TECHNICAL SAFETY BC

INVESTIGATION REPORT

AMMONIA RELEASE

ARCTIC GLACIER - KAMLOOPS
DATE OF INCIDENT: MAY 26, 2022

Safe technical systems. Everywhere.

Technical Safety BC is an independent, self-funded organization that oversees the safe installation and operation of technical systems and equipment. In addition to issuing permits, licences and certificates, we work with industry to reduce safety risks through assessment, education and outreach, enforcement, and research.

TECHNICAL SAFETY BC

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Technical Safety BC incident investigation jurisdiction and role

Technical Safety BC administers the *Safety Standards Act ("Act")* on behalf of the Province of British Columbia[1]. The *Act* and associated *Regulations* apply to the following products, operations and work associated with these products:

(i) amusement devices;
(ii) passenger ropeways;
(iii) boilers and boiler systems;
(iv) electrical equipment;
(v) elevating devices and passenger conveyors;
(vi) gas systems and equipment;
(vii) pressure vessels;
(viii) pressure piping;
(ix) refrigeration systems and equipment; and
(x) any other regulated product specified in the regulations.

The *Act* and Power Engineers, Boiler, Pressure Vessel and Refrigeration Safety Regulation (*"Regulation"*) applies to pressure vessels, pressure piping systems, fittings, refrigeration equipment and refrigeration plants in BC within the identified scope of the *Act* and *Regulation*. The refrigeration system, associated work, and management of the refrigeration equipment at the Arctic Glacier Facility near Kamloops are subject to the *Act* and *Regulation* and some specific sections relevant to the incident are described in Appendix A - Safety Standards Act, regulations and codes.

Incidents involving products or work subject to the *Act* are required to be reported in accordance with Section 36 of the *Act*. Technical Safety BC investigates these incidents in accordance with Section 37 of the *Act* and may appoint persons to assist with an investigation.

The role of Technical Safety BC with respect to the investigation of incidents is to understand relationships between incidents, equipment, and work that are subject to the *Act*. It is our aim to learn from these investigations and to use these findings to prevent future incidents. Often, these investigations are conducted in cooperation with other agencies including fire departments, WorkSafeBC, law enforcement officials, and the Coroners Service.

This investigation report is issued by a provincial safety manager and published in accordance with the *Act*. This report does not address issues of enforcement action taken under the *Act*. Any regulatory enforcement or compliance activities arising from this incident will be documented separately.

[1] Some municipalities administer portions of the Safety Standards Act. Visit www.technicalsafetybc.ca for details.

Summary

Incident

On May 26, 2022, a crew was in the process of cutting up and disassembling two ammonia refrigeration systems (referred to as P24 and P34 in this report) at an Arctic Glacier Inc. (Arctic Glacier) ice distribution facility located in the Mount Paul Industrial Park located on Tk̓emlúps te Secwépemc reserve in Kamloops, British Columbia. Those present understood that ammonia had been previously removed from both systems. During the removal of a section of the P34 system containing the receiver and compressor, it was identified that a valve handle protruded past the frame and could cause issues with the rigging process.

Options to deal with the protruding part, such as turning it, were being discussed and one of the individuals turned the valve handle, resulting in a large release of ammonia. The individual who turned the handle was sprayed by the ammonia and moved further into the building. The remaining members of the crew evacuated through a nearby open bay door. The individual who opened the valve was extracted from the building and pronounced dead following the incident. In addition to the fatality, there were multiple ammonia exposures, a local evacuation, an extended business shutdown, and an environmental response to the release.

Investigation

Technical Safety BC investigated the circumstances that led to the release in order to inform the prevention of similar incidents in the future. Although the action of opening the valve released the ammonia, this action was only conducted under the premise that the vessel it connected to was empty. Consequently, the investigation sought to understand why ammonia was still present during disassembly and if the refrigeration equipment may have contributed to the event. The period of focus for the investigation included the entire shut-down and disassembly process which began in 2015 up until the large ammonia release on May 26, 2022, including personnel and equipment changes during that time.

Cause

The safe dismantling of an ammonia system requires that the system be assessed, and ammonia and oil be removed prior to any disassembly work. Removal of ammonia and oil from a refrigeration system is regulated work that requires the knowledge and skills that a licensed contractor brings with qualified refrigeration mechanics.

The investigation found that the failure to remove ammonia from the refrigeration system, prior to, or during disassembly was the primary cause of the incident.

The contributing factors to the ammonia not being removed were:

1) An incorrect understanding that ammonia had been removed during the shut-down of the system. This understanding was influenced by:

    a. Changes in personnel and their assigned responsibilities.

    b. Misunderstood communications regarding the work completed.

2) Ineffective assessments to identify hazardous quantities of ammonia in the receivers. These assessments were affected by:

    a. The exclusion of a qualified refrigeration mechanic from a dedicated role during the disassembly.

    b. An irregular configuration of the equipment, which created the appearance the P34 system was empty.

Additional considerations

Equipment considerations

The investigation found that there was no physical failure of any ammonia system or component.

In addition, the investigation sought to understand aspects of the equipment that increased the risk of an incident as the system was disassembled. Two aspects of the equipment that increased the risk during disassembly were:

1. At some point, the P34 system was altered by Refrigeration Mechanic A to include a quarter turn ball valve that operates in a binary manner (on-off). When that same valve was opened, the ammonia release was rapid and uncontrolled.

2. The P34 receiver's dedicated pressure relief valve was likely removed during an earlier modification to the system. When the ammonia was later isolated within the receiver (pumped down), the receiver was in a hazardous state which could have resulted in an over pressurization failure at any point after the ammonia was isolated in the receiver in 2016.

Environmental considerations

The investigation sought to understand the amount of ammonia that was present during the event. This finding provides the basis for how much ammonia was likely discharged into the environment during two separate releases. The environmental impact of these releases is outside of the scope of this investigation.

Between May 25, and May 26, 2022, up to 1000 lbs of ammonia was dissolved into water and released directly into the facility parking lot during a 16.5 hour purging operation of the P24 system.

During the fatal incident on May 26, 2022, between 1345 lbs and 1600 lbs of ammonia was released as a vapour directly into the atmosphere from the P34 system.

Post-release considerations

The ammonia released from the P34 system was partially contained within the building and contacted a source of ignition which resulted in an explosion and damage to the facility. As a result of the understanding that no ammonia was present in the facility, the emergency ventilation system was non-functional.

The investigation found that, given the magnitude of the release, a properly functioning ventilation system would not have prevented ammonia concentrations from reaching explosive limits; however, it likely would have lessened the amount of time that the ammonia concentration was combustible and therefore reduced the risk of explosion.

Scope of investigation

The content and findings in this report are based upon the evidence presented and available at the time of Technical Safety BC's investigation, conducted between May and November 2022. The investigation sought to understand both causal and contributing factors that led to the ammonia release for the purpose of informing and preventing these types of incidents in the future.

