Antifreeze Alternatives – Tenting of Insulation

By Kenneth E. Isman, P.E.

Unless you've been hiding under a rock lately, you've heard that antifreeze solutions can pose problems for fire sprinkler systems. At certain concentrations, and in certain conditions, the antifreeze can contribute to the combustion of a fire, which is the opposite of the intent of a fire sprinkler system.

The NFSA has been keeping its membership informed regarding the antifreeze solutions that can be used through its Sprinkler TechNotes newsletter and E-Tech Alert bulletins. This article will not address the use of antifreeze in fire sprinkler systems. For more information on that subject, see the NFSA newsletters and electronic bulletins. Instead, this article will focus on the alternatives to antifreeze so that sprinkler systems can be installed without fear of the water in the piping freezing.

There are several potential alternatives to antifreeze including: the use of dry-pipe and preaction systems, tenting of insulation over pipe in an attic, use of dry type sprinklers to extend protection from a warm space into a freezing space, heat tracing, and the installation of pipe in interior walls with sidewall sprinklers protecting into the rooms.

Several of these topics will be covered in other articles in this same edition of SQ in an effort to concentrate the information in one easy to use location. This article will focus on the tenting of insulation over pipes in an attic space in order to keep them from freezing. The topic of heat tracing was covered in a previous edition of SQ magazine (see Technically Speaking in the July/August 2010 issue (No. 161) pages 15-16).

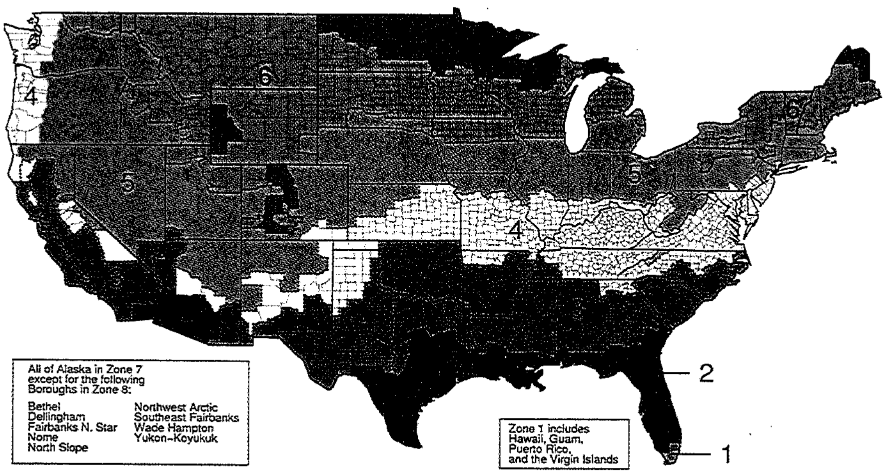

Figure 1 - Climate Zones for Insulation Thickness

What is "Tenting Insulation"?

The process of tenting insulation over pipe is the procedure of laying sufficient insulation on top of pipe to trap the heat coming up from the room below to keep the water in the pipe warm enough to prevent it from freezing. It is important to keep the insulation above the pipe, and to make sure that the insulation does not get under the pipe. If insulation gets under the pipe it actually prevents the warmth from getting to the pipe and the water in the pipe may freeze.

Typically, tenting of insulation is used for the pipe in an attic that is delivering water to pendent sprinklers protecting the story below the attic. Similar concepts would apply to piping being installed in exterior walls, where the insulation would need to be between the exterior of the building and the sprinkler pipe. If the attic space itself needs to be protected with sprinklers, tenting of insulation is generally not sufficient protection because the piping leading to the sprinklers protecting the attic generally cannot be kept in a warm enough space.

The determination of how much insulation needs to be used above the pipe depends on the ambient temperature that will occur in the attic. The United States Department of Energy has divided the country into eight zones in order to recommend insulation thickness. Figure

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1 shows these zones and Table 1 shows the insulation thickness that is needed in each zone for insulation in an attic. For batt insulation, the thickness of the insulation can be found by dividing the R-value by 3.2. This map can be downloaded from the Department of Energy website at: http://www.ornl.gov/sci/roofs+walls/insulation/ins_05.html.

