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Forensic Engineering Analysis of Fuel Usage and Thermostat Settings

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Abstract

According to the Insurance Institute, frozen pipes are one of the leading causes of building damage in the United States. In the forensic engineering analysis of building damage due to burst pipes, fuel tank runout or excessive thermostat setback are common causes of these losses — and may lead to a fuel provider being culpable for a late fuel delivery or the property owner being responsible due to excessively turning down thermostat settings. This paper will address the relationship between thermostat settings and fuel consumption. From a building's demonstrated fuel consumption and known thermostat settings, corresponding changes in thermostat settings and the resulting fuel consumption will be discussed. Department Of Energy adjustments for fuel savings in relation to thermostat setback will be discussed as well as a fuel usage study in an exemplar home. Forensic case examples utilizing this relationship will also be presented.

Keywords

Fuel usage, K factor, burn rate, fuel consumption, frozen pipes, heating degree day, HDD, base temperature

The Heating Degree Day

What is a degree day? In its simplest definition, a degree day is the measure of the need for heating or cooling. It is the average daily temperature above (for cooling) or below (for heating) a base temperature (which is usually 65°F).

The concept of the heating degree day (HDD) can be traced back to British Army Lieutenant General Sir Richard Strachey (1817–1908), who introduced the concept as a way of identifying the growing season for agricultural purposes (**Figure 1**). Terminology and calculation basics of HDD calculations today are still based upon his works from 1878. Although the HDD concept is the basis for fuel consumption prediction in buildings today, it is not unique to building energy analysis with the difference being in the choice of a *base temperature* and what one does with the resulting degree day total.

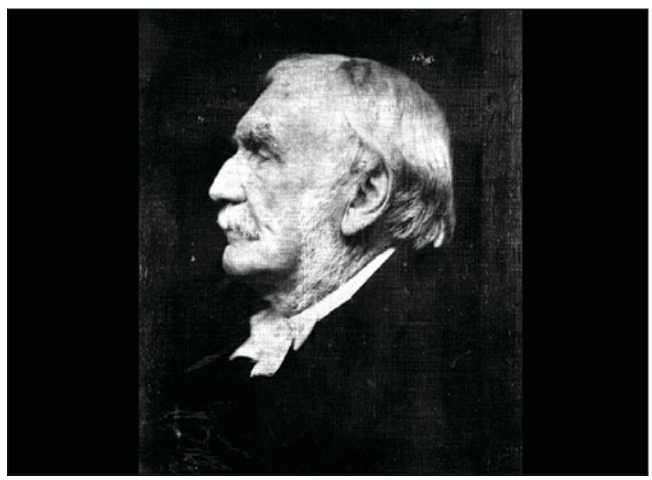

Figure 1
Lieutenant General Sir Richard Strachey (1817–1908).

The HDD procedure's transition from agricultural applications to the heating and fuel delivery industry is evident, as referenced in the *Handbook of Heating, Ventilation and Air Conditioning, HVAC Design Calculations*, which states that in the 1930s gas utility companies used the degree day method to predict gas consumption[1]. This publication also states that the oil embargo of 1973 and subsequent oil supply issues led to an increased awareness of the cost of energy to heat and cool buildings.

The definition of the HDD as "a unit of measurement of the average temperature deficiency during any specific interval of time and to be corrected by heating" was also presented in the 1936 heating technicians' publication *Oil Heating Handbook — The All Inclusive Guide for Every Man Who Designs, Installs, Sells or Uses Oil Heating Equipment*[2]. As such, historical documentation is present, detailing the relationship between the HDD and fuel consumption for the past 80 years.

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Calculation Methods of the Heating Degree Day

The HDD is a factor of the average temperature in a 24-hour period and the base temperature used for the application. The base temperature is defined as the balance point of the building at which the building's internally generated heat begins to counterbalance the loss of heat to the outside (see **Figures 2** and **3**). The opposite of this heat flow direction is true in cooling mode. In heating applications, this is typically 65°F. So, for example, a 24-hour period that has the average temperature of 20°F has a value of 45 HDDs when the HDD base temperature is 65°F.

HDD data can be calculated in specific field locations through a number of means; however, it is usually collected from reliable weather stations maintained by organizations such as the National Oceanic and Atmospheric Administration (NOAA) or the Federal Aviation Administration (FAA). There are also several Internet-based services that provide HDD data collection services as well as HDD-based computer programs used in the fuel delivery industry to schedule delivery of heating oil and propane to tank-based heating systems. There are varying capabilities of specific weather stations to provide data. This affects the accuracy of the heating degree day calculation. For example, given the following 24-hour temperature readings and a base temperature of 65°F, depending on the calculation method, slight variations in the resulting heating degree day exist.

1-12 Hours Average Hourly Temperature	30	30	31	31	30	29	28	28	29	29	30	32
13-24 Hours Average Hourly Temperature	36	37	40	43	43	44	39	39	38	37	32	31

(Daily Average) or Hi-Low Degree Day Calculation Method – (High-Low)/2

44+28/2 = 36°F

65-36 = 29 Heating Degree Days

Whereas if the total number of temperature readings were utilized:

816/24 = 34

65-34 = 31 Heating Degree Days

In reality, weather stations that have reliable 30 minute or hourly temperature readings are not the norm, and may rely upon other approximation methods to calculate HDDs. These methods typically use numerical integration, daily maximum and minimum, or daily average temperature readings.

