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Hydrogen Trailer Storage Facility (Building 878) Consequence Analysis

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Prepared by
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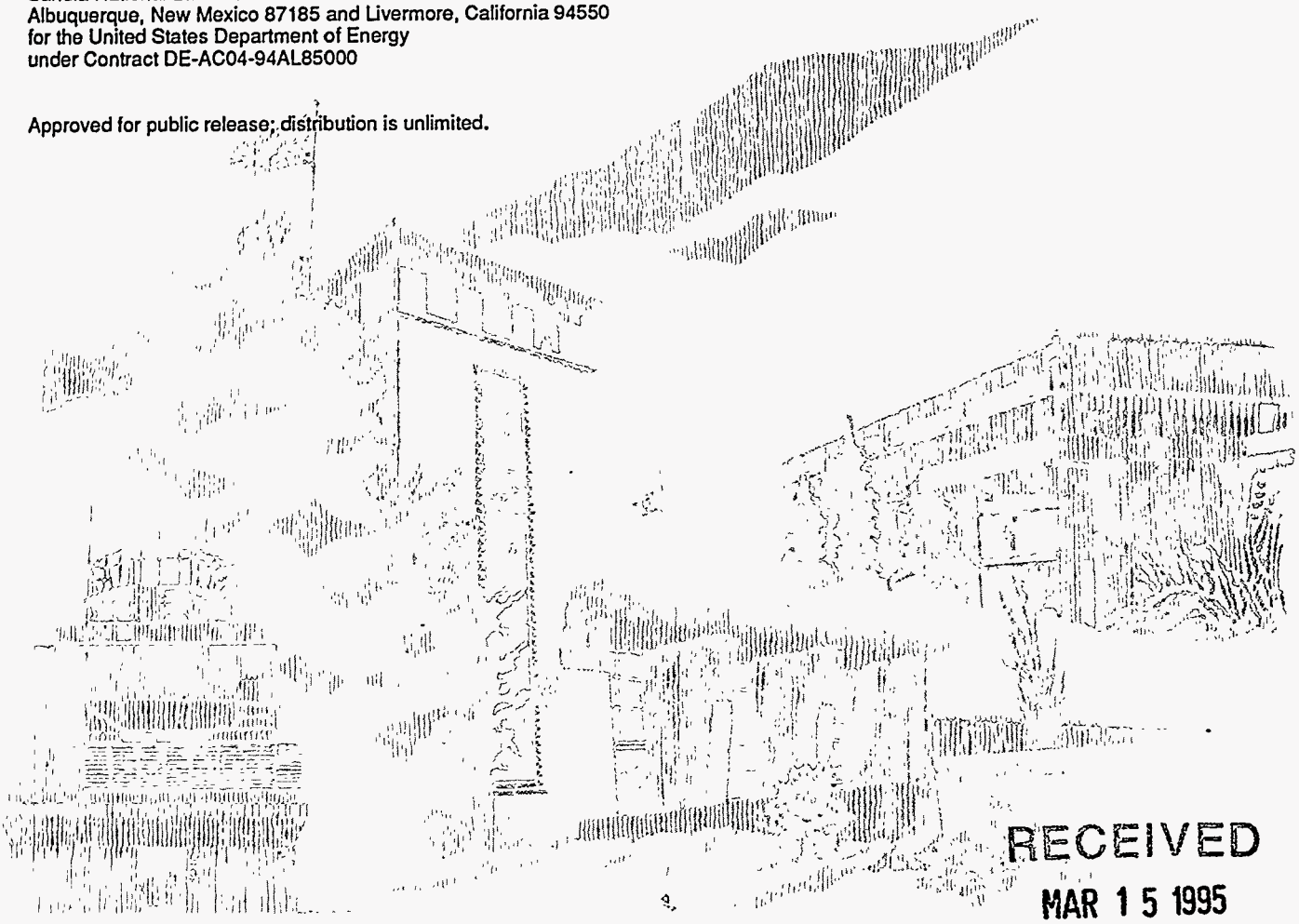

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Abstract

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.

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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.[1] 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."[2]

The maximum amount of hydrogen available for release is 38,000 ft^3 which represents the worst case scenario. The results of the scenarios involving 38,000 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 the Department of Transportation Emergency Response Guidebook.[3]

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 non-flammable 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.

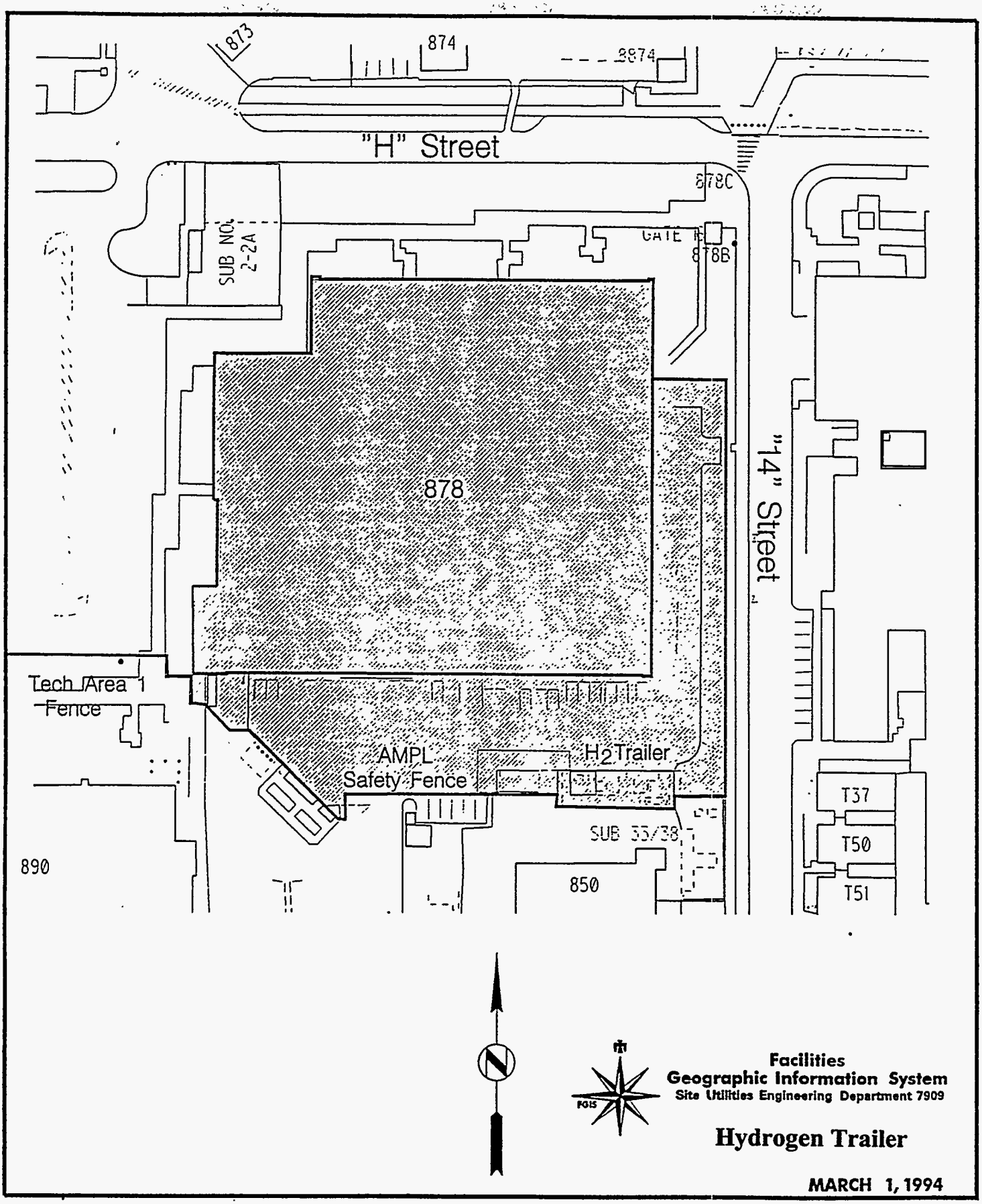
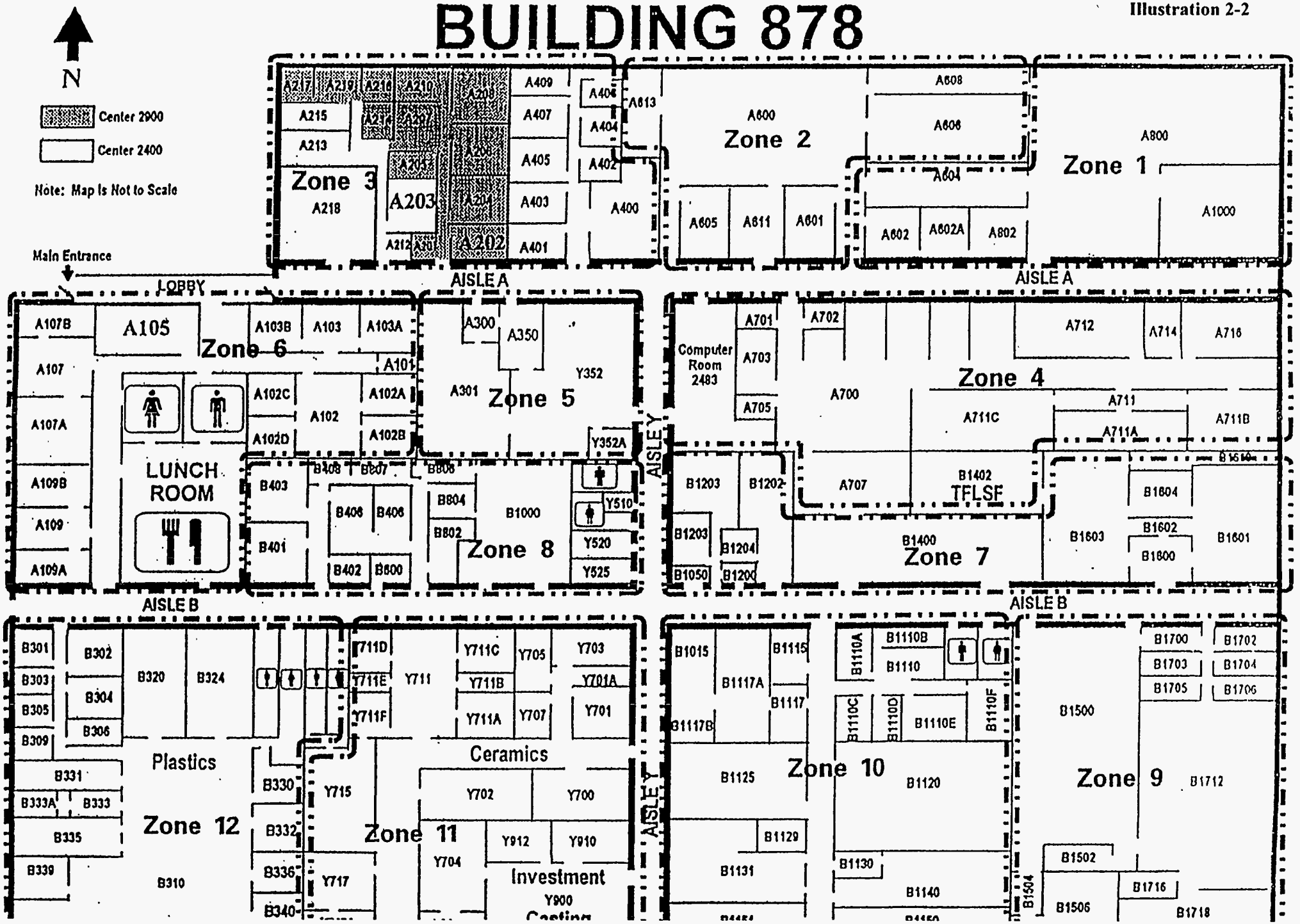


Illustration 2-1

BUILDING 878

Illustration 2-2



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.

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.[4]

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[5] and The National Fire Protection Agency (NFPA) 50A document.[6] 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.[7] 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
• Molecular weight	2.0159
• Specific gravity	0.06952 @ 75° C @ atm
• Density	0.08988 g/liter (7% that of air)
• Melting point	-259° C
• Boiling point	-253° C
• Critical density	0.3136 g/cc
• Critical temperature	-240° C
• Critical pressure	12.8 atm.
• Gross heat of combustion	33.94 cal(gm)/gram.
• Autoig. temp. in air	574° C - 585° C.
• Flammability limits	4.0% to 75.0%.
• Detonation limits	18.3% and 59.0%.
• Heat of vaporization	216. cal(gm)/gm mole° C.
• Specific Volume	1 lb. per 191.3 ft^3

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.[8]

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.[9]

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.

1. 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: [10]

   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.

Table 4.1
Hydrogen Tube Trailer Unconfined Release Scenarios

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

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.

Table 4.2
Hydrogen Tube Trailer Confined Explosion Scenarios

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

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.

1. 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.

Table 4.3
Hydrogen Backup Supply Unconfined Release Scenarios

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

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.

