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ENGINEERING

SYSTEM SOLUTIONS

Designing green is about creating properties that are desirable to own and occupy. As an owner, desirability brings a premium in terms of rental income and property values. It also means lower operating costs. Higher rents and lower operating costs both add to the bottom line. As a commercial tenant, desirability means the workspace is more comfortable and productive. Comfortable environments produce higher performance.

Unfortunately, first cost pressures often eliminate long term, environmentally friendly decisions that pay back quickly. However, high efficiency doesn't always have to cost more. It can cost less.

This newsletter provides several design concepts that demonstrate that you can improve efficiency without adding significant (or any) capital cost. Capital cost, in this case, is defined as the entire mechanical system so you can see relative changes to the cost.

It is important to note that, while the concepts are demonstrated with air handlers and chillers, they can also be applied with rooftops and vertical self-contained systems. This method can be repeated for your building, location and conditions using McQuay Energy Analyzer™. Contact your local McQuay Representative for a copy of Energy Analyzer software and design assistance, or visit www.mcquay.com.

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Designing Green Does Not Have To Cost More

An essential element of designing green and the Leadership in Energy and Environmental Design (LEED) program is that all elements of a building (economy, environment, community) are interdependent and must be considered as part of the whole that makes up a “Green” building. Stated another way, the whole is only as good as the sum of its parts.

The same holds true for designing HVAC systems. Chiller efficiency is important, but it is only one element. Plant efficiency is the bigger picture and harvests the largest returns, but it is also the least understood. A component focus that maximizes the efficiency of a pump or chiller does not exploit the synergies between them. It is possible to purchase more efficient equipment within the limits of the budget or technology. However, the most efficient plant will never achieve its potential until the relationships between equipment are understood and exploited. A well thought out plant strategy can dramatically reduce your energy bill. Saving 20% or more is possible, and these percentages both dwarf and obsolete traditional methods of improving efficiency.

To understand the synergies in the system, Figure 1 shows an average annual "energy pie" of a typical building's mechanical system. Interestingly, fan energy is generally the largest energy consumer in the mechanical system, but chillers tend to receive the overwhelming degree of attention in terms of efficiency. From this, you could draw a conclusion that money spent for high efficiency chiller plants might be better spent on high efficiency airside systems to generate far greater returns.

