3082	114	1.311E+02	6.170E+01	3.241E-02	4.936E-01
3084	116	1.398E+02	5.822E+01	3.435E-02	5.279E-01
3086	118	1.491E+02	5.497E+01	3.638E-02	5.643E-01
3088	120	1.588E+02	5.194E+01	3.851E-02	6.028E-01
3090	122	1.690E+02	4.910E+01	4.073E-02	6.436E-01
3092	124	1.797E+02	4.645E+01	4.305E-02	6.866E-01
3094	126	1.910E+02	4.398E+01	4.548E-02	7.321E-01
3096	128	2.028E+02	4.166E+01	4.801E-02	7.801E-01
3098	130	2.153E+02	3.949E+01	5.065E-02	8.308E-01
3100	132	2.283E+02	3.745E+01	5.340E-02	8.841E-01
3102	134	2.419E+02	3.555E+01	5.626E-02	9.404E-01
3104	136	2.562E+02	3.376E+01	5.924E-02	9.996E-01
3106	138	2.711E+02	3.209E+01	6.233E-02	1.062E+00

CHECKERS NOTE:

CHECK SIGNS → 2 MINUTES 16 SECONDS ⇒ STILL O.K.

[illegible] 3/10/93

In the above table, the concentration in the CR reaches the TLV at time 2970 seconds. At this point, the term "ti/TIi" is summed until that sum exceeds the value of 1, with the elapsed time being the time to incapacitation. The above table shows that the time to incapacitation is 2 minutes 18 seconds. This result indicates that CR operators have sufficient time, according to RG 1.78 (see Section 3.0 above), to respond to the detection of the chlorine and don protective air masks. This result contains additional margin by virtue of the detection limit selected (i.e., 1 ppm). In Reference 14, an odor threshold value of 0.080 ppm is cited, which is based on a critical evaluation of a number of exposure studies to achieve more realistic detection threshold values for humans.

6.2 Model 2, $T_a < T_s$, TOXEVAP

For chemicals that have a boiling point temperature at atmospheric conditions that exceeds ambient temperature the spill is modeled entirely as an evaporation release. The spill release rate (dm/dt) is calculated differently than as described in Section 6.1.5 above. The remaining aspects of the model, including control room buildup, are identical to those outlined above for the continuous release and are not restated in this section. The models for puff release mass and atmospheric dispersion in Sections 6.1.1 and 6.1.2, respectively, are not applicable as there is no initial puff release. Though only the dm/dt model is described below, a complete example has been developed using ethyl alcohol and included in this section. This example served as the model against which the program TOXEVAP was verified similar to TOXPUFF above. TOXEVAP was developed by modifying the verified copy of TOXPUFF above to eliminate the puff release model and replace the mass release rate model. A printout which contains the TOXEVAP calculated outputs is included in Appendix 3. A printout which contains the TOXEVAP formulas is included in Appendix 4.

This section has been subdivided as follows:

6.2.1 Concentration of Evaporation Release at Control Room Intake
6.2.2 Buildup Inside Control Room

As previously, TOXEVAP results are identified and compared to the appropriate input and output values.

6.2.1 Concentration of Evaporation Release at Control Room

For liquid spills whose boiling point is above ambient temperature, the evaporation rate (mass release rate) is calculated as follows:

$$dm/dt = h_e \cdot MW \cdot A(t) \cdot (P_s - P_a)/(R \cdot T_a)$$

(Ref. 2, eq. 2.1-18)

where: MW, A(t), R, and T_a are as defined previously.

P_s = sat. vapor pressure of liquid at T_a (mm·Hg)

P_a = 0 (mm·Hg)

(Ref. 2, Sec. 2.1.3.2)

$$h_e = 0.664 \cdot D \cdot (Re)^{1/2} \cdot (Sc)^{1/3}/L \text{ (cm/s, laminar flow)}$$

(Ref. 2, eq. 2.1-19)

$$h_e = 0.037 \cdot D \cdot (Re)^{0.8} \cdot (Sc)^{1/3}/L \text{ (cm/s, turb. flow)}$$

(Ref. 2, eq. 2.1-20)

$Re = L \cdot U \cdot DENS_a/\mu$

$Sc = \mu/(D \cdot DENS_a)$

μ = viscosity of air (g/cm·s)

U = wind speed (cm/s)

$L = 2\ r(t)$

Note: $L = 2 \cdot r_{max}$ was used in the original study due to the rapid growth of r(t) (Ref. 1). In the TOXEVAP program, r(t) has been modeled instead to account for this growth.

D = diffusion coefficient (cm^2/s)

= 0.2 cm^2/s (for chemicals where all required data to calculate D is unavailable, Ref. 2, Section 2.4.2)

$$= 0.0018583 \cdot T_a^{3/2} \cdot (1/MW_a + 1/MW_b)^{1/2} / (P_a \cdot \sigma_{ab}^2 \cdot \Omega_{ab})$$

(Ref. 2, eq. 2.1-14)

T_a = ambient temperature (°K)

MW_a = molecular weight of air (g/mole)

= 28.84 g/mole

(Ref. 1, pg. A-7)

MW_b = molecular weight of spill material

P_a = 1 atm

$$\sigma_{ab} = (\sigma_a + \sigma_b)/2$$

(Ref. 2, eq. 2.1-15)

σ_a = 3.617 Angstroms for air

(Ref. 1, pg A-7 and Ref. 7, Table B-1)

$$\sigma_b = 2.44 \cdot (T_c/P_c)^{1/3}$$

(Ref. 1, eq. 2.2-7 and Ref. 7, eq. 1.4-13)

T_c = spill critical point temperature (°K)

P_c = spill critical point pressure (atm)

Ω_{ab} = table lookup from Table B-2 of Ref. 7 using kT_a/ϵ_{ab} to find Ω_{ab}

$\epsilon_a/k = .77 \cdot T_c = 97$°K (for air)

(Ref. 1, eq. 2.2-6 and Ref. 7, eq. 1.4-11 and Table B-1)

$\epsilon_b/k = .77 \cdot T_c$ (for spill)

(Ref. 1, eq. 2.2-6 and Ref. 7, eq. 1.4-11)

$$\epsilon_{ab}/k = (\epsilon_a/k \cdot \epsilon_b/k)^{1/2}$$

$$= (97 \cdot .77 \cdot T_c)^{1/2}$$

(Ref. 1, eq. 2.2-5 and Ref. 2, eq. 2.1-16)

Note: The value for D is calculated manually and entered as design input into TOXEVAP.

Example 6-9 (ethyl alcohol):

m_T:

Inputs: V_c = 29,200 gallons · $3.785 \cdot 10^3$ cm^3/gallon

= $1.105 \cdot 10^8$ cm^3

[F10, input]

Note: Conversion coefficient to cm^3 obtained from Table A3 of Reference 4.

$DENS_l$ = 0.789 g/cm^3

(Ref. 6, pg. C290) [F27, input]

Calc: $m_T = V_c \cdot DENS_l$

= $1.105 \cdot 10^8 \cdot 0.789$

= $8.718 \cdot 10^7$ g

From TOXEVAP,

= $8.718 \cdot 10^7$ g

[F42, output]

A(t):

Inputs: m_T = $8.718 \cdot 10^7$ g

$DENS_l$ = 0.789 g/cm^3

g = 981 cm/sec^2 (see Section 6.1.4)

[F37, input]

$DENS_{air}$ = $1.20 \cdot 10^{-3}$ g/cm^3 (see Section 6.1.4)

[F35, input]

Calc: $r_o = (V_c/\pi)^{1/2}$

= $(1.105 \cdot 10^8/\pi)^{1/2}$

= 327.6 cm

From TOXEVAP,

= 327.6 cm

[E50, output]

$A_o = \pi \cdot (327.6)^2$

= $3.373 \cdot 10^5$ cm^2

From TOXEVAP,

$= 3.373 \cdot 10^5$ cm²

[E53, output]

$A_{CH} = 2 \cdot \pi \cdot [981 \cdot 1.105 \cdot 10^8 \cdot (0.789 - 1.2 \cdot 10^{-3})/(\pi \cdot 0.789)]^{1/2}$

$= 1.166 \cdot 10^6$ cm²/sec

From TOXEVAP,

$= 1.166 \cdot 10^6$ cm²/sec

[E57, output]

$A_{max} = 1.105 \cdot 10^8/1$

$= 1.105 \cdot 10^8$ cm²

From TOXEVAP,

$= 1.105 \cdot 10^8$ cm²

[E60, output]

$t_{max} = (1.105 \cdot 10^8 - 3.373 \cdot 10^5)/1.166 \cdot 10^6$

$= 94.48$ sec

From TOXEVAP,

$= 94.46$ sec

[E63, output]

PPM Conversion:

Inputs: $R = 8.205 \cdot 10^{-5}$ atm·m³/mole·°K

[F33, input]

MW = 46.07 g/mole

(Ref. 6, pg. C290) [F29, input]

$T_s = 293.16$°K (see Sectic 1.2)

[F43, output]

$P_s = 1$ atm (see Section 6.1.2)

[F19, input]

Calc:

$X(ppm) = X(g/m^3) \cdot 8.205 \cdot 10^{-5} \cdot 293.16 \cdot 10^6/(46.07 \cdot 1)$

$= X(g/m^3) \cdot 522.1$

From TOXEVAP,

$= X(g/m^3) \cdot 522.11$ ✓

[E114, output] ✓

dm/dt:

Inputs: U = 1 m/sec (see Section 4.2)

[F18, input] ✓

= 100 cm/sec ✓

$L = 2 \cdot r(t) = 2 \cdot (A(t)/\pi)^{1/2}$ ✓

$\mu = 1.834 \cdot 10^{-4}$ g/cm·sec ✓

(Ref. 6, pg. F-56, interpolated to 20°C) [F38, input] ✓

$DENS_{air} = 1.20 \cdot 10^{-3}$ g/cm³ ✓

(see Section 6.1.2) [F35, input] ✓

P_a = 0 mm-Hg ✓

T_a = 293.16°K ✓

MW_a = 28.84 g/mole (Ref. 1, pg. A-7) ✓

MW_b = 46.07 g/mole ✓

σ_a = 3.617 Angstroms (Ref. 1, pg. A-7) ✓

ϵ_a/k = 97°K (for air from Ref. 1, eq. 2.2-6) ✓

T_c = 516°K (Ref. 13)

P_c = 63.1 atm (Ref. 13)

P_s = 40 mm-Hg ✓

(Ref. 6, pg D172, value at 19°C) ✓

Calc: $\sigma_b = 2.44 \cdot (516/63.1)^{1/3}$ ✓

= 4.916 Angstroms ✓

$\sigma_{ab} = (3.671 + 4.916)/2$ ✓

= 4.293 Angstroms ✓

$\epsilon_b/k = 0.77 \cdot 516 = 397.3$°K ✓

$\epsilon_{ab}/k = (97 \cdot 397.3)^{1/2} = 196.3$°K ✓

$kT_a/\epsilon_{ab} = 293.16/196.3 = 1.49$ ✓

From Table B-2 of Ref. 7:

Ω_{ab} = 1.201 (based on linear interpolation)

$D = 0.0018583 \cdot (293.16)^{3/2} \cdot (1/28.84 + 1/46.07)^{\frac{1}{2}} / (1 \cdot 4.293^{2} \cdot 1.201)$ ✓

$= 0.10\ cm^2/sec$ ✓

[F30, input] ✓

$(Sc)^{1/3} = (1.834 \cdot 10^{-4} / 0.1 \cdot 1.20 \cdot 10^{-3})^{1/3}$ ✓

$= 1.152$ ✓

From TOXEVAP,

$= 1.152$ ✓

[F45, output] ✓

As most spills will spread to large areas, h_d is conservatively calculated in TOXEVAP by using the turbulent model. A laminar model value of h_d can be entered, if required, by modifying the equations for dm/dt, h_d, and t_{gone} of TOXEVAP.

$(Re)^{0.8} = (2 \cdot r(t) \cdot 100 \cdot 1.20 \cdot 10^{-3} / 1.834 \cdot 10^{-4})^{0.8}$ ✓

$= 311.5 \cdot r(t)^{0.8}$ ✓

$h_d = 0.037 \cdot 0.1 \cdot 311.5 \cdot r(t)^{0.8} \cdot 1.152 / (2 \cdot r(t))$ ✓

$= 0.6639 / r(t)^{0.2}$ ✓

$dm/dt = (0.6639 / r(t)^{0.2}) \cdot 46.07 \cdot A(t) \cdot (40 - 0) / 8.205 \cdot 10^{-5} \cdot 293.16 \cdot 10^{6} \cdot 760$ ✓

Note: R converted from $atm \cdot m^3/mole \cdot {}^\circ K$ to $mm\text{-}Hg \cdot cm^3/mole \cdot {}^\circ K$ above using $10^6 \cdot cm^3/m^3$ and 760mm-Hg/atm.

$= 6.692 \cdot 10^{-5} \cdot A(t) / ((A(t)/\pi)^{\frac{1}{2}})^{0.2}$ ✓

$= 7.504 \cdot 10^{-5} \cdot A(t)^{0.9}$ ✓

From TOXEVAP,

$= 7.503 \cdot 10^{-5} \cdot A(t)^{0.9}$ ✓

[E75, output] ✓

t_{gone}:

t_{gone} is determined (as previously) by solving the following equation for t_{gone}:

$$m_1 = \int_0^{t_{gone}} dm/dt \cdot dt$$

$$= \int_0^{t_{max}} 7.503 \cdot 10^{-5} \cdot A(t)^{0.9} \cdot dt + \int_{t_{max}}^{t_{gone}} 7.503 \cdot 10^{-5} \cdot (A_{max})^{0.9} \cdot dt$$ ✓

t_{max}

CHECKERS NOTE:

t_{max} BEGINS ON NEXT PAGE

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$$= 7.503 \cdot 10^{-5} \cdot (A_o + A_{CH} \cdot t)^{1.8} \cdot (1/1.9) \cdot (1/A_{CH}) \Big|_0 +$$

$$7.503 \cdot 10^{-5} \cdot A_{max}^{0.8} \cdot (t_{gone} - t_{max})$$

$$t_{gone} = (m_t - 7.503 \cdot 10^{-5} \cdot (1/1.9) \cdot (1/A_{CH}) \cdot [(A_o + A_{CH} \cdot t_{max})^{1.9} - A_o^{1.9}])/$$

$$(7.503 \cdot 10^{-5} \cdot A_{max}^{0.8}) + t_{max}$$

= 67060 sec

From TOXEVAP,

= 67060 sec

[E82, output]

σ and X:

Inputs: x_o = 3218 m (=2 miles) [F11, input]

As x_o is unchanged from the chlorine example in Section 6.1.0 above, the dispersion coefficients for the continuous release remain unchanged.

σ_y = 69.532 m (see Section 6.1.6)

= 69.532 m [E91, output]

σ_z = 16.766 m (see Section 6.1.6)

= 16.766 m [E99, output]

As CR intake height is unchanged, the calculation of σ_{zv} is unchanged:

σ_{zv} = 16.766 m (see Section 6.1.6)

From TOXEVAP,

= 16.766 m

[E102, output]

As A(t) is different, σ_{yv} will change as follows:

$\sigma_{yv} = [(69.532)^2 + \sigma_{yo}(t)^2]^{.5}$ (see Section 6.1.6)

$\sigma_{yo}(t)^2 = [33.73 + 116.6 \cdot (t - 3218)]/4.3^2$ m

for $3218 \le t < 3312$

$\sigma_{yvmax} = [(69.532)^2 + (597.6)]^{.5} = 73.70$ m

for $3312 \le t$

From TOXEVAP,

= 73.704 m

[E106, output]

$$X = (dm/dt)\cdot 522.11\cdot[1/(2\cdot\pi\cdot 16.766\cdot\sigma_{yy}(t)\cdot 1)]\cdot\exp(0)\cdot(\exp[0]+\exp[0])\ (ppm)$$

$$= (dm/dt)\cdot[1/\sigma_{yy}(t)]\cdot 9.912\ (ppm)$$

Examples of values of X(ppm) will now be calculated for each of the various time intervals:

$0 \le t < x_o/U = 3218$ sec:

$X(t) = 0$ ppm

From TOXEVAP,

= 0 ppm

[B147 to B2955, output]

$t = 3220$ sec $[3218 \le t < 3218 + (t_{max} = 94.48)]$:

$$X(3220) = 7.503\cdot 10^{-5}\cdot[3.373\cdot 10^{6} + 1.166\cdot 10^{6}\cdot(3220 - 3218)]^{0.9}\cdot(1/[(69.532)^{1} + (33.73 + 116.6\cdot(3220 - 3218))/4.3^{1}]^{n})\cdot 9.912$$

= 6.49 ppm

From TOXEVAP,

= 6.492 ppm

[B2957, output]

$3312 \le t < 3312 + (t_{pass} = 67060)$:

$$X(t) = 7.503\cdot 10^{-5}\cdot(1.105\cdot 10^{6})^{0.9}\cdot(1/73.70)\cdot 9.912$$

= 175.0 ppm

From TOXEVAP,

= 175.0 ppm [B3004 to B3399 and E137, output]

As shown above, excellent agreement in values of X(t) between TOXEVAP and manual calculations are obtained.

6.2.2 Buildup Inside Control Room

As before, once the concentration outside the CR is known, inside concentration can be calculated as follows:

$$C_{CR}(t_i) = C_{CR}(t_{i-1}) + [X(t_i) - C_{CR}(t_{i-1})]\cdot[1 - \exp(-1\cdot(t_i - t_{i-1})\cdot W/(60\cdot V_{CR}))$$

(see Section 6.1.7 e f. 2, eq. 2.4-2)

The above equation is used when no isolation is employed and the exhaust rate exiting the control room equals the air intake flow rate (W). An example of this approach is provided below which utilizes results from Appendix 3. The buildup and depletion between various time steps were verified to ensure the above equation was correctly incorporated into TOXEVAP. Three time intervals which cover different areas of $X_{evap}(t)$ were selected.

Example 6-10:

Inputs: W = 7440 cfm [F24, input]

V_{CR} = 27000 ft^3 [F23, input]

$C_{CR}(t_{i-1})$ = obtained from Appendix 3

$X_{evap}(t_i)$ = obtained from Appendix 3

t = 20 seconds:

$X_{evap}(20)$ = 0 ppm [B167, output]

$C_{CRevap}(19)$ = 0 ppm [C166, output]

$C_{CRevap}(20) = 0 + [0 - 0] \cdot [1 - \exp(-1 \cdot (20 - 19) \cdot 7440/(60 \cdot 27000))]$

= 0 ppm

From TOXEVAP,

= 0 ppm [C167, output]

t = 3220 seconds:

$X_{evap}(3220)$ = 6.492 ppm [B2957, output]

$C_{CRevap}(3218) = 9.234 \cdot 10^{-3}$ ppm [C2956, output]

$C_{CRevap}(3220) = 9.234 \cdot 10^{-3} + [6.492 - 9.234 \cdot 10^{-3}] \cdot [1 - \exp(-1 \cdot (3220-3218) \cdot 7440/(60 \cdot 27000))]$

$= 6.851 \cdot 10^{-2}$ ppm

From TOXEVAP,

$= 6.851 \cdot 10^{-2}$ ppm [C2957, output]

t = 23,000 seconds

Note: at these later time steps $t_i - t_{i-1}$ = 100 seconds).