The investigation included the gathering and analysis of information from the following sources:

Engineering and analysis

- Lab testing
- Ammonia quantity calculations
- System sizing
- Post-release ventilation and explosion
- Acts, regulations, and codes
- Equipment manufacturer documentation

Site evidence

- Photo documentation and site measurements
- CCTV footage
- Scene and equipment diagrams
- Equipment testing

Interview and administrative evidence

- Correspondence
- Invoices and contracts
- Worker and management interviews
- Witness and first responder information

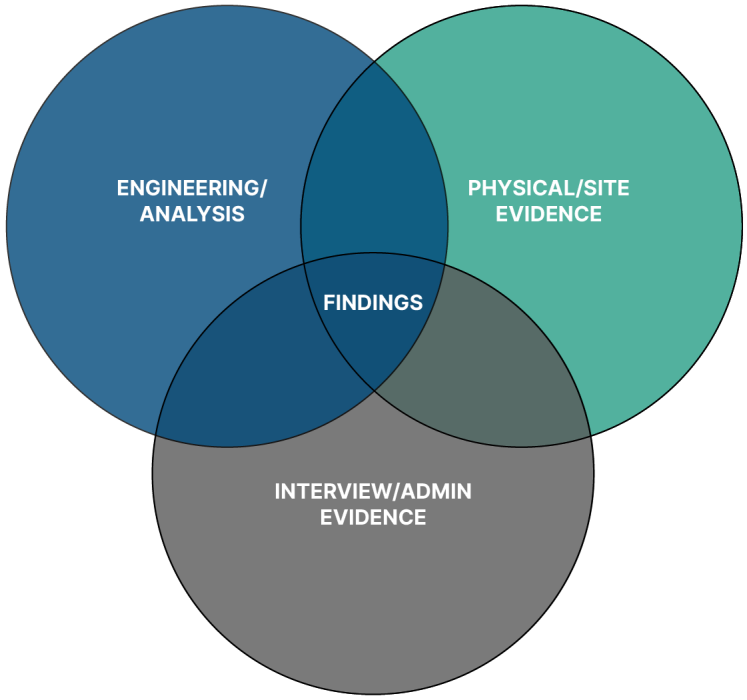


Diagram #1: *Areas of Investigation which contributed to findings.*

Facility and equipment description

Prior to 2016, the Arctic Glacier Kamloops Facility was used for ice production. The facility was a small industrial building with several additions and various equipment used for the production and distribution of ice to retailers. The general layout of the facility is in Diagram #2 shown below:

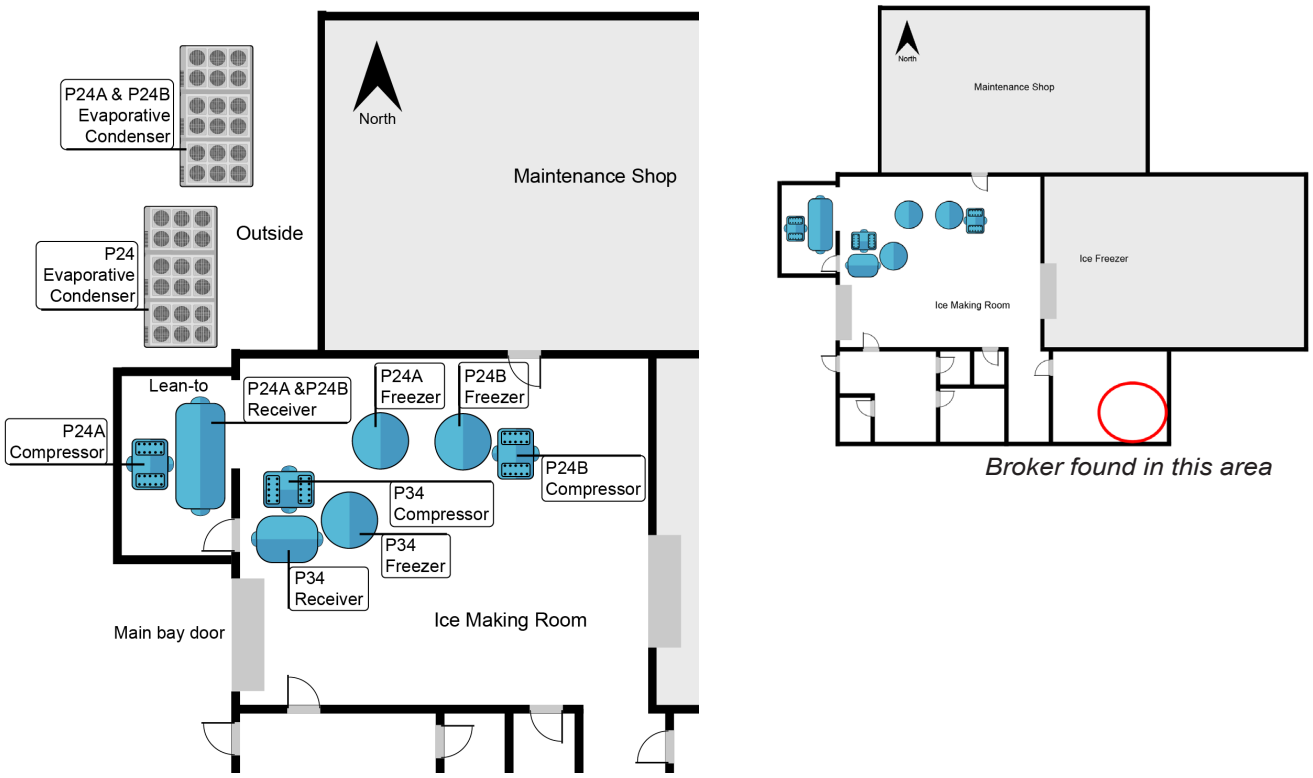


Diagram #2: *Plant layout during ice production*

Ice was produced at the facility by two separate ammonia refrigeration systems referred to as the P24 and the P34 systems. Each system utilized the five standard components of a refrigeration system: a compressor, a condenser, a receiver, an expansion valve, and an evaporator (i.e., freezer/icemaker). Ammonia is circulated through the system and undergoes a change of state from liquid to vapour (evaporator) and then back from vapour to liquid (condenser). Evaporation and condensation facilitate heat transfer needed for refrigeration. During operation, the receiver contains a large amount of liquid ammonia for the process and is also used to store the full system charge of liquid ammonia during shut-down or pumped-down configurations.

The P34 and P24 systems were similar with the exception that the P24 system was comprised of two separate freezer loops that shared a single condenser and receiver. Both systems were modified from the original equipment manufacturer configuration. Simplified diagrams of both system loops are shown below, and a detailed description of each system is provided in Appendix B - Site and equipment:

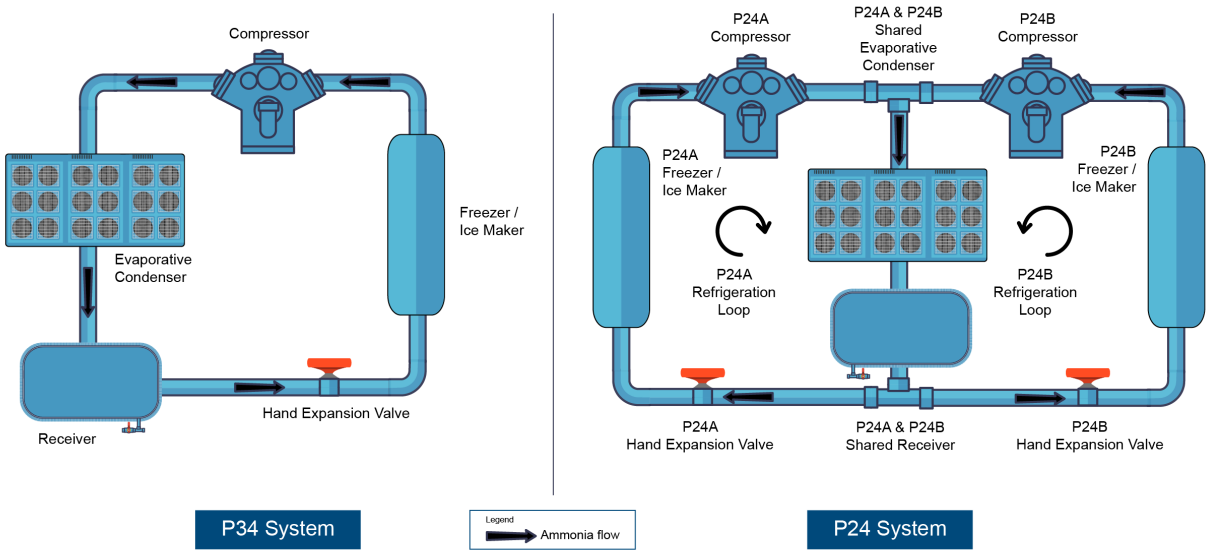


Diagram #3: *Simplified diagrams of the P34 (left) and P24 (right) systems. Note: Piping is not representative of the exact configuration and is for illustration purposes only. Refer to Appendix B for specific system configurations.*

