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Investigation Report

Of

Reportable Occurrence at the Marine Sciences Laboratory (MSL)

On

June 2, 1999

"Entrapment of Two Staff Members in the MSL Walk-in Freezer"

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1. Glossary of Terms and Acronyms

MSL Marine Sciences Laboratory
PNNL Pacific Northwest National Laboratory
SBMS Standards Based Management system

2. Executive Summary

On Wednesday, June 2, 1999, two PNNL staff members entered a walk-in cooler/freezer unit at the Marine Science Laboratory (MSL) located in Sequim, WA, to process legacy waste samples. When they attempted to leave the freezer portion of the unit, they found that the release mechanism was inoperable, trapping them inside. Using makeshift tools, they were able to free the mechanism and exit the unit.

This investigation concluded that the direct cause of this event was that the door design did not prevent moisture from collecting in the space where the safety release mechanism push rod penetrated the door. Due to the subfreezing conditions, the moisture froze and immobilized the push rod. The latch mechanism itself, located on the outside of the door, remained operational. The root cause is that the manufacturer's design of the freezer door did not employ features like heat trace or adequate insulation to prevent moisture in the push rod penetration from freezing and immobilizing the push rod.

The investigation determined that there were several causal factors that contributed to this event:

- A thin layer of insulation was affixed to the outside surface of the door. This modification was apparently not properly analyzed and may have significantly contributed to the event by allowing the safety release mechanism push rod to thermally equalize with the freezer side temperature.

- No periodic functional testing was conducted on the latch and safety release mechanism nor the heat trace to ensure continued operation.

- There are no means to alert staff outside of the freezer/cooler in the event that staff inside the freezer/cooler requires assistance.

- The requirements of Working Alone Standards Based Management System (SBMS) Subject Area were not implemented. The title and applicability of the subject area infer that requirements only apply to one person working alone.

Following the incident, steps were immediately taken to disable the door hardware to preclude recurrence, and administrative controls were put in place to allow staff to safely work in the unit. Additional recommendations under evaluation are permanently modifying the closing mechanism to preclude recurrence, installation of alarm or other communication device for use by staff within the cooler/freezer unit and storage of

adequate protective clothing within the unit. All PNNL building managers were instructed to conduct an immediate self-assessment of similar walk-in spaces, including coolers, freezers, atmospheric or other chambers and incubators, to ensure that a similar incident was prevented. No similar conditions were found.

3. Scope of the Investigation

An examination of the walk-in freezer entrapment incident was conducted to evaluate the causal factors and sequence of actions that led to the event. The evaluation considered the following:

1. Elements of work activities and management systems that should have or could have prevented the incident.

2. System configuration features that could have contributed to the incident.

3. Personnel actions or lack of actions that could have led or contributed to the incident.

Root causal factors and contributing factors were used to develop recommendations for consideration by management that may reduce the likelihood of a recurrence of this type of incident.

Additionally, at the request of the Marine Science Laboratory Manager, the Upland Facility hazardous material storage units and the Beach Facility walk-in cooler were evaluated for likelihood of personnel entrapment.

4. Facts/Observations

On Wednesday, June 2, 1999, a waste management specialist from Pacific Northwest National Laboratory, Richland, WA traveled to the Marine Science Laboratory (MSL) located in Sequim, WA, to assist with waste management activities. A MSL scientist on educational leave, but working hourly, was assigned to assist the waste management specialist locate samples that met the definition of hazardous waste. The purpose of locating the samples was to remove them from storage, label them as hazardous waste, and move them to the less than 90-day accumulation area.

