Winter's Coming - Use Freeze Protection Valves to Keep Lines Flowing

These valves save piping, fittings, and equipment from freeze up and potential damage. Here are selection guidelines and calculation methods for sizing.

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Freeze protection valves are effective in preventing freeze damage in process lines. Unlike steam or electric tracing, which require power and can cause water to overheat, freeze protection valves operate by simply draining or bleeding water as the temperature approaches freezing.

This prevents the formation of ice that can clog lines, shut off flow, and cause pressure within the line to build, cracking pipes, valves, and fittings, as well as damaging equipment (Figure 1). Damage due to ice formation can incur costs for replacement parts and labor, and reduce productivity due to shutdowns.

Nonetheless, freeze protection valves do not necessarily completely prevent the formation of ice. In some cases, ice may still form as a layer on the inside of a pipe. This actually acts as a good insulator, reducing further heat loss to the cold outside air. Also, if the ice does not completely block the pipe or equipment flow area, no damage will occur. Damage due to freezing is caused when a pipe or flow passage in equipment is completely blocked. Then, as additional ice forms, the expansion associated with the ice formation compresses the water and causes a dramatic increase in the internal pressure in the line. When the pressure exceeds the strength of the pipe or housing, these will break.

Valves vs. tracing

When to use tracing - Tracing is required when the temperature to be maintained is above the resupply water temperature; that is, when additional heat input is required. Use tracing if the complexity of the equipment layout makes it difficult or impossible to properly bleed or drain the system. Also, tracing should be used if the discharge from bleeder or drain valves presents a handling problem. This may be the case in plant areas where all discharges must be controlled or reported, or where discharge treatment problems and expenses outweigh the benefits of bleeder/drain valves.

When to use valves - Valves are generally more economical to install and operate than tracing. Use valves in remote plant areas where steam or electricity are not available and the cost to provide them is high. Also, use valves when potential overheating from tracing is a problem. In critical applications, where power failures will cut off electric or steam tracing, select self-operating valves as either the primary or backup freeze protection system.

When selecting the freeze protection valve that is appropriate for your application, a variety of other factors must be taken into account. Specify a valve that is not large enough, for example, and the system may not be able to eliminate cold water quickly enough to prevent freezing. Specify too few valves, and your system could be plagued with "dead legs," areas that the installed valves will not be able to protect.

How these valves work

As already noted, freeze protection valves can either bleed or drain water from the system to be protected. The method used depends on whether you have a resupply or fixed volume type of system.

Such protection also can be provided with standard valves by having an operator open a valve enough to drain the equipment entirely, or crack it open to prevent freezing, and closing it once the danger has passed. However, manual operation is impractical when the cost of labor and the potential for human error are taken into account.

Automatic freeze protection valves eliminate this problem. These valves contain a temperature-sensitive material that contracts when exposed to water temperatures between 40°F and 35°F. This contraction allows the valve to open so water can flow. As the water temperature in the valve approaches 40°F the thermal material expands and closes the valve. In this way, cold water is eventually bled from the system and replaced by warmer resupply water, keeping the water in the system at about 40°F or higher (Figure 2). If no warmer resupply water enters the system, the freeze protection valve typically stays open until all water in the system is drained.

Fixed volume systems

Fixed volume systems, such as water storage tanks, water-cooled engines, or cooling-tower pumps, contain just that - a fixed volume of water. To prevent freezing, these systems must be completely drained when temperatures are low enough to allow ice to form. This can be accomplished by installing freeze protection valves at low points in the system.

The rate at which draining must take place is determined by dividing the volume of water by the required drain time. While the volume of water is usually easy to determine, drain time can be estimated based on experience with the equipment in use, as well as on looking at local weather conditions. To calculate the drain time required to prevent freezing, heat loss from the system must be determined. A calculation may also be employed to estimate the rate at which the water will cool, based on exposed surface areas, and air and water temperatures. Also, the distribution of the water in the system affects the pressure head available for draining. Since pressure is important in determining the drain time, uneven distribution of water at various elevations further complicates calculations. In many cases, a conservative, safe estimate of the required drain time or an estimate based on experience or tests gives more-reliable results. Tests can use thermocouples to determine a cooldown temperature profile, as well as measure the actual drain time for a real system. Together, such data will show how to safely protect a system.

A simple, but safe method of freeze protection is to wait until the water approaches the freezing temperature, and then drain it as quickly as possible. Applying the correct freeze protection valves is then a matter of sizing the valves to achieve the desired flow rate. Divide the desired flow rate by the square root of the average pressure head in lb/in^2 to give C_V, the required valve flow coefficient, and then choose a freeze protection valve with a C_V, of at least the calculated value.

