

Case Study

U.S. CHEMICAL SAFETY AND HAZARD INVESTIGATION BOARD



THE EXPLOSION AT CONCEPT SCIENCES: HAZARDS OF HYDROXYLAMINE

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Tom Volk, The Morning Call

CONCEPT SCIENCES, INC.

Hanover Township, Pennsylvania

February 19, 1999

KEY ISSUES:

- ◆ Hazards of Processing Hydroxylamine
- ◆ Process Hazards Evaluation
- ◆ Chemical Facility Siting

Introduction

This Case Study describes a catastrophic hydroxylamine (HA) explosion that occurred on February 19, 1999, at the Concept Sciences, Inc. (CSI), facility in Hanover Township, Lehigh County, Pennsylvania. Four CSI employees and one employee of an adjacent business were killed; 14 people were injured.

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1.0 Background

At 8:14 pm on February 19, 1999, a process vessel containing several hundred pounds of hydroxylamine (HA) exploded at the Concept Sciences, Inc. (CSI), production facility near Allentown, Pennsylvania. Employees were distilling an aqueous solution of HA and potassium sulfate, the first commercial batch to be processed at CSI's new facility. After the distillation process was shut down, the HA in the process tank and associated piping explosively decomposed, most likely due to high concentration and temperature.

Four CSI employees and a manager of an adjacent business were killed. Two CSI employees survived the blast with moderate-to-serious injuries. Four people in nearby buildings were injured. Six firefighters and two security guards suffered minor injuries during emergency response efforts.

The production facility was extensively damaged (Figure 1). The explosion also caused significant damage to other buildings in the Lehigh Valley Industrial Park and shattered windows in several nearby homes.

CSB Case Studies summarize incident investigation data and present conclusions based on CSB analyses. They do not discuss root and contributing causes or make safety recommendations—unlike the more comprehensive CSB Investigation Reports.



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Figure 1

Damage to Concept Sciences, Inc., HA production facility



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1.1 Incident Review Process

CSB examined physical evidence at the site and reviewed relevant documents, such as a report prepared by Hazards Research Corporation (HRC, 1999) for the Occupational Safety and Health Administration (OSHA). CSB also contracted with the U.S. Department of the Navy, Naval Sea Systems Command, Indian Head Naval Surface Warfare Center, for assistance in evaluating HA chemistry and processing. The center conducts research on energetic materials (explosives, propellants, etc.), including HA and its derivatives.

1.2 Hydroxylamine Properties and Applications

HA is an oxygenated derivative of ammonia, represented by the chemical formula NH_2OH . Table 1 lists its characteristic properties. HA is usually handled as an aqueous solution or as salts. The concentrated free base¹ is susceptible to explosive decomposition.

¹ Ammonia and substituted amines are basic and react reversibly with common acids to form salts. Treatment of the salts with a strong base (e.g., potassium hydroxide) releases the free or unprotonated amine, known as the “free base.”

Table 1
Characteristic Properties
of Solid or Pure Hydroxylamine

| |
|--|
| Colorless or white, thermally unstable, hygroscopic, needle-like crystals |
| Decomposes at room temperature or in hot water |
| Very soluble in liquid ammonia, water, and methanol; soluble in acids |
| Molecular weight: 33.03 |
| Melting point: 34°C (a) |
| Boiling point: 110°C |
| Explosion point: 265°C |
| Density: 1.227 |
| Vapor pressure: 10 mmHg@47.2°C (b) |
| Fire hazard when exposed to heat, flame, and oxidizers |
| May ignite spontaneously in air if a large surface area is exposed |
| Explodes in air when heated above 70°C |
| Ignites on contact with copper (II) sulfate, metals, and oxidants (e.g., chlorine) |

SOURCE: Lewis, 1996.

(a) °C = degrees Celsius.

(b) mmHg = millimeters of mercury.

If not for the explosion, CSI would have been the first company in the United States to manufacture this product in commercial quantities.

On the day of the incident, CSI was producing its first batch of 50 wt-percent HA solution at the new facility.

Only salts of HA were available until the 1980s, when Nissin Chemical Company, Ltd., of Japan, commercialized aqueous free-base HA by adding a proprietary stabilizer to prevent decomposition. HA is commercially available in solutions up to 50 wt-percent.²

Over the past decade, the semiconductor manufacturing industry has used HA solutions in cleaning formulations to strip process residues from integrated circuit devices. HA and its derivatives are also used in the manufacture of nylon, inks, paints, pharmaceuticals, agrochemicals, and photographic developers.

