**Workpaper WPSDGENRWH1202**

**Revision 0**

**San Diego Gas & Electric**

**Energy Efficiency Engineering**

**Pipe insulation**

**(Non-Space Conditioning)**

Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| Revision No. | Date | **Description** | **Author** |
| 0 | June 15, 2012 | Adopted from SCGWP110812A\_Rev2\_Pipe Insulation.docx, updated August 15, 2011. | Chan Paek (SCG) |
| Revised NTG per DEER 2011 | Peter Ford (SDGE) |

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Measure Summary Table 1 – Small Commercial, Pipe Insulation

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Measure Name | CZ | Measure Electric End Use Shape (Load Shape) | EUL or RUL | NTG | Unit Definition | Program Type (NEW, ROB, RET) | Incremental Measure Cost ($/unit) | Gas  Savings (Therms) | Gross Unit Annual Electricity Savings (kWh/unit) | User Entered kW Savings per unit (kW/unit) | % Eligible for TOU AC  Adjustment | Gross  Realization Rate (GRR) |
| Hot Water | | | | | | | | | | | | |
| <1" Pipe | All | N/A | 11 | 0.6 | Linear Foot | RET | $5.22 | 3.3 | N/A | N/A | N/A | 1.00 |
| ≥1" Pipe | All | N/A | 11 | 0.6 | Linear Foot | RET | $5.22 | 5.9 | N/A | N/A | N/A | 1.00 |
| Steam, <15 psig | | | | | | | | | | | | |
| <1" Pipe | All | N/A | 11 | 0.6 | Linear Foot | RET | $5.22 | 5.5 | N/A | N/A | N/A | 1.00 |
| ≥1" Pipe | All | N/A | 11 | 0.6 | Linear Foot | RET | $5.22 | 10.1 | N/A | N/A | N/A | 1.00 |
| Steam, ≥15 psig | | | | | | | | | | | | |
| <1" Pipe | All | N/A | 11 | 0.6 | Linear Foot | RET | $5.22 | 8.9 | N/A | N/A | N/A | 1.00 |
| ≥1" Pipe | All | N/A | 11 | 0.6 | Linear Foot | RET | $5.22 | 16.3 | N/A | N/A | N/A | 1.00 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |

Measure Summary Table 2 – Small Commercial, Fitting Insulation

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Measure Name | CZ | Measure Electric End Use Shape (Load Shape) | EUL or RUL | NTG | Unit Definition | Program Type (NEW, ROB, RET) | Incremental Measure Cost ($/unit) | Gas  Savings (Therms) | Gross Unit Annual Electricity Savings (kWh/unit) | User Entered kW Savings per unit (kW/unit) | % Eligible for TOU AC  Adjustment | Gross  Realization Rate (GRR) |
| Hot Water | | | | | | | | | | | | |
| <1" Pipe | All | N/A | 11 | 0.6 | Each Fitting | RET | $7.80 | 0.9 | N/A | N/A | N/A | 1.00 |
| ≥1" Pipe | All | N/A | 11 | 0.6 | Each Fitting | RET | $8.73 | 2.4 | N/A | N/A | N/A | 1.00 |
| Steam, <15 psig | | | | | | | | | | | | |
| <1" Pipe | All | N/A | 11 | 0.6 | Each Fitting | RET | $8.13 | 1.4 | N/A | N/A | N/A | 1.00 |
| ≥1" Pipe | All | N/A | 11 | 0.6 | Each Fitting | RET | $8.40 | 3.8 | N/A | N/A | N/A | 1.00 |
| Steam, ≥15 psig | | | | | | | | | | | | |
| <1" Pipe | All | N/A | 11 | 0.6 | Each Fitting | RET | $8.13 | 2.3 | N/A | N/A | N/A | 1.00 |
| ≥1" Pipe | All | N/A | 11 | 0.6 | Each Fitting | RET | $8.40 | 6.1 | N/A | N/A | N/A | 1.00 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |

Measure Summary Table 3 – Large Commercial, Pipe Insulation

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Measure Name | CZ | Measure Electric End Use Shape (Load Shape) | EUL or RUL | NTG | Unit Definition | Program Type (NEW, ROB, RET) | Incremental Measure Cost ($/unit) | Gas  Savings (Therms) | Gross Unit Annual Electricity Savings (kWh/unit) | User Entered kW Savings per unit (kW/unit) | % Eligible for TOU AC  Adjustment | Gross  Realization Rate (GRR) |
| Hot Water | | | | | | | | | | | | |
| <1" Pipe | All | N/A | 11 | 0.6 | Linear Foot | RET | $5.22 | 5.9 | N/A | N/A | N/A | 1.00 |
| ≥1" Pipe | All | N/A | 11 | 0.6 | Linear Foot | RET | $5.22 | 10.7 | N/A | N/A | N/A | 1.00 |
| Steam, <15 psig | | | | | | | | | | | | |
| <1" Pipe | All | N/A | 11 | 0.6 | Linear Foot | RET | $5.22 | 9.9 | N/A | N/A | N/A | 1.00 |
| ≥1" Pipe | All | N/A | 11 | 0.6 | Linear Foot | RET | $5.22 | 18.2 | N/A | N/A | N/A | 1.00 |
| Steam, ≥15 psig | | | | | | | | | | | | |
| <1" Pipe | All | N/A | 11 | 0.6 | Linear Foot | RET | $5.22 | 16.0 | N/A | N/A | N/A | 1.00 |
| ≥1" Pipe | All | N/A | 11 | 0.6 | Linear Foot | RET | $5.22 | 29.4 | N/A | N/A | N/A | 1.00 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |

Measure Summary Table 4 – Large Commercial, Fitting Insulation

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Measure Name | CZ | Measure Electric End Use Shape (Load Shape) | EUL or RUL | NTG | Unit Definition | Program Type (NEW, ROB, RET) | Incremental Measure Cost ($/unit) | Gas  Savings (Therms) | Gross Unit Annual Electricity Savings (kWh/unit) | User Entered kW Savings per unit (kW/unit) | % Eligible for TOU AC  Adjustment | Gross  Realization Rate (GRR) |
| Hot Water | | | | | | | | | | | | |
| <1" Pipe | All | N/A | 11 | 0.6 | Each Fitting | RET | $7.80 | 1.7 | N/A | N/A | N/A | 1.00 |
| ≥1" Pipe | All | N/A | 11 | 0.6 | Each Fitting | RET | $8.73 | 4.3 | N/A | N/A | N/A | 1.00 |
| Steam, <15 psig | | | | | | | | | | | | |
| <1" Pipe | All | N/A | 11 | 0.6 | Each Fitting | RET | $8.13 | 2.5 | N/A | N/A | N/A | 1.00 |
| ≥1" Pipe | All | N/A | 11 | 0.6 | Each Fitting | RET | $8.40 | 6.9 | N/A | N/A | N/A | 1.00 |
| Steam, ≥15 psig | | | | | | | | | | | | |
| <1" Pipe | All | N/A | 11 | 0.6 | Each Fitting | RET | $8.13 | 4.1 | N/A | N/A | N/A | 1.00 |
| ≥1" Pipe | All | N/A | 11 | 0.6 | Each Fitting | RET | $8.40 | 11.0 | N/A | N/A | N/A | 1.00 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |

Measure Summary Table 5 – Industrial, Pipe Insulation

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Measure Name | CZ | Measure Electric End Use Shape (Load Shape) | EUL or RUL | NTG | Unit Definition | Program Type (NEW, ROB, RET) | Incremental Measure Cost ($/unit) | Gas  Savings (Therms) | Gross Unit Annual Electricity Savings (kWh/unit) | User Entered kW Savings per unit (kW/unit) | % Eligible for TOU AC  Adjustment | Gross  Realization Rate (GRR) |
| Hot Water | | | | | | | | | | | | |
| <1" Pipe | All | N/A | 11 | 0.6 | Linear Foot | RET | $5.22 | 10.5 | N/A | N/A | N/A | 1.00 |
| ≥1" Pipe | All | N/A | 11 | 0.6 | Linear Foot | RET | $5.22 | 18.9 | N/A | N/A | N/A | 1.00 |
| Steam, <15 psig | | | | | | | | | | | | |
| <1" Pipe | All | N/A | 11 | 0.6 | Linear Foot | RET | $5.22 | 17.6 | N/A | N/A | N/A | 1.00 |
| ≥1" Pipe | All | N/A | 11 | 0.6 | Linear Foot | RET | $5.22 | 32.2 | N/A | N/A | N/A | 1.00 |
| Steam, ≥15 psig | | | | | | | | | | | | |
| <1" Pipe | All | N/A | 11 | 0.6 | Linear Foot | RET | $5.22 | 28.4 | N/A | N/A | N/A | 1.00 |
| ≥1" Pipe | All | N/A | 11 | 0.6 | Linear Foot | RET | $5.22 | 52.0 | N/A | N/A | N/A | 1.00 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |

Measure Summary Table 6 – Industrial, Fitting Insulation

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Measure Name | CZ | Measure Electric End Use Shape (Load Shape) | EUL or RUL | NTG | Unit Definition | Program Type (NEW, ROB, RET) | Incremental Measure Cost ($/unit) | Gas  Savings (Therms) | Gross Unit Annual Electricity Savings (kWh/unit) | User Entered kW Savings per unit (kW/unit) | % Eligible for TOU AC  Adjustment | Gross  Realization Rate (GRR) |
| Hot Water | | | | | | | | | | | | |
| <1" Pipe | All | N/A | 11 | 0.6 | Each Fitting | RET | $7.80 | 3.0 | N/A | N/A | N/A | 1.00 |
| ≥1" Pipe | All | N/A | 11 | 0.6 | Each Fitting | RET | $8.73 | 7.6 | N/A | N/A | N/A | 1.00 |
| Steam, <15 psig | | | | | | | | | | | | |
| <1" Pipe | All | N/A | 11 | 0.6 | Each Fitting | RET | $8.13 | 4.5 | N/A | N/A | N/A | 1.00 |
| ≥1" Pipe | All | N/A | 11 | 0.6 | Each Fitting | RET | $8.40 | 12.2 | N/A | N/A | N/A | 1.00 |
| Steam, ≥15 psig | | | | | | | | | | | | |
| <1" Pipe | All | N/A | 11 | 0.6 | Each Fitting | RET | $8.13 | 7.3 | N/A | N/A | N/A | 1.00 |
| ≥1" Pipe | All | N/A | 11 | 0.6 | Each Fitting | RET | $8.40 | 19.5 | N/A | N/A | N/A | 1.00 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |

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1. General Measure & Baseline Data