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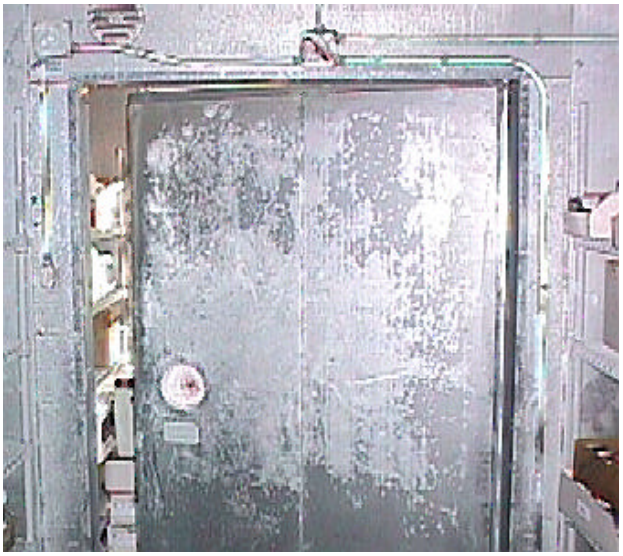
Many of the samples were being stored in a stand-alone cooler/freezer unit located approximately 75 feet north of the "upland" facility loading dock. At approximately 2:00 PM, the two workers went out to the cooler/freezer to search for samples listed on a print-out of the sample inventory. They entered the cooler compartment (34°F) to look for specific sample numbers. The freezer door was not opened. After a short time (about 10 minutes) the workers left the cooler, having decided to get a coat and lab coat respectively, since they were cold and anticipated needing to spend additional time in the freezer (between –15° F and –20° F) to locate the samples.

The workers verified the sample numbers that they needed to locate, opened the freezer door, went into the freezer unit and pulled the door near closed, but not latching it. A short time later, the waste management specialist wanted to verify a sample number on the print out, which had been left in the cooler. He pushed the unlatched door open and exited the freezer into the cooler. The waste management specialist obtained the sample numbers then re-entered the freezer. This time the waste management specialist pulled the door shut and ensured that it latched because he expected to be in the freezer for longer than normal searching for the desired samples. The workers were aware that if the freezer door was left open, the internal temperature increases and a local alarm at the recorder on the outside of the freezer/cooler beeps. After searching for about 10 minutes, the workers decided they needed to check the inventory sheet again (still in the cooler) and prepared to leave because they were getting cold and wanted to warm up.

As they attempted to exit they pressed the push-rod safety latch and found that it would not budge. One worker kicked at the push rod to break it free, but only succeeded in breaking off the plastic glow-in-the-dark knob. An ice chest was then used to hammer on the end of the push rod, but the push rod just punched holes in the ice chest. At this point the workers realized that they were in trouble. An attempt was made to beat on the walls and yell for help, but they quickly decided that was fruitless. One of the workers produced a multiple-purpose pocket knife that he used to remove the four screws and white plastic cowling from around the push-rod safety latch revealing the Styrofoam insulation. He found ice-covering the insulation around the push rod. He removed as much of the insulation (about ¼ inch) and ice from around the push rod as he could by chipping at it with the knife. They then looked for means to reduce the cooling in the freezer by resetting a thermostat. The thermostat only controlled the defrost cycle for the cooling unit inside the freezer. They then thought that they could possibly turn off the cooler by disconnecting the wires in a 4" square junction box just above the door. They used the

knife to remove the cover from the junction box with the idea of disconnecting power to the cooler. They realized that the wires did not go to the cooler so abandoned the idea. These wires provide power to the light and heat trace circuits.

The junction box cover was then wedged between the metal door skin and the insulation just in front of the push rod to provide a larger surface area to strike against. After several attempts striking the cover plate with an ice chest the door latch released and allowed the workers to exit the freezer.



After exiting the cooler/freezer, the workers informed MSL management of the incident. They immediately inspected the freezer door latching mechanism and removed the striker plate to ensure nobody else would get locked in. The lock on the cooler door was subsequently changed and a danger tag was attached.

Design Feature: Doorframe and Door Seal Heat Trace

Heat trace beneath the skin of the doorframe and outer edge of the door keeps these surfaces at about 44° F. The elevated temperature of the surfaces due to the heat trace prevents the formation of ice on the seal surfaces and hence ensures that the door will not stick shut.

Design Feature: Vent Between Cooler and Freezer

A round vent about 6 inches in diameter is installed in the wall between the freezer and the cooler sections. This vent allows the air pressure to equalize between the two sections. Without the vent, when the freezer door is closed, air inside the freezer cools and contracts resulting in the potential for reduced pressure. The relatively higher pressure on the outside surface of the door pushes the door against the seal and prevents it from easily being opened. The vent prevents the development of a low pressure in the freezer with respect to the cooler.

There is no positive fresh air make up provided to either the freezer or the cooler compartments, however, the density difference between the freezer air and the cooler compartment air enhances the exchange. There is a similar exchange between the cooler compartment air and the outside air. Air is exchanged during the time the doors are opened.

