JUL 25 1996
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(21) ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT 602623

2. To: (Receiving Organization) TWRS SAR Engineering	3. From: (Originating Organization) TWRS SAR Engineering	4. Related EDT No.: N/A
5. Proj./Prog./Dept./Div.: 8M100	6. Cog. Engr.: G. W. Ryan	7. Purchase Order No.: N/A
8. Originator Remarks: This document was developed and approved by Westinghouse Savannah River Site (WSRS) personnel and is being submitted for approval and release into the Hanford document control system.		9. Equip./Component No.: N/A 10. System/Bldg./Facility: TWRS
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15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Designator	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition
1	WHC-SD-WM-CN-052	N/A	0	Analysis of NaOH Releases for Hanford Tank Farms	N/A	1,2	1	1

16. KEY

Approval Designator (F)	Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)	1. Approval 2. Release 3. Information	4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment	4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION
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(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.
1	1	Cog.Eng. G. W. Ryan	G. W. Ryan	7/23/96	A3-37						
1	1	Cog. Mgr. D. S. Leach	D S Leach		A3-34						
		QA - n/a									
		Safety - n/a									
		Env. - n/a									
1	1	See Page 1 of 94 for WSRS document approval signatures.									

18.	19.	20.	21. DOE APPROVAL (if required)
G. W. Ryan 7/23/96 Signature of EDT Originator / Date	N/A Authorized Representative for Receiving Organization / Date	D. S. Leach 7/24/96 Cognizant Manager / Date	Ctrl. No. [] Approved [] Approved w/comments [] Disapproved w/comments

BD-7400-172-2 (04/94) GEF097

BD-7400-172-1 (07/91)

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	(C)* Sheet No.	• Enter the sheet number of the information being transmitted. If no sheet number, leave blank.
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(17)	Signature/Distribution	
	(G) Reason	• Enter the code of the reason for transmittal (Block 16).
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*Asterisk denote the required minimum items check by Configuration Documentation prior to release; these are the minimum release requirements.

Analysis of NaOH Releases for Hanford Tank Farms

G. W. Ryan
Westinghouse Hanford Company, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-87RL10930

EDT/ECN: 602623 UC: 510
Org Code: 8M100 Charge Code: N1FC3
B&R Code: EW3120071 Total Pages: 95

Key Words: caustic spray leak, NaOH, sodium hydroxide, caustic addition, TWRS, tank farms

Abstract: This document supports the development and presentation of the following accident scenario in the TWRS Final Safety Analysis Report:

Caustic Spray Leak.

The calculations needed to quantify the risk associated with this accident scenario are included within.

Karen H. Noland 7/25/96
Release Approval Date

Release Stamp

Approved for Public Release

Calculation Cover Sheet

Project Hanford Tank Farm Safety Analysis	Calculation Number S-CLC-G-00126	Project Number N/A
Title Analysis of NaOH Releases for Hanford Tank Farms (u)	Functional Classification SS Discipline HEALTH & SAFETY	Sheet 1 of 94

☐ Preliminary ☐ Committed ☒ Confirmed

Computer Program No. (s)	Version/Release No.
☐ SPRAY	3.2

Purpose and Objective

The purpose of this calculation is to analyze and document the consequences of potential caustic releases related to pH adjustments at the Hanford Tank Farms. The objective is to document the need (or lack thereof) for either safety class or safety significant items associated with caustic addition operations.

Summary of Conclusion

Based on conservative analyses for NaOH, there no requirements for safety class items related to caustic addition. Safety significant controls will, however, need to be put in place to limit the maximum system pressure in order to meet onsite concentration guidelines. The allowable pressure is determined as a function of pipe thickness.

Revisions

Rev. No.	Revision Description
0	Original Issue

Sign Off

Rev No.	Originator (Print) Sign / Date	Verification / Checking Method	Verifier / Checker (Print) Sign / Date	Manager (Print) Sign / Date
0	Ted A. Long Ted A. Long 6-27-96	Verification by Individual Review (Manual E7, Procedure 2.40)	R.D. Graves R.D. Graves 6-27-96	L.A. Wooten LA Wooten 6/28/96

Classification

DOES NOT CONTAIN UNCLASSIFIED CONTROLLED NUCLEAR INFORMATION

Reviewing Official: JK Nickus ADC
(Name and Title)

Date: 7/1/96

Calculation No. S-CLC-G-00126	
Sheet No. 2 of 94	
Rev. 0	

RECORD OF REVISION

Project: Hanford Tank Farm Safety Analysis			Calculation No: S-CLC-G-00126	
Subject: Analysis of NaOH Releases for Hanford Tank Farms			Sheet No: 2 of 94	
Originator: Ted A. Long	Date: 6/10/96	Checker: Ron Graves	Date:	Rev. No: 0

REV. NO.	PAGES REPLACED	PAGES ADDED	PAGES DELETED	PAGES REVISED	DESCRIPTION OF REVISIONS
0					Original Issue

TABLE OF CONTENTS

COMPUTER PROGRAMS USED

NAME	CONFIGURATION Control Version		If NO Description on page/in reference
SPRAY 3.2	(Yes)	No	Controlled at WHC
	Yes	No	
	Yes	No	
	Yes	No	

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Analysis of NaOH Releases for Hanford Tank Farms

CALC-NOTE CHECKLIST

REVIEWER(S)

NAME (PRINT OR TYPE)	SIGNATURE	DATE
Ronald D. Graves	[signature]	6-27-96

CIRCLE ONE

1. Is the Subject and/or Purpose clearly stated? (Yes) No
2. Are the required Input Data and their references and source provided and are they consistent with the Calc-note purpose: (Yes) No
3. Are the Assumptions clearly identified, valid, and consistent with the Calc-note purpose: (Yes) No
4. Are the Analytical Methods clearly identified? (Yes) No
5. Are all pages consecutively numbered and identified by the calc-note number? (Yes) No
6. Is/are the version(s) of the computer program(s) used identified? (Yes) No N/A
7. Are input listings for all computer programs documented in this calc-note? Yes No (N/A)
8. Are the Results and Conclusions clearly stated? (Yes) No
9. Are all OUTPUT documents (if not part of the calculation) clearly referenced in the results section? (Yes) No

IF NO TO ANY OF THE ABOVE, SHEET NUMBER(S) WITH JUSTIFICATION:

REVIEWER'S NOTES (use additional pages as necessary)

Review method used: Alternate calculation___ Attached?: Y__ N__

Approximated Originator steps X

List of Acronyms

BIO	Basis for Interim Operation
ERPG	Emergency Response Planning Guideline
FSAR	Final Safety Analysis Report
NaOH	sodium hydroxide
PEL-TWA	Personnel Exposure Limit-Time Waited Average
RAG	Risk Acceptance Guidelines
WHC	Westinghouse Hanford Company
WSRC	Westinghouse Savannah River Company

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Rev.	**0**

Reference:

1. Risk Acceptance Guidelines, WHC-WM-4-46, Rev. 4, Westinghouse Hanford Company, Richland, Washington, 1996.
2. Perry, R.H., Green, D., Perry's Chemical Engineers' Handbook, Sixth Edition, McGraw-Hill Book Company, New York, New York, 1984.
3. Avallone, E.A., Baumeister, T., Marks' Standard Handbook for Mechanical Engineers, Ninth Edition, McGraw-Hill Book Company, New York, New York, 1987.
4. Van Keuren, J.C., Toxic Chemical Considerations for Tank Farm Releases, WHC-SD-WM-SARR-011, Rev. 2, Westinghouse Hanford Company, Richland, Washington, 1996.
5. Hey, B.E., Leach, D.S., A Model for Predicting Respirable Releases from Pressurized Leaks, WHC-SD-GN-SWD-20007, Rev. 0, Westinghouse Hanford Company, Richland, Washington, 1994.
6. Jenkins, S, Goakey, S.K., System Design Description for the Tank 241-AN-107 Caustic Addition Project, WHC-SD-SM-SDD-051, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
7. White, F.M., Fluid Mechanics, McGraw-Hill Book Company, New York, NewYork, 1979.

Introduction

As needed, caustic (NaOH) solutions are used to maintain the pH of waste tank contents within acceptable litmus to minimize stress corrosion considerations. The caustic solution may be supplied by offsite vendors via one or more 4000 gallon tanker trucks or mixed at onsite facilities. The solution strength may vary from 5 to 50 weight percent NaOH. In addition, the solution may, depending on the tank, be transported through a variety of different pipes and may be routed through a metering pump and a mixer pump, or merely pumped (at pressures as high as 125 psi) in through an available riser.

The Hazard Analysis for the Hanford Tank Farms identified a caustic spray release at tank 241-AN-107 as an accident capable of challenging the risk acceptance guidelines at the Hanford Nuclear Reservation[1]. This calcnote analyzes the consequences from a potential caustic spray release during transfer from a supply tanker truck to a generic storage tank. Only NaOH caustic solutions are analyzed.

The postulated accident is that a small crack occurs in the piping during a caustic transfer which leads to a spray release of caustic solution to the atmosphere. The release rate of respirable particles is calculated based on conservatively chosen physical parameters and a slit width which is optimized for the generation of respirable particles.

Open Items

There are no open items associated with this calcnote.

Input:

1. The only caustic material under consideration is NaOH.
2. The kinematic viscosity of NaOH as a function of temperature for various aqueous solutions is given in Figure 1.
3. The density of NaOH as a function of temperature for various aqueous solutions is given in Table 1.[2]
4. The maximum pressure which can be generated during a caustic addition is 125 psi. This is the peak pressure of the largest compressor available for use at the tank farms.
5. The peak temperature of the caustic solution is less than 50°C. The offsite vendor for 50% caustic solutions loads the tanker truck at 120°F (49°C). The tanker is unheated.
6. Per facility request, piping wall thicknesses as small as that corresponding to 1 inch diameter commercial grade Schedule 10 steel pipe and as large as 2 inch diameter crosslinked polyethylene hose were considered. The calculations were actually carried for the smaller Schedule 5 steel pipe as well. The wall thicknesses are listed in Table 8.7.3 of reference 3 and are repeated in Table 2 below.
7. The thickness of the 2 inch diameter polyethelene piping is 25/64 of an inch.[Appendix D]
8. The X/Q value for maximally exposed offsite receptor is 2.83E-5 s/m^3.[4] This is "less than 1 hour" value as selected by the FSAR methodology. The time frame for the accident is assumed to 15 minutes since the risk acceptance guideline is stated in terms of Peak 15 minute average concentration. Therefore, while the accident may occur over a longer time frame, the consequence calculation is only concerned with the dispersion occurring during the worst 15 minutes.
9. The X/Q value for onsite receptor 100 m from the release is 3.41E-2 s/m^3.[4] The time frame for the accident is assumed to 15 minutes since the risk acceptance guideline is stated in terms of Peak 15 minute average concentration. Therefore, while the accident may occur over a longer time frame, the consequence calculation is only concerned with the dispersion occurring during the worst 15 minutes.