Johnson Degree Day Calculation Method

In the event that compensations for wind speed and solar effects in heating degree calculations are desired, these variables are addressed by the measurement of daily temperatures by the Johnson degree day method. These measurements are taken locally utilizing black-colored containers exposed to both direct sunshine and wind. The accuracy of this method may not completely align itself to the specific building's performance, however, due to differences in the actual building's construction features and that of the collection box.

Weather and Fuel Usage Provides Specific Building Consumption Needs

Once a consistent HDD system is established, the integration of fuel consumption against cumulated HDDs provides fuel delivery companies a means to gauge the need for a fuel delivery ahead of time and schedule their deliveries accordingly (**Figure 2**).

Providers of fuel for tank-based systems routinely recognize a "reserve" minimum amount of fuel in a tank to ensure that unexpected slight increases in fuel consumption between deliveries do not result in a tank running out of fuel.

Fuel providers make note during wintertime heating conditions of how much fuel is consumed in regard to the cumulative HDDs between deliveries. Identification of how many HDDs are provided (to each building) per unit of fuel results in a unit known as the K factor (**Figure 3**). The reciprocal of this value, known as the burn rate, has units of gallons per HDD.

There are many commercial computerized programs available to the fuel delivery industry that make use of the relationship between fuel consumption and HDDs. As long as the temperature being maintained in a building remains constant, these values, which are typically tracked as HDD/gallon (K factor), remain consistent throughout winter months (**Figure 4**).

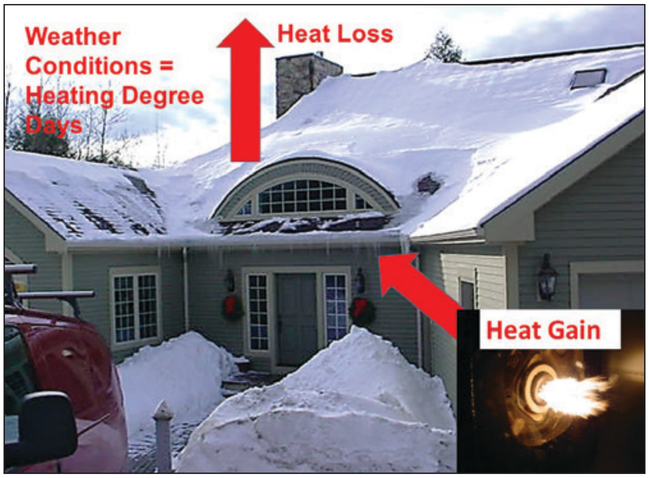


Figure 2
Heat loss and heat gain in a residential structure.

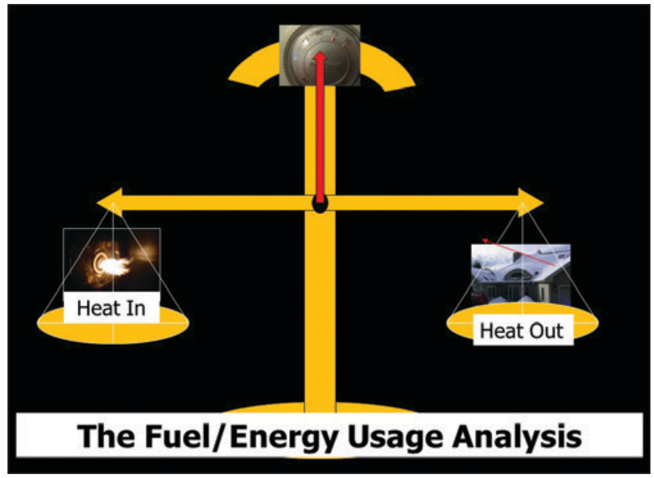


Figure 3
The balance of heat gain and heat loss to maintain temperature.

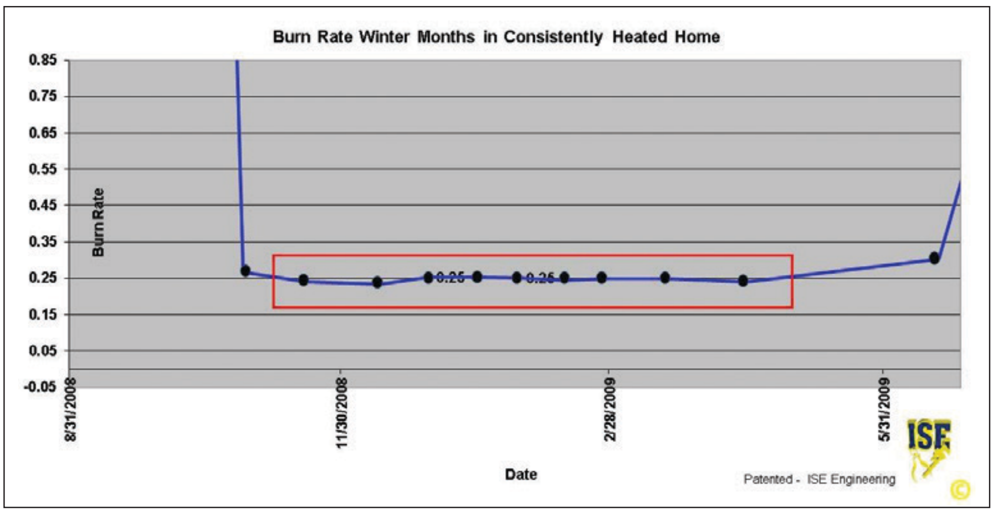


Figure 4
Author's patented fuel usage analysis method showing conditions of consistently heated home.

