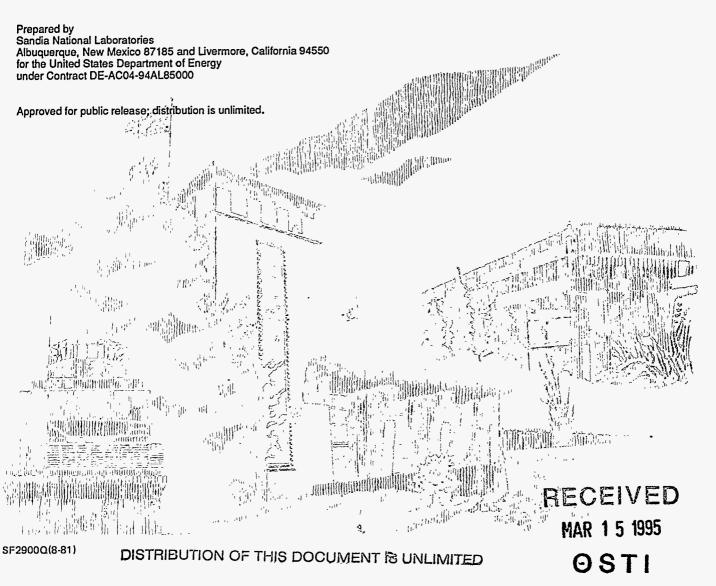
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## SANDIA REPORT

SAND94–3178 • UC–607 Unlimited Release Printed December 1994

# Hydrogen Trailer Storage Facility (Building 878) Consequence Analysis

Zeferino Banda, Project Leader C. L. Wood, Author



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## Hydrogen Trailer Storage Facility (Building 878) **Consequence Analysis**.

Project Leader: Zeferino Banda Author: C. L. Wood

Prepared by Sandia National Laboratories Albuquerque, New Mexico 87185

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#### Abstract

The Department of Energy Order 5500.3A requires facility-specific hazards assessments be prepared, maintained, and used for emergency planning purposes. This consequence analysis documents the impact that a hydrogen accident could have to employees, the general public, and nearby facilities. The computer model ARCHIE was utilized to determine discharge rates, toxic vapor dispersion analyses, flammable vapor cloud hazards, explosion hazards, and flame jets for the Hydrogen Trailer Storage Facility located at Building 878. To determine over pressurization effects, hand calculations derived from the Department of the Air Force Manual, "Structures to Resist the Effects of Accidental Explosions," were utilized. The greatest distances at which a postulated facility event will produce the Lower Flammability and the Lower Detonation Levels are 1,721 feet and 882 feet, respectively. The greatest distance at which 10.0 psi overpressure (i.e., total building destruction) is reached is 153 feet. MASTER



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### **1.0 INTRODUCTORY SUMMARY**

The purpose of this document is to describe the hazards associated with the Hydrogen Trailer Storage Facility (HTSF) located south of the Advanced Manufacturing Processes Laboratory (AMPL), Building 878. The results of this analysis are used to determine the impact that a hydrogen accident could have to employees, the general public, and nearby facilities.

The process used in this analysis involved describing the HTSF and its processes, characterizing hydrogen, postulating scenarios that could precipitate an accident, and determining the consequences of the scenarios and probable Emergency Action Levels (EALs).

The primary hazards associated with the HTSF are fire and explosion. These hazards are analyzed by postulating two general scenarios which include unconfined releases and confined explosions. The potential consequences of the unconfined release scenarios are determined by using the Automated Resource for Chemical Hazard Incident Evaluation (ARCHIE) computer model.<sup>1</sup> The potential consequences of the confined explosions are determined by using hand calculations derived from the Department of the Air Force Manual, "Structures to Resist the Effects of Accidental Explosions."<sup>2</sup>

The maximum amount of hydrogen available for release is 38,000 ft<sup>3</sup> which represents the worst case scenario. The results of the scenarios involving 38,000 ft<sup>3</sup> are described below.

- The farthest Lower Flammability Level distance is 1,721 feet.
- The farthest Lower Detonation Level distance is 882 feet.
- The greatest distance at which 10.0 psi overpressure (i.e., total building destruction) is reached is 153 feet.

The recommended protective action involving a fire at the Hydrogen Trailer Storage Facility is the establishment of a half mile (2,640 ft.) isolation zone as prescribed in the Department of Transportation Emergency Response Guidebook.<sup>3</sup>

In the event of a fire or a hydrogen leak involving the HTSF, the recommended protective action for the AMPL occupants is to evacuate from the northwest corner of the AMPL. In addition, the residents of the trailers within 150 feet of the HTSF should evacuate away from the hydrogen trailer. The recommended protective action for the remaining individuals within the half mile isolation zone is to shelter in place. These individuals should move away from windows and seek shelter within interior rooms or halls, under sturdy furniture or doorways.

### 2.0 DESCRIPTION

The Hydrogen Trailer Storage Facility, Organization 2471-2, is located approximately 100 feet south of the AMPL (Illustration 2-1). The HTSF is not in a DOE secured area, however, it is fully enclosed by the AMPL safety fence.

The HTSF was installed in November 1991 to provide hydrogen to the atmospheric brazing processes associated with the Thin Film, Vacuum, and Brazing Laboratory (zone 9) in the AMPL (Illustration 2-2). The facility consists of two independent hydrogen supplies (a primary and a backup supply), a hydrogen dryer, and all of the associated plumbing.

The primary hydrogen supply is a multi-tube semitrailer. The storage area for the trailer consists of an open air structure possessing no roof. It is enclosed on three sides by 15 foot high concrete walls, while the west side consists of a steel chain-link gate. There are two egress paths from the hydrogen trailer supply area, one through the gate on the west and one through an opening in the block wall on the east.

Three trailers are required to service zone 9. At any specific time, one trailer is in use. The other two are offsite, in the process of being filled by the gas supplier or are full and stored in the Hydrogen Storage Area in Tech Area III. Two of the trailers consist of 30 (9 5/8" outside diameter) tubes with an approximate gas capacity of 30,000 standard cubic feet compressed to 2400 psig (one of the trailer's tubes is 21' long and the other is 20' 6"). The third trailer consists of 38 (9 5/8" outside diameter) tubes (each 21' long) with an approximate gas capacity of 38,000 standard cubic feet compressed to 2400 psig.

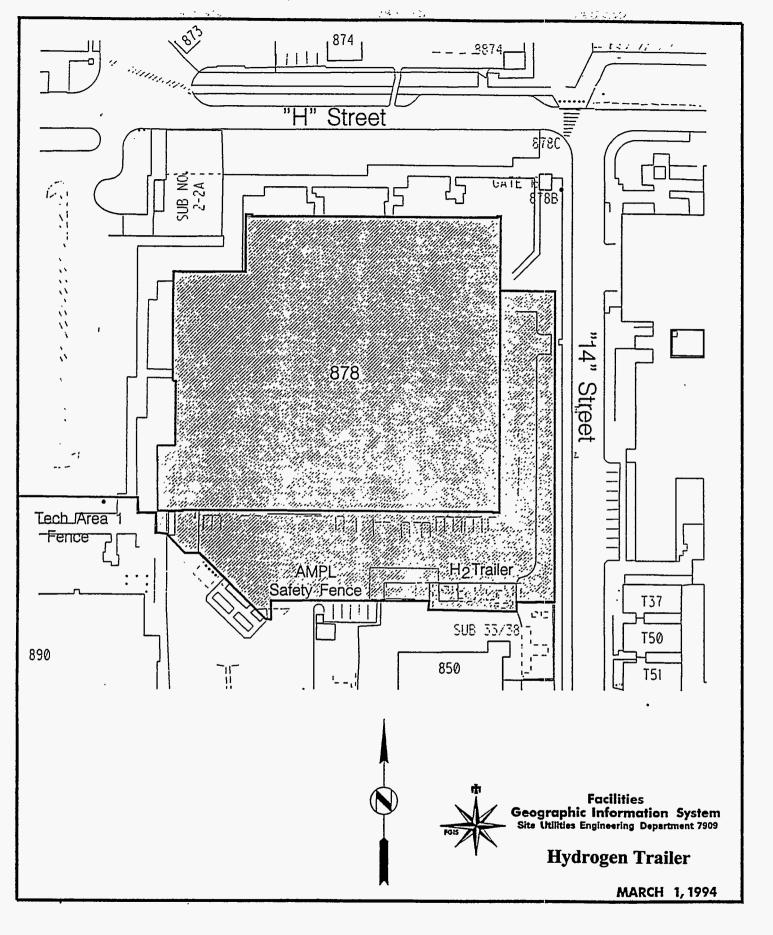
If the trailer supply pressure drops below 40 psig or when the trailers are being changed, hydrogen is supplied by the backup supply system. The backup supply consists of 18 DOT cylinders (~220 standard cubic feet each) of hydrogen, connected in parallel with the supply trailer. The backup supply is enclosed by two concrete block walls and two chain link fences and is covered by a light metal roof. One chain link fence has a gate.

The hydrogen delivery system does not utilize electricity for its power supply. It employs nonflammable nitrogen gas as its energy source for the automatic purge valves. If the trailer pressure and the backup cylinder pressure both drop below or exceed specific set points, the supply gas is automatically switched to argon.

There is a hazardous waste storage area within 30 feet of the HTSF. The hazardous waste includes halogenated, flammable solvents and reagents (acids, bases, oxidizers). There is an administrative limit of 55 gallons of waste which cannot be stored over 60 days.

#### 2.1 PROCESSES

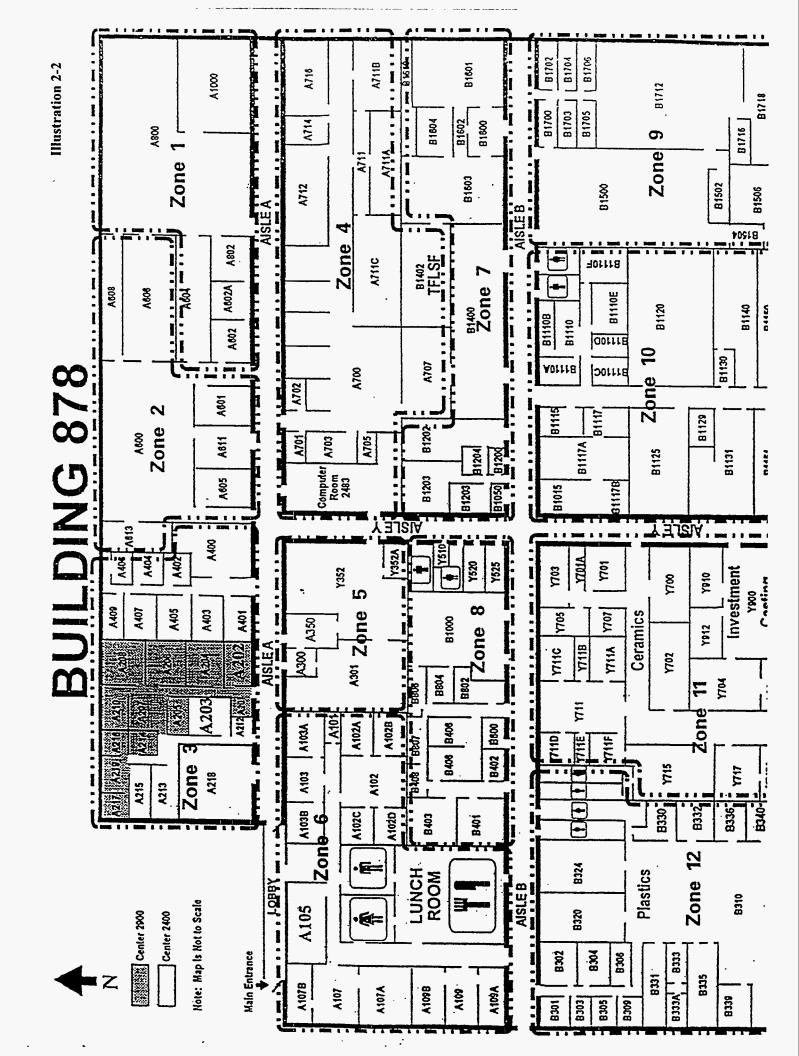
A process associated with the HTSF involves the exchange of two hydrogen trailers. When the trailer pressure drops below 500 psig, a telephone request is made asking that a transportation contractor pick up a full trailer at the Hydrogen Storage Facility located in Tech Area III, deliver it to the AMPL, remove the "empty" (200 to 500 psig) trailer, and transport the empty trailer from the AMPL for filling and storage.



**Illustration 2-1** 

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The exchange of the trailers must be performed by two employees; one who is an authorized operator using a formal checklist, while the other employee performs the checklist steps. The authorized operator must have the gas certification for the replacement trailer before the trailer may be connected to the hydrogen delivery system.

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At the time of hydrogen trailer exchange, the hydrogen delivery system is valved out at the supply trailer manifold. The associated regulators and delivery line are then purged with argon. While the hydrogen trailer is "off-line," hydrogen is supplied to the building by the backup supply. After the tractor bringing the full trailer is unhooked and pulled clear of the trailer, an electrical ground is connected to the trailer. The trailer valves and connections are checked with a hydrogen sniffer to ensure an absence of leaks. Then, the trailer is connected to the hydrogen delivery manifold. After purging the hydrogen delivery manifold with argon, one tube on the trailer is opened and manifold pressure is increased to 40 psig. All non-welded fittings in the delivery manifold are checked with the hydrogen sniffer to detect leaks. If no leaks are found, the other tubes are opened, and all valves are rechecked for hydrogen leaks with a hydrogen sniffer.

## 3.0 CHARACTERIZATION

Hydrogen is a slightly toxic, lighter than air, colorless, odorless, tasteless and flammable gas. Burning hydrogen produces an intensely hot invisible flame unless colored by impurities. Hydrogen has practically no toxicity but it may asphyxiate. It is an extremely dangerous fire and explosion hazard when exposed to heat, flame or a multitude of chemicals especially oxidizers. The maximum explosive yield of hydrogen/oxygen mixture is 20.5 pounds TNT for each pound of hydrogen or 86 sticks of dynamite (7/8" x 8", 90% gel)/lb. hydrogen.

Hydrogen can burn in two modes, deflagration and detonation. During deflagration, or ordinary burning, the flame travels through the gas mixture at subsonic speeds (for example, an unconfined hydrogen-air mixture ignited by a small ignition source). The flame is invisible but observers will hear a noise and may report an "explosion." The pressure wave from this mode of burning is not extremely severe, but it may produce damage.

Detonation is the second mode of burning. It occurs when the flame and shock wave travel together through the mixture at supersonic speed. Detonations generally occur in confined or partially confined areas. Areas with three or more surfaces (i.e., one floor and two walls) frequently produce detonations. Thus, the design of the HTSF when coupled with a sufficient concentration of hydrogen is conducive to detonations. It takes powerful ignition sources to produce a detonation in an unconfined hydrogen-air mixture.<sup>4</sup>

#### 3.1 Inventory

The maximum amount of hydrogen (physical limit) in one hydrogen tube trailer is approximately 38,000 cubic feet which yields 4,071 pounds TNT equivalent (See Appendix B of this document, Hand Calculations, page 22). The maximum amount of hydrogen in the hydrogen backup supply is 3,960 cubic feet which yields 424 pounds TNT equivalent (See Appendix B of this document, Hand Calculations, page 50).

#### 3.2 Conditions of Storage and Use

Both the primary and backup hydrogen reserves are in approved DOT containers and are labeled, maintained, and used in accordance with 29 CFR 1910.103<sup>5</sup> and The National Fire Protection Agency (NFPA) 50A document.<sup>6</sup> In addition, Safe Operating Procedures (SOPs) are used in the AMPL that prescribe requirements for safe handling of gases.

The primary hydrogen is a multi-tube semi-trailer, stored at 2,400 psig. If the tube trailer pressure drops below 40 psig or when the trailers are being changed, hydrogen is supplied by the backup supply system. The AMPL uses approximately 20,000 cubic feet per month.

The 18 hydrogen cylinders in the backup supply are received and stored in DOT approved vessels constructed of alloy steel. The cylinders are secured and manifolded in compliance with 29 CFR 1910.<sup>7</sup> Currently, there are 6 cylinders connected to one manifold with a regulator and 12 cylinders to a separate manifold with a separate regulator. The cylinders are DOT approved for storage of hydrogen at a pressure of 2200 psig. If the backup supply falls below 40 psig, the supply gas is automatically switched to argon.

The backup supply is connected in parallel with the hydrogen tube trailer. The backup supply is enclosed by two concrete block walls and two chain link fences and is covered by a light metal roof. One chain link fence has a gate.

#### 3.3 Properties

Atomic weight	1.008
<ul> <li>Molecular weight</li> </ul>	2.0159
<ul> <li>Specific gravity</li> </ul>	0.06952 @ 75° C @ atm
• Density	0.08988 g/liter (7% that of air)
<ul> <li>Melting point</li> </ul>	-259° C
<ul> <li>Boiling point</li> </ul>	-253° C
Critical density	0.3136 g/cc
Critical temperature	-240° C
Critical pressure	12.8 atm.
<ul> <li>Gross heat of combustion</li> </ul>	33.94 cal(gm)/gram.
<ul> <li>Autoig. temp. in air</li> </ul>	574° C - 585° C.
<ul> <li>Flammability limits</li> </ul>	4.0% to 75.0%.
<ul> <li>Detonation limits</li> </ul>	18.3% and 59.0%.
<ul> <li>Heat of vaporization</li> </ul>	216. cal(gm)/gm mole° C.
Specific Volume	1 lb. per 191.3 ft <sup>3</sup>

#### 3.4 Engineered Controls and Safety Features

There are 5 hydrogen sensors associated with the AMPL: 3 in the hydrogen brazing area, 1 in the dryer, and 1 located in the double wall construction, underground delivery line. If the hydrogen sensor detects hydrogen, both the hydrogen tube trailer and the backup supply are turned off automatically, and the delivery line is purged with argon. Also, an audible alarm will sound in zone 9 of the AMPL, and a visual warning is provided by a flashing light in room B1700, the hydrogen furnace room. In addition, the hydrogen monitor in room B1700 indicates which sensor detects hydrogen and will display the percentage of hydrogen in air. The hydrogen sensors are calibrated quarterly.

The underground delivery line from the hydrogen tube trailer and backup supply to the AMPL is constructed with stainless steel tubing and welded joints. The delivery line was pressurized and leak tested during installation in 1991. The underground delivery line is of double-wall construction; the hydrogen flows in the center pipe.

The hydrogen dryer removes oxygen and water from the source hydrogen. The dryer is protected from over pressurization by two pressure relief valves (one for each drying tube) vented above the building roof.

#### 3.5 Administrative Controls

There are ten safety requirements and or conditions that have been identified for the storage of a hydrogen tube trailer.<sup>8</sup>

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- 1. Hydrogen tube trailers cannot be parked beneath overhead electrical power lines.
- 2. Parked vehicles must be at least 15 feet from the hydrogen tube trailers.
- 3. Hydrogen tube trailers are not to be exposed to other flammable gases or liquids or to ignition points.
- 4. The area around the hydrogen tube trailers must be free of dry vegetation for 15 feet.
- 5. Hydrogen tube trailers are to be stored above ground. If the hydrogen tube trailers are not stored on higher ground, walls or dikes shall be used to prevent accumulation of flammable liquids under the trailers.
- 6. Hydrogen tube trailers shall be marked legibly with the name "Hydrogen." The storage location shall be marked with "No Smoking" and "No Open Flames."
  - **Note:** Smoking, itself, is not an ignition source as the temperature of a cigar or cigarette is not as high as the ignition temperature of hydrogen. The reason for not allowing smoking in the area of hydrogen is because a match or lighter presents an open flame which could cause ignition of a hydrogen-air or a hydrogen-oxygen mixture. Lightning or an electrical spark could ignite hydrogen.<sup>9</sup>
- 7. Hydrogen tube trailers shall be compliant to NFPA 50A with regard to DOT certification, pressure relief devices, tube and fittings, and gages and regulators.
- 8. Hydrogen tube trailers will be protected against physical damage and against tampering by the general public.
- 9. Hydrogen tube trailers shall be grounded during storage.
- 10. Administrative controls shall ensure compliance with these requirements.

### 4.0 SCENARIOS

There are two major hazards associated with the hydrogen in the Hydrogen Storage Facility. These hazards are fire and explosion. The two hazard sources within the HTSF are the hydrogen tube trailer and the backup supply. The following analysis of the tube trailer and the backup supply consists of scenarios involving two events. These hydrogen scenario events include: unconfined releases and confined explosions.

The unconfined release scenarios address the issue of hydrogen dispersal and a resultant unconfined explosion. The principles applied to the unconfined release scenarios were based on the concentration in percentage of hydrogen to air mixtures rich enough in hydrogen to constitute a fire or detonation hazard. The hazardous concentrations are 4 percent or 40,000 ppm hydrogen in air for fire and 18.3 percent or 183,000 ppm hydrogen in air for detonation.

The confined explosion scenarios address the issue of over pressurization due to an internal fire. The results of the following scenarios are summarized in Section 5.0, Event Consequences.

#### 4.1 Hydrogen Tube Trailer

#### 4.1.1 Failure of Primary Barrier

Hydrogen is stored in tubes on the tube trailer. Therefore, the individual tubes are the primary barriers to be considered. The primary barriers could fail through, for example, puncture, fracture, embrittlement/corrosion, misoperation of a valve and overpressure.

- Puncture or fracture to a tube could occur while switching trailers or from a collision of a
  gas powered vehicle with a hydrogen trailer. Due to the configuration of the tubes and
  the presence of individual valves, an accident in retrieval and replacement of the trailers
  could conceivably allow a limited release of hydrogen to occur. Once the puncture or
  fracture occurs, the entire contents of the effected vessel would be expelled at a rate
  determined by the size of the hole. Because of the tube's configuration on the trailers, it
  is possible that a single event could lead to the puncture or fracture of two or more tubes.
- 2. Embrittlement of the tube could occur due to prolonged exposure to hydrogen or corrosive attack on the tube. In theory, the tube could be weakened or breached by embrittlement or corrosion, leading to an unconfined release of hydrogen.
- 3. Damage of a tube stop valve could occur due to inadvertent misoperation or sabotage. The tube trailer is shipped with the rear doors closed concealing the valves at the end of each tube and their common manifold. Once in place inside the HTSF, the rear doors are opened and secured against the sides of the trailer. After the trailer is connected to the hydrogen supply system, the HTSF is secured by a lock on the gate. Thus, in the case of sabotage whether the event occurred while in transport, storage or use, the misoperation of a tube stop valve would require two separate deliberate acts. It is also conceivable that a valve could be inadvertently operated or damaged. The limiting case of this scenario would resemble a puncture or rupture in that the entire contents of the tube would be released at a rate determined by the degree to which the valve was opened. However, if the opening of the valves is a malevolent act, the perpetrator could be

assumed to open all the available tubes to maximize the impact, producing an unconfined release 38 times that of a single tube.

- 4. Overpressure from a fire could occur from a solid particle in the line. This is conceivably the worst case scenario because of its potential effect on the integrity of the entire system and the rate at which pressures compound within a confined environment. The resulting explosion would equal 20.5 pounds of TNT for each pound of hydrogen resulting in the production of both primary and secondary fragments. A solid particle in the line could cause an ignition by the following mechanisms: <sup>10</sup>
  - a. Energy of translation converted to heat by rapid deceleration. Particles traveling at or near sonic speeds possess enough energy to obtain the necessary hydrogen-air ignition temperature of 585° C if the particle is stopped in one collision. Conditions must exist for the sonic velocity to take place (i.e., a large drop in pressure and no slippage between the particle and the gas in which it is flowing). It should be noted that this is most likely to occur in the valve while opening and closing the valve.
  - b. Static charge buildup within flowing gas. A particle with a mass of 0.1 g at or near sonic velocity has a kinetic energy of approximately 50 joules which is sufficient to raise the particle to the hydrogen-air ignition temperature. If the particle converts 20 microjoules to electrical energy, a static discharge could ignite the hydrogen-air mixture upon striking a grounded wall. The process only needs to be a few hundredths of 1% efficient, and the hydrogen is too poor a conductor of electricity to dissipate a charge build-up.
  - c. Particle rupture within a valve seat upon being crushed by a closing valve. A particle passing through a seat valve can be squeezed and ruptured as the valve is closed. The cleavage surface is a high energy, local, hot spot that although less likely than the two previously mentioned scenarios, could possibly cause ignition.

#### 4.1.2 Effects on Other Barriers

The HTSF is an open air facility. Therefore, no physical barriers exist which would prevent the hydrogen from being released to the atmosphere. However, three 15 foot high concrete walls are located five feet from the trailer and enclose the trailer from the north, south, and east. There is a chain link gate located on the west side of the trailer. The concrete walls are eight inches thick and would mitigate the impact of an explosion. It is assumed that a higher overpressure would occur above the trailer and on the west side of the trailer. The resultant consequences are calculated in section 5.0 of this document.

#### 4.1.3 Range of Possible Releases

Scenarios involving barrier failure due to a puncture, fracture, embrittlement/corrosion of a tube or misoperation of a valve would result in the same amount of material released. These failure modes have been assigned release designations P-1 through P-12 and are identified below as Unconfined Releases. Scenarios involving barrier failure due to overpressure of a tube are identified below as Confined Explosions, release designations P-13 through P-16.

	Source Term Parameter	Meteorological Conditions	Release Designation
l Tube	.375" hole in diameter	Average	P-1
1,000 ft <sup>3</sup> of Hydrogen	3 Second Release	Worst Case	P-2
1 Tube	9" hole in diameter	Average	P-3
1,000 ft <sup>3</sup> of Hydrogen	Instantaneous Release	Worst Case	P-4
3 Tubes	(3) .375" holes	Average	P-5
3,000 ft <sup>3</sup> of Hydrogen	3,000 ft <sup>3</sup> of Hydrogen 3 Second Release		P-6
3 Tubes	(3) 9" holes	Average	P-7
3,000 ft <sup>3</sup> of Hydrogen	Instantaneous Release	Worst Case	P-8
30 Tube Stop Valves	.75" (common manifold)	Average	P-9
30,000 ft <sup>3</sup> of Hydrogen	25 Second Release	Worst Case	P-10
38 Tube Stop Valves	.75" (common manifold)	Average	P-11
38,000 ft <sup>3</sup> of Hydrogen	31 Second Release	Worst Case	P-12

 Table 4.1

 Hydrogen Tube Trailer Unconfined Release Scenarios

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#### 4.1.4 Confined Explosions

The following scenarios involve overpressure of tubes due to a fire originating within the confines of the delivery system or a malevolent act, resulting in ground level explosions. Scenarios involving confined explosions do not consider differences in meteorological conditions.

Confined Explosion Scenarios	Release Designation
1 tube/1,000 ft <sup>3</sup> of hydrogen	P-13
3 tubes/3,000 ft <sup>3</sup> of hydrogen	P-14
30 tubes/30,000 ft <sup>3</sup> of hydrogen	P-15
38 tubes/38,000 ft <sup>3</sup> of hydrogen	P-16

Table 4.2
Hydrogen Tube Trailer Confined Explosion Scenarios

#### 4.2 Hydrogen Backup Supply

#### 4.2.1 Failure of Primary Barrier

For the hydrogen backup supply, the hydrogen is stored in alloy steel cylinders. Therefore, the individual cylinders are the primary barriers to be considered. The primary barriers could fail through the same modes described above: puncture, fracture, embrittlement/corrosion of cylinder, misoperation of a valve, or overpressure.

- Puncture or fracture could occur while transporting cylinders. Because the cylinders are
  independent vessels with valves allowing each cylinder to be self contained, it is
  conceivable that if a release were to occur, the amount of materials released from this
  scenario would probably be limited. Once a puncture or fracture occurs, the entire
  contents of the effected vessel would be expelled at a rate determined by the size of the
  hole. Because of the close proximity of the cylinders to each other, it is possible that a
  single event could lead to the puncture or fracture of two or more cylinders.
- 2. Embrittlement of the cylinder could occur, as explained in Section 4.1.1.
- 3. Misoperation or damage of a cylinder stop valve could occur. Cylinders are shipped and stored with protective caps in place, concealing the cylinder valves. The cylinder is secured in place by a chain secured to a wall. It is then connected to the hydrogen backup supply. The HTSF backup system is within a closed fence. Thus, in the case of sabotage whether the event occurred while in transport, storage or use the misoperation of a cylinder stop valve would require two separate deliberate acts. It is also conceivable that a valve could be inadvertently operated or damaged. The limiting case of this scenario would resemble a puncture or rupture in that the entire contents of the cylinder

would be released at a rate determined by the degree to which the valve was opened. However, if the opening of the valves is a malevolent act, the perpetrator could be assumed to open all the available cylinders to maximize the impact, producing a combined release 18 times that of a single cylinder.

4. Overpressure could occur due to a solid particle in the line, as explained in Section 4.1.1.

#### 4.2.2 Effects on Other Barriers

The HTSF backup system is within an open air facility. Therefore, no other barriers exist. An incident involving the HTSF would result in an unconfined release to the atmosphere that would constitute a potential for fire and detonation.

#### 4.2.3 Range of Possible Releases

As mentioned above, barrier failure due to a puncture, fracture, embrittlement/corrosion of a cylinder or misoperation of a valve would result in the same amount of material released. These failure modes have been assigned release designations B-1 through B-8 and are identified below as Unconfined Releases. Scenarios involving barrier failure due to overpressure of a cylinder are identified as Confined Explosions, release designations B-9 through B-12.

Unconfined Release Scenarios	Source Term Parameter	Meteorological Conditions	Release Designation
l cylinder 220 ft <sup>3</sup> of hydrogen	0.375" hole in diameter 1 Second Release	Average	B-1
		Worst Case	B-2
3 cylinders	(3) 0.375" holes	Average	B-3
660 ft <sup>3</sup> of hydrogen	1 Second Release	Worst Case	B-4
12 cylinders	(12) 0.375" holes	Average	B-5
2,640 ft <sup>3</sup> of hydrogen	3 Second Release	Worst Case	B-6
18 cylinder	(18) 0.375" holes	Average	B-7
3,960 ft <sup>3</sup> of hydrogen	3,960 ft <sup>3</sup> of hydrogen 3 Second Release		B-8

 Table 4.3

 Hydrogen Backup Supply Unconfined Release Scenarios

#### 4.2.4 Confined Explosions

The following scenarios involve overpressure of cylinders due to a fire originating within the confines of the delivery system or a malevolent act, resulting in ground level explosions. Scenarios involving confined explosions do not consider differences in meteorological conditions.

Confined Explosion Scenarios	Release Designation
1 cylinder/220 ft <sup>3</sup> of hydrogen	B-9
3 cylinders/660 ft <sup>3</sup> of hydrogen	B-10
12 cylinders/2,640 ft <sup>3</sup> of hydrogen	B-11
18 cylinders/3.960 ft <sup>3</sup> of hydrogen	B-12

Table 4.4					
Hydrogen Backup Supply Confined Explosion Scenarios					

## 5.0 CONSEQUENCES and PROTECTIVE ACTIONS

To determine the consequences of fire and explosion, the computer model ARCHIE, Automated Resource for Chemical Hazard Incident Evaluation,<sup>11</sup> version 1.0, was utilized. ARCHIE was specifically used to determine discharge rates, toxic vapor dispersion analyses, flammable vapor cloud hazards, explosion hazards, and flame jets for the Hydrogen Storage Facility.

The purpose of ARCHIE is to provide emergency planning efforts with the resources necessary to undertake comprehensive evaluations of potentially hazardous facilities and activities within their respective jurisdictions and thereby formulate a basis for their planning efforts. ARCHIE was reviewed and approved for distribution by the DOT, EPA, and FEMA. ARCHIE provides a rough estimate of the magnitude of downwind areas that will be at risk and in no way should the model results be expected to be either highly accurate or precise. The answers produced by vapor dispersion models are considered, by many professionals, to be of acceptable accuracy if they are correct within a factor of two in 50% or more of trials.<sup>12</sup> Even though ARCHIE is a heavy gas model, the resultant consequences, although conservative, provide adequate information for the purpose of emergency planning.

ARCHIE also has a tank over pressurization application but was not utilized because of limitations in ARCHIE's ability to calculate inventories as large as those present in the HTSF. To determine over pressurization effects, hand calculations were applied. These calculations, derived from the Department of the Air Force Manual, "Structures to Resist the Effects of Accidental Explosions,"<sup>13</sup> can be found in Appendix B.

The potential consequences resulting from the unconfined release scenarios and confined explosion scenarios are described below.

#### 5.1 Unconfined Releases

Scenarios involving unconfined releases ranged from a release of 220  $ft^3$  to 38,000  $ft^3$  of hydrogen. The consequences were determined by analyzing the following:

- the distances at which Lower Flammability Levels and Lower Detonation Levels were reached
- the impact to personnel and or the general public should an unconfined explosion occur
- the time permissible to evacuate the area between the AMPL building and the source of the release (approximately 100 ft.) prior to Lower Flammability Levels and Lower Detonation Levels reach the AMPL.

The results of this analysis are depicted in Tables 5.1 and 5.2.

Unconfined Release Consequences involving Puncture, Fracture or Embrittlement					
Release Designation Amount Released	Meteorological Conditions	Unconfined LFL	1. S. W. M. M. S. Margar	Explosion Effects	Evacuation Time at AMPL (~100 ft)
P-1 1,000 ft <sup>3</sup> in 3 sec	Average	457	43	Slight to Serious Injury at 11 ft	0.2 min
P-2 1,000 ft <sup>3</sup> in 3 sec	Worst Case	457	223	Slight to Serious Injury at 11 ft	0.6 min
P-3 1,000 ft <sup>3</sup> in 3 sec	Average	267	152	Slight to Serious Injury at 20 ft	0.2 min
P-4 1,000 ft <sup>3</sup> instantly	Worst Case	914	501	Slight to Serious Injury at 20 ft	0.6 min
P-5 3,000 ft <sup>3</sup> in 3 sec	Average	195	95	Slight to Serious Injury at 15 ft	0.2 min
P-6 3,000 ft <sup>3</sup> in 3 sec	Worst Case	684	366	Slight to Serious Injury at 15 ft	0.6 min
P-7 3,000 ft <sup>3</sup> instantly	Average	267	152	Slight to Serious Injury at 20 ft	0.2 min
P-8 3,000 ft <sup>3</sup> instantly	Worst Case	914	501	Slight to Serious Injury at 20 ft	0.6 min
P-9 30,000 ft <sup>3</sup> in 25 sec	Average	286	119	Slight to Serious Injury at 31 ft	0.2 min
P-10 30,000 ft <sup>3</sup> in 25 sec	Worst Case	1,585	830	Slight to Serious Injury at 31 ft	0.6 min
P-11 38,000 ft <sup>3</sup> instantly	Average	286	119	Slight to Serious Injury at 31 ft	0.2 min
P-12 38,000 ft <sup>3</sup> instantly	Worst Case	1,721	882	Slight to Serious Injury at 31 ft	0.6 min

# Table 5.1Hydrogen Tube Trailer

Note: These results were derived from ARCHIE and can be referenced in Appendix A.

Unconfined	Release Cons	equences in	volving Pun	icture, Fracture or En	nbrittlement
Release Designation Amount Released	Meteorological Conditions	Downwind Unconfined LFL Distance (ft)	Unconfined LDL	Effects	Evacuation Time at AMPL (~100 ft)
B-1 220 ft <sup>3</sup> in 1 sec	Average	78	33	Slight to Serious Injury at 7 ft	0.1 min
B-2 220 ft <sup>3</sup> in 1 sec	Worst Case	255	33	Slight to Serious Injury at 7 ft	0.6 min
B-3 660 ft <sup>3</sup> in 1 sec	Average	120	56	Slight to Serious Injury at 10 ft	0.2 min
B-4 660 ft <sup>3</sup> in 1 sec	Worst Case	397	183	Slight to Serious Injury at 10 ft	0.6 min
B-5 2,640 ft <sup>3</sup> in 3 sec	Average	188	96	Slight to Serious Injury at 15 ft	0.2 min
B-6 2,640 ft <sup>3</sup> in 3 sec	Worst Case	651	347	Slight to Serious Injury at 15 ft	0.6 min
B-7 3,960 ft <sup>3</sup> in 3 sec	Average	219	116	Slight to Serious Injury at 17 ft	0.2 min
B-8 3,960 ft <sup>3</sup> in 3 sec	Worst Case	757	410	Slight to Serious Injury at 17 ft	0.6 min

Table 5.2Hydrogen Unconfined Release Consequences

Note: These results were derived from ARCHIE and can be referenced in Appendix A.

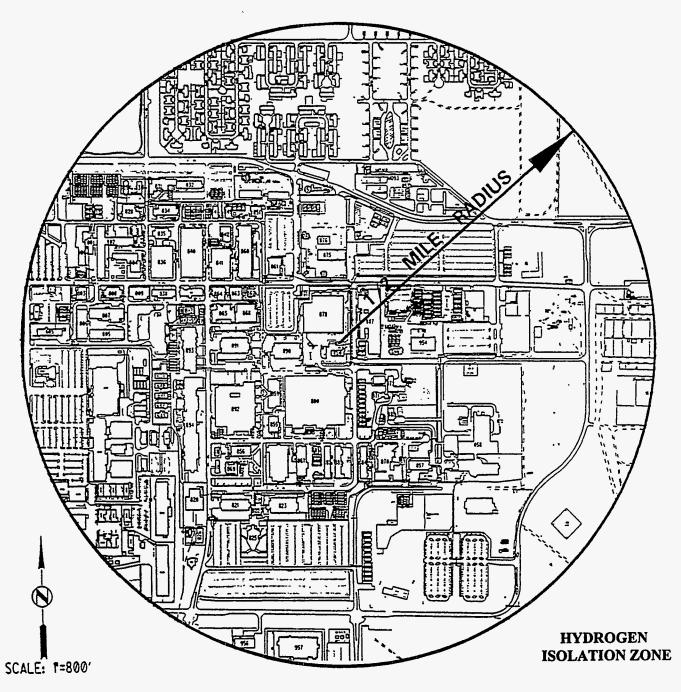
#### 5.1.1 Protective Actions

The correlation of event scenarios and estimated consequences are used to determine the protective actions that are appropriate to the scenarios, as well as the observable indications (i.e., Emergency Action Levels - EALs) to trigger protective actions.

The EAL involves any condition which could breach the cylinder and create a hydrogen release. If one of the five hydrogen sensors associated with the HTSF detects hydrogen, both the hydrogen tube trailer and the backup supply are turned off automatically and the delivery line is purged with argon.

The recommended protective actions involving a fire at the Hydrogen Trailer Storage Facility is the establishment of a half mile (2,640 ft.) isolation zone as prescribed in DOT P-5800.5 (Illustration 5-1). This zone encompasses both the farthest Lower Flammability Level distance (1,721 ft.) and the farthest Lower Detonation Level distance (882 ft.) which were calculated through the ARCHIE computer model.

Hydrogen is not considered a toxic hazard, and therefore, no protective measures concerning toxicity are warranted. However, hydrogen is an extremely dangerous fire and explosion hazard. In the event of a fire or a hydrogen leak, AMPL personnel should evacuate from the northwest corner of the AMPL. In addition, the residents of the trailers within 150 feet of the HTSF should evacuate away from the hydrogen trailer. The recommended protective action for the remaining individuals within the half mile isolation zone is to shelter in place. These individuals should move away from windows and seek shelter within interior rooms or halls, under sturdy furniture or doorways.



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Illustration 5-1

#### 5.2 Confined Explosions

Scenarios involving confined explosions ranged from 220 ft<sup>3</sup> to 38,000 ft<sup>3</sup> of hydrogen. The consequences were determined by analyzing:

- the pressure impacting the nearest structures which included the walls surrounding the HTSF (~5 feet from the HTSF) and the AMPL (~100 ft. from the HTSF)
- the distance at which 1.0 psi overpressure threshold was reached.
- the distance at which 10.0 psi overpressure threshold was reached
- the initial fragment velocity
- the sizes of fragments and the distance to which different sized fragments reached the striking threshold
- the velocity of different sized fragments at the threshold

As calculated in Appendix B, the overpressure levels of concern are 1.0 psi and 10 psi as these overpressures represent conditions ranging from slight/serious injuries from flying glass/objects to lethal effects to personnel and the general public. The following chart depicts the expected damage at various overpressure thresholds.

