ENGINEERING CHANGE NOTICE

Page 1 of 2

1. ECN 609910

Proj. ECN

2. ECN Category (mark one)	3. Originator's Name, Organization, MSIN, and Telephone No.	4. USQ Required?	5. Date
Supplemental [] Direct Revision [x] Change ECN [] Temporary [] Standby [] Supersedure [] Cancel/Void []	R.J. Van Vleet, 403, A3-34, 376-2613	[] Yes [X] No	06/27/97
	6. Project Title/No./Work Order No. Project W-320	7. Bldg./Sys./Fac. No. Tank Farms	8. Approval Designator N/A
	9. Document Numbers Changed by this ECN (includes sheet no. and rev.) WHC-SD-WM-CN-065, Rev. 1	10. Related ECN No(s). N/A	11. Related PO No. N/A

12a. Modification Work	12b. Work Package No.	12c. Modification Work Complete	12d. Restored to Original Condition (Temp. or Standby ECN only)
[] Yes (fill out Blk. 12b) [X] No (NA Blks. 12b, 12c, 12d)	N/A	N/A Design Authority/Cog. Engineer Signature & Date	N/A Design Authority/Cog. Engineer Signature & Date

13a. Description of Change

13b. Design Baseline Document? [] Yes [X] No

Replacement of Rev. 1 with Rev. 2.

The attached Calculation Note documents the originator's analysis only. It shall not be used as the final or sole document for affecting changes to an authorization basis or safety basis for a facility or activity.

14a. Justification (mark one)

Criteria Change	[]	Design Improvement	[X]	Environmental	[]	Facility Deactivation	[]
As-Found	[]	Facilitate Const	[]	Const. Error/Omission	[]	Design Error/Omission	[]

14b. Justification Details

Revision 1 has been updated to include the delivery of caustic soda (sodium hydroxide) to the waste tank using a pressurized cargo tank truck.

15. Distribution (include name, MSIN, and no. of copies)

See attached distribution sheet.

RELEASE STAMP

JUL 08 1997

DATE:

STA: 37

HANFORD RELEASE

ID: 20

A-7900-013-2 (05/96) GEF095

ENGINEERING CHANGE NOTICE

1. ECN (use no. from pg. 1): 609910

16. Design Verification Required	17. Cost Impact				18. Schedule Impact (days)	
	ENGINEERING		CONSTRUCTION			
[] Yes	Additional	[] $	Additional	[] $	Improvement	[]
[X] No	Savings	[] $	Savings	[] $	Delay	[]

19. Change Impact Review: Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 13. Enter the affected document number in Block 20.

SDD/DD	[]	Seismic/Stress Analysis	[]	Tank Calibration Manual	[]
Functional Design Criteria	[]	Stress/Design Report	[]	Health Physics Procedure	[]
Operating Specification	[]	Interface Control Drawing	[]	Spares Multiple Unit Listing	[]
Criticality Specification	[]	Calibration Procedure	[]	Test Procedures/Specification	[]
Conceptual Design Report	[]	Installation Procedure	[]	Component Index	[]
Equipment Spec.	[]	Maintenance Procedure	[]	ASME Coded Item	[]
Const. Spec.	[]	Engineering Procedure	[]	Human Factor Consideration	[]
Procurement Spec.	[]	Operating Instruction	[]	Computer Software	[]
Vendor Information	[]	Operating Procedure	[]	Electric Circuit Schedule	[]
OM Manual	[]	Operational Safety Requirement	[]	ICRS Procedure	[]
FSAR/SAR	[]	IEFD Drawing	[]	Process Control Manual/Plan	[]
Safety Equipment List	[]	Cell Arrangement Drawing	[]	Process Flow Chart	[]
Radiation Work Permit	[]	Essential Material Specification	[]	Purchase Requisition	[]
Environmental Impact Statement	[]	Fac. Proc. Samp. Schedule	[]	Tickler File	[]
Environmental Report	[]	Inspection Plan	[]		[]
Environmental Permit	[]	Inventory Adjustment Request	[]		[]

20. Other Affected Documents: (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.

Document Number/Revision	Document Number/Revision	Document Number Revision
N/A		

21. Approvals

	Signature	Date		Signature	Date
Design Authority			Design Agent		
Cog. Eng. L. C. Lansing	for L. C. Lansing (signature)	06/27/97	PE		
Cog. Mgr. B. E. Hey	(signature)	7/2/97	QA		
QA			Safety		
Safety			Design		
Environ.			Environ.		
Other			Other		
S. R. Gedeon	(signature)	06/30/97			

DEPARTMENT OF ENERGY

Signature or a Control Number that tracks the Approval Signature

ADDITIONAL

Consequence Analysis of a NaOH Solution Spray Release during Addition to Waste Tank

L. C. Lansing
H & R Technical Associates, Richland, WA 99352

for

R. J. Van Vleet
Fluor Daniel Northwest Inc., Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-96RL13200

EDT/ECN: 609910 UC: 510
Org Code: 403 Charge Code: E34272/P3YA00
B&R Code: EW3130010 Total Pages: ~~59~~ 63

Key Words: caustic, NaOH, pH adjustment, spray leak, sodium hydroxide, toxic consequences

Abstract: Toxicological consequences are presented for 3 postulated accidents involving caustic soda (sodium hydroxide) addition to a waste tank to adjust the tank waste pH. These are: spray from the skid mounted delivery system, spray from a cargo tank truck, and rupture of a cargo tank truck. Consequences for the onsite and offsite receptor are calculated.

Release Approval 7-8-97 Date

Approved for Public Release

RECORD OF REVISION

(1) Document Number: WHC-SD-WM-CN-065

Page 1

(2) Title
Consequence Analysis of a NaOH Solution Spray Release During Addition to Waste Tank

CHANGE CONTROL RECORD

(3) Revision	(4) Description of Change - Replace, Add, and Delete Pages	Authorized for Release	
		(5) Cog. Engr.	(6) Cog. Mgr. Date
0	(7) New document released via EDT #142249	D.A. Himes 8/27/96	D.S. Leach 8/27/96
1 RS	Replace revision 0 document via ECN #609892	D.A. Himes [signature] 10/7/96	D.S. Leach [signature] 10/8/96

RECORD OF REVISION	(1) Document Number HNF-SD-WM-CN-065	Page 2

(2) Title
Consequence Analysis of a NaOH Solution Spray Release during Addition to Waste Tank

CHANGE CONTROL RECORD

(3) Revision	(4) Description of Change - Replace, Add, and Delete Pages	Authorized for Release (5) Cog. Engr.	(6) Cog. Mgr. Date
	(7)		
2 RS	Replace Rev. 1 via direct revision as documented in ECN 609910.	L.C. Lansing Rich VanVleet for LCL	B.E. Hey 06/27/97

CONSEQUENCE ANALYSIS OF A NaOH SOLUTION SPRAY RELEASE DURING ADDITION TO WASTE TANK

1.0 PURPOSE

Aqueous sodium hydroxide (NaOH) solutions are added as needed to Hanford waste tanks to adjust waste pH so as to minimize corrosion in the tanks. Sodium hydroxide is either (1) procured from an offsite vendor and transported in 15,140-L (4,000-gal) tanker trucks to the tank farms or (2) mixed on site. The caustic solution may be as strong as 19 M (50 wt%). The solution may be transferred into a given tank by a mixer pump or directly through an available riser (with a fitting). The lightest equipment considered to be suitable for NaOH solution transport is 25.4-mm (1-in.) schedule 10 commercial steel pipe with a wall thickness of 2.77 mm (0.109 in.). The largest pipe or hose considered is 50.8-mm (2-in.) cross linked polyethylene hose with a wall thickness of 10 mm (25/64 in.). The maximum pressure the system can be subjected to is 863 kPa (125 psig) the maximum pressure that can be delivered by the air supply system in the tank farms. The highest temperature at which the tank truck is loaded is 49 °C (120 °F).

