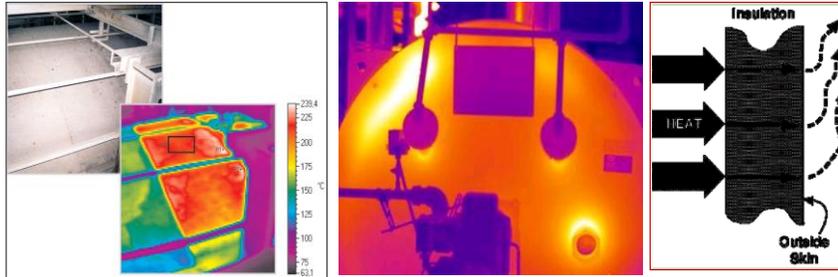


# Reduction of Wall Heat Losses through Use of Proper Insulation

## For Industrial Heating Equipment and Boilers



Prepared for California Energy Commission (CEC)

Prepared By:

Southern California Gas Company  
(A Sempra Energy Utility)

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May 2012

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## **Executive Summary**

This calculator tool allows a user to estimate annual energy savings and the associated cost (US dollars) savings and reduction in CO<sub>2</sub> emissions by insulating hot and exposed surfaces on heating equipment. The wall surface temperature can be reduced by using an appropriate type and thickness of insulation or refractory material. In many cases, the optimum thickness for a given type of insulation depends on two factors: cost of insulation and savings realized from surface heat loss reductions. This calculator does not deal with optimization of wall insulation thickness, but it allows the user to calculate energy and cost savings and its associated CO<sub>2</sub> emission reduction.

This calculator allows the user to change the wall temperature and it requires information including the current wall temperature, wall surface area, ambient temperature, furnace operating conditions, type of opening (rectangular vs. round), size of the opening (width and height or diameter) and the depth of the wall where the opening is located. The heat loss calculations account for convection and radiation heat transfer that occur at the surface. These calculations are based on assumption of a vertical surface with very low (<5 Miles per hour) wind velocity. However, the user is given an option form manually inputting a correction factor for other surface orientation and wind velocity. Energy savings from the modification of insulation to reduce the surface temperature increases the "available heat" for the heating system. The calculator estimates the annual expected energy savings in terms of millions of British thermal units per year (MMBtu/year). It also estimates the energy cost reduction by using the cost of fuel and the number of operating hours per year. This calculator also calculates the reduction of CO<sub>2</sub> emissions that result from the increase in available heat.

The primary objective of this calculator is to identify energy savings potential in industrial heating operations to make a go / no go decision on further detailed engineering and economics analysis. The user is required to give data for several operating parameters that can be measured or estimated from normal operating conditions using available records. All data should be collected at typical or average unit operating conditions.

Calculator results should be considered preliminary estimates of energy savings potential and a starting point for more detailed technical and economic analysis. The accuracy of the calculator's results is expected to be within  $\pm 5$  percent.

## **Note to the user of this calculator tool**

The following terms are used interchangeably used in this document. The terms furnace or heating system represent many different types of equipment used by the industry. They include furnaces, boilers, heaters, ovens, kilns etc.

Use of this tool requires knowledge of design, construction and operation of heating systems such as a furnace, oven, heater, boiler, kiln, dryer etc. The user is referred to several training programs and references quoted at the end of his document for further information on the available resources for getting trainings that would provide additional knowledge for the subject matters discussed in this document.

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## 1. Description of the subject area

This technical guide describes a calculator tool that enables a user to estimate annual energy savings and reduction in CO<sub>2</sub> emissions when heat loss from wall surfaces of heating equipment such as a furnace, an oven, boiler, or a process heater is reduced by changing or installing insulation or refractory. The surface heat losses include heat loss by convection heat transfer and radiation heat transfer. In most cases, heat transfer is a combination of both convection and radiation. However, when the surface temperature is high, greater than 400 °F, radiation becomes the major method of heat transfer. The rate of surface heat loss can be reduced by changing the type or thickness of insulation material, or repairing the insulation that may be missing or has been damaged resulting in hot spots on the walls. The calculator does not include insulation design factors. The user is referred to Reference 1 for more information and calculation methodology for this type of information.

The surface heat loss phenomenon is illustrated in the following Exhibit 1.