The current market for concentrated HA solutions is expanding. If not for the explosion, CSI would have been the first company in the United States to manufacture this product in commercial quantities. Nissin Chemical Company was the sole global supplier of HA up to that time. In early 1999, BASF Aktiengesellschaft started up a new HA production facility in Germany.

Fourteen months following the CSI incident, a catastrophic explosion at the Nissin plant in Japan further decreased the availability of HA, creating market shortages.

²Weight percent (wt-percent) is the weight of HA in a solution divided by the total weight of the solution.

1.3 CSI Operations

CSI began development of its own HA production process through laboratory-scale experimentation in 1997. Development continued with the construction of a 10-gallon pilot plant, which was operational in early 1998. In July 1998, CSI leased approximately 20,000 square feet in a multiple-tenant building and began to set up the production facility.

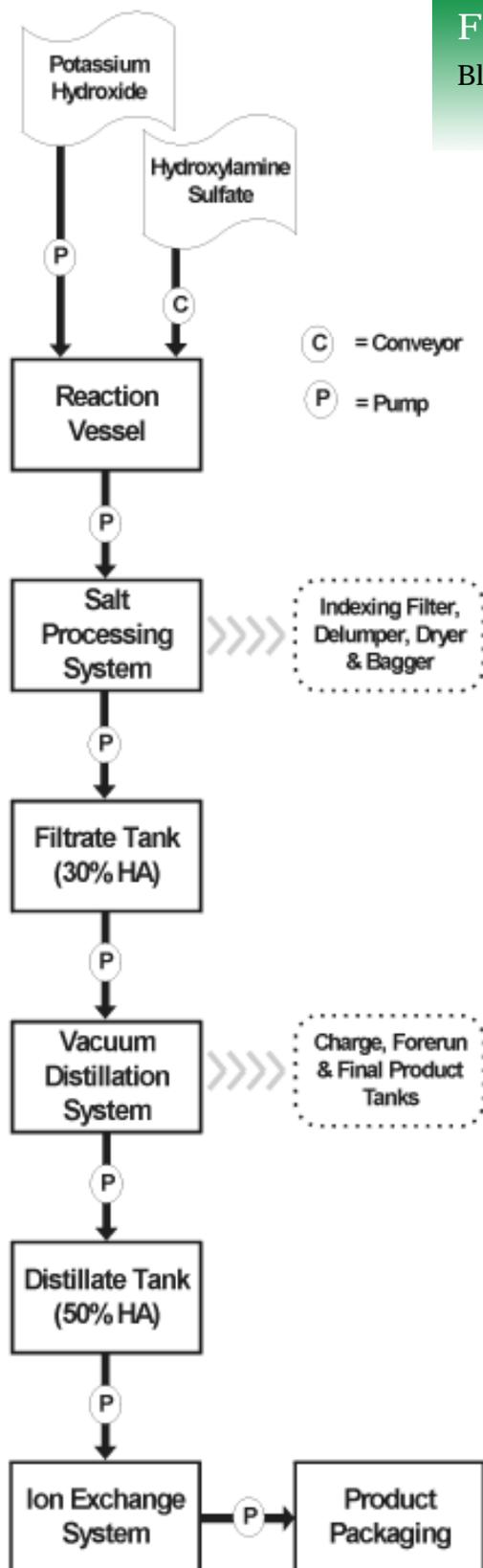
Ashland Chemical Company, a division of Ashland Inc., was CSI's primary customer for purified HA solutions. Ashland used the HA solutions in residue cleaners for the semiconductor industry.

Ashland planned to purchase 2 million pounds of 50 wt-percent HA from CSI. In exchange for discounted pricing of future deliveries of HA solutions, Ashland provided CSI with financial support (\$350,000) to purchase production equipment. By February 1999, CSI had approximately 20 full-time employees, 10 of whom were assigned to the new production facility.

On the day of the incident, CSI was producing its first batch of 50 wt-percent HA solution at the new facility. CSI's production process involved the four basic steps outlined in Figure 2—reaction, filtration, distillation, and ion exchange purification.

Figure 2

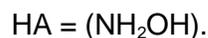
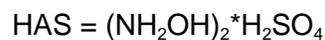
Block flow diagram of the CSI HA production process



1. Reaction of HA sulfate and potassium hydroxide to produce a 30 wt-percent HA and potassium sulfate aqueous slurry:



where:



2. Filtration of the slurry to remove precipitated potassium sulfate solids.
3. Vacuum distillation of HA from the 30 wt-percent solution to separate it from the dissolved potassium sulfate and produce a 50 wt-percent HA distillate.
4. Purification of the distillate through ion exchange cylinders.