Using the K Factor or Burn Rate as an Investigative Tool

By examining historical consumption rates during times of known building occupancy and comparing these rates to those leading to a frozen pipe loss, insight as to the time (and potentially the cause) of the heating system inconsistency (compared to times of known operation) can be identified, such as:

- Excessive thermostat reduction
- Mechanical breakdown and utility failure
- Fuel tank runout

The use of the HDD methodology as an investigative tool relies on evaluating the building's actual performance only against itself, comparing the previous winter season's fuel consumption readings (when occupancy and temperature conditions are known) against the time when these conditions are uncertain. This procedure does not rely upon the calculation of the building's "theoretical" overall coefficient of heat transfer, nor does it apply ASHRAE or similar design calculations. The analysis measures the house's actual thermal resistance performance and not its design performance. Since unknown defects in workmanship or material performance may exist, theoretical heating system design calculations (as to how the building's heating system should perform) may not reconcile with actual "as-built" performance results.

Addressing the possibility of a *Daubert* challenge when the HDD methodology is used for analysis of fuel delivery purposes, it should be recognized that this is the standard practice of trade in the fuel delivery industry. Basing the analysis on a common methodology disputes claims of the HDD analysis basis being a rare and untested procedure. As such, it is less subject to disqualification.

Tank-Based System Delivery Practices and Calculation Adjustments

Actual amounts of fuel consumed by a structure's heating and combustion equipment are evident in natural gas or other "gas meter" measured fuel supply systems. Likewise, tank-based systems (such as propane and No. 2 fuel oil tanks), as shown in **Figure 5,** may be on an HDD delivery method where the tank is filled between deliveries; this makes fuel consumption — and hence the K factor or burn rate — self-evident. Care must be taken, however, with tank-based systems that are not on an automatic "fill-to-capacity" HDD delivery practice when calculating the building's consumption rate during winter months.

Figure 5
Typical home heating oil tank.

For various reasons, many building owners do not allow the fuel provider to use the HDD delivery method to schedule tank fillings and choose to have fuel deliveries for tank-based systems by other means. For example, some homeowners prefer fuel delivered based upon a "will call" tank gauge observation that is initiated when the tank gauge reading indicates it is near empty (**Figure 6**).

Figure 6
Heating tank gauge reading empty.

Likewise, a calendar-based schedule may be in effect that results in fuel being delivered after some number of days have passed, omitting the consideration of the degree of "coldness" in weather conditions.

Complicating this situation is the possibility that tanks may be supplied with fuel by filling them to capacity, by delivering a requested volume of fuel or by having fuel delivered based upon a final cost to the building owner.

Care must be used (when observing the amounts of fuel delivered) to make sure a list of fuel delivery dates and amounts are not confused as being HDD-based "automatic" or "fill-to-capacity" amounts when making fuel calculations. This can usually be resolved by asking the building owner or fuel provider what specific delivery method was in effect at the property.

Observing a Fair Burn Rate for "Will Call" Delivery Calculations

When a "will call" delivery practice is in effect, a schedule of fuel delivery amounts may be presented for evaluation similar to this example.

Date	Amount
November 11, 2014	100 gallons
November 21, 2014	150 gallons
December 3, 2014	100 gallons
December 16, 2014	125 gallons
December 23, 2014	125 gallons

The identification of a burn rate from a "will call" requested delivery schedule is potentially hampered by the starting point of the calculation because it may be unknown how much fuel was in the tank after the first delivery of the period being evaluated. That being said, the longer the period of multiple will call deliveries being evaluated, the less the final cumulative burn rate will vary, since a longer period is being evaluated as well as cumulative fuel consumption amounts. The question is where to start?

As shown in **Figure 7**, considering the outcome of the extreme limits of each scenario, the starting point that embraces the *known* amount of fuel delivered to the tank (at the beginning of the cycle) provides the most reasonable and accurate net outcome burn rate for the entire period.

The extreme limits of the tank being empty or full result in conditions that show either the homeowner was out of fuel or the consumption rate was excessive, providing a calculation point that will not represent actual burn rates within the home. Considering these possible burn rate scenarios, a check of tank size capabilities and identified burn rates can be performed and evaluated against subsequent fuel deliveries to determine if adequate space is present in the tank to receive newly delivered fuel amounts. For example, in the event that a low burn rate is "assumed," resulting in there being 150 gallons in a 250-capacity oil tank, then the accuracy of the lower burn rate would be disputed if a 150-gallon delivery (exceeding the tank capacity) was made.

Figure 7
"Will call" starting point.

Change in the K Factor or Burn Rate

Some insurance carriers now mandate that heat be maintained at a specific "lowest" temperature during winter months. This has been identified as being a minimum temperature of 55°F.