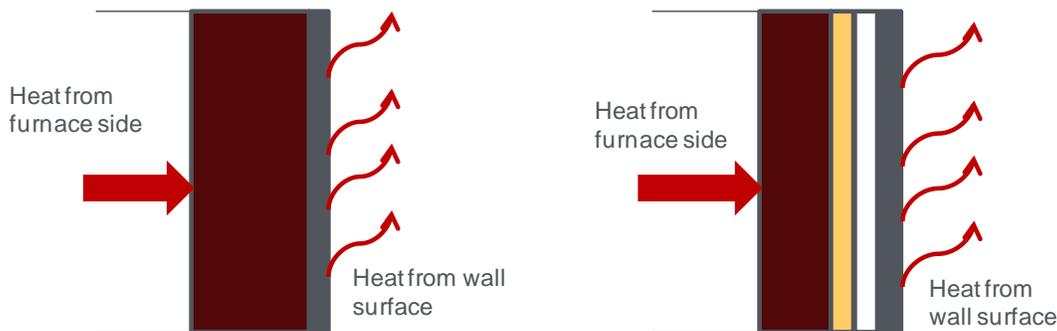


Exhibit 1: Heat transfer mechanism for a typical furnace wall

Heat is transferred to the inside surface of a furnace wall by radiation and convection to raise the wall interior surface. Due to temperature difference between the inside surface and outside surface heat is conducted through the wall, which can be in one or more layers. This results in an increase in outside surface temperature and heat is dissipated or lost from the outside surface by convection and radiation. The outside surface temperature stabilizes at a temperature when the heat coming from the inside of the furnace is equal to the heat loss from the outside surface. The heat loss can be calculated by using detail calculations that require knowledge of the insulation properties, thickness of the insulation, and other relevant details. In many cases, it is difficult to obtain accurate information. However, it is relatively easy to measure the outside surface temperature and calculate heat loss from the surface, which is equal to the heat transferred through the insulation.

Heat transfer from a surface depends on the following parameters.

- Wall surface temperature - Higher temperature gives higher losses
- Ambient temperature - Lower temperature gives higher heat losses
- Surface orientation - Vertical surface is used as base line (a factor of 1.0)
  - Downward-facing horizontal surface – lower heat loss (by about 5% to 10%)

(factor of 0.95)

- Upward-facing horizontal surface – higher heat loss (by about 5% to 10%) (factor of 1.05)
- Wind velocity over the surface - Higher velocity results in higher loss
- Surface emissivity - Higher emissivity results in higher loss at temperature >400 °F

The following actions should be considered to reduce outside surface temperature or surface heat losses.

- **Eliminate or repair hot spots** – This measure is used when the furnace walls have hot spots, which may be due to damaged or missing insulation at some location (usually at the interior wall) within the wall. Examples of such cases where damage occurs to the wall insulation include damage by a material handling system or frequent cycling (heating and cooling) of the furnace that may result in damage to the insulation. A solution to this is to repair or replace the insulation or to better control the heating and cooling rate of the equipment to avoid thermal shock (the sudden thermal expansion or contraction) to insulating materials.
- **Investigate presence of hidden gaps that may allow hot furnace gases to bypass the insulation** - If the insulation is not installed properly and gaps are present between the furnace wall structure and furnace interior, it is likely that hot gases may bypass the insulation and come into direct contact with the furnace casing or exterior structural members. The gaps may be present due to installation errors, shrinkage of the insulation during start up or crack development due to heat cycling. In these cases, it is necessary to repair the gaps as per instructions from the furnace the insulation supplier.
- **Presence of high thermally conductive gases such as hydrogen (H<sub>2</sub>)** – This may be applicable to heat treating furnaces that use special process atmospheres (such as H<sub>2</sub>) that could increase thermal conductivity for the insulation. A high rate of thermal conductivity increases heat transfer through the wall insulation and increases the outside surface temperature. In such cases, it is necessary to change the type of insulation material during a rebuild. It may be possible to use special coatings that prevent migration of furnace gases into the insulation, however this is not considered as an assured measure due to possibilities of cracks developing in the coating itself.
- **Rebuild certain sections or the entire furnace walls using state of the art or improved materials** – Many furnaces built several decades ago used high-density low thermal conductivity insulation or refractory materials that resulted in relatively high surface temperatures. At the time, energy cost was low and surface energy loss from walls was not recognized as a significant cost item. In the last 25 years the industry has developed new materials such as ceramic fibers, boards etc. in various forms such as modules or composites. These materials are lightweight (6 to 10 lb. per cu.ft. vs. 40 to 120 lb./cu.ft for the refractories) and offer much better insulation characteristics. A plant may elect to rebuild the furnace walls by replacing refractory bricks with new low-density higher insulation value material. In most cases, the payback period could be in the range of 1 to 2 years.

A brief summary of the important parameters and their measurements or values for the calculator are discussed below.