Design Feature: Emergency Door Release Push-Rod

A mechanical latch mechanism on the freezer and the cooler doors ensures that enough tension is maintained between the door seal and the frame to prevent air leakage. The latch is released by pulling on an lever on the outside or by depressing a push rod on the inside. The design allows the outer lever to be locked with a padlock for security and still allow the latch to release the door from the inside when the push rod is pressed. The push rod uses a rod similar to a carriage bolt that extends from the outside to the inside of the door. The rounded end of the rod on the outside pushes on the door latch mechanism (see picture below left) and the threaded end extends through the door and has the plastic mushroom shaped glow-in-the-dark knob. Tension from a spring in the door latch mechanism keeps the rod extended into the freezer. The Washington Administrative Code (WAC) 296-24-55005 (10) and WAC 296-307-35009 (9) requires for freezer rooms or refrigerated rooms that the opening device must be a type that when locked from the outside with a lock, can be opened from the inside.

Observations:

The latch mechanism was carefully removed from the exterior (from the perspective of the freezer) side of the door. There was no evidence of ice or other foreign material. There was some evidence of minor corrosion; however, the corrosion was not on any moving surface. The mechanisms functioned freely. The emergency door release push-rod would not move when first opened. After one hour with the cooler door open and the freezer door open, the safety release mechanism push rod was inspected again and found to move freely. The rod was removed and found to be wet. There was some evidence of a buildup of some black material on the surface of the rod where it extended into the wood layer of the door. The buildup did not impair the freedom of the rod in the hole.

The design of the emergency door release is also important. The majority of the push-rod is recessed into the door on the inside. The insulation is cupped out around the rod and a plastic cowling covers the insulation. There was less than 1/4 inch of insulation thickness at the penetration of the rod. This resulted in almost 3 inches of the bolt exposed to the sub-freezing temperature. The exposed rod acted as a heat sink for the portion of the rod in the door. The presence of little insulation and the exposed rod resulted in excellent conditions

for long term buildup of ice.

A ¼ inch layer of foam has been applied to the outside surface of the door. It appeared to be a self stick type. The foam rubber does not appear to be original construction, since it did not cover the entire door.

- The foam rubber did not cover the lower 9 inches of the door.
- The left edge tapered in from the edge of the door at the top to about two inches in at the bottom.
- The foam rubber extended over the right edge of the door.
- The foam rubber was puckered at the bottom.

The foam rubber may have been installed to prevent the buildup of condensation on the surface of the freezer door in the cooler by insulating it. Evidence existed of water buildup on the door surface and on the latch mechanism that was exposed when the door latch was removed further indicating a previous problem of condensation. When questioned, no one was aware of the origin of the foam rubber. The installation of the foam rubber on the door is important to this incident since the foam rubber insulated the door from the warmer environment in the cooler section. The foam rubber reduced the average temperature in the door and could have been a significant contribution to the build up of ice around the push rod.

Ice could have built up in the mechanism by two possible methods.

- With each opening and closing of the freezer door the warm air that entered the freezer was cooled and a low pressure was created inside the freezer. Although the vent alleviates the pressure change, some air moves through all passages including the space between the emergency release mechanism rod and the door penetration. As the moisture-laden air passed over the sub-freezing surfaces of the rod and penetration in the wood core, the moisture collects as frost. Slowly over time, a large enough quantity of frost forms. When the door is left open for a long enough period of time, the frost melts and collects as liquid which freezes again when the door is closed and allowed to equalize in temperature.
- Condensation on the outer surface of the door prior to the application of the foam rubber was very evident from the residual calcium buildup on surfaces under the door latch mechanism. It is very possible that condensation reached the rod and entered the penetration by capillary action.

<u>Interviews</u>:

Staff interviewed by the investigation team included line management and operating staff of the Facility and Operations Directorate and the Environmental Technology Division. The interviews were conducted using common questions. The results are summarized:

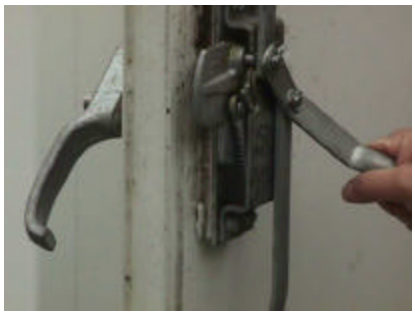
- Management did not have expectations that staff using the freezer/cooler needed to notify anyone when entering the unit.
- Management believed that the freezer/cooler did not pose unusual risk to staff as it is a standard design in common use for many industries.

