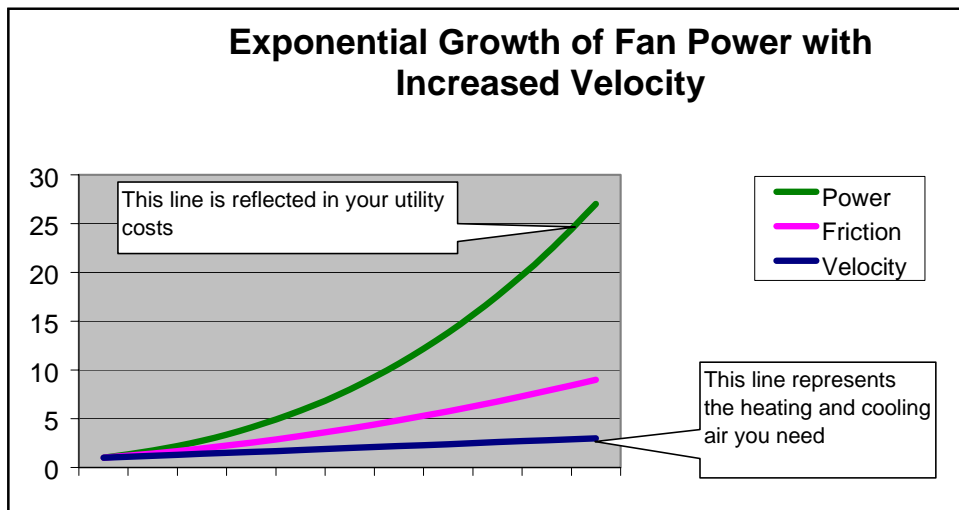


## White Paper #15 Reducing Air Distribution Costs

**The choice to down-size ductwork permanently raises the cost of HVAC operation, so put your designers on an energy diet today. The payback may be quicker than you think, especially if your building has a demand charge.**

Air is a popular energy transport medium for a variety of reasons. Air is cheap, and doesn't make a mess when it leaks. But air is relatively inefficient for moving cooling and heating energy around a building. With its low specific heat, it takes a lot of it. If the ductwork containing the HVAC air stream is too confined, the friction losses increase - exponentially. For example, if two alternate duct designs are proposed and the second one uses smaller ducts but requires the velocity to increase by 50 percent, then the fan power to move the air through the higher velocity system will increase three-fold. Even a small increase in duct velocity of 15 percent will increase fan power by 50 percent. In engineering terms, these are called the "fan laws" and they say, generally, that all things equal, if you double the air flow you will increase pressure (friction) four times and fan horsepower eight times. In other words, don't try to blow through a straw.

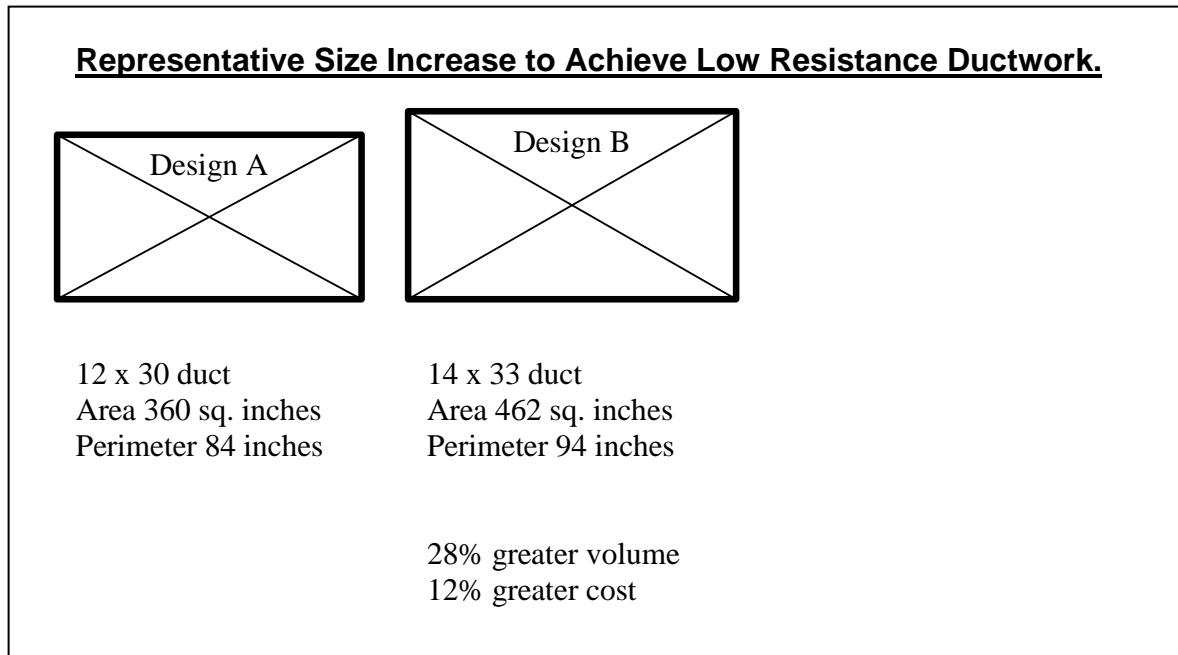


Of course, energy cost is not the only driver in a mechanical design. Large, low-velocity ducts cost more than small high-velocity ducts, and take up more room – taken to extremes, the “optimal” HVAC duct system could cause the building to become taller, just to fit it all in. However, within reason, HVAC duct sizing should be scrutinized more closely than it is. Why?

