Industrial Warehouse Heating Energy Case Study

Evaluation of Heating Strategies for Lanter-Gateway Commerce Center III

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Industrial Heating Performance Testing

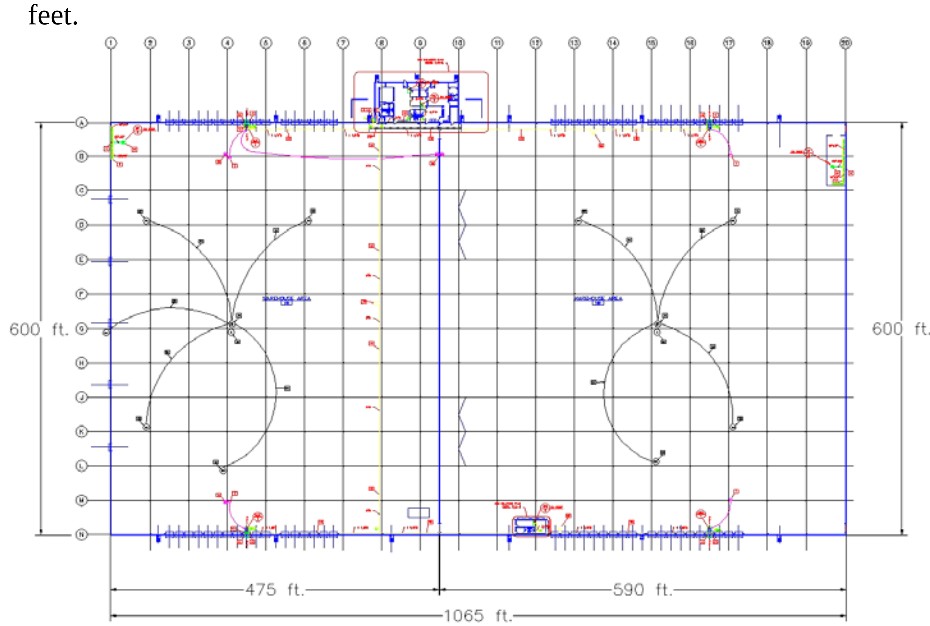
This report documents heating strategies of the Lanter-Gateway Commerce Center III warehouse in St. Louis, Missouri using two direct fired heater configurations:

1) 100% Outdoor Air Direct Fired Heater – Space Thermostat Control
2) Re-circulating Direct Fired Heater – Constant Operation Static Pressure Control

The primary objective of the testing was to rank each heater configuration by its fuel utility usage, electricity utility usage, and air stratification. A secondary objective was to evaluate the impact of the heating configurations on general building comfort and pressure.

Building Description

The Lanter-Gateway Commerce Center III is a 600’ x 1065’ (639,000 square feet) warehouse located in St. Louis, Missouri. The warehouse is divided into two sections by a permanent wall. The north side of the building is 475’ x 600’ (285,000 square feet) and the south side of the building is 590’ x 600’ (354,000 square feet). The average ceiling height of the warehouse is 40 feet.



