APPENDIX C

ESTIMATING THE EFFECTS OF CHLORINE RELEASES

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Information contained in this appendix was excerpted, with permission, from *Estimating the Area Affected by a Chlorine Release (The* Chlorine Institute, 1991). The computer dispersion model used by The Chlorine Institute to generate release scenarios was based on generic industrial accidents and atmospheric conditions. The results depend on the atmospheric conditions and wind speeds assumed for the releases as well as on the terrain. They serve as an aid to estimating the range of potential consequences of chlorine releases. The HAZOP study team used this reference for the release and dispersion of chlorine to understand the potential consequences and impacts of releases.

C.1 Characteristics of Chlorine Releases

Unintended chlorine releases have occurred as a result of industrial accidents involving equipment such as tanks, pipelines, relief valves, and vents.

Chlorine releases can be modeled as either instantaneous puff releases or continuous releases. During an instantaneous release, such as a cylinder rupture, large amounts of chlorine are released in a relatively short period of time. In a continuous release, such as the failure of a gasket, the chlorine release rate is maintained over a period of time until it is controlled or until the cylinder is depleted.

Initially, during a cylinder release, either gaseous or liquid chlorine, or both, may be released. As a result of the release, the pressure and temperature in the cylinder decreases, slowing the release rate. Upon release, pressurized liquid chlorine cools to its boiling point (-29°F) and boils off. Mixing with the atmosphere is delayed because the liquid must first evaporate. Chlorine vapors, **however, mix immediately. If released under pressure, liquid** chlorine can flash to a vapor, resulting in a two-phased jet release.

During the intermediate phases of a chlorine release, the chlorine is most influenced by atmospheric conditions. It continues to mix with the air and with moisture in the air. Depending on atmospheric conditions, aerosols may form. Eventually, a dense gas plume forms. This heavier-than-air plume remains at ground level as it moves downwind until, through dilution, its density equals the density of air.

Because of the atmospheric variability, stability classes are used to predict the dispersion of the plume. In the early morning, the atmosphere is stable. Daytime solar heating creates air movement and an unstable atmosphere. Atmospheric stability classes range from "very unstable" Class A to "very stable" Class G. Dispersion is also affected by the wind, the mixing height, and the terrain.

C.2 Chlorine Release Scenarios

The consequences of the accident scenarios identified during the HAZOP study can be categorized as:

- Chlorine cylinder releases
- Process line breaks and releases
- Process equipment leaks.

The potential accident scenarios are identified in the HAZOP Study Worksheets (Appendix B).

To estimate the potential consequences and impacts of these accidents, release scenarios were selected from *Estimating the Area Affected by a Chlorine Release. The* scenarios are based on typical industrial accidents with conservative modeling assumptions. Five accident scenarios were selected for consideration:

1. A 1-ton cylinder is struck and its liquid valve is sheared off, resulting in the release of liquid chlorine.

2. Half-inch tubing is sheared off and chlorine gas is released (modeled with infinite supply).

3. A l-inch pipe is sheared off and chlorine gas is released (modeled with infinite supply) .

4. Half-inch tubing is sheared off and liquid chlorine is released (modeled with infinite supply).

5. A l-inch pipe is sheared off and liquid chlorine is released (modeled with infinite supply).

The assumptions for these five release scenarios are

- Three-foot release height
- Ambient air temperature of 68°F
- Ambient relative humidity of 50 percent
- Liquid or gaseous chlorine at 68°F
- Changes in ambient temperature or relative humidity assumptions have little effect on dispersion. Changes in assumptions about temperature and pressure of chlorine prior to release can significantly affect dispersion.

- Five-mile-per-hour wind speed. Because ambient concentration is inversely proportional to wind sped, concentrations can reconverted to other wind conditions by dividing 5 miles per hour by the actual wind speed and multiplying the result by the concentration.

- Average wind fluctuation of approximate] y 5°. If wind shifts are greater, the area impacted by the plume is greater.

