It Never Gets that Cold Here…

Sprinkler Systems Subjected to Freezing Temperatures

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Yes. It Does.

Topics

Focus on wet systems

- Review Common Failures Resulting in Sprinkler Pipe Freeze
  - What does the Code say?
  - Why would this ever happen?
- Initial Design Decisions Impacting Performance
  - Space conditioning
  - Insulation assumptions
  - Other Mechanical or Building systems affecting performance

Topics (cont.)

- Installation Issues Impacting Performance
  - Coordination with other trades
    - Framers, Insulation Contractors, HVAC/Electrical, etc.
    - Architectural and MEP (Design Assumptions)
  - Phasing of the project
- Topics We Cannot Reasonably Cover
  - Weather conditions beyond design assumptions
  - Loss of a heating or insulation system based on a system failure out of our control

Owner responsible for maintaining heat…

System Designers are Responsible for:

- Understanding the water supply
- The selection and documentation of the hazards
- The selection of sprinkler head activation temperatures to ensure the heads will operate in a timely manner, yet not be subjected to false activations caused by the normal environment, etc.
- The selection of sprinkler system types in order to avoid damage and loss of reliability caused by freezing.

What Does the Code Say (TAC)?

- Upon Completion TAC Rule §34.718(a)
  - The fire protection system must not be tagged until the system complies with the applicable NFPA installation standard, including freeze protection methods.

- Periodic Inspections
  - ITM looking for deteriorated systems.
  - Hopefully, ITM can also spot a latent defect

What Does the Code Say (NFPA 13)?

- Where any portion of a system is subject to freezing and the temperatures cannot be reliably maintained at or above 40°F (4°C), the system shall be installed as a dry pipe or preaction system.
- Or one of the methods in 16.4.1.2 through 16.4.1.4.1
  - Antifreeze/wet
  - Heat trace
  - Acceptable passive insulation and calculations

What Does the Code Say (NFPA 25)?

4.1.2: The property owner or designated representative shall ensure that water-filled piping is maintained at a minimum temperature of 40°F (4°C) unless an approved antifreeze solution is utilized.

- Maintain temperature
  - Verify that windows, skylights, doors, ventilators, other openings and closures, concealed spaces, unused attics, etc.
  - Maintain temperature in vacant units
- Inspect or delegate inspection of passive insulation to ensure it has not deteriorated over time
- Inspect or delegate inspection of other freeze protection systems
  - Heater thermostats are set, etc.

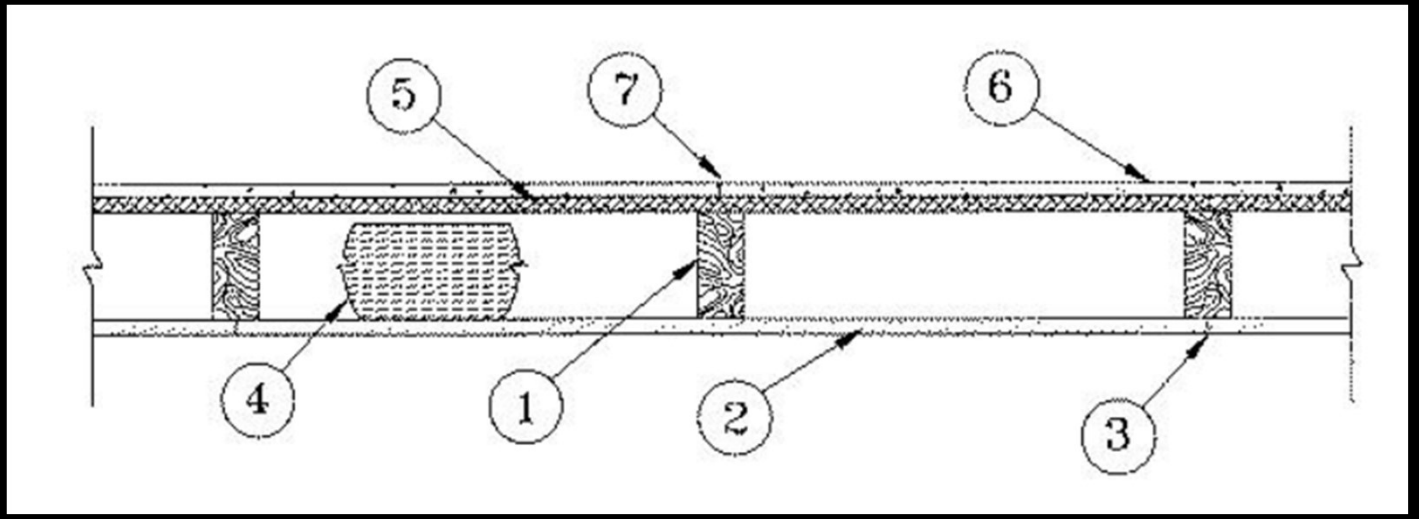
Initial Design Decisions

- Space Conditioning – Looking for:
  - Air diffusers
  - Unit heaters
  - Insulated walls w/Architectural details
- Watch out for:
  - Large intake louvers for equipment
  - Ventilation openings
  - Combustible construction “over build” areas

Insulation Assumptions

- Review architectural details to identify insulated spaces
  - Looking for R values associated with wall and ceiling types
  - RFI – If you are not sure
  - Keep track of changes
- If below-freezing conditions are expected (Breezeways, crawlspace, etc.), need additional data
  - Insulation thickness calculation
  - Antifreeze concentration

Insulation Assumptions



4. **Batts and Blankets*** — Min 3 in. thick mineral wool batts, friction fit between studs.
THERMAFIBER INC — Type SAFB, SAFB FF