Table 4.4
Hydrogen Backup Supply Confined Explosion Scenarios

Confined Explosion Scenarios	Release Designation
1 cylinder/220 ft^3 of hydrogen	B-9
3 cylinders/660 ft^3 of hydrogen	B-10
12 cylinders/2,640 ft^3 of hydrogen	B-11
18 cylinders/3,960 ft^3 of hydrogen	B-12

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,[11] 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.[12] 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,"[13] 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.

Table 5.1
Hydrogen Tube Trailer

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

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

Table 5.2
Hydrogen Unconfined Release Consequences

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

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.

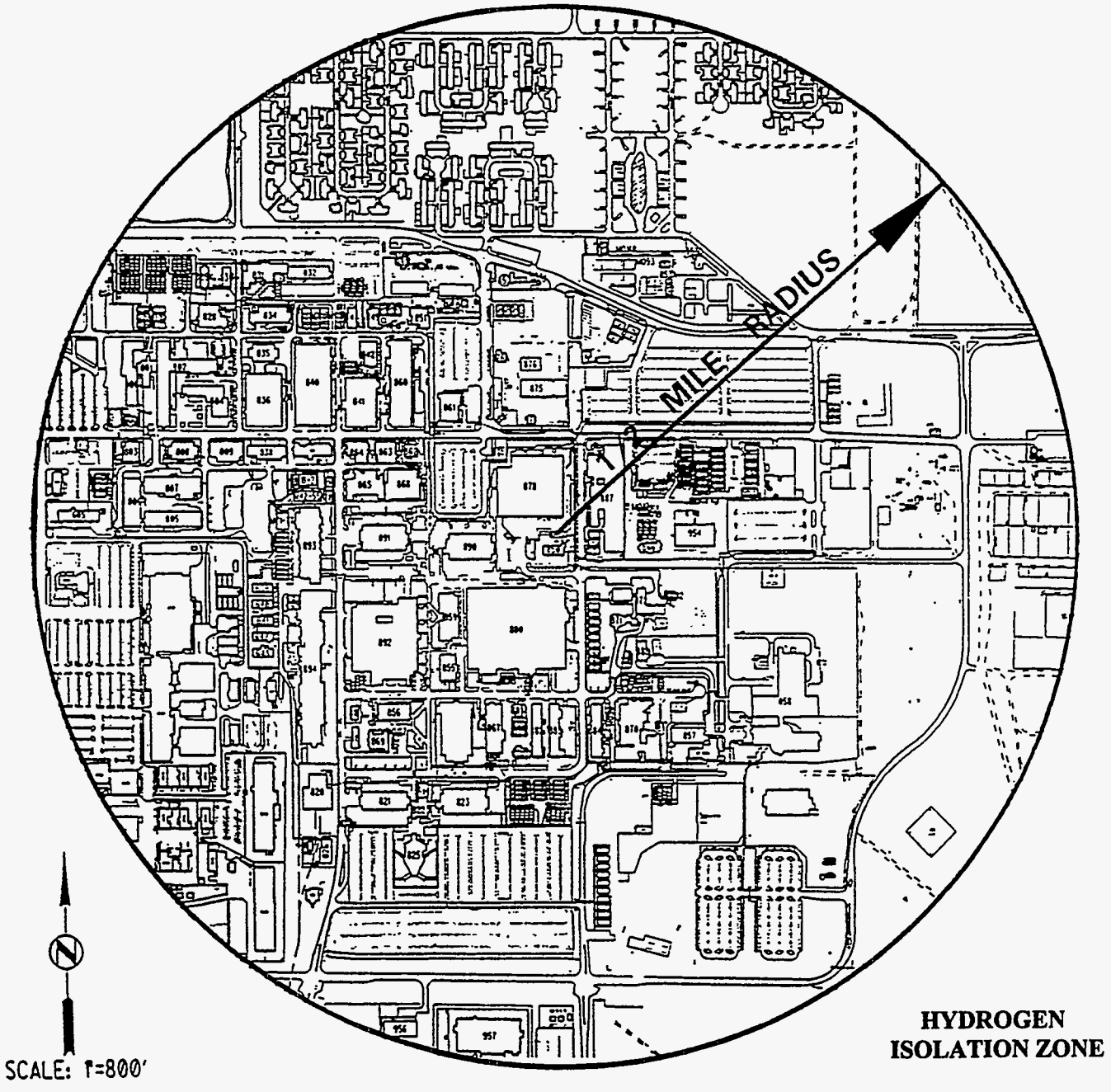


Illustration 5-1

5.2 Confined Explosions

Scenarios involving confined explosions ranged from 220 ft^3 to 38,000 ft^3 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.

Table 5.3

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.

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 (ft/sec)	Distance to Fragment Striking Threshold	Fragment Velocity at Threshold (ft/sec)
P-13 (1)1,000 ft^3	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^3	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^3	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^3	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^3	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^3	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^3	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^3	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

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^3 (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.[14]

6.0 CONCLUSION

As a result of this analysis, the maximum amount of hydrogen available for release is 38,000 ft^3 which represents the worst case scenario. The results of the scenarios involving 38,000 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

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.

******* 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 concentration of 40000 ppm

-- at groundlevel	=	435	feet
-- at discharge height	=	417	feet

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	5.4	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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

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

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

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

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

ISTANCE FROM EXPLOSION (feet)	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 - 7	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.

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	5.24	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 CHARACTERISTICS

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

HAZARDOUS MATERIAL = Hydrogen
ADDRESS \ LOCATION = PDL
DATE OF 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 concentration of 183000 ppm

-- at groundlevel	=	Not observed	
-- at discharge height	=	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

For concentration of	1/2 LFL	LFL	
Downwind hazard distance =	166	126	feet
Max hazard zone width =	83	63	feet
Max weight explosive gas =	5.4	5.4	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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (feet)
32	.01	117665	325152	60
33	.01	121336	309687	58
34	.01	124578	295353	56
35	.01	127409	282048	54
36	.01	129848	269681	52
37	.01	131919	258170	49
37	.01	133643	247444	47
38	.01	135045	237437	44
39	.01	136146	228091	41
40	.01	136971	219352	38
41	.01	137540	211172	34
42	.01	137876	203507	29
42	.01	137998	196318	24
43	.01	137925	189569	17
44	.01	137675	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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
32	.01	.1	.2
33	.01	.1	.2
34	.01	.1	.2
35	.01	.1	.2
36	.01	.1	.2
37	.01	.1	.2
37	.01	.1	.2
38	.01	.1	.2
39	.01	.1	.2
40	.01	.1	.2
41	.01	.1	.2
42	.01	.1	.2
42	.01	.1	.2
43	.01	.1	.2
44	.01	.1	.2

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

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	Horizontal cylinder	
TOTAL WEIGHT OF CONTENTS	=	5.24	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 CHARACTERISTICS

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

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

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 concentration of 40000 ppm

-- at groundlevel	=	435	feet
-- at discharge height	=	417	feet

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	5.4	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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation 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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
100	.02	.6	1.2
124	.03	.8	1.5
148	.03	.9	1.8
172	.04	1	2.1
196	.04	1.2	2.3
220	.05	1.3	2.6
244	.05	1.4	2.9
268	.06	1.6	3.2
291	.06	1.7	3.4
315	.06	1.8	3.7
339	.07	2	4
363	.07	2.1	4.2
387	.08	2.2	4.5
411	.08	2.4	4.8
435	.09	2.5	5

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

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

DISTANCE FROM EXPLOSION (feet)	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 - 7	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.

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	5.24	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 CHARACTERISTICS

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

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

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 concentration of 183000 ppm

-- at groundlevel	=	223	feet
-- at discharge height	=	215	feet

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
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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (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 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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
100	.02	.6	1.2
109	.03	.7	1.3
118	.03	.7	1.4
127	.03	.8	1.5
136	.03	.8	1.7
144	.03	.9	1.7
153	.03	.9	1.8
162	.04	1	1.9
171	.04	1	2
179	.04	1.1	2.1
188	.04	1.1	2.2
197	.04	1.2	2.3
206	.04	1.2	2.4
214	.05	1.3	2.5
223	.05	1.3	2.6

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

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	Horizontal cylinder	
TOTAL WEIGHT OF CONTENTS	=	5.24	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 CHARACTERISTICS

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

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

Downwind distance to concentration of 40000 ppm

-- at groundlevel	=	264	feet
-- at discharge height	=	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	= 35	35	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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (feet)
100	.02	541204	478767	350
112	.03	408945	365860	390
124	.03	315948	285958	430
136	.03	248915	227725	460
147	.03	199494	184267	440
159	.04	162313	151183	430
171	.04	133830	125560	410
182	.04	111653	105415	390
194	.04	94135	89361	360
206	.04	80116	76415	340
217	.05	68764	65860	300
229	.05	59474	57170	270
241	.05	51798	49951	220
253	.05	45399	43904	160
264	.05	40000	38801	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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
100	.02	.2	.3
112	.03	.2	.3
124	.03	.2	.4
136	.03	.2	.4
147	.03	.2	.4
159	.04	.3	.5
171	.04	.3	.5
182	.04	.3	.5
194	.04	.3	.5
206	.04	.3	.6
217	.05	.3	.6
229	.05	.3	.6
241	.05	.4	.7
253	.05	.4	.7
264	.05	.4	.7

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

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

STANCE FROM EXPLOSION (feet)	EXPECTED DAMAGE
369	Occasional breakage of large windows under stress.
52	Some damage to home ceilings; 10% window breakage.
20 - 34	Windows usually shattered; some frame damage.
20	Partial demolition of homes; made uninhabitable.
5 - 20	Range serious/slight injuries from flying glass/object.
12	Partial collapse of home walls/roofs.
9 - 12	Non-reinforced concrete/cinder block walls shattered.
4 - 11	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.
6 - 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.

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	5.24	lbs
DISCHARGE HOLE DIAMETER	=	9	inch(es)
DISCHARGE COEFFICIENT OF HOLE	=	.62	
TEMP OF CONTAINER CONTENTS	=	68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia

ENVIRONMENTAL/LOCATION CHARACTERISTICS

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

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

Downwind distance to concentration of 183000 ppm

-- at groundlevel	=	152	feet
-- at discharge height	=	148	feet

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	= 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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
100	.02	.2	.3
104	.02	.2	.3
108	.03	.2	.3
112	.03	.2	.3
115	.03	.2	.3
119	.03	.2	.4
123	.03	.2	.4
126	.03	.2	.4
130	.03	.2	.4
134	.03	.2	.4
137	.03	.2	.4
141	.03	.2	.4
145	.03	.2	.4
149	.03	.2	.4
152	.03	.2	.4

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

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	Horizontal cylinder	
TOTAL WEIGHT OF CONTENTS	=	5.24	lbs
DISCHARGE HOLE DIAMETER	=	9	inch(es)
DISCHARGE COEFFICIENT OF HOLE	=	.62	
TEMP OF CONTAINER CONTENTS	=	68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia

ENVIRONMENTAL/LOCATION CHARACTERISTICS

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

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

*** 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 height	=	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 = 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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation 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	.09	250618	227401	330
500	.1	183884	169080	370
558	.11	139166	129382	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	38539	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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (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.

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

DISTANCE FROM EXPLOSION (feet)	EXPECTED DAMAGE
369	Occasional breakage of large windows under stress.
52	Some damage to home ceilings; 10% window breakage.
20 - 34	Windows usually shattered; some frame damage.
20	Partial demolition of homes; made uninhabitable.
5 - 20	Range serious/slight injuries from flying glass/object.
12	Partial collapse of home walls/roofs.
9 - 12	Non-reinforced concrete/cinder block walls shattered.
4 - 11	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.
6 - 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.

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	5.24	lbs
DISCHARGE HOLE DIAMETER	=	9	inch(es)
DISCHARGE COEFFICIENT OF HOLE	=	.62	
TEMP OF CONTAINER CONTENTS	=	68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia

ENVIRONMENTAL/LOCATION CHARACTERISTICS

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

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

*** 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 183000 ppm

-- at groundlevel	=	501	feet
-- at discharge height	=	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	=	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	=	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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

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

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

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	Horizontal cylinder	
TOTAL WEIGHT OF CONTENTS	=	5.24	lbs
DISCHARGE HOLE DIAMETER	=	9	inch(es)
DISCHARGE COEFFICIENT OF HOLE	=	.62	
TEMP OF CONTAINER CONTENTS	=	68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia

ENVIRONMENTAL/LOCATION CHARACTERISTICS

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

HAZARDOUS 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 to concentration of 40000 ppm

-- at groundlevel	=	190	feet
-- at discharge height	=	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 =	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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (feet)
100	.02	164977	145944	330
107	.03	146707	130561	320
113	.03	130737	117093	310
120	.03	116785	105268	300
126	.03	104589	94862	290
133	.03	93915	85686	280
139	.03	84556	77578	260
145	.03	76335	70401	250
152	.03	69096	64033	230
158	.03	62707	58373	220
165	.04	57053	53330	200
171	.04	52038	48829	170
177	.04	47576	44801	140
184	.04	43598	41189	98
190	.04	40000	37944	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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
100	.02	.2	.4
107	.03	.2	.4
113	.03	.2	.4
120	.03	.2	.4
126	.03	.2	.4
133	.03	.2	.4
139	.03	.2	.5
145	.03	.2	.5
152	.03	.2	.5
158	.03	.2	.5
165	.04	.3	.5
171	.04	.3	.5
177	.04	.3	.6
184	.04	.3	.6
190	.04	.3	.6

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

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

DISTANCE FROM EXPLOSION (feet)	EXPECTED DAMAGE
285	Occasional breakage of large windows under stress.
41	Some damage to home ceilings; 10% window breakage.
15 - 26	Windows usually shattered; some frame damage.
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.
4	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.