In addition to the added fan horsepower itself, the heat produced by the extra horsepower creates even more cooling load – which then requires even more fan horsepower! The combination of downsized ducts and the summer amplification effect have resulted in a great number of HVAC systems to be put in place with supply fan motor horsepower (Hp) at half of the cooling compressor Hp. These high parasitic losses are the reason to put your designers on an energy diet. By

prescribing that **the fan kW at full load be kept to no more than 20 percent of the cooling equipment kW**, you should have a good balance of first cost and operating cost.

Sounds easy, but is it? Actually, the design parameter change is very easy. For the duct wheel that most designers use, a new mark will be required on the friction scale (such as 0.064 instead of 0.08). For equipment sizing, the criteria of 400 fpm face velocity instead of 500 fpm is all that is required. Since the ducts would be larger, some additional effort may be required to make it fit above the ceilings. Here is a representative size change to illustrate:



Air system friction losses include ductwork, diffusers, dampers, etc. in the distribution system, but also cabinet and coil losses at the central equipment. Often 50 percent or more of the total friction loss occurs at the air handling equipment itself, before it even enters the duct system. So, reducing air system energy penalties should also include the air handling equipment. For first cost reasons, coils and cabinets are usually sized at the smaller end of their range, but doing this builds in permanent system losses which the Owner may not be aware of – until it's too late. Instead of the traditional “500 feet per minute” air velocity through these devices, sizing to 400 fpm will reduce air handler casing losses by nearly half. In practice, this usually means increasing the casing, filter, and coil sizes by one size. After that, the designers can adjust main and branch duct sizes to stay within their fan energy budget.

### **What about cost?**

Upsizing the air handling equipment 25 percent (from 500 fpm to 400 fpm) will increase equipment cost proportionally or approximately 25 percent. Using the same 4/5 ratio as was used in the air handler, we can estimate the effect on ductwork. For the same air flow, the fan hp will be  $(4/5)^3 = 0.512$  (nearly half), which is the same effect we found on the air handler by enlarging those items slightly. To increase the air flow capacity by 25 percent, the duct cross sectional area is increased by 25 percent. Ductwork is normally priced by the pound, and calculated by perimeter length. The added capacity will increase duct weight – and duct cost – by approximately 12-15 percent (same proportion as the change in duct perimeter). The project ratio of equipment cost to ductwork cost will

vary, but for this paper we'll assume the duct portion is no more than half of the equipment cost. So, the HVAV system cost (equipment and ductwork) would increase 22 percent, while reducing fan energy and demand by about 50 percent.

### **What about VAV systems?**

Existing energy codes allow large fan motors and small ducts in VAV systems. The basis for this is that the inefficient full-load operation will only occur occasionally, and that fan Hp demand will drop off quickly for most other times, due to the natural effect of the fan laws. From strictly an energy standpoint this is usually true, but if demand is considered, it is easy to reason that the building demand (and the 12 month ratchet) is likely to be set during the hottest days. The complete answer lies in a "load profile", which compares the overall seasonal effect. While no two buildings are exactly the same, a representative sample load profile is provided at the end of this paper, and shows a payback of about five years for installing a reduced resistance HVAC air flow system. For constant volume systems, systems with extended run times, or systems with greater air flows, the payback time will be shorter. Note that the life of the duct system is normally assumed to be 30 years (ref. ASHRAE), so this investment should pay for itself 5 times over, during its lifetime.

**EVALUATE COST AND SAVINGS FROM LARGER AIR DUCTS**  
**100 TON VAV AIR SYSTEM**

March 2005

1300	Total hours
0.7	Fan eff
0.9	Motor eff
100	Base Load (tons)
400	Air Flow (cfm per ton)
0.8	power factor
4.5	SP Design A
2.3	SP Design B
750	equip cost per ton
50%	duct fraction of equip
0.055	\$ per kWh
9	\$/mo demand
25%	% increase-equipment
12%	% increase - ductwork

Assumptions:  
Air flow rate is proportional to the load  
Cooling Load for excess fan heat ignored  
Load Profile per ARI-550/590  
Minimum System Pressure 1.5 in. w.c.  
Building Break-Even temperature 50 degF  
1425 hours cooling  
2007 hours heating or ventilating, at min air flow  
6am-6pm operating schedule (office building)

VARIABLE AIR VOLUME	htg	clg	clg	clg	clg	Annual Total
Nominal % load	25%	25%	50%	75%	100%	
Cooling Pct time at this load		11%	33%	39%	17%	
Total HVAC run hours						3432
Htg hours	2007					
Cooling Hours at this load		157	470	556	242	1425
Load	25	25	50	75	100	
Air Flow	10,000	10,000	20,000	30,000	40,000	40,000
Minimum pressure	1.50	1.50	1.50	1.50	1.50	
<b>A (regular)</b>						
System pressure	1.50	1.50	1.50	2.53	4.50	
Fan Hp	4	4	7	19	45	
Fan demand kW	2	2	4	11	27	
Fan energy kWh	4,487	350	2,103	6,290	6,499	19,729
Fan heat, tons	0.6	0.6	1.3	3.2	7.6	
<b>B (low pressure)</b>						
System pressure	1.50	1.50	1.50	1.50	2.30	
Fan Hp	4	4	7	11	23	
Fan demand kW	2	2	4	7	14	
Fan energy kWh	4,487	350	2,103	3,727	3,322	13,989
Fan heat, tons	0.6	0.6	1.3	1.9	3.9	

<b>SAVINGS</b>	Energy	5740 kWh	\$316
	Demand	13 kW	\$1,416
	Equip. capacity	3.7 tons	\$2,798
	<b>Total Savings</b>		<b>\$4,530</b>

<b>COST</b>	equipment premium	\$18,750
	ductwork premium	\$4,500
	<b>Total Cost Premium</b>	<b>\$23,250</b>

**Payback**      **Simple Payback**      years      **5.1**