$X_{evap}(23,000)$ = 175.0 ppm [B3341, output]

$C_{CRevap}(22,900)$ = 175.0 ppm [C3340, output]

$C_{CRevap}(23,000)$ = 175.0 ppm [C3341, output]

As the above example demonstrates, the equation which models chemical buildup and subsequent depletion in the control room was correctly incorporated into TOXEVAP. The value itself (i.e., 175.0 ppm) is insignificant since the TLV for ethyl alcohol is 1000 ppm (Reference 14). The results above clearly indicate that the concentration of the chemical realized in the CR never reaches the TLV and, therefore, cannot pose a threat. Reference 14 also notes that the threshold for detection is 180 ppm and that the threshold for recognition is 100 ppm. (Note: The fact that the recognition value is less than the detection value is a reflection of the statistical approach used in Reference 14, involving an averaging of various chemical studies to obtain the published results. If the higher value was conservatively used for the detection threshold, the conclusions would not

change). With the maximum concentration falling within this range, operators will be alerted to the need to consider taking protective actions, even though they will not be exposed to an incapacitating quantity.

7.0 CONCLUSIONS

The TOXPUFF and TOXEVAP spreadsheets have been verified to provide reliable results when compared to manual calculations for the examples of chlorine and ethyl alcohol, respectively. Based on the results for the two examples, the following conclusions can be drawn:

Chlorine: A conservative detection level of 1 ppm is used, even though Reference 14 cites a value of 0.08 ppm. The concentration in the CR reaches the 1 ppm level at time equals 2970 seconds after the spill from the railroad car 2 miles away. The incapacitation analysis performed indicates that an incapacitating concentration in the CR is reached at time equals 3106 seconds after the spill. The time span between detection and reaching an incapacitating concentration is 136 seconds (2 minutes and 16 seconds). This exceeds the limit of 2 minutes set in RG 1.78, meaning that operators have sufficient time to take protective actions. Using the conservative detection level of 1 ppm (verses the more realistic 0.08 ppm value) means that operators would actually have more time to respond to the potential threat. Because the 2 minute limit is exceeded, automatic detection for Chlorine is not required.

Ethyl Alcohol: The concentration in the CR never exceeds 175.0 ppm over the eight hour period modeled which, when compared to the TLV value of 1000 ppm, indicates that CR operator incapacitation will not occur. The maximum concentration seen in the CR (i.e., 175 ppm) is within a range that will alert operators that a foriegn substance is present and that protective actions may be appropriate, even though the analysis shows that an incapacitating concentration will not be reached. Therefore, automatic detection for Ethyl Alcohol is not required.

8.0 FUTURE NEEDS

None.

9.0 APPENDICES and ATTACHMENTS

9.1 Appendices

1. TOXPUFF Results for Chlorine Example
2. TOXPUFF Formula Listing
3. TOXEVAP Results for Ethyl Alcohol Example
4. TOXEVAP Formula Listing

9.2 Attachments

None.

10.0 REFERENCES

1. "Monticello Nuclear Generating Plant, Main Control Room Toxic Chemical Study", prepared by Bechtel Power Corporation, January, 1981. Submitted as Attachment 4 in response to NUREG-0737, DSS Sequence Number MWS00962.

2. NUREG-0570, "Toxic Vapor Concentration in the Control Room Following a Postulated Accidental Release," June, 1979.

3. NUREG/CR-1741, "Models for the Estimation of Incapacitation Times Following Exposures to Toxic Gases or Vapors," December, 1980.

4. Engineering Thermodynamics, second edition, by William C. Reynolds and Henry C. Perkins, 1977.

5. Monticello Nuclear Generating Plant, Operations Manual Section B.8.13-02, Description of Equipment, Revision 1.

6. Handbook of Chemistry and Physics, CRC Press, 55th Edition, 1974-1975.

7. Transport Phenomena, R. Byron Bird, et al., copyright 1960.

8. Meteorology and Atomic Energy 1968, TID-24190, edited by David H. Slade.

9. NRC Regulatory Guide 1.78, "Assumptions for Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release," June 1974.

10. Monticello Nuclear Generating Plant, Updated Safety Analysis Report.

11. SRI 90-013, "Justification for Closing VD-9094A and VD-9094B", DSS Sequence Number PXR00802.

12. GATX Tank Car Manual, 5th Edition, published by General American Transportation Corporation.

13. Perry's Chemical Engineer's Handbook, Fourth Edition, published by McGraw-Hill.

14. Odor Thresholds for Chemicals with Established Occupational Health Standards, published by the American Industrial Hygiene Association, copyright 1989.

15. Monticello Drawing NF-93486, Rev. B.

16. NSP Letter, dated 4/22/93, Dirk Foster to David Sexton, "Monticello Toxic Chemical Study Update, Calculation 196101-2.2, Control Volume and Design Fresh Air Intake Input Concerns," TENERA Control ID No. 196101-2.4-048.

APPENDIX 1

TOXPUFF Results for Chlorine

Note: Because of the size of the spreadsheet (length and width), the following printout has been blocked in ranges. The range is cited before each block.

Range: A1 - G200

A	A	B	C	D	E	F	G
1			Toxic Chemical Spill Calculation				
2			(For chemical boiling point less than ambient temperature)				
3							
4		Last Updated:	5-Mar-93	Analyzed Chemical:	Chlorine		
5							
6	==========						
7	Design Inputs:						
8							
9		Spill Data:					
10				Container Volume (VC, cm**3):		5.204E+07	
11				Spill to CR Intake Distance (XO, m):		3218.0	
12				Spill Type:		Circular	
13							
14							
15		Meteorological Data:					
16				Pasquill's Stability Category:		G	
17				Ambient Temperature (Tac, degrees C):		20	
18				Wind Speed (U, m/sec):		1	
19				Air Pressure (PA, atm):		1	
20							
21		Control Room Data:					
22				Control Room HVAC Intake Height (z, m):		11.28	
23				Control Room Volume (CRV, ft**3):		2.700E+04	
24				CR HVAC Intake Rate (CFIN, ft.**3/minute):		7440	
25							
26		Chemical Data:					
27				Chemical Density (DENS, g/cm**3):		1.570	
28				Boiling Point (Tb, degrees C):		-34.1	
29				Molecular Weight (MW, g/mole):		70.90	
30				Heat Capacity (Cp, cal/g-degree C):		0.226	
31				Heat of Vaporization (Hv, cal/g):		68.8	
32							
33		Constants:					
34		Ideal Gas Constant (R, atm-m**3/mole-degree K):				8.205E-05	
35				Air Density (DAIR, g/cm**3,			
36				at 1 atmosphere and 20 degrees C):		1.20E-03	
37					PI:	3.1415927	
38				Gravitational Constant (G, cm/sec**2):		981	
39				Forced Convection Heat Transfer Coefficient			
40				(hc, cal/cm**2-sec-degree C):		1.6E-04	
41				Atmos. and Solar Heat Flux (qr, cal/cm**2-sec):		2.12E-02	
42							
43		Calculated Design Inputs:					
44							
45				Initial Chemical Mass (MT=VC*DENS, g):		8.170E+07	
46				Ambient Temperature (Ta=Tac+273.16, degrees K):		293.16	
47				Chemical Boiling Point (Tb, degrees K):		239.06	
48				Ground (Earth) Temperature (Te=Ta):		293.16	

```
==========================================================================
Chemical Mass Calculations:

 Mass of Initial Puff Release (M0, g) = MT*Cp*(Ta-Tb)/Hv
                                      = 1.452E+07

               Remaining Mass (MR, g) = MT-M0
                                      = 6.718E+07
==========================================================================
Spill Area Calculations:

        Initial Spill Radius (R0, cm) = [MR/(DENS*PI)]**(1/3)
                                      = 2.388E+02

        Initial Spill Area (A0, cm**2) = PI*(R0**2)
                                      = 1.792E+05

     Area Change Rate (ACH, cm**2/sec) = PI*2*[g*(MR/DENS)*
                                      = (DENS-DAIR)/(DENS*PI)]**1/2
                                      = 7.260E+05

      Maximum Spill Area (Amax, cm**2) = (MR/DENS)/1 cm
                                      = 4.279E+07

   Time When Amax Reached (Tmax, sec) = (Amax-A0)/ACH
                                      =     58.69
==========================================================================
Mass Vaporization Rate Calculation

         Mass Vaporization Rate (V(t),
                        g/sec-cm**2) = V0+VCH/(t**(1/2))
           where:
                    V0 (g/sec-cm**2) = (qr+hc*(Ta-Tb))/Hv
                                      = 4.340E-04

             VCH (g/cm**2*sec**(1/2)) = 197*(Te-Tb)/(Hv*10,000)
                                      = 1.549E-02
==========================================================================
Calculation of Sigmas (Dispersion Coefficients)

   Spill Vapor Density (DVAP, g/m**3) = (MW*PA)/(R*Ta)
                                      = 2.948E+03

      Initial Puff Std. Dev  (SIG0, m) = [M0/((2**(1/2))*(PI**(3/2))*
                                        DVAP)]**(1/3)
                                      =     8.552

Pasq.-Giff. Y Disp Coeff log(SIGY, m) = A+B*log(X0)+C*(log(X0))**2
                                        +D*(log(X0))**3
                          where:    A =    -1.6212
                                    B =     1.0648
                                    C = -0.014857
                                    D = -0.002056
                                 SIGY =     69.532

Pasq.-Giff. Z Disp Coeff log(SIGZ, m) = A+B*log(X0)+C*(log(X0))**2
                                        +D*(log(X0))**3
                          where:    A =    -1.8981
                                    B =     1.1243
                                    C = -0.036447
```

```
                                        D = -0.008635
                                      SIGZ =    16.766

     Inst Puff Y Disp Coeff (SIGYI, m) = (SIGY**2+SIG0**2)**(1/2)
                                       =    70.056

     Inst Puff X Disp Coeff (SIGXI, m) = SIGYI
                                       =    70.056

     Inst Puff Z Disp Coeff (SIGZI, m) = (SIGZ**2+SIG0**2)**(1/2)
                                       =    18.821

    Cont Release Disp Coeff (SIGZM, m) = (SIGZ)
                                       =    16.766

    Cont Release Disp Coeff (SIGYM, m) = (SIGY**2+(Reff*PI**(1/2)/4.3)
                                         **2)**(1/2)
                                       =    71.177 (at Amax)

           Note:
              For Circular Spill, Reff = (A(t)/PI)**(1/2)


=========================================================================
Conversion of g/m**3 to ppm

Conversion to PPM (PPM, ppm/(g/m**3)) = (R*Ta*1.0E+06)/(MW*Pa)
                                      =    339.26
=========================================================================
Calculation of Puff Concentration Outside Control Room

  Puff Conc @ CR Intake (CRP(t), ppm) = [M0/(2**(3/2)*(PI)**(3/2)*SIGX
                                        SIGYI*SIGZI)]*exp[-1/2*x**2/
    where z=h=0 for DVAP>DAIR,          SIGXI**2]*(exp[-1/2*(z-h)**2/
          z=h for DVAP<DAIR,            SIGZI**2]+exp[-1/2*(z+h)**2/
          y=0, and x=X0-U*t             SIGZI**2])*PPM
=========================================================================
Calculation of Continuous Release Conc Outside Control Room

  Cont Conc @ CR Intake (CRC(t), ppm) = (A0+ACH*t)*(V0+VCH/t**(1/2))*
                                        (1/(2*PI*U*SIGYM*SIGZM))*(exp[
    where z=h=0 for DVAP>DAIR,          -1/2*(z-h)**2/SIGZM**2]+exp[
          z=h for DVAP<DAIR,            -1/2*(z+h)**2/SIGZM**2])*PPM
          y=0, A0+ACH*t=Amax for
          t>Tmax, and t=t-X0/U
Note:  CRC(t)=0 for t<X0/U and for t>time when entire spill evaporates
       plus X0/U (Tgone+Tmax+X0/U)
=========================================================================
Calculation of Entire Spill Evaporation Time

   Spill Mass Released by time t=Tmax
                          (MAmax, g) = V0*A0*Tmax+V0*ACH*(Tmax**2)/
                                       2+2*VCH*A0*(Tmax**(1/2))+VCH*
                                       ACH*(Tmax**(3/2))*2/3
                                     = 3.961E+06

   Note:  If MAmax > MR, Tgone is determined by solving the following
          equation for Tgone:

           MR = V0*A0*Tgone+V0*ACH*(Tgone**2)/2+2*VCH*A0*(Tgone**
               (1/2))+VCH*ACH*(Tgone**(3/2))*2/3
```

```
171    Note:  If MAmax < MR, Tgone is determined by solving the following
172           equation for Tgone:
173
174            MR-MAmax = VO*Amax*Tgone+VCH*Amax*(Tgone**(1/2))*2-
175                     -Amax*Tmax*VO-Amax*VCH*2*(Tmax)**(1/2)
176    Note:  Due to the interative nature of solving for Tgone, it is
177           computed manually and entered into the appropriate cell.
178               Amax = 4.279E+07     VCH = 1.549E-02     Tmax =      58.7
179                VO = 4.340E-04 MR-MAmax =6.322E+07 MR-MAmaxc=6.322E+07
180                           Tgone (sec) =    1368.8
181  ================================================================================
182  Calculation of Concentration Inside Control Room
183    Concentration in the CR is computed in a time step-by-step
184    manner by adding the the inside CR concentration (both puff
185    and continuous) at the previous time step to the difference
186    between the current outside concentration minus the previous
187    inside concentration times an exponential buildup factor.
188
189
190  ================================================================================
191  Analysis Results                h=        0
192  Chemical Analyzed:  Chlorine
193                      Outside     Outside     Total       Inside      Inside      Total
194                      CR Conc     CR Conc     Outside     CR Conc     CR Conc     Inside
195                        Puff    Continuous    CR Conc      Puff     Continuous   CR Conc
196  Time (sec)          (ppm)       (ppm)       (ppm)       (ppm)       (ppm)       (ppm)
197  ==========          =====       =====       =====       =====       =====       =====
198           0 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
199           1 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
200           2 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
```

Range: H180 - Q190

```
A       H          I          J          K          L          M
180       \m  (LET G179,C179*C178*E180+E178*C178*2*(E180^(1/2))-C178*C179*G178-C178*E178*2*(G178^(1/2)))
181
182
183
184
185
186
187
188     Constant for Outside Puff: 6.772E+03
189     Constant for Cont. w/Amax: 3.872E+06
190     Constant for Contin. A(t): 6.785E+02
```

Range: A2800 - G3450

```
A       A          B          C          D          E          F          G
2800      2804 1.767E-04 0.000E+00 1.767E-04 9.698E-06 0.000E+00 9.698E-06
2801      2806 2.091E-04 0.000E+00 2.091E-04 1.152E-05 0.000E+00 1.152E-05
2802      2808 2.473E-04 0.000E+00 2.473E-04 1.368E-05 0.000E+00 1.368E-05
2803      2810 2.921E-04 0.000E+00 2.921E-04 1.622E-05 0.000E+00 1.622E-05
2804      2812 3.448E-04 0.000E+00 3.448E-04 1.923E-05 0.000E+00 1.923E-05
2805      2814 4.067E-04 0.000E+00 4.067E-04 2.277E-05 0.000E+00 2.277E-05
2806      2816 4.793E-04 0.000E+00 4.793E-04 2.694E-05 0.000E+00 2.694E-05
2807      2818 5.644E-04 0.000E+00 5.644E-04 3.186E-05 0.000E+00 3.186E-05
```

2808	2820	6.640E-04	0.000E+00	6.640E-04	3.764E-05	0.000E+00	3.764E-05
2809	2822	7.806E-04	0.000E+00	7.806E-04	4.443E-05	0.000E+00	4.443E-05
2810	2824	9.169E-04	0.000E+00	9.169E-04	5.241E-05	0.000E+00	5.241E-05
2811	2826	1.076E-03	0.000E+00	1.076E-03	6.177E-05	0.000E+00	6.177E-05
2812	2828	1.262E-03	0.000E+00	1.262E-03	7.274E-05	0.000E+00	7.274E-05
2813	2830	1.479E-03	0.000E+00	1.479E-03	8.560E-05	0.000E+00	8.560E-05
2814	2832	1.731E-03	0.000E+00	1.731E-03	1.006E-04	0.000E+00	1.006E-04
2815	2834	2.026E-03	0.000E+00	2.026E-03	1.182E-04	0.000E+00	1.182E-04
2816	2836	2.368E-03	0.000E+00	2.368E-03	1.388E-0	000E+00	1.388E-04
2817	2838	2.765E-03	0.000E+00	2.765E-03	1.628E-04	000E+00	1.628E-04
2818	2840	3.227E-03	0.000E+00	3.227E-03	1.909E-04	0.000E+00	1.909E-04
2819	2842	3.763E-03	0.000E+00	3.763E-03	2.235E-04	0.000E+00	2.235E-04
2820	2844	4.385E-03	0.000E+00	4.385E-03	2.616E-04	0.000E+00	2.616E-04
2821	2846	5.104E-03	0.000E+00	5.104E-03	3.058E-04	0.000E+00	3.058E-04
2822	2848	5.938E-03	0.000E+00	5.938E-03	3.573E-04	0.000E+00	3.573E-04
2823	2850	6.901E-03	0.000E+00	6.901E-03	4.172E-04	0.000E+00	4.172E-04
2824	2852	8.014E-03	0.000E+00	8.014E-03	4.866E-04	0.000E+00	4.866E-04
2825	2854	9.300E-03	0.000E+00	9.300E-03	5.672E-04	0.000E+00	5.672E-04
2826	2856	1.078E-02	0.000E+00	1.078E-02	6.606E-04	0.000E+00	6.606E-04
2827	2858	1.249E-02	0.000E+00	1.249E-02	7.688E-04	0.000E+00	7.688E-04
2828	2860	1.446E-02	0.000E+00	1.446E-02	8.939E-04	0.000E+00	8.939E-04
2829	2862	1.672E-02	0.000E+00	1.672E-02	1.039E-03	0.000E+00	1.039E-03
2830	2864	1.933E-02	0.000E+00	1.933E-02	1.206E-03	0.000E+00	1.206E-03
2831	2866	2.232E-02	0.000E+00	2.232E-02	1.399E-03	0.000E+00	1.399E-03
2832	2868	2.575E-02	0.000E+00	2.575E-02	1.621E-03	0.000E+00	1.621E-03
2833	2870	2.968E-02	0.000E+00	2.968E-02	1.878E-03	0.000E+00	1.878E-03
2834	2872	3.419E-02	0.000E+00	3.419E-02	2.173E-03	0.000E+00	2.173E-03
2835	2874	3.935E-02	0.000E+00	3.935E-02	2.513E-03	0.000E+00	2.513E-03
2836	2876	4.526E-02	0.000E+00	4.526E-02	2.904E-03	0.000E+00	2.904E-03
2837	2878	5.200E-02	0.000E+00	5.200E-02	3.353E-03	0.000E+00	3.353E-03
2838	2880	5.971E-02	0.000E+00	5.971E-02	3.868E-03	0.000E+00	3.868E-03
2839	2882	6.849E-02	0.000E+00	6.849E-02	4.459E-03	0.000E+00	4.459E-03
2840	2884	7.851E-02	0.000E+00	7.851E-02	5.136E-03	0.000E+00	5.136E-03
2841	2886	8.992E-02	0.000E+00	8.992E-02	5.912E-03	0.000E+00	5.912E-03
2842	2888	1.029E-01	0.000E+00	1.029E-01	6.798E-03	0.000E+00	6.798E-03
2843	2890	1.177E-01	0.000E+00	1.177E-01	7.812E-03	0.000E+00	7.812E-03
2844	2892	1.344E-01	0.000E+00	1.344E-01	8.970E-03	0.000E+00	8.970E-03
2845	2894	1.535E-01	0.000E+00	1.535E-01	1.029E-02	0.000E+00	1.029E-02
2846	2896	1.751E-01	0.000E+00	1.751E-01	1.180E-02	0.000E+00	1.180E-02
2847	2898	1.995E-01	0.000E+00	1.995E-01	1.351E-02	0.000E+00	1.351E-02
2848	2900	2.273E-01	0.000E+00	2.273E-01	1.547E-02	0.000E+00	1.547E-02
2849	2902	2.586E-01	0.000E+00	2.586E-01	1.769E-02	0.000E+00	1.769E-02
2850	2904	2.940E-01	0.000E+00	2.940E-01	2.022E-02	0.000E+00	2.022E-02
2851	2906	3.340E-01	0.000E+00	3.340E-01	2.309E-02	0.000E+00	2.309E-02
2852	2908	3.791E-01	0.000E+00	3.791E-01	2.634E-02	0.000E+00	2.634E-02
2853	2910	4.300E-01	0.000E+00	4.300E-01	3.003E-02	0.000E+00	3.003E-02
2854	2912	4.873E-01	0.000E+00	4.873E-01	3.421E-02	0.000E+00	3.421E-02
2855	2914	5.518E-01	0.000E+00	5.518E-01	3.895E-02	0.000E+00	3.895E-02
2856	2916	6.243E-01	0.000E+00	6.243E-01	4.430E-02	0.000E+00	4.430E-02
2857	2918	7.058E-01	0.000E+00	7.058E-01	5.035E-02	0.000E+00	5.035E-02
2858	2920	7.973E-01	0.000E+00	7.973E-01	5.718E-02	0.000E+00	5.718E-02
2859	2922	8.998E-01	0.000E+00	8.998E-01	6.488E-02	0.000E+00	6.488E-02
2860	2924	1.015E+00	0.000E+00	1.015E+00	7.357E-02	0.000E+00	7.357E-02
2861	2926	1.143E+00	0.000E+00	1.143E+00	8.335E-02	0.000E+00	8.335E-02
2862	2928	1.287E+00	0.000E+00	1.287E+00	9.436E-02	0.000E+00	9.436E-02
2863	2930	1.448E+00	0.000E+00	1.448E+00	1.067E-01	0.000E+00	1.067E-01
2864	2932	1.628E+00	0.000E+00	1.628E+00	1.206E-01	0.000E+00	1.206E-01
2865	2934	1.829E+00	0.000E+00	1.829E+00	1.363E-01	0.000E+00	1.363E-01
2866	2936	2.052E+00	0.000E+00	2.052E+00	1.538E-01	0.000E+00	1.538E-01
2867	2938	2.301E+00	0.000E+00	2.301E+00	1.734E-01	0.000E+00	1.734E-01
2868	2940	2.578E+00	0.000E+00	2.578E+00	1.954E-01	0.000E+00	1.954E-01