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	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 CHARACTERISTICS

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

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 concentration of 183000 ppm

-- at groundlevel	=	95	feet
-- at discharge height	=	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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (feet)
32	.01	353241	976138	120
37	.01	398128	762495	130
41	.01	413739	616259	150
46	.01	410143	512894	160
50	.01	395204	437583	170
55	.02	374196	380943	160
59	.02	350406	336913	150
64	.02	325804	301555	150
68	.02	301535	272306	140
73	.02	278248	247489	130
77	.02	256287	226000	120
81	.02	235813	207100	97
86	.02	216877	190287	80
90	.02	199459	175204	58
95	.02	183000	161596	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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
32	.01	.1	.2
37	.01	.1	.2
41	.01	.1	.2
46	.01	.1	.2
50	.01	.1	.2
55	.02	.1	.2
59	.02	.1	.3
64	.02	.1	.3
68	.02	.1	.3
73	.02	.1	.3
77	.02	.1	.3
81	.02	.2	.3
86	.02	.2	.3
90	.02	.2	.3
95	.02	.2	.3

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

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	Horizontal cylinder	
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 CHARACTERISTICS

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

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 height	=	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 =	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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (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.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (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

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

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

DISTANCE FROM EXPLOSION (feet)	EXPECTED DAMAGE
285	Occasional breakage of large windows under stress.
41	Some damage to home ceilings; 10% window breakage.
15 - 26	Windows usually shattered; some frame damage.
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.
4	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.

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	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 CHARACTERISTICS

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

HAZARDOUS MATERIAL = Hydrogen
ADDRESS \ LOCATION = PDL
DATE OF ASSESSMENT = 9-9-93
NAME OF DISK FILE = P-6DETON.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 183000 ppm

-- at groundlevel	=	366	feet
-- at discharge height	=	348	feet

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	
Downwind hazard distance =	886	684	feet
Max hazard zone width =	443	342	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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (feet)
100	.02	810178	1000000	73
119	.03	1000000	1000000	87
138	.03	1000000	1000000	110
157	.03	923907	1000000	120
176	.04	809187	878566	130
195	.04	694568	686283	150
214	.05	591586	552273	160
233	.05	503275	454611	170
252	.05	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

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

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

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	Horizontal cylinder	
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 CHARACTERISTICS

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

HAZARDOUS MATERIAL = Hydrogen
ADDRESS \ LOCATION = PDL
DATE OF ASSESSMENT = 9-9-93
NAME OF DISK FILE = P-7.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 distance to concentration of 40000 ppm

-- at groundlevel	=	264	feet
-- at discharge height	=	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	= 35	35	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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (feet)
100	.02	541204	478767	350
112	.03	408945	365860	390
124	.03	315948	285958	430
136	.03	248915	227725	460
147	.03	199494	184267	440
159	.04	162313	151183	430
171	.04	133830	125560	410
182	.04	111653	105415	390
194	.04	94135	89361	360
206	.04	80116	76415	340
217	.05	68764	65860	300
229	.05	59474	57170	270
241	.05	51798	49951	220
253	.05	45399	43904	160
264	.05	40000	38801	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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
100	.02	.2	.3
112	.03	.2	.3
124	.03	.2	.4
136	.03	.2	.4
147	.03	.2	.4
159	.04	.3	.5
171	.04	.3	.5
182	.04	.3	.5
194	.04	.3	.5
206	.04	.3	.6
217	.05	.3	.6
229	.05	.3	.6
241	.05	.4	.7
253	.05	.4	.7
264	.05	.4	.7

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

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

DISTANCE FROM EXPLOSION (feet)	EXPECTED DAMAGE
369	Occasional breakage of large windows under stress.
52	Some damage to home ceilings; 10% window breakage.
20 - 34	Windows usually shattered; some frame damage.
20	Partial demolition of homes; made uninhabitable.
5 - 20	Range serious/slight injuries from flying glass/object.
12	Partial collapse of home walls/roofs.
9 - 12	Non-reinforced concrete/cinder block walls shattered.
4 - 11	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.
6 - 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.

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	15.72	lbs
DISCHARGE HOLE DIAMETER	=	9	inch(es)
DISCHARGE COEFFICIENT OF HOLE	=	.62	
TEMP OF CONTAINER CONTENTS	=	68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia

ENVIRONMENTAL/LOCATION CHARACTERISTICS

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

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 distance to concentration of 183000 ppm

-- at groundlevel	=	152	feet
-- at discharge height	=	148	feet

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 = 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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
100	.02	.2	.3
104	.02	.2	.3
108	.03	.2	.3
112	.03	.2	.3
115	.03	.2	.3
119	.03	.2	.4
123	.03	.2	.4
126	.03	.2	.4
130	.03	.2	.4
134	.03	.2	.4
137	.03	.2	.4
141	.03	.2	.4
145	.03	.2	.4
149	.03	.2	.4
152	.03	.2	.4

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

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	Horizontal cylinder	
TOTAL WEIGHT OF CONTENTS	=	15.72	lbs
DISCHARGE HOLE DIAMETER	=	9	inch(es)
DISCHARGE COEFFICIENT OF HOLE	=	.62	
TEMP OF CONTAINER CONTENTS	=	68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia

ENVIRONMENTAL/LOCATION CHARACTERISTICS

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

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 40000 ppm

-- at groundlevel	=	900	feet
-- at discharge height	=	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 = 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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation 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	.09	250618	227401	330
500	.1	183884	169080	370
558	.11	139166	129382	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	38539	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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (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.

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

DISTANCE FROM EXPLOSION (feet)	EXPECTED DAMAGE
369	Occasional breakage of large windows under stress.
52	Some damage to home ceilings; 10% window breakage.
20 - 34	Windows usually shattered; some frame damage.
20	Partial demolition of homes; made uninhabitable.
5 - 20	Range serious/slight injuries from flying glass/object.
12	Partial collapse of home walls/roofs.
9 - 12	Non-reinforced concrete/cinder block walls shattered.
4 - 11	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.
6 - 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.

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	15.72	lbs
DISCHARGE HOLE DIAMETER	=	9	inch(es)
DISCHARGE COEFFICIENT OF HOLE	=	.62	
TEMP OF CONTAINER CONTENTS	=	68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia

ENVIRONMENTAL/LOCATION CHARACTERISTICS

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

HAZARDOUS MATERIAL = Hydrogen
ADDRESS \ LOCATION = PDL
DATE OF ASSESSMENT = 9-9-93
NAME OF DISK FILE = P-8DETON.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 183000 ppm

-- at groundlevel	=	501	feet
-- at discharge height	=	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	= 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 = 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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

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

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

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	Horizontal cylinder	
TOTAL WEIGHT OF CONTENTS	=	15.72	lbs
DISCHARGE HOLE DIAMETER	=	9	inch(es)
DISCHARGE COEFFICIENT OF HOLE	=	.62	
TEMP OF CONTAINER CONTENTS	=	68	degrees F
TANK RUPTURE PRESSURE	=	2400	psia

ENVIRONMENTAL/LOCATION CHARACTERISTICS

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

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 to concentration of 40000 ppm

-- at groundlevel	=	282	feet
-- at discharge height	=	277	feet

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	1/2 LFL	LFL	
Downwind hazard distance	= 413	286	feet
Max hazard zone width	= 207	143	feet
Max weight explosive gas	= 158	138	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.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (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 VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
100	.02	.2	.7
113	.03	.2	.7
126	.03	.2	.8
139	.03	.2	.8
152	.03	.2	.8
165	.04	.3	.9
178	.04	.3	.9
191	.04	.3	.9
204	.04	.3	1
217	.05	.3	1
230	.05	.3	1
243	.05	.4	1.1
256	.05	.4	1.1
269	.06	.4	1.1
282	.06	.4	1.2

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

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

TANCE FROM EXPLOSION (feet)	EXPECTED DAMAGE
583	Occasional breakage of large windows under stress.
83	Some damage to home ceilings; 10% window breakage.
31 - 54	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.

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	2400	psia

ENVIRONMENTAL/LOCATION CHARACTERISTICS

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

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

Downwind distance to concentration of 183000 ppm

-- at groundlevel	=	119	feet
-- at discharge height	=	111	feet

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 =	207	143	feet
Max weight explosive gas =	158	138	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.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (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.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	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

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

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	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	=	2400	psia

ENVIRONMENTAL/LOCATION CHARACTERISTICS

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

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 height	=	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
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	158	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.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (feet)
100	.02	1000000	1000000	73
206	.04	1000000	1000000	150
311	.06	1000000	1000000	230
416	.08	731894	659465	310
522	.1	485676	448524	380
627	.12	336323	316074	460
732	.14	241649	229896	540
838	.16	179259	172044	610
943	.18	136681	132035	690
1048	.2	106707	103590	770
1153	.22	85018	82853	840
1259	.24	68939	67390	920
1364	.26	56763	55626	1000
1469	.28	47368	46514	1070
1575	.3	40000	39343	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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
100	.02	.6	1.6
206	.04	1.2	2.8
311	.06	1.8	4
416	.08	2.4	5.2
522	.1	3	6.4
627	.12	3.6	7.6
732	.14	4.2	8.8
838	.16	4.8	10
943	.18	5.4	11.2
1048	.2	6	12.4
1153	.22	6.6	13.6
1259	.24	7.2	14.8
1364	.26	7.8	16
1469	.28	8.4	17.2
1575	.3	9	18.4

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

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

DISTANCE FROM EXPLOSION (feet)	EXPECTED DAMAGE
583	Occasional breakage of large windows under stress.
83	Some damage to home ceilings; 10% window breakage.
31 - 54	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.

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	2400	psia

ENVIRONMENTAL/LOCATION CHARACTERISTICS

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

HAZARDOUS MATERIAL = Hydrogen
ADDRESS \ LOCATION = PDL
DATE OF ASSESSMENT = 9-10-93
NAME OF DISK FILE = P-10DETO.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 183000 ppm

-- at groundlevel	=	830	feet
-- at discharge height	=	814	feet

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	158	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.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

ownwind Distance		Groundlevel Concentration	Source Height Concentration	Initial Evacuation Zone Width*
(feet)	(miles)	(ppm)	(ppm)	(feet)
100	.02	1000000	1000000	73
153	.03	1000000	1000000	120
205	.04	1000000	1000000	150
257	.05	1000000	1000000	190
309	.06	1000000	1000000	230
361	.07	926107	822075	270
413	.08	741804	667813	310
465	.09	601639	548838	340
517	.1	493525	455378	380
569	.11	409098	381113	420
622	.12	342434	321573	460
674	.13	289250	273456	500
726	.14	246404	234269	530
778	.15	211566	202112	570
830	.16	183000	175528	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)
100	.02	.6	1.6
153	.03	.9	2.2
205	.04	1.2	2.8
257	.05	1.5	3.4
309	.06	1.8	4
361	.07	2.1	4.6
413	.08	2.4	5.2
465	.09	2.7	5.7
517	.1	3	6.3
569	.11	3.3	6.9
622	.12	3.6	7.5
674	.13	3.9	8.1
726	.14	4.2	8.7
778	.15	4.5	9.3
830	.16	4.8	9.9

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

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	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	=	2400	psia

ENVIRONMENTAL/LOCATION CHARACTERISTICS

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

HAZARDOUS 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 of 40000 ppm

-- at groundlevel	=	282	feet
-- at discharge height	=	277	feet

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	= 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.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (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 VAPOR DISPERSION ANALYSIS RESULTS

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

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

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

;TANCE FROM EXPLOSION (feet)	EXPECTED DAMAGE
583	Occasional breakage of large windows under stress.
83	Some damage to home ceilings; 10% window breakage.
31 - 54	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.

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	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 CHARACTERISTICS

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

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

Downwind distance to concentration of 183000 ppm

-- at groundlevel	=	119	feet
-- at discharge height	=	111	feet

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 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 = 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.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (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.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
100	.02	.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.

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	Horizontal cylinder	
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 CHARACTERISTICS

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

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.