Figure 1 – “Average” Office Building Annual Energy Consumption

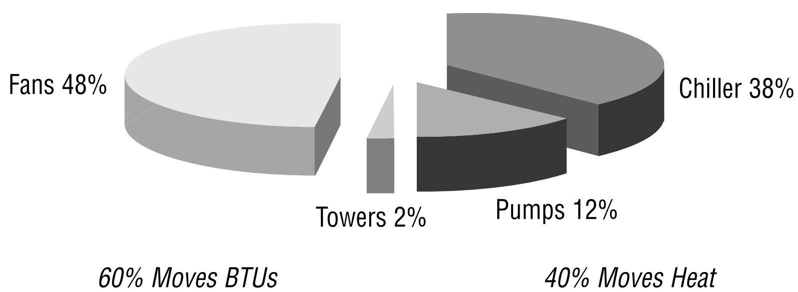
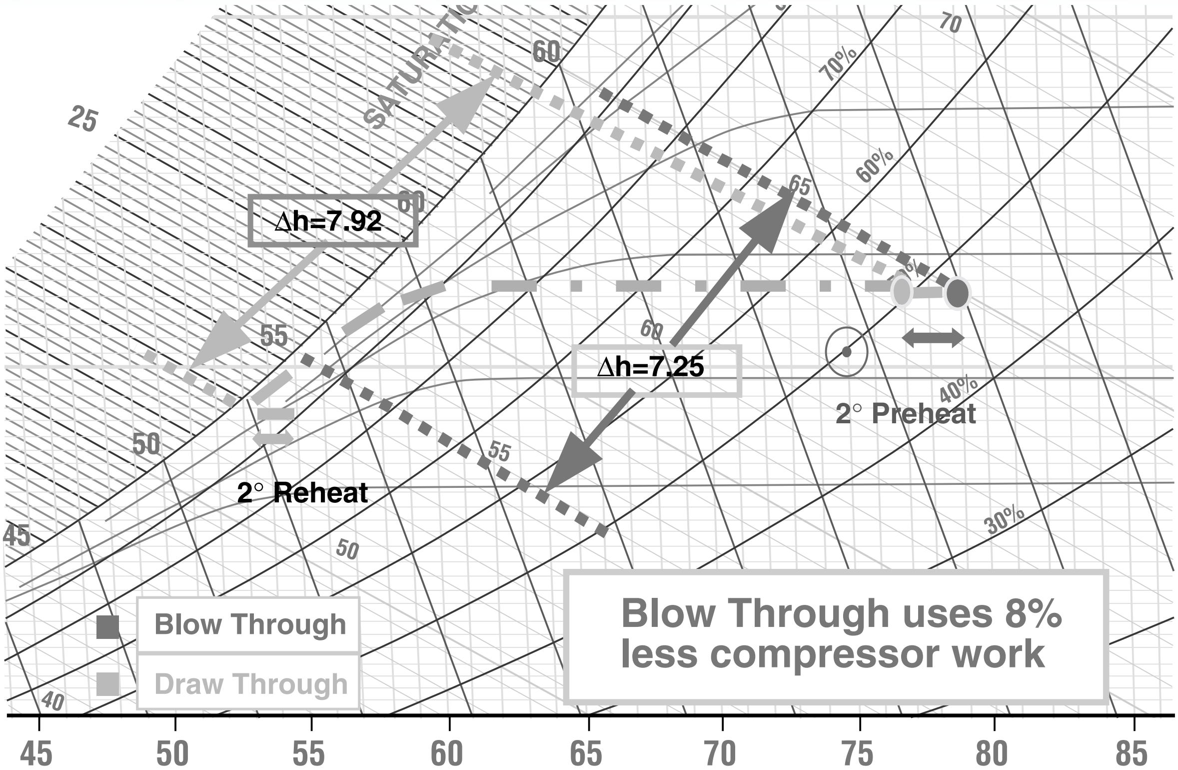


Figure 2 – The Psychrometrics of Blow Through and Draw Through Air Handlers



Chiller Plant Design Begins With the Airside

When considering airside comfort, it is important to understand that many decisions create "defaults" that cascade through the rest of the system. Early decisions can create liabilities that last the life of the building. One of these decisions is the traditional practice of supplying 55°F air with draw through air handlers.

The placement of the fan upstream or downstream of the coil has a big impact on the size, efficiency, and money spent purchasing and operating air conditioning equipment. Blow through air handlers are a better solution in many applications. Unfortunately, traditional design practices almost always eliminate them from consideration.

Concerns with moisture carry over promote draw through air handlers. The root issue is that air handlers are sized at minimums, resulting in velocities that are at the limit of moisture carry over. As a result, draw through air handlers are installed to add "reheat". However, fan heat is a significant portion of the load.

Because draw through air handlers add fan heat after the supply air leaves the coil (typically 2°F-3°F), the coil must produce colder air to compensate for the added heat. This instantly requires added work from the cooling plant.

Conversely, blow through air handlers add "preheat" (fan heat is added before the coil). As a result, the temperature off the coil is the temperature leaving the air handler. As shown in Figure 2, a blow through air handler requires about 8% less compressor work than a draw through air handler, if both are supplying 55°F to the space.

Table 1 provides the results of an energy analysis for three different cities in North America using McQuay Energy Analyzer. Under equal conditions, there is a 6 to 8% improvement in energy use with a blow through design versus a standard draw through design. Depending upon compressor type and manufacturer, the 2°F to 3°F colder suction temperatures for draw through systems to achieve 55°F supply air can require 5% to 10% more effort from the chiller compressor.