ROCKWOOL — Type SAFEnSOUND

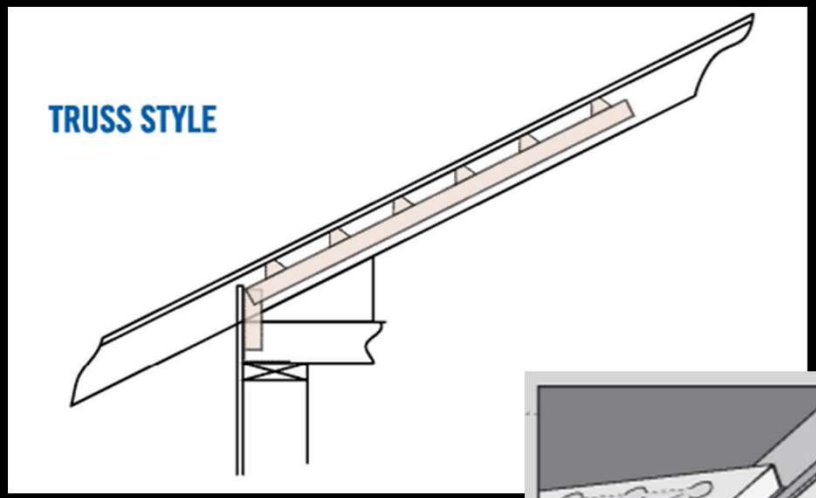
Insulated Roof Decks

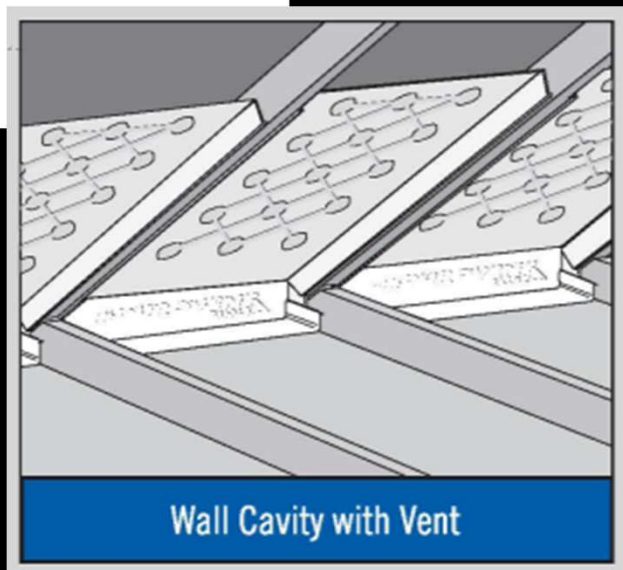
Insulated Ceilings

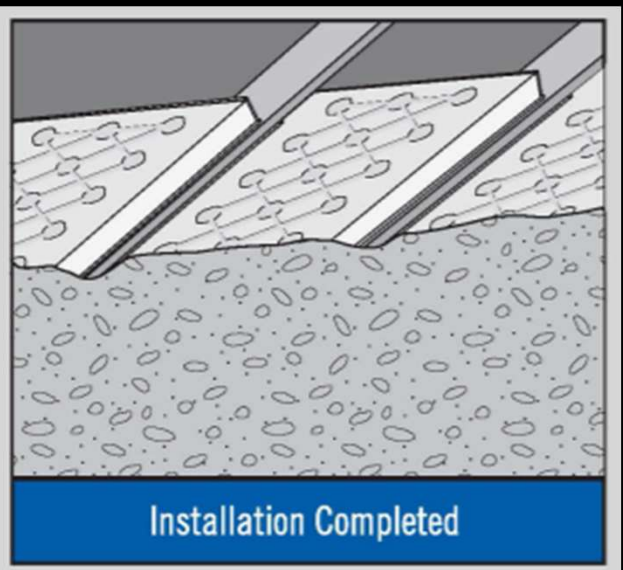
Insulated Ceilings

Mechanical Spaces

Other Air Openings







Exposed Supply Piping

Auxiliary System Assumptions

- Ensure auxiliary systems are present and functional at the time of system tagging
  - Typically provided by other trades…but must be functional
- Unit heaters installed/functional, with thermostats set
  - MEP or sprinkler system commissioning?
- Heat trace system installed and MONITORED per NFPA 13 and NFPA 72