Zone	Attic Insulation Recommendation	Batt Thickness
1	R30 to R49	9.375 to 15.3
2, 3	R30 to R60	9.375 to 18.75
4, 5	R38 to R60	11.875 to 18.75
6, 7, 8	R49 to R60	15.3 to 18.75

Table 1 - Insulation Recommendations from the Department of Energy

Is Tenting Insulation Effective?

In order for tenting of insulation to be effective, the insulation needs to be laid continuously over the pipe without any gaps. If this is accomplished, and the correct thickness is used, the insulation can protect the pipe extremely well (as long as the insulation is above the pipe and not below the pipe). Of course, the assumption that is being made is that the heat will stay on in the room below the pipe. This assumption is not unreasonable given the fact that all wet pipe systems rely on this assumption. Without this assumption, wet pipe systems would never be installed.

In 1999, the NFSA contacted the Owens Corning corporation in an attempt to get them to make some statements on the record as to the effectiveness of tenting insulation over sprinkler pipe. Unfortunately, the engineers at Owens Corning were uncomfortable with their knowledge of fire sprinkler systems and did not want to make definitive statements regarding the temperatures to which sprinkler piping could be protected. But they did state confidently that as long as the following conditions were met, there would be no problem with the insulation protecting the pipe from freezing:

1. Keep the insulation over the pipe and not under it. Note that an air gap around the pipe is not necessary.
2. Do not allow gaps in the insulation, cover all pipe.
3. Keep the insulation in place. Do not allow wind or movement of the insulation off of the pipe.
4. A substantial amount of pipe needs to be in contact with the ceiling so that the heat from the room below can prevent the pipe from freezing.

Many fire sprinkler systems have been installed utilizing these basic common sense rules with wet piping adequately protected from freezing by simply tenting the insulation over the pipe. Where the building contractor is going to use blown in insulation, many sprinkler contractors prefer to use batt insulation over the sprinkler pipe, and then allow the blown in insulation to go over the batt insulation. In this manner the batt insulation protects the sprinkler pipe from freezing, even if the blown in insulation gets moved in the attic. Other sprinkler contractors put plastic sheeting down over the sprinkler pipe prior to the blown-in insulation being installed to make sure that the blown-in insulation does not get under the piping. If this is done, some method of keeping the insulation in place might be needed and other contractors on the job need to be made aware of the importance of keeping the insulation in-tact.

There is no question that tenting of insulation requires more coordination on the part of the fire sprinkler contractor. But the simple design of the wet pipe sprinkler system, and the ability to use this simple system, makes up for the extra time and effort. In some cases, sprinkler contractors have decided to also become insulation contractors in order to ensure that the work gets done correctly (and to make a little extra money in the process).

At What Temperatures is Tenting Effective?

Tenting of insulation over sprinkler piping in an attic can be effectively done in almost any climate. Unfortunately, proving this with exact mathematical calculations can be a challenge. As stated earlier in the article, engineers from Owens Corning did not want to commit themselves to precise numbers regarding the freezing temperatures that sprinkler piping can be protected from. The heat transfer calculations contain difficult variables in order to make them precise.

However, in order to prove that the method can be effective, precise calculations do not need to be performed. Instead, simplifications can be made and conservative estimates can be used to prove that the temperature around the pipe will not get to freezing.

In order to explore this concept more completely, Figure 2 shows an attic space where some basic heat transfer calculations will be performed. This is a typical attic space with wood joists (16 inches on center), a gypsum board ceiling attached to the bottom of the joists, and insulation in the channels between joists. A 2 inch air gap will be left between the gypsum board ceiling and the batt insulation. The temperature in this air gap will be calculated to determine if sprinkler piping in such a space would be subjected to freezing temperatures. In reality, such a large air gap would not be necessary for the sprinkler piping, but this simplification makes the calculations easier and the temperature situation would be even better with the insulation not only above the sprinkler pipe but on both sides as well.