This calculation note analyzes (1) a crack in a caustic skid system (consisting of a 208-L (55-gal) drum, hard pipe, hose, and a pump); (2) a crack in the cargo tank; and (3) a sudden failure of the cargo tank.

A pressurized spray leak of caustic solution during a transfer to a waste tank could disperse a significant amount of respirable sodium hydroxide particles. These particles could cause potentially significant onsite consequences. This analysis will (1) estimate the maximum NaOH air concentrations at the onsite and site boundary receptor locations and (2) develop and analyze precautions which could be taken to mitigate the onsite consequences should a spray leak develop. No radioactive materials are associated with this event.

2.0 ACCIDENT DESCRIPTION

2.1 Spray from Skid System Failure

A pressure of 863 kPa (125 psig) is not expected to be able to cause schedule 10 steel pipe to fail. Schedule 10 steel pipe is rated for a working pressure of about 5.86 MPa (850 psig) for temperatures less than 343.3 °C (650 °F) (Chemetron 1969). The most likely cause of a spray release is considered to be a loose connection, or possibly a cracked circumferential weld joining the pipe to a flange or fitting due to repetitive mechanical stress on the pipe. In the case of a loose fitting, the leak could extend around the full circumference of the sealing surface. The depth (path length) of the opening in such a case, however, would be much greater than the wall thickness of the pipe and so would exhibit a much lower leak rate due to friction losses. Polyethylene is not stiff enough to maintain the fine crack width associated with an atomizing spray over a crack length sufficient to produce a significant leak rate. A split in the polyethylene hose large enough to cause a significant release rate would therefore produce a stream (with little production of small particles) rather than a fine spray. The worst case circumferential crack in a pipe weld able to maintain the narrow width associated with a fine aerosol spray is normally assumed to extend a distance around the pipe equal to one pipe diameter (inside).

The maximum spray leak was therefore assumed to be a crack with a minimum depth equal to the lightest (schedule 10) pipe wall thickness of 2.77 mm (0.109 in.) and a maximum length equal to one pipe diameter, i.e., 25.4 mm (1 in.). The width of the crack was optimized to produce the highest respirable particle fraction using the SPRAY Code (Hey and Leach 1994).

2.2 Spray from Crack in the Cargo Tank

A procedure not analyzed in the 208-L (55-gal) drum and skid system analysis involves a cargo tank attached to an air compressor. The compressor pressurizes the cargo tank, pushing the sodium hydroxide out, and through the connected hose leading into the underground waste tank.

A crack in the cargo tank could create a spray leak of NaOH solution. A crack could develop in the cargo tank for several reasons, including corrosion, stress, fatigue, and impact. New cargo tanks are written to DOT specification 406, 407, or 412. However, older cargo tanks are written to DOT specifications 306, 307, or 312. The minimum cargo tank wall thickness under these specifications is 0.100 inches. The cargo tank is considered to be pressurized up to 863 kPa (125 psig), the maximum available plant air pressure. Since the pressurization of the cargo tank is achieved by use of compressed air, the pressure inside the cargo tank will not drop upon formation of a spray leak. The highest temperature at which the cargo tank is loaded is 49 °C (125 °F).

A spray leak could also develop in the truck transfer piping, due to a loose fitting or crack. This possibility is bounded by those listed above, because the crack in the piping is limited in size (optimum spray typically occurs when the crack is equal to the diameter of the pipe).

2.3 Sudden Failure of the Cargo Tank

A significant release could also result from sudden failure of the cargo tank. A sudden cargo tank failure could result from rapid propagation of an already existing crack, internal overpressurization of the cargo tank, or an external impact to the cargo tank.

An existing stress or corrosion crack could propagate beyond the critical crack length and result in a sudden cargo tank failure. Although stainless steel 316 (typically used in building cargo tanks) is not subject to sudden failure from rapid propagation of an already existing crack, this potential event sequence is discussed here to address the possible use of cargo tanks constructed of materials other than stainless steel 316. Since the pressure inside the cargo tank would remain high, the size of the crack would increase slowly until the critical crack length were reached, at which point the size of the crack would increase rapidly such that the internal pressure is relieved almost instantaneously.

A second mechanism for sudden cargo tank failure would be overpressurization of the cargo tank beyond its structural capacity. The resulting failure of the cargo tank could be expected to be violent and near instantaneous.

In addition to an already existing crack and overpressurization of the cargo tank, an object impact to the cargo tank could cause sudden cargo tank failure. Heavy equipment (cranes, earth movers, etc.) and light vehicles (trucks) are the most likely source of impacts to the cargo tank. If such an impact were to cause the failure of the cargo tank, the internal cargo tank pressure would be relieved almost instantaneously.

3.0 TRANSPORT ASSUMPTIONS

For a ground level release the onsite receptor is normally assumed to be at a distance of 100 m in the worst direction (WHC 1988). The site boundary receptor for purposes of this analysis is located at the site boundary or the near bank of the Columbia River, whichever is closer, in the worst direction. No receptor evacuation was assumed.

Acute 99.5 percentile ground level release dispersion factors (χ/Q) have been generated for the Hanford tank farms using the GXQ code (Hey 1994) at each of the 16 sectors at 100 m and at the site boundary or the near bank of the Columbia River.

3.1 Spray Leaks

Since maximum air concentrations are the primary concern for toxic releases, no plume meander was assumed. The resulting χ/Qs are reported in WHC-SD-WM-SARR-016 Rev 2 (Van Keuren 1996) as 3.41×10^{-2} s/m^3 onsite (100 m E) and 2.83×10^{-5} s/m^3 at the site boundary (8.76 km N).

In the case of a liquid spray release, care must be taken to account for evaporation during transit when estimating the small particle ("respirable") fraction. Particles less than about 10 μm tend to remain suspended in the air for long distances whereas particles larger than 10 μm released from a non-elevated source tend to fall out within the first 50 to 100 m of travel. (The term "respirable fraction" is often used in reference to particles less than 10 μm because this is the size range which can reach the lower lung.) The size of the liquid particles will decrease in transit due to evaporation of the liquid component finally leaving only a smaller particle of the solid material which had been in solution in the liquid. The initial diameter, D_r, of a solution particle with a solid fraction f_s which will evaporate to a particle with a diameter of 10 μm is given by (Hey and Leach 1995)

$$D_r = \frac{10\ \mu m}{f_s^{\frac{1}{3}}} \tag{1}$$

The resulting initial particle diameters are shown in Table 1 along with solution viscosity and density (Perry and Green 1984) for a range of solid fractions of NaOH in water. The leak rate and atomization efficiency increase with decreasing viscosity and hence increasing temperature. The high end of the temperature range for this liquid (50 °C) is therefore assumed.

Table 1: Concentration dependent parameters for caustic soda (NaOH) solutions at 50 °C.

% NaOH	Density (g/cm^3)	Viscosity (centipoise)	D_r (μm)
5	1.041	0.80	27.1
10	1.094	0.96	21.5
12	1.116	1.1	20.3
15	1.148	1.3	18.8
20	1.202	1.9	17.1
30	1.309	4.4	14.9
40	1.410	8.5	13.6
50	1.504	14.3	12.6

It is conservatively assumed here that the liquid fraction of the spray evaporates very quickly. In reality the initial large size of the "respirable" particles would cause rapid initial fallout.