As diagrammed in Figure 3, CSI's distillation process included a 2,500-gallon charge tank (25 feet long and 4 feet in diameter); a vacuum distillation system, which consisted of a glass column (heating column) and remote water heater, a glass condenser (condenser column) and remote chiller, and a vacuum pump; and two product receivers (a forerun tank and a final product tank, both 1,500-gallon tanks, 15 feet long and 4 feet in diameter).³

The distillation is performed in two phases. The first phase of the process begins as a pump circulates the 30 wt-percent HA from the charge tank to the heating column, a vertical tube-in-shell glass heat exchanger. The HA enters the top of the column and is heated by 120 degrees Fahrenheit (°F) distilled water as it cascades through the tubes back to the charge tank.

Vapor from the column is condensed using a chilled water condenser (condenser column). The distillate, initially consisting primarily of water with some HA, is directed into the forerun tank.

³ CSI referred to the larger distillation vessel as the charge tank, though it is commonly called a still pot. The two smaller receiving tanks are commonly referred to as distillate tanks. CSI referred to the vessel receiving the initial cut of distilled HA solution as the forerun tank and the vessel receiving the final cut as the final product tank.

When the concentration of HA reaches 10 wt-percent in the forerun tank, the distillate is diverted to the final product tank, where it is collected until the concentration of the liquid phase in the charge tank is 80 to 90 wt-percent HA.⁴ At this point, the first phase of distillation is complete.

The charge tank and column are cleaned using a 30 wt-percent HA solution, and the charge tank is taken out of service.

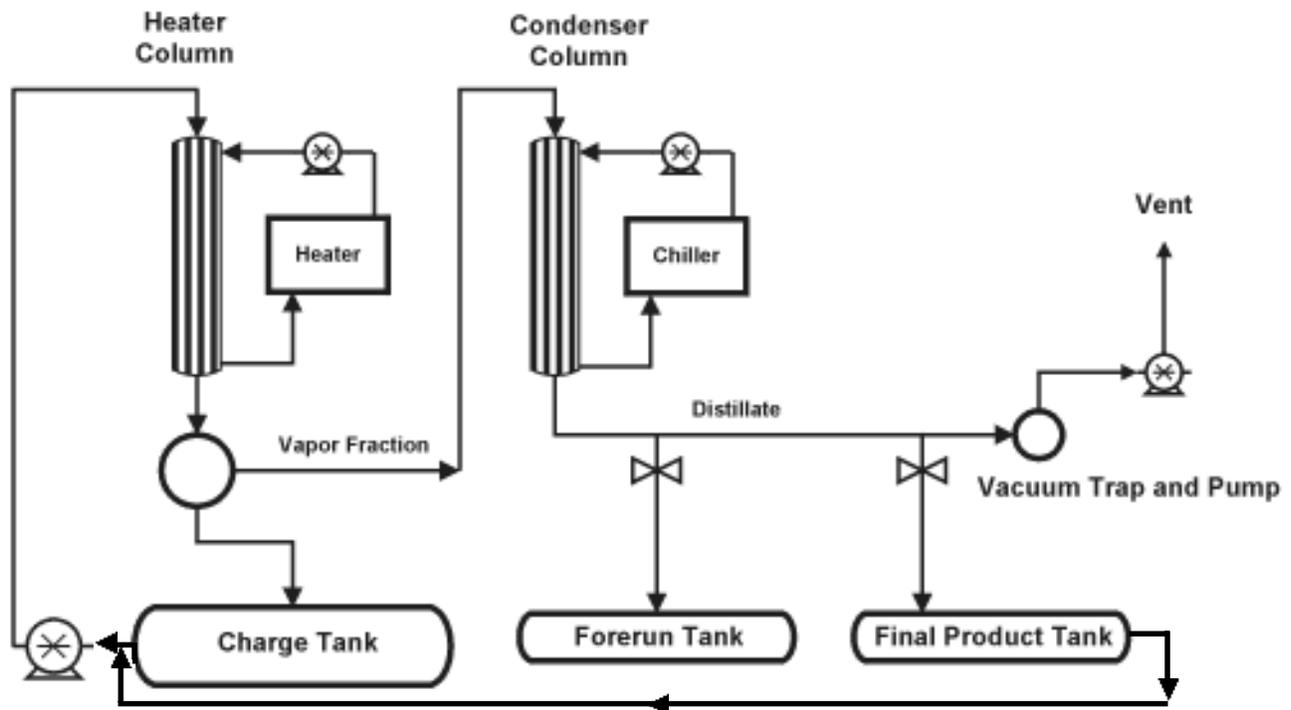
In the second phase of distillation, the 45 wt-percent HA solution collected in the final product tank is further concentrated by redistillation. It is fed back to the top of the heating column and flows through the tubes, where it is heated by 140°F water.