The importance of knowing what temperatures are being maintained applies to both the interests of a property owner as well as a contractor (who may be held liable for improper piping installation). Plumbers or insulation contractors may be blamed for a burst pipe in a susceptible framing cavity or space. It is possible, however, that the temperature maintained in the building was the major contributing factor to this event and not the manner in which the pipe was installed. Likewise, opinions regarding defects in installation can be supported if a fuel usage analysis quantifies proper heat levels being maintained. The correlation of a heating system "failure" to the date of a utility outage or other such event is dependent on knowing the actual fuel consumption rates prior to the loss. As such, verification as to what burn rate was in effect is necessary for this analysis.

The Dangers of Excessive Thermostat Setback

Public service notifications encouraging energy conservation through thermostat setback began with the oil embargos of the early 1970s and continue to this day. As a result, thermostat setback may seem like a simple and safe means for energy cost savings to the public.

An unheated water pipe installed in an exterior wall or in a ceiling abutting an attic (or other unheated building cavity) is reliant upon the heat level maintained and the insulation between it and cold unheated air. Likewise, a wrap-insulated hot water or hydronic heating water pipe that passes through an unheated space relies on frequent cycles of flowing water to prevent the water from freezing.

What's the problem with modern insulation techniques? Pipes installed in unheated building cavities share the same cavity space as the insulation filling this cavity, thereby altering the intended consistency of this same insulation within the cavity (**Figure 8**). Additionally, current use of fiberglass batting or loose fill insulation is prone to separation causing gaps, compression, and settling — all of which reduce their intended performance.

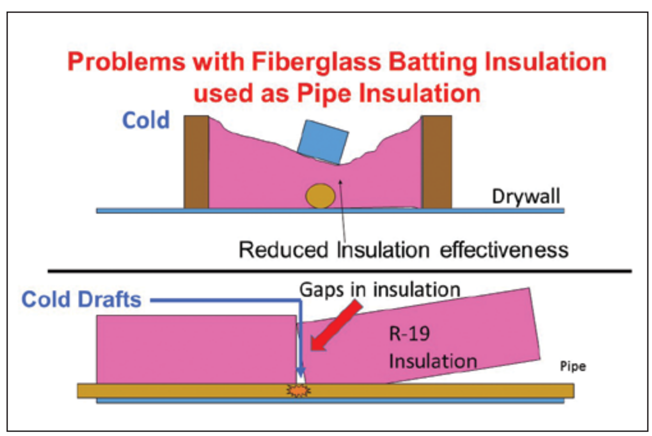


Figure 8
Typical problems with batting-type insulation.

The fastening point of the pipe is also usually on the wooden framing members within the wall cavity. This locates the pipe in the coldest portion of the wall cavity, securing it to the fastening point with the least thermal protection and in an area where the consistency of the insulation is likely at its lowest (**Figure 9**).

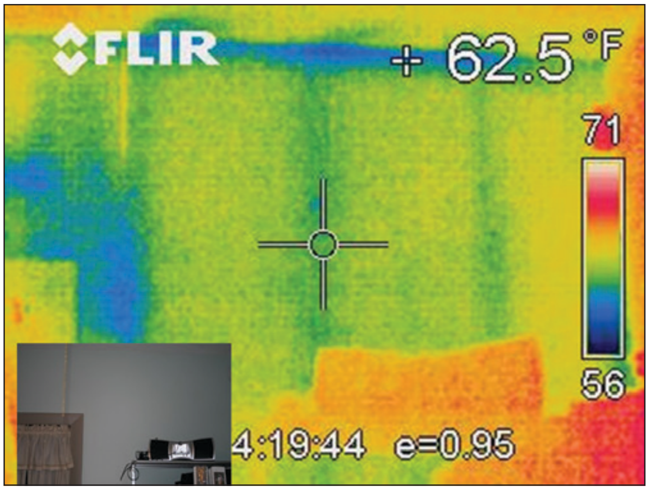


Figure 9
Thermal image of exterior wall shows poor insulation conditions at wooden frame areas. This is known as "thermal bridging."

The poor insulation qualities of the wooden framing — as well as the tendency for air gaps to be present where the insulation meets the framing — all act together to undermine the thermal integrity of the wall system and increase the chances of freezing (**Figure 10**).

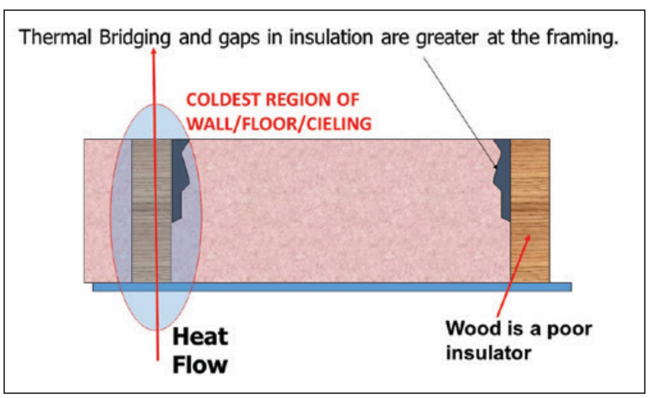


Figure 10
Thermal bridging is a combination of the poor insulating capability of wood and typical gaps where the insulation and framing meet.

All building piping configurations are different. Some may have piping located in chase ways positioned within the interior of the building, while others may have the piping installed in exterior walls or ceilings abutting unheated spaces. This results in vast discrepancies in freeze protection performance during winter months.

