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

1. Approval Reason
   - 1. Approval
   - 2. Release
   - 3. Information
   - 4. Dist. (Receipt Acknow. Required)

2. Review Reason
   - 1. Review
   - 2. Post-Review
   - 3. Dist. (Receipt Acknow. Required)

3. Disapproved Reason
   - 1. Disapproved w/comment
   - 2. Disapproved w/o comment
   - 3. Review w/comment
   - 4. Review w/o comment

4. Disposition
   - 1. Approved
   - 2. Approved w/comment
   - 3. Disapproved w/comment
   - 4. Reviewed w/o comment
   - 5. Reviewed w/comment

5. Receipt Acknowledged
   - 1. Receipt acknowledged

6. Peer Rev.
   - B.E. Hey
   - 6/30/96
   - 1/2

7. Design Authority
   - D.A. Himes
   - 8/27/96
   - 1
   - 1

8. Design Agent
   - D.A. Himes
   - 8/27/96
   - 1

   - 8/27/96
   - 1

10. QA
    - 8/27/96
    - 1

11. Safety
    - 8/27/96
    - 1

12. Env.
    - 8/27/96
    - 1

13. Signature of EDT Originator
    - 8/27/96

14. Authorized Representative Date for Receiving Organization
    - N/A

15. Title or Description of Data Transmitted
    - Consequence Analysis of an Unmitigated NaOH Solution Spray Release During Addition to Waste Tank

16. Approval Designator
    - N/A

17. DOE APPROVAL (if required)
    - Ctrl. No. N/A
    - [N/A] Approved
    - [] Approved w/comments
    - [ ] Disapproved w/comments

18. Design Authority/ Cognizant Manager
    - D.S. Leach
    - 8/27/96
    - 1

19. N/A
    - 8/27/96

20. Date
    - 8/27/96

21. Date
    - 8/27/96
Consequence Analysis of an Unmitigated NaOH Solution Spray Release During Addition to Waste Tank

D.A. Himes
Westinghouse Hanford Company, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-87RL10930

EDT/ECN: 142249    UC: 510
Org Code: 8M400    Charge Code: N1FC3
B&R Code: EW3120071    Total Pages: 26

Key Words: Caustic, NaOH, pH adjustment

Abstract: Toxicological consequences were calculated for a postulated maximum caustic soda (NaOH) solution spray leak during addition to a waste tank to adjust tank pH. Although onsite risk guidelines were exceeded for the unmitigated release, site boundary consequences were below the level of concern. Means of mitigating the release so as to greatly reduce the onsite consequences were recommended.
Aqueous NaOH solutions are added as needed to Hanford waste tanks to adjust waste pH so as to minimize corrosion in the tanks. These additions are normally made from a tank truck through any of a variety of pipes, hoses and pumps. The lightest equipment considered to be suitable for NaOH solution transport is 1 inch schedule 10 commercial steel pipe with a wall thickness of 0.109 inches. The largest pipe or hose considered is 2 inch cross linked polyethylene hose with a wall thickness of 25/64 inch. The maximum pressure the system can be subjected to is 125 psig. The highest temperature at which the tank truck is loaded is 120°F (49°C). The solution concentration could be anywhere in the range 5 to 50% NaOH.

An evaluation is required of the maximum NaOH air concentrations which could occur at the onsite (100 m) and site boundary receptors due to a spray leak during a transfer to a waste tank.

**Accident description:**

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

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

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

Acute 99.5 percentile ground level release dispersion factors (X/Q) have been generated for the Hanford tank farms using the GXQ code (Hey 1994) at each of the 16 sectors at 100 m and at the site boundary or the near bank of the Columbia River. Since maximum air concentrations are the primary concern for toxic releases, no plume meander was assumed. The resulting X/Qs are reported in WHC-SD-WM-SARR-016 (Savino 1996) as 3.41E-2 s/m³ onsite (100 m E) and 2.83E-5 s/m³ at the site boundary (8.76 km N).

