

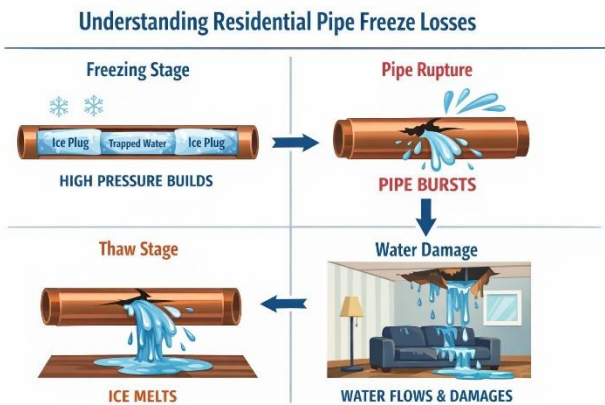
Evaluating Pipe Freeze Losses

INTRODUCTION

Frozen pipe losses often raise critical questions such as:

- **When was heat lost?**
- **Was minimum heat supplied?**
- **What caused the pipe failure?**

Water pipes do not freeze randomly. Freezing requires sustained exposure to sub-freezing interior temperatures. When that occurs, expanding ice generates internal pressure that commonly produces longitudinal “bird-mouth” splits in copper tubing or separation at fittings and joints.



To properly evaluate freeze damage, we must determine if heat was maintained and, if it was not, when it stopped. This white paper outlines a structured, objective method for analyzing heating performance using:

- Natural gas billing records
- Heating Degree Day (HDD) weather data
- Therms-per-HDD comparison
- Cumulative fuel usage reconstruction
- Study of failure
- Study of external temperature

By correlating fuel consumption with documented weather conditions, it is often possible to determine whether a heating system was operating as expected and to estimate the timeframe during which interior temperatures likely declined.

The approach described herein relies on reported utility data and recorded environmental conditions rather than speculation. When combined with physical evidence of freeze damage, it provides a defensible framework for evaluating pipe freeze claims.

1. Typical Water Pressure in Homes

Water distribution systems typically operate within a pressure range of 40 to 80 pounds per square inch (psi).

- Pressures near 40 psi are considered adequate for normal household function.
- Pressures approaching 80 psi are generally the upper acceptable limit for systems.

Many homes are equipped with a pressure-reducing valve (PRV) installed on the incoming domestic water service line near the water meter. This device regulates overall household water pressure.

Components located at the water heater, such as temperature-pressure relief valves or thermal expansion tanks, serve safety and expansion functions and do not regulate system pressure.

2. Copper Pipe

Interior water supply piping is most commonly constructed of copper tubing.

The two types typically encountered are:

- Type L copper (identified by blue lettering)
- Type M copper (identified by red lettering)

In reality, older homes have a mix of old steel piping, valves, and connections of all sorts. The more modifications the more likelihood of problems.



3. PEX Pipe

Water supply piping has historically been constructed of copper tubing, although newer construction increasingly uses PEX piping.

PEX is a flexible plastic water supply tubing commonly used in construction. Unlike copper, PEX can expand when water inside the pipe freezes, making it more resistant to freeze-related splitting.

However, PEX is not freeze-proof.

4. Pipe Failure Modes Due to Excessive Internal Pressure

When internal pressure within a water pipe system becomes sufficiently high, failure generally occurs in one of two predictable ways. These failure modes correspond to the two primary stresses developed in a pressurized cylindrical pipe: hoop stress and longitudinal stress.

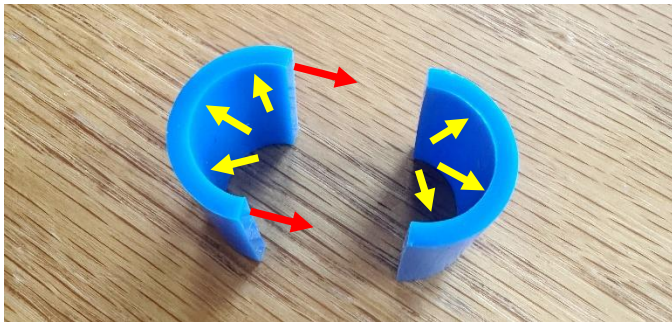
1. Hoop Stress Failure — “Bird-Mouth” Burst
2. Longitudinal Stress Failure — Pull-Apart at Fittings

5. Hoop Stress Failure — “Bird-Mouth” Burst

The most common pressure-related pipe failure is a longitudinal split commonly referred to as a bird-mouth burst.