Explosion Overpressure Damage Estimates				
Overpressure (psig)	Expected Damage			
0.03	Occasional breakage of large windows already under stress.			
0.30	Some damage to house ceilings; 10% window breakage.			
0.5-1.0	Windows usually shattered; some window frame damage.			
1.0	Partial demolition of houses; made uninhabitable.			
1.0-8.0	Range for slight to serious injuries due to skin lacerations from flying glass and other missiles.			
2.0	Partial collapse of walls and roofs of houses.			
2.0-3.0	Non-reinforced concrete/cinder block walls shattered.			
2.4-12.2	Range for 1-90% eardrum rupture among exposed populations.			
2.5	50% destruction of home brickwork.			
3.0-4.0	Frameless steel panel buildings ruined.			
5.0	Wooden utility poles snapped.			
5.0-7.0	Nearly complete destruction of houses.			
10.0	Probable total building destruction.			
14.5-29.0	Range for 1-99% fatalities among exposed populations			
	due to direct blast effects.			

Table 5.3

Source: Lees, F.P., "Loss prevention in the Process Industries", Vol. 1, Butterworths, London and Boston, 1980.

Table 5.3							
Confined Explosions							
Release Designation/ Number of Cylinders	TNT Equivalents (Includes 20% Safety Factor	Pso on Nearest Structure (psi)	1.0 psi Threshold Distance (feet)	10.0 psi Threshold Distance (feet)	initial Fragment Velocity (fl/sec)	Distance to Fragment Striking Threshold	Fragment Velocity at Threshold (fl/sec)
P-13 (1)1,000 ft <sup>3</sup>	128 lbs	1,000 at A 7 at B	227	45	2905	7.8 oz/1584 ft 1.5oz/914 ft	7.8 oz/119 1.5 oz/619
P-14 (3)1,000 ft <sup>3</sup>	386 lbs	4,000 at A 8 at B	328	66	2905	7.8 oz/1584 ft 1.5oz/914 ft	7.8 oz/119 1.5 oz/619
P-15 (30)1,000 ft <sup>3</sup>	3857 lbs	8,000 at A 75 at B	706	141	2905	7.8 oz/1584 ft 1.5oz/914 ft	7.8 oz/119 1.5 oz/619
P-16 (38)1,000 ft <sup>3</sup>	4886 lbs	9,000 at A 80 at B	764	153	2905	7.8 oz/1584 ft 1.5oz/914 ft	7.8 oz/119 1.5 oz/619
B-9 (1)220 ft <sup>3</sup>	28 lbs	800 at A 5 at B	137	27	3025	5.7 oz/1308 ft 1.5oz/454 ft	5.7 oz/163 1.5 oz/619
B-10 (3)220 ft <sup>3</sup>	85 lbs	900 at A 6 at B	198	40	3025	5.7 oz/1308 ft 1.5oz/454 ft	5.7 oz/163 1.5 oz/619
B-11 (12)220 ft <sup>3</sup>	340 lbs	3,000 at A 8 at B	313	63	3025	5.7 oz/1308 ft 1.5oz/454 ft	5.7 oz/163 1.5 oz/619
B-12 (18)220 ft <sup>3</sup>	509 lbs	5,000 at A 9 at B	360	72	3025	5.7 oz/1308 ft 1.5oz/454 ft	5.7 oz/163 1.5 oz/619

Table 5.2

A - The walls surrounding the HTSF (approximately 5 feet from trailer)

**B** - The AMPL (approximately 100 feet from trailer)

Note: These results were derived from calculations identified in AFM 88-22 and DOD 6055.9 which can be referenced in Appendix B.

#### **5.2.1 Protective Actions**

The probable overpressure damage at 10.0 psi is total building destruction. As shown in Table 5.4, the worst case scenario is an explosion involving 38,000 ft<sup>3</sup> (RD P-16) which would result in a 10.0 psi threshold distance of 153 feet. No protective actions could be implemented to warn or evacuate personnel within the 10 psi threshold distance as the explosion and damage would occur instantly.

The eight inch thick concrete walls would mitigate the impact of an explosion. However, the concrete walls, located five feet from the trailer, would be shattered and would not withstand an explosion. As shown in Table 5.4, the overpressure resulting from one cylinder is estimated to be 1,000 psi at the concrete walls. It is assumed that a higher overpressure would occur above the trailer and on the west side of the trailer. It is also assumed that the 20% safety factor calculated in Appendix B of this document would account for the increased overpressure above the trailer and to the west of the trailer.

There are several chemical and waste satellites within this distance that could be adversely impacted by an explosion from the HTSF. In such an event, mitigative measures can be taken to protect the general public from exposure to the chemicals stored in this area. These chemicals belong to various organizations within AMPL, and those that have been determined hazardous are analyzed in the AMPL Hazards Assessment Document.<sup>14</sup>

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### 6.0 CONCLUSION

As a result of this analysis, the maximum amount of hydrogen available for release is  $38,000 \text{ ft}^3$  which represents the worst case scenario. The results of the scenarios involving  $38,000 \text{ ft}^3$  are described below.

- The farthest Lower Flammability Level distance is 1,721 feet.
- The farthest Lower Detonation Level distance is 882 feet.
- The greatest distance at which 10.0 psi overpressure (i.e., total building destruction) is reached is 153 feet.

The recommended protective action involving a fire at the Hydrogen Trailer Storage Facility is the establishment of a half mile (2,640 ft.) isolation zone as prescribed in DOT P-5800.5.

In the event of a fire or a hydrogen leak involving the HTSF, the recommended protective action for the AMPL occupants is to evacuate from the northwest corner of the AMPL. In addition, the residents of the trailers within 150 feet of the HTSF should evacuate away from the hydrogen trailer. The recommended protective action for the remaining individuals within the half mile isolation zone is to shelter in place. These individuals should move away from windows and seek shelter within interior rooms or halls, under sturdy furniture or doorways.

## REFERENCES

- 1. Automated Resource for Chemical Hazard Incident Evaluation (ARCHIE), Version 1.0. Federal Emergency Management Agency (FEMA), Department of Transportation (DOT), and Environmental Protective Agency (EPA).
- 2. Air Force Manual 88-22, Structures to Resist the Effects of Accidental Explosions. Departments of the Army, the Navy, and the Air Force. June 1969.
- 3. DOT P 5800.6, 1993 Emergency Response Guidebook.
- 4. C.J.M. Northrup, Jr., R.P. Wemple, L.P. Baudoin, Considerations when Designing, Assembling, and Operating a Gaseous Hydrogen Pressure System, Development Report, SC-DR-72 0593. November 1972.
- 5. Occupational Safety and Health Administration, Department of Labor, 29 Code of Federal Regulations, Part 1910.103.
- 6. The National Fire Protection Agency (NFPA) 50A document, Standard for Gaseous Hydrogen Systems at Consumer Sites, 1989 Edition.
- 7. Reference 5.
- 8. L.E. Pope. Requirements for Hydrogen Tube Trailer Storage Memo. November 15, 1990.
- 9. F.J. Edeskuty, B. Olinger, W. Clarence Courtright. *Hydrogen-Oxygen Explosion in a Tube Trailer at the Compressed Gas Facility*; *June 3, 1981*, Investigation Report. September, 1981.
- 10. Ibid.
- 11. Reference 1.
- 12. Handbook of Chemical Hazards Analysis Procedures. FEMA, DOT, and EPA.
- 13. Reference 2.
- 14. C.L. Wood, SAND94-1520 Advanced Manufacturing Processes Laboratory Hazards Assessment Document. July, 1994.
- 15. Reference 2.
- 16. 6055.9-STD, Ammunition and Explosives Safety Standards, October 30, 1992.

# Appendix A

# **ARCHIE Dispersion Model Printouts**

Release Designations for Hydrogen Tube Traile	er
RD P-1	1
RD P-2	8
RD P-3	15
RD P-4	
RD P-5	
	36
RD P-7	43
RD P-8	50
RD P-9	57
RD P-10	64
RD P-11	71
RD P-12	78
Release Designations for Hydrogen Backup Su	pply
RD B-1	
RD B-2	92
RD B-3	99
RD B-4	106
	113
RD B-6	120
RD B-7	
RD B-8	

HAZARDOUS MATERIAL	=	Hydrogen
ADDRESS \ LOCATION	=	PDL
DATE OF ASSESSMENT	=	9-8-93
NAME OF DISK FILE	=	P-1.ASF

#### **\*\*\*** SCENARIO DESCRIPTION

One cylinder releases 1,000 cubic feet of hydrogen through a hole 0.375 inches in diameter under average met. conditions taking approximately 3 seconds. ٦

#### \*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	95.1	lbs/min
Duration of discharge	=	.056	minutes
Amount discharged	=	5.24	lbs
State of material	=	Gas	

#### \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwi	nd distance	to	concent	ration	of	40000	ppm
at	groundlevel		=	435		ť	feet
at	discharge h	eigh	it =	417		1	Eeet

Peak concentration on ground is 340516 ppm at a downwind distance of 131 feet for elevated emission source specified by user.

See attached table(s) for further details.

#### \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	289	feet
Safe separation distance	=	578	feet
Flame jet duration	=	.056	minutes

#### \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1,	/2 LFL	LFL	
	Downwind hazard distance	=	589	457	feet
	Max hazard zone width	=	295	229	feet
	Max weight explosive gas			5.4	
	Relative gas/air density				
	Model used in analysis	÷	Neutral	ly buoya	ant
Note:	Clouds or plumes contain:	ing	less the	an 1000	pounds
	of vapor or gas are very	un	likely to	o explo	ie when

completely unconfined, except when one of a cer-

tain few materials have been discharged.

\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

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#### TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind	l Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation Zone Width*
(feet)	(miles)	(ppm)	(ppm)	(feet)
100 102	.02	54954 53699	48614 47557	130 120
103 104	.02	52477 51286	46528	120
106	.02	50126	45525 44549	120
107 108	.03 .03	48996 47895	43598 42671	110 95
109 111	.03 .03	46823 45779	41767 40887	90 83
112 113	.03 .03	44762 43772	40029 39192	76 68
114 116	.03	42807 41868	38377 37582	59 49
117	.03	40953	36807	35
118	.03	40000	36051	1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

#### TOXIC VAPOR DISPERSION ANALYSIS RESULTS

		at Downwind Location	me Contaminant Departure Time at Downwind Location (minutes)
100 102 103 104 106 107 108 109 111 112 113 114 116 117 118	.02 .02 .02 .02 .02 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03	.2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2	. 4 . 4 . 4 . 4 . 4 . 4 . 4 . 4 . 4 . 4

CAUTION: See guide for assumptions used in estimating these times.

			UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS				
tsta	NCE Fi (fee	ROM EXPI t)	OSION EXPECTED DAMAGE				
	198 28		Occasional breakage of large windows under stress. Some damage to home ceilings; 10% window breakage.				
11	- 11	19	Windows usually shattered; some frame damage. Partial demolition of homes; made uninhabitable.				
3	-7	11	Range serious/slight injuries from flying glass/object. Partial collapse of home walls/roofs.				
5	-	7	Non-reinforced concrete/cinder block walls shattered.				
3	6	6	Range 90-1% eardrum rupture among exposed population. 50% destruction of home brickwork.				
4	- 4	5	Frameless steel panel buildings ruined. Wooden utility poles snapped.				
3	- 3	4	Nearly complete destruction of houses. Probable total building destruction.				
2	-	2	Range for 99-1% fatalities among exposed populations due to direct blast effects.				

Note: The center of an unconfined gas/vapor explosion can be anywhere within the ground area passed over by the cloud or plume. See results of the vapor cloud fire hazard analysis for the maximum downwind distance and maximum width of this area. Explosion is assumed to take place on or near the ground.

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#### INPUT PARAMETER SUMMARY

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PHYSIOCHEMICAL PROPERTIES OF MATERI		
NORMAL BOILING POINT	= -423 degrees	F
MOLECULAR WEIGHT	= 2.0159	
VAPOR PRES AT CONTAINER TEMP	<b>–</b>	
	= 124167 mm Hg	
VAPOR PRES AT AMBIENT TEMP	= 2400.1 psia	
	= 124167 mm Hg	
SPECIFIC HEAT RATIO FOR GAS	= 1.4	
LOWER FLAMMABLE LIMIT (LFL)	= 4 vol%	
LOWER HEAT OF COMBUSTION	= 191.7 Btu/lb	
GAS EXPLOSION YIELD FACTOR	= .03	
TOXIC VAPOR LIMIT	= 40000 ppm	
CONTAINER CHARACTERISTICS		
	= Horizontal cylinder	
CONTAINER TYPE	= Horizontal cylinder	
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS	= 5.24 lbs	•
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER	= 5.24 lbs = .375 inch(es	)
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE	= 5.24 lbs = .375 inch(es = .98	
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS	= 5.24 lbs = .375 inch(es = .98 = 68 degrees	
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE	= 5.24 lbs = .375 inch(es = .98	
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE	= 5.24 lbs = .375 inch(es = .98 = 68 degrees = 2400 psia	
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS	= 5.24 lbs = .375 inch(es = .98 = 68 degrees = 2400 psia	F
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIST AMBIENT TEMPERATURE	= 5.24 lbs = .375 inch(es = .98 = 68 degrees = 2400 psia FICS = 68 degrees	F
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS' AMBIENT TEMPERATURE WIND VELOCITY	= 5.24 lbs = .375 inch(es = .98 = 68 degrees = 2400 psia FICS = 68 degrees = 9 mph	F
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIST AMBIENT TEMPERATURE WIND VELOCITY ATMOSPHERIC STABILITY CLASS	= 5.24 lbs = .375 inch(es = .98 = 68 degrees = 2400 psia FICS = 68 degrees = 9 mph = C	F
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS' AMBIENT TEMPERATURE WIND VELOCITY	= 5.24 lbs = .375 inch(es = .98 = 68 degrees = 2400 psia FICS = 68 degrees = 9 mph = C	F

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOU	S MATERIAL	=	Hydrogen
ADDRESS `	\ LOCATION	=	PDL
DATE OF A	ASSESSMENT	=	9-8-93
NAME OF	DISK FILE	=	P-1DETON.ASF

\*\*\* SCENARIO DESCRIPTION

One cylinder releases 1,000 cubic feet of hydrogen through a hole 0.375 inches in diameter under average met. conditions taking approximately four seconds.

\*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	95.1	lbs/min
Duration of discharge	=	.056	minutes
Amount discharged	=	5.24	lbs
State of material	=	Gas	

#### \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind distance to	concentratio	on of 183000 ppm
at groundlevel	= Not d	observed
at discharge heig	ht = 44	feet

Note: Minimum computable answer is 33 feet! Actual hazard distance may be less.

> Peak concentration on ground is 137994.1 ppm at a downwind distance of 43 feet for elevated emission source specified by user.

See attached table(s) for further details.

\*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	289	feet
Safe separation distance	=	578	feet
Flame jet duration	=	.056	minutes

\*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

F	For concentration of	1/2 LF	L LFL	
M M R Note: C C	Downwind hazard distance Max hazard zone width Max weight explosive gas Relative gas/air density Model used in analysis Clouds or plumes containing of vapor or gas are very completely unconfined, estain few materials have b	= 83 = 5.4 = 1.01 = Neut ing less unlikel	63 5.4 1.01 rally buoy than 1000 y to explo when one of	initially ant pounds de when

\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

Downwind	l Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation Zone Width*
(feet)	(miles)	(mdd)	(ppm)	(feet)
32 33 34 35 36 37 37 38 39 40 41 42	.01 .01 .01 .01 .01 .01 .01 .01 .01 .01	117665 121336 124578 127409 129848 131919 133643 135045 136146 136971 137540 137876 137998	325152 309687 295353 282048 269681 258170 247444 237437 228091 219352 211172 203507 196318	60 58 56 54 52 49 47 44 41 38 34 29 24
42 43 44	.01 .01 .01	137925 137675	189569 183000	17 1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

# TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind	Distance	Contaminant Arrival Time at Downwind Location	Contaminant Departure Time at Downwind Location
(feet)	(miles)		(minutes)
32 33 34 35 36 37 37 37 38 39 40	.01 .01 .01 .01 .01 .01 .01 .01 .01 .01	.1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1	.2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2
41 42 42 43 44	.01 .01 .01 .01 .01	.1 .1 .1 .1 .1 .1	.2 .2 .2 .2 .2 .2

CAUTION: See guide for assumptions used in estimating these times.

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PHYSIOCHEMICAL PROPERTIES OF MATER	IAL	
NORMAL BOILING POINT	= -423	degrees F
MOLECULAR WEIGHT	= 2.0159	5
VAPOR PRES AT CONTAINER TEMP	= 2400	psia
	= 124167	mm Hg
VAPOR PRES AT AMBIENT TEMP	= 2400.1	psia
	= 124167	mm Hg
SPECIFIC HEAT RATIO FOR GAS	= 1.4	
LOWER FLAMMABLE LIMIT (LFL)	= 4	vol%
LOWER HEAT OF COMBUSTION	= 191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	= .03	
TOXIC VAPOR LIMIT	= 183000	ppm
CONTAINER CHARACTERISTICS		
CONTAINER TYPE	= Horizontal c	vlinder
TOTAL WEIGHT OF CONTENTS		lbs
DISCHARGE HOLE DIAMETER		inch(es)
DISCHARGE COEFFICIENT OF HOLE		
TEMP OF CONTAINER CONTENTS		degrees F
	= 2400	psia
		2
ENVIRONMENTAL/LOCATION CHARACTERIS	TICS	
AMBIENT TEMPERATURE	= 68	degrees F
WIND VELOCITY	= 9	mph
ATMOSPHERIC STABILITY CLASS	= C	
VAPOR/GAS DISCHARGE HEIGHT	= 5	feet
KEY RESULTS DROUTDED BY HERE INSTE	AD OF BY FUALITAT	TON METHODS

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 9-8-93 NAME OF DISK FILE = P-2.ASF

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\*\*\* SCENARIO DESCRIPTION

One cylinder releases 1,000 cubic feet of hydrogen through a hole 0.375 inches in diam. under worst case met. conditions taking approximately three seconds.

# \*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	95.1	lbs/min
Duration of discharge	=	.056	minutes
Amount discharged	=	5.24	lbs
State of material	=	Gas	

# \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwi	nd distance.	to	concen	tration	of	40000	ppm
at	groundlevel		=	435		1	feet
at	discharge h	eigh	nt =	417		1	Eeet

Peak concentration on ground is 340516 ppm at a downwind distance of 131 feet for elevated emission source specified by user.

See attached table(s) for further details.

\*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	289	feet
Safe separation distance	=	578	feet
Flame jet duration	=	.056	minutes

## \*\*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1/	2 LFL	LFL	
	Downwind hazard distance	=	589	457	feet
	Max hazard zone width	=	295	229	feet
	Max weight explosive gas			5.4	lbs
	Relative gas/air density				initially
	Model used in analysis	=	Neutral	ly buoya	ant
<b>•</b> •	Clouds or plumes containt	na	less the	m 1000	nounde

Note: Clouds or plumes containing less than 1000 pounds of vapor or gas are very unlikely to explode when completely unconfined, except when one of a certain few materials have been discharged.

\*\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

_ownwind	l Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation
(feet)	(miles)	(ppm)	(ppm)	Zone Width* (feet)
100	.02	269870	1000000	73
124	.03	339072	722050	91
148	.03	323748	454929	110
172	.04	278545	311315	130
196	04	230371	227178	150
220	.05	188204	173721	160
244	.05	153736	137334	180
268	.06	126255	111205	200
291	.06	104493	91683	220
315	.06	87229	76664	230
339	.07	73454	64851	250
363	.07	62379	55400	270
387	.08	53399	47731	290
411	.08	46057	41435	290
435	.09	40000	36215	1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind	Distance	Contaminant Arrival Time at Downwind Location	Contaminant Departure Time
(feet)			(minutes)
100 124 148 172 196 220 244 268 291	.02 .03 .03 .04 .04 .04 .05 .05 .05 .06 .06	.6 .8 .9 1 1.2 1.3 1.4 1.6 1.7	1.2 1.5 1.8 2.1 2.3 2.6 2.9 3.2 3.4
315 339 363 387 411 435	.06 .07 .07 .08 .08 .08	1.8 2 2.1 2.2 2.4 2.5	3.7 4 4.2 4.5 4.8 5

CAUTION: See guide for assumptions used in estimating these times.

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# UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

DISTAN	CE F (fee		EXPLOSION EXPECTED DAMAGE
	198		Occasional breakage of large windows under stress.
	28		Some damage to home ceilings; 10% window breakage.
11	-	19	Windows usually shattered; some frame damage.
	11		Partial demolition of homes; made uninhabitable.
3	-	11	Range serious/slight injuries from flying glass/object.
	7		Partial collapse of home walls/roofs.
5	-		Non-reinforced concrete/cinder block walls shattered.
3	-	6	Range 90-1% eardrum rupture among exposed population.
	6		50% destruction of home brickwork.
4	-	5	Frameless steel panel buildings ruined.
	4		Wooden utility poles snapped.
3	-	4	Nearly complete destruction of houses.
	3		Probable total building destruction.
2	-	2	Range for 99-1% fatalities among exposed populations due to direct blast effects.

Note: The center of an unconfined gas/vapor explosion can be anywhere within the ground area passed over by the cloud or plume. See results of the vapor cloud fire hazard analysis for the maximum downwind distance and maximum width of this area. Explosion is assumed to take place on or near the ground.

PHYSIOCHEMICAL PROPERTIES OF MATERI	IAL		
NORMAL BOILING POINT	= -	-423	degrees F
MOLECULAR WEIGHT	=	2.0159	
VAPOR PRES AT CONTAINER TEMP	=	2400	psia
	=	124167	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2400.1	psia
	=	124167	mm Hg
SPECIFIC HEAT RATIO FOR GAS		1.4	•
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%
LOWER HEAT OF COMBUSTION	=	191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
TOXIC VAPOR LIMIT	=	40000	mqq
CONTAINER CHARACTERISTICS			
CONTAINER CHARACTERISTICS CONTAINER TYPE	_	Norigontal a	alindar.
		Horizontal c	lbs
TOTAL WEIGHT OF CONTENTS			
		.375	inch(es)
DISCHARGE COEFFICIENT OF HOLE			
TEMP OF CONTAINER CONTENTS		68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia
ENVIRONMENTAL/LOCATION CHARACTERIS	TIC	S	
AMBIENT TEMPERATURE	=	68	degrees F
WIND VELOCITY	=	2	ngm
ATMOSPHERIC STABILITY CLASS	=	F	-
VAPOR/GAS DISCHARGE HEIGHT			feet
			TON NEWTODO

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 9-8-93 NAME OF DISK FILE = P-2DETON.ASF

\*\*\* SCENARIO DESCRIPTION

One cylinder releases 1,000 cubic feet of hydrogen through a hole 0.375 inches in diam. under worst case met. conditions taking approximately three seconds.

\*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

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Peak discharge rate	=	95.1	lbs/min
Duration of discharge	=	.056	minutes
Amount discharged	=	5.24	lbs
State of material	=	Gas	

## \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwi	nd distand	ce to	concent	tration	of	183000	ppm
at	groundleve	el	=	223		fe	eet
at	discharge	heigh	it =	215		fe	eet

Peak concentration on ground is 340413.4 ppm at a downwind distance of 131 feet for elevated emission source specified by user.

See attached table(s) for further details.

\*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	289	feet
Safe separation distance	=	578	feet
Flame jet duration	=	.056	minutes

## \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1/2 LFL	LFL	
	Downwind hazard distance	= 589	457	feet
	Max hazard zone width	= 295	229	feet
	Max weight explosive gas	= 5.4	5.4 .	lbs
	Relative gas/air density	= 1.01	1.01	initially
	Mcdel used in analysis	= Neutral	ly buoya	ant
Note:	Clouds or plumes contain	ing less th	an 1000	pounds
	of vapor or gas are very	unlikely t	o exploi	le when
	completely unconfined,	except when	one of	a cer-
	tain few materials have	been discha	rged.	

\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

	Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation Zone Width*
(feet)	(miles)	(ppm)	(mgg)	(feet)
100	.02	269870	1000000	73
109	.03	309099	1000000	80
118	.03	331632	829552	86
127	.03	340267	686087	92
136	.03	338468	574951	99
144	.03	329431	487810	110
153	.03	315743	418681	120
162	.04	299348	363207	120
171	.04	281639	318172	130
179	.04	263567	281188	140
188	.04	245760	250470	140
197	.04	228614	224675	150
206	.04	212359	202786	150
214	.05	197114	184029	130
223	.05	183000	167811	1

'Usually safe for < 1 hour release. Longer releases or sudden wind shifts way require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

		Contaminant Arrival Time at Downwind Location	Contaminant Departure Time
		(minutes)	
109 118 127 136 144 153 162 171 179	.02 .03 .03 .03 .03 .03 .03 .04 .04 .04 .04 .04 .04	.6 .7 .7 .8 .8 .9 .9 .9 1 1 1	1.2 1.3 1.4 1.5 1.7 1.7 1.7 1.8 1.9 2 2.1 2.1 2.2
188 197 206 214 223	.04 .04 .04 .05 .05	1.1 1.2 1.2 1.3 1.3	2.2 2.3 2.4 2.5 2.6

CAUTION: See guide for assumptions used in estimating these times.

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PHYSIOCHEMICAL PROPERTIES OF MATERI			-
NORMAL BOILING POINT	= •	-423	degrees F
MOLECULAR WEIGHT	=	2.0159	
VAPOR PRES AT CONTAINER TEMP			psia
	=	124167	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2400.1	psia
	=	124167	mm Hg
SPECIFIC HEAT RATIO FOR GAS	=	1.4	
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%
LOWER HEAT OF COMBUSTION			Btu/lb
GAS EXPLOSION YIELD FACTOR			
TOXIC VAPOR LIMIT		183000	ppm
CONTAINER CHARACTERISTICS		**	
CONTAINER TYPE		Horizontal c	
TOTAL WEIGHT OF CONTENTS		~	lbs
DISCHARGE HOLE DIAMETER		.375	inch(es)
DISCHARGE COEFFICIENT OF HOLE	=	.98	
TEMP OF CONTAINER CONTENTS	=	68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia
		c	
ENVIRONMENTAL/LOCATION CHARACTERIS	TTC		Jammana P
AMBIENT TEMPERATURE	=	68	degrees F
WIND VELOCITY	=	-	mph
ATMOSPHERIC STABILITY CLASS		F	
VAPOR/GAS DISCHARGE HEIGHT	=	5	feet

- KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED
- KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 9-8-93 NAME OF DISK FILE = P-3.ASF

#### \*\*\* SCENARIO DESCRIPTION

One cylinder releases 1,000 cubic feet of hydrogen through a hole 9.0 inches in diameter under average met. conditions instantaneously.

## \*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	34620	lbs/min
Duration of discharge	=	.001	minutes
Amount discharged	=	5.24	lbs
State of material	=	Gas	

# \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Dov	vnwi	ind distanc	e to	concer	ntration	of	40000	ppm
	at	groundleve	1	=	264			feet
	at	discharge	heigh	it =	261		:	feet

Peak concentration on ground is 1000000 ppm at a downwind distance of 35 feet for elevated emission source specified by user.

See attached table(s) for further details.

## \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	6926	feet
Safe separation distance	=	13851	feet
Flame jet duration	=	.001	minutes

#### \*\*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1,	/2 LFL	LFL	
		-			
	Downwind hazard distance	=	341	267	feet
	Max hazard zone width	=	171	134	feet
	Max weight explosive gas				
	Relative gas/air density				
	Model used in analysis	÷	Neutral	ly buoya	ant
Note:	Clouds or plumes contain:	ing	less that	an 1000	pounds
	of vapor or gas are very	un	likely to	o exploa	ie when
	completely unconfined, of	exc	ept when	one of	a cer-
	tain few materials have 1	bee	n discha	rged.	

## \*\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

Downwind Distance		Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (feet)			
(feet)	(miles)	(pp)					
100 112 124 136 147	.02 .03 .03 .03 .03 .03	541204 408945 315948 248915 199494	478767 365860 285958 227725 184267	350 390 430 460 440			
159	.04	162313	151183	430			
171 182 194 206 217 229 241 253	.04 .04 .04 .05 .05 .05 .05	133830 111653 94135 80116 68764 59474 51798 45399	125560 105415 89361 76415 65860 57170 49951 43904	410 390 360 340 300 270 220 160 1			
264	.05	40000	38801	Ť			

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

# TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind	Distance	Contaminant Arrival Time at Downwind Location	Contaminant Departure Time		
(feet)	(miles)	(minutes)	(minutes)		
100 112 124 136 147 159 171 182 194 206 217 229 241	.02 .03 .03 .03 .04 .04 .04 .04 .04 .04 .04 .04 .04 .05 .05 .05	.2 .2 .2 .2 .3 .3 .3 .3 .3 .3 .3 .3 .3 .3 .3 .3 .3	.3 .3 .4 .4 .4 .5 .5 .5 .5 .5 .6 .6 .6 .6 .7		
253 264	.05	.4	.7 .7		

CAUTION: See guide for assumptions used in estimating these times.

## UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

STA		FROM et)	EXPLOSION	EXPECTED DAMAGE
	36 52			hal breakage of large windows under stress. mage to home ceilings; 10% window breakage.
20		34	Windows	usually shattered; some frame damage. demolition of homes; made uninhabitable.
5		20	Range s	erious/slight injuries from flying glass/object. collapse of home walls/roofs.
9		· 12	Non-rei	nforced concrete/cinder block walls shattered.
4	- 11			0-1% eardrum rupture among exposed population. truction of home brickwork.
8	- 7	• 9		ss steel panel buildings ruined. utility poles snapped.
6	5	• 7		complete destruction of houses. e total building destruction.
3		- 4		or 99-1% fatalities among exposed populations direct blast effects.

Note: The center of an unconfined gas/vapor explosion can be anywhere within the ground area passed over by the cloud or plume. See results of the vapor cloud fire hazard analysis for the maximum downwind distance and maximum width of this area. Explosion is assumed to take place on or near the ground.

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PHYSIOCHEMICAL PROPERTIES OF MATERI	IAL		
NORMAL BOILING POINT	≕ -	423	degrees F
MOLECULAR WEIGHT	=	2.0159	-
VAPOR PRES AT CONTAINER TEMP	=	2400	psia
	=	124167	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2400.1	psia
	=	124167	mm Hg
SPECIFIC HEAT RATIO FOR GAS			-
LOWER FLAMMABLE LIMIT (LFL) LOWER HEAT OF COMBUSTION	=	4	vol%
LOWER HEAT OF COMBUSTION	=	191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
TOXIC VAPOR LIMIT	=	40000	ppm
CONTAINER CHARACTERISTICS			
CONTAINER TYPE	_	Horizontal cy	vlinder
TOTAL WEIGHT OF CONTENTS			lbs
DISCHARGE HOLE DIAMETER			inch(es)
DISCHARGE COEFFICIENT OF HOLE			2.10.1 (00)
TEMP OF CONTAINER CONTENTS			degrees F
TANK RUPTURE PRESSURE			psia
	-	2100	5010
ENVIRONMENTAL/LOCATION CHARACTERIS	TICS	5	
AMBIENT TEMPERATURE		68	degrees F
WIND VELOCITY	=	9	mph
ATMOSPHERIC STABILITY CLASS	=	С	
VAPOR/GAS DISCHARGE HEIGHT	=	5	feet

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 9-8-93 NAME OF DISK FILE = P-3DETON.ASF

\*\*\* SCENARIO DESCRIPTION

One cylinder releases 1,000 cubic feet of hydrogen through a hole 9.0 inches in diameter under average met. conditions instantaneously.

\*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	34620	lbs/min
Duration of discharge	=	.001	minutes
Amount discharged	=	5.24	lbs
State of material	=	Gas	

## \*\*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Dov	mwi	Ind distand	ce to	concen	tration	of	183000	mqq
	at	groundleve	el	=	152		fe	eet
	at	discharge	heigh	nt =	148		fe	et

Peak concentration on ground is 1000000 ppm at a downwind distance of 34 feet for elevated emission source specified by user.

See attached table(s) for further details.

#### \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	6926	feet
Safe separation distance	=	13851	feet
Flame jet duration	=	.001	minutes

\*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1,	/2 LFL	LFL	
		-			
	Downwind hazard distance	=	341	267	feet
	Max hazard zone width	=	171	134	feet
	Max weight explosive gas	=	35	35	lbs
	Relative gas/air density	=	1.01	1.01	initially
	Model used in analysis	=	Neutral	ly buoya	ant
Note:	Clouds or plumes contain:	ing	less that	an 1000	pounds
	of vapor or gas are very				
	completely unconfined, e	exc	ept when	one of	a cer-
	tain few materials have !	bee	n <sup>-</sup> discha:	rged.	
				-	

## \*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS	TOXIC	VAPOR	DISPERSION	ANALYSIS	RESULTS
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Downwind Distance		Groundlevel Concentration	Source Height Concentration	Initial Evacuation Zone Width*
(feet)	(miles)	(ppm)	(ppm)	(feet)
100	.02	541204	478767	230
104	.02	494106	438583	230
108	.03	452193	402817	220
112	.03	414795	370863	210
115	.03	381338	342217	200
119	.03	351332	316453	190
123	.03	324352	293214	180
126	.03	300036	272196	170
130	.03	278069	253138	160
134	.03	258178	235816	150
137	.03	240128	220036	140
141	.03	223714	205631	120
145	.03	208756	192453	94
149	.03	195099	180376	67
152	.03	183000	169286	1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

	l Distance	Contaminant Arrival Time at Downwind Location	Contaminant Departure Time
			(minutes)
100 104 108 112 115 119 123 126 130 134 137 141 145	.02 .02 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03	.2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2	.3 .3 .3 .3 .4 .4 .4 .4 .4 .4 .4 .4 .4 .4 .4 .4 .4
149 152	.03 .03	.2 .2	.4

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

CAUTION: See guide for assumptions used in estimating these times.

PHYSIOCHEMICAL PROPERTIES OF MATER	IAL		
NORMAL BOILING POINT		-423	degrees F
MOLECULAR WEIGHT		2.0159	
VAPOR PRES AT CONTAINER TEMP	=	2400	psia
,	=	124167	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2400.1	psia
	=	124167	mm Hg
SPECIFIC HEAT RATIO FOR GAS	=	1.4	5
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%
LOWER HEAT OF COMBUSTION		191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	·
TOXIC VAPOR LIMIT	=	183000	mqq
CONTAINER CHARACTERISTICS			
CONTAINER TYPE	=	Horizontal c	ylinder
TOTAL WEIGHT OF CONTENTS	=	5.24	lbs
DISCHARGE HOLE DIAMETER	=	9	inch(es)
DISCHARGE COEFFICIENT OF HOLE	=		
TEMP OF CONTAINER CONTENTS	=	68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia
ENVIRONMENTAL/LOCATION CHARACTERIS	TIC:		_
AMBIENT TEMPERATURE	=	68	degrees F
WIND VELOCITY	=	9	mph
ATMOSPHERIC STABILITY CLASS		•	
VAPOR/GAS DISCHARGE HEIGHT	=	5	feet

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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#### \*\*\* SCENARIO DESCRIPTION

One cylinder releases 1,000 cubic feet of hydrogen through a hole 9.0 inches in diameter under worst case met. conditions instantaneously.

# \*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	34620	lbs/min
Duration of discharge	=	.001	minutes
Amount discharged	=	5.24	lbs
State of material	=	Gas	

#### \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind distance to	concentration	of 40000 ppm
at groundlevel	= 900	feet
at discharge heigh	it = 887	feet

Peak concentration on ground is 1000000 ppm at a downwind distance of 123 feet for elevated emission source specified by user.

See attached table(s) for further details.

#### \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	6926	feet
Safe separation distance	=	13851	feet
-		.001	minutes

#### \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

For concentration of	1/2 LFL	LFL	
Downwind hazard distar Max hazard zone width Max weight explosive of Relative gas/air densi Model used in analysis Note: Clouds or plumes conta of vapor or gas are ve completely unconfined tain few materials hav	= 594 gas = 35 ity = 1.01 s = Neutra aining less t ery unlikely , except whe	35 1.01 lly buoy han 1000 to explo n one of	lbs initially yant ) pounds ode when

\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

ownwind	l Distance	Groundlevel Concentration	Source Height	Initial Evacuation
(feet)	(miles)	(ppm)	Concentration (ppm)	Zone Width* (feet)
100	.02	1000000	1000000	73
158	.03	1000000	1000000	120
215	.05	1000000	1000000	160
272	.06	819165	720574	200
329	.07	524952	462477	240
386	.08	354610	316911	290
443 500 558	.09 .1 .11	250618 183884 139166	227401 169080 129382	330 370
615 672	.12	108077 85778	101395 81077	410 450 490
729	.14	69350	65956	540
786	.15	56966	54458	
843	.16	47443	45552	620
900	.18	40000	38539	1

'Usually safe for < 1 hour release. Longer releases or sudden wind shifts nay require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

Downwind		Contaminant Arrival Time at Downwind Location	Contaminant Departure Time			
(feet)		(minutes)				
100	.02	.6	1.2			
158	.03	.9	1.8			
215	.05	1.3	2.5			
272	.06	1.6	3.1			
329	.07	1.9	3.8			
386	.08	2.2	4.4			
443	.09	2.6	5.1			
500	.1	2.9	5.7			
558	.11	3.2	6.4			
615	.12	3.5	7			
672	.13	3.9	7.7			
729	.14	4.2 :	8.3			
786	.15	4.5	9			
843	.16	4.8	9.6			
900	.18	5.2	10.3			

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

CAUTION: See guide for assumptions used in estimating these times.

## UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

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DISTAN	ICE F (fee		EXPLOSION EXPECTED DAMAGE
	369 52	)	Occasional breakage of large windows under stress. Some damage to home ceilings; 10% window breakage.
20	20	34	Windows usually shattered; some frame damage. Partial demolition of homes; made uninhabitable.
5	- 12	20	Range serious/slight injuries from flying glass/object. Partial collapse of home walls/roofs.
9	-	12	Non-reinforced concrete/cinder block walls shattered.
4	- 11	11	Range 90-1% eardrum rupture among exposed population. 50% destruction of home brickwork.
8	7	9	Frameless steel panel buildings ruined. Wooden utility poles snapped.
6	- 5	7	Nearly complete destruction of houses. Probable total building destruction.
3	-	4	Range for 99-1% fatalities among exposed populations due to direct blast effects.

Note: The center of an unconfined gas/vapor explosion can be anywhere within the ground area passed over by the cloud or plume. See results of the vapor cloud fire hazard analysis for the maximum downwind distance and maximum width of this area. Explosion is assumed to take place on or near the ground.

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PHYSIOCHEMICAL PROPERTIES OF MATER			
NORMAL BOILING POINT	=	-423	degrees F
MOLECULAR WEIGHT	=	2.0159	5
VAPOR PRES AT CONTAINER TEMP	=	2400	psia
	=	124167	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2400.1	psia
	=	124167	mm Hg
SPECIFIC HEAT RATIO FOR GAS		1.4	
LOWER FLAMMABLE LIMIT (LFL)			vol%
LOWER HEAT OF COMBUSTION			Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
TOXIC VAPOR LIMIT	=	40000	ppm
CONTAINER CHARACTERISTICS			
CONTAINER TYPE	=	Horizontal	cvlinder
	_		
TOTAL WEIGHT OF CONTENTS		5.24	lbs
		5.24	
TOTAL WEIGHT OF CONTENTS	=	5.24 9	lbs
TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER	= =	5.24 9	lbs
TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE		5.24 9 · .62	lbs inch(es)
TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS		5.24 9. .62 68	lbs inch(es) degrees F
TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS		5.24 9. .62 68 2400	lbs inch(es) degrees F
TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE		5.24 9. .62 68 2400	lbs inch(es) degrees F
TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS	= = = = TIC	5.24 9 .62 68 2400 S	lbs inch(es) degrees F psia
TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS AMBIENT TEMPERATURE	= = = TIC = =	5.24 9. .62 68 2400 S 68 2	lbs inch(es) degrees F psia degrees F
TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS AMBIENT TEMPERATURE WIND VELOCITY	= = = = TIC = =	5.24 9. .62 68 2400 S 68 2 F	lbs inch(es) degrees F psia degrees F
TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS AMBIENT TEMPERATURE WIND VELOCITY ATMOSPHERIC STABILITY CLASS	= = = = TIC = =	5.24 9. .62 68 2400 S 68 2 F	lbs inch(es) degrees F psia degrees F mph

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 9-8-93 NAME OF DISK FILE = P-4DETON.ASF

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\*\*\* SCENARIO DESCRIPTION

One cylinder releases 1,000 cubic feet of hydrogen through a hole 9.0 inches in diameter under worst case met. conditions instantaneously.