3.2 Sudden Failure of the Cargo Tank

Since a sudden cargo tank failure release occurs in a very short period of time it can be modeled as a puff release. The puff release χ/Q value for the onsite receptor is 9.85×10^{-3} $/m^3$ (Van Keuren 1996). The puff release χ/Q value for the offsite receptor is 1.14×10^{-7} $/m^3$ (Van Keuren 1996).

4.0 SOURCE TERM

4.1 Spray from Skid System Failure

The SPRAY Code version 3.0 (Hey and Leach 1995) was used to calculate leak rates and small particle fractions for the assumed break (a crack with a minimum depth equal to 2.77 mm [0.109 in.] and a maximum length equal to 25.4 mm [1 in.]) in the liquid containment boundary. The crack width was optimized to maximize the release rate of particles with an initial size less than or equal to the size given as D_r in Table 1.

At low solution concentrations, the viscosity is low (approaching that of water) so that friction losses in the crack are low and solution release rates are relatively high. The NaOH release rate is low, however, due to the low concentration. As concentration increases, the NaOH respirable release rate initially stays fairly constant due to the competing effects of increasing concentration and decreasing initial particle size range due to effects of evaporation. However as concentration is increased further, the increase in solution viscosity causes a rapidly decreasing flow rate. There is also an added effect due to a transition from turbulent flow at low viscosity to laminar flow at higher viscosities. It is expected, therefore, that the maximum small particle NaOH release rate will occur at some optimum solution concentration. A parametric study was performed using the SPRAY Code to determine this optimum solution concentration within the expected range of 5% to 50% NaOH to be used for tank additions. The small particle release rate was therefore calculated over a range of NaOH concentrations with the results shown in Table 2. Standard roughness and flow parameters for steel pipe were assumed as documented in the SPRAY Code output files shown in Attachment 1. For the cases where critical flow developed in the crack, friction factors for laminar flow were assumed for conservatism.

Table 2: Solution spray release parameters.

% NaOH	Optimum Crack Width (m)	Flow Type	Respirable Fraction	Respirable NaOH Release Rate (g/s)
5	9.99 E-05	Turbulent	7.10 E-02	0.193
10	9.81 E-05	Turbulent	3.76 E-02	0.204
12	**4.60 E-05**	**Critical**	**4.12 E-01**	**1.68**
15	4.68 E-05	Critical	3.00 E-01	1.53
20	5.34 E-05	Laminar	1.38 E-01	1.07
30	7.77 E-05	Laminar	2.19 E-02	0.384
40	1.05 E-04	Laminar	5.10 E-03	0.166
50	1.35 E-04	Laminar	1.55 E-03	0.0840

As indicated in the table, the maximum small particle NaOH release rate corresponded to a solution concentration of 12%.

4.2 Spray Leak from Crack in the Cargo Tank

The SPRAY Code version 3.0 (Hey and Leach 1994) was used to calculate leak rates and small particle fractions for various crack lengths in order to find the minimum crack length required to produce offsite consequences. The crack depth is 2.54 mm (0.10 in.) based on the cargo tank wall thickness. The crack width was optimized to maximize the release rate of particles with an initial size less than or equal to the size given as D_r in Table 1.

The caustic spray leak analyzed here has been assigned a frequency of occurrence in the anticipated range (1×10^{-2} to 1.0 per year). The risk guidelines for onsite and site boundary receptors for this frequency range are ERPG-1 and PEL-TWA. Both of these criteria are 2 mg/m^3 for NaOH (Van Keuren 1996).

To calculate the respirable release rate which results in offsite consequences, the offsite concentration limit of 2 mg/m^3 is divided by the offsite χ/Q, as follows:

$$\text{NaOH Respirable Release Rate} = (2\ mg/m^3)/(2.83\ E\text{-}05\ s/m^3) = 7.07\ E\text{+}04\ mg/s.$$

The sodium hydroxide respirable release rate is divided by the sodium hydroxide solution concentration in order to obtain the necessary respirable release rate for the overall solution, see Table 3.

Table 3. Calculation of Respirable Release Rates Required to Exceed Offsite Guidelines.

% NaOH	NaOH Respirable Release Rate (mg/s)	Respirable Release Rate (mg/s)
5	7.07 E+04	1.41 E+06
8	7.07 E+04	8.83 E+05
9	7.07 E+04	7.85 E+05
10	7.07 E+04	7.07 E+05
11	7.07 E+04	6.42 E+05
12	7.07 E+04	5.89 E+05
13	7.07 E+04	5.44 E+05
15	7.07 E+04	4.71 E+05
20	7.07 E+04	3.53 E+05
30	7.07 E+04	2.36 E+05
40	7.07 E+04	1.77 E+05
50	7.07 E+04	1.41 E+05

A parametric study was performed using the SPRAY Code to determine the minimum crack length necessary to achieve offsite consequences of solution concentrations within a range of 5% to 50% NaOH. Standard roughness and flow parameters for steel pipe were assumed as documented in the SPRAY Code output files shown in Attachment 1. For the cases where critical flow developed in the crack, friction factors for laminar flow were assumed for conservatism. The results of the parametric study are shown in Table 4.

Table 4. Solution Spray Release Parameters.

% NaOH	Minimum Length (m)	Optimum Width (m)	Crack Type	Flow Fraction	Respirable Rate (g/s)	Respirable NaOH Release (g/s)
5	1.30	5.19 E-05	Turbulent	6.85 E-01	1.42 E+03	7.10 E+01
8	1.07	4.68 E-05	Critical	5.96 E-01	8.97 E+02	7.18 E+01
9	1.04	4.59 E-05	Critical	5.52 E-01	7.89 E+02	7.10 E+01
10	1.02	4.48 E-05	Critical	5.35 E-01	7.22 E+02	7.22 E+01
11	1.09	4.49 E-05	Critical	4.59 E-01	6.57 E+02	7.23 E+01
12	1.04	4.48 E-05	Critical	4.41 E-01	6.01 E+02	7.21 E+01
13	1.19	4.60 E-05	Critical	3.52 E-01	5.55 E+02	7.22 E+01
15	1.12	4.48 E-05	Laminar	3.32 E-01	4.76 E+02	7.14 E+01
20	1.57	5.13 E-05	Laminar	1.53 E-01	3.56 E+02	7.12 E+01
30	4.37	7.42 E-05	Laminar	2.47 E-02	2.37 E+02	7.11 E+01
40	10.06	1.01 E-04	Laminar	5.70 E-03	1.77 E+02	7.08 E+01
50	19.89	1.28 E-04	Laminar	1.76 E-03	1.42 E+02	7.10 E+01

As indicated in Table 4, the minimum necessary crack length to exceed offsite guidelines corresponds to a solution concentration of 10%, with a minimum crack length of 1.02 m (40 in.). Therefore, in order for the offsite guideline to be exceeded, an optimum crack length of at least 1.02 m (40 in.) must be formed.

To determine if offsite consequences can be reached it is necessary to determine if the cargo tank will support a 1.02 m (40 in.) crack before rupturing. During a cargo tank rupture event the crack would split wide open, no longer supporting the fine spray necessary to aerosolize the sodium hydroxide. The worst case crack length for a spray is therefore directly prior to cargo tank rupture, assuming the crack is maintained at an optimum width to produce a fine spray.

The length at which a crack in a given material will propagate suddenly towards cargo tank rupture can be determined using fracture mechanics. When the stress intensity of the crack exceeds the fracture toughness of the given material, the crack will propagate rapidly. The cargo tank parameters can be used to calculate the stress intensity, as well as the maximum crack length reached before the fracture toughness is exceeded.

Typically, sodium hydroxide cargo tanks are constructed of 316 stainless steel. Stainless steel 316 is extremely ductile and no fracture toughness value exists. A crack is not likely to propagate suddenly towards rupture. It is more likely that the crack will continue to grow in length until the pressure within the cargo tank is relieved. Since the critical crack length is not ascertainable it is necessary to assume the crack length can exceed that necessary to achieve offsite consequences [1.02 m (40 in.)].