******* 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 of 40000 ppm

-- at groundlevel	=	1710	feet
-- at discharge height	=	1700	feet

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

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 = 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.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (feet)
100	.02	1000000	1000000	73
215	.05	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 Distance (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
100	.02	.6	1.7
215	.05	1.3	3
330	.07	1.9	4.3
445	.09	2.6	5.6
560	.11	3.2	6.9
675	.13	3.9	8.2
790	.15	4.5	9.6
905	.18	5.2	10.9
1020	.2	5.8	12.2
1135	.22	6.5	13.5
1250	.24	7.2	14.8
1365	.26	7.8	16.1
1480	.29	8.5	17.4
1595	.31	9.1	18.7
1710	.33	9.8	20

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

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

DISTANCE FROM EXPLOSION (feet)	EXPECTED DAMAGE
583	Occasional breakage of large windows under stress.
83	Some damage to home ceilings; 10% window breakage.
31 - 54	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.

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	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 CHARACTERISTICS

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

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

******* 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 of 183000 ppm

-- at groundlevel	=	882	feet
-- at discharge height	=	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 = 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.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (feet)
100	.02	1000000	1000000	73
156	.03	1000000	1000000	120
212	.05	1000000	1000000	160
268	.06	1000000	1000000	200
324	.07	1000000	967387	240
380	.08	865661	772248	280
435	.09	695432	629741	320
491	.1	567936	521173	360
547	.11	470023	436161	400
603	.12	393317	368358	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 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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
100	.02	.6	1.7
156	.03	.9	2.3
212	.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

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

INPUT PARAMETER SUMMARY

PHYSIOCHEMICAL PROPERTIES OF MATERIAL

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	=	Horizontal cylinder	
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 CHARACTERISTICS

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

HAZARDOUS MATERIAL = Hydrogen
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 concentration of 40000 ppm

-- at groundlevel	=	66	feet
-- at discharge height	=	64	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	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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
32	.01	.1	.1
35	.01	.1	.2
37	.01	.1	.2
40	.01	.1	.2
42	.01	.1	.2
45	.01	.1	.2
47	.01	.1	.2
49	.01	.1	.2
52	.01	.1	.2
54	.02	.1	.2
57	.02	.1	.2
59	.02	.1	.2
61	.02	.1	.2
64	.02	.1	.2
66	.02	.1	.2

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

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

ISTANCE FROM EXPLOSION (feet)	EXPECTED DAMAGE
117	Occasional breakage of large windows under stress.
17	Some damage to home ceilings; 10% window breakage.
7 - 11	Windows usually shattered; some frame damage.
7	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.

INPUT PARAMETER SUMMARY

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	=	40000	ppm

CONTAINER CHARACTERISTICS

CONTAINER TYPE	=	Horizontal cylinder	
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 CHARACTERISTICS

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

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	minutes
Amount discharged	=	1	lbs
State of material	=	Gas	

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

******* 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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

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

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

INPUT PARAMETER SUMMARY

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 cylinder	
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	=	2000	psia

ENVIRONMENTAL/LOCATION CHARACTERISTICS

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

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 height	=	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	
Downwind hazard distance =	326	255	feet
Max hazard zone width =	163	128	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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (feet)
100	.02	63624	298581	73
109	.03	70529	237330	79
117	.03	74124	192025	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	.04	43061	41041	120
214	.05	40000	37371	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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
100	.02	.6	1.2
109	.03	.7	1.3
117	.03	.7	1.4
125	.03	.8	1.5
133	.03	.8	1.6
141	.03	.9	1.7
149	.03	.9	1.8
157	.03	.9	1.8
166	.04	1	1.9
174	.04	1	2
182	.04	1.1	2.1
190	.04	1.1	2.2
198	.04	1.2	2.3
206	.04	1.2	2.4
214	.05	1.3	2.5

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

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

DISTANCE FROM EXPLOSION (feet)	EXPECTED DAMAGE
117	Occasional breakage of large windows under stress.
17	Some damage to home ceilings; 10% window breakage.
7 - 11	Windows usually shattered; some frame damage.
7	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.

INPUT PARAMETER SUMMARY

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	=	40000	ppm

CONTAINER CHARACTERISTICS

CONTAINER TYPE	=	Horizontal cylinder	
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 CHARACTERISTICS

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

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

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

Downwind distance to concentration of 183000 ppm

-- at groundlevel	=	Not observed	
-- at discharge height	=	119	feet

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

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	
Downwind hazard distance =	326	255	feet
Max hazard zone width =	163	128	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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (feet)
100	.02	63624	298581	73
102	.02	64977	287392	74
103	.02	66235	276765	75
104	.02	67399	266665	76
106	.02	68470	257059	77
107	.03	69451	247917	78
108	.03	70342	239213	79
110	.03	71147	230921	80
111	.03	71867	223016	81
112	.03	72506	215477	78
114	.03	73066	208283	70
115	.03	73551	201415	61
116	.03	73963	194855	50
117	.03	74305	188586	36
119	.03	74580	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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
100	.02	.6	1.2
102	.02	.6	1.2
103	.02	.6	1.2
104	.02	.6	1.2
106	.02	.7	1.3
107	.03	.7	1.3
108	.03	.7	1.3
110	.03	.7	1.3
111	.03	.7	1.3
112	.03	.7	1.3
114	.03	.7	1.4
115	.03	.7	1.4
116	.03	.7	1.4
117	.03	.7	1.4
119	.03	.7	1.4

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

INPUT PARAMETER SUMMARY

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 cylinder	
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 CHARACTERISTICS

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

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 height	=	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 =	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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (feet)
100	.02	53827	47617	110
101	.02	52657	46620	110
102	.02	51520	45651	97
103	.02	50414	44708	93
104	.02	49338	43791	89
105	.02	48292	42900	85
106	.02	47274	42032	80
107	.03	46283	41187	75
108	.03	45319	40365	70
109	.03	44380	39565	64
110	.03	43467	38785	57
110	.03	42577	38026	50
111	.03	41712	37286	41
112	.03	40868	36566	29
113	.03	40000	35864	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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
100	.02	.2	.3
101	.02	.2	.3
102	.02	.2	.3
103	.02	.2	.3
104	.02	.2	.3
105	.02	.2	.3
106	.02	.2	.3
107	.03	.2	.3
108	.03	.2	.3
109	.03	.2	.3
110	.03	.2	.3
110	.03	.2	.3
111	.03	.2	.3
112	.03	.2	.3
113	.03	.2	.4

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

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

STANCE FROM EXPLOSION (feet)	EXPECTED DAMAGE
173	Occasional breakage of large windows under stress.
25	Some damage to home ceilings; 10% window breakage.
10 - 16	Windows usually shattered; some frame damage.
10	Partial demolition of homes; made uninhabitable.
3 - 10	Range serious/slight injuries from flying glass/object.
6	Partial collapse of home walls/roofs.
5 - 6	Non-reinforced concrete/cinder block walls shattered.
2 - 5	Range 90-1% eardrum 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% 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.

INPUT PARAMETER SUMMARY

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	=	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 CHARACTERISTICS

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

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

Downwind distance to concentration of 183000 ppm

-- at groundlevel	=	56	feet
-- at discharge height	=	56	feet

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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (feet)
32	.01	249191	688610	91
34	.01	257383	609004	89
36	.01	261499	541249	86
38	.01	262209	483328	83
39	.01	260163	433609	80
41	.01	255951	390760	77
43	.01	250090	353683	73
44	.01	243016	321471	69
46	.01	235089	293371	64
48	.01	226604	268757	59
49	.01	217794	247104	53
51	.01	208842	227975	47
53	.01	199889	211005	38
54	.02	191044	195884	28
56	.02	183000	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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
32	.01	.1	.1
34	.01	.1	.2
36	.01	.1	.2
38	.01	.1	.2
39	.01	.1	.2
41	.01	.1	.2
43	.01	.1	.2
44	.01	.1	.2
46	.01	.1	.2
48	.01	.1	.2
49	.01	.1	.2
51	.01	.1	.2
53	.01	.1	.2
54	.02	.1	.2
56	.02	.1	.2

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

INPUT PARAMETER SUMMARY

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 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 CHARACTERISTICS

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

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	=	372	feet
-- at discharge height	=	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

For concentration of	1/2 LFL	LFL	
Downwind hazard distance =	510	397	feet
Max hazard zone width =	255	199	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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation 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	.06	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 by the user for this scenario was 5 feet.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
100	.02	.6	1.2
120	.03	.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

DISTANCE FROM EXPLOSION (feet)	EXPECTED DAMAGE
173	Occasional breakage of large windows under stress.
25	Some damage to home ceilings; 10% window breakage.
10 - 16	Windows usually shattered; some frame damage.
10	Partial demolition of homes; made uninhabitable.
3 - 10	Range serious/slight injuries from flying glass/object.
6	Partial collapse of home walls/roofs.
5 - 6	Non-reinforced concrete/cinder block walls shattered.
2 - 5	Range 90-1% eardrum 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% 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.

INPUT PARAMETER SUMMARY

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	=	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 CHARACTERISTICS

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

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 height	=	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	1/2 LFL	LFL	
Downwind hazard distance =	510	397	feet
Max hazard zone width =	255	199	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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

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

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

INPUT PARAMETER SUMMARY

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 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 CHARACTERISTICS			
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

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

Downwind distance to concentration of 40000 ppm

-- at groundlevel	=	184	feet
-- at discharge height	=	180	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

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 =	14	14	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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (feet)
100	.02	165216	146156	310
106	.03	146576	130390	300
112	.03	130389	116679	300
118	.03	116323	104716	290
124	.03	104083	94246	280
130	.03	93409	85056	260
136	.03	84079	76969	250
142	.03	75902	69831	240
148	.03	68715	63515	220
154	.03	62381	57912	210
160	.04	56781	52928	190
166	.04	51817	48484	160
172	.04	47403	44510	140
178	.04	43469	40949	93
184	.04	40000	37750	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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
100	.02	.2	.3
106	.03	.2	.4
112	.03	.2	.4
118	.03	.2	.4
124	.03	.2	.4
130	.03	.2	.4
136	.03	.2	.4
142	.03	.2	.5
148	.03	.2	.5
154	.03	.2	.5
160	.04	.3	.5
166	.04	.3	.5
172	.04	.3	.5
178	.04	.3	.5
184	.04	.3	.6

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

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

ISTANCE FROM EXPLOSION (feet)	EXPECTED DAMAGE
272	Occasional breakage of large windows under stress.
39	Some damage to home ceilings; 10% window breakage.
15 - 25	Windows usually shattered; some frame damage.
15	Partial demolition of homes; made uninhabitable.
4 - 15	Range serious/slight injuries from flying glass/object.
9	Partial collapse of home walls/roofs.
7 - 9	Non-reinforced concrete/cinder block walls shattered.
3 - 8	Range 90-1% eardrum rupture among exposed population.
8	50% destruction of home brickwork.
6 - 7	Frameless steel panel buildings ruined.
5	Wooden utility poles snapped.
4 - 5	Nearly complete destruction of houses.
4	Probable total building destruction.
2 - 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.

INPUT PARAMETER SUMMARY

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	=	40000	ppm

CONTAINER CHARACTERISTICS

CONTAINER TYPE	=	Horizontal cylinder	
TOTAL WEIGHT OF CONTENTS	=	13.8	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 CHARACTERISTICS

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

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

Downwind distance to concentration of 183000 ppm

-- at groundlevel	=	96	feet
-- at discharge height	=	89	feet

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 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 =	14	14	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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (feet)
32	.01	391832	1000000	120
37	.01	441930	843180	130
42	.01	458606	679515	150
46	.01	453192	563636	160
51	.01	434538	478712	170
55	.02	408682	414260	160
60	.02	379526	363645	150
64	.02	349510	322639	150
69	.02	320108	288527	140
73	.02	292171	259543	130
78	.02	266139	234516	120
82	.02	242199	212646	98
87	.02	220376	193368	81
91	.02	200599	176265	58
96	.02	183000	161021	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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
32	.01	.1	.2
37	.01	.1	.2
42	.01	.1	.2
46	.01	.1	.2
51	.01	.1	.2
55	.02	.1	.2
60	.02	.1	.2
64	.02	.1	.3
69	.02	.1	.3
73	.02	.1	.3
78	.02	.1	.3
82	.02	.2	.3
87	.02	.2	.3
91	.02	.2	.3
96	.02	.2	.3

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

INPUT PARAMETER SUMMARY

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 cylinder	
TOTAL WEIGHT OF CONTENTS	=	13.8	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 CHARACTERISTICS

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

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

Downwind distance to concentration of 40000 ppm

-- at groundlevel	=	634	feet
-- at discharge height	=	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 = 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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (feet)
100	.02	761887	1000000	73
139	.03	918469	1000000	110
177	.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

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

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

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

DISTANCE FROM EXPLOSION (feet)	EXPECTED DAMAGE
272	Occasional breakage of large windows under stress.
39	Some damage to home ceilings; 10% window breakage.
15 - 25	Windows usually shattered; some frame damage.
15	Partial demolition of homes; made uninhabitable.
4 - 15	Range serious/slight injuries from flying glass/object.
9	Partial collapse of home walls/roofs.
7 - 9	Non-reinforced concrete/cinder block walls shattered.
3 - 8	Range 90-1% eardrum rupture among exposed population.
8	50% destruction of home brickwork.
6 - 7	Frameless steel panel buildings ruined.
5	Wooden utility poles snapped.
4 - 5	Nearly complete destruction of houses.
4	Probable total building destruction.
2 - 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.