Measure & Delivery Description

* + 1. Many commercial and industrial customers – particularly smaller, hard to reach businesses – configure piping systems with sub-optimal amounts of insulation. This measure addresses cost-effective energy efficiency opportunities in the pipe insulation area, and encompasses both fiberglass and heavier duty insulation systems such as Perlite and rigid phenolic insulation. Pipe insulation applications in the industrial sector include brine, plating solutions, steam, condensate, hot water, chilled water, and refrigerant; in the commercial sector they include steam, hot water, chilled water, and refrigerant.
    2. Market Applicibility
       1. Although the payback is short, experience shows that many customers are not installing pipe insulation, perhaps due to a general lack of awareness of the potential energy savings from pipe insulation. The incentives described in this measure are expected to stimulate adoption primarily due to increased awareness, although the incentives also reduce economic barriers.
       2. These measures are applicable to any small or medium commercial or industrial pipe insulation retrofit (i.e., non new construction) application. They cannot be used for residential purposes.
  1. Terms & Conditions
     1. A minimum of 1 inch of insulation must be added to existing bare commercial or industrial steel pipe system applications.
     2. For pipe insulation, the bare pipe size must be 1/2 inch or larger.
     3. The following types of applications are not eligible.
        1. New construction and new pipe system replacement.
        2. Application of the pipe insulation to hot water piping covered by current CA Title 24 and OSHA Standard.
        3. Replacement of existing damaged insulation where the heat loss of a system is unknown.
        4. Residential buildings or fluid used for space heating.
     4. The following information must be provided.
        1. Fluid type.
        2. Pressure of the steam.
        3. The length of insulation to be installed at each pipe size.
        4. Annual boiler operating hours.
        5. Name of the manufacturer.
        6. Insulation material type.
        7. The material K-value or the manufacturer’s specification sheets.

DEER Differences Analysis

These specific measure energy saving results and calculation method are not included in the Database for Energy Efficient Resources (DEER) . However, the EUL, and other values used in this work paper are based on available information in DEER 2008. NTG is based on DEER 2011.

Code Analysis

* + 1. Application of the pipe insulation to hot water piping covered by current CA Title 24 and OSHA Standard is not qualified.

Measure Effective Useful Life

* + 1. EUL, for these measures is listed in the CPUC DEER EUL tables. Its, identifies as having a 11-year life for gas water heater and a life of 13 years for electric water heater. A value of 11 years is used in this work paper as the recommended life of pipe insulation.[[1]](#endnote-1)

Net-to-Gross Ratios for Different Program Strategies

* + 1. The Net-to-Gross ratio for this measure was obtained from the DEER 2011 NTG Tables.[[2]](#endnote-2)

Gross Realization Rate

* + 1. Gross realization rate of 1.00 was applied to measures in this document.

Time-of-Use Adjustment Factor

* + 1. N/A

1. Energy Savings & Demand Reduction Calculations

Load Shapes

* + 1. N/A

Energy Savings

* + 1. Savings are based on installing insulation[[3]](#endnote-3) on bare pipes and fittings. The energy savings that will be achieved depend upon pipe parameters, insulation parameters, boiler efficiency, annual operating hours, and other parameters such as fluid properties and ambient temperature. The energy savings results are expressed per linear foot (LF) of straight pipe or per fitting.
    2. **Pipe Parameters** – Steam and hot water pipe sizes ranging from ½ inch to 4 inches are commonly seen in commercial and industrial facilities. Pipe sizes were divided into two ranges: 1-inch or less, and greater than 1-inch. The physical dimensions of a Schedule-40 standard pipe size of ¾-inch were selected to represent ½-inch, ¾-inch, and 1-inch pipe sizes. The 2006-2008 program evaluation effort found that the average pipe diameter for pipes whose diameter was greater than 1 inch was 1.7 inches. Therefore, the physical dimensions of 1.5-inch and 2-inch Schedule-40 standard pipe sizes were interpolated to represent pipe sizes larger than 1-inch. The thermal conductivity and surface emittance of black steel pipe were applied in all cases. The thermal conductivity of steel (314.4 Btu-in/hr-ft2-F or 26.2 Btu/hr-ft/F) is required to calculate the outside wall temperature of the steel pipe. In addition, the radiation from the bare pipe surface is characterized by an emittance of 0.94.
    3. **Insulation Parameters** – Acceptable types of pipe insulation for hot water pipes include polyethylene foam (up to 180 °F), UV-resistant polyethylene foam, and elastomer foam rubber. Acceptable types of insulation for steam pipes include silicone foam rubber (to 425 °F), melamine foam (to 400 °F), rigid urethane-based foam (to 300 °F, cellular glass (to 400 °F), fiberglass, and mineral wool. The protection offered by jacketing is also recommended, especially outdoors. Only some jacket materials are suitable for outdoor use, such aluminum, UV-resistant PVC, and paints. The parameters used to describe the insulation (thermal conductivity, surface emittance) are generally based on prefabricated 1-inch thick fiberglass pipe insulation with paper or aluminum wrap (paper for indoor locations and aluminum for outdoor locations). The energy savings analysis is based on adding 1-inch thick insulation around bare Schedule 40 black steel pipe. In addition to insulation thickness, it is necessary to know the thermal conductivity of the insulation and the thermal radiation emittance of the insulation wrap. The thermal conductivity of pipe insulation varies somewhat by material and temperature rating. Based on two sources (ASHRAE Handbook and McMaster-Carr catalog, a thermal conductivity value of 0.29 Btu-in / hr-ft2-°F (0.024 Btu/hr-ft-°F) was chosen for both hot water and steam pipe. In addition, the insulation surface participates in radiative heat transfer. Pipe insulation used indoors typically has a paper wrap (with an emittance of about 0.9) and pipe insulation used outdoors typically has an aluminum wrap (with an emittance of about 0.1). These emittances are not critical parameters, since the heat loss is not very sensitive to radiative heat loss from the rather cool surface of the insulation, and average value of 0.5 was applied.
    4. **Boiler Efficiency** – To calculate the natural gas energy savings from insulating bare hot water and steam pipes, it is necessary to have an estimate of the thermal efficiency of the hot water or steam generation boiler. To determine representative boiler efficiencies, data from the California Energy Commission (CEC) was examined. CEC lists several hundred steam boilers, and these boilers were divided into four groups:
       1. ≤ 2 MMBtuh (hot water only)
       2. 2-10 MMBtuh (hot water only)
       3. ≤ 2 MMBtuh (steam only)
       4. 2-10 MMBtuh (steam only)
    5. The CEC results for hot water boilers are plotted in Figure 1 and Figure 2. As shown in both figures, a relatively large number of boilers are rated at 80% thermal efficiency. The combustion efficiency is assumed to be 2% higher than the overall thermal efficiency. Based on these data, a combustion efficiency value of 82% was used to compute the cost of hot water generation.
    6. The CEC results for steam boilers are plotted in Figure 3 and Figure 4. As shown in both figures, most boilers are rated to be in the range of 80% to 82% efficiency. Based on these data, a combustion efficiency value of 83% was used to compute the cost of steam generation.