- Management expectations for maintenance of the freezer/cooler were to repair when necessary; no periodic maintenance was established.
- Staff have a common practice of not closing the door(s) completely when entering the freezer or cooler. This practice was due to reasons like: needed the sunlight to see better or felt too closed in with the door closed.
- There are only two recollections of the safety release mechanism push rod being used in the past. Once when the unit was brand new, the freezer door swung closed after a staff member entered. A second time about two months ago, two staff members tested it in conjunction with looking at the glow-in-the-dark knob. In both instances the safety release mechanism push rod was effective in unlatching the door.
- None of the staff interviewed believed that the Working Alone subject area was applicable, however, they did believe that it was a good idea.
- The equipment file did not contain any information from the vendor on the operation or maintenance of the freezer/cooler unit or it's design features. The file contained only vender information on the compressor and cooler units.
- Staff who maintain the freezer/cooler do not perform any preventive maintenance on the unit.

Conclusion: The impairment of the door latch mechanism, which prevented the staff from opening the door from the inside, is attributed to build-up of moisture between the rod and the wood core of the door. This moisture froze and immobilized the push rod.

Upland Facility Hazardous Material Storage Units

An examination of the Upland Facility hazardous material storage units showed that they are not equipped with self-latching doors. The design of the door latches requires positive action on the user's part to latch the door. The doors are equipped with handles on both the interior and exterior. The potential for entrapment in these units is considered remote. No further evaluation is necessary.



Beach Facility Walk-in Cooler

The Beach Facility walk-in cooler was also evaluated for likelihood of personnel entrapment. It is equipped with a handle and latching mechanism that includes a safety release operable even if the latch is locked. The safety release push rod penetrates the full thickness of the door insulation through a plastic sleeve. This design will keep the push rod from freezing in case of a cooler thermostat failure. The cooler also has a wall penetration opposite the door. The penetration is currently filled with corrugated insulation material, but this could be easily removed if necessary to call for assistance if the cooler door ever became jammed. No further evaluation is needed.

5. Analysis

5.1 Events and Causal Factors Chart (See Attached)

5.2 Barrier/Control Analysis (See Attached)

5.3 Hazards

Entry into the MSL walk-in freezer exposes staff to a frigid environment and potentially to toxic chemical vapors or an oxygen deficient environment. Exposure to cold cannot be eliminated and is normally controlled with appropriate clothing or short stay times.

The potential for encountering toxic vapors in the MSL freezer is considered extremely remote based on the inventory of material that is stored inside. The inventory consists of sealed sediment and tissue samples. The samples are frozen to prevent spoilage, they are not placed in any preserving solution. There isn't a significant source of chemicals in the freezer that could reach a level of concern in a "zero ventilation, saturation model."

It is difficult to estimate how long an individual could remain in the freezer with sufficient oxygen for life due to the variables in estimated oxygen consumption rate, individual metabolism, heat loss, etc…. However, calculations based on conservative assumptions show that two staff members can perform very heavy work for greater than five hours. Normal working stay times in the freezer are typically less than 30 minutes; therefore, the potential for encountering an oxygen deficient atmosphere is considered remote.

6. Conclusions

6.1 Findings

- No alarm or communications capabilities exist for staff in the freezer or cooler compartments to alert external staff for assistance.
- The design of the freezer door facilitated the conditions that resulted in the stuck release mechanism. There are no effective means of preventing moisture from entering the penetration (no seal on the push rod or door latch, no sleeve for the push rod). The door design does incorporate features to prevent the moisture in the penetration from freezing (no heat trace, inadequate insulation).
- A modification to the freezer door was made at some time to add ¼ inch foam rubber insulation to the outer surface of the door, likely to prevent condensation formation. Documentation of the change could not be found. Vender information/consultation was not established as the installer and manufacturer is no longer in business. It cannot be

established that analysis of the impact of the change on other design features was considered.