Common Installation Issues

There are many…Basically, installation should support the design assumptions

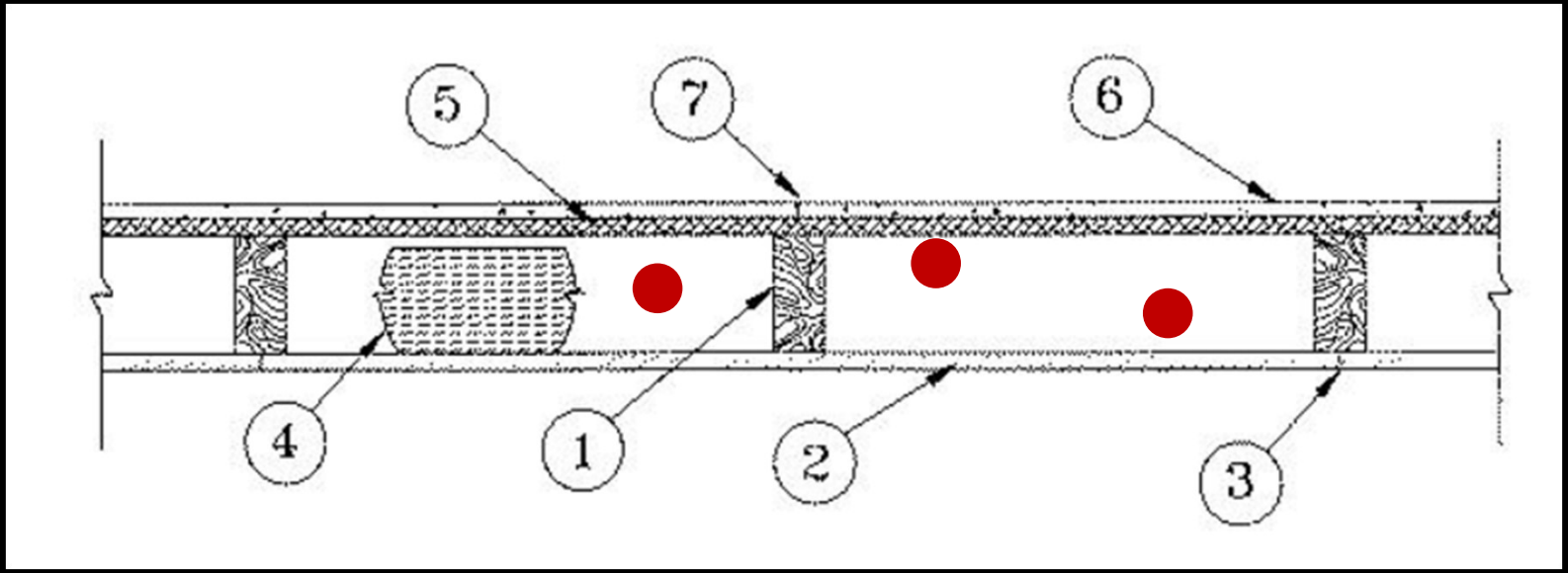
- Maintaining product listings for dry sidewall sprinkler heads
  - Exposure lengths
  - Insulated opening
- Ensuring wall insulation values are reliable
  - Location of pipe drops in stud cavity example
- Attic Insulation and "Tenting" is strongly-dependent on installation practice

Wall Cavity Insulation Example

Apartment complex, CPVC system, wood stud (2x4) exterior walls, insulated with fiberglass batt insulation (by others).

- Attention to pipe drop location in cavity
  - 3.5 in. cavity, 1.3 in. OD for 1-in. pipe, not much left!
- Wall insulation compressed
  - Affects R-Value
- Wall insulation split around pipe
  - Creates voids between pipe and exterior wall

Wall Cavity Insulation Example



Wall Cavity Insulation Example

Uninsulated Concealed Spaces

- Soffits and overhangs in combustible construction with heads supplying balconies
  - Need to get water to the heads through conditioned areas
- Combustible "over-build" roof elements
  - Towers, spires, fake dormers, etc.
  - Almost never heated
  - Hope for the limited combustible (FRTW) exception
- Interstitial floor spaces
  - Watch for complete insulation at the perimeter

Soffits and Overhangs

Interstitial Spaces

Attics/Tenting Pipe

- Insulation between pipe and "cold" space
- NO insulation between pipe and warm space
- Blown insulation needs a physical barrier to prevent spillage under the pipe
- Coordination of trades
  - Sprinkler contractor installs the plastic?
  - Insulator blows in insulation
    - Delays or out of sequence work

Tenting Pipe

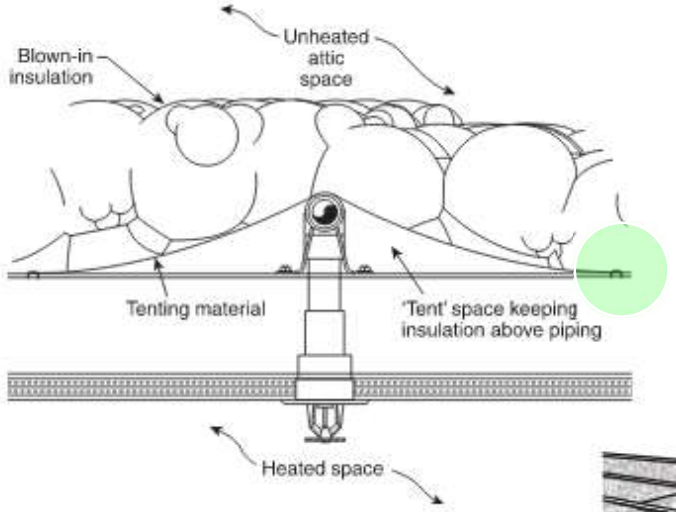


FIGURE A.5.4.2(f) Insulation Recommendations — Arrangement 6.

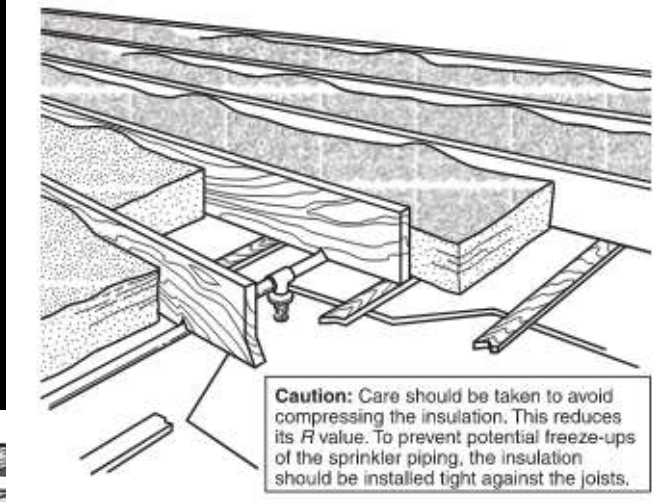


FIGURE A.5.4.2(d) Insulation Recommendations — Arrangement 4.

