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REPORT

EPA CHEMICAL ACCIDENT INVESTIGATION REPORT

Accra Pac Group, Inc.
North Plant
Elkhart, Indiana

Chemical Emergency Preparedness and Prevention Office

Printed on recycled paper

The EPA Chemical Accident Investigation Program

EPA has a responsibility under section 112(r) of the Clean Air Act Amendments of 1990 for the prevention and mitigation of accidental releases. One of the fundamental ways to prevent accidents is to understand why accidents occur and to apply the lessons learned to prevent future incidents. Consequently, EPA has a responsibility to investigate and understand why certain chemical accidents have occurred. A key objective of the EPA chemical accident investigation program is to determine and report to the public the facts, conditions, circumstances, and causes or probable causes of chemical accidents that resulted, or could have resulted, in a fatality, serious injury, substantial property damage, or serious off-site impact, including a large scale evacuation of the general public. The ultimate goal of the accident investigation is to determine the root causes in order to reduce the likelihood of recurrence, to minimize the consequences associated with accidental releases, and to make chemical production, processing, handling, and storage safer. This report is a result of an EPA investigation to describe the accident, determine root causes and contributing factors, and identify findings and recommendations.

In the EPA chemical accident investigation report preparation process, companies mentioned in the report are provided a draft of only the factual portions (no findings, conclusions, or recommendations) for their review for confidential business information. Federal agencies are required by provisions of the Freedom of Information Act (FOIA), the Trade Secrets Act, and Executive Order 12600 to protect confidential business information from public disclosure. As part of this clearance process, companies often will provide additional factual information that EPA considers and evaluates for possible inclusion in the final report.

Chemical accident investigations by EPA Headquarters are conducted by the Chemical Accident Investigation Team (CAIT) located in the Chemical Emergency Preparedness and Prevention Office (CEPPO) at 1200 Pennsylvania Avenue, NW, Washington, DC 20460, 202-260-8600. More information about CEPPO and the CAIT may be found at the CEPPO Homepage on the Internet at “www.epa.gov/swercepp/”. EPA also has accident investigation capability in its ten Regional offices. This Accident Investigation was led by the Region 5 team.

U.S. Chemical Safety and Hazard Investigation Board (CSB)

In 1990, the U.S. Chemical Safety and Hazard Investigation Board (CSB) was created as an independent board in the amendments to the Clean Air Act. Modeled after the National Transportation Safety Board, the CSB was directed by Congress to conduct investigations and report on findings regarding the causes of any accidental chemical releases resulting in a fatality, serious injury, or substantial property damages. In October 1997, Congress authorized initial funding for the CSB. The CSB started its operations in January 1998 and has begun several chemical accident investigations. More information about the CSB may be found at the CSB homepage on the Internet at “www.chemsafety.gov”.

For those joint investigations begun by EPA and the Occupational Safety and Health Administration (OSHA) prior to the initial funding of the CSB, the agencies have committed to completing their ongoing investigations and issuing public reports. Under their existing authorities, both EPA and OSHA will continue to have roles and responsibilities in responding to and investigating chemical accidents. The CSB, EPA, and OSHA (as well as other agencies) are developing approaches for coordinating efforts to support accident prevention programs and to minimize potential duplication of activities.

Basis of Decision to Investigate

An explosion and fire occurred at the Accra Pac Group, Inc., North Plant Facility located in Elkhart, Indiana on June 24, 1997. EPA investigated the accident because of the serious consequences of the incident, the hazardous characteristics of the chemical involved, and the opportunity for lessons learned and prevention of future accidents. This investigation was conducted simultaneously with the Indiana Occupational Safety and Health Administration and the Indiana State Fire Marshall's Office.

Executive Summary

An explosion and fire occurred at the Accra Pac Group, Inc., North Plant Facility located in Elkhart, Indiana on June 24, 1997. This incident killed one employee; caused 59 people, including plant employees, fire department personnel, and residents, to seek medical treatment; and caused extensive damage to the facility. An evacuation extending to a one-mile radius from the facility occurred as a result of the explosion and fire.

The Accra Pac facility produces various pressurized containers, most of which are consumer aerosol products such as hair sprays and deodorants. These pressurized containers typically consist of a product, such as hair spray or deodorant, and a propellant, usually propane, to aerosolize the product and form a spray.

The explosion occurred at the building known as the Gas House for line No. 61, which was one of several such buildings where pressurized containers are filled with propellant. The pressurized containers are usually filled in two stages. In the first stage, the product is placed in the container. Since the products are not hazardous chemicals, this is done in the North Plant Production Building, hereinafter referred to as the Production Building. In the second stage, the propellant is placed into the container. This is performed in the Gas House.

A conveyor system brings the containers from the Production Building to the Gas House. Filled containers are then moved by conveyor back to the Production Building for leak and quality control checks and then on to packaging.

On the day of the explosion, line No. 61 was in the second day of a four-day production run filling containers with ethylene oxide for use as a sterilant, primarily in hospitals. This production run is a variation of the regular pressurized container filling. The ethylene oxide container does not produce an aerosol and has just one chemical - ethylene oxide. The ethylene oxide container consists of only a can with a crimped sealed cap. There are no valves or internal mechanisms for spraying. All the filling of ethylene oxide takes place in the Gas House.

Ethylene oxide is a highly reactive and toxic chemical. It is classified by the National Fire Protection Association (NFPA) as a class 1A flammable liquid, and it is listed by EPA as an "extremely hazardous substance".

Because of ethylene oxide's toxicity, the Gas House operator is required to wear protective clothing and use a respirator during ethylene oxide filling. Supplied breathing air is pumped to the operator's respirator via an air hose.

The ethylene oxide filling operation in the Gas House consists of a feed system where ethylene oxide liquid from a storage tank is brought through a stainless steel pipe to the Gas House at 55-65 pounds-per-square-inch-gauge pressure (psig). In the Gas House, ethylene oxide is fed into the Graco pump, which is a feed-booster pump, where ethylene oxide is pressurized to

600-650 psig and then sent to the "under-the-cup" filling machine. A small amount of ethylene oxide is released into the Gas House during the filling and sealing of each container. Hence, the filling machine meters out approximately 105 grams of ethylene oxide for each 100-gram container it fills. (The target amount for each 100-gram container is 101.5 - 102.5 gram.) Any excess ethylene oxide is sent to a reclamation tank located in the Gas House.

The Gas House is also connected to a catalytic oxidizer, ETO-Abator®, to break down ethylene oxide vapor so that it will not be released into the environment.

About 2:00 p.m. on June 24, the pump that supplied breathing air to the operator in the Gas House stopped. Unable to breathe without supplied breathing air, the operator was forced to quickly shut down the filling operation and leave the Gas House.

After the breathing-air pump was fixed, the operator returned to the Gas House to restart the production line. However, he noticed that an alarm indicating a high level of hydrocarbon vapor had been triggered. The alarm indicated that the level of hydrocarbon vapor had exceeded 40 percent of the lower explosive limit (LEL). (The Gas House is used primarily for processing hydrocarbons such as propane and iso-butane. Since ethylene oxide is not a hydrocarbon, the facility does not know the level of ethylene oxide which would trigger this alarm.) The operator immediately left the Gas House to check on the instrumentation located in the adjacent Production Building.

As he exited the Gas House, a large explosion occurred. The deflagration panels on the Gas House were blown off, the roof bulged and split open, and all the doors were blown off the Gas House. The operator was thrown a distance of about 10 feet. He suffered an injury to his shoulder and received cuts and lacerations.

An Accra Pac employee working in the Production Building across from the Gas House was killed as a result of the explosion. When the Gas House doors were blown off, the door facing the Production Building impacted the Production Building door and caused that door and its frame to be dislodged and blown into the Production Building where it struck and killed the employee.

The EPA Chemical Accident Investigation Team (CAIT) believes that the explosion was caused by ethylene oxide vapor that had accumulated in the Gas House. The vapor exceeded the LEL and contacted an ignition source which initiated the explosion. The CAIT identified the following as root causes and contributing factors in the accident:

- **Inadequate shut-down procedure** - When the breathing air supply to the respirator was interrupted, there was a hurried shut down of the filling operation. The shut down steps taken included blocking off the containers on the incoming conveyor and cutting the air supply used to drive the Graco pump. None of the valves in the ethylene oxide supply system were closed. In the event of a leak in the system within the Gas House, the

pressurized ethylene oxide in the storage tanks located outside the Gas House could discharge into the Gas House.

- **Location of the reclamation tank -** Locating the reclamation tank, which holds up to 20 pounds of ethylene oxide, inside the Gas House violates good industry practice for minimizing the quantity of hazardous material in an occupied area. A leak in the reclamation tank system could result in a discharge that would exceed the LEL. Also, **the reclamation tank did not have instrumentation for monitoring the amount of liquid it contained.** Overfilling the tank could lead to over-pressure which in turn could lead to a rapid release of its contents.

- **Lack of sufficient barriers or separation spacing between the Gas House and the Production Building** - Per National Fire Protection Agency (NFPA) Code 30, 5-3.2.2 "Where Class 1A liquids or unstable liquids, regardless of class, are handled or processed, the exposing walls shall have explosion resistance in accordance with good engineering practice." The Production Building did not provide sufficient explosion resistance to protect the occupants. The door on the Production Building was blown off its mounting. The employee in the Production Building was killed when struck by the door.

- **Insufficient explosion venting to permit adequate pressure release -** Pursuant to determinations using guidelines found in NFPA Code 68, a much larger vent area should have been provided to allow explosion pressure release without destruction of the building. The Gas House is designed with deflagration panels. The deflagration panels are designed to blow out to permit adequate pressure release in the event of an explosion inside the Gas House. The line No. 61 Gas House's deflagration panels were designed for use with members of the NEC Group D flammable vapors, of which propane is a member. The fundamental burning velocity and the rate of explosion pressure rise of ethylene oxide is over twice that of propane. The explosion vents of the Gas House were barely adequate for propane. The explosion vents were not adequate for ethylene oxide which is much more hazardous than propane in terms of explosions.

- **Inadequate door design -** The doors on the Gas House were not permitted to swing open freely in response to the explosion. There was damage on the door jambs. The damage indicated that the doors were closed with the latches in the closed position. NFPA 68, 9-4.1 for venting of deflagrations states that hinged doors should swing outward and have latches that release under slight internal pressure. If the doors were less restrained and able to swing open easily, they could have swung open with the explosion and have been less likely to be blown off, thus reducing the likelihood of injuries and property damage. The doors opening easily would also limit the pressure buildup in the Gas House and reduce the explosion blast effect.

- **Use of electrical equipment that did not meet National Electrical Code (NEC) requirements** - Ethylene oxide is a NEC Class 1, Division 1, Group B material. The Gas

House did not meet the NEC requirement for working with ethylene oxide. The electrical equipment in the Gas House could have provided initiation for the explosion.

Based on the root causes and contributing factors of this accident described above, the CAIT provides the following recommendations to prevent accidents like this one from occurring in the future at this and other facilities:

- **Establish safe emergency shutdown devices and procedures for all operations.** The facility must examine situations where a quick shutdown of operations must occur and ensure that the necessary devices and procedures are in place. Systems and procedures must ensure that critical steps are followed in their proper order and that critical equipment is stopped and valves closed to sufficiently isolate the process. For example, Accra Pac should consider installation of valves in ethylene oxide feed lines that close automatically when the conveyor line is stopped. Depending on operational circumstances, such as in restricted or hazardous areas, facilities should consider manual shutdown devices that can be remotely operated so that employees do not need to enter hazardous situations.

- **Relocate the reclamation tank to a location outside the Gas House to reduce the amount of hazardous material inside the occupied building.** In the event of a tank leak, this would reduce the likelihood of injury to the occupant of the Gas House. Also, **develop a way to monitor the quantity of material in the reclamation tank.** This capability is necessary to avoid overfilling which can lead to an accidental release. Finally, **install a non-return check valve on the reclamation tank.** This would minimize any release should the feed line or any connectors leading to the reclamation tank fail.