Facility management

Since Arctic Glacier acquired the facility in 2014, the facility had both a Plant Manager and Distribution Manager reporting to an Area Vice President with responsibility for several facilities in the western Canada area. The Plant Manager was responsible for the production of ice, including operation and maintenance of the ammonia equipment and management of refrigeration contractors. The Distribution Manager was responsible for the network of ice distribution, including the trucks, drivers, and customers. During the operating period, the plant frequently retained the services of a licensed refrigeration contractor (Refrigeration Mechanic A) to perform maintenance work on the equipment. A more detailed description of roles and responsibilities can be found in Appendix C – Roles.

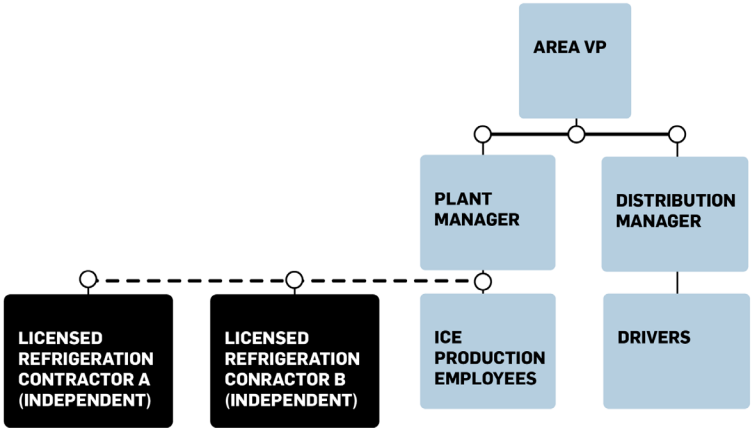


Figure 1: *Arctic Glacier Reporting Structure*

Skills and qualifications

Under the Safety Standards Act there are various licences and certificates of qualification recognized that relate to refrigeration systems. Regulated refrigeration work is reserved for businesses and individuals with these credentials to assure it is completed with the necessary skill and obligation. These include licensed refrigeration contractor, refrigeration mechanic, refrigeration operator and refrigeration safety awareness certificate.

From 2016 to 2022 there were several people who contributed to decisions around the disassembly of the two systems or had direct responsibilities for the ammonia equipment. It's important to understand the qualifications of each in relation to ammonia systems:

The Area Vice President:
No certificates of qualification relating to refrigeration systems in BC.

The Distribution Manager:
No certificates of qualification relating to refrigeration systems in BC.

The Plant Manager:
No certificates of qualification relating to refrigeration systems in BC. Was responsible for plant operations and maintenance and worked with licensed refrigeration contractors for those items.

Refrigeration Mechanic A:
Refrigeration Mechanic A operated as a licensed refrigeration contractor in the province of BC until his retirement in 2016.

Refrigeration Mechanic B:
Refrigeration Mechanic B operated as a licensed refrigeration contractor in the province of BC.

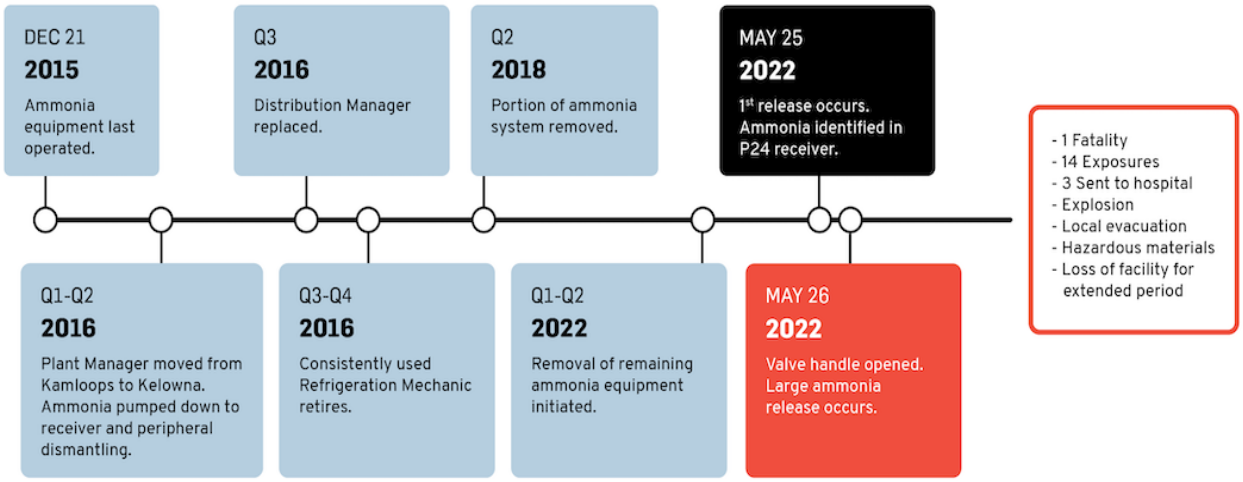
The Buyer*:
No certificates of qualification relating to refrigeration systems in BC. The Buyer reported that he had worked as a refrigeration mechanic and had previously been licensed in the United States for many years. He had the skills and knowledge necessary to work on refrigeration systems however was not authorized to do this work in BC.

The Broker*:
No certificates of qualification relating to refrigeration systems in BC. According to a co-worker, and family member, the Broker had 35 years of experience working on the disassembly of ammonia systems. That same individual stated that in all cases, they worked on systems after the ammonia had been removed. The Broker reportedly did not hold any formal certifications for the handling of ammonia or associated equipment.

* Technical Safety BC's use of the descriptive terms "the Buyer" and "the Broker" for these persons best represents our understanding of their overall relationship to the refrigeration equipment at the time of the incident. "The Broker" had expressed intent to take possession of the refrigeration equipment from Arctic Glacier and had expressed intent to transfer this equipment to "the Buyer", but there is no evidence that Arctic Glacier had requested that the Broker sell or resell the equipment on its behalf. "The Buyer" had expressed intent to evaluate the equipment that he would eventually be purchasing and taking possession. While different agreements existed between the parties involved, Technical Safety BC's use of these terms does not imply a contractual arrangement between these three parties existed.

Relevant timeline of events

In late 2015 and early 2016, a business decision was made to move ice production to a facility in Kelowna and use the Kamloops facility for ice storage, distribution, and refurbishment of commercial ice coolers. Equipment shutdown occurred in late 2015. Afterwards, there was an extended disassembly process that occurred from 2016 to 2022. During this extended period several changes to equipment and personnel were made that contributed to the incident.