Complicating matters are variations in choices as to where the pipe is placed within the framing cavity, fastening methods, as well as insulation placement and thickness. Pipes placed adjacent to exterior wall sheathing are going to be less resistant to cold outdoor temperatures than pipes adjacent to interior sheathing with more insulation between the pipe and the exterior cold.

Additionally, poor details are provided in the installation guidance within the current codes. Statements like "pipes shall not be installed in any location prone to freezing unless they are protected with heat, insulation, or both", without detailing how this is done (in the various piping-insulation configurations encountered), adds to continued problems. There is also no provision for freeze protection of hydronic heating system pipes in the governing mechanical codes other than for energy conservation reasons. Finally, the lack of coordination and the "that's not MY job!" finger pointing mentality between the installing pipefitter and the insulation contractor ensures a never-ending supply of civil cases for the legal system.

When is Thermostat Setback Too Much?

Although encouraged by energy conservation efforts, excessive thermostat setback (especially in extremely cold weather) can have grave consequences.

When temperature settings are reduced, the rate of heat loss through the building wall system is also reduced. If piping is installed in these cavities, there is a corresponding reduction of heat flow and thermal inertia, diminishing the flow of heat through the wall system and reducing the ability of the pipe to overcome any pipe insulation inconsistencies.

Conductive Heat Transfer through Sandwiched Plane

Figure 11 is a theoretical wall system and analysis of conductive heat flow through a sandwiched plane. This model demonstrates a pipe's thermal conditions within an R 13 theoretical wall cavity. The term R value is a reference to the thermal resistance of insulation materials. In this example, the outdoor design temperature is 0°F, and the pipe is positioned approximately one-fourth of the way from the interior sheathing in a 2x4 typical wall construction frame that has a width of 3.5 inches. As seen in **Figure 11** as well as the corresponding table, calculations show the pipe will experience progressively colder temperatures along a linear slope due to thermostat reduction.

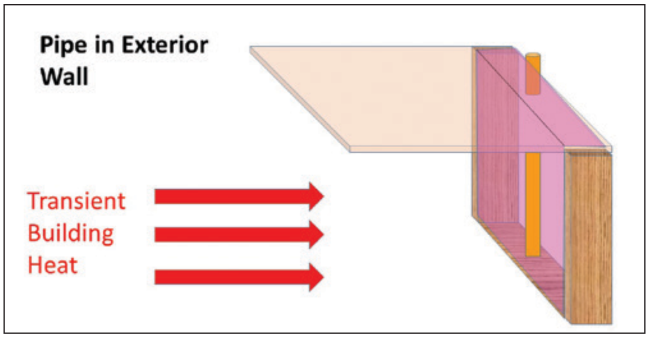


Figure 11
Pipe within theoretical exterior wall.

Inside Temperature Ti	Pipe Temperature Tp
70 degrees	54.32 degrees
65 degrees	49.28 degrees
60 degrees	44.33 degrees
55 degrees	39.32 degrees
50 degrees	34.34 degrees
45 degrees	29.33 degrees

This model also assumes uniform insulation consistencies without any defects caused by insulation compression, settling, or obstructions within the cavity. In reality, most wall systems would fall short of these calculated results, and each building has its own thermal abilities in regard to freeze protection of pipes.

Quantifying Changes in Fuel Consumption in Relation to Thermostat Changes

Various sources claim different correlations between degree of thermostat setback and fuel savings. These range from between 3 to 15 percent savings per °F of thermostat reduction.

According to *Winter Energy Savings from Lower Thermostat Settings* from the U.S. Energy Information Administration (EIA), with every degree of thermostat setback, a certain percentage of fuel savings results[3]:

Natural gas	5%
Fuel oil	4%
Kerosene	5%
Propane	5%
Electricity	6%

Since the loss of heat from an insulated structure follows a linear relationship of the **Q=UAΔT** equation (where heat flow **Q** is a factor of the overall coefficient of heat transfer **U**, the heat transfer area **A** and the difference in temperature between the high and low temperatures of the system Δ**T**), the net fuel consumption output follows a linear relationship when plotted in response to thermostat setback.

Vacant Home Study

In the late fall/early winter of 2015, the reported fuel consumption percentage relationship from the U.S. Energy Information Administration was tested in an unoccupied residential structure.

The home was a 1,750-square-foot structure built in 2001 and was supplied with natural gas. The home was heated by two identical 80,000 BTU/hour gas-fired forced hot air furnaces that did not have a standing pilot flame but rather used a hot surface igniter with intermittent ignition. Domestic hot water was supplied by a 40-gallon water heater that utilized intermittent ignition through a spark ignition system.

Gas meter readings were taken in weekly intervals where the thermostats were set at identical temperatures during periods of wintertime weather conditions. Temperature measurement periods were at thermostat settings ranging from 46°F to 65°F. For each of these weekly intervals, the amount of fuel consumed was recorded and integrated with cumulative HDDs for the interval between readings.