- **Properly locate and provide sufficient barriers between units that have a potential for explosion from other processes in accordance with NFPA 30, 5-3.2.2.** Units that are recognized as hazardous with a potential for explosion should be sufficiently spaced away or provided with blast walls between units such that if an explosion occurs, employees in other locations are not harmed.

- **Provide adequate deflagration venting capability for the Gas House.** The Gas House should have deflagration venting capability that is appropriate for any material that may be handled.

- **Evaluate doors to ensure outward swing action and latches that easily release under slight internal pressure**. Doors that are designed to be of minimum weight and that have latches that easily release (friction, spring loaded, or magnetic devices) will allow the doors to provide additional over-pressure relief. For personnel safety, the doors should be designed to remain attached to the building in the event of an explosion.

- **Limit the electrical equipment in the Gas House to those that meet the NEC rating**

for the type of material being processed. NEC Class I, Group B is required for working with ethylene oxide.

In addition, the following are recommended to improve safety in the Gas House:

- **Ensure the maximum reliability of breathing air systems.** The supplied breathing air system must be designed, maintained, and operated for maximum reliability. In addition, facilities should consider alarms and backup breathing air supplies to ensure the safety of workers, and to allow a safe shutdown of the unit as necessary.

- **Relocate the feed charge pump (Graco or similar).** The feed charge pumps, Graco in this case, and their associated valving could develop into a source of leakage. Locating the pump inside an occupied building such as the Gas House could add to the concentration of ethylene oxide in that occupied area. Locating the pump to a location outside the Gas House would reduce the likelihood of an explosion as a result of pump leakage. The controls for the feed charge pump can be located within the Gas House.

- **Perform process hazard analysis.** A thorough process hazard analysis should be performed before commencing processing of any hazardous material. A hazard analysis that addressed the requirements for each of the individual types of process operations would have identified the conditions that led to the explosion and resultant fatality.

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1.0 Background

The Accra Pac facility in Elkhart, Indiana is located on the corner of Middlebury Street and Middleton Run. Within a one-mile radius of the facility are industrial sites, businesses, a trailer park, and single family homes. The St. Joseph River and the Elkhart River are also located within one-mile of the facility. (See Exhibit 1)

1.1 Operations

Accra Pac has several production lines at the facility. Each production line includes a gas house. Production line No. 61 is used for general pressurized container filling operations, which include ethylene oxide filling. Accra Pac first performed ethylene oxide filling in February 1995. The June 1997 production run was the eighth time that Accra Pac performed ethylene oxide filling. At the time of the explosion, line No. 61 was in the second day of a four-day ethylene oxide filling run.

1.2 Chemical Information

Ethylene Oxide

Ethylene Oxide, C_2H_4O, is a colorless gas at room temperature with an ether-like odor.

Physical Properties	Ethylene Oxide
Boiling Point	51 °F
Liquid Density at 68 °F	7.25 lbs/gal
Flash Point (Tag open cup)	<0 °F
Auto-ignition Temperature	804 °F
Lower Explosive Limit (LEL)	3 %
Upper Explosive Limit (UEL)	100 %

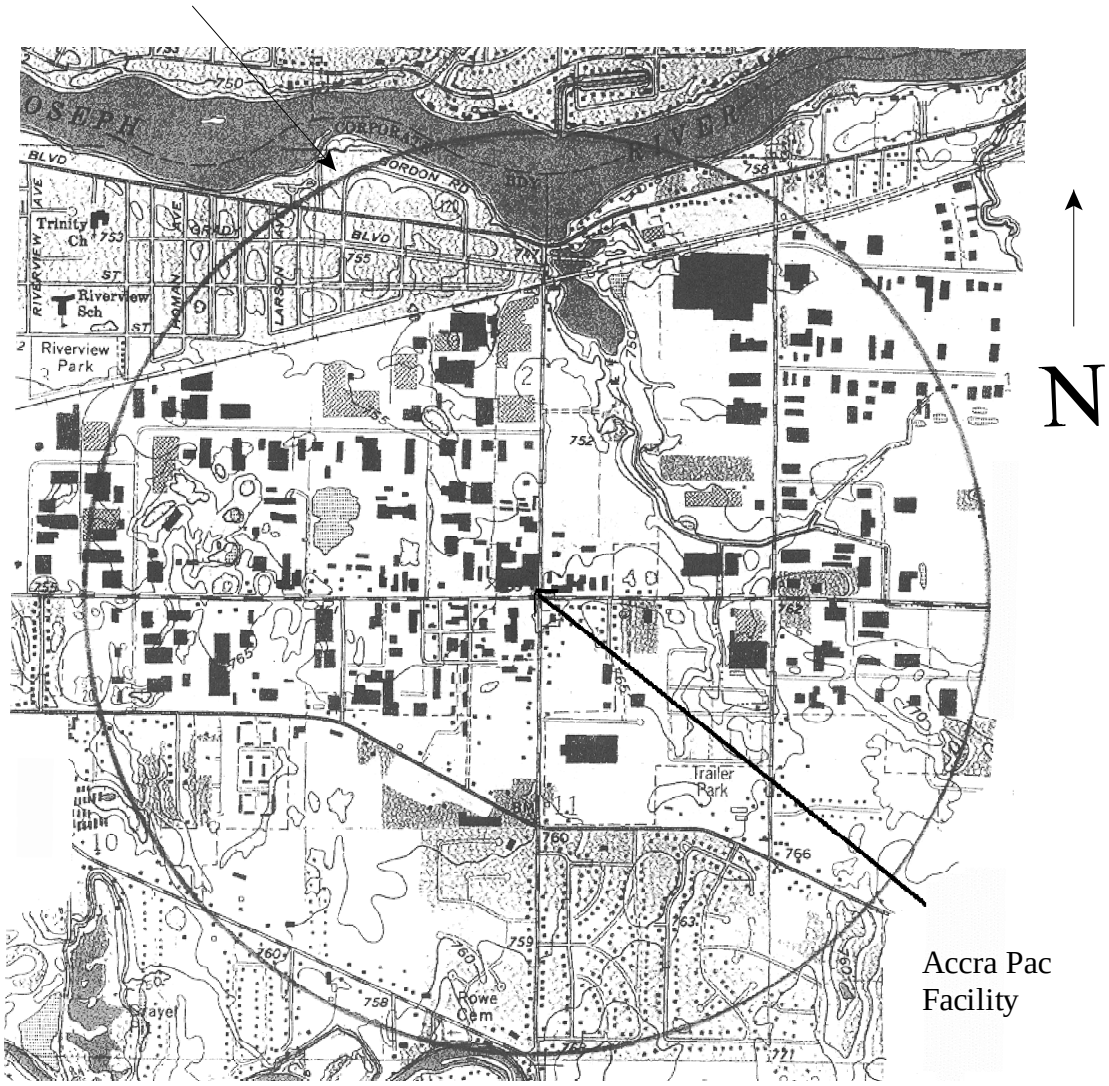
(Kirk-Othmer, 1994)

Ethylene oxide is soluble in water and will react with acidified water to produce ethylene glycol. This water solubility is one of the methods used for disposing of ethylene oxide. Ethylene oxide is incompatible or reactive with strong acids; alkalis and oxidizers; chlorides of iron, aluminum, and tin; and, oxides of iron and aluminum.

Ethylene oxide is an irritant to the eyes, nose, and throat. It can cause damage to eyes, blood, respiratory system, liver, central nervous system, and kidneys. It is also a known human carcinogen. The Immediately Dangerous to Life and Health (IDLH) concentration is 800 parts per million (ppm). (National Institute for Occupational Safety and Health, 1990)

Exhibit 1. Map of the area surrounding the Accra Pac facility.

One Mile Radius



The uses of ethylene oxide include: manufacture of ethylene glycol (antifreeze) and higher glycols, surfactants, acrylonitrile, ethanolamines, petroleum demulsifiers, fumigants, and an industrial sterilant. For sterilizer applications, ethylene oxide is typically supplied as pure liquid or as a mixture with other carriers in cylinders or small canisters under pressure.

1.3 Process Information

Under ambient conditions ethylene oxide is a vapor. In the filling process, ethylene oxide is processed as a liquid. This can be accomplished through one of two ways. Ethylene oxide can be cooled and processed at a temperature below its boiling point, or ethylene oxide can be processed under pressure greater than its vapor pressure. At Accra Pac, filling is done through the application of pressure.

The ethylene oxide filling process begins in the North Plant Production Building, hereinafter referred to as the Production Building, where the empty 100-gram containers are placed in the container holders on the conveyor. The conveyor first moves the empty containers to a station where a cap is placed on each container. The conveyor then transports the containers to the Gas House.

The Gas House is a small, custom built, prefabricated metal building located about eight feet south of the Production Building. The two buildings are linked via a conveyor that loops through the two buildings. (See Exhibit 2) The ethylene oxide filling takes place inside the Gas House.

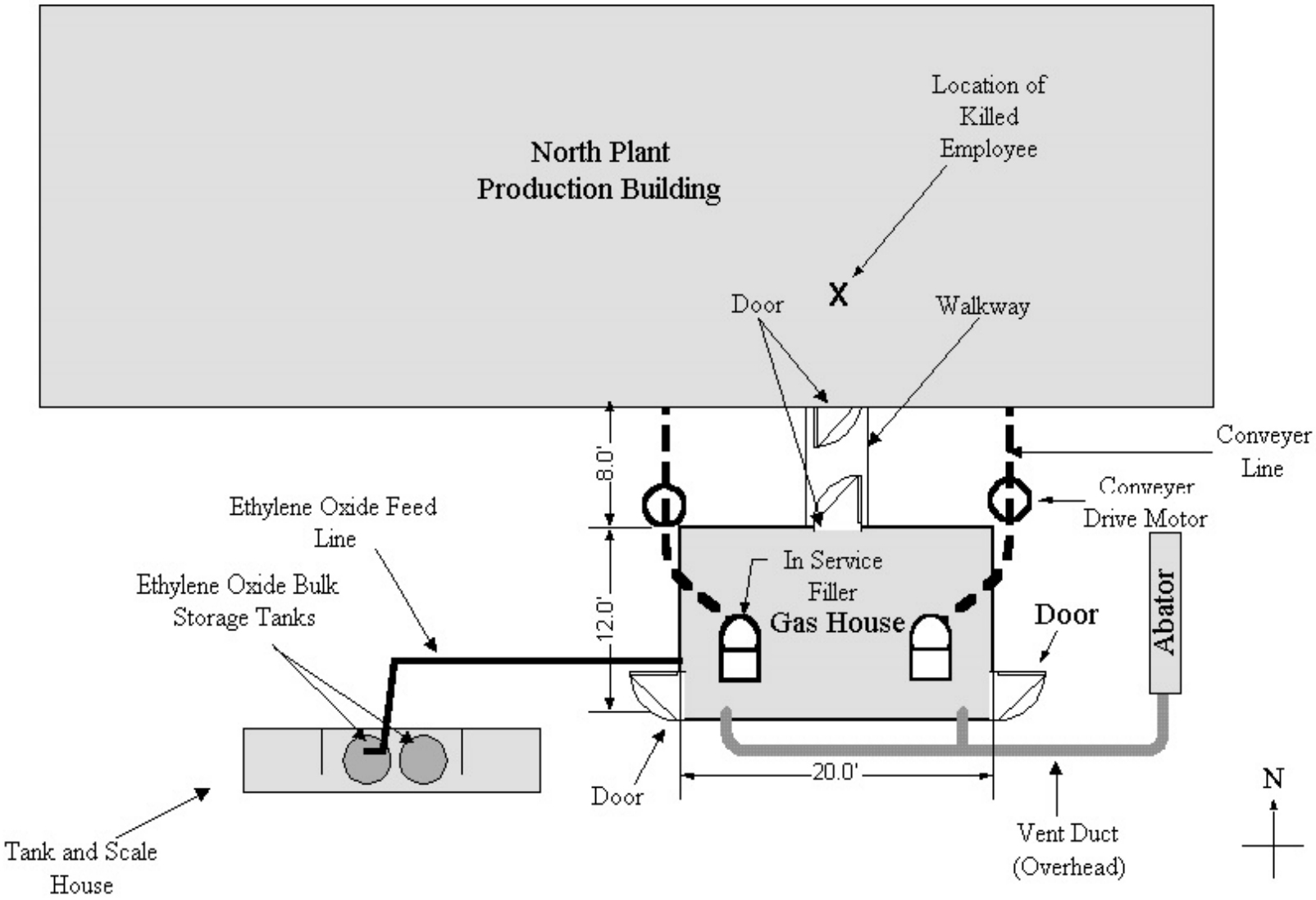
In the Gas House, the containers are placed in filler heads in the under-the-cup filler where approximately 100 grams of ethylene oxide liquid is pumped into each container. While still in the under-the-cup filler, the filled containers are sealed by crimping the caps onto the containers.

