U.S. Chemical Safety and
Hazard Investigation Board

Fatal Liquid Nitrogen Release at Foundation Food Group

Gainesville, GA | *Incident Date: January 28, 2021* | **No. 2021-03-I-GA**

Investigation Report

Published: December 2023

Safety Issues:

- Single Point of Failure
- Atmospheric Monitoring and Alarm Systems
- Emergency Preparedness
- Process Safety Management System
- Product Stewardship

U.S. Chemical Safety and Hazard Investigation Board

The mission of the U.S. Chemical Safety and Hazard Investigation Board (CSB) is to *drive chemical safety excellence through independent investigations to protect communities, workers, and the environment.*

The CSB is an independent federal agency charged with investigating, determining, and reporting to the public in writing the facts, conditions, and circumstances and the cause or probable cause of any accidental chemical release resulting in a fatality, serious injury, or substantial property damages.

The CSB issues safety recommendations based on data and analysis from investigations and safety studies. The CSB advocates for these changes to prevent the likelihood or minimize the consequences of accidental chemical releases.

More information about the CSB and CSB products can be accessed at www.csb.gov or obtained by contacting:

U.S. Chemical Safety and Hazard Investigation Board
1750 Pennsylvania Ave. NW, Suite 910
Washington, DC 20006
(202) 261-7600

The CSB was created by the Clean Air Act Amendments of 1990, and the CSB was first funded and commenced operations in 1998. The CSB is not an enforcement or regulatory body. No part of the conclusions, findings, or recommendations of the Board relating to any accidental release or the investigation thereof shall be admitted as evidence or used in any action or suit for damages arising out of any matter mentioned in such report. 42 U.S.C. § 7412(r)(6)(G).

The January 28, 2021, liquid nitrogen release at Foundation Food Group fatally injured six people:

Jose DeJesus Elias-Cabrera

Corey Alan Murphy

Nelly Gisel Perez-Rafael

Saulo Suarez-Bernal

Victor Vellez

Edgar Vera-Garcia

CONTENTS

ABBREVIATIONS

ACC	American Chemistry Council
ANSI	American National Standards Institute
CCPS	Center for Chemical Process Safety
CFR	Code of Federal Regulations
CGA	Compressed Gas Association
CSB	U.S. Chemical Safety and Hazard Investigation Board
EAP	emergency action plan
EHS	Environmental Health and Safety
EPA	U.S. Environmental Protection Agency
ERP	emergency response plan
FFG	Foundation Food Group
HAZWOPER	Hazardous Waste Operations and Emergency Response
HMI	Human Machine Interface
HR	Human Resources
HVAC	heating, ventilation, and Air Conditioning
ISA	International Society of Automation
ISO	International Organization for Standardization
NFPA	National Fire Protection Association
LEP	Local Emphasis Program
OSHA	U.S. Occupational Safety and Health Administration
PHA	process hazards analysis
PPE	personal protective equipment

PSM	Process Safety Management
RBPS	Risk-Based Process Safety
REP	Regional Emphasis Program
RMP	Risk Management Program
ROEIV	Remotely Operated Emergency Isolation Valve
RTE	Ready-To-Eat
SCBA	Self-Contained Breathing Apparatus
SDS	Safety Data Sheet

Executive Summary

On Thursday, January 28, 2021, between approximately 8:45 and 10:15 a.m., liquid nitrogen overflowed from an immersion freezer located inside the Plant 4 building at the Foundation Food Group (FFG) facility in Gainesville, Georgia. The release began while maintenance workers were troubleshooting operational issues with the freezer, which was designed and owned by Messer LLC (Messer) and leased to FFG. Once released, the liquid nitrogen quickly vaporized, expanded, and accumulated inside a partially enclosed lower-level room that lacked mechanical ventilation. The two maintenance workers who were troubleshooting the freezer at the time of the release were fatally injured by asphyxiation due to the vaporized liquid nitrogen.

The uncontrolled liquid nitrogen release continued, and the two deceased maintenance workers went undetected for 30 to 60 minutes, until another worker went looking for them and saw a four- to five-foot-high vapor cloud filling the room. This worker reported the incident to management, which then initiated an evacuation. During the ensuing building-wide evacuation, at least 14 other FFG employees, including members of management, responded to the incident by either investigating the freezer room or attempting to rescue their coworkers. As a result, four additional FFG employees were fatally injured by asphyxiation, and three other FFG employees and a firefighter were seriously injured presenting asphyxiation symptoms.

Court filings show that after the incident FFG sued its insurance company for damages of roughly $1.7 million. Messer reported business and property losses of roughly $245,000.

Safety Issues

The CSB's investigation identified the safety issues below.

- **Single Point of Failure.** The immersion freezer design included a device called a bubbler tube, which was used to measure the liquid nitrogen level inside the freezer. The bubbler tube was likely bent during maintenance activity, rendering it unable to measure and control the freezer's liquid nitrogen level. As a result, liquid nitrogen overflowed from the freezer and filled the room with vaporized nitrogen. This design was vulnerable to a single point of failure. Once the tube became bent, there was nothing else to prevent the release of liquid nitrogen. The design team did not adequately consider the consequences of the failure of the bubbler tube—a critical safety component—and did not identify appropriate safeguards to mitigate its potential failure. In addition, during fabrication of the immersion freezer, Messer failed to detect a manufacturing defect that exacerbated the potential for the bubbler tube to be bent—a missing clamp meant to secure the bubbler tube to the freezer. (Section 4.1)

- **Atmospheric Monitoring and Alarm Systems.** There is abundant industry guidance on the importance of atmospheric monitoring when the potential for hazardous atmospheres exists. FFG, however, did not install atmospheric monitoring equipment in the freezer room. As such, there was no equipment installed to detect the oxygen-deficient atmosphere in the freezer room, automatically shut off the liquid nitrogen supply, and notify personnel to evacuate the area. (Section 4.2)

- **Emergency Preparedness.** FFG did not inform, train, equip, drill, or otherwise prepare its workforce for a release of liquid nitrogen. FFG's workforce lacked knowledge of the hazards of nitrogen and its ability to create an oxygen-deficient atmosphere, were unable to recognize an oxygen-deficient atmosphere, and lacked any equipment or PPE that would have enabled safe entry into an oxygen-deficient atmosphere. As a result, after the discovery of the first two deceased workers, four other employees who entered the freezer room also died from asphyxiation due to the released nitrogen during response or rescue attempts. Three other employees responded and were seriously injured. At least seven other employees responded and were not seriously injured, but they were at risk of nitrogen asphyxiation due to their proximity to the release. FFG also did not proactively interact with local emergency responders prior to the incident, despite relying upon them to respond to emergencies at its facility. (Section 4.3)

- **Process Safety Management System.** FFG had no documented process safety management policy, allowed the job position responsible for safety management to be vacant for more than a year prior to the incident, did not evaluate the process hazards associated with the freezer, lacked written procedures and a management of change process, and did not train its workers on the asphyxiation hazards of liquid nitrogen. Despite robust industry guidance on process safety management systems, FFG was not required by law to implement it. As a result of the lack of specific regulations for cryogenic asphyxiants, FFG did not implement systems and practices that could have reduced the incident's severity or prevented the accidental release altogether. (Section 4.4)

- **Product Stewardship.** Messer owned the liquid nitrogen bulk storage tanks and the Line 4 immersion-spiral freezer and leased the equipment to FFG. At the time of the incident, Messer had institutional knowledge, experience, policies, and practices for effective product stewardship but applied those practices only to the bulk storage tanks and not to the Line 4 freezer process. Throughout its relationship with FFG, Messer had identified issues with FFG's safety practices and nonconformance to industry guidance, but despite FFG's unsafe practices, Messer continued to supply FFG with liquid nitrogen. Had Messer suspended service until FFG corrected known safety deficiencies, this incident may have been prevented. (Section 4.5)

CAUSE

The CSB determined the cause of the liquid nitrogen release was the failure of the immersion freezer's liquid level control system to accurately measure and control the liquid nitrogen level inside the freezer, which resulted from deformation of the system's bubbler tube component.

Contributing to the incident were 1) Messer's design of the freezer, which allowed the failure of a single level measurement device to result in an uncontrolled loss of containment of liquid nitrogen, 2) FFG's lack of any process safety management systems or practices that could have prevented the incident, 3) a lack of regulatory coverage for liquid nitrogen, which enabled FFG to elect not to implement process safety practices that could have prevented the incident, and 4) Messer's inadequate product stewardship practices, which resulted in Messer continuing to supply FFG with liquid nitrogen despite FFG's unsafe practices.

Contributing to the severity of the incident were 1) FFG's inadequate emergency preparedness, which resulted in at least 14 employees responding to the release by entering the freezer room or the surrounding area to investigate the incident or to attempt to rescue their coworkers, and 2) the absence of atmospheric monitoring and alarm devices that could have alerted workers to the presence of a hazardous atmosphere and warned them against entering it.

RECOMMENDATIONS

To Gold Creek Foods (current owner of the FFG facility)[a]

2021-03-I-GA-R1

Include in the emergency action program provisions for proactively interacting with and informing local emergency response resources of all emergencies at the former FFG Plant 4 facility to which Gold Creek expects them to respond. At a minimum, Gold Creek should:

a) inform local emergency responders of the existence, nature, and location of hazardous substances at its facilities, including liquid nitrogen;

b) inform local emergency responders of the location of emergency-critical equipment such as bulk storage tanks, points of use, isolation valves, E-stop switches, and any other emergency equipment or systems with which emergency responders may need to interact; and,

c) provide local emergency responders with information, such as facility plot plans, engineering drawings, or other information needed to mount an effective emergency response.

To Messer LLC[b]

2021-03-I-GA-R2

Update the company product stewardship policy to:

a) include participation by Messer in customers' process hazard analyses (PHAs). The policy should require that these PHAs be conducted in a manner which conforms with CCPS *Guidelines for Hazard Evaluation Procedures* prior to the startup of a cryogenic freezing process;

b) require verification that proper signage, in accordance with CGA P-76 *Hazards of Oxygen-Deficient Atmospheres*, is displayed on and/or near equipment; and,

c) require a facility and/or equipment siting review to ensure that emergency shutoff devices, including E-stops, are located such that they can be safely actuated during a release of liquid nitrogen.

[a] Gold Creek has developed emergency response procedures that could have reduced the severity of this incident. Consequently, the CSB makes no recommendations to Gold Creek pertaining to the development of emergency preparedness policies or employee training for its emergency action program. Additionally, as of this report's publication, there are no liquid nitrogen freezing processes at the former FFG Plant 4 building which Gold Creek now operates. Consequently the CSB makes no recommendation to Gold Creek related to ventilation or process safety management practices for liquid nitrogen processes.

[b] After the incident Messer revised its freezer design to include multiple layers of protection against liquid nitrogen overflow. Messer also revised its Quality Control process and procedures to require verification of the presence of the necessary bubbler tube clamps and reordered the sequence of inspection steps to facilitate this verification. Consequently the CSB makes no recommendation to Messer regarding the design of its immersion freezers or its Quality Control process.

2021-03-I-GA-R3

Create an informational product that provides Messer customers with information on the safety issues described in this report. In this informational product, recommend that Messer customers develop and implement effective safety management systems to control asphyxiation hazards from inert gases based on the guidance published in CGA P-86 *Guideline for Process Safety Management*, CGA P-12 *Guideline for Safe Handling of Cryogenic and Refrigerated Liquids*, CGA P-18 *Standard for Bulk Inert Gas Systems*, and CGA P-76 *Hazards of Oxygen-Deficient Atmospheres*.

To the U.S. Occupational Safety and Health Administration

2021-03-I-GA-R4

Update the Region 4 Poultry Processing Facilities Regional Emphasis Program to explicitly cover liquid nitrogen freezing processes. At a minimum, the update should encourage practices applicable to managing the hazards of using liquid nitrogen and other cryogenic asphyxiants, including process safety management practices, atmospheric monitoring, employee training and hazard awareness, and emergency preparedness and response.

2021-03-I-GA-R5

Update the Region 5 Regional Emphasis Program for Food Manufacturing Industry to explicitly cover liquid nitrogen freezing processes. At a minimum, the update should encourage practices applicable to managing the hazards of using liquid nitrogen and other cryogenic asphyxiants, including process safety management practices, atmospheric monitoring, employee training and hazard awareness, and emergency preparedness and response.

2021-03-I-GA-R6

Update the Region 6 Poultry Processing Facilities Regional Emphasis Program to explicitly cover liquid nitrogen freezing processes. At a minimum, the update should encourage practices applicable to managing the hazards of using liquid nitrogen and other cryogenic asphyxiants, including process safety management practices, atmospheric monitoring, employee training and hazard awareness, and emergency preparedness and response.

2021-03-I-GA-R7

Promulgate a standard specific to cryogenic asphyxiants. The purpose of this standard shall be the prevention and/or mitigation of hazards arising from the storage, use, and/or handling of these substances. The new standard shall reference applicable national consensus standards such as those published by the Compressed Gas Association and others, as appropriate. At a minimum the new standard shall:

a) Address requirements for the design, construction, and installation of process equipment storing or using cryogenic asphyxiants;

b) Require atmospheric monitoring where equipment storing or using cryogenic asphyxiants is located indoors;

c) Require emergency shutdown systems such that equipment storing or using cryogenic asphyxiants may be isolated during a release without endangerment;

d) Address requirements for employee training and hazard awareness specific to cryogenic asphyxiants;

e) Require an emergency action plan in accordance with 29 CFR 1910.38; and,

f) Address requirements for the use of process safety management elements such as process hazard analysis, management of change, procedures, and others deemed necessary through the rulemaking process to prevent and/or mitigate these hazards.

2021-03-I-GA-R8

Develop and publish a Guidance Document (similar to OSHA 3912-03 *Process Safety Management for Explosives and Pyrotechnics Manufacturing*) for process safety management practices applicable to processes handling compressed gases and cryogenic asphyxiants, including (at a minimum) the practices highlighted in this report.

To the Compressed Gas Association

2021-03-I-GA-R9

Develop a comprehensive standard for the safe storage, handling, and use of liquid nitrogen in stationary applications, comparable to the guidance presented in CGA G-6.5 *Standard for Small Stationary Insulated Carbon Dioxide Systems.* At a minimum, the standard should include:

a) requirements for and guidance on the location, the maintenance, and the functional testing of atmospheric monitoring devices;

b) requirements for visible and audible alarm indication distinct from the building's fire alarm system and at a continuously attended location;

c) guidance on the sizing, design, function, periodic maintenance and testing, and location of room and emergency ventilation systems; and,

d) requirements for and guidance on the location of emergency shutdown devices including E-stops.

2021-03-I-GA-R10

Update P-76 *Hazards of Oxygen-Deficient Atmospheres*. At a minimum, the updated standard should:

a) require that atmospheric monitoring systems *shall be* utilized with processes, equipment, and piping systems capable of producing oxygen-deficient atmospheres;

b) require that atmospheric monitoring systems provide both visible and audible alarm indication distinct from a building's fire alarm system and at a continuously attended location;

c) require that processes, equipment, and piping systems capable of producing oxygen-deficient atmospheres *shall be* equipped with remotely operated emergency isolation valves (ROEIVs); and

d) include guidance on the adequate safe location of emergency stop devices. At a minimum this guidance should be harmonized with the requirements of ISO 13850 *Safety of machinery – Emergency stop function – Principles for design.* As necessary, augment the general guidance of ISO 13850 with guidance specific to processes, equipment, and piping using cryogenic asphyxiants and inert gases.

To the National Fire Protection Association

2021-03-I-GA-R11

Update NFPA 55 *Compressed Gases and Cryogenic Fluids Code* to:

a) require the use of atmospheric monitoring with cryogenic asphyxiants in accordance with industry guidance such as is contained in CGA P-76 *Hazards of Oxygen-Deficient Atmospheres* and CGA P-12 *Safe Handling of Cryogenic Liquids* in addition to CGA P-18 *Standard for Bulk Inert Gas Systems*; and,

b) include guidance on the adequate safe location of manual shutoff valves and devices such as emergency push buttons used to activate remotely operated emergency isolation valves (ROEIVs). At a minimum this guidance should be harmonized with the requirements of ISO 13850 *Safety of machinery – Emergency stop function – Principles for design.*

To the International Code Council

2021-03-I-GA-R12

Update the International Fire Code to:

a) require the use of atmospheric monitoring with cryogenic asphyxiants in accordance with industry guidance such as is contained in CGA P-76 *Hazards of Oxygen-Deficient Atmospheres* and CGA P-12 *Safe Handling of Cryogenic Liquids* in addition to CGA P-18 *Standard for Bulk Inert Gas Systems*; and,

b) include guidance on the adequate safe location of manual shutoff valves and devices such as emergency push buttons used to activate remotely operated emergency isolation valves (ROEIVs) in cryogenic fluid service. At a minimum this guidance should be harmonized with the requirements of ISO 13850 *Safety of machinery – Emergency stop function – Principles for design.*

1 Background

1.1 Companies Involved

1.1.1 Foundation Food Group

Foundation Food Group (FFG) was a poultry processor located in Gainesville, Georgia, formed by a merger of Prime-Pak Foods, Inc. (Prime-Pak)[a] and Victory Processing, Inc. (Victory Processing)[b] in September 2020. Prior to the merger, the two companies had been partners in a joint-venture since 2018; Prime-Pak operated in what became known as the FFG Plant 4 building, discussed further in Section 1.2 below, across the street from Victory Processing.

At the time of the incident, approximately 135 employees worked in the FFG Plant 4 building. The majority of the FFG workforce did not speak English as their primary language or were non-English speaking.

Following the incident, in October 2021, Gold Creek Foods (Gold Creek) acquired FFG.

1.1.2 Messer LLC

Messer LLC (Messer) was formed in March 2019, when Messer Group and CVC Capital Partners Fund VII (CVC) acquired most of the North American gases business of Linde plc (Linde) [1].[c] Messer, which is headquartered in Bridgewater, New Jersey, is an industrial and specialty gases technology and applications supplier for the industrial, food, medical, chemical, and electronics industries [2]. Messer supplied bulk liquid nitrogen for FFG and designed[d] and owned the liquid nitrogen immersion-spiral freezer system, which was leased to and operated by FFG to freeze poultry products.

1.2 Liquid Nitrogen Freezing at FFG

Following the merger between Prime-Pak and Victory Processing, FFG owned four poultry processing plants in Gainesville, Georgia. The former Prime-Pak building became FFG Plant 4, which housed five production lines, denoted as Lines 1 through 5.

Prior to 2020, Prime-Pak and FFG utilized ammonia freezer systems in Plant 4 to freeze poultry products. In early 2020, FFG began introducing Messer's liquid nitrogen freezer systems into Plant 4 to increase production capacity.[e] FFG and Messer worked collaboratively for several months to prepare for the addition of the liquid

[a] Prime-Pak was formed as Milton's Portion-Pak Meats, Inc. in 1973.

[b] Victory Processing was formed in 2006.

[c] Linde was required to divest this business as part of its 2018 merger with Praxair, Inc. [49].

[d] The immersion-spiral freezer was designed by Linde prior to the Messer acquisition, at which point Messer acquired Linde's North American freezer assets.

[e] By transitioning from the ammonia spiral freezer to the liquid nitrogen immersion-spiral freezer process, FFG estimated that it would obtain a 7% increase in the yield of its diced product and eliminate operational issues experienced with the ammonia freezer.

nitrogen freezer systems. Messer and FFG[a] entered into a product supply agreement for the lease of two 13,000-gallon bulk liquid nitrogen tanks, routine liquid nitrogen supply, and a nitrogen spiral freezer. The storage tanks were installed outside the FFG facility, and the spiral freezer was installed on Line 2 in Plant 4 in May 2020. The Line 2 process was commissioned into service later that month.

In July 2020, the agreement was amended to include the lease of one additional 13,000-gallon bulk liquid nitrogen tank and a liquid nitrogen immersion-spiral freezer to be used on Line 4. Installation of the additional storage tank and immersion-spiral freezer began on December 5, 2020.

On December 13, 2020, FFG added walls to the Line 4 freezer room where the freezer was installed to separate the immersion-spiral freezer from the adjacent areas of the plant. Additionally, FFG constructed a “clean room” opposite of the equipment (**Figure 1**).[b] Shortly thereafter, on December 16, 2020, the immersion-spiral freezer installation was completed, and production on Line 4 commenced the following day, approximately five weeks prior to the fatal incident.

1.3 Line 4 Freezing Process

The FFG Plant 4 building (**Figure 1**) consisted of five production lines that made various cooked, partially cooked, and marinated chicken products [3]. Conveyor belts transferred chicken through production equipment, such as ovens, fryers, freezers, and baggers, on each production line. Line 4, where the release occurred, processed cooked chicken products.

The Plant 4 building was separated into two processing areas: the “raw” area and the “Ready-To-Eat” (RTE) area.[c] The Line 4 process began in the raw area with marination and cooking, then continued to the RTE area, which contained a dicer, freezer, and packaging equipment. Workers measured product temperatures at various stages throughout the line to ensure that the product met food safety specifications. Production stopped at the end of each workday and re-started the following morning.

[a] At the time that the product supply agreement was made, FFG had yet to be formed, so Prime-Pak Foods is listed on the agreement.

[b] This was a separate project from the Line 4 freezer project. The clean room, also known as the smock changing area, would allow workers to cross between the raw and RTE areas (Section 1.3) without having to walk around the building. The new clean room was not yet commissioned at the time of the incident.

[c] RTE is defined by the U.S. Food and Drug Administration (FDA) as food for which it is reasonably foreseeable will be eaten without further processing that would significantly minimize biological hazards [48]. The plant is separated into the two processing areas to minimize or prevent the contamination of RTE foods with disease-causing bacteria, such as Listeria [53].

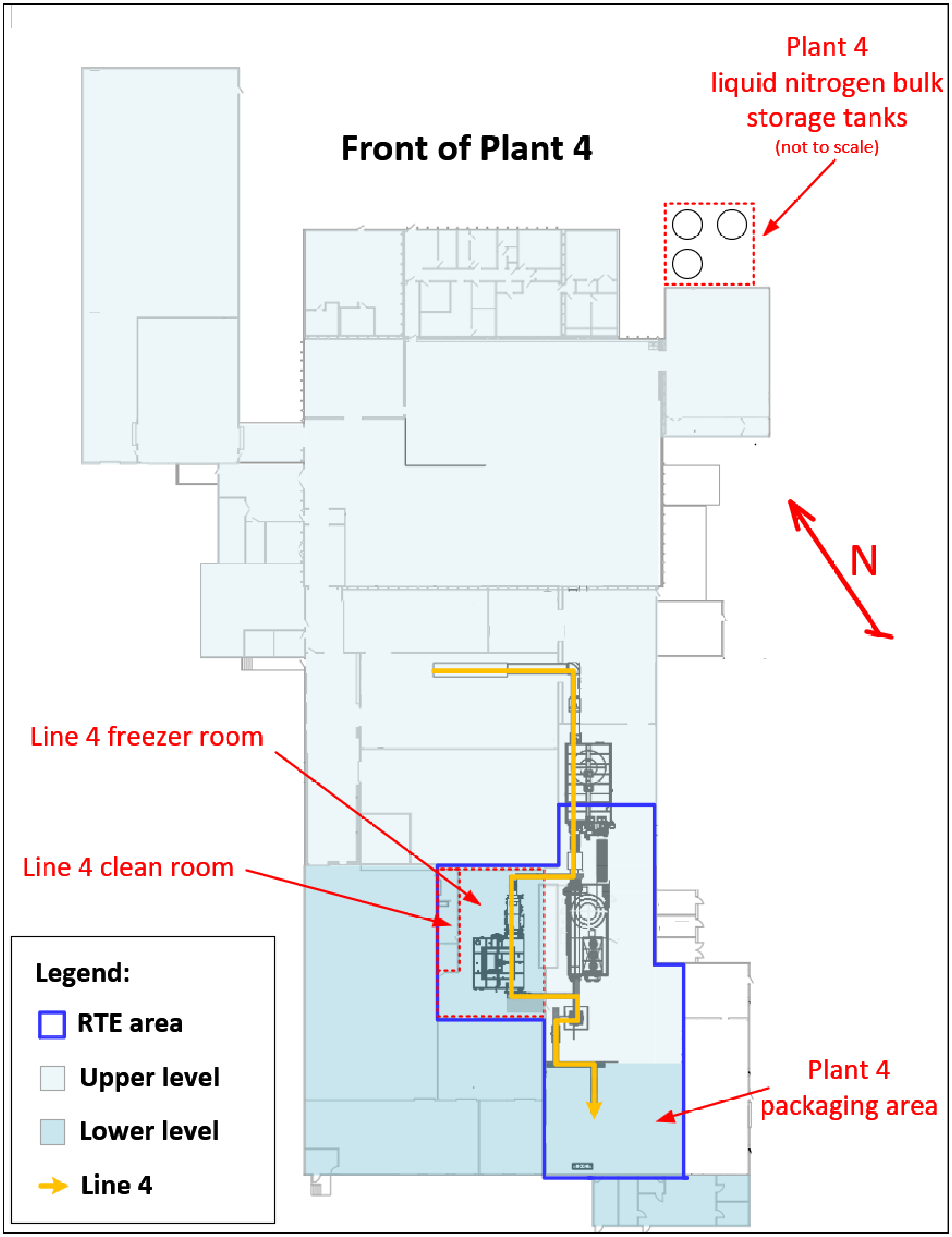


Figure 1. Plot plan of the FFG Plant 4 building. The yellow line indicates the Line 4 process flow on the day of the incident. (Credit: FFG with annotations by CSB)

The Messer Line 4 liquid nitrogen immersion-spiral freezer[a] process (**Figure 2**) occurred in two stages. In the first stage, a conveyor belt carried the fully cooked diced chicken into an immersion freezer where it was partially frozen in a -320°F (-196°C) liquid nitrogen bath. The chicken then moved through a transition box to the second stage, where a conveyor belt carried the partially frozen diced chicken through the spiral freezer as internal fans circulated vaporized liquid nitrogen within the freezer to complete the freezing process. The frozen chicken exited the spiral freezer and was packaged and shipped to customers.

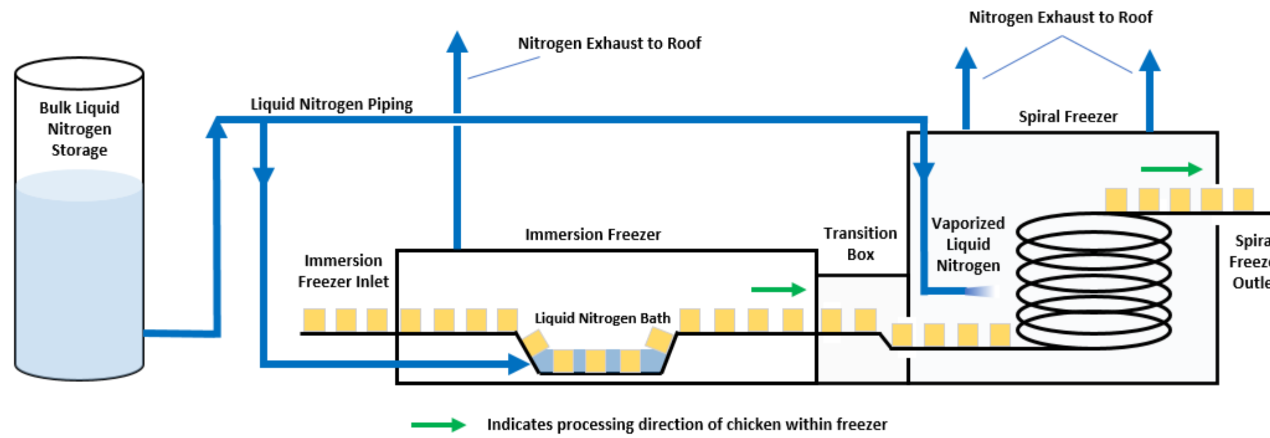


Figure 2. Conceptual diagram of the Line 4 liquid nitrogen freezing system, not drawn to scale. (Credit: Messer, annotations by CSB)

Exhaust systems connected to both the immersion and spiral freezers directed the nitrogen gas from inside the freezers to outside the building through discharge ducting on the roof.

Control valves regulated the flow of liquid nitrogen from storage tanks outside the building through piping along the roof and into each freezer. FFG workers used a computer control system with touch screens, called a Human Machine Interface (HMI), to set operating parameters for the freezer system, such as the liquid nitrogen level inside the immersion freezer, conveyor belt speeds, and exhaust fan speeds. The computer control system programming included safety interlocks to automatically prevent inadvertent, hazardous liquid nitrogen releases, which could be activated either by the control system measuring a high liquid level or by pushing emergency stop (E-stop) buttons located on the freezer exterior. The control system measured the liquid level in the immersion freezer using a device called the bubbler tube, which is discussed in further detail in Section 3.

To enable access to the inside of the immersion freezer, the freezer was also equipped with a lid that could be raised, and the transition box had a door that could be opened. The lid and the door were equipped with permissive proximity switches, or safety switches; as designed, when the lid and door were closed, the safety switches would enable the freezer to operate normally. If the safety switches lost proximity (meaning that the door was open and/or the lid was raised), the freezer system was designed to shut off liquid nitrogen supply to the freezers and to increase the speed of the nitrogen exhaust fans.

[a] The immersion-spiral freezer consisted of two discrete freezers—an immersion freezer and a spiral freezer—connected in series.

1.4 LINE 4 FREEZER ROOM

Figure 3 below illustrates the layout of the FFG Line 4 freezer room.

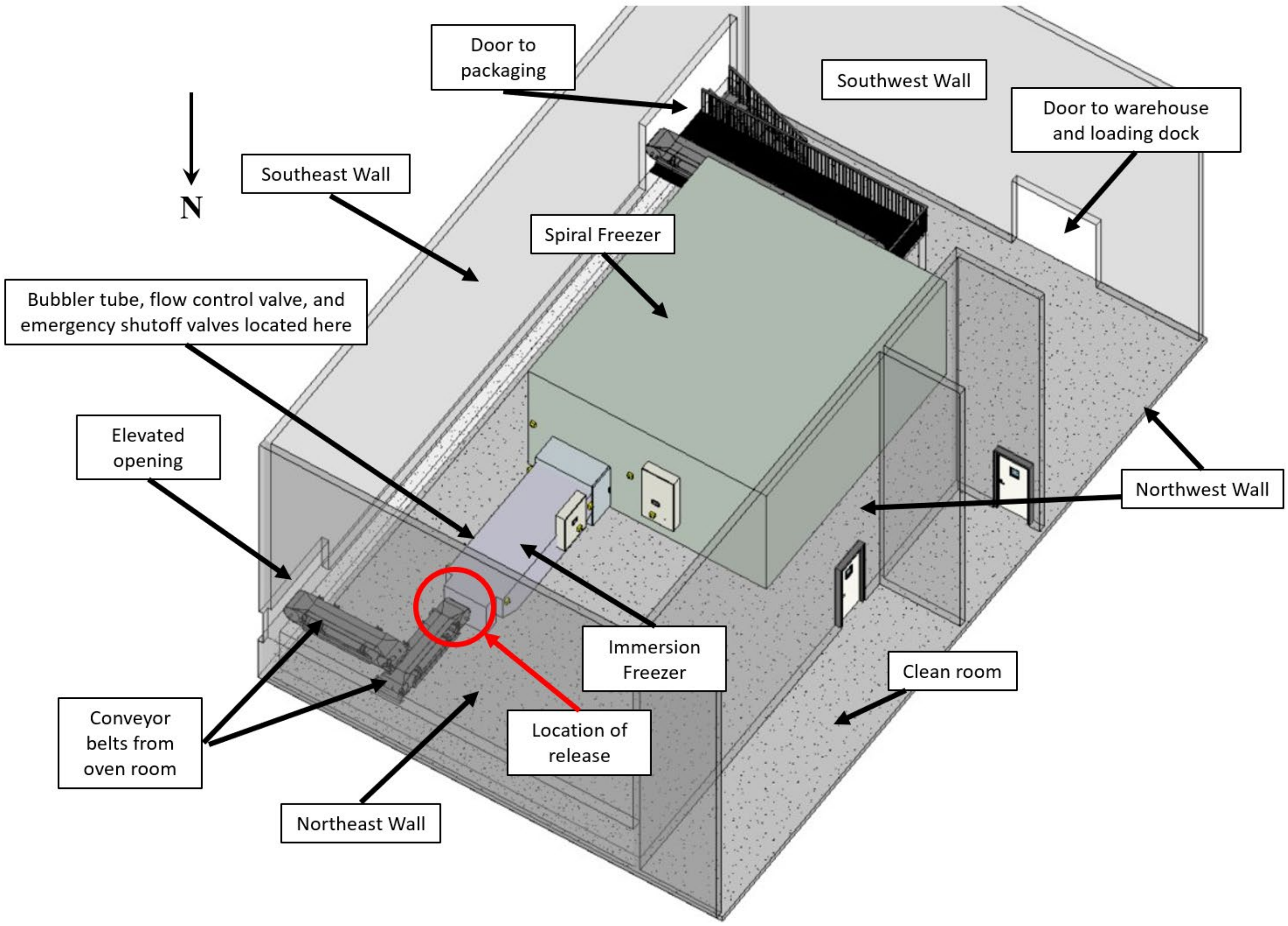


Figure 3. Diagram of the FFG Line 4 freezer room. (Credit: CSB)

In total, the room had four openings. On the southeast wall, there was an elevated opening through which conveyor belts brought product from the oven room into the freezer room. Also on the southeast wall was a large open doorway into the packaging area. Both of these openings on the southeast wall were elevated roughly five feet from the floor of the freezer room. On the southwest wall, there was a large open doorway leading to the warehouse and loading dock area. This doorway contained heavy plastic curtains separating the freezer room from the warehouse and loading dock. On the northwest wall, there was a single door that separated the freezer room from the clean room. There were no openings in the northeast wall.

The rooms adjacent to the Line 4 freezer room on the northeast and southeast sides were elevated roughly five feet above the floor level in the freezer room (**Figure 4**). The adjacent rooms on the southwest and northwest sides were at the same floor elevation as the freezer room. Thus, the room was recessed below adjacent rooms on two sides and level with the adjacent rooms on the two other sides. Ultimately, below the elevation of five feet, the room was very nearly fully enclosed. The only openings in the room below five feet of elevation were a standard-size door on the northwest wall, and a large doorway on the southwest wall that was partially obstructed by heavy plastic strip curtains.