North Side
Re-Circulating Heaters

South Side
100% Outdoor Air Heaters

Figure 1
Lanter-Gateway Warehouse Layout

Figure 2
North Side of Building

Thermocouples Indicated by Curved Lines

Re-circulating Heaters Located above Shipping Doors

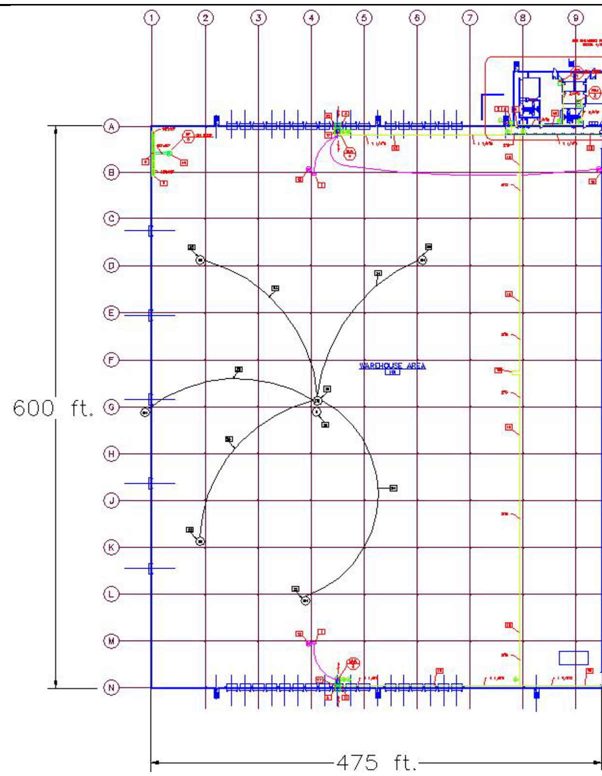


Figure 3
South Side of Building

Thermocouples Indicated by Curved Lines

100% Outdoor Air Heaters Located above Shipping Doors

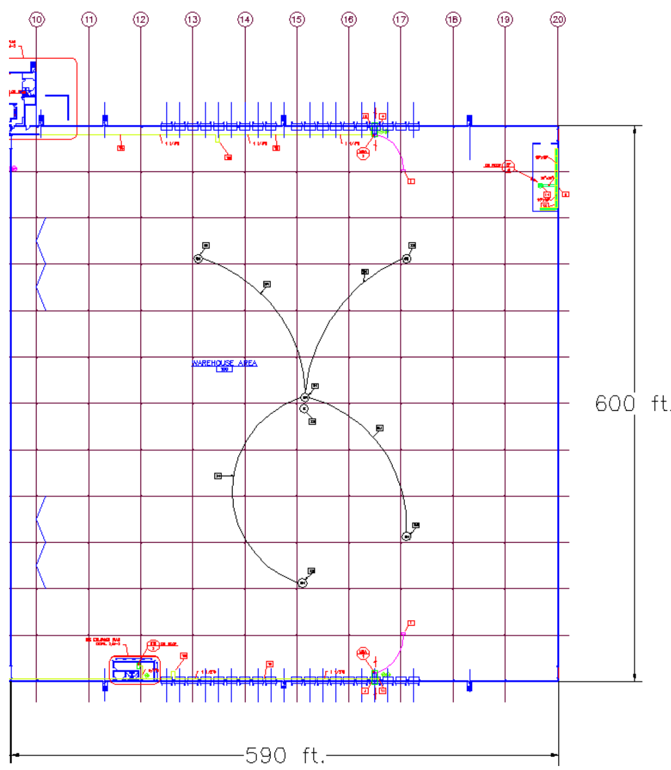


Table 1
Building Construction Summary

Building Construction Summary Total Size = 639,000 square feet (600’ x 1065’), 40 feet tall		
	North Side	South Side
Area	285,000 square feet	354,000 square feet
Length	475 ft.	590 ft.
Width	600 ft.	600 ft.
Height	40 ft.	40 ft.
# of Shipping Doors	39	38
Storage Media	Cleaning Supplies	Pasta

Heating Equipment

The north side of the building is heated with two 17000 CFM, 2.1 MBH re-circulating direct gas fired heaters. The heaters are configured to continuously operate and the outdoor air and return air dampers are configured to operate off of a building static pressure control. The heater continually monitors space temperature and the burner modulates to maintain a constant space temperature.

The south side of the building is heated with two 17000 CFM, 2.1 MBH 100% outdoor air direct gas fired heaters. The heaters are configured to cycle on and off dependent on space temperature. The blower and burner will turn on when the space thermostat is not satisfied and will turn off when the space thermostat is satisfied.

Both heater configurations are designed to maintain a constant indoor air temperature of 65°F

Table 2
Heating Equipment Summary

Heating Equipment Summary		
	North Side	South Side
Model	RAM22-M	RAM22
Quantity	2	2
Total CFM	34,000 CFM	34,000 CFM
BHP	15 BHP/Unit	15 BHP/Unit
Total BTU Rating	4.2 MBH	4.2 MBH
Max. Discharge Temp	125°F	125°F
Space Temp. Set-Point	65°F	65°F
Burner Control Type	Space Temp. Control	Space Temp. Control
Blower Control Type	Constant Operation SP	Thermostat Control

Data Recording System

The data recorded for this case study includes natural gas usage, electricity usage, outdoor air temperature, and indoor air temperature at various locations throughout the building.

Natural gas usage is recorded by a gas meter located at the gas inlet of each heater. A Root/Dresser model 3M175CTR rotary gas meter continually measures gas flow into the heater. Fuel usage is displayed in cubic feet.

