Energy Performance Guidelines for:

- Utility Rebate Programs
- ASHRAE 90.1 Comparisons
- Certified LEED Building Projects
- Selection of Energy Efficient Heating Equipment

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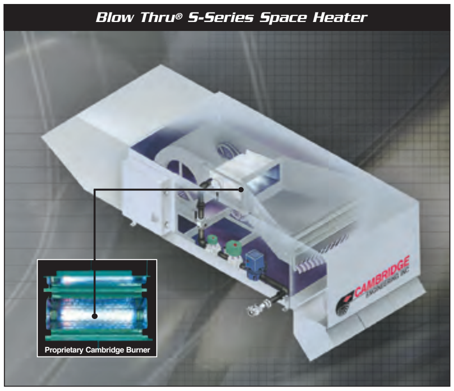
More heat, less energy

WP-EM1-0511



Energy modeling results from this study found High Temperature Heating & Ventilation (HTHV) direct fired blow-thru type heating systems always used the least amount of energy.

Introduction

Space heating and lighting consume most of the energy in non-refrigerated warehouses. Installing more efficient lighting to save electrical energy has been well documented by computer modeling. But what about energy modeling guidelines for selecting more efficient gas-fired heating/ventilating equipment that accounts for 75% to 95% of the gas used at these facilities?

This white paper summarizes the approach, results and conclusions of the first published energy modeling analysis documenting predicted energy performance for six types of gas fired heating systems commonly used in warehouses and commercial/industrial buildings with large open spaces. The computer simulation analysis includes a comparison to the ASHRAE 90.1 baseline heating system used to determine utility rebates, government tax deductions, energy points for LEED certified buildings and other incentives for using energy efficient heating equipment. A set of Best Practices Guidelines is provided at the end of the paper.

Consultant and Software

Independent Consultant

GARD Analytics (Chicago, IL) performed the energy modeling analysis and wrote a detailed 18 page report summarizing their methods and conclusions. They are a consulting service with prior experience in energy modeling and doing evaluations of technologies for providing energy efficient heating services to buildings. GARD was on the team that helped the U.S. Department of Energy (DOE) develop and test the internationally recognized EnergyPlus energy modeling software used for this analysis.

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Energy Modeling Software

EnergyPlus building simulation software developed by DOE was used for this project. It offers simultaneous calculation of envelope and space loads and is able to simulate the energy performance for all seven heating systems. EnergyPlus meets the requirements of the U.S. Green Building Council (USGBC) for determining LEED energy credit points. It conforms to the modeling requirements of ASHRAE Standard 90.1 and is an IRS approved energy modeling software for obtaining Energy Policy Act (EPAct) federal tax deductions.

Warehouse Information

A 200,000 ft^2 generic storage warehouse/distribution center type facility was developed for this study. Building dimensions are 1000' by 200'. Long sides of the building are 30' high. The roof peak running the long direction is 36' high. There are 34 dock doors and the interior of the building is open. The warehouse is constructed and insulated to meet ASHRAE 90.1-2004 guidelines for Columbus, OH (climate zone 5). Internal loads include 50 workers, ten forklift trucks and lighting based on ASHRAE 90.1. Steel products are assumed to be the type of stored materials. Typical warehouse occupancy, dock door activity, equipment operation, lighting and infiltration schedules were all simulated on an hourly basis. No office or cold storage areas were included in the analysis in order to focus on just the warehouse heating/ventilating systems.

Heating/Ventilating Systems

Seven different natural gas-fired heating/ventilating systems were sized and modeled. The first complies with the specifications in Appendix G of ASHRAE Standard 90.1-2004. The other six are common types of heating equipment used for warehouses and commercial/industrial buildings with large open spaces. Equipment sizing was done by the EnergyPlus program.

