THERMA-FUSER™ VAV DIFFUSERS ARE BETTER THAN VAV BOXES

- **Lowest energy VAV terminal**
- **Easily adapts to office layout change**
- **Lowest cost per zone of control**
- **Superior air distribution**
- **Low to no maintenance**

Systems with Therma-Fuser™ diffusers are better than systems with VAV boxes because Therma-Fuser diffusers achieve the ultimate in low energy VAV. Hailed as the first effort to show that individual temperature control can actually reduce energy consumption, a 1993 study comparing a typical VAV box system to a Therma-Fuser diffuser system resulted in energy savings of 35 to 50% for the Therma-Fuser system. A 2007 study now confirms Therma-Fuser system energy savings, 15 to 47%, and also quantifies the sources of the savings for five climate zones.

Studies like these continue to confirm that Therma-Fuser VAV is green VAV. Systems with Therma-Fuser diffusers can achieve all ten LEED-NCv 2.2 points for optimized energy performance. Therma-Fuser diffusers are the preferred VAV terminal. Use them in your VAV systems.

The 2007 Study

This energy study was undertaken to compare a typical VAV Box system with a Therma-Fuser diffuser system. Five climate locations were modeled. Depending on location, the results are **energy savings of 15% – 47%** for the Therma-Fuser diffuser system.

The analysis was performed by an independent engineer using the DOE2.1E software, the most widely-used government-developed program for building energy analysis in the US and 40+ other countries. The building analyzed used a separate air handler per floor with VFD and economizer, a single chilled water plant serving the entire building and hot water heat. Different VAV systems from a VAV reheat box per 3 – 4 offices (base case) to an all low pressure Therma-Fuser diffuser system were analyzed to isolate the sources of energy savings.

Phyical data for the 2007 study was taken from this office building in San Antonio, TX.

The resulting energy savings of the Therma-Fuser diffuser system was broken down into four sources:

1. Individual Temperature Control (Smaller Zones)
2. Lower Turndown than the VAV Box
3. Eliminate Total Pressure Drop Over the VAV Box
4. All Low Pressure Duct System.

Individual Temperature Control, many small zones, prevents over cooling or over heating when spaces are unoccupied. This is possible using a VAV Box per office, but typically is not an economically viable solution. A Therma-Fuser diffuser system offers many small zones at a similar installed first cost to a typical VAV Box system with a single thermostat for three to six rooms. The study modeled a conservative 85% average individual occupancy and only 27% private offices. Resulting energy savings from **Individual Temperature Control** are 1% –15% depending on location. This would be higher in buildings with higher occupancy diversity and more private offices.

Lower Turndown than VAV Box and Eliminate Total Pressure Drop Over The Box are both related to the limitation of air flow measurement with a VAV box. A typical VAV Box operates by using a differential pressure sensor to measure air flow. For this measurement to be accurate, a minimum air velocity must be maintained over the flow cross probe in the inlet of the box. If a box is undersized, there is sufficient velocity over the flow cross at all flow conditions, but at the cost of a large pressure drop. If the box is oversized, the pressure drop is minimized, but the turndown is limited to maintain the minimum velocity over the flow cross. A compromise between the two is typically made which results in a VAV box operating with a 25 – 30% minimum flow and a 0.4 in w.g./100 Pa total pressure drop.

The typical 25 – 30% minimum flow is more minimum flow than is required by ventilation codes. By not being able to turndown further, reheat coils are turned on much sooner than for a Therma-Fuser diffuser system which has minimum flows as low as 10% or less.

Therma-Fuser diffuser systems do not have a velocity

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acutherm™
Therma-Fuser™ Systems

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February 23, 2007

Dear Sir,

Re: Results of Energy Study

This summarizes the results of an engineering study undertaken to compare the energy impact of using small versus large variable air volume (VAV) control zones, and the relative performance of Acutherm's low pressure variable air volume diffuser (Therma-Fuser) versus that of a medium pressure terminal VAV box (0.4 in. w.g. total pressure drop when sized for approximately 3:1 one, or 25% design flow, minimum turndown).

The energy model was built using VisualDOE and analyzed by the DOE2.1E engine to represent a typical 8 story, 154,000 square foot building. Schedules were set that simulate 15% of private offices being unoccupied on any given day.

Overall, the Therma-Fuser system saved between 15% and 47% (depending on climate zone) of the annual HVAC energy costs of the VAV box system. The greatest savings were in climates where significant reheat is required. See the table below.