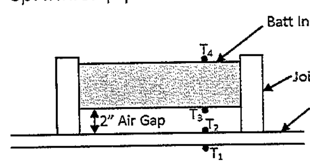

Figure 2
Joist Channel with Air Gap for Calculation Purposes

In order to simplify the heat transfer calculations, the temperatures at four points will be considered. The first point will be the underside of the gypsum ceiling (T_1), which will be the temperature in the heated room below the attic. The second temperature will be on top of the gypsum ceiling just inside the air gap (T_2). This is the temperature that the sprinkler piping would be in contact with if it were installed in the air gap. The third temperature is at the top of the air gap in contact with the bottom of the batt insulation (T_3). This is the temperature which would be in contact with the top of the sprinkler piping. The fourth temperature is on top of the batt insulation (T_4), which would be the temperature in the attic.

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Using this simplified model of a joist channel, the heat transfer from T_1 to T_4 can be calculated using the following formula:

$$q = \frac{T_4 - T_1}{R_{Total}}$$

In the equation above, "q" is the heat transfer rate in watts while R_{Total} is a variable that describes the material properties of the gypsum board, wood joists, batt insulation, and air gap. The R_{Total} variable is a bit tricky to calculate because the heat transfer is occurring in series through the gypsum board, air gap, and batt insulation, while it is occurring in parallel through the gypsum board and wood joists. Given this information R_{Total} can be calculated as follows:

$$R_{Total} = R_A + \left(\frac{1}{\frac{1}{R_B} + \frac{1}{R_C + R_D}} \right)$$

Where:

R_A = properties of gypsum board $= x_A*(k_A*A_A)$

R_B = properties of wood joists $= x_B/(k_B*A_B)$

R_C = properties of insulation $= x_C/(k_C*A_C)$

R_D = properties of air $= x_D/(k_D*A_D)$

x_A = thickness of gypsum board in meters = 0.015 for the initial calculation (5/8 inch)

x_B = height of wood joists in meters = 0.2 for the initial calculation (8 inches)

x_C = thickness of batt insulation in meters = 0.15 for the initial calculation (6 inches)

x_D = thickness of the air gap in meters = 0.05 for the initial calculation (2 inches)

k_A = conduction constant for gypsum board = 0.48

k_B = conduction constant for wood joists = 0.14

k_C = conduction constant for batt insulation = 0.04

k_D = conduction constant for air = 0.025

A note for those of you following the math carefully here, for all of the "R" calculations, an area (A_A, A_B, A_C, and A_D) is needed. For the initial calculations, I picked a nominal length of 3m (118 inches) in the direction in and out of the plane showed in Figure 2. However, since this length is common to all elements in the calculations, it cancels out and makes no difference. Also note that all calculations have been performed in metric units and then converted back to traditional ft-lb units for the convenience of the readers.

Taking all of these variables into account, RTotal is found for the initial conditions described above to be about 3.7. Plugging this value to the equation for the heat transfer, and assuming that we can keep the room below heated to 50°F (10°C) and that the attic be subjected to a low temperature of -20°F (-28.9°C), we find that the heat transfer is a modest -10.5 Watts, calculated as follows:

$$q = \frac{T_4 - T_1}{R_{Total}} = \frac{-28.9 - 10}{3.7} = -10.5$$

Now that we know the overall heat transfer through the assembly, we can use this to calculate other temperatures within the assembly. The temperature at the interface between the air gap and the gypsum ceiling (T_2) can be calculated to be 9.7°C (49.5°F) as follows:

$$T_2 = qR_A + T_1 = -10.5 * 0.027 + 10 = 9.7$$

This calculation shows us that the gypsum board is not a very significant insulator, and most of the heat from the room below is getting up into the air gap. However this is not the temperature throughout the entire air gap, it is only the temperature at the upper surface of the gypsum board. We also need to start from the top (T_4) and calculate down to the underside of the bat insulation at the top of the air gap (T_3). The following formula shows that calculation:

$$T_3 = T_4 - q\left(\frac{1}{\frac{1}{R_B} + \frac{1}{R_C}} \right) = -30 - (-10.5)\left(\frac{1}{\frac{1}{11.9} + \frac{1}{3.4}} \right) = \cdot$$

In this case the temperature at the underside of the batt insulation is -0.7°C (30.7°F). This temperature is just under the freezing condition. However, this does not mean that the water in the piping would freeze. Remember that the piping is also in contact with the temperature of 49.5°F directly below. Still, this might be too close for some authorities, and this condition may not be permitted.

