Cold Storage Facility Design Solutions:
Prevention of Frost Heave with Simple Heating Cable

This paper defines the scope of permafrost and provides detailed information including what it is, and the methods used to prevent costly property damage to cold storage facilities that create permafrost conditions below them.

What is Permafrost?

Permafrost is naturally occurring within the earth; the soil and ice combine in layers that remain frozen all year long. When the ground remains frozen for two or more years, the geological condition that develops is called permafrost. About a quarter of the entire northern hemisphere is permafrost.

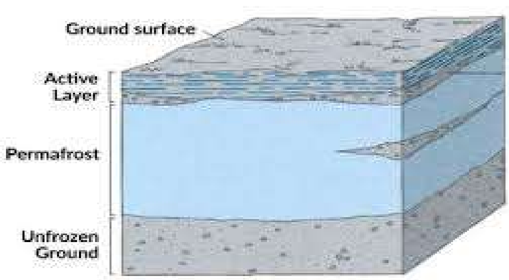


Illustration #1: Permafrost Detail

Permafrost is any ground that remains frozen. Permanently frozen grounds are most common in high mountainous regions and latitudes near the North and South Poles; and it can extend miles deep into the Earth's surface.

Cold Storage Facilities

One of the most important design considerations for your facility is the relationship between vapor pressure and temperature, and their effects on cold storage facilities. Cold air has a lower vapor pressure than warm air. Warm air therefore moves toward cooler air.

Warm air will force its way through the subgrade until the vapor balances or adheres to the underside of an insulating layer. In order to keep the vapor from freezing beneath the slab, the ground/subsoil must be warmed above the freezing point. The freezer slab must also be insulated to help maintain the freezer temperature, slow temperature loss, and stabilize the pressure with the ground below the freezer floor.

Cold Storage Facilities create unintentional permafrost when the ground beneath the facility drops below freezing and the moisture in the subgrade forms ice. As the ice expands, it pushes up on the foundation causing the floor to heave. Floor heave can cause major damage to the building and disrupt operations.

Inside a Cold Storage Facility

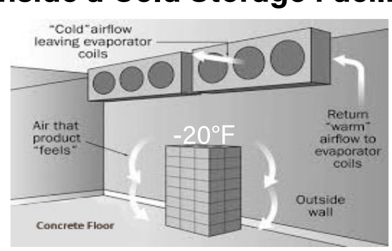


Illustration #2: Typical Cold Storage Facility Layout. Ground beneath the concrete floor has the potential to freeze.

Frost Heave in Action

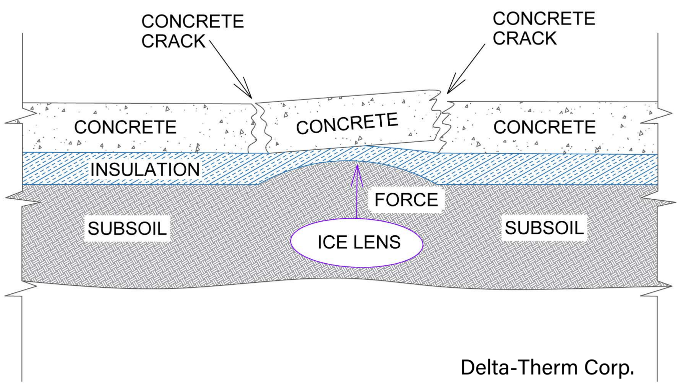


Illustration #3: Frost Heave on a Floor

As ice expands, the freezer floor can heave. This can cause cracks in the floor and distort foundation walls.

Cracks in Freezer Floor caused by Frost Heave

Illustration #4: Frost Heave in Cold Storage Facility Floor

Cracked, damaged floors can render floor space unusable and potentially dangerous for workers in the facility.

The Simple Solution:

Electric Mineral Insulated Cable (M.I.)