\*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	34620	lbs/min
Duration of discharge	=	.001	minutes
Amount discharged	=	5.24	lbs
State of material	=	Gas	

## \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind distance t	to concent	ration	of	183000	ppm
at groundlevel	=	501		fe	eet
at discharge hei	lght =	485		fe	eet

Peak concentration on ground is 1000000 ppm at a downwind distance of 124 feet for elevated emission source specified by user.

See attached table(s) for further details.

## \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	6926	feet
Safe separation distance	=	13851	feet
Flame jet duration	=	.001	minutes

## \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1/2 LFL	LFL	
	Downwind hazard distance	= 1187	914	feet
	Max hazard zone width	= 594	457	feet
	Max weight explosive gas	= 35	35	lbs
	Relative gas/air density	= 1.01	1.01	initially
	Model used in analysis	= Neutral	ly buoya	ant
Note:	Clouds or plumes contain:	ing less th	an 1000	pounds
	of vapor or gas are very	unlikely to	o explo	de when
	completely unconfined, of	except when	one of	a cer-
	tain few materials have ]	been discha	rged.	

\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

Swnwind	l Distance	Groundlevel	Source Height	Initial Evacuation
(feet)	(miles)	Concentration (ppm)	Concentration (ppm)	Zone Width* (feet)
100	.02	1000000	1000000	73
129	.03	1000000	1000000	94
158	.03	1000000	1000000	120
186	.04	1000000	1000000	140
215	.05	1000000	1000000	160
244	.05	1000000	930124	180
272	.06	816419	718084	200
301	.06	648845	569410	220
330	.07	522881	460702	240
358	.07	427017	378773	270
387	.08	353067	315591	290
415	.08	295249	265967	310
444	.09	249457	226393	330
473	.09	212750	194421	340
501	.1	183000	168294	1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind	. Distance	Contaminant Arrival Time at Downwind Location	Contaminant Departure Time
(feet)	(miles)		(minutes)
100 129 158 186 215 244 272 301 330	.02 .03 .03 .04 .05 .05 .06 .06 .07	.6 .8 .9 1.1 1.3 1.4 1.6 1.8 1.9 2.1	1.2 1.5 1.8 2.2 2.5 2.8 3.1 3.5 3.8
358 387 415 444 473 501	.07 .08 .08 .09 .09 .1	2.1 2.2 2.4 2.6 2.7 2.9	4.1 4.4 4.8 5.1 5.4 5.7

CAUTION: See guide for assumptions used in estimating these times.

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PHYSIOCHEMICAL PROPERTIES OF MATERI			
NORMAL BOILING POINT	= •	-423	degrees F
MOLECULAR WEIGHT	=	2.0159	
VAPOR PRES AT CONTAINER TEMP	=	2400	psia
	=	124167	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2400.1	psia
	=	124167	mm Hg
SPECIFIC HEAT RATIO FOR GAS	=	1.4	
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%
LOWER FLAMMABLE LIMIT (LFL) LOWER HEAT OF COMBUSTION	=	191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
TOXIC VAPOR LIMIT	=	183000	ppm
CONTAINER CHARACTERISTICS			
	_	Horizontal c	vlinder
			lbs
TOTAL WEIGHT OF CONTENTS			inch(es)
DISCHARGE HOLE DIAMETER			THCH (62)
DISCHARGE COEFFICIENT OF HOLE			dogwood P
TEMP OF CONTAINER CONTENTS	=	55	degrees F
TANK RUPTURE PRESSURE	=	2400	psia
ENVIRONMENTAL/LOCATION CHARACTERIS	TIC	S	
AMBIENT TEMPERATURE		68	degrees F
	=		mph
ATMOSPHERIC STABILITY CLASS	=	F	-
VAPOR/GAS DISCHARGE HEIGHT	=	5	feet
WEW REGIMES ROUTER DV HEER INCOR	מה	OF BY EVALUAT	TON METHODS

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDO	US MATERIAL	= Hydrogen
ADDRESS	\ LOCATION	= PDL
DATE OF	ASSESSMENT	= 9-9-93
NAME OF	DISK FILE	= P-5.ASF

\*\*\* SCENARIO DESCRIPTION

3 cylinders release a total of 3,000 cubic feet of hydrogen through 3 holes, 0.375 inches in diameter each, under average met. conditions taking approx. three seconds.

#### \*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	285.5	lbs/min
Duration of discharge	=	.056	minutes
Amount discharged	=	15.72	lbs
State of material	=	Gas	

#### \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind distance t	o concentratio:	n of	40000 ppm
at groundlevel	= 190		feet
at discharge hei	.ght = 186		feet

Peak concentration on ground is 414086.5 ppm at a downwind distance of 43 feet for elevated emission source specified by user.

See attached table(s) for further details.

#### \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	501	feet
Safe separation distance	=	1001	feet
Flame jet duration	=	.056	minutes

#### \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1/2	LFL	LFL	
	Downwind hazard distance	= 25	53	195	feet
	Max hazard zone width				feet
	Max weight explosive gas	= 16	5	16	lbs
	Relative gas/air density	= 1.	.01	1.01	initially
	Model used in analysis	≓ Ne	eutrall	Ly buoya	ant
Note:	Clouds or plumes contain	ing le	ess tha	an 1000	pounds
	of vapor or gas are very	unlik	cely to	o exploa	le when
	completely unconfined,	except	: when	one of	a cer-

\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

tain few materials have been discharged.

Downwind Distance		Groundlevel Concentration	Source Height	Initial Evacuation	
(feet)	(miles)	(ppm)	Concentration (ppm)	Zone Width* (feet)	
100 107 113 120 126 133 139	.02 .03 .03 .03 .03 .03 .03 .03 .03	164977 146707 130737 116785 104589 93915 84556	145944 130561 117093 105268 94862 85686 77578	330 320 310 300 290 280 260	
145 152 158 165 171 177 184 190	.03 .03 .04 .04 .04 .04 .04 .04	76335 69096 62707 57053 52038 47576 43598 40000	70401 64033 58373 53330 48829 44801 41189 37944	250 230 220 200 170 140 98 1	

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

## TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind	Distance	Contaminant Arrival Time at Downwind Location	
(feet)	(miles)		(minutes)
100 107 113 120 126 133 139 145 152 152 158 165	.02 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03	.2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2	. 4 . 4 . 4 . 4 . 4 . 4 . 5 . 5 . 5 . 5 . 5 . 5 . 5 . 5
171 177 184 190	.04 .04 .04 .04	.3 ` .3 .3 .3	.5 .6 .6 .6

CAUTION: See guide for assumptions used in estimating these times.

#### UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

T.STAI	NCE FI (feet		EXPLOSION	EXPECTED DAMAGE
	285			al breakage of large windows under stress.
15	41 - 15	26	Windows	age to home ceilings; 10% window breakage. 1sually shattered; some frame damage. demolition of homes; made uninhabitable.
4	10	15	Range se	rious/slight injuries from flying glass/object. collapse of home walls/roofs.
7		10		forced concrete/cinder block walls shattered.
4	- 8	8		-1% eardrum rupture among exposed population. ruction of home brickwork.
6	- 6	7		s steel panel buildings ruined. tility poles snapped.
5	-	6	Nearly c	omplete destruction of houses. total building destruction.
3		3	Range fo	r 99-1% fatalities among exposed populations irect blast effects.

Note: The center of an unconfined gas/vapor explosion can be anywhere within the ground area passed over by the cloud or plume. See results of the vapor cloud fire hazard analysis for the maximum downwind distance and maximum width of this area. Explosion is assumed to take place on or near the ground.

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PHYSIOCHEMICAL PROPERTIES OF MATERI	IAL		
NORMAL BOILING POINT	=	-423	degrees F
MOLECULAR WEIGHT	=	2.0159	•
VAPOR PRES AT CONTAINER TEMP	=	2400	psia
	=	124167	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2400.1	psia
	=	124167	mm Hg
SPECIFIC HEAT RATIO FOR GAS	=	1.4	-
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%
LOWER HEAT OF COMBUSTION		191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	•
TOXIC VAPOR LIMIT		40000	ppm
			<b>* *</b>
CONTAINER CHARACTERISTICS			
CONTAINER TYPE	=	Horizontal	cvlinder
TOTAL WEIGHT OF CONTENTS		15.72	lbs
DISCHARGE HOLE DIAMETER		.65	inch(es)
DISCHARGE COEFFICIENT OF HOLE			••••
TEMP OF CONTAINER CONTENTS		68	degrees F
TANK RUPTURE PRESSURE		2400	psia
			<b>F</b>
ENVIRONMENTAL/LOCATION CHARACTERIS	TIC	S	
AMBIENT TEMPERATURE	=	68	degrees F
WIND VELOCITY	=	9	mph
ATMOSPHERIC STABILITY CLASS	=	C	-
VAPOR/GAS DISCHARGE HEIGHT	=	5	feet

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 9-9-93 NAME OF DISK FILE = P-5DETON.ASF

#### **\*\*\*** SCENARIO DESCRIPTION

3 cylinders release a total of 3,000 cubic feet of hydrogen through 3 holes, 0.375 inches in diameter each, under average met. conditions taking approx. three seconds.

## \*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	285.5	lbs/min
Duration of discharge	=	.056	minutes
Amount discharged	=	15.72	lbs
State of material	=	Gas	

## \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind distance to	o concentration	of	183000 ppm
at groundlevel	= 95		feet
at discharge heig	jht = 88		feet

Peak concentration on ground is 414157.8 ppm at a downwind distance of 42 feet for elevated emission source specified by user.

See attached table(s) for further details.

#### \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	501	feet
Safe separation distance	=	1001	feet
Flame jet duration	=	.056	minutes

#### \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

For concentration of 1/2 LFL LFL

Downwind hazard distance = 253 195 feet Max hazard zone width = 127 98 feet Max weight explosive gas = 16 16 lbs Relative gas/air density = 1.01 1.01 initially Model used in analysis = Neutrally buoyant

Note: Clouds or plumes containing less than 1000 pounds of vapor or gas are very unlikely to explode when completely unconfined, except when one of a certain few materials have been discharged.

\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

Downwind	Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation Zone Width*
(feet)	(miles)	(ppm)	(ppm)	(feet)
32 37 41 46 50 55 59 64 68 73 77	.01 .01 .01 .01 .02 .02 .02 .02 .02 .02 .02 .02 .02 .02	353241 398128 413739 410143 395204 374196 350406 325804 301535 278248 256287 235813	976138 762495 616259 512894 437583 380943 336913 301555 272306 247489 226000 207100	120 130 150 160 170 160 150 150 140 130 120 97
81 86 90 95	.02 .02 .02 .02	235813 216877 199459 183000	190287 175204 161596	80 58 1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

# TOXIC VAPOR DISPERSION ANALYSIS RESULTS

	Distance	Contaminant Arrival Time at Downwind Location	
(feet)	(miles)	(minutes)	(minutes)
32 37	.01 .01	·	.2 .2
41	.01	-	. 2
46 50	.01 .01	.1	.2 .2
55 59	.02 .02	.1	.2 .3
64 68	.02 .02	· · · · ·	.3 .3
73 77	.02 .02	.1	.3 .3
81 86	.02	.2 1	.3 .3
90 95	.02	.2	.3 .3
30	.02	. 4	. J

CAUTION: See guide for assumptions used in estimating these times.

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PHYSIOCHEMICAL PROPERTIES OF MATER	AL	
NORMAL BOILING POINT	= -423 deg	rees F
MOLECULAR WEIGHT	= 2.0159	
VAPOR PRES AT CONTAINER TEMP	= 2400 psi	.a
	= 124167 mm	Hg
VAPOR PRES AT AMBIENT TEMP	= 2400.1 psi	
	= 124167 mm	Hg
SPECIFIC HEAT RATIO FOR GAS	= 1.4	-
LOWER FLAMMABLE LIMIT (LFL)	= 4 vol	~
LOWER HEAT OF COMBUSTION	= 191.7 Btu	ı/lb
GAS EXPLOSION YIELD FACTOR	= .03	
TOXIC VAPOR LIMIT	= 183000 ppm	1
CONTAINER CHARACTERISTICS		
CONTAINER TYPE	= Horizontal cylin	ıder
TOTAL WEIGHT OF CONTENTS	= 15.72 lbs	;
DISCHARGE HOLE DIAMETER	= .65 inc	ch(es)
DISCHARGE COEFFICIENT OF HOLE	= .98	
TEMP OF CONTAINER CONTENTS	= 68 . deg	grees F
TANK RUPTURE PRESSURE	= 2400 psi	.a
ENVIRONMENTAL/LOCATION CHARACTERIS		
AMBIENT TEMPERATURE		grees F
WIND VELOCITY	= 9 mph	1
ATMOSPHERIC STABILITY CLASS		
VAPOR/GAS DISCHARGE HEIGHT	= 5 fee	et

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 9-9-93 NAME OF DISK FILE = P-6.ASF

## \*\*\* SCENARIO DESCRIPTION

3 cylinders release a total of 3,000 cubic feet of hydrogen through 3 holes, 0.375 inches in diameter each, under worst case met. conditions taking approximately 3 seconds.

## \*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	285.5	lbs/min
Duration of discharge	=	.056	minutes
Amount discharged	=	15.72	lbs
State of material	=	Gas	

## \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind distance to	concentration	of 40000 ppm
at groundlevel	= 668	feet
at discharge heigh	t = 653	feet

Peak concentration on ground is 1000000 ppm at a downwind distance of 129 feet for elevated emission source specified by user.

See attached table(s) for further details.

## \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	501	feet
Safe separation distance	=	1001	feet
Flame jet duration	=	.056	minutes

#### \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1,	2 LFL	LFL	
		-			
	Downwind hazard distance	=	886	684	feet
	Max hazard zone width	=	443	342	feet
	Max weight explosive gas	=	16	16	lbs
	Relative gas/air density	Ξ	1.01	1.01	initially
	Model used in analysis				
Note:	Clouds or plumes contain				
	of vapor or gas are very	un	likely to	o explo	de when
	completely unconfined,	exc	ept when	one of	a cer-
	tain few materials have				

\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

ownwind	Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation Zone Width*
(feet)	(miles)	(ppm)	(ppm)	(feet)
100	.02	810178	1000000	73
141	.03	1000000	1000000	110
182	.04	777706	819422	140
222	.05	554249	509437	170
263	.05	394598	348210	200
303	.06	286778	251704	230
344	.07	213674	188847	250
384	.08	163084	145665	280
425	.09	127215	114876	310
465	.09	101168	92288	340
506	.1	81832	75326	370
546	.11	67186	62336	400
587	.12	55893	52216	430
627	.12	47042	44211	460
668	.13	40000	37795	1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

Downwind Distance		Contaminant Arrival Time at Downwind Location	Contaminant Departure Time		
(feet)	(miles)		(minutes)		
100	.02	.6	1.2		
141	.03	.9	1.7		
182	.04	1.1	2.2		
222	.05	1.3	2.6		
263	.05	1.5	3.1		
303	.06	1.8	3.5		
344	.07	2	4		
384	.08	2.2	4.5		
425	.09	2.5	4.9		
465	.09	2.7	5.4		
506	.1	2.9	5.9		
546	.11	3.2 *	6.3		
587	.12	3.4	6.8		
627	.12	3.6	7.2		
668	.13	3.8	7.7		

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

CAUTION: See guide for assumptions used in estimating these times.

#### UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

DISTAN	ICE F (fee		EXPLOSION EXPECTED DAMAGE
	285		Occasional breakage of large windows under stress.
	41		Some damage to home ceilings; 10% window breakage.
15	-		
	15		Partial demolition of homes; made uninhabitable.
4	-	15	Range serious/slight injuries from flying glass/object.
	10		Partial collapse of home walls/roofs.
7	-	10	Non-reinforced concrete/cinder block walls shattered.
4	-	8	Range 90-1% eardrum rupture among exposed population.
	8		50% destruction of home brickwork.
6	-	7	Frameless steel panel buildings ruined.
-	6	-	Wooden utility poles snapped.
5	-	6	Nearly complete destruction of houses.
2	4	Ĵ	Probable total building destruction.
3		3	Range for 99-1% fatalities among exposed populations due to direct blast effects.

Note: The center of an unconfined gas/vapor explosion can be anywhere within the ground area passed over by the cloud or plume. See results of the vapor cloud fire hazard analysis for the maximum downwind distance and maximum width of this area. Explosion is assumed to take place on or near the ground.

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PHYSIOCHEMICAL PROPERTIES OF MATERI	IAL		
NORMAL BOILING POINT	= -	-423	degrees F
MOLECULAR WEIGHT		2.0159	-
VAPOR PRES AT CONTAINER TEMP	=	2400	psia
	=	124167	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2400.1	psia
	=	124167	mm Hg
SPECIFIC HEAT RATIO FOR GAS		1.4	
LOWER FLAMMABLE LIMIT (LFL)		4	vol%
		191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
TOXIC VAPOR LIMIT	=	40000	ppm
CONTAINER CHARACTERISTICS			
CONTAINER TYPE	=	Horizontal c	vlinder
TOTAL WEIGHT OF CONTENTS		15.72	lbs
DISCHARGE HOLE DIAMETER	=	.65	inch(es)
DISCHARGE COEFFICIENT OF HOLE	=	.98	
TEMP OF CONTAINER CONTENTS	=	68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia
ENVIRONMENTAL/LOCATION CHARACTERIS	FIC	S	
AMBIENT TEMPERATURE	=	68	degrees F
WIND VELOCITY	=	2	mph
ATMOSPHERIC STABILITY CLASS			
VAPOR/GAS DISCHARGE HEIGHT	=	5	feet

- KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED
- KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 9-9-93 NAME OF DISK FILE = P-6DETON.ASF

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\*\*\* SCENARIO DESCRIPTION

3 cylinders release a total of 3,000 cubic feet of hydrogen through 3 holes, 0.375 inches in diameter each, under worst case met. conditions taking approximately 3 seconds.

# \*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	285.5	lbs/min
Duration of discharge	=	.056	minutes
Amount discharged	=	15.72	lbs
State of material	=	Gas	

# \*\*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Dov	vnwi	ind distance	to to	concent	tration	of	183000	ppm
	at	groundlevel		=	366		fe	
	at	discharge h	neigh	it =	348		fe	eet

Peak concentration on ground is 1000000 ppm at a downwind distance of 128 feet for elevated emission source specified by user.

See attached table(s) for further details.

# \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	501	feet
Safe separation distance	=	1001	feet
Flame jet duration	=	.056	minutes

# \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1/2 LFL	LFL	
Note:	Downwind hazard distance Max hazard zone width Max weight explosive gas Relative gas/air density Model used in analysis Clouds or plumes contain of vapor or gas are very completely unconfined, e tain few materials have b	= 443 = 16 = 1.01 = Neutrall ing less that unlikely to except when	1.01 Ly buoya an 1000 o explos one of	initially ant pounds le when
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\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

ownwind	Distance	Groundlevel Concentration	Source Height	Initial Evacuation
(feet)	(miles)	(ppm)	Concentration (ppm)	Zone Width* (feet)
100	.02	810178	1000000	73
119	.03	1000000	1000000	87
138 157 176	.03	1000000 923907	1000000 1000000	110 120
176	.04	809187	878566	130
195	.04	694568	686283	150
214	.05	591586	552273	160
233	.05	503275	454611	170
252		429137	380765	190
271	.06	367442	323266	200
290	.06	316214	277455	220
309	.06	273614	240291	230
328	.07	238067	209704	240
347	.07	208269	184232	240
366	.07	183000	162811	1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

TOXIC	VAPOR	DISPERSION	ANALYSIS	RESULTS
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		Contaminant Arrival Time at Downwind Location	
		(minutes)	
100 119 138 157 176 195 214 233 252 271 290 309 328 347	. 02 . 03 . 03 . 04 . 04 . 05 . 05 . 05 . 05 . 05 . 06 . 06 . 06 . 07 . 07	.6 .7 .8 .9 1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 : 1.9 2	1.2 1.5 1.7 1.9 2.1 2.3 2.5 2.8 3 3.2 3.4 3.6 3.8 4
366	.07	2.1	4.3

CAUTION: See guide for assumptions used in estimating these times.

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PHYSIOCHEMICAL PROPERTIES OF MATERI	AL		
		-423	degrees F
		2.0159	-
VAPOR PRES AT CONTAINER TEMP	=	2400	psia
		124167	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2400.1	psia
	=	124167	mm Hg
SPECIFIC HEAT RATIO FOR GAS	=	1.4	-
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%
LOWER HEAT OF COMBUSTION			Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
TOXIC VAPOR LIMIT	=	183000	mqq
CONTAINER CHARACTERISTICS			
CONTAINER TYPE	=	Horizontal c	ylinder
TOTAL WEIGHT OF CONTENTS	=	15.72	lbs
DISCHARGE HOLE DIAMETER	=	.65	inch(es)
DISCHARGE COEFFICIENT OF HOLE	=	.98	
TEMP OF CONTAINER CONTENTS	=	68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia
ENVIRONMENTAL/LOCATION CHARACTERIS	ric		
AMBIENT TEMPERATURE	=	68	degrees F
WIND VELOCITY		2	mph
ATMOSPHERIC STABILITY CLASS		F	~
VAPOR/GAS DISCHARGE HEIGHT	=	5	feet

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOU ADDRESS DATE OF NAME OF	JS MATERIAL = Hydrogen \ LOCATION = PDL ASSESSMENT = 9-9-93 DISK FILE = P-7.ASF				
*** SCEN	NARIO DESCRIPTION				
hydi	ylinders release a total o rogen instantaneously thro meter each, under average	bugl	h 3 holes	s, 9 inc	
* * * * * * *	DISCHARGE RATE/DURATION N	EST	IMATES		
	Compressed gas discharge	fro	om contai	ner	
	Peak discharge rate Duration of discharge Amount discharged State of material		34620 .001 15.72 Gas		lbs/min minutes lbs
******	TOXIC VAPOR DISPERSION AN	NAL	YSIS RESU	ЛТS	
	Downwind distance to cond at groundlevel at discharge height				0 ppm feet feet
	Peak concentration on gra at a downwind distance of elevated emission source	£ 3	5 feet fo	or	
	See attached table(s) for	r f	urther de	etails.	
*****	FLAME JET HAZARD RESULTS				
	Flame jet length Safe separation distance Flame jet duration	=			feet feet minutes
* * * * * * *	FLAMMABLE VAPOR CLOUD HA	ZAR	D RESULT	S	
	For concentration of	1	./2 LFL	LFL	
Note:	Downwind hazard distance Max hazard zone width Max weight explosive gas Relative gas/air density Model used in analysis Clouds or plumes contain of vapor or gas are very completely unconfined,	= iing run	Neutral Jess th Likely t	ly buoy an 1000 o explo	pounds de when
ﻮﻟﻮ ﻣﻮﺭ ﻣﻮﺭ ﻣﻮﺭ ﻣﻮﺭ ﻣﻮﺭ ﻣﻮﺭ ﻣﻮﺭ ﺧﻮﺭ ﻣﻮﺭ ﻣﻮﺭ ﻣﻮﺭ ﻣﻮﺭ ﻣﻮﺭ ﻣﻮﺭ ﻣﻮﺭ ﻣﻮﺭ ﻣﻮﺭ ﻣ	tain few materials have	bee	en discha	rged.	

\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

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Downwind	l Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation Zone Width*
(feet)	(miles)	(ppm)	(ppm)	(feet)
100 112 124 136 147 159 171 182 194 206	.02 .03 .03 .03 .03 .04 .04 .04 .04 .04 .04 .04	541204 408945 315948 248915 199494 162313 133830 111653 94135 80116	478767 365860 285958 227725 184267 151183 125560 105415 89361 76415	350 390 430 460 440 430 410 390 360 340
206 217 229 241 253 264	.04 .05 .05 .05 .05 .05	80116 68764 59474 51798 45399 40000	65860 57170 49951 43904 38801	300 270 220 160 1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

### TOXIC VAPOR DISPERSION ANALYSIS RESULTS

		Contaminant Arrival Time at Downwind Location	at Downwind Location
(feet)	(miles)	(minutes)	(minutes)
100 112	.02 .03	.2 .2	.3 .3
124	.03	.2	. 4
136 147	.03 .03	.2 .2	. <u>4</u> . <u>4</u>
159 171	.04 .04	.3 .3	.5 .5
182	.04	.3 .3	.5
194 206	.04 .04	.3	. 6
217 229	.05 .05	.3 .	.6 .6
241 253	.05 .05	.4	.7 .7
264	.05	. 4	.7

CAUTION: See guide for assumptions used in estimating these times.

#### UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

ISTAN	NCE FF (feet		EXPLOSION EXPECTED DAMAGE
	369 52		Occasional breakage of large windows under stress. Some damage to home ceilings; 10% window breakage.
20	- 20	34	Windows usually shattered; some frame damage. Partial demolition of homes; made uninhabitable.
5	- 12	20	Range serious/slight injuries from flying glass/object. Partial collapse of home walls/roofs.
9	-	12	Non-reinforced concrete/cinder block walls shattered.
4	- 11	11	Range 90-1% eardrum rupture among exposed population. 50% destruction of home brickwork.
8	-7	9	Frameless steel panel buildings ruined. Wooden utility poles snapped.
6	- 5	7	Nearly complete destruction of houses. Probable total building destruction.
3	-	4	Range for 99-1% fatalities among exposed populations due to direct blast effects.

Note: The center of an unconfined gas/vapor explosion can be anywhere within the ground area passed over by the cloud or plume. See results of the vapor cloud fire hazard analysis for the maximum downwind distance and maximum width of this area. Explosion is assumed to take place on or near the ground.

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PHYSIOCHEMICAL PROPERTIES OF MATER	IAL	
NORMAL BOILING POINT	= -423	degrees F
MOLECULAR WEIGHT	= 2.0159	
VAPOR PRES AT CONTAINER TEMP	= 2400	psia
	= 124167	mm Hg
VAPOR PRES AT AMBIENT TEMP		psia
		mm Hg
SPECIFIC HEAT RATIO FOR GAS		-
		vol%
LOWER FLAMMABLE LIMIT (LFL) LOWER HEAT OF COMBUSTION	= 191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	= .03	·
		ppm
CONTAINER CHARACTERISTICS		
CONTAINER TYPE	= Horizontal cy	linder
TOTAL WEIGHT OF CONTENTS	-	lbs
DISCHARGE HOLE DIAMETER		inch(es)
DISCHARGE COEFFICIENT OF HOLE		
TEMP OF CONTAINER CONTENTS	- 68	degrees F
TANK RUPTURE PRESSURE	= 2400	psia
TANK RUFTURE FREBSURE	- 2100	2010
ENVIRONMENTAL/LOCATION CHARACTERIS	TICS	
AMBIENT TEMPERATURE	= 68	degrees F
WIND VELOCITY	= 9	mph
ATMOSPHERIC STABILITY CLASS	= C	
VAPOR/GAS DISCHARGE HEIGHT	= 5	feet
VEN DECIDEC DOMIDED BY HEED INCT	יאה הב פע בתאנוזאייז	ON METHODS

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 9-9-93 NAME OF DISK FILE = P-7DETON.ASF

\*\*\* SCENARIO DESCRIPTION

3 cylinders release a total of 3,000 cubic feet of hydrogen instantaneously through 3 holes, 9 inches in diameter each, under average met. conditions.

# \*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	34620	lbs/min
Duration of discharge	=	.001	minutes
Amount discharged	=	15.72	lbs
State of material	=	Gas	

### \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind	l distance	to	concentr	ation	of	183000	ppm
at gr	coundlevel		= 1	52		fe	et
at di	lscharge he	eigh	nt = 1	48		fe	et

Peak concentration on ground is 1000000 ppm at a downwind distance of 34 feet for elevated emission source specified by user.

See attached table(s) for further details.

#### \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	6926	feet
Safe separation distance	=	13851	feet
Flame jet duration	=	.001	minutes

#### \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1/	2 LFL	LFL	
					<b>-</b> .
	Downwind hazard distance :	=	341	267	feet
	Max hazard zone width :	=	171	134	feet
	Max weight explosive gas :				lbs
	Relative gas/air density :				
	Model used in analysis :	÷	Neutrall	ly buoya	int
2:	Clouds or plumes containing	ng	less that	in 1000	pounds

Note: Clouds or plumes containing less than 1000 pounds of vapor or gas are very unlikely to explode when completely unconfined, except when one of a certain few materials have been discharged.

\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

Downwind	l Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation Zone Width*
(feet)	(miles)	(ppm)	(ppm)	(feet)
100	.02	541204	478767	230
104	.02	494106	438583	230
108	.03	452193	402817	220
112	.03	414795	370863	210
115	.03	381338	342217	200
119	.03	351332	316453	190
123	.03	324352	293214	180
126	.03	300036	272196	170
130	.03	278069	253138	160
134	.03	258178	235816	150
137	.03	240128	220036	140
141	.03	223714	205631	120
145	.03	208756	192453	94
149	.03	195099	180376	67
152	.03	183000	169286	1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

# TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance	Contaminant Arrival Time at Downwind Location	Contaminant Departure Time at Downwind Location
(feet) (miles)	(minutes)	(minutes)
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	.2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2	.3 .3 .3 .3 .4 .4 .4 .4 .4 .4 .4 .4 .4 .4 .4 .4 .4

CAUTION: See guide for assumptions used in estimating these times.

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PHYSIOCHEMICAL PROPERTIES OF MATER	IAL		
NORMAL BOILING POINT	=	-423	degrees F
MOLECULAR WEIGHT	=	2.0159	2
VAPOR PRES AT CONTAINER TEMP	=	2400	psia
	=	124167	mm Hg
VAPOR PRES AT AMBIENT TEMP		2400.1	psia
		124167	mm Hg
SPECIFIC HEAT RATIO FOR GAS			
LOWER FLAMMABLE LIMIT (LFL)		4	vol%
LOWER HEAT OF COMBUSTION			Btu/lb
GAS EXPLOSION YIELD FACTOR		-	
TOXIC VAPOR LIMIT	=	183000	ppm
CONTAINER CHARACTERISTICS			
CONTAINER TYPE	=	Horizontal c	ylinder
TOTAL WEIGHT OF CONTENTS	=	15.72	lbs
DISCHARGE HOLE DIAMETER	=	9	inch(es)
DISCHARGE COEFFICIENT OF HOLE			
TEMP OF CONTAINER CONTENTS		68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia
ENVIRONMENTAL/LOCATION CHARACTERIS	TIC	S	
AMBIENT TEMPERATURE	=	68	degrees F
WIND VELOCITY	=	9	mph
ATMOSPHERIC STABILITY CLASS			
VAPOR/GAS DISCHARGE HEIGHT	=	5	feet

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 9-9-93 NAME OF DISK FILE = P-8.ASF

\*\*\* SCENARIO DESCRIPTION

3 cylinders release a total of 3,000 cubic feet of hydrogen instantaneously through 3 holes, 9 inches in diameter each, under worst case met. conditions.

\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	`=	34620	lbs/min
Duration of discharge	=	.001	minutes
Amount discharged	=	15.72	lbs
State of material	=	Gas	

#### \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind distance to	concentration	of 4	10000 ppm
at groundlevel	= 900		feet
at discharge heigh	nt = 887		feet

Peak concentration on ground is 1000000 ppm at a downwind distance of 123 feet for elevated emission source specified by user.

See attached table(s) for further details.

\*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	6926	feet
Safe separation distance	=	13851	feet
Flame jet duration	=	.001	minutes

### \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1,	/2 LFL	LFL	
	Downwind hazard distance	=	1187	914	feet
	Max hazard zone width	=	594	457	feet
	Max weight explosive gas	=	35	35	lbs
	Relative gas/air density	=	1.01	1.01	initially
	Model used in analysis	÷	Neutral	ly buoya	ant
Note:	Clouds or plumes contain:	ing	less that	an 1000	pounds
	of vapor or gas are very	un	likely to	o exploa	ie when
	completely unconfined,	exc	ept when	one cí	a cer-
	tain few materials have !	bee	n discha	rged.	

\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

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ownwind	Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation
(feet)	(miles)	(ppm)	(ppm)	Zone Width* (feet)
100	.02 .03	1000000	1000000 1000000	73 120
215	.05	1000000	1000000	160
272	.06	819165	720574	200
329	.07	524952	462477	240
386		354610	316911	290
443	.09	250618	227401	330
500	.1	183884	169080	
558	.11	139166	129382	370 410
615	.12	108077	101395	450
672	.13	85778	81077	490
729	.14	69350	65956	540
786	.15	56966	54458	580
843	.16	47443	_ 45552	620
900	.18	40000		1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

		Contaminant Arrival Time at Downwind Location	
(feet)		(minutes)	
100	.02	.6	1.2
158	.03	.9	1.8
215	.05	1.3	2.5
272	.06	1.6	3.1
329	.07	1.9	3.8
386	.08	2.2	4.4
443	.09	2.6	5.1
500	.1	2.9	5.7
558	.11	3.2	6.4
615	.12	3.5	7
672	.13	3.9	7.7
729	.14	4.2	8.3
786	.15	4.5	9
843	.16	4.8	9.6
900	.18	5.2	10.3

CAUTION: See guide for assumptions used in estimating these times.

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## UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

DISTAN	(fee		EXPLOSION EXPECTED DAMAGE
	369 52		Occasional breakage of large windows under stress. Some damage to home ceilings; 10% window breakage.
20	- 20	34	Windows usually shattered; some frame damage. Partial demolition of homes; made uninhabitable.
5		20	Range serious/slight injuries from flying glass/object. Partial collapse of home walls/roofs.
9			Non-reinforced concrete/cinder block walls shattered.
4	-		Range 90-1% eardrum rupture among exposed population.
	11		50% destruction of home brickwork.
8	-	9	Frameless steel panel buildings ruined.
	7		Wooden utility poles snapped.
б	-	7	Nearly complete destruction of houses.
	5		Probable total building destruction.
3	-	4	Range for 99-1% fatalities among exposed populations due to direct blast effects.

Note: The center of an unconfined gas/vapor explosion can be anywhere within the ground area passed over by the cloud or plume. See results of the vapor cloud fire hazard analysis for the maximum downwind distance and maximum width of this area. Explosion is assumed to take place on or near the ground.

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PHYSIOCHEMICAL PROPERTIES OF MATER	IAL		
NORMAL BOILING POINT	=	-423	degrees F
MOLECULAR WEIGHT		2.0159	-
VAPOR PRES AT CONTAINER TEMP	=	2400	psia
	=	124167	mm Hg
VAPOR PRES AT AMBIENT TEMP		2400.1	psia
		124167	mm Hg
SPECIFIC HEAT RATIO FOR GAS	=	1.4	
LOWER FLAMMABLE LIMIT (LFL)			vol%
LOWER HEAT OF COMBUSTION	=	191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
TOXIC VAPOR LIMIT	=	40000	ppm
CONTAINER CHARACTERISTICS			
	=	Horizontal c	ylinder
TOTAL WEIGHT OF CONTENTS	=	15.72	lbs
DISCHARGE HOLE DIAMETER		<b>^</b>	
	=		inch(es)
DISCHARGE COEFFICIENT OF HOLE	=	.62	inch(es)
DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS	=	-	inch(es) degrees F
DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS	=	.62	
DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE	=	.62 68 2400	degrees F
DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS	=	.62 68 2400 S	degrees F psia
DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS AMBIENT TEMPERATURE	=	.62 68 2400 S 68	degrees F psia degrees F
DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS AMBIENT TEMPERATURE WIND VELOCITY	= = = TIC = =	.62 68 2400 S 68 2	degrees F psia
DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS AMBIENT TEMPERATURE WIND VELOCITY ATMOSPHERIC STABILITY CLASS	= = TIC = = =	.62 68 2400 S 68 2 F	degrees F psia degrees F mph
DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS AMBIENT TEMPERATURE WIND VELOCITY	= = TIC = = =	.62 68 2400 S 68 2 F	degrees F psia degrees F
DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS AMBIENT TEMPERATURE WIND VELOCITY ATMOSPHERIC STABILITY CLASS	= = TIC = = =	.62 68 2400 S 68 2 F 5	degrees F psia degrees F mph feet

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 9-9-93 NAME OF DISK FILE = P-8DETON.ASF

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\*\*\* SCENARIO DESCRIPTION

3 cylinders release a total of 3,000 cubic feet of hydrogen instantaneously through 3 holes, 9 inches in diameter each, under worst case met. conditions.

\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	34620	lbs/min
Duration of discharge	=	.001	minutes
Amount discharged	=	15.72	lbs
State of material	=	Gas	

\*\*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind distance t	to concent	ration of	183000 ppm
at groundlevel		501	feet
at discharge hei	ight =	485	feet

Peak concentration on ground is 1000000 ppm at a downwind distance of 124 feet for elevated emission source specified by user.

See attached table(s) for further details.

\*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	6926	feet
Safe separation distance	=	13851	feet
Flame jet duration		.001	minutes

\*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1/2 LFL	LFL	
	Downwind hazard distance Max hazard zone width Max weight explosive gas Relative gas/air density Model used in analysis Clouds or plumes contain: of vapor or gas are very completely unconfined, e tain few materials have b	= 594 = 35 = 1.01 = Neutral ing less the unlikely to except when	35 1.01 Ly buoya an 1000 o exploo one of	initially ant pounds de when
*****	EXPLOSION HAZARDS: See at	ttached tab	le(s)	

ownwind Distance		Groundlevel Concentration	Source Height Concentration	Initial Evacuation	
(feet)	(miles)	(ppm)	(ppm)	Zone Width* (feet)	
100 129 158 186 215 244 272 301 330 358 387	.02 .03 .04 .05 .05 .06 .06 .07 .07 .07	1000000 1000000 1000000 1000000 1000000 1000000	1000000 1000000 1000000 1000000 930124 718084 569410 460702 378773 315591	73 94 120 140 160 - 180 200 220 240 270 290	
415 444 473 501	.08 .09 .09 .1	295249 249457 212750 183000	265967 226393 194421 168294	310 330 340 1	

'Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind		Contaminant Arrival Time at Downwind Location	Contaminant Departure Time
(feet)		(minutes)	
100 129 158 186 215 244 272 301 330 358 387 415 444	.02 .03 .04 .05 .05 .06 .06 .06 .07 .07 .07 .08 .08 .08 .09	.6 .8 .9 1.1 1.3 1.4 1.6 1.8 1.9 2.1 2.2 2.4 2.6	1.2 1.5 1.8 2.2 2.5 2.8 3.1 3.5 3.8 4.1 4.4 4.8 5.1
473 501	.09 .1	2.7 2.9	5.4 5.7

CAUTION: See guide for assumptions used in estimating these times.

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PHYSIOCHEMICAL PROPERTIES OF MATERI	LIAL	
NORMAL BOILING POINT	= -423 degrees F	
MOLECULAR WEIGHT	= 2.0159	
VAPOR PRES AT CONTAINER TEMP	= 2400 psia	
	= 124167 mm Hg	
VAPOR PRES AT AMBIENT TEMP	= 2400.1 psia	
	= 124167 mm Hg	
SPECIFIC HEAT RATIO FOR GAS	= 1.4	
LOWER FLAMMABLE LIMIT (LFL)	= 4 vol%	
LOWER HEAT OF COMBUSTION	= 191.7 Btu/lb	
GAS EXPLOSION YIELD FACTOR	= .03	
TOXIC VAPOR LIMIT	= 183000 ppm	
CONTAINER CHARACTERISTICS CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE	= 68 degrees F = 2400 psia	
ENVIRONMENTAL/LOCATION CHARACTERIS AMBIENT TEMPERATURE WIND VELOCITY ATMOSPHERIC STABILITY CLASS VAPOR/GAS DISCHARGE HEIGHT	= 68 degrees F = 2 mph	

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

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KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 9-9-93 NAME OF DISK FILE = P-9.ASF

### \*\*\* SCENARIO DESCRIPTION

30 cylinder stop valves release 30,000 cubic feet of hydrogen through a common manifold, 0.75 inches in diameter, under average met. conditions taking approximately 25 seconds.