The distillate is directed back to the final product tank. Water is removed from the HA solution until the material in the final product tank reaches 50 wt-percent HA, at which point the distillation is complete.

⁴ The material in the charge tank is a slurry. The solids, which are predominately potassium sulfate, are removed from the liquid to determine the HA concentration of the liquid solution.

Figure 3

Simplified process flow diagram of the CSI HA vacuum distillation process



2.0 Description of Incident

2.1 The Incident

CSI began its first distillation to produce 50 wt-percent HA in the new facility on Monday afternoon, February 15, 1999. The charge tank contained approximately 9,000 pounds of 30 wt-percent HA. About 30 hours of distillation was required to complete the batch under normal conditions.

By Tuesday evening, the concentration of liquid solution in the charge tank was approximately 48 wt-percent, and the product was being collected in the forerun tank. CSB was unable to determine exactly when the product was diverted from the forerun tank to the final product tank.

The process was shut down Tuesday evening for maintenance when it was determined that water had leaked

Between 7:00 and 7:15 pm, the concentration of liquid solution in the charge tank was recorded as 86 wt-percent HA.

HA crystals and solutions are known to explosively decompose at high concentrations . . . Heating and the presence of contaminants can accelerate decomposition.

into the charge tank through broken tubes in the heater column. The necessary repairs were made by Thursday afternoon, and the distillation process was restarted. At 11:15 pm, the concentration of liquid solution in the charge tank was 56 wt-percent, and the concentration of the material collected was 15 wt-percent. The distillation continued until approximately 11:30 pm that evening.

On Friday, February 19, a 1.5-inch feed line to the heater column was replaced with a 2-inch line, which delayed startup until later in the morning. The concentration of liquid solution in the charge tank at that time was about 57 wt-percent HA. It steadily increased throughout the day. Between 7:00 and 7:15 pm, the concentration of liquid solution in the charge tank was recorded as 86 wt-percent HA.

From laboratory distillations, CSI management knew that crystals formed with HA concentrations greater than 80 wt-percent. As noted in Table 1, crystals of HA are unstable and potentially explosive.

Management was also aware of the hazards associated with concentrating HA. As described in CSI's material safety data sheet (MSDS):

Danger of fire and explosion exists as water is removed or evaporated and HA concentration approaches levels in excess of about 70% (CSI, 1997).

CSI personnel visually monitored the distillation system for the formation of crystals. At approximately 7:45 pm Friday, the still was shut down and cleaned with 30 percent HA to wash away crystals that may have formed.⁵ The second phase of distillation was never started.

A manufacturing and engineering supervisor was called at his home and arrived at the facility shortly after 8:00 pm. The explosion occurred at 8:14 pm. The events during the minutes prior to the explosion could not be conclusively determined.

2.2 Overview of Potential Initiating Scenarios

Although a detailed review of potential initiating scenarios is not within the scope of this case study, HA crystals and solutions are known to explosively decompose at high concentrations (85 wt-percent; Koseki and Iwata, 2001). Heating and the presence of contaminants can accelerate decomposition. During the distillation process at CSI, the material from the charge tank was fed to the heating column. The mixture returned to the charge tank had a higher concentration of

⁵ The normal procedure was to add 30 wt-percent HA solution to the charge tank to dilute the material contained in it. This material was then circulated through the heating column and heated to 120°F. The vapors generated (i.e., water with a low concentration of HA) were thought to clean the condenser column.

HA because much of the water had evaporated.

Any of several sequences of events could have caused this incident—addition of excessive heat to the distillation system, physical impacts from partial or total collapse of the glass equipment, or inadvertent introduction of impurities. Friction may have heated the mixture as it passed through the pump that supplied the heating column. With the HA at a high concentration, this source of heat could have caused an explosion within the charge tank or the feed line to the tank.

2.3 Effects of Explosion

Four CSI employees and a manager of an adjacent business were killed. Two CSI employees were buried in the building rubble until rescued by emergency responders; their injuries were moderate to serious. In addition to six firefighters and two security guards, who received minor injuries, four people in a nearby building were also injured.

The explosion damaged 10 buildings within the Lehigh Valley Industrial Park and several local residences. A toy vending machine business adjacent to and in the same building as CSI and a package delivery service facility across the street received significant structural damage. A nearby daycare center had minor structural damage. Most of the residential damage was limited to broken windows. Estimated

property damage in February 1999 was \$3.5 to \$4 million.