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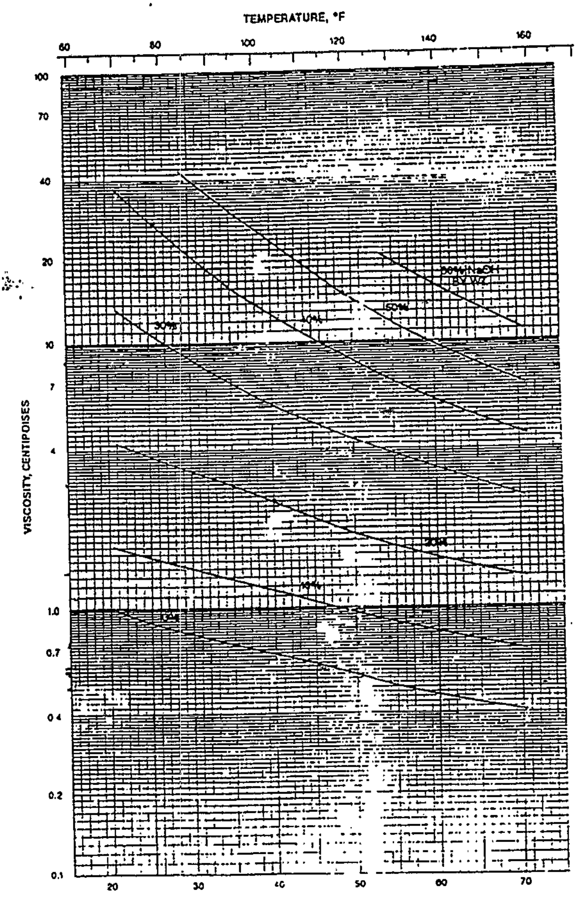
Part 5.8 Viscosity of Aqueous Caustic Soda Solutions



REF.: KRINGS, W. Z. ANORG. CHEM. 255, 294–8 (1948)

Figure 1. Viscosity of NaOH solutions.

Table 1. Density of NaOH solutions.[2] (Underlined numbers are interpolated.)

Weight %	40°C	50°C	60°C
1	1.0033	0.9987	0.9941
2	1.0139	1.0092	1.0045
4	1.0352	1.0303	1.0254
5	1.0459	1.0409	1.0360
8	1.0780	1.0728	1.0676
10	1.0995	1.0942	1.0889
12	1.1210	1.1156	1.1101
15	1.1536	1.1480	1.1424
16	1.1645	1.1588	1.1531
20	1.2079	1.2020	1.1960
24	1.2512	1.2450	1.2388
25	1.2620	1.2557	1.2495
28	1.2942	1.2878	1.2814
30	1.3152	1.3088	1.3023
32	1.3362	1.3297	1.3232
36	1.3768	1.3701	1.3634
40	1.4164	1.4096	1.4027
44	1.4545	1.4475	1.4405
48	1.4922	1.4852	1.4781
50	1.5109	1.5038	1.4967

Table 2. Wall thickness for 1 inch diameter commercial steel piping.

Commercial Steel Pipe Schedule	Wall thickness for 1 inch diameter pipe, inches
5S	0.065
10S	0.109
40 or Standard	0.133
80 or XS	0.179
160	0.250
XXS	0.358

Assumptions:

1. The caustic concentration at the location of the onsite receptor due to a simple tanker truck spill is negligible relative to the spray release. This is an acceptable assumption since the release fraction from a spill should be much less than that from a pressurized release and the aerodynamic entrainment from the pool surface should be negligible compared to the release from a spray release.
2. The spray release occurs through a slit type opening rather than an orifice opening. This is equivalent to assuming that the spray release occurs as a result of cracking or a loose coupling rather than a puncture. This is a conservative assumption since the peak respirable releases from slits always bounds the peak respirable releases from orifices.
3. The effective surface roughness inside the slit or orifice is at least as rough as a typical steel pipe ($\varepsilon \approx 0.0018$ inch).
4. The depth of the slit is no less than the nominal thickness of the pipe wall.. This is conservative since the flow path through the pipe wall is likely to be tortuous and significantly longer than the nominal thickness of the pipe.
5. The contraction loss coefficient for the leak is assumed to be 1.0 as appropriate for cracks which are not similar to sharp edge orifices.
6. The velocity loss coefficient is assumed to be 0.82 as is appropriate for pipe flow without engineered entry and exit geometries.[See reference 5.]

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Analytical Methods and Calculations:

Spray release model

The rate of release of potentially respirable caustic material was conservatively estimated using the SPRAY32 program to determine the size of opening in the piping which causes the largest release of respirable particles. This program is described in reference 5. The input variables are listed in Table 3.

Table 3. Input variables for SPRAY32.

Input variable	Description	Value
Mode	Flag to select an orifice or a slit	This flag is conservatively set to slit (=1) for all calculations.
Friction Factor Flag	Flag to select laminar flow, turbulent flow, or let the program select	See below.
Flow Determination Flag	Flag to have the program determine the optimum hole size, specify a hole diameter, or specify the Reynolds number	This flag was set to have the code calculate the optimum slit width for generating respirable particles.
Starting Particle Size	size of smallest particle bin	This input value only effects the particle binning in the output which is immaterial in the respirable release calculation.
Geometric Step Size	particle distribution step size	This input value only effects the particle binning in the output which is immaterial in the respirable release calculation.
Number of Intervals	number of particle bins	This input value only effects the particle binning in the output which is immaterial in the respirable release calculation.
Initial Slit Width or Orifice Diameter	Slit width in inches.	Since the calculations were all run in optimization mode, this is an unused input value.

Slit Length	Slit length in inches.	This input value was set 1 inch for all calculations. The release values were then scaled to the appropriate slit length in an Excel spreadsheet; see below.
Slit or Orifice Depth	Crack depth in inches.	Varied based on pipe size; see below.
Reynolds Number	Reynolds number of the flow in the slit or orifice.	Since the calculations were all run in optimization mode, this is an unused input value.
Pressure Differential	Driving pressure in psi.	Various; see below.
Absolute Surface Roughness	Roughness for flow in the slit or orifice, in inches.	ε=0.0018 inches; see assumption 3.
Contraction Coefficient	C_C for minor losses	C_C=1.0 for all calculations; see assumption 5.
Velocity Coefficient	C_V for minor losses.	C_V=0.82 for all calculations; see assumption 6.
Fluid Density	Density in gm/l.	Corrected for temperature and concentration of caustic solution; see input data 3.
Dynamic Viscosity	Viscosity in centiPoise.	Corrected for temperature and concentration of caustic solution; see input data 2.
Respirable Diameter	Maximum diameter of generated particles which are included in the calculation of respirable release rate.	Varied from 10 to 46 μm; see below.
Fitting constant, q	An empirically determined constant to fit Sauter Mean Diameter data for particle distributions.	q=2.4 for all calculations; see below.

Friction Factor Flag

All calculations were initially performed allowing the code to select laminar or turbulent flow relations for friction factor. For those calculations where the optimum Reynolds number was in the critical flow range (2000 to 4000), the code occasionally could not converge to a solution. In such instances, the Friction Factor Flag was set laminar in order to provide conservative[1] results.

Effect of Slit Depth (Thickness of Pipe Wall)

The slit or orifice depth is a critical parameter since it directly effects the flow resistance calculations through the resistance coefficient, K = fL/D. Higher flow resistance results in a reduction of the leak rate so using smaller depths (i.e. thinner pipes) results in a larger release. A series of calculations was run to determine the maximum allowable system pressure for various pipe wall thicknesses. At the request of the facility, calculations were run to determine the maximum allowable system pressure for wall thicknesses corresponding to various 1 inch diameter commercial steel pipes. The facility also asked for calculations corresponding to the wall thickness of the 2 inch diameter crosslinked polyethylene hose used for caustic transfer at tank 241-AN-107.

Effect of Evaporation on Liquid Particles

As the liquid caustic solution particles are transported by the atmosphere, the water of solution may evaporate and reduce the size of the particle. Thus, some of the released particle which are initially larger than 10μm (respirable cutoff) may decrease in size so that by the time they reach the site boundary they are respirable. Since amount of water in the released caustic solution varies with solution strength, the respirable diameter for the spray release was calculated for each solution strength considered using the formula from the SPRAY documentation[5].

Equation 1

$$D_{resp} = \frac{10\mu m}{\sqrt[3]{f_s}}$$

The respirable diameter calculation was based on the conservative assumption that all of the water associated with the released liquid particles evaporates (thus reducing the size of the particle) prior to reaching the receptor. The fraction of droplets generated by a spray release which is respirable at the offsite receptor includes all of

[1] In this flow regime, the laminar friction factor is smaller than the turbulent friction factor. The reduced friction allows a higher flow rate through the slit and a correspondingly larger number of respirable particles.

those droplets larger than 10 μm which may evaporate down to 10 μm or less. For solution strength ranging from 1 to 50 weight percent, the respirable diameter input for offsite calculations varies from 46 μm to 13 μm, respectively. The onsite receptor is located 100 m from the spray so the travel time of the particles is short (less than a minute). Thus, the evaporation mechanism was neglected for onsite calculations.

Sauter Mean Diameter Fitting Constant

The fitting constant, q, was set to 2.4 for all calculations. The purpose of this constant is to match the Sauter Mean diameter to experimental data. Smaller values to q correspond to flatter distributions and elevated respirable releases. The value of 2.4 is smaller than the lowest value of q which adequately reproduces experimental data.[5]

Effect of Solution Molarity

The dynamic viscosity of NaOH solutions changes significantly with temperature and solution strength. In addition, the actual concentration of NaOH at the receptor is also a function of solution strengthThe viscosity decreases with increasing temperature so higher temperature correspond to larger releases from the crack (less resistance to flow through the crack). The temperature effect was bounded by using Input Data #3. As the viscosity changes, the optimum crack width changes and the total NaOH in the form of respirable particles changes. The effect of solution strength was accounted for by running a number of SPRAY32 with various solution strengths to determine the bounding consequence for each receptor.

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Results:

Solution strength for Bounding Consequences

As the solution strength decreases, the leak path provides less resistance and more material is released. The total NaOH, release, however, decreases since the solution strength has decreased. The competing effects were investigated by running SPRAY32 for a variety of solution strengths holding all other input variables constant. Specifically, the comparison was made for the bounding offsite case of Schedule 5 piping and 125 psi driving pressure. The results are shown in Figure 2 and the SPRAY32 output are included in Appendix B. The optimum solution strength for releasing NaOH is around 10 to 15 weight percent (about 6 molar). The calculations below use 10 weight percent.

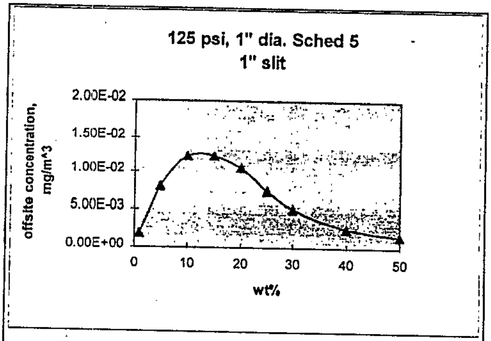

Figure 2. Concentration as a function of solution strength.

Offsite Concentration of NaOH

The first set of calculations performed were to determine a bounding offsite concentration due to NaOH spray releases. Based on input from the facility, the highest driving pressure that could be generated for a caustic transfer is 125 psi. The SPRAY32 code was run with a pressure of 125 psi using the thinnest 1 inch diameter commercial steel pipe (Schedule 5) and a slit length of 1 inch. The results were then scaled using a 30 inch slit length. The SPRAY32 output file is included in Appendix C. Applying the offsite dispersion coefficient to the total respirable release, the highest 15 minute average concentration at the site boundary is

Equation 2

$$C = \left(22.1 \frac{\text{g}}{\text{s} \cdot \text{inch}}\right)(30 \text{ inches})\left(1000 \frac{\text{mg}}{\text{g}}\right)\left(2.83 \times 10^{-5} \frac{\text{s}}{\text{m}^3}\right)\left(0.10 \frac{\text{grams NaOH}}{\text{gram solution}}\right) = 1.88 \frac{\text{mg NaOH}}{\text{m}^3}$$

The offsite risk acceptance guideline for an anticipated chemical release is the PEL-TWA. For NaOH, the PEL-TWA is 2.0 mg/m^3. The corresponding fraction is 0.94.