2869	2942	2.886E+00	0.000E+00	2.886E+00	2.200E-01	0.000E+00	2.200E-01
2870	2944	3.228E+00	0.000E+00	3.228E+00	2.475E-01	0.000E+00	2.475E-01
2871	2946	3.608E+00	0.000E+00	3.608E+00	2.782E-01	0.000E+00	2.782E-01
2872	2948	4.030E+00	0.000E+00	4.030E+00	3.125E-01	0.000E+00	3.125E-01
2873	2950	4.497E+00	0.000E+00	4.497E+00	3.508E-01	0.000E+00	3.508E-01
2874	2952	5.013E+00	0.000E+00	5.013E+00	3.934E-01	0.000E+00	3.934E-01
2875	2954	5.585E+00	0.000E+00	5.585E+00	4.409E-01	0.000E+00	4.409E-01
2876	2956	6.217E+00	0.000E+00	6.217E+00	4.937E-01	0.000E+00	4.937E-01
2877	2958	6.915E+00	0.000E+00	6.915E+00	5.524E-01	0.000E+00	5.524E-01
2878	2960	7.684E+00	0.000E+00	7.684E+00	6.176E-01	0.000E+00	6.176E-01
2879	2962	8.533E+00	0.000E+00	8.533E+00	6.900E-01	0.000E+00	6.900E-01
2880	2964	9.467E+00	0.000E+00	9.467E+00	7.702E-01	0.000E+00	7.702E-01
2881	2966	1.050E+01	0.000E+00	1.050E+01	8.592E-01	0.000E+00	8.592E-01
2882	2968	1.163E+01	0.000E+00	1.163E+01	9.576E-01	0.000E+00	9.576E-01
2883	2970	1.287E+01	0.000E+00	1.287E+01	1.066E+00	0.000E+00	1.066E+00
2884	2972	1.423E+01	0.000E+00	1.423E+01	1.187E+00	0.000E+00	1.187E+00
2885	2974	1.572E+01	0.000E+00	1.572E+01	1.320E+00	0.000E+00	1.320E+00
2886	2976	1.736E+01	0.000E+00	1.736E+01	1.466E+00	0.000E+00	1.466E+00
2887	2978	1.915E+01	0.000E+00	1.915E+01	1.628E+00	0.000E+00	1.628E+00
2888	2980	2.111E+01	0.000E+00	2.111E+01	1.806E+00	0.000E+00	1.806E+00
2889	2982	2.325E+01	0.000E+00	2.325E+01	2.002E+00	0.000E+00	2.002E+00
2890	2984	2.559E+01	0.000E+00	2.559E+01	2.218E+00	0.000E+00	2.218E+00
2891	2986	2.814E+01	0.000E+00	2.814E+01	2.455E+00	0.000E+00	2.455E+00
2892	2988	3.091E+01	0.000E+00	3.091E+01	2.715E+00	0.000E+00	2.715E+00
2893	2990	3.394E+01	0.000E+00	3.394E+01	3.001E+00	0.000E+00	3.001E+00
2894	2992	3.723E+01	0.000E+00	3.723E+01	3.314E+00	0.000E+00	3.314E+00
2895	2994	4.080E+01	0.000E+00	4.080E+01	3.656E+00	0.000E+00	3.656E+00
2896	2996	4.468E+01	0.000E+00	4.468E+01	4.032E+00	0.000E+00	4.032E+00
2897	2998	4.890E+01	0.000E+00	4.890E+01	4.442E+00	0.000E+00	4.442E+00
2898	3000	5.346E+01	0.000E+00	5.346E+01	4.890E+00	0.000E+00	4.890E+00
2899	3002	5.840E+01	0.000E+00	5.840E+01	5.379E+00	0.000E+00	5.379E+00
2900	3004	6.375E+01	0.000E+00	6.375E+01	5.913E+00	0.000E+00	5.913E+00
2901	3006	6.953E+01	0.000E+00	6.953E+01	6.495E+00	0.000E+00	6.495E+00
2902	3008	7.577E+01	0.000E+00	7.577E+01	7.128E+00	0.000E+00	7.128E+00
2903	3010	8.251E+01	0.000E+00	8.251E+01	7.817E+00	0.000E+00	7.817E+00
2904	3012	8.977E+01	0.000E+00	8.977E+01	8.567E+00	0.000E+00	8.567E+00
2905	3014	9.759E+01	0.000E+00	9.759E+01	9.381E+00	0.000E+00	9.381E+00
2906	3016	1.060E+02	0.000E+00	1.060E+02	1.026E+01	0.000E+00	1.026E+01
2907	3018	1.151E+02	0.000E+00	1.151E+02	1.122E+01	0.000E+00	1.122E+01
2908	3020	1.248E+02	0.000E+00	1.248E+02	1.226E+01	0.000E+00	1.226E+01
2909	3022	1.352E+02	0.000E+00	1.352E+02	1.338E+01	0.000E+00	1.338E+01
2910	3024	1.464E+02	0.000E+00	1.464E+02	1.460E+01	0.000E+00	1.460E+01
2911	3026	1.584E+02	0.000E+00	1.584E+02	1.592E+01	0.000E+00	1.592E+01
2912	3028	1.712E+02	0.000E+00	1.712E+02	1.733E+01	0.000E+00	1.733E+01
2913	3030	1.849E+02	0.000E+00	1.849E+02	1.887E+01	0.000E+00	1.887E+01
2914	3032	1.995E+02	0.000E+00	1.995E+02	2.052E+01	0.000E+00	2.052E+01
2915	3034	2.152E+02	0.000E+00	2.152E+02	2.230E+01	0.000E+00	2.230E+01
2916	3036	2.318E+02	0.000E+00	2.318E+02	2.421E+01	0.000E+00	2.421E+01
2917	3038	2.496E+02	0.000E+00	2.496E+02	2.627E+01	0.000E+00	2.627E+01
2918	3040	2.685E+02	0.000E+00	2.685E+02	2.849E+01	0.000E+00	2.849E+01
2919	3042	2.885E+02	0.000E+00	2.885E+02	3.087E+01	0.000E+00	3.087E+01
2920	3044	3.099E+02	0.000E+00	3.099E+02	3.342E+01	0.000E+00	3.342E+01
2921	3046	3.325E+02	0.000E+00	3.325E+02	3.615E+01	0.000E+00	3.615E+01
2922	3048	3.565E+02	0.000E+00	3.565E+02	3.908E+01	0.000E+00	3.908E+01
2923	3050	3.819E+02	0.000E+00	3.819E+02	4.221E+01	0.000E+00	4.221E+01
2924	3052	4.088E+02	0.000E+00	4.088E+02	4.557E+01	0.000E+00	4.557E+01
2925	3054	4.372E+02	0.000E+00	4.372E+02	4.915E+01	0.000E+00	4.915E+01
2926	3056	4.673E+02	0.000E+00	4.673E+02	5.297E+01	0.000E+00	5.297E+01
2927	3058	4.989E+02	0.000E+00	4.989E+02	5.705E+01	0.000E+00	5.705E+01
2928	3060	5.323E+02	0.000E+00	5.323E+02	6.139E+01	0.000E+00	6.139E+01
2929	3062	5.675E+02	0.000E+00	5.675E+02	6.602E+01	0.000E+00	6.602E+01

2930	3064	6.045E+02	0.000E+00	6.045E+02	7.094E+01	0.000E+00	7.094E+01
2931	3066	6.434E+02	0.000E+00	6.434E+02	7.618E+01	0.000E+00	7.618E+01
2932	3068	6.842E+02	0.000E+00	6.842E+02	8.174E+01	0.000E+00	8.174E+01
2933	3070	7.271E+02	0.000E+00	7.271E+02	8.764E+01	0.000E+00	8.764E+01
2934	3072	7.720E+02	0.000E+00	7.720E+02	9.390E+01	0.000E+00	9.390E+01
2935	3074	8.189E+02	0.000E+00	8.189E+02	1.005E+02	0.000E+00	1.005E+02
2936	3076	8.681E+02	0.000E+00	8.681E+02	1.075E+02	0.000E+00	1.075E+02
2937	3078	9.194E+02	0.000E+00	9.194E+02	1.150E+02	0.000E+00	1.150E+02
2938	3080	9.730E+02	0.000E+00	9.730E+02	1.228E+02	0.000E+00	1.228E+02
2939	3082	1.029E+03	0.000E+00	1.029E+03	1.311E+02	0.000E+00	1.311E+02
2940	3084	1.087E+03	0.000E+00	1.087E+03	1.398E+02	0.000E+00	1.398E+02
2941	3086	1.148E+03	0.000E+00	1.148E+03	1.491E+02	0.000E+00	1.491E+02
2942	3088	1.211E+03	0.000E+00	1.211E+03	1.588E+02	0.000E+00	1.588E+02
2943	3090	1.276E+03	0.000E+00	1.276E+03	1.690E+02	0.000E+00	1.690E+02
2944	3092	1.344E+03	0.000E+00	1.344E+03	1.797E+02	0.000E+00	1.797E+02
2945	3094	1.414E+03	0.000E+00	1.414E+03	1.910E+02	0.000E+00	1.910E+02
2946	3096	1.487E+03	0.000E+00	1.487E+03	2.028E+02	0.000E+00	2.028E+02
2947	3098	1.562E+03	0.000E+00	1.562E+03	2.153E+02	0.000E+00	2.153E+02
2948	3100	1.639E+03	0.000E+00	1.639E+03	2.283E+02	0.000E+00	2.283E+02
2949	3102	1.719E+03	0.000E+00	1.719E+03	2.419E+02	0.000E+00	2.419E+02
2950	3104	1.802E+03	0.000E+00	1.802E+03	2.562E+02	0.000E+00	2.562E+02
2951	3106	1.887E+03	0.000E+00	1.887E+03	2.711E+02	0.000E+00	2.711E+02
2952	3108	1.974E+03	0.000E+00	1.974E+03	2.867E+02	0.000E+00	2.867E+02
2953	3110	2.064E+03	0.000E+00	2.064E+03	3.029E+02	0.000E+00	3.029E+02
2954	3112	2.156E+03	0.000E+00	2.156E+03	3.198E+02	0.000E+00	3.198E+02
2955	3114	2.250E+03	0.000E+00	2.250E+03	3.375E+02	0.000E+00	3.375E+02
2956	3116	2.346E+03	0.000E+00	2.346E+03	3.559E+02	0.000E+00	3.559E+02
2957	3118	2.445E+03	0.000E+00	2.445E+03	3.750E+02	0.000E+00	3.750E+02
2958	3120	2.546E+03	0.000E+00	2.546E+03	3.948E+02	0.000E+00	3.948E+02
2959	3122	2.648E+03	0.000E+00	2.648E+03	4.154E+02	0.000E+00	4.154E+02
2960	3124	2.753E+03	0.000E+00	2.753E+03	4.368E+02	0.000E+00	4.368E+02
2961	3126	2.859E+03	0.000E+00	2.859E+03	4.589E+02	0.000E+00	4.589E+02
2962	3128	2.967E+03	0.000E+00	2.967E+03	4.819E+02	0.000E+00	4.819E+02
2963	3130	3.077E+03	0.000E+00	3.077E+03	5.056E+02	0.000E+00	5.056E+02
2964	3132	3.188E+03	0.000E+00	3.188E+03	5.301E+02	0.000E+00	5.301E+02
2965	3134	3.300E+03	0.000E+00	3.300E+03	5.554E+02	0.000E+00	5.554E+02
2966	3136	3.414E+03	0.000E+00	3.414E+03	5.816E+02	0.000E+00	5.816E+02
2967	3138	3.528E+03	0.000E+00	3.528E+03	6.085E+02	0.000E+00	6.085E+02
2968	3140	3.644E+03	0.000E+00	3.644E+03	6.363E+02	0.000E+00	6.363E+02
2969	3142	3.760E+03	0.000E+00	3.760E+03	6.648E+02	0.000E+00	6.648E+02
2970	3144	3.876E+03	0.000E+00	3.876E+03	6.942E+02	0.000E+00	6.942E+02
2971	3146	3.993E+03	0.000E+00	3.993E+03	7.243E+02	0.000E+00	7.243E+02
2972	3148	4.111E+03	0.000E+00	4.111E+03	7.553E+02	0.000E+00	7.553E+02
2973	3150	4.228E+03	0.000E+00	4.228E+03	7.871E+02	0.000E+00	7.871E+02
2974	3152	4.345E+03	0.000E+00	4.345E+03	8.196E+02	0.000E+00	8.196E+02
2975	3154	4.462E+03	0.000E+00	4.462E+03	8.529E+02	0.000E+00	8.529E+02
2976	3156	4.578E+03	0.000E+00	4.578E+03	8.869E+02	0.000E+00	8.869E+02
2977	3158	4.693E+03	0.000E+00	4.693E+03	9.217E+02	0.000E+00	9.217E+02
2978	3160	4.807E+03	0.000E+00	4.807E+03	9.573E+02	0.000E+00	9.573E+02
2979	3162	4.920E+03	0.000E+00	4.920E+03	9.935E+02	0.000E+00	9.935E+02
2980	3164	5.031E+03	0.000E+00	5.031E+03	1.030E+03	0.000E+00	1.030E+03
2981	3166	5.141E+03	0.000E+00	5.141E+03	1.068E+03	0.000E+00	1.068E+03
2982	3168	5.249E+03	0.000E+00	5.249E+03	1.106E+03	0.000E+00	1.106E+03
2983	3170	5.355E+03	0.000E+00	5.355E+03	1.145E+03	0.000E+00	1.145E+03
2984	3172	5.459E+03	0.000E+00	5.459E+03	1.185E+03	0.000E+00	1.185E+03
2985	3174	5.560E+03	0.000E+00	5.560E+03	1.225E+03	0.000E+00	1.225E+03
2986	3176	5.658E+03	0.000E+00	5.658E+03	1.265E+03	0.000E+00	1.265E+03
2987	3178	5.753E+03	0.000E+00	5.753E+03	1.306E+03	0.000E+00	1.306E+03
2988	3180	5.846E+03	0.000E+00	5.846E+03	1.348E+03	0.000E+00	1.348E+03
2989	3182	5.934E+03	0.000E+00	5.934E+03	1.390E+03	0.000E+00	1.390E+03
2990	3184	6.020E+03	0.000E+00	6.020E+03	1.432E+03	0.000E+00	1.432E+03