Use of smaller VAV zones (individual temperature control) reduced the energy requirement of the building regardless of the VAV device used (between 1% and 15% savings) due to reduced overall airflow and overcooling. The area of private offices is 27% of the total area of the building modeled. Savings are expected to be larger for buildings with more private offices and with higher rates of unoccupied private offices.

Use of the Therma-Fuser system offers energy savings across climate zones, primarily due to the following characteristics:
1. Lower minimum turndown capability (between 10% and 28% savings). The typical VAV box can turn down to 25% of the design airflow; better VAV box turndown is possible but at the cost of higher pressure drop or poorer resolution control approaches not supported by many VAV box manufacturers. The Therma-Fuser diffuser control approach allows controlled turndown to the minimum ventilation requirement of the space, reducing the need for reheat.
2. Lower pressure drop (between 2% and 7% savings). The Therma-Fuser system eliminates the use of a pressure-differential flow meter and damper as typically used in VAV boxes, reducing the fan pressure required for operation. Also, elimination of the VAV box often simplifies duct layout and recommended operating pressures are significantly lower for Therma-Fuser diffusers than VAV boxes.

Annual Energy Savings $ and % of Therma-Fuser System vs. VAV Box System

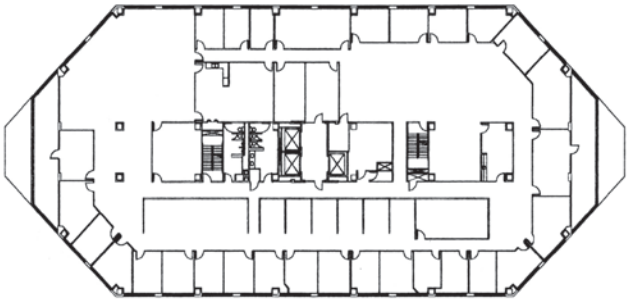
Weather File	Chicago		Los Angeles		Philadelphia		San Antonio		Seattle	
Small Zones Versus Large Zones	$1,055	1%	$8,039	15%	$2,538	3%	$7,196	11%	$567	1%
Lower Minimum Turndown Ratio	$7,952	10%	$13,395	25%	$15,269	16%	$12,350	18%	$16,822	28%
Lower Total System Pressure Drop (1.2" in w.g. Reduction)	$2,293	3%	$4,053	7%	$2,315	2%	$3,843	6%	$1,297	2%
Total Savings	**$11,301**	**15%**	**$25,488**	**47%**	**$20,124**	**21%**	**$23,390**	**34%**	**$18,686**	**31%**

The results show savings across the board for smaller zones, lower minimum turndown ratios, and lower pressure drop systems – all features of a Therma-Fuser diffuser system. For more details of the results, including the impact of a 0.4 in w.g. pressure drop reduction, and of the energy model see my report of February 26, 2007.

Sincerely,

John Weale, P.E.

ENERGY EFFICIENT DESIGN



Typical Floor Layout

limitation because pressure independence is achieved by measuring only static pressure for control of either a fan with VSD or a static pressure damper. Since a minimum air velocity is not required, any static pressure damper may be oversized to minimize the pressure drop without the penalty of increasing minimum flow. Minimizing the pressure drop reduces the total system pressure, reducing the required fan horsepower and energy used. A 25% VAV box turndown was modeled resulting in energy savings for **Lower Turndown Than A VAV Box** of 10% – 28% depending on location. The corresponding savings from **Eliminating Total Pressure Drop Over The Box** are 1% – 2%. A comparison to a box with lower turndown would result in greater savings from **Eliminating Total pressure Drop Over The Box** and less from **Lower Turndown than a VAV Box**.

An **All Low Pressure Duct System** further reduces the total system pressure, further reducing the required fan horsepower and energy used. Unlike the medium pressure VAV Box, the Therma-Fuser diffuser is a low pressure device and only requires a low pressure supply. The resulting energy savings from an **All Low Pressure System** are 1% – 5% depending on location.