4.3 Sudden Failure of Cargo Tank

A detailed source term and consequence model is not developed for sudden cargo tank failure. Instead, a screening calculation, designed to simplify the analysis, is performed to provide the basis for determining if the onsite or offsite evaluation guidelines are challenged.

The basis of the screening calculation is the estimation of the quantity of sodium hydroxide solution which must be made airborne in order to exceed onsite or offsite evaluation guidelines.

The onsite evaluation guideline for sodium hydroxide is 2 mg/m^3 for the anticipated frequency category (Van Keuren 1996). Since the sudden cargo tank failure release occurs in a very short period of time it can be modeled as a puff release. The puff release χ/Q value for the onsite receptor is $9.85 \times 10^{-3}\ /m^3$ (Van Keuren 1996). Thus, the source term of sodium hydroxide which would exceed the onsite guideline is:

$$\text{Onsite Source Term} = (2\ mg/m^3)/(9.85 \times 10^{-3}\ /m^3) = 203\ mg.$$

The sodium hydroxide is in a solution with a maximum concentration of 50 wt%. Therefore, assuming a 50 wt% solution, twice as much solution (as opposed to pure sodium hydroxide) must be transported downwind for a total source term of 406 mg, or 0.406 g of sodium hydroxide solution.

The density of a 50 wt% sodium hydroxide solution is approximately 1.5 g/mL. The source term of 0.406 g is then 0.271 mL, or 7.2×10^{-5} gal.

Given the failure mechanism and associated forces associated with sudden cargo tank failure, it is obvious that a 0.4 g source term is feasible. Therefore, it is concluded that the onsite evaluation guideline would be exceeded by the consequences of this event and no further analysis is performed.

The offsite evaluation guideline for sodium hydroxide is 2 mg/m^3 for the anticipated frequency category (Van Keuren 1996). The puff release χ/Q value for the offsite receptor is $1.14 \times 10^{-7}\ /m^3$ (Van Keuren 1996). Thus, the source term of sodium hydroxide which would result in exceeding of the offsite guideline is:

$$\text{Offsite Source Term} = (2\ mg/m^3)/(1.14 \times 10^{-7}\ /m^3) = 1.75 \times 10^{7}\ mg.$$

Twice as much solution (as opposed to pure sodium hydroxide) must be transported downwind for a total source term of 3.51×10^7 mg, or 3.51×10^4 g of sodium hydroxide solution.

Using the density of 1.5 g/mL, the source term of 3.51×10^4 g is 2.34×10^4 mL, or 23 L. Thus, if 23 L (6.2 gal) of solution were made airborne and transported downwind, the offsite evaluation guideline would be exceeded. Unlike the calculation for the onsite receptor, it is not readily obvious if a 23 L (6.2 gal) source term from the cargo tank is possible. A more detailed analysis of the offsite source term and consequence is necessary.

The source term of 23 L (6.2 gal) represents a release fraction of 8.9×10^{-4}, assuming a full 26,500-L (7,000-gal) cargo tank of the sodium hydroxide solution. DOE-HDBK-3010-94 indicates in Section 3.2.2.3.2 that overall containment failure (sudden tank failure) can have release fractions from 5×10^{-5} for all low pressure (less than 345 kPa or 50 psig) solutions, to 2×10^{-3} for high pressure (greater than 345 kPa or 50 psig), low density (< 1.2 g/cm^3) solutions or 1×10^{-3} for high pressure, high density solutions. The maximum allowable pressure inside the cargo tank is 863 kPa (125 psig) and the density of the solution is 1.5 g/cm^3. Therefore, the proper release fraction for the sudden cargo tank failure would be 1×10^{-3} for the high density, high pressure release. These release fractions do not consider reduction of the source term based on the respirable fractions from DOE-HDBK-3010-94, because sodium hydroxide attacks the eyes, nose, and mouth, and will not be readily ejected from the lungs once larger particles are inhaled.

The actual release fraction of 1×10^{-3} is greater than the release fraction required to exceed the offsite guideline (8.9×10^{-4}). Therefore, the actual release would be greater than that required to exceed the offsite guideline. Based on the release fractions, it can be concluded that the offsite guideline could be exceeded by the consequences of the sudden cargo tank failure.

5.0 RESULTS

5.1 Spray from Skid System Failure

By the definition of the χ/Q, the maximum air concentration of NaOH at a receptor location is just the product of the maximum release rate and the receptor χ/Q. The resulting onsite and site boundary air concentrations of small particle NaOH is shown in Table 7.

Table 7: Resulting NaOH air concentrations

% NaOH	Respirable Rate (mg/s)	Release Concentration (mg/m^3)	
		Onsite (100 m)	Site Boundary
5	1.93 E+02	6.58 E+00	5.46 E-03
10	2.04 E+02	6.96 E+00	5.77 E-03
12	**1.68 E+03**	**5.73 E+01**	**4.75 E-02**
15	1.53 E+03	5.22 E+01	4.33 E-02
20	1.07 E+03	3.65 E+01	3.03 E-02
30	3.84 E+02	1.31 E+01	1.09 E-02
40	1.66 E+02	5.66 E+00	4.70 E-03
50	8.40 E+01	2.86 E+00	2.38 E-03

These results are considered very conservative in this case since they do not take credit for the initially rapid fallout rate of the large liquid particles prior to evaporation of the liquid fraction.

5.2 Spray Leak from Crack in Cargo Tank

The resulting onsite and site boundary air concentrations of small particle NaOH are shown in Table 8.

Table 8. Resulting Spray Leak NaOH Air Concentrations.

% NaOH	Minimum Necessary Crack Length (m)	Concentration (mg/m^3)	
		Onsite (100 m)	Site Boundary
10	1.02	Above Guidelines	

5.3 Sudden Failure of Cargo Tank

The resulting onsite and site boundary air concentrations of small particle NaOH are shown in Table 9 for the sudden cargo tank failure.

Table 9. Resulting Sudden Cargo Tank Failure NaOH Air Concentrations.

% NaOH	Concentration (mg/m^3)	
	Onsite (100 m)	Site Boundary
50	Above Guidelines	

6.0 CONCLUSION

The caustic spray leak analyzed here has been assigned a frequency of occurrence in the anticipated range (10^{-2} - 10^{+0}/y). The risk guidelines for onsite and site boundary receptors for this frequency range are ERPG-1 and PEL-TWA. Both criteria are 2 mg/m^3 for NaOH (Van Keuren 1995). The concentrations at the receptor points and the resulting sum-of-fractions of the risk guidelines are shown in Table 6.

Table 6: Receptor exposures to NaOH

Receptor	NaOH Concentration (mg/m3)	Sum-of-Fractions
Spray Leak from Skid System Failure		
Onsite (100 m E)	5.73 E+01	29
Site Boundary (8.76 km N)	4.75 E-02	0.024
Spray Leak from Crack in Cargo Tank		
Onsite (100 m E)	Above Guidelines	>1
Site Boundary (8.76 km N)	Above Guidelines	>1
Sudden Failure of Cargo Tank		
Onsite (100 m E)	Above Guidelines	>1
Site Boundary (8.76 km N)	Above Guidelines	>1

For the spray leak from the skid system failure, the sum of fractions at the site boundary are far less than the toxicological risk criterion of 1. The criterion is exceeded at the onsite receptor location.

Note that these results are for standard schedule 10 steel pipe. Use of a thinner wall pipe such as schedule 5 (wall thickness 0.065 in.) would increase the maximum release rate and receptor concentrations shown in Tables 5 and 6 by about 30% (due to the smaller crack depth and decreased friction losses). There would be no changes in the conclusions.