- **Surface temperature:** Surface temperature can be measured by using a contact thermocouple or an infrared temperature measuring instrument. Measurements taken using a contact thermocouple (requiring good contact) are more accurate than measurements taken using infrared instruments. Measurement by infrared instrument requires knowledge of wall emissivity (which is usually 0.8 for “aged” steel surfaces) and can change depending on surface type. In cases where shiny surfaces exist, it is necessary to use lower emissivity for measurement or to mark a dark spot using a permanent black marker for spot for measurements. It is also possible to get surface temperature by using a thermal imaging system such as a thermal imaging camera. Thermal imaging systems are very expensive and are used for large surfaces or for measurement that is more precise.
- **Area of the wall surface:** This represents the area for which heat loss calculations are carried out. Furnace drawings or actual measurements can be used to get this value.
- **Orientation of the surfaces:** This represents the surface orientation. It can be stated as vertical, horizontal looking down and horizontal looking up. Inclined surfaces can be approximated by their orientation (i.e. vertical, horizontal looking up or horizontal looking down) with actual surface area. Correction factors for the orientations are discussed in a following section.
- **Flue Gas Temperature:** The temperature of the flue (stack) gases exiting the process before and after implementation of the efficiency measure. This is measured during a flue gas analysis (FGA). In most cases where the flue gas temperature is lower than about 1600°F, it may be adequate to use a shielded thermocouple. Commercially available FGA analysis equipment includes thermocouple and probe assembly that can be used to make this measurement. In cases where it is not possible to measure the flue gas temperature, an estimation can be made using furnace zone temperature plus 25 °F to 50 °F as representative flue gas temperature.
- **Oxygen Concentration in Flue Gas:** The percentage of oxygen contained in the flue gas measured on a dry basis before and after implementation of the energy saving measures. This is normally measured as a part of the FGA activity.
- **Combustion Air Temperature:** The temperature of the combustion air (which is the air mixed with fuel in the burner) measured at the burner by using a shielded thermocouple.
- **Fuel consumption per hour (MMBtu/hour):** The average estimated hourly consumption of natural gas (or other type of fuel) by the baseline combustion system. This should be based on a recent 12-month period (MMBtu/year) and number of hours for the heating system.
- **Number of operating hours (hours/year):** The number of hours for which the equipment is operated. This should be based on a recent 12-month period.

- **Cost of fuel:** The average fuel cost (\$/MMBtu) based on the past history and, if possible, future projected cost based on contacts with the energy supplier.

## **2. Impact of wall heat loss on energy savings and CO<sub>2</sub> emissions**

This calculator allows a user to estimate energy (fuel) savings that can be achieved by reducing heat loss from furnace walls. These fuel savings result in a reduction of CO<sub>2</sub> emissions. All commonly used fossil fuels (such as natural gas) result in the formation of CO<sub>2</sub>. The reduction in CO<sub>2</sub> emissions is directly proportional to the reduction in natural gas use.

The calculator is designed to give results assuming that the industrial process uses natural gas as the sole fuel. The actual savings in fuel consumption and the associated energy costs depend on several design and operating parameters. These include:

- Size, orientation, and emissivity of the surface
- Surface temperature
- Ambient temperature near the surfaces
- Temperature of exhaust gases leaving a furnace or boiler
- Amount of excess air used for combustion as represented by presence of oxygen (dry basis) in the exhaust gases.
- Number of operating hours per year
- Average temperature of the combustion and excess air entering the heating system.
- Cost of fuel in terms of \$/MMBtu

The energy savings can vary from 1% for low-temperature processes to as high as 10% for high-temperature processes. The exact value of savings can be estimated by using this calculator.

Heat required to compensate wall heat losses has to be supplied from the available heat in a furnace. The available heat represents heat remaining in a furnace that is the heat supplied by the burners minus heat lost in flue gases.

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Hence, the actual heat input reduction for a furnace could be considerably higher than the heat loss reduction calculated by using this tool.

The CO<sub>2</sub> savings are directly related to energy savings. According to U.S. Environmental Protection Agency (EPA) estimates (Reference 5), the combustion of natural gas used in USA produces 116.39 lbs. of CO<sub>2</sub> per MM Btu heat input. For convenience, most calculations use 117 lbs. CO<sub>2</sub> emission per MM Btu heat input from natural gas. If the natural gas composition is available, it is advisable to carry out detailed combustion calculations to estimate values that are more accurate for the CO<sub>2</sub> produced by the combustion of natural gas. Reduction in CO<sub>2</sub> emissions is calculated by using the value of reduction in energy (fuel) used for the furnace.

Annual energy cost savings depend on the cost of energy, expressed as US dollars per MM Btu, and the energy savings estimated using the calculator.

### **3. Discussion on the technical approach and the calculations**

Reducing wall heat losses will result in energy savings while maintaining the desired heat output or furnace temperature. The annual energy savings (MMBtu/year) is the difference between the annual energy use by the baseline system and the annual energy use after the implementation of this efficiency improvement measure. In all cases involving wall heat loss reduction, an essential step is to make the following measurements:

- Surface temperature (using a contact thermocouple, an infrared temperature measurement instrument, or a thermal imaging system)
- Ambient temperature near the surfaces
- Dimensions of the surfaces and their orientation
- Flue gas analysis with the following items
  - Flue gas temperature
  - Oxygen concentration
  - Combustion air temperature

A schematic of a heating system considered in the wall heat loss calculation is illustrated in Exhibit 2 below. In this analysis, the total amount of mass exiting the flue includes the combustion air entering through the burner, make up air (if used), and any air leaks into the system. The flue gas exits the heating system chamber through the stack. This tool allows the user to calculate actual heat losses and the reduction in heat input by giving corrections for the available heat using flue gas analysis.