1. CEC Efficiency Data (Hot Water Boilers ≤ 2 MMBtuh)



1. CEC Efficiency Data (Hot Water Boilers 2-10 MMBtuh)



1. CEC Efficiency Data (Steam Boilers ≤ 2 MMBtuh)



1. CEC Efficiency Data (Steam Boilers 2-10 MMBtuh)
   * 1. **Annual Operating Hours and Other Assumptions** – Commercial establishments might operate their steam system anywhere from about 2,000 hours per year (8 hours/day, 5 days/week) to about 6,000 hours per year (16 hours/day, 7 days/week).
        1. The annual operating time for small commercial steam and hot water systems is based on the average operating time of small commercial dry cleaners establishments. Based on a survey performed in Southern California by kW Engineering, the average annual operating time for the small commercial category is 2,425 hours per year.
        2. Operating hours also vary for large commercial applications such as lodging facilities, schools, prisons, office buildings, and dry cleaners serving industrial customers. Based on an operating schedule of 12 hours per day for 365 days per year, an annual operating time of 4,380 hours was adopted.
        3. Actual operating hours of industrial steam and hot water system vary depending on end-use applications, boiler size, and seasonal variations. Also, not every pipe in the system operates for the same number of hours in a year, but most large plants keep the system operating essentially all the time. In this workpaper, the basis used for annual operating hours is large plants that nominally operate 24 hour per day, 7 days per week, except that the majority of the hot water or steam system is assumed to be unheated for a total of six weeks per year to allow for scheduled and unscheduled maintenance activities, implying a total of 7,752 hours per year at normal operating temperature.
     2. To determine the energy savings, additional assumptions were made concerning the pressure, temperature, and average velocity of the hot water and steam inside the pipe; the average ambient temperature; and the average speed of the air moving past the pipe.
        1. The average steam pressure was calculated using an Enbridge survey of steam traps. For this workpaper, the Enbridge data was divided into two pressure groups: ≤ 15 psig and > 15 psig. As shown in Table 1, the average steam pressure for the two groups was calculated by weighting each pressure by the number of leaking traps. For each pressure category, the weighted average is the sum of the average pressure in the range times the number of traps in the range, divided by the sum of the number of traps in the range. The resulting values for the low-and medium-pressure categories are 10.9 and 85.9 psig, respectively.
        2. The temperature ranges of the hot water and low-pressure steam are specified in the 2006 Express Efficiency Rebate Program brochure and are listed in Table 2. Based on Energy Division recommendations, the temperature of the hot water was assumed to be 150 °F. The temperatures of the low-pressure and medium-pressure steam correspond to the saturated temperatures of water at the average steam pressures obtained above, which are 241 °F and 328 °F.
        3. The flow velocity is needed to calculate the pipe inside wall temperature; it is usually based on considerations of pressure drop due to pipe friction. A typical water flow speed of 10 ft/s and a typical steam flow speed of 100 ft/s are assumed. These are not critical parameters, since the heat loss is not very sensitive to fluid velocity inside the pipe.
        4. The Energy Division recommends are ambient temperature of 75 °F. ASHRAE uses an air speed of 7.5 mph for their calculations of the recommended thicknesses for pipe insulation, which is followed here.

Table 1 - Average Steam Pressure Calculation

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Pressure range (psig)** | **Number of Steam Traps** | **Average Pressure in Range (psig)** | **(Average pressure) X (Number in Range)** | **Average Pressure in Category (psig)** |
| Low Pressure (≤ 15 psig) | | | | |
| <5 | 234 | 2.5 | 585 | **10.9** |
| 5 | 0 | 5 | 0 |
| 6 to 9 | 24 | 7.5 | 180 |
| 10 | 515 | 10 | 5150 |
| 11 to 14 | 249 | 12.5 | 3112.5 |
| 15 | 517 | 15 | 7755 |
| Medium Pressure (> 15 psig) | | | | |
| 16 to 19 | 37 | 17.5 | 647.5 | **85.9** |
| 20 | 28 | 20 | 560 |
| 25 | 33 | 25 | 825 |
| 30 | 73 | 30 | 2190 |
| 40 | 61 | 40 | 2440 |
| 50 | 26 | 50 | 1300 |
| 60 | 60 | 60 | 3600 |
| 61 to 99 | 175 | 80 | 14000 |
| 100 | 45 | 100 | 4500 |
| 101 to 124 | 117 | 112.5 | 13162.5 |
| 125 | 14 | 125 | 1750 |
| 150 | 54 | 150 | 8100 |
| 200 | 2 | 200 | 400 |
| 250+ | 26 | 425 | 11050 |

Table 2 - Fluid Temperature Specification and Assumptions

|  |  |  |
| --- | --- | --- |
| **Working Fluid** | **Fluid Temperature (°F)** | |
| Specification | Used in Analysis |
| Hot Water | 120-200 | 150 |
| Low-Pressure Steam | 200-250 | 241 |
| Medium-Pressure Steam | 250-500 | 328 |