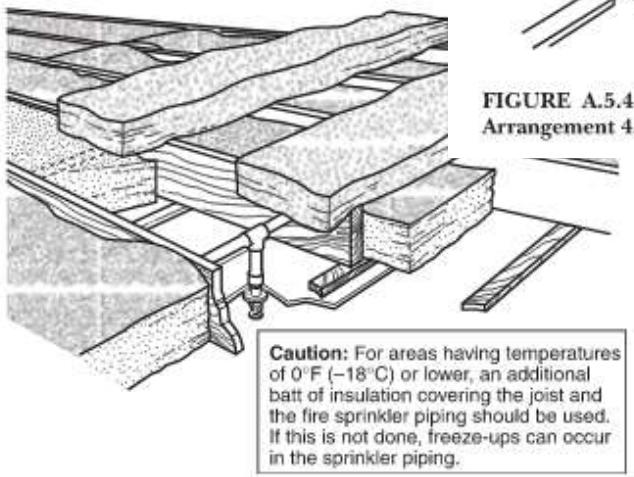


FIGURE A.5.4.2(b) Insulation Recommendations — Arrangement 2.

Tenting Blown Insulation

Tenting Pipe Batt Insulation

Design Assumptions and Decisions

- Study plans and make initial design decisions to the best of your ability as a planner
  - Louvers are hard to see on plans (DuroVent)
  - R-Values are not up to you to decide if they are adequate – but you must telegraph the fact that wet systems must be provided with 40°F ambient temperature
  - Watch out for mechanical rooms requiring natural ventilation
  - Other areas that may be "missed"
    - Overbuild areas, balconies

Checking Assumptions

- Possible Training of Installation Crews
  - Train foreman/Job Supervisors
- Watch for design changes or things that did not show up on plans
  - Last-minute change to add combustion air to a mechanical room
  - Swapping out an insulation type (for cost)
  - Thickness/type of attic insulation
  - Adding a balcony or other dry sidewalls in the field
    - Need to get water to them reliably

Execution

- Running pipe in a way that can benefit from the design assumptions
  - Location in studs and joists
  - Proximity to uninsulated sheathing
- Tenting issues
  - Contractually designating responsibility
  - Prepping the tent (size, fastening method)
  - Phasing the work (final inspection before blowing?)
  - Ensure Batts and Tenting are installed per code details
    - Observe caution language

Execution

- A good idea to perform limited QC of other trades (Framers and Insulators)
  - Compressed/pinched insulation
  - Split insulation
  - Missing Insulation

Questions/Discussion…

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ENGINEERING DESIGN FOR FREEZE PROTECTION OF WATER-BASED FIRE PROTECTION SYSTEMS

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Overview

- Background
- Weather data
- Common scenarios
- Common misconceptions
- Insulation of pipes
- Dry sidewall
- Dry sidewall flex
- Antifreeze systems
- Dry systems
- Heat tracing

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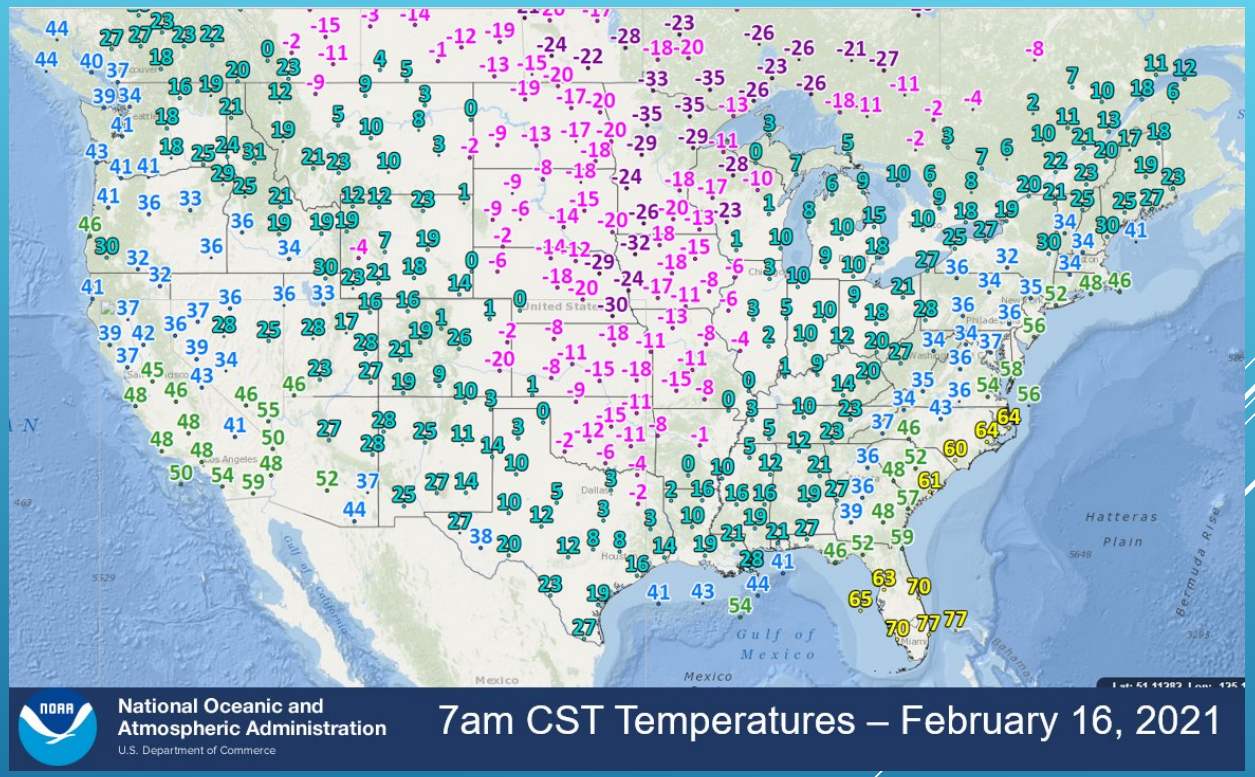
Background