Equipment efficiency and operating characteristics

1. ASHRAE 90.1 baseline – Indirect fired boiler supplying water reheat for VAV system.

- Output – 180°F max water temperature
- Boiler – 80% efficiency
- Provides required ventilation air

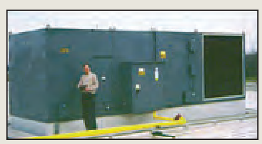
2. HTHV Direct fired, high temperature rise blow-thru heating system

- Output - 160°F max temperature rise
- Burner – 92% efficiency, variable capacity, modulating control
- Provides required ventilation air

3. Direct fired, lower temperature rise draw-thru make-up air heating system

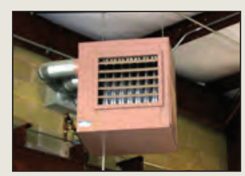
- Output - 120°F max temperature rise
- Burner – 92% efficiency, variable capacity, modulating control
- Provides required ventilation air

4. Direct fired, recirculation heating system



- Output – 49°F max equivalent temperature rise (required by ANSI Standard Z83.18)
- Burner – 92% efficiency, variable capacity, modulating control
- Provides required ventilation air

5. Indirect fired, power vented unit heater system



- Output - 50°F max temperature rise
- Burner – 80% efficiency, single capacity, on/off control
- Indirect fired make-up air heater provides required ventilation air

6. Indirect fired, air turnover (air rotation) heating system

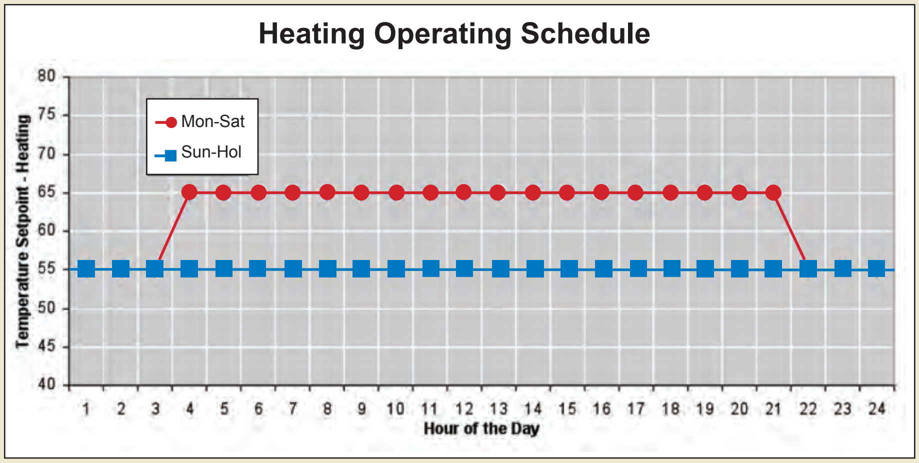
- Output - 35°F max temperature rise
- Burner – 80% efficiency, single capacity, on/off control
- Indirect fired make-up air heater provides required ventilation air

7. Infrared (radiant), high efficiency (condensing tube) heating system

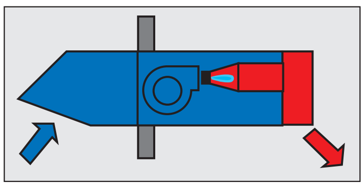
- Output – auto-sized by EnergyPlus program to meet heating load
- Burner – 92% efficiency, single capacity, on/off control
- Direct fired make-up air heater provides required ventilation air

Standard Conditions

- Heating: 65°F during occupied hours; 55°F night/weekend/holiday temperature setback
- Ventilation: 0.06 cfm/ft^2 during occupied hours (to meet ASHRAE Standard 62.1-2007)
- Stratification: 4˚F
- Air Conditioning: Not included in the analysis



HTHV Blow-thru Space Heater



- More energy efficient
- Burner is downstream of blower
- Components in the cold air stream
- 160˚F max temp rise/discharge temp
- Highest Btu/cfm ratio

HTHV Blow-thru heaters used 35% less natural gas and 93% less fan electricity than the ASHRAE 90.1 baseline heating system.

HTHV Blow-thru heaters used the least amount of total energy. Using any other heater type increased total therms required to heat the warehouse by 24% to 59%

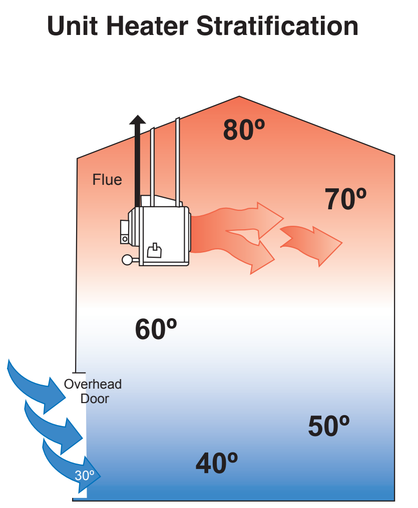
Infrared heaters were auto-sized by EnergyPlus to handle the total heating load. Analysis and load did not incorporate the practice of keeping the space thermostat set 15-20% lower in order to save energy.

