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				Sodium Hydroxide Releases				

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Comparison Between Sodium Nitrite and Sodium Hydroxide Spray Accident

J. C. Williams, & B. E. Hey, Fluor Federal Services
for CH2M HILL Hanford Group, Inc.
Richland, WA 99352
U.S. Department of Energy Contract DE-AC27-99RL14047

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Abstract: The purpose of this analysis is to compare the consequences of an 8 molar NaNO2 spray leak to the Tank Farm Final Safety Analysis Report (FSAR) evaluation of sprays of up to 19 molar (50%) NaOH. Four conditions were evaluated. These are; a spray during transfers from a one-inch pipe, a spray resulting from a truck tank crack, a spray resulting from a truck tank rupture, and a spray in the 204-AR Waste Unloading Facility.

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Comparison of Sodium Nitrite Releases with Sodium Hydroxide Releases

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

CH2MHILL
Hanford Group, Inc.

Richland, Washington

Contractor for the U.S. Department of Energy
Office of River Protection under Contract DE-AC27-99RL14047

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TERMS

AED	aerodynamic equivalent diameter
ERPG	Emergency Response Planning Guideline
ESP	Environmental Simulation Program
FSAR	Final Safety Analysis Report
$NaNO_2$	sodium nitrite
NaOH	sodium hydroxide
PEL-TWA	permissible exposure limit-time weighted average
RPP	River Protection Project
SOF	sum of fractions

1.0 INTRODUCTION AND SCOPE

As part of the tank farm corrosion control program, it is necessary to add up to 8 molar sodium nitrite ($NaNO_2$) to underground waste storage tanks. The purpose of this analysis is to compare the consequences of an $NaNO_2$ spray leak (up to 8 molar) to the consequences presented in HNF-SD-WM-SAR-067, *Tank Farms Final Safety Analysis Report* (FSAR), Section 3.3.2.4.9 and Addendum 1 for up to 19 molar sodium hydroxide (NaOH). The accident conditions evaluated by this analysis are the same as those discussed in the FSAR.

2.0 ANALYSIS METHODOLOGY

Details of the analysis were taken from HNF-SD-WM-CN-065, *Consequence Analysis of a NaOH Solution Spray Release During Addition to Waste Tank.* The SPRAY code (WHC-SD-GN-SWD-20007, *A Model for Predicting Respirable Releases from Pressurized Leaks*), which was used for the NaOH accidents, was used for the evaluation of $NaNO_2$ sprays.

3.0 ACCIDENT ANALYSIS

Four conditions are evaluated in the following subsections:

- A spray during transfers from a 1-in. pipe
- A spray resulting from a truck tank crack
- A spray resulting from a truck tank rupture
- A spray in the 204-AR Waste Unloading Facility.

3.1 SPRAYS DURING TRANSFER

In Section 3.3.2.4.9, the FSAR considers a NaOH spray through a crack in a 1-in. Schedule 10 pipe under 125 lbf/in^2 gauge pressure. The same conditions are assumed for the spray of sodium nitrite solution.

The material properties in Table 1 were generated using the Environmental Simulation Program (ESP) computer code (HNF-3257, *Evaluation of the Environmental Simulation Program (ESP) as a Computer Simulator of Nuclear Waste Processing*). All simulations assume a temperature of 25 °C and a pressure of 1 atmosphere. Molarity was calculated by dividing NO2ION by volume. Weight fraction of sodium nitrite is given by:

$$\text{Weight fraction} = \text{molarity} * \text{molecular weight/solution density}$$

The weight fraction of 8 molar solution was calculated by interpolation to be 0.416 (41.6%). Because it is possible that dilute solutions will be handled, $NaNO_2$ weight percents between 5% and 41.6% will be considered.

Table 1. $NaNO_2$ Material Properties.

ESP Output					Calculated from ESP Output	
Data Point	**NO2ION (mol/h)**	**Volume (L/h)**	**Density (kg/L)**	**Absolute Viscosity (cP)**	**Molarity**	**Weight Fraction**
1	0	1.726	0.997	0.891	0	0
2	3.442	1.814	1.080	1.003	1.897	0.121
3	6.882	1.907	1.151	1.281	3.609	0.126
4	10.324	2.004	1.214	1.664	5.152	0.293
5	13.765	2.104	1.269	2.090	6.542	0.356
6	17.206	2.208	1.317	2.554	7.793	0.408
7	20.647	2.315	1.359	3.037	8.920	0.453
8	21.179	2.331	1.365	3.113	9.084	0.459
					8.0	0.416

Calculations with the SPRAY computer code (WHC-SD-GN-SWD-20007) were made for sodium nitrite concentrations from 5% to 41.6% exiting through a 1-in. crack in a 1-in. Schedule 10 pipe with a wall thickness of 0.109 in. All SPRAY input variables were the same as were used in the NaOH analysis documented in HNF-SD-WM-CN-065, except the material properties of density and viscosity were obtained by interpolation from Table 1 and respirable diameter D_r, in microns, was calculated using the following equation from HNF-SD-WM-CN-065:

$$D_r = \frac{10}{\sqrt[3]{F_s}}$$

where F_s is the volume fraction of $NaNO_2$ in the solution. D_r also can be found from the weight fraction W_f as follows:

$$D_r = \frac{10}{\sqrt[3]{W_f \frac{\rho_s}{\rho_{NaNO2}}}}$$

where ρ_s is the solution density and ρ_{NaNO2} is the density of solid $NaNO_2$ (2.168 kg/L from Section B of the *Handbook of Chemistry and Physics* [Weast 1965]).

The parameters are as follows:

- Crack length – 1 in.
- Crack depth – 0.109 in.
- Pressure – 125 lbf/in.^{2} gauge

- Surface roughness – 0.0018 in.
- Contraction coefficient – 1.00
- Velocity coefficient – 0.82.

The SPRAY code results are summarized in the fifth column of Table 2, Solution Respirable Release Rate. The sodium nitrite respirable release rate is found by multiplying the solution release rate by the sodium nitrite weight fraction. The SPRAY computer code outputs are located in Attachment A.

Table 2. SPRAY Results.

Wt% $NaNO_2$	Density (kg/L)	Absolute Viscosity (cP)	Respirable Diameter (microns)	Solution Respirable Release Rate (g/s)	$NaNO_2$ Respirable Release Rate(g/s)
5	1.031	0.937	34.78	6.36	0.32
10	1.065	0.983	27.30	3.55	0.34
15	1.101	1.087	23.59	2.39	0.36
20	1.139	1.233	21.19	1.73	0.35
25	1.179	1.450	19.45	1.29	0.32
30 (laminar)	1.220	1.713	18.09	6.94	2.08
30 (turbulent)	1.220	1.713	18.09	1.00	0.30
35 (laminar)	1.264	2.052	16.99	4.85	1.70
35 (turbulent)	1.264	2.052	16.99	0.78	0.27
40 (laminar)	1.309	2.481	16.06	3.34	1.34
40 (turbulent)	1.309	2.481	16.06	0.61	0.25
41.6 (laminar)	1.325	2.638	15.79	2.97	1.24
41.6 (turbulent)	1.325	2.638	15.79	0.57	0.24

The SPRAY code calculates the Reynolds number and determines the flow regime. The flow at low concentrations (5% and 10%) was fully turbulent. Flow at the intermediate concentrations (15%, 20%, and 25%) was critical, but behaved as turbulent. Flow at the higher concentrations (40% and 41.6%) was critical, but behaved as laminar. The 30% and 35% concentrations were critical and SPRAY could not determine the flow regime. Runs for the higher concentrations were made for both laminar and turbulent flow. The laminar flow gave significantly larger respirable spray releases, and laminar flow is conservatively assumed for these cases. The peak $NaNO_2$ respirable release is therefore calculated to be 2.08 g/s. The spray leak is specified to be an "anticipated event" in the River Protection Project (RPP) FSAR, Section 3.3.2.4.9. The χ/Qs from the FSAR are 0.0341 s/m^3 onsite and 2.83 x 10^{-5} s/m^3 offsite.