2991	3186	6.101E+03	0.000E+00	6.101E+03	1.475E+03	0.000E+00	1.475E+03
2992	3188	6.179E+03	0.000E+00	6.179E+03	1.518E+03	0.000E+00	1.518E+03
2993	3190	6.252E+03	0.000E+00	6.252E+03	1.561E+03	0.000E+00	1.561E+03
2994	3192	6.321E+03	0.000E+00	6.321E+03	1.604E+03	0.000E+00	1.604E+03
2995	3194	6.386E+03	0.000E+00	6.386E+03	1.648E+03	0.000E+00	1.648E+03
2996	3196	6.446E+03	0.000E+00	6.446E+03	1.692E+03	0.000E+00	1.692E+03
2997	3198	6.502E+03	0.000E+00	6.502E+03	1.736E+03	0.000E+00	1.736E+03
2998	3200	6.552E+03	0.000E+00	6.552E+03	1.780E+03	0.000E+00	1.780E+03
2999	3202	6.598E+03	0.000E+00	6.598E+03	1.824E+03	0.000E+00	1.824E+03
3000	3204	6.638E+03	0.000E+00	6.638E+03	1.868E+03	0.000E+00	1.868E+03
3001	3206	6.673E+03	0.000E+00	6.673E+03	1.912E+03	0.000E+00	1.912E+03
3002	3208	6.703E+03	0.000E+00	6.703E+03	1.956E+03	0.000E+00	1.956E+03
3003	3210	6.728E+03	0.000E+00	6.728E+03	1.999E+03	0.000E+00	1.999E+03
3004	3212	6.747E+03	0.000E+00	6.747E+03	2.043E+03	0.000E+00	2.043E+03
3005	3214	6.761E+03	0.000E+00	6.761E+03	2.086E+03	0.000E+00	2.086E+03
3006	3216	6.769E+03	0.000E+00	6.769E+03	2.129E+03	0.000E+00	2.129E+03
3007	3218	6.772E+03	0.000E+00	6.772E+03	2.171E+03	0.000E+00	2.171E+03
3008	3220	6.769E+03	1.719E+03	8.488E+03	2.213E+03	1.572E+01	2.229E+03
3009	3222	6.761E+03	2.332E+03	9.093E+03	2.255E+03	3.690E+01	2.292E+03
3010	3224	6.747E+03	2.832E+03	9.579E+03	2.296E+03	6.246E+01	2.358E+03
3011	3226	6.728E+03	3.267E+03	9.995E+03	2.336E+03	9.176E+01	2.428E+03
3012	3228	6.703E+03	3.660E+03	1.036E+04	2.376E+03	1.244E+02	2.501E+03
3013	3230	6.673E+03	4.021E+03	1.069E+04	2.416E+03	1.600E+02	2.576E+03
3014	3232	6.638E+03	4.358E+03	1.100E+04	2.454E+03	1.984E+02	2.653E+03
3015	3234	6.598E+03	4.675E+03	1.127E+04	2.492E+03	2.393E+02	2.731E+03
3016	3236	6.552E+03	4.977E+03	1.153E+04	2.529E+03	2.826E+02	2.812E+03
3017	3238	6.502E+03	5.265E+03	1.177E+04	2.566E+03	3.282E+02	2.894E+03
3018	3240	6.446E+03	5.541E+03	1.199E+04	2.601E+03	3.758E+02	2.977E+03
3019	3242	6.386E+03	5.807E+03	1.219E+04	2.636E+03	4.255E+02	3.061E+03
3020	3244	6.321E+03	6.065E+03	1.239E+04	2.669E+03	4.771E+02	3.146E+03
3021	3246	6.252E+03	6.314E+03	1.257E+04	2.702E+03	5.304E+02	3.233E+03
3022	3248	6.179E+03	6.556E+03	1.273E+04	2.734E+03	5.855E+02	3.319E+03
3023	3250	6.101E+03	6.792E+03	1.289E+04	2.765E+03	6.423E+02	3.407E+03
3024	3252	6.020E+03	7.022E+03	1.304E+04	2.794E+03	7.006E+02	3.495E+03
3025	3254	5.934E+03	7.246E+03	1.318E+04	2.823E+03	7.604E+02	3.584E+03
3026	3256	5.846E+03	7.465E+03	1.331E+04	2.851E+03	8.217E+02	3.673E+03
3027	3258	5.753E+03	7.680E+03	1.343E+04	2.877E+03	8.845E+02	3.762E+03
3028	3260	5.658E+03	7.890E+03	1.355E+04	2.903E+03	9.485E+02	3.851E+03
3029	3262	5.560E+03	8.097E+03	1.366E+04	2.927E+03	1.014E+03	3.941E+03
3030	3264	5.459E+03	8.299E+03	1.376E+04	2.950E+03	1.080E+03	4.031E+03
3031	3266	5.355E+03	8.499E+03	1.385E+04	2.972E+03	1.148E+03	4.121E+03
3032	3268	5.249E+03	8.694E+03	1.394E+04	2.993E+03	1.217E+03	4.210E+03
3033	3270	5.141E+03	8.887E+03	1.403E+04	3.013E+03	1.287E+03	4.300E+03
3034	3272	5.031E+03	9.076E+03	1.411E+04	3.031E+03	1.359E+03	4.390E+03
3035	3274	4.920E+03	9.263E+03	1.418E+04	3.048E+03	1.431E+03	4.479E+03
3036	3276	4.807E+03	9.447E+03	1.425E+04	3.064E+03	1.504E+03	4.569E+03
3037	3278	4.693E+03	9.425E+03	1.412E+04	3.079E+03	1.577E+03	4.656E+03
3038	3280	4.578E+03	9.299E+03	1.388E+04	3.093E+03	1.647E+03	4.740E+03
3039	3282	4.462E+03	9.179E+03	1.364E+04	3.106E+03	1.716E+03	4.822E+03
3040	3284	4.345E+03	9.064E+03	1.341E+04	3.117E+03	1.783E+03	4.900E+03
3041	3286	4.228E+03	8.955E+03	1.318E+04	3.127E+03	1.849E+03	4.976E+03
3042	3288	4.111E+03	8.850E+03	1.296E+04	3.136E+03	1.913E+03	5.049E+03
3043	3290	3.993E+03	8.750E+03	1.274E+04	3.144E+03	1.975E+03	5.119E+03
3044	3292	3.876E+03	8.654E+03	1.253E+04	3.151E+03	2.036E+03	5.187E+03
3045	3294	3.760E+03	8.562E+03	1.232E+04	3.156E+03	2.096E+03	5.252E+03
3046	3296	3.644E+03	8.473E+03	1.212E+04	3.161E+03	2.154E+03	5.315E+03
3047	3298	3.528E+03	8.387E+03	1.192E+04	3.164E+03	2.211E+03	5.375E+03
3048	3300	3.414E+03	8.305E+03	1.172E+04	3.166E+03	2.267E+03	5.433E+03
3049	3302	3.300E+03	8.226E+03	1.153E+04	3.167E+03	2.322E+03	5.489E+03
3050	3304	3.188E+03	8.149E+03	1.134E+04	3.168E+03	2.375E+03	5.543E+03
3051	3306	3.077E+03	8.075E+03	1.115E+04	3.167E+03	2.427E+03	5.594E+03

3052	3308	2.967E+03	8.004E+03	1.097E+04	3.165E+03	2.478E+03	5.643E+03
3053	3310	2.859E+03	7.935E+03	1.079E+04	3.162E+03	2.528E+03	5.690E+03
3054	3312	2.753E+03	7.868E+03	1.062E+04	3.158E+03	2.577E+03	5.735E+03
3055	3314	2.648E+03	7.803E+03	1.045E+04	3.154E+03	2.624E+03	5.778E+03
3056	3316	2.546E+03	7.740E+03	1.029E+04	3.148E+03	2.671E+03	5.820E+03
3057	3318	2.445E+03	7.679E+03	1.012E+04	3.142E+03	2.717E+03	5.859E+03
3058	3320	2.346E+03	7.620E+03	9.966E+03	3.135E+03	2.762E+03	5.896E+03
3059	3322	2.250E+03	7.563E+03	9.813E+03	3.126E+03	2.806E+03	5.932E+03
3060	3324	2.156E+03	7.507E+03	9.663E+03	3.11[illegible]E+03	2.849E+03	5.966E+03
3061	3326	2.064E+03	7.453E+03	9.516E+03	3.[illegible]08E+03	2.891E+03	5.999E+03
3062	3328	1.974E+03	7.400E+03	9.374E+03	[illegible].098E+03	2.932E+03	6.030E+03
3063	3330	1.887E+03	7.349E+03	9.235E+[illegible]	3.087E+03	2.972E+03	6.059E+03
3064	3332	1.802E+03	7.299E+03	9.101E+03	3.075E+03	3.012E+03	6.087E+03
3065	3334	1.719E+03	7.250E+03	8.969E+03	3.062E+03	3.051E+03	6.113E+03
3066	3336	1.639E+03	7.203E+03	8.842E+03	3.049E+03	3.089E+03	6.138E+03
3067	3338	1.562E+03	7.157E+03	8.718E+03	3.036E+03	3.126E+03	6.162E+03
3068	3340	1.487E+03	7.111E+03	8.598E+03	3.022E+03	3.162E+03	6.184E+03
3069	3342	1.414E+03	7.068E+03	8.481E+03	3.007E+03	3.198E+03	6.205E+03
3070	3344	1.344E+03	7.025E+03	8.368E+03	2.992E+03	3.233E+03	6.225E+03
3071	3346	1.276E+03	6.983E+03	8.259E+03	2.976E+03	3.267E+03	6.243E+03
3072	3348	1.211E+03	6.942E+03	8.152E+03	2.960E+03	3.301E+03	6.261E+03
3073	3350	1.148E+03	6.90[illegible]+03	8.049E+03	2.943E+03	3.334E+03	6.277E+03
3074	3352	1.087E+03	6.862[illegible]+03	7.950E+03	2.926E+03	3.366E+03	6.292E+03
3075	3354	1.029E+03	6.824E+03	7.853E+03	2.909E+03	3.398E+03	6.307E+03
3076	3356	9.730E+02	6.787E+03	7.760E+03	2.891E+03	3.429E+03	6.320E+03
3077	3358	9.194E+02	6.750E+03	7.670E+03	2.873E+03	3.459E+03	6.332E+03
3078	3360	8.681E+02	6.715E+03	7.583E+03	2.855E+03	3.489E+03	6.344E+03
3079	3362	8.189E+02	6.679E+03	7.498E+03	2.836E+03	3.518E+03	6.354E+03
3080	3364	7.720E+02	6.645E+03	7.417E+03	2.817E+03	3.547E+03	6.364E+03
3081	3366	7.271E+02	6.611E+03	7.338E+03	2.798E+03	3.575E+03	6.373E+03
3082	3368	6.842E+02	6.578E+03	7.263E+03	2.779E+03	3.602E+03	6.381E+03
3083	3370	6.434E+02	6.546E+03	7.189E+03	2.759E+03	3.629E+03	6.388E+03
3084	3372	6.045E+02	6.514E+03	7.[illegible]19E+03	2.740E+03	3.655E+03	6.395E+03
3085	3374	5.675E+02	6.483E+03	7.051E+03	2.720E+03	3.681E+03	6.401E+03
3086	3376	5.323E+02	6.453E+03	6.985E+03	2.700E+03	3.707E+03	6.406E+03
3087	3378	4.989E+02	6.423E+03	6.922E+03	2.680E+03	3.731E+03	6.411E+03
3088	3380	4.673E+02	6.394E+03	6.861E+03	2.660E+03	3.756E+03	6.415E+03
3089	3382	4.372E+02	6.365E+03	6.802E+03	2.639E+03	3.780E+03	6.419E+03
3090	3384	4.088E+02	6.336E+03	6.745E+03	2.619E+03	3.803E+03	6.422E+03
3091	3386	3.819E+02	6.309E+03	6.691E+03	2.598E+03	3.826E+03	6.424E+03
3092	3388	3.565E+02	6.281E+03	6.638E+03	2.578E+03	3.848E+03	6.426E+03
3093	3390	3.325E+02	6.254E+03	6.587E+03	2.557E+03	3.870E+03	6.428E+03
3094	3392	3.099E+02	6.228E+03	6.538E+03	2.537E+03	3.892E+03	6.429E+03
3095	3394	2.885E+02	6.202E+03	6.491E+03	2.516E+03	3.913E+03	6.429E+03
3096	3396	2.685E+02	6.177E+03	6.445E+03	2.496E+03	3.934E+03	6.429E+03
3097	3398	2.496E+02	6.152E+03	6.401E+03	2.475E+03	3.954E+03	6.429E+03
3098	3400	2.318E+02	6.127E+03	6.359E+03	2.455E+03	3.974E+03	6.429E+03
3099	3402	2.152E+02	6.103E+03	6.318E+03	2.434E+03	3.993E+03	6.428E+03
3100	3404	1.995E+02	6.079E+03	6.278E+03	2.414E+03	4.012E+03	6.426E+03
3101	3406	1.849E+02	6.056E+03	6.240E+03	2.393E+03	4.031E+03	6.424E+03
3102	3408	1.712E+02	6.032E+03	6.204E+03	2.373E+03	4.049E+03	6.422E+03
3103	3410	1.584E+02	6.010E+03	6.168E+03	2.353E+03	4.067E+03	6.420E+03
3104	3412	1.464E+02	5.987E+03	6.134E+03	2.333E+03	4.085E+03	6.417E+03
3105	3414	1.352E+02	5.965E+03	6.100E+03	2.313E+03	4.102E+03	6.415E+03
3106	3416	1.248E+02	5.944E+03	6.068E+03	2.293E+03	4.119E+03	6.411E+03
3107	3418	1.151E+02	5.922E+03	[illegible].037E+03	2.273E+03	4.135E+03	6.408E+03
3108	3420	1.060E+02	5.901E+03	6.007E+03	2.253E+03	4.152E+03	6.404E+03
3109	3422	9.759E+01	5.880E+03	5.978E+03	2.233E+03	4.167E+03	6.400E+03
3110	3424	8.977E+01	5.860E+03	5.950E+03	2.213E+03	4.183E+03	6.396E+03
3111	3426	8.251E+01	5.840E+03	5.922E+03	2.194E+03	4.198E+03	6.392E+03
3112	3428	7.577E+01	5.820E+03	5.896E+03	2.175E+03	4.213E+03	6.3[illegible]E+03

3113	3430	6.953E+01	5.800E+03	5.870E+03	2.155E+03	4.227E+03	6.383E+03
3114	3432	6.375E+01	5.781E+03	5.845E+03	2.136E+03	4.242E+03	6.378E+03
3115	3434	5.840E+01	5.762E+03	5.821E+03	2.117E+03	4.255E+03	6.373E+03
3116	3436	5.346E+01	5.743E+03	5.797E+03	2.098E+03	4.269E+03	6.367E+03
3117	3438	4.890E+01	5.725E+03	5.774E+03	2.080E+03	4.282E+03	6.362E+03
3118	3440	4.468E+01	5.707E+03	5.751E+03	2.061E+03	4.295E+03	6.356E+03
3119	3442	4.080E+01	5.689E+03	5.729E+03	2.043E+03	4.308E+03	6.351E+03
3120	3444	3.723E+01	5.671E+03	5.708E+03	2.024E+03	4.321E+03	6.345E+03
3121	3446	3.394E+01	5.653E+03	5.687E+03	2.006E+03	4.333E+03	6.339E+03
3122	3448	3.091E+01	5.636E+03	5.667E+03	1.988E+03	4.345E+03	6.333E+03
3123	3450	2.814E+01	5.619E+03	5.647E+03	1.970E+03	4.356E+03	6.326E+03
3124	3452	2.559E+01	5.602E+03	5.628E+03	1.952E+03	4.368E+03	6.320E+03
3125	3454	2.325E+01	5.585E+03	5.609E+03	1.935E+03	4.379E+03	6.313E+03
3126	3456	2.111E+01	5.569E+03	5.590E+03	1.917E+03	4.390E+03	6.307E+03
3127	3458	1.915E+01	5.553E+03	5.572E+03	1.900E+03	4.400E+03	6.300E+03
3128	3460	1.736E+01	5.537E+03	5.554E+03	1.883E+03	4.411E+03	6.293E+03
3129	3462	1.572E+01	5.521E+03	5.536E+03	1.866E+03	4.421E+03	6.286E+03
3130	3464	1.423E+01	5.505E+03	5.519E+03	1.849E+03	4.431E+03	6.279E+03
3131	3466	1.287E+01	5.490E+03	5.503E+03	1.832E+03	4.440E+03	6.272E+03
3132	3468	1.163E+01	5.474E+03	5.486E+03	1.815E+03	4.450E+03	6.265E+03
3133	3470	1.050E+01	5.459E+03	5.470E+03	1.799E+03	4.459E+03	6.258E+03
3134	3472	9.467E+00	5.444E+03	5.454E+03	1.782E+03	4.468E+03	6.250E+03
3135	3474	8.533E+00	5.430E+03	5.438E+03	1.766E+03	4.477E+03	6.243E+03
3136	3476	7.684E+00	5.415E+03	5.423E+03	1.750E+03	4.486E+03	6.236E+03
3137	3478	6.915E+00	5.401E+03	5.408E+03	1.734E+03	4.494E+03	6.228E+03
3138	3480	6.217E+00	5.387E+03	5.393E+03	1.718E+03	4.502E+03	6.220E+03
3139	3482	5.585E+00	5.372E+03	5.378E+03	1.703E+03	4.510E+03	6.213E+03
3140	3484	5.013E+00	5.359E+03	5.364E+03	1.687E+03	4.518E+03	6.205E+03
3141	3486	4.497E+00	5.345E+03	5.349E+03	1.672E+03	4.525E+03	6.197E+03
3142	3488	4.030E+00	5.331E+03	5.335E+03	1.656E+03	4.533E+03	6.189E+03
3143	3490	3.608E+00	5.318E+03	5.321E+03	1.641E+03	4.540E+03	6.181E+03
3144	3492	3.228E+00	5.304E+03	5.308E+03	1.626E+03	4.547E+03	6.173E+03
3145	3494	2.886E+00	5.291E+03	5.294E+03	1.612E+03	4.554E+03	6.165E+03
3146	3496	2.578E+00	5.278E+03	5.281E+03	1.597E+03	4.560E+03	6.157E+03
3147	3498	2.301E+00	5.265E+03	5.268E+03	1.582E+03	4.567E+03	6.149E+03
3148	3500	2.052E+00	5.253E+03	5.255E+03	1.568E+03	4.573E+03	6.141E+03
3149	3502	1.829E+00	5.240E+03	5.242E+03	1.553E+03	4.579E+03	6.133E+03
3150	3504	1.628E+00	5.228E+03	5.229E+03	1.539E+03	4.585E+03	6.124E+03
3151	3506	1.448E+00	5.215E+03	5.217E+03	1.525E+03	4.591E+03	6.116E+03
3152	3508	1.287E+00	5.203E+03	5.204E+03	1.511E+03	4.596E+03	6.108E+03
3153	3510	1.143E+00	5.191E+03	5.192E+03	1.497E+03	4.602E+03	6.099E+03
3154	3512	1.015E+00	5.179E+03	5.180E+03	1.484E+03	4.607E+03	6.091E+03
3155	3514	8.998E-01	5.167E+03	5.168E+03	1.470E+03	4.612E+03	6.083E+03
3156	3516	7.973E-01	5.155E+03	5.156E+03	1.457E+03	4.617E+03	6.074E+03
3157	3518	7.058E-01	5.144E+03	5.145E+03	1.444E+03	4.622E+03	6.066E+03
3158	3520	6.243E-01	5.132E+03	5.133E+03	1.430E+03	4.627E+03	6.057E+03
3159	3522	5.518E-01	5.121E+03	5.122E+03	1.417E+03	4.631E+03	6.048E+03
3160	3524	4.873E-01	5.110E+03	5.110E+03	1.404E+03	4.636E+03	6.040E+03
3161	3526	4.300E-01	5.099E+03	5.099E+03	1.391E+03	4.640E+03	6.031E+03
3162	3528	3.791E-01	5.088E+03	5.088E+03	1.379E+03	4.644E+03	6.023E+03
3163	3530	3.340E-01	5.077E+03	5.077E+03	1.366E+03	4.648E+03	6.014E+03
3164	3532	2.940E-01	5.066E+03	5.066E+03	1.354E+03	4.652E+03	6.005E+03
3165	3534	2.586E-01	5.055E+03	5.055E+03	1.341E+03	4.655E+03	5.997E+03
3166	3536	2.273E-01	5.044E+03	5.045E+03	1.329E+03	4.659E+03	5.988E+03
3167	3538	1.995E-01	5.034E+03	5.034E+03	1.317E+03	4.662E+03	5.979E+03
3168	3540	1.751E-01	5.023E+03	5.024E+03	1.305E+03	4.666E+03	5.970E+03
3169	3542	1.535E-01	5.013E+03	5.013E+03	1.293E+03	4.669E+03	5.962E+03
3170	3544	1.344E-01	5.003E+03	5.003E+03	1.281E+03	4.672E+03	5.953E+03
3171	3546	1.177E-01	4.993E+03	4.993E+03	1.269E+03	4.675E+03	5.944E+03
3172	3548	1.029E-01	4.983E+03	4.983E+03	1.258E+03	4.678E+03	5.935E+03
3173	3550	8.992E-02	4.973E+03	4.973E+03	1.246E+03	4.680E+03	5.927E+03