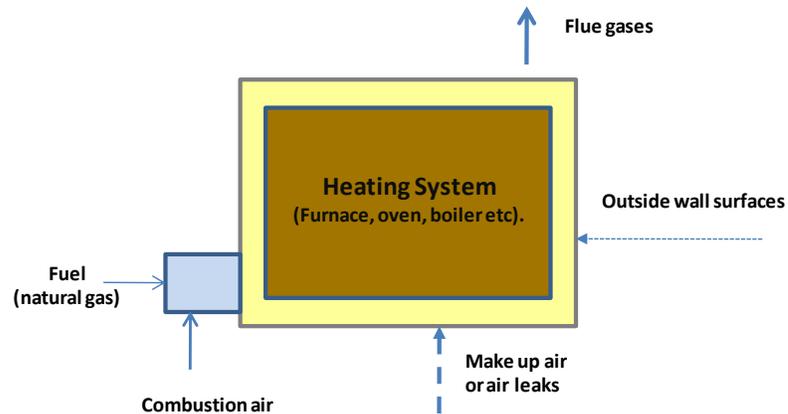


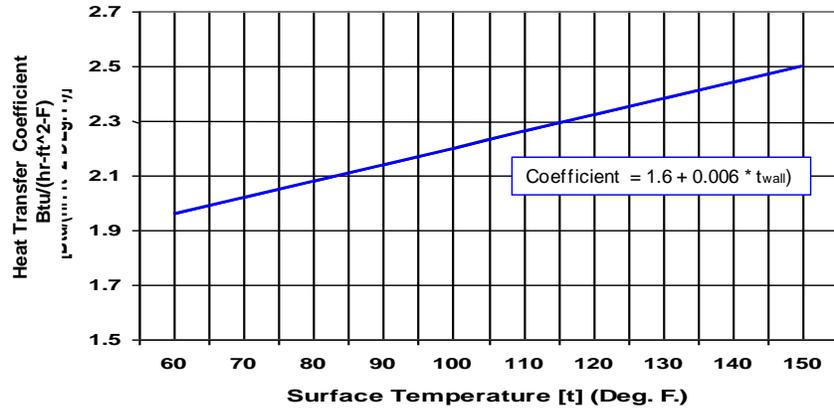
Exhibit 2: Heating system schematic

The total heat loss includes heat loss through both convection and radiation. Since convection and radiation heat transfer are the predominant modes of heat transfer in different temperature ranges, it is necessary to use equations and proven information in three different temperature ranges. These ranges are given below.

- i. Wall surface temperature up to 140°F (low temperature)
- ii. Wall surface temperature between 140°F and 400°F (mid temperature)
- iii. Wall surface temperature above 400°F (high temperature)

Note that the designation of temperature are related to exterior wall temperatures and should not be confused with the furnace interior or flue gas temperature regimes used elsewhere.

The following calculation method derived from Reference 2 is used for the low temperature regime.



Use this as a general guide. Wall heat losses depend on a number of factors such as the surface conditions of the wall surface, ambient wind velocity, orientation of the surface etc.

**Actual heat loss= Heat Transfer Coefficient \* (Temperature Difference between Wall surface temperature (T<sub>wall</sub>) and temperature of the surroundings (T<sub>ambient</sub>))\* Area**

Exhibit 3: Heat transfer coefficient for low temperature regime of wall loss

In the low temperature regime, convection is considered as the major mode of heat transfer and thermal radiation is considered negligible and ignored as heat loss. The heat transfer coefficient is calculated by using the following equation.

Where

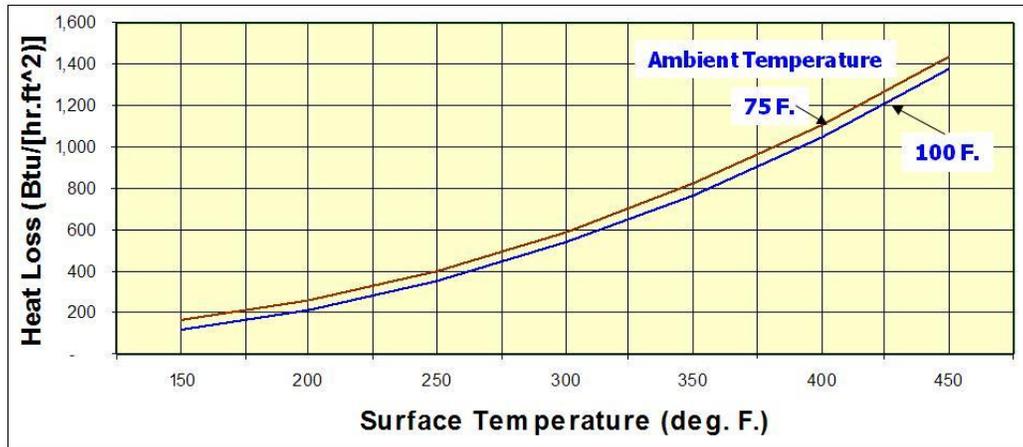
is convection heat transfer coefficient

= Wall or surface temperature (°F )

Heat loss rate per sq. ft. of the surface is calculated by the equation.