Pursuing Airside Savings

Referring back to Figure 1, while fan motors may be smaller than chiller motors, they are used the entire time the building is occupied. The remainder of this newsletter will focus on the affects of improving airside efficiency. For the following examples, we will assume that the blow through system will supply 55°F air to the space and the draw through system

Table 1 – Blow Through and Draw Through Compressor Energy Comparison

	San Francisco	Phoenix	Boston
Draw Through	$11,078	$27,339	$21,458
Blow Through	$10,272	$25,566	$19,761
Improvement	7.3%	6.5%	7.9%

will supply 57°F air to the space (55°F leaving the coil plus 2°F fan heat).

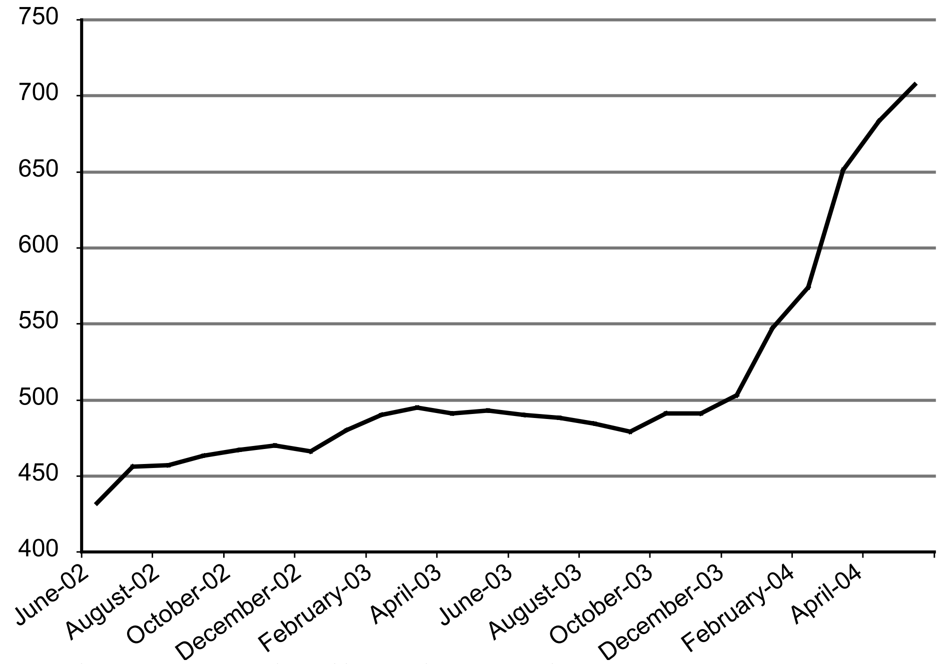
The immediate affect of this 2°F change in delta T is a 10% reduction in air volume for the blow through system. Lowering the air volume can have two benefits. First, the lower air volume can decrease the duct sizes required for the building. This can result in significant first cost savings, particularly given the increased cost of galvanized steel (Figure 3). Another option is to not reduce the ductwork size. In this case, the lower air volume will result in energy savings year after year.

Baseline and Efficient Design Comparisons

1. Baseline Draw Through: To illustrate energy savings, we examined a hypothetical 200,000 ft^2 building in Chicago and designed a baseline HVAC draw through system that met ASHRAE Standard 90.1 (Table 2). This standard design was given an energy efficiency ratio of 1.

2. Baseline to Efficient Draw Through: We then improved upon this design by choosing slightly more efficient fans and a more efficient chiller to provide a basis for an efficient draw through unit (Table 2). Keep in mind that the ECB Method of ASHRAE 90.1 does not allow a change in fan system energy between the baseline system and the proposed design building for ASHRAE 90.1 compliance. However, Appendix G to 90.1 does allow a change in fan efficiency. Refer to Engineering System Solutions Edition 20 (April 2004), *LEED Energy and Atmosphere Credit 1 - Measuring Efficiency to Maximize Points,* for more information on Appendix G.