- Functional checks of the design features were not performed: door/doorframe heat trace, equalizing vent, emergency release mechanism. Manufacturer information on recommended maintenance is not available.
- Working alone standards were not implemented. The title and the applicability of the Working Alone SBMS Subject area infer that the subject area only applies to an individual working alone and not individuals or groups working remotely.
- The two staff entered the freezer/cooler without adequate protective clothing. There were no PNNL personnel protective equipment (coats/gloves) available.

6.2 Probable Causes

Direct Cause:

1. Equipment/Material Problem, f. Contaminant: The design of the freezer door allows introduction of moisture into the safety release mechanism.
   - No seal around push rod
   - No seal around latch mechanism
   - No sleeve for push rod

Root Cause:

4. Design Problem, b. Inadequate or Defective Design: The manufacturer design is inadequate to insure that the freezer door can be opened from the inside. The freezer door's emergency release mechanism had inadequate features to prevent moisture that was present in the mechanism penetration from freezing and immobilizing the push rod.

- Little insulation around the push rod (about ¼ inch)
- No heat trace

Contributing Causes:

4. Design Problem, a. Inadequate Work Environment: There are no alarms or communications for trapped or disabled staff to alert other staff for assistance.

6. Management Problem, b. Work Organization/Planning Deficiency: Impact of adding the foam rubber insulation was not analyzed for impact on other design features. Periodic functional checks were not established after installation of the freezer/cooler to detect design feature failures or performance degradation.

6. Management Problem, d. Improper Resource Allocation: Adequate protective clothing was not provided to mitigate staff exposure to freezing conditions.

6. Management Problem, e. Policy Not Adequately Defined, Disseminated, or Enforced: The requirements of Working Alone Standards Based Management System (SBMS) Subject Area were not implemented. The title and applicability of the subject area infer that requirements only apply to one person working alone.

6.3 Judgements of Need

6.3.1 Conduct a self-assessment of PNNL facilities to identify walk-in freezers, coolers and other similar equipment to ensure similar conditions do not exist where staff can become entrapped and establish additional controls where necessary.

6.3.2 Prepare a service request to:

6.3.2.1 Evaluate alternative modifications to the MSL freezer/cooler design and controls (alarms, communications, removal of the latch, change seal to magnetic type, install a mechanical interlock that prevents the door from closing except by someone on the outside, etc.).

6.3.2.2 Implement the changes.

6.3.2.3 Establish appropriate functional checks for design features (to detect failure or degradation of function).

6.3.3 Review administrative controls to ensure: 1) that new systems, structures and components (SSC) will include owner/operating manuals that include engineered features and recommended service; 2) that modifications to systems, structures and equipment (SSC) similar to the freezer/cooler are reviewed for impact to the function of the engineered features.

6.3.4 Ensure full implementation of the Working Alone subject area.

6.3.5 Revise the applicability of Working Alone SBMS Subject Area to insure it clearly includes groups who are working alone and not just an individual.

6.3.6 Provide protective clothing for use by staff to enter the freezer/cooler compartments.

6.3.7 Submit this event as a Lessons Learned to the PNNL Lessons Learned Coordinator.

7. Lessons Learned

Industry available equipment like a walk-in freezer or cooler is often treated as inherently safe. However, this equipment should have controls in place that treats

entries by the staff as working alone regardless of the number who enter the equipment in order to mitigate entrapment or impairment conditions. Information should be obtained from the manufacturers/suppliers of industry available equipment like walk-in freezers and should include as a minimum the design features and recommended service. Any manufacturer recommended service should be implemented as preventive maintenance or other methods to ensure proper function of design features. Modifications to the design of the equipment should be reviewed for the effect of the changes on the design features. Prolonged exposure to anticipated hazards should be planned for and adequate protective equipment should be provided and employed.

8. Panel's Signatures

[redacted]	Team Leader F&O	[redacted]
[redacted]	Team Member ES&H	[redacted]
[redacted]	Team Member ETD	[redacted]

9. Board Authority

Provided by E-Mail Message From [redacted] to [redacted] on 6/3/99 titled Investigation of the Off-Normal Event (RL-PNNL-PNNL BOPER-1999-0017) Associated with Marine Sciences Laboratory (MSL) Walk-in Freezer.