3174	3552	7.851E-02	4.963E+03	4.963E+03	1.235E+03	4.683E+03	5.918E+03
3175	3554	6.849E-02	4.953E+03	4.953E+03	1.224E+03	4.685E+03	5.909E+03
3176	3556	5.971E-02	4.943E+03	4.943E+03	1.212E+03	4.688E+03	5.900E+03
3177	3558	5.200E-02	4.934E+03	4.934E+03	1.201E+03	4.690E+03	5.891E+03
3178	3560	4.526E-02	4.924E+03	4.924E+03	1.190E+03	4.692E+03	5.882E+03
3179	3562	3.935E-02	4.915E+03	4.915E+03	1.179E+03	4.694E+03	5.874E+03
3180	3564	3.419E-02	4.905E+03	4.905E+03	1.169E+03	4.696E+03	5.865E+03
3181	3566	2.968E-02	4.896E+03	4.896E+03	1.158E+03	4.698E+03	5.856E+03
3182	3568	2.575E-02	4.887E+03	4.887E+03	1.147E+03	4.700E+03	5.847E+03
3183	3570	2.232E-02	4.878E+03	4.878E+03	1.137E+03	4.701E+03	5.838E+03
3184	3572	1.933E-02	4.869E+03	4.869E+03	1.126E+03	4.703E+03	5.829E+03
3185	3574	1.672E-02	4.860E+03	4.860E+03	1.116E+03	4.704E+03	5.820E+03
3186	3576	1.446E-02	4.851E+03	4.851E+03	1.106E+03	4.706E+03	5.812E+03
3187	3578	1.249E-02	4.842E+03	4.842E+03	1.096E+03	4.707E+03	5.803E+03
3188	3580	1.078E-02	4.833E+03	4.833E+03	1.086E+03	4.708E+03	5.794E+03
3189	3582	9.300E-03	4.825E+03	4.825E+03	1.076E+03	4.709E+03	5.785E+03
3190	3584	8.014E-03	4.816E+03	4.816E+03	1.066E+03	4.710E+03	5.776E+03
3191	3586	6.901E-03	4.808E+03	4.808E+03	1.056E+03	4.711E+03	5.767E+03
3192	3588	5.938E-03	4.799E+03	4.799E+03	1.047E+03	4.712E+03	5.758E+03
3193	3590	5.104E-03	4.791E+03	4.791E+03	1.037E+03	4.712E+03	5.750E+03
3194	3592	4.385E-03	4.782E+03	4.782E+03	1.028E+03	4.713E+03	5.741E+03
3195	3594	3.763E-03	4.774E+03	4.774E+03	1.018E+03	4.714E+03	5.732E+03
3196	3596	3.227E-03	4.766E+03	4.766E+03	1.009E+03	4.714E+03	5.723E+03
3197	3598	2.765E-03	4.758E+03	4.758E+03	9.997E+02	4.715E+03	5.714E+03
3198	3600	2.368E-03	4.750E+03	4.750E+03	9.906E+02	4.715E+03	5.705E+03
3199	3700	3.561E-07	4.413E+03	4.413E+03	6.258E+02	4.604E+03	5.229E+03
3200	3800	6.982E-12	4.167E+03	4.167E+03	3.953E+02	4.443E+03	4.838E+03
3201	3900	1.784E-17	3.978E+03	3.978E+03	2.498E+02	4.271E+03	4.521E+03
3202	4000	5.943E-24	3.826E+03	3.826E+03	1.578E+02	4.107E+03	4.265E+03
3203	4100	2.580E-31	3.700E+03	3.700E+03	9.968E+01	3.957E+03	4.057E+03
3204	4200	1.460E-39	3.595E+03	3.595E+03	6.297E+01	3.824E+03	3.887E+03
3205	4300	1.077E-48	3.504E+03	3.504E+03	3.978E+01	3.706E+03	3.746E+03
3206	4400	1.036E-58	3.425E+03	3.425E+03	2.513E+01	3.603E+03	3.628E+03
3207	4500	1.298E-69	3.356E+03	3.356E+03	1.588E+01	3.512E+03	3.528E+03
3208	4600	2.121E-81	3.294E+03	3.294E+03	1.003E+01	3.432E+03	3.442E+03
3209	4700	4.517E-94	0.000E+00	4.517E-94	6.337E+00	2.168E+03	2.174E+03
3210	4800	0.000E+00	0.000E+00	0.000E+00	4.003E+00	1.370E+03	1.374E+03
3211	4900	0.000E+00	0.000E+00	0.000E+00	2.529E+00	8.652E+02	8.678E+02
3212	5000	0.000E+00	0.000E+00	0.000E+00	1.598E+00	5.466E+02	5.482E+02
3213	5100	0.000E+00	0.000E+00	0.000E+00	1.009E+00	3.453E+02	3.463E+02
3214	5200	0.000E+00	0.000E+00	0.000E+00	6.377E-01	2.182E+02	2.188E+02
3215	5300	0.000E+00	0.000E+00	0.000E+00	4.029E-01	1.378E+02	1.382E+02
3216	5400	0.000E+00	0.000E+00	0.000E+00	2.545E-01	8.707E+01	8.733E+01
3217	5500	0.000E+00	0.000E+00	0.000E+00	1.608E-01	5.501E+01	5.517E+01
3218	5600	0.000E+00	0.000E+00	0.000E+00	1.016E-01	3.475E+01	3.485E+01
3219	5700	0.000E+00	0.000E+00	0.000E+00	6.417E-02	2.195E+01	2.202E+01
3220	5800	0.000E+00	0.000E+00	0.000E+00	4.054E-02	1.387E+01	1.391E+01
3221	5900	0.000E+00	0.000E+00	0.000E+00	2.561E-02	8.762E+00	8.788E+00
3222	6000	0.000E+00	0.000E+00	0.000E+00	1.618E-02	5.535E+00	5.552E+00
3223	6100	0.000E+00	0.000E+00	0.000E+00	1.022E-02	3.497E+00	3.507E+00
3224	6200	0.000E+00	0.000E+00	0.000E+00	6.458E-03	2.209E+00	2.216E+00
3225	6300	0.000E+00	0.000E+00	0.000E+00	4.080E-03	1.396E+00	1.400E+00
3226	6400	0.000E+00	0.000E+00	0.000E+00	2.577E-03	8.817E-01	8.843E-01
3227	6500	0.000E+00	0.000E+00	0.000E+00	1.628E-03	5.570E-01	5.587E-01
3228	6600	0.000E+00	0.000E+00	0.000E+00	1.029E-03	3.519E-01	3.529E-01
3229	6700	0.000E+00	0.000E+00	0.000E+00	6.499E-04	2.223E-01	2.230E-01
3230	6800	0.000E+00	0.000E+00	0.000E+00	4.105E-04	1.404E-01	1.409E-01
3231	6900	0.000E+00	0.000E+00	0.000E+00	2.594E-04	8.873E-02	8.899E-02
3232	7000	0.000E+00	0.000E+00	0.000E+00	1.639E-04	5.605E-02	5.622E-02
3233	7100	0.000E+00	0.000E+00	0.000E+00	1.035E-04	3.541E-02	3.552E-02
3234	7200	0.000E+00	0.000E+00	0.000E+00	6.540E-05	2.237E-02	2.244E-02

3235	7300	0.000E+00	0.000E+00	0.000E+00	4.131E-05	1.413E-02	1.417E-02
3236	7400	0.000E+00	0.000E+00	0.000E+00	2.610E-05	8.929E-03	8.955E-03
3237	7500	0.000E+00	0.000E+00	0.000E+00	1.649E-05	5.641E-03	5.657E-03
3238	7600	0.000E+00	0.000E+00	0.000E+00	1.042E-05	3.564E-03	3.574E-03
3239	7700	0.000E+00	0.000E+00	0.000E+00	6.581E-06	2.251E-03	2.258E-03
3240	7800	0.000E+00	0.000E+00	0.000E+00	4.157E-06	1.422E-03	1.426E-03
3241	7900	0.000E+00	0.000E+00	0.000E+00	2.626E-06	8.985E-04	9.011E-04
3242	8000	0.000E+00	0.000E+00	0.000E+00	1.659E-06	5.676E-04	5.693E-04
3243	8100	0.000E+00	0.000E+00	0.000E+00	1.048E-06	3.586E-04	3.597E-04
3244	8200	0.000E+00	0.000E+00	0.000E+00	6.622E-07	2.266E-04	2.272E-04
3245	8300	0.000E+00	0.000E+00	0.000E+00	4.184E-07	1.431E-04	1.435E-04
3246	8400	0.000E+00	0.000E+00	0.000E+00	2.643E-07	9.042E-05	9.068E-05
3247	8500	0.000E+00	0.000E+00	0.000E+00	1.670E-07	5.712E-05	5.729E-05
3248	8600	0.000E+00	0.000E+00	0.000E+00	1.055E-07	3.609E-05	3.619E-05
3249	8700	0.000E+00	0.000E+00	0.000E+00	6.664E-08	2.280E-05	2.286E-05
3250	8800	0.000E+00	0.000E+00	0.000E+00	4.210E-08	1.440E-05	1.444E-05
3251	8900	0.000E+00	0.000E+00	0.000E+00	2.660E-08	9.099E-06	9.126E-06
3252	9000	0.000E+00	0.000E+00	0.000E+00	1.680E-08	5.748E-06	5.765E-06
3253	9100	0.000E+00	0.000E+00	0.000E+00	1.062E-08	3.631E-06	3.642E-06
3254	9200	0.000E+00	0.000E+00	0.000E+00	6.706E-09	2.294E-06	2.301E-06
3255	9300	0.000E+00	0.000E+00	0.000E+00	4.237E-09	1.449E-06	1.454E-06
3256	9400	0.000E+00	0.000E+00	0.000E+00	2.676E-09	9.156E-07	9.183E-07
3257	9500	0.000E+00	0.000E+00	0.000E+00	1.691E-09	5.785E-07	5.801E-07
3258	9600	0.000E+00	0.000E+00	0.000E+00	1.068E-09	3.654E-07	3.665E-07
3259	9700	0.000E+00	0.000E+00	0.000E+00	6.748E-10	2.309E-07	2.315E-07
3260	9800	0.000E+00	0.000E+00	0.000E+00	4.263E-10	1.458E-07	1.463E-07
3261	9900	0.000E+00	0.000E+00	0.000E+00	2.693E-10	9.214E-08	9.241E-08
3262	10000	0.000E+00	0.000E+00	0.000E+00	1.702E-10	5.821E-08	5.838E-08
3263	10100	0.000E+00	0.000E+00	0.000E+00	1.075E-10	3.677E-08	3.688E-08
3264	10200	0.000E+00	0.000E+00	0.000E+00	6.791E-11	2.323E-08	2.330E-08
3265	10300	0.000E+00	0.000E+00	0.000E+00	4.290E-11	1.468E-08	1.472E-08
3266	10400	0.000E+00	0.000E+00	0.000E+00	2.710E-11	9.272E-09	9.299E-09
3267	10500	0.000E+00	0.000E+00	0.000E+00	1.712E-11	5.858E-09	5.875E-09
3268	10600	0.000E+00	0.000E+00	0.000E+00	1.082E-11	3.701E-09	3.711E-09
3269	10700	0.000E+00	0.000E+00	0.000E+00	6.834E-12	2.338E-09	2.345E-09
3270	10800	0.000E+00	0.000E+00	0.000E+00	4.317E-12	1.477E-09	1.481E-09
3271	10900	0.000E+00	0.000E+00	0.000E+00	2.727E-12	9.331E-10	9.358E-10
3272	11000	0.000E+00	0.000E+00	0.000E+00	1.723E-12	5.895E-10	5.912E-10
3273	11100	0.000E+00	0.000E+00	0.000E+00	1.089E-12	3.724E-10	3.735E-10
3274	11200	0.000E+00	0.000E+00	0.000E+00	6.877E-13	2.353E-10	2.360E-10
3275	11300	0.000E+00	0.000E+00	0.000E+00	4.345E-13	1.486E-10	1.491E-10
3276	11400	0.000E+00	0.000E+00	0.000E+00	2.745E-13	9.390E-11	9.417E-11
3277	11500	0.000E+00	0.000E+00	0.000E+00	1.734E-13	5.932E-11	5.949E-11
3278	11600	0.000E+00	0.000E+00	0.000E+00	1.095E-13	3.747E-11	3.758E-11
3279	11700	0.000E+00	0.000E+00	0.000E+00	6.920E-14	2.367E-11	2.374E-11
3280	11800	0.000E+00	0.000E+00	0.000E+00	4.372E-14	1.496E-11	1.500E-11
3281	11900	0.000E+00	0.000E+00	0.000E+00	2.762E-14	9.449E-12	9.476E-12
3282	12000	0.000E+00	0.000E+00	0.000E+00	1.745E-14	5.969E-12	5.987E-12
3283	12100	0.000E+00	0.000E+00	0.000E+00	1.102E-14	3.771E-12	3.782E-12
3284	12200	0.000E+00	0.000E+00	0.000E+00	6.964E-15	2.382E-12	2.389E-12
3285	12300	0.000E+00	0.000E+00	0.000E+00	4.399E-15	1.505E-12	1.509E-12
3286	12400	0.000E+00	0.000E+00	0.000E+00	2.779E-15	9.508E-13	9.536E-13
3287	12500	0.000E+00	0.000E+00	0.000E+00	1.756E-15	6.007E-13	6.025E-13
3288	12600	0.000E+00	0.000E+00	0.000E+00	1.109E-15	3.795E-13	3.806E-13
3289	12700	0.000E+00	0.000E+00	0.000E+00	7.008E-16	2.397E-13	2.404E-13
3290	12800	0.000E+00	0.000E+00	0.000E+00	4.427E-16	1.515E-13	1.519E-13
3291	12900	0.000E+00	0.000E+00	0.000E+00	2.797E-16	9.568E-14	9.596E-14
3292	13000	0.000E+00	0.000E+00	0.000E+00	1.767E-16	6.045E-14	6.063E-14
3293	13100	0.000E+00	0.000E+00	0.000E+00	1.116E-16	3.819E-14	3.830E-14
3294	13200	0.000E+00	0.000E+00	0.000E+00	7.052E-17	2.413E-14	2.420E-14
3295	13300	0.000E+00	0.000E+00	0.000E+00	4.455E-17	1.524E-14	1.529E-14

3296	13400	0.000E+00	0.000E+00	0.000E+00	2.815E-17	9.629E-15	9.657E-15
3297	13500	0.000E+00	0.000E+00	0.000E+00	1.778E-17	6.083E-15	6.101E-15
3298	13600	0.000E+00	0.000E+00	0.000E+00	1.123E-17	3.843E-15	3.854E-15
3299	13700	0.000E+00	0.000E+00	0.000E+00	7.097E-18	2.428E-15	2.435E-15

APPENDIX 2

TOXPUFF Formula Listing

```
A:B1: '          Toxic Chemical Spill Calculation
A:A2: [W10] '      (For chemical boiling point less than ambient temperature)
A:A4: [W10] '      Last Updated:
A:C4: (D1) '5-Mar-93
A:D4: '  Analyzed Chemical:  Chlorine
A:A6: [W10] '==========================================================
A:A7: [W10] 'Design Inputs:
A:A9: [W10] '  Spill Data:
A:C10: 'Container Volume (VC, cm**3):
A:F10: (S3) 52040000
A:B11: '   Spill to CR Intake Distance (X0, m):
A:F11: (F1) 3218
A:D12: '         Spill Type: Circular
A:A15: [W10] '  Meteorological Data:
A:B16: '          Pasquill's Stability Category:
A:F16: '    G
A:B17: '  Ambient Temperature (Tac, degrees C):
A:F17: 20
A:C18: '        Wind Speed (U, m/sec):
A:F18: 1
A:C19: '       Air Pressure (PA, atm):
A:F19: 1
A:A21: [W10] '  Control Room Data:
A:B22: 'Control Room HVAC Intake Height (z, m):
A:F22: 11.28
A:B23: '       Control Room Volume (CRV, ft**3):
A:F23: (S3) 27000
A:A24: [W10] '        CR HVAC Intake Rate (CFIN, ft.**3/minute):
A:F24: 7440
A:A26: [W10] '  Chemical Data:
A:B27: '       Chemical Density (DENS, g/cm**3):
A:F27: (F3) 1.57
A:B28: '          Boiling Point (Tb, degrees C):
A:F28: -34.1
A:B29: '          Molecular Weight (MW, g/mole):
A:F29: (F2) 70.9
A:A30: [W10] '              Heat Capacity (Cp, cal/g-degree C):
A:F30: 0.226
A:A31: [W10] '                Heat of Vaporization (Hv, cal/g):
A:F31: 68.8
A:A33: [W10] '  Constants:
A:A34: [W10] '  Ideal Gas Constant (R, atm-m**3/mole-degree K):
A:F34: (S3) 8.205E-05
A:C35: ' Air Density (DAIR, g/cm**3,
A:B36: '      at 1 atmosphere and 20 degrees C):
A:F36: (S2) 0.0012
A:E37: '       PI:
A:F37: @PI
A:A38: [W10] '           Gravitational Constant (G, cm/sec**2):
A:F38: 981
A:A39: [W10] '     Forced Convection Heat Transfer Coefficient
A:A40: [W10] '                    (hc, cal/cm**2-sec-degree C):
A:F40: (S1) 0.00016
A:A41: [W10] '  Atmos. and Solar Heat Flux (qr, cal/cm**2-sec):
A:F41: (S2) 0.0212
A:A43: [W10] 'Calculated Design Inputs:
```

TENERA

SUBJECT: Verification of TOXPUFF and TOXEVAP LOTUS 1-2-3 Spreadsheets

PREPARED BY: [illegible] DATE: 3/8/93

CHECKED BY: [illegible] DATE: 3/10/93

PROJECT: Monticello Toxic Chemical Study

PREL. SHEET: ____ OF: ____

CONTROL I.D. NO.: 1901-2.2-001 REV. 0

SHEET 50 OF 69 SHEETS

```
A:B45: ' Initial Chemical Mass (MT=VC*DENS, g):
A:F45: (S3) +F10*F27
A:A46: [W10] '  Ambient Temperature (Ta=Tac+273.16, degrees K):
A:F46: +F17+273.16
A:B47: 'Chemical Boiling Point (Tb, degrees K):
A:F47: +F20+273.16
A:B48: '    Ground (Earth) Temperature (Te=Ta):
A:F48: +F46
A:A50: [W10] '==========
A:A51: [W10] 'Chemical Mass Calculations:
A:A53: [W10] ' Mass of Initial Puff Release (M0, g) = MT*Cp*(Ta-Tb)/Hv
A:D54: (S3) '       =
A:E54: (S3) +F45*F30*(F46-F47)/F31
A:B56: '     Remaining Mass (MR, g) = MT-M0
A:D57: '       =
A:E57: (S3) +F45-E54
A:A58: [W10] '==========
A:A59: [W10] 'Spill Area Calculations:
A:A61: [W10] '        Initial Spill Radius (R0, cm) = [MR/(DENS*PI)]**(1/3)
A:D62: '       =
A:E62: (S3) (E57/(F37*F27))^(1/3)
A:A64: [W10] '       Initial Spill Area (A0, cm**2) =
A:E64: 'PI*(R0**2)
A:D65: '       =
A:E65: (S3) +F37*(E62*E62)
A:A67: [W10] '    Area Change Rate (ACH, cm**2/sec) = PI*2*[g*(MR/DENS)*
A:A68: [W10] '                                      = (DENS-DAIR)/(DENS*PI)]**1/2
A:D69: '       =
A:E69: (S3) +F37*2*((F38*(E57/F27)*(F27-F36)/(F27*F37))^(1/2))
A:A71: [W10] '     Maximum Spill Area (Amax, cm**2) = (MR/DENS)/1 cm
A:D72: '       =
A:E72: (S3) +E57/F27
A:A74: [W10] '   Time When Amax Reached (Tmax, sec) = (Amax-A0)/ACH
A:D75: '       =
A:E75: (F2) (E72-E65)/E69
A:A76: [W10] '==========
A:A77: [W10] 'Mass Vaporization Rate Calculation
A:A79: [W10] '        Mass Vaporization Rate (V(t),
A:A80: [W10] '                              g/sec-cm**2) = V0+VCH/(t**(1/2))
A:B81: 'where:
A:C82: ' V0 (g/sec-cm**2) = (qr+hc*(Ta-Tb))/Hv
A:D83: '       =
A:E83: (S3) (F41+F40*(F46-F47))/F31
A:B85: '   VCH (g/cm**2*sec**(1/2)) = 197*(Te-Tb)/(Hv*10,000)
A:D86: '       =
A:E86: (S3) 197*(F48-F47)/(F31*10000)
A:A87: [W10] '==========
A:A88: [W10] 'Calculation of Sigmas (Dispersion Coefficients)
A:A90: [W10] '   Spill Vapor Density (DVAP, g/m**3) = (MW*PA)/(R*Ta)
A:D91: '       =
A:E91: (S3) (F19*F29)/(F34*F46)
A:A93: [W10] '     Initial Puff Std. Dev. (SIG0, m) = [M0/(2**(1/2))*(PI**(3/2))*
A:E94: 'DVAP)]**(1/3)
A:D95: '       =
A:E95: (F3) (454/(2^(1/2)*PI^(3/2)*E91))^(1/3)
A:A97: [W10] 'Pasq.-Giff. Y Disp Coeff log(SIGY, m) =
A:E97: 'A+B*log(X0)+C*(log(X0))**2
A:A98: [W10] '
A:E98: '+D*(log(X0))**3
A:C99: '     where:
A:D99: '       A =
```

