TECHNICAL NOTES

Sprinkler Insulation

A Literature Review

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Fire Protection Research Foundation
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FOREWORD

Recent research and experience with antifreeze in home fire sprinkler systems has resulted in limitations on its use in this application. This literature review was conducted at the request of NFPA's Technical Committee on Residential Sprinkler Systems. Its scope is to identify and gather all pertinent articles that have been published in relation to the use of insulation within residential facilities to protect sprinkler piping from freezing conditions.

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Sprinkler Insulation:
A Literature Review

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This literature review was conducted at the request of NFPA's Technical Committee on Residential Sprinkler Systems. Its scope is to identify and gather all pertinent articles that have been published in relation to the use of insulation within residential facilities to protect sprinkler piping from freezing conditions. This topic is addressed by Chapter 8 of NFPA 13D, *Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes; in* Chapter 5 of NFPA 13R, *Sprinkler Systems in Residential Occupancies Up to and Including Four Stories in Height*; and in 8.16.4 of NFPA 13, *Installation of Sprinkler Systems,* which provides requirements for the protection of sprinkler piping from freezing temperatures. While the methods discussed are applicable to all sprinkler system piping, the focus of this review will be on protecting short runs of wet pipe sprinkler systems used in residential applications within unconditioned freeze areas.

Background

Recent developments regarding the use of antifreeze in residential sprinkler applications has led the industry to develop and review alternate methods of protecting sprinkler piping that travels through unconditioned areas. When possible, sprinkler piping should primarily be run within conditioned areas to ensure the temperature remains above the 40°F minimum temperature requirement of NFPA 13, 13D, and 13R. Within these standards, there are various recommendations for alternate methods of protecting sprinkler systems against freezing conditions—such as the use of a dry-pipe system, pre-action system, dry-pendant or dry-sidewall sprinklers, a heat tracing system, or an insulation system.

The focus of this literature review will be specifically on the protection of short runs of sprinkler piping within freezing conditions—such as in exterior walls and attic spaces—through the use of various insulation techniques, methods, and materials. A second focus of the literature review is to identify existing regulatory requirements that affect the methods and materials used in specific areas.

Literature Review Process

Each document reviewed was numbered and classified according to its content into the following three main categories:

Materials and Properties

- R-Value/Heat Transfer
- Fiberglass Insulation
- Natural Insulation
- Foam Insulation

Insulating Methods

Box-In Method

Tenting Method

Roof Underside Spray Foam Method

Regulatory Requirements

National Requirements

Local Requirements

The documents were further categorized with respect to their relevance to the topic. “Critical” articles contain the most amount of relevant information; “Supplemental Material,” while still relevant and important, are additional articles that give a broader overview of the subject.

The table below summarizes the categorization of each article.

	M (Materials and Properties)	I (Insulating Methods)	R (Regulatory Requirements)
Critical	1, 2, 3, 4, 15, 16, 21	1, 18, 22, 23, 24, 25, 26, 27, 29, 30, 31, 32, 34	3, 37, 38, 39, 41, 44, 45, 50
Supplementary Material	5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 19, 20	28, 33, 35, 36	40, 42, 43, 46, 47, 48, 49, 51

The text that follows is a brief synopsis of each article including key topics, equations and main take-away information.

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Literature Review

Materials and Properties

R-Value/Heat Transfer

1) Uponor AquaSAFE™ Attic Insulation Guide[1]: To protect their sprinkler piping, Uponor published an installation guide to give the two basic variations of the traditional tenting method. To determine the required R-value for colder regions, they recommend using the formula:

$$R_o = R_i\,(T_o\text{-}40)/(40\text{-}\,T_i\,)$$

Where:

R_o = the R-value between the unconditioned space and the pipe

R_i = the R-value between the pipe and conditioned space

T_o = the conditioned space temperature

T_i = the unconditioned space temperature

The higher the R-value, the better insulator it is. The equation above is based on the NFPA guidelines requiring the sprinkler piping to remain between 40°F and 120°F. Using this method of calculating R-value allows for an alternate tenting method of insulation, where insulation is allowed to be between the pipe and the conditioned space as long as the depth of insulation above the pipe is also increased accordingly. Using this alternate method, Uponor created a graph of R-value ratios that compares how much insulation is needed on either side of the pipe with the ambient temperatures of the spaces.

2) Residential Fire Sprinkler Insulation – How much is enough? [2]: To calculate the R-value of a material, the temperature difference and heat transfer per unit area must be taken into account. This article defines R-value as a measure of thermal resistance between two temperature conditions:

$$\text{R-value} = \Delta T/Q_A$$

Where:

ΔT = the difference in temperature between the two spaces

Q_A = the heat transfer per unit area

Insulation manufacturers often use this formula as a comparison between their products, and R-value is given in either unit values for a certain product or a certain value per unit depth of insulation.

3) Antifreeze Alternatives – Tenting of Insulation [3]: When calculating heat transfer through a wall or ceiling structure, there is an excellent example in this article which walks through each step required to calculate the temperature of the sprinkler pipe depending on the varying ambient temperatures, R-values, and distances. This article includes information on how to calculate the combined thermal properties (R-value) of a ceiling using the materials thicknesses, heights, conduction constants, and areas. According to this method, the amount of insulation required by the IECC and Building Code is more than the calculated amount of insulation required to keep the pipe at 40°F.

4) ASHRAE 2005 Handbook: Chapter 26 Freeze Prevention [4]: While the handbook is a wealth of knowledge on many topics, Section 26.2 regarding freeze protection for plumbing piping recognizes that insulation alone cannot prevent freezing without a heat source, since it only slows the rate of heat transfer but doesn't stop it. Assuming that water is not flowing, the time it takes for water to freeze in a pipe that is wrapped in a normal pipe insulation jacket, is given by the following equation:

$$\theta = \rho C_P \pi (\frac{D_1}{2})^2 R_T \ln \left[\frac{t_i - t_a}{t_f - t_a}\right]$$

Where:

θ =time to freezing (h)

ρ = density of water (62.4lb-F)

C_P=specific heat of water (1.0Btu/lb-F)

D_1=inside diameter (ft)

R_T=combined thermal resistance of pipe wall, insulation, exterior air film (for a unit length pipe)

t_i=initial water temp (F)

t_a=ambient air temp (F)

t_f=freezing temp (F)

An excellent diagram and quick reference chart in this article illustrate the time until water freezes for pipe size vs. insulation thickness.

5) Thermal Insulation Materials, Technical Characteristics, and Selection Criteria [5]: While this article refers to ice protection at fisheries, it goes into great detail on heat transmission, definitions, material technical descriptions and properties, and it includes a useful insulation comparison chart.

Fiberglass Insulation

6) Owens Corning Insulation Specifications [6]: While it does not hold any formulas or instructions on how to install insulation, this specifications sheet gives the technical data and characteristics for almost all the insulation products Owens Corning offers. For each product there is a picture, description, perm rating, widths/lengths/thicknesses for each R-value available, burn characteristics, and building construction classifications. This would be a handy quick reference to identify whether a product is available, and some of its characteristics.

7) DOE - Energy Savers: Fiberglass Insulation Material [7]: Fiberglass batt/roll insulation is one of the most common materials for homeowners, due to its ease of installation and widespread availability in home improvement stores nationwide. Manufacturers have created varying densities to allow for higher R-values in smaller cavities. Typically R-values are R-11 to R-15 for 2"x4" construction, up to R-21 for 2"x6" construction, and R-38 for 12" spaces, such as within the attic. Another form would be fiberglass loose-fill insulation which can be up to 30% recycled glass; this type can easily be added into open-blow applications such as attic spaces or closed-cavity walls. Also mentioned is a variation of fiberglass which is a combination of two types of glass fused together. This is naturally held together, less irritating to the eyes and skin, and possibly safer to work with. This variation also can come in a plastic sleeve for easier handling.

8) Recommendations for Installation in Residential and Other Light-Frame Construction [8]: This is a relatively comprehensive guide to installing fiberglass insulation within a residence. It includes sections on where and how much insulation to install, how it is labeled, types of fiberglass, and installation techniques for various scenarios (including pipes).

Natural Insulation

9) CIMA Technical Bulletin #1 – Cellulose Insulation Codes, Regulations and Specifications [9]: Besides its comparable insulating properties to fiberglass, the main benefits of using cellulose insulation are its ability to reduce air infiltration and the environmental aspects. Cellulose insulation is mostly made from "recovered newsprint, the largest single component of residential waste." It can be installed using a blowing machine using various

techniques such as jigs and forms for dry loose-fill cellulose, or spray-applied in wet form in open wall and ceiling cavities. The material is usually held together with a light adhesive, but cellulose will settle over time and it should be accounted for during installation. It can be treated with a flame retardant to reduce its flammability.