Internal pressure acts outward in all directions against the pipe wall. This creates hoop stress, a circumferential tensile force that attempts to pull the pipe apart around its perimeter. Hoop stress is the largest stress acting in a pressurized pipe and is twice the magnitude of longitudinal stress.



When hoop stress exceeds the tensile strength of the pipe material, the pipe tears open lengthwise. The resulting fracture typically appears as:

- A straight longitudinal split,
- Edges opened outward,
- A shape resembling a bird’s open mouth.

6. Longitudinal Stress Failure — Pull-Apart at Fittings

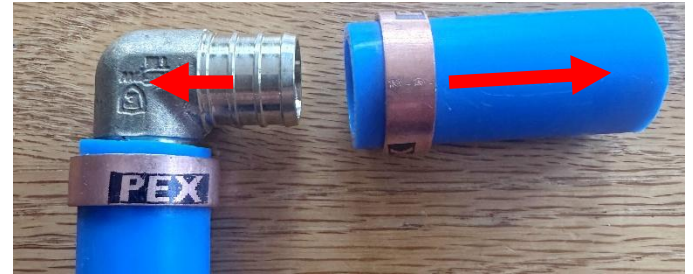
A second, less common failure mode occurs due to longitudinal stress.

Internal pressure also acts against closed ends of the piping system, such as valves, faucets, elbows, or capped pipe ends. This pressure generates an axial force that attempts to pull components apart along the length of the pipe.



If this axial force exceeds the strength of a connection, failure may occur as:

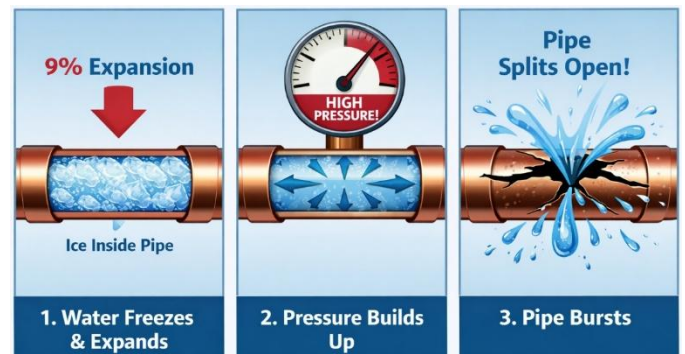
Unlike hoop-stress failures, these ruptures do not produce a longitudinal split in the pipe wall. Instead, the piping system separates at the connections.



7. Ice Expansion Behavior During Freeze Events

When water inside copper tubing freezes, it expands approximately nine percent by volume. This expansion creates internal hydraulic pressure in the unfrozen water. If pressure exceeds the tensile strength of the tubing wall, the pipe will split longitudinally.

Importantly, pipe ruptures typically do not occur at the location where freezing first begins.



8. Water Pressure During a Freeze Condition

When water freezes, it expands approximately nine percent by volume. If freezing occurs within a confined section of pipe, the expanding ice has nowhere to go. Because liquid water is nearly incompressible, the formation of ice creates hydraulic pressures that can rise to several thousand psi, which far exceeds normal operating pressure of 40 to 80 psi.

Importantly, the pipe does not typically rupture at the point where ice first forms. Instead, pressure builds in trapped water, and failure occurs at the weakest section within that trapped segment.

When water freezes in a fully confined, closed system, pressures can exceed 3,000–10,000 psi.

9. Bursting Pressure of Copper Pipe

Copper water tubing used in construction is designed to withstand pressures far greater than typical household operating conditions (40 to 80 psi).