## \*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	380.1	lbs/min
Duration of discharge	=	.414	minutes
Amount discharged	=	157.2	lbs
State of material	=	Gas	

## \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind distance t	to concent	ration	of	40000	ppm
at groundlevel	=	282		f	eet
at discharge hei	ight =	277		f	eet

Peak concentration on ground is 551540.4 ppm at a downwind distance of 43 feet for elevated emission source specified by user.

See attached table(s) for further details.

#### \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	578	feet
Safe separation distance	=	1155	feet
Flame jet duration	=	.414	minutes

### \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

For concentration of	l/	2 LFL	LFL	
Downwind hazard distance			286	feet
Max hazard zone width Max weight explosive gas	=	158	138	feet lbs
Relative gas/air density Model used in analysis	=	Neutral	ly buoya	

Note: Clouds or plumes containing less than 1000 pounds of vapor or gas are very unlikely to explode when completely unconfined, except when one of a certain few materials have been discharged.

Downwind	l Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation Zone Width*
(feet)	(miles)	(ppm)	(mgg)	(feet)
100	.02	238980	211410	350
113	.03	197464	176883	400
126	.03	165437	150095	440
139	.03	140398	128861	490
152	.03	120537	111754	480
165	.04	104564	97787	460
178	.04	91546	86248	440
191	.04	80811	76615	420
204	.04	71860	68498	390
217	.05	64323	61599	360
230	.05	57918	55688	330
243	.05	52431	50589	290
256	.05	47695	46160	240
269	.06	43580	42290	170
282	.06	40000	38889	1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

TOXIC VAP	OR DISPERSION	I ANALYSIS	RESULTS
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Downwind	Distance	Contaminant Arrival Time at Downwind Location	Contaminant Departure Time at Downwind Location
(feet)	(miles)	(minutes)	(minutes)
100 113 126 139 152 165 178 191 204 217 230 243 256	.02 .03 .03 .03 .04 .04 .04 .04 .04 .04 .05 .05 .05 .05	.2 .2 .2 .2 .3 .3 .3 .3 .3 .3 .3 .3 .3 .4 .4	.7 .7 .8 .8 .9 .9 .9 .9 .9 .1 .1 .1 .1
259 282	.06	. 4.	1.1 1.2

CAUTION: See guide for assumptions used in estimating these times.

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### UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

T		FROM eet)	EXPLOSION	EXPECTED DAMAGE
	58 83	33 3	Occasio Some da	onal breakage of large windows under stress. mage to home ceilings; 10% window breakage.
31	. 31	- 54 L	Windows	s usually shattered; some frame damage. . demolition of homes; made uninhabitable.
8	19		Range s	serious/slight injuries from flying glass/object. . collapse of home walls/roofs.
15	-	- 19	Non-rei	nforced concrete/cinder block walls shattered.
7	10	- 17 5	Range 9	0-1% eardrum rupture among exposed population. struction of home brickwork.
12	1.	- 15 1		ess steel panel buildings ruined. utility poles snapped.
9	7	- 11		complete destruction of houses. .e total building destruction.
5		- 6	Range í	for 99-1% fatalities among exposed populations direct blast effects.

Note: The center of an unconfined gas/vapor explosion can be anywhere within the ground area passed over by the cloud or plume. See results of the vapor cloud fire hazard analysis for the maximum downwind distance and maximum width of this area. Explosion is assumed to take place on or near the ground.

Note: Fragments of tanks that suddenly rupture may become airborne and travel considerable distances. See guide for more information. Note that the tank is assumed to be on or near the ground.

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PHYSIOCHEMICAL PROPERTIES OF MATERI			_
NORMAL BOILING POINT	=	-423	degrees F
MOLECULAR WEIGHT	=	2.0159	
VAPOR PRES AT CONTAINER TEMP		2400	psia
		124167	mm Hg
VAPOR PRES AT AMBIENT TEMP		2400.1	psia
	=	124167	mm Hg
SPECIFIC HEAT RATIO FOR GAS	=	1.4	
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%
LOWER HEAT OF COMBUSTION			Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
TOXIC VAPOR LIMIT	=	40000	ppm
CONTAINER CHARACTERISTICS			
CONTAINER TYPE		Horizontal c	
TOTAL WEIGHT OF CONTENTS	=	157.2	lbs
DISCHARGE HOLE DIAMETER	=	.75	inch(es)
DISCHARGE COEFFICIENT OF HOLE	=	.98	
TEMP OF CONTAINER CONTENTS	=	68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia
ENVIRONMENTAL/LOCATION CHARACTERIS	TIC	S	
AMBIENT TEMPERATURE	=	68	degrees F
WIND VELOCITY	=	9	mph
ATMOSPHERIC STABILITY CLASS	=	С	
VAPOR/GAS DISCHARGE HEIGHT	=	5	feet
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KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 9-9-93 NAME OF DISK FILE = P-9DETON.ASF

## \*\*\* SCENARIO DESCRIPTION

30 cylinder stop valves release 30,000 cubic feet of hydrogen through a common manifold, 0.75 inches in diameter, under average met. conditions taking approximately 25 seconds.

\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	380.1	lbs/min
Duration of discharge	=	.414	minutes
Amount discharged	=	157.2	lbs
State of material	=	Gas	

## \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Dov	vnwi	Lnd	distand	ce to	cond	cent		183000	
	at	gro	oundleve	el		=	119	fe	eet
	at	dis	scharge	heigh	nt	=	111	fe	eet

Peak concentration on ground is 551461.9 ppm at a downwind distance of 43 feet for elevated emission source specified by user.

See attached table(s) for further details.

#### \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	578	feet
Safe separation distance	=	1155	feet
Flame jet duration	=	.414.	minutes

#### \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1/2 LFL	LFL	
	Downwind hazard distance	= 413	286	feet
	Max hazard zone width		143	
	Max weight explosive gas			
	Relative gas/air density	= 1.01	1.01	initially
	Model used in analysis			
Note:	Clouds or plumes contain			
	of vapor or gas are very	unlikely t	o explo	de when
	completely unconfined,	except when	one of	a cer-
	tain few materials have 1	been discha	rged.	

TOXIC VAPOR	. DISPERSION	ANALYSIS	RESULTS
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Downwind	l Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation Zone Width*	
(feet)	(miles)	(ppm)	(ppm)	(feet)	
100	.02	238980	211410	130	
102	.02	234268	207484	130	
103	.02	229683	203667	120	
104	.02	225219	199955	120	
106	.02	220875	196344	110	
107	.03	216645	192829	110	
108	.03	212528	189408	98	
110	.03	208518	186076	92	
111	.03	204614	182831	85	
112	.03	200812	. 179669	78	
114	.03	197108	176587	70	
115	.03	193501	173583	61	
116	.03	189986	170653	50	
118	.03	186561	167796	36	
119	.03	183000	165009	1	

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

	Distance	Contaminant Arrival Time at Downwind Location	Contaminant Departure Time at Downwind Location
		(minutes)	
100	.02	.2	.7
102	.02	.2	.7
103	.02	.2	.7
104	.02	.2	.7
106	.02	.2	.7
107	.03	.2	.7
108	.03	.2	.7
110	.03	.2	.7
111	.03	.2	.7
112	.03	.2 .	.7
114	.03	.2 .	. 8
115	.03	.2 .	.8
116	.03	.2	.8
118	.03	.2	.8
119	.03	.2	.8

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

CAUTION: See guide for assumptions used in estimating these times.

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PHYSIOCHEMICAL PROPERTIES OF MATERI	IAL	
NORMAL BOILING POINT	= -423	degrees F
MOLECULAR WEIGHT	= 2.0159	2
VAPOR PRES AT CONTAINER TEMP	= 2400	psia
	= 124167	mm Hg
VAPOR PRES AT AMBIENT TEMP	= 2400.1	psia
	= 124167	mm Hg
SPECIFIC HEAT RATIO FOR GAS	= 1.4	-
LOWER FLAMMABLE LIMIT (LFL)	= 4	vol%
LOWER HEAT OF COMBUSTION	= 191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	= .03	
TOXIC VAPOR LIMIT	= 183000	ppm
CONTAINER CHARACTERISTICS		
CONTAINER TYPE	= Horizontal c	-
TOTAL WEIGHT OF CONTENTS		lbs
DISCHARGE HOLE DIAMETER	= .75	inch(es)
DISCHARGE COEFFICIENT OF HOLE		
TEMP OF CONTAINER CONTENTS	= 68	degrees F
TANK RUPTURE PRESSURE	= 2400	psia
ENVIRONMENTAL/LOCATION CHARACTERIS	TTCS	
AMBIENT TEMPERATURE	= 68	degrees F
WIND VELOCITY	= 9	mph
ATMOSPHERIC STABILITY CLASS		
VAPOR/GAS DISCHARGE HEIGHT		feet
	C C	

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 9-10-93 NAME OF DISK FILE = P-10.ASF

#### \*\*\* SCENARIO DESCRIPTION

30 cylinder stop valves release 30,000 cubic feet of hydrogen through a common manifold, 0.75 inches in diameter, under worst case met. conditions taking approximately 25 seconds.

### \*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	380.1	lbs/min
Duration of discharge	=	.414	minutes
Amount discharged	=	157.2	lbs
State of material	=	Gas	

#### \*\*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind distance to	concentration	of 40000 ppm
at groundlevel	= 1575	feet
at discharge heigh	t = 1564	feet

Peak concentration on ground is 1000000 ppm at a downwind distance of 151 feet for elevated emission source specified by user.

See attached table(s) for further details.

#### \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	578	feet
Safe separation distance	=	1155	feet
		.414	minutes

## \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1/2 LFL	LFL	
	Downwind hazard distance	= 2097	1585	feet
	Max hazard zone width		793	
	Max weight explosive gas	= 158	158	lbs
	Relative gas/air density	= 1.01	1.01	initially
	Model used in analysis	= Neutral	ly buoy	ant
Note:	Clouds or plumes contain	ing less th	an 1000	pounds
	of vapor or gas are very	unlikely t	o explo	de when
	completely unconfined,			a cer-
	tain few materials have	been discha	rged.	

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Jownwind	Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation
(feet)	(miles)	(ppm)	(ppm)	Zone Width* (feet)
100 206 311 416 522 627 732 838 943	.02 .04 .06 .08 .1 .12 .14 .16 .18	1000000 1000000 1000000 731894 485676 336323 241649 179259 136681	1000000 1000000 1000000 659465 448524 316074 229896 172044 132035	73 150 230 310 380 460 540 610
1048 1153 1259 1364 1469 1575	.2 .22 .24 .26 .28 .3	106707 85018 68939 56763 47368 40000	103590 82853 67390 55626 46514 39343	690 770 840 920 1000 1070 1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind	Distance	Contaminant Arrival Time at Downwind Location	
(feet)	(miles)	(minutes)	<i>. .</i> .
100 206 311 416 522 627 732 838 943	.02 .04 .06 .08 .1 .12 .14 .14 .16 .18	.5 1.2 1.8 2.4 3 3.6 4.2 4.8 5.4	1.6 2.8 4 5.2 6.4 7.6 8.8 10 11.2
1048 1153 1259 1364 1469 1575	.2 .22 .24 .26 .28 .3	6 6.6 7.2 7.8 8.4 9	12.4 13.6 14.8 16 17.2 18.4

CAUTION: See guide for assumptions used in estimating these times.

#### UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

DISTAN	ICE F		EXPLOSION	EXPECTED DAMAGE
	583		Occasional b	preakage of large windows under stress.
	83		Some damage	to home ceilings; 10% window breakage.
31	-	54	Windows usua	ally shattered; some frame damage.
	31		Partial demo	olition of homes; made uninhabitable.
8	-	31		s/slight injuries from flying glass/object.
	19		Partial coll	apse of home walls/roofs.
15	-	19	Non-reinford	ed concrete/cinder block walls shattered.
7	-	17		eardrum rupture among exposed population.
	16		50% destruct	ion of home brickwork.
12	-	15	Frameless st	eel panel buildings ruined.
	11		Wooden util:	ty poles snapped.
9	-	11	Nearly comp	lete destruction of houses.
	7		Probable tot	al building destruction.
5	-	6		9-1% fatalities among exposed populations of blast effects.

Note: The center of an unconfined gas/vapor explosion can be anywhere within the ground area passed over by the cloud or plume. See results of the vapor cloud fire hazard analysis for the maximum downwind distance and maximum width of this area. Explosion is assumed to take place on or near the ground.

Note: Fragments of tanks that suddenly rupture may become airborne and travel considerable distances. See guide for more information. Note that the tank is assumed to be on or near the ground.

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PHYSIOCHEMICAL PROPERTIES OF MATER	IAL		
NORMAL BOILING POINT	=	-423	degrees F
MOLECULAR WEIGHT	=	2.0159	
VAPOR PRES AT CONTAINER TEMP	=	2400	psia
	=	124167	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2400.1	psia
	=	124167	mm Hg
SPECIFIC HEAT RATIO FOR GAS	=	1.4	
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%
LOWER HEAT OF COMBUSTION	=	191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
TOXIC VAPOR LIMIT	=	40000	ppm
CONTAINER CHARACTERISTICS			
CONTAINER TYPE	=	Horizontal	cylinder
TOTAL WEIGHT OF CONTENTS	=	157.2	lbs
DISCHARGE HOLE DIAMETER		.75	inch(es)
DISCHARGE COEFFICIENT OF HOLE	=	.98	
TEMP OF CONTAINER CONTENTS	=	68	degrees F
TANK RUPTURE PRESSURE	=		degrees F psia
TANK RUPTURE PRESSURE	=	68 2400	
TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS	=	68 2400 S	psia
TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS AMBIENT TEMPERATURE	=	68 2400 S 68	psia degrees F
TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS AMBIENT TEMPERATURE WIND VELOCITY	= = TIC	68 2400 S 68 2	psia
TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS AMBIENT TEMPERATURE WIND VELOCITY ATMOSPHERIC STABILITY CLASS	= = IIC = = =	68 2400 S 68 2 F	psia degrees F mph
TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS AMBIENT TEMPERATURE WIND VELOCITY	= = IIC = = =	68 2400 S 68 2	psia degrees F

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 9-10-93 NAME OF DISK FILE = P-10DETO.ASF

\*\*\* SCENARIO DESCRIPTION

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30 cylinder stop valves release 30,000 cubic feet of hydrogen through a common manifold, 0.75 inches in diameter, under worst case met. conditions taking approximately 25 seconds.

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\*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	380.1	lbs/min
Duration of discharge	=	.414	minutes
Amount discharged	=	157.2	lbs
State of material	=	Gas	

# \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Dov	vnwi	Ind distanc	e to	concent	ration	of	183000	mqq
	at	groundleve	1	=	830		fe	eet
	at	discharge	heigi	nt =	814		fe	eet

Peak concentration on ground is 1000000 ppm at a downwind distance of 153 feet for elevated emission source specified by user.

See attached table(s) for further details.

\*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	578	feet
Safe separation distance	=	1155	feet
Flame jet duration	=	.414	minutes

## \*\*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1/	2 LFL	LFL	
	Downwind hazard distance	=	2097	1585	feet
	Max hazard zone width	=	1049	793	feet
	Max weight explosive gas			158	
	Relative gas/air density				
	Model used in analysis				
:	Clouds or plumes containi	ng	less that	an 1000	pounds

Note: Clouds or plumes containing less than 1000 pounds of vapor or gas are very unlikely to explode when completely unconfined, except when one of a certain few materials have been discharged.

TOXIC VAPOR	DISPERSION	ANALYSIS	RESULTS
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ownwind	l Distance			
(feet)	(miles)	Concentration (ppm)	Concentration (ppm)	Zone Width* (feet)
100 153 205 257 309 361 413 465 517 569	.02 .03 .04 .05 .06 .07 .08 .09 .1 .11	1000000 1000000 1000000 1000000 1000000 926107 741804 601639 493525 409098	1000000 1000000 1000000 1000000 1000000 822075 667813 548838 455378 381113	73 120 150 190 230 270 310 340 380
622 674 726 778 830	.11 .12 .13 .14 .15 .16	409098 342434 289250 246404 211566 183000	381113 321573 273456 234269 202112 175528	420 460 500 530 570 1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

		Contaminant Arrival Time at Downwind Location	Contaminant Departure Time
			(minutes)
100 153 205 257 309 361 413 465 517 569	.02 .03 .04 .05 .06 .07 .08 .09 .1 .11	.6 .9 1.2 1.5 1.8 2.1 2.4 2.7 3 3.3	1.6 2.2 2.8 3.4 4.6 5.2 5.7 6.3 6.9
622 674 726 778 830	.11 .12 .13 .14 .15 .16	3.3 3.6 3.9 4.2 4.5 4.8	0.9 7.5 8.1 8.7 9.3 9.9

CAUTION: See guide for assumptions used in estimating these times.

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PHYSIOCHEMICAL PROPERTIES OF MATERI		· · · · · · · · · · · · · · · · · · ·	
		-423	degrees F
		2.0159	
VAPOR PRES AT CONTAINER TEMP	=	2400	psia
	=	124167	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2400.1	psia
	=	124167	mm Hg
SPECIFIC HEAT RATIO FOR GAS	=	1.4	
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%
LOWER HEAT OF COMBUSTION	=	191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR			
TOXIC VAPOR LIMIT	=	183000	mqq
CONTAINER CHARACTERISTICS			
CONTAINER TYPE	=	Horizontal c	ylinder
TOTAL WEIGHT OF CONTENTS		157.2	lbs
DISCHARGE HOLE DIAMETER		.75	inch(es)
DISCHARGE COEFFICIENT OF HOLE			
TEMP OF CONTAINER CONTENTS		68	degrees F
TANK RUPTURE PRESSURE		2400	psia
		-	-
ENVIRONMENTAL/LOCATION CHARACTERIS	TIC	S	
AMBIENT TEMPERATURE	=	68	degrees F
WIND VELOCITY	=	2	mph
ATMOSPHERIC STABILITY CLASS	=	F	
VAPOR/GAS DISCHARGE HEIGHT		5	feet
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- KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED
- KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOU	JS MATERIAL	= Hydrogen
ADDRESS	\ LOCATION	= PDL
DATE OF	ASSESSMENT	= 9-10-93
NAME OF	DISK FILE	= P-11.ASF

#### \*\*\* SCENARIO DESCRIPTION

38 cylinder stop valves release 38,000 cubic feet of hydrogen through a common manifold, 0.75 inches in diameter, under average met. conditions taking approximately 31 seconds.

### \*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	380.1	lbs/min
Duration of discharge	=	.524	minutes
Amount discharged	=	199	lbs
State of material	=	Gas	

# \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind distance	to	concentration	oî	40000	ppm
at groundlevel				f	eet
at discharge h	eigh	t = 277		f	eet

Peak concentration on ground is 551540.4 ppm at a downwind distance of 43 feet for elevated emission source specified by user.

See attached table(s) for further details.

#### \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	578	feet
Safe separation distance	=	1155	feet
Flame jet duration	=	.524	minutes

#### \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1,	/2 LFL	LFL	
		-			
	Downwind hazard distance	=	414	286	feet
	Max hazard zone width	=	207	143	feet
	Max weight explosive gas	=	199	138	lbs
	Relative gas/air density	=	1.01	1.01	initially
	Model used in analysis	=	Neutral	ly buoya	ant .
Note:	Clouds or plumes contain	ing	less that	an 1000	pounds
	of vapor or gas are very				
	completely unconfined,	exc	ept when	one of	a cer-
	tain few materials have				

Downwind	Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation Zone Width*
(feet)	(miles)	(ppm)	(ppm)	(feet)
100	.02	238980	211410	350
113	.03	197464	176883	400
126	.03	165437	150095	440
139	.03	140398	128861	490
152	.03	120537	111754	480
165	.04	104564	97787	460
178	.04	91546	86248	440
191	.04	80811	76615	420
204	.04	71860	68498	390
217	.05	64323	61599	360
230	.05	57918	55688	330
243	.05	52431	- 50589	290
256	.05	47695	46160	240
269	.06	43580	42290	170
282	.06	40000	38889	1

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\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

### TOXIC VAPOR DISPERSION ANALYSIS RESULTS

		Contaminant Arrival Time at Downwind Location	
		(minutes)	
100 113 126 139 152 165 178 191 204 217 230	.02 .03 .03 .03 .03 .04 .04 .04 .04 .04 .05 .05	.2 .2 .2 .2 .3 .3 .3 .3 .3 .3 .3 .3 .3 .3 .3	.8 .9 .9 .9 1 1 1.1 1.1 1.1 1.1 1.1 1.2
230 243 256 269 282	.05 .05 .05 .06 .06	. 3 . 4 . 4 . 4 . 4	1.2 1.2 1.2 1.3 1.3

CAUTION: See guide for assumptions used in estimating these times.

#### UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

;TAI		FROM et)	EXPLOSION	EXPECTED DAMAGE
	58 83		Some damag	l breakage of large windows under stress. ge to home ceilings; 10% window breakage.
31	- 31	54	Windows us	sually shattered; some frame damage. emolition of homes; made uninhabitable.
8	- 19	31	Range ser:	ious/slight injuries from flying glass/object. ollapse of home walls/roofs.
15	-	19		orced concrete/cinder block walls shattered.
7	- 16	17	Range 90-1	1% eardrum rupture among exposed population. uction of home brickwork.
12	- 11	15		steel panel buildings ruined. ility poles snapped.
9	7	11		mplete destruction of houses. total building destruction.
5	-	6	Range for	99-1% fatalities among exposed populations rect blast effects.

Note: The center of an unconfined gas/vapor explosion can be anywhere within the ground area passed over by the cloud or plume. See results of the vapor cloud fire hazard analysis for the maximum downwind distance and maximum width of this area. Explosion is assumed to take place on or near the ground.

Note: Fragments of tanks that suddenly rupture may become airborne and travel considerable distances. See guide for more information. Note that the tank is assumed to be on or near the ground.

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PHYSIOCHEMICAL PROPERTIES OF MATERI	AL		
NORMAL BOILING POINT		-423	degrees F
MOLECULAR WEIGHT	=	2.0159	-
VAPOR PRES AT CONTAINER TEMP	=	2400	psia
		124167	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2400.1	psia
		124167	mm Hg
SPECIFIC HEAT RATIO FOR GAS	=	1.4	-
LOWER FLAMMABLE LIMIT (LFL)		4	vol%
LOWER HEAT OF COMBUSTION			Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
TOXIC VAPOR LIMIT		40000	ppm
CONTAINER CHARACTERISTICS			
CONTAINER TYPE	=	Horizontal c	ylinder
TOTAL WEIGHT OF CONTENTS	=	199	lbs
DISCHARGE HOLE DIAMETER		.75	inch(es)
DISCHARGE COEFFICIENT OF HOLE	=	.98	
TEMP OF CONTAINER CONTENTS		68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia
ENVIRONMENTAL/LOCATION CHARACTERIS	TIC	S	
AMBIENT TEMPERATURE	=		degrees F
WIND VELOCITY	=	9	mph
ATMOSPHERIC STABILITY CLASS	=	С	
VAPOR/GAS DISCHARGE HEIGHT		5	feet
THE PROPERTY AND THE PR	Π	OF BY EVALUAT	TON METHODS

- KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED
- KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 9-10-93 NAME OF DISK FILE = P-11DETO.ASF

\*\*\* SCENARIO DESCRIPTION

38 cylinder stop valves release 38,000 cubic feet of hydrogen through a common manifold, 0.75 inches in diameter, under average met. conditions taking approximately 31 seconds.

\*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	380.1	lbs/min
Duration of discharge	=	.524	minutes
Amount discharged	=	199	lbs
State of material	=	Gas	

# \*\*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Dov	vnwi	ind distan	ce to	concent	tration	of	183000	ppm
		groundlev			119		fe	eet
	at	discharge	heigh	nt =	111		fe	eet

Peak concentration on ground is 551461.9 ppm at a downwind distance of 43 feet for elevated emission source specified by user.

See attached table(s) for further details.

## \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	578	feet
Safe separation distance	=	1155	feet
Flame jet duration	=	.524	minutes

#### \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of 1/2 LH		LFL	
	Downwind hazard distance	= 414	286	feet
	Max hazard zone width	= 207	143	feet
	Max weight explosive gas			
	Relative gas/air density			
	Model used in analysis	🗎 Neutral	lly buoy	ant
Note:	Clouds or plumes contain:	ing less th	nan 1000	pounds
	of vapor or gas are very	unlikely t	co explo	de when
	completely unconfined, o	except when	ı one of	a cer-
	tain few materials have 1	been discha	arged.	

Downwind	i Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation Zone Width*
(feet)	(miles)	(mdd)	(ppm)	(feet)
100	.02	238980	211410	130
102	.02	234268	207484	130
103	.02	229683	203667	120
104	.02	225219	199955	120
106	.02	220875	196344	110
107	.03	216645	192829	110
208	.03	212528	189408	98
110	.03	208518	186076	92
111	.03	204614	182831	85
112	.03	200812	179669	78
114	.03	197108	176587	70
115	.03	193501	173583	61
116	.03	189986	170653	50
118	.03	186561	167796	36
119	.03	183000	165009	1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

## TOXIC VAPOR DISPERSION ANALYSIS RESULTS

		Contaminant Arrival Time at Downwind Location		
(feet)	(miles)	(minutes)	(minutes)	
100		.2	.8	
102	.02	.2	.8	
103	.02	.2	.8	
104	.02	.2	.8	
106	.02	.2	.8	
107	.03	.2	.8	
108	.03	.2	.8	
110	.03	.2	.9	
111	.03	.2	.9	
112	.03	.2	.9	
114	.03	.2	.9	
115	.03	.2	.9	
116	.03	.2	.9	
118	.03	.2	.9	
119	.03	.2	.9	

CAUTION: See guide for assumptions used in estimating these times.

PHYSIOCHEMICAL PROPERTIES OF MATER:	PHYSIOCHEMICAL PROPERTIES OF MATERIAL						
NORMAL BOILING POINT	= -423	degrees F					
MOLECULAR WEIGHT	= 2.0159	2					
VAPOR PRES AT CONTAINER TEMP	= 2400	psia					
	= 124167	mm Hg					
VAPOR PRES AT AMBIENT TEMP	= 2400.1	psia					
	= 124167	mim Hg					
SPECIFIC HEAT RATIO FOR GAS	= 1.4	-					
LOWER FLAMMABLE LIMIT (LFL)	= 4	vol%					
LOWER HEAT OF COMBUSTION	= 191.7	Btu/lb					
GAS EXPLOSION YIELD FACTOR	= .03						
TOXIC VAPOR LIMIT	= 183000	ppm					
CONTAINER CHARACTERISTICS							
CONTAINER TYPE	= Horizontal c	ylinder					
TOTAL WEIGHT OF CONTENTS	= 199	lbs					
DISCHARGE HOLE DIAMETER	= .75	inch(es)					
DISCHARGE COEFFICIENT OF HOLE							
TEMP OF CONTAINER CONTENTS	= 68	degrees F					
TANK RUPTURE PRESSURE	= 2400	psia					
ENVIRONMENTAL/LOCATION CHARACTERIS		_					
AMBIENT TEMPERATURE	= 68	degrees F					
WIND VELOCITY	= 9	mph					
ATMOSPHERIC STABILITY CLASS	-	<b>c</b> .					
VAPOR/GAS DISCHARGE HEIGHT	= 5	feet					
	· · · · · · · · · · · · · · · · · · ·						

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 9-10-93 NAME OF DISK FILE = P-12.ASF

\*\*\* SCENARIO DESCRIPTION

38 cylinder stop valves release 38,000 cubic feet of hydrogen through a common manifold, 0.75 inches in diameter, under worst case met. conditions taking approximately 31 seconds.

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\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	380.1	lbs/min
Duration of discharge	=	.524	minutes
Amount discharged	=	199	lbs
State of material	` =	Gas	

# \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind distance	to concen	tration	of	40000	ppm
at groundlevel	=	1710		f	leet
at discharge he	ight =	1700		f	leet

Peak concentration on ground is 1000000 ppm at a downwind distance of 149 feet for elevated emission source specified by user.

See attached table(s) for further details.

\*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	578	feet
Safe separation distance	=	1155	feet
Flame jet duration	=	.524	minutes

## \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

E	For concentration of	1,	/2 LFL	LFL	
Ι	Downwind hazard distance	=	2287	1721	feet
Ν	Max hazard zone width	=	1144	861	feet
	Max weight explosive gas				lbs
F	Relative gas/air density	÷	1.01	1.01	initially
Ν	Model used in analysis	÷	Neutral	ly buoya	ant
		•	7		

Note: Clouds or plumes containing less than 1000 pounds of vapor or gas are very unlikely to explode when completely unconfined, except when one of a certain few materials have been discharged.

ownwind	Distance	Groundlevel Concentration	Source Height Concentration	
(feet)	(miles)	(ppm)	(ppm)	Zone Width* (feet)
100	.02	1000000	1000000	73
215		1000000	1000000	160
330	.07	1000000	940273	250
445	.09	669849	608118.	330
560	.11	449969	418542	410
675	.13	316465	299247	500
790	.15	230549	220476	580
905	.18	172958	166728	660
1020	.2	133059	129019	750
1135	.22	104617	101891	830
1250	.24	83825	81923	910
1365	.26	68285	66918	1000
1480	.29	56437	55429	1080
1595	.31	47244	46485	1170
1710	.33	40000	39415	1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind		Contaminant Arrival Time at Downwind Location	
(feet)		(minutes)	
		.6	1.7
215 330	.05 .07	1.3 1.9	3 4.3
445	.09	2.6	5.6
560	.11	3.2	6.9
675 790	.13 .15	3.9 4.5	8.2 9.6
905	.18	5.2	10.9
1020	.2	5.8	12.2
1135 1250	.22 .24	6.5 7.2	13.5 14.8
	.26	7.8	16.1
	.29	8.5 .	17.4
1595 1710	.31	9.1 9.8	18.7 20

CAUTION: See guide for assumptions used in estimating these times.

## UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

ISTAN	ICE F (fee		EXPLOSION EXPECTED DAMAGE
	583 83		Occasional breakage of large windows under stress. Some damage to home ceilings; 10% window breakage.
31	-		Windows usually shattered; some frame damage.
	31		Partial demolition of homes; made uninhabitable.
8	-	31	Range serious/slight injuries from flying glass/object.
	19		Partial collapse of home walls/roofs.
15	-	19	Non-reinforced concrete/cinder block walls shattered.
7	-	17	Range 90-1% eardrum rupture among exposed population.
	16		50% destruction of home brickwork.
12	-	15	Frameless steel panel buildings ruined.
	11		Wooden utility poles snapped.
9		11	Nearly complete destruction of houses.
-	7		Probable total building destruction.
5	-	6	Range for 99-1% fatalities among exposed populations due to direct blast effects.

Note: The center of an unconfined gas/vapor explosion can be anywhere within the ground area passed over by the cloud or plume. See results of the vapor cloud fire hazard analysis for the maximum downwind distance and maximum width of this area. Explosion is assumed to take place on or near the ground.

Note: Fragments of tanks that suddenly rupture may become airborne and travel considerable distances. See guide for more information. Note that the tank is assumed to be on or near the ground.

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PHYSIOCHEMICAL PROPERTIES OF MATER	IAL	l	
NORMAL BOILING POINT	=	-423	degrees F
MOLECULAR WEIGHT	=	2.0159	-
VAPOR PRES AT CONTAINER TEMP	=	2400	psia
	=	124167	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2400.1	psia
	=	124167	mm Hg
SPECIFIC HEAT RATIO FOR GAS	=	1.4	-
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%
LOWER HEAT OF COMBUSTION	=	191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
TOXIC VAPOR LIMIT	=	40000	ppm
CONTAINER CHARACTERISTICS			
CONTAINER TYPE	=	Horizontal c	ylinder
TOTAL WEIGHT OF CONTENTS	=	199	lbs
DISCHARGE HOLE DIAMETER	=	.75	inch(es)
DISCHARGE COEFFICIENT OF HOLE	=	.98	
TEMP OF CONTAINER CONTENTS	=	68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia
ENVIRONMENTAL/LOCATION CHARACTERIS	TIC	S	
AMBIENT TEMPERATURE	=	68	degrees F
WIND VELOCITY	=	2	mph
ATMOSPHERIC STABILITY CLASS	=	F	
VAPOR/GAS DISCHARGE HEIGHT	=	5	feet
KEY RESULTS PROVIDED BY USER INSTE	$^{\mathrm{AD}}$	OF BY EVALUAT	ION METHODS
NONE OBSERVED			

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 9-10-93 NAME OF DISK FILE = P-12DETO.ASF

\*\*\* SCENARIO DESCRIPTION

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38 cylinder stop valves release 38,000 cubic feet of hydrogen through a common manifold, 0.75 inches in diameter, under worst case met. conditions taking approximately 31 seconds.

\*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	380.1	lbs/min
Duration of discharge	=	.524	minutes
Amount discharged	=	199	lbs
State of material	=	Gas	

# \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind distance t	concentration	of	183000 ppm
at groundlevel	= 882		feet
at discharge hei	ight = 866		feet

Peak concentration on ground is 1000000 ppm at a downwind distance of 147 feet for elevated emission source specified by user.

See attached table(s) for further details.

## \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	578	feet
Safe separation distance	=	1155	feet
Flame jet duration	=	.524	minutes

## \*\*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1,	/2 LFL	LFL	
	Downwind hazard distance	=	2287	1721	feet
	Max hazard zone width	=	1144	861	feet
	Max weight explosive gas	=	200	200	lbs
	Relative gas/air density	=	1.01	1.01	initially
	Model used in analysis	÷	Neutral	ly buoya	ant
Note:	Clouds or plumes contain	ing	less that	an 1000	pounds
	of vapor or gas are very	un	likely to	o explo	de when
	completely unconfined,				

tain few materials have been discharged.

wnwind Distance		Groundlevel	Source Height	Initial Evacuation
		Concentration	Concentration	Zone Width*
(feet)	(miles)	(ppm)	(ppm)	(feet)
100 156 212 268 324 380 435 491 547 603	.02 .03 .05 .06 .07 .08 .09 .1 .11 .11 .12	1000000 1000000 1000000 1000000 865661 695432 567936 470023 393317	1000000 1000000 1000000 967387 772248 629741 521173 436161 368358	73 120 160 200 240 280 320 360 400 440
659	.13	332285	313575	480
715	.14	283118	268868	520
770	.15	243094	232081	570
826	.16	210213	201586	610
882	.17	183000	176135	1

'Usually safe for < 1 hour release. Longer releases or sudden wind shifts nay require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

Downwind	Distance	Contaminant Arrival Time at Downwind Location	Contaminant Departure Time at Downwind Location								
(feet)		(minutes)	(minutes)								
100	.02	.6	1.7								
156	.03	.9	2.3								
	.05	1.3	3								
268	.06	1.6	3.6								
324	.07	1.9	4.3								
380	.08	2.2	4.9								
435	.09	2.5	5.5								
491	.1	2.8	6.2								
547	.11	3.2	6.8								
603	.12	3.5	7.4								
659	.13	3.8	8.1								
715	.14	4.1 .	8.7								
770	.15	4.4 .	9.3								
826	.16	4.7	10								
882	.17	5.1	10.6								

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

CAUTION: See guide for assumptions used in estimating these times.

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PHYSIOCHEMICAL PROPERTIES OF MATERI	AL		
		-423	degrees F
	=	2.0159	-
VAPOR PRES AT CONTAINER TEMP	=	2400	psia
		124167	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2400.1	psia
	=	124167	mm Hg
SPECIFIC HEAT RATIO FOR GAS	=	1.4	
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%
LOWER HEAT OF COMBUSTION		191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
TOXIC VAPOR LIMIT		183000	ppm
CONTAINER CHARACTERISTICS			
CONTAINER TYPE	=	Horizontal c	
TOTAL WEIGHT OF CONTENTS		199	lbs
DISCHARGE HOLE DIAMETER	=	.75	inch(es)
DISCHARGE COEFFICIENT OF HOLE			
TEMP OF CONTAINER CONTENTS	=	68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia
ENVIRONMENTAL/LOCATION CHARACTERIS	ric	S	
AMBIENT TEMPERATURE	=	68	degrees F
WIND VELOCITY	=	—	mph
ATMOSPHERIC STABILITY CLASS	=	F	-
VAPOR/GAS DISCHARGE HEIGHT	=	5	feet

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL	= Hydroger	L
ADDRESS \ LOCATION	= PDL	
DATE OF ASSESSMENT	= 9-16-93	
NAME OF DISK FILE	= B-1.ASF	

## \*\*\* SCENARIO DESCRIPTION

One cylinder releases 220 cubic feet of hydrogen through a hole .375 inches in diameter under average met. conditions taking approximately one second.

## \*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	79.2	lbs/min
Duration of discharge	=	.013	minutes
Amount discharged	=	1	lbs
State of material	=	Gas	

## \*\*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind	distance	to	concent	ration	of	40000	ppm
at gr	oundlevel		=	66		t	feet
at di	scharge he	eigh	it =	64		1	feet

Peak concentration on ground is 79878.1 ppm at a downwind distance of 37 feet for elevated emission source specified by user.

See attached table(s) for further details.

## \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	264	feet
Safe separation distance	=	527	feet
Flame jet duration	=	.013	minutes

## \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

For concentration of			2 LFL	LFL	
	Downwind hazard distance	=	99	78	feet
	Max hazard zone width	=	50	39	feet
	Max weight explosive gas	=	1.1	1.1	lbs
	Relative gas/air density	=	1.01	1.01	initially
	Model used in analysis	÷	Neutral	Ly buoya	ant
	dlauda an mluman armaini				

- Note: Clouds or plumes containing less than 1000 pounds of vapor or gas are very unlikely to explode when completely unconfined, except when one of a certain few materials have been discharged.
- \*\*\*\*\*\* EXPLCSION HAZARDS: See attached table(s)

				*****
Downwind Distance		Groundlevel Concentration	Source Height Concentration	Initial Evacuation Zone Width*
(feet)	(miles)	(mqq)	(mqq)	(feet)
32	.01	76826	212300	120
35	.01	79491	177088	120
37	.01	79826	149328	110
40	.01	78449	127226	110
42	.01	75894	109466	110
45	.01	72583	95064	98
47	.01	68837	83276	93
49	.01	64887	73540	88
52	.01	60896	65422	83
54	.02	56974	58592	76
57	.02	53192	52793	69
59	.02	49594	47827	60
61	.02	46203	43538	50
64	.02	43029	39807	36
66	.02	40000	36536	1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

# TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind	Distance	Contaminant Arrival Time	Contaminant Departure Time
(feet;	(miles)		at Downwind Location (minutes)
32 35 37 40 42 45 47 49 52 54 57 59 61 64 66	.01 .01 .01 .01 .01 .01 .01 .01 .01 .02 .02 .02 .02 .02 .02 .02	.1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1	.1 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2

CAUTION: See guide for assumptions used in estimating these times.

## UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

					 	 	 							-	-
ISTANCE	FROM	EXPLO	SIC	ON			ΕX	PI	ΞC	ΤE	D	D	AM	ÍA	G

EXPECTED DAMAGE

	(feet	t)	
	117		Occasional breakage of large windows under stress.
-	17		Some damage to home ceilings; 10% window breakage.
7	7	11	Windows usually shattered; some frame damage. Partial demolition of homes; made uninhabitable.
2	-	7	Range serious/slight injuries from flying glass/object.
	4		Partial collapse of home walls/roofs.
3	-	4	Non-reinforced concrete/cinder block walls shattered.
2	-	4	Range 90-1% eardrum rupture among exposed population.
	4		50% destruction of home brickwork.
3	-	3	Frameless steel panel buildings ruined.
	3		Wooden utility poles snapped.
2	-	3	Nearly complete destruction of houses.
	2		Probable total building destruction.
1	-	2	Range for 99-1% fatalities among exposed populations due to direct blast effects.

Note: The center of an unconfined gas/vapor explosion can be anywhere within the ground area passed over by the cloud or plume. See results of the vapor cloud fire hazard analysis for the maximum downwind distance and maximum width of this area. Explosion is assumed to take place on or near the ground.