Debris from the blast fell around the immediate area surrounding the CSI facility, and a cloud of chemical residue dispersed downwind of the site. Liquid potassium hydroxide solution drained from two onsite storage tanks onto an adjacent parking lot.

Hazards Research Corporation, an OSHA contractor, noted that sections of the distillation equipment frame were thrown more than 1,000 feet (HRC, 1999). No identifiable sections of the charge tank were recovered, but the end manway of the tank was found about 200 feet east of its original location. Fire damage was primarily limited to CSI's raw materials storage area.

A crater approximately 6 feet wide, 26 feet long, and 16 inches deep was found in the concrete floor directly below where the charge tank had been located (Figure 4). Based on observed crater dimensions, Hazards Research Corporation estimated an explosive force equivalent to 800 pounds of trinitrotoluene (TNT; HRC, 1999).

Because of the lack of batch records, it was not possible to determine the exact amount of HA in the charge tank at the time of the explosion. The explosive energy of HA is essentially equivalent to TNT on a weight basis. Hazards Research Corporation estimated that the HA in the tank was equivalent to 667 pounds of TNT (HRC, 1999).

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3.0 Management of Chemical Process Safety

The CSI incident demonstrates the need for effective process safety management and engineering throughout the development, design, construction, and startup of a hazardous chemical production process.

In *Guidelines for Technical Management of Chemical Process Safety*, the American Institute of Chemical Engineers (AIChE) Center for Chemical Process Safety (CCPS, 1989) describes the 12 core elements of a good process safety management system. Among these elements, deficiencies in “process knowledge

and documentation” and “process safety reviews for capital projects” significantly contributed to the CSI incident.

3.1 Process Knowledge and Documentation

System Components

A process safety management system for chemical manufacturing is only as good as the foundation upon which it is built—the actual research, development, design, construction, and operational data. Basic process safety information includes the following:

- ◆ Chemical, physical, and reactivity properties of materials.
- ◆ Health and toxicity data for reactants and products.
- ◆ Thermal and chemical stability data for reactants and products.
- ◆ Process chemistry and technology information.
- ◆ Range of equipment design temperature and pressure vs process conditions.
- ◆ Equipment and materials of construction specifications.
- ◆ Material and energy balances of chemical process.
- ◆ Safety systems (e.g., interlocks, pressure relief systems, detection or suppression systems).

Figure 4

Building damage and charge tank crater (foreground)



- ◆ Operating procedures and training information.
- ◆ Design codes and regulatory standards.

To achieve accident prevention goals, all of this information should be compiled, analyzed, and updated before initiating design and construction. This information should be made readily available to employees.

Inadequacies of Information Management

At CSI, the development, understanding, and application of process safety information during process design was inadequate for managing the explosive decomposition hazard of HA.

During pilot-plant operation, management became aware of the fire and explosion hazards of HA concentrations in excess of 70-wt percent, as documented in the MSDS (see Section 2.1). This knowledge was not adequately translated into the process design, operating procedures, mitigative measures, or precautionary instructions for process operators.

CSI's HA production process, as designed, concentrated HA in a liquid solution to a level in excess of 85 wt-percent. This concentration is significantly higher than the MSDS-referenced 70 percent concentration at which an explosive hazard exists.

Only sketches and basic process flow diagrams were developed; there

were no standard engineering drawings. Operating procedures provided only rudimentary information. Engineering drawings and detailed operating procedures should have been a key component of operations and maintenance training.

3.2 Process Safety Reviews for Capital Projects

System Components

In the chemical process industry, numerous safety reviews commonly occur during the implementation of capital projects, such as development and construction of a new plant. Among these reviews are hazard reviews (discussed below), siting reviews, and process design reviews.

Hazard Reviews

A hazard review is a systematic method for identifying process and occupational hazards. Many types of hazard reviews may be performed at various stages in a project life cycle.

An adequate reactive chemical hazard evaluation and process hazard analysis (PHA) would have helped CSI quantify, evaluate, and mitigate the hazards of HA production. Such analyses might have caused management to question whether its planned process presented substantial risks to employees and to the community.

◆ CSI's HA production process . . . concentrated HA in a liquid solution to a level in excess of 85 wt-percent . . . significantly higher than the MSDS-referenced 70 percent concentration at which an explosive hazard exists.

◆ An adequate reactive chemical hazard evaluation and process hazard analysis would have helped CSI quantify, evaluate, and mitigate the hazards of HA production.