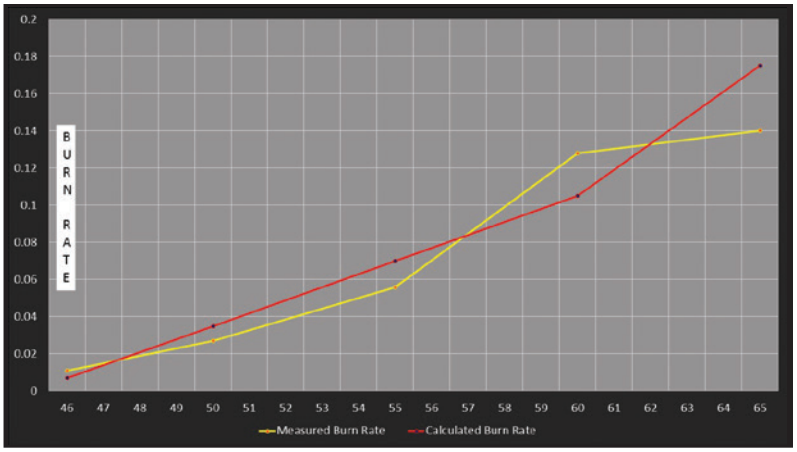
From a known burn rate (utilizing the U.S. Energy Information Administration's savings rate for natural gas of 5% per °F of thermostat setback)[3], for each of the measured gas consumption interval burn rates, the gas consumption burn rates were calculated and compared to measured rates, as shown in **Figure 12.**

Although differences of 0.004 to 0.035 resulted, these small amounts are likely attributed to the test procedure followed. This is suspected because the testing began with lower temperature settings and then moved on to higher settings, causing increased fuel to be consumed in the heating of building components – not maintaining the thermal load in an already-established thermal system.

Situation Recognition

Thermostat Setback Quantification

As seen in **Figure 13**, during a previous winter when the property was known to be occupied and no report of frozen pipes occurred, the consumption rate was 0.18 units of fuel per HDD, for a 5.5 K factor



Thermostat Settings	Measured Burn Rate	Calculated Burn Rate
46	0.011	0.007
50	0.027	0.035
55	0.056	0.07
60	0.128	0.105
65	0.14	0.175

Figure 12
Measured burn rate comparison to Department of Energy standards.

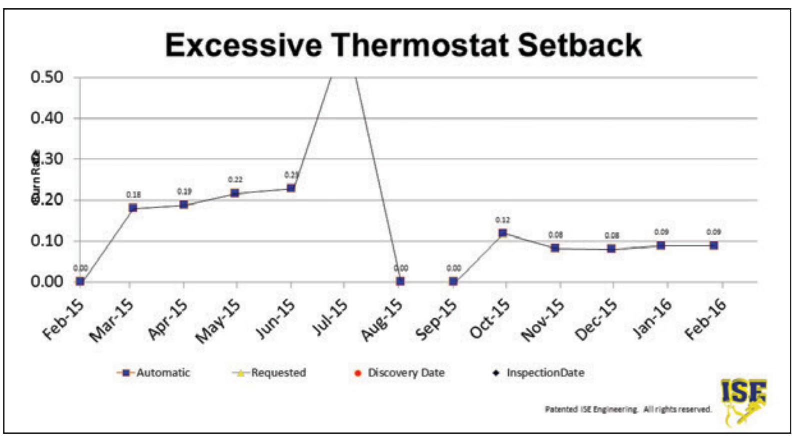


Figure 13
Fuel usage burn rates (Y-axis) showing thermostat setback.

value. Contrary to this, the following winter that burn rate fell to about 0.08 units of fuel per HDD, a difference of 44% or a 56% savings.

At the EIA thermostat setback rate for natural gas of 5% per °F of setback, this equates to a thermostat setback amount (from the previous winter's demonstrated burn rate) of 11.2°F. This is an indication that the thermostats (on average, if there were multiple thermostats) were likely set in the 58°F to 59°F range, which disputes any claim of occupancy – a common requirement for insurance coverage. Later statements from owners of the property confirmed these settings.

Example:
Natural gas DOE value for usage/degree of thermostat setback: 5%

Previous winter's occupied burn rate (thermostats @ ~70°F): 0.18 units/HDD

Current winter's burn rate: 0.08 units/HDD

0.08/0.18 = 0.44 or 44% used in comparison to last winter.

Savings of fuel = 100-44% = 56%

56%/5% = 11.2°F Thermostat Reduction

70°F – 11.2°F = 58.8°F

The same graph may also be indicative of a heating zone in a multi-zoned heating system being inoperable, which would be supported by field observations. It should also be noted that to someone only relying on quantities of fuel usage without consideration of weather conditions may not realize that this property was likely not occupied.

Meter Read Date	Therms Consumed	Calculated Burn Rate
February 9, 2015	223	Start of Calculation
March 11, 2015	230	.18
April 9, 2015	151	.19
May 8, 2015	71	.22
June 9, 2015	28	.23
July 9, 2015	9	Summer Off Scale
August 10, 2015	7	.00
September 9, 2015	6	.00
October 7, 2015	11	.12
November 6, 2015	26	.08
December 8, 2015	51	.08
January 5, 2016	54	.09
February 4, 2016	81	.09

Heat On, Hot Water Pipe Burst in Unheated Building Cavity

This example shows a situation where the fuel tank was found to be empty, and the fuel provider was targeted as being negligent. By merely looking at delivery amounts and not analyzing this data against weather conditions, it was not realized by insurance company representatives that heat in the building was not being maintained. This led to a pipe burst and the perception of there being a negligent act on the part of the fuel provider.