Mineral Insulated heating cables have been used for more than 80 years for specialty heating applications. Drawn in seamless tubing (copper or Alloy 825), these heaters feature an inert high temperature magnesium oxide insulation which surrounds resistance wire that heats when electricity is applied.

The use of under slab M.I. heating cable in conjunction with a temperature sensor placed in the subsoil is an economical and reliable solution to prevent frost heave under the freezer floor.

M.I. cable has been used successfully as a corrective measure to level a damaged freezer floor by melting permafrost below the floor. M.I. cable can be installed inside rigid galvanized conduit in the subsoil or direct buried in the subsoil.

The Benefits of using M.I. Cable for Frost Heave Prevention:

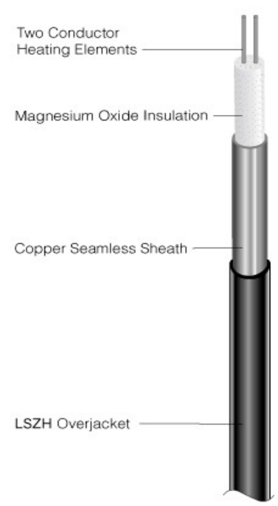


Illustration #5: M.I. Cable Detail

Comprehensive Factory Testing

Each cable undergoes a High Potential (Hi-Pot), Insulation Resistance (IR), and Total Resistance (TR) tests both before and after a 12-hour immersion in water.

M.I. Heating Cable Features:

- No inrush current at start-up means heaters can load a circuit breaker to 80% of actual current rating, the maximum per the National Electrical Code.
- The heaters will not self-combust or support a wet fire.
- Low and high current alarms can be set to monitor the heaters.

Advantages of M.I. Cable:

- Long life expectancy (as much as 30 Years)
- Simplicity of use
- No routine maintenance required
- Replacements can be simple to install in conduit.
- Two installation styles (embedded in sub-soil or placed in conduit in the subsoil)
- Multiple cable options depending on environment
- Affordable operation range (from 0.5 watts/sq. ft. to 2.5 watts/sq. ft.)
- From small to large applications: Cable lengths up to 300′
- Can withstand mechanical impact and compressive stress

Disadvantages of M.I. Cable:

- Wattage limitations of LSZH MI cable options in conduit
- Higher electrical rates will increase operational costs.
- Cannot alter/cut the M.I. cable length in the field, as this will damage the system.
- Contaminated water in metal conduits will attack copper MI cable.

The Design:

Delta-Therm incorporates empirical data with the IEEE 515.1 design recommendations to provide a system that will meet the requirements of the cold storage facility. For new construction and retrofit applications, install a Delta-Therm M.I. cable inside rigid metal conduit using two conductor Copper Sheath M.I. cable. If the conduits cannot be kept dry, Alloy 825 M.I. cable should be used to ensure the cables are protected from corrosives. For new construction, direct-bury single conductor M.I. cable with LSZH is available. It will lower the installation cost. Wattages vary depending on freezer temperatures.

M.I. Cable inside of Buried Conduit with Exterior Power Connections

Illustration #6: Frost Heave Prevention Installation: Freezer floor subsoil conduit runs stubbed outside. 90 degree elbows attached to facility conduit system.

M.I. Design:

M.I. cable assemblies for frost heave prevention reliably maintain the optimum temperature to prevent ice lens formation beneath freezer floors. They come ready to install with factory terminations and resistance testing.

M.I. cables resist fire, corrosion, and degradation, and are available with one or two conductors. Our warranty can be extended up to 15 years with a post installation wiring inspection.

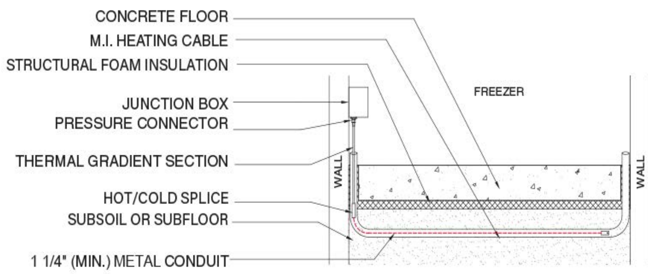
M.I. Cable Maintenance:

No maintenance is required.