The sealed containers are then released from the filler heads and transported back into the Production Building where each container is inspected and quality checked for weight and for leaks. Containers that pass quality inspection continue on the conveyor to a packaging station where they are boxed for shipping.

The off-specification containers, either low weight or leaking, are removed from the conveyor line and placed in a separate 55-gallon drum. The off-specification containers are eventually removed from the 55-gallon drum and discarded.

During the production run, two 400-pound ethylene oxide storage tanks, located in a separate building about 20 feet from the Gas House, are used to provide ethylene oxide for the filling process. Two storage tanks are connected at the same time, as one storage tank becomes emptied, the feed is switched over to the other while the empty storage tank is replaced with a full storage tank.

Exhibit 2. Accra Pac Accident Site



Not to Scale

Nitrogen at 55-65 psig pressure is used to push the liquid ethylene oxide out of the 400-pound ethylene oxide storage tank into a one-inch diameter stainless steel pipe leading to the Gas House. The stainless steel pipe enters the Gas House on the west side of the building. (See Exhibit 3)

In the Gas House, the stainless steel pipe is connected to a flexible fiber-reinforced plastic hose through which ethylene oxide is fed into the Graco pump. The Graco pump is a pneumatically driven, reciprocating pump. The Graco pump raises the ethylene oxide pressure to 600-650 psig. The ethylene oxide then travels through another flexible fiber reinforced plastic hose to the under-the-cup filler machine.

The under-the-cup filler feeds the ethylene oxide into the containers and seals the containers by crimping the top. A small amount of ethylene oxide is released into the Gas House during the filling and sealing of each container. Hence, the filling machine meters out approximately 105 grams (This amount can be as high as 111 grams.) of ethylene oxide for each 100-gram container it fills. The target amount for each can is 101.5 - 102.5 gram. Any excess ethylene oxide is sent to a reclamation tank located in the Gas House.

An operator is in the Gas House at all times during production. The operator is there to monitor filler operations. The appearance of frost on the filler hose is an indication that a filler seal is leaking. (Any ethylene oxide leaked out would quickly evaporate. The formation of frost is caused by the evaporative cooling.) If the operator sees signs that the filler seal is leaking, he is supposed to immediately replace the seal. While working in the Gas House, the operator wears a protective suit, gloves, and boots. The operator also uses a supplied air type respirator to guard against inhalation of ethylene oxide. Breathing air is pumped to the respirator through a hose.

Air containing ethylene oxide vapor is drawn from the Gas House through two ground level vents located on the south side of the building. Once outside, the two vent ducts are joined together in a manifold that feeds into a catalytic oxidizer type pollution control system known as the ETO-Abator®, hereinafter referred to as the Abator. (See Exhibit 4 and 5)

The Abator is located about fifteen feet east of the Gas House. There is a fan at the far end of the Abator that pulls air from the Gas House through the Abator. The Abator works by catalytic breakdown of any ethylene oxide vapor present to form carbon dioxide and water. This is an exothermic process. According to the manufacturer, the Abator is designed to operate below the auto-ignition temperature of ethylene oxide so as to avoid igniting the ethylene oxide vapor and triggering an explosion. If the temperature in the Abator approached the ethylene oxide auto-ignition temperature, the power to the conveyer and the filling machine would be automatically shut off. The Abator is used only during the ethylene oxide filling operation.

The Gas House is also equipped with hydrocarbon detectors and alarms. An audible alarm and amber flashing light are triggered when the hydrocarbon concentration reaches 20 percent of the lower explosive limit (LEL). An audible alarm and a red flashing light are