By comparison, the estimated bursting pressure of common interior copper tubing is substantially higher:

Type L copper (½-inch nominal): approximately 3,000–4,000 psi

Type M copper (½-inch nominal): approximately 2,000–3,000 psi

Actual burst strength varies depending on the material condition, age, and imperfections. However, even conservative estimates show that copper tubing can tolerate pressures dozens of times greater than normal system pressure.

10. The Typical Water Loss Scenario

Most freeze losses follow a predictable sequence.

1. Heat is lost
2. Outside temperatures are sustained below freezing
3. Interior temperatures at a pipe location fall below freezing.
4. Ice forms within the vulnerable sections of piping, typically near exterior walls or uninsulated areas.



5. As freezing progresses, water becomes trapped between ice plugs or between an ice plug and a faucet.
6. The internal pressure rises as the ice plug grows and compresses the water in the confined section.
7. The pipe ruptures often as a longitudinal split. Importantly, the pipe usually breaks while still frozen.
8. A small amount of water leaks from the pipe.
9. When temperatures rise or heat is restored, the ice plug melts.
10. Pressurized water then escapes through the ruptured locations, resulting in active leakage and interior water damage.

In short, the break typically occurs during the freeze, but the water damage occurs during the thaw.

11. Determining When Heat Was Lost

Because pipe freezing requires sustained low interior temperatures, it becomes important to determine when heat was lost.

One reliable method is to compare natural gas usage to outdoor weather conditions. To do this calculation the following are needed:

- 1 to 2 years of Gas Bills
- Recorded maximum and minimum daily temperature.

12. Understanding the Gas Bill

Before analyzing fuel usage, it is important to understand what a gas bill actually represents.

A natural gas utility bill typically includes:

- The billing period (start and end dates)
- Total therms consumed
- The number of days in the billing cycle
- The service address and the meter information

A therm is a unit of heat energy. One therm equals 100,000 British Thermal Units (BTUs). For typical buildings, the majority of therm usage is typically attributable to heating.

13. Why the Billing Period Matters

Gas bills do not report daily usage unless advanced metering is installed. Instead, they report total fuel consumed over a billing period, often 28 to 32 days.

This means the bill tells us how much gas was used over a span of time, not on a specific day.

To estimate daily heating behavior, total therm usage must be evaluated in context with historical fuel usage patterns. Therefore, the first step is looking at what typical past heating looked like.

14. Establishing a Heating Baseline

By reviewing one to two years of prior gas bills, a normal winter heating pattern can be established. This baseline allows us to determine:

- What the home typically consumes during cold weather.
- Whether gas usage during the loss period was consistent with heating demand.
- Whether a significant deviation occurred.

When paired with Heating Degree Day data, the gas bill becomes more than an invoice. It becomes a measurable indicator of whether the heating system was operating as expected.

In freeze-loss investigations, the gas bill often provides one of the most objective pieces of evidence regarding whether and when heat was lost.

15. Understanding Heating Degree Days (HDD)

Heating Degree Days (HDD) are a measure of how cold a given period was. They are calculated relative to a base temperature (typically 65°F). The colder the weather, the higher the HDD value.

Local weather stations provide temperature data. Typically, the high, the low and the average temperature for the day are available.

A Heating Degree Day (HDD) is a numerical value that represents how cold a day was relative to a standard indoor comfort temperature.

HDD is calculated using a base temperature of 65°F. The assumption is that when the outdoor average temperature falls below 65°F, a building will likely require heating.

$HDD = (65^{\circ}F) - (\text{The Average Outdoor Temperature})$

If the average temperature is above 65°F, the HDD for that day is zero (no heating demand).

Daily Average Temperature = $(\text{High} + \text{Low}) / 2$

Example:

Assume the following weather data:

Daily High: 30°F

Daily Low: 10°F

Step 1 – Calculate Average Temperature

$$(30 + 10) / 2 = 20^{\circ}F$$

Step 2 – Calculate HDD

$$65 - 20 = 45 \text{ HDD}$$

That day recorded 45 Heating Degree Days, meaning it required substantial heating demand.

16. Why HDD Matters in Freeze Investigations

HDD quantifies heating demand in a measurable way. The colder the day, the higher the HDD value, and the more fuel a properly operating heating system should consume.