* + 1. **Annual Energy Savings** – The annual energy savings attributed to the installation of pipe insulation was calculated based on the operating time, steam boiler efficiency, and reduction in heat loss. The complete heat loss calculations for straight pipe are included in Attachment #4 [[4]](#endnote-4)and for pipe fittings are included in Attachment #6[[5]](#endnote-5). The calculations included the following heat transfer mechanisms:
       1. Turbulent forced convection heat transfer inside the pipe or fitting
       2. Steady conduction through the pipe or fitting wall and through the insulation
       3. Forced convection around a horizontal cylindrical pipe or fitting if the pipe or fitting is bare and around the insulation if the pipe or fitting is insulated
       4. Radiation from the pipe or fitting surface if the pipe or fitting is bare and from the insulation surface if the pipe or fitting is insulated
    2. Due to the radiation, the heat transfer from the bare pipe, fitting, or insulation is a non-linear function of temperature. In the heat transfer calculations in Attachments #4 and #6, an iterative scheme was used to converge on the temperature of the outer surface of the bare pipe or insulation. With careful choice of initial conditions, satisfactory convergence was achieved in ten iterations for each.
    3. Pipe fittings include elbows, tees, valves, unions, flanges, reducers, bushings, couplings, and more. The pipe fittings were modeled as a piece of straight pipe with the length of a tee and with the outer dimensions of the elbow and tee.
    4. The annual energy saved by pipe insulation can be calculated as follows:
       1. ∆Q = 0.00001 x T x (Qp - Qi) / Eb Eqn-1
          1. ∆Q – Energy Saved (therms/yr/LF), as a result of installing the pipe insulation.
          2. T – Scheduled Operating Time (hrs/yr). The scheduled operating time represents the time that gas boiler is expected to be in operation. Hours when the equipment is shut down are not included.
          3. Qp – Heat Loss from Bare Pipe (Btu/hr/LF)
          4. Qi – Heat Loss from Insulated Pipe (Btu/hr/LF)
          5. Eb – Efficiency (%) of the boiler being used to generate the hot water or steam in the pipe.
    5. The calculated energy savings for all 36 categories (three business sectors, one hot water and two steam pressures, small and large pipe size, straight pipe and pipe fittings) are shown in the tables below.

Table 3 - Key Parameters for Small Commercial Pipe Insulation

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Hot Water** | | **Low-pressure Steam (0-15 psig)** | | **Medium-pressure Steam (>15 psig)** | |
| Pipe Size (inch) | ≤1" | >1" | ≤1" | >1" | ≤1" | >1" |
| Insulation Thickness (inch) | 1 | 1 | 1 | 1 | 1 | 1 |
| Average Steam Pressure (psig) | --- | --- | 10.9 | 10.9 | 85.9 | 85.9 |
| Temperature, Fluid in Pipe (F) | 150 | 150 | 241 | 241 | 328 | 328 |
| Operating Time (hrs/yr) | 2,425 | 2,425 | 2,425 | 2,425 | 2,425 | 2,425 |
| Pipe Parameters |  |  |  |  |  |  |
| Pipe Size for Heat Loss Calculations (inch) | 0.75 | 1.7 | 0.75 | 1.7 | 0.75 | 1.7 |
| Outer Diameter, Pipe, Actual (in.) | 1.05 | 2.09 | 1.05 | 2.09 | 1.05 | 2.09 |
| Heat Loss, Bare Pipe (Btu/hr-LF) | 121 | 216 | 203 | 369 | 325 | 591 |
| Heat Loss, Bare Pipe (therm/yr/LF) | 2.9 | 5.2 | 4.9 | 8.9 | 7.9 | 14.3 |
| Insulation Parameters |  |  |  |  |  |  |
| Outer Diameter, Insulation (in.) | 3.05 | 4.09 | 3.05 | 4.09 | 3.05 | 4.09 |
| Average Heat Loss, Insulation (Btu/hr-LF) | 9.9 | 15.5 | 14.7 | 23.7 | 21.4 | 34.5 |
| Average Heat Loss, Insulation (therm/yr/LF) | 0.2 | 0.4 | 0.4 | 0.6 | 0.5 | 0.8 |
| Annual Energy Savings |  |  |  |  |  |  |
| Boiler Efficiency (%) | 82% | 82% | 83% | 83% | 83% | 83% |
| Annual Gas Savings (therms/year/LF) | 3.3 | 5.9 | 5.5 | 10.1 | 8.9 | 16.3 |

Table 4 - Key Parameters for Small Commercial Pipe Fittings Insulation

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Hot Water** | | **Low-pressure Steam (0-15 psig)** | | **Medium-pressure Steam (>15 psig)** | |
| Pipe Size (inch) | ≤1" | >1" | ≤1" | >1" | ≤1" | >1" |
| Insulation Thickness (inch) | 1 | 1 | 1 | 1 | 1 | 1 |
| Average Steam Pressure (psig) | --- | --- | 10.9 | 10.9 | 85.9 | 85.9 |
| Temperature, Fluid in Pipe (F) | 150 | 150 | 241 | 241 | 328 | 328 |
| Operating Time (hrs/yr) | 2,425 | 2,425 | 2,425 | 2,425 | 2,425 | 2,425 |
| Pipe Parameters |  |  |  |  |  |  |
| Pipe Size for Heat Loss Calculations (inch) | 0.75 | 1.7 | 0.75 | 1.7 | 0.75 | 1.7 |
| Outer Diameter, Pipe, Actual (in.) | 1.46 | 2.6 | 1.46 | 2.6 | 1.46 | 2.6 |
| Heat Loss, Bare Pipe (Btu/hr-LF) | 35 | 87 | 52 | 139 | 83 | 221 |
| Heat Loss, Bare Pipe (therm/yr/LF) | 0.8 | 2.1 | 1.3 | 3.4 | 2.0 | 5.4 |
| Insulation Parameters |  |  |  |  |  |  |
| Outer Diameter, Insulation (in.) | 3.46 | 4.60 | 3.46 | 4.60 | 3.46 | 4.60 |
| Average Heat Loss, Insulation (Btu/hr-LF) | 2.7 | 6.1 | 4.0 | 7.8 | 4.9 | 12.4 |
| Average Heat Loss, Insulation (therm/yr/LF) | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.3 |
| Annual Energy Savings |  |  |  |  |  |  |
| Boiler Efficiency (%) | 82% | 82% | 83% | 83% | 83% | 83% |
| Annual Gas Savings (therms/year/LF) | 0.9 | 2.4 | 1.4 | 3.8 | 2.3 | 6.1 |