INPUT PARAMETER SUMMARY

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	=	40000	ppm

CONTAINER CHARACTERISTICS

CONTAINER TYPE	=	Horizontal cylinder	
TOTAL WEIGHT OF CONTENTS	=	13.8	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 CHARACTERISTICS

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

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 distance to concentration of 183000 ppm

-- at groundlevel	=	347	feet
-- at discharge height	=	329	feet

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	
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 = 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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (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 by the user for this scenario was 5 feet.

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

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

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

INPUT PARAMETER SUMMARY

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 cylinder	
TOTAL WEIGHT OF CONTENTS	=	13.8	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 CHARACTERISTICS

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

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

Downwind distance to concentration of 40000 ppm

-- at groundlevel	=	215	feet
-- at discharge height	=	212	feet

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

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	=	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	=	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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (feet)
100	.02	248633	219949	350
109	.03	211090	188190	380
117	.03	180151	161930	370
125	.03	154603	140087	350
133	.03	133426	121818	340
141	.03	115791	106460	330
150	.03	101028	93483	310
158	.03	88603	82464	300
166	.04	78089	73061	280
174	.04	69143	65000	260
182	.04	61492	58057	230
191	.04	54916	52051	200
199	.04	49235	46832	170
207	.04	44306	42278	120
215	.05	40000	38290	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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
100	.02	.2	.3
109	.03	.2	.4
117	.03	.2	.4
125	.03	.2	.4
133	.03	.2	.4
141	.03	.2	.5
150	.03	.2	.5
158	.03	.2	.5
166	.04	.3	.5
174	.04	.3	.5
182	.04	.3	.6
191	.04	.3	.6
199	.04	.3	.6
207	.04	.3	.6
215	.05	.3	.6

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

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

ISTANCE FROM EXPLOSION (feet)	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	Range serious/slight injuries from flying glass/object.
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.
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.

INPUT PARAMETER SUMMARY

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	=	40000	ppm

CONTAINER CHARACTERISTICS

CONTAINER TYPE	=	Horizontal cylinder	
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

ENVIRONMENTAL/LOCATION CHARACTERISTICS

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

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

Downwind distance to concentration of 183000 ppm

-- at groundlevel	=	116	feet
-- at discharge height	=	110	feet

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

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 =	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 = 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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (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

Downwind Distance (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
100	.02	.2	.3
102	.02	.2	.4
103	.02	.2	.4
104	.02	.2	.4
105	.02	.2	.4
106	.02	.2	.4
107	.03	.2	.4
108	.03	.2	.4
109	.03	.2	.4
110	.03	.2	.4
112	.03	.2	.4
113	.03	.2	.4
114	.03	.2	.4
115	.03	.2	.4
116	.03	.2	.4

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

INPUT PARAMETER SUMMARY

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 cylinder	
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

ENVIRONMENTAL/LOCATION CHARACTERISTICS

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

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 concentration of 40000 ppm

-- at groundlevel	=	742	feet
-- at discharge height	=	728	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 =	982	757	feet
Max hazard zone width =	491	379	feet
Max weight explosive gas =	21	21	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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation Zone Width* (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	.08	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	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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
100	.02	.6	1.2
146	.03	.9	1.8
192	.04	1.1	2.3
238	.05	1.4	2.8
284	.06	1.7	3.3
330	.07	1.9	3.8
375	.08	2.2	4.4
421	.08	2.4	4.9
467	.09	2.7	5.4
513	.1	3	5.9
559	.11	3.2	6.4
604	.12	3.5	7
650	.13	3.7	7.5
696	.14	4	8
742	.15	4.3	8.5

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

UNCONFINED VAPOR CLOUD EXPLOSION EFFECTS

DISTANCE FROM EXPLOSION (feet)	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	Range serious/slight injuries from flying glass/object.
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.
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.

INPUT PARAMETER SUMMARY

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	=	40000	ppm

CONTAINER CHARACTERISTICS

CONTAINER TYPE	=	Horizontal cylinder	
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

ENVIRONMENTAL/LOCATION CHARACTERISTICS

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

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 concentration of 183000 ppm

-- at groundlevel	=	410	feet
-- at discharge height	=	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 =	982	757	feet
Max hazard zone width =	491	379	feet
Max weight explosive gas =	21	21	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)

TOXIC VAPOR DISPERSION ANALYSIS RESULTS

Downwind Distance (feet)	Downwind Distance (miles)	Groundlevel Concentration (ppm)	Source Height Concentration (ppm)	Initial Evacuation 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 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 (feet)	Downwind Distance (miles)	Contaminant Arrival Time at Downwind Location (minutes)	Contaminant Departure Time at Downwind Location (minutes)
100	.02	.6	1.2
123	.03	.7	1.5
145	.03	.9	1.7
167	.04	1	2
189	.04	1.1	2.2
211	.04	1.2	2.5
233	.05	1.4	2.7
255	.05	1.5	3
277	.06	1.6	3.2
300	.06	1.8	3.5
322	.07	1.9	3.8
344	.07	2	4
366	.07	2.1	4.3
388	.08	2.3	4.5
410	.08	2.4	4.8

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

INPUT PARAMETER SUMMARY

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 cylinder	
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

ENVIRONMENTAL/LOCATION CHARACTERISTICS

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

Appendix B

Calculation Sheets

CALCULATION SHEET

CALCULATION TITLE: Primary Fragments from Cased Cylindrical Charges (Hydrogen Trailer - Overpressure of a single cylinder)

CALCULATION ID: RD-P13-001

REVISION: 0

Prepared by:	Carrie L. Wood Signature	Carrie L. Wood Printed Name	12/16/94 Date
Checked by:	Joseph A. Schiner Signature	Joseph A. Schiner Printed Name	12-16-94 Date
Approved by:	William Thornton Signature	William Thornton Printed Name	12/16/94 Date

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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^3 = (Density of H_2 in g/cm^3)/ (Conversion Factor of 27.68) (Reference 15)
De = (0.00008988 g/cm^3)/ (27.68) = 3.2E-06 lbs/in^3

b. Wt. of Fuel in 1 cylinder = (Volume of Fuel)/(Volume of 1 pound of fuel)
Wt. = 1,000 ft^3/191.3 ft^3 = 5.2 lbs

c. 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. Outside Diameter of Casing (d_o) = 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)
h. Density of Casing (dc) = 8.0 g/cm^3 (.289 lbs/in^3)

CALCULATION SHEET

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_c)

$$W_c = \frac{\pi\left[(od)^2 - (id)^2\right](lc)(dc)}{4}$$

$$W_c = \frac{\pi\left[(9.625)^2 - (9)^2\right](252)(0.289)}{4} = 665.8 \text{ lbs}$$

$$\frac{W}{W_c} = \frac{128}{666} = .192 = \text{The ratio of the explosive weight to the casing weight.}$$

Step 3: Initial Fragment Velocity (V_o)

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 SHEET

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_A)

The constant for the explosive charge for TNT in mild steel casing (B) = .30 (Reference 15)

$$M_A = B(tc)^{5/6}(di)^{\frac{1}{3}}\left(1+\frac{tc}{dj}\right)$$

$$M_A = .30(0.3125)^{5/6}(9)^{\frac{1}{3}}\left(1+\frac{0.3125}{9}\right) = 0.245 \text{ lbs}$$

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_f)

$$\ln N_f = \ln\left[\frac{8W_c}{M_A{}^2}\right] - \frac{W_f{}^{1/2}}{M_A}$$

$$\ln N_f = \ln\left[\frac{8(666)}{(0.245)^2}\right] - \frac{(1.5)^{1/2}}{0.245} = 6.39$$

$N_f = 596$ fragments

CALCULATION SHEET

CALCULATION TITLE: Distance to Threshold Blast Overpressures
(Hydrogen Trailer - Overpressure of a single cylinder)

CALCULATION ID: RD-P13-002

REVISION: 0

Prepared by:	Carrie L. Wood Signature	Carrie L. Wood Printed Name	12/15/94 Date
Checked by:	Joseph A. Schriner Signature	Joseph A. Schriner Printed Name	12-15-94 Date
Approved by:	William Thornton Signature	William Thornton Printed Name	12/16/94 Date

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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 ($ft/lb^{1/3}$)

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. 1 psi

$R_G = (128)^{1/3}(45)$
$R_G = 226.8$ ft

B. 10 psi

$R_G = (128)^{1/3}(9)$
$R_G = 45.4$ ft

CALCULATION SHEET

CALCULATION TITLE: Blast Force to Nearby Structures
(Hydrogen Trailer - Overpressure of a single cylinder)

CALCULATION ID: RD-P13-003

REVISION: 0

Prepared by:	Carrie L. Wood Signature	Carrie L. Wood Printed Name	12/15-94 Date
Checked by:	Joseph A. Schriner Signature	Joseph A. Schriner Printed Name	12-15-94 Date
Approved by:	William Thornton Signature	William Thornton Printed Name	12/16/94 Date

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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 ($ft/lb^{1/3}$)

$$Z_G = R_G/W^{1/3}$$

a. <u>The walls surrounding HTSF</u>
(5 ft from trailer)

$Z_G = (5\ ft)/(128)^{1/3}$
$Z_G = .99$

for a:
P_{SO} = 1,000 psi

b. <u>AMPL Building</u>
(approx. 105 ft from trailer)

$Z_G = (105\ ft)/(128)^{1/3}$
$Z_G = 20.8$

for b:
P_{SO} = 6 psi

CALCULATION SHEET

CALCULATION TITLE: Fragment Velocity at Threshold
(Hydrogen Trailer - Overpressure of a single cylinder)

CALCULATION ID: RD-P13-004

REVISION: 0

Prepared by:	Carrie L. Wood Signature	CARRIE L. Wood Printed Name	12/15/94 Date
Checked by:	Joseph A. Schriner Signature	Joseph A. Schriner Printed Name	12-15-94 Date
Approved by:	William Thornton Signature	WILLIAM THORNTON Printed Name	12/16/94 Date

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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 SHEET

CALCULATION TITLE: Distance fragments travel before dropping below threshold velocities (Hydrogen Trailer - Overpressure of a single cylinder)

CALCULATION ID: RD-P13-005

REVISION: 0

Prepared by:	Carrie L. Wood Signature	Carrie L. Wood Printed Name	12/16/94 Date
Checked by:	Joseph A. Schriner Signature	Joseph A. Schriner Printed Name	12-16-94 Date
Approved by:	William Thornton Signature	William Thornton Printed Name	12/16/94 Date

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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:

$$R_f = \frac{\ln \frac{V_o}{V_s}\left(W_f^{1/3}\right)}{.004}$$

A. 7.8 ounce fragment

$$R_f = \frac{\ln \frac{2,905}{119}\left(7.8^{1/3}\right)}{.004} = 1,584.1 \text{ ft}$$

B. 1.5 ounce fragment

$$R_f = \frac{\ln \frac{2,905}{119}\left(1.5^{1/3}\right)}{.004} = 914.4 \text{ ft}$$

CALCULATION SHEET

CALCULATION TITLE: Primary Fragments from Cased Cylindrical Charges (Hydrogen Trailer - Overpressure of three cylinders)

CALCULATION ID: RD-P14-001

REVISION: 0

Prepared by:	Signature	Carrie L. Wood (Printed Name)	12/16/94 (Date)
Checked by:	Signature	Joseph A. Schriver (Printed Name)	12-16-94 (Date)
Approved by:	Signature	William Hurston (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^3 = (Density of H_2 in g/cm^3)/ (Conversion Factor of 27.68) (Reference 15)
De = (0.00008988 g/cm^3)/ (27.68) = 3.2E-06 lbs/in^3

b. Wt. of Fuel in 3 cylinders = (Volume of Fuel)/(Volume of 1 lb. of fuel)
Wt. = 3,000 ft^3/191.3 ft^3 = 15.7 lbs

c. 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_o) = 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)
h. Density of Casing (dc) = 8.0 g/cm^3 (.289 lbs/in^3)

CALCULATION SHEET

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_c)

$$W_c = \frac{\pi\left[(od)^2 - (id)^2\right](lc)(dc)}{4}$$

$$W_c = \frac{\pi\left[(9.625)^2 - (9)^2\right](252)(0.289)}{4} = 665.8 \text{ lbs}$$

$$\frac{W}{W_c} = \frac{128}{666} = .192 = \text{The ratio of the explosive weight to the casing weight.}$$

Step 3: Initial Fragment Velocity (V_o)

TNT in mild steel casing, $(2E')^{1/2} = 6,940$ $(2E')^{1/2} = 6,940$ (Reference 15, Table 4-2)

$$V_o = (2E')^{1/2}\left(\frac{\frac{W}{W_c}}{1+\frac{W}{2W_c}}\right)^{1/2}$$

$$V_o = 6,940\left(\frac{0.192}{1+\frac{.192}{2}}\right)^{1/2} = 2,904.7 \text{ ft./second}$$

CALCULATION SHEET

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_A)