2016 - Equipment shutdown and start of disassembly

In 2016 the ammonia systems at the Kamloops facility were shut down, but the ammonia was not removed from the systems. Refrigeration Mechanic A, who shut the systems down, stated he did not remove the ammonia. The Distribution Manager that was present at the site in 2016 stated during a post-incident interview that he recalled that ammonia remained in the system when he was last there in 2016. However, the Plant Manager and Area Vice President, who were not on site, stated they believed that the ammonia was removed. The misunderstanding about the removal of ammonia persisted until the fatal incident and was likely contributed to by a division of responsibilities, a change in personnel, and the terminology used by those involved.

When production was stopped the Plant Manager was relocated to Kelowna. The Area Vice President assigned a shared responsibility for the ammonia equipment to the Plant Manager, and the Distribution Manager. Refrigeration Mechanic A continued with the shutdown of the ammonia systems and disassembly of the ice bagging equipment. Each of the managers described their role in overseeing the work of Refrigeration Mechanic A as illustrated below:

Area Vice President: *"Overall, between [Distribution Manager] and [Plant Manager], this [management of the refrigeration equipment] was a shared responsibility."*

Plant Manager:
"When it was dismantled/ decommissioned, however you want to phrase it, I wasn't present on site, I wasn't directly overseeing that. . . So, the manager that was responsible for that plant when I was in Kelowna, was [Distribution Manager]."

Distribution Manager:
"I don't think they did anything with the ammonia, the equipment was just sitting there."

Question:
"Did you contract [Refrigeration Mechanic A] to remove Ammonia?"

Answer:
"No."

The Distribution Manager and Refrigeration Mechanic A stated that ammonia had not been removed. Invoices from Refrigeration Mechanic A from that time stated that the system was "pumped down" to the receivers but that ammonia "still had to be moved" (Appendix D – Invoices, Quotes and Scope of Work). In a follow-up interview, Refrigeration Mechanic A stated that ammonia had not been removed. Similarly, the Distribution Manager stated he had not contracted the refrigeration mechanic to remove the ammonia, and he believed it was still in the system at that time.

In contrast, the Plant Manager, who relocated to Kelowna, stated that he believed the ammonia had been removed from the system and this would have been based upon verbal communications he had at the time with the Distribution Manager who was present at the Kamloops site.

Terminology from documents describing the work at the time provide insight into the conversations that likely occurred around the time of the equipment shutdown. One invoice from Refrigeration Mechanic A stated that there were 4 hours spent "dismantling" ice machines. The invoice was not clear as to what was dismantled; however, from an interview with Refrigeration Mechanic A, it was for work done dismantling bagging equipment components that were not part of the ammonia systems. In addition, the local fire department received a call out around the same time as the equipment shut-down due to an ammonia smell in the area. The call out notes stated that they were told the system was being "decommissioned" and that they were "venting residual ammonia" (Appendix E – Fire Department Call Out Notes (2016)). The below excerpt from an internal Arctic Glacier e-mail showed that work was characterized as ammonia

removal by the Distribution Manager following a discussion with Refrigeration Mechanic A about outstanding invoices:

> *"738474 – repairs to facility freezer and NH3 [ammonia] removal*
> *738459 – NH3 removal and blow down of P24's and P34's"*

After the equipment shutdown, Refrigeration Mechanic A retired, and the Distribution Manager left Arctic Glacier. The knowledge that ammonia remained in the system was not transferred to the remaining managers.

As disassembly progressed, the Distribution Manager and Refrigeration Mechanic A, who understood the systems still contained ammonia were no longer engaged with the facility. The managers remaining expressed during interviews that they believed ammonia had been removed; however, there was no purpose to further disassemble the ammonia system, so it remained intact.

2018 - Part of ammonia system removed

In 2018, Arctic Glacier continued to organize the disassembly. They solicited a quote from a second refrigeration mechanic (Refrigeration Mechanic B) for the removal of the system, but only went ahead with the removal of a small section of the P34 system, the evaporative condenser. Refrigeration Mechanic B stated that no ammonia was found during the removal. The Plant Manager and Area Vice President stated this reinforced their belief that ammonia had been previously removed.

The invoice from Refrigeration Mechanic B for the removal of the evaporative condenser did not include any hours for the removal of ammonia (Appendix D – Invoices, quotes and scope of work). In a follow-up interview, Refrigeration Mechanic B indicated that no ammonia was found in the system. It was unclear whether he had checked the entire system, or only the portion he was directed to remove.

The Plant Manager and Area Vice President indicated that the successful removal of the evaporative condenser in 2018 was a ***"check point"*** for them in confirming that ammonia had been previously removed from the system.

Refrigeration Mechanic B's scope was limited to the removal of a small section; and he indicated that he did not remember whether the entire system was assessed. However, he confirmed that the section he was working on, was safe to remove by following his standard practice which would have included checking with his own gauges consistent with industry practice. (Appendix F - Industry practice and awareness study). The International Institute of Ammonia Refrigeration (IIAR) standard 8 is not adopted within British Columbia but provides useful guidance for the safe dismantling of ammonia systems. It is aligned with industry best practice and stated ***"5.2.3.5 Do not physically disconnect and remove system components until the components have been isolated and residual ammonia and lubrication oil have been drained from the components."*** During the removal of the condenser, no ammonia was found and the Plant Manager and Area Vice President continued to operate under the understanding that ammonia had been previously removed from the entire system.

2022 - Initiation of final ammonia systems removal

In 2022, planning began for the removal of the remaining ammonia equipment. The belief that ammonia had previously been removed, coupled with cost considerations, contributed to the exclusion of a qualified refrigeration mechanic with a dedicated role in the ongoing disassembly work.

When this additional removal was being planned, the ammonia systems were still believed to be empty. Arctic Glacier selected a Broker who had experience disassembling ammonia systems. According to a co-worker of the Broker, that experience was limited to systems where the ammonia was already removed. The Broker's name was provided by Arctic Glacier's director, corporate manufacturing, who had used the Broker's services in the United States for the disassembly of a plant. The Broker's arrangement was to do the removal at no cost in exchange for the equipment itself, which he would later sell to a Buyer operating out of the United States (The Buyer). The Buyer previously operated as a licensed refrigeration contractor in the United States and worked to refurbish the equipment to install in other countries.

According to a representative from the Broker's company, who's role was to coordinate administrative functions the Broker had 35 years of experience disassembling ammonia systems. However, in all cases the ammonia was previously removed. The representative stated ***"Again, every time we started a job, it was never our responsibility to pump [ammonia] out. Never. Not once was it part of [The Broker's] responsibility. . . It's just not something we touched."*** The representative from the Broker's company clarified that they were not aware of any certifications held by the Broker for the handling of ammonia. The Buyer was also asked if the Broker had any certifications. The Buyer stated ***"No, to my knowledge no . . .I don't know how much experience he has with ammonia, to be honest with you."***

In an email between Arctic Glacier and the Broker, Arctic Glacier communicated that ***" . . .all vessels evacuated of ammonia"*** (Appendix G - Correspondence). This was reflected in the Broker's scope of removal document: ***"ARCTIC previously removed all ammonia from the ice makers and related refrigeration being removed by [The Broker]"*** (Appendix D – Invoices, quotes and scope of work).