Table 5 - Key Parameters for Large Commercial Pipe Insulation

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Hot Water** | | **Low-pressure Steam (0-15 psig)** | | **Medium-pressure Steam (>15 psig)** | |
| Pipe Size (inch) | ≤1" | >1" | ≤1" | >1" | ≤1" | >1" |
| Insulation Thickness (inch) | 1 | 1 | 1 | 1 | 1 | 1 |
| Average Steam Pressure (psig) | --- | --- | 10.9 | 10.9 | 85.9 | 85.9 |
| Temperature, Fluid in Pipe (F) | 150 | 150 | 241 | 241 | 328 | 328 |
| Operating Time (hrs/yr) | 4,380 | 4,380 | 4,380 | 4,380 | 4,380 | 4,380 |
| Pipe Parameters |  |  |  |  |  |  |
| Pipe Size for Heat Loss Calculations (inch) | 0.75 | 1.7 | 0.75 | 1.7 | 0.75 | 1.7 |
| Outer Diameter, Pipe, Actual (in.) | 1.05 | 2.09 | 1.05 | 2.09 | 1.05 | 2.09 |
| Heat Loss, Bare Pipe (Btu/hr-LF) | 121 | 216 | 203 | 369 | 325 | 591 |
| Heat Loss, Bare Pipe (therm/yr/LF) | 5.3 | 9.5 | 8.9 | 16.1 | 14.2 | 25.9 |
| Insulation Parameters |  |  |  |  |  |  |
| Outer Diameter, Insulation (in.) | 3.05 | 4.09 | 3.05 | 4.09 | 3.05 | 4.09 |
| Average Heat Loss, Insulation (Btu/hr-LF) | 9.9 | 15.5 | 14.7 | 23.7 | 21.4 | 34.5 |
| Average Heat Loss, Insulation (therm/yr/LF) | 0.4 | 0.7 | 0.6 | 1.0 | 0.9 | 1.5 |
| Annual Energy Savings |  |  |  |  |  |  |
| Boiler Efficiency (%) | 82% | 82% | 83% | 83% | 83% | 83% |
| Annual Gas Savings (therms/year/LF) | 5.9 | 10.7 | 9.9 | 18.2 | 16.0 | 29.4 |

Table 6 - Key Parameters for Large Commercial Pipe Fittings Insulation

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Hot Water** | | **Low-pressure Steam (0-15 psig)** | | **Medium-pressure Steam (>15 psig)** | |
| Pipe Size (inch) | ≤1" | >1" | ≤1" | >1" | ≤1" | >1" |
| Insulation Thickness (inch) | 1 | 1 | 1 | 1 | 1 | 1 |
| Average Steam Pressure (psig) | --- | --- | 10.9 | 10.9 | 85.9 | 85.9 |
| Temperature, Fluid in Pipe (F) | 150 | 150 | 241 | 241 | 328 | 328 |
| Operating Time (hrs/yr) | 4,380 | 4,380 | 4,380 | 4,380 | 4,380 | 4,380 |
| Pipe Parameters |  |  |  |  |  |  |
| Pipe Size for Heat Loss Calculations (inch) | 0.75 | 1.7 | 0.75 | 1.7 | 0.75 | 1.7 |
| Outer Diameter, Pipe, Actual (in.) | 1.46 | 2.6 | 1.46 | 2.6 | 1.46 | 2.6 |
| Heat Loss, Bare Pipe (Btu/hr-LF) | 35 | 87 | 52 | 139 | 83 | 221 |
| Heat Loss, Bare Pipe (therm/yr/LF) | 1.5 | 3.8 | 2.3 | 6.1 | 3.6 | 9.7 |
| Insulation Parameters |  |  |  |  |  |  |
| Outer Diameter, Insulation (in.) | 3.46 | 4.60 | 3.46 | 4.60 | 3.46 | 4.60 |
| Average Heat Loss, Insulation (Btu/hr-LF) | 2.7 | 6.1 | 4.0 | 7.8 | 4.9 | 12.4 |
| Average Heat Loss, Insulation (therm/yr/LF) | 0.1 | 0.3 | 0.2 | 0.3 | 0.2 | 0.5 |
| Annual Energy Savings |  |  |  |  |  |  |
| Boiler Efficiency (%) | 82% | 82% | 83% | 83% | 83% | 83% |
| Annual Gas Savings (therms/year/LF) | 1.7 | 4.3 | 2.5 | 6.9 | 4.1 | 11.0 |

