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Refrigerating Engineers & Technicians Association

ONE MAN'S DEATH... AN INVESTIGATIVE REPORT

Reprinted from the July 1990 issue of the RETA Technical Report. The article follows the investigation of a fatal accident involving the explosion of an ice cream maker. The details surrounding this accident are still timely and important and worthy of re-examining.

The reports in this paper were filed by the local fire department, state police and district engineering inspector. These reports appear as they were originally written, with minor editorial revisions. Although there are technical inaccuracies and inconsistencies among the reports, the conclusions about the cause of the accident are correct. The technical inaccuracies are due to a lack of experience, not ability.

The names of the persons involved have been deleted to protect their identities.

THE LOCAL FIRE DEPARTMENT'S INVESTIGATION OF THE INCIDENT INDICATED THE FOLLOWING:

The ice cream maker, circa 1955, Model 11, serial number 1323-311, involved in the explosion developed a leak in the drain valve attached to the oil trap (accumulator). The leak caused anhydrous ammonia to be discarded into the air while the machine was in operation. The machine was used most recently to manufacture ice cream about one week prior to the accident.

On the date of the incident, the plant manager set out to repair the leaky valve by replacing it or attaching another valve to the malfunctioning one.

After the explosion, the liquid valve (liquid ammonia into the freezer), the suction valve (gaseous ammonia return line) and the oil trap drain valve were all found in the closed position. These valves had been closed the morning of the explosion to isolate the machine from the plant refrigeration system, preventing additional anhydrous ammonia from entering the machine.

When the explosion occurred, the plant manager was located to the left side of the freezer, in the area where the force of the blast was directed.

According to employees in the room at the time of the blast, the plant manger had begun draining anhydrous ammonia from the machine into a white plastic pail filled with water – the normal procedure to purge the vessel of ammonia. It was reported that the odor of ammonia was quite strong and irritating during this procedure. A portable rubber hose line was located under the machine, flowing steam gently into the atmosphere.

The anhydrous ammonia contained in the vessel turned from a liquid to a gas from the temperature change of the machine reaching equilibrium at room temperature or higher with the heat of the steam line. This increase

continued on page 2

RETA EDUCATION • EFFICIENCY • DEVELOPMENT

THE TECHNICAL Report

July 2006

continued from page 1

in temperature significantly boosted the pressure in the vessel, leading to an over-pressure rupture. There was no pressure relief valve on the machine, and it appears that the pressure gauge was not operating.

When the over-pressure rupture occurred, the rapid release of anhydrous ammonia gas combined with a small quantity of oil contained in the system caused a flash fire with a simultaneous combustion explosion. The ignition source is believed to have been from electrical arcing caused by mechanical damage to the cables operating the electric motor and freezer controls. Another possible source of ignition, although remote, may have been frictional heat from the metal tearing during the actual rupture of the vessel.

The over-pressure rupture and the combustion explosion caused extensive damage to the plant, possibly as high as $250,000. The plant manger was killed and two other employees in the room were injured. Mechanical systems were destroyed in and around the blast area. In the front offices, ceiling tiles were disturbed, a clock was knocked off the wall (stopped at the time of the blast) and witnesses outside reported the ground shaking and the doors of the plant flying open. Shrapnel from the machine damaged a truss and the underside of the steel roof decking.

Department of Public Safety — State Police Report

The state police responded to the scene of the fatal explosion. An employee was working on an ice cream machine in the processing area when that machine exploded, releasing ammonia into the air. A physician pronounced the victim dead at the scene and his body was still inside the building when the police arrived.

Once the police arrived, the scene was secured and the fire department (which arrived earlier) was using fans to ventilate the building in an attempt to remove the ammonia. The fire chief provided the background information regarding the explosion and the police spoke with the owners of the business. They reported that the blast knocked out ceiling tiles in the front office, jarred clocks from the wall and blew the front doors open. The fire chief said one worker was transported to the hospital with burns on his face and two firemen were also taken to the hospital after becoming overcome by ammonia fumes. One hour after the blast, the ammonia fumes were still too great to enter the building without a breathing device. Outside the building, officers felt a burning of the eyes and tightness in the chest from the ammonia. It also caused a metallic taste in their mouths.

According to one of the owners of the business, the victim was a longtime employee. He was supposed to be changing a valve with a slight ammonia leak on an ice cream maker. The injured worker was walking by the machine area when the explosion occurred. Another worker was said to be walking by the processing room in the front hall when the blast threw him back and told of a cloud coming toward him. He said the victim had been bleeding the machine all morning and the smell of ammonia was very evident. He claimed the victim bled the machine all the time.

The police chief spoke with two workers who were on the scene. When asked what could have caused the explosion, one of the service people stated that a spark from wiring could have caused a flash and an explosion if ammonia was in the air. He said the victim had experience using the system. When asked to

continued on page 3

continued from page 2

explain how to work on the machine safely, the worker said to shut off the valve at the ammonia inlet pipe, leave the valve open at the outlet pipe until all the ammonia was drawn from the machine, then turn the valve off, leaving no ammonia in the machine.

The police entered the accident scene to remove the victim. He was lying on his back to the left of the machine, which was knocked over onto its right side. The box of tools was found beside him and he sustained a severe head injury. The machine had exploded and ruptured a chamber made with 3/8-inch steel. That chamber contained the ammonia used to freeze the ice cream. The explosion blew a hole through the left side of the machine and the top. There was a hole in the ceiling above the machine, approximately 10 feet by 5 feet. There was a small area of black charring on the ceiling indicating some type of fire.