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

\[
D_i = \frac{10 \ \mu m}{f_s^{1/3}}
\]  

(1)

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

<table>
<thead>
<tr>
<th>% NaOH</th>
<th>Density (g/cm³)</th>
<th>Viscosity (centipoise)</th>
<th>D_r (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1.041</td>
<td>0.80</td>
<td>27.1</td>
</tr>
<tr>
<td>10</td>
<td>1.094</td>
<td>0.96</td>
<td>21.5</td>
</tr>
<tr>
<td>12</td>
<td>1.116</td>
<td>1.1</td>
<td>20.3</td>
</tr>
<tr>
<td>15</td>
<td>1.148</td>
<td>1.3</td>
<td>18.8</td>
</tr>
<tr>
<td>20</td>
<td>1.202</td>
<td>1.9</td>
<td>17.1</td>
</tr>
<tr>
<td>30</td>
<td>1.309</td>
<td>4.4</td>
<td>14.9</td>
</tr>
<tr>
<td>40</td>
<td>1.410</td>
<td>8.5</td>
<td>13.6</td>
</tr>
<tr>
<td>50</td>
<td>1.504</td>
<td>14.3</td>
<td>12.6</td>
</tr>
</tbody>
</table>

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

Source term:

The SPRAY Code version 3.0 (Hey and Leach 1995) was used to calculate leak rates and small particle fractions for the assumed break in the liquid containment boundary. As previously developed, the assumed break is a crack with a maximum length of 6.28 inches and a minimum depth of 0.109 inches. (The release rate will decrease with increasing crack depth due to higher friction losses.) The crack width was optimized to maximize the release rate of particles with an initial size less than or equal to the size given as D_r in Table 1.

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

Table 2: Solution spray release parameters

<table>
<thead>
<tr>
<th>% NaOH</th>
<th>Optimum Crack Width (m)</th>
<th>Flow Type</th>
<th>Respirable NaOH Release Rate (g/s)</th>
<th>Respirable Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>9.99E-5</td>
<td>Turbulent</td>
<td>7.10E-2</td>
<td>0.193</td>
</tr>
<tr>
<td>10</td>
<td>9.81E-5</td>
<td>Turbulent</td>
<td>3.76E-2</td>
<td>0.204</td>
</tr>
<tr>
<td>12</td>
<td>4.60E-5</td>
<td>Critical</td>
<td>4.12E-1</td>
<td>1.68</td>
</tr>
<tr>
<td>15</td>
<td>4.68E-5</td>
<td>Critical</td>
<td>3.00E-1</td>
<td>1.53</td>
</tr>
<tr>
<td>20</td>
<td>5.34E-5</td>
<td>Laminar</td>
<td>1.38E-1</td>
<td>1.07</td>
</tr>
<tr>
<td>30</td>
<td>7.77E-5</td>
<td>Laminar</td>
<td>2.19E-2</td>
<td>0.384</td>
</tr>
<tr>
<td>40</td>
<td>1.05E-4</td>
<td>Laminar</td>
<td>5.10E-3</td>
<td>0.166</td>
</tr>
<tr>
<td>50</td>
<td>1.35E-4</td>
<td>Laminar</td>
<td>1.55E-3</td>
<td>0.0840</td>
</tr>
</tbody>
</table>

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

Results:

By the definition of the X/Q, the maximum air concentration of NaOH at a receptor location is just the product of the maximum release rate and the receptor X/Q. The resulting onsite and site boundary air concentrations of small particle NaOH is shown in Table 3.

Table 3: Resulting NaOH air concentrations

<table>
<thead>
<tr>
<th>% NaOH</th>
<th>Respirable Release Rate (mg/s)</th>
<th>Concentration (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Onsite (100 m)</td>
<td>Site Boundary</td>
</tr>
<tr>
<td>5</td>
<td>1.93E+2</td>
<td>6.58E+0</td>
</tr>
<tr>
<td>10</td>
<td>2.04E+2</td>
<td>6.96E+0</td>
</tr>
<tr>
<td>12</td>
<td>1.68E+3</td>
<td>5.73E+1</td>
</tr>
<tr>
<td>15</td>
<td>1.53E+3</td>
<td>5.22E+1</td>
</tr>
<tr>
<td>20</td>
<td>1.07E+3</td>
<td>3.65E+1</td>
</tr>
<tr>
<td>30</td>
<td>3.84E+2</td>
<td>1.31E+1</td>
</tr>
<tr>
<td>40</td>
<td>1.66E+2</td>
<td>5.66E+0</td>
</tr>
<tr>
<td>50</td>
<td>8.40E+1</td>
<td>2.86E+0</td>
</tr>
</tbody>
</table>
These results are considered very conservative in this case since they do not take credit for the initially rapid fallout rate of the large liquid particles prior to evaporation of the liquid fraction.