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PHYSIOCHEMICAL PROPERTIES OF	MATERIAL		
NORMAL BOILING POINT	= -	-423	degrees F
MOLECULAR WEIGHT	=	2.0159	•
VAPOR PRES AT CONTAINER	TEMP =	2000	psia
	=	103472	mm Hg
VAPOR PRES AT AMBIENT TE	MP =	2000.1	psia
	=	103472	mm Hg
SPECIFIC HEAT RATIO FOR	GAS =	1.4	-
LOWER FLAMMABLE LIMIT (L	FL) =	4	vol%
LOWER HEAT OF COMBUSTION	=	191.7	Btu/lb
GAS EXPLOSION YIELD FACT	'OR =	.03	
TOXIC VAPOR LIMIT	=	40000	ppm
CONTAINER CHARACTERISTICS			
CONTAINER TYPE	=	Horizontal cy	
TOTAL WEIGHT OF CONTENTS		_	lbs
DISCHARGE HOLE DIAMETER	=		inch(es)
DISCHARGE COEFFICIENT OF			
TEMP OF CONTAINER CONTEN		68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia
ENVIRONMENTAL/LOCATION CHARAC			•
AMBIENT TEMPERATURE		68	degrees F
WIND VELOCITY	=		mph
ATMOSPHERIC STABILITY CI			-
VAPOR/GAS DISCHARGE HEIG	HT =	5	feet
KEY RESULTS PROVIDED BY USER	TICTEND		TON METHODS
THE RESULTS PROVIDED BY USER	ING LEMU	OF DI EVALUAL	

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 9-16-93 NAME OF DISK FILE = B-1DETON.ASF \*\*\* SCENARIO DESCRIPTION One cylinder releases 220 cubic feet of hydrogen through a hole .375 inches in diameter under average met. conditions taking approximately one second. \*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES Compressed gas discharge from container Peak discharge rate = 79.2 lbs/min Duration of discharge = .013 Amount discharged = 1 State of material = Gas minutes lbs \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS Downwind distance to concentration of 183000 ppm -- at groundlevel = Not observed -- at discharge height = 34 feet Note: Minimum computable answer is 33 feet! Actual hazard distance may be less. Peak concentration on ground is 79916.9 ppm at a downwind distance of 37 feet for elevated emission source specified by user. See attached table(s) for further details. \*\*\*\*\*\* FLAME JET HAZARD RESULTS Flame jet length= 264feetSafe separation distance= 527feetFlame jet duration= .013minutes \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS For concentration of 1/2 LFL LFL Downwind hazard distance = 99 78 feet Max hazard zone width = 50 39 feet Max weight explosive gas = 1.1 1.1 lbs Relative gas/air density = 1.01 1.01 initially Model used in analysis = Neutrally buoyant Note: Clouds or plumes containing less than 1000 pounds of vapor or gas are very unlikely to explode when completely unconfined, except when one of a certain few materials have been discharged. \*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

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Downwind	l Distance	Groundlevel	Source Height	Initial Evacuation
(feet)	(miles)	Concentration (ppm)	Concentration (ppm)	Zone Width* (feet)
32 33 33 33 33 33 33 33 33 34 34	.01 .01 .01 .01 .01 .01 .01 .01 .01 .01	76826 77042 77250 77448 77638 77820 77994 78159 78316 78465	212300 210150 208030 205938 203874 201837 199828 197844 195888 193957	22 22 21 20 19 18 17 16 15 14
34 34 34	.01 .01 .01	78606 78740 78865	192051 190170 188314	12 11 9
34 34	.01	78984 79094	186482 183000	6 1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

# TOXIC VAPOR DISPERSION ANALYSIS RESULTS

	i Distance	Contaminant Arrival Time at Downwind Location	Contaminant Departure Time at Downwind Location
(feet)	(miles)	(minutes)	(minutes)
32	.01	.1	.1
33	.01	.1	.1
33	.01	.1	.1
33	.01	.1	.1
33	.01	.1	.1
33	.01	.1	.1
33	.01	.1	.1
33	.01	.1	.1
34	.01	.1	.1
34	.01	.1	
34	.01	.1 .1 .1	.1
34	.01		.1
34 34	.01	.1	.1
34	.01	.1	.1
	.01	.1	.1

CAUTION: See guide for assumptions used in estimating these times.

PHYSIOCHEMICAL PROPERTIES OF MATER	IAL		
NORMAL BOILING POINT	=	-423	degrees F
MOLECULAR WEIGHT	=	2.0159	<b>J</b>
VAPOR PRES AT CONTAINER TEMP	=	2000	psia
	=	103472	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2000.1	psia
	=	103472	mm Hg
SPECIFIC HEAT RATIO FOR GAS		1.4	-
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%
LOWER HEAT OF COMBUSTION		191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
TOXIC VAPOR LIMIT	=	183000	ppm
CONTAINER CHARACTERISTICS			
CONTAINER TYPE	=	Horizontal c	
TOTAL WEIGHT OF CONTENTS	=	1	lbs
TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER	=	1 .375	
TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE	= =	1 .375 .98	lbs inch(es)
TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS	= =	1 .375 .98 68	lbs inch(es) degrees F
TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE	= =	1 .375 .98	lbs inch(es)
TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE		1 .375 .98 68 2000	lbs inch(es) degrees F
TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS		1 .375 .98 68 2000 S	lbs inch(es) degrees F psia
TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS AMBIENT TEMPERATURE	= = = = TIC: =	1 .375 .98 68 2000 S 68	lbs inch(es) degrees F psia degrees F
TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS AMBIENT TEMPERATURE WIND VELOCITY	= = = TIC: = =	1 .375 .98 68 2000 S 68 9	lbs inch(es) degrees F psia
TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS AMBIENT TEMPERATURE WIND VELOCITY ATMOSPHERIC STABILITY CLASS	= = = = TIC: = = =	1 .375 .98 68 2000 S 68 9 C	lbs inch(es) degrees F psia degrees F mph
TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS AMBIENT TEMPERATURE WIND VELOCITY	= = = TIC: = =	1 .375 .98 68 2000 S 68 9	lbs inch(es) degrees F psia degrees F

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 09-30-93 NAME OF DISK FILE = B-2.ASF

\*\*\* SCENARIO DESCRIPTION

One cylinder releases 220 cubic feet of hydrogen through a hole .375 inches in diameter under worst case met. conditions taking approximately 1 second.

\*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	79.2	lbs/min
Duration of discharge	=	.013	minutes
Amount discharged	=	1	lbs
State of material	=	Gas	

# \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind distance to	concentration	of 40000 ppm
at groundlevel	= 214	feet
at discharge heigh	t = 208	feet

Peak concentration on ground is 74936.3 ppm at a downwind distance of 121 feet for elevated emission source specified by user.

See attached table(s) for further details.

\*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	264	feet
Safe separation distance	=	527	feet
Flame jet duration	=	.013	minutes

## \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1/2 LFL	LFL	
Note:	Downwind hazard distance Max hazard zone width Max weight explosive gas Relative gas/air density Model used in analysis Clouds or plumes contains of vapor or gas are very completely unconfined, et tain few materials have b	= 163 = 1.1 = 1.01 = Neutral ing less that unlikely to except when	1.1 1.01 Ly buoya an 1000 o exploa one of	initially ant pounds ie when
*****	EXPLOSION HAZARDS. See at	tached tah		

\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

Jwnwind	l Distance	Groundlevel	Source Height	Initial Evacuation
(feet)	(miles)	Concentration (ppm)	Concentration (ppm)	Zone Width* (feet)
100 109	,02 .03	63624 70529	298581	73
117	.03	74124	237330 192025	79 85
125	.03	75072	157844	91
133	.03	74079	131618	97
141	.03	71760	111197	110
149	.03	68605	95081	110
157	.03	64975	82201	120
166	.04	61129	71783	130
174	.04	57243	63256	130
182	.04	53435	56199	140
190	.04	49777	50294	140
198	.04	46311	45302	150
206 214	.04	43061 40000	41041 37371	120

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

## TOXIC VAPOR DISPERSION ANALYSIS RESULTS

		Contaminant Arrival Time at Downwind Location	Contaminant Departure Time		
(feet)	(miles)		(minutes)		
100 109 117 125 133 141 149 157 166	.02 .03 .03 .03 .03 .03 .03 .03 .03 .03 .04	.6 .7 .7 .8 .8 .9 .9 .9 .9 .9 .9 .9	1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.8 1.8 1.9		
174 182 190 198 206 214	.04 .04 .04 .04 .04 .05	1 1.1 1.1 1.2 1.2 1.3	2 2.1 2.2 2.3 2.4 2.5		

CAUTION: See guide for assumptions used in estimating these times.

## UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

DISTA	NCE F (fee		EXPLOSION EXPECTED DAMAGE	
	117 17		Occasional breakage of large windows under stress. Some damage to home ceilings; 10% window breakage.	
7	7	11	Windows usually shattered; some frame damage. Partial demolition of homes: made uninhabitable.	
2	- 4	7	Range serious/slight injuries from flying glass/object. Partial collapse of home walls/roofs.	
3	-	4	Non-reinforced concrete/cinder block walls shattered.	
2	-	4	Range 90-1% eardrum rupture among exposed population.	
	4		50% destruction of home brickwork.	
3	-	3	Frameless steel panel buildings ruined.	
	3		Wooden utility poles snapped.	
2	-	3	Nearly complete destruction of houses.	
	2		Probable total building destruction.	
1	-	2	Range for 99-1% fatalities among exposed populations due to direct blast effects.	

Note: The center of an unconfined gas/vapor explosion can be anywhere within the ground area passed over by the cloud or plume. See results of the vapor cloud fire hazard analysis for the maximum downwind distance and maximum width of this area. Explosion is assumed to take place on or near the ground.

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PHYSIOCHEMICAL PROPERTIES OF MATERI	TAL		
NORMAL BOILING POINT	= •	-423	degrees F
MOLECULAR WEIGHT	=	2.0159	
VAPOR PRES AT CONTAINER TEMP	=	2000	psia
	=	103472	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2000.1	psia
	=	103472	mm Hg
SPECIFIC HEAT RATIO FOR GAS	=	1.4	
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%
LOWER HEAT OF COMBUSTION	=	191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
TOXIC VAPOR LIMIT	=	40000	ppm
CONTAINER CHARACTERISTICS			
CONTAINER TYPE	=	Horizontal c	vlinder
TOTAL WEIGHT OF CONTENTS	=	1	lbs
DISCHARGE HOLE DIAMETER	=	.375	inch(es)
DISCHARGE COEFFICIENT OF HOLE	=	.98	
TEMP OF CONTAINER CONTENTS	=	68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia
			-
ENVIRONMENTAL/LOCATION CHARACTERIS	<b>TIC</b>	S	
AMBIENT TEMPERATURE	=	68	degrees F
WIND VELOCITY	=	2	mph
ATMOSPHERIC STABILITY CLASS	=	F	
VAPOR/GAS DISCHARGE HEIGHT	== `	5	feet

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SCME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 09-30-93 NAME OF DISK FILE = B-2DETON.ASF

\*\*\* SCENARIO DESCRIPTION

One cylinder releases 220 cubic feet of hydrogen through a hole .375 inches in diameter under worst case met. conditions taking approximately 1 second.

\*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	= 79	.2 lbs/mir	ı
Duration of discharge	= .03	· · ·	
Amount discharged	= 1	lbs	-
State of material	= Gas	S	

\*\*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Dow	mwi	ind distanc	e to	concent	trat	lon	of	183000	mag
,	at	groundleve	1	=	Not	obs			
	at	discharge	heigh	t =	119			f	eet

Note: Minimum computable answer is 33 feet! Actual hazard distance may be less.

> Peak concentration on ground is 74938.1 ppm at a downwind distance of 121 feet for elevated emission source specified by user.

See attached table(s) for further details.

\*\*\*\*\*\* FLAME JET HAZARD RESULTS

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Flame jet length	=	264	feet
Safe separation distance	=	527	feet
Flame jet duration	=	.013	minutes

\*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1/	2 LFL	LFL	
Note:	Downwind hazard distance Max hazard zone width Max weight explosive gas Relative gas/air density Model used in analysis Clouds or plumes contain: of vapor or gas are, very completely unconfined, e tain few materials have b	= = ing unl	163 1.1 1.01 Neutrall less tha ikely to pt when	1.01 Ly buoya an 1000 o explose one of	initially ant pounds le when

\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

נ ו ו ו		zone width* (feet)	73	74	75	76	77	78	79	80	81	78	70	61	50	36	<b>r-1</b>
100000 01010000 0010100000000000000000	Source Height	CONCENCTACION (ppm)	1 8	8739	76	6666	5705	4791	3921		2301	1547	0828	0141	9485	8858	8300
	Groundlevel		62	97	23	90	47	40	34	71147	86	50	06	ហ	96	430	74580
	l Distance		0	.02	.02	.02	.02	.03	.03	.03	.03	.03	.03	.03	. 03	.03	.03
	puiwuwc		100	0	0	0	Ο	0	0	110	H	H.	$\mathbf{H}$	-1	-1	H.	H

evacuation zone. height specified sudden wind shifts \*Usually safe for < 1 hour release. Longer releases or su may require a larger width or different direction for the see Chapters 3 and 12 cf the guide for details. Source of the user for this scenario was 5 feet.

# TOXIC VAPOR DISPERSION ANALYSIS RESULTS

	Contaminant Departure Time	ac powinting pocarion (minutes)	1.2	1.2	1.2	1.2	1.3	1.3	д. З	1.3	1.3	с. -	1.4	1.4	1.4	1.4	1.4
CITOREN ARAMA NOT ANTI ALL AND ANALY AND	EH C	(minutes)	9.	.9	.6	.6	.7	.7	.7	.7	.7	.7	.7	. 7	.7 .	.7	.7
1 1 1 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	d Distance	(miles)	0.0	.02	.02	.02	.02	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
1 1 1 1 1 1 1 1	Downwind	(feet)	000 1	$\Box$	0	0	0	0	$\mathbf{O}$	<b>1</b> -1	-	-1	r-1	-	-	e l	r-1

. times. these estimating ц. used assumptions for guide See CAUTION:

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 PROPERTIES OF MAREPIAL	

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PHYSIOCHEMICAL PROPERTIES OF MATERI	AL		
NORMAL BOILING POINT	= •	-423	degrees F
MOLECULAR WEIGHT	=	2.0159	
VAPOR PRES AT CONTAINER TEMP	=	2000	psia
	=	103472	mm Hg
VAPOR PRES AT AMBIENT TEMP		2000.1	psia
	=	103472	mm Hg
SPECIFIC HEAT RATIO FOR GAS	=	1.4	
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%
LOWER HEAT OF COMBUSTION	=	191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
TOXIC VAPOR LIMIT	=	183000	ppm
CONTAINER CHARACTERISTICS CONTAINER TYPE	=	Horizontal c	
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS	=	1	lbs
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER	=	1 .375	
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE	=	1 .375 .98	lbs
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS	11 11	1 .375	lbs inch(es)
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE		1 .375 .98 68	lbs inch(es) degrees F
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE		1 .375 .98 68 2400	lbs inch(es) degrees F
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS		1 .375 .98 68 2400	lbs inch(es) degrees F
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE	= = = = TIC	1 .375 .98 68 2400	lbs inch(es) degrees F psia
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS AMBIENT TEMPERATURE	= = = = TIC	1 .375 .98 68 2400 25 68 2 F	lbs inch(es) degrees F psia degrees F mph
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS AMBIENT TEMPERATURE WIND VELOCITY	= = = = TIC = =	1 .375 .98 68 2400 25 68 2	lbs inch(es) degrees F psia degrees F

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

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KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

HAZARDOUS MATERIAL	= Hydrogen
ADDRESS \ LOCATION	= PDL
DATE OF ASSESSMENT	= 10 - 1 - 93
NAME OF DISK FILE	= B-3.ASF

\*\*\* SCENARIO DESCRIPTION

Three cylinders release 660 cubic feet of hydrogen through three holes, .375 inches in diameter each, under average met. conditions taking approximately 1 second.

## \*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	237.9	lbs/min
Duration of discharge	=	.015	minutes
Amount discharged	=	3.5	lbs
State of material	=	Gas	

## \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind distance	to	concentration	of	40000 ppm
at groundlevel		·= 113		feet
at discharge he	eigh	1t = 108		feet

Peak concentration on ground is 261974.3 ppm at a downwind distance of 38 feet for elevated emission source specified by user.

See attached table(s) for further details.

## \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	457	feet
Safe separation distance	=	914	feet
Flame jet duration	=	.015	minutes

## \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1/2 LFL	LFL	
	Downwind hazard distance	= 153	120	feet
	Max hazard zone width	= 77	60	feet
	Max weight explosive gas	= 3.6	3.6	lbs
	Relative gas/air density			
	Model used in analysis			
Note:	Clouds or plumes contain:	ing less th	an 1000	pounds
	of vapor or gas are very	unlikely t	o explo	de when
	completely unconfined,	except when	one of	a cer-

tain few materials have been discharged. \*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

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Downwind	Distance	Groundlevel Concentration	Source Height Concentration	
(feet)	(miles)	(ppm)	(ppm)	Zone Width* (feet)
100 101 102 103 104 105 106 107 108 109 110 110	.02 .02 .02 .02 .02 .02 .02 .02 .02 .03 .03 .03 .03 .03	53827 52657 51520 50414 49338 48292 47274 46283 45319 44380 43467 42577	47617 46620 45651 44708 43791 42900 42032 41187 40365 39565 38785 38026	110 110 97 93 89 85 80 75 70 64 57 50
111 112 113	.03 .03 .03	41712 40868 40000	37286 36566 35864	41 29 1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

## TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind	i Distance	Contaminant Arrival Time at Downwind Location	Contaminant Departure Time
(feet)	(miles)		(minutes)
100 101 102 103 104 105 106 107 108 109	.02 .02 .02 .02 .02 .02 .02 .02 .03 .03 .03	.2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2	.3 .3 .3 .3 .3 .3 .3 .3 .3 .3 .3 .3 .3
110 110 111 112 113	.03 .03 .03 .03 .03	.2 .2 .2 .2 .2 .2	.3 .3 .3 .4

CAUTION: See guide for assumptions used in estimating these times.

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

STA			EXPLOSION	EXPECTED DAMAGE
	(16	et)		
	17	3	Occasior	al breakage of large windows under stress.
		5	· Some dan	nage to home ceilings; 10% window breakage.
10		16	Windows	usually shattered; some frame damage.
	10		Partial	demolition of homes; made uninhabitable.
3	-	· 10		erious/slight injuries from flying glass/object.
	6		Partial	collapse of home walls/roofs.
5	-	6	Non-reir	nforced concrete/cinder block walls shattered.
2		- 5		)-1% eardrum rupture among exposed population.
	5			cruction of home brickwork.
4	-	-		ss steel panel buildings ruined.
	4			stility poles snapped.
3	-	• 4		complete destruction of houses.
	3			e total building destruction.
2	-	· 2		or 99-1% fatalities among exposed populations
			due to a	direct blast effects.

Note: The center of an unconfined gas/vapor explosion can be anywhere within the ground area passed over by the cloud or plume. See results of the vapor cloud fire hazard analysis for the maximum downwind distance and maximum width of this area. Explosion is assumed to take place on or near the ground.

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PHYSIOCHEMICAL PROPERTIES OF MATERI			
NORMAL BOILING POINT	= ·	-423	degrees F
MOLECULAR WEIGHT	=	2.0159	
VAPOR PRES AT CONTAINER TEMP	=	2000	psia
	=	103472	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2000.1	psia
	=	103472	mm Hg
SPECIFIC HEAT RATIO FOR GAS	=	1.4	
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%
LOWER HEAT OF COMBUSTION	=	191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
		40000	ppm
CONTAINER CHARACTERISTICS			
CONTAINER TYPE	=	Horizontal	cylinder
TOTAL WEIGHT OF CONTENTS	=	3.5	lbs
DISCHARGE HOLE DIAMETER	=	.65	inch(es)
DISCHARGE COEFFICIENT OF HOLE	=	.98	
TEMP OF CONTAINER CONTENTS	=	68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia
ENVIRONMENTAL/LOCATION CHARACTERIS	TIC	S	
AMBIENT TEMPERATURE	=	68	degrees F
WIND VELOCITY	=	9	mph
ATMOSPHERIC STABILITY CLASS	=	С	
VAPOR/GAS DISCHARGE HEIGHT	=	5	feet
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KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

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KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 10-1-93 NAME OF DISK FILE = B-3DETON.ASF

## \*\*\* SCENARIO DESCRIPTION

Three cylinders release 660 cubic feet of hydrogen through three holes, .375 inches in diameter each, under average met. conditions taking approximately 1 second.

\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	237.9	lbs/min
Duration of discharge	=	.015	minutes
Amount discharged	=	3.5	lbs
State of material	=	Gas	

# \*\*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

	ind distand				of	183000	ppm
 at	groundleve	el	=	56		fe	eet
 at	discharge	heigh	nt =	56		fe	eet

Peak concentration on ground is 261918.3 ppm at a downwind distance of 36 feet for elevated emission source specified by user.

See attached table(s) for further details.

## \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	457	feet
Safe separation distance	=	914	feet
Flame jet duration	=	.015	minutes

## \*\*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

For concentration of 1/2 LFL LFL Downwind hazard distance = 153 120 feet Max hazard zone width = 77 60 feet Max weight explosive gas = 3.6 3.6 lbs Relative gas/air density = 1.01 1.01 initially Model used in analysis = Neutrally buoyant Note: Clouds or plumes containing less than 1000 pounds of vapor or gas are very unlikely to explode when completely unconfined, except when one of a certain few materials have been discharged.

\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

	Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation Zone Width*
(feet)	(miles)	(mqq)	(ppm)	(feet)
32 34 36 38 39 41 43 44	.01 .01 .01 .01 .01 .01 .01 .01 .01	249191 257383 261499 262209 260163 255951 250090 243016	688610 609004 541249 483328 433609 390760 353683 321471	91 89 86 83 80 77 73 69
44 46 49 51 53 54 56	.01 .01 .01 .01 .01 .02 .02	235089 226604 217794 208842 199889 191044 183000	293371 268757 247104 227975 211005 195884 183000	69 64 59 53 47 38 28 1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

## TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind	Distance	Contaminant Arrival Time at Downwind Location	Contaminant Departure Time at Downwind Location
(feet)	(miles)	(minutes)	(minutes)
32 34 36 38 39 41 43 44 46 48 49 51	.01 .01 .01 .01 .01 .01 .01 .01 .01 .01	.1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1	.1 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2
53 54 56	.01 .02 .02	.1 .1 .1	.2 .2 .2

CAUTION: See guide for assumptions used in estimating these times.

			•
PHYSIOCHEMICAL PROPERTIES OF MATERI	IAL		
NORMAL BOILING POINT	=	-423	degrees F
MOLECULAR WEIGHT	=	2.0159	
VAPOR PRES AT CONTAINER TEMP	=	2000	psia
	=	103472	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2000.1	psia
	=	103472	mm Hg
SPECIFIC HEAT RATIO FOR GAS	=	1.4	
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%
LOWER HEAT OF COMBUSTION	=	191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	•
TOXIC VAPOR LIMIT	=	183000	ppm
· · · · · · · · · · · · · · · · · · ·			
CONTAINER CHARACTERISTICS			
CONTAINER TYPE	=	Horizontal c	ylinder
TOTAL WEIGHT OF CONTENTS	=	3.5	lbs
DISCHARGE HOLE DIAMETER	=	.65	inch(es)
DISCHARGE COEFFICIENT OF HOLE			
TEMP OF CONTAINER CONTENTS	=	68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia
			-
ENVIRONMENTAL/LOCATION CHARACTERIST	CIC:	5	
AMBIENT TEMPERATURE	=	68	degrees F
WIND VELOCITY	=	9	mph
ATMOSPHERIC STABILITY CLASS	=	С	-
VAPOR/GAS DISCHARGE HEIGHT	=	5	feet

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 10-1-93 NAME OF DISK FILE = B-4.ASF

\*\*\* SCENARIO DESCRIPTION

Three cylinders release 660 cubic feet of hydrogen through three holes, .375 inches in diameter each, under worst case met. conditions taking approximately 1 second.

\*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	237.9	lbs/min
Duration of discharge	=	.015	minutes
Amount discharged	=	3.5	lbs
State of material	=	Gas	

## \*\*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind distance to	concentration	of 40000 ppm
at groundlevel		feet
at discharge heigh	t = 354	feet

Peak concentration on ground is 259468.5 ppm at a downwind distance of 124 feet for elevated emission source specified by user.

See attached table(s) for further details.

\*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	457	feet
Safe separation distance	=	914	feet
Flame jet duration	=	.015	minutes

## \*\*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

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\*\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

.ownwind	Distance	Groundlevel Concentration	Source Height	Initial Evacuation	
(feet)	(miles)	(ppm)	Concentration (ppm)	Zone Width* (feet)	
100	.02	219615	1000000	73	
120	.03	258367	614295	87	
139	.03	250330	399347	110	
159	.03	222788	278350	120	
178	.04	190968	205213	130	
198	.04	161216	158053	150	
217	.05	135530	125829	160	
236	.05	114100	102699	180	
256	.05	96469	85419	190	
275	.06	82025	72098	200	
295	.06	70179	61574	220	
314		60427	53098	230	
333	.07	52357	46167	250	
353	.07	45639	40427	240	
372	.08	40000	35623	1	

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified 'y the user for this scenario was 5 feet.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

			******	
		Contaminant Arrival Time at Downwind Location		
(feet)		(minutes)		
100	.02	6	1.2	
120	.03	, <b>.</b> 7	1.4	
139	.03	.8	1.6	
159	.03	1	1.9	
178	.04	1.1	2.1	
198	.04	1.2	2.3	
217	.05	1.3	2.5	
236	.05	1.4	2.7	
256	.05	1.5	3	
275	.06	1.6	3.2	
295	.06	1.7 .	3.4	
314	.06	1.8 ,	3.6	
333	.07	1.9	3.8	
353	.07	2.1	4.1	
372	.08	2.2	4.3	

CAUTION: See guide for assumptions used in estimating these times.

# UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

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	E F (fee		EXPLOSION	EXPECTED DAMAGE
	173		Occasional brea	kage of large windows under stress.
10	25	30	Some damage to	home ceilings; 10% window breakage.
10	- 10	70	Windows usually	shattered; some frame damage.
3		10	Range serious/s	ion of homes; made uninhabitable. light injuries from flying glass/object.
•	6		Partial collaps	e of home walls/roofs.
5	-	6	Non-reinforced	concrete/cinder block walls shattered.
2	-	5	Range 90-1% ear	drum rupture among exposed population.
	5		50% destruction	of home brickwork.
4		5	Frameless steel	panel buildings ruined.
-	4		Wooden utility	poles snapped.
3		4	Nearly complete	destruction of houses.
-	3	_	Probable total	building destruction.
2	-	2	Range for 99-1% due to direct b	fatalities among exposed populations last effects.

Note: The center of an unconfined gas/vapor explosion can be anywhere within the ground area passed over by the cloud or plume. See results of the vapor cloud fire hazard analysis for the maximum downwind distance and maximum width of this area. Explosion is assumed to take place on or near the ground.

PHYSIOCHEMICAL PROPERTIES OF MATER	IAL			
NORMAL BOILING POINT	=	-423	degrees F	
MOLECULAR WEIGHT		2.0159	5	
VAPOR PRES AT CONTAINER TEMP	=	2000	psia	
	=	103472	mm Hg	
VAPOR PRES AT AMBIENT TEMP	=	2000.1	psia	
•	=	103472	mm Hg	
SPECIFIC HEAT RATIO FOR GAS		1.4	-	
LOWER FLAMMABLE LIMIT (LFL)		4	vol%	
LOWER HEAT OF COMBUSTION		191.7	Btu/lb	
GAS EXPLOSION YIELD FACTOR	=	.03		
TOXIC VAPOR LIMIT	=	40000	ppm	
CONTAINER CHARACTERISTICS				
CONTAINER TYPE	=	Horizontal cy		
TOTAL WEIGHT OF CONTENTS	=	3.5	lbs	
		.65	inch(es)	
DISCHARGE COEFFICIENT OF HOLE				
TEMP OF CONTAINER CONTENTS		68	degrees F	
TANK RUPTURE PRESSURE	=	2400	psia	
		a		
ENVIRONMENTAL/LOCATION CHARACTERIS	LTC			
AMBIENT TEMPERATURE	=	68	degrees F	
WIND VELOCITY	=	2	mph	
ATMOSPHERIC STABILITY CLASS	=	F 5	<b>-</b> .	
VAPOR/GAS DISCHARGE HEIGHT	=	5	feet	
עבע סבפות שם ספרמוזהם שע גונבים דאנמשפי	. תא			

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 10-1-93 NAME OF DISK FILE = B-4DETON.ASF

\*\*\* SCENARIO DESCRIPTION

Three cylinders release 660 cubic feet of hydrogen through three holes, .375 inches in diameter each, under worst case met. conditions taking approximately 1 second.

\*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	237.9	lbs/min
Duration of discharge	=	.015	minutes
Amount discharged	=	3.5	lbs
State of material	=	Gas	

## \*\*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind distance	to concentration	of	183000 ppm
at groundlevel	= 183		feet
at discharge he	ight = 186		feet

Peak concentration on ground is 259367 ppm at a downwind distance of 126 feet for elevated emission source specified by user.

See attached table(s) for further details.

## \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	457	feet
Safe separation distance	=	914	feet
Flame jet duration	=	.015	minutes

## \*\*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of		/2 LFL	LFL	
	Downwind hazard distance	=	510	397	feet
	Max hazard zone width	=	255	199	feet
	Max weight explosive gas			3.6	
	Relative gas/air density	=	1.01	1.01	initially
	Model used in analysis	ly buoy	ant		
Note:	Clouds or plumes contain:	ing	less th	an 1000	pounds
	of monow of mon own more				

of vapor or gas are very unlikely to explode when completely unconfined, except when one of a certain few materials have been discharged.