The constant for the explosive charge for TNT in mild steel casing (B) = .30 (Reference 15)

$$M_A = B(tc)^{5/6}(di)^{\frac{1}{3}}\left(1+\frac{tc}{dj}\right)$$

$$M_A = .30(0.3125)^{5/6}(9)^{\frac{1}{3}}\left(1+\frac{0.3125}{9}\right) = 0.245 \text{ lbs}$$

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_f)

$$\ln N_f = \ln\left[\frac{8W_c}{M_A{}^2}\right] - \frac{W_f{}^{1/2}}{M_A}$$

$$\ln N_f = \ln\left[\frac{8(666)}{(0.245)^2}\right] - \frac{(1.5)^{1/2}}{0.245} = 6.39$$

$N_f = 596$ fragments = 1,788 for 3 cylinders

CALCULATION SHEET

CALCULATION TITLE: Distances to Threshold Blast Overpressures
(Hydrogen Trailer - Overpressure of three cylinders)

CALCULATION ID: RD-P14-002

REVISION: 0

	Signature	Printed Name	Date
Prepared by:	Carrie L. Wood	CARRIE L. WOOD	12/15/94
Checked by:	Joseph A. Schriner	Joseph A. Schriner	12-15-94
Approved by:	William Thornton	WILLIAM THORNTON	12/16/94

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 ($ft/lb^{1/3}$)

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. 1 psi

$R_G = (386.2)^{1/3}(45)$
$R_G = 327.6$ ft

B. 10 psi

$R_G = (383.8)^{1/3}(9)$
$R_G = 65.5$ ft

CALCULATION SHEET

CALCULATION TITLE: Blast Force to Nearby Structures
(Hydrogen Trailer - Overpressure of three cylinders)

CALCULATION ID: RD-P14-003

REVISION: 0

Prepared by:	Carrie L Wood Signature	Carrie L. Wood Printed Name	12/15/94 Date
Checked by:	Joseph A. Schriner Signature	Joseph A Schriner Printed Name	12 15 94 Date
Approved by:	William Thornton Signature	William Thornton Printed Name	12/16/94 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 ($ft/lb^{1/3}$)

$$Z_G = R_G/W^{1/3}$$

a. <u>The walls surrounding HTSF</u>
(5 ft from trailer)

$Z_G = (5\ ft)/(386.2)^{1/3}$
$Z_G = .69$

for a:
$P_{SO} = 4{,}000$ psi

b. <u>AMPL Building</u>
(approx. 105 ft from trailer)

$Z_G = (105\ ft)/(386.2)^{1/3}$
$Z_G = 14.4$

for b:
$P_{SO} = 8$ psi

CALCULATION SHEET

CALCULATION TITLE: Fragment Velocity at Threshold
(Hydrogen Trailer - Overpressure of three cylinders)

CALCULATION ID: RD-P14-004

REVISION: 0

Prepared by:	Carrie L. Wood Signature	CARRIE L. Wood Printed Name	12/15/94 Date
Checked by:	Joseph A. Schriner Signature	Joseph A. Schriner Printed Name	12-15-94 Date
Approved by:	William Thornton Signature	WILLIAM THORNTON Printed Name	12/16/94 Date

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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 SHEET

CALCULATION TITLE: Distance fragments travel before dropping below threshold velocities (Hydrogen Trailer - Overpressure of three cylinders)

CALCULATION ID: RD-P14-005

REVISION: 0

	Signature	Printed Name	Date
Prepared by:	Carrie L. Wood	CARRIE L. WOOD	12/16/94
Checked by:	Joseph A. Schriner	Joseph A. Schriner	12-16-94
Approved by:	William Thornton	WILLIAM THORNTON	12/16/94

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:

$$R_f = \frac{\ln \frac{V_o}{V_s}\left(W_f^{1/3}\right)}{.004}$$

A. 7.8 ounce fragment

$$R_f = \frac{\ln \frac{2,905}{119}\left(7.8^{1/3}\right)}{.004} = 1,584.1 \text{ ft}$$

B. 1.5 ounce fragment

$$R_f = \frac{\ln \frac{2,905}{119}\left(1.5^{1/3}\right)}{.004} = 914.4 \text{ ft}$$

CALCULATION SHEET

CALCULATION TITLE: Primary Fragments from Cased Cylindrical Charges (Hydrogen Trailer - Overpressure of 30 cylinders)

CALCULATION ID: RD-P15-001

REVISION: 0

Prepared by:	Carrie L. Wood Signature	CARRIE L. Wood Printed Name	12/16/94 Date
Checked by:	Joseph A. Schimmels Signature	Joseph A. Schimmels Printed Name	12-16-94 Date
Approved by:	William Thornton Signature	WILLIAM THORNTON Printed Name	12/16/94 Date

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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^3 = (Density of H_2 in g/cm^3)/ (Conversion Factor of 27.68) (Reference 15)
De = (0.00008988 g/cm^3)/ (27.68) = 3.2E-06 lbs/in^3

b. Wt. of Fuel in 30 cylinders = (Volume of Fuel)/(Volume of 1 lb of fuel)
Wt. = 30,000 ft^3/191.3 ft^3 = 156.8 lbs

c. 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. Outside Diameter of Casing (d_o) = 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)
h. Density of Casing (dc) = 8.0 g/cm^3 (.289 lbs/in^3)

CALCULATION SHEET

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_c)

$$W_c = \frac{\pi[(od)^2 - (id)^2](lc)(dc)}{4}$$

$$W_c = \frac{\pi[(9.625)^2 - (9)^2](252)(0.289)}{4} = 665.8 \text{ lbs}$$

$$\frac{W}{W_c} = \frac{128}{666} = .192 = \text{The ratio of the explosive weight to the casing weight.}$$

Step 3: Initial Fragment Velocity (V_o)

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 SHEET

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_A)

The constant for the explosive charge for TNT in mild steel casing (B) = .30 (Reference 15)

$$M_A = B(tc)^{5/6}(di)^{\frac{1}{3}}\left(1+\frac{tc}{dj}\right)$$

$$M_A = .30(0.3125)^{5/6}(9)^{\frac{1}{3}}\left(1+\frac{0.3125}{9}\right) = 0.245 \text{ lbs}$$

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_f)

$$\ln N_f = \ln\left[\frac{8W_c}{M_A{}^2}\right] - \frac{W_f{}^{1/2}}{M_A}$$

$$\ln N_f = \ln\left[\frac{8(666)}{(0.245)^2}\right] - \frac{(1.5)^{1/2}}{0.245} = 6.39$$

$N_f = 596$ fragments per cylinder (30 cylinders) = 17,880 fragments

CALCULATION SHEET

CALCULATION TITLE: Distance to Threshold Blast Overpressures
(Hydrogen Trailer - Overpressure of 30 cylinders)

CALCULATION ID: RD-P15-002

REVISION: 0

	Signature	Printed Name	Date
Prepared by:	Carrie L. Wood	CARRIE L. WOOD	12/15/94
Checked by:	Joseph A. Schmacr	Joseph A. Schmacr	12-15-94
Approved by:	William Thornton	WILLIAM THORNTON	12/16/94

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 ($ft/lb^{1/3}$)

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. 1 psi

$R_G = (3{,}857.3)^{1/3}(45)$
$R_G = 705.7$ ft

B. 10 psi

$R_G = (3{,}857.3)^{1/3}(9)$
$R_G = 141.1$ ft

CALCULATION SHEET

CALCULATION TITLE: Blast Force to Nearby Structures
(Hydrogen Trailer - Overpressure of 30 cylinders)

CALCULATION ID: RD-P15-003

REVISION: 0

	Signature	Printed Name	Date
Prepared by:	Carrie L. Wood	Carrie L. Wood	12/15/94
Checked by:	Joseph A. Schriner	Joseph A Schriner	12 15-94
Approved by:	William Thornton	William Thornton	12/16/94

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 ($ft/lb^{1/3}$)

$$Z_G = R_G/W^{1/3}$$

a. <u>The walls surrounding HTSF</u>
(5 ft from trailer)

$Z_G = (5\ ft)/(3{,}857.3)^{1/3}$
$Z_G = .32$

for a:
P_{SO} = 8,000 psi

b. <u>AMPL Building</u>
(approx. 105 ft from trailer)

$Z_G = (105\ ft)/(3{,}857.3)^{1/3}$
$Z_G = 6.7$

for b:
P_{SO} = 75 psi

CALCULATION SHEET

CALCULATION TITLE: Fragment Velocity at Threshold
(Hydrogen Trailer - Overpressure of 30 cylinders)

CALCULATION ID: RD-P15-004

REVISION: 0

Prepared by:	Carrie L Wood Signature	CARRIE L. Wood Printed Name	12/15/94 Date
Checked by:	Joseph A. Schriner Signature	Joseph A. Schriner Printed Name	12-15-94 Date
Approved by:	William Thornton Signature	WILLIAM THORNTON Printed Name	12/16/94 Date

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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. 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 SHEET

CALCULATION TITLE: Distance fragments travel before dropping below threshold velocities (Hydrogen Trailer - Overpressure of 30 cylinders)

CALCULATION ID: RD-P15-005

REVISION: 0

	Signature	Printed Name	Date
Prepared by:	Carrie L. Wood	CARRIE L. Wood	12/16/94
Checked by:	Joseph A. Schriner	Joseph A. Schriner	12-16-94
Approved by:	William Thornton	WILLIAM THORNTON	12/16/94

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:

$$R_f = \frac{\ln \frac{V_o}{V_s}\left(W_f^{1/3}\right)}{.004}$$

A. <u>7.8 ounce fragment</u>

$$R_f = \frac{\ln \frac{2,905}{119}\left(7.8^{1/3}\right)}{.004} = 1,584.1 \text{ ft}$$

B. <u>1.5 ounce fragment</u>

$$R_f = \frac{\ln \frac{2,905}{119}\left(1.5^{1/3}\right)}{.004} = 914.4 \text{ ft}$$

CALCULATION SHEET

CALCULATION TITLE: Primary Fragments from Cased Cylindrical Charges (Hydrogen Trailer - Overpressure of 38 cylinders)

CALCULATION ID: RD-P16-001

REVISION: 0

Prepared by:	Carrie L. Ward (Signature)	Carrie L. Ward (Printed Name)	12/16/94 (Date)
Checked by:	Joseph A. Schriner (Signature)	Joseph A. Schriner (Printed Name)	12-16-94 (Date)
Approved by:	William Thornton (Signature)	William Thornton (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^3 = (Density of H_2 in g/cm^3)/ (Conversion Factor of 27.68) (Reference 15)
De = (0.00008988 g/cm^3)/ (27.68) = 3.2E-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

c. 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_o) = 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)
h. Density of Casing (dc) = 8.0 g/cm^3 (.289 lbs/in^3)

CALCULATION SHEET

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_c))

$$W_c = \frac{\pi\left[(od)^2 - (id)^2\right](lc)(dc)}{4}$$

$$W_c = \frac{\pi\left[(9.625)^2 - (9)^2\right](252)(0.289)}{4} = 665.8 \text{ lbs}$$

$$\frac{W}{W_c} = \frac{128}{666} = .192 = \text{The ratio of the explosive weight to the casing weight.}$$

Step 3: Initial Fragment Velocity (V_o)

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 SHEET

CALCULATION TITLE: Primary Fragments from Cased Cylindrical Charges (Hydrogen Trailer - Overpressure of 38 cylinders

CALCULATION ID: RD-P16-001 (cont'd)

REVISION: 0

Step 4: Fragment Distribution Parameter (M_A)

The constant for the explosive charge for TNT in mild steel casing (B) = .30 (Reference 15)

$$M_A = B(tc)^{5/6}(di)^{\frac{1}{3}}\left(1+\frac{tc}{dj}\right)$$

$$M_A = .30(0.3125)^{5/6}(9)^{\frac{1}{3}}\left(1+\frac{0.3125}{9}\right) = 0.245 \text{ lbs}$$

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_f)

$$\ln N_f = \ln\left[\frac{8W_c}{M_A{}^2}\right] - \frac{W_f{}^{1/2}}{M_A}$$

$$\ln N_f = \ln\left[\frac{8(666)}{(0.245)^2}\right] - \frac{(1.5)^{1/2}}{0.245} = 6.39$$

N_f = 596 fragments per cylinder (38 cylinders) = 22,648 fragments

CALCULATION SHEET

CALCULATION TITLE: Distance to Threshold Blast Overpressures
(Hydrogen Trailer - Overpressure of 38 cylinders)

CALCULATION ID: RD-P16-002

REVISION: 0

Prepared by:	Carrie L. Wood (Signature)	CARRIE L. WOOD (Printed Name)	12/15/94 (Date)
Checked by:	Joseph A. Schriner (Signature)	Joseph A. Schriner (Printed Name)	12-15-94 (Date)
Approved by:	William Thornton (Signature)	WILLIAM THORNTON (Printed Name)	12/16/94 (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 ($ft/lb^{1/3}$)

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. 1 psi

$R_G = (4{,}885.6)^{1/3}(45)$
$R_G = 763.6$ ft

B. 10 psi

$R_G = (4{,}885.6)^{1/3}(9)$
$R_G = 152.7$ ft

CALCULATION SHEET

CALCULATION TITLE: Blast Force to Nearby Structures
(Hydrogen Trailer - Overpressure of 38 cylinder)