For the spray leak from crack in cargo tank, the sum-of-fractions of risk guidelines is exceeded at both the offsite and onsite receptor locations.

For the sudden failure of the cargo tank, the sum-of-fractions of risk guidelines is exceeded at both the offsite and onsite receptor locations.

7.0 RECOMMENDATIONS FOR MITIGATION

Since the liquid being transferred is relatively cool (<50 °C) and is at relatively low pressure (≤863 kPa or 125 psig), containment of a possible spray release would be easy. Plastic sleeving or wrap taped in place around the fittings would be sufficient to contain the spray. Using the total optimal leak rate of 3.04 x 10^{-5} m^3/s (see attached Spray Code run for 12% solution) and the crack area produces a maximum liquid spray velocity of 26 m/s. Even assuming the spray to come out in a parallel (rather than a radial) stream, the maximum resulting reaction force of the worst-case spray would be about 0.88 N (0.20 lbf). Assuming the plastic to form a 90° corner under the impact of the spray, the maximum stress produced in 4 mil material would be about 35 psi. Standard 4 mil polyethylene (or similar material) sleeving or wrap would therefore have ample strength to contain the spray. The sleeving/wrap would not be expected to be pressure tight, however, and the solution would still leak out, producing a minor local cleanup problem, but there would be no significant aerosol release.

The aerosol release rate for the mitigated spray can be estimated by calculating how much mist generated inside the plastic sleeving could be displaced out of the sleeving by the solution leaking out of the pipe. The maximum total solution leak rate equal to 7.18 x 10^{-5} m^3/s occurs at a solution concentration of 50% (see the GXQ results for 50% solution in attachment 1). This total leak rate is assumed to displace the same amount of air out of the sleeving. The maximum air loading of an aerosol mist is normally assumed to be 100 mg/m^3 (ANSI N46.1 1980). However, since the air loading here is for a short-time transient condition, ten times this value, or 1 g/m^3 is assumed for conservatism. Then assuming that no liquid is leaking from the sleeving (it is just filling with liquid), a displaced volume rate of 7.18 x 10^{-5} m/s would force 7.18 x 10^{-5} g/s of solution, or 3.59 x 10^{-2} mg/s of NaOH, out of the sleeving. Using the same transport assumptions as before, the resulting receptor concentrations are 1.22 x 10^{-3} mg/m^3 and 1.02 x 10^{-6} mg/m^3 for the onsite and site boundary receptors, respectively. Both concentrations are negligible compared to the risk guidelines of 2 mg/m^3 for both receptors.

8.0 REFERENCES

ANSI N46.1, 1980, *American National Standard - Guidance for Defining Safety-Related Features of Nuclear Fuel Cycle Facilities*, American Nuclear Society, La Grange Park, Illinois.

Chemetron 1969, *Piping Engineering*, Tube Turns Division of Chemetron Corporation, Louisville, Kentucky, October 1969.

DOE-HDBK-3010-YR, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, U.S. Department of Energy, Washington D.C., 1994.

Hey 1994, B.E. Hey, *GXQ Program User's Guide*, WHC-SD-GN-SWD-30002, Rev. 1, December 1994.

Hey and Leach 1994, B.E. Hey and D.S. Leach, *A Model for Predicting Respirable Releases from Pressurized Leaks*, WHC-SD-GN-SWD-20007 Rev 0, April 1994.

Perry and Green 1984, R.H. Perry and D. Green, *Perry's Chemical Engineers' Handbook*, Sixth Edition, McGraw-Hill, New York, 1984.

Van Keuren 1996, J.C. Van Keuren, *Tank Waste Compositions and Atmospheric Dispersion Coefficients for use in Accelerated Safety Analysis Consequence Assessments*, WHC-SD-WM-SARR-016 Rev 2, July 1996.

Van Keuren 1995, J.C. Keuren, J.S. Davis, and M.L. Dentler, *Toxic Chemical Considerations for Tank Farm Releases*, WHC-SD-WM-SARR-011 Rev 1, November 1995.

WHC 1996, *Safety Assessment for Tank 241-C-106 Waste Retrieval Project W-320*, WHC-SD-WM-SAD-024 Rev 0, May 1996.

Attachment 1
SPRAY Code Files

SPRAY Version 3.0
May 3, 1994

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


Run Date = 08/21/96/
Run Time = 08:03:04.56


INPUT ECHO:
c unmitigated caustic spray - 5% NaOH
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)    (μm)            (q)
c
    1.04100E+00    8.00000E-01      2.71000E+01     2.40000E+00
```

MESSAGES:
Slit Model
Code search for optimal equivalent diameter.

OUTPUT:

```
     Liquid Velocity =  6.76E+01 ft/s       2.06E+01 m/s
     Reynolds Number =  5.33E+03 Turbulent Flow
Sauter Mean Diameter =  5.26E+01 μm
  Optimum Slit Width =  3.93E-03 in         9.99E-05 m
 Respirable Fraction =  7.10E-02
     Total Leak Rate =  8.28E-01 gpm        5.22E-05 m3/s       5.44E+01 g/s
Respirable Leak Rate =  5.88E-02 gpm        3.71E-06 m3/s       3.86E+00 g/s
```

SPRAY Version 3.0
May 3, 1994

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


Run Date = 08/21/96/
Run Time = 08:08:31.64


INPUT ECHO:
c unmitigated caustic spray - 10% NaOH
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)    (μm)           (q)
c   ____________    ____________     ____________   ____________
    1.09400E+00     9.60000E-01      2.15000E+01    2.40000E+00
```

MESSAGES:
Slit Model
Code search for optimal equivalent diameter.

OUTPUT:

```
     Liquid Velocity =  6.53E+01 ft/s       1.99E+01 m/s
     Reynolds Number =  4.43E+03 Turbulent Flow
Sauter Mean Diameter =  5.48E+01 μm
  Optimum Slit Width =  3.86E-03 in         9.81E-05 m
 Respirable Fraction =  3.76E-02
     Total Leak Rate =  7.86E-01 gpm        4.96E-05 m3/s        5.42E+01 g/s
Respirable Leak Rate =  2.96E-02 gpm        1.87E-06 m3/s        2.04E+00 g/s
```

```
                    _________________________

                       SPRAY Version 3.0
                          May 3, 1994

                    _________________________

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


Run Date = 08/21/96/
Run Time = 08:24:57.06


INPUT ECHO:
c unmitigated caustic spray - 12% NaOH
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)    (μm)           (q)
c
    1.11600E+00      1.10000E+00      2.03000E+01    2.40000E+00
```

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

OUTPUT:

```
     Liquid Velocity =  8.54E+01 ft/s       2.60E+01 m/s
     Reynolds Number =  2.43E+03 Critical Flow
Sauter Mean Diameter =  1.73E+01 μm
  Optimum Slit Width =  1.81E-03 in         4.60E-05 m
 Respirable Fraction =  4.12E-01
     Total Leak Rate =  4.82E-01 gpm        3.04E-05 m3/s       3.40E+01 g/s
Respirable Leak Rate =  1.98E-01 gpm        1.25E-05 m3/s       1.40E+01 g/s
```

```
                    _______________________________

                         SPRAY Version 3.0
                            May 3, 1994

                    _______________________________

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


Run Date = 08/21/96/
Run Time = 08:28:44.89


INPUT ECHO:
c unmitigated caustic spray - 15% NaOH
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)    (μm)           (q)
c   ___________      ____________     ___________    ___________
    1.14800E+00      1.30000E+00      1.88000E+01    2.40000E+00
```