- The February 2021 cold wave brought some of the lowest temperatures on record to Texas, with temperatures more than 50°F below normal
- Data from this freeze event can be used to model worst case scenarios when performing freeze protection calculations
- NOAA publishes hourly data for each weather station that can be used for area-specific calculations



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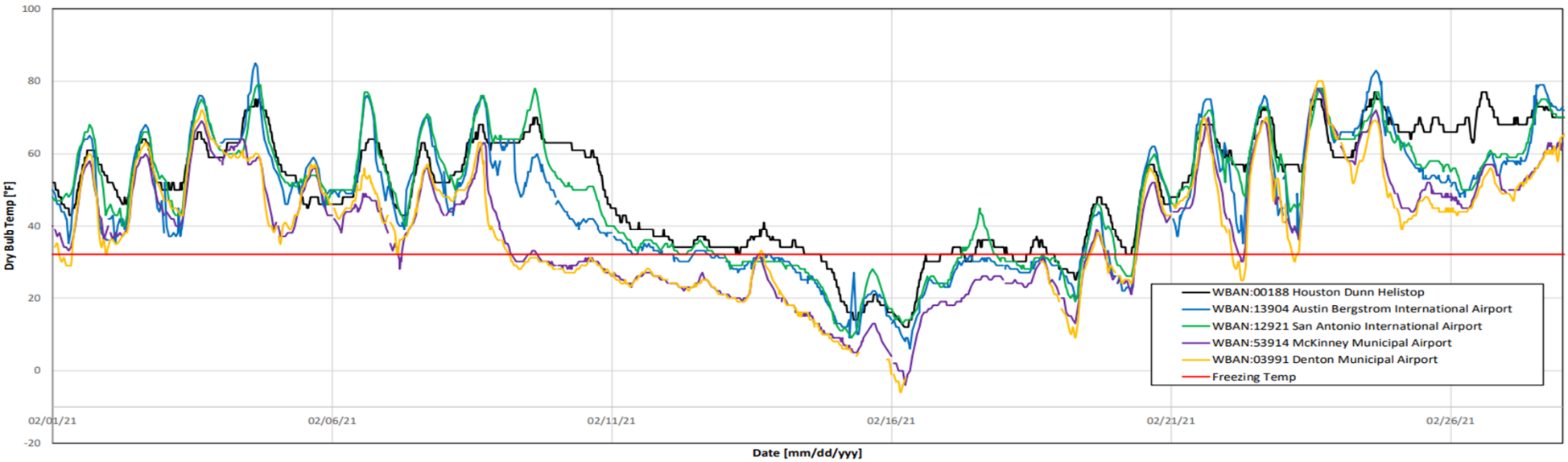
Weather Data - February 2021



Location	Freeze Duration [hrs]	Minimum Temperature[F]	Average Temp During Freeze [F]	Average Temp Before Freeze [F]
Houston (WBAN:00188)	120	12	27	52
Austin (WBAN:13904)	201	6	26	54
San Antonio (WBAN:12921)	195	9	26	54
McKinney (WBAN:53914)	268	-4	22	46
Denton (WBAN:03991)	268	-6	22	49

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Common Scenarios

- Wet pipe crossing through unconditioned space such as breezeway or parking garage
- Apartment balconies
- Large overhangs
- Residential sprinkler risers in garages
- Sprinkler system lead–ins on retrofits
- Corridors