Risk guidelines for $NaNO_2$ are 3.5 mg/m^3 onsite and 3.5 mg/m^3 offsite as taken from Appendix D of WHC-SD-WM-SARR-011, *Toxic Chemical Considerations for Tank Farm Releases*. This onsite guideline is based on the Emergency Response Planning Guideline, ERPG-1, and this

offsite guideline is the permissible exposure limit-time-weighted average (PEL-TWA). These are the FSAR reference numbers and will be used for this analysis.

3.1.1 Unmitigated Results

3.1.1.1 Onsite Results

The Tank Farm FSAR potential toxic releases are evaluated by calculating a sum of fractions (SOF) of concentrations at the receptor. The SOF for a $NaNO_2$ release is given by

$$\begin{aligned} SOF &= (\text{release rate g/s})\ (X/Q\ \text{s/m}^3)\ (1000\ \text{mg/g})\ /\ \text{ERPG-1}\ (\text{mg/m}^3) \\ &= (2.08\ \text{g/s})\ (0.0341\ \text{s/m}^3)\ (1000\ \text{mg/g})\ /\ (3.5\ \text{mg/m}^3) \\ &= 20 \end{aligned}$$

The unmitigated onsite SOF for the NaOH spray accident is 29 from FSAR Table 3.3.2.4.9-1.

3.1.1.2 Offsite Results

$$\begin{aligned} SOF &= (2.08)\ (2.83 \times 10^{-5})\ (1000)\ /\ 3.5 \\ &= 0.017 \end{aligned}$$

The unmitigated offsite SOF for the NaOH spray accident is 0.024 from FSAR Table 3.3.2.4.9-1.

The FSAR NaOH sums of fractions bound the nitrite releases.

3.1.2 Mitigated Results

The principal mitigation for a NaOH spray release is plastic sleeving around the pipe. It is assumed that sleeving also is required for nitrite transfers, because the onsite SOF is above 1.0. Using the methodology of HNF-SD-WM-CN-065, the solution leaking from the pipe is assumed to displace an equal volume of air out of the sleeving. The maximum air loading of an aerosol mist inside the sleeving is conservatively assumed to be 1 g/m^3. For example, a leak rate of 100 m^3/s would force 100 g/s of solution out of the sleeving. The $NaNO_2$ release rate depends on the solution concentration.

The maximum total solution leak rate is found to be 5.47E-05 m^3/s (equivalent to 5.47E-05 g/s) at a concentration of 5% (see SPRAY runs in Attachment A). However, Table 3 shows that the maximum $NaNO_2$ leak rate occurs when the concentration is 41.6% and turbulent flow is assumed.

Table 3. Leak Rate Comparison for Mitigated Accident.

Case	Solution leak rate, m^3/s	$NaNO_2$ leak rate, g/s
5%	5.47E-05	2.74E-06
10%	5.15E-05	5.15E-06
15%	4.98E-05	7.47E-06
20%	4.85E-05	9.70E-06
25%	4.75E-05	1.19E-05
30% (laminar)	3.05E-05	9.15E-06
30% (turbulent)	4.67E-05	1.40E-05
35% (laminar)	3.22E-05	1.13E-05
35% (turbulent)	4.59E-05	1.61E-05
40% (laminar)	3.42E-05	1.37E-05
40% (turbulent)	4.53E-05	1.81E-05
41.6% (laminar)	3.44E-05	1.43E-05
41.6% (turbulent)	4.50E-05	1.87E-05

The onsite concentration is, therefore, (1.87E-05 g/s) (0.0341 s/m^3) (1000 mg/g) or 6.38E-04 mg/m^3. The corresponding NaOH concentration from HNF-SD-WM-CN-065 is 1.22E-03 mg/m^3.

The offsite concentration is, therefore, (1.87E-05 g/s) (2.83E-05 s/m^3) (1000 mg/g) or 5.29E-07 mg/m^3. The corresponding NaOH concentration from HNF-SD-WM-CN-065 is 1.02E-06 mg/m^3.

The FSAR NaOH concentrations bound the $NaNO_2$ concentrations for the mitigated release.

3.2 ANALYSIS OF THE TRUCK SPRAY RELEASE AND TRUCK RUPTURE

Addendum 1 of the FSAR deals with a spray release from the truck containing NaOH. A qualitative analysis is presented that indicates that the spray release from the truck could result in concentrations above both the onsite and the offsite risk guidelines. The accident is prevented by controls requiring that the tanker trucks meet the applicable U.S. Department of Transportation specifications and that traffic barriers surround the parked cargo truck.

The unmitigated truck accident is discussed only qualitatively in the FSAR. A parametric study was performed using the SPRAY code to compare the release rate of $NaNO_2$ to that of NaOH for similar conditions. As in Section 3.1, turbulent flow was assumed for the 10% and 20% concentrations. Laminar flow was assumed for the 30% and 40% concentrations. Table 4 shows

that the inhalable release rate for $NaNO_2$ is less than that for NaOH for low concentrations, but is greater for high concentrations. The SPRAY computer code outputs are located in Attachment A.

Table 4. Release Rate Comparison for Tank Truck Spray Release.

$NaNO_2$ or NaOH (wt%)	Crack Length (m)	Solution Inhalable Release Rate (g/s)	$NaNO_2$ Inhalable Release Rate (g/s)	NaOH Inhalable Release Rate (g/s)
10	1.02	154	15.4	72.2
20	1.57	117	23.4	71.2
30	4.37	1270	381	71.1
40	10.06	1430	572	70.8

NaOH Inhalable Release Rate data is from HNF-SD-WM-CN-065, Table 4.

Addendum 1 of the FSAR also deals with a rupture of the NaOH tank truck. Using the methodology found in HNF-SD-WM-CN-065, the amount of solution needed to exceed the onsite and offsite guidelines is calculated.

Dividing the offsite ERPG (3.5 mg/m^3) by the offsite puff release χ/Q (1.14E-07 m^{-3}) yields 3.07E+07 mg of $NaNO_2$ (3.07E+01 kg). This is equivalent to 7.38E+01 kg of 41.6% solution, or 5.57E+01 L. Assuming a release fraction of 0.001, the truck would have to hold 5.57E+04 L of solution. Because the tanker truck holds only 2.65E+04 L, the truck rupture will not exceed the offsite guideline.

Dividing the onsite EPRG (3.5) by the onsite puff release χ/Q (9.85E-03) yields a source term of 355.3 mg of $NaNO_2$ (3.55E-04 kg). This is equivalent to 8.53E-04 kg of 41.6% solution, or 6.44E-04 L. This is higher than the NaOH source term of 0.271 mL calculated in WHC-SD-WM-CN-065 as required to exceed the onsite guideline, but it is less than the capacity of the truck.

3.3 204-AR WASTE UNLOADING FACILITY

A spray release of NaOH in the 204-AR Waste Unloading Facility is evaluated in WHC-SD-WM-CN-085, *Consequence Evaluation of a Caustic Spray Leak in the 204-AR Facility*. This facility will not be used to add sodium nitrite to the waste storage tanks, so a comparison to the NaOH spray release is not relevant, and no analysis is needed.

3.4 KEY ASSUMPTIONS, SENSITIVITIES, AND UNCERTAINTIES

No specific key assumptions are made in this analysis. Some uncertainty exists as to whether the flow regime of the spray is laminar or turbulent. Where this uncertainty exists, the flow regime

was chosen that provided the more conservative result. Other phenomenological processes, such as leak plugging by suspended solids, are conservatively neglected for the sake of simplicity.

4.0 CONCLUSIONS

The conclusions of this analysis are as follows:

Transfer Line Leak. The FSAR accident scenarios bound the consequences of a potential $NaNO_2$ spray event, both mitigated and unmitigated, for a transfer line leak.

Crack in the Truck Tank. The FSAR accident scenarios do not bound the consequences of a potential unmitigated $NaNO_2$ spray release resulting from a crack in a pressurized truck tank. Because the mitigation controls are preventive in nature, no mitigated consequences were required to be calculated.