Exhibit 3. Ethylene Oxide - Simplified Filling Configuration

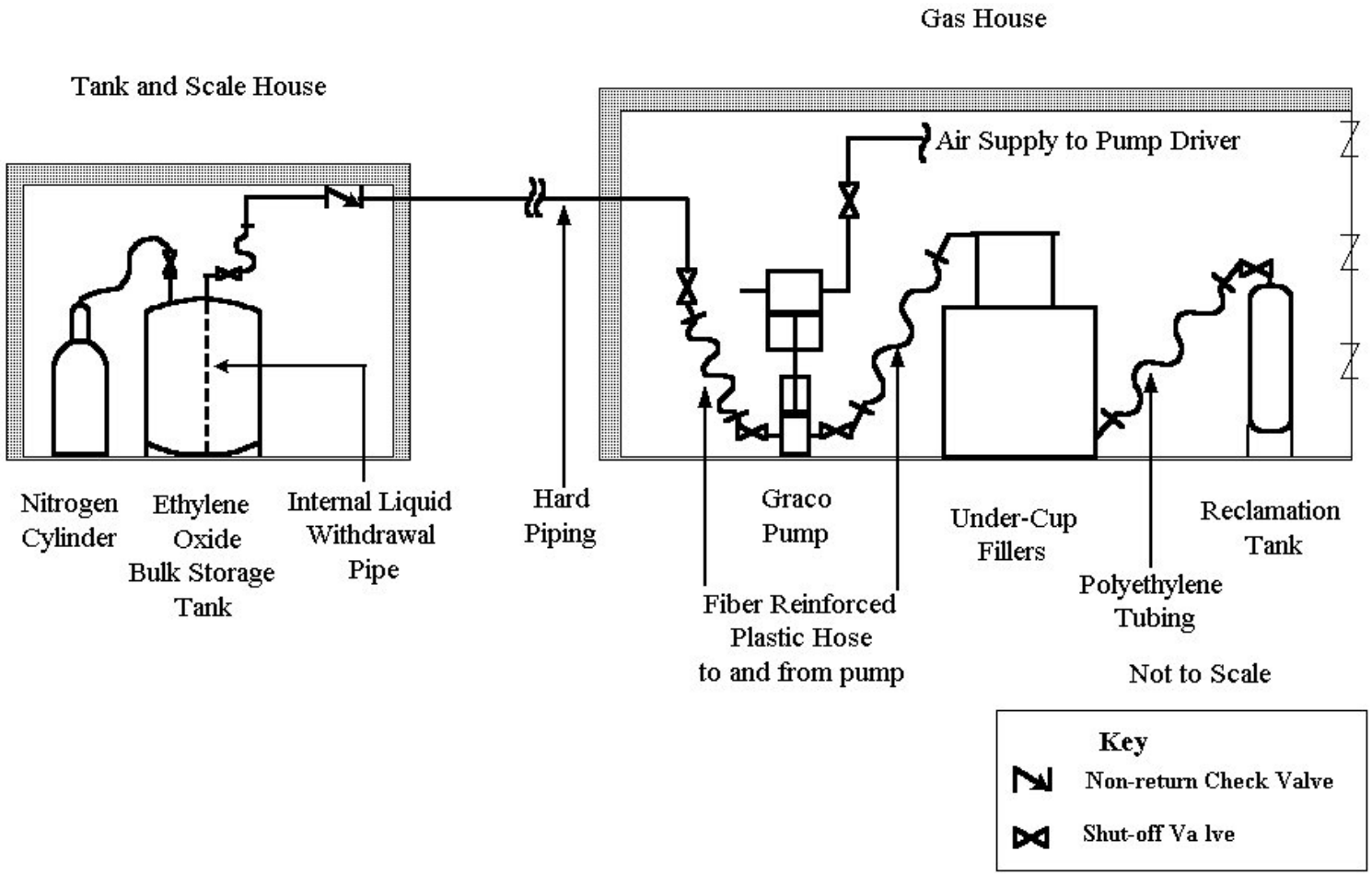


Exhibit 4. Gas House Ethylene Oxide Vapor Recovery and Disposal System

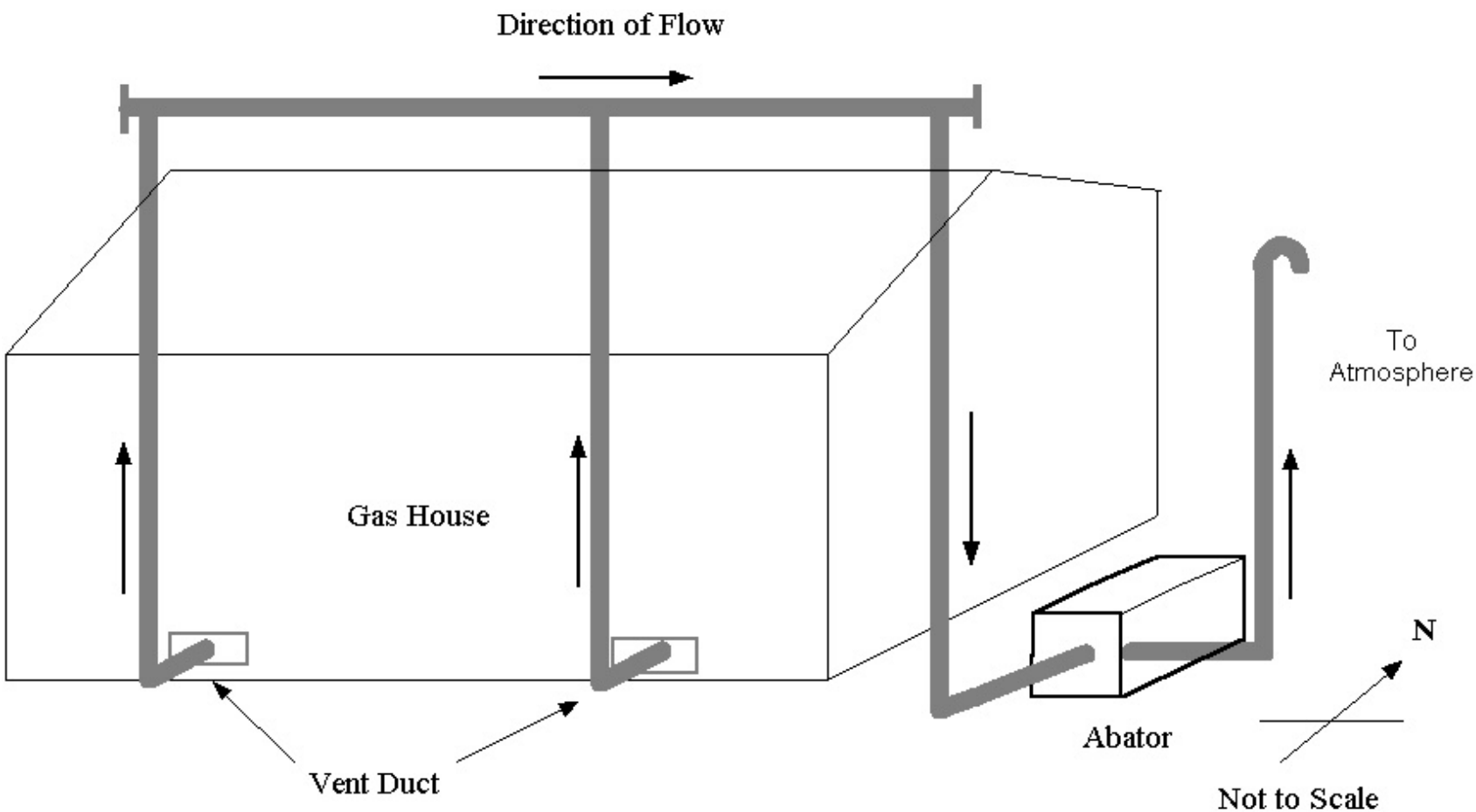
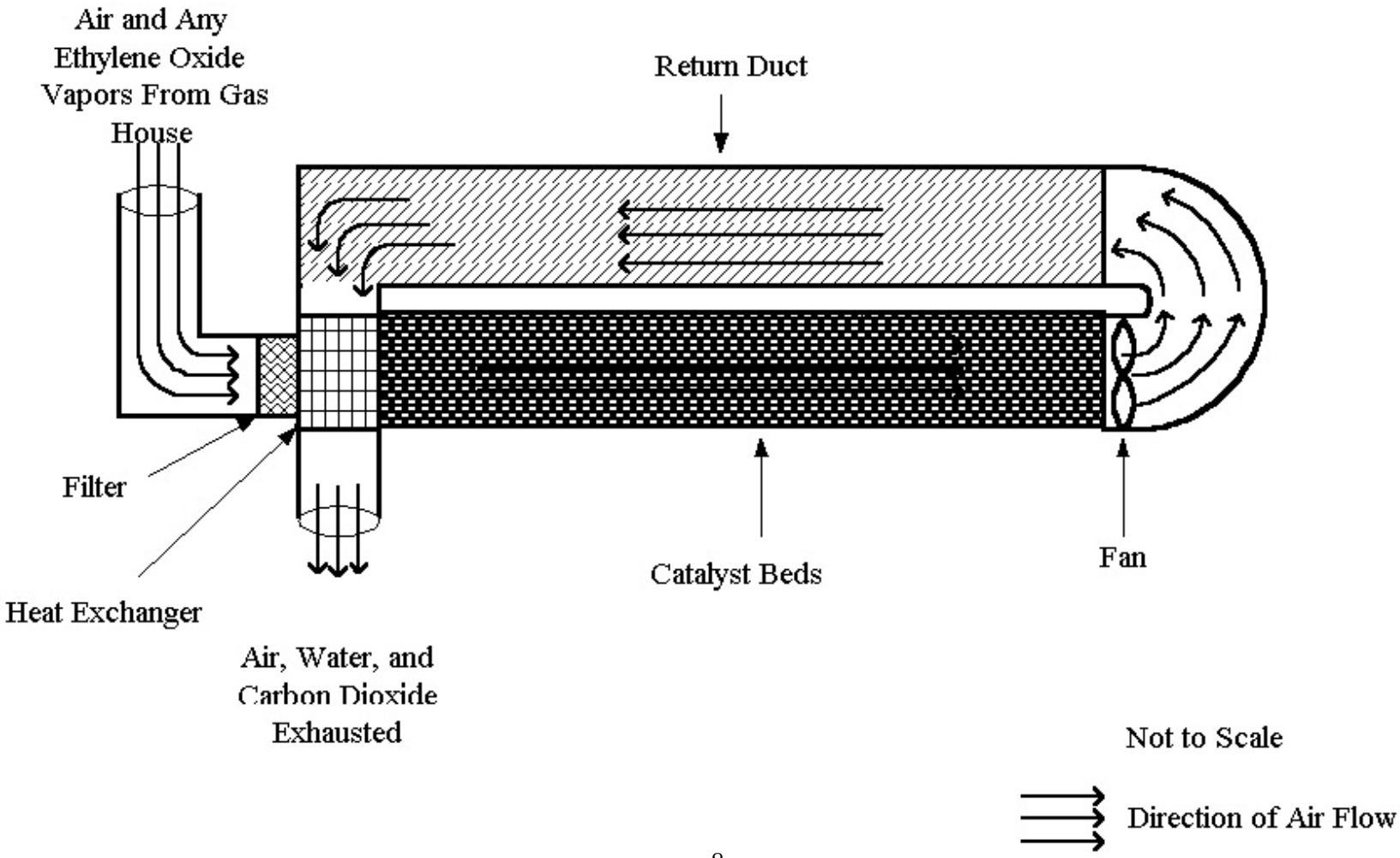


Exhibit 5. Ethylene Oxide Abator



triggered when concentration of hydrocarbon reaches 40 percent of the LEL. (These detectors installed to trigger the audible and visual alarms and to actuate the shutdown devices were calibrated for the specific hydrocarbon propellant normally used in the Gas House. Since the sensors were not recalibrated for concentrations of ethylene oxide, it cannot be assumed that they would actuate at concentration levels 20 and 40 percent of the LEL for ethylene oxide.)

Alarm activity is automatically recorded. When the 40 percent of LEL alarm sounds, the power to the conveyer and the filling machine is automatically shut off. The Gas House doors are also to remain closed during production. There is also an audible alarm that sounds if a door is left ajar.

2.0 Description of the Accident

2.1 Preparation for Ethylene Oxide Filling

Prior to beginning ethylene oxide filling, all other processes in the Gas House are discontinued. Pipelines into the Gas House are vacuum-purged and closed to prevent other chemicals from contaminating the ethylene oxide. Teflon encapsulated seals are installed on the under-the-cup filler. For filling ethylene oxide, only three of the nine filler heads on the under-the-cup filler are used.

The Abator is engaged and the regular ventilation fans in the Gas House are disconnected to prevent accidental venting of ethylene oxide into the atmosphere.

Two 400-pound storage tanks containing ethylene oxide are placed on the weigh scales that are used to monitor the amount of ethylene oxide left in the tanks. Nitrogen supply piping and ethylene oxide delivery piping are connected to the storage tanks and the process line is pressurized. Nitrogen is used to push liquid ethylene oxide through the piping, and a non-return check valve is used to prevent back flow into the 400-pound storage tanks.

2.2 Events Preceding the Accident

Accra Pac scheduled the ethylene oxide filling operation to run for ten hours per day for four days.

Mechanics modified line No. 61 for ethylene oxide filling on Saturday, June 21, 1997. Before beginning operations, the production crew took ethylene oxide hazard awareness training that addressed safety and health hazards of ethylene oxide.

Ethylene oxide filling started at 6:00 a.m., on Monday, June 23. When the process line started, the under-the-cup filler developed leaks around the seals and the process was stopped. The wrong seals had been installed on the filler heads. The correct seals were installed and the process was successfully restarted. The process continued until about 9:00 a.m. when a high catalyst-bed temperature alarm shut the Abator down. The high catalyst-bed temperature may have been caused by a brief surge of ethylene oxide vapor from seal leakage. After the Abator cooled down, the process was restarted and continued operating for the remainder of the shift.

On Monday, June 23, Accra Pac also had problems with the pump that supplied breathing air to the Gas House operator. The pump repeatedly overheated and shut off. Each time the pump shut off, the production line had to be shut down.

2.3 The Explosion and Fire

On Tuesday, June 24, the employees started the second day of production at about 6:00 a.m. One operator was on duty in the Gas House while other production crew members

were working in the Production Building. The production crew in the Production Building made sure that the containers were properly loaded onto the conveyor line. The operator in the Gas House made sure that the containers arriving from the Production Building were properly filled and that the equipment in the Gas House was working as intended.

The filling continued until about 2:00 p.m. At about 2:00 p.m., the breathing air pump overheated and shut off. Not able to breathe without supplied breathing air, the operator quickly shut down the filling process.

The operator blocked off the portion of the conveyor that supplied empty containers to the under-the-cup filler. He waited for the filled containers to be transported out of the Gas House, then shut off the air supply that drives the Graco pump and left the Gas House. The nitrogen supply valve to the ethylene oxide storage tanks and the ethylene oxide supply valves were not shut off.

While the air pump was being repaired, the operator and production crew on line No. 61 took a break.

At about 2:30 p.m., after the breathing air pump had been fixed, the operator proceeded to the Gas House to restart the production line. As the operator approached the Gas House, he noticed an alarm sounding and thought that it was caused by the Gas House "door ajar" alarm. As he entered the Gas House, he noticed that the red strobe light for the 40 percent LEL alarm was flashing. (This implied that the hydrocarbon level in the Gas House had exceeded 40 percent of the lower explosive limit.) The operator turned to leave the Gas House to check the remote gas manager/monitor panel inside the Production Building. He took about two steps out of the Gas House when the explosion occurred. The operator was thrown about 10 feet. He suffered an injury to his shoulder and also cuts and lacerations.

All three doors to the Gas House were blown off by the explosion. The door on the east side was propelled across a public street and landed about 225 feet away. The door on the west side struck a fork lift truck that was about 20 feet away from the Gas House. The door on the north side struck the door on the Production Building directly across from it. The impact knocked the Production Building door and its frame off the wall and into the building where it struck and killed a member of the production crew working there. (See Appendix A-1 and A-2)

The deflagration panels located in the Gas House walls blew out as designed and some of the contents of the Gas House were blown out of the building. The metal roof of the Gas House also bulged and split open at the ridge seam. The explosion triggered a fire.

The Halon and water deluge systems in the Gas House automatically activated. However, these fire suppression systems were not designed to prevent an explosion. They were damaged by the explosion and were not effective in putting out the fire. Plant security immediately called the local fire department.

2.4 Emergency Response

The Elkhart police and fire departments, the Elkhart County Local Emergency Planning Committee (LEPC), and the Indiana State Emergency Response Commission (SERC) responded to the emergency call. The police department controlled traffic and went door-to-door to evacuate people within a one-mile radius of the plant. The decision to evacuate was based on the Emergency Response Guide (US Department of Transportation, 1990) and was done as a precautionary measure. The LEPC and SERC assisted with emergency response decision making. The evacuation lasted about five hours.

Fifty-nine persons, including Accra Pac employees, local responders, and some members of the community sought medical attention, mostly for respiratory distress.

After fighting the fire for about three-and-one-half hours, a fireman in protective gear entered the Gas House and saw that the fire was being fed by material flowing from a metal pipe, later identified as the ethylene oxide supply line. The fireman closed a valve, in the Gas House, on that pipe. The flow of ethylene oxide stopped. Shortly thereafter, around 7:00 p.m., the fire was extinguished.

After the fire, Accra Pac personnel tested the Production Building area for the presence of ethylene oxide. No ethylene oxide was detected. No additional testing was conducted beyond the facility fence line.

The water from the fire fighting effort was collected in the facility's retention pond. An analysis of this water found no ethylene oxide. Following this analysis, the water was discharged through the Elkhart city water treatment plant. No fish kill was observed in the portion of the St. Joseph and Elkhart Rivers within a one-mile radius of the facility.

3.0 Investigation Findings

EPA investigators visited the accident site, examined evidence (including tests conducted on equipment), interviewed witnesses, and reviewed company documents to determine the events leading to the explosion and fire. An event and causal factor chart was developed. (See Exhibit 6)

Based on physical evidence and information collected from witnesses, it is believed that ethylene oxide vapor accumulated in the Gas House beyond the LEL followed by contact with an ignition source initiating the explosion. EPA investigators examined the Gas House for potential ethylene oxide sources and potential ignition sources.

3.1 Potential Sources of Ethylene Oxide

Two sources are capable of providing sufficient ethylene oxide that could lead to the accumulation of ethylene oxide vapor beyond the LEL in the Gas House: the ethylene oxide feed system leading to the under-the-cup filler and the ethylene oxide reclamation tank.