By comparing:

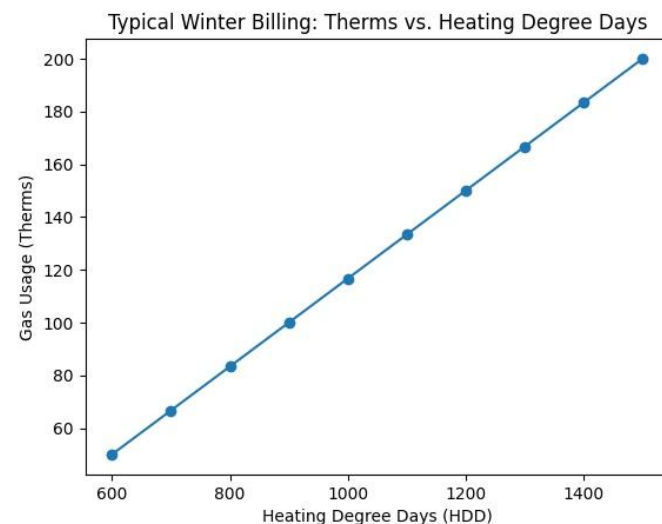
- Daily HDD values
- Historical therms per HDD ratios
- Actual gas consumption

it becomes possible to evaluate whether the heating system was operating in proportion to weather demand.

In freeze-loss investigations, HDD data provides the weather-based benchmark against which fuel usage is measured.

17. Graphing Therms Used vs. Heating Degree Days

Plotting gas usage (therms) on the vertical axis and HDD on the horizontal axis will result in a straight line for a specific home.



Under normal conditions, as HDD increases (the outside gets colder weather), gas usage increases proportionally.

The relationship is typically linear for a properly operating and heated home.

This graph will also show us the typical ratio of Therms/HDD.

This ratio will be different for different homes based on occupancy use and insulation of the house.

Under stable occupancy and stable thermostat conditions, heat loss characteristics of a home remain relatively consistent from month to month.

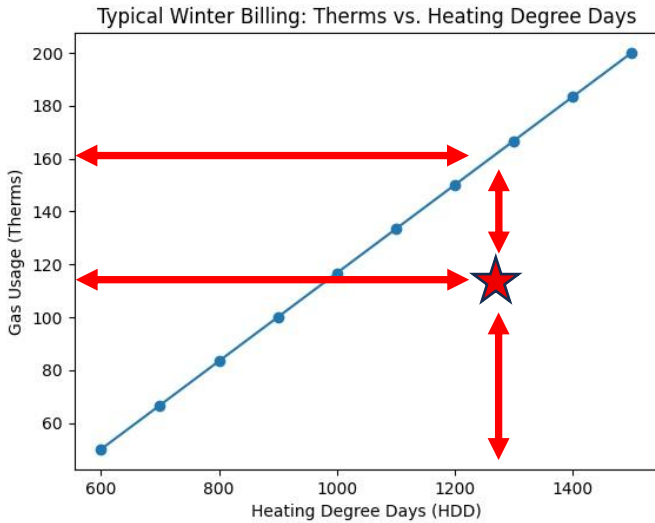
18. Deviations in the Therms vs HDD Graph

If a heating system stops operating, the gas usage drops even though HDD remains high.

On the graph, this appears as:

- A data point that falls well below the established trend line.
- High HDD with unusually low therm usage.

That deviation can indicate that the heating system was not operating during that billing period.



By comparing gas consumption to weather severity, it is often possible to determine:

- Whether the heating system was functioning.
- Approximately when heat was lost.
- Whether the duration of heat loss was sufficient to allow pipes to freeze.

This method relies on measurable fuel consumption and recorded weather data. When properly analyzed, it provides an objective way to evaluate whether freezing conditions inside the structure were likely due to a loss of heat.

19. Normalizing Gas Usage as Therms / HDD

While graphing therms versus Heating Degree Days (HDD) is helpful, the relationship becomes even clearer when gas usage is normalized by HDD.