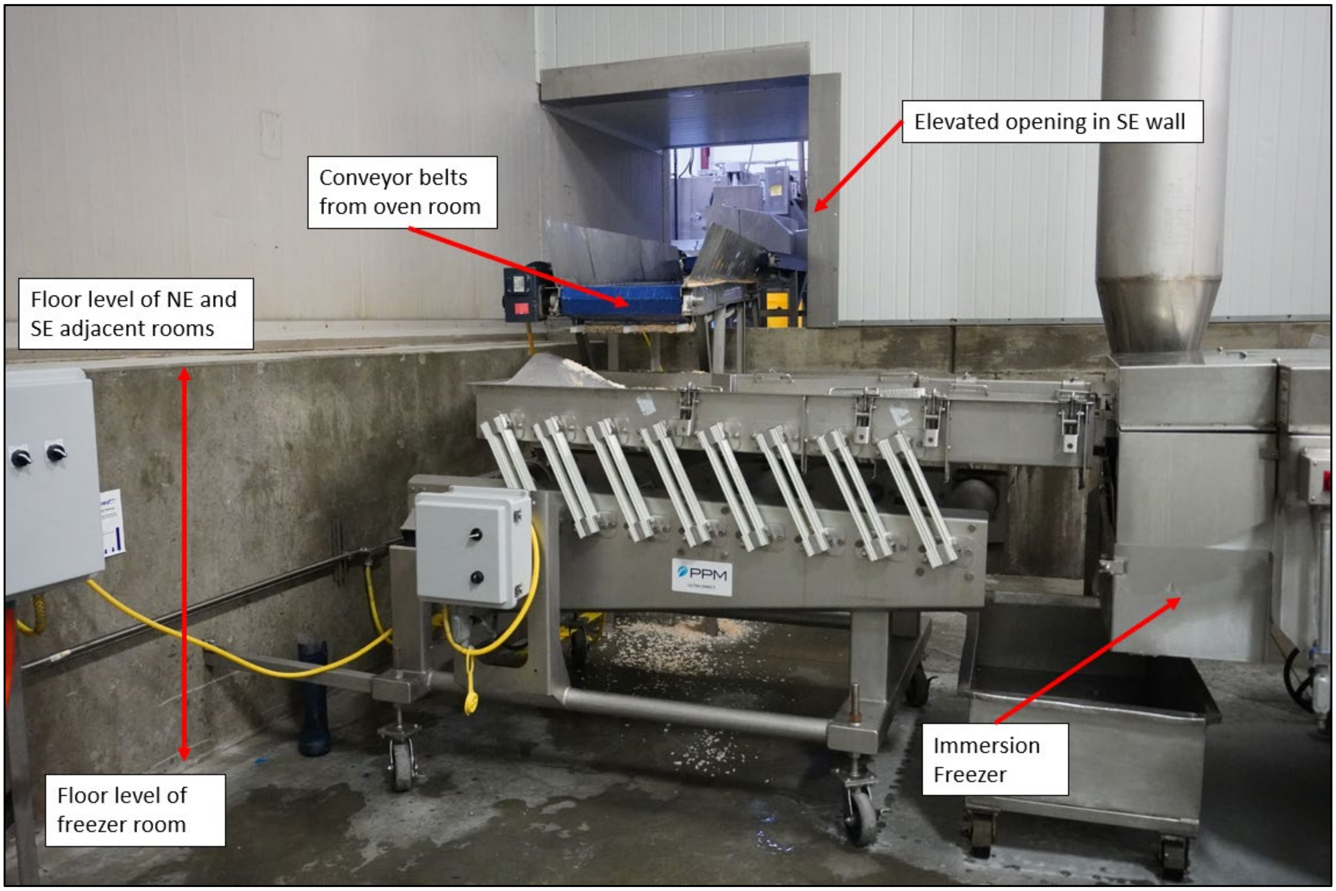


Figure 4. Photo showing difference in elevation between Line 4 freezer room and the adjacent rooms on the northeast and southeast sides. (Credit: CSB)

Air circulated through the room through the four openings described above. The room had no mechanical ventilation or heating, ventilation, and air conditioning (HVAC), although the immersion-spiral freezers contained exhaust systems designed to remove the vaporized nitrogen from the normal operation of the freezers (described previously in Section 1.3 and **Figure 2**).

1.5 Division of Responsibilities Between FFG and Messer

As part of FFG's and Messer's supply agreement, Messer retained ownership[a] of the bulk liquid nitrogen tanks, the Line 2 spiral freezer, and the Line 4 immersion-spiral freezer equipment. Messer also supplied FFG with liquid nitrogen and maintained and inspected the bulk tanks. FFG was responsible for maintaining the equipment site; ensuring the site complied with safety and environmental regulations; providing necessary

[a] FFG leased the equipment from Messer.

utilities, piping, and connections for use of the equipment; providing adequate security; and maintaining freezer equipment per Messer instructions.

The companies summarized the division of responsibilities as shown in **Figure 5**.

Task Responsibility	Messer Responsibility	FOUNDATION FOOD GROUP
Sign Agreements	X	X
Site-survey for pad and tank location	X	
Tank pad (Messer to provide specification drawing)		X
Tank Freight and Rigging	X	
Fence, lighting, dedicated phone line (if necessary)		X
All building penetrations and sealing		X
Clear access to area for installation		X
All electrical connections to the equipment and exhaust		X
Liquid and gaseous Nitrogen piping from the tank to the equipment	X	X
Exhaust System	X	
Provide air supply to equipment if necessary		X
All Liquid Nitrogen cryogenic valves	X	
All required make-up air		X
Exhaust blower control: VFD, power supply, etc.	X	
Any required building permits		X
Any modifications to the processing line, conveyors, etc.		X
Liquid Nitrogen Product Safety Training	X	
Initial Optimization of System	X	
Safe operation and sanitation of the equipment		X
Equipment maintenance		X
Exhaust duct insulation if necessary		X

Task Responsibility chart does not indicate cost responsibility

Figure 5. Liquid nitrogen freezer division of responsibilities between Messer and FFG (Credit: FFG, annotations by CSB)

1.6 LIQUID NITROGEN

1.6.1 PROPERTIES

Nitrogen is a colorless, odorless, non-flammable, non-toxic, inert gas that is abundant in air.[a] Under specific temperature and pressure conditions,[b] Nitrogen is a cryogenic liquid, which is also colorless, odorless, non-flammable, and non-toxic.

Liquid nitrogen boils at -320 °F (-196 °C) at atmospheric pressure. It produces large volumes of nitrogen gas when it vaporizes [4]. Nitrogen gas readily mixes with air at room temperature; however, cold nitrogen gas is

[a] Nitrogen makes up about 78% of the earth's atmosphere [52].

[b] A cryogenic liquid is a refrigerated liquefied gas with a boiling point less than -130°F (-90°C) at atmospheric pressure [5, p. 2].

denser than air and can settle and collect in low areas [4]. Contact with liquid nitrogen or cold nitrogen gas can cause severe cold burns, frostbite, and hypothermia.[a] Prolonged breathing of extremely cold gas may damage lung tissue.

1.6.2 Asphyxiation

Liquid nitrogen has a liquid-to-gas expansion ratio of 1 to 696 at 70°F (21°C), meaning that nitrogen gas will expand to fill the volume of a space 696 times greater than its volume when in the liquid phase [5, p. 5]. High concentrations of nitrogen gas in an enclosed area will displace oxygen, creating an oxygen-deficient atmosphere. Atmospheres containing less than 19.5% oxygen are considered oxygen-deficient and can cause a range of effects on the human body, as shown in **Figure 6**. Atmospheres containing very low oxygen concentrations can lead to asphyxiation, an effect in which the body receives inadequate oxygen, resulting in loss of consciousness or death [6].[b] At these very low oxygen concentrations (i.e., less than 10%), exposure may result in the rapid loss of consciousness without warning [7], which can occur in as few as one or two breaths [6, p. 4].

Atmospheric Oxygen Concentration (%)	Possible Results
20.9	Normal
19.0	Some unnoticeable adverse physiological effects
16.0	Increased pulse and breathing rate, impaired thinking and attention, reduced coordination
14.0	Abnormal fatigue upon exertion, emotional upset, faulty coordination, poor judgment
12.5	Very poor judgment and coordination, impaired respiration that may cause permanent heart damage, nausea, and vomiting
<10	Inability to move, loss of consciousness, convulsions, death

Figure 6. Effects of oxygen deficiency on the human body [8, p. 3]. (Credit: CSB)

1.7 Liquid Nitrogen in Food Processing

Cryogenic freezers using inert gases, such as liquid nitrogen, have become common in the food processing industry due to their relatively low capital investment, smaller size, and faster freezing time compared with

[a] Symptoms of hypothermia include a slowing down of physical and mental responses, unreasonable behavior, speech or vision difficulty, stumbling, and cramps and shivers.

[b] Typically, air contains about 21% oxygen [52]. Symptoms of asphyxia may include rapid breathing, nausea, vomiting, inability to move, convulsive movements, collapse, abnormal pulse, rapid fatigue, faulty judgment, insensitivity to pain, and abnormal emotions.

ammonia-based mechanical freezers [9]. In addition to Messer, several companies manufacture cryogenic freezers for the food processing industry comparable to the one discussed in this report.

Cryogenic immersion-spiral freezers are used in various food freezing applications, including the freezing of poultry, beef, diced luncheon meats, pizza toppings, marinated meats and vegetables, shrimp, and seafood fillets [10].

Within the United States, at least 220 poultry processing facilities handle cryogenic liquids. In June 2021, the U.S. Poultry & Egg Association polled poultry processing facilities and found that 74% of the respondents use cryogenic freezers, with 22% using liquid nitrogen, 33% using carbon dioxide, and 19% using both liquid nitrogen and carbon dioxide, as shown in **Figure 7**.

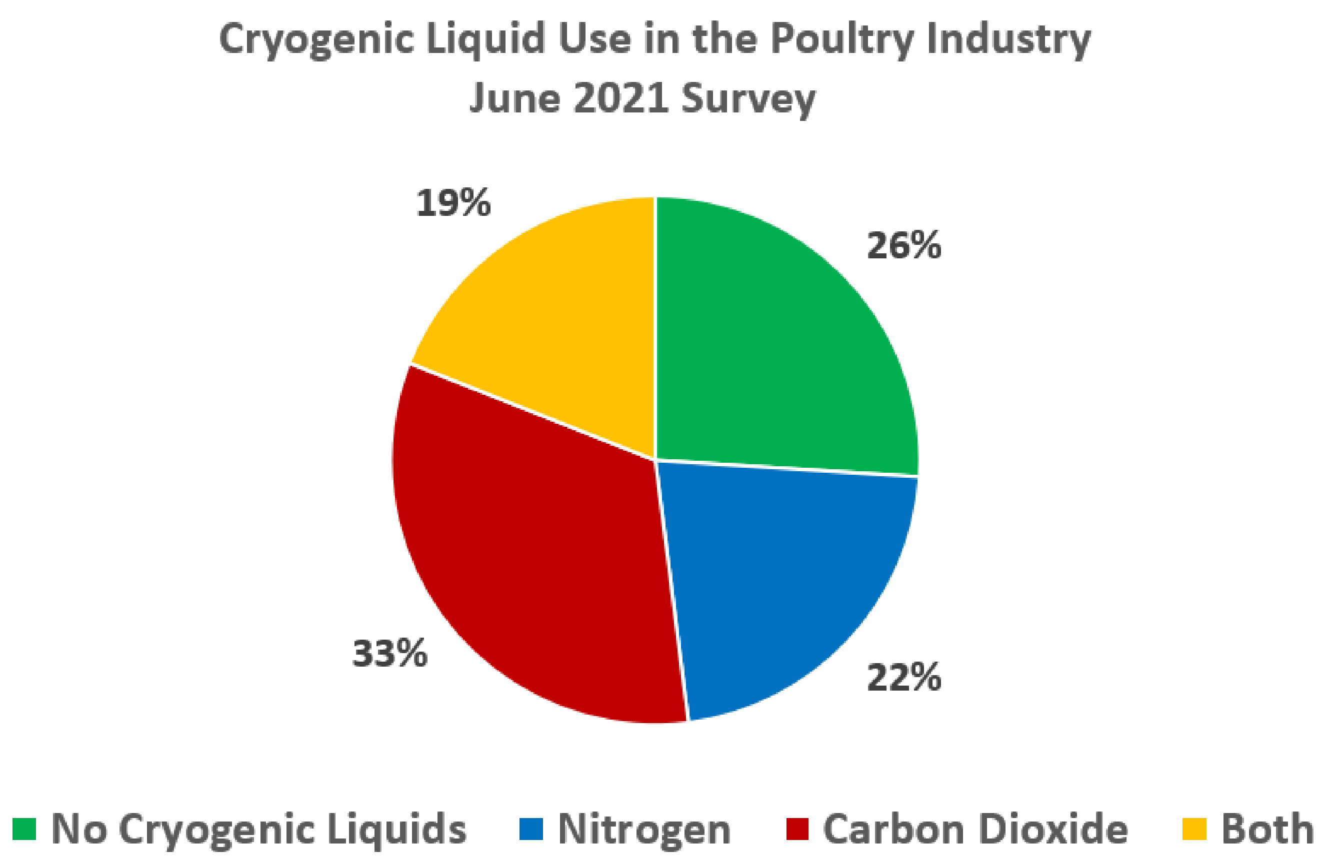


Figure 7. Cryogenic use in the poultry industry. (Credit: U.S. Poultry & Egg Association, formatted by CSB)

1.8 Regulatory Coverage

The U.S. Occupational Safety and Health Administration (OSHA) and the U.S. Environmental Protection Agency (EPA) do not define liquid nitrogen as a highly hazardous chemical or extremely hazardous substance. Consequently, OSHA's Process Safety Management (PSM) standard (29 CFR 1910.119) and the EPA's Risk Management Program (RMP) rule (40 CFR 68) did not apply to FFG's liquid nitrogen process [11, 12]. Although FFG also utilized anhydrous ammonia (which is regulated by PSM and RMP) in processes separate from the Line 4 liquid nitrogen process, FFG asserted that its ammonia processes were also not covered under the regulations because FFG's ammonia processes were not interconnected and each utilized a quantity of anhydrous ammonia less than the quantity required to trigger regulatory coverage. Various other regulations applied to FFG, and they are discussed in the relevant portions of the report below.

1.9 Description of Surrounding Area

Figure 8 shows the FFG facility and depicts the area within one, three, and five miles of the facility boundary. Summarized demographic data for the approximately one-mile vicinity of the FFG facility are shown below in **Table 1**. There are over 26,000 people residing in over 7,600 housing units, most of which are single family units, within one mile of the FFG facility. Detailed demographic data are included in **Appendix B.**

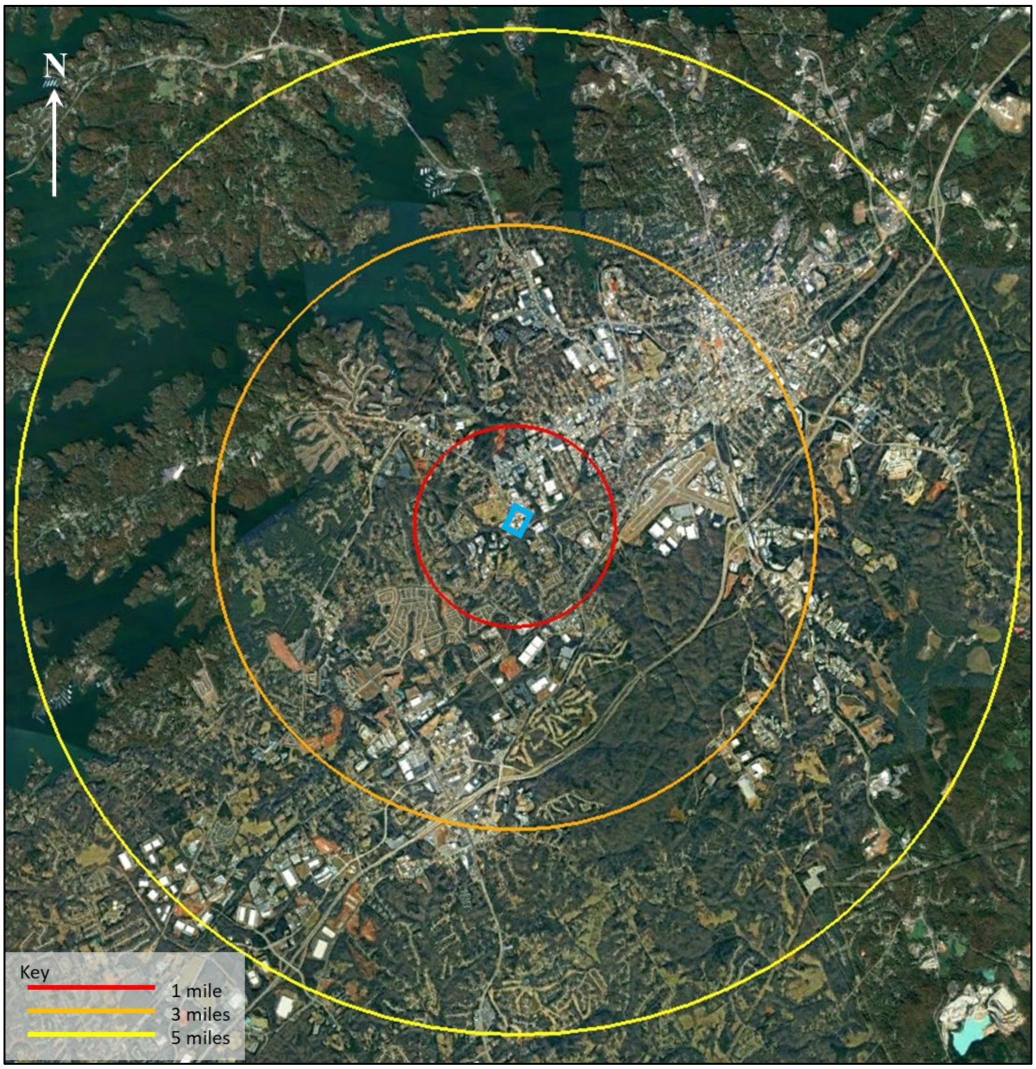


Figure 8. Overhead satellite image of the FFG facility and the surrounding area. (Credit: Google, annotatons by CSB)

Table 1. Summarized demographic data for approximately one-mile vicinity of FFG facility (Credit: CSB using data obtained from Census Reporter)

<table>
<tr><th>Population</th><th colspan="2">Race and Ethnicity</th><th>Per Capita Income[a]</th><th>% Below Poverty Line</th><th>Number of Housing Units</th><th colspan="2">Types of Housing Units</th></tr>
<tr><td rowspan="8">26,093</td><td>White</td><td>25%</td><td rowspan="8">$22,177</td><td rowspan="8">21%</td><td rowspan="8">7,651</td><td>Single Unit</td><td>70%</td></tr>
<tr><td>Black</td><td>8%</td><td>Multi-Unit</td><td>22%</td></tr>
<tr><td>Native</td><td>0%</td><td>Mobile Home</td><td>8%</td></tr>
<tr><td>Asian</td><td>5%</td><td>Boat, RV, Van, etc.</td><td>0%</td></tr>
<tr><td>Islander</td><td>0%</td><td colspan="2" rowspan="4"></td></tr>
<tr><td>Other</td><td>0%</td></tr>
<tr><td>Two+</td><td>2%</td></tr>
<tr><td>Hispanic</td><td>59%</td></tr>
</table>

2 Incident Description

2.1 Operational Issues

After the Line 4 immersion-spiral freezer was commissioned in December 2020, FFG experienced a series of operational problems with the equipment. Messer returned to the FFG facility on multiple occasions to troubleshoot these operational issues, including problems with belt loading, liquid nitrogen level control, and freezing.

With regard to the belt loading issues, diced chicken product was shifting unevenly to one side of the conveyor belt as it traveled through the immersion freezer to the spiral freezer. Messer thought that the flow of liquid nitrogen into the immersion freezer tub was potentially pushing the chicken product to the opposite side of the conveyor belt, causing the uneven belt loading. Accordingly, on January 23, 2021, Messer modified the design of the end of the liquid nitrogen inlet piping into the immersion freezer to slow the velocity of liquid nitrogen entering the immersion tub.[b] At the time of the incident, Messer and FFG had resolved most, but not all, uneven belt loading issues in the freezer system.

FFG also reported to Messer that it believed that the liquid nitrogen level indicated on the control panel was lower than the expected level given the specified level setpoint. In an attempt to address the perceived level control discrepancy, on January 23, 2021, Messer replaced the liquid nitrogen control valve and transducer on the immersion freezer. At the time of the incident, Messer believed the liquid nitrogen level control issues had been resolved, but Messer and FFG were continuing to make other adjustments to the system.[c]

[a] The Census Bureau reports that the 2021 per capita income for the United States is $41,285 [54].

[b] Messer also re-centered the conveyor belt in the immersion freezer and added product guides to the belt to address the belt loading issues.

[c] The liquid nitrogen control valve uses a level set point to determine appropriate valve position to control liquid nitrogen flow into the freezer.

Also, beginning two days prior to the incident, FFG experienced issues when the immersion-spiral freezer was not fully freezing the diced chicken product. FFG employees stopped Line 4 production operations multiple times to troubleshoot the problem. On January 26, 2021, Messer was on-site to witness FFG's attempt to process the diced product. Based on observations that day, the liquid nitrogen level in the immersion freezer was lowered to avoid uneven belt loading, which Messer suspected was causing the freezing issues.

The next day, on January 27, 2021, FFG continued to experience freezing issues. FFG increased the liquid level in the immersion freezer in an attempt to resolve the problem, but this action did not resolve the issue. Subsequently, an FFG maintenance worker reported to management that he believed the liquid nitrogen level was too low. As a result, the manager called Messer for guidance. Messer recommended that FFG further increase the nitrogen level in the freezer and provided FFG with the username and password required to modify this parameter in the system. Production on the immersion-spiral freezer resumed that afternoon and continued through the end of the workday.

2.2 Day of Incident

2.2.1 Liquid Nitrogen Release

On January 28, 2021, operations on Line 4 commenced at approximately 7:16 a.m. Continuing the trend from the previous days, soft, partially-frozen chicken product was observed coming out of the immersion-spiral freezer. As a result, Line 4 stopped processing chicken at approximately 8:14 a.m. so that maintenance personnel could troubleshoot the issue. At approximately 8:20 a.m., the Line 4 Packaging Supervisor[a] instructed the Line 4 workers to go on break while maintenance workers attempted to resolve the freezing issue. The maintenance workers conducted the maintenance without shutting down the freezer and with the transition box door and immersion freezer lid safety switches intentionally bypassed.

The U.S. Chemical Safety and Hazard Investigation Board (CSB) determined that, likely while the Line 4 workers were on break, the bubbler tube in the immersion freezer somehow became bent, thereby preventing the freezer's liquid nitrogen level control system from working properly (described further in Section 3). The liquid nitrogen level then increased in an uncontrolled manner, and liquid nitrogen overflowed from the immersion freezer, filling the freezer room with vaporized nitrogen that displaced the room's oxygen.

After about 20 minutes, at approximately 8:40 a.m., the Line 4 workers returned from break. At this time the workers noticed a cloud of white fog coming from the Line 4 freezer room but took no further action. According to one employee, because workers regularly observed white fog in the freezer room, they did not believe there was a problem. By 9:40 a.m., having not heard from the Line 4 Packaging Supervisor for over an hour, one of the Line 4 workers decided to look for him. The Line 4 worker entered the Line 4 freezer room through an elevated opening,[b] pictured in **Figure 3** and **Figure 9**.

---

[a] The Line 4 Packaging Supervisor was later found fatally injured.

[b] Chicken enters the freezer room via conveyor belt through this opening. The bottom edge of this opening is elevated approximately 4 feet and 9 inches above the freezer room floor. This opening was not intended for human use as a passageway and was intended only to allow for the conveyor belts to enter the freezer room, and to allow for some make-up ventilation. The Line 4 worker crouched down and crawled through the opening.

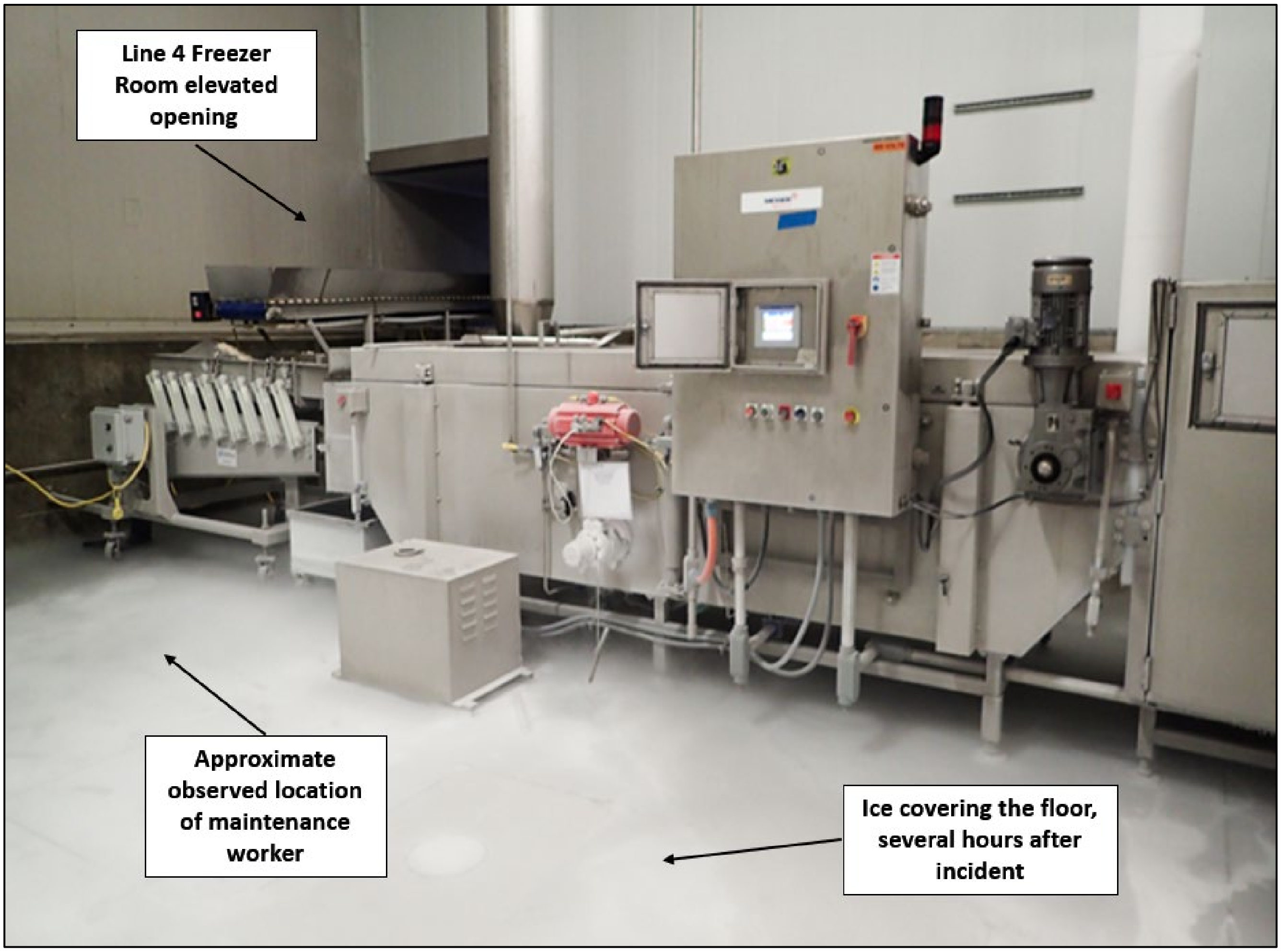


Figure 9. Line 4 immersion-spiral freezer in Line 4 freezer room several hours after the incident. (Credit: Hall County Fire Services, annotations by CSB)

The Line 4 worker observed a dense white cloud approximately four feet high filling the room.[a] She also saw one of the maintenance workers lying motionless on the ground in front of the conveyor belt. The Line 4 worker exited the freezer room by crawling back through the elevated opening and returned to where the other Line 4 workers were congregated in the RTE area. She informed the other workers of what she saw and then crawled through the elevated opening again, this time with another worker to confirm her observations. The Line 4 workers again returned to the area where the other workers were congregated and then left to locate the Line 1 Packaging Supervisor to inform him about what they had observed.

2.2.2 Incident Response

Because FFG did not have a surveillance system, the only evidence available to the CSB to use to reconstruct response activities were the firsthand accounts of the employees who were not fatally injured during the

[a] Cold nitrogen gas could create a fog cloud of condensed moisture in the air. This white cloud may obscure visibility [7].

incident. The CSB was not able to fully account for the actions of the six fatally injured employees and was also not able to fully establish the chronological order of the events employees described.

At approximately 9:55 a.m., upon hearing what the Line 4 workers saw in the freezer room, the Line 1 Packaging Supervisor escorted the Line 1 and Line 4 workers from the building.[a] The Line 1 Packaging Supervisor was subsequently seen re-entering the building.[b] Around the same time, other line supervisors began evacuating the rest of the Plant 4 employees from the building and notified management about the emergency. Approximately 130 workers were evacuated from the building.

During the evacuation, at least 14 FFG employees responded to the Line 4 freezer area to try to determine what happened or attempt rescue efforts. Of the employees that responded to the area, four were fatally injured, three were seriously injured, and at least seven sustained minor injuries or were uninjured.

After hearing about an issue in the Line 4 freezer room, the Production Logistics Manager proceeded to the area and discovered the Line 4 Packaging Supervisor unconscious in the shipping area adjacent to the Line 4 freezer room. The Production Logistics Manager attempted to move the Line 4 Packaging Supervisor to the loading dock but became affected by the nitrogen vapors and retreated to the clean room, which was adjacent to the Line 4 freezer room. The Production Logistics Manager leaned against the clean room wall and became unconscious from his exposure to nitrogen.

Around the same time, the Maintenance Manager arrived at the clean room area to assess the situation. He observed a Line 4 production worker lying unconscious on the floor. He bent down and attempted to remove her from the area but was also affected by the liquid nitrogen vapors. He reported stumbling and nearly fainting before retreating to exit the building. Realizing that there was a liquid nitrogen release, the Maintenance Manager and two other FFG employees proceeded to the liquid nitrogen storage tanks located at the front of the building to manually shut off the liquid nitrogen supply.

At 10:11 a.m., the Director of Prepared Foods Operations called 911 to report the incident.[c] During the 911 call, another FFG employee activated the Plant 4 fire alarm near the front of the building. After making the initial 911 call, the Director of Prepared Foods Operations proceeded to the Line 4 freezer room and called the Environmental Health and Safety (EHS)/Wastewater Manager and Senior Vice President of Operations to inform them of the situation. These three managers met and proceeded to the clean room adjacent to the Line 4 freezer room where they discovered the Production Logistics Manager leaning against the wall, unconscious, as well as two other FFG employees (the Line 1 Packaging Supervisor and the Line 4 production worker whom the Maintenance Manager attempted to rescue) lying unconscious on the floor. In response, the three managers pulled the Production Logistics Manager[d] from the clean room to the loading dock at the back of the building.

Firefighters from Hall County Fire Rescue arrived on the scene at around 10:18 a.m., at which time other FFG employees had already moved the Line 4 Packaging Supervisor out of the affected area. Wearing self-contained breathing apparatus (SCBA), the emergency responders entered the Line 4 freezer room and encountered a four-

[a] Line 1 quality assurance records indicate that the last temperature reading was taken at 9:54 a.m.

[b] The Line 1 Packaging Supervisor was later found fatally injured.

[c] The Director of Prepared Foods Operations called 911 after receiving a call from the Production Logistics Manager who had encountered the Line 4 Packaging Supervisor in the shipping area adjacent to the Line 4 freezer room.

[d] The Production Logistics Manager survived the incident but spent two days recovering in the hospital.

foot-tall white cloud that obscured their visibility in the room. Floor temperatures in the room measured less than -100°F (-73°C). Emergency responders pulled the two maintenance workers and the Plant 4 Superintendent[a] from the Line 4 freezer room and subsequently removed the Line 1 Packaging Supervisor and the Line 4 production worker[b] from the clean room. At 10:36 a.m., one of the firefighters activated two of the immersion-spiral freezer's E-stop buttons.

2.3 Incident Consequences

Five FFG employees died at the FFG facility.[c] Another died later, after being taken to the hospital. Following evacuation from the facility, several additional FFG employees experienced symptoms consistent with asphyxiation, including dizziness, headaches, nausea, and fainting. Many of the employees experiencing these symptoms were treated by paramedics onsite; however, seven FFG employees were transported by ambulance and three were transported privately into the local hospital for evaluation and treatment. Of the 10 employees that went to the hospital, six were treated in the emergency room and released later the same day, three were admitted, and one was pronounced dead in the emergency room.

Additionally, four of the five emergency responders who entered the building wearing SCBA were also transported to the hospital after experiencing dizziness, shortness of breath, and abdominal pain. Three of the emergency responders were treated in the emergency room and released the same day; the fourth was released the following day.

Ultimately, the liquid nitrogen release in the FFG Line 4 freezer room fatally injured six FFG employees (the two maintenance workers, the Lines 1 and 4 Packaging Supervisors, the Plant 4 Superintendent, and a Line 4 worker). Autopsy results revealed that all six employees asphyxiated. The incident also resulted in the serious injury of three FFG employees and one firefighter.

Court filings show that after the incident FFG sued its insurance company for damages of roughly \$1.7 million. Messer reported business and property losses of roughly \$245,000.

[a] The Plant 4 Superintendent was seen "late in the 9:00 hour" by the Director of Prepared Foods Operations. According to the Director, the Superintendent entered the Director's office and informed him of "a problem and [that] he was going to go check it out."

[b] This worker was alive but in critical condition when she was removed from the building. She was transported to the hospital and died in the emergency room.

[c] Five of the fatal injuries occurred at the facility; the sixth fatal injury occurred in the emergency room.

3 Technical Analysis

After the incident, the CSB examined the immersion freezer. Part of the examination involved raising the freezer lid and conducting a visual examination inside the freezer. The CSB found the bubbler tube bent, as shown in **Figure 10**.