HA has long been recognized as an unstable chemical and explosive when concentrated at high temperatures.

Inadequacies of Reactive Hazard Review

Typically, the first step in a reactive hazard evaluation is a literature search. HA has long been recognized as an unstable chemical and explosive when concentrated at high temperatures. *Bretherick's Handbook* (1999) describes a 1948 incident in which an extremely violent explosion occurred toward the end of vacuum distillation.

Additional incidents involving HA or its salts are also documented. As demonstrated in the Hazards Research Corporation report, a literature review would have readily identified that HA is subject to rapid exothermic decomposition and exhibits an explosive force equivalent to TNT (HRC, 1999).

HA could have been tested within CSI's process parameters to establish the magnitude of potential reactive chemical hazards.⁶ Basic reaction hazard testing and evaluation procedures are readily available. For example, the following documents contain review assessment and evaluation strategies, including commonly available screening methods:

- ◆ *Chemical Reaction Hazards* (Barton and Rogers, 1997).

⁶ Although CSI conducted numerous laboratory tests to assess the stability of HA—particularly with respect to stabilizers—it is not evident that it completed a detailed reactive analysis of specific process conditions and deviations, such as the presence of HA crystals or the addition of heat.

- ◆ *Guidelines for Chemical Reactivity Evaluation and Application to Process Design* (CCPS, 1995a).
- ◆ *Guidelines for Safe Storage and Handling of Reactive Materials* (CCPS, 1995b).

The Health and Safety Executive (HSE) of the United Kingdom has published additional guidance since the CSI incident (*Designing and Operating Safe Chemical Reaction Processes* [HSE, 2000]).

As demonstrated during laboratory distillations, CSI's process chemistry created the potential for HA crystal formation and exothermic decomposition. During preproduction development, the potential of HA concentrations exceeding 70 wt-percent to explosively decompose should have been investigated to determine the magnitude of the hazard.

Prior to or during development of the process design, CSI should have systematically evaluated the reactive hazards of its process and identified control measures. Potential reactive hazards include concentration peaks, temperature variations, possible interactions with impurities or contaminants, and stabilizer requirements.

Inadequacies of Process Hazard Analysis

CSI purchased equipment before it had conducted a formal engineering design review for the specific manufacturing process. CSI's design

and safety review was inadequate given the hazards of highly concentrated HA. A critical evaluation of process materials, conditions, equipment, and development experience would have indicated that credible scenarios presented the potential of a catastrophic HA explosion.

Process development records show that CSI was aware that its process created potentially hazardous conditions in the charge tank (i.e., HA concentration exceeding 80 wt-percent mixed with solid potassium sulfate). An effective PHA during process design would have provided CSI with scenarios resulting in explosions similar to the one that occurred. CSI could have then developed appropriate control measures or modified the process chemistry to avoid high concentrations of HA.

CSI performed a “What If” PHA, which was reported in a one-page document. However, it did not adequately address the prevention or consequences of events that could trigger an explosion of high concentrations of HA, such as the following:

- ◆ High concentrations of potassium sulfate in the charge tank.
- ◆ Potential formation of solid HA crystals in the condenser and charge tank.
- ◆ Potassium sulfate blockage of reboiler tubes.
- ◆ Adequacy of flow and temperature indicators.

- ◆ Failure of process equipment and controls.
- ◆ Inappropriate facility siting (i.e., proximity to the public).

The PHA recognized the potential danger of the process and identified safeguards, such as remote control operation, blowout walls, and shielding for protecting employees if foreseeable hazards were realized. However, CSI did not implement any of these safeguards.

3.3 Subsequent Incidents Involving Hydroxylamine

Subsequent to the CSI incident, Koseki and Iwata (2001) evaluated the ability of HA to detonate at high concentrations while under containment. The June 10, 2000, Nissin Chemical Company HA incident, in Gunma, Japan, caused four fatalities, injured 58 people, destroyed the HA distillation tower, and significantly damaged the plant. To produce 50 wt-percent HA solutions, Nissin used a process similar to CSI’s.

Prior to the explosion at Nissin, the HA process had been shut down for 5 hours to replace oil in a vacuum pump. The explosion occurred approximately 30 minutes after startup, during distillation. The process concentration of HA, prior to the incident, was 85 wt-percent. The results of Koseki’s steel tube test indicated that 85 wt-percent HA was easily detonated.

◆ A critical evaluation of process materials, conditions, equipment, and development experience would have indicated that credible scenarios presented the potential of a catastrophic HA explosion.