Rupture of the Truck Tank. The FSAR accident scenarios bound the offsite consequences of a potential unmitigated $NaNO_2$ release caused by a large rupture of a pressurized truck tank. For the onsite unmitigated accident scenario, the risk guideline may be exceeded. This is the same conclusion as stated in the FSAR for NaOH. Because the mitigation controls are preventive in nature, no mitigated consequences were required to be calculated.

204-AR. The 204-AR Waste Unloading Facility is not planned for use in adding $NaNO_2$ to waste storage tanks. Consequently, no analyses of $NaNO_2$ spray events within the 204-AR Waste Unloading Facility were performed.

5.0 SOFTWARE CODE DESCRIPTION

The two codes used in this analysis are briefly described in the following paragraphs.

5.1 SPRAY CODE

The atomization of liquid jets has importance in safety analysis and many other engineering applications. Liquid hazardous waste frequently is pressurized during transport, storage, or treatment. In the past, leaks in pressurized waste streams on the Hanford Site have resulted in contamination of the surrounding environment. The SPRAY code provides the safety analyst with a means to assess the consequences of pressurized leaks from liquid hazardous waste operations. Atomization of a liquid jet can occur because of the kinetic energy of the jet, exposure to a high-velocity gas stream, or externally applied mechanical energy. The SPRAY code evaluates the atomization of a liquid jet caused by the kinetic energy of the jet itself. Because atomization of a liquid jet is a random process, the resultant spray consists of a wide range of drop sizes and is represented by a distribution rather than a single parameter.

SPRAY is written in the FORTRAN 77 computer language using Version 5.01 of the compiler made by Lahey Computer Systems, Inc.[1] The Fluor Federal Services software configuration control requirements are contained in Practice 134-290-1114, *Software Configuration Control*, and Practice 134-200-0960, *Control of Engineering Software*. SPRAY is under the configuration control requirements of Fluor Federal Services. These practices require descriptions of the mathematical models and calculational methods employed, evaluation of the correctness of the calculations carried out, instructions on how to use the software, and plans for controlling the software within Fluor Federal Services. The user's manual and verification and validation documentation can be obtained from Hanford Document Control (WHC-SD-GN-SWD-20007).

5.2 ENVIRONMENTAL SIMULATION PROGRAM

The Environmental Simulation Program, or ESP, is a chemical process simulator extensively used at Hanford and other U.S. Department of Energy sites, and by many chemical, oil, and mineral processing companies. ESP, produced by OLI Systems[2], was originally licensed in 1993 for use at the Hanford Site for 12 years. Previously, ProChem[3] (the predecessor of ESP) was used at the Hanford Site for many years.

ESP is designed to model the processing of complex, concentrated aqueous solutions, organic liquids, solids, and vapors. It uses sophisticated thermodynamic models to predict the activity coefficients and equilibrium constants of most species and the equilibrium relationships that can exist in tank waste or during processing of such waste. It can be used to calculate the equilibrium or time-dependent composition of mixtures of solids, liquids, and gases.

ESP calculates the thermodynamic equilibrium of all phases by minimizing the chemical potential of a system in an iterative process. The thermodynamic properties of aqueous species are calculated either using the Helgeson-Kirkham-Flowers Equation of State correlation or from reference state data. The equilibrium constants of aqueous and solid species are calculated from empirical temperature- and pressure-dependent correlations of experimental data or from the thermodynamic properties of the species involved. Activity coefficients of aqueous ions are calculated using the Bromely-Zemaitis model, while the same is calculated for neutral or molecular aqueous solutes using a simplified form of the Pitzer excess property model. Partial molal volumes and other properties are calculated using similar models.

Some parameters necessary for modeling Hanford Site waste processing have been custom fitted by OLI Systems, the producer of ESP, at the request of, and sometimes using data supplied by, Hanford Site personnel.

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1 Lahey Computer Systems is a trademark of Lahey Computer Systems, Inc., Incline Village, Nevada.

2 Environmental Simulation Program or ESP is a trademark of OLI Systems, Morris Plains, New Jersey.

3 ProChem is a trademark of ProChem Chemicals, Inc., High Point, North Carolina.

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ATTACHMENT A

SPRAY COMPUTER CODE OUTPUT

SPRAY Version 3.0
May 3, 1994

```
Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company

Run Date = 11/02/01/
Run Time = 10:48:49.10

INPUT ECHO:
c 5% Sodium Nitrite 1 inch pipe 1 in slit 125 psi
c SPRAY Version 3 Input Deck
c   mode iflow iopt
    2    0     T
c
c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c        2 then slit leak with friction assumed
c iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c      = 1 friction based on laminar relation
c      = 2 friction based on turbulent relation
c iopt = T then optimal diameter search performed
c      = F then no optimal search
c
c PARAMETER INPUT:
c
c   Initial Slit                    Slit or
c   Width or        Slit            Orifice
c   Orifice Dia.    Length          Depth
c   (in)            (in)            (in)
c   ____________    ____________    ____________
    1.00000E-03     1.00000E+00     1.09000E-01
c
c                   Absolute
c                   Surface
c                   Roughness       Contraction     Velocity
c                   (in)            Coefficient     Coefficient
c   Pressure        0.00006 tube    0.61    and     0.98  for sharp edge orifice
c   Differential    0.0018  steel   1.00    and     0.98  for rounded orifice
c   (psi)           0.0102  iron    1.00    and     0.82  for square edge orifice
c   ____________    ____________    ____________    ____________________________
    1.25000E+02     1.80000E-03     1.00000E+00     8.20000E-01
c
c   Fluid           Dynamic         Respirable      RR Fitting
c   Specific        Viscosity       Diameter        Constant
c   Gravity         (centi-poise)   (æm)            (q)
c   ____________    ____________    ____________    ____________
    1.03100E+00     9.37000E-01     3.47800E+01     2.40000E+00


MESSAGES:
Slit Model
```