- Stability Classes:

  -- Stability Class B: Strong and moderate solar radiation with low wind speed. Occurs during the day, generally in the mornings, with clear skies and wind speed less than 10 miles per hour.

  -- Stability Class F: Occurs at night, with wind sped less than 6 miles per hour, and with less than 40 percent cloud cover.

  -- Stability Class D: Used when classes B and F are not applicable.

C.3 Predicted Chlorine Consequences

Figures C-1 through C-5 show graphically the areas potentially affected by chlorine releases for five generic accident scenarios*. Downstream distances are depicted at which chlorine concentrations exceed 25 parts per million (ppm) and 10 ppm.

The dispersion distances and downwind concentrations of chlorine resulting from the scenario modelling are summarized in Table C-1. The 25-ppm chlorine concentration is the immediately-dangerous-to-life-or-health (IDLH) level for chlorine, and 10 ppm is 40 percent of the IDLH. Ten ppm was chosen as a reference point for emergency planning because of the uncertainty in dispersion modeling.

* The graphs in Figures C-1 through C-5 are truncated on the right-hand side of the x-axis. In fact, these curves extend to meet the x-axis. Limitations in display prevented the full extension from being shown.

C.4 Potential Impacts of Chlorine Releases at the Hanford 300-Area Water Treatment Facility

If a large chlorine release occurs from the Hanford 300-Area Water Treatment Facility, wind from the northwest, west, and southwest would disperse it across the Columbia River to the residences on the far side, more than 3/4 of a mile away. In addition, boaters on the river and any workers occupying the pump house would also likely be exposed. The pump house, however, is normally unoccupied.

Wind from the north would carry a large chlorine plume to the 337 Office Building, resulting in the potential exposure of its more than 300 occupants. Small releases of chlorine would probably result in minor irritations to workers in the area.

Table C-1. Summary of Dispersion Distances and Downwind Concentrations for Chlorine Release Scenarios

Scenario Description	Stability Class B Distance in feet and miles		Stability Class D Distance in feet and miles		Stability Class F Distance in feet and miles	
	25 ppm	10 ppm	25 ppm	10 ppm	25 ppm	10 ppm
1) A l-ton cylinder is struck and its liquid valve is shared off. Liquid chlorine is released from a 3/8-inch hole.	3,600 0.7	**5,400** 1.0	**5,400** 1.0	9,600 1.8	10,800 2.0	18,000 3.4
2) Half-inch, type-K copper tubing is sheared off. Chlorine gas is released (modeled with infinite supply).	800 0.2	1,200 0.2	1,200 0.2	2,100 0.4	1,800 0.3	3,300 0.6
3) A l-inch schedule-80 pipe is sheared off. Chlorine gas is released (modeled with infinite supply).	1,600 0.3	2,800 0.5	2,600 0.5	**4,400** 0.8	**4,200** 0.8	**7,400** 1.4
4) Half-inch, type-K copper tubing is sheared off. Liquid chlorine is released (modeled with infinite supply).	2,000 0.4	3,750 0.7	3,000 0.6	5,500 1.0	5,250 1.0	9,250 1.8
5) A l-inch schedule-80 pipe is sheared off. Liquid chlorine is released (modeled with infinite supply).	4,000 0.8	7,000 1.3	7,000 1.3	7,000 2.0	11,000 2.0	18,500 3.5

Scenario Description:

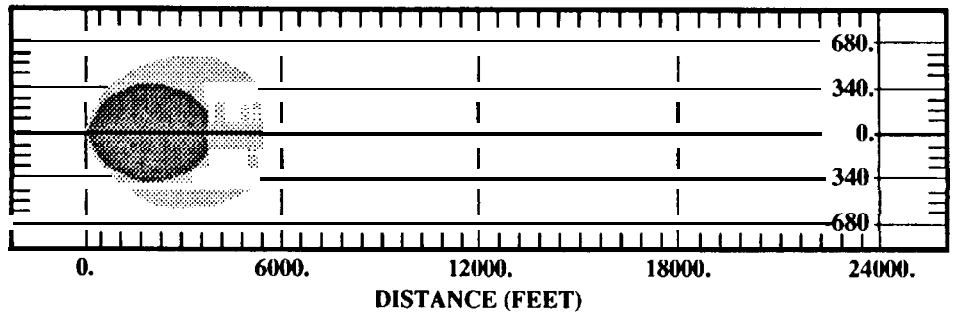
a. A 1-ton cylinder is struck and its liquid valve is sheared off. Liquid chlorine is released from a 3/8-inch hole.

b. The container is full = 2,000 pounds Cl_2.

c. The valve body has a 3/8-inch hole.

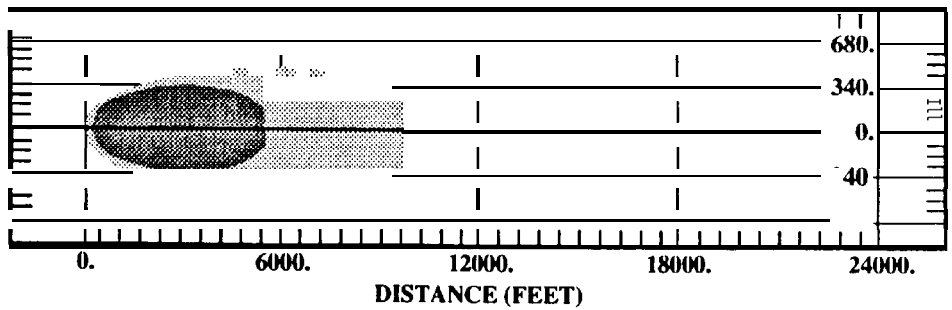
d. Release height is 3 feet. The container is on a concrete slab.

Stability Class B
Morning - Clear, Low Winds
Y-Axis Distance in Feet



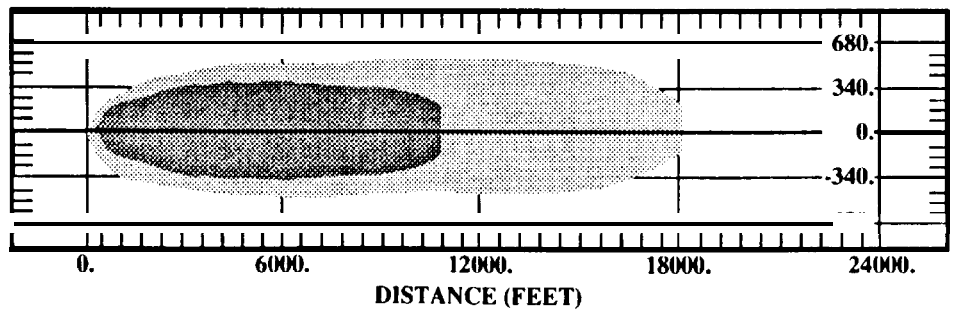
Dark shading Concentration Exceeds 25 ppm
Light shading Concentration Exceeds 10 ppm

Stability Class D
All other Conditions
Y-Axis Distance in Feet



Dark shading Concentration Exceeds 25 ppm
Light shading Concentration Exceeds 10 ppm

Stability Class F
Nighttime - Mostly Clear Skies, Low Winds
Y-Axis Distance in Feet



Dark shading Concentration Exceeds 25 ppm
Light shading Concentration Exceeds 10 ppm