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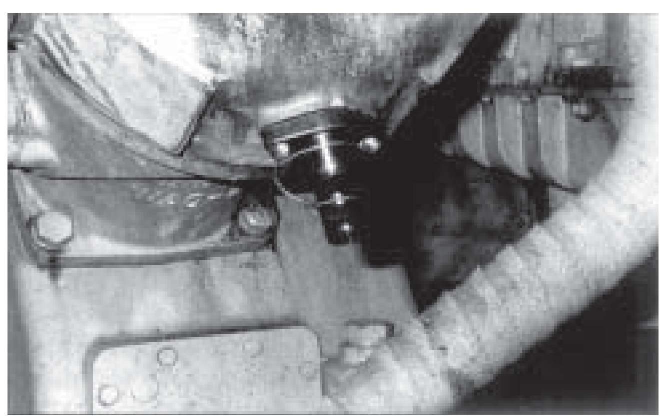
Resupply calculations

Most water piping systems and some types of equipment are connected to a continuous source of supply water. Examples of resupply systems are process, utility, potable, and safety shower water, as well as some fire protection sprinkler piping. The source of resupply is typically underground water systems that are insulated from cold ambient temperatures. The temperature in underground mains is usually well above that in the exposed piping parts of the system, typically above 40°F in even the coldest weather. Freeze protecting these systems involves bleeding off the near-freezing water from the exposed piping and allowing the system to refill with the warmer resupply water.



■ **Figure 1. A 1-in. flange-mounted stainless steel valve protects a water-cooled air compressor.**

Designing the correct freeze protection on a resupply system considers two factors: determining the heat loss of the exposed piping and establishing bleed flow through all sections of the system to eliminate dead legs. The warmer resupply water must then be bled through the exposed piping fast enough to provide heat to offset the heat loss to the cold ambient temperature and keep the system above freezing. The factors that determine the flow needed to prevent freezing and correctly size the freeze protection valves required for this flow rate are:

- Exposed pipe surface area;
- Minimum ambient temperature;
- Resupply water temperature;
- Pipe flow area;
- Efficiency of insulation, if any, on piping; and
- Water pressure.

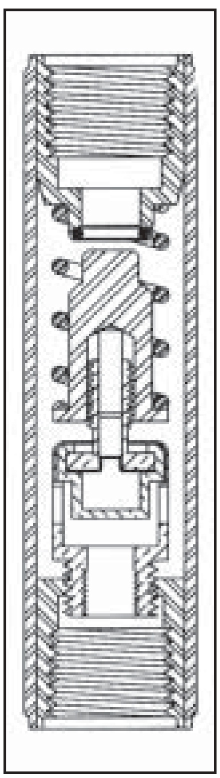
A simplified formula that combines the piping heat loss equations, the heat gained from the incoming warmer water, and the flow required to achieve the desired heat gain is given below. This formula determines the flow required to prevent freezing:

$$GPM = [A_1A_2(0.5t_w - t_a + 16)]/[40.1d^2(t_w - 32)] \quad (1)$$

where:

GPM = water flow, gal/min
A_1 = pipe flow area, ft^2
A_2= exposed pipe surface area, ft^2
t_w = minimum temperature of resupply water, °F
t_a = minimum air temperature, °F
d = ID of pipe, ft.

This method yields a conservative answer giving more flow to prevent freezing than is actually necessary. A contributing factor is that, even after water reaches 32°F, it will not freeze until the heat of fusion is released, 144 Btu/lb. Another assumption is that enough wind wipe is present such that the boundary layer at the outside surface of the pipe or equipment is disrupted, which gives the highest heat loss figures. Equation 1 was derived based on heat loss and flow calculations.



■ Figure 2. Cutaway of freeze protection valve (top inlet) shows plug (in center), which is positioned in response to water temperature by inner thermal actuator, and, above it, valve seat (with O-ring).

Size and number of valves

Once the flow required to prevent freezing is established, the size and number of valves must be determined. In a single run of piping, the automatic bleeder valves can be simply installed at the far end of the piping. If multiple valves are needed to achieve the required flow rate, all of the valves should be installed at the far end to assure required flow through the entire pipe length. On a more typical system with many branches, a bleeder valve must be installed at the far end of each branch. Tests indicate that dead legs as short as a couple of pipe diameters can freeze even if water is flowing through a tee at the junction with the main line. This may result in sizing valves that handle more than the calculated flow, but it is important to satisfy both criteria: handling the required flow and eliminating dead legs.

The formula for determining the number and size of the freeze protection valves needed is based on the flow rate requirement and system water pressure, from which the flow coefficient C_V can be calculated:

$$C_V = GPM/(\Delta P)^{1/2} \quad (2)$$

where:

GPM = is from Eq. 1
ΔP = pressure drop, psi.