\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

		~~~~~~~~~~~		
_ownwind	Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation
(feet)	(miles)	(ppm)	(ppm)	Zone Width* (feet)
100	.02	219615	1000000	73
107	.03	238803	865893	78
113	.03	251227	735026	82
119	.03	257772	629832	87
125	.03	259489	544393	91
131	.03	257413	474355	96
137	.03	252478	416458	100
143	.03	245473	368225	110
150	.03	237043	327747	110
156	.03	227696	293536	120
162	.04	217829	264425	120
168	.04	207737	239486	130
174	.04	197643	217984	130
180	.04	187706	199325	95
186	.04	178038	183000	1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance		Contaminant Arrival Time	Contaminant Departure Time		
		at Downwind Location (minutes)	at Downwind Location (minutes)		
100 107 113 119 125 131 137 143 150	. 02 . 03 . 03 . 03 . 03 . 03 . 03 . 03 . 03	.6 .7 .7 .7 .8 .8 .8 .8 .8 .9 .9	1.2 1.3 1.3 1.4 1.5 1.6 1.6 1.7 1.8		
156 162 168 174 180 186	.03 .04 .04 .04 .04 .04 .04	.9 1 . 1 . 1.1 1.1	1.8 1.9 2 2.1 2.2		

CAUTION: See guide for assumptions used in estimating these times.

PHYSIOCHEMICAL PROPERTIES OF MATERIAL						
NORMAL BOILING POINT	=	-423	degrees F			
MOLECULAR WEIGHT	=	2.0159	•			
VAPOR PRES AT CONTAINER TEMP	=	2000	psia			
	=	103472	mm Hg			
VAPOR PRES AT AMBIENT TEMP	=	2000.1	psia			
		103472	mm Hg			
SPECIFIC HEAT RATIO FOR GAS		1.4				
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%			
LOWER HEAT OF COMBUSTION	=	191.7	Btu/lb			
GAS EXPLOSION YIELD FACTOR	=	.03				
TOXIC VAPOR LIMIT	=	183000	ppm			
CONTAINER CHARACTERISTICS						
CONTAINER TYPE	=	Horizontal cy	vlinder			
TOTAL WEIGHT OF CONTENTS		3.5	lbs			
DISCHARGE HOLE DIAMETER		.65	inch(es)			
DISCHARGE COEFFICIENT OF HOLE						
		68	degrees F			
TANK RUPTURE PRESSURE	=	2400	psia			
			-			
ENVIRONMENTAL/LOCATION CHARACTERISTICS						
AMBIENT TEMPERATURE	==	68	degrees F			
	=		mph			
ATMOSPHERIC STABILITY CLASS						
VAPOR/GAS DISCHARGE HEIGHT	=	5	feet			

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 10-1-93 NAME OF DISK FILE = B-5.ASF

\*\*\* SCENARIO DESCRIPTION

12 cylinders release 2,640 cubic feet of hydrogen through a common manifold, 0.75 inches in diameter, under average met. conditions taking approximately 3 seconds.

\*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	316.7	lbs/min
Duration of discharge	=	.044	minutes
Amount discharged	=	13.8	lbs
State of material	=	Gas	

## \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Dov	mwż	nd	distand	e to	conc	ent	ration	oí	40000	ppm
	at	gro	oundleve	el		=	184		t	feet
	at	dis	scharge	heigh	ıt	=	180		t	feet

Peak concentration on ground is 458863.6 ppm at a downwind distance of 42 feet for elevated emission source specified by user.

See attached table(s) for further details.

### \*\*\*\*\*\* FLAME JET HAZARD RESULTS

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Flame jet length	=	527	feet
Safe separation distance	=	1054	feet
Flame jet duration	=	.044	minutes

\*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1/2 LFL	LFL	
	Downwind hazard distance	= 243	188	feet
	Max hazard zone width	= 122	94	feet
	Max weight explosive gas			
	Relative gas/air density			
	Model used in analysis	= Neutral	ly buoy	ant
Note:	Clouds or plumes contain	ing less th	an 1000	pounds
	of vapor or gas are very	unlikely t	o explo	de when
	completely unconfined,			
	tain few materials have 1	been discha	rged.	
			-	

\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

Downwind	l Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation Zone Width*
(feet)	(miles)	(ppm)	(mqq)	(feet)
100 106 112 118 124 130 136 142 148	.02 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03	165216 146576 130389 116323 104083 93409 84079 75902 68715	146156 130390 116679 104716 94246 85056 76969 69831 63515	310 300 300 290 280 260 250 240 220
154 160 166 172 178 184	.03 .04 .04 .04 .04 .04	62381 56781 51817 47403 43469 40000	57912 52928 48484 44510 40949 37750	210 190 160 140 93 1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

#### TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind		Contaminant Arrival Time at Downwind Location	
(feet)	(miles)		(minutes)
100 106 112 118 124 130 136 142 148 154	.02 .03 .03 .03 .03 .03 .03 .03 .03 .03 .03	.2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2	.3 .4 .4 .4 .4 .4 .4 .5 .5
154 160 166 172 178 184	.03 .04 .04 .04 .04 .04	.2 .3 .3 .3 .3 .3 .3	.5 .5 .5 .5 .5 .6

CAUTION: See guide for assumptions used in estimating these times.

#### UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

ISTAN	ICE F		EXPLOSION EXPECTED DAMAGE	
	272 39		Occasional breakage of large windows Some damage to home ceilings; 10% win	dow breakage.
15	- 15	25	Windows usually shattered; some frame Partial demolition of homes; made uni	
4	- 9	15	Range serious/slight injuries from fl Partial collapse of home walls/roofs.	
7	-	9	Non-reinforced concrete/cinder block	
3	- 8	8	Range 90-1% eardrum rupture among exp 50% destruction of home brickwork.	osed population.
6	- 5	7	Frameless steel panel buildings ruine Wooden utility poles snapped.	ed.
4	- 4	5	Nearly complete destruction of houses Probable total building destruction.	5.
2		3	Range for 99-1% fatalities among expo due to direct blast effects.	osed populations

Note: The center of an unconfined gas/vapor explosion can be anywhere within the ground area passed over by the cloud or plume. See results of the vapor cloud fire hazard analysis for the maximum downwind distance and maximum width of this area. Explosion is assumed to take place on or near the ground.

			•
PHYSIOCHEMICAL PROPERTIES OF MATER			
NORMAL BOILING POINT	=	-423	degrees F
		2.0159	-
VAPOR PRES AT CONTAINER TEMP			psia
	=	103472	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2000.1	psia
	=	103472	mm Hg
SPECIFIC HEAT RATIO FOR GAS	=	1.4	-
			vol%
LOWER FLAMMABLE LIMIT (LFL) LOWER HEAT OF COMBUSTION	=	191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
TOXIC VAPOR LIMIT			ppm
CONTAINER CHARACTERISTICS			
		Horizontal o	-
TOTAL WEIGHT OF CONTENTS			lbs
DISCHARGE HOLE DIAMETER			inch(es)
DISCHARGE COEFFICIENT OF HOLE			• _
TEMP OF CONTAINER CONTENTS			degrees F
TANK RUPTURE PRESSURE	=	2400	psia
ENVIRONMENTAL/LOCATION CHARACTERIS	TIC	S	
AMBIENT TEMPERATURE	=		degrees F
	=		mph
ATMOSPHERIC STABILITY CLASS			
VAPOR/GAS DISCHARGE HEIGHT	_	5	feet
VALONY GAD DIDCHARGE MEIGHT	-	2	LOCU

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 10-1-93 NAME OF DISK FILE = B-5DETON.ASF

\*\*\* SCENARIO DESCRIPTION

12 cylinders release 2,640 cubic feet of hydrogen through a common manifold, 0.75 inches in diameter, under average met. conditions taking approximately 3 seconds.

\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	316.7	lbs/min
Duration of discharge	=	.044	minutes
Amount discharged	=	13.8	lbs
State of material	=	Gas	

## \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Dov	vnwi	ind distance	τo	concentra	tion	oí	183000	mqq
		groundlevel					fe	eet
	at	discharge h	eigì	t = 89	•		fe	eet

Peak concentration on ground is 458959.7 ppm at a downwind distance of 42 feet for elevated emission source specified by user.

See attached table(s) for further details.

### \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	527	feet
Safe separation distance	=	1054	feet
Flame jet duration	=	.044	minutes

\*\*\*\*\*\* FLAMMABLE VAPOR CLCUD HAZARD RESULTS

	For concentration of	1/2 LFL	LFL	
	Downwind hazard distance	= 243	188	feet
	Max hazard zone width	= 122	94	feet
	Max weight explosive gas		14	
	Relative gas/air density	= 1.01	1.01	initially
	Model used in analysis	= Neutral	ly buoy	ant
Note:	Clouds or plumes contain:			
	of vapor or gas are very	unlikely t	o explo	de when
	completely unconfined, e	except wher	n one of	a cer-
	tain few materials have h	been discha	arged.	

\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

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Downwind	Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation Zone Width*
(feet)	(miles)	(ppm)	(ppm)	(feet)
32 37 42 46 51	.01 .01 .01 .01 .01 .01	391832 441930 458606 453192 434538	1000000 843180 679515 563636 478712	120 130 150 160 170
55 60 6 <u>4</u> 69 73 78	.02 .02 .02 .02 .02 .02 .02	408682 379526 349510 320108 292171 266139	414260 363645 322639 288527 259543 234516	160 150 140 130 120
82 87 91 96	.02 .02 .02 .02	242199 220376 200599 183000	212646 193368 176265 161021	98 81 58 1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

#### TOXIC VAPOR DISPERSION ANALYSIS RESULTS

	Distance	Contaminant Arrival Time at Downwind Location	Contaminant Departure Time at Downwind Location
(feet)	(miles)	(minutes)	(minutes)
32 37 42 46 51 55 60 64 69 73 78 82 87	.01 .01 .01 .01 .02 .02 .02 .02 .02 .02 .02 .02 .02 .02	.1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .2 .2	.2 .2 .2 .2 .2 .2 .2 .2 .3 .3 .3 .3 .3 .3 .3 .3 .3 .3 .3 .3 .3
91 96	.02 .02	.2 .2	.3 .3

CAUTION: See guide for assumptions used in estimating these times.

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PHYSIOCHEMICAL PROPERTIES OF MATER	IAL		
NORMAL BOILING POINT	=	-423	degrees F
MOLECULAR WEIGHT	=	2.0159	
VAPOR PRES AT CONTAINER TEMP		2000	psia
	=	103472	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2000.1	psia
	=	103472	mm Hg
SPECIFIC HEAT RATIO FOR GAS		1.4	2
LOWER FLAMMABLE LIMIT (LFL)			vol%
LOWER HEAT OF COMBUSTION			Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
TOXIC VAPOR LIMIT	=	183000	ppm
CONTAINER CHARACTERISTICS			
CONTAINER TYPE		Horizontal	
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS	=	13.8	cylinder ĺbs
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER	=	13.8 .75	
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE		13.8 .75 .98	ĺbs
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS	н п п п	13.8 .75 .98 68	ĺbs
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS	н п п п	13.8 .75 .98	lbs inch(es)
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE		13.8 .75 .98 68 2400	lbs inch(es) degrees F
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS		13.8 .75 .98 68 2400 S	lbs inch(es) degrees F psia
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS' AMBIENT TEMPERATURE		13.8 .75 .98 68 2400 S 68	lbs inch(es) degrees F psia degrees F
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIST AMBIENT TEMPERATURE WIND VELOCITY	= = = TIC. = =	13.8 .75 .98 68 2400 S 68 9	lbs inch(es) degrees F psia
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIS AMBIENT TEMPERATURE WIND VELOCITY ATMOSPHERIC STABILITY CLASS	= = = = TIC. = =	13.8 .75 .98 68 2400 S 68 9 C	lbs inch(es) degrees F psia degrees F mph
CONTAINER TYPE TOTAL WEIGHT OF CONTENTS DISCHARGE HOLE DIAMETER DISCHARGE COEFFICIENT OF HOLE TEMP OF CONTAINER CONTENTS TANK RUPTURE PRESSURE ENVIRONMENTAL/LOCATION CHARACTERIST AMBIENT TEMPERATURE WIND VELOCITY	= = = = TIC. = =	13.8 .75 .98 68 2400 S 68 9	lbs inch(es) degrees F psia degrees F

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 10-1-93 NAME OF DISK FILE = B-6.ASF

\*\*\* SCENARIO DESCRIPTION

12 cylinders release 2,640 cubic feet of hydrogen through a common manifold, 0.75 inches in diameter, under worst case met. conditions taking approximately 3 seconds.

\*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	316.7	lbs/min
Duration of discharge	=	.044	minutes
Amount discharged	=	13.8	lbs
State of material	=	Gas	

# \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Dov	vnwi	ind distance	τo	concentration	of	40000 ppm
		groundlevel				feet
	at	discharge he	igh	t = 619		feet

Peak concentration on ground is 936792.7 ppm at a downwind distance of 129 feet for elevated emission source specified by user.

See attached table(s) for further details.

\*\*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	527	feet
Safe separation distance	=	1054	feet
Flame jet duration	=	.044	minutes

\*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1,	/2 LFL	LFL	
		-			
	Downwind hazard distance	=	842	651	feet
	Max hazard zone width	=	421	326	feet
	Max weight explosive gas	=	14	14	lbs
	Relative gas/air density	=	1.01	1.01	initially
	Model used in analysis	=	Neutral	ly buoy	ant
Note:	Clouds or plumes contain:	ing	less th	an 1000	pounds
	of vapor or gas are very	un	likely t	o explo	de when
	completely unconfined, a	exc	ept when	one of	a cer-
	tain few materials have ]	bee	n discha	rged.	
				5	

\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

ownwind	l Distance	Groundlevel Concentration	Source Height Concentration	<ul> <li>Initial Evacuation Zone Width*</li> </ul>
(feet)	(miles)	(ppm)	(mqq)	(feet)
100	.02	761887 918469	1000000 1000000	73 110
139 177	.03 .04	724070	784904	130
215	.05	524185	488931	160
253	.05	377923	335213	190
291	.06	277344	243345	220
329	.07	208209	183431	240
367	.07	159858	142131	270
405	.08	125290	112554	300
443	.09	100021	90755	330
481	.1	81159	74315	360
520	.1	66808	61672	380
558	.11	55701	51785	410
596	.12	46968	43940	440
634	.12	40000	37633	1

Usually safe for < 1 hour release. Longer releases or sudden wind shifts ay require a larger width or different direction for the evacuation zone. ee Chapters 3 and 12 of the guide for details. Source height specified v the user for this scenario was 5 feet.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

		Contaminant Arrival Time at Downwind Location	Contaminant Departure Time at Downwind Location					
	(miles)	(minutes)	(minutes)					
100 139 177 215 253 291 329 367 405 443 481 520 558 596	.02 .03 .04 .05 .05 .06 .07 .07 .07 .07 .07 .08 .09 .1 .1 .11 .11 .12	6 .8 1.1 1.3 1.5 1.7 1.9 2.1 2.4 2.6 2.8 3 3.2 3.4	1.2 1.7 2.1 2.5 3 3.4 3.8 4.3 4.7 5.1 5.6 6 6 6.4 6.9					
634	.12	3.7	7.3					

CAUTION: See guide for assumptions used in estimating these times.

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### UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

	E FI feet		EXPLOSION	EXPECTED DAMAGE
	272		Occasional bre	akage of large windows under stress.
	39		Some damage to	home ceilings; 10% window breakage.
15	-	25	Windows usuall	y shattered; some frame damage.
	15		Partial demoli	tion of homes; made uninhabitable.
4	-	15	Range serious/	slight injuries from flying glass/object.
	9		Partial collar	se of home walls/roofs.
7	-	9		concrete/cinder block walls shattered.
3	-	8	Range 90-1% ea	rdrum rupture among exposed population.
	8		50% destruction	n of home brickwork.
6	-	7	Frameless stee	l panel buildings ruined.
	5		Wooden utility	poles snapped.
4	-	5	Nearly complet	e destruction of houses.
	4			building destruction.
2	-	3	Range for 99-1 due to direct	% fatalities among exposed populations blast effects.

Note: The center of an unconfined gas/vapor explosion can be anywhere within the ground area passed over by the cloud or plume. See results of the vapor cloud fire hazard analysis for the maximum downwind distance and maximum width of this area. Explosion is assumed to take place on or near the ground.

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PHYSIOCHEMICAL PROPERTIES OF MATER	 ТДТ.		
NORMAL BOILING POINT		-423	degrees F
MOLECULAR WEIGHT	=		
VAPOR PRES AT CONTAINER TEMP	=		psia
	=		mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2000.1	psia
	=	103472	mm Hg
SPECIFIC HEAT RATIO FOR GAS	=	1.4	-
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%
LOWER HEAT OF COMBUSTION	=	191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
TOXIC VAPOR LIMIT	=	40000	ppm
CONTAINER CHARACTERISTICS			<b>.</b>
CONTAINER TYPE	=		
TOTAL WEIGHT OF CONTENTS	=		lbs
DISCHARGE HOLE DIAMETER		.75	inch(es)
DISCHARGE COEFFICIENT OF HOLE		.98	
TEMP OF CONTAINER CONTENTS	=		degrees F
TANK RUPTURE PRESSURE	=	2400	psia
		io.	
ENVIRONMENTAL/LOCATION CHARACTERIS AMBIENT TEMPERATURE		.5 68	degrees F
WIND VELOCITY	=	-	mph
ATMOSPHERIC STABILITY CLASS			urbju
VAPOR/GAS DISCHARGE HEIGHT			feet
VAPOR/GAD DISCHARCE HEICHI	-	2	2000
KEY RESULTS PROVIDED BY USER INSTE	AD	OF BY EVALUA	FION METHODS

NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 10-1-93 NAME OF DISK FILE = B-6DETON.ASF

\*\*\* SCENARIO DESCRIPTION

12 cylinders release 2,640 cubic feet of hydrogen through a common manifold, 0.75 inches in diameter, under worst case met. conditions taking approximately 3 seconds.

### \*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	316.7	lbs/min
Duration of discharge	=	.044	minutes
Amount discharged	=	13.8	lbs
State of material	=	Gas	

#### \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind dista	nce to	concent	ration	of	183000	ppm
at groundle	vel	=	347		fe	eet
at discharg	e heigh	nt =	329		fe	eet

Peak concentration on ground is 937173.6 ppm at a downwind distance of 127 feet for elevated emission source specified by user.

See attached table(s) for further details.

#### \*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	527	feet
Safe separation distance	=	1054	feet
Flame jet duration	=	.044	minutes

### \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1/2 LFL	LFL	
Note:	Downwind hazard distance Max hazard zone width Max weight explosive gas Relative gas/air density Model used in analysis Clouds or plumes contain of vapor or gas are very completely unconfined, tain few materials have	= 421 = 14 = 1.01 = Neutral ing less th unlikely t except when	14 1.01 ly buoya an 1000 o explo- one of	lbs initially ant pounds de when

\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

_ownwind	Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation Zone Width*
(feet)	(miles)	(mgg)	(mdd)	(feet)
100	.02	761887	1000000	73
118	.03	919921	1000000	86
136	.03	926391	1000000	99
153	.03	855459	1000000	120
171	.04	757136	852859	130
189	.04	656681	667714	140
206	.04	564704	538312	150
224	.05	484548	443970	170
241	.05	416321	372675	180
259	.05	358866	317190	190
277	.06	310664	272980	210
294	.06	270219	237086	220
312	.06	236204	207502	230
330	.07	207491	182816	220
347	.07	183000	162007	1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified 'y the user for this scenario was 5 feet.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

	Distance	Contaminant Arrival Time at Downwind Location	
(feet)	(miles)		(minutes)
100 118 136 153 171 189 206 224 241 259	.02 .03 .03 .04 .04 .04 .04 .04 .05 .05 .05	.6 .7 .8 .9 1 1.1 1.2 1.3 1.4 1.5	1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3
277 294 312 330 347	.06 .06 .06 .07 .07	1.6 1.7 1.8 1.9 2	3.2 3.4 3.6 3.8 4

CAUTION: See guide for assumptions used in estimating these times.

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PHYSIOCHEMICAL PROPERTIES OF MATERI	IAL		
NORMAL BOILING POINT	= •	-423	degrees F
MOLECULAR WEIGHT	=	2.0159	
VAPOR PRES AT CONTAINER TEMP	=	2000	psia
	=	103472	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2000.1	psia
	=	103472	mm Hg
SPECIFIC HEAT RATIO FOR GAS	=	1.4	
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%
LOWER HEAT OF COMBUSTION	=	191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR		.03	
TOXIC VAPOR LIMIT	=	183000	ppm
CONTAINER CHARACTERISTICS		The sector sector and the sector s	
CONTAINER TYPE		Horizontal c	-
TOTAL WEIGHT OF CONTENTS		13.8	lbs
DISCHARGE HOLE DIAMETER		.75	inch(es)
DISCHARGE COEFFICIENT OF HOLE			
TEMP OF CONTAINER CONTENTS	=	68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia
ENVIRONMENTAL/LOCATION CHARACTERIS	ͲŦĊ	q	
AMBIENT TEMPERATURE	=	68	degrees F
WIND VELOCITY	=	2	mph
ATMOSPHERIC STABILITY CLASS		F	
VAPOR/GAS DISCHARGE HEIGHT	=	5	feet
VAPOR/GAS DISCHARGE HEIGHI	-	5	

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 10-1-93 NAME OF DISK FILE = B-7.ASF

\*\*\* SCENARIO DESCRIPTION

18 cylinders release 3,960 cubic feet of hydrogen through two manifolds, 0.75 inches in diameter each, under average met. conditions taking approximately 3 seconds.

\*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	476.6	lbs/min
Duration of discharge	=	.044	minutes
Amount discharged	=	20.7	lbs
State of material	=	Gas	

# \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Dov	vnwi	ind	distand	ce to	cond	cent	ration	of	40000	ppm
	at	gro	oundleve	el		=	215		ţ	feet
	at	dis	scharge	heig	ht	=	212		1	Eeet

Peak concentration on ground is 690687.7 ppm at a downwind distance of 42 feet for elevated emission source specified by user.

See attached table(s) for further details.

\*\*\*\*\*\* FLAME JET HAZARD RESULTS

······································		647	feet
Safe separation distance	=	1293	feet
Flame jet duration	=	.044	minutes

### \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1	/2 LFL	LFL		
	Downwind hazard distance	=	282	219	feet	
	Max hazard zone width	=	141	110	feet	
	Max weight explosive gas	=	21	21	lbs	
	Relative gas/air density	=	1.01	1.01	initially	
	Model used in analysis					
Note:	Clouds or plumes contain:					
	of vapor or gas are very					
	completely unconfined,					

tain few materials have been discharged.

\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

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Downwind	l Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation
(feet)	(miles)	(ppm)	(ppm)	Zone Width* (feet)
100 109 117 125 133 141 150 158 166 174 182	.02 .03 .03 .03 .03 .03 .03 .03 .04 .04 .04 .04	248633 211090 180151 154603 133426 115791 101028 88603 78089 69143 61492	219949 188190 161930 140087 121818 106460 93483 82464 73061 65000 58057	350 380 370 350 340 330 310 300 280 260 230
191 199 207 215	.04 .04 .04 .05	54916 49235 44306 40000	52051 46832 42278 38290	200 170 120 1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

### TOXIC VAPOR DISPERSION ANALYSIS RESULTS

		Contaminant Arrival Time at Downwind Location	
(feet)	(miles)	(minutes)	(minutes)
100 109 117 125 133 141 150 158	.02 .03 .03 .03 .03 .03 .03 .03 .03 .03	.2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2	.3 .4 .4 .4 .4 .4 .5 .5 .5 .5
166 174 182 191 199 207 215	.04 .04 .04 .04 .04 .04 .04 .05	.3 .3 .3 .3 .3 .3 .3 .3	.5 .5 .6 .6 .6 .6 .6

CAUTION: See guide for assumptions used in estimating these times.

			UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS
ISTAN	NCE Fi (fee		EXPLOSION EXPECTED DAMAGE
	312 44		Occasional breakage of large windows under stress. Some damage to home ceilings; 10% window breakage.
17	- 17	29	Windows usually shattered; some frame damage. Partial demolition of homes; made uninhabitable.
5	- 10	17	Range serious/slight injuries from flying glass/object. Partial collapse of home walls/roofs.
8	-	10	Non-reinforced concrete/cinder block walls shattered.
4	- 9	9	Range 90-1% eardrum rupture among exposed population. 50% destruction of home brickwork.

Frameless steel panel buildings ruined.

Nearly complete destruction of houses.

Range for 99-1% fatalities among exposed populations

Probable total building destruction.

Note: The center of an unconfined gas/vapor explosion can be anywhere

within the ground area passed over by the cloud or plume. See results of the vapor cloud fire hazard analysis for the maximum downwind distance and maximum width of this area. Explosion is

Wooden utility poles snapped.

due to direct blast effects.

assumed to take place on or near the ground.

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PHYSIOCHEMICAL PROPERTIES OF MATERI	AL		
NORMAL BOILING POINT	= •	-423	degrees F
MOLECULAR WEIGHT	=	2.0159	
VAPOR PRES AT CONTAINER TEMP	=	2000	psia
	=	103472	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2000.1	psia
	=	103472	mm Hg
SPECIFIC HEAT RATIO FOR GAS	=	1.4	
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%
LOWER HEAT OF COMBUSTION	=	191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
TOXIC VAPOR LIMIT	=	40000	ppm
CONTAINER CHARACTERISTICS			
CONTAINER TYPE		Horizontal	
TOTAL WEIGHT OF CONTENTS		20.7	lbs
DISCHARGE HOLE DIAMETER		.92	inch(es)
DISCHARGE COEFFICIENT OF HOLE	=		
TEMP OF CONTAINER CONTENTS	=	68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia
	•	_	
ENVIRONMENTAL/LOCATION CHARACTERIS		S	Jamma a F
AMBIENT TEMPERATURE	=	68	degrees F
WIND VELOCITY	=	9	mph
ATMOSPHERIC STABILITY CLASS		C	foor
VAPOR/GAS DISCHARGE HEIGHT	=	5	feet

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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. 、 HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 10-1-93 NAME OF DISK FILE = B-7DETON.ASF

\*\*\* SCENARIO DESCRIPTION

18 cylinders release 3,960 cubic feet of hydrogen through two manifolds, 0.75 inches in diameter each, under average met. conditions taking approximately 3 seconds.

\*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	476.6	lbs/min
Duration of discharge	=	.044	minutes
Amount discharged	=	20.7	lbs
State of material	=	Gas	

## \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Dov	vnwi	nd	distand	e to	con	cent	ration		
	at	gro	oundleve	<b>2</b> 1		=	116	fe	eet
	at	dis	scharge	heigh	nt	=	110	fe	eet

Peak concentration on ground is 690610.5 ppm at a downwind distance of 43 feet for elevated emission source specified by user.

See attached table(s) for further details.

#### \*\*\*\*\*\* FLAME JET HAZARD RESULTS

No

Flame jet length	=	647	feet
Safe separation distance	=	1293	feet
Flame jet duration			minutes

#### \*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1/2 LFL		LFL	
	Downwind hazard distance		 282	219	feet
	Max hazard zone width			110	
	Max weight explosive gas			21	
	Relative gas/air density				
	Model used in analysis	. <b>≓</b>	Neutral	Ly buoya	nt
ote:	Clouds or plumes contain: of vapor or gas are very completely unconfined,	unl	likely to	o exploa	le when
	tain few materials have 1				

\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

	Distance	Groundlevel Concentration	Source Height Concentration	Zone Width*
(feet)	(miles)	(ppm)	(ppm)	(feet)
100	.02	248633	219949	120
102	.02	243135	215297	120
103	.02	237778	210766	110
104	.02	232560	206353	110
105	.02	227477	202054	99
106	.02	222524	197866	94
107	.03	217700	193784	89
108	.03	213000	189807	84
109	.03	208421	185930	78
110	.03	203960	182151	71
112	.03	199614	178467	64
113	.03	195380	174875	55
114	.03	191254	171373	45
115	.03	187235	167957 .	32
116	.03	183000	164626	1

\*Usually safe for < 1 hour release. Longer releases or sudden wind shifts may require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

## TOXIC VAPOR DISPERSION ANALYSIS RESULTS

	Distance	Contaminant Arrival Time at Downwind Location	
		(minutes)	(minutes)
100 102 103 104 105 106 107 108 109 110 112	.02 .02 .02 .02 .02 .02 .02 .03 .03 .03 .03 .03 .03	.2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2	.3 .4 .4 .4 .4 .4 .4 .4 .4 .4 .4 .4 .4
113 114 115 116	.03 .03 .03 .03	.2 .2 .2 .2	. 4 . 4 . 4 . 4 . 4

CAUTION: See guide for assumptions used in estimating these times.

PHYSIOCHEMICAL PROPERTIES OF MATER:	IAL
NORMAL BOILING POINT	= -423 degrees F
MOLECULAR WEIGHT	= 2.0159
VAPOR PRES AT CONTAINER TEMP	
	= 103472 mm Hg
VAPOR PRES AT AMBIENT TEMP	= 2000.1 psia
	= 103472 mm Hg
SPECIFIC HEAT RATIO FOR GAS	= 1.4
LOWER FLAMMABLE LIMIT (LFL)	= 4 vol%
LOWER HEAT OF COMBUSTION	= 191.7 Btu/lb
GAS EXPLOSION YIELD FACTOR	= .03
TOXIC VAPOR LIMIT	= 183000 ppm
CONTAINER CHARACTERISTICS	
CONTAINER TYPE	= Horizontal cylinder
TOTAL WEIGHT OF CONTENTS	= 20.7 lbs
DISCHARGE HOLE DIAMETER	= .92 inch(es)
DISCHARGE COEFFICIENT OF HOLE	
TEMP OF CONTAINER CONTENTS	= 68 degrees F
TANK RUPTURE PRESSURE	= 2400 psia
ENVIRONMENTAL/LOCATION CHARACTERIS	TICS
AMBIENT TEMPERATURE	= 68 degrees F
WIND VELOCITY	= 9 mph
ATMOSPHERIC STABILITY CLASS	
VAPOR/GAS DISCHARGE HEIGHT	= 5 feet

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 10-1-93 NAME OF DISK FILE = B-8.ASF

\*\*\* SCENARIO DESCRIPTION

18 cylinders release 3,960 cubic feet of hydrogen through two manifolds, 0.75 inches in diameter each, under worst case met. conditions taking approximately 3 seconds.

\*\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	476.6	lbs/min
Duration of discharge	=	.044	minutes
Amount discharged	=	20.7	lbs
State of material	=	Gas	

## \*\*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind distance to	o concent	tration	of	40000	ppm
at groundlevel	=	742		t	feet
at discharge heig	ght =	728		1	feet

Peak concentration on ground is 1000000 ppm at a downwind distance of 130 feet for elevated emission source specified by user.

See attached table(s) for further details.

\*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	647	feet
Safe separation distance	=	1293	feet
Flame jet duration	=	.044	minutes

\*\*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1,	2 LFL	LFL	
					_
	Downwind hazard distance			757	feet
	Max hazard zone width	=	491	379	feet
	Max weight explosive gas			21	
	Relative gas/air density	⇒	1.01	1.01	initially
	Model used in analysis	÷	Neutral	ly buoya	ant
Note:	Clouds or plumes contain:	ing	less that	an 1000	pounds
	of vapor or gas are very	un	likely to	o exploa	le when
	completely unconfined, a	exce	ept when	one of	a cer-
	tain few materials have !	beer	n discha:	rged.	

\*\*\*\*\*\*\* EXPLOSION HAZARDS: See attached table(s)

wnwind	l Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation Zone Width*
(feet)	(miles)	(ppm)	(ppm)	(feet)
100	.02	1000000	1000000	73
146	.03	1000000	1000000	110
192	.04	959325	960524	140
238	.05	645750	580178	180
284	.06	441940	. 387938	210
330	.07	312294	275155	240
375	.0 <u>.8</u>	227941	203109	280
421	.08	171286	154530	310
467	.09	132011	120475	340
513	.1	103987	95860	380
559	.11	83468	77614	410
604	.12	68101	63794	440
650	.13	56361	53130	480
696	.14	47231	44765	510
742	.15	40000	38107	` <b>1</b>

'Usually safe for < 1 hour release. Longer releases or sudden wind shifts way require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified by the user for this scenario was 5 feet.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

		Contaminant Arrival Time at Downwind Location	Contaminant Departure Time
			(minutes)
100 146 192 238 284 330 375 421 467 513 559 604 650 696	.02 .03 .04 .05 .06 .07 .08 .08 .08 .09 .1 .11 .11 .12 .13 .14	.6 .9 1.1 1.4 1.7 1.9 2.2 2.4 2.7 3 3.2 .7 3.5 .3.5 3.7 4	1.2 1.8 2.3 2.8 3.3 3.8 4.4 4.9 5.4 5.9 6.4 7 7.5 8
742	.15	4.3	8.5

CAUTION: See guide for assumptions used in estimating these times.

.

#### UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

DISTAN	CE FI (fee		EXPLOSION EXPECTED DAMAGE
	312		Occasional breakage of large windows under stress.
	44		Some damage to home ceilings; 10% window breakage.
17	-	29	Windows usually shattered; some frame damage.
	17		Partial demolition of homes; made uninhabitable.
5	-	17	
	10		Partial collapse of home walls/roofs.
8	-	10	Non-reinforced concrete/cinder block walls shattered.
4	-	9	Range 90-1% eardrum rupture among exposed population.
	9		50% destruction of home brickwork.
7	-	8	Frameless steel panel buildings ruined.
	6		Wooden utility poles snapped.
5		6	Nearly complete destruction of houses.
2	4	-	Probable total building destruction.
3		4	Range for 99-1% fatalities among exposed populations due to direct blast effects.

Note: The center of an unconfined gas/vapor explosion can be anywhere within the ground area passed over by the cloud or plume. See results of the vapor cloud fire hazard analysis for the maximum downwind distance and maximum width of this area. Explosion is assumed to take place on or near the ground.

|--|

PHYSIOCHEMICAL PROPERTIES OF MATER	IAL		
NORMAL BOILING POINT	=	-423	degrees F
MOLECULAR WEIGHT		2.0159	_
VAPOR PRES AT CONTAINER TEMP	=	2000	psia
	=	103472	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2000.1	psia
	=	103472	mm Hg
SPECIFIC HEAT RATIO FOR GAS		1.4	-
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%
LOWER HEAT OF COMBUSTION			Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
TOXIC VAPOR LIMIT	=	40000	ppm
CONTAINER CHARACTERISTICS			
CONTAINER TYPE		Horizontal c	ylinder
TOTAL WEIGHT OF CONTENTS		20.7	lbs
DISCHARGE HOLE DIAMETER		.92	inch(es)
DISCHARGE COEFFICIENT OF HOLE	=	.98	
TEMP OF CONTAINER CONTENTS		68	degrees F
TANK RUPTURE PRESSURE		2400	psia
	=	2400	Pota
			pora
ENVIRONMENTAL/LOCATION CHARACTERIS			Pora
AMBIENT TEMPERATURE		S	degrees F
AMBIENT TEMPERATURE WIND VELOCITY	FIC = =	S 68 2	-
AMBIENT TEMPERATURE WIND VELOCITY ATMOSPHERIC STABILITY CLASS	FIC = = =	S 68 2 F	degrees F mph
AMBIENT TEMPERATURE WIND VELOCITY	FIC = = =	S 68 2 F	degrees F

- KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED
- KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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سكالمستحد سيستحد المرار المراجع

HAZARDOUS MATERIAL = Hydrogen ADDRESS \ LOCATION = PDL DATE OF ASSESSMENT = 10-1-93 NAME OF DISK FILE = B-8DETON.ASF

\*\*\* SCENARIO DESCRIPTION

18 cylinders release 3,960 cubic feet of hydrogen through two manifolds, 0.75 inches in diameter each, under worst case met. conditions taking approximately 3 seconds.

\*\*\*\*\*\* DISCHARGE RATE/DURATION ESTIMATES

Compressed gas discharge from container

Peak discharge rate	=	476.6	lbs/min
Duration of discharge	=	.044	minutes
Amount discharged	=	20.7	lbs
State of material	=	Gas	

#### \*\*\*\*\*\* TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind distance to		
at groundlevel	= 410	feet
at discharge heig	sht = 392	feet

Peak concentration on ground is 1000000 ppm at a downwind distance of 130 feet for elevated emission source specified by user.

See attached table(s) for further details.

\*\*\*\*\*\* FLAME JET HAZARD RESULTS

Flame jet length	=	647	feet
Safe separation distance	=	1293	feet
Flame jet duration	=	.044	minutes

\*\*\*\*\*\* FLAMMABLE VAPOR CLOUD HAZARD RESULTS

	For concentration of	1/2 LFL	LFL	
	Downwind hazard distance Max hazard zone width Max weight explosive gas Relative gas/air density Model used in analysis Clouds or plumes contain of vapor or gas are very completely unconfined, tain few materials have	= 491 = 21 = 1.01 = Neutral ing less th unlikely t except when	379 21 1.01 ly buoya an 1000 o exploa one of	lbs initially ant pounds de when
******	EXPLOSION HAZARDS: See a	ttached tab	le(s)	

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Jownwind	Distance	Groundlevel Concentration	Source Height Concentration	Initial Evacuation
(feet)	(miles)	(ppm)	(ppm)	Zone Width* (feet)
100	.02	1000000	1000000	73
123	.03	1000000	1000000	* 89
145	.03	1000000	1000000	110
167	.04	1000000	1000000	130
189	.04	985126	999964	140
211	.04	814612	766500	160
233	.05	672432	607553	170
255	.05	557206	493494	190
277	.06	464703	408277	210
300	.06	390474	342644	220
322	.07	330668	290915	240
344	.07	282182	249406	250
366	.07	242588	215615	270
388	.08	210009	187778	270
410	.08	183000	164613	1

'Usually safe for < 1 hour release. Longer releases or sudden wind shifts nay require a larger width or different direction for the evacuation zone. See Chapters 3 and 12 of the guide for details. Source height specified y the user for this scenario was 5 feet.

## TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind	Distance	Contaminant Arrival Time	Contaminant Departure Time
	(miles)	at Downwind Location (minutes)	(minutes)
123 145 167 189 211 233 255 277 300 322	.02 .03 .04 .04 .04 .04 .05 .05 .05 .06 .06 .06 .07	.6 .7 .9 1 1.1 1.2 1.4 1.5 1.6 1.8 1.9 2	1.2 1.5 1.7 2 2.2 2.5 2.7 3 3.2 3.5 3.8
344 366 388 410	.07 .07 .08 .08	2 . 1 2.1 2.3 2.4	4 4.3 4.5 4.8

CAUTION: See guide for assumptions used in estimating these times. ;

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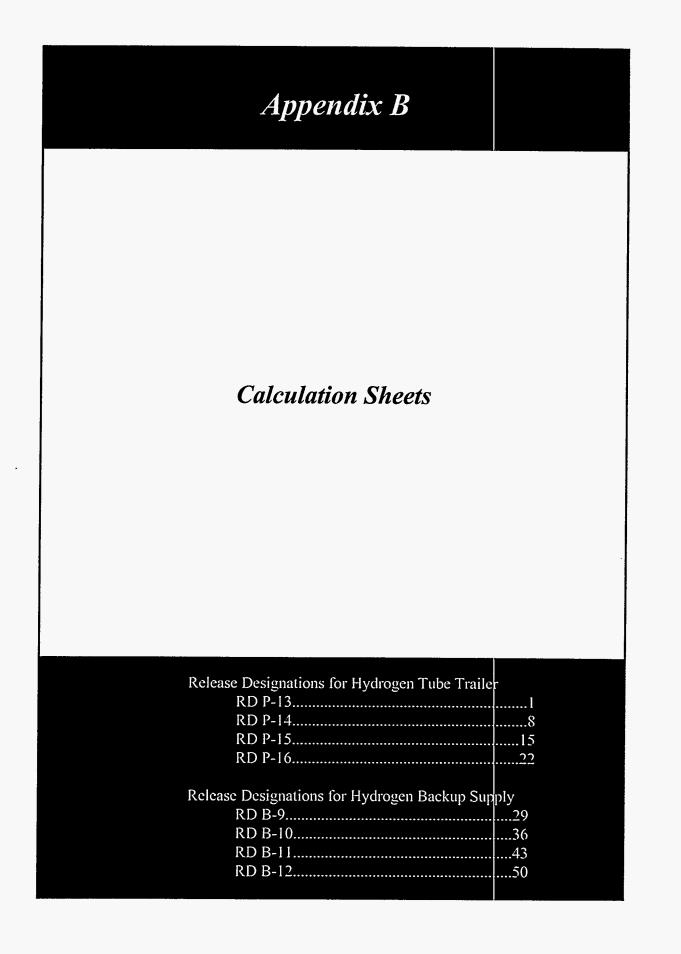
- -

PHYSIOCHEMICAL PROPERTIES OF MATERI	AL		_
NORMAL BOILING POINT	= -	-423	degrees F
	=	2.0159	
VAPOR PRES AT CONTAINER TEMP	=.	2000	psia
	=	103472	mm Hg
VAPOR PRES AT AMBIENT TEMP	=	2000.1	psia
	=	103472	mm Hg
SPECIFIC HEAT RATIO FOR GAS	=	1.4	
LOWER FLAMMABLE LIMIT (LFL)	=	4	vol%
LOWER FLAMMABLE LIMIT (LFL) LOWER HEAT OF COMBUSTION	=	191.7	Btu/lb
GAS EXPLOSION YIELD FACTOR	=	.03	
TOXIC VAPOR LIMIT		183000	ppm
CONTAINER CHARACTERISTICS			
CONTAINER CHARACTERISTICS CONTAINER TYPE	_	Horizontal c	vlinder
TOTAL WEIGHT OF CONTENTS		20.7	lbs
		.92	inch(es)
DISCHARGE COEFFICIENT OF HOLE			
TEMP OF CONTAINER CONTENTS		68	degrees F
TANK RUPTURE PRESSURE		2400	psia
TANK ROFTORE FRESDORE	-	a 100	Free
ENVIRONMENTAL/LOCATION CHARACTERIS	TIC	S	
AMBIENT TEMPERATURE		68	degrees F
WIND VELOCITY		2	mph
ATMOSPHERIC STABILITY CLASS		F	_
VAPOR/GAS DISCHARGE HEIGHT	=	5	feet
THE PROPERTY DATE INCOME	<b>~</b> ~	OF BY EVALUAT	TON METHODS

KEY RESULTS PROVIDED BY USER INSTEAD OF BY EVALUATION METHODS NONE OBSERVED

KEY RESULTS OVERRIDDEN BY USER AT SOME POINT AFTER COMPUTATION NONE OBSERVED

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- <u>-</u> - -

- A Carrier

CALCULATION TITLE:	Primary Fragments from Cased Cylindrical Charges (Hydrogen Trailer - Overpressure of a single cylinder)
CALCULATION ID:	RD-P13-001
<b>REVISION:</b> 0	
Prepared by: Cattant	Mo <u>APRIEL Wood</u> <u>12/16/94</u> gnature Printed Name Date
Checked by:	gnature Printed Name Date
Approved by: Willing Si	gnature WILLIAM THURADA 12/16/94 Printed Name Date
Prepared by: Checked by: Approved by: MUL	mature Printed Name Date Date ULLIAM THURKON 12/16/94

The following calculations depict the size, velocity, and the distance a fragment would travel in an accident involving the overpressure of a single cylinder. Although multiple cylinders may be involved in an incident, the only factor expected to change significantly would be the number of fragments which would be multiplied by the number of cylinders involved in the event.

Step 1:	Given:	Type of Explosive = Hydrogen
	a.	Density of Explosive (De) in lbs/in <sup>3</sup> = (Density of H <sub>2</sub> in g/cm <sup>3</sup> )/ (Conversion Factor of 27.68) (Reference 15) De = $(0.00008988 \text{ g/cm}^3)/(27.68) = 3.2\text{E-}06 \text{ lbs/in}^3$
	b.	Wt. of Fuel in 1 cylinder = (Volume of Fuel)/(Volume of 1 pound of fuel) Wt. = 1,000 ft <sup>3</sup> /191.3 ft <sup>3</sup> = 5.2 lbs
	с.	Weight of explosive (TNT Equivalent) in 1 cylinder (W) = (Weight of fuel)(TNT Equivalent of 20.5) W = (5.2)(20.5) = 106.6 plus a 20% safety factor = 128 lbs
	d. e. f. g. h.	Outside Diameter of Casing $(d_0) = 9.625$ inches Inside Diameter of Casing $(d_i) = 9$ inches Thickness of Casing $(t_c) = .3125$ inches Length of Charge $(lc) = 21$ feet (252 inches) Density of Casing $(dc) = 8.0$ g/cm <sup>3</sup> (.289 lbs/in <sup>3</sup> )

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CALCULATION TITLE: Primary Fragments from Cased Cylindrical Charges (Hydrogen Trailer - Overpressure of a single cylinder)

CALCULATION ID: RD-P13-001 (cont'd)

## **REVISION:** 0

Step 2: Total weight of the cylindrical portion of the metal casing (W<sub>c</sub>)

$$W_{c} = \frac{\pi [(od)^{2} - (id)^{2}](lc)(dc)}{4}$$
$$W_{c} = \frac{\pi [(9.625)^{2} - (9)^{2}](252)(0.289)}{4} = 665.8 \text{ lbs}$$

 $\frac{W}{W_c} = \frac{128}{666} = .192$  = The ratio of the explosive weight to the casing weight.

Step 3: Initial Fragment Velocity (V<sub>0</sub>)

TNT in mild steel casing,  $(2E')^{1/2} = 6,940$  (Reference 15, Table 4-2)

$$V_{o} = (2E')^{1/2} \left(\frac{\frac{W}{W_{c}}}{1 + \frac{W}{2W_{c}}}\right)^{1/2}$$

$$V_o = 6,940 \left(\frac{0.192}{1+\frac{.192}{2}}\right)^{1/2} = 2,904.7 \text{ ft./second}$$

CALCULATION TITLE:	Primary Fragments from Cased Cylindrical Charges		
	(Hydrogen Trailer - Overpressure of a single cylinder)		

CALCULATION ID: RD-P13-001 (cont'd)

**REVISION:** 0

Step 4: Fragment Distribution Parameter (M<sub>A</sub>)

The constant for the explosive charge for TNT in mild steel casing (B) = .30 (Reference 15)

$$M_{A} = B(tc)^{5/6} (di)^{\frac{1}{3}} \left(1 + \frac{tc}{dj}\right)$$

MA = .30(0.3125)<sup>5/6</sup>(9)<sup>$$\frac{1}{3}$$</sup> $\left(1+\frac{0.3125}{9}\right) = 0.245$  lbs

Step 5: Weight of the largest fragment

$$W_{f} = \left[ M_{A} \ln \left( \frac{8 W_{c}}{M_{A}^{2}} \right) \right]^{2}$$
$$W_{f} = \left[ 0.245 \ln \left( \frac{8(666)}{(0.245)^{2}} \right) \right]^{2} = 7.8 \text{ ounces}$$

Step 6:

Striking Velocity  $(V_S)$ 

If the distance traveled by the fragment is less than 20 feet, the striking velocity is taken as equal to the initial velocity for all size fragments.

Therefore,  $V_s = V_o = 2,905$  ft./second

Step 7:

7: Number of fragments having a weight greater than 1-1/2 ounces (Nf)

$$\ln N_{\rm f} = \ln \left[ \frac{8W_{\rm c}}{M_{\rm A}^2} \right] - \frac{W_{\rm f}^{1/2}}{M_{\rm A}}$$
$$\ln N_{\rm f} = \ln \left[ \frac{8(666)}{(0.245)^2} \right] - \frac{(1.5)^{1/2}}{0.245} = 6.39$$

 $N_f = 596$  fragments

CALCULATIO	N TITLE:		old Blast Overpressures - Overpressure of a single cylin	nder)
CALCULATIO	ON ID:	RD-P13-002		
<b>REVISION:</b>	0 1.		<u>^</u>	
Prepared by:	amie N	ignature	<u>ARRIE L. Wood</u> Printed Name	<u>12/15/94</u> Date
Checked by:	Joseph	gnature	Joseph A. Schuner	<u>12-15-94</u> Date
Approved by:	William	ignature	WILLIAM THOENTON Printed Name	<u>12(16/94</u> Date

The following calculations identify those distances at which the overpressures are 1 psi and 10 psi.

# AIRBLAST EFFECTS ON PERSONNEL AND PROPERTY

Dose (psi)	Effect
1.0	Partial demolition of houses; made uninhabitable
1.0-8.0	Range from slight to serious injuries due to skin lacerations from flying glass
	and other missiles with eardrum rupture evidenced at 3.4 psi.
10.0	Threshold for lung rupture and probable total building destruction.

 $R_G$  = Ground distances W = TNT equivalent in lbs including a 20% safety factor  $Z_G$  = Scaled Ground Distance (ft/lb<sup>1/3</sup>)

Note:  $Z_G$  may be used as a constant if a particular psi is known.

For 1 psi,  $Z_G = 45$ For 10 psi,  $Z_G = 9$ 

$$R_G = (W)^{1/3} (Z_G)$$

Α. <u>1 psi</u> B. <u>10 psi</u>

 $R_G = (128)^{1/3}(9)$  $R_G = 45.4$  ft  $R_G = (128)^{1/3}(45)$  $R_G = 226.8 \text{ ft}$ 

CALCULATION TITLE:	Blast Force to Nearby Stru (Hydrogen Trailer - Overpi	ctures ressure of a single cylinder)	
CALCULATION ID:	RD-P13-003		
<b>REVISION:</b> 0			
Prepared by:	gnature CARRI	<u>ELUOO 12/15</u> Printed Name Da	<i>-94</i> te
Checked by:	gnature Description	A. Schringer 12-15. Printed Name Da	
Approved by: William	gnature I	rinted Name Da	4-11

To determine the Peak Positive Incident Pressure ( $P_{SO}$ ) impacting the nearest structure (i.e. the walls surrounding the HTSF -5 ft. away and the AMPL - est. 105 ft away), the scaled ground distance ( $Z_G$ ) was calculated and applied to a shock-wave parameter scale for hemispherical TNT surface explosions (Reference 15, Figure 4-12).

 $R_G$  = Ground distances W = TNT equivalent in lbs including a 20% safety factor  $Z_G$  = Scaled Ground Distance (ft/lb<sup>1/3</sup>)

$$Z_{\rm G} = R_{\rm G} / W^{1/3}$$

a. The walls surrounding HTSF (5 ft from trailer)  $Z_G = (5 \text{ ft})/(128)^{1/3}$   $Z_G = .99$  for a: P\_{SO} = 1,000 psi
b. <u>AMPL Building</u> (approx. 105 ft from trailer)  $Z_G = (105 \text{ ft})/(128)^{1/3}$   $Z_G = 20.8$  for b: P\_{SO} = 6 psi

CALCULATIO	ON TITLE:	Fragment Velocity (Hydrogen Trailer	at Threshold - Overpressure of a single cyline	ier)
CALCULATIC	ON ID:	RD-P13-004		
<b>REVISION:</b>	0		<b>2</b>	
Prepared by:	<u>Catholica</u> Si	gnature	CARRIE L. Whod Printed Name	<u>12/15/44</u> Date
Checked by:	loseph a.	<u>gnature</u>	Joseph A. Schriner Printed Name	<u>12-15-94</u> Date
Approved by:	William	Shinton gnature	William Hordford Printed Name	<u>12/16/94</u> Date

The following calculations depict the velocity at which fragments exceed the permissible exposure level of 58 ft/lb as prescribed in DOD 6055.9 (Reference 16). Two fragment sizes are calculated for their velocity: a 7.8 ounce fragment (the largest fragment) and a 1.5 ounce fragment.

Step 1: Given:

 $V_s$  = The velocity in ft/sec at which a given object must travel to achieve 58 ft/lb of energy. W = The weight of the object in pounds.

C = Constant which is 58.

A.

Step 2:

 $V_s = \frac{C}{W}$ 

B. <u>1.5 ounce fragment</u>

$$V_s = \frac{58}{0.09375} = 618.66$$
 ft/sec

 $V_{\rm s} = \frac{58}{0.4875} = 118.97 \, {\rm ft/sec}$ 

7.8 ounce fragment

## CALCULATION TITLE:

Distance fragments travel before dropping below threshold velocities (Hydrogen Trailer - Overpressure of a single cylinder)

## CALCULATION ID: RD-P13-005

<b>REVISION:</b>	0		
Prepared by:	Carrie L. Wood	<u>APRIE /. Wood</u> Printed Name	<u>12/16/94/</u> Date
Checked by:	Geph a Schning Signature	Sosch A. Schemer Printed Name	<u>17.16-94</u> Date
Approved by:	11/04	DILLIAM HORATOK Printed Name	<u>12/16/94</u> Date

The following calculations depict the distances at which fragments contain energies less than the 58 ft/lb threshold as prescribed by DOD 6055.9 (Reference 16).

Step 1: Given:

 $v_s$  = Striking velocity at a given distance.  $v_o$  = Initial velocity. e = Natural antilogarithm.  $R_f$  = Distance traveled by a fragment.  $W_f$  = Weight of the fragment.

Step 2:

$$R_{f} = \frac{\ln \frac{V_{o}}{V_{s}} (W_{f}^{1/3})}{.004}$$

B.

A.

7.8 ounce fragment

1.5 ounce fragment

$$R_f = \frac{\ln \frac{2,905}{119} (7.8^{1/3})}{.004} = 1,584.1 \text{ ft}$$

$$R_{f} = \frac{\ln \frac{2,905}{119} (1.5^{1/3})}{.004} = 914.4 \text{ ft}$$

CALCULATION TITLE:	• •	rom Cased Cylindrical Charge Overpressure of three cylinders	
CALCULATION ID:	RD-P14-001		
REVISION: 0	11 1	Δ .	
Prepared by: <u>Calva h la</u>	gnature	CAPPIE L.Mac	<u>12/16/94</u> Date
Checked by:	Same _	Printed Name	<u></u>  Date
Approved by: William	Shinter	WILLIAM HURATON Printed Name	<u>17716/94</u> Date

The following calculations depict the size, velocity, and the distance a fragment would travel in an accident involving the overpressure of a single cylinder. Although multiple cylinders may be involved in an incident, the only factor expected to change significantly would be the number of fragments which would be multiplied by the number of cylinders involved in the event.

Step 1:	Given:	Type of Explosive = Hydrogen
	a.	Density of Explosive (De) in lbs/in <sup>3</sup> = (Density of H <sub>2</sub> in g/cm <sup>3</sup> )/ (Conversion Factor of 27.68) (Reference 15) De = $(0.00008988 \text{ g/cm}^3)/(27.68) = 3.2\text{E-06} \text{ lbs/in}^3$
	b.	Wt. of Fuel in 3 cylinders = (Volume of Fuel)/(Volume of 1 lb. of fuel) Wt. = $3,000 \text{ ft}^3/191.3 \text{ ft}^3 = 15.7 \text{ lbs}$
	с.	Weight of explosive (TNT Equivalent) in 1 cylinder (W) = (Weight of fuel)(TNT Equivalent of 20.5) W = (15.7)(20.5) = 321.85 + a 20% safety factor = 386.2 lbs
	d.	Outside Diameter of Casing $(d_0) = 9.625$ inches
	e.	Inside Diameter of Casing $(d_i) = 9$ inches
	f.	Thickness of Casing $(t_c) = .3125$ inches
	g.	Length of Charge $(lc) = 21$ feet (252 inches)
	1	

h. Density of Casing (dc) =  $8.0 \text{ g/cm}^3$  (.289 lbs/in<sup>3</sup>)

CALCULATION TITLE: Primary Fragments from Cased Cylindrical Charges (Hydrogen Trailer - Overpressure of three cylinders)

CALCULATION ID: RD-P14-001 (cont'd)

**REVISION:** 0

Step 2: Total weight of the cylindrical portion of the metal casing (W<sub>c</sub>)

$$W_{c} = \frac{\pi [(od)^{2} - (id)^{2}](lc)(dc)}{4}$$
$$W_{c} = \frac{\pi [(9.625)^{2} - (9)^{2}](252)(0.289)}{4} = 665.8 \text{ lbs}$$

 $\frac{W}{W_c} = \frac{128}{666} = .192 =$ The ratio of the explosive weight to the casing weight.

Step 3: Initial Fragment Velocity (V<sub>0</sub>)

TNT in mild steel casing,  $(2E')^{1/2} = 6,940 (2E')^{1/2} = 6,940$  (Reference 15, Table 4-2)

$$V_{o} = (2E')^{1/2} \left( \frac{\frac{W}{W_{c}}}{1 + \frac{W}{2W_{c}}} \right)^{1/2}$$

$$V_o = 6,940 \left(\frac{0.192}{1+\frac{.192}{2}}\right)^{1/2} = 2,904.7 \text{ ft./second}$$

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CALCULATION TITLE:	Primary Fragments from Cased Cylindrical Charges (Hydrogen Trailer - Overpressure of three cylinders)
CALCULATION ID:	RD-P14-001 (cont'd)

**REVISION:** 0

Step 4: Fragment Distribution Parameter (M<sub>A</sub>)

The constant for the explosive charge for TNT in mild steel casing (B) = .30 (Reference 15)

$$M_{A} = B(tc)^{5/6} (di)^{\frac{1}{3}} \left(1 + \frac{tc}{dj}\right)$$

MA = .30(0.3125)<sup>5/6</sup>(9)<sup>$$\frac{1}{3}$$</sup> $\left(1+\frac{0.3125}{9}\right) = 0.245$  lbs

Step 5: Weight of the largest fragment

$$W_{f} = \left[ M_{A} \ln \left( \frac{8W_{c}}{M_{A}^{2}} \right) \right]^{2}$$
$$W_{f} = \left[ 0.245 \ln \left( \frac{8(666)}{(0.245)^{2}} \right) \right]^{2} = 7.8 \text{ ounces}$$

Step 6: Striking Velocity (V<sub>S</sub>)

If the distance traveled by the fragment is less than 20 feet, the striking velocity is taken as equal to the initial velocity for all size fragments.

Therefore,  $V_s = V_o = 2,905$  ft./second

Step 7: Number of fragments having a weight greater than 1-1/2 ounces (N<sub>f</sub>)

$$\ln N_{\rm f} = \ln \left[ \frac{8W_{\rm c}}{M_{\rm A}^2} \right] - \frac{W_{\rm f}^{1/2}}{M_{\rm A}}$$
$$\ln N_{\rm f} = \ln \left[ \frac{8(666)}{(0.245)^2} \right] - \frac{(1.5)^{1/2}}{0.245} = 6.39$$

 $N_f = 596$  fragments = 1,788 for 3 cylinders

TITLE:		-	
ID:	RD-P14-002		
n /	1, 1	$\Lambda$	
Cappel Si	gnature	CAPRIE L-Uhod Printed Name	<u> 2 15 94</u> Date
Jupph a.	Schniner	<u>Soscph A. Schr</u> Printed Name	<u>Date</u>
Villing	Show for gnature	Printed Name	<u>ToN 12 16/94</u> Date
	ND: Caller Si Mph A. Si Si Si	(Hydrogen Trailer	(Hydrogen Trailer - Overpressure of three of NID: RD-P14-002 <u>Capie / Ubbd</u> Signature <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Signature</u> <u>Sig</u>

The following calculations identify those distances at which the overpressures are 1 psi and 10 psi.

#### AIRBLAST EFFECTS ON PERSONNEL AND PROPERTY

Dose (psi)	Effect
1.0	Partial demolition of houses; made uninhabitable
1.0-8.0	Range from slight to serious injuries due to skin lacerations from flying glass
	and other missiles with eardrum rupture evidenced at 3.4 psi.
10.0	Threshold for lung rupture and probable total building destruction.

 $R_G$  = Ground distances W = TNT equivalent in lbs including a 20% safety factor  $Z_G$  = Scaled Ground Distance (ft/lb<sup>1/3</sup>)

Note:  $Z_G$  may be used as a constant if a particular psi is known.

For 1 psi,  $Z_G = 45$ For 10 psi,  $Z_G = 9$ 

$$R_{G} = (W)^{1/3} (Z_{G})$$

A. <u>1 psi</u>

740

B. <u>10 psi</u>

$$R_G = (386.2)^{1/3}(45)$$
 $R_G = (383.8)^{1/3}(9)$  $R_G = 327.6 \text{ ft}$  $R_G = 65.5 \text{ ft}$ 

CALCULATIO	N TITLE:	Blast Force to Nea (Hydrogen Trailer	rby Structures - Overpressure of three cylinde	ers)
CALCULATIO	N ID:	RD-P14-003		
<b>REVISION:</b> 0	$\Lambda$	л 1/1 Л		
Prepared by:	Cathin	gnature / .	CARRIE L. WOod Printed Name	<u> 2  5  94</u> Date
Checked by:	USE MAR	gnature	South A Schriner Printed Name	<u> 7 15 94</u> Date
Approved by:	Wilhinsi	gnature	William Hondron Printed Name	<u>12/15/94</u> Date

To determine the Peak Positive Incident Pressure  $(P_{SO})$  impacting the nearest structure (i.e. the walls surrounding the HTSF -5 ft. away and the AMPL - est. 105 ft away), the scaled ground distance  $(Z_G)$  was calculated and applied to a shock-wave parameter scale for hemispherical TNT surface explosions (Reference 15, Figure 4-12).

 $R_G$  = Ground distances W = TNT equivalent in lbs including a 20% safety factor  $Z_G$  = Scaled Ground Distance (ft/lb<sup>1/3</sup>)

$$Z_{G} = R_{G} / W^{1/3}$$

a. The walls surrounding HTSF b. AMPL Building (5 ft from trailer) b. AMPL Building (approx. 105 ft from trailer)  $Z_G = (5 \text{ ft})/(386.2)^{1/3}$   $Z_G = .69$ for a:  $P_{SO} = 4,000 \text{ psi}$  b. AMPL Building (approx. 105 ft from trailer)  $Z_G = (105 \text{ ft})/(386.2)^{1/3}$   $Z_G = 14.4$ for b:  $P_{SO} = 8 \text{ psi}$ 

CALCULATION	5	ty at Threshold or - Overpressure of three cylinder	s)
CALCULATION	<b>D:</b> RD-P14-004		
<b>REVISION:</b> 0	ΛΛΙΛ		
Prepared by:	Mui Molo Signature	CARRIE L. Wood	<u> 12/15/94</u> Date
Checked by:	Signature	<u>Seph A. Schract</u> Printed Name	<u>12-15-44</u> Date
Approved by: <u>U</u>	Signature	WILLIAM HORNTON Printed Name	12/16/94 Date

The following calculations depict the velocity at which fragments exceed the permissible exposure level of 58 ft/lb as prescribed in DOD 6055.9 (Reference 16). Two fragment sizes are calculated for their velocity: a 7.8 ounce fragment (the largest fragment) and a 1.5 ounce fragment.

Step 1: Given:

 $V_s$  = The velocity in ft/sec at which a given object must travel to achieve 58 ft/lb of energy. W = The weight of the object in pounds.

C = Constant which is 58.

Step 2:

$$V_s = \frac{C}{W}$$

A. 7.8 ounce fragment

$$V_s = \frac{58}{0.4875} = 118.97 \text{ ft/sec}$$

B. 1.5 ounce fragment

 $V_s = \frac{58}{0.09375} = 618.66 \text{ ft/sec}$ 

-

CALCULATION TITLE:	ITLE: Distance fragments travel before dropping below threshold velocities (Hydrogen Trailer - Overpressure of three cylinders)		
CALCULATION ID:	RD-P14-005		
REVISION: 0	1/1 A	$\Lambda$ (	
Prepared by: Calling	Signature	<u>CARRIE L. Wood</u> Printed Name	<u> 2/16/94</u> Date
Checked by:	Signature	Printed Name	<u> </u>
Approved by: Willic	in Shownfen Signature	WILLIAM THORNTON Printed Name	12/16/94 Date

The following calculations depict the distances at which fragments contain energies less than the 58 ft/lb threshold as prescribed by DOD 6055.9 (Reference 16).

Step 1: Given:

Step 2:

$$R_{f} = \frac{\ln \frac{V_{o}}{V_{s}} (W_{f}^{1/3})}{.004}$$

A. <u>7.8 ounce fragment</u>

B. <u>1.5 ounce fragment</u>

$$R_{f} = \frac{\ln \frac{2,905}{119} (7.8^{1/3})}{.004} = 1,584.1 \text{ ft}$$

$$R_{f} = \frac{\ln \frac{2,905}{119} (1.5^{1/3})}{.004} = 914.4 \text{ ft}$$

CALCULATION TITLE:		ts from Cased Cylindrical Charges r - Overpressure of 30 cylinders)	S
CALCULATION ID:	RD-P15-001		
<b>REVISION:</b> 0	1 / I A	Λ	
Prepared by: <u>Callur</u> Si	gnature	APRIE L. Wood	<u>/2/16/94</u> Date
Checked by:	gnature	Printed Name	<u>12-16-99</u> Date
Approved by: William	Shunten	WILLIAM THORATION Printed Name	<u>1 7/16/94</u> Date

The following calculations depict the size, velocity, and the distance a fragment would travel in an accident involving the overpressure of a single cylinder. Although multiple cylinders may be involved in an incident, the only factor expected to change significantly would be the number of fragments which would be multiplied by the number of cylinders involved in the event.

Step 1:	Given:	Type of Explosive = Hydrogen
	a.	Density of Explosive (De) in lbs/in <sup>3</sup> = (Density of H <sub>2</sub> in g/cm <sup>3</sup> )/ (Conversion Factor of 27.68) (Reference 15) De = $(0.00008988 \text{ g/cm}^3)/(27.68) = 3.2\text{E-06} \text{ lbs/in}^3$
	b.	Wt. of Fuel in 30 cylinders = (Volume of Fuel)/(Volume of 1 lb of fuel) Wt. = $30,000 \text{ ft}^3/191.3 \text{ ft}^3 = 156.8 \text{ lbs}$
	с.	Weight of explosive (TNT Equivalent) in 1 cylinder (W) = (Weight of fuel)(TNT Equivalent of 20.5) W = (156.8)(20.5) = 3,214.4 + a 20% safety factor =3,857.3 lbs
	d. e. f. g. h.	Outside Diameter of Casing $(d_0) = 9.625$ inches Inside Diameter of Casing $(d_i) = 9$ inches Thickness of Casing $(t_c) = .3125$ inches Length of Charge $(lc) = 21$ feet (252 inches) Density of Casing $(dc) = 8.0$ g/cm <sup>3</sup> (.289 lbs/in <sup>3</sup> )

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CALCULATION TITLE:	Primary Fragments from Cased Cylindrical Charges
	(Hydrogen Trailer - Overpressure of 30 cylinders)

CALCULATION ID: RD-P15-001 (cont'd)

**REVISION:** 0

Step 2: Total weight of the cylindrical portion of the metal casing (W<sub>c</sub>)

$$W_{c} = \frac{\pi [(od)^{2} - (id)^{2}](lc)(dc)}{4}$$
$$W_{c} = \frac{\pi [(9.625)^{2} - (9)^{2}](252)(0.289)}{4} = 665.8 \text{ lbs}$$

 $\frac{W}{W_c} = \frac{128}{666} = .192$  = The ratio of the explosive weight to the casing weight.

Step 3: Initial Fragment Velocity (V<sub>0</sub>)

TNT in mild steel casing,  $(2E')^{1/2} = 6,940$  (Reference 15, Table 4-2)

$$V_{o} = (2E')^{1/2} \left( \frac{\frac{W}{W_{c}}}{1 + \frac{W}{2W_{c}}} \right)^{1/2}$$

$$V_o = 6,940 \left(\frac{0.192}{1+\frac{.192}{2}}\right)^{1/2} = 2,904.7 \text{ ft./second}$$

CALCULATION TITLE: Primary Fragments from Cased Cylindrical Charges (Hydrogen Trailer - Overpressure of 30 cylinders)

CALCULATION ID: RD-P15-001 (cont'd)

**REVISION:** 0

Step 4: Fragment Distribution Parameter (M<sub>A</sub>)

The constant for the explosive charge for TNT in mild steel casing (B) = .30 (Reference 15)

$$M_{A} = B(tc)^{5/6} (di)^{\frac{1}{3}} \left(1 + \frac{tc}{dj}\right)$$

MA = .30(0.3125)<sup>5/6</sup>(9)<sup>$$\frac{1}{3}$$</sup> $\left(1+\frac{0.3125}{9}\right) = 0.245$  lbs

Step 5: Weight of the largest fragment

$$W_{f} = \left[ M_{A} \ln \left( \frac{8W_{c}}{M_{A}^{2}} \right) \right]^{2}$$
$$W_{f} = \left[ 0.245 \ln \left( \frac{8(666)}{(0.245)^{2}} \right) \right]^{2} = 7.8 \text{ ounces}$$

Step 6: Striking Velocity  $(V_s)$ 

If the distance traveled by the fragment is less than 20 feet, the striking velocity is taken as equal to the initial velocity for all size fragments.

Therefore,  $V_s = V_o = 2,905$  ft./second

Step 7: Number of fragments having a weight greater than 1-1/2 ounces (N<sub>f</sub>)

$$\ln N_{\rm f} = \ln \left[ \frac{8 W_{\rm c}}{M_{\rm A}^2} \right] - \frac{W_{\rm f}^{1/2}}{M_{\rm A}}$$

$$\ln N_{\rm f} = \ln \left[ \frac{8(666)}{(0.245)^2} \right] - \frac{(1.5)^{1/2}}{0.245} = 6.39$$

 $N_f = 596$  fragments per cylinder (30 cylinders) = 17,880 fragments

17

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CALCULATION TIT		nold Blast Overpressures - Overpressure of 30 cylinders)	
CALCULATION ID:	RD-P15-002		
<b>REVISION:</b> 0	A A	A	
Prepared by:	<u>Nic / Wedd</u> Signature	CARRIE L. WOOD Printed Name	<u> 2 15 94</u> Date
Checked by:	M. M. M. M. Signature	<u>Scseph A. Schunce</u> Printed Name	<u>12-15-94</u> Date
Approved by: Wi	llim Signature	WILLIAM HORATON Printed Name	<u>17/16/94</u> Date

The following calculations identify those distances at which the overpressures are 1 psi and 10 psi.

#### AIRBLAST EFFECTS ON PERSONNEL AND PROPERTY

Dose (psi)	Effect
1.0	Partial demolition of houses; made uninhabitable
1.0-8.0	Range from slight to serious injuries due to skin lacerations from flying glass
	and other missiles with eardrum rupture evidenced at 3.4 psi.
10.0	Threshold for lung rupture and probable total building destruction.

 $R_G$  = Ground distances W = TNT equivalent in lbs including a 20% safety factor  $Z_G$  = Scaled Ground Distance (ft/lb<sup>1/3</sup>)

Note:  $Z_G$  may be used as a constant if a particular psi is known.

For 1 psi,  $Z_G = 45$ For 10 psi,  $Z_G = 9$ 

$$R_G = (W)^{1/3} (Z_G)$$

Α. <u>1 psi</u> B. <u>10 psi</u>

 $R_G = (3,857.3)^{1/3}(45)$  $R_G = 705.7$  ft  $R_G = (3,857.3)^{1/3}(9)$  $R_G = 141.1 \text{ ft}$ 

CALCULATION TITLE:	Blast Force to Nea (Hydrogen Trailer	rby Structures - Overpressure of 30 cylinders)	
CALCULATION ID:	RD-P15-003		
REVISION: 0	<sup>1</sup> // /	2	
Prepared by:	Mard	ARRIE L. Wood	12/15/94
Checked by:	gnature gnature	Printed Name	Date <u>17 15-94</u> Date
Approved by: Ulliam	<u>Shownfon</u> gnature	WILLIAM HURNOW Printed Name	<u>  2/1 (/9</u> 4) Date

To determine the Peak Positive Incident Pressure  $(P_{SO})$  impacting the nearest structure (i.e. the walls surrounding the HTSF -5 ft. away and the AMPL - est. 105 ft away), the scaled ground distance  $(Z_G)$  was calculated and applied to a shock-wave parameter scale for hemispherical TNT surface explosions (Reference 15, Figure 4-12).

 $R_G$  = Ground distances W = TNT equivalent in lbs including a 20% safety factor  $Z_G$  = Scaled Ground Distance (ft/lb<sup>1/3</sup>)

$$Z_{G} = R_{G} / W^{1/3}$$

Ъ.

a. <u>The walls surrounding HTSF</u> (5 ft from trailer)

> $Z_G = (5 \text{ ft})/(3,857.3)^{1/3}$  $Z_G = .32$

for a: P<sub>SO</sub> = 8,000 psi <u>AMPL Building</u> (approx. 105 ft from trailer)

$$Z_G = (105 \text{ ft})/(3,857.3)^{1/3}$$
  
 $Z_G = 6.7$ 

for b:  $P_{SO} = 75 \text{ psi}$ 

CALCULATION TITLE:	Fragment Velocity : (Hydrogen Trailer -	at Threshold • Overpressure of 30 cylinders)	
CALCULATION ID:	RD-P15-004		
REVISION: 0	Ala C		
Prepared by: <u>AMu</u> Si	gnature/	CARRIE L. Wood Printed Name	<u> 2  5 94</u> Date
Checked by:	gnature	Printed Name	<u>12 15-94</u> Date
Approved by: Willim	Shunt-	WILLIAM THORNTON Printed Name	<u>12/16/94</u> Date

The The following calculations depict the velocity at which fragments exceed the permissible exposure level of 58 ft/lb as prescribed in DOD 6055.9 (Reference 16). Two fragment sizes are calculated for their velocity: a 7.8 ounce fragment (the largest fragment) and a 1.5 ounce fragment.

Step 1: Given:

 $V_s$  = The velocity in ft/sec at which a given object must travel to achieve 58 ft/lb of energy. W = The weight of the object in pounds. C = Constant which is 58.

Step 2:

$$V_s = \frac{C}{W}$$

A. <u>7.8 ounce fragment</u>

$$V_s = \frac{58}{0.4875} = 118.97$$
 ft/sec

B. <u>1.5 ounce fragment</u>

$$V_s = \frac{58}{0.09375} = 618.66 \text{ ft/sec}$$

CALCULATION TITLE:		travel before dropping below the Trailer - Overpressure of 30 c	
CALCULATION ID:	RD-P15-005		
REVISION: 0	11 A	$\hat{D}$ , $i$	
Prepared by: <u>Alia</u> Si	gnature	CARRIE L. MOOD Printed Name	<u>12/16/94</u> Date
Checked by:	gnature .	Printed Name	<u>  2-  6-94</u> Date
Approved by: Willing	gnature	WILLIAM HORATON Printed Name	<u>  Z   I 6 /4 /</u> Date

The following calculations depict the distances at which fragments contain energies less than the 58 ft/lb threshold as prescribed by DOD 6055.9 (Reference 16).

Step 1: Given:

Step 2:

$$R_{f} = \frac{\ln \frac{V_{o}}{V_{s}} (W_{f}^{1/3})}{.004}$$

B.

A. <u>7.8 ounce fragment</u>

1.5 ounce fragment

$$R_{\rm f} = \frac{\ln \frac{2,905}{119} (7.8^{1/3})}{.004} = 1,584.1 \text{ ft}$$

$$R_{\rm f} = \frac{\ln \frac{2,905}{119} (1.5^{1/3})}{.004} = 914.4 \text{ ft}$$

CALCULATION TITLE:		from Cased Cylindrical Charges - Overpressure of 38 cylinders)	8
CALCULATION ID:	RD-P16-001		
REVISION: 0	A I A	h	
Prepared by:	gnature	CARRIE L- Ubro	<u> 2  6 94</u> Date
Checked by:	gnature	Dseph A. Shriner Printed Name	<u>/7 /4-94</u> Date
Approved by: Willi	Shinton gnature	WILLIAM HORNTON Printed Name	12/16/94 Date

The following calculations depict the size, velocity, and the distance a fragment would travel in an accident involving the overpressure of a single cylinder. Although multiple cylinders may be involved in an incident, the only factor expected to change significantly would be the number of fragments which would be multiplied by the number of cylinders involved in the event.

Step 1:	Given:	Type of Explosive = Hydrogen
	a.	Density of Explosive (De) in lbs/in <sup>3</sup> = (Density of H <sub>2</sub> in g/cm <sup>3</sup> )/ (Conversion Factor of 27.68) (Reference 15) De = $(0.00008988 \text{ g/cm}^3)/(27.68) = 3.2\text{E-06 lbs/in}^3$
	b.	Wt. of Fuel in 3 cylinders = (Volume of Fuel)/(Volume of 1 lb. of fuel) Wt. = 38,000 $ft^3/191.3 ft^3 = 198.6$ lbs
	с.	Weight of explosive (TNT Equivalent) in 1 cylinder (W) = (Weight of fuel)(TNT Equivalent of 20.5) W = (198.6)(20.5) = 4,071.3 + a 20% safety factor = 4,885.6 lbs
	d.	Outside Diameter of Casing $(d_0) = 9.625$ inches
	e.	Inside Diameter of Casing $(d_i) = 9$ inches
	f.	Thickness of Casing $(t_c) = .3125$ inches
	g.	Length of Charge $(lc) = 21$ feet (252 inches)
	g. h.	Density of Casing (dc) = $8.0 \text{ g/cm}^3$ (.289 lbs/in <sup>3</sup> )

CALCULATION TITLE: Primary Fragments from Cased Cylindrical Charges (Hydrogen Trailer - Overpressure of 38 cylinders)

CALCULATION ID: RD-P16-001 (cont'd)

#### **REVISION:** 0

Step 2: Total weight of the cylindrical portion of the metal casing (W<sub>c</sub>))

$$W_{c} = \frac{\pi [(od)^{2} - (id)^{2}](lc)(dc)}{4}$$
$$W_{c} = \frac{\pi [(9.625)^{2} - (9)^{2}](252)(0.289)}{4} = 665.8 \text{ lbs}$$

 $\frac{W}{W_c} = \frac{128}{666} = .192$  = The ratio of the explosive weight to the casing weight.

Step 3: Initial Fragment Velocity (V<sub>0</sub>)

TNT in mild steel casing,  $(2E')^{1/2} = 6,940$  (Reference 15, Table 4-2)

$$V_{o} = (2E')^{1/2} \left( \frac{\frac{W}{W_{c}}}{1 + \frac{W}{2W_{c}}} \right)^{1/2}$$

$$V_o = 6,940 \left(\frac{0.192}{1+\frac{.192}{2}}\right)^{1/2} = 2,904.7 \text{ ft./second}$$

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CALCULATION TITLE:	Primary Fragments from Cased Cylindrical Charges (Hydrogen Trailer - Overpressure of 38 cylinders
	(Hydrogen Trailer - Overpressure of 58 cylinders

CALCULATION ID: RD-P16-001 (cont'd)

**REVISION:** 0

Step 4: Fragment Distribution Parameter (M<sub>A</sub>)

The constant for the explosive charge for TNT in mild steel casing (B) = .30 (Reference 15)

$$M_{A} = B(tc)^{5/6} (di)^{\frac{1}{3}} \left(1 + \frac{tc}{dj}\right)$$

MA = .30(0.3125)<sup>5/6</sup>(9)<sup>$$\frac{1}{3}$$</sup> $\left(1+\frac{0.3125}{9}\right) = 0.245$  lbs

Step 5: Weight of the largest fragment

$$W_{f} = \left[ M_{A} \ln \left( \frac{8W_{c}}{M_{A}^{2}} \right) \right]^{2}$$
$$W_{f} = \left[ 0.245 \ln \left( \frac{8(666)}{(0.245)^{2}} \right) \right]^{2} = 7.8 \text{ ounces}$$

Step 6: Striking Velocity (V<sub>s</sub>)

If the distance traveled by the fragment is less than 20 feet, the striking velocity is taken as equal to the initial velocity for all size fragments.

Therefore,  $V_s = V_o = 2,905$  ft./second

Step 7: Number of fragments having a weight greater than 1-1/2 ounces (N<sub>f</sub>)

$$\ln N_{f} = \ln \left[ \frac{8W_{c}}{M_{A}^{2}} \right] - \frac{W_{f}^{1/2}}{M_{A}}$$
$$\ln N_{f} = \ln \left[ \frac{8(666)}{(0.245)^{2}} \right] - \frac{(1.5)^{1/2}}{0.245} = 6.39$$

 $N_f = 596$  fragments per cylinder (38 cylinders) = 22,648 fragments

RD-P16-002		
1	,	
ignature	<u>ARRIEL-Wood</u> Printed Name	<u>12/15/94</u> Date
ignature	Printed Name	<u> 2-15-44</u> Date
ignature	Printed Name	<u>  2/16/94</u> Date
	(Hydrogen Trailer - ( RD-P16-002 ignature ignature	ignature <u>Printed Name</u> <u>I. Achiment</u> <u>Joseph A. Schrine</u> ignature <u>Printed Name</u> <u>Joseph A. Schrine</u> <u>Printed Name</u> <u>WILLIAM IMERATOR</u>

The following calculations identify those distances at which the overpressures are 1 psi and 10 psi.

### AIRBLAST EFFECTS ON PERSONNEL AND PROPERTY

<u>Dose (psi)</u>	Effect
1.0	Partial demolition of houses; made uninhabitable
1.0-8.0	Range from slight to serious injuries due to skin lacerations from flying glass
	and other missiles with eardrum rupture evidenced at 3.4 psi.
10.0	Threshold for lung rupture and probable total building destruction.

 $R_G$  = Ground distances W = TNT equivalent in lbs including a 20% safety factor  $Z_G$  = Scaled Ground Distance (ft/lb<sup>1/3</sup>)

Note: Z<sub>G</sub> may be used as a constant if a particular psi is known.

For 1 psi,  $Z_G = 45$ For 10 psi,  $Z_G = 9$ 

$$R_{\rm G} = (W)^{1/3} (Z_{\rm G})$$

A. <u>1 psi</u>

B. <u>10 psi</u>

$$\begin{array}{ll} R_{G} = (4,885.6)^{1/3}(45) & R_{G} = (4,885.6)^{1/3}(9) \\ R_{G} = 763.6 \ \mathrm{ft} & R_{G} = 152.7 \ \mathrm{ft} \end{array}$$

CALCULATION TITLE:	Blast Force to Nea (Hydrogen Trailer	rby Structures - Overpressure of 38 cylinder)	
CALCULATION ID:	RD-P16-003		
REVISION: 0	ΛιΛ	<b>1</b>	
Prepared by: <u>Callie K</u>	<u> </u>	CARRIE L. Wood	<u>12/15/94</u> Date
Checked by:	ignature	Sosenh A. Schriner Printed Name	17  5-94 Date
Approved by: Willie	ignature	WILLIAM THORATON Printed Name	<u>12/16/94</u> Date

To determine the Peak Positive Incident Pressure ( $P_{SO}$ ) impacting the nearest structure (i.e. the walls surrounding the HTSF -5 ft. away and the AMPL - est. 105 ft away), the scaled ground distance ( $Z_G$ ) was calculated and applied to a shock-wave parameter scale for hemispherical TNT surface explosions (Reference 15, Figure 4-12).

 $R_G$  = Ground distances W = TNT equivalent in lbs including a 20% safety factor  $Z_G$  = Scaled Ground Distance (ft/lb<sup>1/3</sup>)

$$Z_{\rm G} = R_{\rm G} / W^{1/3}$$

a.The walls surrounding HTSF<br/>(5 ft from trailer)b.AMPL Building<br/>(approx. 105 ft from trailer) $Z_G = (5 ft)/(4,885.6)^{1/3}$ <br/> $Z_G = .29$  $Z_G = (105 ft)/(4,885.6)^{1/3}$ <br/> $Z_G = 6.19$  $Z_G = (105 ft)/(4,885.6)^{1/3}$ <br/> $Z_G = 6.19$ for a:<br/> $P_{SO} = 9,000 \text{ psi}$ for b:<br/> $P_{SO} = 80 \text{ psi}$ 

CALCULATIO	ON TITLE:	Fragment Velocity (Hydrogen Trailer	at Threshold - Overpressure of 38 cylinders)	
CALCULATI	ON ID:	RD-P16-004		
<b>REVISION:</b>	0		Λ ,	
Prepared by:	Caspie L.	11000	CARRIE L. Wood	<u>12/15/94</u>
Checked by:	Couph 1	gpature <u> <u> <u> </u> <u> </u></u></u>	Printed Name	Date <u>/7_15-9</u> 4 
Approved by:	Willias	Sharten_ gnature	WILLIAM THORNFOR Printed Name	<u>12/16/94</u> Date

The following calculations depict the velocity at which fragments exceed the permissible exposure level of 58 ft/lb as prescribed in DOD 6055.9 (Reference 16). Two fragment sizes are calculated for their velocity: a 7.8 ounce fragment (the largest fragment) and a 1.5 ounce fragment.

Step 1: Given:

- $V_s$  = The velocity in ft/sec at which a given object must travel to achieve 58 ft/lb of energy. W = The weight of the object in pounds.
- C = Constant which is 58.

Step 2:

$$V_s = \frac{C}{W}$$

7.8 ounce fragment A.

$$V_s = \frac{58}{0.4875} = 118.97 \text{ ft/sec}$$

B. 1.5 ounce fragment

 $V_s = \frac{58}{0.09375} = 618.66$  ft/sec

CALCULATION TITLE:	-	travel before dropping below th en Trailer - Overpressure of 38 c	
CALCULATION ID:	RD-P16-005		
REVISION: 0		A	
Prepared by: <u>Ahha</u> , Si	gnature	ARRIE L- Wood Printed Name	<u>12/16/94</u> Date
Checked by:	gnature	Dseph A. Schrinzer Printed Name	<u>12. 16. 94</u> Date