= Ambient or surrounding temperature (

For intermediate or med temperature (140 to 400°F ) regime the following graph (Exhibit 4) derived from Reference 2 and other manuals used by several furnace companies (proprietary information) is used. This graph with its temperature dependency was translated in a polynomial equation and used for calculations and includes the effects of convection and radiation heat transfer.



Use this as a general guide. Wall heat losses depend on a number of factors such as the surface conditions of the wall surface, ambient wind velocity, orientation of the surface etc.  
Source: Calculations by Arvind Thekdi, E3M, Inc.

Exhibit 4: Heat loss for mid temperature regime of wall loss

For high temperature regime (>400°F) effect of convection is considered minor and it has been ignored. Basic equation for thermal radiation is given below.

Where

$Q$  = Rate of heat transfer, Btu/hour

$\epsilon$  = Emissivity of the source surface

$F_{1-2}$  = A factor related to arrangement (line of sight) of the two surfaces

$T_{\text{source}}$  = Absolute ( $^{\circ}\text{F} + 460$ ) temperature of the radiation source

$T_{\text{sink}}$  = Absolute ( $^{\circ}\text{F} + 460$ ) temperature of the receiving surface

$A$  = Opening or Surface area, sq. ft.

For most commonly encountered cases, the emissivity can be assumed to be 0.9 and  $F_{1-2}$  value as 1.0 since the walls are directly exposed to ambient temperature.

$T_{\text{source}}$  is the temperature of radiation source. In this case, it is the interior temperature of the furnace in the area of the opening. It can be measured by using a thermocouple, radiation pyrometer, or infrared temperature measuring device. If it is difficult or impossible to measure this temperature, use the furnace temperature as indicated by the instrumentation for the furnace control system.

$T_{\text{sink}}$  is the temperature of the receiving surface, which, in most cases, would be the ambient temperature.

$A$  is area of the surface based on its dimensions. .

Since surface heat loss is a fraction of the available heat for the furnace, it is necessary to apply an available heat factor (sometime known as combustion efficiency) to calculate the actual heat

input required to compensate for the heat loss.

The term “available heat” is defined as the difference in total heat input and the heat content of exhaust gases leaving the furnace system. It is usually expressed as percentage (%) and represents the amount of heat remaining in a furnace as a fraction of the heat input to the furnace.

The following symbols are used in the equations below:

= Furnace heat demand (Btu/hr)

= Available heat (Btu/hr)

= Heat input in the furnace (Btu/hr)

= Heat content of exhaust gases leaving the heating system or furnace (Btu/hr)

= Percent available heat

The total heat input is

So                    -

Available heat expressed as a percentage is used as a good indication of performance of a heating system and it is given as

So

The term  $H_f$  represents the sum of heat used for the load and heat losses (including wall heat loss, opening loss, cooling medium loss etc.). Hence, a reduction in wall heat losses loss would result in reduction in  $H_f$  (furnace heat demand) . Calculation of the actual reduction in heat input resulting from wall heat loss reduction requires correction as given below.

For calculating energy savings by reducing wall heat losses, we have to consider two different operating conditions. One condition (referred to as Current) is an existing furnace with existing wall insulation and corresponding surface temperature and the other (referred to as Modified) would be when actions are taken to reduce heat losses and the wall surface temperature is lowered. Note that in each case, other furnace heat demands (i.e. heat for the load, opening loss, cooling loss etc.) are considered constant.

- = Opening loss with current conditions
- = Available heat at current operating conditions
- = Opening loss with modified condition
- = Available heat at modified operating conditions

Reduction in wall loss is

However, reduction in heat input or energy savings ( ) depends on the available heat at each operating condition and savings in energy or reduction in burner heat input can be expressed as

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The results are usually expressed in terms of Btu/hour. Annual energy savings ( ) can be calculated by multiplying the value of by annual operating hours. Wall losses are present at all times as long as the furnace is maintained at temperature higher than the ambient temperature. In many cases, the furnace is maintained at the operating temperature or slightly lower temperature whether or not a load is being processed. Hence, the operating hours would represent actual time for which the furnace is maintained “hot”.

Avht(%), the available heat expressed as a percentage, depends on the following variables:

- Fuel composition
- Exhaust gas temperature
- Combustion air temperature
- Percent oxygen (dry) in the exhaust gases.

Available heat can be calculated by using combustion calculations for a given fuel. For this wall heat loss calculator tool, these calculations use a typical natural gas composition as found in California and the rest of the USA.

The natural gas composition used for calculations in this tool is given below. Note that the user gives the composition in the column marked “By Volume”. If the values in column “By Volume” do not add up to 100% the program will adjust the percentages under column “Adjusted by Volume” to add up to 100% by changing the value of each component % proportionately. In most cases, the total under column “By Volume” is not equal to 100% due to rounding error.