Figure 10. Immersion freezer bubbler tube, as found during the post-incident examination of the freezer. As designed, the tube should be pointing straight downward. (Credit: CSB)

As discussed previously, the immersion freezer was designed to submerge product in a bath of liquid nitrogen, maintaining a user-specified liquid height in the bath. Messer's predecessor, Linde, designed the immersion freezer with a liquid level measurement device called a bubbler tube.[a] As shown in **Figure 11**, a bubbler tube works by maintaining a constant flow rate of vapor through the tube and into the liquid and measuring the differential pressure between the liquid and atmospheric pressure [11, p. 113]. The immersion freezer control system then used that differential pressure measurement to calculate the liquid level in the bath and would change the position of the liquid nitrogen flow control valve to maintain the liquid level at the user-specified setpoint. Messer also equipped the freezer with a high-level safety interlock that when activated was designed to

[a] Also referred to as a "dip tube" [11, p. 113].

close valves to shut off the flow of additional liquid nitrogen into the freezer, shown below in **Figure 12**. The level control loop and the high-level safety interlock both used the bubbler tube as the input sensor.

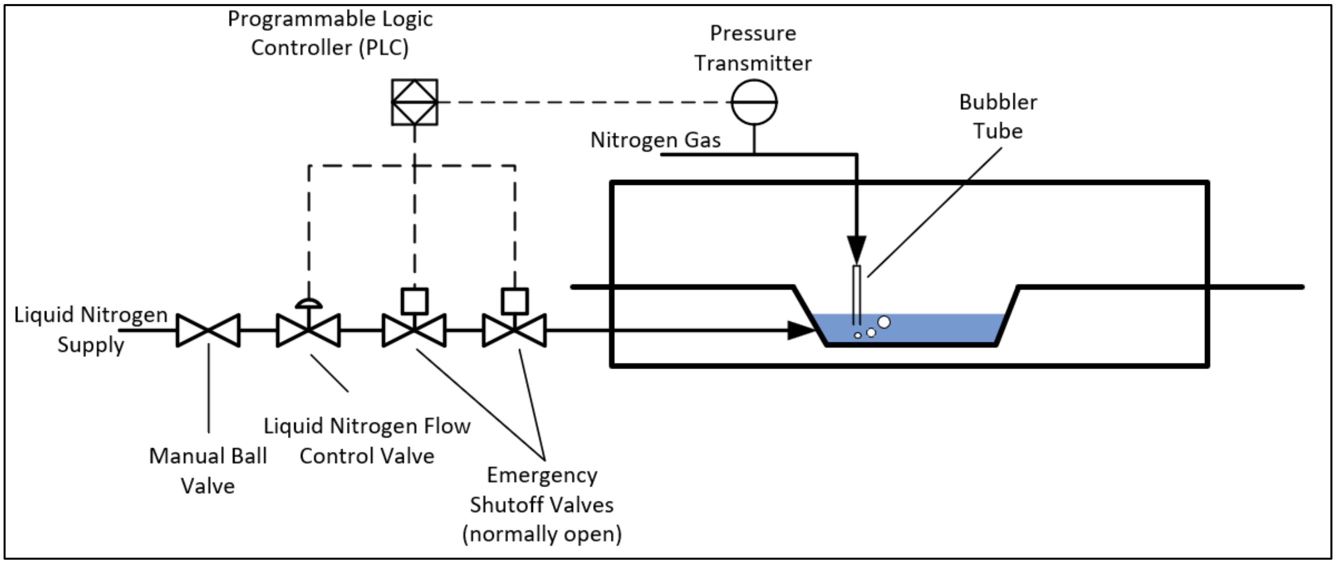


Figure 11. Simplified conceptual diagram of the immersion freezer level control and high-level safety interlock system. Not drawn to scale. (Credit: CSB)

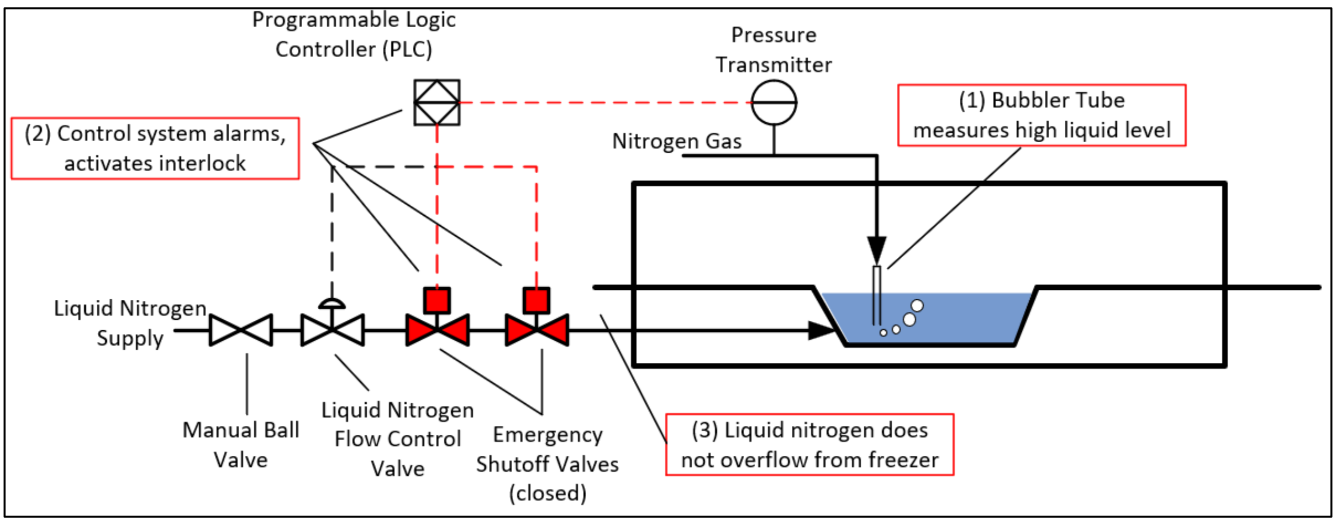


Figure 12. Simplified conceptual diagram showing the normal function of the immersion freezer high-level safety interlock. Not drawn to scale. (Credit: CSB)

The CSB tested the functionality of the immersion freezer level control system after the incident. The test involved filling the immersion tub with water, with the intent of determining 1) whether liquid would overflow from the freezer, 2) the location from which the liquid would overflow, and 3) the position of the tip of the bent bubbler tube relative to the overflow liquid level in the tub.

During the test, the CSB documented the following conditions, pictured below in **Figure 13** and illustrated in **Figure 14**:

- Water overflowed from the inlet side of the freezer.
- The overflow liquid level was lower than the elevation of the tip of the bent bubbler tube.
- The freezer level control system measured no liquid level during the test, and the system called for the maximum flow of liquid for the duration of the test.

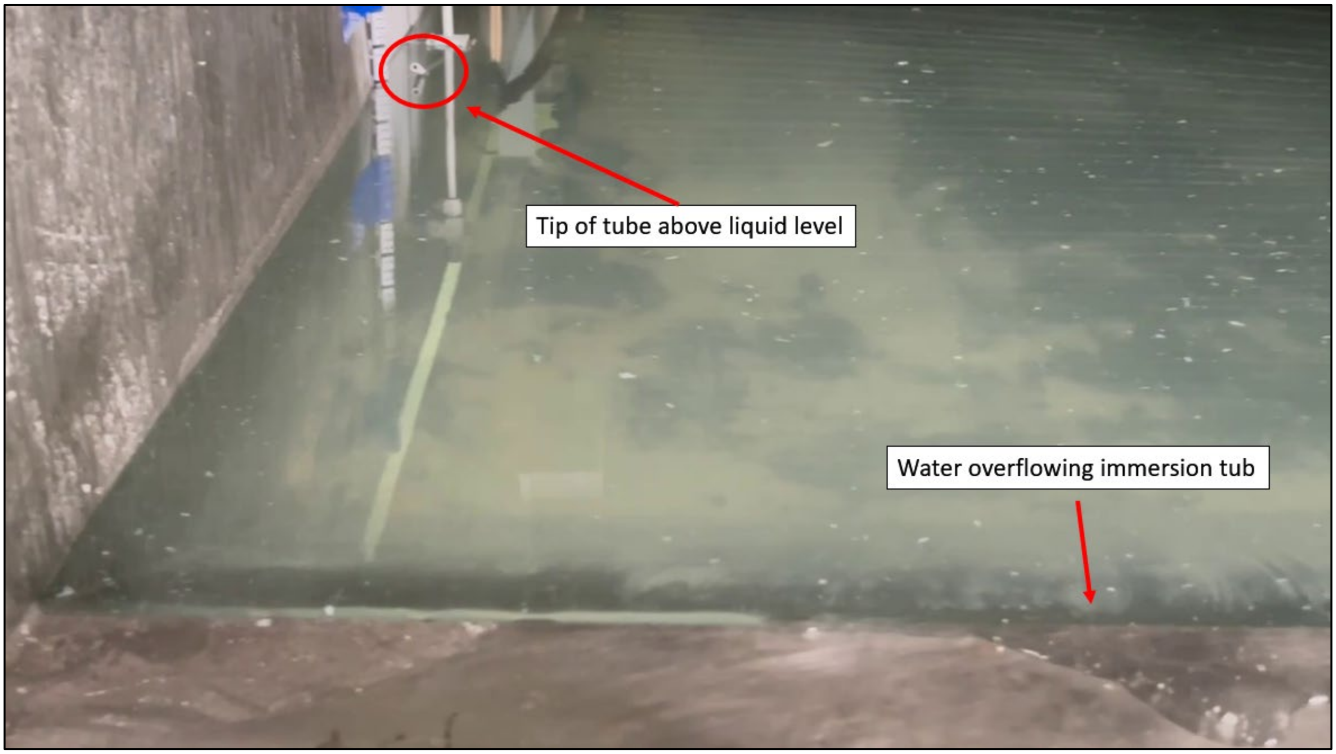


Figure 13. Water overflowing from the immersion freezer tub during post-incident overflow test. (Credit: CSB)

During the incident, because the tip of the tube was bent above the overflow level, the level control system would have incorrectly measured no liquid level and would have continued calling for additional liquid nitrogen even though the immersion tub overflowed. Also, because the level measurement would have been artificially low, the high-level interlock would not have functioned correctly (as illustrated in **Figure 14**). The CSB examined the freezer alarm and event log and confirmed that no high-level event was recorded by the freezer control system during the incident. The CSB concludes that liquid nitrogen overflowed from the immersion freezer. The liquid nitrogen overflow was caused by the failure of the freezer's level control and high-level safety interlock systems.

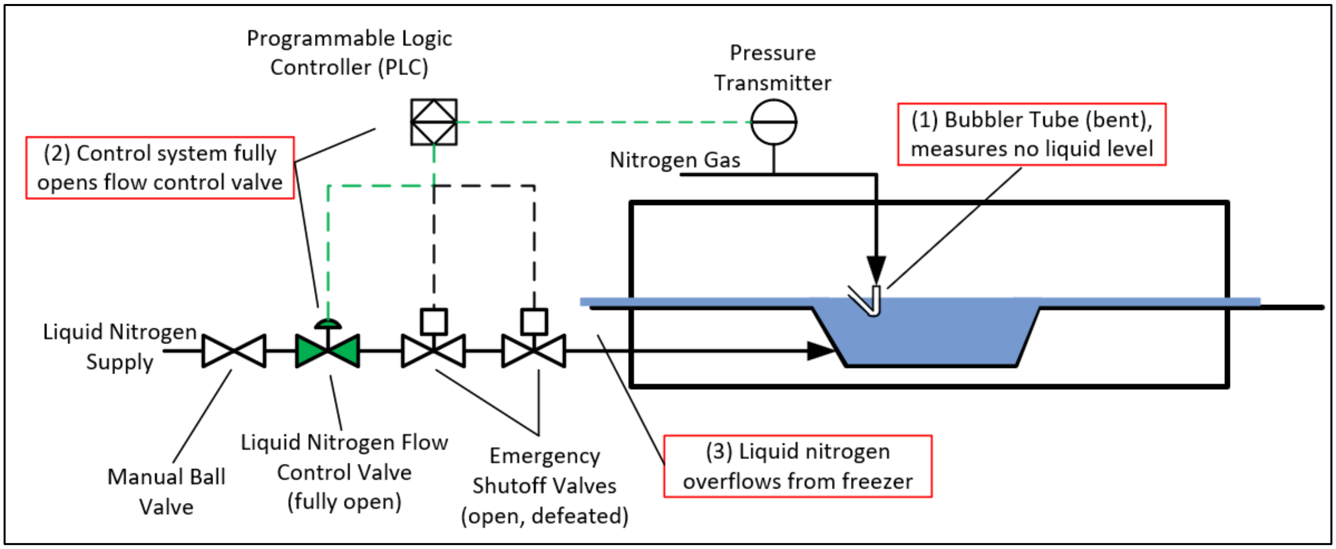


Figure 14. Simplified conceptual diagram showing the failure state of the immersion freezer level control system. Not drawn to scale. (Credit: CSB)

The CSB conducted a second overflow test using an as-designed exemplar bubbler tube in place of the bent incident tube. Both the level control and high-level interlock systems operated as designed (as shown in **Figure 12**), indicating that during the incident there was likely nothing preventing the correct function of any of the level control or interlock equipment other than the bent bubbler tube. The CSB concludes that the failure of the freezer's level control and high-level safety interlock systems was caused by the deformation of the bubbler tube.

The immersion freezer level control system operated as designed (and the freezer did not overflow) in the days leading up to the incident including up until 8:14 a.m. on the morning of the incident when production was stopped and the freezer was turned over to maintenance. Therefore, the CSB concludes that the bubbler tube was likely bent on the morning of the incident during maintenance troubleshooting activities, likely between 8:20 a.m. and approximately 9:30 a.m. However, there was insufficient evidence to determine exactly when the tube was bent. Therefore, the CSB was not able to determine precisely when the uncontrolled release began.

There was insufficient evidence to determine how the bubbler tube was bent. The CSB considered several competing hypotheses, including 1) intentional or unintentional human manipulation of the tube by hand or using various tools, 2) frozen product impacting the tube and bending it over time, and 3) a mass of frozen product becoming wedged between the tube and the wall of the immersion freezer or the conveyor belt.

Various hypotheses were tested extensively by the CSB, Messer, and FFG. Though several of the tests produced results similar to the as-found condition of the incident tube, none of the tests reproduced the exact state in which the incident tube was found (such as the degree of the bend, the direction of the bend, or the presence or absence of certain "witness marks," which are specific impressions such as scratches and dents left in the metal). As a result, the CSB was not able to definitively determine how the tube was bent.

There was also insufficient evidence to determine the actions that the two maintenance workers took during their troubleshooting efforts, or the sequence of events that took place in the freezer room between when the freezer was turned over from operations to maintenance and when the Line 4 workers first identified the emergency. Because it was impossible to determine 1) when and how the tube was bent, 2) what actions the maintenance workers took, 3) whether the workers were aware of the bent tube, 4) whether the workers were aware of the rising level of liquid nitrogen in the freezer, or 5) whether they were aware of the hazard that the rising liquid level presented, the CSB could not determine whether the two maintenance workers had sufficient awareness, time, and ability to avert the release by activating an E-stop or to escape the room safely prior to the loss of containment. Messer trained the workers to operate and maintain the freezer, and thus the workers may have been able to recognize the freezer's improper function and may have been able to activate an E-stop to avert the overflow. Ultimately, however, the CSB could not determine whether the workers were aware of the impending release, and the workers did not activate an E-stop or escape the room.

The Maintenance Manager told the CSB that he manually closed the liquid nitrogen bulk storage tank discharge valves (Section 2.2.2), but he was unable to identify at what time he did so. Based on his and others' accounts of events, and a 911 call he made at 10:18 a.m., the CSB estimates that the Maintenance Manager closed the valves at approximately 10:15 a.m.[a] The CSB concludes that the uncontrolled release of liquid nitrogen likely ceased at approximately 10:15 a.m. when the bulk storage tank manually-operated discharge valves, located outside the building, were closed.

Messer reported that roughly 6,300 gallons of liquid nitrogen flowed to the Line 4 immersion-spiral freezer combination between 8:21 a.m. and 10:51 a.m.[b] Not all the liquid nitrogen flow that Messer reported would have released, as the system split the total flow between the immersion and the spiral freezers. The CSB concludes that at most, approximately 6,300 gallons (approximately 42,400 pounds) of liquid nitrogen released from the FFG Line 4 immersion freezer, though the actual released quantity was likely less. There was insufficient evidence to determine the exact quantity of released liquid nitrogen because it was not possible to determine when the release began.

The Georgia Bureau of Investigation determined that all six fatally injured employees asphyxiated. As discussed in Section 1.4, the freezer room was partially recessed, nearly fully enclosed below five feet of elevation, and the room was ventilated only by the building's make-up air system. Cold nitrogen vapors are heavier than air, and numerous employees and first responders reported seeing a thick, visible cloud of vapor roughly four to five feet high in the freezer room.[c] The CSB concludes that the released liquid nitrogen vaporized, collected in the freezer room, and produced an oxygen-deficient atmosphere inside the room.

[a] The freezer event log shows that the E-stop was activated at 10:36 a.m., and so at the latest, the uncontrolled flow of liquid nitrogen to the immersion freezer would have ceased at 10:36 a.m. when the E-stop was activated.

[b] A mass flow meter measured and totalized the liquid nitrogen flow once every 30 minutes.

[c] Because nitrogen is not visible, the cloud seen by witnesses was the result of moisture in the air condensing due to the reduced temperature caused by the release.

4 Safety Issues

The following sections discuss the safety issues contributing to the incident, which include:

- Single Point of Failure (Section 4.1);
- Atmospheric Monitoring and Alarm Systems (Section 4.2);
- Emergency Preparedness (Section 4.3);
- Process Safety Management System (Section 4.4); and
- Product Stewardship (Section 4.5).

4.1 Single Point of Failure

Processes and equipment handling hazardous chemicals should be robust enough such that the failure of a single component does not result in a catastrophic incident. Regardless of how the bubbler tube became bent, designing the freezer to avoid this single point of failure could have prevented this incident.

The CSB found that the freezer was not designed according to industry good practice guidance, that Linde's design-phase process hazards analysis (PHA) did not identify the single-point failure, and that during fabrication of FFG's immersion freezer, Messer did not detect a manufacturing defect—a missing second clamp meant to secure the bubbler tube to the freezer—that exacerbated the bubbler tube's vulnerability to deformation.

4.1.1 Single Point of Failure

The design of the immersion freezer involved in the incident was such that the bubbler system used a single bubbler tube device to measure liquid level, thus making the bubbler tube a safety-critical device. The bubbler tube was the sole input to both the level control loop and the high-level safety interlock, which was configured to stop the flow of liquid nitrogen to the immersion freezer in the event that the liquid reached an unsafe level.[a] As a result, as shown above in **Figure 14,** when the bubbler tube was bent to the point where the end of the tube was higher than the overflow level for the freezer, the liquid nitrogen level control system was unable to detect or modulate the level of liquid in the freezer, and the high-level safety interlock designed to prevent overflow from the equipment was defeated. The CSB concludes that the immersion freezer was designed such that the failure of a single level measurement device could defeat both the nitrogen level control system and the emergency interlock intended to stop nitrogen flow to the freezer. After the bubbler tube was bent, there was nothing to prevent the nitrogen release from the freezer.

In general, systems should not be designed with single points of failure since, by definition, there would be no other redundant or independent safety system available in case of failure. There are several industry guidance documents that discuss this topic. The Center for Chemical Process Safety (CCPS) *Guidelines for Safe and Reliable Instrumented Protective Systems* explains the decision-making processes for the management of instrumented protective systems throughout a project's life cycle [12].

The "Understanding Failure" section of the guidelines contains a discussion on common cause failure, a term used to describe random and systematic events that cause multiple devices, systems, or layers to fail simultaneously [12, p. 322]. According to the CCPS, there are essentially two types of common cause failures: 1) single points of failure where one malfunctioning device causes an instrumented protective function[b] failure, and 2) single events that lead to multiple failures in a redundant subsystem [12, p. 323]. Single point of failure events can occur due to systematic failure events that result from human error or random failure events [12, p. 323]. These random failures are typically managed using redundancy and other means [12, p. 323]. Additionally, the International Society of Automation (ISA)[c] Standard 61511 *Functional Safety – Safety*

[a] The high-level safety interlock was responsible for discontinuing the flow of liquid nitrogen to the immersion freezer in the event that level feedback input exceeded the set deviation limit.

[b] Instrumented protective function is a safety function designed to achieve a safe state for a specific hazardous event.

[c] The ISA is a non-profit professional association of engineers, technicians, and management engaged in industrial automation.

Instrumented Systems for the Process Industry Sector contains similar guidance regarding single points of failure [13].

Redundant or independent safety systems, such as additional bubbler tube sensors, or another technology to detect the presence of a high liquid level independent of the bubbler tube, could have prevented the release of liquid nitrogen regardless of the damage to the bubbler tube.

The CSB concludes that Linde did not design the immersion-spiral freezer in accordance with industry guidance regarding single points of failure for instrumented systems. Had Linde or Messer included additional independent safeguards to protect against overflow events, this incident could have been prevented.

KEY LESSON

Processes and equipment that utilize hazardous materials should be designed robustly enough that the failure of a single component cannot result in a catastrophic incident.

4.1.2 Linde's Design-Phase PHA

Prior to the Messer-Linde acquisition in 2005, Linde performed a PHA on the general immersion-spiral freezer design. The CCPS defines a PHA as an organized effort to identify and evaluate hazards associated with processes and operations to enable their control [14]. According to CCPS, a PHA generally involves the use of qualitative techniques to identify and assess the significance of hazards, followed by the development of conclusions and recommendations to address the hazards. In addition to PHAs conducted on processes that are already installed and operating, a PHA is often conducted during the design phase of a project in an effort to identify potential hazards and the need for additional safeguards prior to fabricating the equipment.

4.1.2.1 Insufficient Safeguards

According to the completed PHA, potential process deviations for the immersion-spiral freezer identified by the PHA team included high flow, high level, and loss of containment, among other deviations. Regarding causes of these deviations,[a] the PHA lists several potential issues, including failure of the bubbler system, which could consequently result in the release of liquid nitrogen from the immersion freezer. The safeguards identified to mitigate the potential "bubbler failure" and other identified causes included a high-level alarm for the immersion freezer, a low temperature alarm/shutdown, the assumed presence of atmospheric monitoring equipment, and maintaining a preventative maintenance schedule on the components (**Figure 15**).

[a] Potential causes of loss of containment from the immersion freezer and high level in the immersion freezer are linked to the potential causes of high flow in the immersion freezer, which include temperature control system malfunction, I/P failure or miscalibration, equipment malfunction – actuated supply/control valve, equipment malfunction – bubbler failure, and improper calibration of the control valve.

Item	Deviation	Causes	Consequences	Safeguards
1.1	High flow	Temperature control system malfunction I/P failure/miscalibration Equipment malfunction - actuated supply/control valve Equipment malfunction - bubbler failure Improper calibration of control valve	Release of nitrogen outside freezer	High level alarm for immersion freezer Low temperature alarm/shutdown Atmospheric monitoring outside freezer
			Asphyxiation	
			Personal injury	
			Reduced visibility	
			Loss of Production/damaged product	
			Low temperature (linked to 1.6)	
			Low temperature - Exhaust (linked to 2.6)	
			Loss of containment (linked to 1.12)	
			Equipment damage	
			High level - Immersion freezer (linked to 1.7)	

Figure 15. Excerpt from Linde PHA showing connection between failure and safeguards. (Credit: Messer, annotations by CSB)

Generally, a high-level alarm is a logical safeguard to prevent high flow, high level, and/or loss of containment. However, in the event of the failure mode that occurred in this incident, it was ineffective because the damage to the bubbler tube effectively disabled both the level control loop and the high-level safety alarm. Consequently, the high-level alarm and interlock could not serve as a safeguard, as Linde intended. Further, the only other identified safeguard against bubbler failure was the presence of atmospheric monitoring outside the freezer, which FFG did not have. Even if FFG did have monitoring and alarm equipment, such systems could not have prevented the damage to the bubbler system or liquid nitrogen from overflowing from the freezer; it could only have reduced the severity or consequences of a release.

The CSB concludes that Linde did not adequately consider the failure of the liquid nitrogen level control system and did not identify appropriate safeguards to mitigate the potential failure. In essence, Linde incorrectly identified the bubbler tube as a safeguard for itself.

4.1.2.2 PHA Technique

The CCPS publication *Guidelines for Hazard Evaluation Procedures* discusses risk-based determination of the adequacy of safeguards identified using scenario-based hazard evaluation [15]. According to these guidelines, safeguards should be analyzed to determine whether they are adequate to mitigate potential failures. Determining the adequacy of safeguards is generally done by analyzing the risk associated with one scenario at a time. The guidelines state:

> The common element […] is the development of incident scenarios that are more or less detailed time-sequence descriptions of unique initiating cause/loss event combinations, sometimes termed “cause-consequence pairs.” Each initiating cause might lead to more than one loss event […]; likewise, a given loss event […] might have various possible initiating causes. However, it is unique initiating cause/loss event combinations that form the scenarios of interest […] [15, p. 213].

Grouped Scenario Causes

Linde did not evaluate unique cause-consequence scenarios in its design-phase PHA. Instead, Linde grouped potential causes of the identified process deviations together. This makes it inherently difficult to determine the sequence of events leading from each cause to the consequence. In the absence of a clear sequence of events, potential consequences and safeguards identified to protect against the impacts can vary depending on how the scenario develops.

For example, “Improper calibration of control valve” and “Equipment malfunction – bubbler failure” can both result in excess liquid nitrogen being introduced into the immersion freezer, resulting in an overflow of liquid nitrogen. However, the safeguards to protect against each of the causes would be different (**Figure 16**). In the case of a control valve malfunction, the high-level alarm/safety interlock would likely identify the hazard and shut off liquid nitrogen supply to the freezer using separate shutoff valves, as shown in blue in **Figure 16**.

Yet, in the event of a bent bubbler tube, as was the failure mode in this incident, both the level control device and high-level alarm/safety interlock would lose the ability to detect liquid nitrogen level in the immersion freezer (illustrated in **Figure 14**). Therefore, the high-level alarm/safety interlock would not have been a valid safeguard for the failure of the bubbler panel system or a bent bubbler tube, as shown in red in **Figure 16**. By grouping potential causes together in this manner, a PHA team can lose sight of which safeguards protect against which causes.

Item	Deviation	Causes	Consequences	Safeguards
1.1	High flow	Temperature control system malfunction I/P failure/miscalibration Equipment malfunction - actuated supply/control valve Equipment malfunction - bubbler failure Improper calibration of control valve	Release of nitrogen outside freezer	High level alarm for immersion freezer Low temperature alarm/shutdown Atmospheric monitoring outside freezer No identified safeguard
			Asphyxiation	
			Personal injury	
			Reduced visibility	
			Loss of Production/damaged product	
			Low temperature (linked to 1.6)	
			Low temperature - Exhaust (linked to 2.6)	
			Loss of containment (linked to 1.12)	
			Equipment damage	
			High level - Immersion freezer (linked to 1.7)	

Figure 16. Excerpt from Linde PHA showing connection between failure, consequence, and safeguards. (Credit: Messer, annotations by CSB)

Generic Scenarios

There was also a lack of specificity in the causes identified in the PHA. For instance, the PHA generically listed "Equipment malfunction – bubbler failure" as a cause of high flow, high level, and/or loss of containment from the immersion freezer. However, there are several potential failure modes that could cause the bubbler tube to fail to provide an accurate measurement to the level control loop and the high-level alarm/safety interlock. For example, there could be incorrect pressure of the gaseous nitrogen being supplied to the bubbler tube, there could be a leak in the fittings, the tubing could be plugged with solids, or the end of the bubbler tube could be bent and not fully submerged in the liquid nitrogen, as was the case in this incident. Being specific with cause descriptions would allow the PHA team to fully understand each scenario and analyze which safeguards would be expected to function correctly in a particular scenario, and which could not be relied upon due to a common-mode failure.

The CSB concludes that Linde did not identify specific incident scenarios or cause-consequence pairs when conducting the PHA for the immersion-spiral freezer, which resulted in Linde's failure to identify adequate safeguards to protect against the overflow of liquid nitrogen from the immersion freezer.

4.1.3 Manufacturing Quality Control

The immersion freezer[a] involved in this incident was fabricated in early 2016.[b] Once fabrication of the immersion freezer was complete, the fabrication team[c] completed a Quality Control inspection of the equipment to ensure that it was fabricated in accordance with design specifications. Following completion of this Quality Control inspection, the immersion freezer remained in Messer's possession until FFG agreed to lease the freezer from Messer in July 2020. Once FFG committed to leasing the equipment, Messer performed a "functional checkout" of the immersion freezer in August 2020.

As discussed in Section 1.2, installation of the Line 4 immersion-spiral freezer began on December 5, 2020, and was complete by December 16, 2020.

According to design specifications, the bubbler tube should have been secured to the interior wall of the immersion freezer with two support clamps (**Figure 17**). Following the incident, however, the CSB found that only one support clamp had been utilized to secure the bubbler tube to the interior of the immersion freezer (**Figure 18**).

[a] Model no. KFI 38-13

[b] The immersion freezer was fabricated for Linde by SWF Industries.

[c] Linde originally inspected the immersion freezer; Messer later acquired Linde. See Section 1.1.2 for more details on the Linde/Messer relationship.

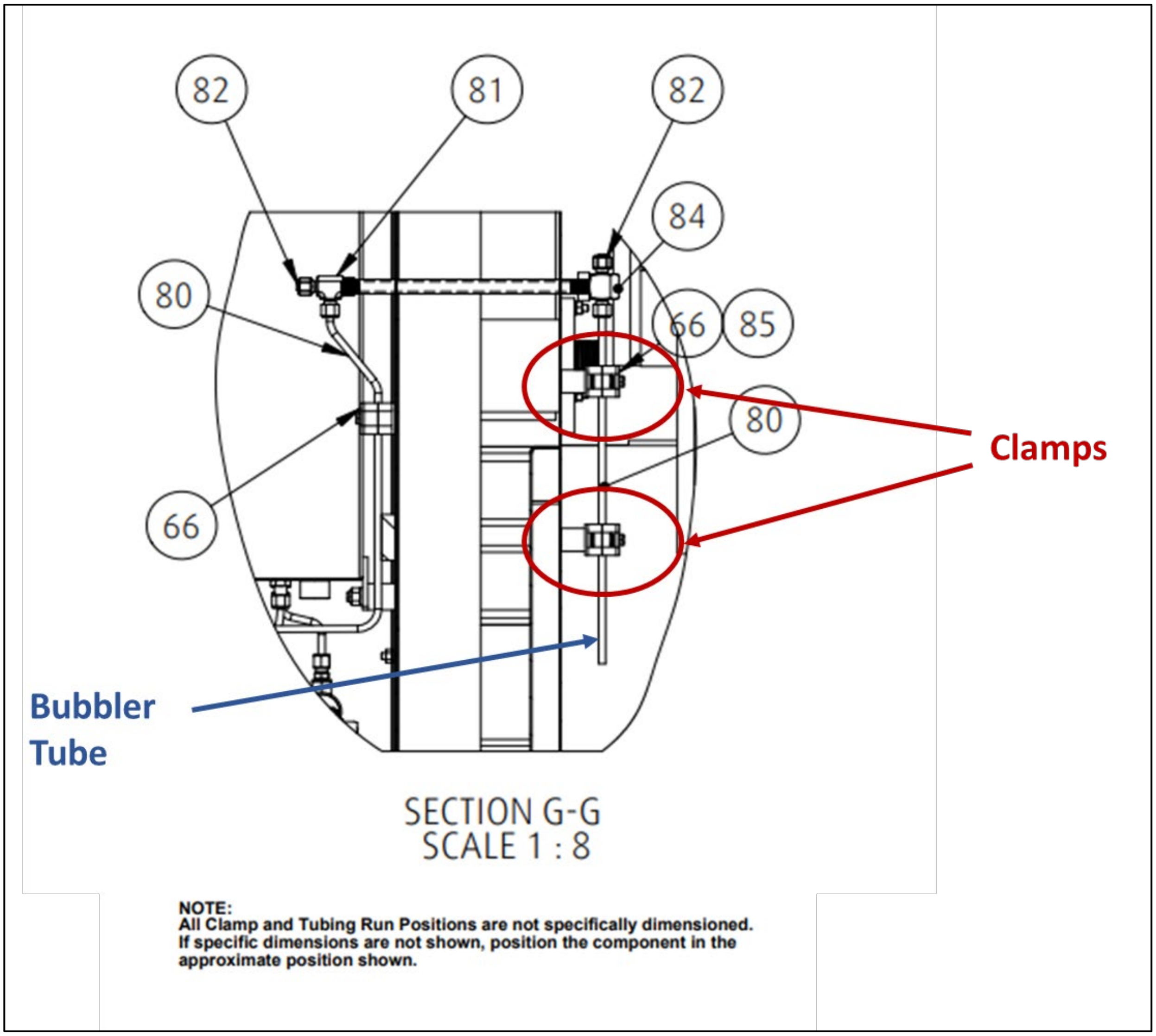


Figure 17. Excerpt from piping layout drawing showing the two clamps on the bubbler tube. (Credit: Messer, annotations by CSB)

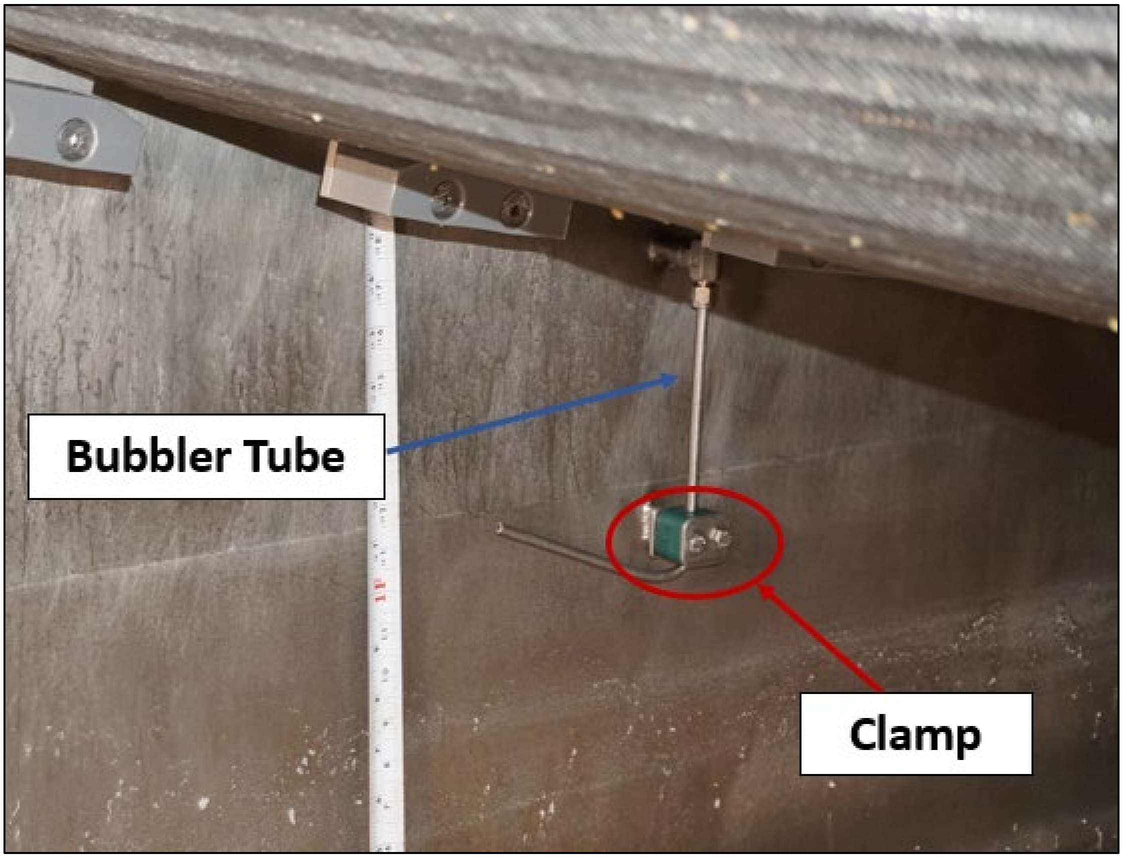


Figure 18. Photo of bubbler tube secured to immersion freezer tub with one clamp. (Credit: CSB)

The missing support clamp was not identified in June 2016 when the initial Quality Control inspection of the equipment was completed post-fabrication. The Quality Control Checkout form for the immersion freezer includes a *Bubbler Panel and Pan Purge* section with several line item verifications related to the equipment. One line item contained in this section directs the user to “check that all support clamps are in place.” The completed form from June 2016 indicates that this line item was verified at the time of inspection (**Figure 19**).