Conclusion:

The caustic spray leak analyzed here has been assigned a frequency of occurrence in the anticipated range \((10^{-2} - 10^{-6})/y\). The risk guidelines for onsite and site boundary receptors for this frequency range are ERPG-1 and PEL-TWA. Both criteria are 2 mg/m\(^3\) for NaOH (Van Keuren 1995). The concentrations at the receptor points and the resulting sum of fractions of the risk guidelines are shown in Table 4.

<table>
<thead>
<tr>
<th>Receptor</th>
<th>NaOH Concentration (mg/m(^3))</th>
<th>Sum of Fractions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Boundary</td>
<td>4.75E-2</td>
<td>0.024</td>
</tr>
<tr>
<td>at 8.76 km N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Onsite</td>
<td>5.73E+1</td>
<td>29</td>
</tr>
<tr>
<td>at 100 m E</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The sum of fractions at the site boundary are far less than the toxicological risk criterion of 1. The criterion is exceeded at the onsite receptor location.

Note that these results are for standard schedule 10 steel pipe. Use of a thinner wall pipe such as schedule 5 (wall thickness 0.065 in.) would increase the maximum release rate and receptor concentrations shown in Tables 3 and 4 by about 30% (due to the smaller crack depth and decreased friction losses). There would be no changes in the conclusions.

Recommendations for mitigation:

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

References:


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


Attachment 1
SPRAY Code Files
Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company

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

INPUT ECHO:
c unmitigated caustic spray - 5% NaOH
c SPRAY Version 3 Input Deck
c mode iflow iopt
  2  0  T
c
MODE OPTIONS:
c mode = 1 then orifice leak with friction assumed
  2 then slit leak with friction assumed
  iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c   = 1 friction based on laminar relation
  = 2 friction based on turbulent relation
  iopt = T then optimal diameter search performed
c   = F then no optimal search

c PARAMETER INPUT:
c
Initial Slit Width or Orifice Dia. Slit or Orifice
Slit Length Depth
(in) (in) (in)
1.00000E-03 1.00000E+00 1.09000E-01

Absolute Surface Roughness Contraction Velocity
(in) Coefficient Coefficient
Pressure Differential
0.00006 tube 0.0018 steel 0.0102 iron
0.61 and 1.00 and 1.00 and
0.98 for sharp edge orifice 0.98 for rounded orifice 0.82 for square edge orifice

1.25000E+02 1.80000E-03 1.00000E+00 8.20000E-01

8
<table>
<thead>
<tr>
<th>Fluid</th>
<th>Dynamic Viscosity (centi-poise)</th>
<th>Respirable Diameter (μm)</th>
<th>RR Fitting Constant (q)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.04100E+00</td>
<td>8.00000E-01</td>
<td>2.71000E+01</td>
<td>2.40000E+00</td>
</tr>
</tbody>
</table>

MESSAGES:
Slit Model
Code search for optimal equivalent diameter.

OUTPUT:
- Liquid Velocity = 6.76E+01 ft/s = 2.06E+01 m/s
- Reynolds Number = 5.33E+03 Turbulent Flow
- Sauter Mean Diameter = 5.26E+01 μm
- Optimum Slit Width = 3.93E-03 in = 9.99E-05 m
- Respirable Fraction = 7.10E-02
- Total Leak Rate = 8.28E-01 gpm = 5.22E-05 m³/s = 5.44E+01 g/s
- Respirable Leak Rate = 5.88E-02 gpm = 3.71E-06 m³/s = 3.86E+00 g/s
### Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company

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

**INPUT ECHO:**
c unmitigated caustic spray - 10% NaOH
c SPRAY Version 3 Input Deck
c mode iflow iopt
   2  0  T

c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c  2   then slit leak with friction assumed
c iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c = 1 friction based on laminar relation
c = 2 friction based on turbulent relation
c iopt = T then optimal diameter search performed
c = F then no optimal search

c PARAMETER INPUT:
c Initial Slit Width or Orifice Dia.
  slit  slit or
  (in)  (in)  (in)
  1.0000E-03  1.0000E+00  1.0900E-01

c Absolute Surface
  Roughness  Contraction  Velocity
  (in)  Coefficient  Coefficient
  Pressure  Differential  (psi)  (psi)  (psi)
  tube  steel  iron  0.0006  0.0018  0.0102
  0.61  1.00  1.00  0.98  0.98  0.82
  1.2500E+02  1.8000E-03  1.0000E+00  8.2000E-01
Fluid Dynamic Respirable RR Fitting

Specific Viscosity Diameter Constant
(centi-poise) (µm) (q)

1.0940E+00 9.60000E-01 2.15000E+01 2.40000E+00

MESSAGES:
Slit Model
Code search for optimal equivalent diameter.