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

```
OUTPUT:
     Liquid Velocity =  8.20E+01 ft/s       2.50E+01 m/s
     Reynolds Number =  2.06E+03 Critical Flow
Sauter Mean Diameter =  1.89E+01 μm
  Optimum Slit Width =  1.84E-03 in         4.68E-05 m
 Respirable Fraction =  3.00E-01
     Total Leak Rate =  4.71E-01 gpm        2.97E-05 m3/s        3.41E+01 g/s
Respirable Leak Rate =  1.41E-01 gpm        8.91E-06 m3/s        1.02E+01 g/s
```

SPRAY Version 3.0
May 3, 1994

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

Run Date = 08/21/96/
Run Time = 08:36:42.36

```
INPUT ECHO:
c unmitigated caustic spray - 20% NaOH
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   ____________   ___________   ___________
    5.00000E-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)    (µm)             (q)
c
    1.20200E+00      1.90000E+00      1.71000E+01      2.40000E+00
```

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

OUTPUT:

```
     Liquid Velocity =  7.83E+01 ft/s      2.39E+01 m/s
     Reynolds Number =  1.61E+03 Laminar Flow
Sauter Mean Diameter =  2.48E+01 µm
  Optimum Slit Width =  2.10E-03 in        5.34E-05 m
 Respirable Fraction =  1.38E-01
     Total Leak Rate =  5.14E-01 gpm       3.24E-05 m3/s      3.90E+01 g/s
Respirable Leak Rate =  7.07E-02 gpm       4.46E-06 m3/s      5.36E+00 g/s
```

SPRAY Version 3.0
May 3, 1994

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

Run Date = 08/21/96/
Run Time = 08:39:43.06

```
INPUT ECHO:
c unmitigated caustic spray - 30% NaOH
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   ____________    ____________     ____________
    5.00000E-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)     (µm)              (q)
c   ______________    ______________    ______________    ______________
    1.30900E+00       4.40000E+00       1.49000E+01       2.40000E+00
```

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

```
OUTPUT:
     Liquid Velocity =  7.40E+01 ft/s       2.26E+01 m/s
     Reynolds Number =  1.04E+03 Laminar Flow
Sauter Mean Diameter =  4.77E+01 µm
  Optimum Slit Width =  3.06E-03 in         7.77E-05 m
 Respirable Fraction =  2.19E-02
     Total Leak Rate =  7.06E-01 gpm        4.45E-05 m3/s        5.83E+01 g/s
Respirable Leak Rate =  1.54E-02 gpm        9.74E-07 m3/s        1.28E+00 g/s
```

```
                    SPRAY Version 3.0
                       May 3, 1994

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


Run Date = 08/21/96/
Run Time = 13:50:03.03


INPUT ECHO:
c unmitigated caustic spray - 40% NaOH
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   ____________    ___________    ___________
    5.00000E-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)    (μm)           (q)
c   ____________     ____________     ____________   ____________
    1.41000E+00      8.50000E+00      1.36000E+01    2.40000E+00
```

MESSAGES:
Slit Model
Code search for optimal equivalent diameter.

OUTPUT:

```
     Liquid Velocity =  7.09E+01 ft/s       2.16E+01 m/s
     Reynolds Number =  7.48E+02 Laminar Flow
Sauter Mean Diameter =  8.02E+01 μm
  Optimum Slit Width =  4.13E-03 in         1.05E-04 m
 Respirable Fraction =  5.10E-03
     Total Leak Rate =  9.12E-01 gpm        5.75E-05 m3/s       8.11E+01 g/s
Respirable Leak Rate =  4.65E-03 gpm        2.93E-07 m3/s       4.14E-01 g/s
```

```
                    ________________________
                       SPRAY Version 3.0
                          May 3, 1994
                    ________________________

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


Run Date = 08/21/96/
Run Time = 13:52:17.92


INPUT ECHO:
c unmitigated caustic spray - 50% NaOH
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   ____________    ____________   ____________
    5.00000E-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)    (µm)           (q)
c   ___________     ____________     ___________    ___________
    1.50400E+00     1.43000E+01      1.26000E+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 =  5.91E+02 Laminar Flow
Sauter Mean Diameter =  1.22E+02 µm
  Optimum Slit Width =  5.30E-03 in        1.35E-04 m
 Respirable Fraction =  1.55E-03
     Total Leak Rate =  1.14E+00 gpm       7.18E-05 m3/s       1.08E+02 g/s
Respirable Leak Rate =  1.77E-03 gpm       1.11E-07 m3/s       1.68E-01 g/s
```

```
                    ________________________

                       SPRAY Version 3.0
                          May 3

                    ________________________

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


Run Date = 03/02/97/
Run Time = 13:10:19.21


INPUT ECHO:
c SPRAY Version 3 Input Deck
c   unmitigated caustic spray -        5%
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     5.10000E+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)   (μm)           (q)
c   ___________    ___________     ___________    ___________
    1.04100E+00    8.00000E-01     2.71000E+01    2.40000E+00
```

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

```
OUTPUT:
     Liquid Velocity =  9.75E+01 ft/s       2.97E+01 m/s
     Reynolds Number =  4.01E+03 Turbulent Flow
Sauter Mean Diameter =  1.67E+01 μm
  Optimum Slit Width =  2.04E-03 in         5.19E-05 m
 Respirable Fraction =  6.85E-01
     Total Leak Rate =  3.17E+01 gpm        2.00E-03 m3/s       2.08E+03 g/s
Respirable Leak Rate =  2.17E+01 gpm        1.37E-03 m3/s       1.42E+03 g/s
```

```
                    SPRAY Version 3.0
                       May 3

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

Run Date = 03/02/97/
Run Time = 14:56:38.42

INPUT ECHO:
c SPRAY Version 3 Input Deck
c   unmitigated caustic spray -        8%
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     4.20000E+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 Specific Gravity	Dynamic Viscosity (centi-poise)	Respirable Diameter (μm)	RR Fitting Constant (q)
c	1.07300E+00	8.90000E-01	2.32000E+01	2.40000E+00

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

OUTPUT:

Liquid Velocity =	9.22E+01 ft/s	2.81E+01 m/s	
Reynolds Number =	3.17E+03 Critical Flow		
Sauter Mean Diameter =	1.58E+01 μm		
Optimum Slit Width =	1.84E-03 in	4.68E-05 m	
Respirable Fraction =	5.96E-01		
Total Leak Rate =	2.22E+01 gpm	1.40E-03 m3/s	1.51E+03 g/s
Respirable Leak Rate =	1.32E+01 gpm	8.36E-04 m3/s	8.97E+02 g/s

```
                    SPRAY Version 3.0
                       May 3

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


Run Date = 03/02/97/
Run Time = 14:57:49.93


INPUT ECHO:
c SPRAY Version 3 Input Deck
c   unmitigated caustic spray -        9%
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    4.10000E+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)    (µm)            (q)
c   ____________     _____________    ____________    ____________
    1.08500E+00      9.50000E-01      2.23000E+01     2.40000E+00
```

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

```
OUTPUT:
     Liquid Velocity =  9.03E+01 ft/s      2.75E+01 m/s
     Reynolds Number =  2.89E+03 Critical Flow
Sauter Mean Diameter =  1.60E+01 µm
  Optimum Slit Width =  1.81E-03 in        4.59E-05 m
 Respirable Fraction =  5.52E-01
     Total Leak Rate =  2.09E+01 gpm       1.32E-03 m3/s      1.43E+03 g/s
Respirable Leak Rate =  1.15E+01 gpm       7.27E-04 m3/s      7.89E+02 g/s
```

SPRAY Version 3.0
May 3

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

Run Date = 03/03/97/
Run Time = 07:02:45.08