A. The ethylene oxide feed system could be a source for the ethylene oxide leading to the explosion in the Gas House.

- The valves on the ethylene oxide feed line were left open when the filling process was shut down. In the event of a leak in the feed line or valves connected to the feed line within the Gas House, the ethylene oxide in the storage tank would discharge into the Gas House.

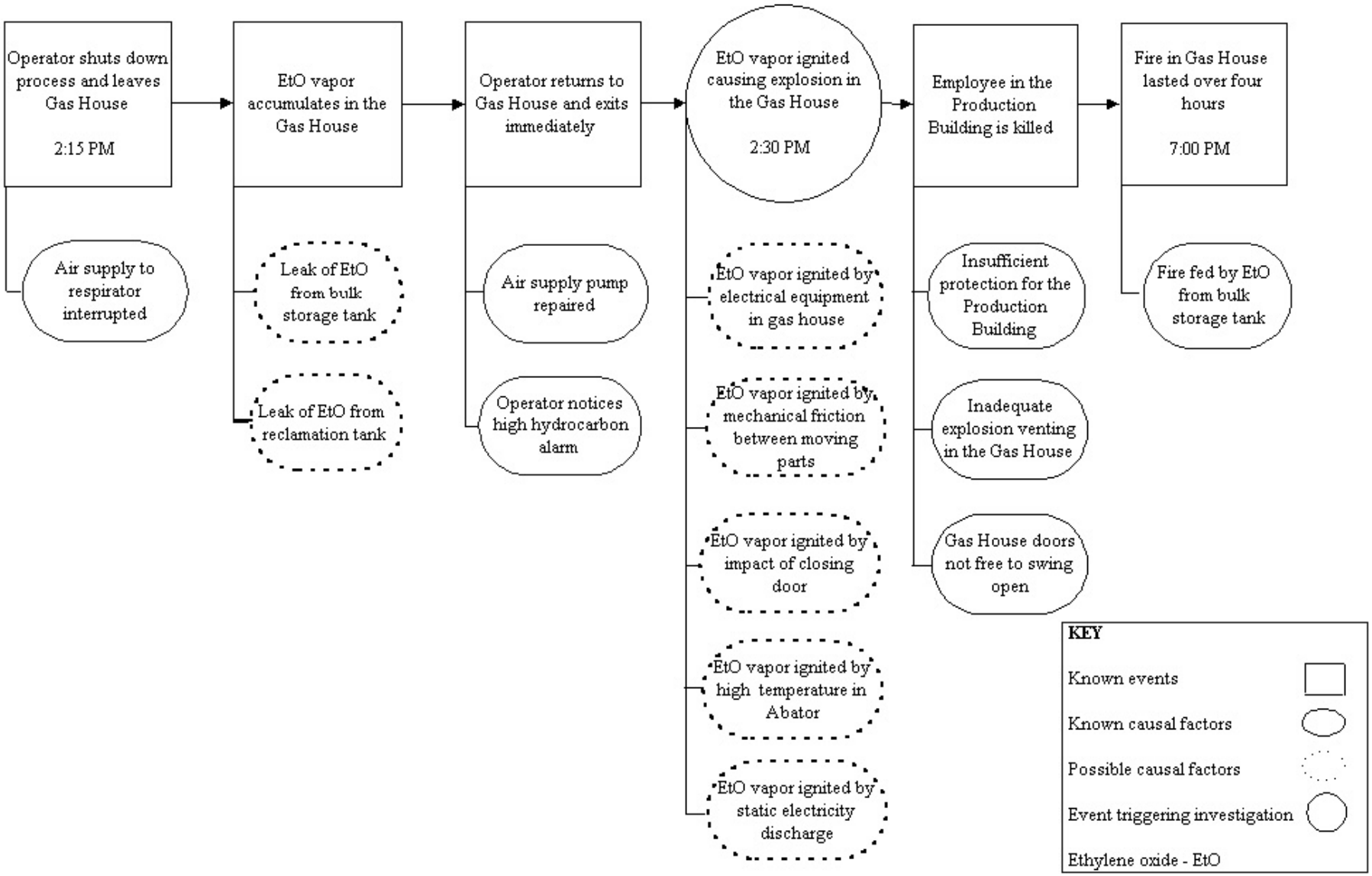
- Ethylene oxide has a boiling point of 51 ^{0}F. It is processed as a liquid through the application of pressure. As the temperature of the ethylene oxide increases, the pressure in the feed line will correspondingly increase. At the time of the explosion, the ambient temperature was around 93 ^{0}F. The feed line was not insulated or cooled. With the filling operation stopped, the ethylene oxide left in the feed line would eventually reach and even exceed the ambient temperature since part of the feed line was exposed to direct sunlight.

- While the ethylene oxide feed line outside the Gas House was made out of stainless steel, some of the ethylene oxide feed lines inside the Gas House were flexible fiber reinforced plastic hoses. These were not as strong as the “hard”(not flexible) stainless steel pipes. There were also several connections and valves. These fittings are much more susceptible to leaks.

- The flexible lines inside the Gas House were damaged to the point where they could not be analyzed to determine an exact leak source. The “hard” steel piping was tested and showed no leaks. It is not clear whether the feed system failed and caused the explosion and fire or if the explosion and fire caused by ethylene oxide release from the

Exhibit 6. Event and Causal Factors Diagram

Accra Pac Inc. - Elkhart, Indiana
June 24, 1997 Explosion and fire



reclamation tank (discussed below) caused the damage to the feed system.

B. The reclamation tank could be a source for the ethylene oxide leading to the explosion in the Gas House.

- Accra Pac employees reported that on the day of the explosion four 400-pound tanks of the ethylene oxide had been consumed in the filling operation. For each 100-gram container filled, approximately 105 grams are metered to assure a complete fill. One hundred grams is a nominal value. The target value for each container is between 101.5 and 102.5 grams. Records indicate that it is common to have as much as five percent variations in the amount discharged by the filler head and received by the cans. For each 100-gram container filled, 3 to 9 grams of the excess ethylene oxide may be recovered in the reclamation tank. Based on this estimate, the reclamation tank could have reached its capacity and contained up to 20 pounds of ethylene oxide at the time of the explosion. The reclamation tank had not been emptied since the beginning of the production run.

- The Graco pump raises the ethylene oxide pressure to 600-650 psig for filling the containers. With each container filled, the excess ethylene oxide is drained from the filler head to the reclamation tank. In the beginning of the process the reclamation tank will be at ambient pressure while the ethylene oxide in the filler head is around 600 psig. As the reclamation tank is filled, the pressure in it will increase. Since liquid ethylene oxide is not compressible, when the reclamation tank becomes liquid full, the pressure in the reclamation tank will increase rapidly and ultimately approach that in the filler head.

- Polyethylene tubing was used to carry excess ethylene oxide from the under-the-cup filler to the reclamation tank. The polyethylene tubing is much more susceptible to failure than metal tubes. There is no non-return check valve on the connection of this tubing to the reclamation tank. If this polyethylene tubing failed or became disconnected, ethylene oxide would rapidly escape from the reclamation tank.

- The ethylene oxide reclamation tank in the Gas House was found to have been crushed by the force of the explosion. (See Appendix A-3) The tank collapsed from three sides leaving almost no void volume. Had the reclamation tank been substantially full of liquid, which is not compressible, the reclamation tank would not have become crushed in the explosion. The reclamation tank showed no signs of puncture or rupture. Thus, any release of ethylene oxide would have had to have occurred in the connectors, valves, or tubing associated with the reclamation tank.

3.2 Potential Sources of Ignition

There were numerous types of equipment in the Gas House and the area surrounding the Gas House which could be potential sources of ignition. These types of equipment were examined and evaluated for their potential as sources of ignition. These evaluations included the

following:

A. Electrical equipment could have been the ignition source.

- The wiring and electrical systems within the Gas House including lights, sensors, and alarms were rated for a location fitting NEC Class I, Division 1, Group C and D. This classification is appropriate for most of the filling operations in the Gas House. However, according to NFPA 70, Article 500, ethylene oxide requires a Class I, Division 1, Group B, which is more stringent.

- There were also pieces of electrical equipment located within the Gas House that were not appropriate for use in Class I, Division 1, Group B locations. This electrical equipment included the electric drive motor for the filling machine, a computer and video monitor, and an electrical scale whose seal appeared to have been compromised.

- Two conveyer motors located near the Gas House were not turned off when the operator left the Gas House. One motor ran the conveyer for incoming containers and the other for outgoing containers. Since these electrical motors would have been automatically shut off when the 40 percent LEL alarm was activated, this would reduce their likelihood as ignition sources.

B. Mechanical equipment could have generated high temperature from friction to cause ignition.

- When the operator left the Gas House, the conveyer system was still running with the container on the conveyer blocked off from entering the under-the-cup filler. The friction between the conveyer and the container holders on the conveyer could result in high temperatures. Again, since the electrical motors would have been automatically shut off when the 40 percent LEL alarm was activated, this would make them less probable ignition sources.

- The Graco pump could have become bound or restricted to the point where friction could have generated temperatures reaching the ignition point. Since the Graco pump had been deactivated in the shut down process, the pump was thought to be an unlikely source of ignition.

C. Spark generated from impact could have ignited the ethylene oxide.

The explosion occurred as the operator left the Gas House and the Gas House door closed. The Abator draws air out of the Gas House at a rate of 1,500 cubic feet per minute. This would cause the atmospheric pressure inside of the Gas House to be lower than that outside. The pressure difference could cause the door to slam, and this impact of the metal Gas House door onto the metal door frame could have generated a spark of ignition intensity.

D. High catalyst bed temperature in the Abator could have ignited the ethylene oxide.

Even though the Abator was located outside the Gas House, this system was examined because the chemical reaction involving the catalyst could develop temperatures in excess of the ethylene oxide ignition temperature. The ignition of the ethylene oxide vapor can potentially flash back into the Gas House triggering an explosion. The catalyst bed temperature recorder chart indicated that this equipment was operating properly and showed that the catalyst bed temperatures were in their normal operating range. However, the thermocouple in the Abator is not located directly in the catalyst bed. The location of the thermocouple could result in readings that are less than the temperature within the catalyst beds and would also result in a delay between when the temperature change occurred and when the readings appeared. However, the recorded temperature does not support the Abator as the ignition source. More important, damage to the Abator resulted from external impact which suggests that the Abator was not the source of ignition. Also, the Abator internals and the duct piping were examined for evidence of an internal flashback or flame front and no such evidence was found.

E. Static electricity could produce a charge sufficient to provide ignition.

- During the period preceding the explosion, the conveyer was running while the containers were blocked off from entering the filler. The friction between the conveyer and the container holder riding on the conveyer could result in a significant static charge buildup. However, the weather conditions at the time, high humidity with temperature in the 90's, would diminish this likelihood.

- Also, a jet type leak of ethylene oxide into the air could have been a static electricity generator. Again, the weather conditions at the time, high humidity with temperature in the 90's, would diminish this likelihood.

3.3 Death of Employee

The employee working in the Production Building was killed when struck by the Production Building door and its frame that faced the Gas House. The explosion blew the doors off the Gas House. The Gas House door facing the Production Building struck the door directly facing it on the Production Building. The impact knocked the Production Building door and its frame off the wall. The door and frame then struck and killed the employee working in the Production Building. According to NFPA 30, 5-3.2.2, “Where Class 1A liquids or unstable liquids, regardless of class, are handled or processed, the exposing walls shall have explosion resistance in accordance with good engineering practice.” The two buildings are located about 8 feet apart. The two doors are directly opposed and are connected by a short walkway. They did not have the prescribed resistance to the explosion.

3.4 Gas House Construction

- **Structural members** – The metal frame of the Gas House was severely distorted as a result of the explosion. The metal roof of the Gas House bulged and split along the length of the Gas House roof ridge seam. The deflagration panels on the Gas House were blown off.