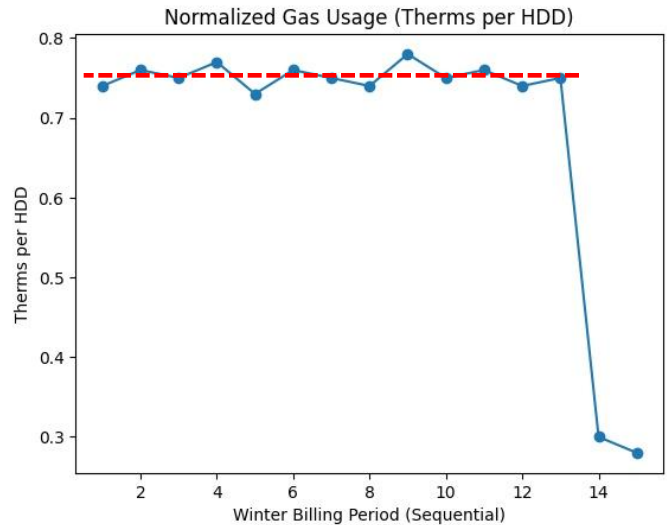
Normalization simply means adjusting for weather severity so different billing periods can be compared directly.

For each billing period:

$$\text{Therms / HDD} = \frac{\text{Total Therms Used}}{\text{Total HDD for That Period}}$$

This produces a ratio that reflects how much gas was required for each unit of cold weather.

A typical Therm/HDD graph will hover around a specific value such as 0.75. When heat is lost in the house during a billing cycle the value will drop significantly, showing that heat used was much less than energy supplied.



20. Establishing a Baseline Therms / HDD

During periods when the heating system was functioning normally, the therms/HDD ratio will remain relatively consistent.

For example:

- December: 0.75 therms per HDD
- January: 0.78 therms per HDD
- February: 0.74 therms per HDD

Small variations are expected due to:

- Occupant behavior
- Wind exposure
- Solar gain
- Minor thermostat differences

However, the ratio typically stays within a narrow band.

21. Identify Abnormal Drops in Therms / HDD

If heat is lost during a billing period:

- HDD may remain high (cold weather persisted)
- Total therm usage will drop
- The therms/HDD ratio will fall significantly below the established baseline

For example:

- Normal range: 0.75 therms per HDD
- Suspect period: 0.28 therms per HDD

That drop indicates the heating system was not consuming fuel consistent with weather demand.

Using Therms/HDD removes the influence of changing weather. It allows the analysis to focus strictly on system performance.

If cold weather demand remained high but gas usage fell, the evidence strongly suggests that:

- The furnace was not operating
- Gas service may have been interrupted
- The home was intentionally or unintentionally left unheated

When correlated with freeze damage evidence (such as longitudinal pipe splits or joint separation), this analysis helps establish whether interior temperatures likely fell below freezing and when that condition occurred.

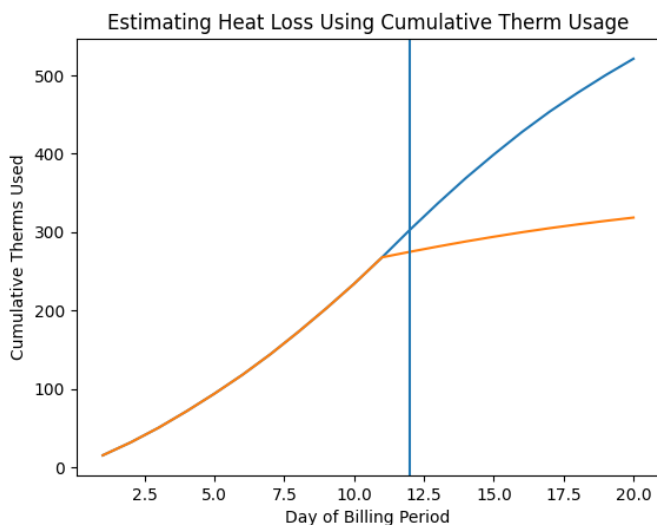
22. Daily Reconstruction Method

In some cases, it is possible to narrow the timing of heat loss to a specific day.