Figure 3 – Galvanized Steel Pricing (June 2002 to April 2004)



Source: http://www.meps.co.uk/World%20Carbon%20Price.htm

This resulted in a 27% improvement in efficiency over the standard design, but it also added some capital cost to the system.

3. Efficient Draw Through to Efficient Blow Through: In order to continue increasing the efficiency of the system, we changed the design from draw through to blow through (Table 2). The blow through unit would be a smaller, but longer, to accommodate a diffuser in front of the coils. The draw through unit would be larger (more CFM), but shorter. Since the duct work is held constant, the external static pressure is reduced in the blow through system.

Changing the HVAC design to blow through resulted in an additional 6% energy savings over the efficient draw through design. This 6% decrease in energy is at no capital cost premium. The efficient blow through design results in a 31% decrease over the Standard draw through design. This change resulted in a 10% reduction in air volume and a 20% reduction in duct friction losses from the efficient draw through design. Because the cooling coil leaving air temperature is the same for both the blow through and draw through systems, there was no penalty on the chiller size or efficiency.

Table 2 – Baseline Draw Through to Efficient Blow Through

Units (kWh)	Chiller Plant	Fans	Total	kWh/ft2	Energy Ratio	Capital Cost Ratio
1. Standard Design Meeting 90.1	297,244	308,354	605,598	3.03	1.00	1.000
2. Efficient Draw Through Design	244,394	196,950	441,344	2.21	0.73	1.004
3. Efficient Blow Through Design	253,491	162,456	415,947	2.08	0.69	1.001

4. Efficient Blow Through to Optimal Air Blow Through: To further improve upon the design, the supply air temperature to the space was lowered from the standard 55°F to 50°F, which reduced the CFM requirement (Table 3). Like the switch from blow through to draw through, savings from the reduced CFM can be taken up front, in the form of lower capital costs by downsizing the ductwork, or they can be taken over the life of the equipment in the form of energy savings. In this example, the ductwork remained equal for both systems. The chilled water supply temperature was lowered to 40°F in order to produce the lower air temperature. As a result, the compressor work increased by 13%.

One important obstacle when comparing a standard 55°F air unit to an optimal air design (50°F) is that we need to trade fan energy for chiller energy. That is, we need to save fan energy quicker than we gain chiller energy. This can be very difficult in some climates. For example, more humid climates have a much higher latent load when moving from 55°F to 50°F, resulting in more load on the chiller.