```
INPUT ECHO:
c SPRAY Version 3 Input Deck
c   unmitigated caustic spray -        10%
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   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)    (μm)             (q)
c
    1.09400E+00      9.60000E-01      2.15000E+01      2.40000E+00
```

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

```
OUTPUT:
     Liquid Velocity =  8.90E+01 ft/s      2.71E+01 m/s
     Reynolds Number =  2.77E+03 Critical Flow
Sauter Mean Diameter =  1.57E+01 μm
  Optimum Slit Width =  1.76E-03 in        4.48E-05 m
 Respirable Fraction =  5.35E-01
     Total Leak Rate =  1.96E+01 gpm       1.23E-03 m3/s       1.35E+03 g/s
Respirable Leak Rate =  1.05E+01 gpm       6.60E-04 m3/s       7.22E+02 g/s
```

```
                    SPRAY Version 3.0
                       May 3

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


Run Date = 03/02/97/
Run Time = 15:00:45.03


INPUT ECHO:
c SPRAY Version 3 Input Deck
c   unmitigated caustic spray -        11%
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     4.30000E+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 Specific Gravity	Dynamic Viscosity (centi-poise)	Respirable Diameter (μm)	RR Fitting Constant (q)
c	1.10600E+00	1.10000E+00	2.08000E+01	2.40000E+00

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

OUTPUT:

Liquid Velocity =	8.64E+01 ft/s	2.63E+01 m/s	
Reynolds Number =	2.38E+03 Critical Flow		
Sauter Mean Diameter =	1.67E+01 μm		
Optimum Slit Width =	1.77E-03 in	4.49E-05 m	
Respirable Fraction =	4.59E-01		
Total Leak Rate =	2.05E+01 gpm	1.29E-03 m3/s	1.43E+03 g/s
Respirable Leak Rate =	9.41E+00 gpm	5.94E-04 m3/s	6.57E+02 g/s

```
                    SPRAY Version 3.0
                       May 3

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


Run Date = 03/02/97/
Run Time = 14:52:49.16


INPUT ECHO:
c SPRAY Version 3 Input Deck
c   unmitigated caustic spray -        12%
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    4.10000E+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)    (μm)            (q)
c   ___________     _____________    ___________     ___________
    1.11600E+00     1.10000E+00      2.03000E+01     2.40000E+00
```

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

```
OUTPUT:
     Liquid Velocity =  8.60E+01 ft/s      2.62E+01 m/s
     Reynolds Number =  2.38E+03 Critical Flow
Sauter Mean Diameter =  1.67E+01 μm
  Optimum Slit Width =  1.76E-03 in        4.48E-05 m
 Respirable Fraction =  4.41E-01
     Total Leak Rate =  1.94E+01 gpm       1.22E-03 m3/s      1.36E+03 g/s
Respirable Leak Rate =  8.54E+00 gpm       5.39E-04 m3/s      6.01E+02 g/s
```

```
                    ______________________

                      SPRAY Version 3.0
                         May 3

                    ______________________

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


Run Date = 03/03/97/
Run Time = 07:09:42.52


INPUT ECHO:
c SPRAY Version 3 Input Deck
c   unmitigated caustic spray -        13%
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     4.70000E+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)      (μm)               (q)
c   ___________        _____________      ___________        ___________
    1.12700E+00        1.30000E+00        1.97000E+01        2.40000E+00
```

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

```
OUTPUT:
     Liquid Velocity =  8.36E+01 ft/s      2.55E+01 m/s
     Reynolds Number =  2.03E+03 Critical Flow
Sauter Mean Diameter =  1.83E+01 μm
  Optimum Slit Width =  1.81E-03 in        4.60E-05 m
 Respirable Fraction =  3.52E-01
     Total Leak Rate =  2.22E+01 gpm       1.40E-03 m3/s      1.58E+03 g/s
Respirable Leak Rate =  7.81E+00 gpm       4.92E-04 m3/s      5.55E+02 g/s
```

```
                    ________________________

                       SPRAY Version 3.0
                    ,     May 3

                    ________________________

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


Run Date = 03/02/97/
Run Time = 15:09:10.68


INPUT ECHO:
c SPRAY Version 3 Input Deck
c   unmitigated caustic spray -        15%
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    4.40000E+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)   (µm)            (q)
c   ___________    _____________   ___________     ___________
```

```
    1.14800E+00    1.30000E+00    1.88000E+01    2.40000E+00

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


OUTPUT:
     Liquid Velocity =  8.20E+01 ft/s      2.50E+01 m/s
     Reynolds Number =  1.98E+03 Laminar Flow
Sauter Mean Diameter =  1.80E+01 µm
  Optimum Slit Width =  1.76E-03 in        4.48E-05 m
 Respirable Fraction =  3.32E-01
     Total Leak Rate =  1.98E+01 gpm       1.25E-03 m3/s      1.44E+03 g/s
Respirable Leak Rate =  6.58E+00 gpm       4.15E-04 m3/s      4.76E+02 g/s
```

```
                 SPRAY Version 3.0
                       May 3

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


Run Date = 03/02/97/
Run Time = 15:10:16.70


INPUT ECHO:
c SPRAY Version 3 Input Deck
c   unmitigated caustic spray -        20%
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     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)   (μm)            (q)
c   ___________     ____________    ___________     ___________
    1.20200E+00     1.90000E+00     1.71000E+01     2.40000E+00
```

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

```
OUTPUT:
     Liquid Velocity =  7.85E+01 ft/s       2.39E+01 m/s
     Reynolds Number =  1.55E+03 Laminar Flow
Sauter Mean Diameter =  2.36E+01 μm
  Optimum Slit Width =  2.02E-03 in         5.13E-05 m
 Respirable Fraction =  1.53E-01
     Total Leak Rate =  3.06E+01 gpm        1.93E-03 m3/s      2.32E+03 g/s
Respirable Leak Rate =  4.70E+00 gpm        2.96E-04 m3/s      3.56E+02 g/s
```

```
                    SPRAY Version 3.0
                       May 3

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

Run Date = 03/02/97/
Run Time = 15:10:39.33

INPUT ECHO:
c SPRAY Version 3 Input Deck
c   unmitigated caustic spray -         30%
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     1.72000E+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)    (µm)             (q)
c
    1.30900E+00      4.40000E+00      1.49000E+01      2.40000E+00
```

MESSAGES:
Slit Model
Code search for optimal equivalent diameter.

OUTPUT:

```
     Liquid Velocity =  7.41E+01 ft/s       2.26E+01 m/s
     Reynolds Number =  9.97E+02 Laminar Flow
Sauter Mean Diameter =  4.53E+01 µm
  Optimum Slit Width =  2.92E-03 in         7.42E-05 m
 Respirable Fraction =  2.47E-02
     Total Leak Rate =  1.16E+02 gpm        7.32E-03 m3/s       9.59E+03 g/s
Respirable Leak Rate =  2.87E+00 gpm        1.81E-04 m3/s       2.37E+02 g/s
```

```
                    ________________________

                        SPRAY Version 3.0
                           May 3

                    ________________________

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


Run Date = 03/03/97/
Run Time = 05:38:27.21


INPUT ECHO:
c SPRAY Version 3 Input Deck
c   unmitigated caustic spray -         40%
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     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)     (μm)              (q)
c
    1.41000E+00       8.50000E+00       1.36000E+01       2.40000E+00
```

MESSAGES:
Slit Model
Code search for optimal equivalent diameter.

```
OUTPUT:
     Liquid Velocity =  7.12E+01 ft/s       2.17E+01 m/s
     Reynolds Number =  7.25E+02 Laminar Flow
Sauter Mean Diameter =  7.65E+01 μm
  Optimum Slit Width =  3.97E-03 in         1.01E-04 m
 Respirable Fraction =  5.70E-03
     Total Leak Rate =  3.49E+02 gpm        2.20E-02 m3/s       3.10E+04 g/s
Respirable Leak Rate =  1.99E+00 gpm        1.25E-04 m3/s       1.77E+02 g/s
```