This requires three pieces of information:

- The established therms-per-HDD ratio for the home (based on 1–2 years of historical data).
- Reliable daily Heating Degree Day (HDD) data from a nearby weather station.
- Knowledge of when the furnace resumed operation (for example, a service record or homeowner statement).

When these elements are available, fuel usage can be reconstructed on a daily basis. The graph below shows the exact day when heat was lost within a billing cycle.



23. Establish the Expected Daily Gas Use

To predict the exact day heat was lost, we must rely on historical baseline of the determined Therms/HDD Ratio.

Knowing this ratio, we can estimate daily use by:

Expected Daily Therms = Daily HDD × Normal Therms/HDD Ratio

Example:

If the home historically uses 0.75 therms per HDD, and

January 10 recorded 40 HDD, then:

$40 \times 0.75 = 30$ therms expected for that day

This represents the amount of gas that should have been consumed if the heating system was operating normally.

24. Compare Expected Usage to Actual Billing Data

The total therm usage for the billing cycle is obtained directly from the utility bill.

By distributing expected Therm usage across each day (using actual daily HDD values), a cumulative expected usage curve can be created.

If the furnace was operating normally, cumulative expected usage will closely match the total Therm billed.

However, if heat was lost during part of the cycle:

- The expected cumulative usage will exceed the actual billed Therm.
- The difference represents days when the furnace was not operating.

25. When Heat is Restored but is a Unknown Date

In some cases, the heating system may stop operating for several days and then resume operation before the end of the same gas billing cycle. When this occurs, utility billing data will show a reduction in total fuel consumption relative to expected heating demand, but it may not identify the exact shutdown or restart dates.

Gas bills report total therms used over an entire billing period, not daily furnace operation. A deficit between the expected therm usage (based on Heating Degree Days) and actual billed therms indicates that heating demand was not fully met. This deficit represents missing heating energy, which corresponds to a period when the furnace was likely not operating.

However, multiple combinations of days within the billing period could produce the same cumulative fuel deficit. Without independent information such as service records, thermostat history, or daily meter data, the precise dates of shutdown and restoration cannot be uniquely determined.

Accordingly, fuel usage analysis can reliably estimate the duration of heat interruption and identify the most probable cold-weather window when heat was not maintained, while recognizing that billing data alone does not establish an exact calendar day of furnace restart.

26. When Heat is Restored and the Date is Known

If the furnace restart date is known, the expected daily therm usage can be reconstructed from cumulative therm consumption data.

For example:

- The furnace was confirmed to be operating again on January 18 based on a service call.
- The billing period showed a total Therm used was 600 therms.
- The expected usage from January 1–31 (based on daily HDD and normal ratio) calculates to be 750 Therms required.

This suggests a shortfall of 150 Therms in a time period ending on January 18.

By calculating the expected daily consumption and comparing it to remaining available therms, the likely day of heat loss can be estimated.

27. Why This Method Is Reliable

This approach:

- Uses the home's own historical heating behavior.
- Relies on measured utility data.
- Incorporates recorded weather conditions.
- Does not depend on memory or assumption.

While it may not determine the exact hour, it often narrows heat loss to within one or two days.

When correlated with:

- Freeze damage patterns,
- Ice formation locations,
- and pipe rupture characteristics,

this analysis provides a defensible estimate of when interior temperatures likely dropped below freezing.

28. Failure Event vs Outside Temperatures

Evaluation of freeze-related water losses should include a review of daily outdoor temperature trends, including recorded high, low, and average temperatures during the loss period.

Fuel usage analysis may indicate when heat was reduced or lost; however, pipe failure and water damage do not always occur at the same time as heat loss. Freeze losses commonly follow a sequence controlled by outdoor temperatures.

Freeze losses typically involve three distinct events:

1. Heat Loss Event

The furnace stops operating or provides insufficient heat. Interior temperatures begin to decline but pipes may not immediately freeze.