Computer Modeling Results

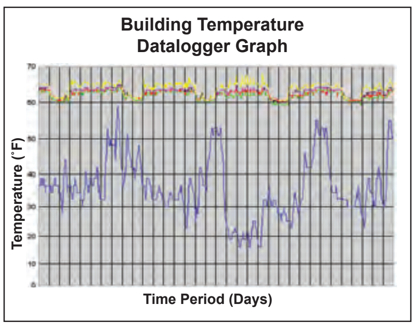
Energy Comparison for Heating Systems
Standard Conditions

Equal Stratification for All Systems (4°F), ASHRAE 62.1 Ventilation (0.06 cfm/ft^2)

Energy Consumption	*Gas (therms)*	*Fan Electric (kWh)*
ASHRAE 90.1 Baseline	30,907	76,733
HTHV/Blow-Thru	20,220	5,758
Draw-Thru	25,052	7,317
Recirculation	25,910	52,644
Unit Heater	30,481	16,289
Air Turnover	26,822	17,153
Infrared	32,156	11,164
% Savings vs. 90.1 Baseline		
HTHV/Blow-Thru	34.6%	92.5%
Draw-Thru	18.9%	90.5%
Recirculation	16.2%	31.4%
Unit Heater	1.4%	78.8%
Air Turnover	13.2%	77.6%
Infrared	-4.0%	85.5%
% Increase vs. HTHV Blow-Thru		
Draw-Thru	23.9%	27.1%
Recirculation	28.1%	814.2%
Unit Heater	50.7%	182.9%
Air Turnover	32.6%	197.9%
Infrared	59.0%	93.9%



HTHV Blow-thru Heaters Reduce Stratification



Building studies show small HTHV type space heaters reduce stratification with their high velocity vertical throw diffusers. They achieve 3°F to 5°F temperature variation, which is the same or better than large air turnover systems while using much less energy.

Stratification

A potentially important energy issue for warehouse heating is temperature stratification. Warehouses typically have high open ceilings where significant differences in air temperature can occur between floor level and the ceiling due to lack of adequate air movement. High levels of stratification will waste energy. Reduced stratification is a claimed benefit of destratifying ceiling fans and three of the heating systems modeled in this analysis (HTHV, Air Turnover and Infrared). Energy modeling software, including EnergyPlus, cannot predict the amount of stratification created by each heating system but it can determine the additional energy used for specific levels of stratification. Therefore each heating system was first modeled using just 4°F stratification and then a second set of modeling results were obtained for 10°F stratification to determine the predicted amount of additional energy used for those buildings that do not use a destratifying heating system or fans.

Computer Modeling Results

Stratification Comparison

4°F Stratification for HTHV, Air Turnover*, Infrared
10°F Stratification for all other systems
ASHRAE 62.1 Ventilation (0.06 cfm/ft^2)

Energy Consumption	*Gas (therms)*	*Fan Electric (kWh)*
ASHRAE 90.1 Baseline	32,563	78,594
HTHV/Blow-Thru	20,220	5,758
Draw-Thru	27,506	7,589
Recirculation	27,805	52,644
Unit Heater	32,833	16,875
Air Turnover	26,822	17,153
Infrared	32,156	11,164
% Savings vs. 90.1 Baseline		
HTHV/Blow-Thru	37.9%	92.7%
Draw-Thru	15.5%	90.3%
Recirculation	14.6%	33.0%
Unit Heater	-0.8%	78.5%
Air Turnover	17.6%	78.2%
Infrared	1.2%	85.8%
% Increase vs. HTHV Blow-Thru		
Draw-Thru	36.0%	31.8%
Recirculation	37.5%	814.2%
Unit Heater	62.4%	193.1%
Air Turnover	32.6%	197.9%
Infrared	59.0%	93.9%

* Low velocity constant air turnover units require 2-3 building air turnovers per hour to minimize stratification.

LEED Green Building Rating System

Indoor Environmental Quality (Indoor Air Quality – IAQ)

Minimum IAQ Performance (Prerequisite)

Intent - LEED Certified buildings must meet the minimum requirements of Sections 4 through 7 of ASHRAE Standard 62.1 or applicable local code whichever is more stringent. ASHRAE 62.1 requires a continuous ventilation rate of 0.06 cfm/ft^2 during occupied periods for most warehouse applications.