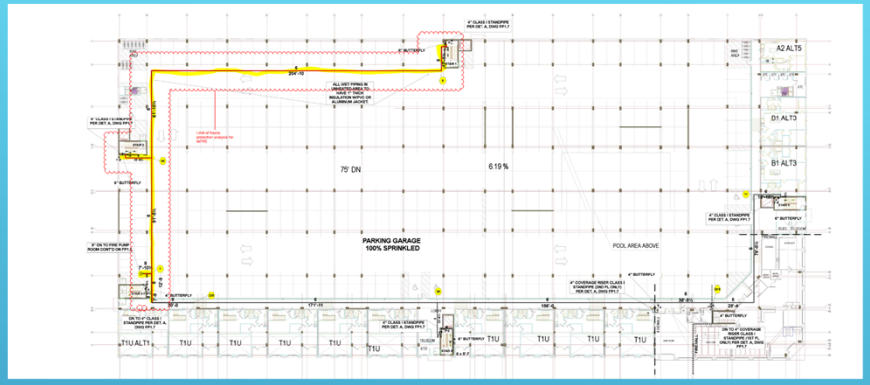

Fig 1: Unheated Parking Garage

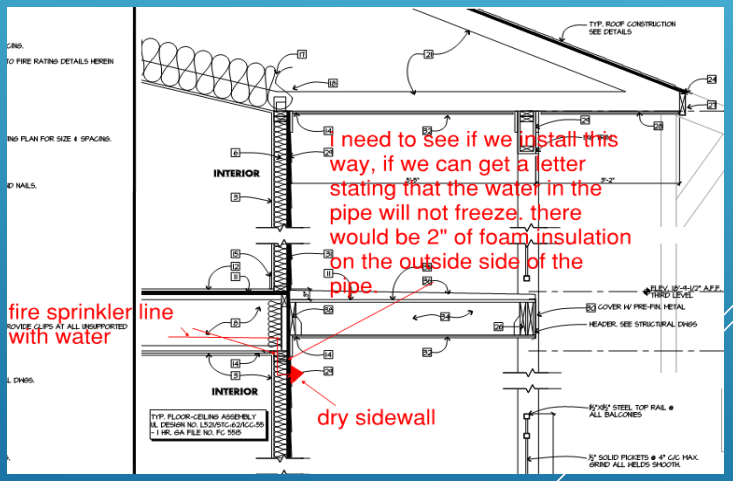

Fig 2: Sprinklered Apartment Balcony

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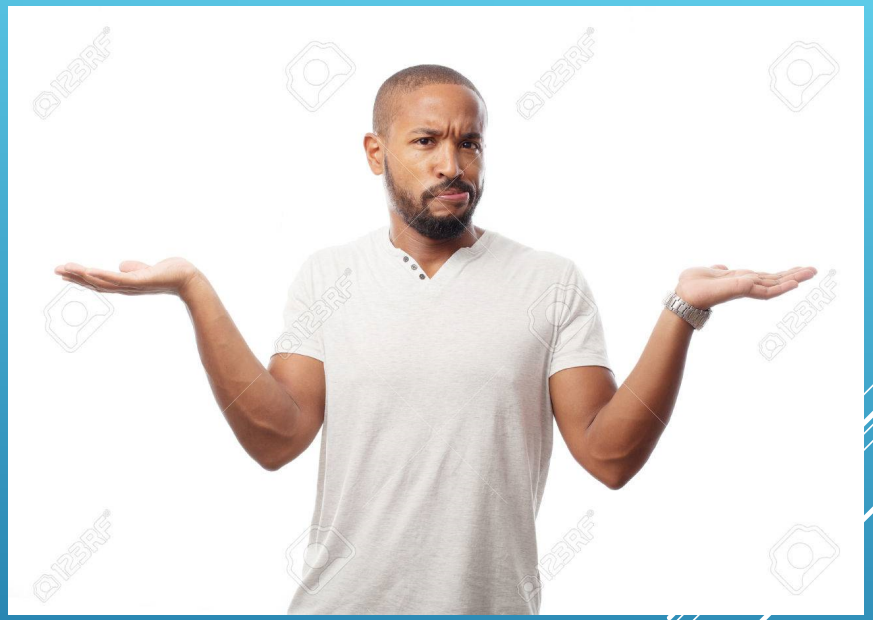
Common Misconceptions

- "It's just a canned letter"
- "All I need is a calculation"
- "Every situation can be fixed with a calculation"
- Standardized starting conditions
- Standardized design goals - What are we trying to accomplish?



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Insulation of Pipes for Freeze Protection

- In areas where wet pipe systems are subject to cold temperatures, wrapping in insulation can be used to prevent the water inside from freezing
- Temperatures before and during the February freeze event can be used as a model to calculate the time to freezing
- IMPORTANT! - No amount of insulation will prevent freezing indefinitely; In situations where longer durations of freeze protection are needed, other methods may be considered

Location	Freeze Duration [h]	Minimum Temperature[F]	Average Temp During Freeze [°F] (t_a)	Average Temp Before Freeze [°F] (t_i)
Houston (WBAN:00188)	120	12	27	52
Austin (WBAN:13904)	201	6	26	54
San Antonio (WBAN:12921)	195	9	26	54
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Insulation of Pipes for Freeze Protection

Calculation Methodologies

- ASHRAE Method (ASHRAE Fundamentals Handbook Ch 23)- **Not steady state**
- Internal Energy Method - Determine the internal energy of the water at initial temperature and calculate temperature drop based on steady state heat loss. **Steady state**
- Computer Aided Modeling - (CFD Programs such as COMSOL, ANSYS, OpenFOAM) Most accurate, scenario specific, time consuming and expensive – **This solution is often worse than the problem**

ASHRAE METHOD

$$\Theta=\rho C_p \Pi (D_1/2)^2 R_T \ln[(t_i-t_a)/(t_f-t_a)]$$

where

Θ *= time to freezing, h*

ρ *=density of water=62.4 lb/ft^3*

C_p *=specific heat of water= 1.0 Btu/lb°F*

D_1 *=inside diameter of pipe, ft*

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

t_i *=initial water temperature*

t_a *=ambient air temperature °F*

t_f *=freezing temperature °F*

$$R_T=12 \ln(D_3/D_2)/(2\Pi k)$$

where

D_3 *=outer diameter of insulation, ft*

D_2 *=inner diameter of insulation, ft*

k *= thermal conductivity of insulation material, Btu*in/h*ft^2 *°F*

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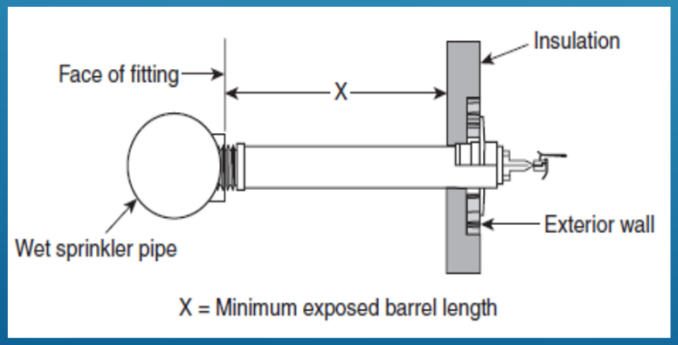
Dry Sidewall

- Dry sprinklers can be connected to wet pipe sprinkler systems in areas subject to freezing
- NFPA13 dictates the minimum exposed barrel length permitted depending on what the ambient temperature is
- Barrel length is measured from the face of the sprinkler fitting to the inside surface of the exterior wall or insulation- whichever is closest to the fitting