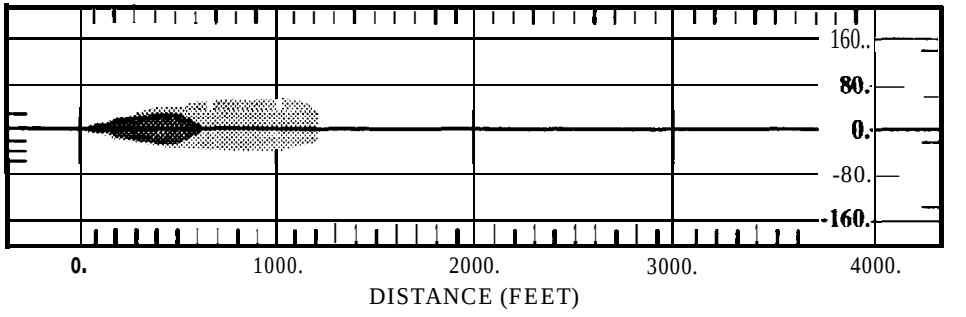
Figure C-1. One-Ton Liquid Chlorine Release from Sheared-off Valve

scenario Description:

a. Half-inch, type-K copper tubing is sheared off. Chlorine gas is released (modeled with infinite supply).

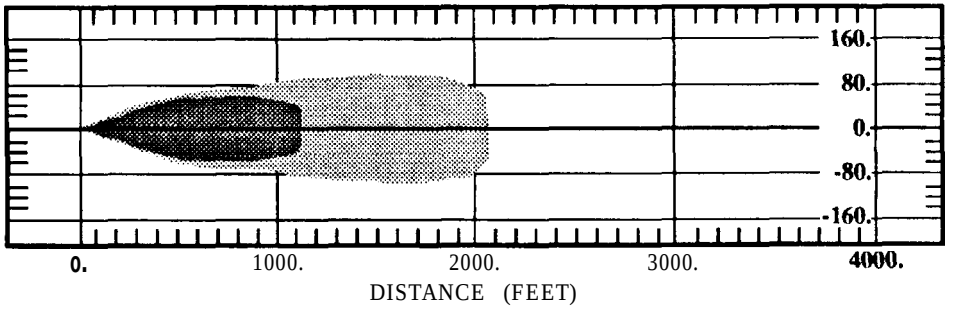
b. Release height is 3 feet.

Stability Class B
Morning - Clear, Low Winds
Y-Axis Distance in Feet



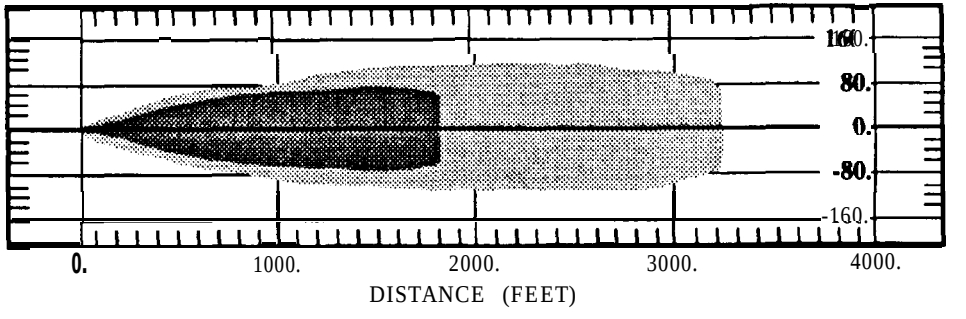
Dark shading Concentration Exceeds 25 ppm
Light shading Concentration Exceeds 10 ppm

Stability Class D
All other Conditions
Y-Axis Distance in Feet



Dark shading Concentration Exceeds 25 ppm
Light shading Concentration Exceeds 10 ppm

Stability Class F
Nighttime - Mostly Clear Skies, Low Winds
Y-Axis Distance in Feet



Dark shading Concentration Exceeds 25 ppm
Light shading Concentration Exceeds 10 ppm