10) DOE - Energy Savers: Cellulose Insulation Material [10]: This loose fill insulation is mostly recycled wood fiber (usually newspaper) with a thermal resistance of R-3.6 to R-3.8 per inch. Chemicals are added to make the material insect- and fire-resistant. "The major disadvantage of cellulose is that it absorbs more water than fiberglass or mineral wool … and stores it … which can wash away the fire retardant."

11) DOE - Energy Savers: Natural Fiber Insulation Materials [11]: While they are not as common as synthetic materials, cotton, sheep's wool, and hemp can be used as insulation materials. These natural materials can be treated with a chemical called borate as a flame, insect, and rodent repellant. The benefits of cotton are that it is non-toxic, easy to install in batt form, R-3.4 per inch, and can use recycled cloth to reduce emissions. A disadvantage is that the cost is usually 15%-20% more than fiberglass insulation. Sheep's wool is also treated with borate, and, while it can offer slightly better thermal insulation of R-3.5 per inch, it can hold larger amounts of water which can wash away the borate's benefits. Hemp is no longer commonly used in the United States, but at a thermal value of R-3.5, it could be offered as another fibrous alternative.

12) DOE - Energy Savers: Mineral Wool Insulation Materials [12]: Typically, this category can be broken into rock wool, "man-made material consisting of natural minerals like basalt or diabase" and Slag wool, "man-made material from blast furnace slag (the scum that forms on the surface of molten metal)." Typically it is made up of 75% post-industrial recycled content, naturally fire resistant, and can come in blanket (batt or roll) and loose-fill form. While typical thermal values are from R-3.0 to R-3.1, this article mentions a Canadian batt insulation product with an R-value of R-3.7, which is comparable to spray foam.

13) The Burning Question: The Truth about Cellulose and Fire [13]: This article confronts the accusation that cellulose insulation is more fire-prone than other types of insulation. It cites various studies and research done on incidents regarding cellulose insulation fires and finds that it is just as prone to fire as other types of insulation.

14) Comparing Fiber Glass and Cellulose Insulation [14]: This very useful article compares the benefits of fiberglass and cellulose insulation side-by-side. It covers topics such as Thermal R-value, settling and consequent loss of R-value, water absorption, convection, fire safety, air leakage, and sound control.

Foam Insulation

15) DOE - Energy Savers: Polyurethane Insulation Materials [15]: Polyurethane is available in two forms, spray foam and rigid board.

    Spray foam consists of two basic categories, closed cell and open cell. Closed-cell spray foam is much denser (2.0 lb/ft^3) than open-cell foam, and uses a low-conductivity gas [usually hydrochlorofluorocarbons (HCFC) or non-CFC gas] to make the foam expand and fill any area. The main benefits of spray foam are that it has one of the highest thermal insulating values(R-7 to R-8 per inch) and its ability to expand and create an airtight seal in any area. While using a CFC gas creates a better insulator, a non-CFC gas is less destructive to the ozone. A phenomenon known as *thermal drift* occurs in the first two years after manufacturing; the initial gas used is replaced with air, lowering the insulating value usually two R-value levels (e.g. R-8.5 to R-6.5 per inch). Low density open-cell polyurethane is also available for high expansion uses, such as in open wall cavities. Carbon dioxide (CO_2) is usually used to create a density of 0.5 lb/ft^3 and an insulating value of R-3.6 per inch.

    Foam board is the same dense closed cell foam as spray foam, but in a pre-packaged form that can easily be cut into any size. Foil and plastic can also be added to the facings of the board to stabilize the R-value, preventing thermal drift and at times acting as a radiant barrier, adding to the R-value. Boards can easily have a stabilized R-value of R-7.1 to R-8.7 per inch.

16) NCFI Polyurethanes – Spraying SPF to CPVC Pipes [16]: The compatibility of spray foam insulation and CPVC was tested in multiple studies which showed that If the spray foam is applied according to manufacturer's instructions, both open and closed cell spray foam do not cause any negative effects with regards to chemical compatibility or exothermic heating during or after the foaming process. The pipes can be damaged by mechanical stress, though, and extra effort should be used to ensure the pipes are not put under any mechanical stresses. Both open and closed cell foam were evaluated on Blazemaster and Flow Guard Gold ® piping in both wet/dry, high/low pressure, and varying diameter situations, according to this article. Closed-cell foams should be applied in a maximum pass thickness of 2 inches, waiting 10 minutes between passes, and open-cell foams should not exceed 12 inches in a single pass.

17) Paschal Engineering & Forensic Consulting Tests [17]: A published letter summarizing the testing conducted by Paschal Engineering states that the tests conducted were specifically aimed at environmental stress cracking (ESC) and to determine whether spray polyurethane foam (SPF) caused any damage to the CPVC piping. Even testing the "worst-case" scenario, with potential ESC agents (phosphate ester flame retardants) at their maximum concentrations, using medium closed-cell, low-density open cell, and closed-cell one-component foams, the end result was the same. The study states that "the results of the

study show that all of the SPF products tested, including open-cell SPF, closed-cell SPF, one-component foams, and foams made from natural-oil based materials do not cause ESC and are compatible in direct contact with CPVC piping systems."

18) Update on Compatibility Testing of Spray Polyurethane Foam with CPVC [18]: This is the full report that is summarized in Paschal Engineering's letter, above. The study was conducted by the "Center for the Polyurethane Industry (CPI) and the Spray Polyurethane Foam Alliance (SPFA), along with Lubrizol Advanced Materials, Inc., a leading CPVC resin manufacturer" to find the chemical, physical, and thermal compatibility of SPF and CPVC piping. The report goes into details regarding CVPC, spray foam, their testing methods, and the issue that led them to conduct the research.

19) NCFI Polyurethane's Spray Foam System 11-016 Technical Data Sheet [19]: This technical data sheet on NCFI's closed-cell spray foam gives in-depth details on where the foam is applicable, typical physical properties, applicable codes and standards, and safe handling and storing instructions. At a density of 2.0 lb./ft^3 , this spray foam gives an R-value of R-6.8 per inch, flame spread of <25, and a smoke development of <450, which meets ASTM E-84 and NFPA 285 requirements. If stored properly, the chemicals used to make this closed-cell foam have a shelf life of up to six months.

20) NCFI Polyurethane's Spray Foam System 12-002 Technical Data Sheet [20]: This technical data sheet on NCFI's open-cell spray foam gives in-depth details on where the foam is applicable, typical physical properties, applicable codes and standards, and safe handling and storing instructions. Open=cell foam is much less dense than closed-cell foam, with a density of only 0.5 lb./ft^3 ; this allows the same volume of liquid spray foam to expand to fill a much larger area and insulate into cracks. As a result of its being less dense, the open-cell foam has an R-value of R-4.1 per inch for thermal insulation. With a flame spread rate of <25, and a smoke Development of <450, this open-cell foam also meets ASTM E-84 and NFPA 285 requirements. If stored properly, the chemicals used to make this open-cell foam have a shelf life of up to three months.

21) Insulating Unvented Attics with Spray Foam [21]: As an "extremely effective insulator and air barrier all in one," states this article, spray foam conforms to fill any shape. "Chemically, all brands are nearly identical," in that they all have a resin and a non-toxic blowing agent. Open-cell foam typically has a density of 0.5 lb./ft^3, with an R-value or R-3.5 per inch. "This type of foam is relatively permeable; at 5 inches thick, it is rated at about 10 perms," which classifies it as an air barrier but not a vapor barrier. It easily expands to over 100 times its initial size and is then trimmed to fit precisely flush with the joists to allow for flush drywall. Closed-cell foam is must denser at 2 lb/ft^3 but with a much higher R-value of R-6.6 per inch. It also expands less, at only 30-50 times the initial volume. While most of the time the foam does not expand enough to inhibit the drywall, it is much denser than the drywall and therefore more difficult to cut. Some advantages of closed-cell foam are that it offers more

R-value per volume, the ability to create an air and vapor barrier if over 2 inches of insulation are used, and the ability to leave an air gap since air movement does not degrade the insulation.