A serviceman inspected the valves on the machine and reported that all the valves were shut off. He said if there was still some ammonia in the machine, then pressure could have built up, causing the explosion. Another serviceman also inspected the scene. He said the leaky valve was located on the right side of the machine and that the valve was closed. He said the valve is used to bleed oil from the machine. He checked and found no relief valve on the machine. The state inspector of refrigeration also inspected the machine and found the same facts. The machine was approximately 30 years old.

The fire department did not shut off the inlet or outlet valve on the machine or bleed the valve. The fire chief found a steam and hot water hose coming from the connection on the wall, which was steaming underneath the machine. One of the servicemen stated he had previously seen steam used on the machine to melt the ice build up around the valves and to heat the oil in the machine to make it drain easier.

A meeting to find the cause of the explosion was held with the police and fire chiefs, and a local refrigeration expert. They concluded that ammonia was trapped in the machine when all the valves were shut off. The steam hose was used somehow during the work on the machine, causing a pressure build up. The bleed valve was closed and there was no relief valve on the machine. These factors caused a pressure build up which resulted in an over pressurization explosion. A flash fire occurred when the ammonia and oil mix was ignited by arcing from the electrical connection when the machine blew up, or by friction ignition caused by the explosion. One of the injured workers remembers seeing a flash of orange during the explosion. The victim was found on the opposite side of the valve he was working on, in the area of the steam shut-off. It is possible that the victim was going to shut off the steam when the explosion occurred. Because the victim is deceased, we cannot say exactly what happened, but the facts show that the victim used steam on the machine which caused the over pressurization explosion and flash fire.

District Engineering Inspector's Report

I went to the scene of the accident and spoke with the owners, the fire chief, the state fire marshal investigator, an OSHA inspector and serviceman from a refrigeration company. We discussed the accident in general, disbursed, and then met again at the fire department headquarters to further discuss our findings.

Afterwards, I returned to the accident scene and spoke with one of the owners and an insurance company engineer. I also met the fire chief at his office and we further discussed the events of the explosion.

The ice cream machine that exploded was built in 1950 and purchased by the company in 1952 from another ice cream maker going out of business.

The machine was 6 feet high, 30 feet wide and 4 feet long, with a dome-shaped top. It was covered with a light gauge stainless steel at both ends. The total volume of the ammonia system in the machine was about five cubic feet. Ammonia was fed and exhausted from the machine through overhead lines approximately 10 feet off the floor. Supply and return lines were valved off within one foot of these overhead lines, which originated from an adjacent machinery room, the doorway of which was about 120 feet away.

The machine had not been used for about a week, but the oil drain valve

continued on page 4

ONE MAN'S DEATH

continued from page 3

on the bottom of the evaporator had been leaking sufficiently to cause an ammonia smell surrounding the machine. A decision was made to replace it.

At approximately 9:30 a.m., the victim began working on the machine. Prior to the explosion, the victim and the injured worker stepped out of the production room (site of the explosion), then returned. Upon returning to the accident site, the victim went to the left of the machine when the explosion occurred. The injured worker was about 20 feet away from the freezer when it exploded.

When fire the department arrived, the injured employee was removed from the scene and the ammonia fumes were dissipated. The fire chief observed a black rubber hose which was connected to a low-pressure steam line (approximately 5 PSI). The hose was issuing steam under the machine, which was lying on its side due to the violent explosion. The fire department noted that the overhead ammonia valve to and from the machine was in the closed position. The machine was completely isolated and the ammonia system was not protected by a safety valve or any type of relief mechanism. The pressure gauge had no glass or indicator point on it. The numbers on the face were so badly corroded that it was extremely difficult to read.

The accident occurred when steam was directed on or underneath the machine. We do not know whether it was used to melt ice on the drain valve or to help evacuate the system. The victim's action could have been intentional or accidental. The temperature of the ammonia was raised, which also leads to a pressure increase. Without a safety valve, the pressure in the system kept climbing until it finally exceeded the bursting point of the ammonia vessel resulting in a violent explosion and killing the victim.

COMMENTARY BY JIM MARRELLA

Hydrostatic expansion or thermal expansion of a liquid was responsible for the victim's death. Hydrostatic expansion occurs when a liquid, in this case ammonia, completely fills or almost fills an enclosed volume. Trapped with no space for normal expansion caused by temperature variations, pressure can greatly exceed those on refrigerant pressure/temperature charts, which are most familiar. Just a few degrees change in temperature will result in hundreds or even thousands of pounds of pressure change.

It is the purpose of this article to bring to the forefront hydrostatic expansion, in the hopes that education and awareness can prevent these disasters in the future.

Because hydrostatic expansion is capable of such extreme pressures, safety measures should be taken to prevent its occurrence. For more information about this subject and its prevention, the following material is strongly recommended: *Engine Room Safety* (published by RETA); *Avoiding Component Failure in Industrial Refrigeration Systems Caused by Abnormal Pressure or Shock, Bulletin No. 109 and IIAR Minimum Safety Criteria for a Safe Ammonia Refrigeration System* (published by IIAR); and *ANSI/ASHRAE 15-1989, Safety Code for Mechanical Refrigeration* (published by ASHRAE).

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Editor
Rob Greer
Kemper Refrigeration
209.339.0234
rob@kemperrefrigeration.com

Staff
Don Tragethon • don@reta.com
Jan Tragethon • jan@reta.com
Scott Henderson • scott@reta.com
Susan Brown • susan@reta.com
Julie Mower-Payne • julie@reta.com

Refrigerating Engineers & Technicians Association
PO Box 1819
Salinas, CA 93902
Tel: 831.455.8783 Fax: 831.455.7856
www.RETA.com