The good news is that this calculation was done with only 6 inches of batt insulation and an initial assumption of a temperature of -20°F in the attic. In reality such a combination would not occur. In portions of the country where the temperature in the attic was expected to be -20°F, the insulation would be thicker and have a greater R value. In fact, NFPA 13 contains a map of 48 of the states in the United States (and parts of Canada) and the lowest one-day mean temperature experienced in those states in Figure A.10.5.1. According to this figure, portions of the United States that are expected to be exposed to temperatures of -20°F would need a minimum of R49 (15.3 inches) of insulation in accordance with the Department of Energy map that is Figure 1 in this article.

If the calculations were redone with half this amount of insulation (7.6 inches), the temperature at the top of the gypsum board would still be 49.5°F while the temperature at the underside of the batt insulation would be 33.6°F which would insure that the water in the pipe would never freeze. In fact, the average temperature in the space would be 41.6°F, which is above the limit of 40°F set by NFPA 13.

Table 2 has been developed with a computer program that follows the procedures outlined in this article. By making different assumptions about the temperatures in the heated room, temperatures in the attic, and thicknesses of insulation, different conditions can be

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proven to maintain suitable conditions in the air gap for sprinkler pipe. This computer program can be made available to NFSA members upon request.

Insulation Thickness	Attic Temp	Room Temp	Temp Above Gypsum Board	Temp Below Batt Insulation	Average Temp in Air Gap
6 inches	-20°F	50°F	49.5°F	30.7°F	40.1°F
6 inches	-20°F	52°F	51.5°F	32.2°F	41.8°F
6 inches	-15°F	50°F	49.6°F	32.1°F	40.9°F
9 inches	-20°F	50°F	49.6°F	36.0°F	42.8°F
9 inches	-15°F	50°F	49.7°F	37.0°F	43.3°F
9 inches	-30°F	50°F	49.6°F	34.0°F	41.8°F

Table 2
Temperatures in the Air Gap for a Variety of Conditions

As Table 2 shows, the temperature of the air gap for all of these conditions will be sufficient to keep the piping from freezing, and the average temperature in the air gap is above the 40°F limit set by NFPA 13. Note that all of the temperatures calculated in this table utilize far less insulation than what is required for the zones discussed in Figure 1. If the right amount of insulation were used even greater freeze protection would be provided by the tenting of the insulation.

Does NFPA 13 Permit Tenting to Protect Wet Pipe?

NFPA 13 does not directly address the use of insulation to protect wet piping. However, this does not mean that the tenting of insulation is prohibited. Section 8.16.4.1 of NFPA 13 requires that water filled piping be installed in spaces that are reliably heated to at least 40°F. As the calculations earlier in this article have shown, tenting of insulation can easily meet this requirement. Therefore the use of insulation to keep wet piping freezing when it is run in an attic space is permitted by NFPA 13.

Of course, in order to be used in such a manner, the insulation needs to be installed as discussed previously in this article in order to insure that the piping remains protected from freezing.

Do NFPA 13R and NFPA 13D Permit Tenting to Protect Wet Pipe?

NFPA 13R and NFPA 13D both directly address the tenting of insulation over wet piping in an attic. Section 5.4.2 of NFPA 13R contains basic criteria for keeping water filled piping in a space reliably maintained at 40°F. An annex note to this section specifically addresses the tenting of insulation over pipe, and five diagrams are included in the standard to show how to properly lay batt insulation over the sprinkler piping.

A similar situation occurs in NFPA 13D. Section 8.3.1 requires water filled piping to be in a space reliably maintained at 40°F. An annex note to that section contains the same five diagrams as those in NFPA 13 R, showing how to properly lay the batt insulation over the sprinkler piping.

Summary

As this article has shown, batt insulation can be effectively used in an attic space to protect sprinkler piping from freezing without the need of antifreeze solutions. The procedures for laying the insulation in the attic space need to be carefully controlled, but the end result is an inexpensive and effective fire protection system well worth the extra coordination cost of working with the insulation contractor.