Insulating Methods

Box-In Method

22) City of Vancouver Frost Protection for Sprinkler Piping [22]: This bulletin from the Building official and plumbing inspection branch manager states that using NFPA 13, the City of Vancouver has created a minimum requirement to protect their sprinkler piping from freezing in their harsh winters. Regarding exterior walls, the only requirement is that the piping is on the conditioned side of the insulation within the wall behind the gypsum. In the attic, the recommended method of protection is to box in the sprinkler piping with either ½-inch gypsum wall board or ½-inch plywood sheathing, and to provide a minimum of 6 inches of uncompressed insulation (or R-20 equivalent) uniformly distributed over the boxing and any exposed sides. Where space limits this method, the piping must be boxed in and run below the ceiling joists or exposed under the finished ceiling. An alternative method used in neighboring areas such as British Columbia, is the use of insulation foam board instead of the plywood to make a box around piping. According to Vancouver's diagram, if foam board is used, the sides must be at least R-20, and the tops must be R-28. This bulletin includes attached diagrams of both of the methods discussed (in Annex C).

23) Park Ridge Residential Sprinkler Piping in Cold Space [23]: This guide for general practices of insulating sprinkler piping in cold weather suggests laying the piping in a single stud/joist space when possible, using a criss-cross pattern of two batts of insulation over piping running perpendicular to the joists, and boxing the sprinkler piping in with plywood before adding the insulation. Once the box is created, insulation is placed on the unconditioned side of the pipe along the inside of the box and on the outside to the correct depth. A general rule of thumb provided by this guide is that of doubling; since R-19 is so commonly used, R-38 is recommended in cold spaces where the space is available. It suggests installing louvered vents between the box and the conditioned space to help move warm air into the box and to warm through convection. Sealing the box's edges will prevent the warm air from simply rising to the attic.

Tenting Method

24) Antifreeze Alternatives – Tenting of Insulation [24]: Tenting is a common method used as an alternative to antifreeze when insulating sprinkler piping sections that are run within any unconditioned space, such as an attic or an exterior wall. There must be sufficient insulation between the unconditioned space and the sprinkler piping to keep the water temperature

within the piping at or above 40°F. In order for it to be effective, the insulation must be continuous over the pipe, with the assumption that any heat lost through the insulation will be replaced by the conditioned space. In working with Owens Corning, the authors of this article stated that as long as the following conditions were met, there would be no issue with insulation protecting the sprinkler piping from freezing:

1) Keep the insulation over the pipe and not under it.

2) Do not allow gaps in the insulation.

3) Keep the insulation in place.

4) Keep a substantial amount of pipe in contact with the ceiling (heated from below).

25) Residential Fire Sprinkler Insulation – How much is enough? [25]: Figure 4 in this article illustrates a cross-sectional view of tenting, where fiberglass batting is stapled over rafters, enclosing the sprinkler pipe from the unconditioned space, then using loose-fill insulation over the batts to give the required depth of insulation. This article emphasizes that this method is used in traditional unconditioned and vented attics, and therefore any insulation used must provide reasonable precautions to prevent "cold air infiltration (convective loss)," which would significantly reduce the temperature of the piping. "Of course it cannot be stressed enough that any concept presented here assumes the fire sprinkler piping is located above a heated conditioned space." Presuming the insulation is the correct thickness per regulation, is properly secured, and is heated by a conditioned space below, adequate protection should be achieved for the sprinkler piping.

26) CertainTeed Corporation Technical Bulletin #42 (R) [26]: Since automatic sprinklers are required in many new houses and the trend seems to be spreading, the focus in colder climates has become how to protect these sprinkler systems from freezing. "The ideal answer would be to keep all sprinkler piping on the inside (heated side) of all the insulation. This would make it no more susceptible to freezing that the rest of the plumbing." "Simply surrounding sprinkler pipe will not prevent it from freezing… because insulation slows heat loss but can't stop it completely." As a variation to traditional tenting, which would have no insulation between the pipe and the conditioned space, CertainTeed uses what can be called the "percentage method" of insulation, where a specified percentage of the insulation can be between the sprinkler piping and the conditioned space.

This technical bulletin includes a table (here shown as Table 26.1), a quick reference for the percentages required outside the pipe compared with the total amount given the lowest recorded temperature within the area. An example in this bulletin is sprinkler piping run over 2"x8" constructions in an area where the temperature has never dropped below 0°F. Since the 2"x8"s are actually only 7 ¼" tall, the top of the pipe would be ~8" above the gypsum. If R-30 insulation (11 ¾" thickness) was used, there would be 11 ¾"–8" or 3 ¾" of

insulation above the pipe, which is only 32% of the total insulation (which can protect down to only 20°F according to the chart for this method). If we need to protect for 0°F, 50% of the insulation must be above the piping, therefore 8” + 8” or 16” must be used, which is just over most R-42 insulation, so R-44 should be used.

Lowest Expected Attic Temperature, °F	Percentage of Insulation That Must Be Outside of Piping to Prevent Freezing
+20°F	30%
+15°F	36%
+10°F	42%
+5°F	46%
+0°F	50%
-5°F	53%
-10°F	56%
-15°F	59%
-20°F	61%
-25°F	63%
-30°F	65%
-35°F	67%
-40°F	68%

Table 26.1: Percentage of insulation required between pipe and unconditioned space

27) CAU Frozen Sprinkler Pipes [27]: From the perspective of an Insurance underwriter, burst sprinkler piping is a preventable loss that, if not addressed ahead of time, can typically cost over $30,000 each event, and hundreds of millions of dollars in damage each winter. Some of the recommendations in this report include:

1) “Maintain heat in all buildings and units.

2) Require annual service and maintenance contracts for the sprinkler system.

3) Provide additional insulation for unheated areas such as attics.

4) Install water flow alarms to alert occupants the water is flowing.

5) Install freeze alarms to warn of potential freezing conditions before the pipes freeze.”

When water freezes, it can expand up to 10% in volume and increase the pressure to a point where the pipe/fitting/sprinkler can burst open, releasing up to 30 gallons per minute (assuming 1”pipe at 70psi). To protect against this, contractors can use dry-pipe systems, special dry heads, or “place insulation over the pipe in the shape of a tent to trap heat around the sprinkler pipe.” Systems are usually installed during the warmer months, when

frozen pipes are often not considered as often as they should be; extra precautions must be taken from the installation and onward.

28) Design Considerations for CPVC Pipe Sprinkler Systems [28]: This article states, "CPVC is ideal for residential and light hazard commercial applications because of the reduced friction loss, flexibility, ease of pipe preparation, ability for field cutting, and typically small pipe diameters." The insulation protects not only from cold weather, says this article, but also from heat, which is important because CPVC can soften and lose strength at high temperatures. With CPVC, the typical freeze prevention option of a dry-pipe system is not allowed, because the pipe must always have pressurized water—never air—in the system to keep it from bursting. Insulation and designing the sprinkler system to be insulated are a priority when installing, to ensure cost-efficient and effective protection from the cold. An example given in this article is a sprinkler pipe 3 feet off the attic floor, an installation that may be practical for installation, but would be nearly impossible to insulate. Another example in this article shows CPVC piping under insulation in an attic, which was stepped on and broke, causing extensive damage. The contractor chose to simply put the insulation under the piping so they could see the piping more easily, which only led to freezing trouble later on. Instead, the contractor should have protected the piping with a catwalk, board, or other sturdy structure.

29) Prince George's County Residential Sprinkler Seminar [29]: After mandating residential sprinklers in 1992, Prince George's County held a seminar in 1995, where key groups in the area gathered to work on a residential sprinkler handbook and laid down a foundation for what inspectors, installers, and code officials there reference to this day. One of the important issues they discussed was "Protection Against Freezing." Along with informative diagrams illustrating the methods they would accept, the group accepted code requirements (Washington Suburban Sanitary Commission Regulations), and requirements for R-24 insulation minimum above the pipe, continuous layer of insulation, placement of the pipe, and inspection. The seminar further outlined the following regulations:

> The continuous insulation layer must fit snugly to the framing members, stapled securely in place to the bottom of the members, extend at least 12 inches past the piping at the end of branch lines, and extend to the next framing member at horizontal turns.
>
> "All sprinkler piping in the attic should be (securely) installed at or near the center of the space between the framing members."
>
> "Sprinkler piping attached to the sides of framing members in the attic shall require additional insulation material to protect the piping from freezing on the opposite side of the framing member."

"Piping should be flush with the top of the ceiling joists or roof trusses wherever possible."

All sprinklers must also be inspected prior to closing in the ceiling with gypsum.

30) The Washington Suburban Sanitary Commission [30]: The attendees of Prince George's County Residential Sprinkler Seminar agreed to protect sprinkler piping according to the plumbing code of nearby Washington DC. In Section 302.5, Freeze Protection of Water Piping, the regulations state that piping shall not be installed outside of the conditioned space. The code goes on to state that piping is allowed "in outside walls, ceilings, and split foyer landings provided the piping is as close as possible to conditioned interior space and a minimum of R-24 insulation is installed between the pipe and the outside environment. The piping itself shall not be insulated." It later states, regarding crawl spaces, that no insulation should be placed between the pipe and the conditioned space.