TENERA

SUBJECT Verification of TOXPUFF and TOXEVAP
LOTUS 1-2-3 Spreadsheets
PROJECT Monticello Toxic Chemical Study
CONTROL I.D. NO. 1961-2.2-001 REV. 0

PREPARED BY [illegible] DATE 3/8/93
CHECKED BY [illegible] DATE 3/10/93
PREL. SHEET ____ OF ____
SHEET 51 OF 69 SHEETS

```
A:E99: -1.6212
A:D100: '      B =
A:E100: 1.0648
A:D101: '      C =
A:E101: -0.014857
A:D102: '      D =
A:E102: -0.0020555
A:D103: '   SIGY =
A:E103: (F3) 10^(+E99+E100*@LOG(F11)+E101*(@LOG(F11)^2)+E102*(@LOG(F11)^3))
A:A105: [W10] 'Pasq.-Giff. Z Disp Coeff log(SIGZ, m) =
A:E105: 'A+B*log(X0)+C*(log(X0))**2
A:A106: [W10] '
A:E106: '+D*(log(X0))**3
A:C107: '    where:
A:D107: '      A =
A:E107: -1.8981
A:D108: '      B =
A:E108: 1.1243
A:D109: '      C =
A:E109: -0.036447
A:D110: '      D =
A:E110: -0.0[illegible]
A:D111: '   SIGZ =
A:E111: (F3) 10^(+E107+E108*@LOG(F11)+E109*(@LOG(F11)^2)+E110*(@LOG(F11)^3))
A:A113: [W10] '    Inst Puff Y Disp Coeff (SIGYI, m) =
A:E113: '(SIGY^2+SIG0**2)**(1/2)
A:D114: '      =
A:E114: (F3) (E95^2+E103^2)^(1/2)
A:A116: [W10] '    Inst Puff X Disp Coeff (SIGXI, m) =
A:B116: 'SIGYI
A:D117: '      =
A:E117: (F3) +E114
A:A119: [W10] '    Inst Puff Z Disp Coeff (SIGZI, m) =
A:E119: '(SIGZ**2+SIG0**2)**(1/2)
A:D120: '      =
A:E120: (F3) (E95^2+E118^2)^(1/2)
A:A122: [W10] '    Cont Release Disp Coeff (SIGZM, m) =
A:E122: '(SIGZ)
A:D123: '      =
A:E123: (F3) (E119)
A:A125: [W10] '    Cont Release Disp Coeff (SIGYM, m) =
A:E125: '(SIGY**2+(Reff**2)**(1/2)/4.3)
A:E126: '**2)**(1/2)
A:D127: '      =
A:E127: (F3) (E103^2+E72/184900)^(1/2)
A:F127: (F3) '(at Amax)
A:B128: 'Note:
A:B129: '   For Circular Spill, Reff = (A(t)/PI)**(1/2)
A:A132: [W10] '==========
A:A133: [W10] 'Conversion of g/m**3 to ppm
A:A135: [W10] 'Conversion to PPM (PPM, ppm/(g/m**3)) =
A:E135: '(R*Ta*1.0E+06)/(MW*Pa)
A:D136: '      =
A:E136: (F2) (F34*F46*1000000)/(F19*F29)
A:A137: [W10] '==========
A:A138: [W10] 'Calculation of Puff Concentration Outside Control Room
A:A140: [W10] '  Puff Conc @ CR Intake (CRP(t), ppm) =
A:E140: '(M0/(2**(3/2)*(PI)**(3/2)*SIGXI*
A:E141: 'SIGYI*SIGZI)]*exp[-1/2*x**2/
A:A142: [W10] '    where z=h=0 for DVAP>DAIR,
A:E142: 'SIGXI**2]*(exp[-1/2*(z-h)**2/
```

```
A:A143: [W10] '          ,=h for DVAP<DAIR,
A:E143: 'SIGZI**2)+exp[-1/2*(z+h)**2/
A:B144: 'y=0, and x=XO-U*t
A:E144: 'SIGZI**2])*PPM
A:A145: [W10] '*************************************************************************
A:A146: [W10] 'Calculation of Continuous Release Conc Outside Control Room
A:A148: [W10] '  Cont Conc @ CR Intake (CRC(t), ppm) =
A:E148: '(AO+ACH*t)
A:F148: '*(VO+VCH/t**(1/2))*
A:E149: '(1/(2*PI*U*SIGYM*SIGZM))*(exp[
A:A150: [W10] '    where z=h=/- for DVAP>DAIR,
A:E150: '-1/2*(z-h)**2/SIGZM**2)+exp[
A:A151: [W10] '          z=h for DVAP<DAIR,
A:E151: '-1/2*(z+h)**2/SIGZM**2])*PPM
A:B152: 'y=0, AO+ACH*t=Amax for
A:B153: 't>Tmax, and t=t-XO/U
A:A154: [W10] 'Note:  CRC(t)=0 for t<XO/U and for t>time when entire spill evaporates
A:A155: [W10] '       plus XO/U (Tgone+Tmax+XO/U)
A:A156: [W10] '*************************************************************************
A:A157: [W10] 'Calculation of Entire Spill Evaporation Time
A:A159: [W10] '   Spill Mass Released by time t=Tmax
A:B160: '                (MAmax, g) =
A:E160: 'VO*AO*Tmax+VO*ACH*(Tmax**2)/
A:E161: '2+2*VCH*AO*(Tmax**(1/2))+VCH*
A:E162: 'ACH*(Tmax**(3/2))*2/3
A:D163: '        =
A:E163: (S3) +E83*E65*E75+E83*2/9*(E75^2)/2+2*E86*E65*(E75^(1/2))+2/3*E86*E69*(E75^(3/2))*2/3
A:A165: [W10] '  Note:  If MAmax > MR, Tgone is determined by solving the following
A:A166: [W10] '         equation for Tgone:
A:B168: 'MR = VO*AO*Tgone+VO*ACH*(Tgone**2)/2+2*VCH*AO*(Tgone**
A:B169: '    (1/2))+VCH*ACH*(Tgone**(3/2))*2/3
A:A171: [W10] '  Note:  If MAmax < MR,  gone is determined by solving the following
A:A172: [W10] '         equation for Tgone:
A:B174: 'MR-MAmax = VO*Amax*Tgone+VCH*Amax*(Tgone**(1/2))*2-
A:B175: '           -Amax*Tmax*VO-Amax*VCH*2*(Tmax)**(1/2)
A:A176: [W10] '  Note:  Due to the interative nature of solving for Tgone, it is
A:A177: [W10] '         computed manually and entered into the appropriate cell.
A:B178: '   Amax =
A:C178: (S3) +E72
A:D178: '    VCH =
A:E178: (S3) +E86
A:F178: '   Tmax =
A:G178: (F1) +E75
A:B179: '     VO =
A:C179: (S3) +E83
A:D179: 'MR-MAmax =
A:E179: (S3) +E57-E163
A:F179: 'MR-MAmax=
A:G179: (S3) 63221105.5346888537
A:C180: '      Tgone (sec) =
A:E180: 1368.8
A:H180: '       \m
A:I180: (S3) '{LET G179,C179*C178*E180+E178*C178*2*(E180^(1/2))-C178*C179*G178-C178*E178*2*(G178^(1/2))}
A:A131: [W10] '*************************************************************************
A:A182: [W10] 'Calculation of Concentration Inside Control Room
A:A183: [W10] '  Concentration in the CR is computed in a time step-by-step
A:A184: [W10] '  manner by adding the the inside CR concentration (both puff
A:A185: [W10] '  and continuous) at the previous time step to the difference
A:A186: [W10] '  between the current outside concentration minus the previous
A:A187: [W10] '  inside concentration times an exponential buildup factor.
A:H188: '   Constant for Outside Puff:
```

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SUBJECT Verification of TOXPUFF and TOXEVAP
Lotus 1-2-3 Spreadsheets

PREPARED BY [illegible] DATE 3/8/93
CHECKED BY [illegible] DATE 3/10/93

PROJECT Monticello Toxic Chemical Study

PREL. SHEET ____ OF ____

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```
A:K188: (S3)
        +$E$136*($E$54/(((2^(3/2))*($F$37^(3/2))*$E$117*$E$114*$E$120))*(1+@EXP(-0.5*(($D$191+$D$191)^2)/($
        E$120^2)))
A:H189: '   Constant for Cont. w/Amax:
A:K189: (S3) +$E$136*$E$72*(1/(2*$F$37*$E$127*$E$123*$F$18))*(1+@EXP(-0.5*(($D$191+$D$191)^2)/($E$123^2)))
A:A190: [W10] '**********************************************************************
A:H190: '   Constant for Contin. A(t):
A:K190: (S3) +$E$136*(1+@EXP(-0.5*(($D$191+$D$191)^2)/($E$123^2)))
A:A191: [W10] 'Analysis Results
A:C191: '         hs
A:D191: @IF(E91/1000000>f36,0,f22)
A:A192: [W10] 'Chemical Analyzed:  Chlorine
A:I192: 'For A(t)
A:J192: 'For Amax
A:B193: ' Outside
A:C193: ' Outside
A:D193: '  Total
A:E193: '  Inside
A:F193: '  Inside
A:G193: '  Total
A:H193: ' Outside
A:I193: ' Outside
A:J193: ' Outside
A:K193: '  Inside
A:L193: '  Inside
A:B194: ' CR Conc
A:C194: ' CR Conc
A:D194: ' Outside
A:E194: ' CR Conc
A:F194: ' CR Conc
A:G194: '  Inside
A:H194: ' CR Conc
A:I194: ' CR Conc
A:J194: ' CR Conc
A:K194: ' CR Conc
A:L194: ' CR Conc
A:B195: '   Puff
A:C195: 'Continuous
A:D195: ' CR Conc
A:E195: '   Puff
A:F195: 'Continuous
A:G195: ' CR Conc
A:H195: '   Puff
A:I195: 'Continuous
A:J195: 'Continuous
A:K195: '   Puff
A:L195: 'Continuous
A:M195: ' SIGYM(t)
A:A196: [W10] 'Time (sec)
A:B196: '  (ppm)
A:C196: '  (ppm)
A:D196: '  (ppm)
A:E196: '  (ppm)
A:F196: '  (ppm)
A:G196: '  (ppm)
A:H196: '  (ppm)
A:I196: '  (ppm)
A:J196: '  (ppm)
A:K196: '  (ppm)
A:L196: '  (ppm)
A:M196: '   (m)
```

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SUBJECT Verification of TOXPUFF and TOXEVAP
LOTUS 1-2-3 Spreadsheets

PROJECT Monticello Toxic Chemical Study

CONTROL I.D. NO. 1961-2.2-001 REV. 0

PREPARED BY [illegible] DATE 3/8/93

CHECKED BY [illegible] DATE 3/10/93

PREL. SHEET ___ OF ___

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```
A:A197: [W10] '**********
A:B197: '  *****
A:C197: '  *****
A:D197: '  *****
A:E197: '  *****
A:F197: '  *****
A:G197: '  *****
A:H197: '  *****
A:I197: '  *****
A:J197: '  *****
A:K197: '  *****
A:L197: '  *****
A:M197: '    ***
A:A198: [W10] 0
A:B198: (S3) @IF(H198<1E-99,0,H198)
A:C198: (S3) @IF(($E$180+$G$178+$F$11/$F$18-A198)<0,0,@IF((A198-$F$11/$F$18)<$E$75,I198,J198))
A:D198: (S3) +B198+C198
A:E198: (S3) 0
A:F198: (S3) 0
A:G198: (S3) +E198+F198
A:H198: (S3) +$K$188*@EXP(-0.5*((($F$11-$F$18*A198)^2)/($E$117^2))
A:I198: (S3)
        @IF((A198-$F$11/$F$18)<=0,0,($E$65+$E$69*(A198-$F$11/$F$18))*($E$83+$E$86/((A198-$F$11/$F$18)^(1/2
        )))*(1/(2*$F$37*M198*$E$123*$F$18))*$K$190)
A:J198: (S3) ($E$83+$E$86/((A198-$F$11/$F$18)^(1/2)))*$K$189
A:K198: (S3) 0
A:L198: (S3) 0
A:M198: (S3) ($E$103^2+($E$65+$E$69*(A198-$F$11/$F$18))/184900)^(1/2)
A:A199: [W10] +A198+1
A:B199: (S3) @IF(H199<1E-99,0,H199)
A:C199: (S3) @IF(($E$180+$G$178+$F$11/$F$18-A199)<0,0,@IF((A199-$F$11/$F$18)<$E$75,I199,J199))
A:D199: (S3) +B199+C199
A:E199: (S3) @IF(K199<1E-99,0,K199)
A:F199: (S3) @IF(L199<1E-99,0,L199)
A:G199: (S3) +E199+F199
A:H199: (S3) +$K$188*@EXP(-0.5*(($F$11-$F$18*A199)^2)/($E$117^2))
A:I199: (S3)
        @IF((A199-$F$11/$F$18)<=0,0,($E$65+$E$69*(A199-$F$11/$F$18))*($E$83+$E$86/((A199-$F$11/$F$18)^(1/2
        )))*(1/(2*$F$37*M199*$E$123*$F$18))*$K$190)
A:J199: (S3) ($E$83+$E$86/((A199-$F$11/$F$18)^(1/2)))*$K$189
A:K199: (S3) +E198+(B199-E198)*(1-@EXP(-1*$F$24*(A199-A198)/($F$23*60)))
A:L199: (S3) +F198+(C199-F198)*(1-@EXP(-1*$F$24*(A199-A198)/($F$23*60)))
A:M199: (S3) ($E$103^2+($E$65+$E$69*(A199-$F$11/$F$18))/184900)^(1/2)
A:A200: [W10] +A199+1
A:B200: (S3) @IF(H200<1E-99,0,H200)
A:C200: (S3) @IF(($E$180+$G$178+$F$11/$F$18-A200)<0,0,@IF((A200-$F$11/$F$18)<$E$75,I200,J200))
A:D200: (S3) +B200+C200
A:E200: (S3) @IF(K200<1E-99,0,K200)
A:F200: (S3) @IF(L200<1E-99,0,L200)
A:G200: (S3) +E200+F200
A:H200: (S3) +$K$188*@EXP(-0.5*(($F$11-$F$18*A200)^2)/($E$117^2))
A:I200: (S3)
        @IF((A200-$F$11/$F$18)<=0,0,($E$65+$E$69*(A200-$F$11/$F$18))*($E$83+$E$86/((A200-$F$11/$F$18)^(1/2
        )))*(1/(2*$F$37*M200*$E$123*$F$18))*$K$190)
A:J200: (S3) ($E$83+$E$86/((A200-$F$11/$F$18)^(1/2)))*$K$189
A:K200: (S3) +E199+(B200-E199)*(1-@EXP(-1*$F$24*(A200-A199)/($F$23*60)))
A:L200: (S3) +F199+(C200-F199)*(1-@EXP(-1*$F$24*(A200-A199)/($F$23*60)))
A:M200: (S3) ($E$103^2+($E$65+$E$69*(A200-$F$11/$F$18))/184900)^(1/2)
```

APPENDIX 3

TOXEVAP Results for Ethyl Alcohol Analysis

Range: A1 - G150

A	A	B	C	D	E	F	G
1			Toxic Chemical Spill Calculation				
2		(for chemical boiling point greater than ambient temperature)					
3							
4		Last Updated: 06-Mar-93		Analyzed Chemical:		Ethyl Alcohol	
5							
6	**********						
7	Design Inputs:						
8							
9		Spill Data:					
10				Container Volume (VC, cm**3):		1.105E+08	
11				Spill to CR Intake Distance (XO, m):		3218.0	
12					Spill Type:	Circular	
13							
14							
15		Meteorological Data:					
16				Pasquill's Stability Category:		G	
17				Ambient Temperature (Tac, degrees C):		20	
18				Wind Speed (U, m/sec):		1	
19				Air Pressure (PA, atm):		1	
20				Air Pressure (Pa, mm-Hg):		0	
21		Control Room Data:					
22				Control Room HVAC Intake Height (z, m):		11.28	
23				Control Room Volume (CRV, ft**3):		2.700E+04	
24				CR HVAC Intake Rate (CFIN, ft.**3/minute):		7440	
25							
26		Chemical Data:					
27				Chemical Density (DENS, g/cm**3):		0.789	
28				Boiling Point (Tb, degrees C):		78.5	
29				Molecular Weight (MW, g/mole):		46.07	
30				Diffusion Coefficient (D, cm**2/sec):		0.1	
31				Vapor Presssure (Ps, mm-Hg):		40	
32		Constants:					
33		Ideal Gas Constant (R, atm-m**3/mole-degree K):				8.205E-05	
34				Air Density (DAIR, g/cm**3,			
35				at 1 atmosphere and 20 degrees C):		1.20E-03	
36					PI:	3.1415927	
37				Gravitational Constant (G, cm/sec**2):		981	
38				Air Viscosity (VISC @ Ta, g/cm-sec):		1.834E-04	
39							
40		Calculated Design Inputs:					
41							
42				Initial Chemical Mass (MT=VC*DENS, g):		8.718E+07	
43				Ambient Temperature (Ta=Tac+273.16, degrees K):		293.16	
44				Chemical Boiling Point (Tb, degrees K):		351.66	
45		Schmidt Number (Sc**(1/3), (VISC/D*DAIR)**(1/3)):				1.152E+00	
46	**********						
47		Spill Area Calculations:					
48							
49			Initial Spill Radius (RO, cm) = (VC/PI)**(1/3)				
50				= 3.276E+02			

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SUBJECT Verification of TOXPUFF and TOXEVAP
LOTUS 1-2-3 Spreadsheets
PROJECT Monticello Toxic Chemical Study
CONTROL I.D. NO. 1961-2.2-001 REV. 0