<b>Fuel Gas Analysis</b> (See note below)		
<b>Gas composition</b>	<b>By volume</b>	<b>Adjusted by volume</b>
<b>CH4</b>	<b>94.10%</b>	<b>94.241%</b>
<b>C2H6</b>	<b>2.40%</b>	<b>2.404%</b>
<b>N2 and other inert</b>	<b>1.41%</b>	<b>1.412%</b>
<b>H2</b>	<b>0.03%</b>	<b>0.030%</b>
<b>C3H8</b>	<b>0.49%</b>	<b>0.491%</b>
<b>C4H10 + CnH2n</b>	<b>0.29%</b>	<b>0.290%</b>
<b>H2O</b>	<b>0.00%</b>	<b>0.000%</b>
<b>CO</b>	<b>0.42%</b>	<b>0.421%</b>
<b>CO2</b>	<b>0.71%</b>	<b>0.711%</b>
<b>SO2</b>	<b>0.00%</b>	<b>0.000%</b>
<b>O2</b>	<b>0.00%</b>	<b>0.000%</b>
<b>Total of fuel components</b>	<b>99.85%</b>	<b>100.000%</b>
<b>Difference</b>	<b>0.15%</b>	<b>0.00%</b>
<p><b>Note: The fuel gas composition is in volume %. The higher hydrocarbons in fuel are treated as same as C4H10 and all other inert gases are treated as N2.</b></p>		

Exhibit 5: Composition of natural gas used for calculations

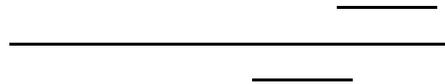
For this calculator, the “higher heating value” or “gross heating value” for the fuel is used. The higher or gross heating value for commonly used natural gas with the composition shown in **Exhibit 5** is 1,020 Btu per standard cubic foot (scf). Natural gas heating value varies from as low as 970 Btu/scf to as high as 1,200 Btu/scf. However, in many situations 1,000 Btu/scf is considered a good approximation. Note that minor discrepancies in the heating value have very little effect on the savings achieved with changes (usually reduction) in wall heat losses.

It is recognized that natural gas composition may vary somewhat during the year or from location to location. However, a series of calculations shows that the variation in natural gas composition has very small effect on the available heat as a percentage of the heating value. Therefore, available heat changes are within a narrow range and the error for this value is relatively small (within  $\pm 5\%$ ). Thus, we advise users of this calculator that the accuracy of its estimates will be in the same order of magnitude, i.e.  $\pm 5\%$ . A separate calculator is available to

calculate the exact value of available heat when the fuel composition is known or when the natural gas composition is significantly different from that stated in Exhibit 5.

Further discussion on available heat and the effect of fuel composition is discussed in References 1 and 2.

Annual energy savings ( $H_{\text{annual}}$ ) can be expressed in terms of Btu/year, Therms/year or million Btu/year (MMBtu/year) by using the appropriate equations given below.



The CO<sub>2</sub> savings can be calculated by using the fuel combustion calculations or by using the EPA guidelines for CO<sub>2</sub> generation calculations. Reference 5 gives details of US EPA guidelines.



#### **4. Instruction on use of the calculator**

The following list summarizes the user inputs that are required. The user should collect this information before using this calculator tool.

- Company name, plant location and address
- Customer name and contact information
- Heating equipment description (where the energy-saving measure is applied)
- Equipment type (furnace, oven, kiln, heater, boiler)
- Equipment use (e.g., textile drying, aluminum melting, food processing)

Note that some of this information may be optional for the web-based calculators due to users' concerns about privacy.

- Average surface temperature (°F)
- Ambient temperature (°F)
- Correction factor (user defined)
- Surface area (ft<sup>2</sup>)
- Flue gas temperature (°F).
- Oxygen in flue gas (% , dry basis)
- Combustion air temperature (°F)

- Number of operating hours per year (hrs/year)
- Cost of fuel (energy) in terms of \$ per MMBtu

The calculator gives following results:

- Heat loss (Btu/hr·ft<sup>2</sup>) for the surface
- Energy or heat used per year (MMBtu/year) for the wall loss
- Heat (energy) savings per year (MMBtu/year)
- Cost of fuel used for losses (\$/year)
- Energy cost savings (\$/year per furnace)
- CO<sub>2</sub> savings per year (tons/year)

Note that the CO<sub>2</sub> savings are based on natural gas as the fuel for the heating equipment. A correction factor must be applied if any other fuel is used.

The opening loss calculator requires the following input parameters describing the heating process in order to estimate the savings. **Exhibit 6** shows the user information screen and **Exhibit 7** shows the calculator screen.

The first section requires information about the user, equipment, and process.

Line 1 – Name of the company

Line 2 – Name or known designation such as “main plant” or “secondary plant” if applicable

Line 3 – Plant address

Line 4 – Contact name for the plant – This is the individual who is main contact and is responsible for collecting and providing the required information.