Code search for optimal equivalent diameter.

```
OUTPUT:
     Liquid Velocity =  6.88E+01 ft/s       2.10E+01 m/s
     Reynolds Number =  4.72E+03 Turbulent Flow
Sauter Mean Diameter =  5.51E+01 æm
  Optimum Slit Width =  4.04E-03 in         1.03E-04 m
 Respirable Fraction =  1.13E-01
     Total Leak Rate =  8.67E-01 gpm        5.47E-05 m3/s       5.64E+01 g/s
Respirable Leak Rate =  9.77E-02 gpm        6.16E-06 m3/s       6.36E+00 g/s
```

```
SPRAY Version 3.0
May 3, 1994

Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company

Run Date = 11/02/01/
Run Time = 10:50:55.54

INPUT ECHO:
c 10% Sodium Nitrite 1 inch pipe 1 in slit 125 psi
c SPRAY Version 3 Input Deck
c   mode iflow iopt
    2    0     T
c
c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c        2 then slit leak with friction assumed
c iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c      = 1 friction based on laminar relation
c      = 2 friction based on turbulent relation
c iopt = T then optimal diameter search performed
c      = F then no optimal search
c
c PARAMETER INPUT:
c
c   Initial Slit                    Slit or
c   Width or        Slit            Orifice
c   Orifice Dia.    Length          Depth
c   (in)            (in)            (in)
c   ____________    ____________    ____________
    1.00000E-03     1.00000E+00     1.09000E-01
c
c                   Absolute
c                   Surface
c                   Roughness       Contraction     Velocity
c                   (in)            Coefficient     Coefficient
c   Pressure        0.00006 tube    0.61   and      0.98  for sharp edge orifice
c   Differential    0.0018  steel   1.00   and      0.98  for rounded orifice
c   (psi)           0.0102  iron    1.00   and      0.82  for square edge orifice
c   ____________    ____________    ____________    ____________________________
    1.25000E+02     1.80000E-03     1.00000E+00     8.20000E-01
c
c   Fluid           Dynamic         Respirable      RR Fitting
c   Specific        Viscosity       Diameter        Constant
c   Gravity         (centi-poise)   (æm)            (q)
c   ____________    ____________    ____________    ____________
    1.06500E+00     9.83000E-01     2.73000E+01     2.40000E+00

MESSAGES:
Slit Model
Code search for optimal equivalent diameter.
```

```
OUTPUT:
     Liquid Velocity =  6.67E+01 ft/s       2.03E+01 m/s
     Reynolds Number =  4.37E+03 Turbulent Flow
Sauter Mean Diameter =  5.52E+01 æm
  Optimum Slit Width =  3.93E-03 in         9.97E-05 m
 Respirable Fraction =  6.47E-02
     Total Leak Rate =  8.16E-01 gpm        5.15E-05 m3/s       5.48E+01 g/s
Respirable Leak Rate =  5.28E-02 gpm        3.33E-06 m3/s       3.55E+00 g/s
```

```
                    SPRAY Version 3.0
                      May 3, 1994

Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company


Run Date = 11/02/01/
Run Time = 10:52:18.97


INPUT ECHO:
c 15% Sodium Nitrite 1 inch pipe 1 in slit 125 psi
c SPRAY Version 3 Input Deck
c   mode iflow iopt
    2    0     T
c
c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c        2 then slit leak with friction assumed
c iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c      = 1 friction based on laminar relation
c      = 2 friction based on turbulent relation
c iopt = T then optimal diameter search performed
c      = F then no optimal search
c
c PARAMETER INPUT:
c
c   Initial Slit                    Slit or
c   Width or        Slit            Orifice
c   Orifice Dia.    Length          Depth
c   (in)            (in)            (in)
c   ____________    ____________    ____________
    1.00000E-03     1.00000E+00     1.09000E-01
c
c                   Absolute
c                   Surface
c                   Roughness       Contraction     Velocity
c                   (in)            Coefficient     Coefficient
c   Pressure        0.00006 tube    0.61    and     0.98  for sharp edge orifice
c   Differential    0.0018  steel   1.00    and     0.98  for rounded orifice
c   (psi)           0.0102  iron    1.00    and     0.82  for square edge orifice
c   ____________    ____________    ____________    ____________________________
    1.25000E+02     1.80000E-03     1.00000E+00     8.20000E-01
c
c   Fluid           Dynamic         Respirable      RR Fitting
c   Specific        Viscosity       Diameter        Constant
c   Gravity         (centi-poise)   (æm)            (q)
c   ____________    ____________    ____________    ____________
    1.10100E+00     1.08700E+00     2.35900E+01     2.40000E+00


MESSAGES:
Slit Model
Code search for optimal equivalent diameter.
```

```
OUTPUT:
     Liquid Velocity =  6.52E+01 ft/s      1.99E+01 m/s
     Reynolds Number =  3.95E+03 Critical Flow
Sauter Mean Diameter =  5.65E+01 æm
  Optimum Slit Width =  3.88E-03 in        9.86E-05 m
 Respirable Fraction =  4.35E-02
     Total Leak Rate =  7.89E-01 gpm       4.98E-05 m3/s      5.48E+01 g/s
Respirable Leak Rate =  3.43E-02 gpm       2.17E-06 m3/s      2.39E+00 g/s
```

```
                    SPRAY Version 3.0
                      May 3, 1994

Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company


Run Date = 11/02/01/
Run Time = 10:53:31.74


INPUT ECHO:
c 20% Sodium Nitrite 1 inch pipe 1 in slit 125 psi
c SPRAY Version 3 Input Deck
c   mode iflow iopt
    2    0     T
c
c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c        2 then slit leak with friction assumed
c iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c      = 1 friction based on laminar relation
c      = 2 friction based on turbulent relation
c iopt = T then optimal diameter search performed
c      = F then no optimal search
c
c PARAMETER INPUT:
c
c   Initial Slit                    Slit or
c   Width or        Slit            Orifice
c   Orifice Dia.    Length          Depth
c   (in)            (in)            (in)
c   ____________    ____________    ____________
    1.00000E-03     1.00000E+00     1.09000E-01
c
c                   Absolute
c                   Surface
c                   Roughness       Contraction     Velocity
c                   (in)            Coefficient     Coefficient
c   Pressure        0.00006 tube    0.61    and     0.98  for sharp edge orifice
c   Differential    0.0018  steel   1.00    and     0.98  for rounded orifice
c   (psi)           0.0102  iron    1.00    and     0.82  for square edge orifice
c   ____________    ____________    ____________    ____________________________
    1.25000E+02     1.80000E-03     1.00000E+00     8.20000E-01
c
c   Fluid           Dynamic         Respirable      RR Fitting
c   Specific        Viscosity       Diameter        Constant
c   Gravity         (centi-poise)   (æm)            (q)
c   ____________    ____________    ____________    ____________
    1.13900E+00     1.23300E+00     2.11900E+01     2.40000E+00


MESSAGES:
Slit Model
Code search for optimal equivalent diameter.
```

```
OUTPUT:
     Liquid Velocity =  6.39E+01 ft/s       1.95E+01 m/s
     Reynolds Number =  3.52E+03 Critical Flow
Sauter Mean Diameter =  5.83E+01 æm
  Optimum Slit Width =  3.86E-03 in         9.81E-05 m
 Respirable Fraction =  3.13E-02
     Total Leak Rate =  7.69E-01 gpm        4.85E-05 m3/s       5.53E+01 g/s
Respirable Leak Rate =  2.41E-02 gpm        1.52E-06 m3/s       1.73E+00 g/s\
```

```
                    SPRAY Version 3.0
                      May 3, 1994

Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company


Run Date = 11/02/01/
Run Time = 10:55:16.65


INPUT ECHO:
c 25% Sodium Nitrite 1 inch pipe 1 in slit 125 psi
c SPRAY Version 3 Input Deck
c   mode iflow iopt
    2    0     T
c
c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c        2 then slit leak with friction assumed
c iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c      = 1 friction based on laminar relation
c      = 2 friction based on turbulent relation
c iopt = T then optimal diameter search performed
c      = F then no optimal search
c
c PARAMETER INPUT:
c
c   Initial Slit                    Slit or
c   Width or        Slit            Orifice
c   Orifice Dia.    Length          Depth
c   (in)            (in)            (in)
c   ____________    ____________    ____________
    1.00000E-03     1.00000E+00     1.09000E-01
c
c                   Absolute
c                   Surface
c                   Roughness       Contraction     Velocity
c                   (in)            Coefficient     Coefficient
c   Pressure        0.00006 tube    0.61   and      0.98  for sharp edge orifice
c   Differential    0.0018  steel   1.00   and      0.98  for rounded orifice
c   (psi)           0.0102  iron    1.00   and      0.82  for square edge orifice
c   ____________    ____________    ____________    ____________________________
    1.25000E+02     1.80000E-03     1.00000E+00     8.20000E-01
c
c   Fluid           Dynamic         Respirable      RR Fitting
c   Specific        Viscosity       Diameter        Constant
c   Gravity         (centi-poise)   (æm)            (q)
c   ____________    ____________    ____________    ____________
    1.17900E+00     1.45000E+00     1.94500E+01     2.40000E+00


MESSAGES:
Slit Model
Code search for optimal equivalent diameter.
```

```
OUTPUT:
     Liquid Velocity =  6.27E+01 ft/s      1.91E+01 m/s
     Reynolds Number =  3.03E+03 Critical Flow
Sauter Mean Diameter =  6.09E+01 æm
  Optimum Slit Width =  3.86E-03 in        9.80E-05 m
 Respirable Fraction =  2.31E-02
     Total Leak Rate =  7.54E-01 gpm       4.75E-05 m3/s      5.61E+01 g/s
Respirable Leak Rate =  1.74E-02 gpm       1.10E-06 m3/s      1.29E+00 g/s
```

```
SPRAY Version 3.0
May 3, 1994

Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company

Run Date = 11/02/01/
Run Time = 10:57:11.28

INPUT ECHO:
c 30% Sodium Nitrite 1 inch pipe 1 in slit 125 psi laminar
c SPRAY Version 3 Input Deck
c   mode iflow iopt
    2    1     T
c
c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c        2 then slit leak with friction assumed
c iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c      = 1 friction based on laminar relation
c      = 2 friction based on turbulent relation
c iopt = T then optimal diameter search performed
c      = F then no optimal search
c
c PARAMETER INPUT:
c
c   Initial Slit                    Slit or
c   Width or        Slit            Orifice
c   Orifice Dia.    Length          Depth
c   (in)            (in)            (in)
c   ____________    ____________    ____________
    1.00000E-03     1.00000E+00     1.09000E-01
c
c                   Absolute
c                   Surface
c                   Roughness       Contraction     Velocity
c                   (in)            Coefficient     Coefficient
c   Pressure        0.00006 tube    0.61   and      0.98  for sharp edge orifice
c   Differential    0.0018  steel   1.00   and      0.98  for rounded orifice
c   (psi)           0.0102  iron    1.00   and      0.82  for square edge orifice
c   ____________    ____________    ____________    ____________________________