Since, in most applications, the freeze protection valves discharge to atmospheric pressure, the pressure drop is the total water pressure. From the calculated required C_V choose any combination of freeze protection valves that will equal or exceed that value. The C_V's of freeze protection valves are published in the valve manufacturers' product bulletin sheets.

Note that while self-operating freeze protection bleeder valves can be undersized, they cannot be oversized. For example, if two valves are installed on a piping system where one has an adequate flow rate, the total amount of water discharged will be the same. This is because the amount of water discharged from a specific system under the same atmospheric conditions depends on the water temperature, not the number of valves. This can be appreciated by examining Eq. 1. For a given piping system size and air temperature, the flow required is proportional to the water temperature, not the valve size.

Example

A fire-protection water supply line in a plant consists of 1,200 ft of uninsulated 2-in. Sch. 80 piping. The system water pressure is 100 psig. The minimum ambient air temperature is -10°F. The resupply water comes from underground piping and its minimum temperature is 42°F. Referring to piping data tables and using Eq. 1:

$A_1 = 0.0205\ ft^2$
$A_2 = 0.622\ ft^2/ft \times 1{,}200\ ft$
$= 746.4\ ft^2$
$t_w = 42°F$
$t_a = -10°F$
$d = 0.1616\ ft$

$$GPM = [(0.0205)(746.4)[0.5(42) - (-10) + 16))]/ 40.1(0.1616)^2 (42 - 32)] = 68.7\ gal/min$$

Since, in most freeze protection applications, the automatic bleeder valves discharge directly to the atmosphere, the pressure drop across the valve is 100 psig discharging to 0 psig. Using the required flow rate and pressure drop in Eq. 2:

$$C_V = 68.7/(100)^{1/2} = 6.87$$

Select a freeze protection valve with a C_V of at least 6.87, or multiples of smaller valves can be installed with their total C_V's adding up to at least 6.87. An advantage of using multiple smaller valves is that the risk of all of the valves failing is much less than the risk of one failing. If one valve fails in a multiple valve installation, you can still achieve adequate freeze protection for all but the most severe conditions. And since milder freezing conditions are often experienced prior to the most severe weather, maintenance personnel will have a chance to notice the failed valve and repair or replace it.

The automatic freeze protection valves should also be installed so that when the valve opens, bleed water can flow through the entire run of pipe. As already noted, this usually means installing the valves at the end of the line farthest from the main supply. For any side branches, additional freeze protection valves should be installed to prevent deadlegs.

Other factors in selection

Despite the importance of heat loss and pressure in valve selection, there are a number of other factors that must also be considered:

Corrosion resistance - Corrosion can considerably shorten valve life. Because of this, it's a good idea to choose a valve made of corrosion-resistant materials, such as stainless steel or brass. This will also provide the strength that's needed to withstand years of use. In some special cases, such as with deionized systems or saltwater Systems, pay particular attention to the materials of construction. Type 316 stainless steel or special bronze alloys may be required.

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Dirt handling ability - The valve you choose should be able to operate and afford a tight seal without leaking, despite the presence of dirt in the system. Valves that are too easily blocked by dirt will not perform effectively. The valve manufacturer should have conducted dirt-handling tests to develop a design that will give good service life.

Easy installation - A valve that is too time-consuming or costly to install may never be used. To keep labor costs and downtime to a minimum, be sure to choose a valve that requires a minimum of tools, labor, and downtime.

Actuators - The actuator is the heart of a valve. Some manufacturers specifically design actuators for each application, and can produce them to your specific requirements. For example, many actuators operate over a 10°F range from 35°F fully open to 45°F fully closed. An optimized actuator for freeze protection valves can offer a 5°F operating temperature range. This is important, particularly given the effect on water consumption. During a winter season in most parts of the U.S., a freeze protection valve that closes at 45°F will typically waste more than twice as much water as one that closes at 40°F.

Different valve configurations available - A variety of valve configurations is available. Examine your needs to get the most convenient configuration for your installation. The most commonly used protection valves are inline modulating styles. Typical models are ½ and ¾ in., stainless steel. These are installed on pipe tees in the main piping system or at the end of pipelines. Modulating valves gradually start to open at a pre-set temperature and progressively open further as the water temperature drops. When temperature rises, these valves gradually close further and further.

An interchangeable cartridge type also has a modulating action, but allows insertion into threaded openings in pipes, pumps, larger valves, and other equipment. Snap-on styles stay completely closed until a specific low temperature is reached and then suddenly open fully. CEP

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