CALCULATION ID: RD-P16-003

REVISION: 0

Prepared by:	Carrie L. Wood Signature	CARRIE L. Wood Printed Name	12/15/94 Date
Checked by:	Joseph A. Schriner Signature	Joseph A. Schriner Printed Name	12 15-94 Date
Approved by:	William Thornton Signature	WILLIAM THORNTON Printed Name	12/16/94 Date

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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 ($ft/lb^{1/3}$)

$$Z_G = R_G/W^{1/3}$$

a. The walls surrounding HTSF
(5 ft from trailer)

$Z_G = (5\ ft)/(4{,}885.6)^{1/3}$
$Z_G = .29$

for a:
$P_{SO} = 9{,}000$ psi

b. AMPL Building
(approx. 105 ft from trailer)

$Z_G = (105\ ft)/(4{,}885.6)^{1/3}$
$Z_G = 6.19$

for b:
$P_{SO} = 80$ psi

CALCULATION SHEET

CALCULATION TITLE: Fragment Velocity at Threshold
(Hydrogen Trailer - Overpressure of 38 cylinders)

CALCULATION ID: RD-P16-004

REVISION: 0

Prepared by:	Carrie L. Wood Signature	CARRIE L. WOOD Printed Name	12/15/94 Date
Checked by:	Joseph A. Schriner Signature	Joseph A Schriner Printed Name	12-15-94 Date
Approved by:	William Thornton Signature	WILLIAM THORNTON Printed Name	12/16/94 Date

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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 SHEET

CALCULATION TITLE: Distance fragments travel before dropping below threshold velocities (Hydrogen Trailer - Overpressure of 38 cylinders)

CALCULATION ID: RD-P16-005

REVISION: 0

	Signature	Printed Name	Date
Prepared by:	Carrie L. Wood	Carrie L. Wood	12/16/94
Checked by:	Joseph A. Schriner	Joseph A. Schriner	12.16.94
Approved by:	William Thornton	William Thornton	12/16/94

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:

$$R_f = \frac{\ln \frac{V_o}{V_s}\left(W_f^{1/3}\right)}{.004}$$

A. 7.8 ounce fragment

$$R_f = \frac{\ln \frac{2,905}{119}\left(7.8^{1/3}\right)}{.004} = 1,584.1 \text{ ft}$$

B. 1.5 ounce fragment

$$R_f = \frac{\ln \frac{2,905}{119}\left(1.5^{1/3}\right)}{.004} = 914.4 \text{ ft}$$

CALCULATION SHEET

CALCULATION TITLE: Primary Fragments from Cased Cylindrical Charges
(Hydrogen Backup Supply - Overpressure of a single cylinder)

CALCULATION ID: RD-B9-001

REVISION: 0

	Signature	Printed Name	Date
Prepared by:	Carrie L. Wood	CARRIE L. WOOD	12/16/94
Checked by:	Joseph A. Schriner	Joseph A. Schriner	12-16-94
Approved by:	William Thornton	WILLIAM THORNTON	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^3 = (Density of H_2 in g/cm^3)/ (Conversion Factor of 27.68) (Reference 15)
De = (0.00008988 g/cm^3)/ (27.68) = 3.2E-06 lbs/in^3

b. Wt. of Fuel in 1 cylinder = (Volume of Fuel)/(Volume of 1 pound of fuel)
Wt. = 220 ft^3/191.3 ft^3 = 1.15 lbs

c. 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_o) = 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 g/cm^3 (.289 lbs/in^3)

CALCULATION SHEET

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_c)

$$W_c = \frac{\pi\left[(od)^2 - (id)^2\right](lc)(dc)}{4}$$

$$W_c = \frac{\pi\left[(9.625)^2 - (9)^2\right](51)(0.289)}{4} = 135 \text{ lbs}$$

$$\frac{W}{W_c} = \frac{28.3}{135} = 0.21 = \text{The ratio of the explosive weight to the casing weight.}$$

Step 3: Initial Fragment Velocity (V_o)

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 SHEET

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_A)

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

$$W_f = \left[M_A \ln\left(\frac{8W_c}{M_A{}^2}\right)\right]^2$$

$$W_f = \left[0.245 \ln\left(\frac{8(135)}{(0.245)^2}\right)\right]^2 = 5.7 \text{ounces}$$

Step 6: Striking Velocity (V_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, $V_S = V_O$ =3,025.4 ft./second

Step 7: Number of fragments having a weight greater than 1-1/2 ounces (N_f)

$$\ln N_f = \ln\left[\frac{8W_c}{M_A{}^2}\right] - \frac{W_f{}^{1/2}}{M_A}$$

$$\ln N_f = \ln\left[\frac{8(135)}{(0.245)^2}\right] - \frac{(1.5)^{1/2}}{0.245} = 4.798$$

N_f = 121 fragments

CALCULATION SHEET

CALCULATION TITLE: Distance to Threshold Blast Overpressures
(Hydrogen Backup Supply - Overpressure of a single cylinder)

CALCULATION ID: RD-B9-002

REVISION: 0

Prepared by:	Carrie L. Wood Signature	Carrie L. Wood Printed Name	12/15/94 Date
Checked by:	Joseph A. Schriner Signature	Joseph A. Schriner Printed Name	12-15-94 Date
Approved by:	William Thornton Signature	William Thornton Printed Name	12/16/94 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 ($ft/lb^{1/3}$)

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. 1 psi

$R_G = (28.3)^{1/3}(45)$
$R_G = 137.1$ ft

B. 10 psi

$R_G = (28.3)^{1/3}(9)$
$R_G = 27.4$ ft

CALCULATION SHEET

CALCULATION TITLE: Blast Force to Nearby Structures
(Hydrogen Backup Supply - Overpressure of a single cylinder)

CALCULATION ID: RD-B9-003

REVISION: 0

	Signature	Printed Name	Date
Prepared by:	Carrie L. Wood	CARRIE L. WOOD	12/15/94
Checked by:	Joseph A. Schriner	Joseph A Schriner	12 15 94
Approved by:	William Thornton	WILLIAM THORNTON	12/16/94

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 ($ft/lb^{1/3}$)

$$Z_G = R_G/W^{1/3}$$

a. <u>The walls surrounding HTSF</u>
(5 ft from trailer)

$Z_G = (5\ ft)/(28.3)^{1/3}$
$Z_G = 1.63$

for a:
$P_{SO} = 800$ psi

b. <u>AMPL Building</u>
(approx. 105 ft from trailer)

$Z_G = (105\ ft)/(28.3)^{1/3}$
$Z_G = 34.4$

for b:
$P_{SO} = 6$ psi

CALCULATION SHEET

CALCULATION TITLE: Fragment Velocity at Threshold
(Hydrogen Backup Supply- Overpressure of a single cylinder)

CALCULATION ID: RD-B9-004

REVISION: 0

Prepared by:	Carrie L. Wood Signature	CARRIE L. Wood Printed Name	12/15/94 Date
Checked by:	Joseph A. Schuler Signature	Joseph A. Schuler Printed Name	12-15-94 Date
Approved by:	William Thornton Signature	WILLIAM THORNTON 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 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

$$V_s = \frac{58}{0.35625} = 162.8 \text{ ft/sec}$$

B. 1.5 ounce fragment

$$V_s = \frac{58}{0.09375} = 618.66 \text{ ft/sec}$$

CALCULATION SHEET

CALCULATION TITLE: Distance fragments travel before dropping below threshold velocities (Hydrogen Backup Supply - Overpressure of a single cylinder)

CALCULATION ID: RD-B9-005

REVISION: 0

	Signature	Printed Name	Date
Prepared by:	Carrie L. Wood	CARRIE L. WOOD	12/16/94
Checked by:	Joseph A. Schriner	Joseph A. Schriner	12-16-94
Approved by:	William Thornton	WILLIAM THORNTON	12/16/94

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:

$$R_f = \frac{\ln \frac{V_o}{V_s}\left(W_f^{1/3}\right)}{.004}$$

A. 5.7 ounce fragment

$$R_f = \frac{\ln \frac{3,025.4}{162.8}\left(5.7^{1/3}\right)}{.004} = 1,308.1\,\text{ft}$$

B. 1.5 ounce fragment

$$R_f = \frac{\ln \frac{3,025.4}{618.7}\left(1.5^{1/3}\right)}{.004} = 454.2\,\text{ft}$$

CALCULATION SHEET

CALCULATION TITLE: Primary Fragments from Cased Cylindrical Charges (Hydrogen Backup Supply - Overpressure of three cylinders)

CALCULATION ID: RD-B10-001

REVISION: 0

	Signature	Printed Name	Date
Prepared by:	Carrie L. Wood	Carrie L. Wood	12/16/94
Checked by:	Joseph A. Schriner	Joseph A. Schriner	12-16-94
Approved by:	William Thornton	William Thornton	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^3 = (Density of H_2 in g/cm^3)/ (Conversion Factor of 27.68) (Reference 15)
De = (0.00008988 g/cm^3)/ (27.68) = 3.2E-06 lbs/in^3

b. Wt. of Fuel in 3 cylinders = (Volume of Fuel)/(Volume of 1 lb. of fuel)
Wt. = 660 ft^3/191.3 ft^3 = 3.45 lbs

c. 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_o) = 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 g/cm^3 (.289 lbs/in^3)

CALCULATION SHEET

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_c)

$$W_c = \frac{\pi[(od)^2 - (id)^2](lc)(dc)}{4} ,$$

$$W_c = \frac{\pi[(9.625)^2 - (9)^2](51)(0.289)}{4} = 135 \text{ lbs}$$

$$\frac{W}{W_c} = \frac{28.3}{135} = 0.21 = \text{The ratio of the explosive weight to the casing weight.}$$

Step 3: Initial Fragment Velocity (V_o)

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 SHEET

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_A)

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

$$W_f = \left[M_A \ln\left(\frac{8W_c}{M_A{}^2}\right)\right]^2$$

$$W_f = \left[0.245 \ln\left(\frac{8(135)}{(0.245)^2}\right)\right]^2 = 5.7 \text{ ounces}$$

Step 6: Striking Velocity (V_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, $V_S = V_O$ =3,025.4 ft./second

Step 7: Number of fragments having a weight greater than 1-1/2 ounces (N_f)

$$\ln N_f = \ln\left[\frac{8W_c}{M_A{}^2}\right] - \frac{W_f{}^{1/2}}{M_A}$$

$$\ln N_f = \ln\left[\frac{8(135)}{(0.245)^2}\right] - \frac{(1.5)^{1/2}}{0.245} = 4.798$$

N_f = 121 fragments (3 cylinders) = 363 fragments

CALCULATION SHEET

CALCULATION TITLE: Distance to Threshold Blast Overpressures
(Hydrogen Backup Supply - Overpressure of three cylinders)

CALCULATION ID: RD-B10-002

REVISION: 0

	Signature	Printed Name	Date
Prepared by:	Carrie L. Wood	CARRIE L. WOOD	12/15/94
Checked by:	Joseph A. Schriner	Joseph A. Schriner	12-15-94
Approved by:	William Thurston	WILLIAM THURSTON	12/16/94

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 ($ft/lb^{1/3}$)

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. 1 psi

$R_G = (84.9)^{1/3}(45)$
$R_G = 197.8$ ft

B. 10 psi

$R_G = (84.9)^{1/3}(9)$
$R_G = 39.6$ ft

CALCULATION SHEET

CALCULATION TITLE: Blast Force to Nearby Structures
(Hydrogen Backup Supply - Overpressure of threee cylinders)

CALCULATION ID: RD-B10-003

REVISION: 0

	Signature	Printed Name	Date
Prepared by:	Carrie L. Wood	Carrie L. Wood	12/15/94
Checked by:	Joseph A. Schriner	Joseph A. Schriner	12-15-94
Approved by:	William Thornton	William Thornton	12/16/94

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 ($ft/lb^{1/3}$)

$$Z_G = R_G/W^{1/3}$$

a. <u>The walls surrounding HTSF</u>
(5 ft from trailer)

$Z_G = (5\ ft)/(84.9)^{1/3}$
$Z_G = 1.14$

for a:
$P_{SO} = 80$ psi

b. <u>AMPL Building</u>
(approx. 105 ft from trailer)

$Z_G = (105\ ft)/(84.9)^{1/3}$
$Z_G = 23.9$

for b:
$P_{SO} = 7$ psi

CALCULATION SHEET

CALCULATION TITLE: Fragment Velocity at Threshold
(Hydrogen Backup Supply- Overpressure of three cylinders)

CALCULATION ID: RD-B10-004

REVISION: 0

Prepared by:	Carrie L. Wood Signature	CARRIE L. WOOD Printed Name	12/15/94 Date
Checked by:	Joseph A. Schiner Signature	Joseph A. Schiner Printed Name	12-15-94 Date
Approved by:	William Thornton Signature	WILLIAM THORNTON Printed Name	12/16/94 Date