BUBBLER PANEL and PAN PURGE

1.	Check components and assembly against system drawing	✓	✓
2.	Check that the pressure regulator, back pressure regulator, vacuum breaker and check valves are installed properly. See figure 2-2	✓	✓
3.	Check that all support clamps are in place	✓	✓
4.	Purge the freezer inner pan/outer pan annular space as follows: NOTE: This must be completed before any N_2 is introduced into the tub a. Loosen the handle lock nut on the back pressure regulator (92) and turn the handle counter	✓	✓

Figure 19. Excerpt from Messer Quality Control checklist indicating that all support clamps were in place at the time of June 2016 and August 2020 Quality Control inspections. (Credit: Messer, annotations by CSB)

After the incident, the Messer engineer who completed the inspection explained that the only line items related to the bubbler tube assembly on the Quality Control Checkout form were bubbler panel and pan purge components, all of which were located on the exterior of the immersion freezer. As a result, he did not believe that this line item (the one indicated in **Figure 19**) included verification of the presence of the two support clamps on the bubbler tube inside of the freezer. Additionally, he indicated that the line items on the Quality Control Checkout form were meant to be completed in sequential order and that, at this point in the inspection, the lid on the immersion freezer would have been closed.[a] As a result, it would have been impossible to ensure that the two support clamps on the bubbler tube were in place as part of this line item instruction. The Messer engineer indicated that there was no instruction on the Quality Control Checkout form that specifically directed him to verify the presence of the two interior support clamps on the bubbler tube. Additionally, Messer's process did not appear to involve cross-checking the freezer as built against the engineering drawings (excerpted in **Figure 17**). Doing so would have presented another opportunity for the quality control inspector to detect the missing clamp. The CSB concludes that Messer's Quality Control procedures and practices were ineffective in ensuring that the two support clamps on the bubbler tube were in place at the time of inspection. As a result, Messer failed to identify the missing support clamp during Quality Control inspection.[b]

Following this incident, Messer examined another immersion freezer that was fabricated at the same time as the freezer involved in this incident. Inspection of this freezer revealed that, similar to the freezer involved in the incident, the bubbler tube was secured to the interior of the freezer by a single support clamp. The bubbler tube was also found to be bent, though to a lesser degree than the bubbler tube in the freezer at FFG.

Messer later completed a survey of 14 additional immersion freezers to determine whether the bubbler tubes in any of these freezers were either bent or damaged, or secured using a single clamp configuration. As a result of this survey, Messer discovered two additional damaged bubbler tubes, both of which were secured by two support clamps, as designed. No other single support clamp configurations were identified.

While any length of unsecured tubing is susceptible to physical damage and movement, the combination of unsecured tubing length and support clamp location directly affects to what degree the tubing can be bent. Consequently, the CSB concludes that the combination of unsecured tubing length and support clamp location worsened the potential for the bubbler tube to become bent, which ultimately resulted in the bubbler system becoming non-functional.[c]

4.1.4 Messer Post-Incident Actions

Following the incident, Messer implemented several changes to its existing immersion freezer design. The changes are intended to provide additional layers of protection against the possibility of an overflow of liquid nitrogen. Among the additional layers of protection are 1) a dual bubbler panel system with two independent bubbler tubes, constructed of schedule 80 piping to provide increased resistance to displacement, 2) an external resistance temperature detector (RTD) located on the horizontal portion of the freezer inlet, intended to detect

[a] The lid is not raised until two sections later in the QC procedure in the "Hydraulic Power Unit" section.

[b] After the incident, Messer revised its Quality Control process and procedures to require verification of the presence of the bubbler tube clamps and reordered the sequence of inspection steps to facilitate this verification. Consequently, the CSB makes no recommendation to Messer regarding its Quality Control process.

[c] After the incident Messer revised its freezer design such that it now includes multiple layers of protection against liquid nitrogen overflow. Consequently, as noted below, the CSB makes no recommendation to Messer regarding the design of its immersion freezers.

the presence of cryogenic liquid and activate safety interlocks, 3) changes to the programmable logic controller to accommodate for the additional bubbler panel and RTD, and 4) vaporization of liquid nitrogen to gaseous nitrogen for use in the bubbler systems at the bulk storage tanks rather than at the freezer equipment.

Because Messer's freezer design now includes multiple layers of protection against liquid nitrogen overflow, the CSB makes no recommendation to Messer regarding the design of its immersion freezers.

Messer has also revised its Quality Control process and procedures to require verification of the presence of the bubbler tube clamps and re-ordered the sequence of inspection steps to facilitate this verification. Therefore, the CSB makes no recommendation to Messer regarding its Quality Control process.

4.2 Atmospheric Monitoring and Alarm Systems

Atmospheric monitoring and alarm systems provide important mitigative protection against hazards in the atmosphere when preventive measures fail to contain the hazardous materials inside a process. Fixed atmospheric monitoring and alarm systems are essential for preventing people from entering unsafe environments, such as areas affected by uncontrolled liquid nitrogen releases. To effectively implement these safety-critical systems, it is necessary to assess application-specific and site-specific conditions.

Liquid nitrogen rapidly expands when it evaporates, and in a poorly ventilated area, nitrogen gas can quickly displace oxygen, creating an oxygen-deficient atmosphere (Section 1.6.1). When people breathe in air that does not have enough oxygen, immediate effects, including unconsciousness after only one or two breaths, and ultimately death, can occur (Section 1.6.2). The exposed person has no warning and cannot sense that the oxygen level is too low [8, p. 2]. Therefore, active monitoring of the oxygen concentration in areas where oxygen deficiency may occur, with an associated audible and visual alarm to alert people to the hazard, is a common and effective strategy to prevent worker exposure to hazardous atmospheres [16, p. 68].

4.2.1 Atmospheric Monitoring and Alarms at FFG

Absence of monitoring and alarms on Line 2

FFG had operated a liquid nitrogen spiral freezer on Line 2 beginning in May 2020 (Section 1.2). FFG and Messer divided their responsibilities according to the chart shown in **Figure 5** (Section 1.5). The task responsibility chart did not specifically mention atmospheric monitoring.

During the Line 2 freezer installation, Messer conducted several training and product stewardship activities with maintenance technicians and the packaging supervisor using a checklist titled the "Food Projects Checklist."[a] The checklist included specific items that each referenced atmospheric monitoring in some way, including:

[a] This checklist documented Messer's customer stewardship practices by providing customer interface with the necessary training and documentation on the equipment and liquid nitrogen.

- transmitting the Safety Data Sheet (SDS)[a] for liquid nitrogen to FFG. The SDS mentioned the use of atmospheric monitoring as a safety precaution;
- discussing the availability of additional resources for safe handling, such as guidance from the Compressed Gas Association (CGA), the National Fire Protection Association (NFPA), and OSHA, each of which, to varying extents, mention the need for atmospheric monitoring;
- submitting Line 2 freezer operation and maintenance manuals to FFG (which mentioned the use of atmospheric monitoring); and,
- a line item directing Messer to discuss atmospheric monitoring with FFG. The checklist box for atmospheric monitoring did not indicate a "Yes" for verification like the others for completion but instead was blank.

This checklist was completed and signed by FFG and Messer on May 19, 2020.

Messer recommended, via its SDS, that its liquid nitrogen customers implement oxygen detection systems at their facilities. The SDS stated that "oxygen detectors should be used when asphyxiating gases may be released" as an appropriate engineering control.

The Line 2 spiral freezer PHA,[b] conducted by a Messer predecessor, identified that a loss of containment of liquid nitrogen could result in oxygen deficiency and personal injury. Among other safeguards, the PHA listed the use of atmospheric monitors as a recommended safeguard. This PHA was not shared with FFG and was not specific to FFG's process and facility, but it shows that Messer had institutional knowledge about the need for atmospheric monitoring.

Despite the actions discussed above, FFG did not install atmospheric monitoring and alarm equipment on the Line 2 liquid nitrogen spiral freezer.

In August 2020, after visiting the FFG plant, a Messer employee emailed the FFG Senior Vice President of Operations to express concern and to highlight the absence of atmospheric monitoring equipment at an area of the plant adjacent to Line 2. The email stated:

> We highly recommend the use of permanently mounted Oxygen […] monitors augmented with the use of personal/portable monitors as part of the plant's safety system.
>
> I have attached a gas monitor letter with recommended manufacturers of monitors.

FFG did not respond to the email.

---

[a] The Hazard Communication Standard (29 CFR 1910.1200(g)), revised in 2012, requires that the chemical manufacturer, distributor, or importer SDSs (formerly MSDSs or Material Safety Data Sheets) for each hazardous chemical to downstream users to communicate information on these hazards. The SDS includes information such as the properties of each chemical; the physical, health, and environmental health hazards; protective measures; and safety precautions for handling, storing, and transporting the chemical.

[b] The PHA was conducted in 2004 by BOC, which was eventually acquired by Linde and subsequently Messer.

Absence of monitoring and alarms on Line 4

When FFG installed the Line 4 immersion-spiral freezer, Messer and FFG documented the same task responsibility chart for Line 4 as they did for Line 2. As with Line 2, the chart included no specific mention of atmospheric monitoring, though several of the tasks included information that mentioned the need. After the incident, FFG management told the CSB that they were unaware of the need for atmospheric monitoring. Conversely, Messer told the CSB, that “it was communicated to them [FFG] that they needed to have an [oxygen] monitor.” Ultimately, neither FFG nor Messer installed atmospheric monitoring and alarm equipment in the Line 4 freezer room or on the freezer equipment.

Messer believed that at the time, it had no legal or contractual obligation to install atmospheric monitoring and alarm systems at FFG; nor did contemporary guidance from the CGA, further discussed below in Section 4.2.2.3, require the use of such systems at FFG (although they were recommended). Contractual or legal obligations aside, in terms of safety, whether it was FFG’s or Messer’s responsibility to install atmospheric monitoring and alarm systems is irrelevant; both companies could have and should have taken action to maximize the safety of the FFG Line 4 freezer operation.

In summary, the CSB concludes that Messer informed FFG of the need for atmospheric monitoring of its liquid nitrogen processes on at least three occasions. Despite Messer’s recommendations, neither FFG nor Messer took action to install monitoring or alarm equipment on the Line 4 process, which could have alerted workers to the presence of an oxygen-deficient atmosphere, and, if designed accordingly, could have triggered an emergency shutdown of the liquid nitrogen systems.

As discussed in Section 1.1.1, Gold Creek currently owns and operates the former FFG facility. As of this report’s publication, there are currently no liquid nitrogen freezing processes at the former FFG Plant 4 building which Gold Creek now operates. Therefore, the CSB does not issue a recommendation to Gold Creek related to atmospheric monitoring or ventilation of liquid nitrogen processes.

4.2.2 Existing Industry Guidance for Atmospheric Monitoring and Alarm Systems

The risk of oxygen-deficient atmospheres is well understood, and there is a wealth of guidance available, discussed below, that if followed, could have helped reduce the severity of this incident.

4.2.2.1 CSB Guidance

In June 2003, the CSB published a Nitrogen Asphyxiation Safety Bulletin.[a] The bulletin states [8, pp. 6-8]:

> The atmosphere in a small, enclosed area may be unfit for breathing prior to entry, or it may change over time, depending on the type of equipment or work being performed. Recognizing this hazard, good practice calls for continuous monitoring of an enclosed area to detect oxygen-deficient atmospheres.

[a] This CSB product, along with a safety video on the same topic, can be located here: Hazards of Nitrogen Asphyxiation | CSB

[…]

Warning and protection devices, if properly installed and maintained, warn workers of hazardous atmospheres.

The safe handling of nitrogen, described above, is effective only if personnel are trained on the importance of atmospheric monitoring equipment—both how to use it and how to determine when it is not working properly. Personnel should be trained on how to properly respond and evacuate in the event of failure of the system.

4.2.2.2 CCPS Guidance

The CCPS book *Continuous Monitoring for Hazardous Material Releases* provides guidance on the use of indoor atmospheric monitoring [17, pp. 63-64]:

> There are occasions when process equipment must be located indoors due to weather-related or quality control issues. Combustible [and oxygen][a] gas detection should be provided in these buildings […]. This detection should be configured to:
>
> - Send an alarm signal to a continuously manned location
> - Activate visible and audible alarm devices on the exterior of the building at each entranceway and within the structure. The devices within the structure should be configured using the guidance for fire alarm devices, as provided in NFPA 72, *National Fire Alarm and Signaling Code*
>
> In some cases, it may also be advantageous for the detection system to initiate an automatic shutdown and/or isolation of the potential release sources within the structure. […] In many cases, remote-operated shutdown and isolation systems and/or remotely located isolation means will suffice.[b]

4.2.2.3 Compressed Gas Association Guidance

The CGA has numerous guidelines and publications that address many aspects of the safe handling of industrial gases, including the safe handling of cryogenic liquids, storage of compressed gases in containers, and oxygen-deficient atmospheres.

[a] Although this excerpt concerns atmospheric monitoring for combustible gases, the guidance is equally applicable to toxic gases or to oxygen-deficiency hazards.

[b] The ISA Technical Report *ISA-TR84.00.07, Guidance on the Evaluation of Fire, Combustible Gas, and Toxic Gas System Effectiveness* [55] offers actionable guidance on the design and implementation of atmospheric monitoring and automated emergency shutdown systems.

CGA P-12 Guideline for Safe Handling of Cryogenic and Refrigerated Liquids

CGA P-12 is intended to provide "general information about the properties, transportation, storage, safe handling, and safe use of the cryogenic and refrigerated liquids commonly used by industry and institutions. It is intended for cryogenic and refrigerated liquid users, shippers, carriers, distributors, equipment designers or installers, safety administrators, and anyone seeking an introduction to cryogenic and refrigerated liquids [18, p. 1]."

At the time of the incident, the standard stated:

> If low oxygen atmospheres are possible, installation of analyzers equipped with alarms **should be** used to monitor the oxygen content. Whenever personnel enter enclosed areas, the breathing atmosphere shall be constantly monitored by appropriate instrumentation [5, p. 17] (emphasis added).

In January 2023, CGA issued the seventh edition of CGA P-12, which updated the following language concerning oxygen monitoring from "should be" to "shall be" [18, pp. 8, 11]:[a]

> Areas where an oxygen-deficient atmosphere can occur **shall be** monitored by an area monitoring system, [personal atmospheric monitoring systems],[b] or a combination of the two as determined by a hazard assessment [18, p. 8] (emphasis added).
>
> If low oxygen atmospheres are possible as determined by a hazard assessment, installation of analyzers equipped with alarms **shall be** used to monitor the oxygen content. Whenever personnel enter enclosed areas, the breathing atmosphere shall be constantly monitored by appropriate instrumentation [18, p. 11] (emphasis added).

CGA P-18 Standard for Bulk Inert Gas Systems

According to the CGA:

> This standard contains minimum requirements for locating/siting, selecting equipment, installing, starting up, maintaining, and removing bulk inert gas supply systems [19, p. 1].

The CGA defines the boundary of a bulk inert supply system:

> The bulk inert supply system terminates at the source valve, where the gas or liquid supply first enters the supply line [19, p. 1].

[a] The change in this guideline from "should be" to "shall be" was made after the FFG incident in 2021.

[b] Personal atmospheric monitoring systems are typically body-mounted or hand-held atmospheric monitoring equipment, as opposed to fixed or permanently mounted atmospheric monitors.

The standard states:

> Indoor areas where bulk inert gas systems are installed **shall be** continuously monitored with an atmosphere monitoring system. The system shall provide an audible and visual alarm when the oxygen level drops to 19.5%. The alarm shall be located inside the area and immediately outside of all entrances to the indoor area. The atmosphere monitoring system also shall send a signal to a central monitoring station or a continuously occupied location if one is provided on-site. Design of the monitoring system shall allow for routine testing to demonstrate functionality [19, p. 17] (emphasis added).

It should be noted that this requirement applies to bulk storage systems that are installed indoors, and not to application equipment such as FFG's immersion freezer, or to bulk storage systems installed outdoors, as was the case at FFG. However, CGA P-18 is among the many pieces of guidance issued by the CGA highlighting the importance of using atmospheric monitoring when the potential for an oxygen-deficient atmosphere exists.

CGA P-76 Hazards of Oxygen-Deficient Atmospheres

Relevant guidance from CGA P-76 includes:

> In processes where cryogenic liquids are handled and vaporization takes place, care shall be taken to avoid situations where personnel are exposed to oxygen deficiency [6, p. 5].

The standard contains a list of examples of such spaces, and among the various examples, rooms containing liquid nitrogen food freezers are explicitly identified [6, p. 5].

> There are a number of situations where the need for ventilation or atmospheric monitoring shall be assessed in order to avoid asphyxiation incidents from inert gases and/or oxygen depletion.
>
> The occurrence of an oxygen-deficient atmosphere within an area depends upon the ventilation of the area, the volume of the space, and how much gas flow (flow rate or quantity) could be released. From this consideration, a risk assessment shall be carried out and suitable control measure implemented to reach the expected level of safety [6, p. 7].
>
> **Consideration should also be given** to the use of workplace atmospheric monitoring, for example, wearing a personal oxygen analyzer or installing an analyzer in the work area. The location of the monitor shall be based on an assessment […] [6, p. 8] (emphasis added).

4.2.2.4 International Code Council Guidance

The International Code Council (ICC) [20] authors the *International Fire Code* (IFC). The IFC contains guidance for both compressed gases and cryogenic liquids, including those that are not flammable or combustible. With regard to atmospheric monitoring for compressed gases, the IFC states:

> **Gas detection system.** In rooms or areas not provided with ventilation […], a gas detection system [or] an oxygen depletion alarm system, either of which initiates audible and visible alarm signals in the room or area where sensors are installed, shall be provided [21, pp. 53-7].[a]

This guidance did not apply to FFG's liquid nitrogen system because the IFC only applies it to compressed gases. Regarding the use of atmospheric monitoring for cryogenic liquids, the standard states:

> Inert cryogenic fluids, including argon, helium and nitrogen, shall comply with ANSI/CGA P-18 [21, pp. 55-1].[b]

4.2.2.5 NFPA Guidance

Concerning the use of cryogenic fluids, NFPA 55, *Compressed Gases and Cryogenic Fluids Code* states:

> Storage, use, and handling of inert cryogenic fluids shall be in accordance with ANSI/CGA P-18, *Standard for Bulk Inert Gas Systems at Consumer Sites* [22, pp. 55-35].[c]

NFPA 55 contains guidance on the use of atmospheric monitoring for corrosive gases,[d] toxic and highly toxic gases,[e] hydrogen,[f] carbon dioxide,[g] ethylene oxide,[h] and acetylene,[i] but not for cryogenic asphyxiants such as liquid nitrogen.

4.2.2.6 Lack of Adherence to Industry Guidance

Despite industry guidance, FFG did not equip the Line 4 freezer room with an atmospheric monitoring system that would continuously monitor for a breathable atmosphere and notify personnel by alarms to evacuate the area if unsafe. Not implementing such a system resulted in at least 14 employees entering or approaching the oxygen-deficient atmosphere on the day of the incident. FFG workers were not trained on the hazards of oxygen-deficient atmospheres (Section 4.4.1.5). Without atmospheric monitoring and alarms, site personnel

[a] IFC § 5307.2.1 (2021 ed.)
[b] IFC § 5501.1 (2021 ed.)
[c] NFPA 55 § 8.1.2 (2020 ed.)
[d] NFPA 55 § 7.5 (2020 ed.)
[e] NFPA 55 § 7.9 (2020 ed.)
[f] NFPA 55 § 10 (2020 ed.)
[g] NFPA 55 § 13 (2020 ed.)
[h] NFPA 55 § 14 (2020 ed.)
[i] NFPA 55 § 15 (2020 ed.)

were likely unaware of the hazard around them when the freezer overflowed. The CSB concludes that FFG did not follow industry guidance concerning the use of atmospheric monitoring and alarms for its liquid nitrogen process, and as a result, many personnel were unaware that the freezer room was unsafe to enter on the day of the incident.

The CSB concludes that had Messer or FFG properly considered, designed, installed, tested, and maintained an atmospheric monitoring and alarm system in the freezer room, workers would have been warned against entering the oxygen-deficient atmosphere, which could have prevented the subsequent fatalities and serious injuries to FFG workers.

4.2.3 Gaps in Industry Guidance for Atmospheric Monitoring and Alarm Systems

There is abundant industry guidance for the need for and use of atmospheric monitoring and alarms to prevent human exposure to unsafe atmospheres. However, this guidance could be strengthened to prevent future incidents involving cryogenic asphyxiants.

KEY LESSON

Facilities that handle hazardous gases or cryogenic asphyxiants should have a functioning atmospheric monitoring and alarm system based on a properly conducted risk assessment. Functioning atmospheric monitoring systems consist of equipment that has been properly designed, installed, maintained, inspected, and tested, and will alert personnel of a hazardous atmosphere using audible and visual alarms.

Need for Harmonization of CGA Standards

As noted earlier, both CGA P-12 and CGA P-18 guidelines require atmospheric monitoring in areas where an oxygen-deficient atmosphere can occur. However, CGA P-76 describes the use of such systems as a consideration rather than a requirement.

The CSB recommends that the CGA update CGA P-76 to require that atmospheric monitoring systems *shall be* utilized with processes, equipment, and piping systems capable of producing oxygen-deficient atmospheres, and to require that atmospheric monitoring systems provide both visible and audible alarm indication distinct from the building's fire alarm system at a continuously attended location.

Gap in ICC and NFPA Cryogenic Fluids Guidance

The IFC and NFPA 55 both contain guidance for using and handling compressed gases and cryogenic fluids. In both standards, the guidance for the use of compressed gases is extensive, and for the use of atmospheric monitoring for compressed gases, both standards' guidance is typically either prescriptive or required as an alternative to adequate ventilation, depending on the characteristics of the compressed gas and the application. This guidance could have reduced the severity of this incident had it applied to cryogenic asphyxiants like liquid nitrogen and been applied at FFG. Instead, for the use of atmospheric monitoring with liquid nitrogen, both standards simply refer to CGA P-18 *Standard for Bulk Inert Gas Systems* and otherwise contain no specific guidance regarding atmospheric monitoring for liquid nitrogen.

CGA P-18 only covers the bulk storage of inert gases and cryogenic liquids, not the end use of equipment such as the FFG Line 4 immersion-spiral freezer, and therefore the standard did not apply to the FFG immersion freezer or the room in which it was located. There is thus a gap in NFPA's and ICC's coverage of atmospheric monitoring for cryogenic asphyxiants including liquid nitrogen. The NFPA and the ICC should close this gap.

The CSB recommends that the ICC update the International Fire Code to require the use of atmospheric monitoring with cryogenic asphyxiants in accordance with industry guidance such as is contained in CGA P-76 *Hazards of Oxygen-Deficient Atmospheres* and CGA P-12 *Safe Handling of Cryogenic Liquids* in addition to CGA P-18 *Standard for Bulk Inert Gas Systems*.

The CSB recommends that NFPA update its *Compressed Gases and Cryogenic Fluids Code* to require the use of atmospheric monitoring with cryogenic asphyxiants in accordance with industry guidance such as is contained in CGA P-76 *Hazards of Oxygen-Deficient Atmospheres* and CGA P-12 *Safe Handling of Cryogenic Liquids* in addition to CGA P-18 *Standard for Bulk Inert Gas Systems*.

Need for a Comprehensive Liquid Nitrogen Standard

The CGA has established guidelines for the safe production, storage, transportation, handling, and use of gaseous, liquid, and solid carbon dioxide, an asphyxiant with hazards similar to liquid nitrogen. CGA G-6.5, *Standard for Small Stationary Insulated Carbon Dioxide Systems,*[a] serves as a comprehensive standard for carbon dioxide application systems [23, p. 1].[b] CGA G-6.5 discusses the implementation of key asphyxiation hazard safeguards, including:

- the location and required maintenance of atmospheric monitors [23, pp. 7-8, 10];
- requirements for visual and audible alarms in response to an oxygen-deficient atmosphere [23, p. 9];
- design, function, and location of room ventilation systems [23, p. 6];
- PPE requirements for entering an oxygen-deficient atmosphere caused by the presence of carbon dioxide [23, p. 6];
- hazards introduced by installing carbon dioxide systems in enclosed, recessed, and unventilated spaces [23, p. 8]; and,
- Entry restrictions to areas with potential for oxygen-deficient atmospheres [23, p. 15].

Despite the general guidance from CGA mentioned elsewhere in this report, no equivalent comprehensive standard exists specifically for liquid nitrogen application systems. CGA G-6.5 presents several critical safeguards equally applicable for both carbon dioxide and liquid nitrogen systems with asphyxiation risks, as discussed below.

[a] The CSB chose CGA G-6.5, *Standard for Small Stationary Insulated Carbon Dioxide Systems* as an example comprehensive standard due to the similar natures of cryogenic liquid carbon dioxide and nitrogen, and their similar use in the food industry. Specifically, the small stationary standard for carbon dioxide systems addresses operations like those facilities with nitrogen systems at chicken processing facilities—as opposed to a similar standard for large systems, CGA G-6.1 *Standard for Large Insulated Liquid Carbon Dioxide Systems at User Sites.*

[b] The IFC also provides comparable guidance for carbon dioxide systems in Section 5307.3 *Insulated liquid carbon dioxide systems used in beverage dispensing applications*.

Regarding the requirement for alarmed atmospheric monitoring, CGA G-6.5 states:

> A carbon dioxide detector with an appropriate alarm system **shall** be installed where dangerous concentrations of carbon dioxide **can accumulate** […] [23, p. 6] (emphasis added);
>
> A carbon dioxide monitoring system with appropriate visual and/or audible alarm **shall be** installed to detect dangerous concentrations of carbon dioxide [23, p. 9] (emphasis added);
>
> The carbon dioxide leak detection system when activated shall sound an audible alarm within the room or area in which the system is installed. Gas detection systems **shall be installed and maintained** in accordance with the manufacturer's instructions [23, p. 10] (emphasis added); and
>
> Installed carbon dioxide monitors should be checked according to the carbon dioxide monitor manufacturer's guidelines for proper operation and inspection frequency […]. Ensure placement of carbon dioxide monitors and warning signs meet the [local] requirements [23, p. 15].

With regard to locating cryogenic asphyxiant equipment in enclosed areas and the critical need for properly installed ventilation, CGA G-6.5 states:

> Enclosed, improperly ventilated areas can include […] outside locations such as one with four solid walls open to the atmosphere. Even if there is no roof or ceiling this is still considered an enclosed space because the carbon dioxide will not disperse as it is heavier than air [23, p. 7];
>
> Ventilation systems shall exhaust from the lowest level with the make-up air entering at a higher point.[a] Make up and exhaust rate of flow shall meet code requirements [23, p. 6];
>
> Standard commercial HVAC systems or additional fans typically do not provide sufficient protection […] for carbon dioxide ventilation [23, p. 6]; and
>
> [O]penings […] shall be spaced to create cross ventilation and located as low as possible to ensure that carbon dioxide will not pool and cause exposure to occupants. Any installation that does not meet these criteria should be considered an enclosed installation [23, p. 8].

The CSB concludes that industry guidance for carbon dioxide is extensive. Comparable, specific guidance for liquid nitrogen could help prevent future incidents similar to the one at FFG.

[a] Carbon dioxide is heavier than air and accumulates at low points, similar to cold, vaporized liquid nitrogen.

Consequently, the CSB recommends that the CGA develop a comprehensive standard for the safe storage, handling, and use of liquid nitrogen in stationary applications, comparable to the guidance presented in CGA G-6.5 *Standard for Small Stationary Insulated Carbon Dioxide Systems.* At a minimum, the standard should include:

a) requirements for and guidance on the location, the maintenance, and the functional testing of atmospheric monitoring devices;

b) requirements for visual and audible alarms distinct from the building's fire alarm system and at a continuously attended location; and,

c) guidance on the sizing, design, function, periodic maintenance and testing, and location of room and emergency ventilation systems.

4.3 Emergency Preparedness

Effective emergency preparedness can reduce the consequences of a catastrophic incident. FFG had no emergency action plan (EAP) for a liquid nitrogen release, did not train its employees on how to recognize or respond to such a release, and did not equip them to safely respond.

4.3.1 Regulatory Requirements

EPCRA

The Emergency Planning and Community Right-to-Know Act (EPCRA), which is a portion of the Superfund Amendments and Reauthorization Act (SARA), establishes many requirements for community emergency preparedness [24]. Because FFG utilized more than 10,000 pounds of liquid nitrogen, Sections 311-312 of EPCRA required FFG to submit certain information to local emergency response organizations.

Under EPCRA, FFG was required to 1) submit an SDS for liquid nitrogen to local response organizations, and 2) submit an annual report to those organizations detailing, among other requirements, that FFG utilized liquid nitrogen, its inventory of liquid nitrogen, and where and how at its facility liquid nitrogen was utilized.

OSHA HAZWOPER

OSHA's Hazardous Waste Operations and Emergency Response (HAZWOPER) regulation (found at 29 CFR 1910.120) requires under § 1910.120(q)(1) that employers develop an emergency response plan (ERP). Under § 1910.120(q)(2), the regulation requires, among other things, that ERPs contain provisions for:

- pre-planning and coordination with outside response organizations;
- emergency recognition and prevention;
- emergency alerting and response procedures;
- employee training such that only trained employees respond to an emergency; and,
- PPE and emergency equipment.

The applicability of the HAZWOPER standard is not limited to substances covered under OSHA's PSM standard. OSHA, on its website,[a] has a flowchart for use in determining whether an incident requires emergency response. According to the flowchart, an incident involving liquid nitrogen, which can create an oxygen-deficient atmosphere, requires either emergency response under HAZWOPER or evacuation under 29 CFR 1910.38.

[a] https://www.osha.gov/emergency-preparedness/hazardous-waste-operations/background

4.3.2 Ineffective Emergency Preparedness

FFG Emergency Action Plan

FFG's EAP consisted of a 46-page slideshow presentation written in English.[a] The EAP contained the following material:

- Evacuation routes and rally points specific to each building at the facility
- General exit route safety requirements, such as the requirement for an adequate number of available routes, that routes have adequate signage, and that routes be kept clear of obstacles that might hinder use
- Shelter-in-place locations
- Safety shower and eyewash station locations
- The requirement that "designated personnel will perform rescue […] medical and first aid duties"
- Incident reporting requirements

FFG's EAP did not mention liquid nitrogen. Other than general evacuation and shelter-in-place directions, the plan contained no guidance to employees on how, whether, or when to respond to an emergency, or what constituted an emergency. The plan did call for "designated personnel" to perform rescue and first aid duties, but in a response to a CSB information request, FFG wrote that:

> FFG has no employees trained or qualified to perform rescue duties nor first aid duties. When the need arises we would call 911 for assistance from the [fire department].

The CSB found no evidence that FFG had any formalized policies or procedures for responding to a liquid nitrogen release. The CSB concludes that although FFG had a written emergency action plan, it was severely inadequate to address a liquid nitrogen emergency. Its inadequacies included 1) that it was not written in Spanish, the primary language of many of FFG's workers; 2) that it made no mention of the existence of liquid nitrogen at the facility; 3) that it made no mention of the hazards of liquid nitrogen; 4) that it had no instructions for how, whether, or when to respond to a release of liquid nitrogen other than general evacuation instructions; 5) that it contained no information or plan for how employees were to be notified of an emergency; 6) that it contained no information on what constituted an emergency or what types of emergencies to which employees might need to respond; and 7) that it had no provision for proactively interacting with local emergency responders despite the company's stated practice of relying on them for emergency response.

Lack of Warning and Poor Emergency Communication

As discussed above, FFG had no atmospheric monitoring systems or alarms to alert employees to a release of liquid nitrogen or the presence of an oxygen-deficient atmosphere (Section 4.2.1). The result was that many of

[a] The overwhelming majority of the FFG Plant 4 workforce, including five of the six fatally injured workers, were either non-English speaking or spoke English as a non-primary language.

the employees responding to the incident or evacuating the facility had no idea what the emergency was; only that some of their coworkers were missing. Further, news of the emergency and the order to evacuate was only spread by word of mouth, rather than by a plant-wide alarm or notification system, which did not exist at the facility (other than the building's fire alarm). The CSB concludes that as a result of FFG's poor emergency communication, employees attempting to respond to the incident or evacuate the building were only minimally informed, if at all, of the nature and severity of the emergency.

Delay in Emergency Notification

There was a delay in notification to the fire department. FFG began the building evacuation at roughly 9:55 a.m., but the first call to 911 was not until 10:11 a.m. (Section 2.2.2).

One of the fatally injured workers was still alive when she was retrieved by firefighters but died shortly thereafter in the hospital emergency department. **Table 2** below summarizes the response timeline with respect to this fatally injured worker. Prompt notification to emergency responders is critical in emergencies and might have prevented the death of this worker.

