ThermOmegaTech®

BASICS OF FREEZING

INFORMATIONAL SUMMARY

Most people, regardless of their background, are aware of some of the basic elements of freezing. This paper contains some of the less well-known, less obvious facts about how and why things freeze and what happens as a result. It is our hope that there will be something new here for everyone that will, perhaps, make dealing with freezing and its prevention easier.

Through the use of anecdotal examples, we will provide a reference usable throughout industry for anyone who needs to deal with almost any form of freeze protection. We hope that you will feel free to utilize this "primer" on freezing as you look for solutions to problems which might include locomotive cooling systems freezing, industrial process systems freezing, solar collector systems freezing and others.

Facts About Water Freezing

Water, when it freezes, changes from liquid to solid. As the temperature drops, the molecules become less energetic, moving more slowly, until they reach a point at which the molecular structure changes, followed by the transformation into ice, or solid water. Unlike most substances which shrink in volume as they freeze, water expands since ice's molecular structure takes up more space than water. Conversely, when you heat water, the molecules become more excited until they reach the point where the water vaporizes and becomes steam.

There is a misconception that if water can be kept moving, it won't freeze. Wrong! Water freezes at 32°F (0°C). Period.

Since the expansion of water as it freezes is a fact of life, what things should we know about this process in order to create effective means of dealing with it in industry? Water that has frozen in piping systems does more than simply clog the system and shut off the flow. Because ice takes up more room than liquid, when freezing occurs in a confined space like a steel pipe, the ice will build up extreme internal pressure which is often enough to break the pipe and its associated valves and fittings.

Damage from a burst pipe or valve can escalate beyond just replacing the broken parts, into labor costs for the repair and time/money lost from "down-time" in the affected area. Before effective measures can be taken to prevent such disasters, we need to learn about and understand what is happening.

The Physical Principles of Freezing

What are the underlying principles that determine whether the water in a given device (pipe, valve, etc.) will freeze? We already know that water freezes at 32°F. To arrive at this temperature, heat must be removed (transferred) from the water (Remember - heat always travels from high temperature areas to lower temperature areas). Heat transfer, or the removal of heat from one place to another (i.e. from the 45°F water inside a pipe to the 25°F air outside a pipe) is one of the basic laws of nature. Heat is a form of energy. Others include chemical, electrical, mechanical and nuclear, and each is convertible from one form to another. In the USA, heat is usually measured in BTUs, or British Thermal Units. One BTU is the amount of energy which, when added to one pound of water, will raise the temperature of that water by one Fahrenheit degree (as from 65°F to 66°F).

This process is also totally reversible. By transferring one BTU of energy out of one pound of water, the temperature will decrease by one Fahrenheit degree. If you transfer enough heat energy out of a given amount of water, the temperature will drop until it reaches 32°F and the water freezes. The amount of water involved will affect the decrease in temperature. Based on the definition of BTU, it becomes obvious that with two containers full of water, one of which contains twice as much water as the other, twice as much heat will need to be removed from the larger container to lower its temperature the same amount as the smaller container. One good example of this is a pond. Ponds tend to fill fairly shallow depressions in the earth, and range from a few inches deep at their edges to several feet deep near their centers. Where the water is shallow, it freezes solid very quickly. Where the water is deeper, the freezing process occurs more slowly. The greater amount of water near the center of the pond requires more heat to be removed, so it takes longer for the water temperature to reach the freezing point.

At its most basic, if freezing is to occur, it will be determined by both the amount of water present and the rate of heat loss from the water. Some of the most important factors that influence the rate of heat loss from a pipe are:

- The thermal resistance of the pipe wall
- The outside surface area of the pipe
- The wind velocity over/around the pipe
- The temperature difference between the water in the pipe and the outside air.

Both the "surface area" and "temperature difference" factors are directly proportional to the heat loss rate. If you double either of these factors, the rate of heat loss will double. By the way, adding heavy insulation to a non-flowing pipe will greatly decrease the rate of heat loss (you are increasing the thermal resistance of the pipe), but it will not stop it (no insulation is perfect), and the water in the pipe will still eventually freeze.