In **Figures 14** and **15**, both the fuel usage analysis graph and the system diagram show the effects of a hydronic heating system pipe break. The loss of heated water while being resupplied with cold make-up water causes accelerated fuel consumption.

Idle Boiler or Furnace

Patterns in the trends of fuel consumption over time may also identify conditions indicative of inoperable equipment.

Water-bearing appliances that maintain a minimum temperature, such as a water heater or boiler, will consume fuel while idle. These appliances are not intended to be shut down entirely since condensation and contraction extremes may damage them. The number of standing pilot gas-fired appliances a home has, as well as the adjustment of the pilot flame, determines how much gas a home may consume for pilot flame usage. Measurements have been made where a 1,000 BTU quantity of natural gas is consumed in a single appliance in between 45 and 90 minutes. At approximately 540 hours per month, this equates to about 540,000 BTU per month or 5.4 Therms per month.

As seen in **Figure 16**, the fuel usage burn rates show the heating system capable of operating; however, the usage rates do not show that heat is being supplied to the building. This type of failure is indicative of the thermostats being turned off or some interruption of boiler hydronic water or furnace heated air flow.

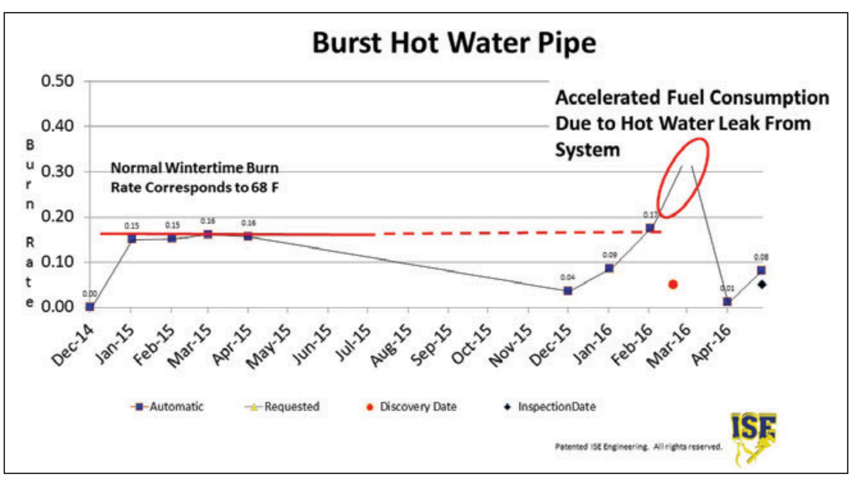


Figure 14
Fuel usage burn rates showing hot water pipe burst.

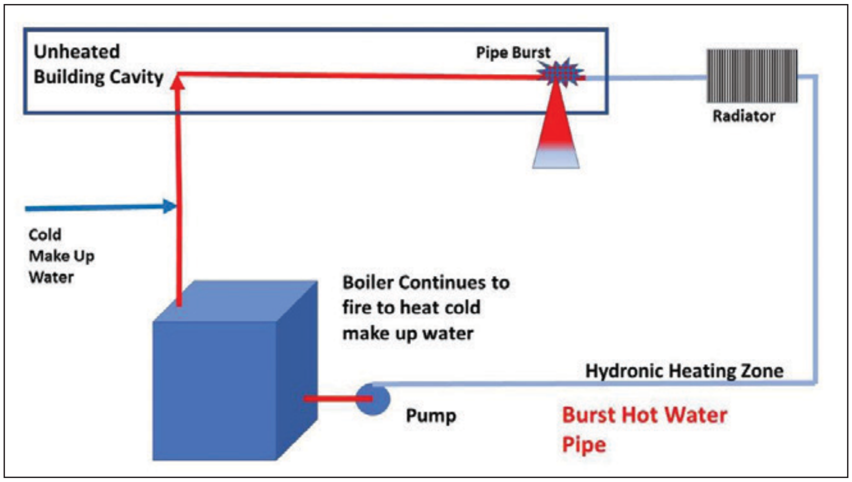


Figure 15
Hydronic heating system pipe break results in accelerated fuel consumption.

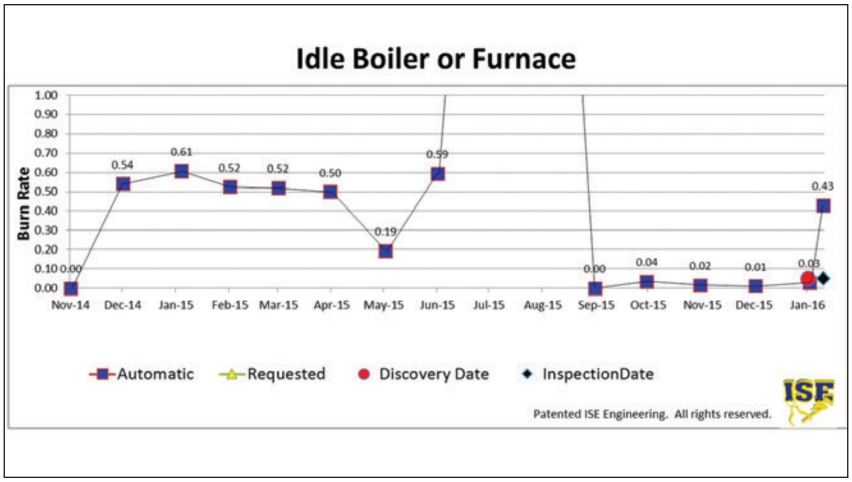


Figure 16
Fuel usage burn rates showing idle boiler or furnace prior to failure.