Electricity usage is recorded by an hour meter installed on the power wiring for each heater motor. An hour meter from Grainger, model number 6X139, is installed in each heater and measures the number of hours that the motor operates. Time is displayed in number of hours.

Indoor and outdoor temperature is also recorded for this case study. All temperature readings are measured with two Fluke Hydra Series 2625A data loggers. J-Type thermocouples are wired throughout the building and temperatures are taken every 2 hours at every thermocouple. There is one data logger on each side of the building. The outdoor air temperature is measured in one spot and the indoor air temperature is monitored in 16 different spots. The temperature is measured at 8 spots on each side of the building. The 8 spots consist of 4 ceiling level readings and 4 readings just above floor level. The thermocouple building grid positions are indicated in the table below and the grid is defined in figures 1-3.

Table 3
Thermocouple Positions

Thermocouple Position Summary			
North Side (Re-circulating)		South Side (100% Outdoor Air)	
Channel	Column	Channel	Column
2	D2 Ceiling	2	C13 Ceiling
3	D2 Floor	3	C13 Floor
4	D6 Ceiling	4	D17 Ceiling
5	D6 Floor	5	D17 Floor
6	K2 Ceiling	6	K14 Ceiling
7	K2 Floor	7	K14 Floor
8	L4 Ceiling	8	J17 Ceiling
9	L4 Floor	9	J17 Floor
10	G1 Outdoor Temperature		

Fuel and Electricity Usage

Fuel and electricity usage are the two costs of operating direct fired heating equipment. Direct fired heaters operate at 92% fuel combustion efficiency and have a distinct advantage over less efficient indirect fired heaters. Fuel usage is the most significant utility cost of warehouse heating. Average industrial fuel costs are $.78/Therm whereas average industrial electricity costs are $.047/kW-hr.

In this case study, fuel and electricity costs are measured for each of the four heaters on the building during the heating season. Usages and costs are summarized below:

Table 4
Utility Usage Summary

Utility Usage Summary		
Unit	Fuel Usage (Cubic Feet)	Hours of Operation
NE Re-circ	121920	3533
NW Re-circ	146370	3997
SE 100% OA	235800	1924
SW 100% OA	140420	1193

Table 5
Utility Cost Summary

Utility Cost Summary		
Unit	Fuel Cost $	Electricity Cost $
NE Re-circ	$9,985	$1,858
NW Re-circ	$11,988	$2,102
SE 100% OA	$19,312	$1,012
SW 100% OA	$11,500	$627

To directly compare the cost of operating the 100% outdoor air units to the re-circulating units, the cost are calculated on a square foot basis. The results are shown below:

Table 6
Utility Cost / Square Foot

Utility Cost / Square Foot of Building			
	Fuel Cost / Square Foot	Electricity Cost / Square Foot	Total Heating Cost / Square Foot
Re-circulating Heaters	$0.077	$0.014	$0.091
100% OA Heaters	$0.087	$0.005	$0.092

The re-circulating heaters consume 12.9% less fuel than the 100% OA heaters whereas the continuous operation of the re-circulating heaters resulted in 2.8 times more electricity usage than the 100% OA heaters. The total cost of operating each system is nearly identical as shown above.

Air Stratification

Hot air stratification in a warehouse environment translates directly into wasted energy. The hot ceiling temperatures cause more heat transfer through the roof of the structure and while the hot air is stratified, the heating value of this air is not being used where it is needed.

This case study analyzes the difference in hot air stratification between 100% outdoor air heaters and re-circulating heaters. The average outdoor, floor, and ceiling temperatures for this warehouse are illustrated below. Also, the average temperature for each thermocouple location is illustrated below.

Table 7
Average Temperatures

Average Temperatures		
Location	North Side (Re-circulating)	South Side (100% OA)
Average Outdoor Air Temp.	38.65°F	
Average Indoor Air Temp.	64.93°F	65.01°F
Average Ceiling Temp.	65.65°F	65.87°F
Average Floor Temp.	64.19°F	64.14°F
Average Floor to Ceiling	1.46°F	1.73°F