Some Applied Solutions

"An ounce of prevention is worth a pound of cure."
Benjamin Franklin

There are two basic techniques used to prevent frozen water lines in industry: tracing and bleed/drain.

With the tracing technique one of two systems is generally applied. In the first, "electric tracing", an electrical heating cable is fastened to the underside of the pipe, beneath the insulation. The heat generated by the cable off-sets the heat loss of the pipe so that the pipe and the water it contains are kept safely above freezing.

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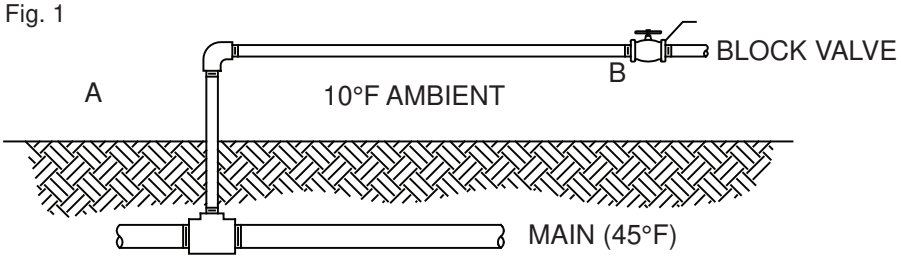
Fig. 1



In large installations this might not be practical because of the cost of both the cable and the electricity used to generate the heat, as well as the possibility for breakage of the cable, which would leave everything beyond the break vulnerable. Additionally, the use of electricity in a facility handling combustible substances is dangerous due to the possibility of sparks. In the second system, "steam tracing", the electric cable is replaced with small diameter copper tubing, which is connected to a steam supply. While cheaper to run, this system must rely on steam traps located at the end of the tracing line. These traps can fail and leave the pipe line unprotected.

The bleed/drain technique, which avoids the expense of heating pipe lines, uses a temperature sensitive valve to "bleed" or "drain" the water from the system involved. Which method, bleed or drain, is used depends on the nature of the water system: Fixed volume or Re-supply.

Re-Supply Systems

When water is lost from this system, it is replaced, or "re-supplied" by the pressurizing source. A very obvious and simple example is your garden hose. As the water comes out of the nozzle, or is "lost", it is replaced, or re-supplied, from the house spigot. Three examples of industrial re-supply systems include:

1. The potable water system in a lab or office
2. Safety showers in potentially dangerous work areas
3. The fire-fighting water system in a factory or petro-chemical plant.

In all these systems, the water originates with a reservoir or well. It is pressurized by elevation or a pump and can flow for several miles underground until it surfaces at or near the point of use. It is here, as the water enters the local area piping system, that freeze protection becomes necessary. (see FIG.1 - schematic representation of system) The pipe above ground (from A to B) gradually loses heat to the 10°F air. The temperature of the water inside the pipe drops, assuming that the block valve (B) is closed, until the water freezes.

Now consider what would happen if, as the water temperature at point B reached 40°F, the valve were to be opened very slightly. Water would begin to flow from the main, which is underground and at 45°F, through the above ground length and out the valve. If the flow were just right, the water entering at 45°F would cool to no less than 40°F at the valve. If the temperature dropped further, or a strong wind were to blow across the pipe (see the previous section on principles of freezing), the valve would have to be opened further to increase the flow of warmer water and keep the temperature at 40°F at the outlet. The warmer water from underground purges the colder water from the system through the open valve.

It would be ridiculous to station a person at each valve with a thermometer to be able to adjust the valve with each change in water temperature. For this reason **Therm-Omega-Tech®,Inc.** has engineered and manufactured a line of high-quality and utterly reliable valves that do all of the above automatically. They do this by sensing the water temperature in the pipe near the valve and gradually opening as needed to establish a flow which will prevent freezing. As the air temperature, wind velocity or other factors which affect the rate of heat loss from the pipe change, the valves automatically adjust the flow rate of the water to maintain temperature and prevent freezing. Since the temperature sensors (thermostats) in the valves also serve as the actuators that move the valve plug, no external source of power is needed. These "modulating" type valves, which open and close to regulate flow to maintain temperature, are part of **Therm-Omega-Tech®'s** family of **HAT/FP** freeze protection devices.