Approved by: Willing	Shinta- gnature	WILLIAM HORATON Printed Name	 Date

The following calculations depict the distances at which fragments contain energies less than the 58 ft/lb threshold as prescribed by DOD 6055.9 (Reference 16).

Step 1: Given:

 $v_s$  = Striking velocity at a given distance.  $v_o$  = Initial velocity. e = Natural antilogarithm.  $R_f$  = Distance traveled by a fragment.  $W_f$  = Weight of the fragment.

Step 2:

$$R_{f} = \frac{\ln \frac{V_{o}}{V_{s}} (W_{f}^{1/3})}{.004}$$

A. <u>7.8 ounce fragment</u>

 $R_{\rm f} = \frac{\ln \frac{2,905}{119} (7.8^{1/3})}{.004} = 1,584.1 \text{ ft}$ 

B. 1.5 ounce fragment

$$R_{f} = \frac{\ln \frac{2,905}{119} (1.5^{1/3})}{.004} = 914.4 \text{ ft}$$

CALCULATION TITLE:	• •	from Cased Cylindrical Charges Supply - Overpressure of a singl	
CALCULATION ID:	RD-B9-001		
<b>REVISION:</b> 0	1 / / Л		
Prepared by:	gnature	CAPRIE L. Wood Printed Name	<u>12/16/94</u> Date
Checked by:	<u>a. Schund</u>	Printed Name	<u> </u>
Approved by: Approved by:	gnature .	William THORNTON Printed Name	<u>12/10/94</u> Date

The following calculations depict the size, velocity, and the distance a fragment would travel in an accident involving the overpressure of a single cylinder. Although multiple cylinders may be involved in an incident, the only factor expected to change significantly would be the number of fragments which would be multiplied by the number of cylinders involved in the event.

Step 1:	Given:	Type of Explosive = Hydrogen
	а.	Density of Explosive (De) in lbs/in <sup>3</sup> = (Density of H <sub>2</sub> in g/cm <sup>3</sup> )/ (Conversion Factor of 27.68) (Reference 15) De = $(0.00008988 \text{ g/cm}^3)/(27.68) = 3.2\text{E-06} \text{ lbs/in}^3$
	b.	Wt. of Fuel in 1 cylinder = (Volume of Fuel)/(Volume of 1 pound of fuel) Wt. = 220 ft <sup>3</sup> /191.3 ft <sup>3</sup> = 1.15 lbs
	с.	Weight of explosive (TNT Equivalent) in 1 cylinder (W) = (Weight of fuel)(TNT Equivalent of 20.5) W = (1.15)(20.5) = 23.58 plus a 20% safety factor = 28.3 lbs
	d.	Outside Diameter of Casing $(d_0) = 9.625$ inches
	e.	Inside Diameter of Casing $(d_i) = 9$ inches
	f.	Thickness of Casing $(t_c) = .3125$ inches
	g.	Length of Charge $(lc) = 51$ inches
	g. h.	Density of Casing (dc) = $8.0 \text{ g/cm}^3$ (.289 lbs/in <sup>3</sup> )

29

CALCULATION TITLE: Primary Fragments from Cased Cylindrical Charges (Hydrogen Backup Supply - Overpressure of a single cylinder)

CALCULATION ID: RD-B9-001 (cont'd)

**REVISION:** 0

Step 2: Total weight of the cylindrical portion of the metal casing (W<sub>c</sub>)

$$W_{c} = \frac{\pi [(od)^{2} - (id)^{2}](lc)(dc)}{4}$$
$$W_{c} = \frac{\pi [(9.625)^{2} - (9)^{2}](51)(0.289)}{4} = 135 \text{ lbs}$$

 $\frac{W}{W_c} = \frac{28.3}{135} = 0.21$  = The ratio of the explosive weight to the casing weight.

TNT in mild steel casing,  $(2E')^{1/2} = 6,940$  (Reference 15, Table 4-2)

$$V_{o} = (2E')^{1/2} \left(\frac{\frac{W}{W_{c}}}{1 + \frac{W}{2W_{c}}}\right)^{1/2}$$

$$V_o = 6,940 \left(\frac{0.21}{1+\frac{0.21}{2}}\right)^{1/2} = 3,025.4 \text{ ft./second}$$

30

CALCULATION TITLE:	Primary Fragments from Cased Cylindrical Charges
	(Hydrogen Backup Supply - Overpressure of a single cylinder)

CALCULATION ID: RD-B9-001 (cont'd)

**REVISION:** 0

Step 4: Fragment Distribution Parameter (M<sub>A</sub>)

The constant for the explosive charge for TNT in mild steel casing (B) = .30 (Reference 15)

$$M_{A} = B(t_{c})^{5/6} d_{i}^{\frac{1}{3}} \left(1 + \frac{t_{c}}{d_{j}}\right)$$

$$M_{A} = .30(0.3125)^{5/6}(9)^{\frac{1}{3}} \left(1 + \frac{0.3125}{9}\right) = 0.245$$

Step 5: Weight of the largest fragment

$$W_{f} = \left[ M_{A} \ln \left( \frac{8 W_{c}}{M_{A}^{2}} \right) \right]^{2}$$
$$W_{f} = \left[ 0.245 \ln \left( \frac{8(135)}{(0.245)^{2}} \right) \right]^{2} = 5.7 \text{ ounces}$$

Step 6: Striking Velocity (V<sub>s</sub>)

If the distance traveled by the fragment is less than 20 feet, the striking velocity is taken as equal to the initial velocity for all size fragments.

Therefore,  $V_s = V_o = 3,025.4$  ft./second

Step 7: Number of fragments having a weight greater than 1-1/2 ounces (Nf)

$$\ln N_{f} = \ln \left[ \frac{8W_{c}}{M_{A}^{2}} \right] - \frac{W_{f}^{1/2}}{M_{A}}$$
$$\ln N_{f} = \ln \left[ \frac{8(135)}{(0.245)^{2}} \right] - \frac{(1.5)^{1/2}}{0.245} = 4.798$$

 $N_f = 121$  fragments

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CALCULATION TITLE:		hold Blast Overpressures p Supply - Overpressure of a singl	le cylinder)
CALCULATION ID:	RD-B9-002		
<b>REVISION:</b> 0	Aria		
Prepared by:	Signature	CARRIE L. WOOD Printed Name	<u> 2  5 94</u> Date
Checked by:	<u>Signature</u>	Joseph A. Schemel Printed Name	<u> </u>
Approved by: Willi	Signature	WILLIAM THORATON Printed Name	<u>  2/(6/94</u> Date

The following calculations identify those distances at which the overpressures are 1 psi and 10 psi.

#### AIRBLAST EFFECTS ON PERSONNEL AND PROPERTY

Dose (psi)	Effect
1.0	Partial demolition of houses; made uninhabitable
1.0-8.0	Range from slight to serious injuries due to skin lacerations from flying glass
	and other missiles with eardrum rupture evidenced at 3.4 psi.
10.0	Threshold for lung rupture and probable total building destruction.

 $\label{eq:RG} \begin{array}{l} R_G = \mbox{Ground distances} \\ W = \mbox{TNT equivalent in lbs including a 20\% safety factor} \\ Z_G = \mbox{Scaled Ground Distance (ft/lb^{1/3})} \end{array}$ 

Note:  $Z_G$  may be used as a constant if a particular psi is known.

For 1 psi,  $Z_G = 45$ For 10 psi,  $Z_G = 9$ 

$$R_{c} = (W)^{1/3} (Z_{c})$$

A. <u>1 psi</u>

B. <u>10 psi</u>

 $R_G = (28.3)^{1/3}(45)$  $R_G = (28.3)^{1/3}(9)$  $R_G = 137.1 \text{ ft}$  $R_G = 27.4 \text{ ft}$ 

CALCULATION TITLE:	Blast Force to Nea (Hydrogen Backuj	arby Structures p Supply - Overpressure of a sing	le cylinder)
CALCULATION ID:	RD-B9-003		
<b>REVISION:</b> 0	Λ		
Prepared by: <u>CalMin</u>	gnature	CARPE L. WOOC	12/15/94
Checked by:	gnature	Soseph A Schriner Printed Name	Date <u>12 15 94</u> Date
Approved by: Wilhing	gnature	WILLIAM THURNTON Printed Name	<u>12/16/9</u> 4 Date

To determine the Peak Positive Incident Pressure  $(P_{SO})$  impacting the nearest structure (i.e. the walls surrounding the HTSF -5 ft. away and the AMPL - est. 105 ft away), the scaled ground distance  $(Z_G)$  was calculated and applied to a shock-wave parameter scale for hemispherical TNT surface explosions (Reference 15, Figure 4-12).

 $R_G$  = Ground distances W = TNT equivalent in lbs including a 20% safety factor  $Z_G$  = Scaled Ground Distance (ft/lb<sup>1/3</sup>)

$$Z_{\rm G} = R_{\rm G} / W^{1/3}$$

b.

a. <u>The walls surrounding HTSF</u> (5 ft from trailer)

> $Z_{\rm G} = (5 \text{ ft})/(28.3)^{1/3}$  $Z_{\rm G} = 1.63$

for a: P<sub>SO</sub> = 800 psi <u>AMPL Building</u> (approx. 105 ft from trailer)

$$Z_{G} = (105 \text{ ft})/(28.3)^{1/3}$$
  
 $Z_{G} = 34.4$ 

for b:  $P_{so} = 6 psi$ 

CALCULATION		y at Threshold p Supply- Overpressure of a sing	le cylinder)
CALCULATION	ID: RD-B9-004		
<b>REVISION:</b> 0	1 A i I A	Λ	
Prepared by:	<u>assie – Wille</u> Signature	<u>ARRIE L. Wood</u> Printed Name	<u> 2 15 94</u> Date
Checked by:	Signature	Printed Name	<u>/2 15-44</u> Date
Approved by: U	Signature	WILLIAM THORATON Printed Name	<u>  2/16/94</u> Date

The following calculations depict the velocity at which fragments exceed the permissible exposure level of 58 ft/lb as prescribed in DOD 6055.9 (Reference 16). Two fragment sizes are calculated for their velocity: a 5.7 ounce fragment (the largest fragment) and a 1.5 ounce fragment.

Step 1: Given:

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 $V_s$  = The velocity in ft/sec at which a given object must travel to achieve 58 ft/lb of energy. W = The weight of the object in pounds.

C = Constant which is 58.

A.

Step 2:

$$V_s = \frac{C}{W}$$

B. <u>1.5 ounce fragment</u>

$$V_s = \frac{58}{0.09375} = 618.66$$
 ft/sec

$$V_s = \frac{58}{0.35625} = 162.8 \text{ ft/sec}$$

5.7 ounce fragment

CALCULATION TITLE:	Distance fragments travel before dropping below threshold
	velocities (Hydrogen Backup Supply - Overpressure of a single
	cylinder)

CALCULATI	<b>ON ID:</b> RD-B9-005		
<b>REVISION:</b>	0	2	
Prepared by:	Carrie L. Marga- Signature	<u>ARRIE L. Willo</u> Printed Name	<u>12/16/94</u> Date
Checked by:	Signature	<u>Disch A. Schemer</u> Printed Name	<u> 12-16-99</u> Date
Approved by:	Willin Shampen Signature	WILLIAM HORATAN Printed Name	12/16/94 Date

The following calculations depict the distances at which fragments contain energies less than the 58 ft/lb threshold as prescribed by DOD 6055.9 (Reference 16).

Step 1: Given:

Step 2:

$$R_{f} = \frac{\ln \frac{V_{\circ}}{V_{s}} (W_{f}^{1/3})}{.004}$$

B.

A. 5.7 ounce fragment

1.5 ounce fragment

$$R_{f} = \frac{\ln \frac{3,025.4}{162.8} (5.7^{1/3})}{.004} = 1,308.1 \,\text{ft}$$

$$R_{f} = \frac{\ln \frac{3,025.4}{618.7} (1.5^{1/3})}{.004} = 454.2 \,\text{ft}$$

CALCULATION TITLE:		from Cased Cylindrical Charges Supply - Overpressure of three of	
CALCULATION ID:	RD-B10-001		
<b>REVISION:</b> 0	1 I I A	2	
Prepared by: Cather	gnature ,	CARRIE L. MOOD Printed Name	<u> 2  6 94</u> Date
Checked by:	gnature	hseph A. Schriner Printed Name	<u>12 16-94</u> Date
Approved by: Willing	Shumfen .	WILLIAM I HORATDA/ Printed Name	<u>12/16/94</u> Date

The following calculations depict the size, velocity, and the distance a fragment would travel in an accident involving the overpressure of a single cylinder. Although multiple cylinders may be involved in an incident, the only factor expected to change significantly would be the number of fragments which would be multiplied by the number of cylinders involved in the event.

Step 1:	Given:	Type of Explosive = Hydrogen
	а.	Density of Explosive (De) in lbs/in <sup>3</sup> = (Density of H <sub>2</sub> in g/cm <sup>3</sup> )/ (Conversion Factor of 27.68) (Reference 15) De = $(0.00008988 \text{ g/cm}^3)/(27.68) = 3.2\text{E-06} \text{ lbs/in}^3$
	b.	Wt. of Fuel in 3 cylinders = (Volume of Fuel)/(Volume of 1 lb. of fuel) Wt. = $660 \text{ ft}^3/191.3 \text{ ft}^3 = 3.45 \text{ lbs}$
	с.	Weight of explosive (TNT Equivalent) in 1 cylinder (W) = (Weight of fuel)(TNT Equivalent of 20.5) W = (3.45)(20.5) = 70.73 + a 20% safety factor = 84.9 lbs
	d.	Outside Diameter of Casing $(d_0) = 9.625$ inches
	e.	Inside Diameter of Casing $(d_i) = 9$ inches
	f.	Thickness of Casing $(t_c) = .3125$ inches
	g.	Length of Charge $(lc) = 51$ inches
	ĥ.	Density of Casing (dc) = $8.0 \text{ g/cm}^3$ (.289 lbs/in <sup>3</sup> )

#### CALCULATION TITLE: Primary Fragments from Cased Cylindrical Charges (Hydrogen Backup Supply - Overpressure of three cylinders)

CALCULATION ID: RD-B10-001 (cont'd)

#### **REVISION:** 0

Step 2: Total weight of the cylindrical portion of the metal casing (W<sub>c</sub>)

$$W_{c} = \frac{\pi [(od)^{2} - (id)^{2}](lc)(dc)}{4}$$

$$W_{c} = \frac{\pi [(9.625)^{2} - (9)^{2}](51)(0.289)}{4} = 135$$
 lbs

 $\frac{W}{W_c} = \frac{28.3}{135} = 0.21 = \text{The ratio of the explosive weight to the casing weight.}$ 

Step 3: Initial Fragment Velocity (V<sub>0</sub>)

TNT in mild steel casing,  $(2E')^{1/2} = 6,940$  (Reference 15, Table 4-2)

$$V_{o} = (2E')^{1/2} \left(\frac{\frac{W}{W_{c}}}{1 + \frac{W}{2W_{c}}}\right)^{1/2}$$

$$V_o = 6,940 \left(\frac{0.21}{1+\frac{0.21}{2}}\right)^{1/2} = 3,025.4 \text{ ft./second}$$

CALCULATION TITLE:	Primary Fragments from Cased Cylindrical Charges (Hydrogen Backup Supply - Overpressure of three cylinders)

CALCULATION ID: RD-B10-001 (cont'd)

**REVISION:** 0

Step 4: Fragment Distribution Parameter (M<sub>A</sub>)

The constant for the explosive charge for TNT in mild steel casing (B) = .30 (Reference 15)

MA = B(tc)<sup>5/6</sup> di<sup>$$\frac{1}{3} \left(1 + \frac{tc}{d_j}\right)$$</sup>

$$M_{A} = .30(0.3125)^{5/6}(9)^{\frac{1}{3}} \left(1 + \frac{0.3125}{9}\right) = 0.245$$

Step 5: Weight of the largest fragment

$$W_{f} = \left[ M_{A} \ln \left( \frac{8 W_{c}}{M_{A}^{2}} \right) \right]^{2}$$
$$W_{f} = \left[ 0.245 \ln \left( \frac{8(135)}{(0.245)^{2}} \right) \right]^{2} = 5.7 \text{ ounces}$$

Step 6: Striking Velocity (V<sub>s</sub>)

If the distance traveled by the fragment is less than 20 feet, the striking velocity is taken as equal to the initial velocity for all size fragments.

Therefore,  $V_s = V_0 = 3,025.4$  ft./second

Step 7: Number of fragments having a weight greater than 1-1/2 ounces (N<sub>f</sub>)

$$\ln N_{f} = \ln \left[ \frac{8W_{c}}{M_{A}^{2}} \right] - \frac{W_{f}^{1/2}}{M_{A}}$$
$$\ln N_{f} = \ln \left[ \frac{8(135)}{(0.245)^{2}} \right] - \frac{(1.5)^{1/2}}{0.245} = 4.798$$

 $N_f = 121$  fragments (3 cylinders) = 363 fragments

	ance to Threshold Blast Overpressures frogen Backup Supply - Overpressure of three cylind	lers)
CALCULATION ID: RD-H	B10-002	
<b>REVISION:</b> 0		
Prepared by:	re <u>ARRIEL-Wood</u> 12, re Printed Name	<u>/15/94</u> Date
Checked by:	re <u>Soseph A. Schriner</u> 12-	<u>-15-94</u> Date
Approved by: William Signatur	re William HKirkton 12/	<u>16/9 1</u> Date

The following calculations identify those distances at which the overpressures are 1 psi and 10 psi.

### AIRBLAST EFFECTS ON PERSONNEL AND PROPERTY

<u>Dose (psi)</u>	Effect
1.0	Partial demolition of houses; made uninhabitable
1.0-8.0	Range from slight to serious injuries due to skin lacerations from flying glass
	and other missiles with eardrum rupture evidenced at 3.4 psi.
10.0	Threshold for lung rupture and probable total building destruction.

 $R_G$  = Ground distances W = TNT equivalent in lbs including a 20% safety factor  $Z_G$  = Scaled Ground Distance (ft/lb<sup>1/3</sup>)

Note:  $Z_G$  may be used as a constant if a particular psi is known.

For 1 psi,  $Z_G = 45$ For 10 psi,  $Z_G = 9$ 

$$R_G = (W)^{1/3} (Z_G)$$

A. <u>1 psi</u>

B. <u>10 psi</u>

 $R_G = (84.9)^{1/3}(45)$  $R_G = (84.9)^{1/3}(9)$  $R_G = 197.8 \text{ ft}$  $R_G = 39.6 \text{ ft}$ 

CALCULATION TITLE:	Blast Force to Near (Hydrogen Backup	by Structures Supply - Overpressure of threee	cylinders)
CALCULATION ID:	RD-B10-003		
REVISION: 0	ΛιΛ	<i>.</i> <b>)</b> <i></i>	
Prepared by: <u>Calkin L</u>	gnature / /	<u>ARRIE L. Wood</u> Printed Name	<u>12/15/94</u> Date
Checked by:	gnature	Printed Name	<u> </u>
Approved by: (1) illi	gnature	WILLIAM RORATON Printed Name	<u>12/16/94</u> Date

To determine the Peak Positive Incident Pressure  $(P_{SQ})$  impacting the nearest structure (i.e. the walls surrounding the HTSF -5 ft. away and the AMPL - est. 105 ft away), the scaled ground distance  $(Z_G)$  was calculated and applied to a shock-wave parameter scale for hemispherical TNT surface explosions (Reference 15, Figure 4-12).

 $R_G$  = Ground distances W = TNT equivalent in lbs including a 20% safety factor  $Z_G$  = Scaled Ground Distance (ft/lb<sup>1/3</sup>)

$$Z_{G} = R_{G} / W^{1/3}$$

a. The walls surrounding HTSF (5 ft from trailer)  $Z_{G} = (5 \text{ ft})/(84.9)^{1/3}$   $Z_{G} = 1.14$ for a: P\_{SO} = 80 \text{ psi}
b. <u>AMPL Building</u> (approx. 105 ft from trailer)  $Z_{G} = (105 \text{ ft})/(84.9)^{1/3}$   $Z_{G} = 23.9$ for b: P\_{SO} = 7 \text{ psi}

CALCULATION TITLE:	Fragment Velocity (Hydrogen Backup	at Threshold Supply- Overpressure of three c	ylinders)
CALCULATION ID:	RD-B10-004		
REVISION: 0		Λ	
Prepared by: Callie K	gpature	ARRIE L- WOOd Printed Name	<u>12/15/94</u> Date
Checked by:	<u>Achina</u> gnature	Printed Name	<u>12-15-94</u> Date
Approved by: Williem	Shamps	WILLIAM THORATON	<u>17/16/9</u> 4 Date

The following calculations depict the velocity at which fragments exceed the permissible exposure level of 58 ft/lb as prescribed in DOD 6055.9 (Reference 16). Two fragment sizes are calculated for their velocity: a 5.7 ounce fragment (the largest fragment) and a 1.5 ounce fragment.

Step 1: Given:

- $V_s$  = The velocity in ft/sec at which a given object must travel to achieve 58 ft/lb of energy. W = The weight of the object in pounds.
- C = Constant which is 58.

Step 2:

$$V_s = \frac{C}{W}$$

A. 5.7 ounce fragment

 $V_s = \frac{58}{0.35625} = 162.8 \text{ ft/sec}$ 

$$V_s = \frac{58}{0.09375} = 618.66$$
 ft/sec

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CALCULATION TITLE: Distance fragments travel before dropping below threshold velocities (Hydrogen Backup Supply - Overpressure of three cylinders)

CALCULATIO	<b>N ID:</b> RD-B10-005		
<b>REVISION:</b>	0	$\rho$ , $\epsilon$	
Prepared by:	<u>Alui L. Wood</u> Signature	CARRIEL. Wood Printed Name	<u> 2/16/94</u> Date
Checked by:	Signature	Joseph A. Schemer Printed Name	<u>/2-16 44</u> Date
Approved by:	Willim Shamfon Signature	WILLIAM THOONTON Printed Name	<u>12/16/94</u> Date

The following calculations depict the distances at which fragments contain energies less than the 58 ft/lb threshold as prescribed by DOD 6055.9 (Reference 16).

Step 1: Given:

 $v_s$  = Striking velocity at a given distance.  $v_o$  = Initial velocity. e = Natural antilogarithm.  $R_f$  = Distance traveled by a fragment.  $W_f$  = Weight of the fragment.

Step 2:

$$R_{f} = \frac{\ln \frac{V_{o}}{V_{s}} (W_{f}^{1/3})}{.004}$$

A. <u>5.7 ounce fragment</u>

B. <u>1.5 ounce fragment</u>

$$R_{f} = \frac{\ln \frac{3,025.4}{162.8} (5.7^{1/3})}{.004} = 1,308.1 \,\text{ft}$$

$$R_{f} = \frac{\ln \frac{3,025.4}{618.7} (1.5^{1/3})}{.004} = 454.2 \,\text{ft}$$

CALCULATION TITLE:		ts from Cased Cylindrical Charg p Supply - Overpressure of twelv	
CALCULATION ID:	RD-B11-001		
<b>REVISION:</b> 0	Acta	$\rho$	
Prepared by: <u><u>Allie</u></u>	gyature	<u>APRIE L. WORC</u> Printed Name	<u> 2/16/99</u> Date
Checked by:	gnature	Joseph A. Schuner Printed Name	<u>12 · 16 - 44</u> Date
Approved by: Willici	gnature	WILLIAM HORATON Printed Name	<u>12/16/94</u> Date
······			

The following calculations depict the size, velocity, and the distance a fragment would travel in an accident involving the overpressure of a single cylinder. Although multiple cylinders may be involved in an incident, the only factor expected to change significantly would be the number of fragments which would be multiplied by the number of cylinders involved in the event.

Step 1:	Given:	Type of Explosive = Hydrogen
	a.	Density of Explosive (De) in lbs/in <sup>3</sup> = (Density of H <sub>2</sub> in g/cm <sup>3</sup> )/ (Conversion Factor of 27.68) (Reference 15) De = $(0.00008988 \text{ g/cm}^3)/(27.68) = 3.2\text{E-06} \text{ lbs/in}^3$
	b.	Wt. of Fuel in 3 cylinders = (Volume of Fuel)/(Volume of 1 lb. of fuel) Wt. = 2,640 ft <sup>3</sup> /191.3 ft <sup>3</sup> = 13.8 lbs
	с.	Weight of explosive (TNT Equivalent) in 1 cylinder (W) = (Weight of fuel)(TNT Equivalent of 20.5) W = (13.8)(20.5) = 282.9 + a 20% safety factor = 339.5 lbs
	d.	Outside Diameter of Casing $(d_0) = 9.625$ inches
	e.	Inside Diameter of Casing $(d_i) = 9$ inches
	f.	Thickness of Casing $(t_c) = .3125$ inches
	g.	Length of Charge $(lc) = 51$ inches
	ĥ.	Density of Casing (dc) = $8.0 \text{ g/cm}^3$ (.289 lbs/in <sup>3</sup> )

CALCULATION TITLE: Primary Fragments from Cased Cylindrical Charges (Hydrogen Backup Supply - Overpressure of twelve cylinders)

CALCULATION ID: RD-B11-001 (cont'd)

**REVISION:** 0

Step 2: Total weight of the cylindrical portion of the metal casing (W<sub>c</sub>)

$$W_{c} = \frac{\pi [(od)^{2} - (id)^{2}](lc)(dc)}{4}$$
$$W_{c} = \frac{\pi [(9.625)^{2} - (9)^{2}](51)(0.289)}{4} = 135 \text{ lbs}$$

 $\frac{W}{W_c} = \frac{28.3}{135} = 0.21 = \text{The ratio of the explosive weight to the casing weight.}$ 

Step 3: Initial Fragment Velocity (V<sub>0</sub>)

TNT in mild steel casing,  $(2E')^{1/2} = 6,940$  (Reference 15, Table 4-2)

$$V_o = (2E')^{1/2} \left(\frac{\frac{W}{W_c}}{1+\frac{W}{2W_c}}\right)^{1/2}$$

$$V_{o} = 6,940 \left(\frac{0.21}{1+\frac{0.21}{2}}\right)^{1/2} = 3,025.4 \,\text{ft./second}$$

CALCULATION TITLE:	Primary Fragments from Cased Cylindrical Charges
	(Hydrogen Backup Supply - Overpressure of twelve
	cylinders)

CALCULATION ID: RD-B11-001 (cont'd)

**REVISION:** 0

Step 4: Fragment Distribution Parameter (M<sub>A</sub>)

The constant for the explosive charge for TNT in mild steel casing (B) = .30 (Reference 15)

$$M_{A} = B(t_{c})^{5/6} d_{i}^{\frac{1}{3}} \left(1 + \frac{t_{c}}{d_{j}}\right)$$

$$M_{A} = .30(0.3125)^{5/6} (9)^{\frac{1}{3}} \left(1 + \frac{0.3125}{9}\right)^{\frac{1}{2}} = 0.245$$

Step 5: Weight of the largest fragment

$$W_{f} = \left[ M_{A} \ln \left( \frac{8 W_{c}}{M_{A}^{2}} \right) \right]^{2}$$
$$W_{f} = \left[ 0.245 \ln \left( \frac{8(135)}{(0.245)^{2}} \right) \right]^{2} = 5.7 \text{ ounces}$$

Step 6: Striking Velocity (V<sub>s</sub>)

If the distance traveled by the fragment is less than 20 feet, the striking velocity is taken as equal to the initial velocity for all size fragments.

Therefore,  $V_s = V_o = 3,025.4$  ft./second

Step 7: Number of fragments having a weight greater than 1-1/2 ounces (N<sub>f</sub>)

$$\ln N_{\rm f} = \ln \left[ \frac{8W_{\rm c}}{M_{\rm A}^2} \right] - \frac{W_{\rm f}^{1/2}}{M_{\rm A}}$$
$$\ln N_{\rm f} = \ln \left[ \frac{8(135)}{(0.245)^2} \right] - \frac{(1.5)^{1/2}}{0.245} = 4.798$$

 $N_f = 121$  fragments (12 cylinders) = 1,452 fragments

CALCULATION TITLE: Distance to Threshold Blast Overpressures (Hydrogen Backup Supply - Overpressure of twelve cylinders)	
--------------------------------------------------------------------------------------------------------------------------------	--

CALCULATIO	<b>NID:</b> RD-B11-002		
<b>REVISION:</b>	0 1/11	$\wedge$	,
Prepared by:	Carrie L. Wood	CARRIE L-Wood Printed Name	<u> 2 15/94</u> Date
Checked by:	Signature	Doseph A. Shrince Printed Name	<u>/2 (5-94</u> Date
Approved by:	William Thomas Signature	WILLIAM THORATON Printed Name	<u>/2/16/G4</u> Date

The following calculations identify those distances at which the overpressures are 1 psi and 10 psi.

#### AIRBLAST EFFECTS ON PERSONNEL AND PROPERTY

Dose (psi)	Effect
1.0	Partial demolition of houses; made uninhabitable
1.0-8.0	Range from slight to serious injuries due to skin lacerations from flying glass
	and other missiles with eardrum rupture evidenced at 3.4 psi.
10.0	Threshold for lung rupture and probable total building destruction.

 $R_G$  = Ground distances W = TNT equivalent in lbs including a 20% safety factor  $Z_G$  = Scaled Ground Distance (ft/lb<sup>1/3</sup>)

Note:  $Z_G$  may be used as a constant if a particular psi is known.

For 1 psi,  $Z_G = 45$ For 10 psi,  $Z_G = 9$  $R_G = (W)^{1/3} (Z_G)$ 

Α. <u>1 psi</u> B. <u>10 psi</u>

$$R_G = (339.5)^{1/3}(45)$$
 $R_G = (339.5)^{1/3}(9)$  $R_G = 312.75 \text{ ft}$  $R_G = 62.82 \text{ ft}$ 

CALCULATIO	N TITLE:	Blast Force to Nea (Hydrogen Backup cylinders)	rby Structures Supply - Overpressure of twelv	e
CALCULATIO	N ID:	RD-B11-003		
<b>REVISION:</b>	0	1 л		
Prepared by:	Cattie L.	CIBO gnature	<u>APRIE L. (Ibcc</u> Printed Name	<u>12/15/94</u> Date
Checked by:	Couple (	gnature	Soseph A. Schriner Printed Name	<u>/2 (5-9</u> 4) Date
Approved by:	Willinsi	gnature	WILLIAM HORATON Printed Name	<u>12/16/</u> G4 Date

To determine the Peak Positive Incident Pressure  $(P_{SO})$  impacting the nearest structure (i.e. the walls surrounding the HTSF -5 ft. away and the AMPL - est. 105 ft away), the scaled ground distance  $(Z_G)$  was calculated and applied to a shock-wave parameter scale for hemispherical TNT surface explosions (Reference 15, Figure 4-12).

 $R_G$  = Ground distances W = TNT equivalent in lbs including a 20% safety factor  $Z_G$  = Scaled Ground Distance (ft/lb<sup>1/3</sup>)

$$Z_{G} = R_{G} / W^{1/3}$$

a. <u>The walls surrounding HTSF</u> (5 ft from trailer)

$$Z_{\rm G} = (5 \text{ ft})/(339,5)^{1/3}$$
  
 $Z_{\rm G} = .72$ 

for a: P<sub>SO</sub> = 3,000 psi b. <u>AMPL Building</u> (approx. 105 ft from trailer)

> $Z_G = (105 \text{ ft})/(339.5)^{1/3}$  $Z_G = 15.04$

for b: P<sub>so</sub> = 8 psi

CALCULATION TITLE:	Fragment Velocity (Hydrogen Backup cylinders)	at Threshold Supply- Overpressure of twelve	
CALCULATION ID:	RD-B11-004		
<b>REVISION:</b> 0	Arres	2	
Prepared by: Caller Si	gnature	ARRIE L. U.GOC	<u> 2/15/94</u> Date
Checked by:	Achnull	Printed Name	<u>12-15-9</u> 4 Date
Approved by: Willing	gnature	WILLIAM THURATON Printed Name	<u>  2 / 1 6 / 9</u> 4 Date

The following calculations depict the velocity at which fragments exceed the permissible exposure level of 58 ft/lb as prescribed in DOD 6055.9 (Reference 16). Two fragment sizes are calculated for their velocity: a 5.7 ounce fragment (the largest fragment) and a 1.5 ounce fragment.

Step 1: Given:

 $V_s$  = The velocity in ft/sec at which a given object must travel to achieve 58 ft/lb of energy. W = The weight of the object in pounds. C = Constant which is 58.

Step 2:

$$V_s = \frac{C}{W}$$

A. <u>5.7 ounce fragment</u>

$$V_s = \frac{58}{0.35625} = 162.8$$
 ft/sec

B. <u>1.5 ounce fragment</u>

$$V_s = \frac{58}{0.09375} = 618.66$$
 ft/sec

CALCULATION TITLE:	Distance fragments travel before dropping below threshold
	velocities (Hydrogen Backup Supply - Overpressure of twelve
	cylinders)

CALCULATION ID: RD-B11-005

<b>REVISION:</b>	0		
Prepared by:	<u>Signature</u>	AFRIE L. Wood Printed Name	<u>12/16/99</u> Date
Checked by:	Geoph I. Schning Signature	Printed Name	<u> /Z_ 16 - 44</u> Date
Approved by:	Willin Short Signature	WILLIAM HERATON Printed Name	<u>12/16/94</u> Date

The following calculations depict the distances at which fragments contain energies less than the 58 ft/lb threshold as prescribed by DOD 6055.9 (Reference 16).

Step 1: Given:

 $v_s = \text{Striking velocity at a given distance.} \\ v_o = \text{Initial velocity.} \\ e = \text{Natural antilogarithm.} \\ R_f = \text{Distance traveled by a fragment.} \\ W_f = \text{Weight of the fragment.}$ 

Step 2:

$$R_{\rm f} = \frac{\ln \frac{V_{\rm o}}{V_{\rm s}} (W_{\rm f}^{1/3})}{.004}$$

A. <u>5.7 ounce fragment</u>

B. <u>1.5 ounce fragment</u>

$$R_{f} = \frac{\ln \frac{3,025.4}{162.8} (5.7^{1/3})}{.004} = 1,308.1 \,\text{ft}$$

$$R_{f} = \frac{\ln \frac{3,025.4}{618.7} (1.5^{1/3})}{.004} = 454.2 \,\text{ft}$$

CALCULATION TITLE:	• •	from Cased Cylindrical Charges Supply - Overpressure of eighte	
CALCULATION ID:	RD-B12-001		
<b>REVISION:</b> 0	Λιια		
Prepared by: Si	gnature	CARRIE L. Wood	<u> 2/16/94</u> Date
Checked by:	gnature	Soch A Scharer	<u>12-16-94</u> Date
Approved by:	gnature	WILLIAM THORATON Printed Name	<u>12/16/9</u> 4 Date

The following calculations depict the size, velocity, and the distance a fragment would travel in an accident involving the overpressure of a single cylinder. Although multiple cylinders may be involved in an incident, the only factor expected to change significantly would be the number of fragments which would be multiplied by the number of cylinders involved in the event.

Step 1:	Given:	Type of Explosive = Hydrogen
	a.	Density of Explosive (De) in lbs/in <sup>3</sup> = (Density of H <sub>2</sub> in g/cm <sup>3</sup> )/ (Conversion Factor of 27.68) (Reference 15) De = $(0.00008988 \text{ g/cm}^3)/(27.68) = 3.2\text{E-}06 \text{ lbs/in}^3$
	b.	Wt. of Fuel in 3 cylinders = (Volume of Fuel)/(Volume of 1 lb. of fuel) Wt. = 3,960 ft <sup>3</sup> /191.3 ft <sup>3</sup> = 20.7 lbs
	c.	Weight of explosive (TNT Equivalent) in 1 cylinder (W) = (Weight of fuel)(TNT Equivalent of 20.5) W = (20.7)(20.5) = 424.4 + a 20% safety factor = 509.3 lbs
	d.	Outside Diameter of Casing $(d_0) = 9.625$ inches
	e.	Inside Diameter of Casing $(d_i) = 9$ inches
	f.	Thickness of Casing $(t_c) = .3125$ inches
	g.	Length of Charge $(lc) = 51$ inches
	h.	Density of Casing (dc) = $8.0 \text{ g/cm}^3$ (.289 lbs/in <sup>3</sup> )

#### CALCULATION TITLE: Primary Fragments from Cased Cylindrical Charges (Hydrogen Backup Supply - Overpressure of eighteen cylinders)

CALCULATION ID: RD-B12-001 (cont'd)

**REVISION:** 0

Step 2: Total weight of the cylindrical portion of the metal casing (W<sub>c</sub>)

$$W_{c} = \frac{\pi [(od)^{2} - (id)^{2}](lc)(dc)}{4}$$
$$W_{c} = \frac{\pi [(9.625)^{2} - (9)^{2}](51)(0.289)}{4} = 135 \text{ lbs}$$

 $\frac{W}{W_c} = \frac{28.3}{135} = 0.21 = \text{The ratio of the explosive weight to the casing weight.}$ 

Step 3: Initial Fragment Velocity (V<sub>0</sub>)

TNT in mild steel casing,  $(2E')^{1/2} = 6,940$  (Reference 15, Table 4-2)

$$V_{o} = (2E')^{1/2} \left(\frac{\frac{W}{W_{c}}}{1 + \frac{W}{2W_{c}}}\right)^{1/2}$$

$$V_o = 6,940 \left(\frac{0.21}{1+\frac{0.21}{2}}\right)^{1/2} = 3,025.4 \text{ ft./second}$$

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CALCULATION TITLE: Primary Fragments from Cased Cylindrical Charges (Hydrogen Backup Supply - Overpressure of eighteen cylinders)

CALCULATION ID: RD-B12-001 (cont'd)

**REVISION:** 0

Step 4: Fragment Distribution Parameter (M<sub>A</sub>)

The constant for the explosive charge for TNT in mild steel casing (B) = .30 (Reference 15)

MA = B(tc)<sup>5/6</sup> di<sup>$$\frac{1}{3} \left(1 + \frac{tc}{d_j}\right)$$</sup>

$$M_{A} = .30(0.3125)^{5/6}(9)^{\frac{1}{3}} \left(1 + \frac{0.3125}{9}\right) = 0.245$$

Step 5: Weight of the largest fragment

$$W_{f} = \left[ M_{A} \ln \left( \frac{8 W_{c}}{M_{A}^{2}} \right) \right]^{2}$$
$$W_{f} = \left[ 0.245 \ln \left( \frac{8(135)}{(0.245)^{2}} \right) \right]^{2} = 5.7 \text{ ounces}$$

Step 6: Striking Velocity (V<sub>s</sub>)

If the distance traveled by the fragment is less than 20 feet, the striking velocity is taken as equal to the initial velocity for all size fragments.

Therefore,  $V_s = V_0 = 3,025.4$  ft./second

Step 7: Number of fragments having a weight greater than 1-1/2 ounces (N<sub>f</sub>)

$$\ln N_{f} = \ln \left[ \frac{8W_{c}}{M_{A}^{2}} \right] - \frac{W_{f}^{1/2}}{M_{A}}$$
$$\ln N_{f} = \ln \left[ \frac{8(135)}{(0.245)^{2}} \right] - \frac{(1.5)^{1/2}}{0.245} = 4.798$$

 $N_f = 121$  fragments (18 cylinders) = 2,178 fragments

CALCULATION TITLE:		old Blast Overpressures Supply - Overpressure of eighte	en
CALCULATION ID:	RD-B12-002		
<b>REVISION:</b> 0	Aun	1	
Prepared by: <u>Callie</u> Si	<u>, /////</u> gnature/	<u>ARRIE L. Wood</u> Printed Name	<u> 2 15 94</u> Date
Checked by:	gnature	Printed Name	<u>17-15-94</u> Date
Approved by: William	gnature	WILLIAM THORATOR Printed Name	12/16/90 Date

The following calculations identify those distances at which the overpressures are 1 psi and 10 psi.

#### AIRBLAST EFFECTS ON PERSONNEL AND PROPERTY

<u>Dose (psi)</u>	Effect
1.0	Partial demolition of houses; made uninhabitable
1.0-8.0	Range from slight to serious injuries due to skin lacerations from flying glass
	and other missiles with eardrum rupture evidenced at 3.4 psi.
10.0	Threshold for lung rupture and probable total building destruction.

 $R_G$  = Ground distances W = TNT equivalent in lbs including a 20% safety factor  $Z_G$  = Scaled Ground Distance (ft/lb<sup>1/3</sup>)

 $R_G = (509.3)^{1/3}(45)$  $R_G = 359.6 \text{ ft}$ 

Note:  $Z_G$  may be used as a constant if a particular psi is known.

For 1 psi,  $Z_G = 45$ For 10 psi,  $Z_G = 9$ 

$$R_{G} = (W)^{1/3} (Z_{G})$$

A. <u>1 psi</u>

 $R_{\rm G} = (509.3)^{1/3}(9)$  $R_{G} = 71.9 \text{ ft}$ 

<u>10 psi</u>

В.

CALCULATION TITLE:		Blast Force to Nearby Structures (Hydrogen Backup Supply - Overpressure of eighteen cylinders)			
CALCULATION ID:		RD-B12-003			
<b>REVISION:</b>	0	1		ţ	
Prepared by:	(asia h	gnature	CARRIE L. Printed	Wood	<u>12/15/94</u> Date
Checked by:	Couple a	gnature	Soseph A Printed	Schnacr	<u>    (2-15-94</u> Date
Approved by:	William	gnature	Nici, Am Printed	HORNTON Name	<u>12/16/94</u> Date

To determine the Peak Positive Incident Pressure ( $P_{SO}$ ) impacting the nearest structure (i.e. the walls surrounding the HTSF -5 ft. away and the AMPL - est. 105 ft away), the scaled ground distance ( $Z_G$ ) was calculated and applied to a shock-wave parameter scale for hemispherical TNT surface explosions (Reference 15, Figure 4-12).

 $R_G$  = Ground distances W = TNT equivalent in lbs including a 20% safety factor  $Z_G$  = Scaled Ground Distance (ft/lb<sup>1/3</sup>)

$$Z_{\rm G} = R_{\rm G} / W^{1/3}$$

a.The walls surrounding HTSF<br/>(5 ft from trailer)b.AMPL Building<br/>(approx. 105 ft from trailer) $Z_G = (5 ft)/(509.3)^{1/3}$ <br/> $Z_G = .63$  $Z_G = (105 ft)/(509.3)^{1/3}$ <br/> $Z_G = 13.14$  $Z_G = (105 ft)/(509.3)^{1/3}$ <br/> $Z_G = 13.14$ for a:<br/> $P_{SO} = 5,000 psi$ for b:<br/> $P_{SO} = 8 psi$ 

CALCULATION	Ç .	y at Threshold p Supply- Overpressure of eighted	en cylinders)
CALCULATION	<b>ID:</b> RD-B12-004		
<b>REVISION:</b> 0	$\rho$ $\Lambda$ $\Lambda$ $\Lambda$		
Prepared by:	Signature	<u>AFFIE L. Ward</u> Printed Name	<u> 2/15/9</u> 4 Date
Checked by:	Joseph A. Schumer Signature	Joseph A. Schriner Printed Name	<u>/2-/5-9</u> 4 Date
Approved by:	William Shownfan Signature	WILLIAM HORNTON Printed Name	<u>12416 (</u> 14 Date

The following calculations depict the velocity at which fragments exceed the permissible exposure level of 58 ft/lb as prescribed in DOD 6055.9 (Reference 16). Two fragment sizes are calculated for their velocity: a 5.7 ounce fragment (the largest fragment) and a 1.5 ounce fragment.

Step 1: Given:

 $V_s$  = The velocity in ft/sec at which a given object must travel to achieve 58 ft/lb of energy. W = The weight of the object in pounds.

C = Constant which is 58.

Step 2:

$$V_s = \frac{C}{W}$$

5.7 ounce fragment A.

$$V_s = \frac{58}{0.35625} = 162.8 \text{ ft/sec}$$

B. 1.5 ounce fragment

$$V_s = \frac{58}{0.09375} = 618.66$$
 ft/sec

**CALCULATION TITLE:** Distance fragments travel before dropping below threshold velocities (Hydrogen Backup Supply - Overpressure of eighteen cylinders)

RD-B12-005		
Λιια		
11000	CARRIE L. Wood	12/16/94
Signature / /	, Printed Name	Date
<u>I Settime</u>	Dech H. Schriner	<u>17-//e 94</u> Date
Thomas	WILLIAM THORITON Printed Name	<u>12/16/94</u> Date
	Signature Signature Signature	Signature Signature Signature Signature Thomas William HopArton

The following calculations depict the distances at which fragments contain energies less than the 58 ft/lb threshold as prescribed by DOD 6055.9 (Reference 16).

Step 1: Given:

 $v_s$  = Striking velocity at a given distance.  $v_o$  = Initial velocity. e = Natural antilogarithm.  $R_f$  = Distance traveled by a fragment.  $W_f$  = Weight of the fragment.

Step 2:

$$R_{f} = \frac{\ln \frac{V_{o}}{V_{s}} (W_{f}^{1/3})}{.004}$$

A. <u>5.7 ounce fragment</u>

B. <u>1.5 ounce fragment</u>

$$R_{f} = \frac{\ln \frac{3,025.4}{162.8} (5.7^{1/3})}{.004} = 1,308.1 \,\text{ft}$$

$$R_{f} = \frac{\ln \frac{3,025.4}{618.7} (1.5^{1/3})}{.004} = 454.2 \,\text{ft}$$

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