OUTPUT:

Liquid Velocity = 6.53E+01 ft/s 1.99E+01 m/s
Reynolds Number = 4.43E+03 Turbulent Flow
Sauter Mean Diameter = 5.48E+01 µm
Optimum Slit Width = 3.86E-03 in 9.81E-05 m
Respirable Fraction = 3.76E-02
Total Leak Rate = 7.86E-01 gpm 4.96E-05 m³/s 5.42E+01 g/s
Respirable Leak Rate = 2.96E-02 gpm 1.87E-06 m³/s 2.04E+00 g/s
## SPRAY Version 3.0
May 3, 1994

This is a record of a spray leak code produced by Radiological & Toxicological Analysis, Westinghouse Hanford Company. The code was run on August 21, 1996, at 08:24:57.06. The input echo indicates an unmitigated caustic spray with 12% NaOH. The model options include:

- Mode 1: orifice leak with friction assumed
- Mode 2: slit leak with friction assumed
- Iflow: 0 for Reynolds number determines friction relation (laminar or turbulent), 1 for laminar relation, and 2 for turbulent relation
- Iopt: T for optimal diameter search performed, F for no optimal search

The parameter input includes:

- Initial Slit Width or Orifice Dia.: 1.00000E-03
- Slit or Orifice Depth: 1.09000E-01
- Slit Length: 1.00000E+00
- Absolute Surface Roughness: 0.00006 tube, 0.0018 steel, 0.0102 iron
- Pressure: 1.25000E+02 psi, Differential: 1.80000E-03 psi
- Contraction Coefficient: 0.61 for sharp edge orifice, 1.00 for rounded orifice, 0.82 for square edge orifice
- Velocity Coefficient: 0.98 for sharp edge orifice, 0.98 for rounded orifice, 0.82 for square edge orifice

---

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Slit Width or Orifice Dia.</td>
<td>1.00000E-03</td>
</tr>
<tr>
<td>Slit or Orifice Depth</td>
<td>1.09000E-01</td>
</tr>
<tr>
<td>Slit Length</td>
<td>1.00000E+00</td>
</tr>
<tr>
<td>Absolute Surface Roughness</td>
<td>0.00006 tube</td>
</tr>
<tr>
<td>Pressure</td>
<td>1.25000E+02</td>
</tr>
<tr>
<td>Differential</td>
<td>1.80000E-03</td>
</tr>
<tr>
<td>Contraction Coefficient</td>
<td>0.61</td>
</tr>
<tr>
<td>Velocity Coefficient</td>
<td>0.98</td>
</tr>
</tbody>
</table>
MESSAGES:
Slit Model
Code search for optimal equivalent diameter.
Friction factor based on laminar flow.

OUTPUT:
Liquid Velocity = 8.54E+01 ft/s  2.60E+01 m/s
Reynolds Number = 2.43E+03 Critical Flow
Sauter Mean Diameter = 1.73E+01 μm
Optimum Slit Width = 1.81E-03 in  4.60E-05 m
Respirable Fraction = 4.12E-01
Total Leak Rate = 4.82E-01 gpm  3.04E-05 m3/s  3.40E+01 g/s
Respirable Leak Rate = 1.98E-01 gpm  1.25E-05 m3/s  1.40E+01 g/s
Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company

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

INPUT ECHO:
c unmitigated caustic spray - 15% NaOH
c SPRAY Version 3 Input Deck
c mode iflow iopt
   2  1  T

c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c = 2 then slit leak with friction assumed
iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c = 1 friction based on laminar relation
c = 2 friction based on turbulent relation
iopt = T then optimal diameter search performed
iopt = F then no optimal search

c PARAMETER INPUT:
c
<table>
<thead>
<tr>
<th>Initial Slit Width or Orifice Dia.</th>
<th>Slit or Orifice Depth</th>
<th>Slit or Orifice Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00000E-03</td>
<td>1.00000E-03</td>
<td>1.09000E-01</td>
</tr>
</tbody>
</table>

c
<table>
<thead>
<tr>
<th>Absolute Surface Roughness</th>
<th>Contraction Coefficient</th>
<th>Velocity Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure</td>
<td>Differential (psi)</td>
<td></td>
</tr>
<tr>
<td>0.00006 tube</td>
<td>0.61</td>
<td>0.98 for sharp edge orifice</td>
</tr>
<tr>
<td>0.0018 steel</td>
<td>1.00</td>
<td>0.98 for rounded orifice</td>
</tr>
<tr>
<td>0.0102 iron</td>
<td>1.00</td>
<td>0.82 for square edge orifice</td>
</tr>
<tr>
<td>1.25000E+02</td>
<td>1.80000E-03</td>
<td>1.00000E+00</td>
</tr>
</tbody>
</table>
Fluid Specific Gravity
1.14800 E+00