Table 2. Incident timeline focusing on worker who died at the hospital.

Time	Event
9:55 a.m. (approx.)	FFG begins evacuation of Plant 4
Between 9:55-10:10 a.m. (estimated)	Worker enters Line 4 freezer room and becomes unconscious
10:11 a.m.	First FFG call to 911
10:21 a.m. (approx.)	Firefighters arrive on scene
10:36 a.m. (approx.)	Worker retrieved from FFG Plant 4
10:46 a.m.	Worker delivered alive, but in critical condition, to emergency department
11:00 a.m.	Worker pronounced dead

Unprepared Workforce

FFG employees at all levels of the organization were unaware of either the existence of liquid nitrogen at the facility, the hazards of liquid nitrogen, or both (**Table 3**, Section 4.4.1.5). In addition to this widespread lack of awareness of the presence and hazards of liquid nitrogen, multiple employees told the CSB that the company did not conduct any drills for a liquid nitrogen release or fire.

Four additional employees perished (including the employee who died at the hospital) and three were seriously injured during the response to the liquid nitrogen release and the evacuation. None of these employees normally worked in the Line 4 freezer room, and their normal evacuation routes from the facility would not have taken them through the freezer room. The CSB concludes that the four workers who subsequently were fatally injured were attempting some sort of response to the release. The CSB found no evidence that FFG trained its employees not to respond to emergencies. In addition to not mentioning liquid nitrogen or its hazards, FFG's EAP slideshow, shown to employees upon initial hiring, did not direct employees *not* to respond and instead simply contained instructions on how to evacuate the building. In post-incident statements provided to OSHA, a few workers (fewer than 10) told OSHA that they had watched a video or had been told by supervisors in the past to evacuate the building during an emergency, but none of them mentioned liquid nitrogen in those statements, and most of the workers' statements focused on fire or weather emergencies.

Several FFG employees[a] who were exposed to the oxygen-deficient atmosphere but survived the incident told the CSB that they were directly investigating or otherwise responding to the incident when they were injured or nearly injured, despite lacking any training or equipment[b] to safely do so. One of them lost consciousness and was rescued by other responding employees; he spent two days recovering in the hospital. Another reported bending down to attempt to rescue another employee (the worker discussed above in **Table 2**), feeling dizzy and disoriented, and nearly fainting before escaping under his own power.[c] Multiple other employees who reported responding to the incident were not injured or sustained minor injuries. However, any of them could easily have been seriously or fatally injured. In total, at least 14 employees (roughly 10% of the workforce at the facility) responded to the liquid nitrogen release: four of them were fatally injured,[d] three were seriously injured, and at least seven were uninjured or sustained minor injuries.

The CSB concludes that FFG did not prepare its workforce in any meaningful way to respond to a release of liquid nitrogen. The company's deficiencies included 1) its lack of emergency response training for its workforce, 2) its lack of employee training on how to identify a liquid nitrogen release, 3) the lack of automated means to detect and inform its workers of a liquid nitrogen release, and 4) insufficient direction to its employees not to respond or attempt rescue during a liquid nitrogen release.

As a result of FFG's unpreparedness, the severity of the incident was greatly increased during evacuation and response activities when four additional employees were fatally injured, three employees were seriously injured, and at least seven others sustained minor injuries or were uninjured but easily could have been seriously or fatally injured. Had FFG effectively prepared its workforce for a liquid nitrogen release, the four additional fatalities and three of the four serious injuries could have been prevented.[e]

---

[a] The CSB is aware of at least seven employees who responded in some way but were either uninjured or not seriously injured.

[b] FFG had no equipment or PPE that would have enabled workers to enter an oxygen-deficient atmosphere, such as supplied air systems or SCBA.

[c] This employee (the Plant 4 Maintenance Manager) very nearly asphyxiated during his attempted response. However, because he was not admitted to the hospital, his injuries were not considered "serious" according to the CSB's injury reporting requirements. Although he is not counted among the four serious injuries (three employees and a firefighter) that resulted from this incident, this employee could have easily died.

[d] These are in addition to the two maintenance workers who died initially.

[e] The fourth serious injury was suffered by a firefighter responding to the incident, and this injury likely would have occurred regardless of any action taken by FFG other than preventing the release altogether.

4.3.3 Post-Incident Actions – Emergency Preparedness

The CSB requested information from Gold Creek pertaining to its emergency preparedness policies and procedures. Gold Creek submitted a policy document titled *Emergency Action Program* and several emergency procedures. The emergency procedures offer checklist-style instructions for Gold Creek's facilities in the event of fire, tornado, ammonia release, liquid nitrogen release, earthquake, and other emergencies. Each of the emergency procedures is written in both English and Spanish.

The CSB concludes that Gold Creek's policy documents and emergency procedures are more robust than FFG's emergency action plan was at the time of the incident and could have reduced the severity of this incident had FFG implemented similar policies and procedures. Consequently, the CSB makes no recommendations to Gold Creek pertaining to the development of emergency preparedness policies or procedures. However, policies and procedures must be effectively implemented and communicated in relevant languages. Gold Creek's EAP includes provisions for training at initial hiring, with annual refresher trainings at minimum. Therefore, the CSB makes no recommendation to Gold Creek pertaining to employee training for its EAP.

Gold Creek's emergency action program, like FFG's before it, relies upon local emergency responders to perform firefighting, rescue, and medical duties during liquid nitrogen releases and other emergencies. However, the policy has no provision for interaction with those local responders to inform them of and prepare them for the emergencies to which Gold Creek expects them to respond. Therefore, the CSB recommends to Gold Creek to include in its emergency action program provisions for proactively interacting with and informing local emergency response resources of all emergencies at the former FFG Plant 4 facility to which Gold Creek expects them to respond. At a minimum, Gold Creek should:

a) inform local emergency responders of the existence, nature, and location of hazardous substances at its facilities, including liquid nitrogen;

b) inform local emergency responders of the location of emergency-critical equipment such as bulk storage tanks, points of use, isolation valves, E-stop switches, and any other emergency equipment or systems with which emergency responders may need to interact; and,

c) provide local emergency responders with information, such as facility plot plans, engineering drawings, or other information needed to mount an effective emergency response.

4.3.4 Emergency Stops

As shown below in **Figure 20**, the FFG Line 4 freezer room was equipped with 10 E-stop buttons, which were designed to shut down the immersion and spiral freezers as well as to close the liquid nitrogen supply valves to the freezers.

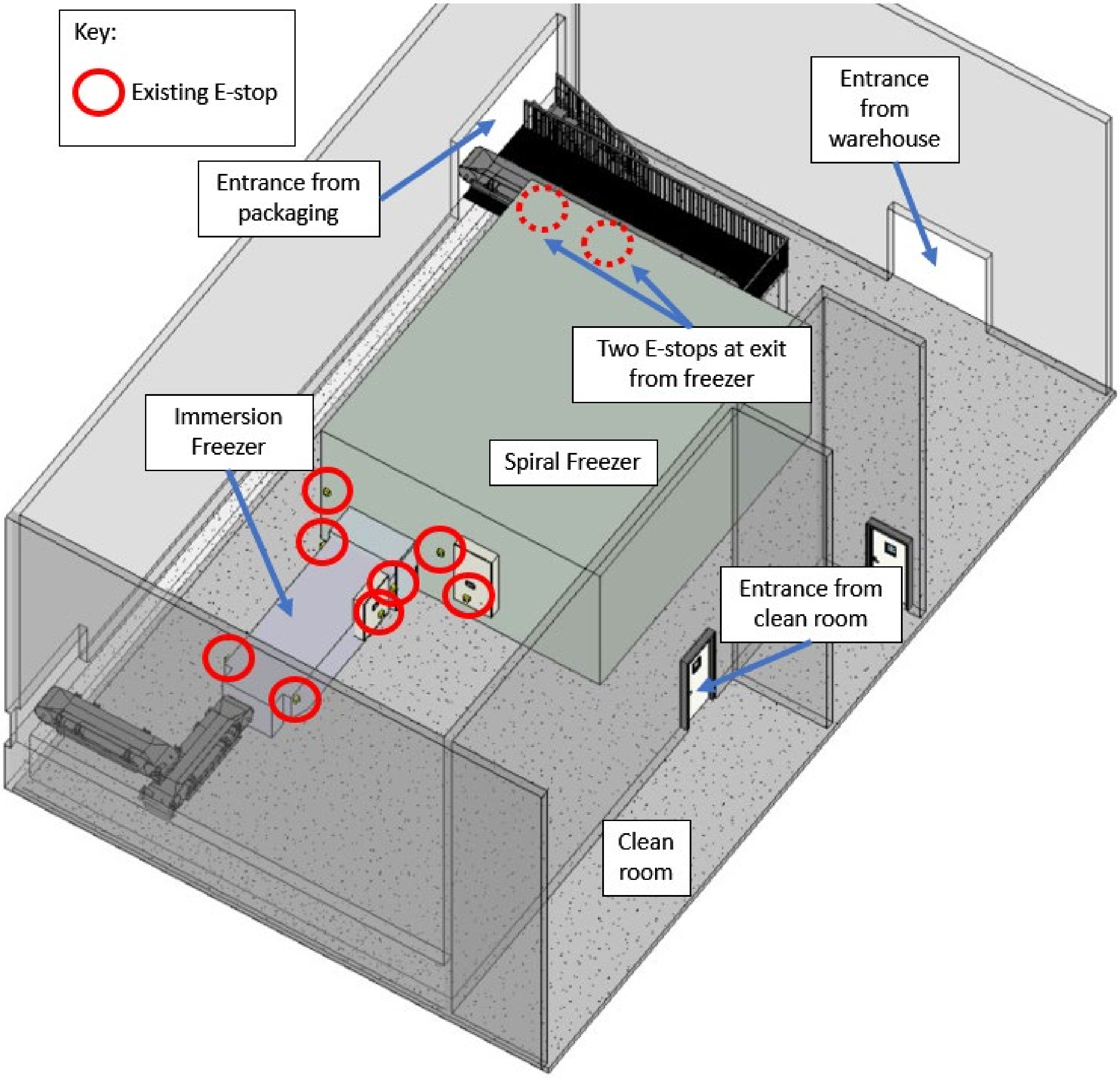


Figure 20. Locations of the Line 4 immersion-spiral freezer E-stops at the time of the incident. (Credit: CSB)

As shown, the 10 E-stop buttons consisted of five buttons on each freezer; one on either side of the inlet and outlet of each freezer, and one on each HMI panel. All 10 buttons were located within the freezer room. The result of this placement was that activation of any of the E-stop buttons required someone to approach the source of the release to activate an E-stop. As stated earlier, FFG had no employees equipped for or trained in emergency response, and as a result, after the release began, no one at the company could safely activate any of the E-stops.[a] The only way that anyone at the company could safely shut off the flow of liquid nitrogen during

[a] As discussed above, the two FFG maintenance workers may have had the opportunity to activate an E-stop and avert the release, but it was impossible to determine whether the two workers were aware of the bent bubbler tube, whether they had sufficient knowledge and training to understand what hazard the bent tube presented, or to what extent the workers were aware of the impending overflow.

an uncontrolled release was by manually closing the bulk storage tank discharge valves, which were located outside, and at the other end of, the building.

The CSB concludes that the placement of the Line 4 immersion-spiral freezer E-stop buttons required a responding employee or person not otherwise in the freezer room to enter an oxygen-deficient atmosphere during a release of liquid nitrogen to activate an E-stop. This design was unsafe. As a result, once FFG's two maintenance workers became incapacitated, the uncontrolled liquid nitrogen release could not be safely stopped until employees manually closed valves at the bulk liquid nitrogen storage tanks outside of the building, or until emergency responders equipped for entry into an oxygen-deficient atmosphere could enter the freezer room and activate an E-stop. Safer placement of E-stop buttons, and effective employee training on their use, might have helped prevent the death of some or all of the four employees who perished during emergency response.

4.3.5 Industry Guidance for Emergency Shutoff Location

Various industry groups offer guidance on the proper design and location of emergency shutoff systems for use with processes such as the one at FFG.

ISO 13850

ISO 13850 *Safety of machinery – Emergency stop function – Principles for design* is an international standard published by the International Organization for Standardization (ISO). Regarding the placement of E-stops, the standard requires a risk assessment, and states:

> An emergency stop device shall be located:
>
> - At each operator control station, except where the risk assessment indicates that this is not necessary;
> - At other locations, as determined by the risk assessment, e.g.;
>   - At entrance and exit locations;
>   - At locations where intervention to the machinery is needed, e.g. operations with a hold-to-run control function;
>   - At all places where a [human]/machine interaction is expected by design.
>
> Emergency stop devices shall be positioned so that they are directly accessible and capable of non-hazardous actuation by the operator and others who could need to actuate them [25, p. 7].

This guidance, though general, could potentially have reduced the severity of this incident had it been implemented at the FFG facility.

The CSB concludes that had FFG and Messer installed E-stop buttons outside the Line 4 freezer room, such as at the entrances to the room or at the bulk storage tanks, the uncontrolled release could have been stopped more expediently.

An example of such a design philosophy is shown below in **Figure 21**:

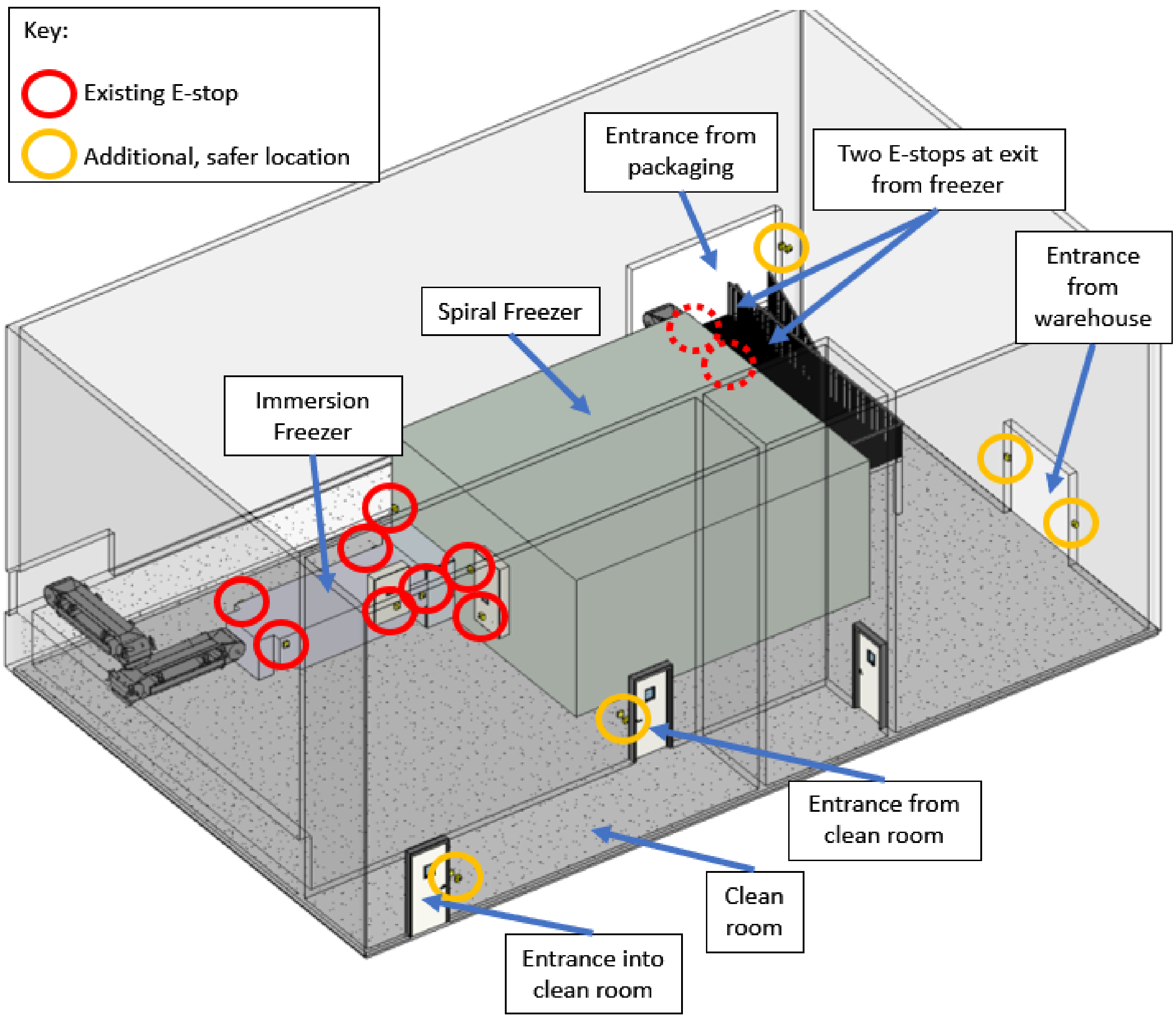


Figure 21. An example of potential additional safer E-stop placement. (Credit: CSB)

CGA P-76

CGA P-76 *Hazards of Oxygen-Deficient Atmospheres* explicitly identifies liquid nitrogen food freezers as an example of equipment that can produce oxygen-deficient atmospheres [6, p. 5]. Section 6 of the standard contains specific guidance on hazard mitigation and preventive measures for such systems. The standard states that pipelines carrying inert gases "should be provided with a readily accessible isolation valve outside the building" [6, p. 7]. The standard states that such valves "Ideally […] should be remotely activated by push buttons or other safety-monitoring equipment" [6, p. 7]. As discussed above, remotely operated emergency isolation valves (ROEIVs) were installed on the liquid nitrogen supply piping to the FFG Line 4 liquid nitrogen freezers, but the E-stop buttons to activate them were all located within the immediate vicinity of the freezers.

As currently written, CGA P-76 only recommends that equipment using inert gases *should* be equipped with isolation valves, and only recommends that those valves *ideally should* be remotely activated. This guidance is too permissive; as demonstrated by this incident and others (**Table 4**, Section 4.4.2.1), cryogenic asphyxiants and inert gases can produce multiple-fatality incidents in the event of loss of containment. Further, the standard contains no guidance on the proper location of remote activation devices (such as E-stop buttons). The CSB recommends that the CGA update P-76 *Hazards of Oxygen-Deficient Atmospheres*. At a minimum, the updated standard should:

a) Require that processes, equipment, and piping systems capable of producing oxygen-deficient atmospheres *shall be* equipped with remotely operated emergency isolation valves (ROEIVs).

b) Include guidance on the adequate safe location of emergency stop devices. At a minimum this guidance should be harmonized with the requirements of ISO 13850 *Safety of machinery – Emergency stop function – Principles for design.* As necessary, augment the general guidance of ISO 13850 with guidance specific to processes, equipment, and piping using cryogenic asphyxiants and inert gases.

In Section 4.2.3, the CSB recommended that the CGA develop a comprehensive liquid nitrogen standard containing guidance on the use of atmospheric monitoring and alarm systems. The CSB also recommends that that standard include requirements and guidance on the location of emergency shutdown devices such as E-stops.

NFPA 55

NFPA 55 *Compressed Gases and Cryogenic Fluids Code* contains specific guidance on the use of bulk oxygen systems, bulk liquefied hydrogen systems, bulk carbon dioxide systems, and liquid nitrous oxide systems,[a] but not for liquid nitrogen systems. For cryogenic liquid systems other than those with specific guidance (those listed above), NFPA 55 requires that the use of such systems comply with CGA P-18 *Standard for Bulk Inert Gas Systems* (Section 4.2.2.5).[b]

For the use of all cryogenic fluids including liquid nitrogen, NFPA 55 requires that "accessible manual or automatic emergency shutoff valves shall be provided"[c] and that such valves be located at the point of use, at the tank or bulk source, and at the point where the system piping enters the building [22, p. 41].[d] The standard also requires that "manual emergency shutoff valves or the device that activates an automatic emergency shutoff valve […] shall be identified by means of a sign" [22, p. 41].[e] The phrase "devices that activate an automatic emergency shutoff valve" applies to both manual emergency push buttons (E-stops) as well as atmospheric

[a] NFPA 55 § 9; § 11; § 13; § 16. (2020 ed.)
[b] NFPA 55 § 8.13.11.1 (2020 ed.); § 8.13.11.2.1 (2020 ed.)
[c] NFPA 55 § 8.13.11.2.3.1 (2020 ed.)
[d] NFPA 55 § 8.13.11.2.3.2 (2020 ed.)
[e] NFPA 55 § 8.13.11.2.3.1.(A) (2020 ed.)

monitoring devices interlocked to ROEIVs. However, the standard contains no guidance on the adequate location of such devices. The CSB recommends to NFPA to update NFPA 55 *Compressed Gases and Cryogenic Fluids Code* to include guidance on the adequate safe location of manual shutoff valves and devices such as emergency push buttons used to activate remotely operated emergency isolation valves (ROEIVs). At a minimum this guidance should be harmonized with the requirements of ISO 13850 *Safety of machinery – Emergency stop function – Principles for design.*

IFC

The IFC requires that "shutoff valves shall be installed in piping containing cryogenic fluids where needed to limit the volume of liquid discharged in the event of piping or equipment failure [21, pp. 55-4]."[a] The standard does not specify whether shutoff valves should be manually or automatically actuated and offers no guidance on the safe location of manual shutoff valves or devices used to remotely activate shutoff valves.

Therefore, the CSB recommends that the ICC update the IFC to include guidance on the adequate safe location of manual shutoff valves and devices such as emergency push buttons used to activate remotely operated emergency isolation valves (ROEIVs) in cryogenic fluid service. At a minimum this guidance should be harmonized with the requirements of ISO 13850 *Safety of machinery – Emergency stop function – Principles for design.*

[a] IFC § 5505.1.2.3.2

4.4 PROCESS SAFETY MANAGEMENT SYSTEM

OSHA and EPA do not define liquid nitrogen as a highly hazardous chemical or extremely hazardous substance, and therefore neither OSHA's Process Safety Management (PSM) Standard nor EPA's Risk Management Program (RMP) Rule[a] applies to liquid nitrogen processes, such as the Line 4 freezer process at FFG [26, 27]. Because of this, no regulation required FFG to implement process safety management[b] practices for its liquid nitrogen freezer process.

CCPS's *Guidelines for Risk Based Process Safety* presents a broadly accepted framework for process safety management consisting of 20 elements to help organizations design and implement more effective process safety management systems [28, p. 2]. The CCPS developed the Risk Based Process Safety (RBPS) approach in response to the stagnation and decline of process safety management system implementation that it perceived within many organizations [28, p. 1]. The CCPS lists several possible causes of process safety management performance stagnation, including:

- In the United States, process safety management has become synonymous with OSHA's PSM regulation, meaning organizations may fail to manage process safety when not required by regulation.
- Since worker injuries are much more frequent and are easier to measure, company resources disproportionately focus on *personal safety* rather than *process safety*.
- Process safety management was developed by and for big companies. Small companies may believe they do not have the capability to implement these systems [28, p. 2].

RBPS was intended as a framework that companies of any size and risk profile can adapt to their operations. Regardless of the applicability of PSM regulatory requirements, RBPS was an applicable guideline available for FFG to establish an effective process safety management system.

4.4.1 FFG'S INEFFECTIVE PROCESS SAFETY MANAGEMENT PRACTICES

FFG did not have an established process safety management program to identify and control the hazards of the liquid nitrogen process. The following sections present key process safety management elements that, if FFG had implemented, may have prevented the incident or mitigated its severity.[c]

[a] In addition to nitrogen, anhydrous ammonia (a highly hazardous chemical/extremely hazardous substance) was present on the FFG site at the time of the incident. However, FFG claimed that the ammonia within each process was below the threshold quantity that would have required it to conform to the PSM standard and RMP rule. This report does not analyze FFG's anhydrous ammonia processes, except by noting that FFG did not have an established process safety management system.

[b] This report distinguishes the terms "process safety management" (lower case) as the practices used to improve process safety and "Process Safety Management (PSM)" to refer to OSHA's PSM standard.

[c] The CSB identified issues and missed opportunities with FFG's safety practices related to many of the RBPS process safety management elements. This report, however, will highlight only those elements that were causal or presented an opportunity to prevent or mitigate the incident.

4.4.1.1 Process Safety Culture and Leadership Responsibility

The RBPS element *Process Safety Culture* discusses how the combination of group values and behaviors determines how process safety is managed [28, p. 40]. "The process safety culture of an organization is a significant determinant of how it will approach process risk control issues, and process safety management system failures can often be linked to cultural deficiencies" [28, p. 41]. The CCPS acknowledges that management systems, policies, and procedures depend on individuals for their successful implementation [28, p. 42]. Accordingly, the CCPS provides the following guidance for ensuring an organization maintains an effective process safety culture:

> The leadership of an organization has the primary responsibility for identifying the need for, and fostering, cultural change and for sustaining a sound culture once it is established [28, p. 44].
>
> Visible, active, and consistent support for process safety programs and objectives exists at all levels of management within the organization. […] The concept of process safety as a line responsibility is carried down through all levels of the organization [28, p. 46].
>
> The organization provides clear delegation of, and accountability for, safety-related responsibilities. Accordingly, employees are provided the necessary authority and resources to allow success in their assigned roles. Personnel accept and fulfill their individual process safety responsibilities, and management expects and encourages the sharing of process safety concerns by all members of the organization [28, p. 47].
>
> The organization places a high value on the training and development of individuals and groups. […] The organization maintains a sufficient level of expertise required for safe operations [28, p. 47].
>
> Include in each manager's job description explicit responsibilities that support process safety culture initiatives […]. Provide accountabilities for successfully carrying out these responsibilities [28, p. 59].

After Prime-Pak and Victory Processing formed the FFG joint venture in 2018, the safety responsibilities from the two organizations were reorganized. FFG reassigned the EHS Manager from Victory Processing and the Safety Coordinator from Prime-Pak into a new structure within the FFG Human Resources (HR) Department. In addition, FFG discontinued the Safety Coordinator's practice of performing regular safety walkthroughs of the facility. By September 2019, the Safety Coordinator had resigned, and the EHS Manager had been was terminated. Positions with responsibility for safety management were vacant for at least 15 months, until December 2020, when FFG assigned EHS management responsibilities to the FFG Wastewater Manager, within the Maintenance Department, less than two months prior to the incident. **Figure 22** shows the safety management organizational structure at the time of the incident.

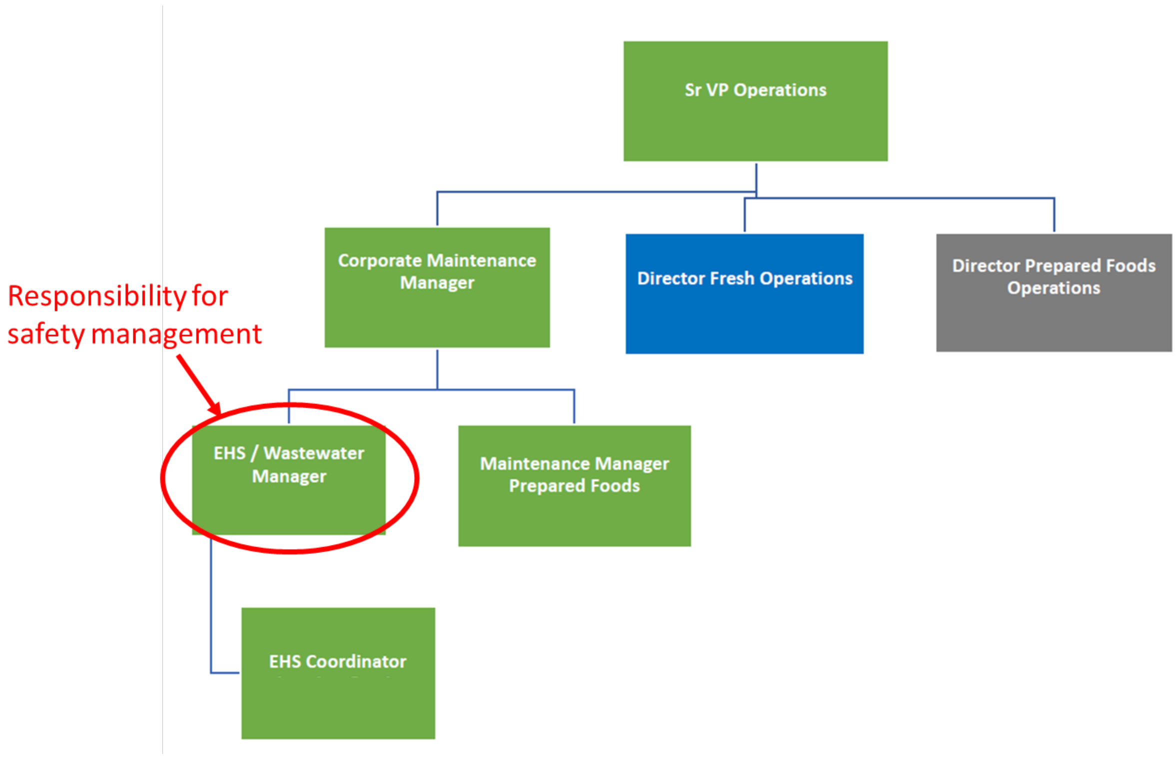


Figure 22. FFG organization chart depicting safety management responsibilities at the time of the incident.[a] (Credit: FFG, annotations and redactions by CSB)

Despite being the designated responsible person for safety management, the FFG EHS/Wastewater Manager's primary responsibility was maintenance and operation of the wastewater system, not safety, with approximately 10% or less of his working hours dedicated to safety-related tasks. In addition, the EHS/Wastewater Manager was not involved in activities at Plant 4, the location of the liquid nitrogen freezer process, and instead deferred Plant 4 responsibilities to the Maintenance Manager of Prepared Foods.

The CSB concludes that for several months prior to the incident, FFG's safety management organization did not include employees with direct responsibility over the safety practices. Had FFG established process safety programs and objectives; assigned qualified personnel clear responsibilities over process safety management; defined, implemented, and tracked process safety objectives; and ensured organization leaders demonstrated commitment to process safety principles, FFG could have prevented the incident.

KEY LESSON

Safety leadership begins with management. Designating competent and resourced staff with responsibility over specific safety programs is key to ensuring effective process safety. Management must be knowledgeable and involved in each of these safety programs to provide effective oversight.

[a] The EHS Coordinator position originated with Victory Processing in 2012 and was staffed until the time of the incident. This role was responsible for worker's compensation, accident reports, and occupational injury investigations such as slips, falls, and cuts. This role had no explicit responsibility for implementation of a safety program, process safety, or safety training.

4.4.1.2 Process Hazard Analysis

The RBPS element *Hazard Identification and Risk Analysis* encompasses all activities involved in identifying hazards and evaluating risk at a facility throughout the facility's life cycle, to ensure that risks to workers, the public, and the environment are consistently controlled. The analysis should assess and ask:

- Hazard – What can go wrong?
- Consequences – How bad could it be?
- Likelihood – How often might it happen [28, p. 210]?

The understanding of risk developed from these exercises helps form the basis for establishing most of the other process safety management activities undertaken by the facility [28, p. 211].

In the United States, a PHA is typically performed to meet industry guidance for a hazard identification and risk analysis [28, p. 210]. As discussed in Section 4.1.2, Linde previously performed a design-phase PHA on the immersion-spiral freezer. The PHA evaluated the immersion-spiral freezer design and equipment but did not specifically evaluate the hazards of the process as installed and operated at the FFG facility. Messer did not update this PHA to include facility-specific scenarios prior to supplying FFG with the liquid nitrogen freezer system. In addition, FFG did not perform a risk assessment or work with Messer to update the PHA on the liquid nitrogen freezer process to evaluate specific hazards associated with the process as installed and operated at its facility.[a] The CSB concludes that FFG did not identify or evaluate hazards specific to its process, such as the liquid nitrogen overflow and asphyxiation risks, and did not implement effective controls to mitigate the risk.

KEY LESSON

A PHA can only be effective if it is specific to the process it evaluates. Not considering facility-specific scenarios misses opportunities to effectively identify, evaluate, and control hazards. Companies installing equipment into a process at their facility should always perform a PHA considering the hazards introduced by the process, equipment, facility or room layout, ventilation, surrounding area, and external factors.

4.4.1.3 Procedures

The RBPS element *Operating Procedures* states that organizations should develop "written instructions that (1) list the steps for a given task and (2) describe the way the steps are to be performed. Good procedures describe the process, hazards, tools, protective equipment, and controls in enough detail that operators understand the hazards, can verify that controls are in place, and can confirm that the process responds in an expected manner" [28, pp. 245-246].

FFG did not develop written procedures for the operation or maintenance of the liquid nitrogen freezer. In addition, Messer did not provide FFG with any operating manuals for the freezer equipment prior to the

[a] While Section 4.1.2 discusses the design PHA inadequacies as it relates to identification and management of safety-critical safeguards, the process owner/operator is ultimately responsible for PHA execution. As a distinction from Section 4.1.2, this section highlights the absence of FFG's PHA execution for its specific process.

incident.[a] FFG relied on verbal communications with Messer for information on operating the freezer. As the FFG Plant 4 Maintenance Manager described:

> The freezer for Line 4 and the [immersion] freezer, we did not have any documents or any type of books yet […] Usually I'm used to, any time a new machine comes in, I get a box full of manuals and all kinds of stuff. […] And, honestly, I wasn't really too concerned about the book right now because I had [the Messer Sales Engineer] here. He was my book…

There was insufficient evidence to determine how the bubbler tube was bent. One of the hypotheses the CSB considered and tested was intentional or unintentional human manipulation of the bubbler tube. Although the CSB could not determine whether anyone manipulated the tube, proper maintenance procedures and training could have better informed employees about safety-critical devices, which might have prevented the release.

The CSB concludes that FFG did not have written procedures to operate or maintain the liquid nitrogen freezer, and therefore the FFG employees were not provided with clear instructions and precautions in operating the equipment. Had FFG developed clear written procedures, it is likely that the FFG workers would have understood the function of the freezer, the importance of critical components, and proper precautions when operating and troubleshooting the equipment, which may have prevented the release.

4.4.1.4 Management of Change

The RBPS element *Management of Change* ensures that changes to a process do not inadvertently introduce new hazards or increase the risk of existing hazards [28, p. 424]. A proper management of change program will recognize change situations, evaluate hazards associated with the change, decide whether to allow the change to be made, and complete necessary risk control measures [28, p. 423]. According to CCPS, organizations should establish and implement procedures to manage changes that address:

- the technical basis for the proposed change;
- impact of the proposed change on safety and health; and
- authorization requirements for the proposed change [28, p. 435].