SPRAY Version 3.0
May 3

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


Run Date = 03/03/97/
Run Time = 07:11:56.81


INPUT ECHO:
c SPRAY Version 3 Input Deck
c   unmitigated caustic spray -        50%
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     7.83000E+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)    (μm)            (q)
c   ___________    _____________    ___________     ___________
    1.50400E+00    1.43000E+01      1.26000E+01     2.40000E+00
```

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

```
OUTPUT:
     Liquid Velocity =  6.89E+01 ft/s      2.10E+01 m/s
     Reynolds Number =  5.67E+02 Laminar Flow
Sauter Mean Diameter =  1.16E+02 μm
  Optimum Slit Width =  5.05E-03 in        1.28E-04 m
 Respirable Fraction =  1.76E-03
     Total Leak Rate =  8.49E+02 gpm       5.36E-02 m3/s       8.06E+04 g/s
Respirable Leak Rate =  1.49E+00 gpm       9.42E-05 m3/s       1.42E+02 g/s
```

PEER AND HEDOP CHECKLISTS

CHECKLIST FOR PEER REVIEW

Document Reviewed: **CONSEQUENCE ANALYSIS OF A NaOH SOLUTION SPRAY RELEASE DURING ADDITION TO WASTE TANK**, D.A. Himes, 10/3/96

Scope of Review: entire document

Yes	No	NA		
[ ]	[ ]	[X]	*	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
[X]	[ ]	[ ]		Problem completely defined.
[X]	[ ]	[ ]		Accident scenarios developed in a clear and logical manner.
[X]	[ ]	[ ]		Necessary assumptions explicitly stated and supported.
[X]	[ ]	[ ]		Computer codes and data files documented.
[X]	[ ]	[ ]		Data used in calculations explicitly stated in document.
[X]	[ ]	[ ]		Data checked for consistency with original source information as applicable.
[X]	[ ]	[ ]		Mathematical derivations checked including dimensional consistency of results.
[X]	[ ]	[ ]		Models appropriate and used within range of validity or use outside range of established validity justified.
[X]	[ ]	[ ]		Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
[X]	[ ]	[ ]		Software input correct and consistent with document reviewed.
[X]	[ ]	[ ]		Software output consistent with input and with results reported in document reviewed.
[X]	[ ]	[X] BGH		Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
[X]	[ ]	[ ]		Safety margins consistent with good engineering practices.
[X]	[ ]	[ ]		Conclusions consistent with analytical results and applicable limits.
[X]	[ ]	[ ]		Results and conclusions address all points required in the problem statement.
[ ]	[ ]	[X]		Format consistent with appropriate NRC Regulatory Guide or other standards
[ ]		[X]	*	Review calculations, comments, and/or notes are attached.
[X]	[ ]	[ ]		**Document approved.**

Brit Hey [signature] — 10/6/96

Reviewer (Printed Name and Signature) — Date

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

HEDOP REVIEW CHECKLIST
for
Radiological and Nonradiological Release Calculations

Document reviewed (include title or description of calculation, document number, author, and date, as applicable):

CONSEQUENCE ANALYSIS OF A NaOH SOLUTION SPRAY RELEASE DURING ADDITION TO WASTE TANK, D.A. Himes, 10/3/96

Submitted by: D.A. Himes   Date Submitted:

Scope of Review: entire document

YES	NO*	N/A		
[X]	[ ]	[ ]	1.	A detailed technical review and approval of the environmental transport and dose calculation portion of the analysis has been performed and documented.
[X]	[ ]	[ ]	2.	Detailed technical review(s) and approval(s) of scenario and release determinations have been performed and documented.
[ ]	[ ]	[X]	3.	HEDOP-approved code(s) were used.
[X]	[ ]	[ ]	4.	Receptor locations were selected according to HEDOP recommendations.
[X]	[ ]	[ ]	5.	All applicable environmental pathways and code options were included and are appropriate for the calculations.
[X]	[ ]	[ ]	6.	Hanford site data were used.
[X]	[ ]	[ ]	7.	Model adjustments external to the computer program were justified and performed correctly.
[ ]	[ ]	[X]	8.	The analysis is consistent with HEDOP recommendations.
[ ]		[X]	9.	Supporting notes, calculations, comments, comment resolutions, or other information is attached. (Use the "Page 1 of X" page numbering format and sign and date each added page.)
[X]	[ ]		10.	**Approval is granted on behalf of the Hanford Environmental Dose Overview Panel.**

* All "NO" responses must be explained and use of nonstandard methods justified.

Brit Hey [signature]   10/7/96
HEDOP-Approved Reviewer (Printed Name and Signature)   Date

COMMENTS (add additional signed and dated pages if necessary):

CHECKLIST FOR PEER REVIEW

Document Reviewed: HNF-SD-WM-CN-065, Rev. 2, **CONSEQUENCE ANALYSIS OF A NaOH SOLUTION SPRAY RELEASE DURING ADDITION TO WASTE TANK,** L. Lansing, 05/27/96

Scope of Review: Entire document

Yes	No	NA	
[✓]	[ ]	[ ] *	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
[✓]	[ ]	[ ]	Problem completely defined.
[✓]	[ ]	[ ]	Accident scenarios developed in a clear and logical manner.
[✓]	[ ]	[ ]	Necessary assumptions explicitly stated and supported.
[✓]	[ ]	[ ]	Computer codes and data files documented.
[✓]	[ ]	[ ]	Data used in calculations explicitly stated in document.
[✓]	[ ]	[ ]	Data checked for consistency with original source information as applicable.
[✓]	[ ]	[ ]	Mathematical derivations checked including dimensional consistency of results.
[✓]	[ ]	[ ]	Models appropriate and used within range of validity or use outside range of established validity justified.
[✓]	[ ]	[ ]	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
[✓]	[ ]	[ ]	Software input correct and consistent with document reviewed.
[✓]	[ ]	[ ]	Software output consistent with input and with results reported in document reviewed.
[✓]	[ ]	[ ]	Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
[✓]	[ ]	[ ]	Safety margins consistent with good engineering practices.
[✓]	[ ]	[ ]	Conclusions consistent with analytical results and applicable limits.
[✓]	[ ]	[ ]	Results and conclusions address all points required in the problem statement.
[✓]	[ ]	[ ]	Format consistent with appropriate NRC Regulatory Guide or other standards
[ ]		[✓] *	Review calculations, comments, and/or notes are attached.
[✓]	[ ]	[ ]	**Document approved.**

[signature] SR Gedeon — 06/30/97

Reviewer (Printed Name and Signature) — Date

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

DISTRIBUTION SHEET

To	From	Page 1 of 1
Project W-320 DE&S Hanford, Inc.	Fluor Daniel Northwest Safety Analysis & Risk Assessment	Date 06/27/97
Project Title/Work Order		EDT No. N/A
HNF-SD-WM-CN-065, Rev. 2, *Consequence Analysis of a NaOH Solution Spray Release during Addition to Waste Tank*		ECN No. 609910

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
J.C. Conner	A2-25	X			
J.P. Harris	S2-48	X			
B.E. Hey	A3-34	X			
D.A. Himes	A3-34	X			
R.J. Van Vleet	A3-34	X			
S.R. Gedeon	H0-35	X			
Central Files	A3-88	X (Original + 1)			
Docket Files	B1-17	X (2)			
TWRS S&L Files	A2-26	X (2)			