The Broker inspected the equipment in April 2022 and confirmed it was ready for his removal. The Broker was also provided a quote for the labor by Refrigeration Mechanic B supplied through Arctic Glacier. However, based on cost, and the belief ammonia was previously removed, the Broker hired Riggers directly to remove the equipment under his supervision:

"I left a message with [Refrigeration Mechanic B]. After seeing their quote – looks like they want more $$ than I am willing to pay . . ." – Email from Broker to Arctic Glacier

Technical Safety BC concluded that based on the apparent belief that ammonia was removed, and cost, no licensed refrigeration contractor was engaged to validate that ammonia had been removed prior to continuing disassembly. Had a licensed contractor been involved at this stage a qualified refrigeration mechanic would have likely involved an assessment that would have correctly identified the ammonia in the systems (Appendix F - Industry practice and awareness study). On May 24, 2022, the Broker began disassembly work with the help of the Riggers.

Image #1: *The P34 system on May 25, 2022, prior to removal (Photograph taken by the Buyer).*

May 25, 2022 – First incident, ammonia purging and incorrect assessments

Up until May 25, 2022, there was an incorrect understanding that ammonia had previously been removed from both systems. On May 25, an ammonia release incident occurred that led to the identification of the presence of liquid ammonia within the P24 receiver. Following the release, the amount of ammonia in the P24 system was under-assessed to be residual amounts by the Buyer and the Broker. A purging activity was initiated on May 25 to remove ammonia from the P24 receiver. Additionally, the P34 receiver was visually assessed, and incorrectly concluded to not contain ammonia.

The May 25 incident occurred early in the day when one of the Riggers released ammonia while cutting a pipe during the disassembly process of the P24 system. The Rigger stated ***"When I hit it, I got a face full of gas that pretty much . . . took my breath away and it hurt my eyes . . .I physically couldn't breathe and my eyes hurt."***

Following this ammonia release, there were two individuals on site with the knowledge and skills to assess and handle ammonia systems. However, both stated they had not come to the site with the intention of assisting with the disassembly. The Buyer, stated he had come to the site to look at the condition of the vessels he would eventually take possession of. The contact information for Refrigeration Mechanic A (retired) was provided to the Broker by Arctic Glacier (Appendix G - Correspondence) and this retired mechanic stated he chose to attend the site out of curiosity.

> ***". . . but like I said my brain was in a different spot. . . .My only concern was the condition of the [equipment]." – Buyer***

> ***"So, I went over there just to have a look out of curiosity cause I pretty well know the place" – Refrigeration Mechanic A***

The P24 system was assessed and found to have some ammonia. The Buyer characterized this ammonia as being 'residual'. He stated ***"My feeling was there was no more than 30-40 lbs maximum. Probably less. Probably more in the neighbourhood of 10 lbs of ammonia. Just residual that was you know on the bottom of the receiver. Cause there was nothing showing on the glass there was nothing showing on the receiver whatsoever."*** Refrigeration Mechanic A also commented on the contents of the P24 system. He stated ***"when I went over there, the [the Buyer] cracked a pipe, and he had liquid ammonia coming out of it, right out of that receiver. . . you know there is liquid coming out because the pipe frosts."***

During the assessment, the system's pressure and level gauges were used to determine the amount of ammonia in the P24 system. Technical Safety BC's investigation identified that both the pressure and level gauges were behind closed valves and did not provide any indication of ammonia levels in the receiver (Appendix B - Site and equipment).

***"There was nothing showing on the glass . . . and the sight glass, I opened and checked the sight glass, I poured hot water on it. . . you know banged on it to see if it sounded empty."* – Buyer**

***"[The Buyer] took us to that tank, he showed us the gauges, saying its reading zero. He was tapping the tank, and he was like, there is no difference in the noise here, it's got to be empty."* – Rigger**

Following the assessments, the Riggers were convinced that their work could continue once the remaining ammonia was removed from the P24 system. Regarding the decision-making process to start the purging, the Buyer stated ***"there's some refrigerant in there. It's probably just residual that condensed over time but it's in there. I [the Buyer] said what do you want to do? [the Broker] said 'well what would you do?' I said well normally if I'm on a site I will diffuse it just like what you do on a normal plant."*** The Broker agreed and a purging[1] operation was started by the Buyer to remove the ammonia.

***Image #2** - Purge vessel and hoses that were in place prior to the incident. Hoses were connected to a water source and the ammonia receiver (red square) in the side building.*

[1]Purging: In this case, the act of intentionally removing ammonia from a refrigeration system by releasing it through a hose to dissolve into water.

***Figure 2** - Flooded parking lot from the "purging" of the P24 system*

It is likely that the purging operation removed what would have been the entire operating charge of ammonia from the P24 system. A timeline analysis of the water/ammonia mixture released into the parking lot revealed that the purging likely lasted for approximately 16.5 hours before being shut-off so workers could continue disassembling the next day (Appendix H – Ammonia purge timeline). In addition, the Riggers stated that the purging operation was done overnight. An independent engineering report that analyzed the purging operation concluded that a full operating charge of ammonia (up to 1000 lbs) could have been removed based on the provided timeline (Appendix I – Engineering analysis by Laporte Engineering Ltd). A review of documentation and correspondence from the years leading up to the incident found that there was no record of the systems being emptied completely of ammonia The refrigeration mechanics that worked on the system following its shut-down stated that they did not remove the charge of ammonia. Even after the purging occurred Technical Safety BC's investigation found that approximately 100 lbs of liquid ammonia was still present in the P24 system (Appendix J – Complete climate control report).

***Figure 3** - Distinct frost line showing liquid ammonia levels in the P24 system during purging by Technical Safety BC post-incident..*

The P34 system was also visually assessed by the Buyer, Refrigeration Mechanic A, and the Broker following the May 25 incident. Similar to the P24 system, the pressure and level gauges were behind closed valves, and did not reflect the amount of ammonia present within the receiver. In addition, there were cut pipes exiting the receiver that created the appearance the system was empty. Technical Safety BC's investigation included a review of the Vogt ice making system manual, the discharge gas line (the cut pipe being referred to) entered and exited the receiver in a closed loop (Appendix K - Vogt ice making machine manual). A simplified diagram of the receiver at the time it was assessed is shown below:

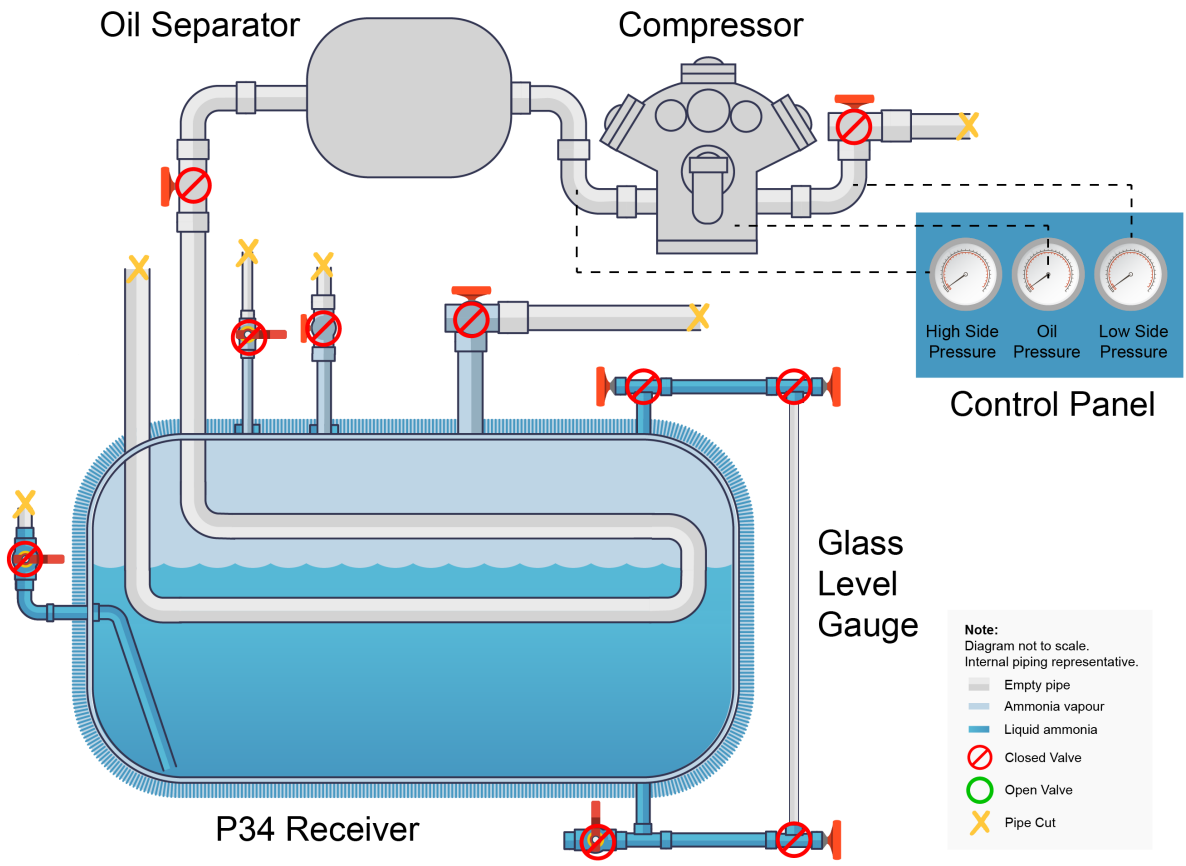


Figure 4 *- The configuration of the P34 Receiver on May 25, 2022*

The assessments done on the receiver in this partially disassembled configuration led to the incorrect conclusion that the P34 system was empty. When asked why Refrigeration Mechanic A thought is was empty, he stated ***"Oh because the pipes were cut open and there was nothing in 'em."*** Similarly, the Buyer stated ***"That vessel . . . that tank was completely, they had already cut all the lines on that. That was completely already isolated from the system."*** The Riggers stated that the assessment had gone one step further and considered the gauges. One Rigger stated ***"before we'd done anything we'd walked around and looked***

at the gauges on all the instrument panels on both P34 and P24. Both had about a 2ft x 2ft panel with 4 gauges on them, all diaphragm style, and all of them read zero. And we did look at that, and it was talked about that they all read zero." The other Rigger stated, ***"After talking to both*** [the Buyer and the Broker] ***that were explaining all these things, all I thought was*** [they] ***know exactly what they're talking about, everything lines up like gauges are telling me they're zero and they're telling me that there's only this little bit which kind of made sense to me. I'm taking the word of two, 35 years experienced in this industry's word for it being done, so we stayed."***

The assessments failed to challenge the previously held understanding that ammonia had been evacuated from the systems. No licensed refrigeration mechanic was hired to correctly assess the amount of ammonia in both systems and remove the identified ammonia from the P24 system. Disassembly work continued on May 26 with the P34 system partially dismantled and the P34 receiver full of ammonia.

May 26, 2022 – Fatal incident and effects of the ammonia release

On May 26, 2022, the P34 receiver was still thought to be empty; despite ammonia being found in the P24 system the day before. Technical Safety BC's investigation included conducting a leak check test of the P34 receiver in this configuration and confirmed that the vessel and piping could have retained ammonia with the ball valve in the closed position (Appendix L - Leak test report). The fatal ammonia release occurred when a ball valve was opened because it was believed that the receiver it was connected to was empty.

On May 26, 2022, the Broker and Riggers returned to site. During the course of disassembly, it was identified that the handle of a valve connected to the P34 receiver was protruding past the skid. This would affect the Riggers' ability to lay it down on its side for removal from the building. As the Broker and Riggers were considering ways to deal with the protruding part, including if they could turn it, the Broker rotated the valve handle upwards (from closed, to open) causing an uncontrolled release of ammonia directed at the Broker's body.

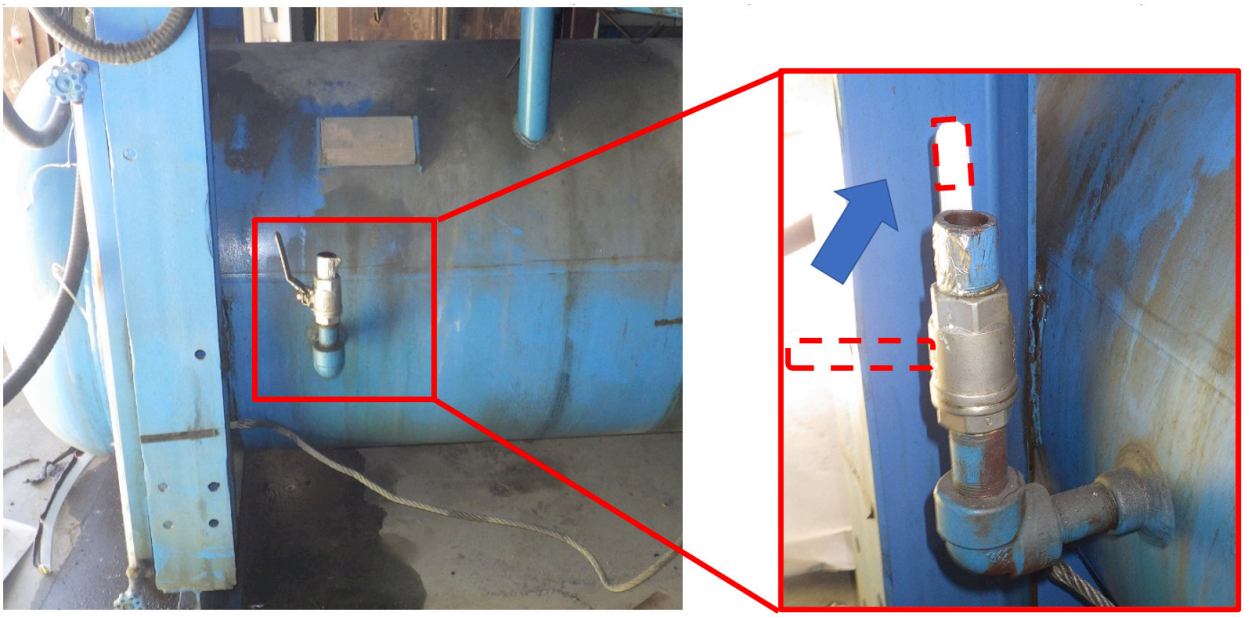


Image #3 *- Ammonia receiver after the incident with the side view of the stainless-steel ball valve in the red rectangle. The valve was found in the open position post incident as shown. The red dashed lines indicate the valve handle position in the closed position. The valve handle would have extended past the steel frame.*