Change from Ammonia to Liquid Nitrogen Freezers

As discussed in Section 1.2, FFG installed the liquid nitrogen immersion-spiral freezer in 2020 to expand the capabilities and increase efficiency of the Line 4 product line. The new freezer system could be utilized as an alternative to the previously used ammonia spiral freezer in the adjacent room. To support product flow, FFG selected the Lower Dry Storage Room, a storage space recessed from some of the surrounding rooms, and without mechanical ventilation (shown in **Figure 23**), to house the new liquid nitrogen freezer equipment.

[a] In a post-incident civil lawsuit deposition, a Messer employee stated that not only did Messer not provide the manuals to FFG, but that the manuals weren't fully written yet and were still being updated to reflect the customizations made to the FFG Line 4 freezers even after the freezers had begun operation.

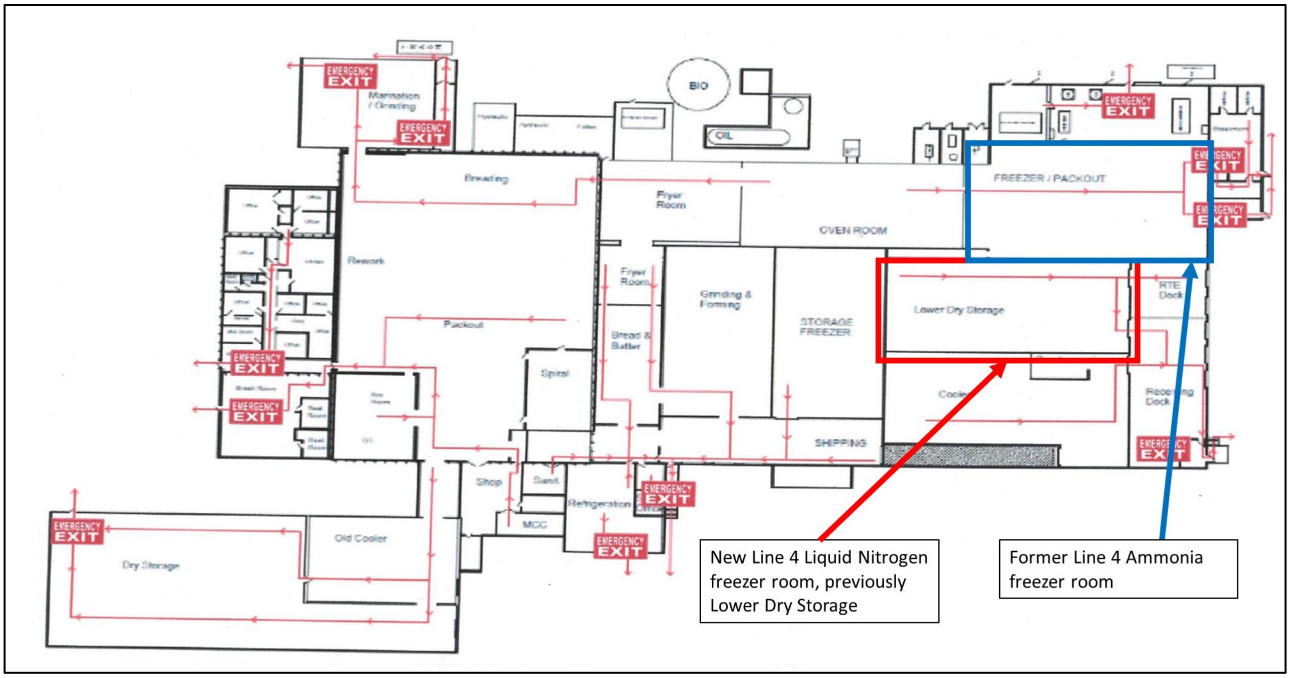


Figure 23. The former Lower Dry Storage room was selected to house the Line 4 liquid nitrogen freezer equipment. (Credit: FFG, annotations by CSB)

FFG modified the Lower Dry Storage room by adding walls to separate the immersion-spiral freezer from the adjacent areas of the plant and constructed a clean room opposite the equipment. Other than the installation of the liquid nitrogen freezer equipment, FFG made no other major modifications to the Lower Dry Storage area.

FFG did not have an established management of change process and did not consider how changes to the process, building, and equipment could impact process safety.

Review and Approval of Changes

FFG completed a Capital Expenditure Request in 2020 to manage and approve the building modifications required for the liquid nitrogen freezer transition. The request included a description of the necessary building and equipment modifications, a project justification that considered impacts to production and efficiency, and approvals by the Senior Vice President of Operations, Senior Vice President of Sales, Chief Financial Officer, and Chief Executive Officer (CEO).[a] The Capital Expenditure Request was not approved by anyone with explicit responsibility for safety, however, and the Safety Manager role was vacant until December 2020. The request did not include a technical basis for the change and did not consider process safety.

Failure to Consider Equipment Location Risks

The Dry Product Storage room, where the liquid nitrogen freezer was ultimately installed, was recessed roughly five feet from the floor of two of the surrounding rooms, as shown in **Figure 24** and discussed in Section 1.4.

[a] A similar process was used to approve Line 2 modifications. In 2019, FFG completed a Capital Expenditure Request to install a new liquid nitrogen spiral freezer on Line 2, which included the same review and approval authorities as the 2020 Line 4 request.

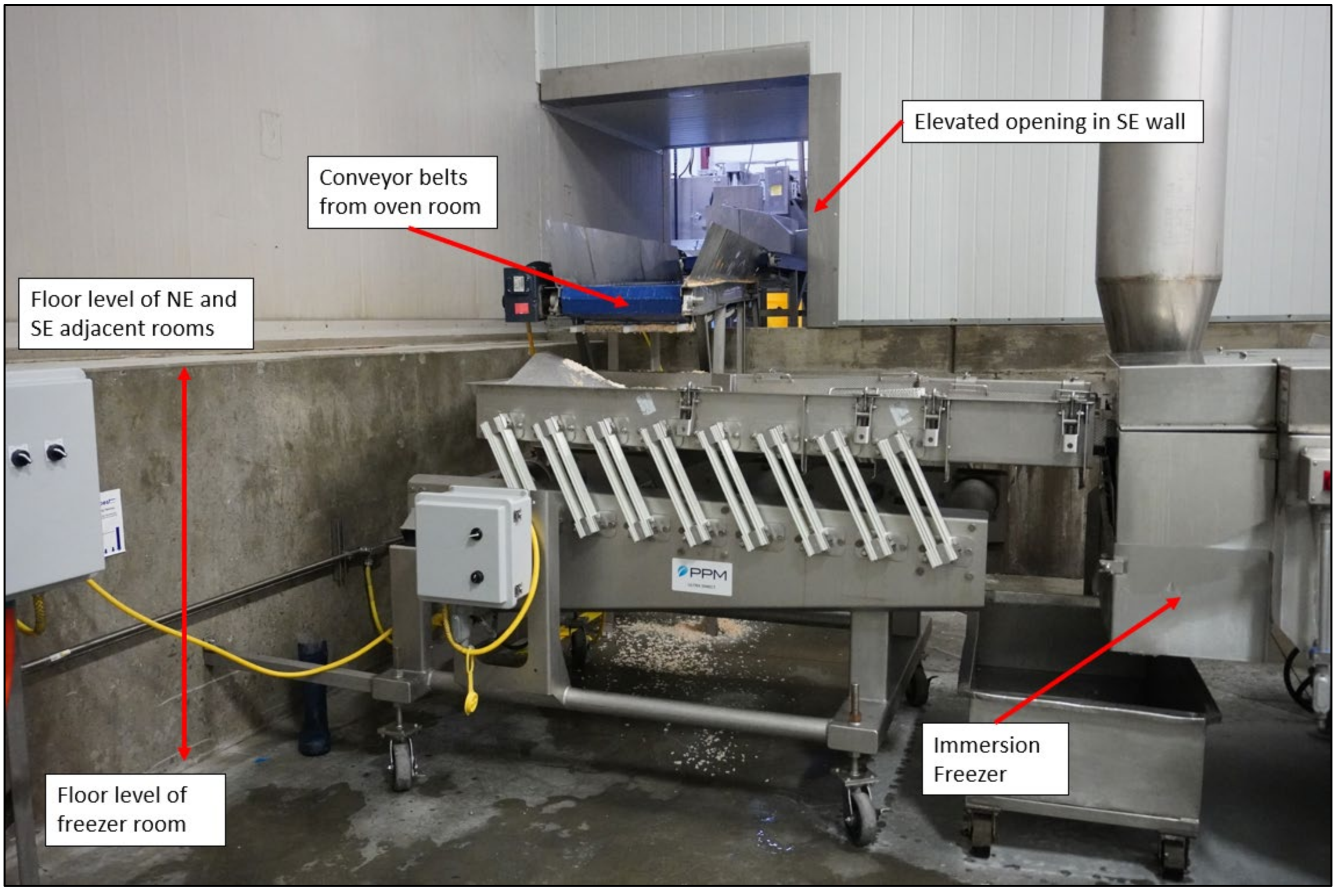


Figure 24. Immersion freezer room recessed nearly five feet from two adjacent rooms. (Credit: CSB)

The only openings in the freezer room at the same level as the floor were the standard-sized door leading to the clean room and the large doorway leading to the warehouse and loading dock (which was partially enclosed by a heavy plastic strip curtain). The other two openings in the room were both elevated roughly five feet above the floor of the room.

Ultimately, between the floor and roughly five feet of elevation, two of the walls in the freezer room were fully enclosed, one was nearly fully enclosed (containing only a standard-sized door for personnel entry and exit), and the fourth had a large doorway that was partially enclosed by heavy plastic strip curtains (which partially restricted airflow through the door). As a result, the portion of the room most susceptible to oxygen deficiency—the lower portions of the room, since cold nitrogen vapors are heavier than air—was nearly fully enclosed, and thus was easily capable of retaining a large volume of cold, vaporized nitrogen.

CGA P-76 *Hazards of Oxygen-Deficient Atmospheres* provides guidance on controlling asphyxiation hazards when handling cryogenic liquids:

> Poorly ventilated areas, […] enclosures, and low-grade areas can contain oxygen-deficient atmospheres. […] An oxygen-deficient atmosphere can bring about unconsciousness without warning. In as little as one or two breaths, an individual's life can be endangered by low oxygen intake [6, p. 4].

> In processes where cryogenic liquids are handled and vaporization takes place, care shall be taken to avoid situations where personnel are exposed to oxygen deficiency. Examples of such spaces include […] rooms where liquid nitrogen food freezers are operated […] [6, p. 5].

CGA P-76 provides additional guidance on required ventilation within enclosed spaces:

> Examples of enclosures include […] rooms where inert cryogenic liquid is used or stored. Building/room size, ventilation capacity, and system pressures shall be determined for each specific case. The following control measures may be applied to ventilation system design:
>
> - Continuous ventilation while the hazard exists. This can be achieved by interlocking the ventilation system with the process power supply;
> - Adequate air flow around the normal operating areas;
> - Minimum ventilation capacity of 6 air changes per hour [6, p. 8].

The Dry Product Storage room was not equipped with HVAC or mechanical ventilation, and FFG did not install ventilation after the installation of the liquid nitrogen freezer. As the Plant 4 FFG Maintenance Manager described:

> There's not an HVAC system in that room. We open the wall from our oven room area to allow air to flow […] through our makeup air system.

The CSB concludes that FFG did not have a management of change process to identify, assess, and manage risk introduced by process changes. During the introduction of the liquid nitrogen immersion-spiral freezer, FFG did not consider how the change could impact process safety, did not include approval authorities with explicit responsibilities for safety, and did not address conformance with industry guidance. As a result, FFG did not manage the risks associated with using a mostly enclosed, partially recessed room without mechanical ventilation and installed the liquid nitrogen freezer in an area particularly susceptible to an oxygen-deficient atmosphere.

4.4.1.5 Training, Hazard Awareness, and Communication

The RBPS element *Training and Performance Assurance* describes practical instruction in job requirements and methods to enable workers to meet performance standards and maintain proficiency [28, p. 396]. According to CCPS:

- A set of training materials should be developed for each training need [28, p. 397].
- A training record should be provided for each worker showing that person's training needs, the dates on which initial training and any refresher training was satisfactorily completed, and a schedule of future training classes [28, p. 397].

- An appropriate approach for verifying performance should be documented [28, p. 397].
- Examiners should be provided with the resources necessary to test workers [28, p. 397].
- In addition to the specific task training, the training program should provide workers with an overview of the process and an understanding of its hazards [28, p. 402].

In addition, the RBPS element *Workforce Involvement* states that "workers, at all levels and in all positions in an organization, should have roles and responsibilities for enhancing and ensuring the safety of the organization's operations" [28, p. 124]. An effective process safety management system "provides workers the information necessary to understand the hazards to which they may be exposed" [28, p. 126] and "requires the active involvement of workers who (1) are aware of the hazards in the workplace, (2) understand the engineered controls and management systems provided to address those hazards, and (3) accept and strive to fulfill their roles and responsibilities in support of providing a safe work environment" [28, p. 128].

Furthermore, CGA P-76 *Hazards of Oxygen Deficient Atmospheres* states that individuals who handle or use inert gases shall be trained and informed of safety measures, hazards of release, and the potential for oxygen depletion [6, p. 6].

4.4.1.6 Lack of Training

While FFG maintenance workers received training on general occupational safe work practices, such as lock-out/tag-out, FFG did not develop training plans to provide its workers with specific, documented training on the function and operation of the liquid nitrogen freezer system. During the freezer startup effort, Messer provided three FFG employees with an in-person instruction on the operation and maintenance of the freezer, potential hazards, and safe gas handling. However, this training was not adopted by FFG as a formal training, did not include a written element, and had no means to confirm the competency of those receiving the training.

Other than the three employees who received Messer's training (which included two maintenance technicians and the Line 4 Packaging Supervisor, all three of whom were fatally injured as a result of this incident), FFG did not train its employees on the hazards of liquid nitrogen, including the risk of asphyxiation. Employees at all levels of the organization reported having limited or no knowledge of the hazards of liquid nitrogen or of its use at the facility, as summarized in **Table 3**.

KEY LESSON

It is critical for workers to be trained on the hazards of the materials they encounter. Non-flammable, non-toxic chemicals, such as nitrogen, can be incorrectly assumed to be non-hazardous without proper training and hazard communication. Companies handling these materials have an obligation to train and inform their employees.

Table 3. Selection of employee interview responses about their knowledge of liquid nitrogen at the facility.

Employee Title	Interviewer Question	Answer
Company Executive[a]	How much did you know about how the equipment worked or the hazards associated with [liquid nitrogen]?	That is not something I got involved with or engaged with.
Company Executive	Have you heard of any talk about the hazards or safety risks of bringing liquid nitrogen in this plant […] for the first time?	No.
Senior Vice President	Have you ever talked about […] ammonia safety, or […] liquid nitrogen safety?	No.
Corporate Maintenance Manager	During the course of these projects [to install liquid nitrogen freezers at FFG], do you recall any discussions of the hazards of liquid nitrogen […]?	No.
Corporate Maintenance Manager	What is your knowledge of the hazards of liquid nitrogen?	I just know that it expands when it's heated. That's pretty much it.
Environmental, Health, and Safety Manager	Prior to this incident, were you aware of any safety hazards associated with these new freezers from Messer?	Absolutely not. I had no clue.
Company Logistics Manager	Were you aware of the […] hazards involved with the liquid nitrogen?	The only thing would be from my chemistry classes in college.
Line 4 Supervisor	When [the company] built the nitrogen freezers on Lines 2 and 4, do you remember any training that [the company] gave about the hazards of nitrogen?	I don't recall that. […] I know it displaces the air when it enters into a room. But besides that, that's what I knew on that.
Line 4 Worker A	Were you aware of any other chemicals besides ammonia?	No, they had only told us about ammonia.
Line 4 Worker B	So when [the company] installed the nitrogen freezers for the facility […] did anyone say what […] the potential dangers would be?	No, I don't remember.

[a] Process safety leadership responsibility means company executives have ultimate responsibility to ensure risks are properly managed. Following the Macondo blowout and explosion, the CSB issued the *CSB Best Practice Guidance for Corporate Boards of Directors and Executives in the Offshore Oil and Gas Industry for Major Accident Prevention*, which states: "When a corporation operates in a high-hazard industry, […] its […] executives should ensure that there are effective safety management systems in place to properly manage risks with the goal of preventing major accidents and protecting workers, the public, and the environment. Implementing a robust process safety program is important to a company's overall success." [56]. Given the potential for catastrophic consequences, these principles apply to executives whose companies handle and process cryogenic asphyxiants just as they apply to the oil and gas industry.

Employee Title	Interviewer Question	Answer
Line 4 Worker C	Are you aware of any chemicals that are being used in the facility?	When they got the new freezer, nobody told us that [it] was working with a chemical or anything. I just learned about the nitrogen in the news, after the accident.
External Organization Staff with daily presence in FFG Plant 4	So you were never provided any training about the hazards of ammonia or liquid nitrogen?	No. […] I had no clue how dangerous liquid nitrogen was. I didn't know at all.

The CSB concludes that FFG had no system, plan, or program to train and verify the competency of its employees when operating the liquid nitrogen freezer and working with or near hazardous liquid nitrogen. As a result, FFG employees at all levels of the organization were not aware of the hazards of liquid nitrogen and were unaware of precautions that should have been taken.

4.4.1.7 Lack of Hazard Communication

CGA P-76 *Hazards of Oxygen-Deficient Atmospheres* specifies that, along with a proper training program discussed above, areas with potential asphyxiation hazards shall be identified or have restricted access. CGA provides an example of a warning sign used to communicate the risk of asphyxiation hazards (**Figure 25**).

Figure 25. Example of a warning sign for asphyxiation hazard [6, p. 7]. (Credit: CGA)

Neither FFG nor Messer provided such warning signage for the asphyxiation hazard in the Line 4 freezer room, as shown in **Figure 26**. By not restricting entrance to the freezer room or providing adequate warning signage, workers were able to enter the freezer room unaware of the potential asphyxiation hazards.

Figure 26. Lack of warning signs for the presence of liquid nitrogen and asphyxiation hazard at the entrance to the freezer room from the loading dock (left) and clean room (right). (Credit: CSB and Messer)

In addition, the freezer equipment included no signage warning of the risks of liquid nitrogen. OSHA's Hazard Communication (HazCom) standard requires employers to label containers of hazardous chemicals with words, pictures, and/or symbols to provide information regarding hazards.[a] As part of the equipment installation, Messer provided liquid nitrogen warning labels (with both English and Spanish text) to be affixed to the freezer equipment, as shown in **Figure 27**. However, these labels were stored within a folder inside the freezer HMI and were never affixed to the freezer. Neither FFG nor Messer applied the labels to the equipment prior to the incident, and thus the information was not properly displaced to workers.

[a] 29 CFR 1910.1200(f)(6)(ii)

Figure 27. Liquid nitrogen warning labels were located inside the HMI and were not affixed to equipment. (Credit: CSB)

The CSB concludes that had the liquid nitrogen freezer equipment and the entrance to the Line 4 freezer room been affixed with proper warning signage and labels, workers could have been made aware of the asphyxiation risks within the room.

4.4.1.8 Conclusions

The CSB concludes that FFG lacked an effective process safety management system to identify, evaluate, and control the hazards of the liquid nitrogen process. The lack of safety oversight by FFG leadership, absence of a systematic process hazard analysis, lack of written procedures, lack of any management of change practices, and failure to communicate hazards resulted in the unmitigated handling of a cryogenic asphyxiant by untrained and unprepared personnel. This incident could have been prevented had FFG practiced robust process safety management.

As discussed in Section 1.1.1, Gold Creek currently owns and operates the former FFG facility. As of this report's publication, there are currently no liquid nitrogen freezing processes at the former FFG Plant 4 building that Gold Creek now operates. Therefore, the CSB does not issue a recommendation to Gold Creek related to process safety management of liquid nitrogen processes.

KEY LESSON

Food manufacturers are not immune from chemical hazards and process safety risks. Whenever an organization introduces a hazardous chemical into its process, it should implement robust process safety management practices to effectively control the risks, regardless of whether any regulation requires the organization to do so.

4.4.2 Lack of Regulations for Cryogenic Asphyxiants

As discussed in Section 4.4, the FFG liquid nitrogen freezer process was not subject to OSHA's PSM standard (or EPA's RMP rule). In addition, there is no existing regulation that requires organizations that handle or process cryogenic asphyxiants to adhere to the requirements of CGA, CCPS, or any safe handling and safety management system guidelines.

4.4.2.1 Fatalities from Liquid Nitrogen Release Incidents

By OSHA's definition, a highly hazardous chemical is "a substance possessing toxic, reactive, flammable, or explosive properties" [26].[a] Since liquid nitrogen is not toxic, reactive, flammable, or explosive, it does not meet OSHA's definition of a highly hazardous chemical.[b] Regardless, uncontrolled liquid nitrogen releases have resulted in serious injuries and fatalities in several industries. Since 2008, the CSB is aware of at least seven incidents involving liquid nitrogen that have resulted in 13 fatalities in the United States, as shown in **Table 4**. None of these incidents were subject to a regulated process safety management standard for liquid nitrogen.

[a] 29 CFR 1910.119(b)

[b] Liquid nitrogen meets the CSB's definition of an "extremely hazardous substance," which is defined in 40 CFR 1604.2 as "any substance which may cause death, serious injury, or substantial property damage […]."

Table 4. Liquid nitrogen asphyxiation fatalities since 2008

Company	Location	Date of Incident	Severity	Industry
Foundation Food Group	Gainesville, Georgia	January 28, 2021	6 fatalities	Food Manufacturing
California Ranch Food Company	Vernon, California	December 1, 2020	2 fatalities	Food Manufacturing
Custom Genetic Solutions, LLC	Mitchell, South Dakota	November 20, 2019	1 fatality	Genetics
XYTEC	Augusta, Georgia	February 5, 2017	1 fatality	Genetics
ATI Allvac	Richburg, South Carolina	June 26, 2012	1 fatality	Metalworking
Blowout Tools, Inc.	Fannin, Texas	October 30, 2010	1 fatality	Equipment Manufacturing
Blommer Chocolate Company	Chicago, Illinois	June 8, 2008	1 fatality	Food Manufacturing

The liquid nitrogen asphyxiation incidents occurring at California Ranch Food Company (California Ranch) and FFG collectively resulted in eight fatalities within less than two months.

4.4.2.2 Existing Regulations and Guidance

OSHA's stated mission is to "ensure safe and healthful working conditions for workers by setting and enforcing standards and by providing training, outreach, education and assistance" [29]. Since OSHA's standards cover FFG and its workers, the violations cited by OSHA at the FFG facility prior to and following the January 2021 incident provide insight into the scope of applicable existing regulations.

OSHA Citations Prior to the FFG Incident

Between 2016 and 2020, OSHA inspected the FFG facility three times, as shown in **Table 5**. While OSHA found several violations, OSHA did not document any findings or concerns relating to FFG's handling of liquid nitrogen during these visits.

Table 5. OSHA inspection citations at FFG between 2016 and 2020

Inspection Date	Citation(s)	Violation (Paraphrased)
December 10, 2020	General Duty Clause Section 5(a)(1)	Workers were struck by 40-pound blocks of frozen chicken traveling on a conveyor.
	Control of Hazardous Energy 29 CFR 1910.147	FFG did not inspect equipment-specific procedures, nor train employees, exposing workers to amputation hazards.

Inspection Date	Citation(s)	Violation (Paraphrased)
	Machine Guarding 29 CFR 1910.212	Machines were not properly guarded, exposing workers to laceration and amputation hazards.
June 5, 2019	Eye and Face Protection 29 CFR 1910.133	An employee handling corrosive material was not wearing eye protection.
	Powered Industrial Trucks 29 CFR 1910.178	FFG did not certify employees operating forklifts.
July 11, 2017[a]	Machine Guarding 29 CFR 1910.212	Employee suffered partial amputation following the removal of a machine guard.

OSHA Citations Following the FFG Incident

Following the liquid nitrogen release and fatal injuries at FFG, OSHA performed an investigation at the FFG facility and issued three citations documenting 26 violations. As shown in **Figure 28**, OSHA's findings included violations related to walking-working surfaces, stairs, exit routes, PPE, confined space, control of hazardous energy, first aid, HazCom, and the General Duty Clause. None related directly to FFG's handling of liquid nitrogen, however.

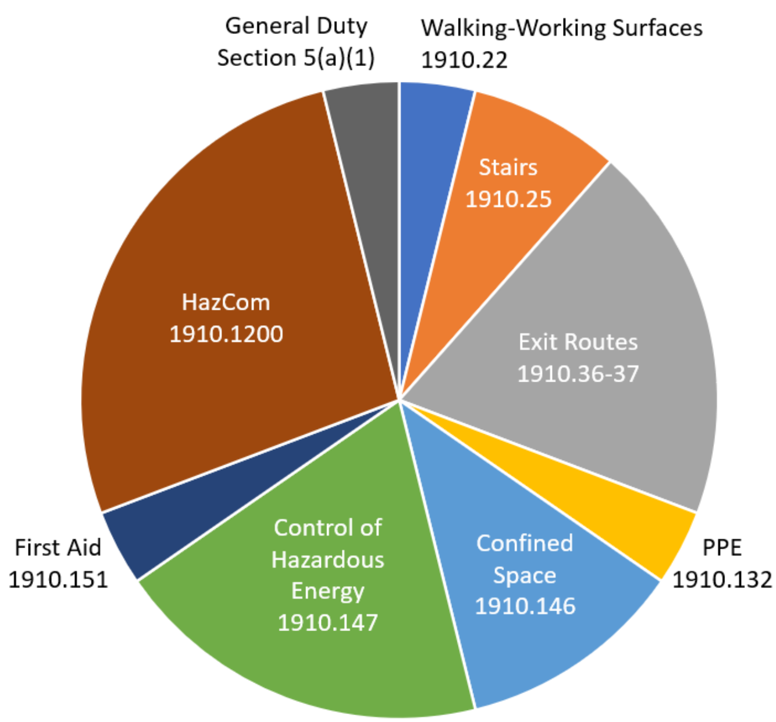


Figure 28. Summary of OSHA violations issued to FFG post-incident. (Credit: CSB)[b]

[a] During this inspection, the plant was operated by Prime Pak.

[b] All references are to 29 CFR 1910 and are abbreviated in the figure for presentation.

Since there is no specific OSHA standard governing the use of liquid nitrogen, there is a serious gap in regulations that address preventative and mitigative measures to safely handle liquid nitrogen and other cryogenic asphyxiants. As discussed below, there are several regulations that applied to FFG and apply to other users of liquid nitrogen. None of the existing regulations would have prevented the accidental release, however.

Hazard Communication (29 CFR 1910.1200)

OSHA's HazCom standard found in 29 CFR 1910.1200 is intended to "ensure that the hazards of all chemicals produced […] are classified, and that information concerning the classified hazards is transmitted to employers and employees" [30].[a] The standard "requires chemical manufacturers […] to classify the hazards of chemicals which they produce […], and all employers to provide information to their employees about the hazardous chemicals to which they are exposed, by means of a hazard communication program, labels and other forms of warning, safety data sheets, and information and training" [30].[b]

As discussed in Section 4.4.1.5, had FFG better informed its workforce about the presence and hazards of liquid nitrogen, its workers may not have decided to enter the freezer room to attempt to rescue their coworkers. This could have reduced the severity of the incident by preventing some or all of the additional four employee deaths and three serious injuries. More effective hazard communication likely would not have prevented the accidental release.

Control of Hazardous Energy (29 CFR 1910.147)

OSHA's Control of Hazardous Energy (Lockout/Tagout) standard found in 29 CFR 1910.147 "covers the servicing and maintenance of machines and equipment in which the unexpected energization or start up of the machines or equipment, or release of stored energy could cause injury to employees" [31].[c] The standard "requires employers to establish a program and utilize procedures for affixing appropriate lockout devices or tagout devices to energy isolating devices, and to otherwise disable machines or equipment to prevent unexpected energization, start-up or release of stored energy in order to prevent injury to employees" [31].[d]

Since this incident involved the failure of a safety-critical level control device during active troubleshooting activities, proper energy isolation activities may have impacted the outcome of this incident. As discussed in Section 2.2.1, two FFG workers were attempting to troubleshoot the liquid nitrogen flow without turning off the freezer or isolating the flow of liquid nitrogen when the release began. However, even if the flow of nitrogen had been isolated during the troubleshooting, at some point the workers likely would have unlocked and re-engaged the flow, likely resulting in the same outcome. Isolating the nitrogen flow likely would not have prevented the damage to the bubbler tube. As identified in OSHA's investigation, FFG did not adhere to many of the requirements of the Control of Hazardous Energy standard.[e] However, in this particular incident, the Control of Hazardous Energy standard would not have prevented the release or the subsequent fatalities.

[a] 29 CFR 1910.1200(a)(1)
[b] 29 CFR 1910.1200(b)(1)
[c] 29 CFR 1910.147(a)(1)(i)
[d] 29 CFR 1910.147(a)(3)(i)
[e] FFG has contested the Lockout/Tagout violations.

General Duty Clause (Section 5(a)(1))

The Occupational Safety and Health (OSH) Act of 1970, Section 5(a)(1), also known as the General Duty Clause, requires employers to "furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees" [32]. While the General Duty Clause requires employers to ensure that the workplace is free from recognized hazards, it is a reactive regulation that OSHA relies upon to cite employers for hazards that are not explicitly covered in other regulations. The General Duty Clause contains no guidance on how to prevent incidents.

HAZWOPER (29 CFR 1910.120)

OSHA's HAZWOPER standard found in 29 CFR 1910.120 applies to "emergency response operations for releases of, or substantial threats of releases of, hazardous substances without regard to the location of the hazard," among other subjects [33].[a] The standard requires that employers develop an ERP that addresses "emergency recognition and prevention" [33].[b] The standard regulates response to an incident that has already occurred and does not prevent incidents in the first place. Additionally, the standard simply requires employers to develop a plan that "addresses" prevention, with no specific guidance or requirements on how to do so.

In general, the HAZWOPER standard seeks to prevent untrained employees from responding to an incident. The regulation requires employers to either develop an EAP (in compliance with 29 CFR 1910.38) that requires and trains all employees to evacuate all emergencies, or to develop an ERP (in compliance with 29 CFR 1910.120) that requires that employees designated for response activities be properly trained and equipped for response. In either case, employees who are not trained to respond must not respond. In the FFG incident, numerous untrained people responded to the liquid nitrogen release by entering the Line 4 freezer room or rooms adjacent to it. Nevertheless, OSHA did not cite FFG for violating the HAZWOPER standard or for violating the EAP requirements of 29 CFR 1910.38. As noted in Section 4.3, FFG had an EAP purportedly intended for compliance with 29 CFR 1910.38, meaning that at the policy level, FFG elected not to respond to any emergencies and instead evacuate. However, among the people who responded were management officials who would have been responsible for implementing FFG's asserted policy of evacuation without response.

Other Regulations Cited by OSHA

Many of the OSHA-cited violations issued in response to the Line 4 incident were not relevant to the liquid nitrogen release, as discussed below:

- *Confined Space (29 CFR 1910.146)* – The incident did not involve confined space entry.
- *Exit Routes (29 CFR 1910.36-37)* – Given the nature of the release, the egress path available to the workers likely did not contribute to this incident.

[a] 29 CFR 1910.120(a)(1)(v)
[b] 29 CFR 1910.120(q)(2)(iii)

- *First Aid (29 CFR 1910.151)*[a] – The availability of an eye wash station or safety shower is irrelevant to this incident.
- *PPE (29 CFR 1910.132)* – The availability of differing PPE for workers would not have prevented the accidental release, although it could have lessened the severity of the incident had responding workers been equipped with personal oxygen monitors or equipment suitable for entry into an oxygen-deficient atmosphere.
- *Stairs (29 CFR 1910.25)* – The condition of stairs is irrelevant to this incident.
- *Walking-Working Surfaces (29 CFR 1910.22)* – The condition of walking surfaces is irrelevant to this incident.

OSHA's Recommended Practices for Safety and Health Programs

In response to other similar liquid nitrogen asphyxiation incidents,[b] OSHA has urged employers to follow OSHA's Recommended Practices for Safety and Health Programs, a voluntary resource that includes Management Leadership, Hazard Identification and Assessment, Hazard Prevention and Control, and Education and Training [34, 35]. However, OSHA's Recommended Practices for Safety and Health Programs are not enforceable.

4.4.2.3 Emphasis Programs

According to OSHA,

> Local Emphasis Programs (LEPs) are enforcement strategies designed and implemented at the regional office and/or area office levels. These programs are intended to address hazards or industries that pose a particular risk to workers in the office's jurisdiction. The emphasis programs may be implemented by a single area office, or at the regional level (Regional Emphasis Programs [REPs]), and applied to all of the area offices within the region. These LEPs will be accompanied by outreach intended to make employers in the area aware of the program as well as the hazards that the programs are designed to reduce or eliminate [36].

Currently, there are three REPs covering the meat and poultry processing industry; Region 4 [37] (covering Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee), Region 5 [38] (covering Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin), and Region 6 [39] (covering Arkansas, Louisiana, New Mexico, Oklahoma, and Texas). The Region 4 REP became effective on April 1,

---

[a] This OSHA-cited violation concerned availability of an eye wash and safety shower in the vicinity of corrosive materials.

[b] In response to the November 2019 asphyxiation fatality caused by a release of liquid nitrogen at the Custom Genetic Solutions LLC in Mitchell, South Dakota, OSHA issued a press release that states: "OSHA's Recommended Practices for Safety and Health Programs provides employers with a plan for managing safety and health within their workplaces, including hazard identification and assessment, hazard prevention and control, and education and training." [34]

2022 (after the incident at FFG), and the Regions 5 and 6 REPs became effective on October 1, 2023. The REPs cover the elements shown in **Table 6** below.

Table 6. Regions 4, 5, and 6 meat and poultry industry REP elements.

Region 4 (AL, FL, GA, KY, MS, NC, SC, TN)	**Region 5 (IL, IN, MI, MN, OH, WI)**
OSHA Recordkeeping	Machine Guarding
Medical Records	Control of Hazardous Energy
Ergonomics	Hazard Communication
Process Safety Management	Other Hazards
Confined Spaces	**Region 6 (AR, LA, NM, OK, TX)**
Electrical Hazards	OSHA Recordkeeping
Hazard Communication	Medical Records
Hexavalent Chromium	Ergonomics
Machine Guarding/Lockout-Tagout	Process Safety Management
Biological Hazards	Hazard Communication
Other Hazards	Machine Guarding/Lockout-Tagout
	Biological Hazards
	Occupational Noise Hazards

Among the "other hazards" included in the Region 4 REP, OSHA inspectors are directed to "identify and evaluate potential chemical or physical hazards including carbon dioxide [and]…non-PSM refrigerant chemical[s] [37, p. 15]." Likewise, the Region 5 REP includes "refrigeration chemicals (e.g., carbon dioxide, ammonia) [38, p. 27]." Liquid nitrogen is not specifically mentioned in any of the REPs.