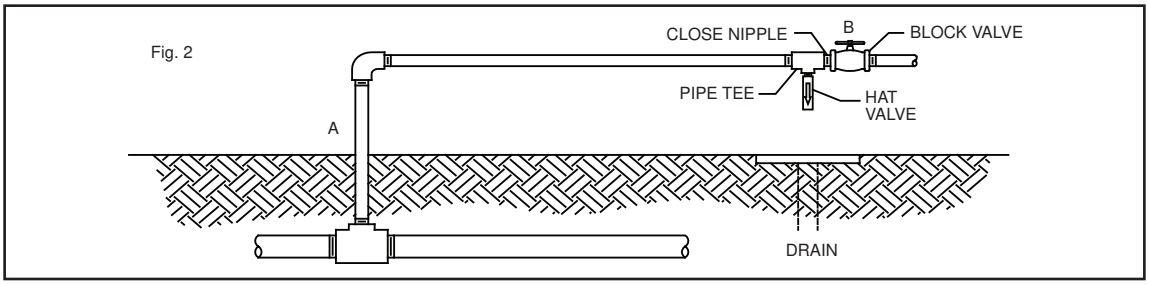
Please Note: Freeze protection valves must be installed as close to the far end of the exposed pipe as possible, since any water downstream from the valve will not be purged and could freeze. (Please see FIG.2 for proper placement of the valve.) Also, any side branches attached to the exposed run of pipe must each have a freeze protection valve at their far ends, and the discharge from the valve must not be piped to the drain, as that pipe might freeze and block the purging flow.

Recommended Do's And Don'ts

These are specifically intended for the HAT series valves and for re-supply systems. Due to the peculiarities inherent in locomotive configurations (see Fixed Volume Systems), we suggest that you contact Therm-Omega-Tech® directly for application suggestions.

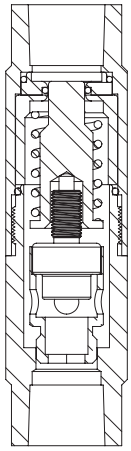
- **DO** locate the **Therm-Omega-Tech®** freeze protection

Fig. 2



valves at the extreme ends of any pipe lines.

• **DON'T** insulate any **Therm-Omega-Tech®** valve. It should be placed so as to have the quickest cooling rate so as to reach opening temperature before any other part of the pipe line reaches freezing temperature. In a sense, these valves act like circuit breakers in an electrical system. They must be the most sensitive components in the system and are the first to react to a circuit abnormality and save the system from damage.



• **DON'T** locate the **HAT** valve near a heat source, such as a steam line (even if it is insulated). The radiant heat from the steam pipe could warm the valve just enough to prevent operation, even though a portion of the pipe not near the steam line is starting to freeze.

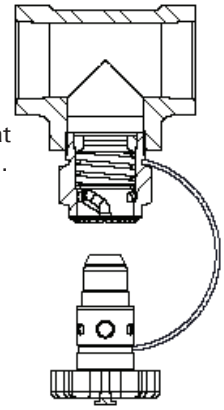
• **DO** test **HAT** valves before each cold season. A simple test consists of slipping an ice-filled can up and around the valve. In several minutes the can should start to overflow, which indicates that the valve is opening. Remove the can, and in a few minutes the valve should close. If it performs this way, it is fine.

• **DO** calculate the proper **HAT** valve size for your pipe application. There is a sample calculation in the appendix of the **Therm-Omega-Tech®** catalog. (See Application Profile #3 or **Therm-Omega-Tech®'s** "FREEZPRO" Valve Sizing Software)

• **DO** call **Therm-Omega-Tech®** at **1-877-379-8258** if you have any questions.

Fixed Volume Systems

This system is defined by its name: fixed volume. It has a definite volume of water in it which does not fluctuate. It may be separately pressurized or operate under its own head pressure. The cooling systems in use on US and Canadian diesel locomotives are fixed volume systems. Because it is not economical to use an anti-freeze solution due to heat transfer efficiency of the engine, these railroads use all-water cooling. As a result, should the engine be shut down for any reason during sub-freezing weather, there is a definite danger of freeze damage that could reach thousands of dollars in parts and labor. The engine cooling system is a closed loop, with a pump circulating the water from the engine, where the water absorbs heat, to the radiators, where the heat is dissipated, and back to the engine.