    1.25000E+02     1.80000E-03     1.00000E+00     8.20000E-01
c
c   Fluid           Dynamic         Respirable      RR Fitting
c   Specific        Viscosity       Diameter        Constant
c   Gravity         (centi-poise)   (æm)            (q)
c   ____________    ____________    ____________    ____________
    1.22000E+00     1.71300E+00     1.80900E+01     2.40000E+00

MESSAGES:
Slit Model
Code search for optimal equivalent diameter.
Friction factor based on laminar flow.
```

```
OUTPUT:
     Liquid Velocity =  7.78E+01 ft/s      2.37E+01 m/s
     Reynolds Number =  1.71E+03 Laminar Flow
Sauter Mean Diameter =  2.29E+01 æm
  Optimum Slit Width =  1.99E-03 in        5.07E-05 m
 Respirable Fraction =  1.86E-01
     Total Leak Rate =  4.84E-01 gpm       3.05E-05 m3/s      3.73E+01 g/s
Respirable Leak Rate =  9.01E-02 gpm       5.69E-06 m3/s      6.94E+00 g/s
```

```
                    SPRAY Version 3.0
                      May 3, 1994

Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company


Run Date = 11/02/01/
Run Time = 10:58:16.31


INPUT ECHO:
c 30% Sodium Nitrite 1 inch pipe 1 in slit 125 psi turbulent
c SPRAY Version 3 Input Deck
c   mode iflow iopt
    2    2     T
c
c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c        2 then slit leak with friction assumed
c iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c      = 1 friction based on laminar relation
c      = 2 friction based on turbulent relation
c iopt = T then optimal diameter search performed
c      = F then no optimal search
c
c PARAMETER INPUT:
c
c   Initial Slit                    Slit or
c   Width or        Slit            Orifice
c   Orifice Dia.    Length          Depth
c   (in)            (in)            (in)
c   ____________    ____________    ____________
    1.00000E-03     1.00000E+00     1.09000E-01
c
c                   Absolute
c                   Surface
c                   Roughness       Contraction     Velocity
c                   (in)            Coefficient     Coefficient
c   Pressure        0.00006 tube    0.61   and      0.98  for sharp edge orifice
c   Differential    0.0018  steel   1.00   and      0.98  for rounded orifice
c   (psi)           0.0102  iron    1.00   and      0.82  for square edge orifice
c   ____________    ____________    ____________    ____________________________
    1.25000E+02     1.80000E-03     1.00000E+00     8.20000E-01
c
c   Fluid           Dynamic         Respirable      RR Fitting
c   Specific        Viscosity       Diameter        Constant
c   Gravity         (centi-poise)   (æm)            (q)
c   ____________    ____________    ____________    ____________
    1.22000E+00     1.71300E+00     1.80900E+01     2.40000E+00


MESSAGES:
Slit Model
Code search for optimal equivalent diameter.
Friction factor based on turbulent flow.
```

```
OUTPUT:
     Liquid Velocity =  6.15E+01 ft/s       1.88E+01 m/s
     Reynolds Number =  2.61E+03 Critical Flow
Sauter Mean Diameter =  6.37E+01 æm
  Optimum Slit Width =  3.86E-03 in         9.80E-05 m
 Respirable Fraction =  1.75E-02
     Total Leak Rate =  7.40E-01 gpm        4.67E-05 m3/s       5.70E+01 g/s
Respirable Leak Rate =  1.29E-02 gpm        8.16E-07 m3/s       9.96E-01 g/s
```

```
SPRAY Version 3.0
May 3, 1994

Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company


Run Date = 11/02/01/
Run Time = 11:00:57.90


INPUT ECHO:
c 35% Sodium Nitrite 1 inch pipe 1 in slit 125 psi laminar
c SPRAY Version 3 Input Deck
c   mode iflow iopt
    2    1     T
c
c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c        2 then slit leak with friction assumed
c iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c      = 1 friction based on laminar relation
c      = 2 friction based on turbulent relation
c iopt = T then optimal diameter search performed
c      = F then no optimal search
c
c PARAMETER INPUT:
c
c   Initial Slit                    Slit or
c   Width or        Slit            Orifice
c   Orifice Dia.    Length          Depth
c   (in)            (in)            (in)
c   ____________    ____________    ____________
    1.00000E-03     1.00000E+00     1.09000E-01
c
c                   Absolute
c                   Surface
c                   Roughness       Contraction     Velocity
c                   (in)            Coefficient     Coefficient
c   Pressure        0.00006 tube    0.61    and     0.98  for sharp edge orifice
c   Differential    0.0018  steel   1.00    and     0.98  for rounded orifice
c   (psi)           0.0102  iron    1.00    and     0.82  for square edge orifice
c   ____________    ____________    ____________    ____________________________
    1.25000E+02     1.80000E-03     1.00000E+00     8.20000E-01
c
c   Fluid           Dynamic         Respirable      RR Fitting
c   Specific        Viscosity       Diameter        Constant
c   Gravity         (centi-poise)   (æm)            (q)
c   ____________    ____________    ____________    ____________
    1.26400E+00     2.05200E+00     1.69900E+01     2.40000E+00


MESSAGES:
Slit Model
Code search for optimal equivalent diameter.
Friction factor based on laminar flow.
```

```
OUTPUT:
     Liquid Velocity =  7.62E+01 ft/s       2.32E+01 m/s
     Reynolds Number =  1.56E+03 Laminar Flow
Sauter Mean Diameter =  2.63E+01 æm
  Optimum Slit Width =  2.15E-03 in         5.45E-05 m
 Respirable Fraction =  1.19E-01
     Total Leak Rate =  5.10E-01 gpm        3.22E-05 m3/s       4.07E+01 g/s
Respirable Leak Rate =  6.08E-02 gpm        3.83E-06 m3/s       4.85E+00 g/s
```

```
                    SPRAY Version 3.0
                      May 3, 1994

Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company


Run Date = 11/02/01/
Run Time = 11:02:05.96


INPUT ECHO:
c 35% Sodium Nitrite 1 inch pipe 1 in slit 125 psi turbulent
c SPRAY Version 3 Input Deck
c   mode iflow iopt
    2    2     T
c
c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c        2 then slit leak with friction assumed
c iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c      = 1 friction based on laminar relation
c      = 2 friction based on turbulent relation
c iopt = T then optimal diameter search performed
c      = F then no optimal search
c
c PARAMETER INPUT:
c
c   Initial Slit                    Slit or
c   Width or        Slit            Orifice
c   Orifice Dia.    Length          Depth
c   (in)            (in)            (in)
c   ____________    ____________    ____________
    1.00000E-03     1.00000E+00     1.09000E-01
c
c                   Absolute
c                   Surface
c                   Roughness       Contraction     Velocity
c                   (in)            Coefficient     Coefficient
c   Pressure        0.00006 tube    0.61   and      0.98  for sharp edge orifice
c   Differential    0.0018  steel   1.00   and      0.98  for rounded orifice
c   (psi)           0.0102  iron    1.00   and      0.82  for square edge orifice
c   ____________    ____________    ____________    ____________________________
    1.25000E+02     1.80000E-03     1.00000E+00     8.20000E-01
c
c   Fluid           Dynamic         Respirable      RR Fitting
c   Specific        Viscosity       Diameter        Constant
c   Gravity         (centi-poise)   (æm)            (q)
c   ____________    ____________    ____________    ____________
    1.26400E+00     2.05200E+00     1.69900E+01     2.40000E+00


MESSAGES:
Slit Model
Code search for optimal equivalent diameter.
Friction factor based on turbulent flow.
```

```
OUTPUT:
     Liquid Velocity =  6.04E+01 ft/s      1.84E+01 m/s
     Reynolds Number =  2.22E+03 Critical Flow
Sauter Mean Diameter =  6.69E+01 æm
  Optimum Slit Width =  3.86E-03 in        9.81E-05 m
 Respirable Fraction =  1.34E-02
     Total Leak Rate =  7.28E-01 gpm       4.59E-05 m3/s      5.80E+01 g/s
Respirable Leak Rate =  9.75E-03 gpm       6.15E-07 m3/s      7.77E-01 g/s
```

```
                    ____________________

                       SPRAY Version 3.0
                         May 3, 1994

                    ____________________

Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company


Run Date = 11/02/01/
Run Time = 11:04:06.57


INPUT ECHO:
c 40% Sodium Nitrite 1 inch pipe 1 in slit 125 psi laminar
c SPRAY Version 3 Input Deck
c   mode iflow iopt
    2    1     T
c
c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c        2 then slit leak with friction assumed
c iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c      = 1 friction based on laminar relation
c      = 2 friction based on turbulent relation
c iopt = T then optimal diameter search performed
c      = F then no optimal search
c
c PARAMETER INPUT:
c
c   Initial Slit                    Slit or
c   Width or        Slit            Orifice
c   Orifice Dia.    Length          Depth
c   (in)            (in)            (in)
c   ____________    ____________    ____________
    1.00000E-03     1.00000E+00     1.09000E-01
c
c                   Absolute
c                   Surface
c                   Roughness       Contraction     Velocity
c                   (in)            Coefficient     Coefficient
c   Pressure        0.00006 tube    0.61   and      0.98  for sharp edge orifice
c   Differential    0.0018  steel   1.00   and      0.98  for rounded orifice
c   (psi)           0.0102  iron    1.00   and      0.82  for square edge orifice
c   ____________    ____________    ____________    ____________________________
    1.25000E+02     1.80000E-03     1.00000E+00     8.20000E-01
c
c   Fluid           Dynamic         Respirable      RR Fitting
c   Specific        Viscosity       Diameter        Constant
c   Gravity         (centi-poise)   (æm)            (q)
c   ____________    ____________    ____________    ____________
    1.30900E+00     2.48100E+00     1.60600E+01     2.40000E+00


MESSAGES:
Slit Model
Code search for optimal equivalent diameter.
Friction factor based on laminar flow.
```

```
OUTPUT:
     Liquid Velocity =  7.47E+01 ft/s       2.28E+01 m/s
     Reynolds Number =  1.42E+03 Laminar Flow
Sauter Mean Diameter =  3.05E+01 æm
  Optimum Slit Width =  2.33E-03 in         5.92E-05 m
 Respirable Fraction =  7.47E-02
     Total Leak Rate =  5.42E-01 gpm        3.42E-05 m3/s       4.48E+01 g/s
Respirable Leak Rate =  4.05E-02 gpm        2.55E-06 m3/s       3.34E+00 g/s
```

```
                    SPRAY Version 3.0
                      May 3, 1994

Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company


Run Date = 11/02/01/
Run Time = 11:05:16.88


INPUT ECHO:
c 40% Sodium Nitrite 1 inch pipe 1 in slit 125 psi turbulent
c SPRAY Version 3 Input Deck
c   mode iflow iopt
    2    2     T
c
c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c        2 then slit leak with friction assumed
c iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c      = 1 friction based on laminar relation
c      = 2 friction based on turbulent relation
c iopt = T then optimal diameter search performed