31) Prescott, AZ Fire Dept. Freeze Protection for CPVC Fire Sprinkler Piping [31]: Local sprinkler regulation for Prescott mandates "foil backed or approved paper-backed [insulation], with an R-value of R-11 (3.5 in.) or higher shall be stapled … every 6 inches along the bottom edge." On each side of the pipe, there must be a minimum of 2 ft of insulation, and it must extend at least 1 ft past the end of the pipe. The piping must be on the heated side of the insulation, and there should not be any gap in insulation. "Batt insulation shall be installed as noted above prior to blowing in insulation." The code requires that the system and insulation be inspected prior to covering the area with gypsum. Three photos are attached to the document (in Annex B) as examples of proper tenting method techniques.

32) Cross Member & Sprinkler Head Insulation Tenting Shell [32]: These PowerPoint slides and related test results of this patent pending product show another variation of tenting over sprinkler piping, but in this case the material is dense polystyrene foam with a channel for the pipe cut from the bottom. The tenting modules are sized to press fit between the 2"x 4" or 2"x 6" construction frames and can be sealed with spray adhesive. There is a "step" interlock overlap between modules, greatly reducing any space between the modules. The simplicity of this method allows for easy production and the possibility of pre-fabricated sections that can be bought and installed quickly with the same results as traditional batts. One benefit of this system is that it greatly reduces the air gap created, therefore possibly meeting ENERGY STAR qualifications. (These are shown in Annex B.)

33) Contractor Insulation Details [33]: This document contains 8 pictures of proper tenting methods of running CVPC piping over the joists within an unfinished residence. (These are shown in Annex B.)

34) Protecting Against Freezing Year-round [34]: This article touches upon many key points regarding sprinkler pipes and freezing, such as the high pressures created by ice expanding

within the piping. More than 90% of all sprinkler systems are wet-pipe systems, and insulation should never be between the pipe and the conditioned area. NFPA codes are mentioned; included are diagrams from NFPA 13D and 13R's annexes, as well as the NFPA 25 requirement for annual inspection of the sprinkler system for cold weather protection. Due to economic times where heating a home can be expensive, owners should be aware of these guidelines and ensure that their residence remains consistently conditioned to proper temperatures to keep the pipes from freezing.

35) Standard Practice for Installing Cellulose Building Insulation. [35]: A common practice is that, after tenting over a sprinkler pipe with batt insulation, blow-in insulation is used throughout to bring the insulation thickness to the required depth overall. This article addresses how to properly install blow in cellulose insulation in attics, new and existing walls, and ceilings. It lists some of the applicable documents, preparation, and application procedures necessary to properly insulate any location in a residence.

Roof Underside Spray Foam Method

36) Insulating Unvented Attics with Spray Foam [36]: While spray foam insulation may be a slightly more expensive option, the benefits outweigh the greater cost. As outlined in the 2006 International Residential Code, spray polyurethane foam (SPF) reduces energy loss, protects against rot and mold by preventing moisture from passing through, prevents ice dams, and turns an unconditioned attic into a conditioned usable space. This method is ideal for unvented, shallow spaced, flat, or cathedral ceilings, and for roofs where high R-value and low permeability are essential. Either open-cell or closed-cell foam can be used, depending on the density, R-value, space available, and permeability required. One of the advantages to using closed-cell foam in this case is the ability to pack more R-value in less space; if the foam is over 2 ½", it is not only an air barrier but also a vapor retarder. Regarding fire resistance, if the insulation is covered over with gypsum board, that is already a code-approved thermal barrier. In an attic, where it is accessible for utility service, the foam must be covered with an ignition barrier. Another consideration discussed in this report is that the applicator must be able to get to within 16-20 inches of the wall/ceiling and be pretty much straight on, so access to the locations is important. "An average sized closed-cell foam insulation project is between $1.10 and $1.40 per board foot of material. For R-30, that comes out to about $5 per square foot of roof area. The exact codes regarding this method are still new and changing, so pre-planning with the local AHJ is the safest option to know exactly what needs to be done."

Regulatory Requirements

National Requirements

37) NFPA 13D – Section 8.3 [37]: The 2011 NFPA codes do not go into detail regarding how to insulate a sprinkler pipe, but they do give some of the requirements to help determine whether a method is acceptable. NFPA 13D, Section 8.3.1 regarding wet pipe systems states "A wet pipe system shall be permitted to be used where all piping is installed in areas maintained above 40°F (4°C), including areas properly insulated to maintain 40°F (4°C)." The next section, 8.3.2, indicates that when the piping is located in areas that can reach below to 40°F limit, the piping must be replaced with a dry pipe system, use antifreeze (although a TIA released since has banned its use in residential occupancies), or use dry-pendant or dry-sidewall sprinklers extending from pipe in a conditioned room nearby. While 8.3.2 gives some alternatives, the related Annex A material for 8.3.1 specifically mentions that "In areas subject to freezing, care should be taken in unheated attic spaces to cover sprinkler piping completely with insulation." Insulation manufacturers have their own guidelines that should be followed, but the A.8.3.2 includes five pictures of tented insulation, examples for proper insulation techniques contractors can use. Diagrams given by the NFPA as insulation tenting examples are in the Annex and as such are not mandatory but informational only. These are shown in Annex A.

38) NFPA 13R – Section A.5.4.2 [38]: The 2011 NFPA codes do not go into detail regarding how to insulate a sprinkler pipe, but they do give some of the requirements to help determine whether a method is acceptable. For instance, the related Annex A material for 5.4.2 states, "Piping covered by insulation, as shown in Figure A.5.4.2(a) through Figure A.5.4.2(e), is considered part of the area below the ceiling and not part of the unheated attic area" (where the figures are the same from NFPA 13D, Section A.8.3.1). Therefore, as long as the sprinkler piping is insulated well enough to ensure the sprinkler pipe remains above 40°F, the gap beneath the insulation around the pipe can be considered part of the conditioned area. There is a caution on each picture stressing the importance of installing the insulation tight against the joists and not allowing any voids where convective air could enter to cool the pipe.

39) NFPA 13 – Section 8.16.4 [39]: While it does not give details on how to install or what to use for insulation, this section deals directly with the "protection of piping against freezing." It states that where sprinkler piping cannot be kept above 40°F, a system must be put in place to keep the pipe from freezing, included but not limited to a dry pipe system, listed heat trace system, and/or insulation.

40) NFPA Journal – Keeping Warm [40]: One of NFPA's articles on sprinkler pipe freeze protection references NFPA 25's minimum temperature requirements and insulation inspection. The 2011 edition of NFPA 25, *Inspection, Testing, and Maintenance of Water-Based Fire*

Protection Systems, changed the inspection requirements in Section 4.1.1.1 from an annual inspection to a continuous inspection by the homeowner, who is now responsible to verify protection throughout the entire winter. Often projects such as "installation of outside lighting, running electrical cables, reworking piping systems, and general building repairs" can dislodge insulation during warmer weather, and proper replacement is forgotten about, since freezing temperatures are far from the homeowner's thoughts. This subtle change in the code will hopefully remind owners to verify year round that the piping is protected.

41) International Energy Conservation Code – Chapter 4 Residential Energy Efficiency [41]: The IECC discusses here two main concepts regarding sprinkler piping insulation: climate zones and residential energy efficiency. Building design is based largely on the location of the building and the weather expected for that location. The IECC climate zone map breaks the U.S. into 7 climate zones, with specific requirements per zone. A valuable table for this is the 2009 IECC's Table 402.1.1, which includes insulation and fenestration requirements by component.

    This code is also where inspection requirements and both prescriptive and performance based insulation requirements for residential occupancies can be found. Specifically, a few substitution rules are found in Sections 402.2.1 and 402.2.2, where a lower R-value can be substituted for the required amount if specific conditions are met, such as if the insulation extends over the wall top plate at the eaves in an attic, or if space requirements do not allow the full thickness of insulation for 20% or less of an unvented roof. Section 402.4.2 indicates that building envelope air tightness and insulation installation must pass either a blower door air leakage test or field verification from a local AHJ before it can be considered acceptable.

42) ENERGY STAR Qualified Homes Thermal Bypass Inspection Checklist Ver. 2 [42]: This checklist must be completed before homes can earn the ENERGY STAR label. Accredited home energy rating systems (HERS) providers and certified raters use this checklist as a guide to identify areas that could disqualify a home from being ENERGY STAR rated. Some AHJs have begun to use this checklist as a reason for not accepting insulation tenting methods, because the air gap left below the sprinkler pipe violates the first section of the checklist, Overall Air Barrier and Thermal Barrier Alignment; that requirement states "Insulation shall be installed in full contact with sealed interior and exterior air barrier" where the air barrier in this case is usually the gypsum wall board.