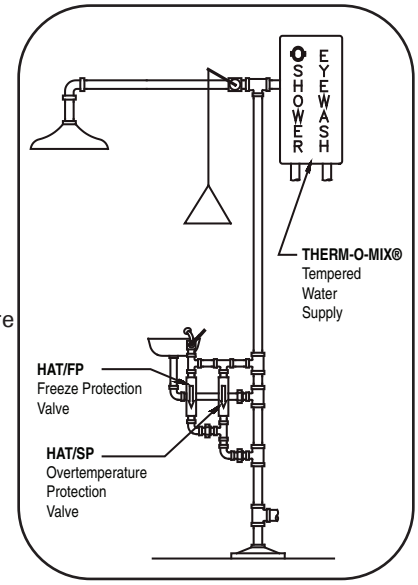


Therm-Omega-Tech®'s railroad freeze protection valves, called **GURU® Plugs**, were developed expressly for this application, for which a patent was granted. This valve should be installed at the lowest point in the cooling system. Since this valve, or plug, is designed to sense both water and air temperatures, when the engine is running, the very warm water passing by the valve keeps the valve shut. After engine shutdown, the whole system cools down. At some time before a series of small tubes in the system can freeze, the air sensing qualities of the **GURU® Plug** cause it to snap open. This drains the whole system rapidly before any freeze can occur. This snap acting valve must be used because there is no source of warmer water to purge the system, as there was in the re-supply system. By installing the valve at the lowest point in the loop, complete drainage is ensured.

Two Brief Case Histories

For over twenty five years, **Therm-Omega-Tech®, Inc.** has manufactured and sold tens of thousands of freeze protection valves all over the United States and Canada. They are protecting millions of dollars worth of railroads, factories and petro-chemical plants. Because every valve is calibrated and tested before it is shipped, our reliability is second to none. The following examples serve to illustrate two of hundreds of possible applications of our freeze protection technology.

Several major railroads located in the northeast and midwestern U.S. (a part of the country where freezing is a fact of life for at least five months of the year if not longer), have installed **Guru® Plugs** on nearly all their locomotives. One of their managers told us that he was pleasantly surprised to find out that these "snap-acting" plugs do exactly what they are supposed to do. As the temperature of the cooling water in the piping dropped to near freezing in one of their locomotives in shut-down mode (unintentionally left for too long), the plug snapped open, draining the system of its water and thereby eliminating any possibility of a damaging freeze within the system. After refilling the system and re-inserting the warmed cartridge into the **Guru® Plug**, the locomotive was back in operation within hours, quickly and efficiently. Had the "dump" not occurred, thousands of dollars worth of damage could (more likely would) have been done, taking the locomotive out of operation for a long period of repair. In the past, the only sure way of avoiding freezes without such system protection was to leave the engines running constantly, resulting in a tremendous waste of fuel and energy and contributing unnecessarily to air pollution. Guru® Plugs, by their very nature, reduce fuel expenditures, creating yet another form of economy by avoiding unnecessary energy usage.



Most major emergency eyewash/safety shower manufacturers are currently using **Therm-Omega-Tech®'s HAT/FP** for freeze protection of their safety showers and eyewash stations, as well as **HAT/SP's** for overtemperature protection.

Remember that freezing water can cause extensive damage to equipment but it is possible to reduce or eliminate the possibility of freezing through application of Therm-Omega-Tech® technology. Should you have any questions concerning a particular application of freeze protection technology for your plant or railroad, do not hesitate to call Therm-Omega-Tech®'s engineers at 1-877-379-8258 or FAX your request to 1-215-674-8594.

Reliable, long lasting valves for...