Onsite Concentration of NaOH

As a first estimate of the onsite consequences, the onsite concentration at 100 m was calculated using the same conditions as for the offsite calculation, including the conservative assumption that the particle sizes are reduced by evaporation before the cloud reaches the receptor. The SPRAY32 output files are included in Appendix C. Applying the onsite dispersion coefficient to the total respirable release, the highest 15 minute average concentration 100 m from the release is

Equation 3

$$C = \left(22.1 \frac{\text{g}}{\text{s} \cdot \text{inch}}\right)(30 \text{ inches})\left(1000 \frac{\text{mg}}{\text{g}}\right)\left(3.41 \times 10^{-2} \frac{\text{s}}{\text{m}^3}\right)\left(0.10 \frac{\text{grams NaOH}}{\text{gram solution}}\right) = 2260 \frac{\text{mg NaOH}}{\text{m}^3}$$

The onsite risk acceptance guideline for an anticipated chemical release is the ERPG-1. For NaOH, the ERPG-1 is 2.0 mg/m^3. The corresponding fraction is 1130. Thus, the conservative calculation for onsite consequences is well above the guidelines using the same conditions as the offsite consequence calculation. Note that if the accident were considered in the extremely unlikely frequency bin, the conservative onsite consequence calculation would still be over the risk acceptance guidelines by a factor of 23.

At a control meeting held at the end of May, the facility agreed to use a Safety Significant pressure relief device to limit the driving force behind potential caustic spray releases and remain within the risk acceptance guidelines. Since the facility may be using a variety of different pipes and hoses for NaOH transfers, calculations were performed to determine the highest pressure for which the spray release is still below the risk acceptance guidelines. The pressure was determined as a function of pipe wall thickness. The range of wall thicknesses was based on the 1 inch diameter commercial steel piping ranging from Schedule 5 to Schedule XXS and also included one data point to account for the use of 2 inch diameter crosslinked polyethelene hose as described in the 241-AN-107 caustic addition system[6]. As for the offsite calculations, the SPRAY32 code was run in optimization mode assuming a 1 inch slit. Evaporation effects were neglected for the onsite calculations since the travel time of the liquid particles to the onsite receptor is less than a minute. The respirable releases were then scaled to a 30 inch long slit. The results are tabulated in Table 4 along with the calculated onsite consequences.

Table 4. Onsite consequences for various pipe thicknesses

Pipe Schedule	Diameter	Wall thickness, inches	Pressure, psi	Respirable release for 1 inch slit, g/s	Respirable release for 30 inch slit, g/s	Concentration at 100 m	Sum of fraction
5	1	0.065	8	0.0171	0.513	1.75	0.87
10	1	0.109	10	0.0171	0.513	1.75	0.87
40	1	0.133	11	0.0175	0.525	1.79	0.90
80	1	0.179	13	0.0190	0.570	1.94	0.97
160	1	0.250	15	0.0189	0.567	1.93	0.97
XXS	1	0.358	17	0.0177	0.531	1.81	0.91
2" dia. poly-ethylene	2	0.391	18	0.0185	0.555	1.89	0.95

Note that the consequences were calculated by substituting the appropriate release rate into equation 3 above.

Conclusion:

Based on the offsite concentrations, no safety class SSCs or TSRs are required for NaOH transfers.

Based on the onsite concentration calculations, the step curve in Figure 3 represents the maximum system pressure limits as a function of pipe wall thickness. Any pipe wall thickness and system pressure combination which falls **below** the step curve will result in acceptable onsite consequences for an NaOH spray release.

In reality, the consequences calculated here are very conservative for a number of reasons.

- The calculations assume that the slit width is always the optimum size for generating respirable particle. Especially for a long slit, the width is likely to vary significantly from end to end. Either doubling or halving the slit width will result in a significant reduction (50 to 90%) in the amount of respirable material released. Slits that are 30 inches long (as assumed in this calculation) are likely to be much wider in the center than toward the ends, thus producing fewer respirable particles and simultaneously reducing the internal driving pressure by allowing more substantial amounts of fluid to leak out. If the leak is large enough, it can no longer be considered a spray release and would be treated as a spill with a reduced consequence.
- For the offsite calculations, the assumption that all of the water of solution evaporates and some of the large particles are reduced down to respirable sizes neglects the effects of agglomeration and deposition of large liquid particles.
- The likelihood of long undetected cracks which produce large amounts of liquid particles is probably unlikely or extremely unlikely. All of the scenarios considered here, however, were conservatively compared to anticipated guidelines.
- The flow resistance through the slit should be significantly more than in the above calculations since a thin crack is likely to have a tortuous flow path. The increased resistance will reduce the total flow through the crack.

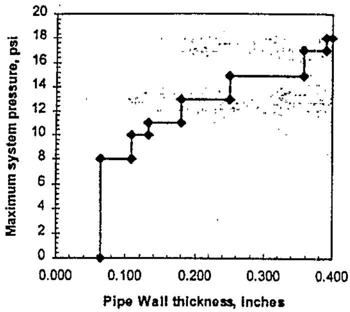

Figure 3. Allowable system pressure for various pipe wall thicknesses.

Appendix A

Maximum slit length determination

Although the following methodology was not used in the final version of the calcnote, some of the earlier decisions were based on calculations using this method in conjunction with the system description for 241-AN-107 caustic additions. When the calculation was broadened to include other NaOH transfer where the flow rate and pressure would not be restricted by the metering pump performance, the method became indeterminant without placing an additional safety significant restriction on the facility to regulate the maximum flowrate. Given a flowrate inside the pipe, a bounding slit length can be determined based on the parameters of the problem rather than an engineering judgement regarding the maximum length of a crack. The drawback, however, is that this method can lead to extremely large crack lengths if an independent flow rate restriction can not be imposed. Such considerations led to use of a maximum crack length of 30 inches in the body of the calcnote. The discussion is included for information only.

The choice of bounding values for most of the SPRAY parameters is fairly straight forward. The slit could, however, be in either the circumferential or longitudinal directions depending on the type of pipe and the cause of the failure so selecting a bounding the slit length is not obvious. A simple assumption of 2 inches (as used in the ASA) has no basis. This is an important parameter since the code optimizes the slit width with no consideration for the slit length but calculates the release rate based on the cross-sectional area of the slit. Thus, the release rate scales linearly with the slit length.

Since the slit length is independent of the remaining variables in the SPRAY model and there is no feedback mechanism in the model to reduce the driving pressure to account for the head loss from the leak, it is possible to choose a slit length which that results in a larger flow rate through the leak than is initially in the pipe. This behavior in the model is a result of the inherent assumption that the leak rate is small with respect to the base flow. The release can be bounded by requiring that the leak rate not exceed the total flow rate in the pipe. The calculation for the respirable fraction depends on the optimized slit width but is unaffected by the slit length. Thus a bounding release can be calculated by conservatively assuming that *all* of the flow in the pipe escapes through the slit at the rate determined using the peak system pressure and with the calculated respirable fraction.

Since the above method leads to unacceptable onsite consequences, a less bounding approach was used in this calcnote which takes credit for the fact that the driving pressure in the pipe decreases as material is removed through the leak. This effect is negligible for relatively short slit lengths but may be significant for long, longitudinal slits. Rather than add another layer of iteration to the SPRAY models, the driving pressure was stepped down in 2.5 psi or greater increments by varying the slit length. For each pressure level, the total flow rate through the leak in order to reduce the pressure to the next level was combined with the respirable fraction and the dispersion factor to determine the contribution to the caustic concentration at the receptor. Once the pressure in the pipe was stepped down a value where the respirable release was negligible, the total release of respirable particles was used to calculate the concentration at the receptor. This process is diagrammed in Figure A1.

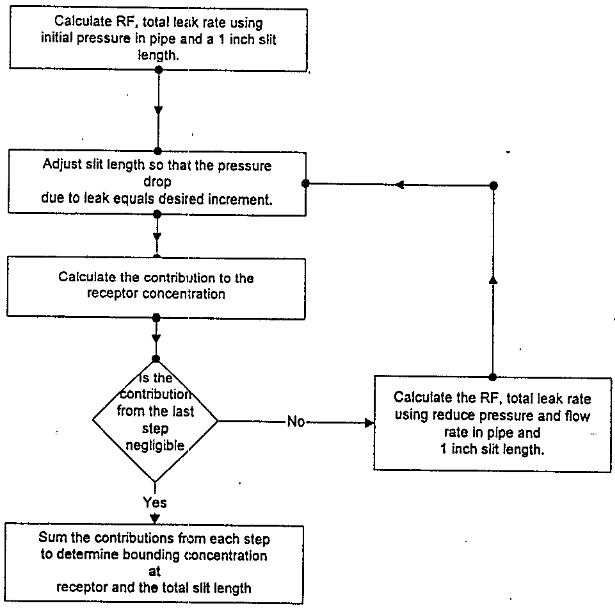

Figure A1. Bounding slit length methodology

The pressure reduction due to the flow through the leak was calculated from the relationship between pressure drop and flow rate for turbulent flow in a pipe.[7]

Equation A1

$$\Delta p \approx 0.241 L \rho^{0.75} \mu^{0.25} d^{-4.75} Q^{1.75}$$

Since ρ, μ, and d are constant in the pipe,

Equation A2

$$\Delta p \approx A L Q^{1.75}$$

where A is a constant. The pressure drop with respect to L is conservatively ignored so that

Equation A3

$$\Delta p \approx \hat{A} Q^{1.75}$$

where $\hat{A}$ is a new constant. Using the definitions in Figure A2,

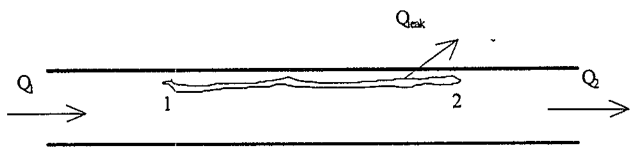

Figure A2. Schematic of longitudinal crack.

Equation A4

$$\frac{\Delta p_{leak}}{\Delta p_{noleak}} = \left(\frac{Q_2}{Q_1}\right) = \left(\frac{Q_1 - Q_{leak}}{Q_1}\right)$$

and

Equation A5

$$\Delta p_{leak} = \Delta p_{noleak}\left(1 - \frac{Q_{leak}}{Q_1}\right)$$

The initial Q and Δp must be updated at the beginning of each step but are conservatively held constant over each step. The step size chosen for Δp ranged from 2.5 psi to 25 psi depending the size of the change.

Appendix B

SPRAY32 output files for worst case solution strength determination.