43) ENERGY STAR Qualified Homes Thermal Bypass Inspection Checklist Ver. 3 [43]: This checklist is the next version and will take effect by January 1, 2012. Most AHJs have already transitioned to this version, so most new homes must be at this level to earn the ENERGY STAR label. While the checklist does not directly address insulation, Section 3 would still be violated if the air barriers (the insulation backing and the drywall) are not fully aligned (touching) in the ceilings and/or exterior walls.

44) Home Energy Rating Systems (HERS) Field Verification and Diagnostic Testing Regulations [44]: This is the 2005 Building Energy Efficiency Standard for low-rise residential buildings in California. It is an example of what the state looks for in insulation, and includes much more detail and definitions. Air barrier, for instance, is addressed here; "attic insulation must be in substantial contact with the assembly air barrier (usually the ceiling drywall) on one side for it to perform at its rated R-Value." Under RH-3 this standard states that "if the insulation is faced, it must be placed toward the living space and be in contact with the underside of the floor sheathing." For special situations such as colder climates, the document states that "there must be at least two-thirds of the insulation between the water pipe and the outside" unless the pipe is near the outside, in which case as much insulation as possible should be placed between the pipe and outside—nothing can be placed between the pipe and the inside. Whichever insulating material is used, RH-6 states that the material must comply with the "flame spread rating and smoke density requirements of Sections 2602 and 707 of the Title 24, Part 2 (aThat is, flame spread <25 and smoke development <450).

45) Antifreeze Solutions in Home Fire Sprinkler Systems [45] : This is the final report of an in-depth study regarding antifreeze solutions. It finds that "under certain conditions, solutions of glycerin and propylene glycol antifreeze have been found to ignite when discharged from automatic sprinkler systems." The topic of this article is a key piece to understanding why sprinkler insulation is currently becoming a popular solution to pipe freezing issues.

Local Requirements

46) County of Prince William Building Official Interpretations [46, 47, 48]: This report is an example of a local jurisdiction not allowing tenting as a viable option; on three separate occasions over a 10 year period, this county's building official was asked for an interpretation of 13R and 13D to allow tenting insulation, and he denied it all three times. The question asked was "If the wet pipe sprinkler system is installed in the attic space directly above a heated room, and the insulation is "tented" over the sprinkler system, does it meet the intent of the code?" The building official's answer was, "No, NFPA 13R, 6.1.4.1.2 states … pipe shall be protected against freezing by insulating coverings, frost proof casings, or other reliable means capable of maintaining a minimum temperature between 40°F and 120°F." "Laying or 'tenting' the insulation over or around the sprinkler system piping or component is not reliable." He does go on to say that if a method is developed that can be easily maintained, a code modification request would be considered.

49) ICAA Technical Bulletin - Disclaimers [49] : This general disclaimer put out by this insulation contractors' association recommends against putting any sprinkler piping in any walls, ceilings, or floors adjacent to unconditioned spaces. It further states that the "contractor cannot warrant or guarantee that the sprinkler system … will not freeze, burst or cause loss

of life damages to property, or loss of the use of property, or any other damages from any cause." The association uses the same disclaimer for normal plumbing as well.

50) CIMA Cellulose Insulation – Codes, Regulations, and Specifications [50]: While it is focused specifically on cellulose, this report is a good representation of the testing and regulations that are required for insulation methods and materials. Some of the material tests that are conducted are "16 CFR Part 1209 (the CPSC Safety Standard), 16 CFR Part 460 (the FTC R-value Rule), ASTM C-739 [Standard Specification for Cellulosic Fiber (Wood-Base) Loose-Fill Thermal Insulation], HH-I-515E (the General Services Administration Purchasing Specification). The main standard among these is the CPSC Safety Standard, which addresses attributes such as critical radiant flux, smoldering combustion, corrosiveness, and settled density. To address any gaps such as compressive packaging, ASTM C-739 adds a pre-blow step to more closely simulate a real installation. During installation, standards such as ASTM C-1015, Standard Practice for Installation of Cellulosic and Mineral Fiber Loose-Fill Thermal Insulation, determine the required methods and details.

51) Potential Pitfalls of Unsprinklered (and Sprinklered) Attics [51]: Depending on whether you are using NFPA 13, 13D, or 13R, you may or may not be required to sprinkler the attic. "NFPA 13D and 13R both allow omissions of sprinklers from attics not used or intended for living purposes (or storage, in the case of 13R) and that do not contain fuel-fired equipment." Whereas NFPA 13 considers both life safety and property protection, it therefore requires sprinklers in all combustible attic spaces unless they have no access or limited access. This article's list of potential problems includes improper insulation is listed where wet pipe systems extend into an unheated attic to serve sprinklers to the heated floor area below. A common mistake mentioned is the use of pipe wrap insulation which insulates pipe from the warm as much as the cold; when there is no flow through the pipes, this can lead to freezing and pipe rupture. If blow-in insulation is used, tenting batt insulation over the pipe first can prevent insulation from falling below the pipe.

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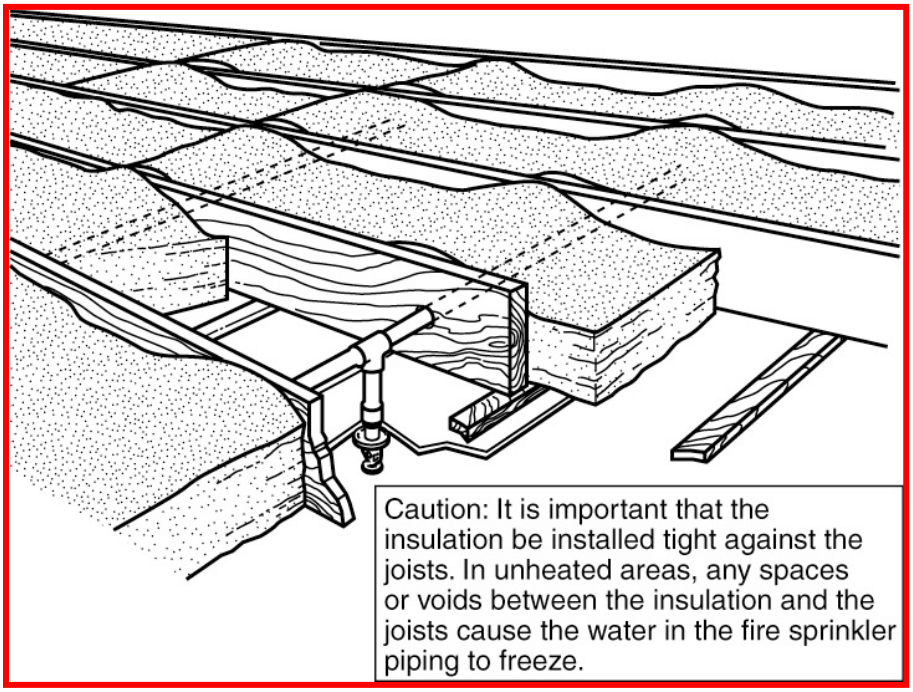
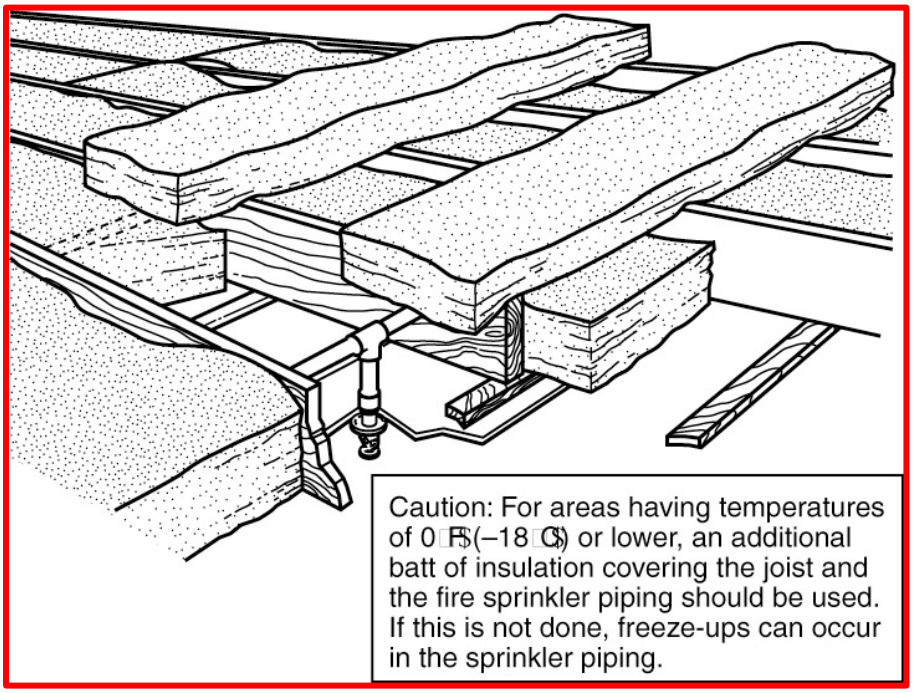
Annex A: NFPA Insulation Layout Recommendations