Table 8
Average Thermocouple Temperatures

Thermocouple Average Temperature Summary			
North Side (Re-circulating)		South Side (100% Outdoor Air)	
Column	Average Temperature	Column	Average Temperature
D2 Ceiling	64.88°F	C13 Ceiling	66.97°F
D2 Floor	63.44°F	C13 Floor	64.26°F
D6 Ceiling	66.41°F	D17 Ceiling	65.34°F
D6 Floor	65.49°F	D17 Floor	64.18°F
K2 Ceiling	65.04°F	K14 Ceiling	65.53°F
K2 Floor	63.21°F	K14 Floor	64.36°F
L4 Ceiling	66.32°F	J17 Ceiling	65.63°F
L4 Floor	64.64°F	J17 Floor	63.77°F
G1 Outdoor	38.65°F		

While both heaters maintained a rather consistent average space temperature, the hot air stratification was lower on the re-circulating heater side of the building by .27°F. This is a direct result of using the warm ceiling air as the return air source.

The daily average indoor ceiling, indoor floor, and outdoor temperatures are shown in the following graphs. The first graph shows the north (re-circulating) side of the building and the second graphs shows the south (100% OA) side of the building.

Figure 4
Daily Average North Side of Building Temperatures

Re-circulating

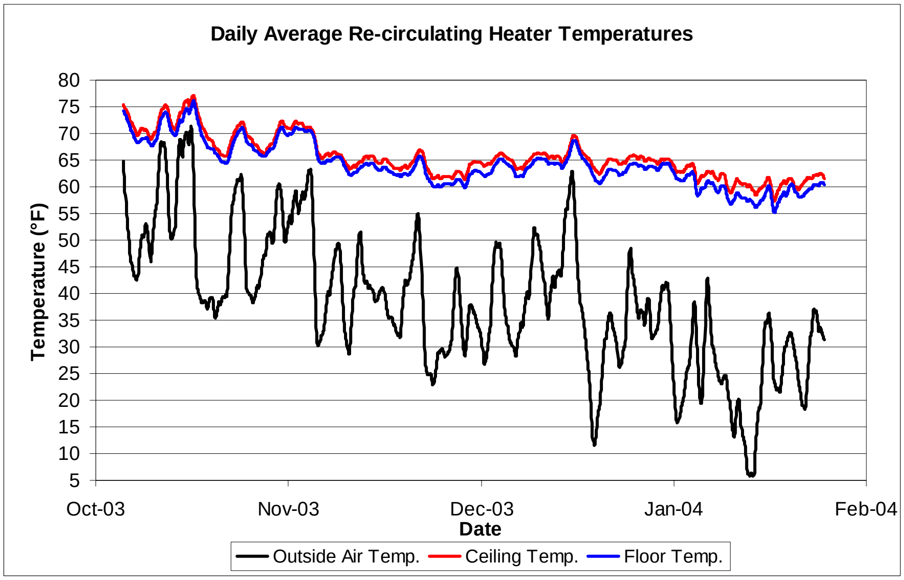
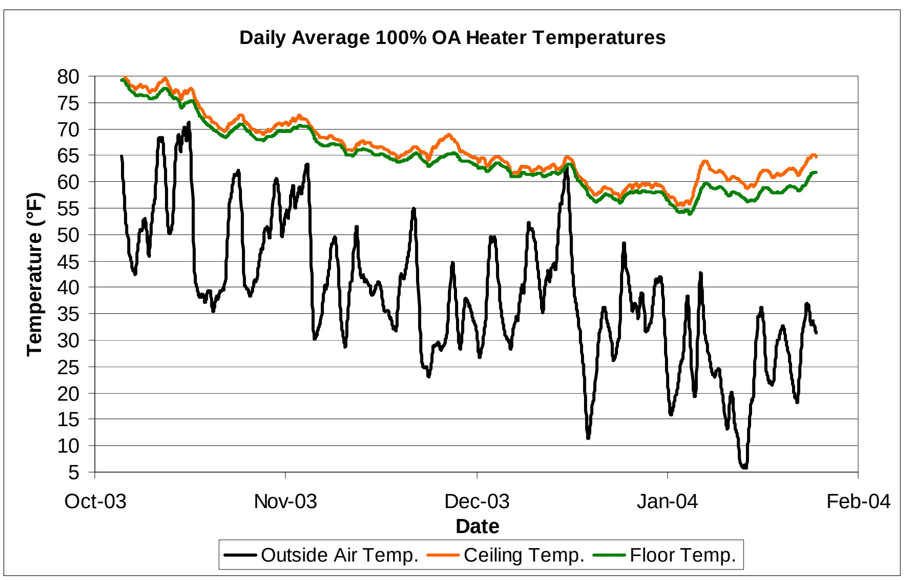


Figure 5
Daily Average South Side of Building Temperatures

100% Outdoor Air



The coldest portion of the analyzed timeframe is shown in the graphs below. The first graph shows the north (re-circulating) side of the building and the second graphs shows the south (100% OA) side of the building.