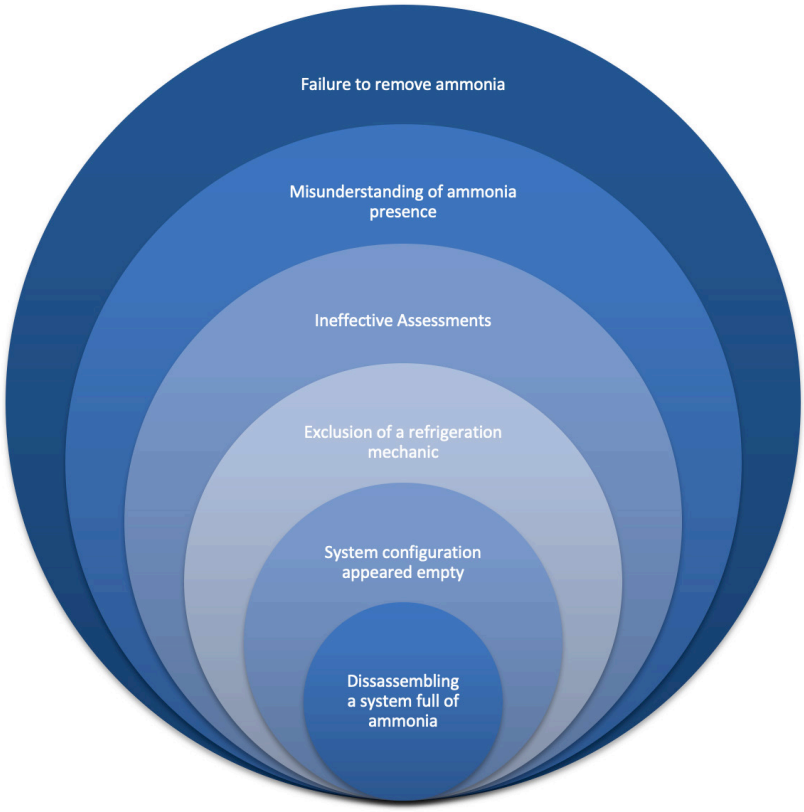
The Riggers were able to evacuate through the front bay door; however, the Broker, having been exposed to ammonia, moved further into the building. A quantity of ammonia was released that created a large cloud that migrated out the bay door and into the surrounding area. Once outside, the Riggers called for emergency services. A short time after the building was evacuated, the ammonia cloud within the building contacted a source of ignition and ignited. The fire quickly self extinguished but there was significant fire damage. When the fire department arrived, a hole had to be cut into the side of the building to extract the Broker from a room with the only exit blocked by the ammonia.

***Image #4** - Ammonia cloud billowing out of the building at the West open shutter door at 10:18am on May 26, 2022.*

Technical Safety BC's investigation found that the valve did not malfunction in the incident and the receiver would have been capable of holding pressure. For investigation purposes, the valve that was opened was removed from the P34 receiver and retained for further testing (Appendix L – Valve Specification Sheet). A leak test was done to determine whether the remaining pipes and valves connected to the receiver could hold pressure. The receiver held pressure with no leaks (Appendix M – Leak test report). The valve that was removed was then brought to an independent engineering laboratory for testing. The engineering lab found that the valve had not failed and held pressure (Appendix N – Acuren laboratory analysis report).

Neighbouring businesses were also affected by the release and were evacuated. Fourteen additional persons experienced respiratory problems from ammonia inhalation, and three were sent to hospital for assessment.

Investigation Findings



Finding 1: The cause of the incident was the failure to remove ammonia from the refrigeration system, prior to, and during disassembly.

An essential step in the disassembly of an ammonia system is the removal of all ammonia and oil. Ammonia was not removed following the system shutdown in 2016. Ammonia was identified in the P24 system on May 25, 2022, during disassembly; however, was not effectively assessed and removed from the P34 receiver. At no point in the disassembly timeline was a licensed contractor directly engaged with the task of identifying or removing ammonia from the entire system.

The failure to remove ammonia on multiple occasions over the disassembly timeline is the reason the receivers were full while uncertified and unqualified persons proceeded to disassemble the system.

Finding 2: Following equipment shutdown, there was an incorrect understanding that ammonia had been previously removed.

Between 2016 and 2022, ammonia was not removed because managers at Arctic Glacier stated they believed that previous work had removed the ammonia. This incorrect understanding was influenced by personnel changes and misunderstood terminology.

There were several changes to personnel and their responsibilities between 2016 and 2022. The Plant Manager was relocated to Kelowna and was therefore disengaged from the day-to-day shut-down operations at the Kamloops site. People who understood that ammonia had not been removed were no longer present; the Distribution Manager left and Refrigeration Mechanic A retired. The Plant Manager stated they relied upon their recollection of discussions with the Distribution Manager for their understanding of the equipment condition.

Technical Safety BC's investigation obtained documentation from the shut-down period that included the terms "decommissioning," "NH3 removal" and "venting residual ammonia," among others. These terms likely reflect those used during conversations during the shut-down period and can be interpreted in different ways depending on the context in which they are used. For example, whether they apply to a whole system, or a portion thereof (such as in early 2016). The two individuals who used these terms were very clear in post-incident interviews that ammonia had not been removed from the systems. However, the Plant Manager had limited context while operating remotely and verbal communications likely contributed to the misunderstanding that the systems had been emptied of ammonia.

Finding 3: After discovering ammonia, assessments were ineffective in determining the location and quantity of ammonia.

Technical Safety BC's investigation found no evidence that the incorrect understanding that the system was empty was challenged between 2016 and 2022. On May 25, 2022, an ammonia release occurred while a Rigger was cutting a pipe. This release and the purging operation that followed should have invalidated the assumption that all of the ammonia had been removed previously. A re-evaluation of the system did occur by those at the site. However, the assessments were ineffective due to the exclusion of a qualified refrigeration mechanic in a dedicated role during the assessment and an irregular equipment configuration.

Exclusion of a refrigeration mechanic from a dedicated role in the disassembly

Qualified refrigeration mechanics understand the steps required to properly evaluate and disassemble refrigeration systems safely when contracted to do so. Technical Safety BC's investigation evaluated the typical steps that qualified refrigeration mechanics approach disassembly with, and their procedures were found to consistently include steps that would

detect a volume of ammonia prior to disconnection of piping. The Broker was hired with the explicit understanding removal of non-residual amounts of ammonia was not part of the scope of work. The Broker deemed the quote from a licensed contractor to be too expensive and did not hire this company to participate in the removal.

When ammonia was encountered on May 25, 2022, the Buyer was asked by the Broker how to proceed. According to his co-worker, he did not have experience handling ammonia as it is normally removed before his involvement. The Buyer and Refrigeration Mechanic A, who were on site for different reasons, assessed the systems. These assessments were not completed in a manner that included the typical steps a licensed contractor is tasked with when assessing and preparing equipment for disassembly. The assessments were therefore not completed with the same rigour that would be expected had they been hired specifically to validate that the system was empty. In addition, these informal assessments provided the remaining workers who were unqualified to handle ammonia, with the confidence to proceed. Had the workers not been convinced by these assessments, they likely would have discontinued the work or required the involvement of someone else with the skills and knowledge to validate that the work was safe to continue.

Irregular equipment configuration which created the appearance the system was empty

At the time of the incident on May 26, the system was already partially disassembled with open and cut pipes. This partially disassembled configuration was incorrectly interpreted as indicating an empty system. The investigation found that the indicators deemed by those on site to verify the system was empty did not accurately reflect the pressure or contents of the receiver.

1. An open, cut pipe exiting the receiver was misinterpreted to mean the receiver was open to atmosphere. However, the pipe entered and exited the receiver as a separate closed loop.

2. It was not identified that the three pressure gauges for the P34 system showed pressures in or near the compressor, which was isolated from the receiver.