Buckley, Glenn D
From: [redacted]
Sent: Thursday, June 03, 1999 4:34 PM
To: [redacted]
Cc: [redacted]; [redacted]; [redacted]; [redacted]; [redacted]; [redacted]; [redacted]; [redacted]
Subject: Investigation of the Off-Normal Event (RL-PNNL-PNNL BOPER-1999-0017) Associated with Marine Sciences Laboratory (MSL) Walk-in Freezer

Please lead an investigation of the subject off-normal event at MSL involving two staff members becoming trapped in a walk-in freezer on June 2, 1999.

Your investigation team should include:

- [redacted] - ETD
- [redacted] - Accident Investigator

You are also authorized to include other technical expertise on your team (manufacturer representative, engineering/maintenance expert) as appropriate.

Please provide your report to my office on or before COB, June 11, 1999. Your report should include causal factors and recommendations for corrective action.

10. Individuals Interviewed

[redacted]

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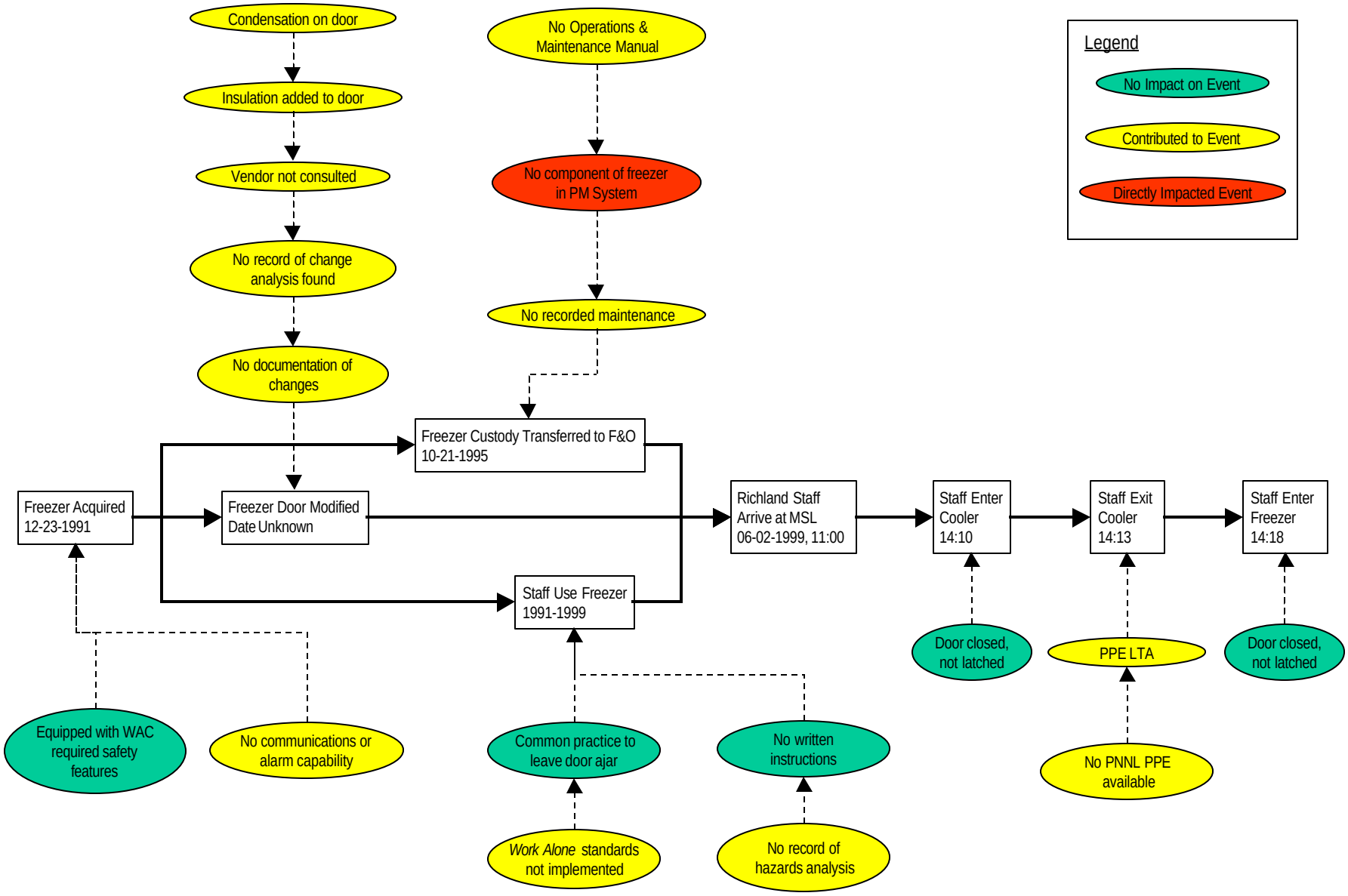
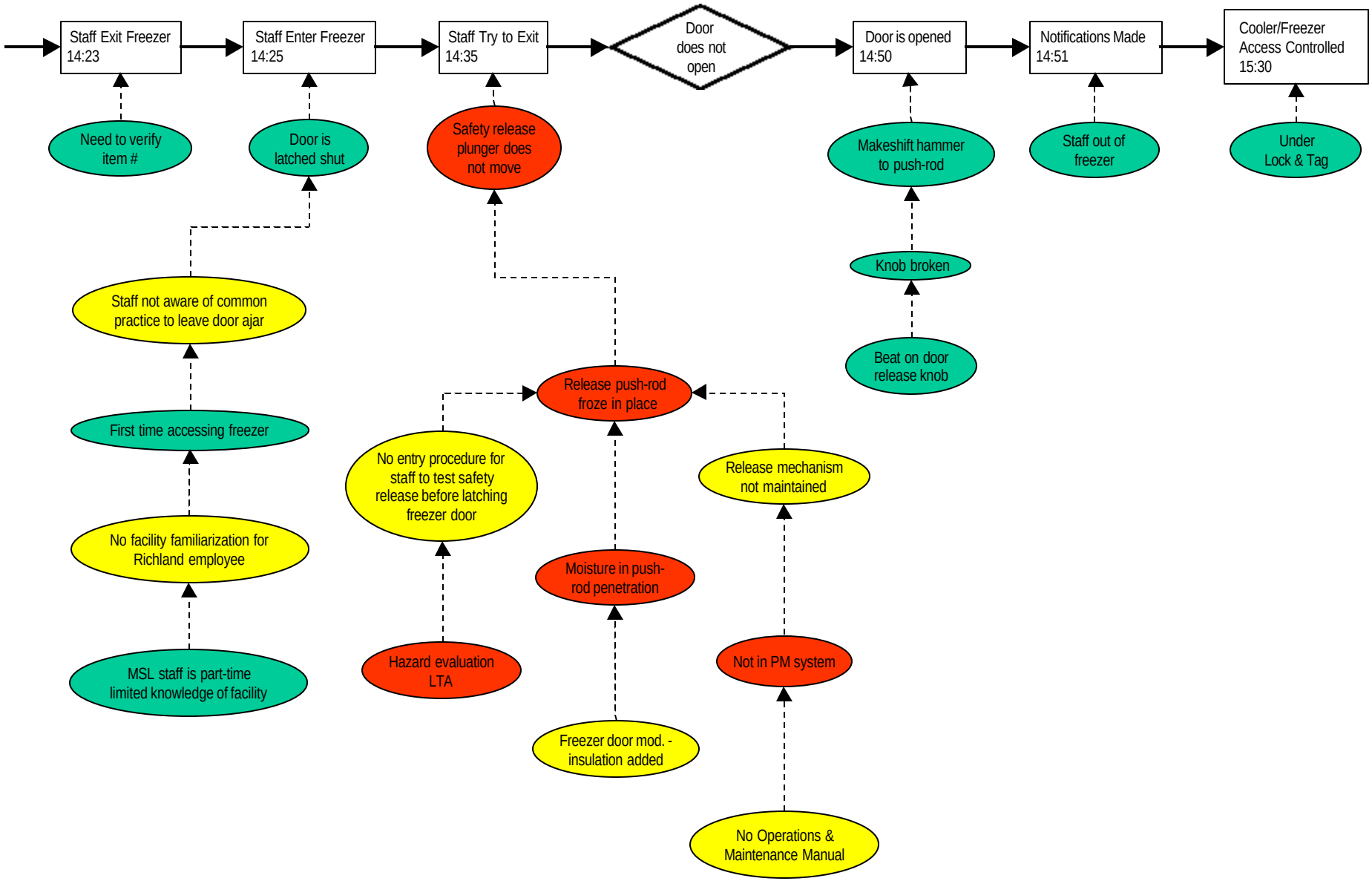
5.2 Barrier/Control Analysis