Reprinted by permission from the National Fire Protection Association, 2011:



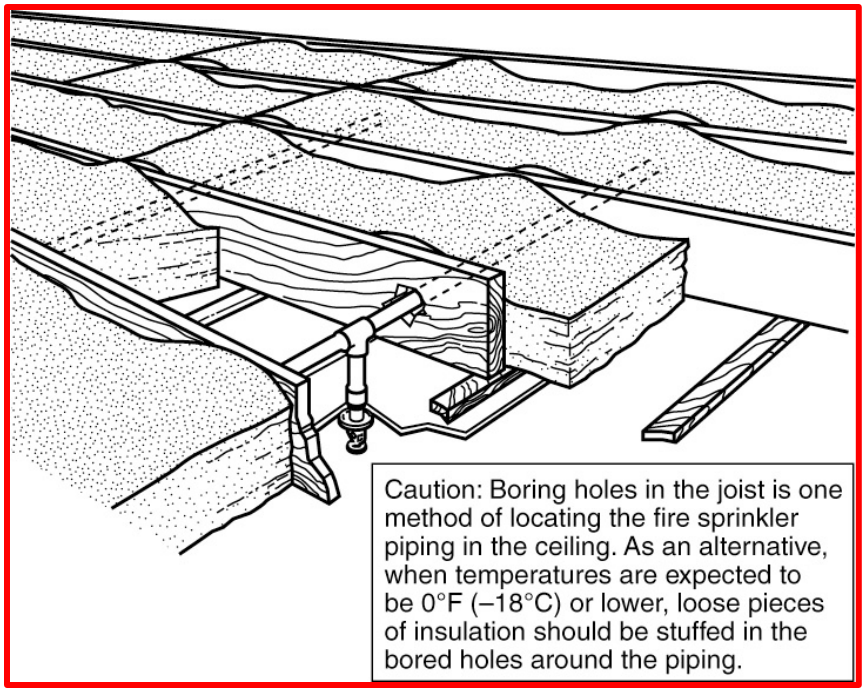
NFPA 13R Figure A.5.4.2(a)

Insulation Recommendations — Arrangement 1.



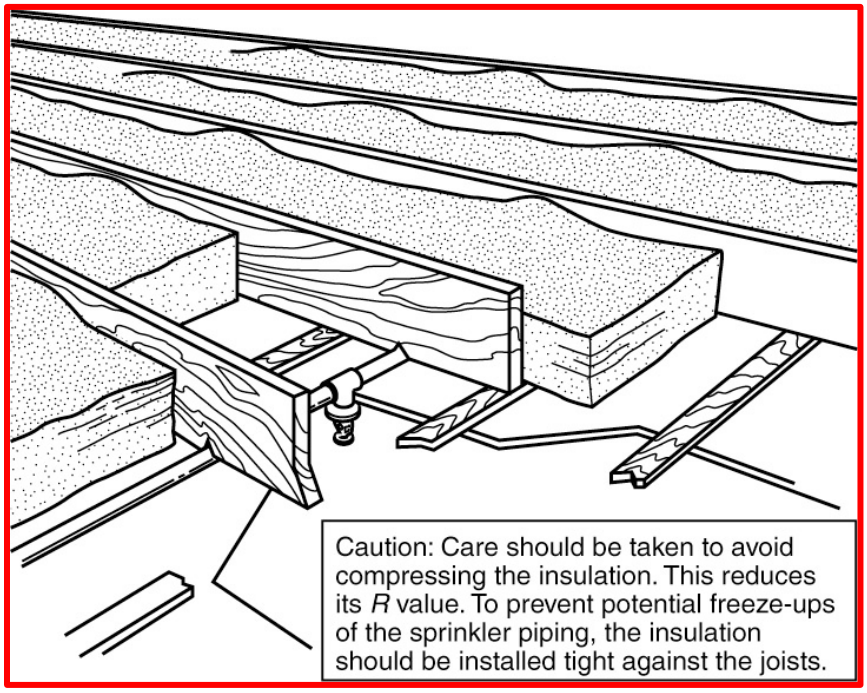
NFPA 13R Figure A.5.4.2(b)

Insulation Recommendations — Arrangement 2.



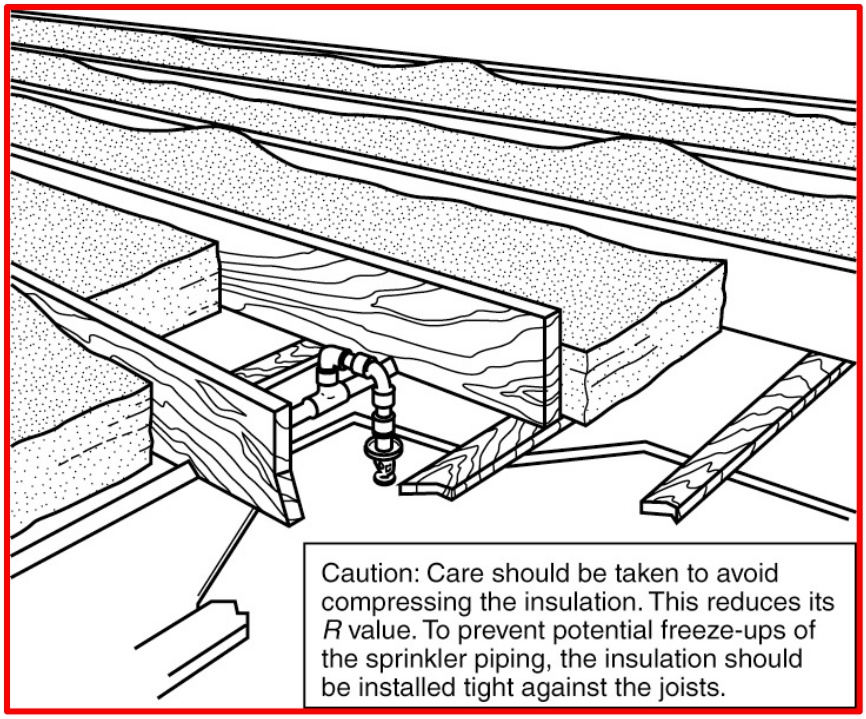
NFPA 13R Figure A.5.4.2(c)

Insulation Recommendations — Arrangement 3.



NFPA 13R Figure A.5.4.2(d)

Insulation Recommendations — Arrangement 4.



NFPA 13R Figure A.5.4.2(e)

Insulation Recommendations — Arrangement 5.

Annex B: Example Photos of Tenting Insulation

Reprinted by permission from the Prescott, AZ Fire Department:

Figure 1. CPVC piping mounted on the side of the joist within the air gap.

Figure 2. Insulation tented over CPVC piping perpendicular to the 2”x4” ceiling joists.

Figure 3. CPVC transition between ceiling and exterior wall.

Reprinted by permission from Metropolitan Fire Protection:

Figure 4. Insulation air gap channel for CPVC piping parallel to the 2”x4” ceiling joists.

Figure 5. Insulation tented over CPVC perpendicular to 2”x4” ceiling joists.

Figure 6. Insulation coverage for over and between 2”x4” ceiling joists.