3.4 Regulatory Coverage of Hydroxylamine

OSHA's Process Safety Management (PSM) standard (29 CFR 1910.119) regulates facilities with any process that contains 2,500 pounds or more of HA.

On August 11, 1999, OSHA issued CSI several willful and serious citations, alleging multiple violations of the PSM standard. CSI contested the citations. On November 5, 2001, a settlement was reached between OSHA and CSI in which the citations were kept, but with willful violations reclassified.⁷

The OSHA citations included the following PSM violations:

- ◆ Failure to compile written process safety information to enable the employer and employees to identify and understand specific hazards.
- ◆ Failure to develop and implement written operating procedures for safety systems and their functions—startup, shutdown, and normal operation—or for the consequences of deviation from operating limits.

- ◆ Failure to document that the process equipment complied with generally accepted good engineering practices.
- ◆ Failure to conduct an adequate and appropriate process hazard analysis.
- ◆ Failure to conduct adequate process training.
- ◆ Failure to perform a prestartup safety review.
- ◆ Failure to establish and implement procedures for the management of change.

On November 9, 2000, a Federal grand jury indicted the president of CSI for alleged criminal violations of the PSM standard. The U.S. Attorney's Office for the Eastern District of Pennsylvania subsequently prosecuted these criminal charges pursuant to Section 17(e) of the Occupational Safety and Health Act (29 U.S.C. § 666(e)). On September 5, 2001, as a result of the defendant's Motion to Dismiss, a U.S. District Court dismissed the indictment, specifying that the PSM regulation is ambiguous with respect to whether CSI's HA production process is covered, and that informal interpretations issued by OSHA are prohibited from being used against the defendant in a criminal case.

⁷Willful violations were changed to violations under "Section 17" of the Occupational Safety and Health Act of 1970.

4.0 Hazardous Chemical Facility Siting

4.1 Site Evaluation and Selection

Facility siting evaluations typically include process safety analyses and reviews of government regulations, industry guidelines, and local emergency planning requirements. CSI was located in a multiple-tenant building within a suburban industrial park. Fortunately, the timing of the explosion—8:14 pm on a Friday—limited the number of fatalities and injuries.

One of the fatalities was an employee of another company, whose work area was separated from CSI by a concrete block wall. Several workers at a package delivery service facility—located directly across the street—were injured, and the building was extensively damaged (see top left corner of cover photograph). A daycare center located within 900 feet of the explosion and several nearby residences received minor damage.

Facility siting should consider all potential hazards (e.g., fire, explosion, toxic material release) to people, property, and the environment. Siting evaluations should be an integral part of process design. If CSI had performed an adequate PHA for the planned HA manufacturing operation, it would have recognized the danger to the public. Management could have

selected an alternate site where no one at neighboring facilities would be exposed to such a substantial risk.

Ashland Chemical Company raised the facility siting issue in its process review. The original siting location considered by CSI was similar to the one finally chosen. It was described by Ashland as:

... an office/commercial type building ... not a separate building but connected in a strip to other buildings.

Ashland concluded that the building was “not a good location for a chemical process.”

4.2 Industry Guidance

The explosives industry uses physical separation between explosive hazards and occupied buildings as an effective mitigation technique. The *American Table of Distances for Storage of Explosive Materials*, published by the Institute of Makers of Explosives (IME, 1991), provides guidance on the safe separation of explosive hazards from inhabited buildings. Although this information was developed for the manufacture and storage of commercial explosives, it demonstrates the importance of chemical facilities also ensuring the safe siting of potentially explosive operations.

If CSI had performed an adequate [process hazard analysis] for the planned HA manufacturing operation, it would have recognized the danger to the public.

... the zoning ordinance did not prohibit chemical manufacturing facilities in Lehigh Valley Industrial Park in July 1998.

CSI provided the local township with MSDSs for raw materials and finished products, but did not alert it to the process hazards associated with HA production.

Several industrial risk insurers provide siting guidance for petroleum and chemical facilities. This guidance is developed primarily for determining appropriate spacing between process units within plants to minimize property losses and is not intended to provide for the safety of building occupants.

Available industry guidance includes:

- ◆ Factory Mutual Insurance Company's Property Loss Prevention Data Sheet, *Spacing of Facilities in Outdoor Chemical Plants* (2000).
- ◆ Industrial Risk Insurers' IRInformation guideline, *Oil and Chemical Plant Layout and Spacing* (2000).
- ◆ CCPS's *Guidelines for Evaluating Process Plant Buildings for External Explosions and Fires* (1996).
- ◆ American Petroleum Institute's (API) *Management of Hazards Associated With Location of Process Plant Buildings* (1995).