Meter Read Date	Therms Consumed	Burn Rate Calculated
February 10, 2015	600	.52
March 10, 2015	614	.52
April 9, 2015	420	.50
May 11, 2015	69	.19
June 10, 2015	88	.59
July 10, 2015	79	Summer Off Scale
August 11, 2015	4	Summer Off Scale
September 9, 2015	4	.00
October 9, 2015	4	.04
November 9, 2015	5	.02
December 11, 2015	7	.01
January 11, 2016	21	.03
January 19, 2016	123	.43

Domestic Hot Water Consumption Adjustment to Fuel Usage

Identification of domestic hot water needs and the associated impact on fuel consumption can be identified through the fuel usage analysis specifically for a home by using the summer gas meter readings or "end of heating season" for tank-based delivery amounts. With tank-based systems such as LP gas or heating oil, if these tanks are supplied on a delivery basis that fills the tank to its maximum capacity, the "end of summer" tank volume delivered helps to provide this value.

By identifying the amount of fuel used between the end of the previous heating season and the beginning of the following heating season — and then factoring this against the identified wintertime burn rate — the amount of fuel used for the last remnants of the previous winter (when heat was needed) can be identified. If this number is subtracted from the total fuel consumed during this period, this identifies the amount of fuel used for domestic hot water usage.

Using this volume of fuel, the total number of days between the end of heating season and the delivery of fuel prior to the start of the next heating season identifies the gallons of fuel per day per household. Dividing this value by the number of people in the home then identifies the gallons of fuel used per person per day for domestic hot water usage. This methodology can be hampered for fuel-consuming "luxury" appliances such as spas or swimming pool heaters unless consistency in their use is assumed.

Does Domestic Hot Water Usage Affect the Building's Burn Rate?

If the building's burn rate between deliveries is known and the building is assumed to be unoccupied, the effect of domestic water usage on the burn rate can be calculated by adding that period's fuel consumption amount to the amount of fuel that would have been used based upon that building's occupancy and the number of days in question. Typically, single occupancy home domestic fuel usage does not alter the burn rate past the thousands of a decimal point whereas a four-person-occupied structure may change it three one hundredths (0.03) of the burn rate.

Example:

Buildings winter time burn rate: 0.25 gallons/HDD

11 May 2016 – 7 October 2016 = 149 calendar days: 170 HDDs

Fuel used between 11 May 2016 – 7 October 2016: 124 gallons

Home housed 4 occupants

170 HDD @ 0.25 gallons/HDD = 42.5 gallons used for heat

124 – 42.5 = 81.5 gallons of fuel used for domestic hot water

81.5 gallons fuel / 149 days = 0.54 gallons per day per household

0.54 gallons/day/household (4 persons) / 4 persons = 0.136 gallons fuel/day/person for domestic hot water usage

The Effect on Burn Rate

For the period in question (March 7-31, 2016) 24 days, 108.75 gallons delivered, 435 HDD, burn rate 0.25 gallons/HDD (Occupied)

Full Household (4 People)

24 days x 0.54 gallons (4 people) = 12.96 gallons

108.75 gallons – 12.96 gallons = 95.79 gallons of fuel used for heat

95.79 gallons/435 HDD = 0.22 gallons/HDD burn rate drop for 4 person household due to non-occupancy

A change of 0.03 gallons/HDD from identified normal occupied homes burn rate

Only one Occupant in Same House

24 x 0.136 = 3.26 gallons

108.75 – 3.26 = 105.49 gallons of fuel used for heat

105.49 gallons/435 HDD = 0.243 gallons/HDD: little perceptible change

Different reports of occupancy numbers and dates can be used to apply this correction factor on a case-by-case basis.

Conclusion

Typically, from past investigations, most homes and buildings that experience frozen pipe damage are vacant or not visited on a frequent basis. This makes eyewitness, first-hand observations of daily transitions into a frozen pipe event rare.

Forensic engineers have the ability to identify occupancy and heating system time events and conditions independent of what they are told by various parties involved in the loss. Fuel usage analysis data can also support or dispute conclusions resulting from only an examination of the mechanical component evidence. The investigator must realize that what he or she may be told by a property owner, fuel delivery company, or heating system repair technician may all be potentially self-serving and not be true.

The identification of reasonable fuel consumption rates in relation to building performance, as well as the ability to quantify deviations from known baseline rates, is a vital tool to the forensic engineer in evaluating these types of losses. The ability to identify conditions such as fuel tank runout, system breakdown, excessive thermostat setback, and utility failure all require that a representative consumption rate of fuel for the building (leading to the loss date) be identified. Deviations from known consumption rates must also be recognized as to their meaning and quantified to identify their implication of changes in temperatures or the time period in which the heating system is in operation.

Since frozen pipes are a leading cause of building damage in the United States, a focused investigation procedure for these types of losses is vital as well as the ability to derive useful information from property fuel and energy usage. The reconciliation of an energy analysis with field statements and findings can be a reliable methodology in which confidence in an investigation outcome can be achieved; therefore, the ability to correlate fuel usage to identifiable, real-world implications is vital for the forensic engineer.

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