Reprinted by permission from John Certuse P.E.:

(Patent Pending US Patent Office 61/452,926)

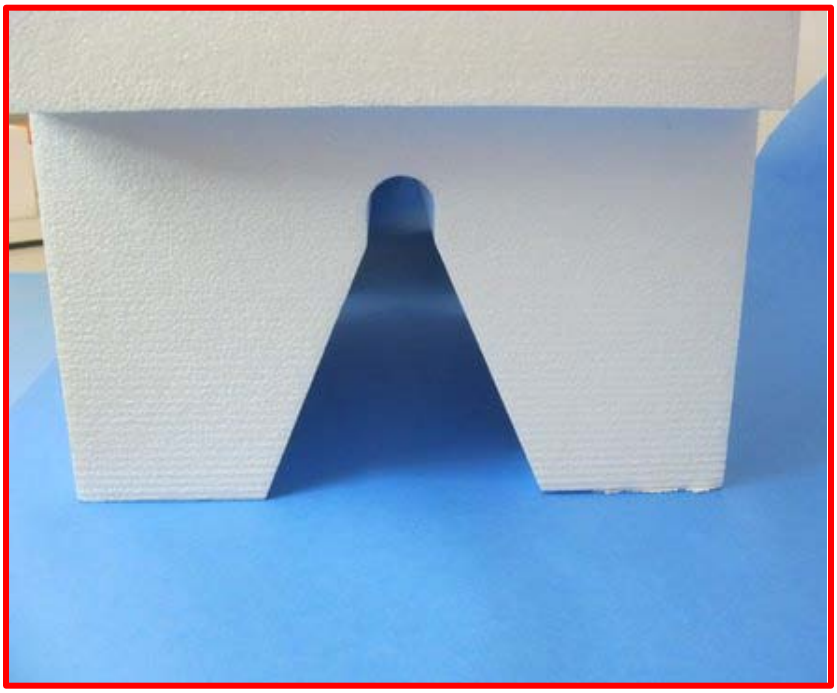


Figure 7. Polystyrene pre-formed pipe insulation with V-channel opening to conditioned surface.

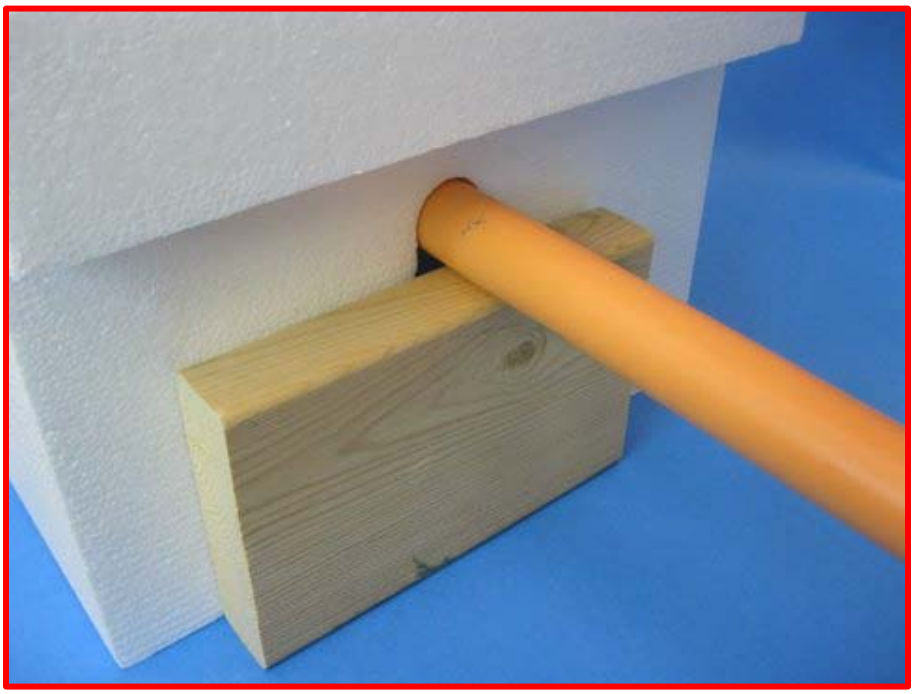


Figure 8. Designed to fit with various joist dimensions.

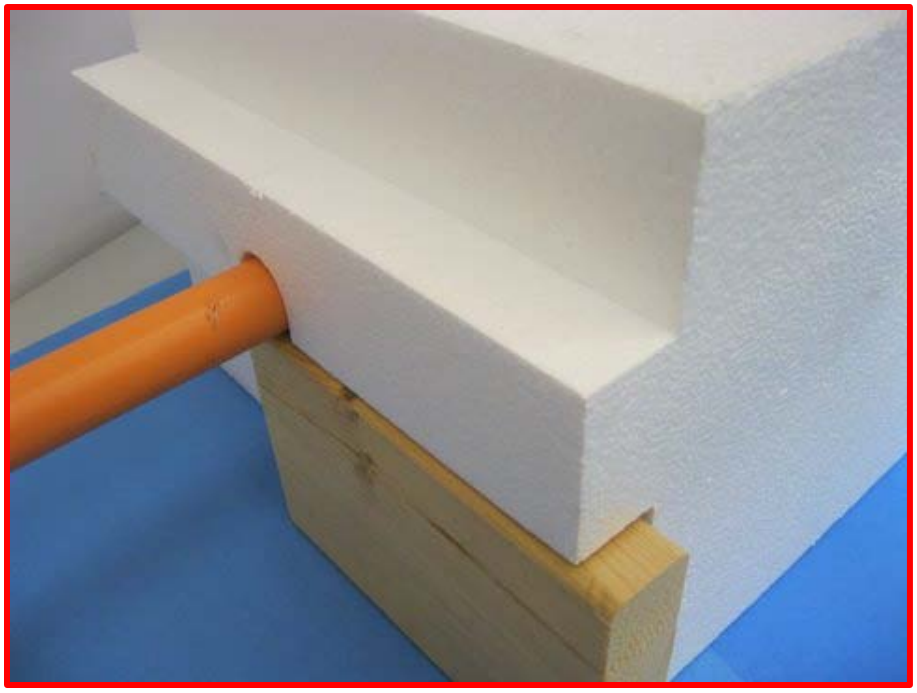
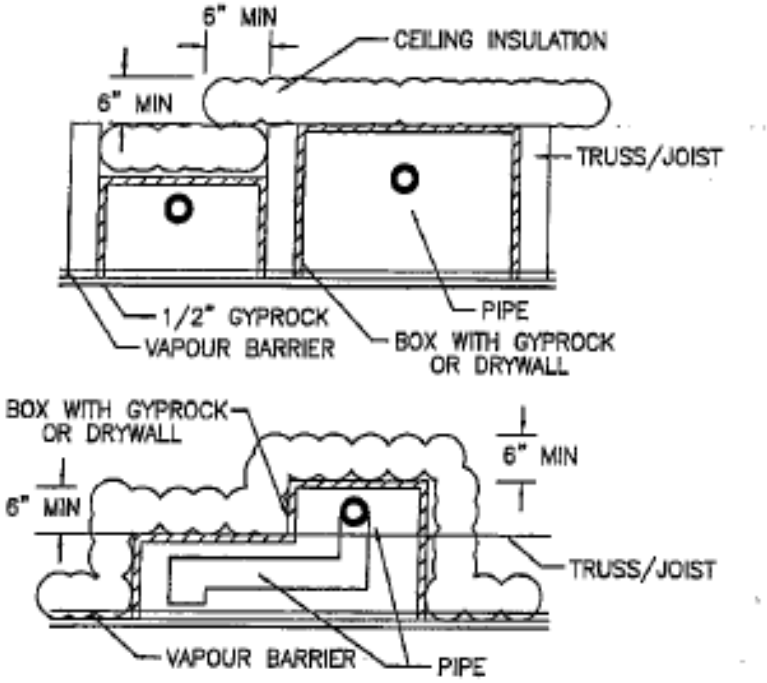


Figure 9. Pre-formed or jobsite-applied continuous insulation over joists.

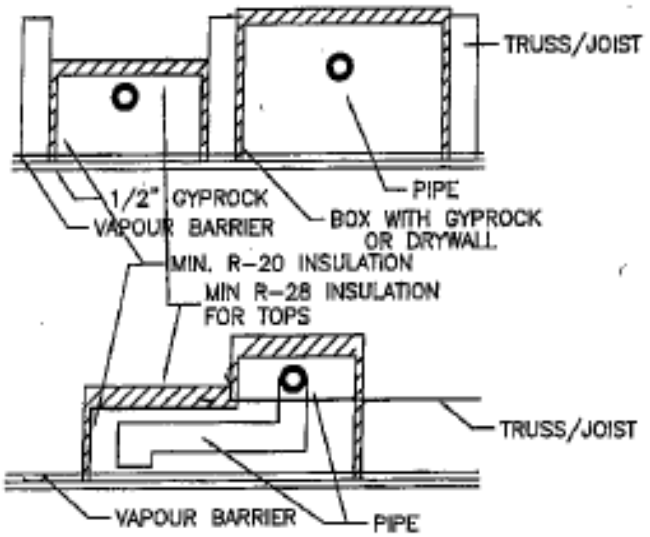
Figure 10. Interlocking joints ensure minimal gap between units.

Annex C: Box-In Method Examples

Reprinted by permission from the City of Vancouver's Plumbing and Gas Inspection Branch:



VANCOUVER INSULATION DETAIL N.T.S.