Finding 4: There was no physical failure of any component or assembly within the ammonia system.

The investigation found that no physical failure of the refrigeration equipment or its components contributed to the cause of the incident. The investigation concluded that the ball valve was opened by the Broker as it interfered with the rigging of the equipment. Independent testing confirmed that the valve did not fail and operated as the manufacturer intended.

Finding 5: The quarter turn ball valve resulted in the release being rapid and uncontrolled.

Typically, ammonia systems incorporate multi-turn valves such as globe valves. These valves operate similarly to common household water hose valves in that the handle must make several complete rotations to open the valve. In this case, at some point in the past when the system was altered, a quarter turn ball valve was added to the liquid feed line from the receiver. This type of valve requires just 90 degrees of rotation to go from fully closed to fully open. As the movement is short and takes some force to open, the handle moves rapidly from fully closed to fully open in one smooth motion. This makes “cracking” the valve to test for pressure difficult. In this case, there is no indication that the Broker wanted to check the valve before opening, but the binary nature of the valve (either open or closed) resulted in a rapid and uncontrolled release of ammonia the consequences of which are seen in the outcomes of the incident.

Finding 6: There was an increased risk of an overpressure failure from the P34 system for several years prior to the incident as a result of it being left full of ammonia with no connected relief valve.

Although it did not contribute to the incident, the P34 system likely contained a full charge of ammonia with no dedicated relief valve for the receiver for several years before the incident. During a previous alteration, the dedicated relief valve for the receiver appeared to have been removed. The removal of this relief valve rendered the vessel vulnerable when it was isolated from the rest of the system.

In 2016 when the ammonia was “pumped down” into the receiver the isolation valves entering and exiting the receiver would have been closed to hold the ammonia in place. This posed an increased risk of overpressure and potential failure had the vessel been exposed to a large enough heat source during that time period. The result was a full receiver with no relief valve. The Laporte engineering report found that “A vessel without a relief valve in service has the potential to reach high pressures quickly with large heat inputs.” Similarly, “Smaller heat inputs can cause overpressure of a vessel without in service relief valves provided they have extended exposure time.”

Finding 7: 1000 lbs of ammonia was likely purged through water and released into the facility parking lot from the P24 system between May 25 and 26, 2022.

As the investigation found that no ammonia was removed prior to or during disassembly, it is likely that the full operating charge, or approximately 1000 lbs of ammonia, was purged from the P24 system during purging on May 25 and 26, 2022. Analysis of the purging through CCTV

and engineering calculations confirmed this was a reasonable conclusion (See Appendix H – Ammonia purge timeline and Appendix I – Engineering analysis by Laporte Engineering Ltd).

“Purging” in this case, is intentionally dissolving ammonia through constantly flowing water to remove it from a vessel. Ammonia vapour (NH3) released into water (H20) results in a mixture that is typically treated as hazardous waste during disposal.

Finding 8: During the incident on May 26, 2022, between 1300 and 1645 lbs of ammonia was likely released directly into the atmosphere from the P34 system.

It is likely between 1300 and 1645 lbs of ammonia was released from the P34 receiver when the valve was opened on May 26, 2022. This amount was calculated from analysis of the release and is consistent with the investigation findings that no ammonia had been removed from the vessel since it was shut down in late 2015.

The release resulted in a large cloud of ammonia that propagated to neighbouring businesses and exposed a number of individuals. The resulting cloud was also ignited within the building, causing a deflagration which damaged the facility.

Finding 9: A functioning exhaust system may have reduced the probability of an explosion occurring after the release.

As Arctic Glacier personnel believed they no longer had ammonia in their facility, their ammonia emergency exhaust systems were not functional at the time of the incident. One of the reasons ventilation requirements are identified in the code is to prevent the concentration of ammonia from reaching the lower explosive limit and thus preventing an explosion from the long term build up of ammonia gases.

When a large and sudden release occurs, it is not possible to have sufficient ventilation to ensure that these concentrations are not reached. However, the Laporte engineering report found that having a functioning ventilation system would have reduced the time period when ammonia was in a flammable range; thus, reducing the probability of an explosion.

Key Learnings and Recommendations

Technical Safety BC's aim is to learn from these incidents and use the investigation findings to prevent a similar occurrence. Based on the findings of this investigation, three recommendations are made to seek improvements towards the:

- roles and responsibilities when dismantling refrigeration systems; and
- engagement of licensed refrigeration contractors when dismantling refrigeration equipment.

Recommendation 1: to owners and/or managers of refrigeration systems

Our safety system is built upon a foundation of ensuring that activities associated with hazards are restricted to those persons who have the necessary knowledge and skills. This principle applies throughout the life cycle of regulated systems. Serious hazards exist with the alteration of refrigeration systems during decommissioning and disassembly and that work requires the involvement of licensed refrigeration contractors or qualified professionals.

Owners and managers of refrigeration systems are reminded that it is their duty to ensure the safety of pressure piping and system work being conducted at their facility (Appendix A - Safety Standards Act, regulations and codes). The managers of the refrigeration system referred a refrigeration mechanic to the broker early in the disassembly planning and were aware of his exclusion from the disassembly process. The managers of the refrigeration system stated that leading up to the incident they thought ammonia had been removed, yet they had never directly engaged a licensed contractor to remove the ammonia and oil from the entire system. They were incorrect about the absence of ammonia within their system and when they became aware of the presence of ammonia, they did not require the involvement of a licensed refrigeration contractor to assess and remove all ammonia and oil.

> **It is recommended that when planning for and facilitating the final shut down and disassembly of refrigeration equipment, owners and managers directly engage a licensed contractor to validate:**
>
> - **ammonia and oil are removed**
> - **equipment is ready for safe disassembly and transportation**

International Institute of Ammonia Refrigeration (IIAR) ANSI/IIAR-2020-8 contains useful procedures for the decommissioning of ammonia systems and components that should be considered by owners and managers.

Recommendation 2: to persons who hold or previously held a technical qualification

Qualified persons understand how to identify and mitigate hazards with regulated equipment when working within their scope. Refrigeration mechanics typically follow standard practices and procedures when working with ammonia systems, which includes validating the removal of ammonia and oil prior to disassembling equipment. Leading up to this incident, a person who used to work as a refrigeration mechanic counseled others who were unqualified on how to assess the refrigeration systems for the presence of ammonia and how to purge ammonia. Counseling persons to do regulated work while not overseeing that work, puts those people at risk and prevents the inclusion of those who are authorized to perform those activities safely and responsibly.

> **It is recommended that persons who previously held, or currently hold a technical qualification do not counsel unqualified persons to do regulated work. Qualified persons are reminded that the Safety Standards Act and Regulations prohibit unauthorized persons from doing regulated work unless they are being supervised by a qualified person.**

Recommendation 3: to the Canadian Standards Association (CSA)

The adopted standard for refrigeration systems in BC is CSA B52 – Mechanical Refrigeration Code. The scope of this code is defined as the design, construction, installation, inspection and maintenance of mechanical refrigeration systems. There are no specific or useful requirements aimed at the dismantling, disassembly or decommissioning of refrigeration systems or equipment.

> **It is recommended that CSA adopt or develop requirements for the dismantling, disassembly and/or decommissioning of refrigeration systems and equipment.**

The International Institute of Ammonia Refrigeration (IIAR) ANSI/IIAR-2020-8 contains useful procedures for the decommissioning of ammonia systems and components that should be considered by owners and managers.

Appendices

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