SPRAY Version 3.2

August 31, 1995

Spray Leak Code

Produced by Radiological & Toxicological Analysis

Westinghouse Hanford Company

Run Date = 06/11/96/

Run Time = 15:32:39.52

INPUT ECHO:

```
c 1% NaOH solution, 125 psi, 50 C
c SPRAY Code Version 3.2 Input File
c
c MODEL OPTIONS:
c
c mode  - program calculation mode
c         = 1 for orifice leak
c         = 2 for slit leak
c ifric - integer flag for friction factor
c         = 0 for program selection
c         = 1 for laminar relation
c         = 2 for turbulent relation
```

Calculation No.	S-CLC-G-00126
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```
c iopt  - integer flag for flow determination
c          = 0 for optimal diameter search given initial guess diameter and
Re
c          = 1 for flow based on user specified diameter
c          = 2 for flow based on user specified Reynold's number
c
c   mode ifric iopt
    2    1     0
c
c PARTICLE SIZE DISTRIBUTION TABLE PARAMETERS:
c
c   Starting
c   Particle
c   Size            Geometric      Number of
c   (um)            Step Size      Intervals
c   ____________    ___________    ___________
    1.00000E+00     2.00000E+00    10
c
c PARAMETER INPUT:
c
c   Initial Slit                   Slit or
c   Width or        Slit           Orifice
c   Orifice Dia.    Length         Depth          Reynold's
c   (in)            (in)           (in)           Number
c   ____________    ___________    ___________    ___________
    1.00000E-02     1.00000E+00    6.50000E-02    2.00000E+03
c
c                   Absolute
c                   Surface
c                   Roughness      Contraction    Velocity
c                   (in)           Coefficient    Coefficient
```

Calculation No. S-CLC-G-00126
Sheet No. 29 of 94
Rev. 0


```
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      Density        Viscosity      Diameter       Constant
c      (g/cc)         (centi-poise)  (µm)           (q)
c      ___________    ____________   ___________    ___________
       9.98700E-01    5.80000E-01    4.60000E+01    2.40000E+00
c
c      Ambient        Wind
c      Density        Speed
c      (g/cc)         (m/s)
c      ___________    ____________
       1.22000E-03    1.50000E+00


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


OUTPUT:
     Liquid Velocity =  1.09E+02 ft/s      3.33E+01 m/s
                 Reynolds   Number   =      9.31E+03   Turbulent   Flow
```

Calculation No. S-CLC-G-00126	
Sheet No. 30 of 94	
Rev. 0	

Sauter Mean Diameter =	2.41E+01 æm		
Mass Median Diameter =	3.16E+01 æm		
Characteristic Dia. =	3.68E+01 æm		
Optimum Slit Width =	3.21E-03 in	8.15E-05 m	
Respirable Fraction =	8.19E-01		
Total Leak Rate =	1.09E+00 gpm	6.89E-05 m3/s	6.88E+01 g/s
Respirable Leak Rate =	8.94E-01 gpm	5.64E-05 m3/s	5.63E+01 g/s
Jet Rise =	1.03E+00 ft	3.15E-01 m	

Particle Diameter Sections (m)	Section Release Rate (kg/s)	Cumulative Release Rate (kg/s)	Cumulative Percent (%)
1.00E-06	1.20E-05	1.20E-05	0.02
2.00E-06	5.13E-05	6.33E-05	0.09
4.00E-06	2.70E-04	3.34E-04	0.48
8.00E-06	1.41E-03	1.74E-03	2.53
1.60E-05	6.97E-03	8.71E-03	12.66
3.20E-05	2.64E-02	3.51E-02	51.05
6.40E-05	3.21E-02	6.72E-02	97.70
1.28E-04	1.59E-03	6.88E-02	100.00
2.56E-04	0.00E+00	6.88E-02	100.00
5.12E-04	0.00E+00	6.88E-02	100.00

SPRAY Version 3.2

August 31, 1995

Spray Leak Code

Produced by Radiological & Toxicological Analysis

Westinghouse Hanford Company

Run Date = 06/11/96/

Run Time = 15:40:41.43

INPUT ECHO:

```
c 5% NaOH solution, 125 psi, 50 C
c SPRAY Code Version 3.2 Input File
c
c MODEL OPTIONS:
c
c mode  - program calculation mode
c          = 1 for orifice leak
c          = 2 for slit leak
c ifric - integer flag for friction factor
c          = 0 for program selection
c          = 1 for laminar relation
c          = 2 for turbulent relation
```

```
c iopt  - integer flag for flow determination
c          = 0 for optimal diameter search given initial guess diameter and
Re
c          = 1 for flow based on user specified diameter
c          = 2 for flow based on user specified Reynold's number
c
c   mode ifric iopt
    2    0     0
c
c PARTICLE SIZE DISTRIBUTION TABLE PARAMETERS:
c
c   Starting
c   Particle
c   Size             Geometric       Number of
c   (um)             Step Size       Intervals
c   ___________      ___________     ___________
    1.00000E+00      2.00000E+00     10
c
c PARAMETER INPUT:
c
c   Initial Slit                     Slit or
c   Width or         Slit            Orifice
c   Orifice Dia.     Length          Depth            Reynold's
c   (in)             (in)            (in)             Number
c   ___________      ___________     ___________      ___________
    1.00000E-02      1.00000E+00     6.50000E-02      2.00000E+03
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    Density        Viscosity        Diameter       Constant
c    (g/cc)         (centi-poise)    (µm)           (q)
c    ___________    ___________      ___________    ___________
     1.04090E+00    7.40000E-01      2.70000E+01    2.40000E+00
c
c    Ambient        Wind
c    Density        Speed
c    (g/cc)         (m/s)
c    ___________    ___________
     1.22000E-03    1.50000E+00


MESSAGES:
Slit Model
Code search for optimal equivalent diameter.


OUTPUT:
     Liquid Velocity =  7.11E+01 ft/s      2.17E+01 m/s
                Reynolds    Number    =      4.96E+03    Turbulent    Flow

Sauter Mean Diameter =  3.87E+01 æm
```

Calculation No. S-CLC-G-00126	
Sheet No. 34 of 94	
Rev. 0	

Analysis of NaOH Releases for Hanford Tank Farms

Mass Median Diameter =	5.07E+01 æm		
Characteristic Dia. =	5.91E+01 æm		
Optimum Slit Width =	3.21E-03 in	8.16E-05 m	
Respirable Fraction =	1.41E-01		
Total Leak Rate =	7.12E-01 gpm	4.49E-05 m3/s	4.68E+01 g/s
Respirable Leak Rate =	1.01E-01 gpm	6.35E-06 m3/s	6.61E+00 g/s
Jet Rise =	6.82E-01 ft	2.08E-01 m	

Particle Diameter Sections (m)	Section Release Rate (kg/s)	Cumulative Release Rate (kg/s)	Cumulative Percent (%)
1.00E-06	2.62E-06	2.62E-06	0.01
2.00E-06	1.12E-05	1.38E-05	0.03
4.00E-06	5.90E-05	7.28E-05	0.16
8.00E-06	3.10E-04	3.83E-04	0.82
1.60E-05	1.60E-03	1.99E-03	4.25
3.20E-05	7.59E-03	9.58E-03	20.48
6.40E-05	2.32E-02	3.28E-02	70.17
1.28E-04	1.39E-02	4.67E-02	99.83
2.56E-04	7.88E-05	4.68E-02	100.00
5.12E-04	0.00E+00	4.68E-02	100.00

SPRAY Version 3.2

August 31, 1995

Spray Leak Code

Produced by Radiological & Toxicological Analysis

Westinghouse Hanford Company

Run Date = 06/11/96/

Run Time = 15:40:09.96

INPUT ECHO:

```
c 1% NaOH solution, 125 psi, 50 C
c SPRAY Code Version 3.2 Input File
c
c MODEL OPTIONS:
c
c mode  - program calculation mode
c         = 1 for orifice leak
c         = 2 for slit leak
c ifric - integer flag for friction factor
c         = 0 for program selection
c         = 1 for laminar relation
c         = 2 for turbulent relation
```

```
c iopt  - integer flag for flow determination
c         = 0 for optimal diameter search given initial guess diameter and
Re
c         = 1 for flow based on user specified diameter
c         = 2 for flow based on user specified Reynold's number
c
c   mode ifric iopt
     2     0     0
c
c PARTICLE SIZE DISTRIBUTION TABLE PARAMETERS:
c
c   Starting
c   Particle
c   Size             Geometric        Number of
c   (um)             Step Size        Intervals
c   _____________    ____________     ___________
    1.00000E+00      2.00000E+00      10
c
c PARAMETER INPUT:
c
c   Initial Slit                      Slit or
c   Width or         Slit             Orifice
c   Orifice Dia.     Length           Depth            Reynold's
c   (in)             (in)             (in)             Number
c   _____________    ____________     ____________     ____________
    1.00000E-02      1.00000E+00      6.50000E-02      2.00000E+03
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   Density        Viscosity        Diameter       Constant
c   (g/cc)         (centi-poise)    (μm)           (q)
c   ___________    _____________    ___________    ___________
    9.98700E-01    5.80000E-01      4.60000E+01    2.40000E+00
c
c   Ambient        Wind
c   Density        Speed
c   (g/cc)         (m/s)
c   ___________    _____________
    1.22000E-03    1.50000E+00


MESSAGES:
Slit Model
Code search for optimal equivalent diameter.


OUTPUT:
     Liquid Velocity =  7.88E+01 ft/s      2.40E+01 m/s
                   Reynolds    Number    =       8.01E+03    Turbulent    Flow

Sauter Mean Diameter =  4.13E+01 æm
```

Calculation No. S-CLC-G-00126
Sheet No. 38 of 94
Rev. 0

Mass Median Diameter =	5.41E+01 æm		
Characteristic Dia. =	6.30E+01 æm		
Optimum Slit Width =	3.83E-03 in	9.72E-05 m	
Respirable Fraction =	3.75E-01		
Total Leak Rate =	9.40E-01 gpm	5.93E-05 m3/s	5.92E+01 g/s
Respirable Leak Rate =	3.52E-01 gpm	2.22E-05 m3/s	2.22E+01 g/s
Jet Rise =	8.38E-01 ft	2.56E-01 m	

Particle Diameter Sections (m)	Section Release Rate (kg/s)	Cumulative Release Rate (kg/s)	Cumulative Percent (%)
1.00E-06	2.84E-06	2.84E-06	0.00
2.00E-06	1.22E-05	1.50E-05	0.03
4.00E-06	6.41E-05	7.91E-05	0.13
8.00E-06	3.37E-04	4.16E-04	0.70
1.60E-05	1.75E-03	2.16E-03	3.65
3.20E-05	8.40E-03	1.06E-02	17.84
6.40E-05	2.77E-02	3.82E-02	64.55
1.28E-04	2.08E-02	5.90E-02	99.58
2.56E-04	2.49E-04	5.92E-02	100.00
5.12E-04	0.00E+00	5.92E-02	100.00

SPRAY Version 3.2

August 31, 1995

Spray Leak Code

Produced by Radiological & Toxicological Analysis

Westinghouse Hanford Company

Run Date = 06/11/96/

Run Time = 15:32:41.11

INPUT ECHO:

```
c 15% NaOH solution, 125 psi, 50 C
c SPRAY Code Version 3.2 Input File
c
c MODEL OPTIONS:
c
c mode   - program calculation mode
c          = 1 for orifice leak
c          = 2 for slit leak
c ifric - integer flag for friction factor
c          = 0 for program selection
c          = 1 for laminar relation
c          = 2 for turbulent relation
```

Calculation No. S-CLC-G-00126
Sheet No. 40 of 94
Rev. 0


```
c iopt  - integer flag for flow determination
c          = 0 for optimal diameter search given initial guess diameter and
Re
c          = 1 for flow based on user specified diameter
c          = 2 for flow based on user specified Reynold's number
c
c   mode ifric iopt
    2    1     0
c
c PARTICLE SIZE DISTRIBUTION TABLE PARAMETERS:
c
c   Starting
c   Particle
c   Size            Geometric     Number of
c   (um)            Step Size     Intervals
c   ____________    ___________   ___________
    1.00000E+00     2.00000E+00   10
c
c PARAMETER INPUT:
c
c   Initial Slit                  Slit or
c   Width or        Slit          Orifice
c   Orifice Dia.    Length        Depth          Reynold's
c   (in)            (in)          (in)           Number
c   ____________    ___________   ___________    ___________
    1.00000E-03     1.00000E+00   6.50000E-02    2.00000E+03
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    Density        Viscosity       Diameter       Constant
c    (g/cc)         (centi-poise)   (æm)           (q)
c.   ___________    _____________   ___________    ___________
     1.14800E+00    1.35000E+00     1.90000E+01    2.40000E+00
c
c    Ambient        Wind
c    Density        Speed
c    (g/cc)         (m/s)
c    ___________    _____________
     1.22000E-03    1.50000E+00
```

MESSAGES:

Slit Model

Code search for optimal equivalent diameter.

Friction factor based on laminar flow.

OUTPUT:

```
     Liquid Velocity =  8.48E+01 ft/s      2.59E+01 m/s
                   Reynolds    Number    =       1.75E+03    Laminar    Flow
```

Sauter Mean Diameter =	1.52E+01 æm			
Mass Median Diameter =	1.99E+01 æm			
Characteristic Dia. =	2.32E+01 æm			
Optimum Slit Width =	1.57E-03 in	3.98E-05 m		
Respirable Fraction =	4.62E-01			
Total Leak Rate =	4.15E-01 gpm	2.62E-05 m3/s	3.00E+01 g/s	
Respirable Leak Rate =	1.92E-01 gpm	1.21E-05 m3/s	1.39E+01 g/s	
Jet Rise =	5.22E-01 ft	1.59E-01 m		

Particle Diameter Sections (m)	Section Release Rate (kg/s)	Cumulative Release Rate (kg/s)	Cumulative Percent (%)
1.00E-06	1.59E-05	1.59E-05	0.05
2.00E-06	6.79E-05	8.38E-05	0.28
4.00E-06	3.56E-04	4.40E-04	1.46
8.00E-06	1.81E-03	2.25E-03	7.49
1.60E-05	7.87E-03	1.01E-02	33.69
3.20E-05	1.65E-02	2.66E-02	88.56
6.40E-05	3.43E-03	3.00E-02	100.00
1.28E-04	3.22E-07	3.00E-02	100.00
2.56E-04	0.00E+00	3.00E-02	100.00
5.12E-04	0.00E+00	3.00E-02	100.00

SPRAY Version 3.2

August 31, 1995

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


Run Date = 06/11/96/
Run Time = 15:32:41.60


INPUT ECHO:
c 20% NaOH solution, 50 psi, 50C
c SPRAY Code Version 3.2 Input File
c
c MODEL OPTIONS:
c
c mode  - program calculation mode
c         = 1 for orifice leak
c         = 2 for slit leak
c ifric - integer flag for friction factor
c         = 0 for program selection
c         = 1 for laminar relation
c         = 2 for turbulent relation
```

```
c iopt  - integer flag for flow determination
c         = 0 for optimal diameter search given initial guess diameter and
Re
c         = 1 for flow based on user specified diameter
c         = 2 for flow based on user specified Reynold's number
c
c   mode ifric iopt
    2     1     0
c
c PARTICLE SIZE DISTRIBUTION TABLE PARAMETERS:
c
c   Starting
c   Particle
c   Size            Geometric      Number of
c   (um)            Step Size      Intervals
c   ____________    ___________    ___________
    1.00000E+00     2.00000E+00    10
c
c PARAMETER INPUT:
c
c   Initial Slit                   Slit or
c   Width or        Slit           Orifice
c   Orifice Dia.    Length         Depth          Reynold's
c   (in)            (in)           (in)           Number
c   ____________    ___________    ___________    ___________
    1.00000E-03     1.00000E+00    6.50000E-02    2.00000E+03
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   Density         Viscosity       Diameter        Constant
c   (g/cc)          (centi-poise)   (æm)            (q)
c   ____________    ____________    ____________    ____________
    1.20200E+00     1.90000E+00     1.70000E+01     2.40000E+00
c
c   Ambient         Wind
c   Density         Speed
c   (g/cc)          (m/s)
c   ____________    ____________
    1.22000E-03     1.50000E+00
```

MESSAGES:

Slit Model

Code search for optimal equivalent diameter.

Friction factor based on laminar flow.

OUTPUT:

Liquid Velocity = 7.93E+01 ft/s   2.42E+01 m/s

Reynolds Number = 1.29E+03 Laminar Flow

Sauter Mean Diameter =	1.85E+01 æm		
Mass Median Diameter =	2.43E+01 æm		
Characteristic Dia. =	2.83E+01 æm		
Optimum Slit Width =	1.67E-03 in	4.23E-05 m	
Respirable Fraction =	2.55E-01		
Total Leak Rate =	4.12E-01 gpm	2.60E-05 m3/s	3.12E+01 g/s
Respirable Leak Rate =	1.05E-01 gpm	6.63E-06 m3/s	7.97E+00 g/s
Jet Rise =	5.16E-01 ft	1.57E-01 m	

Particle Diameter Sections (m)	Section Release Rate (kg/s)	Cumulative Release Rate (kg/s)	Cumulative Percent (%)
1.00E-06	1.03E-05	1.03E-05	0.03
2.00E-06	4.38E-05	5.41E-05	0.17
4.00E-06	2.30E-04	2.84E-04	0.91
8.00E-06	1.19E-03	1.47E-03	4.71
1.60E-05	5.55E-03	7.03E-03	22.50
3.20E-05	1.61E-02	2.31E-02	73.96
6.40E-05	8.11E-03	3.12E-02	99.92
1.28E-04	2.57E-05	3.12E-02	100.00
2.56E-04	0.00E+00	3.12E-02	100.00
5.12E-04	0.00E+00	3.12E-02	100.00

SPRAY Version 3.2

August 31, 1995

Spray Leak Code

Produced by Radiological & Toxicological Analysis

Westinghouse Hanford Company

Run Date = 06/11/96/

Run Time = 15:32:42.10

```
INPUT ECHO:
c 25% solution, 125 psi, 50C
c SPRAY Code Version 3.2 Input File
c
c MODEL OPTIONS:
c
c mode  - program calculation mode
c         = 1 for orifice leak
c         = 2 for slit leak
c ifric - integer flag for friction factor
c         = 0 for program selection
c         = 1 for laminar relation
c         = 2 for turbulent relation
```

```
c iopt  - integer flag for flow determination
c          = 0 for optimal diameter search given initial guess diameter and
Re
c          = 1 for flow based on user specified diameter
c          = 2 for flow based on user specified Reynold's number
c
c   mode ifric iopt
    2    1    0
c
c PARTICLE SIZE DISTRIBUTION TABLE PARAMETERS:
c
c   Starting
c   Particle
c   Size          Geometric      Number of
c   (um)          Step Size      Intervals
c   ____________  ____________   ____________
    1.00000E+00   2.00000E+00    10
c
c PARAMETER INPUT:
c
c   Initial Slit                 Slit or
c   Width or      Slit           Orifice
c   Orifice Dia.  Length         Depth          Reynold's
c   (in)          (in)           (in)           Number
c   ____________  ____________   ____________   ____________
    1.00000E-03   1.00000E+00    6.50000E-02    2.00000E+03
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    Density          Viscosity        Diameter        Constant
c    (g/cc)           (centi-poise)    (µm)            (q)
c    ___________      ____________     ___________     ___________
     1.25570E+00      2.90000E+00      1.60000E+01     2.40000E+00
c
c    Ambient          Wind
c    Density          Speed
c    (g/cc)           (m/s)
c    ___________      ____________
     1.22000E-03      1.50000E+00


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


OUTPUT:
     Liquid Velocity =  7.63E+01 ft/s      2.33E+01 m/s
                 Reynolds   Number   =      1.01E+03    Laminar    Flow
```

Sauter Mean Diameter =	2.54E+01 æm		
Mass Median Diameter =	3.33E+01 æm		
Characteristic Dia. =	3.88E+01 æm		
Optimum Slit Width =	1.97E-03 in	5.01E-05 m	
Respirable Fraction =	1.13E-01		
Total Leak Rate =	4.69E-01 gpm	2.96E-05 m3/s	3.71E+01 g/s
Respirable Leak Rate =	5.28E-02 gpm	3.33E-06 m3/s	4.18E+00 g/s
Jet Rise =	5.63E-01 ft	1.72E-01 m	

Particle Diameter Sections (m)	Section Release Rate (kg/s)	Cumulative Release Rate (kg/s)	Cumulative Percent (%)
1.00E-06	5.72E-06	5.72E-06	0.02
2.00E-06	2.45E-05	3.02E-05	0.08
4.00E-06	1.29E-04	1.59E-04	0.43
8.00E-06	6.72E-04	8.31E-04	2.24
1.60E-05	3.35E-03	4.18E-03	11.26
3.20E-05	1.32E-02	1.74E-02	46.77
6.40E-05	1.84E-02	3.58E-02	96.41
1.28E-04	1.33E-03	3.71E-02	100.00
2.56E-04	0.00E+00	3.71E-02	100.00
5.12E-04	0.00E+00	3.71E-02	100.00

```
SPRAY Version 3.2
August 31, 1995

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

Run Date = 06/11/96/
Run Time = 15:32:42.59

INPUT ECHO:
c 30% NaOH solution, 125 psi, 50C
c SPRAY Code Version 3.2 Input File
c
c MODEL OPTIONS:
c
c mode   - program calculation mode
c          = 1 for orifice leak
c          = 2 for slit leak
c ifric - integer flag for friction factor
c          = 0 for program selection
c          = 1 for laminar relation
c          = 2 for turbulent relation
c iopt   - integer flag for flow determination
```

```
c          = 0 for optimal diameter search given initial guess diameter and
Re
c          = 1 for flow based on user specified diameter
c          = 2 for flow based on user specified Reynold's number
c
c   mode ifric iopt
    2     1     0
c
c PARTICLE SIZE DISTRIBUTION TABLE PARAMETERS:
c
c   Starting
c   Particle
c   Size            Geometric      Number of
c   (um)            Step Size      Intervals
c   ____________    ___________    ___________
    1.00000E+00     2.00000E+00    10
c
c PARAMETER INPUT:
c
c   Initial Slit                   Slit or
c   Width or        Slit           Orifice
c   Orifice Dia.    Length         Depth          Reynold's
c   (in)            (in)           (in)           Number
c   ____________    ___________    ___________    ___________
    1.00000E-02     1.00000E+00    6.50000E-02    2.00000E+03
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    Density        Viscosity        Diameter        Constant
c    (g/cc)         (centi-poise)    (μm)            (q)
c    ___________    _____________    ___________     ___________
     1.30880E+00    4.30000E+00      1.50000E+01     2.40000E+00
c
c    Ambient        Wind
c    Density        Speed
c    (g/cc)         (m/s)
c    ___________    _____________
     1.22000E-03    1.50000E+00


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


OUTPUT:
     Liquid Velocity =  7.41E+01 ft/s      2.26E+01 m/s
                 Reynolds   Number   =      8.15E+02   Laminar   Flow
```

Calculation No.	S-CLC-G-00126
Sheet No.	54 of 94
Rev.	0

Sauter Mean Diameter =	3.44E+01 æm		
Mass Median Diameter =	4.51E+01 æm		
Characteristic Dia. =	5.26E+01 æm		
Optimum Slit Width =	2.34E-03 in	5.94E-05 m	
Respirable Fraction =	4.81E-02		
Total Leak Rate =	5.40E-01 gpm	3.41E-05 m3/s	4.46E+01 g/s
Respirable Leak Rate =	2.60E-02 gpm	1.64E-06 m3/s	2.15E+00 g/s
Jet Rise =	6.21E-01 ft	1.89E-01 m	

Particle Diameter Sections (m)	Section Release Rate (kg/s)	Cumulative Release Rate (kg/s)	Cumulative Percent (%)
1.00E-06	3.31E-06	3.31E-06	0.01
2.00E-06	1.41E-05	1.75E-05	0.04
4.00E-06	7.46E-05	9.21E-05	0.21
8.00E-06	3.92E-04	4.84E-04	1.08
1.60E-05	2.01E-03	2.49E-03	5.59
3.20E-05	9.19E-03	1.17E-02	26.21
6.40E-05	2.39E-02	3.56E-02	79.89
1.28E-04	8.96E-03	4.46E-02	99.98
2.56E-04	9.39E-06	4.46E-02	100.00
5.12E-04	0.00E+00	4.46E-02	100.00

SPRAY Version 3.2

August 31, 1995

Spray Leak Code

Produced by Radiological & Toxicological Analysis

Westinghouse Hanford Company

Run Date = 06/11/96/

Run Time = 15:32:43.09

INPUT ECHO:

```
c 40% NaOH solution, 125 psi, 50C
c SPRAY Code Version 3.2 Input File
c
c MODEL OPTIONS:
c
c mode  - program calculation mode
c         = 1 for orifice leak
c         = 2 for slit leak
c ifric - integer flag for friction factor
c         = 0 for program selection
c         = 1 for laminar relation
c         = 2 for turbulent relation
```

```
c iopt   - integer flag for flow determination
c          = 0 for optimal diameter search given initial guess diameter and
Re
c          = 1 for flow based on user specified diameter
c          = 2 for flow based on user specified Reynold's number
c
c   mode ifric iopt
    2    1     0
c
c PARTICLE SIZE DISTRIBUTION TABLE PARAMETERS:
c
c   Starting
c   Particle
c   Size            Geometric      Number of
c   (um)            Step Size      Intervals
c   ___________     ___________    ___________
    1.00000E+00     2.00000E+00    10
c
c PARAMETER INPUT:
c
c   Initial Slit                   Slit or
c   Width or        Slit           Orifice
c   Orifice Dia.    Length         Depth          Reynold's
c   (in)            (in)           (in)           Number
c   ___________     ___________    ___________    ___________
    1.00000E-02     1.00000E+00    6.50000E-02    2.00000E+03
c
c                   Absolute
c                   Surface
c                   Roughness      Contraction    Velocity
c                   (in)           Coefficient    Coefficient
```

Calculation No. S-CLC-G-00126
Sheet No. 57 of 94
Rev. 0


```
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    1.02000E-02    1.00000E+00    8.20000E-01
c
c   Fluid          Dynamic          Respirable     RR Fitting
c   Density        Viscosity        Diameter       Constant
c   (g/cc)         (centi-poise)    (æm)           (q)
c   ___________    _____________    __________     __________
    1.40960E+00    8.50000E+00      1.40000E+01    2.40000E+00
c
c   Ambient        Wind
c   Density        Speed
c   (g/cc)         (m/s)
c   ___________    ___________
    1.22000E-03    1.50000E+00
```

MESSAGES:

Slit Model

Code search for optimal equivalent diameter.