- **Doors dislodged** – All three doors on the Gas House were blown off. The metal door jambs on the Gas House were bent outward indicating that the doors had been latched at the time of the explosion. According to NFPA 68, 9-4.1 for venting of deflagration, hinged doors should swing outward and have latches that would release under slight internal pressure.

- **Blast resistance** – The Gas House is considered a low strength structure. According to information presented in Factory Mutual Document "Series 132 Gas House from BWI KP Aerofill, J.I. 2W0A0.AF (7146)," dated September 27, 1997, this structure would be capable of withstanding an internal pressure of 200 psfg (pounds per square foot gauge) or 1.39 psig.

- **Venting capability** –According to calculation methods used in NFPA 68, the vent area on the Gas House is less than required for processing ethylene oxide. (See Appendix B for calculation.)

4.0 Accident Scenarios

Based on the amount of void space in the Gas House, six-and-a-half pounds of ethylene oxide would be sufficient to place the entire atmosphere inside the Gas House above the LEL. In order for ethylene oxide vapor in the Gas House to reach LEL, the ethylene oxide release must be quick and in sufficient quantities to overcome the removal capacity of the Abator. The boiling point of ethylene oxide is 51°F. At the time of accident, the temperature in the Gas House was more than 90°F. Since the liquid ethylene oxide is stored under pressure, any leak would result in a rapid discharge of ethylene oxide which would quickly vaporize to form an explosive mixture.

Furthermore, even though air is drawn through the Gas House and out to the Abator, the flow through the Gas House does not ensure uniform mixing. This situation would be influenced by the magnitude and direction of release of the ethylene oxide into the Gas House interior. A pocket of vapor in the explosive range and occupying a fraction of the space inside the building, and involving less than 6.5 pounds of ethylene oxide could exist inside the building and be capable of an explosion.

However, given the impact of the explosion, chances are the explosion involved significantly larger amounts than a localized LEL concentration of ethylene oxide. (See Exhibit 6)

Scenario 1

Ethylene oxide released into the Gas House from the feed system. The ethylene oxide is stored as a liquid under pressure in a 400-pound storage tank located in a separate building. During the shut down, the air supply to the Graco pump driver was shut off. But, the valves on the feed line leading from the storage tanks were not shut off and the ethylene oxide in the storage tank remained pressurized with nitrogen at 55-65 psig. Therefore, any leak from the feed line or filling equipment located in the Gas House would have the potential to allow a large quantity of ethylene oxide to be released inside the Gas House.

Scenario 2

Ethylene oxide released into the Gas House from the reclamation tank. Based on interviews with the operator concerning the number of containers that had been filled, it was estimated that the reclamation tank may have been liquid full. The reclamation tank can hold about 20 pounds of ethylene oxide. The amount of ethylene oxide vapor required to exceed the LEL in the Gas House and assuming no forced ventilation is about 6.5 pounds, or about one-third of the contents of a full reclamation tank.

The mechanism of ethylene oxide release from the reclamation tank is not known. It is, however, known that the feed line to the reclamation tank was made of polyethylene tubing which could be a weak link in that part of the process. Also, the feed line to the reclamation tank did

not contain a non-return check valve which would prevent release from the tank in case of failure in the line. Furthermore, there was no provision for monitoring the quantity of material in the reclamation tank. This situation raises the possibility that the reclamation tank could have been overfilled which could lead to it becoming over-pressured and leading to the release of ethylene oxide.

5.0 Root Causes and Contributing Factors of the Accident

Based on evidence collected and analyses performed, the EPA Chemical Accident Investigation Team (CAIT) identified the following as root causes and contributing factors in the accident:

- **Inadequate shut-down procedure** - When the breathing air supply to the respirator was interrupted, there was a hurried shut down of the filling operation. The shut down steps taken included blocking off the containers on the incoming conveyor and cutting the air supply used to drive the Graco pump. None of the valves in the ethylene oxide supply system were closed. In the event of a leak in the system within the Gas House, the pressurized ethylene oxide in the storage tanks located outside the Gas House could discharge into the Gas House.

- **Location of the reclamation tank -** Locating the reclamation tank, which holds up to 20 pounds of ethylene oxide, inside the Gas House violates good industry practice for minimizing the quantity of hazardous material in an occupied area. A large leak in the reclamation tank system could result in a discharge that would far exceed the LEL. Also, **the reclamation tank did not have instrumentation for monitoring the amount of liquid it contained.** Overfilling the tank would lead to over-pressure which in turn could lead to a rapid release of its contents.

- **Lack of sufficient barriers or separation spacing between the Gas House and the Production Building** - Per National Fire Protection Agency (NFPA) Code 30, 5-3.2.2 "Where Class 1A liquids or unstable liquids, regardless of class, are handled or processed, the exposing walls shall have explosion resistance in accordance with good engineering practice." The Production Building did not provide sufficient explosion resistance to protect the occupants. The door on the Production Building was blown off its mounting. The employee in the Production Building was killed when struck by the door.

- **Insufficient explosion venting to permit adequate pressure release -** Pursuant to determinations using guidelines found in NFPA Code 68, a much larger vent area should have been provided to allow explosion pressure release without destruction of the building. The Gas House is designed with deflagration panels. The deflagration panels are designed to blow out to permit adequate pressure release in the event of an explosion inside the Gas House. The line No. 61 Gas House's deflagration panels were designed for use with members of the NEC Group D flammable vapors, of which propane is a member. The fundamental burning velocity and the rate of explosion pressure rise of ethylene oxide is over twice that of propane. The explosion vents of the Gas House were barely adequate for propane. The explosion vents were not adequate for ethylene oxide which is much more hazardous than propane in terms of explosions.

- **Inadequate door design -** The doors on the Gas House were not permitted to swing

open freely in response to the explosion. There was damage on the door jambs. The damage indicated that the doors were closed with the latches in the closed position. NFPA 68, 9-4.1 for venting of deflagrations states that hinged doors should swing outward and have latches that release under slight internal pressure. If the doors were less restrained and able to swing open easily, they could have swung open with the explosion and have been less likely to be blown off, thus reducing the likelihood of injuries and property damage. The doors opening easily would also limit the pressure buildup in the Gas House and reduce the explosion blast effect.

- **Use of electrical equipment that did not meet National Electrical Code (NEC) requirements** - Ethylene oxide is a NEC Class 1, Division 1, Group B material. The Gas House did not meet the NEC requirement for working with ethylene oxide. The electrical equipment in the Gas House could have provided initiation for the explosion.

6.0 Recommendations

Based on the root causes and contributing factors of this accident described above, the CAIT provides the following recommendations to prevent accidents like this one from occurring in the future at this and other facilities:

- **Establish safe emergency shutdown devices and procedures for all operations.** The facility must examine situations where a quick shutdown of operations must occur and ensure that the necessary devices and procedures are in place. Systems and procedures must ensure that critical steps are followed in their proper order and that critical equipment is stopped and valves closed to sufficiently isolate the process. For example, Accra Pac should consider installation of valves in ethylene oxide feed lines that close automatically when the conveyor line is stopped. Depending on operational circumstances, such as in restricted or hazardous areas, facilities should consider manual shutdown devices that can be remotely operated so that employees do not need to enter hazardous situations.

- **Relocate the reclamation tank to a location outside the Gas House to reduce the amount of hazardous material inside the occupied building.** In the event of a tank leak, this would reduce the likelihood of injury to the occupant of the Gas House. Also, **develop a way to monitor the quantity of material in the reclamation tank.** This capability is necessary to avoid overfilling which can lead to an accidental release. Finally, **install a non-return check valve on the reclamation tank.** This would minimize any release should the feed line or any connectors leading to the reclamation tank fail.

- **Properly locate and provide sufficient barriers between units that have a potential for explosion from other processes in accordance with NFPA 30, 5-3.2.2.** Units that are recognized as hazardous with a potential for explosion should be sufficiently spaced away or provided with blast walls between units such that if an explosion occurs, employees in other locations are not harmed.

- **Provide adequate deflagration venting capability for the Gas House.** The Gas House should have deflagration venting capability that is appropriate for any material that may be handled.

- **Evaluate doors to ensure outward swing action and latches that easily release under slight internal pressure**. Doors that are designed to be of minimum weight and that have latches that easily release (friction, spring loaded, or magnetic devices) will allow the doors to provide additional over-pressure relief. For personnel safety, the doors should be designed to remain attached to the building.

- **Limit the electrical equipment in the Gas House to those that meet the NEC rating for the type of material being processed.** NEC Class I, Group B is required for working

with ethylene oxide.

In addition, the following are recommended to improve safety in the Gas House:

- **Ensure the maximum reliability of breathing air systems.** The supplied breathing air system must be designed, maintained, and operated for maximum reliability. In addition, facilities should consider alarms and backup breathing air supplies to ensure the safety of workers, and to allow a safe shutdown of the unit as necessary.

- **Relocate the feed charge pump (Graco or similar).** The feed charge pumps, Graco in this case, and their associated valving could develop into a source of leakage. Locating the pump inside an occupied building such as the Gas House could add to the concentration of ethylene oxide in that occupied area. Locating the pump to a location outside the Gas House would reduce the likelihood of an explosion as a result of pump leakage. The controls for the feed charge pump can be located within the Gas House.

- **Perform process hazard analysis.** A thorough process hazard analysis should be performed before commencing processing of any hazardous material. A hazard analysis that addressed the requirements for each of the individual types of process operations would have identified the conditions that led to the explosion and resultant fatality.

References

Frank P. Lees. 1996. *Loss Prevention in the Process Industries Hazard Identification, Assessment and Control 2nd ed.* Oxford, Great Britain: Butterworth-Heinemann.

Kirk-Othmer. 1994. *Encyclopedia of Chemical Technology, Fourth Edition*. New York: John Wiley and Sons.

National Fire Protection Association. 1996. *NFPA 30, Flammable and Combustible Liquids Code.* Quincy, MA: National Fire Protection Association.

National Fire Protection Association. 1998. *NFPA 68, Guide for Venting of Deflagrations.* Quincy, MA: National Fire Protection Association.

National Fire Protection Association. 1999. *National Electrical Code Handbook 8th ed*. Quincy, MA: National Fire Protection Association.

National Institute for Occupational Safety and Health. 1990. *NIOSH Pocket Guide to Chemical Hazards.* Washington, DC: National Institute for Occupational Safety and Health.

Public Health Service, National Toxicology Program. 2000. "Ninth Report on Carcinogens." U.S. Department of Health and Human Services.

Research and Special Programs Administration. 1990. *1990 Emergency Response Guidebook.* U.S. Department of Transportation.