c      = F then no optimal search
c
c PARAMETER INPUT:
c
c   Initial Slit                    Slit or
c   Width or        Slit            Orifice
c   Orifice Dia.    Length          Depth
c   (in)            (in)            (in)
c   ____________    ____________    ____________
    1.00000E-03     1.00000E+00     1.09000E-01
c
c                   Absolute
c                   Surface
c                   Roughness       Contraction     Velocity
c                   (in)            Coefficient     Coefficient
c   Pressure        0.00006 tube    0.61   and      0.98  for sharp edge orifice
c   Differential    0.0018  steel   1.00   and      0.98  for rounded orifice
c   (psi)           0.0102  iron    1.00   and      0.82  for square edge orifice
c   ____________    ____________    ____________    ____________________________
    1.25000E+02     1.80000E-03     1.00000E+00     8.20000E-01
c
c   Fluid           Dynamic         Respirable      RR Fitting
c   Specific        Viscosity       Diameter        Constant
c   Gravity         (centi-poise)   (æm)            (q)
c   ____________    ____________    ____________    ____________
    1.30900E+00     2.48100E+00     1.60600E+01     2.40000E+00


MESSAGES:
Slit Model
Code search for optimal equivalent diameter.
Friction factor based on turbulent flow.
```

```
OUTPUT:
     Liquid Velocity =  5.94E+01 ft/s      1.81E+01 m/s
     Reynolds Number =  1.87E+03 Laminar Flow
Sauter Mean Diameter =  7.05E+01 æm
  Optimum Slit Width =  3.88E-03 in        9.85E-05 m
 Respirable Fraction =  1.03E-02
     Total Leak Rate =  7.17E-01 gpm       4.53E-05 m3/s      5.92E+01 g/s
Respirable Leak Rate =  7.42E-03 gpm       4.68E-07 m3/s      6.12E-01 g/s
```

```
SPRAY Version 3.0
May 3, 1994

Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company


Run Date = 11/02/01/
Run Time = 11:07:04.70


INPUT ECHO:
c 41.6% Sodium Nitrite 1 inch pipe 1 in slit 125 psi laminar
c SPRAY Version 3 Input Deck
c   mode iflow iopt
    2    1     T
c
c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c        2 then slit leak with friction assumed
c iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c      = 1 friction based on laminar relation
c      = 2 friction based on turbulent relation
c iopt = T then optimal diameter search performed
c      = F then no optimal search
c
c PARAMETER INPUT:
c
c   Initial Slit                    Slit or
c   Width or        Slit            Orifice
c   Orifice Dia.    Length          Depth
c   (in)            (in)            (in)
c   ____________    ____________    ____________
    1.00000E-03     1.00000E+00     1.09000E-01
c
c                   Absolute
c                   Surface
c                   Roughness       Contraction     Velocity
c                   (in)            Coefficient     Coefficient
c   Pressure        0.00006 tube    0.61   and      0.98  for sharp edge orifice
c   Differential    0.0018  steel   1.00   and      0.98  for rounded orifice
c   (psi)           0.0102  iron    1.00   and      0.82  for square edge orifice
c   ____________    ____________    ____________    ____________________________
    1.25000E+02     1.80000E-03     1.00000E+00     8.20000E-01
c
c   Fluid           Dynamic         Respirable      RR Fitting
c   Specific        Viscosity       Diameter        Constant
c   Gravity         (centi-poise)   (æm)            (q)
c   ____________    ____________    ____________    ____________
    1.32500E+00     2.63800E+00     1.57900E+01     2.40000E+00


MESSAGES:
Slit Model
Code search for optimal equivalent diameter.
Friction factor based on laminar flow.
```

```
OUTPUT:
     Liquid Velocity =  7.38E+01 ft/s       2.25E+01 m/s
     Reynolds Number =  1.36E+03 Laminar Flow
Sauter Mean Diameter =  3.18E+01 æm
  Optimum Slit Width =  2.37E-03 in         6.02E-05 m
 Respirable Fraction =  6.52E-02
     Total Leak Rate =  5.45E-01 gpm        3.44E-05 m3/s       4.56E+01 g/s
Respirable Leak Rate =  3.55E-02 gpm        2.24E-06 m3/s       2.97E+00 g/s
```

```
SPRAY Version 3.0
May 3, 1994

Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company


Run Date = 11/02/01/
Run Time = 11:08:03.74


INPUT ECHO:
c 41.6% Sodium Nitrite 1 inch pipe 1 in slit 125 psi turbulent
c SPRAY Version 3 Input Deck
c   mode iflow iopt
    2    2     T
c
c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c        2 then slit leak with friction assumed
c iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c      = 1 friction based on laminar relation
c      = 2 friction based on turbulent relation
c iopt = T then optimal diameter search performed
c      = F then no optimal search
c
c PARAMETER INPUT:
c
c   Initial Slit                    Slit or
c   Width or        Slit            Orifice
c   Orifice Dia.    Length          Depth
c   (in)            (in)            (in)
c   ____________    ____________    ____________
    1.00000E-03     1.00000E+00     1.09000E-01
c
c                   Absolute
c                   Surface
c                   Roughness       Contraction     Velocity
c                   (in)            Coefficient     Coefficient
c   Pressure        0.00006 tube    0.61    and     0.98  for sharp edge orifice
c   Differential    0.0018  steel   1.00    and     0.98  for rounded orifice
c   (psi)           0.0102  iron    1.00    and     0.82  for square edge orifice
c   ____________    ____________    ____________    ____________________________
    1.25000E+02     1.80000E-03     1.00000E+00     8.20000E-01
c
c   Fluid           Dynamic         Respirable      RR Fitting
c   Specific        Viscosity       Diameter        Constant
c   Gravity         (centi-poise)   (æm)            (q)
c   ____________    ____________    ____________    ____________
    1.32500E+00     2.63800E+00     1.57900E+01     2.40000E+00


MESSAGES:
Slit Model
Code search for optimal equivalent diameter.
Friction factor based on turbulent flow.
```

```
OUTPUT:
     Liquid Velocity =  5.90E+01 ft/s      1.80E+01 m/s
     Reynolds Number =  1.77E+03 Laminar Flow
Sauter Mean Diameter =  7.16E+01 æm
  Optimum Slit Width =  3.88E-03 in        9.85E-05 m
 Respirable Fraction =  9.54E-03
     Total Leak Rate =  7.13E-01 gpm       4.50E-05 m3/s      5.96E+01 g/s
Respirable Leak Rate =  6.80E-03 gpm       4.29E-07 m3/s      5.68E-01 g/s
```

```
SPRAY Version 3.0
May 3, 1994

Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company


Run Date = 11/02/01/
Run Time = 13:34:15.78


INPUT ECHO:
c 10% Sodium Nitrite tank truck crack 125 psi
c SPRAY Version 3 Input Deck
c   mode iflow iopt
    2    0     T
c
c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c        2 then slit leak with friction assumed
c iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c      = 1 friction based on laminar relation
c      = 2 friction based on turbulent relation
c iopt = T then optimal diameter search performed
c      = F then no optimal search
c
c PARAMETER INPUT:
c
c   Initial Slit                    Slit or
c   Width or        Slit            Orifice
c   Orifice Dia.    Length          Depth
c   (in)            (in)            (in)
c   ____________    ____________    ____________
    1.00000E-03     4.00000E+01     1.00000E-01
c
c                   Absolute
c                   Surface
c                   Roughness       Contraction     Velocity
c                   (in)            Coefficient     Coefficient
c   Pressure        0.00006 tube    0.61   and      0.98  for sharp edge orifice
c   Differential    0.0018  steel   1.00   and      0.98  for rounded orifice
c   (psi)           0.0102  iron    1.00   and      0.82  for square edge orifice
c   ____________    ____________    ____________    ____________________________
    1.25000E+02     1.80000E-03     1.00000E+00     8.20000E-01
c
c   Fluid           Dynamic         Respirable      RR Fitting
c   Specific        Viscosity       Diameter        Constant
c   Gravity         (centi-poise)   (æm)            (q)
c   ____________    ____________    ____________    ____________
    1.06500E+00     9.83000E-01     2.73000E+01     2.40000E+00


MESSAGES:
Slit Model
Code search for optimal equivalent diameter.
```

```
OUTPUT:
     Liquid Velocity =  6.71E+01 ft/s       2.04E+01 m/s
     Reynolds Number =  4.23E+03 Turbulent Flow
Sauter Mean Diameter =  5.23E+01 æm
  Optimum Slit Width =  3.76E-03 in         9.55E-05 m
 Respirable Fraction =  7.31E-02
     Total Leak Rate =  3.14E+01 gpm        1.98E-03 m3/s       2.11E+03 g/s
Respirable Leak Rate =  2.30E+00 gpm        1.45E-04 m3/s       1.54E+02 g/s
```

```
                    ____________________

                       SPRAY Version 3.0
                         May 3, 1994

                    ____________________

Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company


Run Date = 11/02/01/
Run Time = 13:36:43.75


INPUT ECHO:
c 20% Sodium Nitrite tank truck crack 125 psi
c SPRAY Version 3 Input Deck
c   mode iflow iopt
    2    0     T
c
c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c        2 then slit leak with friction assumed
c iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c      = 1 friction based on laminar relation
c      = 2 friction based on turbulent relation
c iopt = T then optimal diameter search performed
c      = F then no optimal search
c
c PARAMETER INPUT:
c
c   Initial Slit                    Slit or
c   Width or        Slit            Orifice
c   Orifice Dia.    Length          Depth
c   (in)            (in)            (in)
c   ____________    ____________    ____________
    1.00000E-03     6.20000E+01     1.00000E-01
c
c                   Absolute
c                   Surface
c                   Roughness       Contraction     Velocity
c                   (in)            Coefficient     Coefficient
c   Pressure        0.00006 tube    0.61    and     0.98  for sharp edge orifice
c   Differential    0.0018  steel   1.00    and     0.98  for rounded orifice
c   (psi)           0.0102  iron    1.00    and     0.82  for square edge orifice
c   ____________    ____________    ____________    ____________________________
    1.25000E+02     1.80000E-03     1.00000E+00     8.20000E-01
c
c   Fluid           Dynamic         Respirable      RR Fitting
c   Specific        Viscosity       Diameter        Constant
c   Gravity         (centi-poise)   (æm)            (q)
c   ____________    ____________    ____________    ____________
    1.13900E+00     1.23300E+00     2.11900E+01     2.40000E+00


MESSAGES:
Slit Model
Code search for optimal equivalent diameter.
```

```
OUTPUT:
     Liquid Velocity =  6.42E+01 ft/s      1.96E+01 m/s
     Reynolds Number =  3.39E+03 Critical Flow
Sauter Mean Diameter =  5.53E+01 æm
  Optimum Slit Width =  3.69E-03 in        9.38E-05 m
 Respirable Fraction =  3.56E-02
     Total Leak Rate =  4.58E+01 gpm       2.89E-03 m3/s      3.29E+03 g/s
Respirable Leak Rate =  1.63E+00 gpm       1.03E-04 m3/s      1.17E+02 g/s
```