INSULATION DETAIL N.T.S.

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Figure 1. Foam board used to box in the pipe

Figure 2. Batt Insulation used in addition to the foam board to reach the required R-value.

Figure 3. CPVC run in foam board box.

Figure 4. Notch removed for installation, but resealed to ensure proper air and thermal barrier.

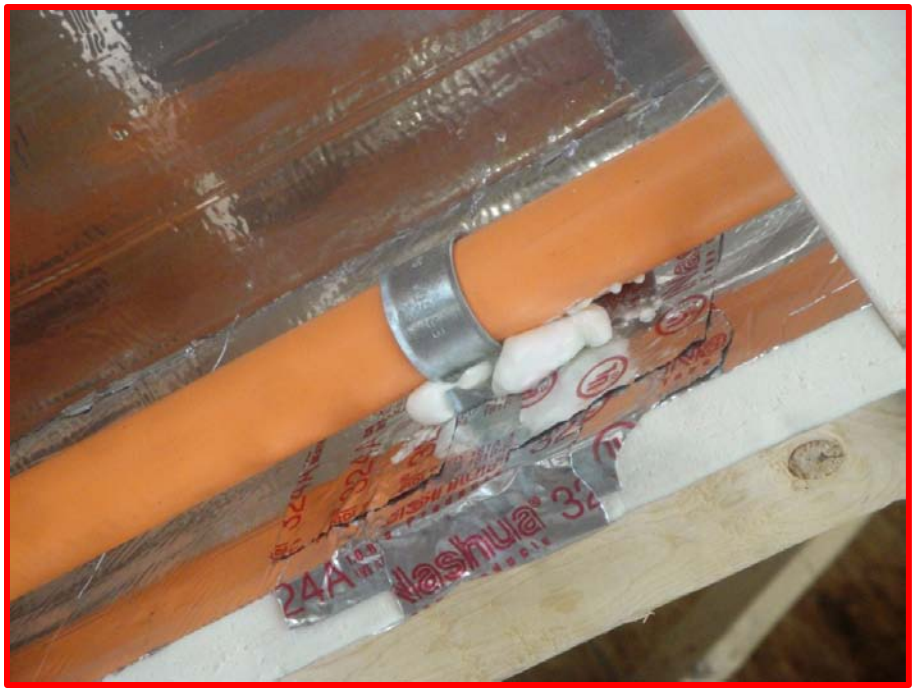

Figure 5. Notch removed for installation has been resealed to ensure proper air and thermal barrier.

Figure 6. Hole cut for pipe through end wall.

Annex D: Spray Foam Method Examples

Reprinted by permission from NCFI Polyurethanes, "InsulStar Architectural and Installation Specifications." Dec., 2009. http://www.insulstar.com/uploads/InsulStar%20Architectural%20Specifications%20200912071.pdf (accessed June 20, 2011).

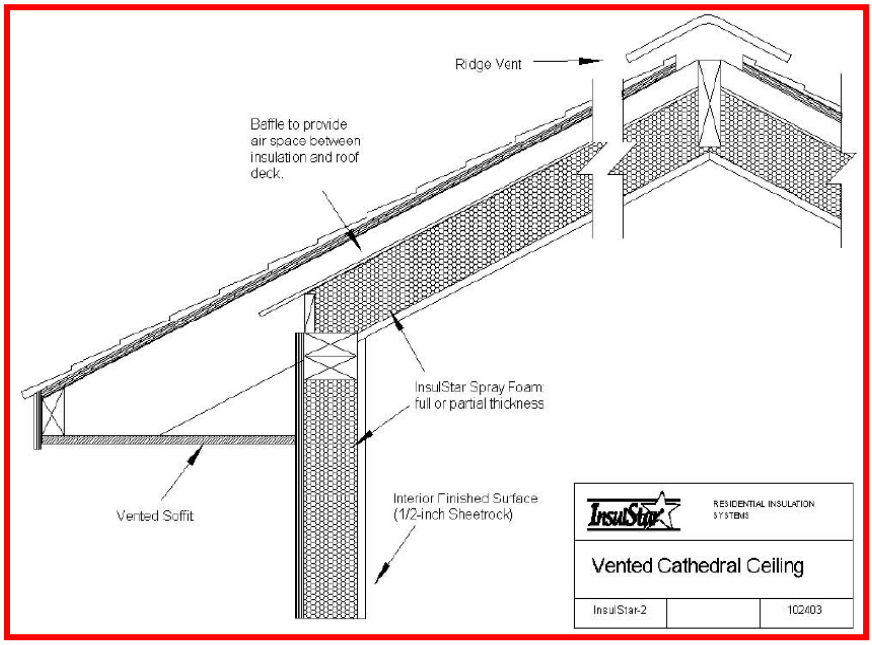

Figure 1. Spray foam applied to a Vented Cathedral Ceiling.

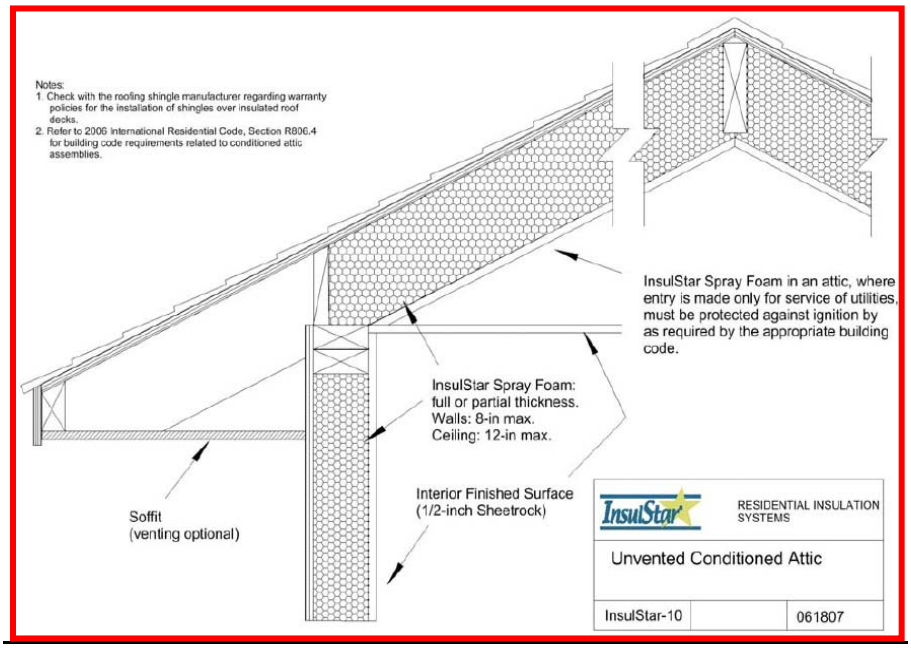

Figure 2. Spray foam applied to an Unvented Conditioned Attic.

Figure 3. InsulBloc 2lb/ft^3 closed cell spray foam insulation on underside of the roof deck.

Figure 4. InsulStar 2lb/ft^3 closed cell spray foam insulation on underside of the roof deck.

Reprinted by permission from the Advanced Insulation Concepts (http://www.aicfoam.com/photo/photo.shtml):

Figure 5. Polyurethane Spray Foam easily fills gaps to insulate roofs and walls.

Figure 6. Quick installation onto any surface type or angle.

Figure 7. Once the gap is filled it must be trimmed to allow for flush drywall.

Figure 8. Spray foam is often used on cathedral or peaked ceilings where depth is limited.

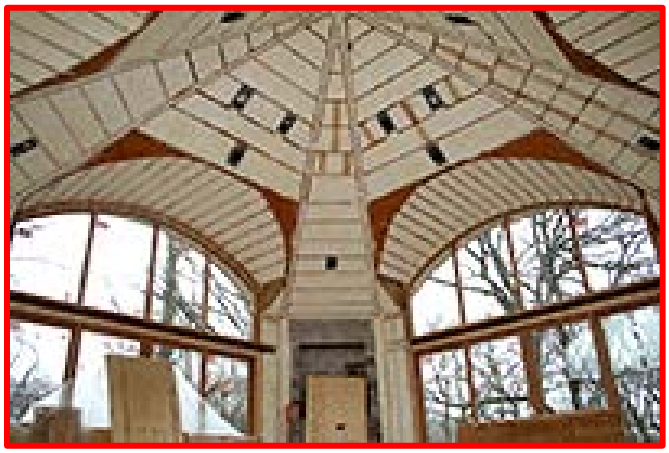

Figure 9. Spray foam conforms to the shape it is filling making it ideal for unique designs.