Table 7 - Key Parameters for Industrial Pipe Insulation

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Hot Water** | | **Low-pressure Steam (0-15 psig)** | | **Medium-pressure Steam (>15 psig)** | |
| Pipe Size (inch) | ≤1" | >1" | ≤1" | >1" | ≤1" | >1" |
| Insulation Thickness (inch) | 1 | 1 | 1 | 1 | 1 | 1 |
| Average Steam Pressure (psig) | --- | --- | 10.9 | 10.9 | 85.9 | 85.9 |
| Temperature, Fluid in Pipe (F) | 150 | 150 | 241 | 241 | 328 | 328 |
| Operating Time (hrs/yr) | 7,752 | 7,752 | 7,752 | 7,752 | 7,752 | 7,752 |
| Pipe Parameters |  |  |  |  |  |  |
| Pipe Size for Heat Loss Calculations (inch) | 0.75 | 1.7 | 0.75 | 1.7 | 0.75 | 1.7 |
| Outer Diameter, Pipe, Actual (in.) | 1.05 | 2.09 | 1.05 | 2.09 | 1.05 | 2.09 |
| Heat Loss, Bare Pipe (Btu/hr-LF) | 121 | 216 | 203 | 369 | 325 | 591 |
| Heat Loss, Bare Pipe (therm/yr/LF) | 9.4 | 16.7 | 15.8 | 28.6 | 25.2 | 45.8 |
| Insulation Parameters |  |  |  |  |  |  |
| Outer Diameter, Insulation (in.) | 3.05 | 4.09 | 3.05 | 4.09 | 3.05 | 4.09 |
| Average Heat Loss, Insulation (Btu/hr-LF) | 9.9 | 15.5 | 14.7 | 23.7 | 21.4 | 34.5 |
| Average Heat Loss, Insulation (therm/yr/LF) | 0.8 | 1.2 | 1.1 | 1.8 | 1.7 | 2.7 |
| Annual Energy Savings |  |  |  |  |  |  |
| Boiler Efficiency (%) | 82% | 82% | 83% | 83% | 83% | 83% |
| Annual Gas Savings (therms/year/LF) | 10.5 | 18.9 | 17.6 | 32.2 | 28.4 | 52.0 |

Table 8 - Key Parameters for Industrial Pipe Fittings Insulation

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Hot Water** | | **Low-pressure Steam (0-15 psig)** | | **Medium-pressure Steam (>15 psig)** | |
| Pipe Size (inch) | ≤1" | >1" | ≤1" | >1" | ≤1" | >1" |
| Insulation Thickness (inch) | 1 | 1 | 1 | 1 | 1 | 1 |
| Average Steam Pressure (psig) | --- | --- | 10.9 | 10.9 | 85.9 | 85.9 |
| Temperature, Fluid in Pipe (F) | 150 | 150 | 241 | 241 | 328 | 328 |
| Operating Time (hrs/yr) | 7,752 | 7,752 | 7,752 | 7,752 | 7,752 | 7,752 |
| Pipe Parameters |  |  |  |  |  |  |
| Pipe Size for Heat Loss Calculations (inch) | 0.75 | 1.7 | 0.75 | 1.7 | 0.75 | 1.7 |
| Outer Diameter, Pipe, Actual (in.) | 1.46 | 2.6 | 1.46 | 2.6 | 1.46 | 2.6 |
| Heat Loss, Bare Pipe (Btu/hr-LF) | 35 | 87 | 52 | 139 | 83 | 221 |
| Heat Loss, Bare Pipe (therm/yr/LF) | 2.7 | 6.7 | 4.0 | 10.8 | 6.4 | 17.1 |
| Insulation Parameters |  |  |  |  |  |  |
| Outer Diameter, Insulation (in.) | 3.46 | 4.60 | 3.46 | 4.60 | 3.46 | 4.60 |
| Average Heat Loss, Insulation (Btu/hr-LF) | 2.7 | 6.1 | 4.0 | 7.8 | 4.9 | 12.4 |
| Average Heat Loss, Insulation (therm/yr/LF) | 0.2 | 0.5 | 0.3 | 0.6 | 0.4 | 1.0 |
| Annual Energy Savings |  |  |  |  |  |  |
| Boiler Efficiency (%) | 82% | 82% | 83% | 83% | 83% | 83% |
| Annual Gas Savings (therms/year/LF) | 3.0 | 7.6 | 4.5 | 12.2 | 7.3 | 19.5 |

1. Base Case & Measure Costs

Base Case Cost

* + 1. The base case cost is $0.00 as a “do-nothing” case.

Gross Measure Cost

* + 1. Pipe Insulation
       1. Measure costs for pipe insulation adopts the information provided in 2008 DEER measure cost summary[[6]](#endnote-6) as shown in Table x below.
       2. DEER 2008 cost data is available on pipe insulation for space heating and cooling. It oesn’t provide the costs for high pressure steam (greater than 15 psig). The costs of pipe insulation for non-space hating application and of high pressure steam, as covered in this document, are assumed to be the same as shown in Table x below.

Table 9 - Pipe Insulation Cost in DEER 2008

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Cost Case Description** | **Cost Case ID** | **Program Delivery Strategies** | **Material Cost** | **Installation Man Hours - Retrofit** | **Installation Labor Cost - Retrofit** | **Normalizing Unit** | **IMC** |
| Pipe Insulation - 1" Hot Water 120-200F, over 2" pipe | PipeIns-1inch-200to250F-lt15psigsteam | Downstream Prescriptive Rebates/Incentives | $1.59 | $0.07 | $3.63 | Ln. Ft. | $5.22 |
| Pipe Insulation - 1" Low Pressure (<15psig) steam 200 -250F, over 2" pipe | PipeIns-1inch-120to200F-hth2o | Downstream Prescriptive Rebates/Incentives | $1.59 | $0.07 | $3.63 | Ln. Ft. | $5.22 |

* + 1. Fitting Insulation

Fitting insulation costs (cost of insulation materials plus cost of installation) were determined based on telephone conversations with and written quotes provided pipe insulation vendors. They provided installed cost for a selection of typical insulation jobs for steam and hot water piping systems. The data was processed to get a breakout of the cost to insulate straight pipe and the pipe fittings, as listed in Table Y. Indoor installations specified an all-service jacket (ASJ), while outdoor installations specified a more durable aluminum wrap. The vendor quoted 1 inch of insulation on hot water pipe and 1.5 inches on steam pipe. The average costs represent an average of typical indoor and outdoor costs.