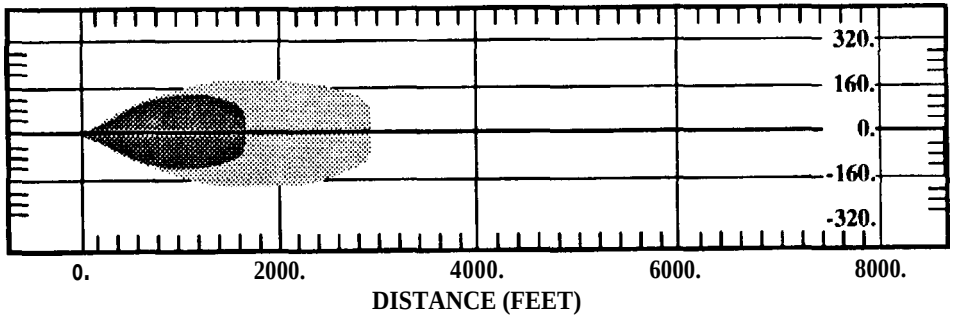
Figure C-2. Chlorine Gas Release from Sheared-off 1/2-inch Tubing

Scenario Description:

a. A l-inch, schedule-80 pipe is sheared off. Chlorine gas is released (modeled with **infinite** supply).

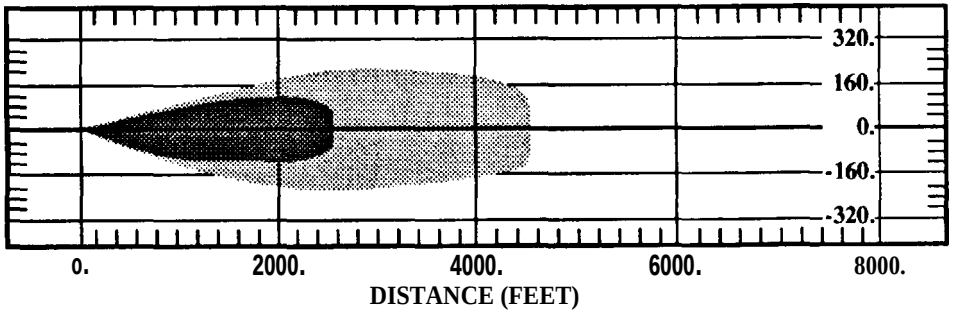
b. Release height is 3 feet.

Stability Class B
Morning - Clear, Low Winds
Y-Axis Distance in Feet



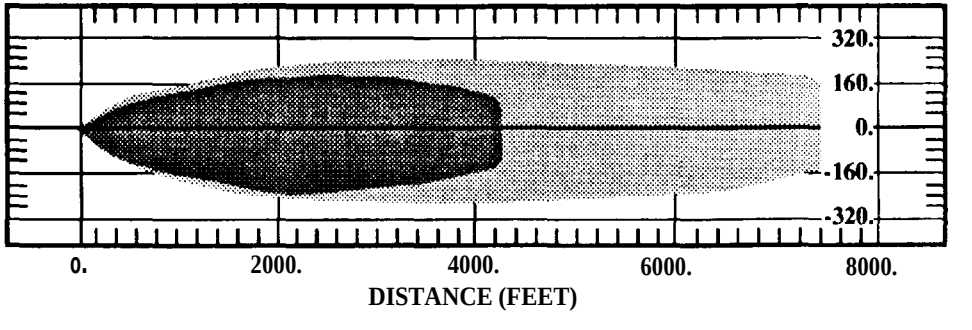
Dark shading Concentration Exceeds 25 ppm
Light shading Concentration Exceeds 10 ppm

Stability Class D
All other Conditions
Y-Axis Distance in Feet



Dark shading Concentration Exceeds 25 ppm
Light shading Concentration Exceeds 10 ppm

Stability Class F
Nighttime - Mostly Clear Skies, **Low** Winds
Y-Axis Distance in Feet



Dark shading Concentration Exceeds 25 ppm
Light shading Concentration Exceeds 10 ppm