Factory Mutual. September 27, 1997. "Series 132 Gas House from BWI KP Aerofill, J.I. 2W0a0.AF (7146)"

Chemical Accident Investigation Team (CAIT) Members

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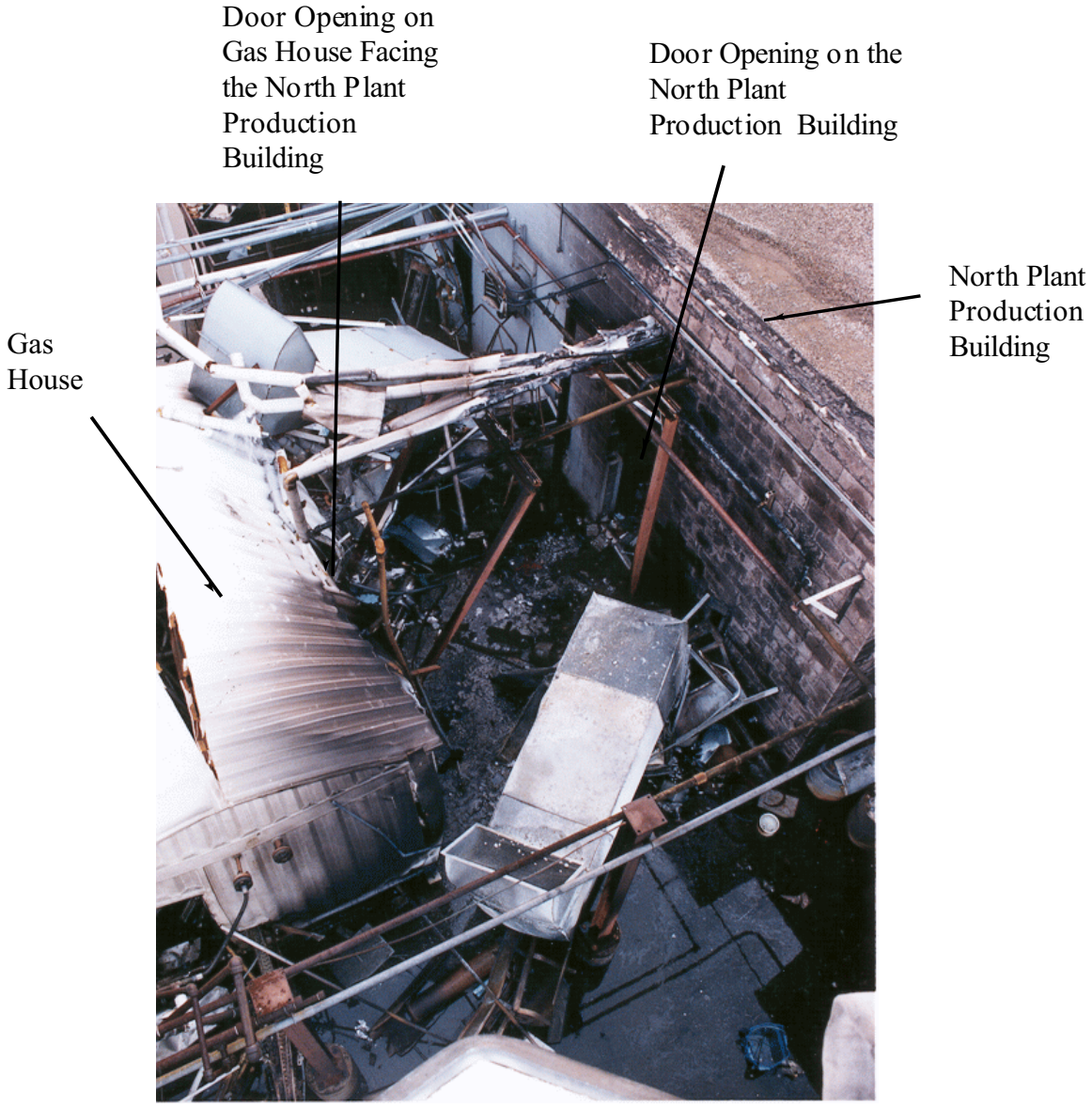
Byron Maggos	EPA Region 5
George Rancich	EPA Region 5
David Chung	EPA Headquarters
Armando Santiago	EPA Headquarters
Jim Wescoat	EPA Headquarters

Appendix A: Photographs of Damages to Facility and Equipment

A-1: The Gas House and the Production Building after the explosion and fire.

A-2: Top View of the separation between the Gas House and the Production Building after the explosion and fire.



A-3: Side and bottom view of the ethylene oxide reclamation tank after the explosion and fire.

Ethylene Oxide Reclamation Tank

Appendix B: Vent Area Calculation

According to analysis in NFPA 68, the venting area needed so as not to exceed the limiting internal pressure is given by the following equation:

$$A_v = C(A_s)/(P_{red})^{1/2}$$

where

A_v	=	vent area (ft^2 or m^2)
C	=	venting equation constant characteristic for the fuel
A_s	=	internal surface area of enclosure (ft^2 or m^2)
P_{red}	=	maximum internal pressure that can be withstood by the weakest structural element not intended to fail (in psi or bar, not to exceed 1.5 psi or 0.1 bar)

The maximum internal pressure for the Gas House is P_{red} = 1.39 psi.

For propane, n-butane, and isobutane, which are NEC Group D gases, NFPA 68 suggests a constant value of C = 0.17.

The internal area of the Gas House is approximately 960 ft^2, A_s = 960 ft^2.

The required vent area, A_v, calculated using $A_v = C(A_s)/(P_{red})^{1/2}$ is 138 ft^2.

The actual area of the Gas House relief panels is 88 ft^2, about 36 percent less than the amount recommended by NFPA.

Since ethylene oxide is a faster burning chemical than NEC Group D gases, a vent area even larger than the 138 ft^2 would be required for ethylene oxide.

Appendix C: Material Safety Data Sheet for Ethylene Oxide

Material Safety Data Sheet
ETHYLENE OXIDE

Manufactured by:

ARC Chemical Division

Balchem Corporation
Routes 6 & 284
P. O. Box 180
Slate Hill, New York 10973

Information Telephone (914) 355-2891
EMERGENCY TELEPHONE (800) 424-9300 (CHEMTREC)

Section 1
Identification

PRODUCT NAME: Ethylene Oxide
CHEMICAL NAME: Ethylene Oxide
FORMULA: $(CH_2)_2O$
MOLECULAR WEIGHT: 44
CAS NUMBER: 75-21-8
CAS NAME: Oxirane
SYNONYMS: EO, EtO, Dihydroxirene, 1-2 Epoxyethane, Dimethylene Oxide, Oxane, Oxirane, Anprolene, Alpha/Beta-Oxidoethane, Oxacyclopropane.
PRODUCT USE: Used primarily as a chemical intermediate in the manufacture of anti-freeze, polyester resins, non-ionic surfactants and specialty solvents. Used as a sterilizing agent (100% EtO alone or diluted with an inert gas) in health care applications. Used as a fumigant for the control of microorganisms and insect infestation in ground spices and other processed natural seasoning materials.

DEPARTMENT OF TRANSPORTATION INFORMATION:
SHIPPING NAME: Ethylene Oxide
HAZARD CLASSIFICATION: 2.3 Poison Gas, Flammable Gas
UNITED NATIONS NUMBER: UN 1040
EMERGENCY RESPONSE GUIDE NO.: 69
REPORTABLE QUANTITY: 10 lb./4.54 Kg.

Section 2
Hazardous Component Information

COMPONENT	WEIGHT BY %	CAS NUMBER
Ethylene Oxide	100%	75-21-8

OSHA ACTION LEVEL (8 HR. TWA): 0.5 ppm
OSHA PEL 8 HR. TWA: 1 ppm
OSHA 15 MINUTE EXCURSION LIMIT: 5 ppm, 9 mg/m^3
ACGIH TLV:
TLV-TWA: 1 ppm, 2 mg/m^3
IDLH: 800 ppm
LD_{50}: 72 mg/kg, Rat-Oral
LC_{50} (4-hour): 1460 ppm, Rat-Inh
LC_{50} (1-hour): 5748 ppm, Male Rat-Inh.
4439 ppm, Female Rat-Inh.
5029 ppm, Combined Sexes

Section 3
Physical Data

BOILING POINT: 50.9°F (10.5°C)
FREEZING POINT: -169°F (-111.7°C)
SPECIFIC GRAVITY: 0.871
VAPOR PRESSURE: 1094 mm Hg
VAPOR DENSITY (AIR=1): 1.5
SOLUBILITY IN WATER (%): 100%
MOLECULAR WEIGHT: 44 grams/mole
PERCENT VOLATILES BY VOLUME: 100
EVAPORATION RATE (BuAc=1): 72
pH: 7 (neutral)
APPEARANCE AND ODOR: Colorless liquid or gas with sweet ether-like odor. Odor threshold: 700 ppm.

Section 4
Fire and Explosion Data

FLAMMABLE LIMITS IN AIR (% BY VOLUME):
UPPER: 100%
LOWER: 3.0%
NFPA HAZARD SYMBOL CODES:
FLAMMABILITY: 4
HEALTH: 3
REACTIVITY: 3
FLASH POINT (TEST METHOD):
TAG OPEN CUP: <-0°F (<-18°C)
TAG CLOSED CUP: -4°F (-20°C)
AUTO IGNITION TEMP.: 804°F (429°C)

EXTINGUISHING MEDIA: Carbon dioxide, dry chemical for small fires. Polymer or alcohol foam for large fires. Dilution of ethylene oxide with 23 volumes of water renders it non-flammable. A ratio of 100 parts water to one part ethylene oxide may be required to control build up of flammable vapors in closed system. Water spray can be used to reduce intensity of flames and to dilute spills to non-flammable mixtures.

HAZARDOUS DECOMPOSITION BYPRODUCTS: Carbon monoxide and carbon dioxide.

SPECIAL FIRE FIGHTING PROCEDURES: Wear a NIOSH approved self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand or positive-pressure mode. Fight fires from explosion-proof locations. After fire burns out, flush with water.

Material Safety Data Sheet
ETHYLENE OXIDE

Section 4
Fire & Explosion Data, Con't

UNUSUAL FIRE AND EXPLOSION HAZARDS: Ethylene oxide is dangerously explosive and flammable over an extremely large range of concentrations in air. Vapors may travel along surfaces to reach distant, low-lying sources of ignition and flash back.

Section 5
Reactivity Data

STABILITY: Material is stable in closed, airtight, pressurized containers at room temperature under normal storage and handling conditions. Potentially unstable at temperatures above 85°F (29°C). Violently decomposes at temperatures above 800°F (426°C).

HAZARDOUS POLYMERIZATION: Can occur.

INCOMPATIBILITY (MATERIALS TO AVOID): EO reacts with active catalysts that promote explosive, heat-producing self-polymerization. These initiators include potassium; anhydrous chlorides of tin, aluminum and iron; alcohols; mercaptans; copper; pure oxides of iron or aluminum; magnesium perchlorate; acids and bases such as KOH and NaOH.

CONDITIONS TO AVOID: Contact with incompatible chemicals. Prevent exposure to any and all sources of ignition such as heat, flame, lighted tobacco products, electrical or mechanical sparks, etc.

Section 6
Health Hazard Data

ROUTES OF ENTRY:

SKIN CONTACT:	Yes
SKIN ABSORPTION:	Yes
EYE CONTACT:	Yes
INHALATION:	Yes
INGESTION:	Yes

EFFECTS OF ACUTE EXPOSURE TO PRODUCT:

SKIN CONTACT: Liquid EO in contact with the skin will evaporate and may cause sufficient cooling to result in frostbite. Prolonged contact of liquid or aqueous solutions of EO with skin can cause severe irritation, blistering, burns, edema, formations of vescicles and severe dermatitis. Contact will occur from wearing contaminated clothing or may arise from EO becoming trapped under ring or watchband. The reaction may not appear for several hours after exposure.

SKIN ABSORPTION: Sustained contact with the skin is unlikely, but can cause headache, dizziness, nausea and vomiting. Dilute solution may penetrate the skin, causing a chemical burn.

Section 6
Health Hazard Data, Con't

EYE CONTACT: Ethylene oxide liquid in diluted aqueous solutions splashed in the eyes can cause severe irritation and may result in corneal injury and permanent eye damage. EO vapors can also cause eye irritation.

INHALATION: Ethylene oxide is a central nervous system depressant. Acute inhalation can progressively cause: mucous membrane irritation, headache, vomiting, cyanosis, drowsiness, weakness, incoordination, CNS depression, lachrymation, nasal discharge and salivation, gasping, labored breathing. Delayed effects include nausea, diarrhea, edema of the lungs, paralysis, convulsions and death.

INGESTION: A highly unlikely route of exposure. Will cause severe irritation and ulceration of the mouth and throat, abdominal pain, nausea, vomiting, collapse and coma.

EFFECTS OF CHRONIC EXPOSURE TO PRODUCT:

SKIN CONTACT: Skin sensitization has been reported in some volunteer subjects.