EQ Credit 2: Increase Ventilation (Potential Points: 1)

Intent - Provide more outdoor air ventilation than that required by ASHRAE 62.1 to improve indoor air quality. For mechanically ventilated spaces this means increasing the ventilation rate by at least 30%. For most warehouse applications this would require a continuous ventilation rate of 0.078 cfm/ft^2 during occupied periods.

Warehouse Heater Contribution

HTHV Direct gas-fired heaters certified to ANSI Standard Z83.4 can help meet this requirement because they use only 100% non-recirculated outside air. Consult with the heater manufacturer to explore the best options for this credit. This may be a "free point" if the heating equipment already has the capability to provide 0.078 cfm/ft^2. However, it may not make sense to increase the continuous ventilation rate for large unoccupied warehouse areas because this will increase operating costs and energy use without a significant benefit to the building's occupants.

Ventilation Rate

ASHRAE Standard 62.1 requires a continuous supply of ventilation air at the minimum rate of 0.06 cfm/ft^2 for warehouse applications during periods of occupancy. This is a prerequisite for all LEED projects and is also required by many local codes. All seven heating systems were modeled to meet this ventilation requirement. A 30% higher ventilation rate of 0.078 cfm/ft^2 will earn an indoor environmental quality credit point for LEED projects. An additional set of modeling results was obtained for this condition to determine its impact on energy use.

Computer Modeling Results

Combined Increased Ventilation & Stratification Comparison

4°F Stratification for HTHV, Air Turnover*, Infrared
10°F Stratification for all other systems
30% higher than required ASHRAE 62.1 Ventilation (0.078 cfm/ft^2)

Energy Consumption	***Gas (therms)***	***Fan Electric (kWh)***
ASHRAE 90.1 Baseline	35,608	78,483
HTHV/Blow-Thru	22,435	7,350
Draw-Thru	29,214	8,950
Recirculation	27,805	52,644
Unit Heater	36,344	19,636
Air Turnover	29,802	32,256
Infrared	34,978	14,514
% Savings vs. 90.1 Baseline		
HTHV/Blow-Thru	37.0%	90.6%
Draw-Thru	18.0%	88.6%
Recirculation	21.9%	32.9%
Unit Heater	-2.1%	75.0%
Air Turnover	16.3%	58.9%
Infrared	1.8%	81.5%
% Increase vs. Blow-Thru (HTHV)		
Draw-Thru	30.2%	21.8%
Recirculation	23.9%	616.2%
Unit Heater	62.0%	167.6%
Air Turnover	32.8%	338.9%
Infrared	55.9%	97.5%

* Low velocity constant air turnover units require 2-3 building air turnovers per hour to minimize stratification.

HTHV Blow-thru Space Heaters

Figure 1
Computer Modeling
Predicted Energy Savings with HTHV Space Heater

Other Industrial Heating Systems	Energy Savings with HTHV Space Heaters
Indirect Gas-Fired Systems	
Boilers	53%
Unit Heaters	51%
Air Turnover	33%
Infrared (Radiant)	59%
Direct gas-Fired Systems	
Draw-Thru (LTLV)	24%
Recirculation	28%

Conclusions

1. HTHV Direct gas-fired, high temperature rise blow-thru space heaters used 35% to 38% less gas (therms) than the ASHRAE 90.1 baseline heating system for all cases included in this computer analysis. Using any other heater type increased the total therms required to heat the facility by at least 24% to 59% as shown
   in Figure 1.

   HTHV heaters use the least amount of energy to heat/ventilate large warehouses based on the following advantages of their design:
   - Higher 92% efficiency vs. 80% rating for all indirect gas fired systems
   - More efficient, variable capacity, modulating control burner
   - Better performance from dual 160°F maximum temperature rise/ discharge temperature capability providing a high Btu/cfm ratio, which reduces the effective heating load relative to other direct fired heating systems.
   - Electrical energy use is reduced by small blower motor, lower static pressure and ability to provide both space heat and tempered ventilation using the least amount of outside air.

2. Air turnover, draw-thru make-up air and recirculation type heating systems outperformed the ASHRAE 90.1 baseline heating systems by only13% to 22%.

3. Power vented unit heaters are a common way to heat warehouses and were found to virtually match the ASHRAE 90.1 baseline heating system for natural gas use.