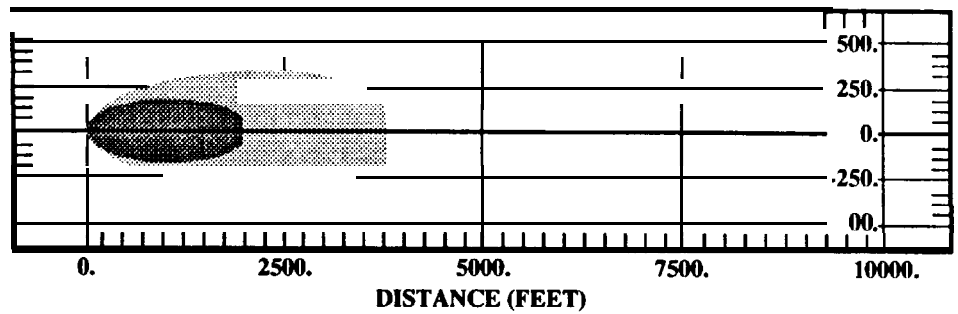
Figure C-3. Chlorine Gas Release from 1-inch Pipe Break

Scenario Description:

a. Half-inch, type-K copper tubing is sheared off. Liquid chlorine is released (modeled with infinite supply).

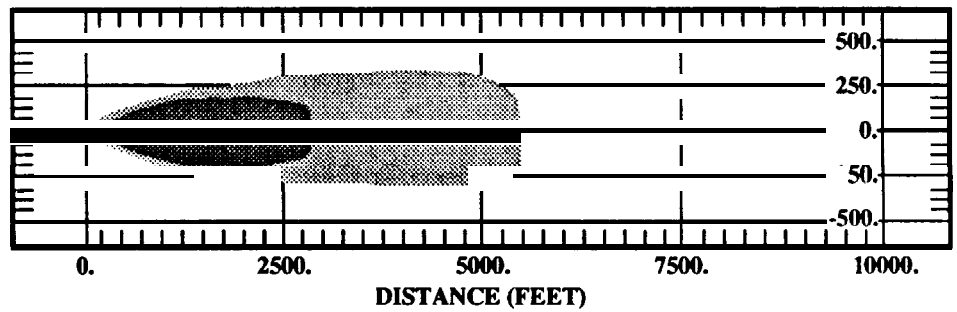
b. Release height is 3 feet.

Stability Class B
Morning - Clear, Low Winds
Y-Axis Distance in Feet



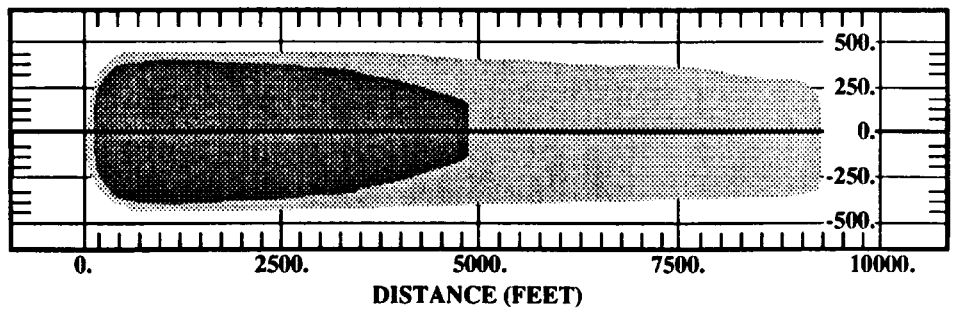
Dark shading Concentration Exceeds 25 ppm
Light shading Concentration Exceeds 10 ppm

Stability Class D
All other Conditions
Y-Axis Distance in Feet



Dark shading Concentration Exceeds 25 ppm
Light shading Concentration Exceeds 10 ppm

Stability Class F
Nighttime - Mostly Clear Skies, Low Winds
Y-Axis Distance in Feet



Dark shading Concentration Exceeds 25 ppm
Light shading Concentration Exceeds 10 ppm