Dynamic Viscosity (centi-poise)
1.30000 E+00

Respirable Diameter (μm)
1.88000 E+01

RR Fitting Constant (q)
2.40000 E+00

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

OUTPUT:

Liquid Velocity = 8.20E+01 ft/s 2.50E+01 m/s
Reynolds Number = 2.06E+03 Critical Flow
Sauter Mean Diameter = 1.89E+01 μm
Optimum Slit Width = 1.84E-03 in 4.68E-05 m
Respirable Fraction = 3.00E-01
Total Leak Rate = 4.71E-01 gpm 2.97E-05 m3/s 3.41E+01 g/s
Respirable Leak Rate = 1.41E-01 gpm 8.91E-06 m3/s 1.02E+01 g/s
Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company

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

INPUT ECHO:
c unmitigated caustic spray - 20% NaOH
c SPRAY Version 3 Input Deck

c mode iflow iopt
   2 1 T

c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c   2 then slit leak with friction assumed
c iflow = 0 Reynold's number determines friction relation (i.e. laminar or turb.
c   = 1 friction based on laminar relation
c   = 2 friction based on turbulent relation
c iopt = T then optimal diameter search performed
c   = F then no optimal search

c PARAMETER INPUT:

c Initial Slit Slit or
   Width or Orifice
   Orifice Dia. Length Depth
   (in) (in) (in)

5.00000E-03 1.00000E+00 1.09000E-01

c Absolute
   Surface
   Roughness Contraction Velocity
   (in) Coefficient Coefficient

c Pressure Differential Pressure
   0.00006 tube 0.018 steel 0.0102 iron
   0.61 and 1.00 and 1.00 and
   0.98 for sharp edge orifice
   0.98 for rounded orifice
   0.82 for square edge orifice

1.25000E+02 1.80000E-03 1.00000E+00 8.20000E-01
Fluid Dynamic Respirable RR Fitting
Specific Viscosity Diameter Constant
Gravity (centi-poise) (μm) (q)

1.20200E+00 1.90000E+00 1.71000E+01 2.40000E+00

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

OUTPUT:

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid Velocity</td>
<td>7.83E+01 ft/s 2.39E+01 m/s</td>
</tr>
<tr>
<td>Reynolds Number</td>
<td>1.61E+03 Laminar Flow</td>
</tr>
<tr>
<td>Sauter Mean Diameter</td>
<td>2.48E+01 μm</td>
</tr>
<tr>
<td>Optimum Slit Width</td>
<td>2.10E-03 in 5.34E-05 m</td>
</tr>
<tr>
<td>Respirable Fraction</td>
<td>1.38E-01</td>
</tr>
<tr>
<td>Total Leak Rate</td>
<td>5.14E-01 gpm 3.24E-05 m³/s 3.90E+01 g/s</td>
</tr>
<tr>
<td>Respirable Leak Rate</td>
<td>7.07E-02 gpm 4.46E-06 m³/s 5.36E+00 g/s</td>
</tr>
</tbody>
</table>
**Spray Leak Code**  
Produced by Radiological & Toxicological Analysis  
Westinghouse Hanford Company

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

**INPUT ECHO:**  
c unmitigated caustic spray - 30% NaOH  
c SPRAY Version 3 Input Deck  
c mode iflow iopt  
  2  0  T

c **MODEL OPTIONS:**  
c mode = 1 then orifice leak with friction assumed  
c = 2 then slit leak with friction assumed  
c iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.  
c = 1 friction based on laminar relation  
c = 2 friction based on turbulent relation  
c iopt = T then optimal diameter search performed  
c = F then no optimal search

c **PARAMETER INPUT:**

c Initial Slit Width or Orifice Dia.  
c Slit Slit or Orifice Length Depth  
  (in) (in) (in)

c 5.00000E-03 1.00000E+00 1.09000E-01

c Absolute Surface 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
### Fluid Dynamic Respirable RR Fitting Specific Viscosity Diameter Constant