Table 10 - Pipe Insulation Costs (Material & Installation) Provided by Vendor

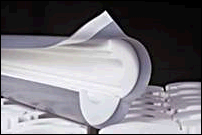
|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Hot Water** | | **Low-pressure Steam (0-15 psig)** | | **High-pressure Steam (>15 psig)** | |
| Pipe Size (inch) | 0.75 | 2 | 0.75 | 2 | 0.75 | 2 |
| Insulation Thickness (inch) | 1 | 1 | 1.5 | 1.5 | 1.5 | 1.5 |
| Pipe Fittings | | | | | | |
| Indoors ($/fitting) | $7.73 | $7.87 | $7.60 | $9.47 | $7.60 | $9.47 |
| Outdoors ($/fitting) | $7.87 | $9.60 | $8.67 | $7.33 | $8.67 | $7.33 |
| Average ($/fitting) –  **Measure Cost** | **$7.80** | **$8.73** | **$8.13** | **$8.40** | **$8.13** | **$8.40** |

Incremental Measure Cost

* + 1. The incremental measure costs are the same as the measure case costs since the base case cost is $0.

# Appendix A. Measure Description

* A variety of pipe insulation products are commercially available, to provide energy savings and to protect personnel from burns. In addition to hot water and steam, pipe insulation is applied to process fluid piping, HVAC piping, and cryogenic piping. The difficult task is determining not what type of insulation could be used, but what type of insulation should be used in a specific application. The answer depends on why the insulation is needed, its required lifetime, the pipe temperature, and its environment (indoors, outdoors, near food products, near corrosive chemicals, underfoot, overhead, etc.). Equally important to the proper selection of the insulation material is the quality of workmanship involved in the installation, e.g., properly sealing the jacket to keep the insulation dry.
* **Insulation Materials**
* Pipe insulation typically consists of the insulation material and a protective jacket (see ). Both are available in a wide variety of materials. Before an insulation material and jacketing system can be chosen, many parameters must be considered. Fiberglass, mineral wool, calcium silicate, ceramic fiber, perlite, cellular glass, removable covers and more recently, high temperature polyisocyanurate, all have maximum operating temperatures good to 450 °F or above. Preformed or fabricated, these insulation materials are readily available.



* *Courtesy of Accessible Products Company*

Figure 1. Pipe Insulation with Flexible Jacket

* **Material Selection**
* Criteria for selecting insulation material should include the reason for insulating. Most piping is insulated to protect personnel or to provide an acceptable heat loss. In the high temperature market, the primary reason for insulating a process line is process control. Insulation may be extremely critical to the process.
* Each manufacturer publishes test data for the product it makes. They typically list physical properties such as thermal conductivity, compressive strength, density, temperature range and flame and smoke development. Each characteristic has a direct bearing on the insulation product’s ability to perform properly during operation of a given process or application at its service temperature.
* **Installation**
* Common problems associated with failed insulation could be avoided if the substrate could be designed to allow for the proper insulation application. Design features that interfere with the insulator’s ability to properly insulate the system include the following:
* Pipes that are not spaced far enough apart and do not allow for the correct insulation thickness to be installed, nor enough room to work and provide a good installation of the insulation.
* Flanges, valves, elbows and other items installed too close together, making it impossible to properly insulate.
* The use of valves that do not have extended bonnets on them to allow for the correct insulation thickness under the valve handle or allow for maintenance of the valve.
* I-beams, braces, brackets and other items coming in contact with the pipe, causing a thermal short.
* Gauges, pipes, and man-way doors installed too close to the vessel or equipment, making it impossible to insulate around or above.
* Improper type of pipe support used.
* Pipes not primed before insulation is installed because it was never specified.
* **Final Design Considerations**
* The biggest reason for insulation failure is water; all choices for the system must be reviewed to make sure that the system is breathable, yet water-tight. Additional lines of defense against water should be incorporated into the total design.
* Water ingress can be noted under improperly installed or maintained jacket laps, improper spacing of jacket ends, at fittings, flanges, valves and other areas. The minimum insulation surface temperature for personnel protection is approximately 110 °F. Even when considering high-temperature lines of pipe to 450 °F, the thickness of insulation will experience a temperature gradient from 450 ºF to 212 ºF, which is below the temperature of steam, to 110 °F at the surface. The thickness of insulation that lies between 212 °F and 110 °F is where water can be retained in the insulation. If left in operation, this portion can be dried, but the resulting expense is not only an increase in energy required to dry the system, but the added danger of a raised surface temperature. Since water is a conductor, not an insulator, the surface temperature will rise and may exceed that which is safe for personnel. The presence of water also increases in the risk of corrosive under the insulation, which will eventually destroy the piping, at huge expense to the owner.

References

1. EUL Summary Table, DEER, 2008

    [↑](#endnote-ref-1)
2. DEER 2011 Net-to-Gross Table

    [↑](#endnote-ref-2)
3. See **Appendix A** above for a description of pipe insulation. Adapted from “Temperature’s Rising, an analysis of insulation options for hot applications,” by Robin DeGraff and Mike Irlbacher. [↑](#endnote-ref-3)
4. Key Parameters for Pipe - Attachment # 4

    [↑](#endnote-ref-4)
5. Key Parameters for Pipe Fittings Insulation - Attachment # 6

    [↑](#endnote-ref-5)
6. Revised DEER Measure Cost Summary (05\_30\_2008) Revised (06\_02\_2008).xls

    [↑](#endnote-ref-6)