EYE CONTACT: Some cases of cataract formation have been reported.

INHALATION: Respiratory irritation, chromosomal aberrations and peripheral neurotoxic effects, numbing sense of smell.

INGESTION: A highly unlikely route of exposure. Excessive overexposure may cause anemia, gastrointestinal irritation, effects on liver, kidneys and adrenal glands.

IRRITANCY OF MATERIAL: Severe irritant.

SENSITIZATION: Material is sensitizing.

CARCINOGENICITY:

OSHA:	Noted as cancer/reproductive hazard.
ACGIH:	Classified as suspected human carcinogen.
NTP:	Classified as anticipated human carcinogen.
IARC:	Classified as probable human carcinogen.

OSHA REGULATED: Yes

TERATOGENICITY: Teratogenic effects noted in animals exposed to 100 ppm EO and above.

REPRODUCTIVE TOXICITY: Reproductive effects have been shown in experimental animals exposed to ethylene oxide vapors.

MUTAGENICITY: Chronic exposure has been shown to induce chromosomal aberrations.

EMERGENCY AND FIRST AID PROCEDURES:

EYE EXPOSURE: Immediately flush eyes, including under the eyelids, gently but thoroughly with plenty of running water for at least 15 minutes. Do not wear contact lenses when working with this material.

Material Safety Data Sheet
ETHYLENE OXIDE

Section 6
Health Hazard Data, Con't

SKIN EXPOSURE: Immediately remove clothing and shoes. Wash contaminated skin with soap and water for at least 15 minutes. Contact a physician at once. Treat for possible cryogenic injury.

INHALATION: Remove exposed person to fresh air. If breathing has stopped, give artificial respiration, then oxygen if needed. Contact physician immediately.

Section 7
Spill, Leak & Disposal Procedures

SPILL/LEAK PROCEDURES: Treat any ethylene oxide gas leak as an emergency. If material is released or spilled, eliminate all ignition sources. Ethylene oxide/air mixtures may detonate upon ignition. Evacuate all personnel from the area except for those engaged in stopping the leak or in clean up. Cleanup personnel must have protection against contact with, and inhalation of vapor (see §8).

WASTE MANAGEMENT/DISPOSAL: Suggested method of waste material disposal is by incineration in approved liquid burning hazardous waste incinerator. It is your duty to dispose of chemical materials in accordance with applicable Federal, State and local regulations regarding disposal. Return used drums to manufacturer only.

OSHA DESIGNATIONS:

SPECIALLY REGULATED SUBSTANCE:	29 CFR § 1910.1047
EPA DESIGNATIONS:	40 CFR § 302.4
RCRA HAZARDOUS WASTE NO.:	U115
CERCLA RQ:	10 lb. (4.54 Kg) per RCRA §3001

Section 8
Special Protection Information

EYE PROTECTION: Always wear chemical safety goggles. If splashing may occur, wear a full face shield as a supplementary protective measure. Do not wear contact lenses when working with EO. Follow the eye and face protection regulations cited 29 CFR §1910.133.

RESPIRATOR: Wear a NIOSH approved respirator for maximum use concentrations. For emergency or nonroutine use wear self-contained breathing apparatus with a full facepiece operated in the pressure-demand or positive pressure mode. Refer to OSHA respirator regulations cited at 29 CFR §1910.134 and 29 CFR § 1910.1047

Section 8
Special Protection Information, Con't

OTHER: Wear impervious gloves (OSHA currently recommends PVC); boots; aprons; head cover; and clean impervious body-covering clothing to prevent any possibility of skin contact. All clothing must be flame-resistant. Launder contaminated clothing and discard contaminated leather shoes.

WORKPLACE CONSIDERATIONS: (see 29 CFR § 1910.1047)

VENTILATION: Install and operate general and local ventilation systems powerful enough to maintain airborne levels of ethylene oxide below the OSHA PEL (1ppm 8 hr. TWA). Make all ventilation systems of maximum explosion-proof design.

SAFETY SHOWERS: Make eyewash stations, emergency deluge showers, and washing facilities available in all areas of use and handling.

OTHER: Design all engineering systems to be explosion-proof in any area where this gas may occur. Container and system must be electrically grounded/bonded before unloading. Practice good personal hygiene; always wash thoroughly after using this material. Do not eat, drink or smoke in any work area. Avoid inhalation of vapor.

Section 9
Special Precautions

STORAGE SEGREGATION: Store ethylene oxide in a cool, dry, well-ventilated area away from incompatible chemicals and sources of ignition (see §5). Storage vessels should be insulated and have pressure relief valves. To avoid contamination, install double-block valves on outlet of storage vessels. Store cylinders upright, secure them tightly, do not drag or slide them, and move in a carefully supervised manner with a suitable hand truck. Outside or detached storage is suggested.

STATE REGULATORY INFORMATION:

NJ/PA/MA: RIGHT-TO-KNOW

CALIFORNIA: This product contains one or more chemicals known to the State of California to cause cancer, birth defects or other reproduction harm.

TRANSPORTATION DATA:	49 CFR § 172.101-2
DOT SHIPPING NAME:	Ethylene Oxide
DOT LABEL(S):	Poison Gas, Flammable Gas
DOT CLASS:	2.3
IMO LABEL(S):	Poison Gas, Flammable Gas
IMO CLASS:	2.3
UN REGISTER:	UN1040

Material Safety Data Sheet
ETHYLENE OXIDE

Section 9
Special Precautions, Con't

SPECIAL HANDLING/STORAGE: Preplan handling and emergency response procedures prior to use. Protect containers from physical damage and regularly inspect them for cracks, leaks or faulty valves. Monitor inventory; we recommend this material not be stored over 6 months. Monitor purity specifications that may indicate the degree of molecular arrangement/polymerization of this material.

ENGINEERING CONTROLS: All engineering systems must be of maximum explosion-proof design. Ethylene oxide must be used in closed engineering systems because of its flammability/explosability hazards (see §4). This prevents dispersion of this highly flammable gas into work areas. WARNING: Ethylene oxide has extremely

Section 9
Special Precautions, Con't

poor warning properties. Its odor is not detectable by the user until its concentration reaches 700 ppm. An air-monitoring system is needed to maintain the 1 ppm standard because even highly toxic concentrations of this material will be colorless and odorless.

SPECIAL SHIPPING INFORMATION:

Ethylene oxide is shipped and stored in DOT 5P drums. Nitrogen is charged into the drum after filling with ethylene oxide, bringing the total drum pressure up to 50 p.s.i. This inerts the headspace and provides positive pressure to the drum. Before returning drum to supplier: Pressurize drum with Nitrogen to 50 p.s.i. total pressure at 70°F; Replace valve plugs tightly in outlets; Check container valves and plugs for leaks prior to shipment.

DISCLAIMER

OSHA Regulations are specific to Ethylene Oxide and it is imperative that the user be familiar with and adhere to 29CFR S1910.1047 as well as any other applicable Federal, State or local government regulations. This data is furnished gratuitously independent of any sale of the product, only for your investigation and independent verification. While the information is believed correct, ARC makes no representation as to the accuracy of the information contained herein. ARC shall in no event be responsible for any damages of whatsoever nature directly or indirectly resulting from publication or use of, or reliance upon, data contained herein. No warranty (either expressed or implied) of merchantability or of fitness or of any nature with respect to the product or to the data herein is made hereunder.

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GLOSSARY FOR § 2 COMPONENTS INFORMATION

ACGIH	AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	PEL	PERMISSIBLE EXPOSURE LIMIT
CAS	CHEMICAL ABSTRACT SERVICE	SARA	SUPERFUND AMENDMENTS & REAUTHORIZATION ACT
IDLH	IMMEDIATELY DANGEROUS TO LIFE OR HEALTH	STEL	SHORT TERM EXPOSURE LIMIT
OSHA	OCCUPATIONAL SAFETY & HEALTH ADMINISTRATION	TLV	THRESHOLD LIMIT VALVE
		TWA	8 HOUR TIME WEIGHTED AVERAGE

MSDS DEFINITIONS

This definition page is intended for use with Material Safety Data Sheets supplied by ARC Chemical Division Balchem Corporation. Recipients of these data sheets should consult the OSHA Safety and Health Standards (29 CFR § 1910), particularly subpart G- Occupational Health and Environmental Control, and subpart I - Personal Protective Equipment, for general guidance on control of potential Occupational Health and Safety Hazards.

SECTION 1
PRODUCT IDENTIFICATION

GENERAL OR GENERIC ID: Chemical family or product description.
DOT HAZARD CLASSIFICATION: Product meets DOT criteria for hazards listed.

SECTION 2
COMPONENTS

Components are listed in this section if they present a physical or health hazard and are listed at or above 1% in the mixture. If a component is identified as CARCINOGEN by NTP, IARC, or OSHA as of the date on the MSDS, it will be listed in this section when present at or above 0.1% in the product. Negative conclusions concerning carcinogenicity are not reported. Additional health information may be found in Section 6.
PERMISSIBLE EXPOSURE LIMIT: For product.
THRESHOLD LIMIT VALUE: For product.
Exposure recommendations are for components. OSHA Permissible Exposure Limits (PEL'S) and American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs) appear on the line with the component identification.

SECTION 3
PHYSICAL DATA

BOILING POINT: Of product if known. The lowest value of the components is listed for mixtures.
VAPOR PRESSURE: Of product if known. The highest value of the components is listed for mixtures.
SPECIFIC VAPOR DENSITY: Compared to AIR = 1. If Specific Vapor Density of product is not known, the value is expressed as lighter or heavier than air.
SPECIFIC GRAVITY: Compared to WATER = 1. If Specific Gravity of product is known, the value is expressed as less than or greater than water.
pH: If applicable.
PERCENT VOLATILES: Percentage of material with initial boiling point below 425 degrees Fahrenheit and vapor pressure above 0.1mm Hg at 68°F.
EVAPORATION RATE: Indicated as faster or slower than ETHYL ETHER, unless otherwise stated.

SECTION 4
FIRE AND EXPLOSION DATA

FLASH POINT: Method identified.
EXPLOSION LIMITS: For product if known. The lowest value of the components is listed for mixtures.
HAZARDOUS DECOMPOSITION PRODUCTS: Known or expected hazardous products resulting from heating, burning or other reactions.
EXTINGUISHING MEDIA: Following National Fire Protection Association criteria.
FIREFIGHTING PROCEDURES: Minimum equipment to protect firefighters from toxic products of vaporization, combustion or decomposition in fire situations. Other firefighting hazards may also be indicated.
SPECIAL FIRE AND EXPLOSION HAZARDS: States hazards not covered by other sections.
NFPA CODES: Hazard ratings assigned by the National Fire Protection Association.

SECTION 5
REACTIVITY DATA

HAZARDOUS POLYMERIZATION: Conditions to avoid to prevent hazardous polymerization resulting in a large release of energy.
STABILITY: Conditions to avoid to prevent hazardous or violent decomposition.
INCOMPATIBILITY: Materials and conditions to avoid to prevent hazardous reactions.

SECTION 6
HEALTH HAZARD DATA

EFFECTS OF ACUTE OVEREXPOSURE: Potential local and systemic effects due to single or short term overexposure to the eyes and skin or through inhalation or ingestion.
FIRST AID: Procedures to be followed when dealing with accidental overexposure.
PRIMARY ROUTE OF ENTRY: Based on properties and expected use.

SECTION 7
SPILL OR LEAK PROCEDURES

Reasonable precautions to be taken and methods of containment, clean-up and disposal. Consult federal, state and local regulations for accepted procedures and any reporting of notification requirements.

SECTION 8
PROTECTIVE EQUIPMENT TO BE USED

Protective equipment which may be needed when handling the product.

SECTION 9
SPECIAL PRECAUTIONS OR OTHER COMMENTS

Covers any relevant points not previously mentioned.