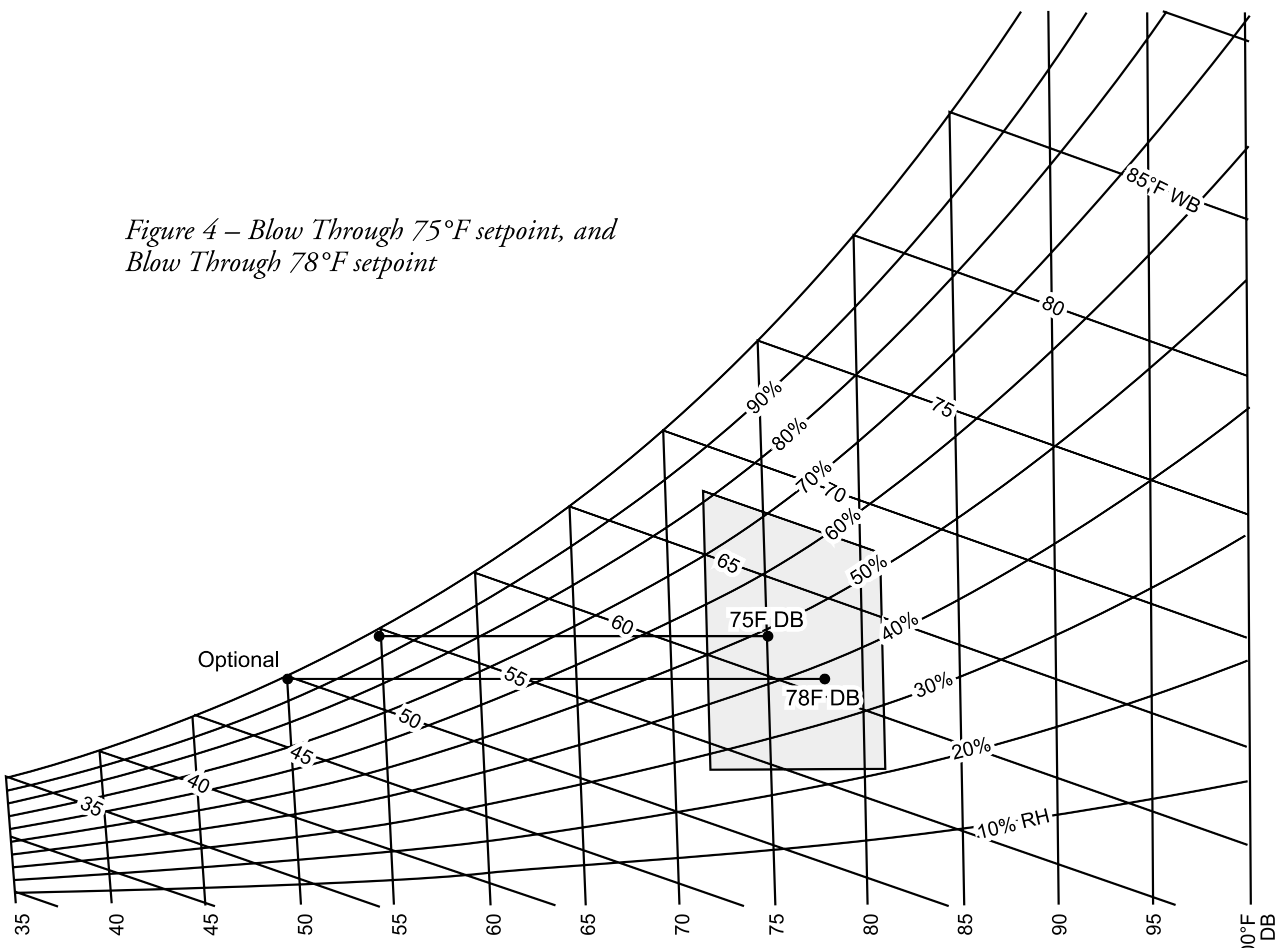
5. Optimal Air Blow Through to 78°F Setpoint: Because the 50°F air will be drier, it is possible to raise the setpoint in the space (from 75°F to 78°F). Following the comfort settings of ASHRAE Standard 55, the drier environment shows that 80% of occupants will be just as comfortable at a higher setpoint due to the lower humidity (Figure 4).

Increasing the setpoint to 78°F resulted in a 38% improvement over the Baseline design. It also resulted in a 15% improvement over the efficient draw through design with no added capital cost (Table 4).

Table 3 – Baseline Draw Through to Optimal Air Blow Through

Units (kWh)	Chiller Plant	Fans	Total	kWh/ft2	Energy Ratio	Capital Cost Ratio
1. Standard Design Meeting 90.1	297,244	308,354	605,598	3.03	1.00	1.000
2. Efficient Draw Through Design	244,394	196,950	441,344	2.21	0.73	1.004
3. Efficient Blow Through Design	253,491	162,456	415,947	2.08	0.69	1.001
4. Optimal Air Blow Through Design	308,956	115,188	424,144	2.12	0.70	1.007

Figure 4 – Blow Through 75°F setpoint, and Blow Through 78°F setpoint



6. Optimal Air Blow Through with 78°F Setpoint and Optimized Chiller: In much the same way that we improved upon the baseline design of the draw through system, we can also improve upon the optimal air blow through design by adding a variable frequency drive and selecting a dual compressor centrifugal chiller (Table 4).