Minimize Wall Surface Heat Losses (Calculator for Reduction in Wall Losses through Proper Insulation)			
1	Company name	ABC Corporation	
2	Plant name or designation	LA Plant	
3	Plant address	12345 Main Street, Gabriel, CA 90878	
4	Contact name	Bob Smith	
5	Contact address	54321 First Street, North Warren, CA 90878	
6	Contact phone number and e-mail	Phone: 916-756-9923	E-mail: <a href="mailto:b.smith@abccorp.com">b.smith@abccorp.com</a>
7	Date (format mm/date/year)	May 12, 2010	
<b>Heating equipment description (where the energy saving measure is applied)</b>			
8	Equipment type (e.g. furnace, oven, kiln, heater, boiler)	Oven	
9	Equipment use (e.g., textile drying, aluminum melting)	Metal coating	
10	Other comments if any	The oven is designed to run continuously	

Exhibit 6: Required information for the calculator user

Line 5 – Address for the contact person

Line 6 – Contact phone number and e-mail to be used for all future communications

Line 7 – Date when the calculations are carried out

Line 8 – Type of heating equipment – This can be an oven, furnace, boiler, heater, etc. This is the heating equipment where data is collected and the given energy saving measure is to be applied.

Line 9 – Process or function for which the heating equipment is used – This can be name of the process such as drying, melting, water heating, etc.

Line 10 – Any additional information that can be useful in application of the results

The second section of the calculator is used for collecting the necessary data and reporting the estimated savings.

As shown in Exhibit 7, there are two columns for the calculator. The “Current” column represents the conditions or data collected as average values for each of the parameters. Details of the data are given below. Data for the “Modified” conditions represents the values for each of the inputs after the suggested measure (the reduction of wall temperature) is implemented. The calculator cells are color coded. The white colored cells are used for data input by the user while the colored (yellow and light blue or green) color cells are protected and give results of the calculations. The user is not allowed change numbers shown in the colored cells.

In most cases, the only input parameter that will change is combustion air temperature. All other values will be same as the “Current” conditions.

Line 11 – Surface temperature (°F) – Give the surface temperature (in °F) as an average value of measurements made at several locations on the surface (or an appropriate temperature measuring device). Surface temperature can be measured by using a contact thermocouple, infrared temperature measuring instrument, or thermal imaging camera. In most cases, an arithmetic average of the temperature measurements is adequate for these calculations. The temperature readings should be taken when the furnace is operating at normal operating conditions and has been “soaked out” (at steady state condition) and the surface temperatures remain constant for several hours. Readings taken at non-average production or operating conditions can give unreliable results.

Line 12 – Ambient temperature (°F) – Provide the ambient temperature at or near location of the surfaces.

Line 13 – Heat loss [Btu/(hr·ft<sup>2</sup>)] – This is calculated value using the heat transfer equations discussed earlier. No user input required.

Line 14 – Correction factor for surface orientation – This factor is used to allow for variation in heat loss due to the surface orientation. We recommend using 1.05 for a horizontal surface looking upwards and 0.95 for horizontal surface looking downwards. This factor can also be used to account for emissivity, higher wind velocity etc.

Line 15 – Estimated heat loss for the surfaces [Btu/(hr·ft<sup>2</sup>)] – This is calculated value using heat loss calculated from Line 13 and correction factor given in line 14. No user input required.

- Line 16 – Surface area (ft<sup>2</sup>) – This is value of surface area for which heat loss calculations are carried out. It can be obtained by using furnace drawings or actual measurements.
- Line 17 – Furnace flue gas temperature (°F) – Give the flue gas temperature as measured as close to the exit of the furnace as possible. Note that when preheating is done in an extended furnace section or unfired preheat section, this represents flue gas temperature coming out of the furnace and entering the preheat section. Obtain flue gas temperature measurements as close to the exit of the furnace as possible. The flue gas temperature should be taken when the furnace is operating at normal operating conditions from the middle of the stack. Measuring the temperature at the top of the stack or very close to the wall of the discharge duct can give erroneous reading.
- Readings taken at non-average production or operating conditions can give unreliable results. Make sure that the flue gases are NOT mixed with cold air before the temperature is measured. Note that in almost all cases the flue gas exit temperature does not change when using load preheating since the furnace zone temperatures are controlled to meet the required process conditions.
- Line 18 – Percent oxygen (O<sub>2</sub>) in flue gases – This value is obtained from a flue gas analysis using commonly available flue gas analyzers. These analyzers give measurements of flue gas components on dry basis in addition to other. The gas analysis sample should be taken when the furnace is operating at normal operating conditions. Readings taken at non-average production or operating conditions can give unreliable results. It is necessary to make sure that the flue gases are not mixed with cold air before the temperature is measured. Care should be taken to locate the sampling probe in the middle of the stack or area from where the flue gases are discharged.
- Line 19 – Combustion air temperature (°F) – The temperature of combustion air entering the burners. In many cases it is not feasible to obtain exact air temperatures at the burner. A common practice is to use air temperature entering the combustion air blower or ambient temperature as the combustion air temperature if no air preheater is installed. If an air preheater is installed, use the air temperature exiting the recuperator or entering the burner.
- Line 20 – Cost of fuel (\$/Million Btu) – The cost should include all charges related to use of fuel at “the burner tip”. This value can be obtained directly from monthly or annual gas bills. It is often stated as a line item on the bill. If the bill does not specifically mention the gas cost then it is necessary to calculate average cost of fuel by using values of total fuel cost and annual fuel used.
- Line 21 – Operating hours/year – This represents annual operating hours for which the furnace is maintained at a temperature or remains “hot”.
- Line 22 – Energy used per year (MM Btu/year) – This is a calculated value and represents the heat input required (after allowing for the available heat) in the burners to compensate the heat loss calculated above.