<table>
<thead>
<tr>
<th>Fluid Specific Gravity</th>
<th>Viscosity (centi-poise)</th>
<th>Respirable Diameter (µm)</th>
<th>RR Fitting Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.30900E+00</td>
<td>4.40000E+00</td>
<td>1.49000E+01</td>
<td>2.40000E+00</td>
</tr>
</tbody>
</table>

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

**OUTPUT:**
- Liquid Velocity = 7.40E+01 ft/s  2.26E+01 m/s
- Reynolds Number = 1.04E+03 Laminar Flow
- Sauter Mean Diameter = 4.77E+01 µm
- Optimum Slit Width = 3.06E-03 in  7.77E-05 m
- Respirable Fraction = 2.19E-02
- Total Leak Rate = 7.06E-01 gpm  4.45E-05 m3/s  5.83E+01 g/s
- Respirable Leak Rate = 1.54E-02 gpm  9.74E-07 m3/s  1.28E+00 g/s
Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company

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

INPUT ECHO:
c unmitigated caustic spray - 40% NaOH
c SPRAY Version 3 Input Deck
c mode iflow iopt
   2  0  T

c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c 2 then slit leak with friction assumed
iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c 1 friction based on laminar relation
c 2 friction based on turbulent relation
iopt = T then optimal diameter search performed
  = F then no optimal search

c PARAMETER INPUT:
c Initial Slit Slit or
Width or Slit Orifice
Orifice Dia. Length Depth
(in) (in) (in)
5.00000E-03 1.00000E+00 1.09000E-01

Absolute
Surface Roughness Contraction Velocity
(in) Coefficient Coefficient
Pressure 0.00006 tube 0.61 and 0.98 for sharp edge orifice
Differential 0.0018 steel 1.00 and 0.98 for rounded orifice
(ksi) 0.0102 iron 1.00 and 0.82 for square edge orifice
1.25000E+02 1.80000E-03 1.00000E+00 8.20000E-01
<table>
<thead>
<tr>
<th>Fluid Specific Gravity</th>
<th>Dynamic Viscosity (centi-poise)</th>
<th>Respirable Diameter (µm)</th>
<th>RR Fitting Constant (q)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.41000E+00</td>
<td>8.50000E+00</td>
<td>1.36000E+01</td>
</tr>
</tbody>
</table>

MESSAGES:
Slit Model
Code search for optimal equivalent diameter.

OUTPUT:
Liquid Velocity = 7.09E+01 ft/s 2.16E+01 m/s
Reynolds Number = 7.48E+02 Laminar Flow
Sauter Mean Diameter = 8.02E+01 µm
Optimum Slit Width = 4.13E-03 in 1.05E-04 m
Respirable Fraction = 5.10E-03
Total Leak Rate = 9.12E-01 gpm 5.75E-05 m³/s 8.11E+01 g/s
Respirable Leak Rate = 4.65E-03 gpm 2.93E-07 m³/s 4.14E-01 g/s
Spray Leak Code
Produced by Radiological & Toxicological Analysis
Westinghouse Hanford Company

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

INPUT ECHO:
c unmitigated caustic spray - 50% NaOH
c SPRAY Version 3 Input Deck
c mode iflow iopt
  2  0  T

c MODEL OPTIONS:
c mode = 1 then orifice leak with friction assumed
c 2 then slit leak with friction assumed
c iflow= 0 Reynold's number determines friction relation (i.e. laminar or turb.
c = 1 friction based on laminar relation
c = 2 friction based on turbulent relation
c iopt = T then optimal diameter search performed
c = F then no optimal search

c PARAMETER INPUT:
c
  Initial Slit Width or Orifice Dia.
  Slit or Slit Length Depth
  (in) (in) (in)

  5.00000E-03  1.00000E+00  1.09000E-01

c Absolute
Surface Roughness Contraction Velocity
(in) Coefficient Coefficient

  Pressure Differential (psi)
  0.00006  0.0018  0.0102
  tube  steel  iron

  1.25000E+02  1.80000E-03  1.00000E+00  8.20000E-01
Fluid Dynamic Respirable RR Fitting Specific Viscosity Diameter Constant

Gravity (centi-poise) (μm) (q)

1.50400E+00 1.43000E+01 1.26000E+01 2.40000E+00

MESSAGES:
Slit Model
Code search for optimal equivalent diameter.