Applicability of Liquid Nitrogen within Current REPs

Emphasis programs are an important tool for OSHA to proactively inspect facilities for common hazards prior to an incident occurring. They also generate data for potential future rulemaking actions. OSHA currently has three active REPs that cover the meat and poultry processing industries. None of the existing REPs specifically mention liquid nitrogen, although the Regions 4 and 5 REPs cover "non-PSM refrigerant" chemicals and "refrigeration chemicals," respectively.

It is unclear whether the Region 4 REP (which covers the state of Georgia, where the FFG incident occurred) would have applied to FFG's liquid nitrogen processes had it been in effect prior to the incident. Its application depends on OSHA's interpretation of the word "refrigerant." The Region 6 REP covers PSM-regulated chemicals such as ammonia freezing and refrigeration processes or chlorine used for water treatment processes but lacks the same provision for non-PSM substances that the Region 4 REP contains. Therefore, the CSB recommends that OSHA:

- Update the Region 4 Poultry Processing Facilities Regional Emphasis Program to explicitly cover liquid nitrogen freezing processes. At a minimum, the update should encourage practices applicable to managing the hazards of using liquid nitrogen and other cryogenic asphyxiants, including process safety management practices, atmospheric monitoring, employee training and hazard awareness, and emergency preparedness and response;
- Update the Region 5 Regional Emphasis Program for Food Manufacturing Industry to explicitly cover liquid nitrogen freezing processes. At a minimum, the update should encourage practices applicable to managing the hazards of using liquid nitrogen and other cryogenic asphyxiants, including process safety management practices, atmospheric monitoring, employee training and hazard awareness, and emergency preparedness and response; and,
- Update the Region 6 Poultry Processing Facilities Regional Emphasis Program to explicitly cover liquid nitrogen freezing processes. At a minimum, the update should encourage practices applicable to managing the hazards of using liquid nitrogen and other cryogenic asphyxiants, including process safety management practices, atmospheric monitoring, employee training and hazard awareness, and emergency preparedness and response.

4.4.2.4 Conclusions

As discussed throughout this report, there is abundant industry guidance concerning the proper handling and safety management of cryogenic asphyxiants and cryogenic systems. CCPS provides guidance on the design of instrumented systems (Section 4.1), the execution of PHAs (Section 4.1), the use of atmospheric monitoring (Section 4.2.2.2), and the implementation of a process safety management system (Section 4.4). CGA requires the use of atmospheric monitoring (Section 4.2.2.3), provides guidance on isolation valve placement and design (Section 4.3.5), presents facility design considerations (4.4.1.4), requires proper hazard communication and training (Section 4.4.1.5), and provides guidelines for process safety management systems (Section 4.5.2). NFPA requires the use of atmospheric monitoring (Section 4.2.2.5) and the installation of emergency isolation valves (Section 4.3.5).

Despite the plethora of industry guidance, none of these requirements and guidelines are currently enforceable by regulation.

The CSB concludes that there is no regulation requiring employers handling or processing cryogenic liquid asphyxiants, such as liquid nitrogen, to adhere to industry guidance concerning proper design and safe handling, nor to implement a robust and systematic approach to process safety. Because it was not required to, FFG did not implement important process safety practices that could have either prevented the accidental release, or reduced its severity. In addition, there is no specific guidance from OSHA on the process safety practices necessary for the safe use of cryogenic asphyxiants.

The CSB recommends that OSHA promulgate a standard specific to cryogenic asphyxiants. The purpose of this standard shall be the prevention and/or mitigation of hazards arising from the storage, use, and/or handling of these substances. The new standard shall reference applicable national consensus standards such as those published by the Compressed Gas Association and others, as appropriate. At a minimum the new standard shall:

a) Address requirements for the design, construction, and installation of process equipment storing or using cryogenic asphyxiants;

b) Require atmospheric monitoring where equipment storing or using cryogenic asphyxiants is located indoors;

c) Require emergency shutdown systems such that equipment storing or using cryogenic asphyxiants may be isolated during a release without endangerment;

d) Address requirements for employee training and hazard awareness specific to cryogenic asphyxiants;

e) Require an emergency action plan in accordance with 29 CFR 1910.38; and,

f) Address requirements for the use of process safety management elements such as process hazard analysis, management of change, procedures, and others deemed necessary through the rulemaking process to prevent and/or mitigate these hazards.

KEY LESSON

Regulations are minimum requirements. The need for robust process safety management practices exists wherever hazardous chemicals are manufactured, processed, stored, and used, regardless of their regulatory coverage. Companies must be cognizant of the hazards posed by the chemicals they handle and should implement effective process safety management systems to control process safety risks.

In addition, the CSB recommends that OSHA develop and publish a Guidance Document (similar to OSHA 3912-03 Process Safety Management for Explosives and Pyrotechnics Manufacturing) for process safety management practices applicable to processes handling compressed gases and cryogenic asphyxiants, including (at a minimum) the practices highlighted in this report.

4.5 Product Stewardship

The owner/operator of a hazardous process has the ultimate responsibility for the safety of its processes, facility, and people who work at its facility. In situations like FFG, where the owner and operator of a process are two different companies (FFG operated the equipment, but Messer owned it), responsibility for safety should be shared. Despite FFG's poor safety practices, Messer had the expertise, ability, and opportunity to take effective action to prevent this incident or reduce its likelihood or severity.

Product stewardship refers to the management practice supporting a philosophy of service to customers and minimizing effects on health and the environment throughout the complete life cycle of a product [40].

The American Chemistry Council (ACC), a trade organization that represents chemical companies in the United States, provides product stewardship guidelines through its Responsible Care® program [41, 42]. According to the ACC, Responsible Care® companies are committed to a culture of continual improvement in product safety and product stewardship for each stage of a product's life cycle. As part of this, the ACC developed the Product Safety Code, which provides a set of practices to manage chemical product safety and enhance it as part of its industry's health, safety, security, and environmental management system. The Product Safety Code requires that companies include product safety and product stewardship as part of their management systems. According to the ACC, product safety includes exchanging information regarding product hazards, intended uses, handling practices, exposures, and risks. The ACC describes product stewardship as the responsibility to understand, manage, and communicate the health and environmental impacts throughout the life cycle of chemical products. The customers of member companies and users of the members' products are an important focus of product stewardship [43, 44].

4.5.1 Messer's Product Stewardship Practices

Messer is a member of the ACC's Responsible Care® program and has stated its commitment to the Responsible Care® Guiding Principles "to work with customers, carriers, suppliers, distributors and contractors to foster the safe and secure use, transport and disposal of chemicals and provide hazard and risk information that can be accessed and applied in their operations and products" [45]. However, in a statement to the CSB, Messer clarified that its food freezer business had not been audited and certified under its Responsible Care® program, stating:

> Currently, the Food Freezer Market business is not part of the Responsible Care Certification Program. The Food Freezer Markets business is scheduled for inclusion into the certification program beginning in year 2024 […]. As it relates to Messer-installed equipment at FFG, only the bulk liquid nitrogen storage tanks were developed using the Responsible Care Management System Guidelines.

Regardless, as part of the Line 4 liquid nitrogen freezer startup effort, Messer completed a product stewardship checklist with FFG employees, with the stated purpose to "document the suggested customer interface training and submittals to [e]nsure Messer is providing good safe customer stewardship of our products and services." However, while specific items in the checklist were marked as complete, FFG never signed the checklist acknowledging completion of the items. Furthermore, the CSB found inconsistencies between items marked complete by Messer and actual implementation, as shown in **Table 7**.

Table 7. Messer Responsible Care checklist items.

Action	Verified? (As marked by Messer)	CSB Observations
"Discuss risk assessment results, potential exposures, and mitigation with customer."	Yes	Although the checklist item stated only to "discuss" the results of a risk assessment, FFG never performed a risk assessment, and Messer did not provide the previously performed PHA to FFG prior to startup. (Section 4.4.1.2)
"Delivered all required manuals."	Not yet	As the checklist indicated, Messer did not provide FFG with equipment, operating, or maintenance manuals prior to the incident. (Section 4.4.1.3)
"Training completed: safety and potential hazards, safe gas handling, equipment O&M, [and] process. Attendance list documented to Messer and Customer."	Yes	Messer provided hands-on operational training and a verbal overview of the equipment to three FFG maintenance employees (two maintenance technicians and the Line 4 Packing Supervisor, all three of whom were fatally injured), but the training content was not documented. (Section 4.4.1.5)
"All decals and warning signs in place – Messer equipment, piping …, room entries…"	Yes	Decals and warning signs were never affixed to equipment or room entries. (Section 4.4.1.5)
"Atmosphere monitoring use discussed."	Yes	Although the checklist item stated only to "discuss" the use of monitoring, atmospheric monitors were not installed in the freezer room in accordance with Messer's recommendation, and workers were not provided with personal detectors. (Section 4.2.1)

Former Practices

Prior to the Messer's acquisition of Linde's liquid nitrogen freezer business (see Section 1.1.2), Linde provided customers with a detailed awareness training presentation on the hazards of oxygen deficiency and asphyxiation when handling nitrogen. This training included a list of several minimum requirements and key recommendations for customers, including ensuring that:

- safety information sheets are kept as a record by the customer;
- the customer is aware of safety documentation from gas industry associations, such as CGA;

- information on relevant safety services is available locally to safeguard against asphyxiation;
- gas analyzers are in the correct location, are calibrated, and function;
- ventilation systems are operational and effective; and
- adequate warning signs are in place.

Linde stated that its "Duty of Care" to customers was to:

> …provide a good design and installation of equipment [and] take appropriate action if unsafe use of Linde products becomes apparent (i.e. being a responsible supplier). […] In high risk [situations, Linde] **will have to consider terminating supply**. (emphasis added)

After Messer's acquisition of Linde's liquid nitrogen freezer business, Messer did not continue Linde's "Duty of Care" practices.

4.5.2 Ineffective Product Stewardship

Prior to and following the startup of the liquid nitrogen freezer system, Messer was aware of FFG's poor safety practices. Nevertheless, Messer continued to supply FFG with liquid nitrogen despite FFG's failure to correct the issues. Examples of Messer's inadequate product stewardship are presented below.

Commitment to Process Safety

The CGA is a trade association that develops safety standards and safe practice guidelines for the industrial, medical, food, and specialty compressed and liquefied gases industries [46]. The CGA's standards and guidelines are applicable to liquid nitrogen freezers, such as the one Messer leased to FFG. Messer is a CGA member company and is therefore aware of the CGA's standards and their applicability.

CGA P-86, *Guideline for Process Safety Management* presents 21 process safety management elements in its process safety framework, as shown in **Table 8** [47, pp. 3-4].

Table 8. CGA P-86 Process Safety Management elements.

CGA Element Number	CGA Process Safety Management Element	CGA Element Number	CGA Process Safety Management Element
Process Safety Leadership		**Risk Management**	
1	Leadership Commitment and Responsibility	8	Process and Operational Status Monitoring and Handover
2	Compliance with Legislation and Industry Standards	9	Operating Procedures
3	Employee Selection, Training, and Competency	10	Management of Operational Interfaces
4	Workforce Involvement	11	Standards and Practices
5	Communication and Stakeholders	12	Management of Change

CGA Element Number	CGA Process Safety Management Element	CGA Element Number	CGA Process Safety Management Element
Risk Identification and Assessment		13	Operational Readiness and Process Startup
6	Hazard Identification and Risk Assessment	14	Emergency Management
7	Documentation, Records, and Knowledge Management	15	Inspection and Maintenance
Review and Improvement		16	Management of Safety Critical Devices
19	Incident Investigation	17	Work Control, Permit-to-Work, and Task Risk Management
20	Audit, Management Review, and Intervention	18	Contractors and Suppliers
21	Measures and Metrics		

According to the CGA, "The process safety management framework may be applied to all processes within the industrial […] gases industry. It is designed to address process safety hazards and be equally suitable for the processes that are found in the industry including […] **customer installations**." (emphasis added) [47, p. 1].

CGA P-86 Element 5, *Communication with stakeholders,* states:

> In relation to major hazards, management shall identify key stakeholder groups and develop and maintain a good working relationship […], understanding and addressing their issues and concerns. […] External stakeholders may include […] **customers**. (emphasis added) [47, p. 7].
>
> Appropriate safety information is shared with stakeholders to demonstrate the organization's **commitment to process safety**. (emphasis added) [47, p. 7].

CGA P-86 Element 6, *Hazard identification and risk assessment,* states:

> [Organizations] should ensure that a comprehensive risk assessment process systematically identifies, assesses, and provides mitigations for the risks arising from […] operations [47, p. 7].
>
> Risk assessments consider **process safety risk** as well as risk to […] asset integrity, […] and **customers**. (emphasis added) [47, p. 8].
>
> Identified stakeholders are kept informed about the risk assessment process and results [47, p. 8].

As discussed in Section 4.4.1, FFG did not have an established process safety management system and lacked many important process safety management practices. FFG further lacked the institutional knowledge and experience required to implement such practices. Conversely, industrial gas suppliers like Messer have extensive expertise with and knowledge of the process safety risks posed by the materials and equipment they provide to their customers.

While the owner or operator of a facility has the ultimate responsibility to implement effective practices and safeguards to manage process safety risks and to protect its workers, industrial gas suppliers are often more knowledgeable of the hazards of their products and equipment than their customers, as was the case with Messer and FFG. Thus, companies like Messer should work with their customers to ensure effective process safety management practices are utilized, particularly when the knowledge base and experience required to do so may not be present at the customer level.

Awareness of the Absence of Atmospheric Monitoring

During a site visit to a separate Plant 4 production line[a] in August 2020, Messer recognized that FFG did not have proper atmospheric monitoring based on the hazards posed by the cryogenic liquids being handled. In response, the Messer Sales Engineer sent an email to the FFG Senior Vice President of Operations stating:

> [Messer] highly recommend[s] the use of permanently mounted [o]xygen and [carbon dioxide] monitors augmented with the use of personal/portable monitors as part of the plant's safety system.

Along with this notification in August 2020, Messer provided FFG with information on Messer's Responsible Care initiative and information on how to obtain atmospheric monitors, as shown in **Figure 29**.

Permanent Gas Monitors

As part of Messer's "Responsible Care" initiative, our ongoing commitment to safety, and our concern for our customers and their employees, vendors and contractors, Messer strongly recommends the use of permanent gas monitors whenever industrial gases are used in an indoor or enclosed work environment.

While Messer does not design gas monitoring systems nor endorse a specific meter or company, the attached list of gas monitoring equipment manufacturers can assist you in selecting a proper monitoring or detection system to meet your specific facility needs.

Gas monitoring, detection and alarm should be an important part of any plant safety system. Consult with your monitor manufacturer to ensure adherence to their recommended installation, operating and maintenance instructions.

OXYGEN CONCENTRATION MONITORS
Use to ensure safe oxygen concentrations maintained. Used in nitrogen, argon, and helium applications.

Figure 29. Excerpt from Messer's notification to FFG on the need for atmospheric monitoring. (Credit: Messer)

As discussed in Section 4.2.1, FFG continued to operate the freezer without atmospheric monitoring at the time of the incident.

Awareness of No Mechanical Ventilation and Risks Presented by Freezer Location

As discussed in Section 4.4.1.4, the FFG Line 4 freezer room was not equipped with either HVAC or industrial ventilation. During the freezer installation, Messer was aware of the lack of mechanical ventilation in the room FFG selected to install the freezer equipment. The exhaust system installed on the freezer equipment required a

[a] The process line being observed handled cryogenic carbon dioxide, which poses an asphyxiation hazard similar to liquid nitrogen.

supply of fresh air to replenish air removed from the exhaust system, called make-up air. Contractually, Messer provided the make-up air volume calculation to FFG, and FFG was responsible for ensuring the ventilation requirements were met. In a post-incident interview with the CSB, the Messer Project Manager conveyed concerns about the lack of ventilation and insufficient make-up air in the freezer room:

> Usually, customers have massive make-up air units in their room, so when you add [the freezer] in there, it doesn't matter. You're still going to get the circulation. Some of them actually have to add blowers to the make-up air units to basically compensate for what we're taking out.
>
> [In the Line 4 freezer room], I didn't see any make-up air, what we call forced circulation.

The Messer Project Manager added:

> [Messer doesn't] do a whole HVAC calculation and assess the actual size of the room and calculate what's going on. We just know that this freezer's [exhaust is] pulling this amount of air from the room, and if you want to maintain the integrity of that room, just make sure you can replace that same, make sure that same supply is in there.

As discussed in Section 4.4.1.4, FFG relied on the opening from the adjacent processing room to supply make-up air. This method of supplying make-up air is unreliable, as described by the Messer Project Manager:

> With the […] opening, that's natural circulation. So we don't count on natural circulation as flow because that can vary and it's very hard to measure. We count on forced circulation. So that means you put a certain make-up air unit in there. You know what it is. You can count on it. And it's shooting in the space, and it's doing its job.

Following a site visit elsewhere in the facility in August 2020, the Messer Sales Engineer sent an email to the FFG Senior Vice President of Operations conveying concerns about FFG's general ventilation design:

> Messer would like to emphasize the need for adequate ventilation/exhaust systems to ensure the plant atmosphere contains levels of [carbon dioxide] and [nitrogen] below exposure limits and oxygen levels are above 19.5%.

FFG did not address the ventilation concerns. As discussed in Sections 4.4.1.4 and 4.2.1, FFG continued to operate the freezer without mechanical room ventilation and atmospheric monitoring and alarm systems.

Messer also would have been aware that the room was mostly enclosed above five feet of elevation and nearly fully enclosed below five feet of elevation. Despite the inherent risks of the Line 4 freezer room, Messer did not object to FFG's placement of the freezer, either in the proposal stage or the construction stage, and Messer continued to supply FFG with liquid nitrogen. Messer was leasing the freezer to FFG and could have objected to the placement of the freezer, suspended liquid nitrogen supply, or terminated[a] the agreement.

Awareness of Defeated Interlocks

On January 26, 2021, two days prior to the incident, the Messer Sales Engineer was observing the Line 4 immersion-spiral freezer when he discovered that an interlocked freezer door was open while the freezer was operating, a condition that normally would automatically shut down nitrogen flow to the freezer. According to the Messer Sales Engineer, when the door and lid safety are properly installed, it is not possible to open the door during operations under normal conditions:

> Those doors have to be shut in order for the freezer to operate. So they're all sealed during operation. If you open those doors, those magnetic switches will alarm and shut off everything and ramp up the exhaust to full speed.

Upon discovering this situation, the Messer Sales Engineer verbally informed the FFG Maintenance Manager that the inoperable interlock posed a safety hazard and needed to be repaired:

> Well, initially the machine was in a shutdown mode so the machine was not actually running, and so I had no response to the transition door being open under those conditions. But once they started running the machine and I noticed that the transition box door was still open, I recognized that that is not a condition that is acceptable. And I told [the FFG Maintenance Manager] and the maintenance guy that that is an unsafe condition and that it needed to be repaired.

During the investigation, the CSB determined that the transition box door and freezer lid safety switches had been tampered with such that they were defeated, as shown in **Figure 30**. In the as-found condition, the system would recognize the door and lid as closed, regardless of their actual positions, allowing the door or lid to be opened to access the freezer interior even when the freezer was operational. As the Messer Sales Engineer told the CSB:

> That magnet has been removed from the door and taped to the switch. Somebody has removed the magnet from the door and taped it to the switch so they can open the door while the freezer's running.

[a] Since Messer owned the immersion-spiral freezer, FFG contractually would not be able to replace Messer with a different liquid nitrogen supplier without also replacing the equipment.

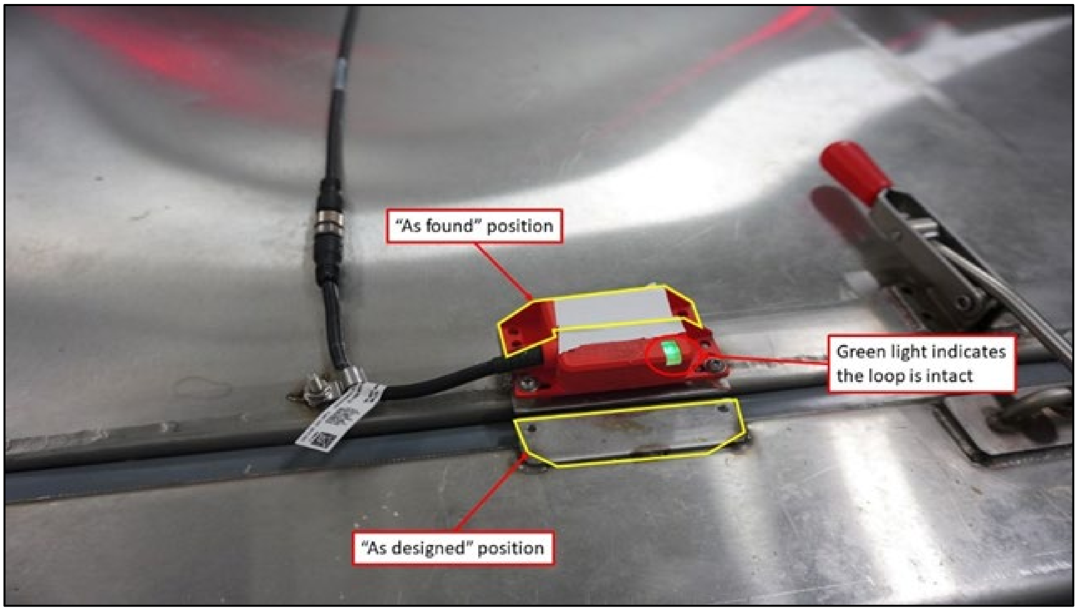


Figure 30. Defeated transition box door safety switches. (Credit: CSB)

Prior to the incident, the Messer Sales Engineer did not report this condition to anyone at Messer, purportedly because he was told by FFG's maintenance personnel that the switches would be restored to their proper positions. Nevertheless, FFG had not repaired the defeated interlocked door switches prior to the incident.

The CSB concludes that Messer did not practice effective product stewardship prior to the incident. Messer was aware of several instances of FFG's process safety deficiencies and poor safety practices yet still commissioned the freezer to FFG. Using more effective product stewardship, Messer could have prevented this incident by 1) objecting to the placement of the freezer in a room particularly susceptible to oxygen deficiency, 2) refusing to commission its freezer equipment until FFG provided adequate atmospheric monitoring and alarm systems, 3) suspending supply of liquid nitrogen until safety deficiencies had been addressed, or 4) ending the relationship with FFG and removing its equipment.

4.5.3 Messer Post-Incident Actions

Following the incident, Messer has implemented a new product stewardship safety program, which includes a safety assessment process for freezer equipment and associated supply piping at Messer customer sites, applicable to sites where Messer supplies liquid nitrogen and liquid carbon dioxide. As part of the program, Messer will perform safety inspections when engaging in new business or additional use for new food freezer applications, at customer request, or when a Messer employee notes a concern. Additionally, Messer will perform a safety inspection for all existing food freezing customers. The safety inspections will include reviews of:

- atmospheric conditions;
- atmospheric monitoring interlocked into cryogenic liquid supply;
- exhaust systems;

- cryogenic liquid piping supply application equipment;
- pressure relief devices;
- material compatibility;
- safety permissives, interlocks, and alarms;
- equipment clearances;
- SDS;
- product training materials; and
- equipment manuals and drawings.

When engaging in new business, Messer requires the following at a customer site:

- Permanently mounted atmospheric monitoring interlocked into application equipment or emergency shut off valves that shut off supply of cryogenic liquid when in an alarm state;
- Proof of exhaust installed and interlocked into all application equipment that will not allow the flow of cryogenic liquid when exhaust is not operating;
- Safe cryogenic liquid piping systems installed; and
- Presence of Messer nitrogen and/or carbon dioxide SDS and product safety sheets, and product safety training materials.

For existing customers, Messer established a color-coded rating system, as shown in **Figure 31**. In response to a customer rating of Red, Messer may choose to shut down the customer process.

Figure 31. Messer customer safety rating system (Credit: Messer)

The CSB concludes Messer's newly developed customer safety inspection program provides a robust review of liquid nitrogen customer safety practices and can help prevent future incidents similar to the one at FFG.

Despite these positive changes, Messer's product stewardship program does not involve any review or participation in a customer's PHA, a critical practice in which facility- and process-specific hazards are identified and controlled. Although Messer cannot force its customers to conduct a PHA or to hire a third party to conduct a PHA, Messer can participate in PHAs conducted by those customers willing to do so and can consider taking any of the product stewardship actions discussed above for those customers unwilling to do so.

As discussed in Section 4.5.2, CGA P-86 states that organizations should complete a comprehensive risk assessment to consider process safety risks to customers. In addition, as discussed in Section 4.1.2, CCPS *Guidelines for Hazard Evaluation Procedures* provides guidance on PHA execution. Additionally, Messer's product stewardship program does not involve the verification of proper signage, labeling, and hazard communication, nor does it explicitly mention emergency shutoff devices (E-stops). Therefore, the CSB recommends that Messer update the company product stewardship policy to:

a) include participation by Messer in customers' process hazard analyses (PHAs). The policy should require that these PHAs be conducted in a manner which conforms with CCPS *Guidelines for Hazard Evaluation Procedures* prior to the startup of a cryogenic freezing process;

b) require verification that proper signage, in accordance with CGA P-76 *Hazards of Oxygen-Deficient Atmospheres*, is displayed on and/or near equipment; and

c) require a facility and/or equipment siting review to ensure that emergency shutoff devices, including E-stops, are located such that they can be safely actuated during a release of liquid nitrogen.

In addition, the CSB recommends that Messer create an informational product that provides Messer customers with information on the safety issues described in this report. In this informational product, recommend that Messer customers develop and implement effective safety management systems to control asphyxiation hazards from inert gases based on the guidance published in CGA P-86 *Guideline for Process Safety Management*, CGA P-12 *Guideline for Safe Handling of Cryogenic and Refrigerated Liquids*, CGA P-18 *Standard for Bulk Inert Gas Systems*, and CGA P-76 *Hazards of Oxygen-Deficient Atmospheres*.

5 Conclusions

5.1 Findings

Technical Analysis

1. Liquid nitrogen overflowed from the immersion freezer. The liquid nitrogen overflow was caused by the failure of the freezer's level control and high-level safety interlock systems.

2. The failure of the freezer's level control and high-level safety interlock systems was caused by the deformation of the bubbler tube.

3. The bubbler tube was likely bent on the morning of the incident during maintenance troubleshooting activities, likely between 8:20 a.m. and approximately 9:30 a.m.

4. There was insufficient evidence to determine exactly when the tube was bent. Therefore, the CSB was not able to determine precisely when the uncontrolled release began.

5. The CSB was not able to definitively determine how the tube was bent.

6. The CSB could not determine whether the two maintenance workers had sufficient awareness, time, and ability to avert the release by activating an E-stop or to escape the room safely prior to the loss of containment.

7. The uncontrolled release of liquid nitrogen likely ceased at approximately 10:15 a.m. when the bulk storage tank manually-operated discharge valves, located outside the building, were closed.

8. At most, approximately 6,300 gallons (approximately 42,400 pounds) of liquid nitrogen released from the FFG Line 4 immersion freezer, though the actual released quantity was likely less. There was insufficient evidence to determine the exact quantity of released liquid nitrogen because it was not possible to determine when the release began.

9. The released liquid nitrogen vaporized, collected in the freezer room, and produced an oxygen-deficient atmosphere inside the room.

Single Point of Failure

10. The immersion freezer was designed such that the failure of a single level measurement device could defeat both the nitrogen level control system and the emergency interlock intended to stop nitrogen flow to the freezer. After the bubbler tube was bent, there was nothing to prevent the nitrogen release from the freezer.

11. Linde did not design the immersion-spiral freezer in accordance with industry guidance regarding single points of failure for instrumented systems. Had Linde or Messer included additional independent safeguards to protect against overflow events, this incident could have been prevented.

12. Linde did not adequately consider the failure of the liquid nitrogen level control system and did not identify appropriate safeguards to mitigate the potential failure. In essence, Linde incorrectly identified the bubbler tube as a safeguard for itself.
13. Linde did not identify specific incident scenarios or cause-consequence pairs when conducting the PHA for the immersion-spiral freezer, which resulted in Linde's failure to identify adequate safeguards to protect against the overflow of liquid nitrogen from the immersion freezer.
14. Messer's Quality Control procedures and practices were ineffective in ensuring that the two support clamps on the bubbler tube were in place at the time of inspection. As a result, Messer failed to identify the missing support clamp during Quality Control inspection.
15. The combination of unsecured tubing length and support clamp location worsened the potential for the bubbler tube to become bent, which ultimately resulted in the bubbler system becoming non-functional.

Atmospheric Monitoring and Alarm Systems

16. Messer informed FFG of the need for atmospheric monitoring of its liquid nitrogen processes on at least three occasions. Despite Messer's recommendations, neither FFG nor Messer took action to install monitoring or alarm equipment on the Line 4 process, which could have alerted workers to the presence of an oxygen-deficient atmosphere, and, if designed accordingly, could have triggered an emergency shutdown of the liquid nitrogen systems.
17. FFG did not follow industry guidance concerning the use of atmospheric monitoring and alarms for its liquid nitrogen process, and as a result, many personnel were unaware that the freezer room was unsafe to enter on the day of the incident.
18. Had Messer or FFG properly considered, designed, installed, tested, and maintained an atmospheric monitoring and alarm system in the freezer room, workers would have been warned against entering the oxygen-deficient atmosphere, which could have prevented the subsequent fatalities and serious injuries to FFG workers.
19. Industry guidance for carbon dioxide is extensive. Comparable, specific guidance for liquid nitrogen could help prevent future incidents similar to the one at FFG.

Emergency Preparedness

20. Although FFG had a written emergency action plan, it was severely inadequate to address a liquid nitrogen emergency. Its inadequacies included 1) that it was not written in Spanish, the primary language of many of FFG's workers; 2) that it made no mention of the existence of liquid nitrogen at the facility; 3) that it made no mention of the hazards of liquid nitrogen; 4) that it had no instructions for how, whether, or when to respond to a release of liquid nitrogen other than general evacuation instructions; 5) that it contained no information or plan for how employees were to be notified of an emergency; 6) that it contained no information on what constituted an emergency or what types of emergencies to which employees might need to respond; and 7) that it had no provision for proactively interacting with local emergency responders despite the company's stated practice of relying on them for emergency response.

21. As a result of FFG's poor emergency communication, employees attempting to respond to the incident or evacuate the building were only minimally informed, if at all, of the nature and severity of the emergency.

22. The four workers who subsequently were fatally injured were attempting some sort of response to the release.

23. FFG did not prepare its workforce in any meaningful way to respond to a release of liquid nitrogen. The company's deficiencies included 1) its lack of emergency response training for its workforce, 2) its lack of employee training on how to identify a liquid nitrogen release, 3) the lack of automated means to detect and inform its workers of a liquid nitrogen release, and 4) insufficient direction to its employees not to respond or attempt rescue during a liquid nitrogen release.

24. As a result of FFG's unpreparedness, the severity of the incident was greatly increased during evacuation and response activities when four additional employees were fatally injured, three employees were seriously injured, and at least seven others sustained minor injuries or were uninjured but easily could have been seriously or fatally injured. Had FFG effectively prepared its workforce for a liquid nitrogen release, the four additional fatalities and three of the four serious injuries could have been prevented.

25. Gold Creek's policy documents and emergency procedures are more robust than FFG's emergency action plan was at the time of the incident and could have reduced the severity of this incident had FFG implemented similar policies and procedures.

26. The placement of the Line 4 immersion-spiral freezer E-stop buttons required a responding employee or person not otherwise in the freezer room to enter an oxygen-deficient atmosphere during a release of liquid nitrogen to activate an E-stop. This design was unsafe. As a result, once FFG's two maintenance workers became incapacitated, the uncontrolled liquid nitrogen release could not be safely stopped until employees manually closed valves at the bulk liquid nitrogen storage tanks outside of the building, or until emergency responders equipped for entry into an oxygen-deficient atmosphere could enter the freezer room and activate an E-stop. Safer placement of E-stop buttons, and effective employee training on their use, might have helped prevent the death of some or all of the four employees who perished during emergency response.

27. Had FFG and Messer installed E-stop buttons outside the Line 4 freezer room, such as at the entrances to the room or at the bulk storage tanks, the uncontrolled release could have been stopped more expediently.

Process Safety Management System

28. For several months prior to the incident, FFG's safety management organization did not include employees with direct responsibility over the safety practices. Had FFG established process safety programs and objectives; assigned qualified personnel clear responsibilities over process safety management; defined, implemented, and tracked process safety objectives; and ensured organization leaders demonstrated commitment to process safety principles, FFG could have prevented the incident.

29. FFG did not identify or evaluate hazards specific to its process, such as the liquid nitrogen overflow and asphyxiation risks, and did not implement effective controls to mitigate the risk.

30. FFG did not have written procedures to operate or maintain the liquid nitrogen freezer, and therefore the FFG employees were not provided with clear instructions and precautions in operating the equipment. Had FFG developed clear written procedures, it is likely that the FFG workers would have understood the function of the freezer, the importance of critical components, and proper precautions when operating and troubleshooting the equipment, which may have prevented the release.

31. FFG did not have a management of change process to identify, assess, and manage risk introduced by process changes. During the introduction of the liquid nitrogen immersion-spiral freezer, FFG did not consider how the change could impact process safety, did not include approval authorities with explicit responsibilities for safety, and did not address conformance with industry guidance. As a result, FFG did not manage the risks associated with using a mostly enclosed, partially recessed room without mechanical ventilation and installed the liquid nitrogen freezer in an area particularly susceptible to an oxygen-deficient atmosphere.

32. FFG had no system, plan, or program to train and verify the competency of its employees when operating the liquid nitrogen freezer and working with or near hazardous liquid nitrogen. As a result, FFG employees at all levels of the organization were not aware of the hazards of liquid nitrogen and were unaware of precautions that should have been taken.

33. Had the liquid nitrogen freezer equipment and the entrance to the Line 4 freezer room been affixed with proper warning signage and labels, workers could have been made aware of the asphyxiation risks within the room.