Figure 6
Coldest Days of North Side of Building Temperatures

Re-circulating

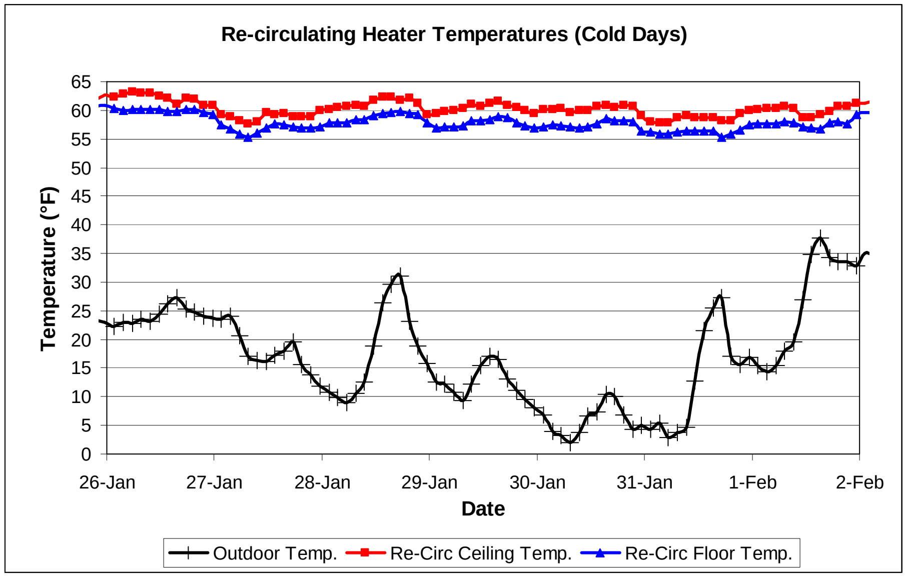
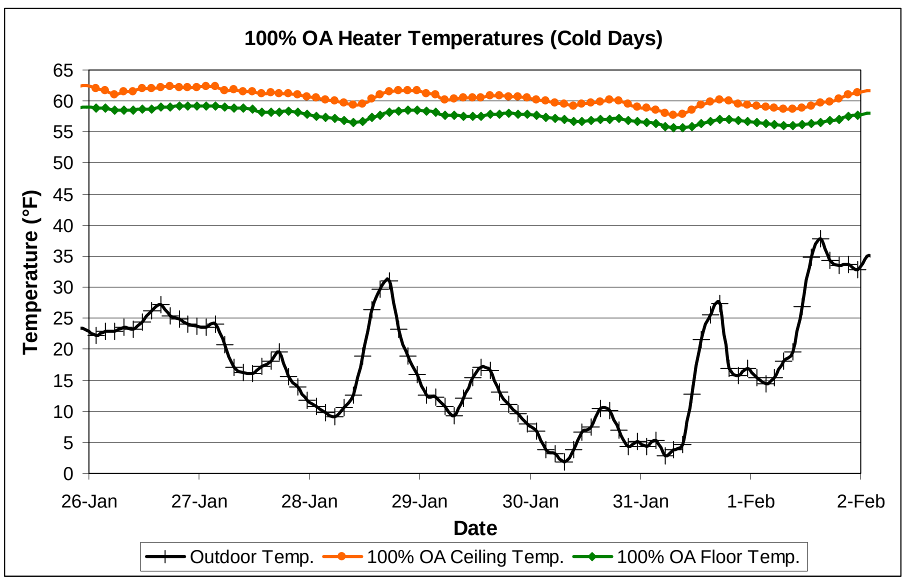


Figure 7
Coldest Days of South Side of Building Temperatures

100% Outdoor Air



Building Comfort

Two factors that effect building comfort are temperature and pressure. Temperature can have a direct effect on employee comfort and productivity. Building pressure can effect cold air infiltration and the draftiness of a building. Pressure can also impact employee safety by making doors hard to open or open uncontrollably.