Hazard	Direct Barrier / Control Failure	Possible Contributing Factors to Barrier / Control Failures	Possible Root Causes of Failures	Loss / Potential Loss Event	Evaluation
Entrapment	Inner door latch release mechanism froze in position	Moisture enters the freezer door emergency door release mechanism push-rod penetration, freezes and immobilizes the push rod.	The design of the freezer door allows introduction of moisture into the safety release mechanism. • No seal around push rod • No seal around latch mechanism • No sleeve for push rod	Hypothermia or frostbite	1. Equipment/Material Problem, f. Contaminant
		Moisture present in the emergency release mechanism penetration freezes.	Manufacturer's design is inadequate. The freezer door's emergency release mechanism had inadequate features to prevent moisture that was present in the mechanism penetration from freezing and immobilizing the push rod. • Very little insulation around push rod (about ¼ inch) • No heat trace	Hypothermia or frostbite	4. Design Problem, b. Inadequate or Defective Design
		Design modification to add insulation without determining impact on other design features like release mechanism	Impact of the modification adding the foam rubber insulation was not analyzed for impact on other design features.	Hypothermia or frostbite	4. Design Problem, b. Inadequate or Defective Design
		No periodic functional check of release mechanism	Periodic functional checks were not established after installation of the freezer/cooler that could detect design feature failures or performance degradation.	Hypothermia or frostbite	6. Management Problem, b. Work Organization/Planning Deficiency.
		Staff entrapment can not be detected	The requirements of Working Alone Standards Based Management System (SBMS) Subject Area were not implemented. The title and applicability of the subject area infer that requirements only apply to one person working alone.	Hypothermia or frostbite	6. Management Problem, e. Policy Not Adequately Defined, Disseminated, or Enforced
		Staff entrapment can not be detected by outside staff	There are no alarms or communications for trapped or disabled staff in the freezer/cooler to alert other staff for assistance	Hypothermia or frostbite	4 Design Problem, a. Inadequate Work Environment
Extreme Cold	Protective clothing was not adequate for job conditions.	Adequate protective clothing is not available	Adequate protective clothing was not provided to mitigate staff exposure to freezing conditions	Hypothermia or frostbite	6. Management Problem, d. Improper Resource Allocation


Condensation on door
Insulation added to door
Vendor not consulted
No record of change analysis found
No documentation of changes
No Operations & Maintenance Manual
No component of freezer in PM System
No recorded maintenance
Legend
No Impact on Event
Contributed to Event
Directly Impacted Event
Freezer Custody Transferred to F&O 10-21-1995
Freezer Acquired 12-23-1991
Freezer Door Modified Date Unknown
Staff Use Freezer 1991-1999
Richland Staff Arrive at MSL 06-02-1999, 11:00
Staff Enter Cooler 14:10
Staff Exit Cooler 14:13
Staff Enter Freezer 14:18
Door closed, not latched
PPE LTA
Door closed, not latched
Equipped with WAC required safety features
No communications or alarm capability
Common practice to leave door ajar
No written instructions
No PNNL PPE available
Work Alone standards not implemented
No record of hazards analysis


Staff Exit Freezer 14:23
Staff Enter Freezer 14:25
Staff Try to Exit 14:35
Door does not open
Door is opened 14:50
Notifications Made 14:51
Cooler/Freezer Access Controlled 15:30
Need to verify item #
Door is latched shut
Safety release plunger does not move
Makeshift hammer to push-rod
Staff out of freezer
Under Lock & Tag
Knob broken
Beat on door release knob
Staff not aware of common practice to leave door ajar
First time accessing freezer
No facility familiarization for Richland employee
MSL staff is part-time limited knowledge of facility
Release push-rod froze in place
No entry procedure for staff to test safety release before latching freezer door
Hazard evaluation LTA
Moisture in push-rod penetration
Freezer door mod. - insulation added
Release mechanism not maintained
Not in PM system
No Operations & Maintenance Manual