34. FFG lacked an effective process safety management system to identify, evaluate, and control the hazards of the liquid nitrogen process. The lack of safety oversight by FFG leadership, absence of a systematic process hazard analysis, lack of written procedures, lack of any management of change practices, and failure to communicate hazards resulted in the unmitigated handling of a cryogenic asphyxiant by untrained and unprepared personnel. This incident could have been prevented had FFG practiced robust process safety management.

35. There is no regulation requiring employers handling or processing cryogenic liquid asphyxiants, such as liquid nitrogen, to adhere to industry guidance concerning proper design and safe handling, nor to implement a robust and systematic approach to process safety. Because it was not required to, FFG did not implement important process safety practices that could have either prevented the accidental release or reduced its severity.

36. There is no specific guidance from OSHA on the process safety practices necessary for the safe use of cryogenic asphyxiants.

Product Stewardship

37. Messer did not practice effective product stewardship prior to the incident. Messer was aware of several instances of FFG's process safety deficiencies and poor safety practices yet still commissioned the freezer to FFG. Using more effective product stewardship, Messer could have prevented this incident by

1) objecting to the placement of the freezer in a room particularly susceptible to oxygen deficiency, 2) refusing to commission its freezer equipment until FFG provided adequate atmospheric monitoring and alarm systems, 3) suspending supply of liquid nitrogen until safety deficiencies had been addressed, or 4) ending the relationship with FFG and removing its equipment.

38. Messer's newly developed customer safety inspection program provides a robust review of liquid nitrogen customer safety practices and can help prevent future incidents similar to the one at FFG.

5.2 Cause

The CSB determined the cause of the liquid nitrogen release was the failure of the immersion freezer's liquid level control system to accurately measure and control the liquid nitrogen level inside the freezer, which resulted from deformation of the system's bubbler tube component.

Contributing to the incident were 1) Messer's design of the freezer, which allowed the failure of a single level measurement device to result in an uncontrolled loss of containment of liquid nitrogen, 2) FFG's lack of any process safety management systems or practices that could have prevented the incident, 3) a lack of regulatory coverage for liquid nitrogen, which enabled FFG to elect not to implement process safety practices that could have prevented the incident, and 4) Messer's inadequate product stewardship practices, which resulted in Messer continuing to supply FFG with liquid nitrogen despite FFG's unsafe practices.

Contributing to the severity of the incident were 1) FFG's inadequate emergency preparedness, which resulted in at least 14 employees responding to the release by entering the freezer room or the surrounding area to investigate the incident or to attempt to rescue their coworkers, and 2) the absence of atmospheric monitoring and alarm devices that could have alerted workers to the presence of a hazardous atmosphere and warned them against entering.

6 RECOMMENDATIONS

To prevent future chemical incidents, and in the interest of driving chemical safety excellence to protect communities, workers, and the environment, the CSB makes the following safety recommendations:

6.1 GOLD CREEK FOODS[a]

2021-03-I-GA-R1

Include in the emergency action program provisions for proactively interacting with and informing local emergency response resources of all emergencies at the former FFG Plant 4 facility to which Gold Creek expects them to respond. At a minimum, Gold Creek should:

a) inform local emergency responders of the existence, nature, and location of hazardous substances at its facilities, including liquid nitrogen;

b) inform local emergency responders of the location of emergency-critical equipment such as bulk storage tanks, points of use, isolation valves, E-stop switches, and any other emergency equipment or systems with which emergency responders may need to interact; and,

c) provide local emergency responders with information, such as facility plot plans, engineering drawings, or other information needed to mount an effective emergency response.

6.2 MESSER LLC[b]

2021-03-I-GA-R2

Update the company product stewardship policy to:

a) include participation by Messer in customers' process hazard analyses (PHAs). The policy should require that these PHAs be conducted in a manner which conforms with CCPS *Guidelines for Hazard Evaluation Procedures* prior to the startup of a cryogenic freezing process;

b) require verification that proper signage, in accordance with CGA P-76 *Hazards of Oxygen-Deficient Atmospheres*, is displayed on and/or near equipment; and,

[a] Gold Creek has developed emergency response procedures that could have reduced the severity of this incident. Consequently, the CSB makes no recommendations to Gold Creek pertaining to the development of emergency preparedness policies or employee training for its emergency action program. Additionally, as of this report's publication, there are no liquid nitrogen freezing processes at the former FFG Plant 4 building which Gold Creek now operates. Consequently, the CSB makes no recommendation to Gold Creek related to process safety management practices for liquid nitrogen processes.

[b] After the incident Messer revised its freezer design to include multiple layers of protection against liquid nitrogen overflow. Messer also revised its Quality Control process and procedures to require verification of the presence of the necessary bubbler tube clamps and reordered the sequence of inspection steps to facilitate this verification. Consequently, the CSB makes no recommendation to Messer regarding the design of its immersion freezers or its Quality Control process.

c) require a facility and/or equipment siting review to ensure that emergency shutoff devices, including E-stops, are located such that they can be safely actuated during a release of liquid nitrogen.

2021-03-I-GA-R3

Create an informational product that provides Messer customers with information on the safety issues described in this report. In this informational product, recommend that Messer customers develop and implement effective safety management systems to control asphyxiation hazards from inert gases based on the guidance published in CGA P-86 *Guideline for Process Safety Management*, CGA P-12 *Guideline for Safe Handling of Cryogenic and Refrigerated Liquids*, CGA P-18 *Standard for Bulk Inert Gas Systems*, and CGA P-76 *Hazards of Oxygen-Deficient Atmospheres*.

6.3 U.S. Occupational Safety and Health Administration (OSHA)

2021-03-I-GA-R4

Update the Region 4 Poultry Processing Facilities Regional Emphasis Program to explicitly cover liquid nitrogen freezing processes. At a minimum, the update should encourage practices applicable to managing the hazards of using liquid nitrogen and other cryogenic asphyxiants, including process safety management practices, atmospheric monitoring, employee training and hazard awareness, and emergency preparedness and response.

2021-03-I-GA-R5

Update the Region 5 Regional Emphasis Program for Food Manufacturing Industry to explicitly cover liquid nitrogen freezing processes. At a minimum, the update should encourage practices applicable to managing the hazards of using liquid nitrogen and other cryogenic asphyxiants, including process safety management practices, atmospheric monitoring, employee training and hazard awareness, and emergency preparedness and response.

2021-03-I-GA-R6

Update the Region 6 Poultry Processing Facilities Regional Emphasis Program to explicitly cover liquid nitrogen freezing processes. At a minimum, the update should encourage practices applicable to managing the hazards of using liquid nitrogen and other cryogenic asphyxiants, including process safety management practices, atmospheric monitoring, employee training and hazard awareness, and emergency preparedness and response.

2021-03-I-GA-R7

Promulgate a standard specific to cryogenic asphyxiants. The purpose of this standard shall be the prevention and/or mitigation of hazards arising from the storage, use, and/or handling of these substances. The new standard shall reference applicable national consensus standards such as those published by the Compressed Gas Association and others, as appropriate. At a minimum the new standard shall:

a) Address requirements for the design, construction, and installation of process equipment storing or using cryogenic asphyxiants;

b) Require atmospheric monitoring where equipment storing or using cryogenic asphyxiants is located indoors;

c) Require emergency shutdown systems such that equipment storing or using cryogenic asphyxiants may be isolated during a release without endangerment;

d) Address requirements for employee training and hazard awareness specific to cryogenic asphyxiants;

e) Require an emergency action plan in accordance with 29 CFR 1910.38; and,

f) Address requirements for the use of process safety management elements such as process hazard analysis, management of change, procedures, and others deemed necessary through the rulemaking process to prevent and/or mitigate these hazards.

2021-03-I-GA-R8

Develop and publish a Guidance Document (similar to OSHA 3912-03 Process Safety Management for Explosives and Pyrotechnics Manufacturing) for process safety management practices applicable to processes handling compressed gases and cryogenic asphyxiants, including (at a minimum) the practices highlighted in this report.

6.4 Compressed Gas Association (CGA)

2021-03-I-GA-R9

Develop a comprehensive standard for the safe storage, handling, and use of liquid nitrogen in stationary applications, comparable to the guidance presented in CGA G-6.5 *Standard for Small Stationary Insulated Carbon Dioxide Systems.* At a minimum, the standard should include:

a) requirements for and guidance on the location, the maintenance, and the functional testing of atmospheric monitoring devices;

b) requirements for visible and audible alarm indication distinct from the building's fire alarm system and at a continuously attended location;

c) guidance on the design, function, periodic maintenance and testing, and location of room and emergency ventilation systems; and,

d) requirements for and guidance on the location of emergency shutdown devices including E-stops.

2021-03-I-GA-R10

Update P-76 *Hazards of Oxygen-Deficient Atmospheres*. At a minimum, the updated standard should:

a) require that atmospheric monitoring systems *shall be* utilized with processes, equipment, and piping systems capable of producing oxygen-deficient atmospheres;

b) require that atmospheric monitoring systems provide both visible and audible alarm indication distinct from a building's fire alarm system and at a continuously attended location;

c) require that processes, equipment, and piping systems capable of producing oxygen-deficient atmospheres *shall be* equipped with remotely operated emergency isolation valves (ROEIVs); and

d) include guidance on the adequate safe location of emergency stop devices. At a minimum this guidance should be harmonized with the requirements of ISO 13850 *Safety of machinery – Emergency stop function – Principles for design.* As necessary, augment the general guidance of ISO 13850 with guidance specific to processes, equipment, and piping using cryogenic asphyxiants and inert gases.

6.5 National Fire Protection Association (NFPA)

2021-03-I-GA-R11

Update NFPA 55 *Compressed Gases and Cryogenic Fluids Code* to:

a) require the use of atmospheric monitoring with cryogenic asphyxiants in accordance with industry guidance such as is contained in CGA P-76 *Hazards of Oxygen-Deficient Atmospheres* and CGA P-12 *Safe Handling of Cryogenic Liquids* in addition to CGA P-18 *Standard for Bulk Inert Gas Systems*; and,

b) include guidance on the adequate safe location of manual shutoff valves and devices such as emergency push buttons used to activate remotely operated emergency isolation valves (ROEIVs). At a minimum this guidance should be harmonized with the requirements of ISO 13850 *Safety of machinery – Emergency stop function – Principles for design*.

6.6 International Code Council (ICC)

2021-03-I-GA-R12

Update the International Fire Code to:

a) require the use of atmospheric monitoring with cryogenic asphyxiants in accordance with industry guidance such as is contained in CGA P-76 *Hazards of Oxygen-Deficient Atmospheres* and CGA P-12 *Safe Handling of Cryogenic Liquids* in addition to CGA P-18 *Standard for Bulk Inert Gas Systems*; and,

b) include guidance on the adequate safe location of manual shutoff valves and devices such as emergency push buttons used to activate remotely operated emergency isolation valves (ROEIVs) in cryogenic fluid service. At a minimum this guidance should be harmonized with the requirements of ISO 13850 *Safety of machinery – Emergency stop function – Principles for design.*

7 KEY LESSONS FOR THE INDUSTRY

To prevent future chemical incidents, and in the interest of driving chemical safety excellence to protect communities, workers, and the environment, the CSB urges companies to review these key lessons:

1. Processes and equipment that utilize hazardous materials should be designed robustly enough that the failure of a single component cannot result in a catastrophic incident.

2. Facilities that handle hazardous gases or cryogenic asphyxiants should have a functioning atmospheric monitoring and alarm system based on a properly conducted risk assessment. Functioning atmospheric monitoring systems consist of equipment that has been properly designed, installed, maintained, inspected, and tested and will alert personnel of a hazardous atmosphere using audible and visual alarms.

3. Safety leadership begins with management. Designating competent and resourced staff with responsibility over specific safety programs is key to ensuring effective process safety. Management must be knowledgeable and involved in each of these safety programs to provide effective oversight.

4. A PHA can only be effective if it is specific to the process it evaluates. Not considering facility-specific scenarios misses opportunities to effectively identify, evaluate, and control hazards. Companies installing equipment into a process at their facility should always perform a PHA considering the hazards introduced by the process, equipment, facility or room layout, surrounding area, and external factors.

5. It is critical for workers to be trained on the hazards of the materials they encounter. Non-flammable, non-toxic chemicals, such as nitrogen, can be incorrectly assumed to be non-hazardous without proper training and hazard communication. Companies handling these materials have an obligation to train and inform their employees.

6. Food manufacturers are not immune from chemical hazards and process safety risks. Whenever an organization introduces a hazardous chemical into its process, it should implement robust process safety management practices to effectively control the risks, regardless of whether any regulation requires the organization to do so.

7. Regulations are minimum requirements. The need for robust process safety management practices exists wherever hazardous chemicals are manufactured, processed, stored, and used, regardless of their regulatory coverage. Companies must be cognizant of the hazards posed by the chemicals they handle and should implement effective process safety management systems to control process safety risks.

8 REFERENCES

[1] Messer Americas, "Messer Brings Gases Expertise to Americas, After Mess Group, CVC Close Acquisition," 1 March 2019. [Online]. Available: https://www.messeramericas.com/news/messer-brings-gases-americas.

[2] Messer Americas, "About Messer Americas," [Online]. Available: https://www.messeramericas.com/our-company.

[3] Foundation Food Group, "Products," [Online]. Available: https://www.foundationfoodgroup.com/products.html. [Accessed 17 March 2021].

[4] P. Yanisko and D. Croll, "Use Nitrogen Safely," March 2012. [Online]. Available: https://www.airproducts.com.tw/~/media/downloads/article/U/en-use-nitrogen-safely-312-12-023.pdf. [Accessed 19 March 2021].

[5] Compressed Gas Association (CGA), *CGA P-12 Safe Handling of Cryogenic Liquids,* 6th ed., 2017.

[6] Compressed Gas Association (CGA), *CGA P-76 Hazards of Oxygen-Deficient Atmospheres,* 1st ed., 2018.

[7] Messer North America, Inc., "Nitrogen, Refrigerated Liquid Safety Data Sheet," [Online]. Available: https://www.messer-us.com/products/nitrogen. [Accessed 17 March 2021].

[8] U.S. Chemical Safety and Hazard Investigation Board (CSB), "Safety Bulletin: Hazards of Nitrogen Asphyxiation," 2003.

[9] C. Kennedy, "Review of cryogenic vs. mechanical freezers," *Air Products - Cold feat: choosing the right freezing technology for your production line,* 2014.

[10] Messer, *Fact Sheet: Nitrogen Immersion-Spiral Freezers,* 2019.

[11] N. E. Battikha, The Condensed Handbook of Measurement and Control, 3rd ed., The Instrumentation, Systems, and Automation Society, 2007.

[12] Center for Chemical Process Safety (CCPS), Guidelines for Safe and Reliable Instrumented Protective Systems, 2007: Wiley, New York.

[13] International Society of Automation (ISA), *ISA 61511 Functional Safety — Safety Instrumented Systemsfor the Process Industry Sector,* Washington: American National Standards Institute (ANSI), 2018.

[14] Center for Chemical Process Safety (CCPS), "CCPS Process Safety Glossary," [Online]. Available: https://www.aiche.org/ccps/resources/glossary. [Accessed 16 August 2023].

[15] Center for Chemical Process Safety (CCPS), Guidelines for Hazard Evaluation Procedures (3rd Edition), New York: Wiley, 2008.

[16] T. J. Peterson and J. G. Weisend II, "Cryogenic Safety A Guide to Best Practice in the Lab and Workplace," in *International Cryogenics Monagraph Series*, 2019.

[17] Center for Chemical Process Safety (CCPS), Continuous Monitoring for Hazardous Material Releases, Wiley, 2009.

[18] Compressed Gas Association (CGA), *P-12 Guideline for Safe Handling of Cryogenic and Refrigerated Liquids,* 7th ed., 2023.

[19] Compressed Gas Association (CGA), *CGA P-18 Standard for Bulk Inert Gas Systems,* 5th ed., 2020.

[20] International Code Council (ICC), "Who We Are," [Online]. Available: https://www.iccsafe.org/about/who-we-are/#:~:text=The%20International%20Code%20Council%20is,technology%2C%20training%2C%20and%20certification.. [Accessed 25 August 2023].

[21] International Code Council (ICC), *Internatinal Fire Code (IFC),* 2021.

[22] National Fire Protection Association (NFPA), *NFPA 55 Compressed Gases and Cryogenic Fluids Code,* 2020 ed., 2019.

[23] Compressed Gas Association (CGA), *G-6.5 Standard for Small Stationary Insulated Carbon Dioxide Systems,* 5th ed., 2022.

[24] U.S. Environmental Protection Agency (EPA), "Emergency Planning and Community Right-to-Know Act (Non-Section 313) Regulations and Amendments," [Online]. Available: https://www.epa.gov/epcra/emergency-planning-and-community-right-know-act-non-section-313-regulations-and-amendments. [Accessed 11 Nov 2023].

[25] International Organization for Standardization (ISO), *ISO-13850 Safety of machinery - Emergency stop function - Principles of design,* 3rd ed., 2015.

[26] 29 CFR 1910.119, *Process safety management of highly hazardous chemicals.*

[27] 40 CFR 68, *Chemical Accident Prevention Provisions.*

[28] Center for Chemical Process Safety (CCPS), Guidelines for Risk Based Process Safety, Hoboken, NJ: John Wiley & Sons, 2007.

[29] U.S. Occupational Safety and Health Administration (OSHA), "About OSHA," [Online]. Available: https://www.osha.gov/aboutosha. [Accessed 5 October 2023].

[30] 29 CFR 1910.1200, *Hazard Communication,* Occupational Safety and Health Administration (OSHA).

[31] 29 CFR 1910.147, *Control of Hazardous Energy (Lockout/Tagout),* Occupational Safety and Health Adminstration (OSHA).

[32] OSH Act of 1970 Section 5(a)(1), *General Duty Clause,* Occupational Safety and Health Administration (OSHA).

[33] 29 CFR 1910.120, *Hazardous Waste Operations and Emergency Response,* Occupational Safety and Health Administration (OSHA).

[34] U.S. Department of Labor, "U.S. Department of Labor Cites South Dakota Bull Stud Facility After Employee Asphyxiated While Handling Liquid Nitrogen," *OSHA News Release - Region 8,* 20 May 2020.

[35] U.S. Occupational Safety and Health Administration (OSHA), "Recommended Practices for Safety and Health Programs," [Online]. Available: https://www.osha.gov/safety-management.

[36] U.S. Occupational Safety and Health Administration (OSHA), "Directives - Regional LEP," [Online]. Available: https://www.osha.gov/enforcement/directives/lep. [Accessed 19 Oct 2023].

[37] U.S. Occupational Safety and Health Administration (OSHA), "Regional Emphasis Program for Poultry Processing Facilities [Region 4]," [Online]. Available: https://www.osha.gov/sites/default/files/enforcement/directives/CPL_23-09-CPL_04.pdf. [Accessed 19 Oct 2023].

[38] Occupational Safety and Health Administration (OSHA), "CPL 04-05-2306 Regional Emphasis Program for Food Manufacturing Industry," 2023.

[39] U.S. Occupational Safety and Health Administration (OSHA), "Regional Emphasis Program for Poultry Processing Facilities [Region 6]," [Online]. Available: https://www.osha.gov/sites/default/files/enforcement/directives/CPL_2_02-02-030B.pdf. [Accessed 19 Oct 2023].

[40] Center for Chemical Process Safety (CCPS), "Process Safety Glossary: Product Stewardship," [Online]. Available: https://www.aiche.org/ccps/resources/glossary/process-safety-glossary/product-stewardship. [Accessed 2 August 2023].

[41] American Chemistry Council (ACC), "About ACC," [Online]. Available: https://www.americanchemistry.com/about-acc. [Accessed 23 April 2023].

[42] American Chemistry Council (ACC), "Responsible Care®: Driving Safety & Industry Performance," [Online]. Available: https://www.americanchemistry.com/chemistry-in-america/responsible-care-driving-safety-industry-performance. [Accessed 23 April 2023].

[43] American Chemistry Council (ACC), "Product Safety Code," [Online]. Available: https://www.americanchemistry.com/chemistry-in-america/responsible-care-driving-safety-industry-performance/management-system-certification/product-safety-code. [Accessed 23 April 2023].

[44] American Chemistry Council, "American Chemistry Council | Responsible Care® | Product Safety Code of Management Practices," 8 June 2022. [Online]. Available: https://www.americanchemistry.com/media/files/acc/chemistry-in-america/responsible-care-driving-safety-industry-performance/management-system-certification/files/responsible-care-product-safety-code. [Accessed 23 April 2023].

[45] Messer North America, Inc., "Responsible Care, A Commitment to Health, Safety and Security," [Online]. Available: https://www.messer-us.com/cs/c/?cta_guid=d30a9eae-0e83-4696-b814-ef52590e8431&signature=AAH58kFSeF-N-iZNIaLKAj1V3YMP7vfU2g&pageId=23835413904&placement_guid=6251434b-b9bc-46b9-b1fe-fa67977ff9cb&click=73bee1a7-5235-45e4-bf17-9d4e96e1d900&hsutk=7f85692fab6d.

[46] Compressed Gas Association (CGA), "About Us," [Online]. Available: https://www.cganet.com/about-us/. [Accessed 1 August 2023].

[47] Compressed Gas Association (CGA), *P-86 Guideline for Process Safety Management,* 1st ed., 2020.

[48] Code of Federal Regulations Title 12, Volume 2, "Part 117 Subpart A Section 117.3 Definitions," 1 April 2020. [Online]. Available: https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfCFR/CFRSearch.cfm?fr=117.3. [Accessed 17 March 2021].

[49] Federal Trade Commission, "Linde AG and Praxair, Inc., In the Matter of," 22 November 2022. [Online]. Available: https://www.ftc.gov/legal-library/browse/cases-proceedings/c4660-linde-ag-praxair-inc-matter.

[50] Center for Chemical Process Safety (CCPS), "Field Review of Permits - Possible Work Flow," [Online]. Available: https://www.aiche.org/ccps/resources/tools/safe-work-practices/field-review-permits/possible-work-flow. [Accessed December 2022].

[51] Center for Chemical Process Safety, "Field Review of Permits - Common Program Practices," [Online]. Available: https://www.aiche.org/ccps/resources/tools/safe-work-practices/field-review-permits/common-program-practices. [Accessed December 2022].

[52] National Aeronautics and Space Administration (NASA), "Earth Fact Sheet," 25 November 2020. [Online]. Available: https://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html. [Accessed 17 March 2021].

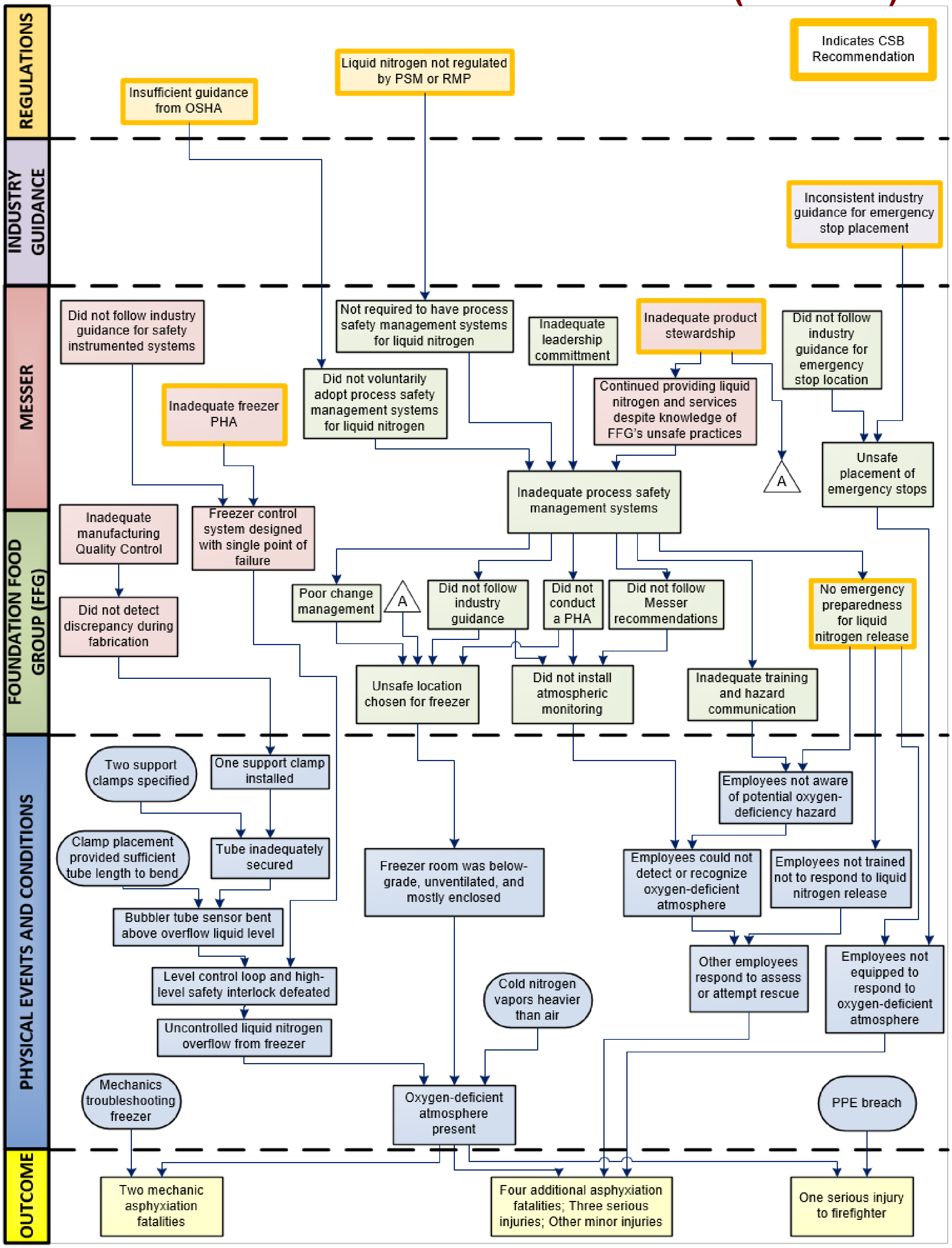
[53] Center for Food Safety and Applied Nutrition, "Control of Listeria monocytogenes in Ready-To-Eat Foods; Guidance for Industry," U.S. Department of Health and Human Services, Food and Drug Administration, January 2017. [Online]. Available: https://www.fda.gov/files/food/published/Draft-Guidance-for-Industry--Control-of-Listeria-monocytogenes-in-Ready-To-Eat-Foods-%28PDF%29.pdf. [Accessed 24 March 2021].

[54] United States Census Bureau, "Historical Income Tables: People," 2022. [Online]. Available: https://www.census.gov/data/tables/time-series/demo/income-poverty/historical-income-people.html. [Accessed 12 April 2023].

[55] International Society of Automation (ISA), *ISA-TR84.00.07 Guidance on the Evaluation of Fire, Combustible Gas, and Toxic Gas System Effectiveness,* 2018.

[56] U.S. Chemical Safety and Hazard Investigation Board (CSB), "CSB Best Practice Guidance for Corporate Boards of Directors and Executives in the Offshore Oil and Gas Industry for Major Accident Prevention".

Appendix A—Simplified Causal Analysis (AcciMap)



APPENDIX B—DESCRIPTION OF SURROUNDING AREA

Figure 32 shows the census blocks immediately surrounding the Foundation Food Group facility. The census information for the blocks shown is presented in **Table 9** .[a]

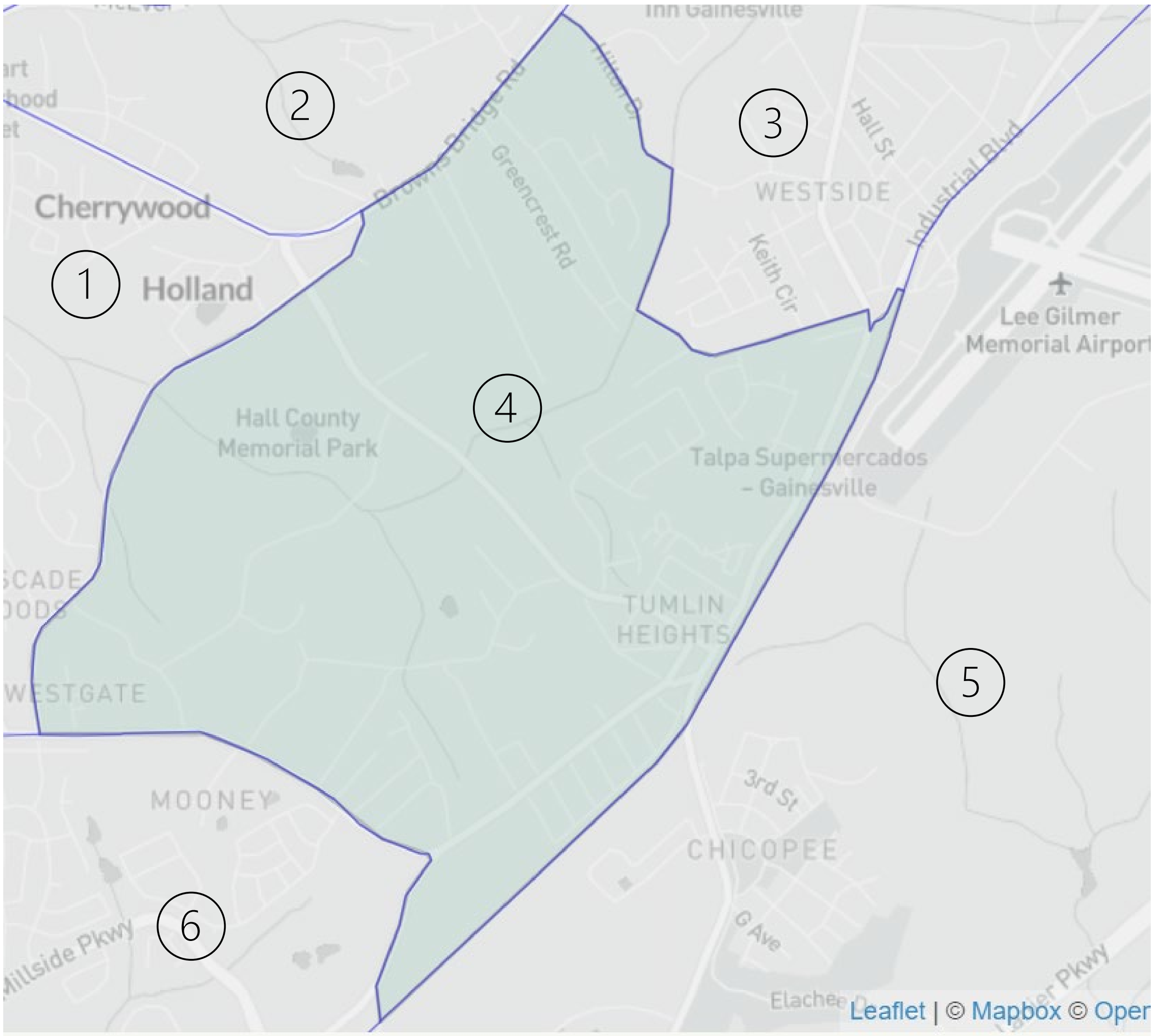


Figure 32. Census blocks within the approximately one-mile distance from the FFG facility. (Credit: Census Reporter, annotations by CSB)

[a] This information was compiled using 2020 Census data as presented by Census Reporter [50]. "Census Reporter is an independent project to make data from the American Community Survey easier to use. [It is] unaffiliated with the U.S. Census Bureau. A News Challenge grant from the Knight Foundation funded the initial build-out of the site. … Support for [Census Reporter's] 2020 Decennial Census features was provided by the Google News Initiative. … [T]he Medill School of Journalism at Northwestern University, home of the Knight Lab, [] provides in-kind support for some of Census Reporter's ongoing development. Most of [Census Reporter's] server hosting infrastructure is [] provided by the Oregon State University Open Source Lab" [51].

Table 9. Tabulation of demographic data for the populations within the census blocks and tracts shown in Figure 32.

Tract Number	Population	Median Age	Race and Ethnicity		Per Capita Income	% Below Poverty Line	Number of Housing Units	Types of Structures	
1	5,546	29.5	29.0%	White	$20,864	0.3%	1,739	85%	Single Unit
			5.0%	Black				14%	Multi-Unit
			0.0%	Native				1%	Mobile Home
			9.0%	Asian				0%	Boat, RV, van, etc.
			0.0%	Islander					
			0.0%	Other					
			0.0%	Two+					
			57.0%	Hispanic					
2	2,134	23.6	18.0%	White	$14,582	40.4%	825	9%	Single Unit
			20.0%	Black				88%	Multi-Unit
			0.0%	Native				3%	Mobile Home
			7.0%	Asian					Boat, RV, van, etc.
				Islander					
				Other					
			3.0%	Two+					
			53.0%	Hispanic					
3	5,872	27.5	4%	White	$11,519	41.4%	1,412	61%	Single Unit
			10%	Black				20%	Multi-Unit
			0%	Native				19%	Mobile Home
			0%	Asian				0%	Boat, RV, van, etc.

Tract Number	Population	Median Age	Race and Ethnicity		Per Capita Income	% Below Poverty Line	Number of Housing Units	Types of Structures	
			0%	Islander					
			0%	Other					
			2%	Two+					
			84%	Hispanic					
4	4,452	30.6	15%	White	$23,731	24.9%	1,161	77%	Single Unit
			5%	Black				15%	Multi-Unit
			0%	Native				7%	Mobile Home
			5%	Asian				0%	Boat, RV, van, etc.
			0%	Islander					
			0%	Other					
			1%	Two+					
			73%	Hispanic					
5	4,274	34.8	46%	White	$27,575	14.1%	1,175	79%	Single Unit
			13%	Black				7%	Multi-Unit
			1%	Native				14%	Mobile Home
			4%	Asian				0%	Boat, RV, van, etc.
			0%	Islander					
			0%	Other					
			1%	Two+					
			33%	Hispanic					
6	3,815	34.9	41%	White	$36,881	9.1%	1,339	86%	Single Unit
			1%	Black				12%	Multi-Unit
			0%	Native				2%	Mobile Home

Tract Number	Population	Median Age	Race and Ethnicity		Per Capita Income	% Below Poverty Line	Number of Housing Units	Types of Structures	
			7%	Asian				0%	Boat, RV, van, etc.
			0%	Islander					
			0%	Other					
			5%	Two+					
			41%	Hispanic					

[Page intentionally left blank]

U.S. Chemical Safety and Hazard Investigation Board

Members of the U.S. Chemical Safety and Hazard Investigation Board:

Steve Owens
Chairperson

Sylvia E. Johnson, Ph.D.
Member

Catherine J. K. Sandoval
Member