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PREL. SHEET ___ OF ___
SHEET 56 OF 69 SHEETS

```
51
52          Initial Spill Area (A0, cm**2) = PI*(R0**2)
53                                         = 7.373E+05
54
55       Area Change Rate (ACH, cm**2/sec) = PI*2*[g*(VC)*
56                                         = (DENS-DAIR)/(DENS*PI)]**1/2
57                                         = 1.166E+06
58
59         Maximum Spill Area (Amax, cm**2) = VC/1 cm
60                                          = 1.105E+08
61
62      Time When Amax Reached (Tmax, sec) = (Amax-A0)/ACH
63                                         =     94.46
64  ================================================================
65  Calculation of dm/dt and Tgone (turbulent flow)
66
67                          dm/dt (g/sec) = hd*A(t)*MW*(Ps-Pa)/R*Ta
68
69                            hd (cm/sec) = [0.037*(U*100)**(1/3))*D*(PI**0.1)
70                                          *(U*100*DAIR/VISC)**0.8]/
71                                          [(  *0.2)*(A(t)**0.1)]
72    Combining these eqs. gives:
73                           dm/dt (g/sec) = K*(A(t)**(0.9))
74                          where:
75                                      K = 7.503E-05
76    The following eq. is solved for Tgone when Tgone > Tmax:
77
78                                     MT = K*(1/(1.9)*(1/ACH)*[(A0 + ACH*
79                                          Tmax)**(1.9) - A0**(1.9)] +
80                                          K*(Amax**(0.9))*(Tgone - Tmax)
81
82                               Tgone (sec) = 6.706E+04
83  ================================================================
84  Calculation of Sigmas (Dispersion Coefficients)
85  Pasq.-Giff. Y Disp Coeff log(SIGY, m) = A+B*log(X0)+C*(log(X0))**2+
86                                          D*(log(X0))**3
87                             where:    A =   -1.6212
88                                       B =    1.0648
89                                       C = -0.01485
90                                       D = -0.002056
91                                    SIGY =    69.532
92
93  Pasq.-Giff. Z Disp Coeff log(SIGZ, m) = A+B*log(X0)+C*(log(X0))**2+
94                                          D*(log(X0))**3
95                             where:    A =   -1.8981
96                                       B =    1.1243
97                                       C = -0.036447
98                                       D = -0.008635
99                                    SIGZ =    16.766
100
101     Cont Release Disp Coeff (SIGZM, m) = (SIGZ)
102                                        =    16.766
103
104     Cont Release Disp Coeff (SIGYM, m) = (SIGY**2+(Reff*PI**(1/2)/4.3)
105                                          **2)**(1/2)
106                                        =    73.704 (at Amax)
107           Note:
108              For Circular Spill, Reff = (A(t)/PI)**(1/2)
109
110 ================================================================
111 Conversion of g/m**3 to ppm
```

```
112
113  Conversion to PPM (PPM, ppm/(g/m**3)) = (R*Ta*1.0E+06)/(MW*Pa)
114                                        =    522.11
115  ********************************************************************
116  Calculation of Continuous Release Conc Outside Control Room
117
118    Cont Conc @ CR Intake (CRC(t), ppm) = K*(AD+ACH*t)*
119                                          (1/(2*PI*U*SIGYM*SIGZM))*(exp[
120      where z=h=0 for DVAP>DAIR,          -1/2*(z-h)**2/SIGZM**2)+exp[
121            z=h for DVAP<DAIR,            -1/2*(z+h)**2/SIGZM**2))*PPM
122            y=0, AD+ACH*t=Amax for
123            t>Tmax, and t=t-X0/U
124  Note:  CRC(t)=0 for t<X0/U and for t>time when entire spill evaporates
125         plus X0/U (Tmax+Tgone+X0/U)
126
127                          DVAP (g/cm**3) = MW*PA/R*Ta
128                                         = 1.915E-03
129  ********************************************************************
130  Calculation of Concentration Inside Control R
131    Concentration in the CR is computed in a time step-by-step
132    manner by adding the the inside CR concentration
133    at the previous time step to the difference
134    between the current outside concentration minus the previous
135    inside concentration times an exponential buildup factor.
136  ********************************************************************
137   X(t) for Tgone+Tmax+X0/U>t>Tmax+X0/U:  1.750E+02
138  X(t) Constant for Tmax+X0/U> t > X0/U:  7.437E-04
139  ********************************************************************
140  Analysis Results              h=        0
141
142              Outside     Inside    Outside     Inside  Chemical Analyzed:
143              CR Conc    CR Conc    CR Conc    CR Conc     Ethyl Alcohol
144             Continuous Continuous Continuous Continuous
145  Time (sec)   (ppm)       (ppm)      (ppm)      (ppm)
146  ==========  =======     =======    =======    =======
147           0 0.000E+00   0.000E+00  0.000E+00  0.000E+00
148           1 0.000E+00   0.000E+00  0.000E+00  0.000E+00
149           2 0.000E+00   0.000E+00  0.000E+00  0.000E+00
150           3 0.000E+00   0.000E+00  0.000E+00  0.000E+00
```

CHECKER NOTE:
A(t) TERM SHOULD BE A(t)^0.9
THIS ENTRY IS TEXT ONLY & DOES NOT AFFECT THE CALCULATION WHICH USES THE PROPER VALUES
[illegible] 3/10/93

Range: A2950 - G3400

A	A	B	C	D	E	F	G
2950	3206	0.000E+00	0.000E+00	0.000E+00	0.000E+00		
2951	3208	0.000E+00	0.000E+00	0.000E+00	0.000E+00		
2952	3210	0.000E+00	0.000E+00	0.000E+00	0.000E+00		
2953	3212	0.000E+00	0.000E+00	0.000E+00	0.000E+00		
2954	3214	0.000E+00	0.000E+00	0.000E+00	0.000E+00		
2955	3216	0.000E+00	0.000E+00	0.000E+00	0.000E+00		
2956	3218	1.010E+00	9.234E-03	1.010E+00	9.234E-03		
2957	3220	6.492E+00	6.851E-02	6.492E+00	6.851E-02		
2958	3222	1.141E+01	1.722E-01	1.141E+01	1.722E-01		
2959	3224	1.608E+01	3.177E-01	1.608E+01	3.177E-01		
2960	3226	2.059E+01	5.030E-01	2.059E+01	5.030E-01		
2961	3228	2.498E+01	7.268E-01	2.498E+01	7.268E-01		
2962	3230	2.927E+01	9.878E-01	2.927E+01	9.878E-01		
2963	3232	3.348E+01	1.285E+00	3.348E+01	1.285E+00		
2964	3234	3.763E+01	1.617E+00	3.763E+01	1.617E+00		
2965	3236	4.171E+01	1.984E+00	4.171E+01	1.984E+00		

2966	3238	4.573E+01	2.384E+00	4.573E+01	2.384E+00
2967	3240	4.971E+01	2.816E+00	4.971E+01	2.816E+00
2968	3242	5.363E+01	3.281E+00	5.363E+01	3.281E+00
2969	3244	5.752E+01	3.777E+00	5.752E+01	3.777E+00
2970	3246	6.137E+01	4.303E+00	6.137E+01	4.303E+00
2971	3248	6.518E+01	4.860E+00	6.518E+01	4.860E+00
2972	3250	6.895E+01	5.446E+00	6.895E+01	5.446E+00
2973	3252	7.269E+01	6.061E+00	7.269E+01	6.061E+00
2974	3254	7.640E+01	6.704E+00	7.640E+01	6.704E+00
2975	3256	8.008E+01	7.375E+00	8.008E+01	7.375E+00
2976	3258	8.373E+01	8.073E+00	8.373E+01	8.073E+00
2977	3260	8.735E+01	8.798E+00	8.735E+01	8.798E+00
2978	3262	9.095E+01	9.549E+00	9.095E+01	9.549E+00
2979	3264	9.452E+01	1.033E+01	9.452E+01	1.033E+01
2980	3266	9.807E+01	1.113E+01	9.807E+01	1.113E+01
2981	3268	1.016E+02	1.196E+01	1.016E+02	1.196E+01
2982	3270	1.051E+02	1.281E+01	1.051E+02	1.281E+01
2983	3272	1.086E+02	1.368E+01	1.086E+02	1.368E+01
2984	3274	1.120E+02	1.458E+01	1.120E+02	1.458E+01
2985	3276	1.155E+02	1.550E+01	1.155E+02	1.550E+01
2986	3278	1.189E+02	1.645E+01	1.189E+02	1.645E+01
2987	3280	1.223E+02	1.742E+01	1.223E+02	1.742E+01
2988	3282	1.257E+02	1.841E+01	1.257E+02	1.841E+01
2989	3284	1.290E+02	1.942E+01	1.290E+02	1.942E+01
2990	3286	1.324E+02	2.045E+01	1.324E+02	2.045E+01
2991	3288	1.357E+02	2.150E+01	1.357E+02	2.150E+01
2992	3290	1.390E+02	2.258E+01	1.390E+02	2.258E+01
2993	3292	1.423E+02	2.367E+01	1.423E+02	2.367E+01
2994	3294	1.455E+02	2.479E+01	1.455E+02	2.479E+01
2995	3296	1.488E+02	2.592E+01	1.488E+02	2.592E+01
2996	3298	1.520E+02	2.707E+01	1.520E+02	2.707E+01
2997	3300	1.552E+02	2.824E+01	1.552E+02	2.824E+01
2998	3302	1.584E+02	2.944E+01	1.584E+02	2.944E+01
2999	3304	1.616E+02	3.064E+01	1.616E+02	3.064E+01
3000	3306	1.648E+02	3.187E+01	1.648E+02	3.187E+01
3001	3308	1.680E+02	3.312E+01	1.680E+02	3.312E+01
3002	3310	1.711E+02	3.438E+01	1.711E+02	3.438E+01
3003	3312	1.742E+02	3.566E+01	1.742E+02	3.566E+01
3004	3314	1.750E+02	3.693E+01	1.750E+02	3.693E+01
3005	3316	1.750E+02	3.819E+01	1.750E+02	3.819E+01
3006	3318	1.750E+02	3.944E+01	1.750E+02	3.944E+01
3007	3320	1.750E+02	4.068E+01	1.750E+02	4.068E+01
3008	3322	1.750E+02	4.191E+01	1.750E+02	4.191E+01
3009	3324	1.750E+02	4.313E+01	1.750E+02	4.313E+01
3010	3326	1.750E+02	4.433E+01	1.750E+02	4.433E+01
3011	3328	1.750E+02	4.553E+01	1.750E+02	4.553E+01
3012	3330	1.750E+02	4.671E+01	1.750E+02	4.671E+01
3013	3332	1.750E+02	4.788E+01	1.750E+02	4.788E+01
3014	3334	1.750E+02	4.904E+01	1.750E+02	4.904E+01
3015	3336	1.750E+02	5.019E+01	1.750E+02	5.019E+01
3016	3338	1.750E+02	5.134E+01	1.750E+02	5.134E+01
3017	3340	1.750E+02	5.247E+01	1.750E+02	5.247E+01
3018	3342	1.750E+02	5.359E+01	1.750E+02	5.359E+01
3019	3344	1.750E+02	5.470E+01	1.750E+02	5.470E+01
3020	3346	1.750E+02	5.580E+01	1.750E+02	5.580E+01
3021	3348	1.750E+02	5.688E+01	1.750E+02	5.688E+01
3022	3350	1.750E+02	5.796E+01	1.750E+02	5.796E+01
3023	3352	1.750E+02	5.903E+01	1.750E+02	5.903E+01
3024	3354	1.750E+02	6.009E+01	1.750E+02	6.009E+01
3025	3356	1.750E+02	6.114E+01	1.750E+02	6.114E+01
3026	3358	1.750E+02	6.218E+01	1.750E+02	6.218E+01

3027	3360	1.750E+02	6.322E+01	1.750E+02	6.322E+01
3028	3362	1.750E+02	6.424E+01	1.750E+02	6.424E+01
3029	3364	1.750E+02	6.525E+01	1.750E+02	6.525E+01
3030	3366	1.750E+02	6.625E+01	1.750E+02	6.625E+01
3031	3368	1.750E+02	6.725E+01	1.750E+02	6.725E+01
3032	3370	1.750E+02	6.823E+01	1.750E+02	6.823E+01
3033	3372	1.750E+02	6.921E+01	1.750E+02	6.921E+01
3034	3374	1.750E+02	7.017E+01	1.750E+02	7.017E+01
3035	3376	1.750E+02	7.113E+01	1.750E+02	7.113E+01
3036	3378	1.750E+02	7.208E+01	1.750E+02	7.208E+01
3037	3380	1.750E+02	7.302E+01	1.750E+02	7.302E+01
3038	3382	1.750E+02	7.396E+01	1.750E+02	7.396E+01
3039	3384	1.750E+02	7.488E+01	1.750E+02	7.488E+01
3040	3386	1.750E+02	7.579E+01	1.750E+02	7.579E+01
3041	3388	1.750E+02	7.670E+01	1.750E+02	7.670E+01
3042	3390	1.750E+02	7.760E+01	1.750E+02	7.760E+01
3043	3392	1.750E+02	7.849E+01	1.750E+02	7.849E+01
3044	3394	1.750E+02	7.937E+01	1.750E+02	7.937E+01
3045	3396	1.750E+02	8.025E+01	1.750E+02	8.025E+01
3046	3398	1.750E+02	8.111E+01	1.750E+02	8.111E+01
3047	3400	1.750E+02	8.197E+01	1.750E+02	8.197E+01
3048	3402	1.750E+02	8.282E+01	1.750E+02	8.282E+01
3049	3404	1.750E+02	8.366E+01	1.750E+02	8.366E+01
3050	3406	1.750E+02	8.450E+01	1.750E+02	8.450E+01
3051	3408	1.750E+02	8.532E+01	1.750E+02	8.532E+01
3052	3410	1.750E+02	8.614E+01	1.750E+02	8.614E+01
3053	3412	1.750E+02	8.696E+01	1.750E+02	8.696E+01
3054	3414	1.750E+02	8.776E+01	1.750E+02	8.776E+01
3055	3416	1.750E+02	8.856E+01	1.750E+02	8.856E+01
3056	3418	1.750E+02	8.935E+01	1.750E+02	8.935E+01
3057	3420	1.750E+02	9.013E+01	1.750E+02	9.013E+01
3058	3422	1.750E+02	9.091E+01	1.750E+02	9.091E+01
3059	3424	1.750E+02	9.167E+01	1.750E+02	9.167E+01
3060	3426	1.750E+02	9.244E+01	1.750E+02	9.244E+01
3061	3428	1.750E+02	9.319E+01	1.750E+02	9.319E+01
3062	3430	1.750E+02	9.394E+01	1.750E+02	9.394E+01
3063	3432	1.750E+02	9.468E+01	1.750E+02	9.468E+01
3064	3434	1.750E+02	9.541E+01	1.750E+02	9.541E+01
3065	3436	1.750E+02	9.614E+01	1.750E+02	9.614E+01
3066	3438	1.750E+02	9.686E+01	1.750E+02	9.686E+01
3067	3440	1.750E+02	9.758E+01	1.750E+02	9.758E+01
3068	3442	1.750E+02	9.828E+01	1.750E+02	9.828E+01
3069	3444	1.750E+02	9.898E+01	1.750E+02	9.898E+01
3070	3446	1.750E+02	9.968E+01	1.750E+02	9.968E+01
3071	3448	1.750E+02	1.004E+02	1.750E+02	1.004E+02
3072	3450	1.750E+02	1.010E+02	1.750E+02	1.010E+02
3073	3452	1.750E+02	1.017E+02	1.750E+02	1.017E+02
3074	3454	1.750E+02	1.024E+02	1.750E+02	1.024E+02
3075	3456	1.750E+02	1.031E+02	1.750E+02	1.031E+02
3076	3458	1.750E+02	1.037E+02	1.750E+02	1.037E+02
3077	3460	1.750E+02	1.044E+02	1.750E+02	1.044E+02
3078	3462	1.750E+02	1.050E+02	1.750E+02	1.050E+02
3079	3464	1.750E+02	1.057E+02	1.750E+02	1.057E+02
3080	3466	1.750E+02	1.063E+02	1.750E+02	1.063E+02
3081	3468	1.750E+02	1.069E+02	1.750E+02	1.069E+02
3082	3470	1.750E+02	1.075E+02	1.750E+02	1.075E+02
3083	3472	1.750E+02	1.082E+02	1.750E+02	1.082E+02
3084	3474	1.750E+02	1.088E+02	1.750E+02	1.088E+02
3085	3476	1.750E+02	1.094E+02	1.750E+02	1.094E+02
3086	3478	1.750E+02	1.100E+02	1.750E+02	1.100E+02
3087	3480	1.750E+02	1.106E+02	1.750E+02	1.106E+02

3088	3482	1.750E+02	1.112E+02	1.750E+02	1.112E+02
3089	3484	1.750E+02	1.117E+02	1.750E+02	1.117E+02
3090	3486	1.750E+02	1.123E+02	1.750E+02	1.123E+02
3091	3488	1.750E+02	1.129E+02	1.750E+02	1.129E+02
3092	3490	1.750E+02	1.135E+02	1.750E+02	1.135E+02
3093	3492	1.750E+02	1.140E+02	1.750E+02	1.140E+02
3094	3494	1.750E+02	1.146E+02	1.750E+02	1.146E+02
3095	3496	1.750E+02	1.151E+02	1.750E+02	1.151E+02
3096	3498	1.750E+02	1.157E+02	1.750E+02	1.157E+02
3097	3500	1.750E+02	1.162E+02	1.750E+02	1.162E+02
3098	3502	1.750E+02	1.168E+02	1.750E+02	1.168E+02
3099	3504	1.750E+02	1.173E+02	1.750E+02	1.173E+02
3100	3506	1.750E+02	1.178E+02	1.750E+02	1.178E+02
3101	3508	1.750E+02	1.183E+02	1.750E+02	1.183E+02
3102	3510	1.750E+02	1.189E+02	1.750E+02	1.189E+02
3103	3512	1.750E+02	1.194E+02	1.750E+02	1.194E+02
3104	3514	1.750E+02	1.199E+02	1.750E+02	1.199E+02
3105	3516	1.750E+02	1.204E+02	1.750E+02	1.204E+02
3106	3518	1.750E+02	1.209E+02	1.750E+02	1.209E+02
3107	3520	1.750E+02	1.214E+02	1.750E+02	1.214E+02
3108	3522	1.750E+02	1.219E+02	1.750E+02	1.219E+02
3109	3524	1.750E+02	1.223E+02	1.750E+02	1.223E+02
3110	3526	1.750E+02	1.228E+02	1.750E+02	1.228E+02
3111	3528	1.750E+02	1.233E+02	1.750E+02	1.233E+02
3112	3530	1.750E+02	1.238E+02	1.750E+02	1.238E+02
3113	3532	1.750E+02	1.242E+02	1.750E+02	1.242E+02
3114	3534	1.750E+02	1.247E+02	1.750E+02	1.247E+02
3115	3536	1.750E+02	1.252E+02	1.750E+02	1.252E+02
3116	3538	1.750E+02	1.256E+02	1.750E+02	1.256E+02
3117	3540	1.750E+02	1.261E+02	1.750E+02	1.261E+02
3118	3542	1.750E+02	1.265E+02	1.750E+02	1.265E+02
3119	3544	1.750E+02	1.270E+02	1.750E+02	1.270E+02
3120	3546	1.750E+02	1.274E+02	1.750E+02	1.274E+02
3121	3548	1.750E+02	1.278E+02	1.750E+02	1.278E+02
3122	3550	1.750E+02	1.283E+02	1.750E+02	1.283E+02
3123	3552	1.750E+02	1.287E+02	1.750E+02	1.287E+02
3124	3554	1.750E+02	1.291E+02	1.750E+02	1.291E+02
3125	3556	1.750E+02	1.295E+02	1.750E+02	1.295E+02
3126	3558	1.750E+02	1.300E+02	1.750E+02	1.300E+02
3127	3560	1.750E+02	1.304E+02	1.750E+02	1.304E+02
3128	3562	1.750E+02	1.308E+02	1.750E+02	1.308E+02
3129	3564	1.750E+02	1.312E+02	1.750E+02	1.312E+02
3130	3566	1.750E+02	1.316E+02	1.750E+02	1.316E+02
3131	3568	1.750E+02	1.320E+02	1.750E+02	1.320E+02
3132	3570	1.750E+02	1.324E+02	1.750E+02	1.324E+02
3133	3572	1.750E+02	1.328E+02	1.750E+02	1.328E+02
3134	3574	1.750E+02	1.331E+02	1.750E+02	1.331E+02
3135	3576	1.750E+02	1.335E+02	1.750E+02	1.335E+02
3136	3578	1.750E+02	1.339E+02	1.750E+02	1.339E+02
3137	3580	1.750E+02	1.343E+02	1.750E+02	1.343E+02
3138	3582	1.750E+02	1.347E+02	1.750E+02	1.347E+02
3139	3584	1.750E+02	1.350E+02	1.750E+02	1.350E+02
3140	3586	1.750E+02	1.354E+02	1.750E+02	1.354E+02
3141	3588	1.750E+02	1.357E+02	1.750E+02	1.357E+02
3142	3590	1.750E+02	1.361E+02	1.750E+02	1.361E+02
3143	3592	1.750E+02	1.365E+02	1.750E+02	1.365E+02
3144	3594	1.750E+02	1.368E+02	1.750E+02	1.368E+02
3145	3596	1.750E+02	1.372E+02	1.750E+02	1.372E+02
3146	3598	1.750E+02	1.375E+02	1.750E+02	1.375E+02
3147	3600	1.750E+02	1.378E+02	1.750E+02	1.378E+02
3148	3700	1.750E+02	1.515E+02	1.750E+02	1.515E+02