2. Pipe Freeze Event

After sustained exposure to sufficiently cold outdoor temperatures, localized sections of piping reach freezing conditions. This may occur days after heat loss,

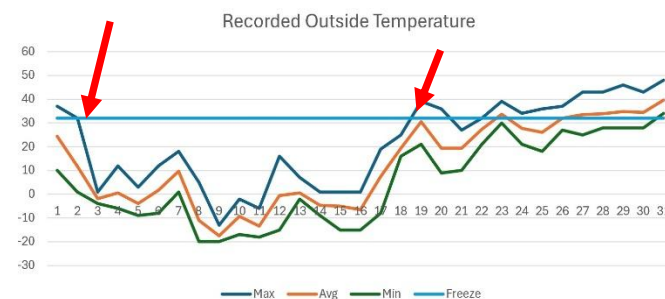
particularly in exterior walls, attics, or poorly insulated areas.

3. Pipe Thaw and Water Release

When outdoor temperatures rise or heat is restored, frozen sections thaw. Pressurized water (40 – 80 psi) then escapes through the previously formed rupture, and active water damage becomes visible.

Because discovery of water typically occurs during thaw, the observed loss date often corresponds to warming temperatures, not the coldest day.

The graph below shows important dates when outside temperatures drop below the freezing point.



29. Practical Implications of Temperature Study

Plotting outdoor temperature data alongside estimated heat-loss events helps establish a logical sequence linking:

- furnace performance,
- freeze formation,
- and the eventual water loss event.

This comparison provides important context when correlating utility data with physical damage observations. The practical limitations can include:

- Heat loss may occur when outdoor temperatures are not yet cold enough to freeze pipes.
- Minimal or intermittent heat may prevent widespread freezing but still allow localized freezing in vulnerable areas.
- Water discharge frequently begins during warming conditions rather than extreme cold.

30. Field Evaluation: What to Look for in a Pipe Freeze Claim

When evaluating a pipe freeze loss, both physical evidence and environmental conditions should be documented. The goal is to determine whether freezing conditions likely occurred and whether the observed damage is consistent with freeze expansion.

31. Pipe Failure Characteristics to Document

A visual inspection should not be relied upon to find all leaks. This is the job of a plumber. A plumber is needed to pressurize the system, fix the break locations, and save damaged pipe.

A forensic inspection determines things like cause and timing. The inspection should include things like:

- Examining the failed piping and fittings:
- Documenting “bird-mouth” splits in copper tubing
- Documenting cracks in fittings, valves, or manifolds
- Documenting separation at soldered joints
- Documenting splits in PEX tubing or failure at crimp/expansion fittings
- Documenting the locations of the known failures and their proximity to exterior walls, rim joists, attics, crawlspaces, or unconditioned spaces.

32. Insulation and Air Leakage Conditions

A visual inspection should include looking for surrounding building components such as:

- Missing or displaced insulation
- Air gaps at rim joists or top plates
- Unsealed wall penetrations
- Open attic bypasses

Cold air intrusion combined with inadequate insulation is a common contributing factor.

33. Heating System Operation

A forensic evaluation should include considering a timeline of events to reconstruct the loss event.

- Furnace operation status
- Thermostat settings
- Fuel supply
- Service records or interruption history
- Gas billing records for fuel usage analysis.

34. Interior Conditions

A forensic evaluation should look for indicators of prior low interior temperature:

- Frozen toilet bowls
- Frost on sheathing or framing
- Condensation patterns
- Ice accumulation

35. Timeline and Occupancy

A forensic evaluation should try to establish:

- Date of last known heat operation
- Date of discovery
- Occupancy or vacancy status
- Outdoor temperature conditions during the loss period

36. Summary

The objective of the investigation is not merely to describe damage, but to establish a defensible explanation supported by physical evidence and measurable data.

A pipe freeze claim should be evaluated using both physical damage patterns and environmental evidence. The rupture location(s), failure mode(s), building insulation conditions, heating performance, and documented weather data collectively provide the basis for determining whether the loss is consistent with sustained freezing conditions.

While the technical details of a pipe freeze event can be complex and informative, the investigation must ultimately serve a practical purpose. If the analysis does not help answer the questions relevant to coverage determination or assist in restoring the property to its pre-loss condition, its value is limited.

A proper pipe freeze investigation should therefore focus on addressing the specific questions posed by the client. Clearly defining those questions prior to the investigation is essential to conducting an efficient and meaningful evaluation.

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