4. Although infrared (radiant) heating is a good way to heat stationary objects and small facilities with open spaces, these computer simulation results indicate it to be a poor performer for large buildings that require both space heating and mechanical ventilation. Some manufacturers of infrared heaters recommend using their systems with a rated output 80% to 85% lower than the heat loss calculated by the ASHRAE Handbook or by turning down the room thermostat by an equivalent amount. This analysis did not incorporate either approach.

5. The ASHRAE 90.1 boiler baseline heating system had much higher fan (electrical) energy use due to the significant static pressure associated with using a ducted heating system for a large open area.

6. The combined effects of ceiling stratification and increased ventilation beyond ASHRAE 62.1 requirements can result in a significant 10% to 25% energy increase.

The following guidelines are recommended for the selection of energy efficient space heating equipment used in warehouses and commercial/industrial buildings with large open spaces.

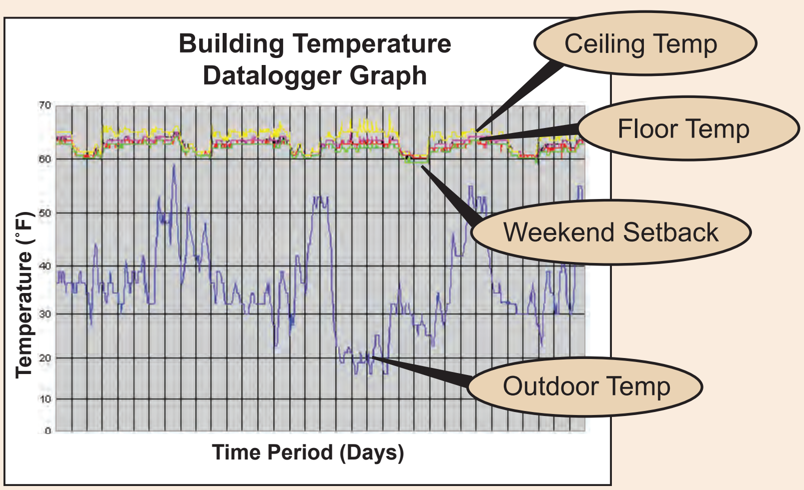
- **90+% Efficient Heaters** - Select space heaters with energy efficiency ratings above 90% to get every possible Btu out of the fuel as usable heat.

Direct-Fired HTHV Heaters
- 100% combustion efficiency (E_c)
- 92% thermal efficiency (E_t)

- **Consider Ventilation and IAQ** - Be sure the heating system accounts for the facility's ventilation and indoor air quality requirements. The use of direct gas-fired, non-recirculating heating equipment certified to ANSI Standard Z83.4 is an energy efficient solution.

ANSI Standard Z83.4/CSA 3.7

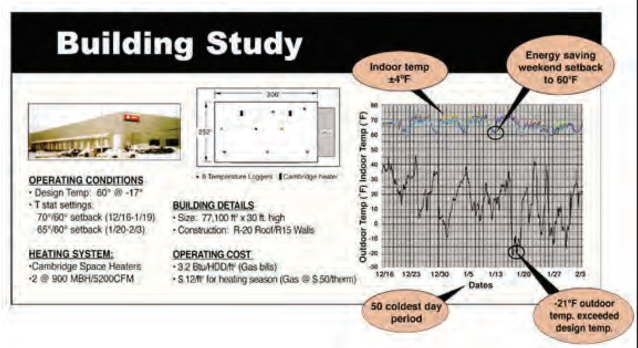
- **Reduce Stratification** - Reduce temperature stratification in buildings with high ceilings. Options include: small HTHV space heaters with their high velocity vertical throw diffusers; large, low velocity constant air turnover heating units that provide two to three building air-volume turnovers per hour; infrared heating; or the use of ceiling fans.



- **Be ASHRAE 90.1 Compliant** - Heating equipment should, at a minimum, be compliant with ASHRAE Energy Building Standard 90.1. As shown by this energy modeling report, this does not necessarily assure you are getting the most energy efficient heating equipment. But it is a requirement for many government tax incentives and utility rebate programs. It is also a prerequisite for LEED buildings. The heater manufacturer should have this stamped on their nameplate.

ASHRAE 90.1 COMPLIANT

- **Document Energy Savings** - Since actual energy savings are the real goal, use a proven technology from an experienced manufacturer that can document energy savings with studies of existing buildings and energy modeling.



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