ANNUAL ENERGY COST SAVINGS by Source

Region Summer Winter **City**	Mid West Humid Cold **Chicago**	Pacific/CA Warm/Dry None **Los Angeles**	Atlantic Humid Cold **Philadelphia**	South Hot/Humid None **San Antonio**	Pacific/NW Mild Cool **Seattle**
Smaller VAV Zones	2%	15%	3%	10%	1%
Lower Minimum Turndown	10%	25%	16%	18%	28%
Lower Pressure Drop System	2%	5%	2%	4%	1%
Eliminate Pressure Drop Over Box	1%	2%	1%	2%	1%
TOTAL	**15%**	**47%**	**22%**	**34%**	**31%**

ANNUAL ENERGY COST SAVINGS by System Component

City	**Chicago**	**Los Angeles**	**Philadelphia**	**San Antonio**	**Seattle**
Cooling	5%	21%	11%	17%	3%
Heating	6%	18%	8%	9%	25%
AHU Fan	4%	8%	3%	8%	3%
TOTAL	**15%**	**47%**	**22%**	**34%**	**31%**

The 1993 Study

This energy study was undertaken to compare a typical VAV Box system with a Therma-Fuser diffuser system. Both nine hour and twelve hour operational days were modeled. The results are **energy savings of 35% and 50%** for the Therma-Fuser diffuser system.

The analysis was performed by an independent engineer using the Trace 600 software, the most widely-used software at that time. The building analyzed used air handlers with VFD's, a single chilled water plant serving the entire building and hot water heat. A VAV system with a box per six offices and an all low pressure Therma-Fuser diffuser system were analyzed to determine energy savings. The VAV boxes on the perimeter had hot water coils for heating only (IAQ was not a big enough issue in 1993 for reheat to be used). Physical data was from an actual 66,000 square foot building.

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ANNUAL kWh SAVINGS by System Component

Operational Day	**9 Hours**	**12 Hours**
Cooling	15%	26%
Heating	0%*	0%*
AHU Fan	20%	24%
TOTAL	**35%**	**50%**

*Heating savings are negligible

acutherm™

Based on 35,520 square feet of interior space and 30,480 square feet of exterior space, the Therma-Fuser diffuser system reduced the electrical **energy savings by 35%** for a nine hour operational day for the total HVAC system. For a twelve hour operational day total HVAC electrical **savings were 50%**. These savings tend to be higher than the 2007 study because of lower average individual occupancy and more private offices. Note that the heating savings are negligible because there was no reheat.

"The significance of this study is that it's the first effort that I'm aware of to demonstrate that individual room temperature control can actually reduce energy consumption compared to conventional multi-room zone control.

— Robert T. Korte, Editor
Heating/Piping/Air Conditioning Magazine

Excerpts from C.A. Pieper Report, September 19, 1993

This engineering study was undertaken to demonstrate the impact of zoning and duct pressure on HVAC system energy consumption. Multi-room zoning typical of a VAV box system was compared to low pressure individual temperature control zoning typical of a Therma-Fuser VAV system. Calculations were performed on a computer using the Trace 600 program written by the Trane Company. Physical data for the calculations were taken from an actual 66,000 square foot office building in Nashville, Tennessee.

Physical data for the 1993 study was taken from this office building in Nashville, TN.

Calculations were performed for both a nine hour operational day and a 12 hour operational day for the HVAC system, beginning 7:00 a.m. on weekdays. The calculations were separately run for interior and exterior spaces.

The study attempts to follow operation of an office building controlled by the General Services Administration.

That input and other conditions of the study are:

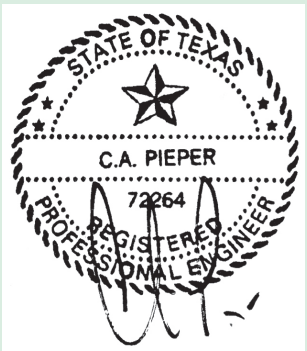
1) The individual office is vacant for daily work breaks and for an amount of time to account for absences such as vacation, travel, holidays, training and sick leave. GSA building management calculated the average daily individual office occupancy to be 5.95 hours. This was rounded to six hours for the study. (Most commercial office building managers find six hours too high.)

2) At least one interior office and one exterior office per zone are occupied while the HVAC system is in operation. The heaviest occupancy is scheduled between the hours of 8:00 a.m. and 5:00 p.m., lightened between 11:00 a.m. and 1:00 p.m.

3) GSA regulations are followed for temperature set points and allowable temperature drift in the occupied offices.

4) GSA regulations are followed in that lights and equipment are off when the office is unoccupied.

The HVAC electrical energy savings of the Therma-Fuser diffuser system for a nine hour operational day were 29% for exterior zones and 40% for interior zones which resulted in energy savings of 35% for the total HVAC system. When offices are occupied six hours of a twelve hour operational day total HVAC savings were 50%, 42% for exterior zones and 57% for interior zones.



Both studies available from Acutherm on request.

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