3149	3800	1.750E+02	1.602E+02	1.750E+02	1.602E+02
3150	3900	1.750E+02	1.656E+02	1.750E+02	1.656E+02
3151	4000	1.750E+02	1.691E+02	1.750E+02	1.691E+02
3152	4100	1.750E+02	1.712E+02	1.750E+02	1.712E+02
3153	4200	1.750E+02	1.726E+02	1.750E+02	1.726E+02
3154	4300	1.750E+02	1.735E+02	1.750E+02	1.735E+02
3155	4400	1.750E+02	1.740E+02	1.750E+02	1.740E+02
3156	4500	1.750E+02	1.744E+02	1.750E+02	1.744E+02
3157	4600	1.750E+02	1.746E+02	1.750E+02	1.746E+02
3158	4700	1.750E+02	1.747E+02	1.750E+02	1.747E+02
3159	4800	1.750E+02	1.748E+02	1.750E+02	1.748E+02
3160	4900	1.750E+02	1.749E+02	1.750E+02	1.749E+02
3161	5000	1.750E+02	1.749E+02	1.750E+02	1.749E+02
3162	5100	1.750E+02	1.749E+02	1.750E+02	1.749E+02
3163	5200	1.750E+02	1.749E+02	1.750E+02	1.749E+02
3164	5300	1.750E+02	1.749E+02	1.750E+02	1.749E+02
3165	5400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3166	5500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3167	5600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3168	5700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3169	5800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3170	5900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3171	6000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3172	6100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3173	6200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3174	6300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3175	6400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3176	6500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3177	6600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3178	6700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3179	6800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3180	6900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3181	7000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3182	7100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3183	7200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3184	7300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3185	7400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3186	7500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3187	7600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3188	7700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3189	7800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3190	7900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3191	8000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3192	8100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3193	8200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3194	8300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3195	8400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3196	8500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3197	8600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3198	8700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3199	8800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3200	8900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3201	9000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3202	9100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3203	9200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3204	9300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3205	9400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3206	9500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3207	9600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3208	9700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3209	9800	1.750E+02	1.750E+02	1.750E+02	1.750E+02

3210	9900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3211	10000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3212	10100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3213	10200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3214	10300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3215	10400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3216	10500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3217	10600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3218	10700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3219	10800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3220	10900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3221	11000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3222	11100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3223	11200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3224	11300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3225	11400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3226	11500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3227	11600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3228	11700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3229	11800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3230	11900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3231	12000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3232	12100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3233	12200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3234	12300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3235	12400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3236	12500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3237	12600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3238	12700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3239	12800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3240	12900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3241	13000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3242	13100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3243	13200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3244	13300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3245	13400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3246	13500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3247	13600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3248	13700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3249	13800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3250	13900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3251	14000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3252	14100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3253	14200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3254	14300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3255	14400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3256	14500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3257	14600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3258	14700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3259	14800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3260	14900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3261	15000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3262	15100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3263	15200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3264	15300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3265	15400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3266	15500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3267	15600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3268	15700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3269	15800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3270	15900	1.750E+02	1.750E+02	1.750E+02	1.750E+02

3271	16000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3272	16100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3273	16200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3274	16300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3275	16400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3276	16500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3277	16600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3278	16700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3279	16800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3280	16900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3281	17000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3282	17100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3283	17200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3284	17300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3285	17400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3286	17500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3287	17600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3288	17700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3289	17800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3290	17900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3291	18000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3292	18100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3293	18200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3294	18300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3295	18400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3296	18500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3297	18600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3298	18700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3299	18800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3300	18900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3301	19000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3302	19100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3303	19200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3304	19300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3305	19400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3306	19500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3307	19600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3308	19700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3309	19800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3310	19900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3311	20000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3312	20100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3313	20200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3314	20300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3315	20400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3316	20500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3317	20600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3318	20700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3319	20800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3320	20900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3321	21000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3322	21100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3323	21200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3324	21300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3325	21400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3326	21500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3327	21600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3328	21700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3329	21800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3330	21900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3331	22000	1.750E+02	1.750E+02	1.750E+02	1.750E+02

3332	22100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3333	22200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3334	22300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3335	22400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3336	22500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3337	22600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3338	22700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3339	22800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3340	22900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3341	23000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3342	23100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3343	23200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3344	23300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3345	23400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3346	23500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3347	23600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3348	23700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3349	23800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3350	23900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3351	24000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3352	24100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3353	24200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3354	24300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3355	24400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3356	24500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3357	24600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3358	24700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3359	24800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3360	24900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3361	25000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3362	25100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3363	25200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3364	25300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3365	25400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3366	25500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3367	25600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3368	25700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3369	25800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3370	25900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3371	26000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3372	26100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3373	26200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3374	26300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3375	26400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3376	26500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3377	26600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3378	26700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3379	26800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3380	26900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3381	27000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3382	27100	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3383	27200	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3384	27300	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3385	27400	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3386	27500	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3387	27600	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3388	27700	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3389	27800	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3390	27900	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3391	28000	1.750E+02	1.750E+02	1.750E+02	1.750E+02
3392	28100	1.750E+02	1.750E+02	1.750E+02	1.750E+02

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3393    28200 1.750E+02 1.750E+02 1.750E+02 1.750E+02
3394    28300 1.750E+02 1.750E+02 1.750E+02 1.750E+02
3395    28400 1.750E+02 1.750E+02 1.750E+02 1.750E+02
3396    28500 1.750E+02 1.750E+02 1.750E+02 1.750E+02
3397    28600 1.750E+02 1.750E+02 1.750E+02 1.750E+02
3398    28700 1.750E+02 1.750E+02 1.750E+02 1.750E+02
3399    28800 1.750E+02 1.750E+02 1.750E+02 1.750E+02
3400
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APPENDIX 4

TOXEVAP Formula Listing

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A:B1: '          Toxic Chemical Spill Calculation
A:A2: [W10] '      (For chemical boiling point greater than ambient temperature)
A:A4: [W10] '     Last Updated:
A:C4: (D1) @INT(@NOW)
A:D4: '  Analyzed Chemical:  Ethyl Alcohol
A:A6: [W10] '==========================================================================
A:A7: [W10] 'Design Inputs:
A:A9: [W10] '  Spill Data:
A:C10: 'Container Volume (VC, cm**3):
A:F10: (S3) 110500000
A:B11: '   Spill to CR Intake Distance (XD, m):
A:F11: (F1) 3218
A:D12: '          Spill Type: Circular
A:A15: [W10] '  Meteorological Data:
A:B16: '          Pasquill's Stability Category:
A:F16: '    G
A:B17: '  Ambient Temperature (Tac, degrees C):
A:F17: 20
A:C18: '        Wind Speed (U, m/sec):
A:F18: 1
A:C19: '       Air Pressure (PA, atm):
A:F19: 1
A:C20: '     Air Pressure (Pa, mm-Hg):
A:F20: 0
A:A21: [W10] '  Control Room Data:
A:B22: 'Control Room HVAC Intake Height (z, m):
A:F22: 11.28
A:B23: '       Control Room Volume (CRV, ft**3):
A:F23: (S3) 27000
A:A24: [W10] '        CR HVAC Intake Rate (CFIN, ft.**3/minute):
A:F24: 7440
A:A26: [W10] '  Chemical Data:
A:B27: '       Chemical Density (DENS, g/cm**3):
A:F27: (F3) 0.789
A:B28: '          Boiling Point (Tb, degrees C):
A:F28: 78.5
A:B29: '          Molecular Weight (MW, g/mole):
A:F29: (F2) 46.07
A:A30: [W10] '            Diffusion Coefficient (D, cm**2/sec):
A:F30: 0.1
A:C31: ' Vapor Presssure (Ps, mm-Hg):
A:F31: 40
A:A32: [W10] '  Constants:
A:A33: [W10] '  Ideal Gas Constant (R, atm-m**3/mole-degree K):
A:F33: (S3) 8.205E-05
A:C34: ' Air Density (DAIR, g/cm**3,
A:B35: '     at 1 atmosphere and 20 degrees C):
A:F35: (S2) 0.0012
A:E36: '       PI:
A:F36: @PI
A:A37: [W10] '            Gravitational Constant (G, cm/sec**2):
A:F37: 981
A:B38: '   Air Viscosity (VISC @ Ta, g/cm-sec):
A:F38: (S3) 0.0001834
A:A40: [W10] 'Calculated Design Inputs:
A:B42: ' Initial Chemical Mass (MT=VC*DENS, g):
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A:F42: (S3) +F10*F27
A:A43: [W10] '  Ambient Temperature (Ta=Tac+273.16, degrees K):
A:F43: +F17+273.16
A:B44: 'Chemical Boiling Point (Tb, degrees K):
A:F44: +F28+273.16
A:A45: [W10] 'Schmidt Number (Sc**(1/3), (VISC/D*DAIR)**(1/3)):
A:F45: (S3) (F38/(F30*F35))^(1/3)
A:A46: [W10] '==========================================================================
A:A47: [W10] 'Spill Area Calculations:
A:A49: [W10] '        Initial Spill Radius (R0, cm) = (VC/PI)**(1/3)
A:D50: '        =
A:E50: (S3) (F10/F36)^(1/3)
A:A52: [W10] '        Initial Spill Area (A0, cm**2) =
A:E52: 'PI*(R0**2)
A:D53: '        =
A:E53: (S3) +F36*(E50*E50)
A:A55: [W10] '     Area Change Rate (ACH, cm**2/sec) = PI*2*[g*(VC)*
A:A56: [W10] '                                       = (DENS-DAIR)/(DENS*PI)]**1/2
A:D57: '        =
A:E57: (S3) +F36*2*((F37*F10*(F27-F35)/(F27*F36))^(1/2))
A:A59: [W10] '     Maximum Spill Area (Amax, cm**2) = VC/1 cm
A:D60: '        =
A:E60: (S3)  10
A:A62: [W10]      Time When Amax Reached (Tmax, sec) = (Amax-A0)/ACH
A:D63: '        =
A:E63: (F2) (E60-E53)/E57
A:A64: [W10] '==========================================================================
A:A65: [W10] 'Calculation of dm/dt and Tgone (turbulent flow)
A:C67: '     dm/dt (g/sec) =
A:E67: 'hd*A(t)*MW*(Ps-Pa)/R*Ta
A:C69: '        hd (cm/sec) =
A:E69: '[0.037*(Sc**(1/3))*D*(PI**0.1)
A:E70: '*(U*100*DAIR/VISC)**0.8]/
A:E71: (S3) '[(2**0.2)*(A(t)**0.1)]
A:A72: [W10] '  Combining these eqs. gives:
A:C73: '     dm/dt (g/sec) =
A:E73: 'K*(A(t)**(0.9))
A:C74: '    where:
A:D75: '        K =
A:E75:  (S3)
        ((F36^0.1)*0.037*F45*F30*(((F18*100*F35/F38)^0.8)/(2^0.2)))*F29*(F31-F20)/(F33*F43*1000000*760)
A:A76: [W10] '  The following eq. is solved for Tgone when Tgone > Tmax:
A:C78: '                MT =
A:E78: 'K*(1/1.9)*(1/ACH)*[(A0 + ACH*
A:E79: (S3) 'Tmax)**(1.9) - A0**(1.9)] +
A:E80: 'K*(Amax**(0.9))*(Tgone - Tmax)
A:C82: '        Tgone (sec) =
A:E82: (S3) (F42-E75*(1/1.9)*(1/E57)*((E53+E57*E63)^(1.9)-E53^(1.9)))/(E75*(E60^(0.9)))+E63
A:A83: [W10] '==========================================================================
A:A84: [W10] 'Calculation of Sigmas (Dispersion Coefficients)
A:A85: [W10] 'Pasq.-Giff. Y Disp Coeff log(SIGY, m) =
A:E85: 'A+B*log(X0)+C*(log(X0))**2+
A:A86: [W10] '
A:E86: 'D*(log(X0))**3
A:C87: '     where:
A:D87: '        A =
A:E87: -1.6212
A:D88: '        B =
A:E88: 1.0648
A:D89: '        C =
A:E89: -0.014857
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A:D90: '      D =
A:E90: -0.0020555
A:D91: '   SIGY =
A:E91: (F3) 10^(+E87+E88*@LOG(F11)+E89*(@LOG(F11)^2)+E90*(@LOG(F11)^3))
A:A93: [W10] 'Pasq.-Giff. Z Disp Coeff log(SIGZ, m) =
A:E93: 'A+B*log(X0)+C*(log(X0))**2+
A:A94: [W10] '
A:E94: 'D*(log(X0))**3
A:C95: '    where:
A:D95: '      A =
A:E95: -1.8981
A:D96: '      B =
A:E96: 1.1243
A:D97: '      C =
A:E97: -0.036447
A:D98: '      D =
A:E98: -0.0086351
A:D99: '   SIGZ =
A:E99: (F3) 10^(+E95+E96*@LOG(F11)+E97*(@LOG(F11)^2)+E98*(@LOG(F11)^3))
A:A101: [W10] '   Cont Release Disp Coeff (SIGZM, m) =
A:E101: '(SIGZ)
A:D102: '        =
A:E102: (F3) (E99)
A:A104: [W10] '   Cont Release Disp Coeff (SIGYM, m) =
A:E104: '(SIGY**2+(Reff*PI**(1/2)/4.3)
A:E105: '**2)**(1/2)
A:D106: '        =
A:E106: (F3) (E91^2+E60/184900)^(1/2)
A:F106: (F3) '(at Amax)
A:B107: 'Note:
A:B108: '   For Circular Spill, Reff = (A(t)/PI)**(1/2)
A:A110: [W10] '=============================================================================
A:A111: [W10] 'Conversion of g/m**3 to ppm
A:A113: [W10] 'Conversion to PPM (PPM, ppm/(g/m**3)) =
A:E113: '(R*Ta*1.0E+06)/(MW*Pa)
A:D114: '        =
A:E114: (F2) (F33*F43*1000000)/(F19*F29)
A:A115: [W10] '=============================================================================
A:A116: [W10] 'Calculation of Continuous Release Conc Outside Control Room
A:A118: [W10] '  Cont Conc @ CR Intake (CRC(t), ppm) =
A:E118: 'K*(A0+ACH*t)*
A:E119: '(1/(2*PI*U*SIGYM*SIGZM))*(exp[
A:A120: [W10] '    where z=h=0 for DVAP>DAIR,
A:E120: '-1/2*(z-h)**2/SIGZM**2]+exp[
A:A121: [W10] '          z=h for DVAP<DAIR,
A:E121: '-1/2*(z+h)**2/SIGZM**2])*PPM
A:B122: 'y=0, A0+ACH*t=Amax for
A:B123: 't>Tmax, and t=t-X0/U
A:A124: [W10] 'Note:  CRC(t)=0 for t<X0/U and for t>time when entire spill evaporates
A:A125: [W10] '       plus X0/U (Tmax+Tgone+X0/U)
A:C127: '   DVAP (g/cm**3) =
A:E127: 'MW*PA/R*Ta
A:D128: '        =
A:E128: (S3) (F29*F19)/(F33*F43*1000000)
A:A129: [W10] '=============================================================================
A:A130: [W10] 'Calculation of Concentration Inside Control Room
A:A131: [W10] '  Concentration in the CR is computed in a time step-by-step
A:A132: [W10] '  manner by adding the the inside CR concentration
A:A133: [W10] '  at the previous time step to the difference
A:A134: [W10] '  between the current outside concentration minus the previous
A:A135: [W10] '  inside concentration times an exponential buildup factor.
```

CHECKER'S NOTE:
SEE NOTE ON PAGE 57 [illegible] 3/10/93

TENERA

SUBJECT Verification of TOXPUFF and TOXEVAP
LOTUS 1-2-3 Spreadsheets

PREPARED BY [illegible] DATE 3/8/93

CHECKED BY [illegible] DATE 3/10/93

PROJECT Monticello Toxic Chemical Study

PREL. SHEET ____ OF ____

CONTROL I.D. NO. 1961-2.2-001 REV. 0

SHEET 69 OF 69 SHEETS

```
A:A136: [W10] '==========
A:A137: [W10] ' X(t) for Tgone<Tmax<XO/u>t>Tmax+XO/U:
A:E137: (S3)
        ($E$60^(0.9))*$E$114*$E$75*;1/(2*$F$36*$E$102*$E$106*$F$18))*(1+@EXP(-0.5*(($D$140+$D$140)^2)/($_$
        102^2)))
A:A138: [W10] 'X(t) Constant for Tmax+XO/U> t > XO/U:
A:E138: (S3) +$E$114*$E$75*(1/(2*$F$36*$E$102*$F$18))*(1+@EXP(-0.5*(($D$140+$D$140)^2)/($E$102^2)))
A:A139: [W10] '==========
A:A140: [W10] 'Analysis Results
A:C140: '       h=
A:D140: @IF(E128>F35,0,F22)
A:B142: ' Outside
A:C142: '  Inside
A:D142: ' Outside
A:E142: '  Inside
A:F142: 'Chemical Analyzed:
A:B143: ' CR Conc
A:C143: ' CR Conc
A:D143: ' CR Conc
A:E143: ' CR Conc
A:F143: '  Ethyl Alcohol
A:B144: 'Continuous
A:C144: 'Continuous
A:D144: 'Continuous
A:E144: 'Continuous
A:A145: [W10] 'Time (sec)
A:B145: '  (ppm)
A:C145: '  (ppm)
A:D145: '  (ppm)
A:E145: '  (ppm)
A:A146: [W10] '==========
A:B146: '  =====
A:C146: '  =====
A:D146: '  =====
A:E146: '  =====
A:A147: [W10] 0
A:B147: (S3) @IF(D147<1E-98,0,D147)
A:C147: (S3) @IF(E147<1E-98,0,E147)
A:D147: (S3) 0
A:E147: (S3) 0
A:A148: [W10] +A147+1
A:B148: (S3) @IF(D148<1E-98,0,D148)
A:C148: (S3) @IF(E148<1E-98,0,E148)
A:D148: (S3)
        @IF((A148-$F$11/$F$18)<0,0,@IF(A148>=$F$11/$F$18+$E$82+$E$63,0,@IF(A148>=$F$11/$F$18+$E$63,$E$137,
        $E$138*((($E$53+$E$57*(A148-$F$11/$F$18))^(0.9))*(1/(($E$91^2+($E$53+$E$57*(A148-$F$11/$F$18))/1849
        00)^(1/2))))))
A:E148: (S3) +C147+(B148-C147)*(1-@EXP(-1*$F$24*(A148-A147)/($F$23*60)))
```