Friction factor based on laminar flow.

OUTPUT:

Liquid Velocity = 7.10E+01 ft/s   2.16E+01 m/s

Reynolds Number = 5.80E+02 Laminar Flow

Calculation No. S-CLC-G-00126
Sheet No. 58 of 94
Rev. 0

Sauter Mean Diameter =	5.89E+01 æm		
Mass Median Diameter =	7.72E+01 æm		
Characteristic Dia. =	9.00E+01 æm		
Optimum Slit Width =	3.19E-03 in	8.11E-05 m	
Respirable Fraction =	1.14E-02		
Total Leak Rate =	7.06E-01 gpm	4.45E-05 m3/s	6.28E+01 g/s
Respirable Leak Rate =	8.07E-03 gpm	5.09E-07 m3/s	7.18E-01 g/s
Jet Rise =	7.50E-01 ft	2.29E-01 m	

Particle Diameter Sections (m)	Section Release Rate (kg/s)	Cumulative Release Rate (kg/s)	Cumulative Percent (%)
1.00E-06	1.28E-06	1.28E-06	0.00
2.00E-06	5.48E-06	6.77E-06	0.01
4.00E-06	2.89E-05	3.57E-05	0.06
8.00E-06	1.53E-04	1.88E-04	0.30
1.60E-05	7.99E-04	9.87E-04	1.57
3.20E-05	4.05E-03	5.04E-03	8.02
6.40E-05	1.74E-02	2.24E-02	35.68
1.28E-04	3.43E-02	5.67E-02	90.26
2.56E-04	6.11E-03	6.28E-02	100.00
5.12E-04	2.91E-07	6.28E-02	100.00

SPRAY Version 3.2
August 31, 1995

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

Run Date = 06/11/96/
Run Time = 15:41:01.37

INPUT ECHO:

```
c 50% solution, 125 psi, 50C
c SPRAY Code Version 3.2 Input File
c
c MODEL OPTIONS:
c
c mode  - program calculation mode
c         = 1 for orifice leak
c         = 2 for slit leak
c ifric - integer flag for friction factor
c         = 0 for program selection
c         = 1 for laminar relation
c         = 2 for turbulent relation
```

```
c iopt  - integer flag for flow determination
c          = 0 for optimal diameter search given initial guess diameter and
Re
c          = 1 for flow based on user specified diameter
c          = 2 for flow based on user specified Reynold's number
c
c   mode ifric iopt
    2     1     0
c
c PARTICLE SIZE DISTRIBUTION TABLE PARAMETERS:
c
c   Starting
c   Particle
c   Size            Geometric       Number of
c   (um)            Step Size       Intervals
c   ___________     ___________     ___________
    1.00000E+00     2.00000E+00     10
c
c PARAMETER INPUT:
c
c   Initial Slit                    Slit or
c   Width or        Slit            Orifice
c   Orifice Dia.    Length          Depth           Reynold's
c   (in)            (in)            (in)            Number
c   ___________     ___________     ___________     ___________
    1.00000E-02     1.00000E+00     6.50000E-02     2.00000E+03
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 1.02000E-02 1.00000E+00 8.20000E-01

c

Fluid Density (g/cc)	Dynamic Viscosity (centi-poise)	Respirable Diameter (μm)	RR Fitting Constant (q)
1.50380E+00	1.45000E+01	1.30000E+01	2.40000E+00

c

Ambient Density (g/cc)	Wind Speed (m/s)
1.22000E-03	1.50000E+00

MESSAGES:

Slit Model

Code search for optimal equivalent diameter.

Friction factor based on laminar flow.

OUTPUT:

Liquid Velocity = 6.88E+01 ft/s 2.10E+01 m/s

Reynolds Number = 4.53E+02 Laminar Flow

Sauter Mean Diameter =	9.04E+01 æm			
Mass Median Diameter =	1.19E+02 æm			
Characteristic Dia. =	1.38E+02 æm			
Optimum Slit Width =	4.12E-03 in	1.05E-04 m		
Respirable Fraction =	3.43E-03			
Total Leak Rate =	8.83E-01 gpm	5.57E-05 m3/s	8.38E+01 g/s	
Respirable Leak Rate =	3.03E-03 gpm	1.91E-07 m3/s	2.88E-01 g/s	
Jet Rise =	8.80E-01 ft	2.68E-01 m		

Particle Diameter Sections (m)	Section Release Rate (kg/s)	Cumulative Release Rate (kg/s)	Cumulative Percent (%)
1.00E-06	6.11E-07	6.11E-07	0.00
2.00E-06	2.61E-06	3.22E-06	0.00
4.00E-06	1.38E-05	1.70E-05	0.02
8.00E-06	7.28E-05	8.98E-05	0.11
1.60E-05	3.83E-04	4.73E-04	0.56
3.20E-05	1.99E-03	2.47E-03	2.94
6.40E-05	9.75E-03	1.22E-02	14.58
1.28E-04	3.51E-02	4.73E-02	56.48
2.56E-04	3.54E-02	8.27E-02	98.76
5.12E-04	1.04E-03	8.38E-02	100.00

Appendix C

SPRAY32 output files for bounding concentration determination.

SPRAY Version 3.2
August 31, 1995

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

Run Date = 06/25/96/
Run Time = 21:15:29.11

```
INPUT ECHO:
c 10% NaOH solution, 8  psi, 50 C
c SPRAY Code Version 3.2 Input File
c
c MODEL OPTIONS:
c
c mode   - program calculation mode
c          = 1 for orifice leak
c          = 2 for slit leak
c ifric - integer flag for friction factor
c          = 0 for program selection
c          = 1 for laminar relation
c          = 2 for turbulent relation
c iopt   - integer flag for flow determination
c          = 0 for optimal diameter search given initial guess diameter and Re
```

```
c          = 1 for flow based on user specified diameter
c          = 2 for flow based on user specified Reynold's number
c
c   mode ifric iopt
    2     1     0
c
c PARTICLE SIZE DISTRIBUTION TABLE PARAMETERS:
c
c   Starting
c   Particle
c   Size            Geometric       Number of
c   (um)            Step Size       Intervals
c   ___________     ___________     ___________
    1.00000E+00     2.00000E+00     10
c
c PARAMETER INPUT:
c
c  Initial Slit                    Slit or
c  Width or         Slit           Orifice
c  Orifice Dia.     Length         Depth          Reynold's
c  (in)             (in)           (in)           Number
c  ___________      ___________    ___________    ___________
   1.00000E-03      1.00000E+00    6.50000E-02    2.00000E+03
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 orific
```

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```
c    ____________   ______________   ____________   ____________
     8.00000E+00    1.80000E-03      1.00000E+00    8.20000E-01
c
c    Fluid          Dynamic          Respirable     RR Fitting
c    Density        Viscosity        Diameter       Constant
c    (g/cc)         (centi-poise)    (µm)           (q)
c    ____________   ______________   ____________   ____________
     1.09420E+00    9.60000E-01      1.00000E+01    2.40000E+00
c
c    Ambient        Wind
c    Density        Speed
c    (g/cc)         (m/s)
c    ____________   ______________
     1.22000E-03    1.50000E+00


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


OUTPUT:
      Liquid Velocity =  2.04E+01 ft/s       6.21E+00 m/s
      Reynolds Number =  8.15E+02 Laminar Flow
Sauter Mean Diameter =  9.28E+01 æm
Mass Median Diameter =  1.22E+02 æm
Characteristic Dia.  =  1.42E+02 æm
  Optimum Slit Width =  2.27E-03 in        5.76E-05 m
 Respirable Fraction =  1.72E-03
     Total Leak Rate =  1.44E-01 gpm       9.10E-06 m3/s     9.95E+00 g/s
```

Respirable Leak Rate = 2.48E-04 gpm 1.57E-08 m3/s 1.71E-02 g/s

Jet Rise = 1.58E-01 ft 4.81E-02 m

Particle Diameter Sections (m)	Section Release Rate (kg/s)	Cumulative Release Rate (kg/s)	Cumulative Percent (%)
1.00E-06	6.83E-08	6.83E-08	0.00
2.00E-06	2.92E-07	3.60E-07	0.00
4.00E-06	1.54E-06	1.90E-06	0.02
8.00E-06	8.13E-06	1.00E-05	0.10
1.60E-05	4.28E-05	5.29E-05	0.53
3.20E-05	2.23E-04	2.76E-04	2.77
6.40E-05	1.10E-03	1.37E-03	13.79
1.28E-04	4.03E-03	5.40E-03	54.29
2.56E-04	4.39E-03	9.79E-03	98.40
5.12E-04	1.60E-04	9.95E-03	100.00

SPRAY Version 3.2

August 31, 1995

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


Run Date = 06/25/96/
Run Time = 21:18:20.65


INPUT ECHO:
c 10% NaOH solution, 10 psi, 50 C
c SPRAY Code Version 3.2 Input File
c
c MODEL OPTIONS:
c
c mode   - program calculation mode
c          = 1 for orifice leak
c          = 2 for slit leak
c ifric - integer flag for friction factor
c          = 0 for program selection
c          = 1 for laminar relation
c          = 2 for turbulent relation
```