SPRAY Version 3.0
May 3, 1994

```
Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company


Run Date = 11/02/01/
Run Time = 13:42:07.87


INPUT ECHO:
c 30% Sodium Nitrite tank truck crack 125 psi laminar
c SPRAY Version 3 Input Deck
c   mode iflow iopt
    2    1     T
c
c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c        2 then slit leak with friction assumed
c iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c      = 1 friction based on laminar relation
c      = 2 friction based on turbulent relation
c iopt = T then optimal diameter search performed
c      = F then no optimal search
c
c PARAMETER INPUT:
c
c   Initial Slit                    Slit or
c   Width or        Slit            Orifice
c   Orifice Dia.    Length          Depth
c   (in)            (in)            (in)
c   ____________    ____________    ____________
    1.00000E-03     1.72000E+02     1.00000E-01
c
c                   Absolute
c                   Surface
c                   Roughness       Contraction     Velocity
c                   (in)            Coefficient     Coefficient
c   Pressure        0.00006 tube    0.61    and     0.98  for sharp edge orifice
c   Differential    0.0018  steel   1.00    and     0.98  for rounded orifice
c   (psi)           0.0102  iron    1.00    and     0.82  for square edge orifice
c   ____________    ____________    ____________    ____________________________
    1.25000E+02     1.80000E-03     1.00000E+00     8.20000E-01
c
c   Fluid           Dynamic         Respirable      RR Fitting
c   Specific        Viscosity       Diameter        Constant
c   Gravity         (centi-poise)   (æm)            (q)
c   ____________    ____________    ____________    ____________
    1.22000E+00     1.71300E+00     1.80900E+01     2.40000E+00


MESSAGES:
Slit Model
Code search for optimal equivalent diameter.
Friction factor based on laminar flow.
```

```
OUTPUT:
     Liquid Velocity =  7.81E+01 ft/s      2.38E+01 m/s
     Reynolds Number =  1.66E+03 Laminar Flow
Sauter Mean Diameter =  2.18E+01 æm
  Optimum Slit Width =  1.92E-03 in        4.88E-05 m
 Respirable Fraction =  2.06E-01
     Total Leak Rate =  8.05E+01 gpm       5.08E-03 m3/s      6.20E+03 g/s
Respirable Leak Rate =  1.66E+01 gpm       1.04E-03 m3/s      1.27E+03 g/s
```

```
SPRAY Version 3.0
May 3, 1994

Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company


Run Date = 11/02/01/
Run Time = 13:44:46.05


INPUT ECHO:
c 40% Sodium Nitrite tank truck crack 125 psi laminar
c SPRAY Version 3 Input Deck
c   mode iflow iopt
    2    1     T
c
c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c        2 then slit leak with friction assumed
c iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c      = 1 friction based on laminar relation
c      = 2 friction based on turbulent relation
c iopt = T then optimal diameter search performed
c      = F then no optimal search
c
c PARAMETER INPUT:
c
c   Initial Slit                    Slit or
c   Width or        Slit            Orifice
c   Orifice Dia.    Length          Depth
c   (in)            (in)            (in)
c   ____________    ____________    ____________
    1.00000E-03     3.96000E+02     1.00000E-01
c
c                   Absolute
c                   Surface
c                   Roughness       Contraction     Velocity
c                   (in)            Coefficient     Coefficient
c   Pressure        0.00006 tube    0.61   and      0.98  for sharp edge orifice
c   Differential    0.0018  steel   1.00   and      0.98  for rounded orifice
c   (psi)           0.0102  iron    1.00   and      0.82  for square edge orifice
c   ____________    ____________    ____________    ____________________________
    1.25000E+02     1.80000E-03     1.00000E+00     8.20000E-01
c
c   Fluid           Dynamic         Respirable      RR Fitting
c   Specific        Viscosity       Diameter        Constant
c   Gravity         (centi-poise)   (æm)            (q)
c   ____________    ____________    ____________    ____________
    1.30900E+00     2.48100E+00     1.60600E+01     2.40000E+00


MESSAGES:
Slit Model
Code search for optimal equivalent diameter.
Friction factor based on laminar flow.
```

```
OUTPUT:
     Liquid Velocity =  7.48E+01 ft/s      2.28E+01 m/s
     Reynolds Number =  1.36E+03 Laminar Flow
Sauter Mean Diameter =  2.90E+01 æm
  Optimum Slit Width =  2.23E-03 in        5.67E-05 m
 Respirable Fraction =  8.38E-02
     Total Leak Rate =  2.06E+02 gpm       1.30E-02 m3/s      1.70E+04 g/s
Respirable Leak Rate =  1.73E+01 gpm       1.09E-03 m3/s      1.43E+03 g/s
```