OUTPUT:
Liquid Velocity = 6.88E+01 ft/s 2.10E+01 m/s
Reynolds Number = 5.91E+02 Laminar Flow
Sauter Mean Diameter = 1.22E+02 μm
Optimum Slit Width = 5.30E-03 in 1.35E-04 m
Respirable Fraction = 1.55E-03
Total Leak Rate = 1.14E+00 gpm 7.18E-05 m³/s 1.08E+02 g/s
Respirable Leak Rate = 1.77E-03 gpm 1.11E-07 m³/s 1.68E-01 g/s
CHECKLIST FOR PEER REVIEW

Document Reviewed: CONSEQUENCE ANALYSIS OF AN UNMITIGATED NaOH SOLUTION SPRAY RELEASE DURING ADDITION TO WASTE TANK, D.A. Himes, 8/21/96

Scope of Review: entire document

Yes No NA

[ ] [ ] [x] * Previous reviews complete and cover analysis, up to scope of this review, with no gaps.

[ ] [ ] [ ] Problem completely defined.

[ ] [ ] [ ] Accident scenarios developed in a clear and logical manner.

[ ] [ ] [ ] Necessary assumptions explicitly stated and supported.

[ ] [ ] [ ] Computer codes and data files documented.

[ ] [ ] [ ] Data used in calculations explicitly stated in document.

[ ] [ ] [ ] Data checked for consistency with original source information as applicable.

[ ] [ ] [ ] Mathematical derivations checked including dimensional consistency of results.

[ ] [ ] [x] Models appropriate and used within range of validity or use outside range of established validity justified.

[ ] [ ] [ ] Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.

[ ] [ ] [ ] Software input correct and consistent with document reviewed.

[ ] [ ] [ ] Software output consistent with input and with results reported in document reviewed.

[ ] [ ] [x] Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.

[ ] [ ] [ ] Safety margins consistent with good engineering practices.

[ ] [ ] [ ] Conclusions consistent with analytical results and applicable limits.

[ ] [ ] [x] Results and conclusions address all points required in the problem statement.

[ ] [ ] [x] Format consistent with appropriate NRC Regulatory Guide or other standards

[ ] [ ] [x] * Review calculations, comments, and/or notes are attached.

[ ] [ ] [ ] Document approved.

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

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

CONSEQUENCE ANALYSIS OF AN UNMITIGATED NaOH SOLUTION SPRAY RELEASE
DURING ADDITION TO WASTE TANK, D.A. Himes, 8/21/96

Submitted by: D.A. Himes Date Submitted:

Scope of Review: entire document

YES  NO*  N/A

[ ] [ ] 1. A detailed technical review and approval of the environmental transport and dose calculation portion of the analysis has been performed and documented.

[ ] [ ] 2. Detailed technical review(s) and approval(s) of scenario and release determinations have been performed and documented.

[ ] [ ] 3. HEDOP-approved code(s) were used.

[ ] [ ] 4. Receptor locations were selected according to HEDOP recommendations.

[ ] [ ] 5. All applicable environmental pathways and code options were included and are appropriate for the calculations.

[ ] [ ] 6. Hanford site data were used.

[ ] [ ] 7. Model adjustments external to the computer program were justified and performed correctly.

[ ] [ ] 8. The analysis is consistent with HEDOP recommendations.

[ ] [ ] 9. Supporting notes, calculations, comments, comment resolutions, or other information is attached. (Use the "Page 1 of X" page numbering format and sign and date each added page.)

[ ] [ ] 10. Approval is granted on behalf of the Hanford Environmental Dose Overview Panel.

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

HEDOP-Approved Reviewer (Printed Name and Signature) Date

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

25
# DISTRIBUTION SHEET

**To:** Consequence Analysis 8M400  
**From:** Consequence Analysis 8M400  
**Page 1 of 1**  
**Date:** 8/15/96  
**EDT No.:** 142249  
**ECN No.:** N/A

**Project Title/Work Order**
Consequence Analysis of an Unmitigated NaOH Solution Spray Release During Addition to Waste Tank

<table>
<thead>
<tr>
<th>Name</th>
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<th>Attach./ Appendix Only</th>
<th>EDT/ECN Only</th>
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<td>G.W. Ryan</td>
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<td>TWRS S &amp; L Files (2)</td>
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