The spacing distances provided in these guidelines demonstrate the value of using physical separation to protect buildings located near hazardous processes.

4.3 Local Planning and Zoning Authorities

CSI considered two locations near Allentown, Pennsylvania, for the HA production facility. There are two

Hanover Townships in this area, one in Northampton County and the other in Lehigh County.

CSI first considered a site in Hanover Township, Northampton County, the site referenced in the Ashland process review (Section 4.1). This township's zoning ordinance included regulations for applying to the planned industrial/business park district, which did not permit the siting of a manufacturing facility "whose primary uses involve chemical manufacturing or . . . hazardous chemicals or materials" without conditional approval. CSI was notified on March 30, 1998, that the zoning officer could not issue a building permit or a certificate of occupancy.

CSI then identified the site on Roble Road in Hanover Township, Lehigh County. Hanover Township granted CSI a certificate of occupancy for this site on September 16, 1998. According to a township representative, the zoning ordinance did not prohibit chemical manufacturing facilities in Lehigh Valley Industrial Park in July 1998. Hanover Township issued a zoning permit to Lehigh Realty Associates, owner of the building, on September 18, 1998.

CSI provided the local township with MSDSs for raw materials and finished products, but did not alert it to the process hazards associated with HA production.

4.4 Local Emergency Planning Committees

As a result of the Federal Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA; 42 U.S.C. § 11011-11050), Local Emergency Planning Committees (LEPCs) were established across the country, most commonly as county-level organizations. Their responsibilities included the review or development of local emergency plans for responding to hazardous chemical releases, and the collection and dissemination of chemical information to the public.

In 1990, Pennsylvania implemented EPCRA by promulgating Act 165, known as the Hazardous Materials Emergency Planning and Response Act (35 Pa. Stat. Ann. § 6022.101-6022.307). It established a system of fees and grants to support LEPCs in meeting the requirements of EPCRA. Each of Pennsylvania's 67 counties is designated as a Local Emergency Planning District, and each is required to have a planning committee.

Pennsylvania LEPC responsibilities are essentially those established by EPCRA, with additional specific requirements under Act 165. One of these requirements is promulgated in Section 203(g)(5), which describes one of the duties of an LEPC as follows:

Meet, when appropriate, with any Commonwealth agency or

local or regional agency, which is empowered to exercise the governmental functions of planning and zoning, to regulate land use and land use development, or to authorize the siting of a facility within the county to discuss and review with the Commonwealth agency and local agency all mitigation factors necessary to protect the health, safety and welfare of the general public from a potential release of hazardous materials from a proposed facility. Mitigation factors include, but are not limited to, environmental impacts, shelter and evacuation feasibility, emergency warning and communications, availability of response equipment and future population and economic growth in the area of the proposed facility.

Act 165 allowed the Lehigh County LEPC to become engaged in the facility siting process prior to the issuance of an occupancy permit for the industrial park location. However, the LEPC was not notified of the CSI siting issue. Prior to and as of this writing, no planning or zoning authority has notified the Lehigh County LEPC of any new chemical facility development within the county.

Act 165 allowed the Lehigh County LEPC to become engaged in the facility siting process prior to the issuance of an occupancy permit for the industrial park location. However, the LEPC was not notified of the CSI siting issue.

CSI's process safety management systems were insufficient to properly address the hazards inherent in its HA manufacturing process . . .

Government agencies, local officials, suppliers, and customers share a responsibility for reducing the likelihood and serious consequences of [similar] incidents . . .

5.0 Conclusion

The following factors contributed to the cause and serious consequences of the CSI incident:

- ◆ CSI's process safety management systems were insufficient to properly address the hazards inherent in its HA manufacturing process and to determine whether these hazards presented substantial risks.
- ◆ Inadequate collection and analysis of process safety information contributed to CSI's failure to recognize specific explosion hazards.
- ◆ Basic process safety and chemical engineering practices—such as process design reviews, hazard analyses, corrective actions, and reviews by appropriate technical experts—were not adequately implemented.
- ◆ The existing system of siting approval by local authorities allowed a highly hazardous

facility to be inappropriately located in a light industrial park.

The hazards and complexity of CSI's HA production process required careful and comprehensive application of current engineering codes, guidelines, and good practices. Based on many years of research and experience, these tools are well established and represent the fundamental principles of chemical engineering design.

Manufacturers should take the necessary actions to minimize hazards and implement appropriate safeguards while developing HA production capabilities. Government agencies, local officials, suppliers, and customers share a responsibility for reducing the likelihood and serious consequences of incidents similar to that which occurred at CSI.

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