CHECKLIST FOR TECHNICAL PEER REVIEW

Document Reviewed: Comparison of Sodium Nitrate Releases with Sodium Hydroxide Releases RPP-8939 Rev. 0.

Scope of Review (e.g., document section or portion of calculation): All

Yes	No	NA*		
[ ]	[ ]	[X]	1.	Previous reviews are complete and cover the analysis, up to the scope of this review, with no gaps.
[X]	[ ]	[ ]	2.	Problem is completely defined.
[X]	[ ]	[ ]	3.	Accident scenarios are developed in a clear and logical manner.
[X]	[ ]	[ ]	4.	Analytical and technical approaches and results are reasonable and appropriate. *(ORP QAPP criterion 2.8)*
[X]	[ ]	[ ]	5.	Necessary assumptions are reasonable, explicitly stated, and supported. *(ORP QAPP criterion 2.2)*
[X]	[ ]	[ ]	6.	Computer codes and data files are documented.
[X]	[ ]	[ ]	7.	Data used in calculations are explicitly stated.
[X]	[ ]	[ ]	8.	Bases for calculations, including assumptions and data, are consistent with the supported safety basis document (e.g., the Tank Farms Final Safety Analysis Report).
[X]	[ ]	[ ]	9.	Data were checked for consistency with original source information as applicable. *(ORP QAPP criterion 2.9)*
[X]	[ ]	[ ]	10.	For both qualitative and quantitative data, uncertainties are recognized and discussed, as appropriate. *(ORP QAPP criterion 2.17)*
[X]	[ ]	[ ]	11.	Mathematical derivations were checked including dimensional consistency of results. *(ORP QAPP criterion 2.16)*
[X]	[ ]	[ ]	12.	Models are appropriate and were used within their established range of validity or adequate justification was provided for use outside their established range of validity.
[X]	[ ]	[ ]	13.	Spreadsheet results and all hand calculations were verified.
[X]	[ ]	[ ]	14.	Calculations are sufficiently detailed such that a technically qualified person can understand the analysis without requiring outside information. *(ORP QAPP criterion 2.5)*
[X]	[ ]	[ ]	15.	Software input is correct and consistent with the document reviewed.
[X]	[ ]	[ ]	16	Software output is consistent with the input and with the results reported in the document reviewed.
[X]*	[ ]	[ ]	17.	Software verification and validation are addressed adequately. *(ORP QAPP criterion 2.6)*
[X]	[ ]	[ ]	18.	Limits/criteria/guidelines applied to the analysis results are appropriate and referenced. Limits/criteria/guidelines were checked against references. *(ORP QAPP criterion 2.9)*
[X]	[ ]	[ ]	19.	Safety margins are consistent with good engineering practices.
[X]	[ ]	[ ]	20.	Conclusions are consistent with analytical results and applicable limits.

* The ESP code has been in use for many years and is believed to provide valid results. A formal validation package is being assembled as part of a separate effort.

[X]	[ ]	[ ]	21. Results and conclusions address all points in the purpose. *(ORP QAPP criterion 2.3)*
[X]	[ ]	[ ]	22. All references cited in the text, figures, and tables are contained in the reference list.
[X]	[ ]	[ ]	23. Reference citations (e.g., title and number) are consistent between the text callout and the reference list.
[X]	[ ]	[ ]	24. Only released (i.e., not draft) references are cited. *(ORP QAPP criterion 2.1)*
[X]	[ ]	[ ]	25. Referenced documents are retrievable or otherwise available.
[X]	[ ]	[ ]	26. The most recent version of each reference is cited, as appropriate. *(ORP QAPP criterion 2.1)*
[X]	[ ]	[ ]	27. There are no duplicate citations in the reference list.
[X]	[ ]	[ ]	28. Referenced documents are spelled out (title and number) the first time they are cited.
[X]	[ ]	[ ]	29. All acronyms are spelled out the first time they are used.
[X]	[ ]	[ ]	30. The Table of Contents is correct.
[X]	[ ]	[ ]	31. All figure, table, and section callouts are correct.
[X]	[ ]	[ ]	32. Unit conversions are correct and consistent.
[X]	[ ]	[ ]	33. The number of significant digits is appropriate and consistent.
[X]	[ ]	[ ]	34. Chemical reactions are correct and balanced.
[X]	[ ]	[ ]	35. All tables are formatted consistently and are free of blank cells.
[X]	[ ]	[ ]	36. The document is complete (pages, attachments, and appendices) and in the proper order.
[X]	[ ]	[ ]	37. The document is free of typographical errors.
[X]	[ ]	[ ]	38. The tables are internally consistent.
[X]	[ ]	[ ]	39. The document was prepared in accordance with HNF-2353, Section 4.3, Attachment B, "Calculation Note Format and Preparation Instructions".
[X]	[ ]	[ ]	**Concurrence**

Bruce D. Zimmerman Bruce Zimmerman 11-6-01
Reviewer (Printed Name and Signature) Date

* If No or NA is chosen, an explanation must be provided on this form.

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