FREEZE PROTECTION

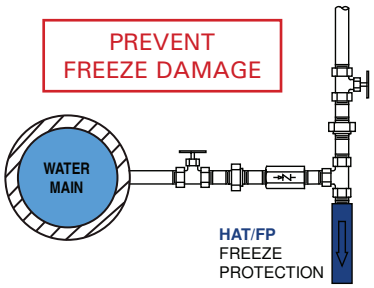


HAT/FP

THERM-OMEGA-TECH® HAT/FP valves automatically bleed lines to eliminate low temperature water when there is a danger of freezing. This prevents costly damage and pipe breakage. When the water temperature rises to 40°F, the valve modulates to its full closed position, for maximum water conservation.

Freeze protection **HAT/FP** valves are installed at termination points in water systems to protect piping, valves, fittings and other components.

Applications include: Safety showers and eyewash stations, fire lines, potable or process water lines, etc.



FREEZE PROTECTION OF WATER MAINS AND PIPE RUNS

HAT/FP valves may serve as primary protection on untraced systems or as a fail-safe backup for traced water systems. Various sizes and C_V's are available. Typical set point: open 35°F, closed 40°F.

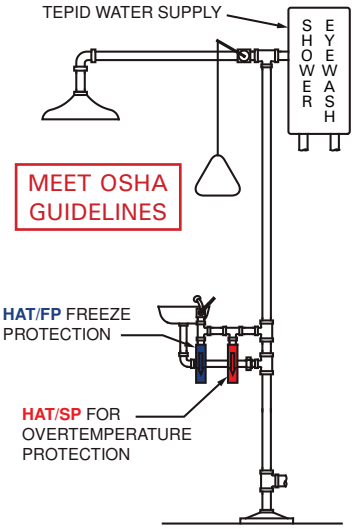
OVERTEMPERATURE PROTECTION



HAT/SP

In safety showers and eyewash stations, **THERM-OMEGA-TECH® HAT/SP** valves can protect employees from the effect of solar heated water lines. Scald protection **HAT/SP** valves are reverse-acting, bleeding off hot water when it goes above the 95°F setpoint, keeping it within **OSHA** guidelines.

THERM-OMEGA-TECH® also manufactures tempered water supplies to provide constant temperature water for emergency showers. Available as steam/water mixing or water/water mixing.



OVERTEMPERATURE PROTECTION, FREEZE PROTECTION, AND MORE

Safety showers and Eyewash stations can be safe and operational year round. **HAT/SP** 95°F or 115°F provides scald protection from solar heating of pipes. **HAT/FP** 35°F provides freeze protection.

STEAM TRACING SYSTEMS

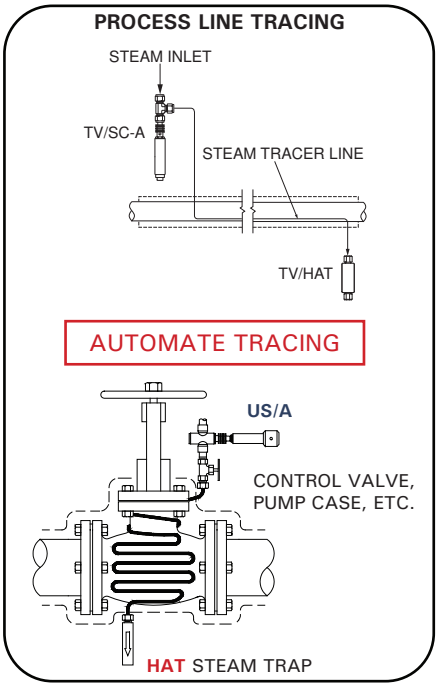


US/A

THERM-OMEGA-TECH® US/A valves are used to automate seasonal tracing based on ambient temperatures, providing steam savings of up to 90% (30-60% typical).

HAT valve sub-cooled steam traps can be used to efficiently trace process lines, instruments, pumps, etc. HAT valves respond only to condensate temperature, allowing maximum energy use. Typical setpoints include: 105°F, 125°F, 180°F, 210°F and 240°F.

Instrument enclosures and analyzer housings can be maintained at a constant temperature year round with **THERM-OMEGA-TECH® TV/SC-I** valves.



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Freeze_Basics
Rev: 5/1/2020

Because of continuous improvements, Therm-Omega-Tech®, Inc. reserves the right to change the design and specifications without notice