```
c iopt - integer flag for flow determination
c        = 0 for optimal diameter search given initial guess diameter and
Re
c        = 1 for flow based on user specified diameter
c        = 2 for flow based on user specified Reynold's number
c
c   mode ifric iopt
    2    1     0
c
c PARTICLE SIZE DISTRIBUTION TABLE PARAMETERS:
c
c   Starting
c   Particle
c   Size            Geometric        Number of
c   (um)            Step Size        Intervals
c   ____________    ____________     ____________
    1.00000E+00     2.00000E+00      10
c
c PARAMETER INPUT:
c
c   Initial Slit                     Slit or
c   Width or        Slit             Orifice
c   Orifice Dia.    Length           Depth            Reynold's
c   (in)            (in)             (in)             Number
c   ____________    ____________     ____________     ____________
    1.00000E-03     1.00000E+00      1.09000E-01      2.00000E+03
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              __________         __________        __________
__________________________________
    1.00000E+01    1.80000E-03    1.00000E+00    8.20000E-01
c
c   Fluid          Dynamic        Respirable     RR Fitting
c   Density        Viscosity      Diameter       Constant
c   (g/cc)         (centi-poise)  (µm)           (q)
c   __________     __________     __________     __________
    1.09420E+00    9.60000E-01    1.00000E+01    2.40000E+00
c
c   Ambient        Wind
c   Density        Speed
c   (g/cc)         (m/s)
c   __________     __________
    1.22000E-03    1.50000E+00
```

MESSAGES:

Slit Model

Code search for optimal equivalent diameter.

Friction factor based on laminar flow.

OUTPUT:

Liquid Velocity = 2.28E+01 ft/s   6.94E+00 m/s

Reynolds Number = 1.11E+03 Laminar Flow

Sauter Mean Diameter =	1.06E+02 æm		
Mass Median Diameter =	1.39E+02 æm		
Characteristic Dia. =	1.62E+02 æm		
Optimum Slit Width =	2.78E-03 in	7.05E-05 m	
Respirable Fraction =	1.26E-03		
Total Leak Rate =	1.97E-01 gpm	1.24E-05 m3/s	1.36E+01 g/s
Respirable Leak Rate =	2.48E-04 gpm	1.56E-08 m3/s	1.71E-02 g/s
Jet Rise =	2.02E-01 ft	6.15E-02 m	

Particle Diameter Sections (m)	Section Release Rate (kg/s)	Cumulative Release Rate (kg/s)	Cumulative Percent (%)
1.00E-06	6.82E-08	6.82E-08	0.00
2.00E-06	2.92E-07	3.60E-07	0.00
4.00E-06	1.54E-06	1.90E-06	0.01
8.00E-06	8.12E-06	1.00E-05	0.07
1.60E-05	4.28E-05	5.28E-05	0.39
3.20E-05	2.24E-04	2.77E-04	2.03
6.40E-05	1.12E-03	1.40E-03	10.28
1.28E-04	4.53E-03	5.93E-03	43.58
2.56E-04	7.01E-03	1.29E-02	95.12
5.12E-04	6.63E-04	1.36E-02	100.00

SPRAY Version 3.2

August 31, 1995

Spray Leak Code

Produced by Radiological & Toxicological Analysis

Westinghouse Hanford Company

Run Date = 06/25/96/

Run Time = 21:13:31.74

INPUT ECHO:

```
c 10% NaOH solution, 11 psi, 50 C
c SPRAY Code Version 3.2 Input File
c
c MODEL OPTIONS:
c
c mode  - program calculation mode
c         = 1 for orifice leak
c         = 2 for slit leak
c ifric - integer flag for friction factor
c         = 0 for program selection
c         = 1 for laminar relation
c         = 2 for turbulent relation
```

```
c iopt  - integer flag for flow determination
c          = 0 for optimal diameter search given initial guess diameter and
Re
c          = 1 for flow based on user specified diameter
c          = 2 for flow based on user specified Reynold's number
c
c   mode ifric iopt
    2     1     0
c
c PARTICLE SIZE DISTRIBUTION TABLE PARAMETERS:
c
c   Starting
c   Particle
c   Size           Geometric      Number of
c   (um)           Step Size      Intervals
c   ____________   ___________    ___________
    1.00000E+00    2.00000E+00    10
c
c PARAMETER INPUT:
c
c   Initial Slit                  Slit or
c   Width or       Slit           Orifice
c   Orifice Dia.   Length         Depth          Reynold's
c   (in)           (in)           (in)           Number
c   ____________   ___________    ___________    ___________
    1.00000E-03    1.00000E+00    1.33000E-01    2.00000E+03
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          _______________       _______________    _______________
_______________________________
     1.10000E+01    1.80000E-03    1.00000E+00    8.20000E-01
c
c    Fluid          Dynamic          Respirable     RR Fitting
c    Density        Viscosity        Diameter       Constant
c    (g/cc)         (centi-poise)    (μm)           (q)
c    ____________   ______________   ____________   ____________
     1.09420E+00    9.60000E-01      1.00000E+01    2.40000E+00
c
c    Ambient        Wind
c    Density        Speed
c    (g/cc)         (m/s)
c    ____________   ______________
     1.22000E-03    1.50000E+00
```

MESSAGES:

Slit Model

Code search for optimal equivalent diameter.

Friction factor based on laminar flow.

OUTPUT:

```
     Liquid Velocity =  2.40E+01 ft/s      7.30E+00 m/s
                 Reynolds    Number    =        1.27E+03    Laminar    Flow
```

Sauter Mean Diameter = 1.11E+02 æm
Mass Median Diameter = 1.45E+02 æm
Characteristic Dia. = 1.69E+02 æm
Optimum Slit Width = 3.01E-03 in   7.66E-05 m
Respirable Fraction = 1.12E-03
Total Leak Rate = 2.25E-01 gpm   1.42E-05 m3/s   1.55E+01 g/s
Respirable Leak Rate = 2.53E-04 gpm   1.60E-08 m3/s   1.75E-02 g/s
Jet Rise = 2.24E-01 ft   6.83E-02 m

Particle Diameter Sections (m)	Section Release Rate (kg/s)	Cumulative Release Rate (kg/s)	Cumulative Percent (%)
1.00E-06	6.96E-08	6.96E-08	0.00
2.00E-06	2.98E-07	3.67E-07	0.00
4.00E-06	1.57E-06	1.94E-06	0.01
8.00E-06	8.29E-06	1.02E-05	0.07
1.60E-05	4.37E-05	5.39E-05	0.35
3.20E-05	2.28E-04	2.82E-04	1.82
6.40E-05	1.15E-03	1.43E-03	9.23
1.28E-04	4.78E-03	6.22E-03	40.01
2.56E-04	8.27E-03	1.45E-02	93.26
5.12E-04	1.05E-03	1.55E-02	100.00

```
SPRAY Version 3.2
August 31, 1995

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

Run Date = 06/25/96/
Run Time = 21:25:29.34

INPUT ECHO:
c 10% NaOH solution, 13 psi, 50 C
c SPRAY Code Version 3.2 Input File
c
c MODEL OPTIONS:
c
c mode  - program calculation mode
c          = 1 for orifice leak
c          = 2 for slit leak
c ifric - integer flag for friction factor
c          = 0 for program selection
c          = 1 for laminar relation
c          = 2 for turbulent relation
```

```
c iopt  - integer flag for flow determination
c         = 0 for optimal diameter search given initial guess diameter and
Re [illegible]
c         = 1 for flow based on user specified diameter
c         = 2 for flow based on user specified Reynold's number
c
c   mode ifric iopt
     2     1     0
c
c PARTICLE SIZE DISTRIBUTION TABLE PARAMETERS:
c
c   Starting
c   Particle
c   Size            Geometric      Number of
c   (um)            Step Size      Intervals
c   ____________    ___________    __________
    1.00000E+00     2.00000E+00    10
c
c PARAMETER INPUT:
c
c   Initial Slit                   Slit or
c   Width or        Slit           Orifice
c   Orifice Dia.    Length         Depth          Reynold's
c   (in)            (in)           (in)           Number
c   ____________    ___________    ___________    ___________
    1.00000E-03     1.00000E+00    1.79000E-01    2.00000E+03
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              ___________        ___________      ___________
______________________________
     1.30000E+01    1.80000E-03    1.00000E+00    8.20000E-01
c
c    Fluid          Dynamic         Respirable     RR Fitting
c    Density        Viscosity       Diameter       Constant
c    (g/cc)         (centi-poise)   (µm)           (q)
c    ___________    ___________     ___________    ___________
     1.09420E+00    9.60000E-01     1.00000E+01    2.40000E+00
c
c    Ambient        Wind
c    Density        Speed
c    (g/cc)         (m/s)
c    ___________    ___________
     1.22000E-03    1.50000E+00
```

MESSAGES:

Slit Model

Code search for optimal equivalent diameter.

Friction factor based on laminar flow.

OUTPUT:

```
     Liquid Velocity =  2.59E+01 ft/s      7.89E+00 m/s
               Reynolds    Number    =      1.51E+03    Laminar    Flow
```

Sauter Mean Diameter =	1.15E+02	æm				
Mass Median Diameter =	1.51E+02	æm				
Characteristic Dia. =	1.76E+02	æm				
Optimum Slit Width =	3.32E-03	in	8.43E-05	m		
Respirable Fraction =	1.03E-03					
Total Leak Rate =	2.68E-01	gpm	1.69E-05	m3/s	1.85E+01	g/s
Respirable Leak Rate =	2.75E-04	gpm	1.74E-08	m3/s	1.90E-02	g/s
Jet Rise =	2.58E-01	ft	7.88E-02	m		

Particle Diameter Sections (m)	Section Release Rate (kg/s)	Cumulative Release Rate (kg/s)	Cumulative Percent (%)
1.00E-06	7.57E-08	7.57E-08	0.00
2.00E-06	3.24E-07	3.99E-07	0.00
4.00E-06	1.71E-06	2.11E-06	0.01
8.00E-06	9.01E-06	1.11E-05	0.06
1.60E-05	4.75E-05	5.86E-05	0.32
3.20E-05	2.49E-04	3.07E-04	1.66
6.40E-05	1.26E-03	1.57E-03	8.46
1.28E-04	5.33E-03	6.90E-03	37.28
2.56E-04	1.00E-02	1.69E-02	91.47
5.12E-04	1.58E-03	1.85E-02	100.00

SPRAY Version 3.2

August 31, 1995

Spray Leak Code

Produced by Radiological & Toxicological Analysis

Westinghouse Hanford Company

Run Date = 06/25/96/

Run Time = 21:24:45.95

```
INPUT ECHO:
c 10% NaOH solution, 15 psi, 50 C
c SPRAY Code Version 3.2 Input File
c
c MODEL OPTIONS:
c
c mode  - program calculation mode
c         = 1 for orifice leak
c         = 2 for slit leak
c ifric - integer flag for friction factor
c         = 0 for program selection
c         = 1 for laminar relation
c         = 2 for turbulent relation
```

```
c iopt  - integer flag for flow determination
c          = 0 for optimal diameter search given initial guess diameter and
Re
c          = 1 for flow based on user specified diameter
c          = 2 for flow based on user specified Reynold's number
c
c  mode ifric iopt
    2    1     0
c
c PARTICLE SIZE DISTRIBUTION TABLE PARAMETERS:
c
c  Starting
c  Particle
c  Size           Geometric      Number of
c  (um)           Step Size      Intervals
c  ____________   ___________    ___________
   1.00000E+00    2.00000E+00    10
c
c PARAMETER INPUT:
c
c  Initial Slit                  Slit or
c  Width or       Slit           Orifice
c  Orifice Dia.   Length         Depth          Reynold's
c  (in)           (in)           (in)           Number
c  ____________   ___________    ___________    ___________
   1.00000E-03    1.00000E+00    2.50000E-01    2.00000E+03
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        ___________           ____________     __________
_____________________________