The north side of this building, heated by the re-circulating heaters, has a very constant pressure compared to the outside of the building. The heater return and outdoor air dampers modulate to maintain a constant pressure relative to the outdoor pressure. Cold air drafts and cold air infiltration are eliminated by maintaining a constant indoor slightly positive pressure. Doors can be opened and closed very easily on this side of the building. Also, when doors are opened, cold air does not rush into the building.

The south side of this building, heated by the 100% outdoor air heaters has, an unpredictable pressure compared to the outside of the building. The heater cycles on and off based on the space thermostat requirement. When the heater is on, there is a positive pressure inside the building. When the heater is off, the inside of the building becomes negative. Doors are harder to open when the heaters are off and open easily, and sometimes violently, when the heaters are on. The south side of the building is much draftier due to the inconsistencies in building pressure. Cold air also rushes in open doors when the heaters are off.

Another trend is observed in the warmer months, where the average indoor temperature of the constant operation re-circulation side of the building is lower than the average indoor temperature of the thermostat controlled 100% OA side of the building. The continuous operation of the re-circulating heaters on the north side of the building helped maintain lower indoor temperatures in the warmer months by constantly delivering air during the day and night. The cooler outside air temperatures at night helped keep the re-circulating indoor air temperature 6.7°F cooler during the day with constant blower operation as shown below.

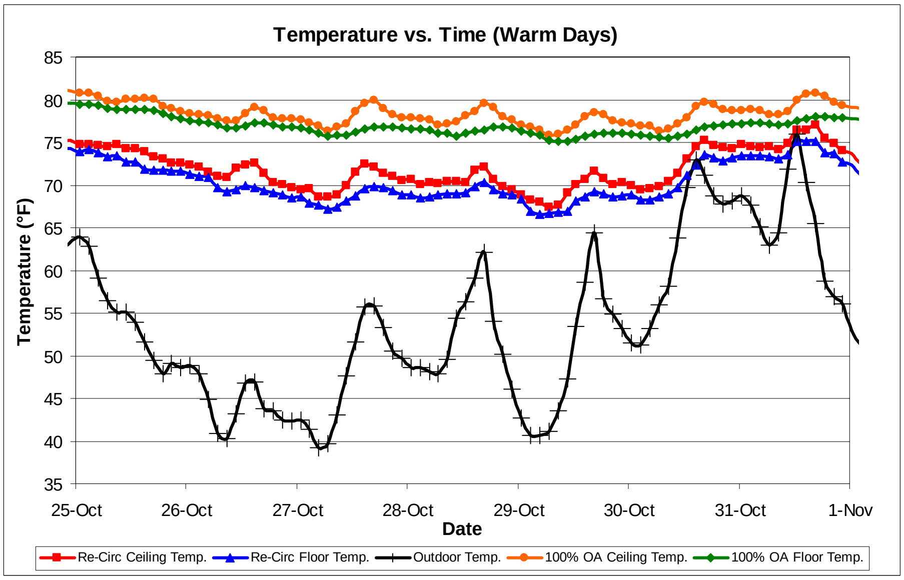


Figure 8
Warmest Days of Outdoor air Temperatures

Conclusion

The results of the heater testing demonstrated distinct differences between the two configurations. Test results, however, clearly show that the costs of operating direct fired heating equipment is very low.

The re-circulating heater was superior to the 100% outdoor air heater in the ability to heat warehouse space using 12.9% less fuel than the 100% outdoor air unit. The lower fuel consumption is a result of utilizing the warmer stratified air in the space and re-circulating it through the heater. This in turn reduced the temperature difference between the floor and the ceiling of the re-circulating side of the warehouse.

The average difference in floor to ceiling temperature for the re-circulating side of the building was 1.46°F compared to 1.73°F for the 100% OA side of the building. This 0.27°F difference correlates directly into fuel savings for the re-circulating heater. Less warm air stratification due to re-circulating heaters also reduce the amount of heat transfer loss through the roof of the building, which translates into more fuel savings.

While the electricity costs were higher for the re-circulating units, the benefits of continuous blower operation are evident. Constant pressurization of a building creates a draft free environment with less cold air infiltration. Doors are much easier to open and open doors do not allow a huge inrush of cold air into the building. Continuous blower operation also revealed a lower indoor building temperature in warmer months. The cooler night outside air delivered into the building helped maintain a cooler indoor air temperature during the warm portion of the day.