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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

$$V_s = \frac{58}{0.35625} = 162.8 \text{ ft/sec}$$

B. 1.5 ounce fragment

$$V_s = \frac{58}{0.09375} = 618.66 \text{ ft/sec}$$

CALCULATION SHEET

CALCULATION TITLE: Distance fragments travel before dropping below threshold velocities (Hydrogen Backup Supply - Overpressure of three cylinders)

CALCULATION ID: RD-B10-005

REVISION: 0

Prepared by:	Carrie L. Wood Signature	CARRIE L. Wood Printed Name	12/16/94 Date
Checked by:	Joseph A. Schriner Signature	Joseph A. Schriner Printed Name	12-16-94 Date
Approved by:	William Thornton Signature	WILLIAM THORNTON Printed Name	12/16/94 Date

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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:

$$R_f = \frac{\ln \frac{V_o}{V_s}\left(W_f^{1/3}\right)}{.004}$$

A. 5.7 ounce fragment

$$R_f = \frac{\ln \frac{3,025.4}{162.8}\left(5.7^{1/3}\right)}{.004} = 1,308.1\,\text{ft}$$

B. 1.5 ounce fragment

$$R_f = \frac{\ln \frac{3,025.4}{618.7}\left(1.5^{1/3}\right)}{.004} = 454.2\,\text{ft}$$

CALCULATION SHEET

CALCULATION TITLE: Primary Fragments from Cased Cylindrical Charges
(Hydrogen Backup Supply - Overpressure of twelve cylinders)

CALCULATION ID: RD-B11-001

REVISION: 0

Prepared by:	Carrie L. Wood Signature	Carrie L. Wood Printed Name	12/16/94 Date
Checked by:	Joseph A. Schriner Signature	Joseph A. Schriner Printed Name	12-16-94 Date
Approved by:	William Thornton Signature	William Thornton Printed Name	12/16/94 Date

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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^3 = (Density of H_2 in g/cm^3)/ (Conversion Factor of 27.68) (Reference 15)
De = (0.00008988 g/cm^3)/ (27.68) = 3.2E-06 lbs/in^3

b. Wt. of Fuel in 3 cylinders = (Volume of Fuel)/(Volume of 1 lb. of fuel)
Wt. = 2,640 ft^3/191.3 ft^3 = 13.8 lbs

c. 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_o) = 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 g/cm^3 (.289 lbs/in^3)

CALCULATION SHEET

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_c)

$$W_c = \frac{\pi[(od)^2 - (id)^2](lc)(dc)}{4}$$

$$W_c = \frac{\pi[(9.625)^2 - (9)^2](51)(0.289)}{4} = 135 \text{ lbs}$$

$$\frac{W}{W_c} = \frac{28.3}{135} = 0.21 = \text{The ratio of the explosive weight to the casing weight.}$$

Step 3: Initial Fragment Velocity (V_o)

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 SHEET

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_A)

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

$$W_f = \left[M_A \ln\left(\frac{8W_c}{M_A^2}\right)\right]^2$$

$$W_f = \left[0.245 \ln\left(\frac{8(135)}{(0.245)^2}\right)\right]^2 = 5.7 \text{ounces}$$

Step 6: Striking Velocity (V_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, $V_S = V_O$ =3,025.4 ft./second

Step 7: Number of fragments having a weight greater than 1-1/2 ounces (N_f)

$$\ln N_f = \ln\left[\frac{8W_c}{M_A^2}\right] - \frac{W_f^{1/2}}{M_A}$$

$$\ln N_f = \ln\left[\frac{8(135)}{(0.245)^2}\right] - \frac{(1.5)^{1/2}}{0.245} = 4.798$$

N_f = 121 fragments (12 cylinders) = 1,452 fragments

CALCULATION SHEET

CALCULATION TITLE: Distance to Threshold Blast Overpressures (Hydrogen Backup Supply - Overpressure of twelve cylinders)

CALCULATION ID: RD-B11-002

REVISION: 0

	Signature	Printed Name	Date
Prepared by:	Carrie L. Wood	CARRIE L. Wood	12/15/94
Checked by:	Joseph A. Schriner	Joseph A. Schriner	12-15-94
Approved by:	William Thornton	WILLIAM THORNTON	12/16/94

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 ($ft/lb^{1/3}$)

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. 1 psi

$R_G = (339.5)^{1/3}(45)$
$R_G = 312.75$ ft

B. 10 psi

$R_G = (339.5)^{1/3}(9)$
$R_G = 62.82$ ft

CALCULATION SHEET

CALCULATION TITLE: Blast Force to Nearby Structures
(Hydrogen Backup Supply - Overpressure of twelve cylinders)

CALCULATION ID: RD-B11-003

REVISION: 0

Prepared by:	Carrie L. Wood Signature	CARRIE L. Wood Printed Name	12/15/94 Date
Checked by:	Joseph A. Schriner Signature	Joseph A. Schriner Printed Name	12 15-94 Date
Approved by:	William Thornton Signature	WILLIAM THORNTON Printed Name	12/16/94 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 ($ft/lb^{1/3}$)

$$Z_G = R_G/W^{1/3}$$

a. <u>The walls surrounding HTSF</u>
(5 ft from trailer)

$Z_G = (5\ ft)/(339.5)^{1/3}$
$Z_G = .72$

for a:
P_{SO} = 3,000 psi

b. <u>AMPL Building</u>
(approx. 105 ft from trailer)

$Z_G = (105\ ft)/(339.5)^{1/3}$
$Z_G = 15.04$

for b:
P_{SO} = 8 psi

CALCULATION SHEET

CALCULATION TITLE: Fragment Velocity at Threshold
(Hydrogen Backup Supply- Overpressure of twelve cylinders)

CALCULATION ID: RD-B11-004

REVISION: 0

Prepared by:	Carrie L Wood Signature	CARRIE L. WOOD Printed Name	12/15/94 Date
Checked by:	Joseph A. Schriner Signature	Joseph A. Schriner Printed Name	12-15-94 Date
Approved by:	William Thornton Signature	WILLIAM THORNTON 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 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

$$V_s = \frac{58}{0.35625} = 162.8 \text{ ft/sec}$$

B. 1.5 ounce fragment

$$V_s = \frac{58}{0.09375} = 618.66 \text{ ft/sec}$$

CALCULATION SHEET

CALCULATION TITLE: Distance fragments travel before dropping below threshold velocities (Hydrogen Backup Supply - Overpressure of twelve cylinders)

CALCULATION ID: RD-B11-005

REVISION: 0

Prepared by:	Carrie L. Wood Signature	CARRIE L. WOOD Printed Name	12/16/94 Date
Checked by:	Joseph A. Schriner Signature	Joseph A. Schriner Printed Name	12-16-94 Date
Approved by:	William Thornton 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:

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:

$$R_f = \frac{\ln \frac{V_o}{V_s}\left(W_f^{1/3}\right)}{.004}$$

A. 5.7 ounce fragment

$$R_f = \frac{\ln \frac{3,025.4}{162.8}\left(5.7^{1/3}\right)}{.004} = 1,308.1\,\text{ft}$$

B. 1.5 ounce fragment

$$R_f = \frac{\ln \frac{3,025.4}{618.7}\left(1.5^{1/3}\right)}{.004} = 454.2\,\text{ft}$$

CALCULATION SHEET

CALCULATION TITLE: Primary Fragments from Cased Cylindrical Charges (Hydrogen Backup Supply - Overpressure of eighteen cylinders)

CALCULATION ID: RD-B12-001

REVISION: 0

	Signature	Printed Name	Date
Prepared by:	Carrie L. Wood	CARRIE L. WOOD	12/16/94
Checked by:	Joseph A. Schriner	Joseph A. Schriner	12-16-94
Approved by:	William Thornton	WILLIAM THORNTON	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^3 = (Density of H_2 in g/cm^3)/ (Conversion Factor of 27.68) (Reference 15)
De = (0.00008988 g/cm^3)/ (27.68) = 3.2E-06 lbs/in^3

b. Wt. of Fuel in 3 cylinders = (Volume of Fuel)/(Volume of 1 lb. of fuel)
Wt. = 3,960 ft^3/191.3 ft^3 = 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_o) = 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 g/cm^3 (.289 lbs/in^3)

CALCULATION SHEET

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_c)

$$W_c = \frac{\pi\left[(od)^2 - (id)^2\right](lc)(dc)}{4}$$

$$W_c = \frac{\pi\left[(9.625)^2 - (9)^2\right](51)(0.289)}{4} = 135 \text{ lbs}$$

$$\frac{W}{W_c} = \frac{28.3}{135} = 0.21 = \text{The ratio of the explosive weight to the casing weight.}$$

Step 3: Initial Fragment Velocity (V_o)

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 SHEET

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_A)

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

$$W_f = \left[M_A \ln\left(\frac{8W_c}{M_A^2}\right)\right]^2$$

$$W_f = \left[0.245 \ln\left(\frac{8(135)}{(0.245)^2}\right)\right]^2 = 5.7 \text{ounces}$$

Step 6: Striking Velocity (V_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, $V_S = V_O$ =3,025.4 ft./second

Step 7: Number of fragments having a weight greater than 1-1/2 ounces (N_f)

$$\ln N_f = \ln\left[\frac{8W_c}{M_A^2}\right] - \frac{W_f^{1/2}}{M_A}$$

$$\ln N_f = \ln\left[\frac{8(135)}{(0.245)^2}\right] - \frac{(1.5)^{1/2}}{0.245} = 4.798$$

N_f = 121 fragments (18 cylinders) = 2,178 fragments

CALCULATION SHEET

CALCULATION TITLE: Distance to Threshold Blast Overpressures (Hydrogen Backup Supply - Overpressure of eighteen cylinders)

CALCULATION ID: RD-B12-002

REVISION: 0

	Signature	Printed Name	Date
Prepared by:	Carrie L. Wood	CARRIE L. WOOD	12/15/94
Checked by:	Joseph A. Schriner	Joseph A. Schriner	12-15-94
Approved by:	William Thornton	WILLIAM THORNTON	12/16/94

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 ($ft/lb^{1/3}$)

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. 1 psi

$R_G = (509.3)^{1/3}(45)$
$R_G = 359.6$ ft

B. 10 psi

$R_G = (509.3)^{1/3}(9)$
$R_G = 71.9$ ft

CALCULATION SHEET

CALCULATION TITLE: Blast Force to Nearby Structures
(Hydrogen Backup Supply - Overpressure of eighteen cylinders)

CALCULATION ID: RD-B12-003

REVISION: 0

Prepared by:	Carrie L. Wood Signature	CARRIE L. WOOD Printed Name	12/15/94 Date
Checked by:	Joseph A. Schriner Signature	Joseph A. Schriner Printed Name	12-15-94 Date
Approved by:	William Thornton Signature	WILLIAM THORNTON Printed Name	12/16/94 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 ($ft/lb^{1/3}$)

$$Z_G = R_G/W^{1/3}$$

a. <u>The walls surrounding HTSF</u>
(5 ft from trailer)

$Z_G = (5\ ft)/(509.3)^{1/3}$
$Z_G = .63$

for a:
P_{so} = 5,000 psi

b. <u>AMPL Building</u>
(approx. 105 ft from trailer)

$Z_G = (105\ ft)/(509.3)^{1/3}$
$Z_G = 13.14$

for b:
P_{so} = 8 psi

CALCULATION SHEET

CALCULATION TITLE: Fragment Velocity at Threshold
(Hydrogen Backup Supply- Overpressure of eighteen cylinders)

CALCULATION ID: RD-B12-004

REVISION: 0

Prepared by:	Carrie L. Wood Signature	Carrie L. Wood Printed Name	12/15/94 Date
Checked by:	Joseph A. Schriner Signature	Joseph A. Schriner Printed Name	12-15-94 Date
Approved by:	William Thornton Signature	William Thornton Printed Name	12/16/94 Date

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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

$$V_s = \frac{58}{0.35625} = 162.8 \text{ ft/sec}$$

B. 1.5 ounce fragment

$$V_s = \frac{58}{0.09375} = 618.66 \text{ ft/sec}$$

CALCULATION SHEET

CALCULATION TITLE: Distance fragments travel before dropping below threshold velocities (Hydrogen Backup Supply - Overpressure of eighteen cylinders)

CALCULATION ID: RD-B12-005

REVISION: 0

	Signature	Printed Name	Date
Prepared by:	Carrie L. Wood	CARRIE L. WOOD	12/16/94
Checked by:	Joseph A. Schriner	Joseph A. Schriner	12-16 94
Approved by:	William Thornton	WILLIAM THORNTON	12/16/94

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:

$$R_f = \frac{\ln \frac{V_o}{V_s}\left(W_f^{1/3}\right)}{.004}$$

A. 5.7 ounce fragment

$$R_f = \frac{\ln \frac{3,025.4}{162.8}\left(5.7^{1/3}\right)}{.004} = 1,308.1\,\text{ft}$$

B. 1.5 ounce fragment

$$R_f = \frac{\ln \frac{3,025.4}{618.7}\left(1.5^{1/3}\right)}{.004} = 454.2\,\text{ft}$$

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