M.I. Replacement:

If necessary, M.I. cables are easily replaced when the cables are installed inside rigid galvanized conduit located in the subsoil.

Mineral Insulated Cable (M.I.)
Design of M.I. Cable in Conduit System



Detail 3. Dual conductor M.I. cable in conduit. M.I. cable is being pulled through a 90° elbow. M.I. cable pressure connector is installed to conduit.

Illustration #7: Cross Section of M.I. Cable in Conduit Under Insulation in Subsoil

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An Alternate Solution: Hydronic

Circulating warm fluid in a hose, tube, or piping closed system

Illustration #8: Hydronic Tubing

A hydronic system will install in the subsoil and perform similarly to an electrical system. Utility rates should be compared to determine the best energy source for your site.

Hydronic systems consist of a network of tubes or hoses connected to a heat source by supply and return lines linked by a manifold system. The heat source will have a variety of devices connected that control expansion, air separation, flow and fluid temperatures. The materials flowing through the tubes is traditionally an inhibited glycol mixture with water.

Hydronic Design:

Systems may be balanced under load conditions using thermostatically controlled valves to measure the difference between the supply and return temperature of each loop. Unbalanced systems may allow permafrost to form.

Hydronic Maintenance:

The Radiant Panel Association (RPA) guidelines state: Hydronic system antifreeze should be tested annually for inhibitor concentrations, freeze point, and any significant changes in fluid quality.

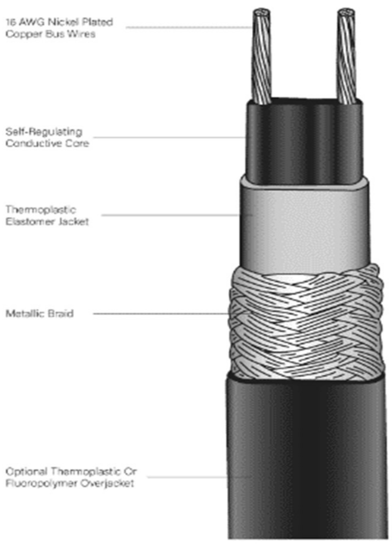
System installers should provide a maintenance schedule to check for system leaks, fluid pH, antifreeze levels, corrosion inhibitors, and correct system operation. You should consider replacement of parts such as circulators, expansion tanks, mixing valves, and pressure relief valves. Anti-freeze could be a toxic substance. If it leaks or spills during installation, the EPA must be notified.

Hydronic Hose/Tube/Pipe Replacement:

Damaged hoses or tubes must be replaced or repaired. Replacement and repair will require a partial or complete facility shut down as floor removal will be required in the affected areas.

Another Cable Type Solution: Self-Regulating Cable

SR Cable Construction



Delta-Therm Corp.

Illustration #9: SR Cable Detail

Illustration #10: SR Cable Inside of Metal Conduit Buried in Subsoil

Self-regulating heating cable increases heat output as pipe temperature decreases, and conversely, decreases heat output as pipe temperature increases.

SR cable is intended for use on metal pipes. Industrial Series cables contain two parallel bus wires electrically connected by a web of PTC (positive temperature coefficient) conductive polymer. A thermoplastic elastomer jacket surrounds the cable to provide mechanical protection and electrical isolation. A tinned copper (CB) or stainless steel braid (SSB) provides additional mechanical protection as well as a ground path for fault currents.

Self-Regulating Cable Design:

Though self-regulating cable is sometimes used for frost heave prevention, Delta-Therm recommends using only M.I. cable because of the longevity it offers and the precise control and monitoring that can be achieved compared to using SR cable.