NFPA13 Table 8.4.9.1(a)			
Ambient Temperature Exposed to Discharge End of Sprinkler [°F]	**Minimum Exposed Barrel Length when Exposed to 40°F**	**Minimum Exposed Barrel Length when Exposed to 50°F**	**Minimum Exposed Barrel Length when Exposed to 60°F**
40	0	0	0
30	0	0	0
20	4	0	0
10	8	1	0
0	12	3	0
-10	14	4	1
-20	14	6	3
-30	16	8	4
-40	18	8	4
-50	20	10	6
-60	20	10	6

Location	Average Temp During Freeze [°F]
Houston (WBAN:00188)	27
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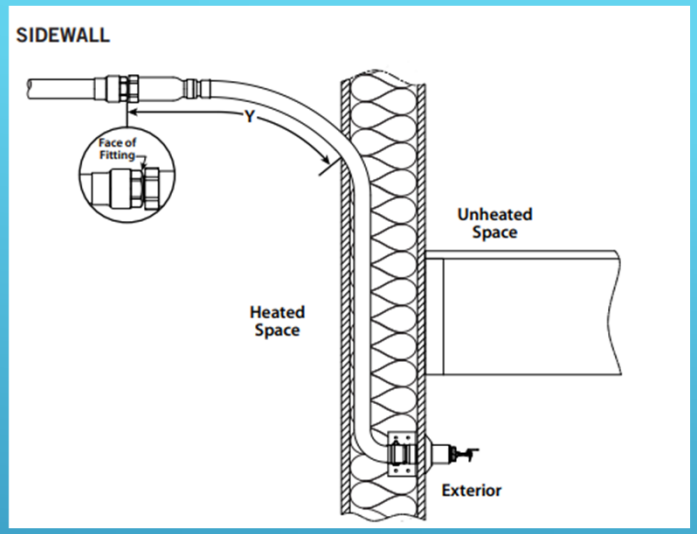
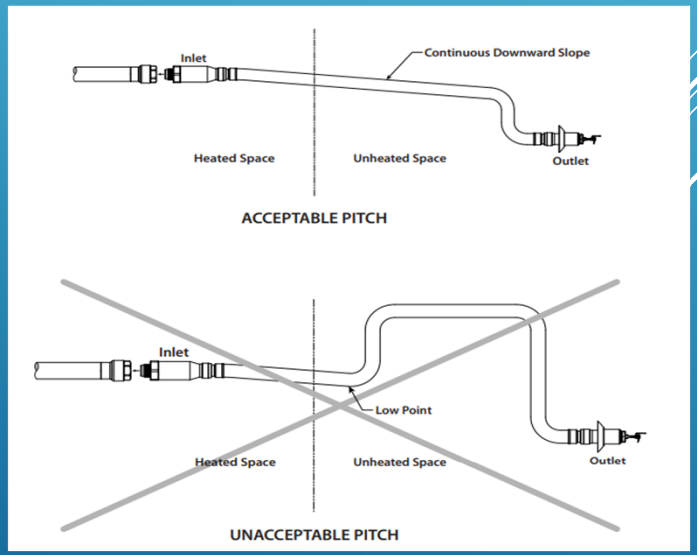
Dry Sidewall Flex

- Dry flex sidewall sprinklers operate in a similar fashion to standard dry sidewall sprinklers but provide more flexibility in installation
- Flexible barrel is generally long enough that barrel length is less of a concern
- Care must be taken during installation to avoid low spots in the flexible barrel
- Expensive and take time to order compared to regular dry sidewall





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Antifreeze Systems

- Previously a common design approach, fell out of use due to regulatory restrictions, just recently making a small comeback with listed solutions
- Solution used must be listed from a national laboratory
- Premixed solutions are required with few exceptions
- In systems larger than 40 gal, the Darcy-Weisbach formula must be used to calculate friction loss in addition to the Hazen Williams equation
- Extra cost for equipment and antifreeze solution, generally only used when other options are not available

Darcy-Weisbach Formula

$$\Delta P = 0.000216\, f \frac{l \rho Q^2}{d^5}$$

Where

ΔP = friction loss (psi)

f = *friction loss factor from Moody diagram*

l = length of pipe (ft)

ρ = density of fluid(lb/ft^3)

Q = flow in pipe (gpm)

d= inside diameter of pipe (in)

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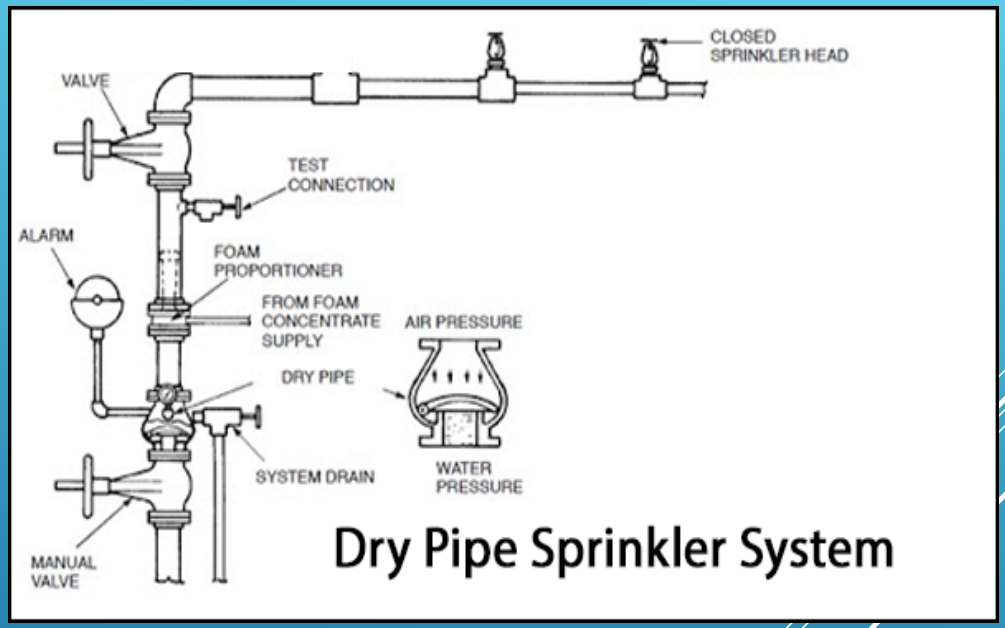
Dry Systems