In this case we were able to draw another 10% savings out of the HVAC system. This final result does add capital cost to the system, but the year over year performance of an energy efficient system may be an attractive trade-off depending upon energy rates.

Dollars and Cents

As we have demonstrated thus far, plant efficiency is not just about purchasing high efficiency equipment. It is understanding the synergies between components and making them work together. In the previous examples, we were able to show a 15% improvement in energy efficiency without increasing capital cost dollars. In fact, as shown in Table 5, we actually started to save on capital costs by downsizing the airside significantly.

When comparing the cooling system changes with the whole building energy use, the changes due to increased HVAC efficiency resulted in a 7% decrease in energy used by the overall building. The 7% overall energy reduction is more than half way to a LEED point in a new building, and nearly two LEED points in an existing building (See Engineering System Solutions, Edition 16, April 2003, *Building Sustainability and HVAC Systems*). The blow through system would work very well in an existing building because the duct work will already be in place, and is likely to have been sized for a 55°F supply air temperature draw through system.

Conclusion

Is this the most efficient HVAC system design? The answer is no. The entire building must be considered, including the lighting and envelope. For instance, by decreasing the W/ft^2 of lighting in the space, the size of the HVAC system would decrease, resulting in less energy used by both the lighting and HVAC systems. Depending on the location and building type, there may be other options that will save energy.

In addition, energy efficiency is not the only benefit of this system. Significant capital cost savings can result from reducing duct sizes in response to the lower air volume. While the energy costs will remain somewhat flat, the capital costs could be significant given the rising cost of galvanized steel. In this case, it would be beneficial to consider the life cycle impact of initial cost savings versus the year over year energy savings.

Table 4 – Baseline Draw Through to Optimal Air Blow Through, Optimized Chiller Plant

Units (kWh)	Chiller Plant	Fans	Total	kWh/ft2	Energy Ratio	Capital Cost Ratio
1. Standard Design Meeting 90.1	297,244	308,354	605,598	3.03	1.00	1.000
2. Efficient Draw Through Design	244,394	196,950	441,344	2.21	0.73	1.004
3. Efficient Blow Through Design	253,491	162,456	415,947	2.08	0.69	1.001
4. Optimal Air Blow Through Design	308,956	115,188	424,144	2.12	0.70	1.007
5. Optimal Air Blow Through Design With 78°F Setpoint	282,588	93,600	376,188	1.88	0.62	0.998
6. Optimal Air Blow Through Design With 78°F Setpoint/Optimized Chiller	238,225	93,600	331,825	1.66	0.55	1.003

Table 5 – System comparisons in dollars and cents

Units (kWh)	Chiller Plant	Fans	Total	kWh/ft2	Energy Ratio	Capital Cost Ratio
1. Standard Design Meeting 90.1	29,170	30,261	59,431	0.30	1.00	1.000
2. Efficient Draw Through Design	24,306	19,587	43,893	0.22	0.74	1.004
3. Efficient Blow Through Design	25,296	16,192	41,488	0.21	0.70	1.001
4. Optimal Air Blow Through Design	30,817	11,490	42,307	0.21	0.71	1.007
5. Optimal Air Blow Through Design With 78°F Setpoint	28,221	9,348	37,569	0.19	0.63	0.998
6. Optimal Air Blow Through Design With 78°F Setpoint/Optimized Chiller	23,824	9,360	33,184	0.17	0.56	1.003

The data and suggestions in this document are believed current and accurate at the time of publication, but they are not a substitute for trained, experienced professional service. Individual applications and site variations can significantly affect the results and effectiveness of any information, the reader must satisfy him/herself regarding the applicability of any article and seek professional evaluation of all materials. McQuay disclaims any responsibility for actions based on this document.

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