Figure C-4. Liquid Chlorine Release from Sheared-off 1/2-inch Tubing

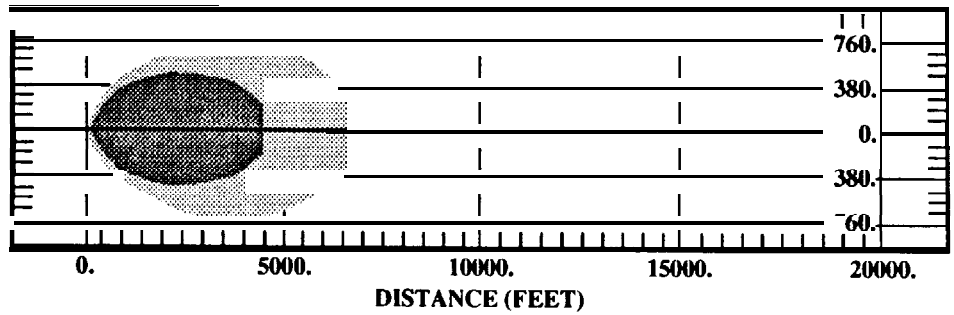
Scenario Description:

a. A 1-inch, schedule-80 pipe is sheared off. Liquid chlorine is released (modeled with infinite supply).

b. Release height is 3 feet.

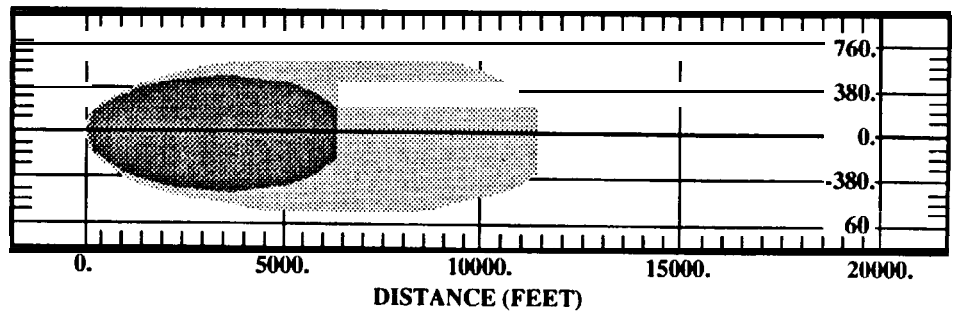
Stability Class B
Morning - Clear, Low Winds
Y-Axis Distance in Feet

Dark shading Concentration Exceeds 25 ppm
Light shading Concentration Exceeds 10 ppm



Stability Class D
All other Conditions
Y-Axis Distance in Feet

Dark shading Concentration Exceeds 25 ppm
Light shading Concentration Exceeds 10 ppm



Stability Class F
Nighttime - Mostly Clear Skies, Low Winds
Y-Axis Distance in Feet

Dark shading Concentration Exceeds 25 ppm
Light shading Concentration Exceeds 10 ppm

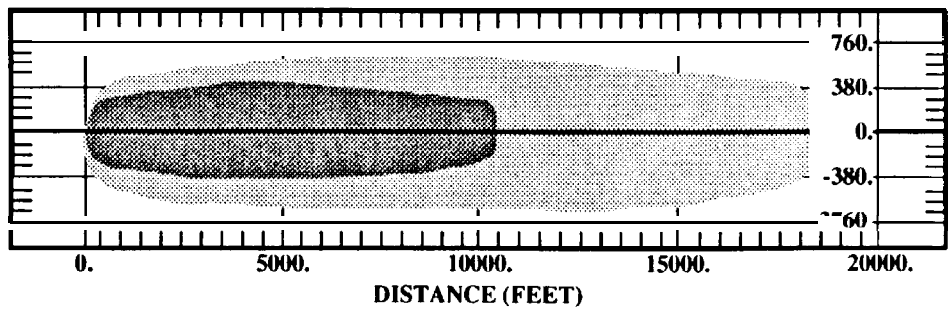


Figure C-S. Liquid Chlorine Release from 1-inch Pipe Break