- In cases where the entire area being protected is subject to freezing temperatures, a dry system can be used
- Drawbacks include, added cost over wet systems, additional space requirements, continual maintenance and corrosion concerns
- Auxiliary dry systems can provide cost effective solutions for many scenarios and are easier to implement than full dry systems



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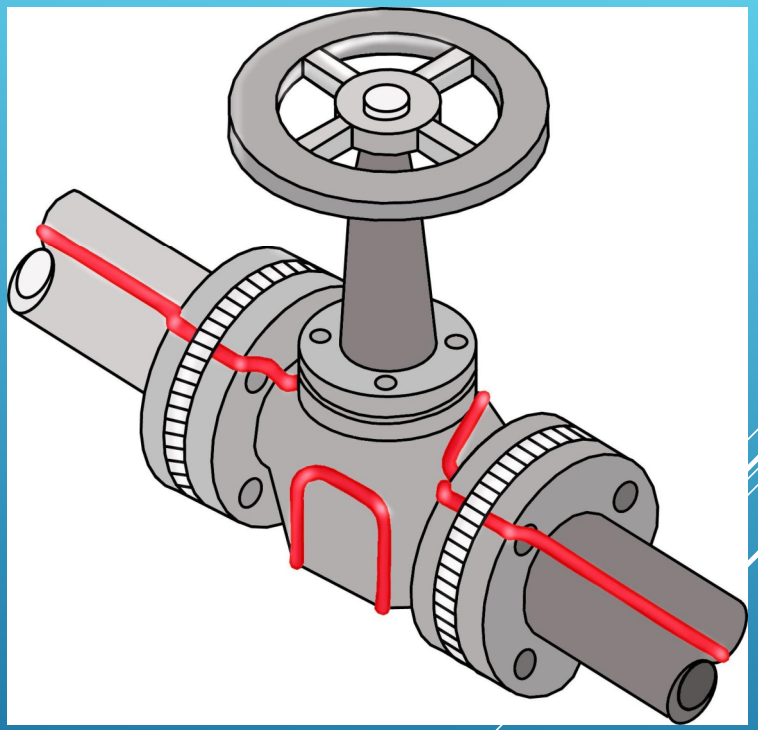
Heat Tracing

- Heat tracing can be used to directly heat pipes to prevent freezing
- Used in situations where insulation alone will not meet required design specifications
- There are limited products that are listed for heat tracing sprinkler branchlines
- Requires extensive coordination early on in project and engineered design in most jurisdictions
- Generally more expensive than other methods
- Insulation is still required!



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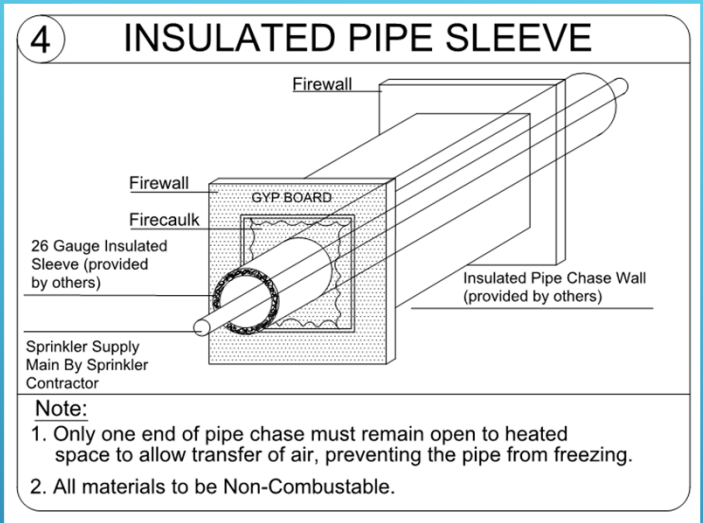
Providing a conditioned space

- In scenarios where other methods are not sufficient, heating the design area may be the best way to prevent freezing
- Extending heated area by use of an insulated chase or box



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Final Takeaways

- There are a variety of methods that can be used for freeze protection of water-based fire protection systems
- Historic freeze in February provided an opportunity to analyze data and develop new starting conditions for design
- Often the process of engineering evaluations for freeze protection are over-simplified into "I need a calculation"
- It is important to check with AHJ to determine acceptable design outcomes and starting conditions

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References

- "23- Insulation for Mechanical Systems." In *ASHRAE Handbook- Fundamentals 2017*. American Society of Heating Refrigerating and Air-Conditioning Engineers, Inc, 2017.
- National Centers for Environmental Information (NCEI). "Data Tools: Local Climatological Data (LCD)." National Climatic Data Center (NCDC). National Oceanic and Atmospheric Administration. Accessed September 15, 2021. https://www.ncdc.noaa.gov/cdo-web/datatools/lcd.
- *NFPA 13, Standard for the Installation of Sprinkler Systems*. National Fire Protection Association (NFPA), 2016.
- "U.S. Had Its COLDEST February in More than 30 Years." National Oceanic and Atmospheric Administration. National Oceanic and Atmospheric Administration. Accessed September 15, 2021. https://www.noaa.gov/news/us-had-its-coldest-february-in-more-than-30-years.

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