     1.50000E+01    1.80000E-03    1.00000E+00    8.20000E-01
c
c    Fluid          Dynamic         Respirable    RR Fitting
c    Density        Viscosity       Diameter      Constant
c    (g/cc)         (centi-poise)   (μm)          (q)
c    ___________    _____________   ___________   ___________
     1.09420E+00    9.60000E-01     1.00000E+01   2.40000E+00
c
c    Ambient        Wind
c    Density        Speed
c    (g/cc)         (m/s)
c    ___________    _____________
     1.22000E-03    1.50000E+00
```

MESSAGES:

Slit Model

Code search for optimal equivalent diameter.

Friction factor based on laminar flow.

OUTPUT:

Liquid Velocity = 2.80E+01 ft/s   8.54E+00 m/s

Reynolds Number = 1.89E+03 Laminar Flow

Calculation No.	S-CLC-G-00126
Sheet No.	83 of 94
Rev.	0

Sauter Mean Diameter =	1.26E+02 æm		
Mass Median Diameter =	1.66E+02 æm		
Characteristic Dia. =	1.93E+02 æm		
Optimum Slit Width =	3.83E-03 in	9.74E-05 m	
Respirable Fraction =	8.20E-04		
Total Leak Rate =	3.35E-01 gpm	2.11E-05 m3/s	2.31E+01 g/s
Respirable Leak Rate =	2.74E-04 gpm	1.73E-08 m3/s	1.89E-02 g/s
Jet Rise =	3.07E-01 ft	9.37E-02 m	

Particle Diameter Sections (m)	Section Release Rate (kg/s)	Cumulative Release Rate (kg/s)	Cumulative Percent (%)
1.00E-06	7.54E-08	7.54E-08	0.00
2.00E-06	3.23E-07	3.98E-07	0.00
4.00E-06	1.70E-06	2.10E-06	0.01
8.00E-06	8.98E-06	1.11E-05	0.05
1.60E-05	4.74E-05	5.84E-05	0.25
3.20E-05	2.48E-04	3.07E-04	1.33
6.40E-05	1.27E-03	1.57E-03	6.82
1.28E-04	5.61E-03	7.18E-03	31.10
2.56E-04	1.27E-02	1.99E-02	86.00
5.12E-04	3.23E-03	2.31E-02	100.00

```
SPRAY Version 3.2
August 31, 1995

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

Run Date = 06/27/96/
Run Time = 13:18:10.96

INPUT ECHO:
c 10% NaOH solution, 17 psi, 50 C
c SPRAY Code Version 3.2 Input File
c
c MODEL OPTIONS:
c
c mode  - program calculation mode
c         = 1 for orifice leak
c         = 2 for slit leak
c ifric - integer flag for friction factor
c         = 0 for program selection
c         = 1 for laminar relation
c         = 2 for turbulent relation
```

```
c iopt  - integer flag for flow determination
c          = 0 for optimal diameter search given initial guess diameter and
Re
c          = 1 for flow based on user specified diameter
c          = 2 for flow based on user specified Reynold's number
c
c   mode ifric iopt
    2     1     0
c
c PARTICLE SIZE DISTRIBUTION TABLE PARAMETERS:
c
c   Starting
c   Particle
c   Size            Geometric       Number of
c   (um)            Step Size       Intervals
c   ____________    ____________    ___________
    1.00000E+00     2.00000E+00     10
c
c PARAMETER INPUT:
c
c   Initial Slit                    Slit or
c   Width or        Slit            Orifice
c   Orifice Dia.    Length          Depth           Reynold's
c   (in)            (in)            (in)            Number
c   ____________    ____________    ___________     ____________
    1.00000E-03     1.00000E+00     3.58000E-01     2.00000E+03
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           ___________                 ____________       __________
_____________________________
       1.70000E+01     1.80000E-03     1.00000E+00     8.20000E-01
c
c     Fluid           Dynamic          Respirable      RR Fitting
c     Density         Viscosity        Diameter        Constant
c     (g/cc)          (centi-poise)    (µm)            (q)
c     ___________     ____________     __________      __________
      1.09420E+00     9.60000E-01      1.00000E+01     2.40000E+00
c
c     Ambient         Wind
c     Density         Speed
c     (g/cc)          (m/s)
c     ___________     ____________
      1.22000E-03     1.50000E+00
```

MESSAGES:

Slit Model

Code search for optimal equivalent diameter.

Friction factor based on laminar flow.

OUTPUT:

Liquid Velocity = 2.97E+01 ft/s   9.05E+00 m/s

Reynolds Number = 2.31E+03 Critical Flow

Calculation No. S-CLC-G-00126
Sheet No. 87 of 94
Rev. 0

Sauter Mean Diameter =	1.41E+02 æm		
Mass Median Diameter =	1.85E+02 æm		
Characteristic Dia. =	2.16E+02 æm		
Optimum Slit Width =	4.42E-03 in	1.12E-04 m	
Respirable Fraction =	6.28E-04		
Total Leak Rate =	4.09E-01 gpm	2.58E-05 m3/s	2.82E+01 g/s
Respirable Leak Rate =	2.57E-04 gpm	1.62E-08 m3/s	1.77E-02 g/s
Jet Rise =	3.58E-01 ft	1.09E-01 m	

Particle Diameter Sections (m)	Section Release Rate (kg/s)	Cumulative Release Rate (kg/s)	Cumulative Percent (%)
1.00E-06	7.07E-08	7.07E-08	0.00
2.00E-06	3.02E-07	3.73E-07	0.00
4.00E-06	1.60E-06	1.97E-06	0.01
8.00E-06	8.42E-06	1.04E-05	0.04
1.60E-05	4.44E-05	5.48E-05	0.19
3.20E-05	2.33E-04	2.88E-04	1.02
6.40E-05	1.20E-03	1.49E-03	5.26
1.28E-04	5.53E-03	7.01E-03	24.83
2.56E-04	1.50E-02	2.20E-02	77.83
5.12E-04	6.25E-03	2.82E-02	99.96

SPRAY Version 3.2
August 31, 1995

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

Run Date = 06/25/96/
Run Time = 21:30:53.51

INPUT ECHO:

```
c 10% NaOH solution, 18 psi, 50 C
c SPRAY Code Version 3.2 Input File
c
c MODEL OPTIONS:
c
c mode   - program calculation mode
c           = 1 for orifice leak
c           = 2 for slit leak
c ifric - integer flag for friction factor
c           = 0 for program selection
c           = 1 for laminar relation
c           = 2 for turbulent relation
```

```
c iopt  - integer flag for flow determination
c          = 0 for optimal diameter search given initial guess diameter and
Re
c          = 1 for flow based on user specified diameter
c          = 2 for flow based on user specified Reynold's number
c
c   mode ifric iopt
     2    1    0
c
c PARTICLE SIZE DISTRIBUTION TABLE PARAMETERS:
c
c   Starting
c   Particle
c   Size              Geometric       Number of
c   (um)              Step Size       Intervals
c   ______________    ____________    ____________
    1.00000E+00       2.00000E+00     10
c
c PARAMETER INPUT:
c
c   Initial Slit                      Slit or
c   Width or          Slit            Orifice
c   Orifice Dia.      Length          Depth           Reynold's
c   (in)              (in)            (in)            Number
c   ______________    ____________    ____________    ____________
    1.00000E-03       1.00000E+00     3.90500E-01     2.00000E+03
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

1.80000E+01 1.80000E-03 1.00000E+00 8.20000E-01

c

	Fluid Density (g/cc)	Dynamic Viscosity (centi-poise)	Respirable Diameter (μm)	RR Fitting Constant (q)
	1.09420E+00	9.60000E-01	1.00000E+01	2.40000E+00

c

	Ambient Density (g/cc)	Wind Speed (m/s)
	1.22000E-03	1.50000E+00

MESSAGES:

Slit Model

Code search for optimal equivalent diameter.

Friction factor based on laminar flow.

OUTPUT:

Liquid Velocity = 3.06E+01 ft/s 9.32E+00 m/s

Reynolds Number = 2.45E+03 Critical Flow

Sauter Mean Diameter =	1.42E+02 æm		
Mass Median Diameter =	1.87E+02 æm		
Characteristic Dia. =	2.17E+02 æm		
Optimum Slit Width =	4.55E-03 in	1.16E-04 m	
Respirable Fraction =	6.18E-04		
Total Leak Rate =	4.34E-01 gpm	2.74E-05 m3/s	3.00E+01 g/s
Respirable Leak Rate =	2.68E-04 gpm	1.69E-08 m3/s	1.85E-02 g/s
Jet Rise =	3.76E-01 ft	1.15E-01 m	

Particle Diameter Sections (m)	Section Release Rate (kg/s)	Cumulative Release Rate (kg/s)	Cumulative Percent (%)
1.00E-06	7.37E-08	7.37E-08	0.00
2.00E-06	3.15E-07	3.89E-07	0.00
4.00E-06	1.66E-06	2.05E-06	0.01
8.00E-06	8.78E-06	1.08E-05	0.04
1.60E-05	4.63E-05	5.72E-05	0.19
3.20E-05	2.43E-04	3.00E-04	1.00
6.40E-05	1.25E-03	1.55E-03	5.18
1.28E-04	5.78E-03	7.33E-03	24.48
2.56E-04	1.58E-02	2.32E-02	77.28
5.12E-04	6.79E-03	2.99E-02	99.96

Appendix D

Calculation No.	S-CLC-G-00126
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Rev.	0

/ /96 10:58 ☎509 373 4095 2750E LOBBY 007
ANA CORP/ BOSTON 46E D 2621868 0001507 0 E-14-05

Green Cross Linked

CROSS-LINKED POLYETHYLENE HOSE

TUBE	Cross Linked Polyethylene.
REINFORCEMENT	2 textile braids—helical wire.
COVER	EPDM.
COLOR	Green.
TEMPERATURE RANGE	−45°F to +150°F.
TYPE OF BRANDING	Impression.
SUCTION	Full vacuum.
WORKING PRESSURE	100-150 PSI.*
TYPE OF COUPLING	Non-Reattachable (Swaged), Cam and Groove, or Combination Nipple. Clamps—Interlocking, Single Bolt, Double Bolt, Band, or Wire

*Depends on Coupling.

⚠ WARNING
Consult with the coupling manufacturer to make sure you choose the correct coupling for the application and proper assembly. See coupling section, page 84, for further safety information.

Features
- EPDM cover
- Clear cross linked polyethylene tube
- Continuous printed brand/ green cover
- Smooth bore
- Serialized Lengths

Benefits
- Chemical and ozone resistant—longer hose life
- Chemical, petroleum, and solvent resistant. Won't contaminate or discolor fluids.
- Easy identification
- Rapid fluid flow
- Easy to clean
- Safety and maintenance records

Markets / Applications

Markets	Applications
Chemical/Petroleum Industry	Transfer of acids, chemicals, solvents, and petroleum products.
Lumber/Woodworking, Plywood Mfg., Pulp Processing	Transfer chemicals and solvents for processing products.
Tank Truck, Railroad Tank Car, Waste Hauling	Loading or unloading—pumping, suction, or gravity flow discharge.

CODE	NOMINAL I.D. (IN.)	NOMINAL I.D. (MM)	BRAID	NOMINAL O.D. (IN.)	NOMINAL O.D. (MM)	APPROXIMATE WEIGHT POUNDS PER 100 FT.	MAXIMUM RECOMMENDED WORKING PRESS. (PSI)	MINIMUM RECOMMENDED BEND RADIUS (IN.)	MINIMUM RECOMMENDED BEND RADIUS (MM)	STANDARD FEET
43-0378-36	1	25.4	2	1 11/16	42.9	72	150	5	127.0	60
43-0378-14	1¼	31.8	2	1 53/64	46.4	86	150	8	203.2	50
43-0378-40	1½	38.1	2	2 5/16	58.7	121	150	8	203.2	60
43-0378-42	2	50.8	2	2 25/32	70.6	146	150	9	228.6	60
43-0378-43	3	76.2	2	3 27/32	97.8	252	150	16	406.4	60
43-0378-44	4	101.6	2	4 13/16	122.2	348	100	21	533.4	50

⚠ WARNING
Before using any hoses in this section consult the chemical resistance chart and safety section on pages 85 through 83.

DANA CORP/BOSTON INDUSTRIAL PRODUCTS DIV

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DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	G. W. Ryan	Date 7/23/96
Project Title/Work Order		EDT No. N/A
Analysis of NaOH Releases for Hanford Tank Farms.		ECN No. 602623

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
C. Carro	A2-34	X			
D. S. Leach	A3-34	X			
TWRS S & L Project Files (2)	A2-26	X			
G. W. Ryan	A3-37	X			
Central Files (Original + 1)	A3-88	X			

A-6000-135 (01/93) WEF067