<b>MINIMIZE WALL SURFACE HEAT LOSS</b>			
<b>(Use proper insulation for the walls and doors)</b>			
		<b>Current</b>	<b>New</b>
11	Surface temperature (°F)	200	140
12	Ambient temperature (°F)	60	60
13	Heat Loss [Btu/(hr.ft <sup>2</sup> )]	299	185
14	Correction factor for surface orientation etc.	1.10	1.10
15	Estimated heat loss for the surfaces (Btu/(hr-ft <sup>2</sup> ))	329	203
16	Surface area (ft <sup>2</sup> )	1,200	1,200
17	Furnace flue gas temperature (°F)	1,100	1,100
18	% Oxygen in flue gases	5.00	5.00
19	Combustion air temperature (°F)	80	80
20	Cost of fuel (\$/Million Btu)	\$10.00	\$10.00
21	Operating hours/year	8,400	8,400
22	Energy used per year (MM Btu/year)	5,324	3,284
23	<b>Energy saved per year (MM Btu/year)</b>	<b>Base</b>	<b>2,040</b>
24	Cost of fuel used (\$/year)	\$48,398	\$29,853
25	<b>Savings (\$/year)</b>	<b>Base</b>	<b>\$18,545</b>
26	<b>Energy cost savings (\$/year-ft<sup>2</sup>)</b>		<b>\$15.45</b>
27	<b>CO<sub>2</sub> savings (tons/year)</b>		<b>119</b>

Exhibit 7: Example of calculator inputs and results

Line 23 – Energy saved per year (MM Btu/year) – This is a calculated value and represents the difference between energy used per year for current condition and modified condition.

Line 24 – Cost of fuel used per year (\$/year) – Calculated value of fuel cost that is associated with heat input under current and modified conditions.

Line 25– Cost savings (\$/year) – Calculated savings using energy saved per year (Line 23) and cost of fuel used calculated in Line 24 and cost of fuel given in Line 20.

Line 26– Energy cost savings (\$/year-ft<sup>2</sup>) – Calculated savings using cost of fuel used calculated in Line 25 and total surface area (ft<sup>2</sup>) for which the savings are calculated. This value is useful in comparing savings to the cost of insulation or the differential cost of upgrading insulation that may be present or suggested by the furnace supplier.

Line 27 – Reduction in CO<sub>2</sub> emissions (tons/year) – These savings are calculated based on annual fuel savings, assuming the fuel used is natural gas. The savings are in Short (US) tons, not in Metric tons.

*Note that this calculator does not include any input or result related to water savings. In most cases, reduction in opening losses has no direct effect on water savings..*

## 5. References and Resources

1. W Trinks; Matthew Holmes Mawhinney, “*Industrial Furnaces*”. 4<sup>th</sup> edition, Published by Wiley, 1967.
2. *North American Combustion Handbook*, Third Edition, 1986. Published by North American Mfg. Company, Cleveland, OH.
3. *Combustion Technology Manual*, Fifth Edition, 1994. Published by Industrial Heating Equipment Association, Cincinnati, OH.
4. *Improving Process Heating System Performance: A Sourcebook for Industry*, U.S. Department of Energy and Industrial Heating Equipment Association. Available online at  
[http://www1.eere.energy.gov/industry/bestpractices/pdfs/process\\_heating\\_source\\_book2.pdf](http://www1.eere.energy.gov/industry/bestpractices/pdfs/process_heating_source_book2.pdf)
5. *Unit Conversions, Emission Factors and Other Reference Data*, published by the U.S. EPA, November 2004. Available online at  
<http://www.epa.gov/cpd/pdf/brochure.pdf>
6. *Tip sheets and Technical Briefs*, published by The U.S. Department of Energy. Available online at  
[http://www1.eere.energy.gov/industry/utilities/steam\\_tools.html](http://www1.eere.energy.gov/industry/utilities/steam_tools.html)
7. Training opportunities for process heating technology
  - The U. S. Department of Energy (DOE), Energy Efficiency and Renewable Energy (EERE) Office of Industrial Technologies (ITP) web site. <http://www1.eere.energy.gov/industry/>
  - Sempra Energy – Southern California Gas Company web site.  
[www.socalgas.com](http://www.socalgas.com)
  - California Energy Commission web site.  
<http://energy.ca.gov>