Advantages of Self-Regulating Cable:

- Field terminated
- Cut to length in field

Self-Regulating Cable Disadvantages for Frost Heave Protection:

- Inrush current at start-up limits circuit length and requires oversized breakers based on the operating load.
- Nuisance tripping of ground fault systems due to wet conduit and splices can occur.
- The material has been known to combust and continue to burn if power is applied. This is known as a “wet fire.”
- Monitoring can be difficult because of the variable nature of the cable output, which means the monitor system requires much greater tolerance so as not to give false alarms.
- Limited cable life

Maintenance:

Annually check system for output power.

Replacement:

SR can be replaced if the cable is installed inside a metallic conduit.

Natural Ventilation & Forced Air:

Natural Ventilation/Forced Air for Frost Heave Prevention

Credit: Geoplast

Illustration #11: Construction of a Ventilated Freezer Floor in a Cold Storage Facility.

A crawl space that is suitable for cold storage facilities has open voids in all directions which will allow natural ventilation or forced air to temper the air underneath the freezer floor to prevent frost heaving.

Natural Ventilation System

Illustration #12: Ventilation Intake for Underfloor Frost Heave Prevention Utilizing Outside Air

Natural Ventilation Design

The operation of a natural ventilation system for frost heave prevention (also known as vent pipes) can utilize ductwork for tempering the air underneath a freezer floor. This type of system depends on density differences between cool air leaving the ductwork and warm air entering the pipe or ductwork. Special considerations should be adhered to when designing such a system. The piping or ductwork should be at least 6″ – 8″ in diameter and pitched in a way to allow for condensation to drain properly.

Advantages of Natural Ventilation

- Construction is economical and system does not require operating expense to perform.

Disadvantages of Natural Ventilation

- Complex thermodynamic calculations
- Air flows to least resistance
- Debris can stop airflow, requiring maintenance

Maintenance

- Inspect ductwork for frost and other debris
- Must remove ice that can form inside of pipe or ductwork
- Expensive to repair because piping material deteriorates over time

Replacement

Damaged material must be replaced or abandoned. Replacement will require a partial or complete facility shut down as floor removal would be necessary in the affected areas.

Forced Air System

Illustration # 13: Outdoor Air Intake for Underfloor Forced Air Frost Heave Prevention

Though similar to natural ventilation, Forced Air Systems use a network of ductwork and piping to pass tempered air under the insulation of a cold storage facility. In this case, air is forced through the network by a fan so the rate of heat input can be better controlled compared to the natural convection air ventilation system. In addition, temperature and relative humidity of the air delivered to the under-floor heat network can be controlled.

The ductwork is typically 4 to 8 inches (10-20 cm) in diameter, and the maximum run length is dependent upon the static pressure capabilities of the supply fan. The source of air for under-floor heat can be outside air, warm exhaust air from a process, warm air from the engine room or any other source conveniently located in a space that has a heat source. Caution should be taken to avoid using air with high moisture content as this could condense and freeze in the ductwork. The air may also be heated to provide additional protection and better temperature control.

The most common methods for providing heat are using a furnace/makeup air unit or recovered heat from the hot gas coming off the refrigeration system.

Advantages of Forced Air Ventilation

- Duct size can be smaller than natural ventilation.
- Duct runs can be longer than natural ventilation.
- Provides more control over subsoil temperature than natural ventilation
- Can use heat reclaimed from refrigeration system

Disadvantages of Forced Air Ventilation

- More expensive to operate and maintain than natural ventilation
- Difficult to repair a damaged or blocked circuit
- Requires periodic inspection to ensure the ducts are clear and the fan is properly delivering adequate air flow.

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Decision Making

The information contained in this paper can help building owners, facility managers and designers make an informed decision about how to protect their cold storage facility from frost heave damage.

Since 1968 Delta-Therm Corporation has engineered and manufactured heating solutions using Mineral Insulated (MI) heating cable for its high temperature capabilities and longevity. For more information on electric Permafrost Prevention (frost heave prevention) or an evaluation of your application, contact Delta-Therm. **www.delta-therm.com** .