

# HVAC Systems

## Right Sizing



## Summary

The need to provide 100% uptime with a near equivalent reliability in critical facilities does not preclude the opportunity to reduce first cost and improve efficiency by avoiding inefficient oversizing of mechanical equipment. Providing redundant capacity and sizing for true peak loads can be done in a manner that improves overall system efficiency, but only if a system design approach is used that considers efficiency among the design parameters.

Upsizing the duct and piping infrastructure used to supply ventilation and cooling to the cleanroom offers significant operating cost and future flexibility benefits. New VFD (variable frequency drive) chillers significantly reduce the penalty from oversized chillers and are highly recommended. Pursuing efficient design techniques such as medium temperature cooling loops and waterside free cooling can also mitigate the impact of oversizing by eliminating the need for electric chillers during the lowest load periods of the year.

Cooling towers are a very small portion of plant energy consumption and upsizing them can provide a significant improvement to chiller performance and waterside free cooling system operation. There is little downside to upsizing them: a slight increase in cost and footprint are required. Boilers are a more difficult design problem. The gas consumption associated with maintaining excess boiler capacity (at operating temperature) at idle can

be a significant cost. The use of heat recovery, run around coils or recirculation air for reheat can allow for the majority of a boiler plant to be shutdown during specific seasons.

## Principles

- Have designing engineers, operating engineers (process and facility) and owner explicitly set loads, oversizing and safety factors early in design. Use these collaboratively derived values, rather than the traditional ad-hoc approach that leads to multiple safety factors accumulating through various design stages.
- Upsize ducts and piping to allow for future flexibility and to gain immediate operation and equipment downsizing benefits.
- Size chillers and boilers with care to avoid efficiency penalties when operating at normal loads that are far below the required peak capacity. Unequal unit sizing and a modular approach to add more capacity as load grows is often called for.
- Utilize variable frequency drives to acquire operational savings from oversized fans, pumps, cooling towers, and some types of chillers.
- Deploy redundant air handler, scrubber and cooling tower units in a manner that they can be used in normal operation to reduce pressure drop, reducing power requirements and providing backup capacity.
- Size coils and heat exchangers to provide the proper design temperature differential at all loads.

## Approach

Right sizing means taking an in-depth, analytical approach to designing the *system*, not just components. Standard rules of thumb and design assumptions can produce an operable system, but they often result in grossly oversized and inefficient systems. While redundancy and future flexibility requirements typically demand a certain amount of surplus capacity, careful design can minimize (or reduce) the first cost and actually improve performance.

To right size a facility's systems, an early coordination meeting between the design engineers, the operating engineers (facilities and process) and the owner is required. At the meeting, the required safety factor, design redundancy and oversizing for future growth should be explicitly stated and documented. A number of key design parameters, such as W/sf (Watts per square foot) process loads, redundancy requirement, and desired surplus capacity, have impacts throughout the design. For example, the table below shows the evolution of the W/sf design value in a typical, uncoordinated design effort where information is handed off between disciplines with little in-depth coordination.

**Table 1. Impact of Implicit Oversizing Creep**

W/sf Effective Design Value	Cumulative Safety / Oversize Factor	Design Participant
50 W/sf	1	Actual requirement. Typically, can only be determined by direct measurement after completion. Note that nameplate electrical data is typically maximum startup value only.
100 W/sf	2	Process Engineers. A safety factor is added to allow for unknown future loads or equipment additions late in the design process to set this requirement. Can also include the influence of manufacturer's data, which often has a large safety factor added in by the manufacturer (particularly in exhaust rates).
100 W/sf	2	Architect / General Contractor. Typically the client requirements are passed through directly to engineers.
150 W/sf	3	Mechanical Engineer. To provide a design safety factor, an additional 50% - 100% sizing factor is added. Influences design from chiller plant to coils to fans.
225 W/sf	4.5	Electrical Engineer. To provide for future capacity, equipment sizes are rounded up. Oversized mechanical equipment also needs to be fully served, having a noticeable impact on the total W/sf requirements of the space.

The above table is an extreme example of what can happen in an ad hoc design process where everyone adds in an additional oversizing factor. Several design parameters can undergo such oversizing creep. Communication across the disciplines is required from the initial design stages to prevent the operating and first cost bloat that can result from oversizing creep. Safety factors and future capacity oversizing requests should be clearly stated and then conformed to by all disciplines rather than allowing them to grow haphazardly. Wherever possible, design criteria should be based on measurements of equivalent facilities and oversizing factors should be clearly recognized as a significant cost-adder to the project.

Different disciplines may have different redundancy requirements, such as N+2 on electrical transformers, N+1 on makeup air handlers, and no redundancy on emergency generators. Likewise, individual systems may have different redundancy requirements, such as N+1 on makeup air units but no redundancy on recirculation units where loss of a single unit may result in a permissively small (and temporary) reduction in recirculation rate. The oversizing requirements are complex issues that require ongoing coordination efforts and should be treated accordingly. Further notes on the effects of oversizing on individual systems follow.

### *Ducts and Pipes, Fans and Pumps*

Traditional approaches to sizing ducts and piping have been developed over the years with a typical office building bias. Office buildings typically operate for only half the year, 4,300 hours or less, and the rules of thumb for duct and pipe sizing reflect this. In a critical facility the energy cost of operating the system is a proportionally higher concern than the first cost. Sizing air handlers for 500 fpm (feet per minute), ducts for 0.1 in. w.g. (water gauge) constant friction or piping for 3 ft. w.g./100 ft. is often a poor tradeoff of first costs versus high operating costs incurred in 24-hour use facilities. Sizing decisions should consider the actual operating costs of the system in the context of its cleanroom application.

Lower pressure drop systems offer an immediate savings in smaller fans, pumps and electrical power distribution. When sizing duct and piping circuits, consider the first-cost savings that can result from reducing the size of fan or pump motors, motor drives, and associated circuits. The most efficient system designs will use large ducts and pipes on the critical circuits and small fans and pumps; the fan and pump downsizing helps to offset the additional first cost of larger ducts and pipes and yields ongoing energy savings.

The future exhaust, ventilation and cooling requirements of cleanrooms can be very difficult to predict. Sizing ducts and piping to provide for future growth of the facility is a prudent measure. Due to the square relationship between pressure drop and flow (doubling flow requires four times the power), ducts and pipes tend to be the limiting factor when looking to increase flow. During expansions, it is usually a feasible, if not simple, task to upsize a pump and motor or add an additional air handler, but increasing the duct or piping capacity throughout an operating cleanroom tends to be very difficult and expensive.

### *Air Handlers and Scrubbers*

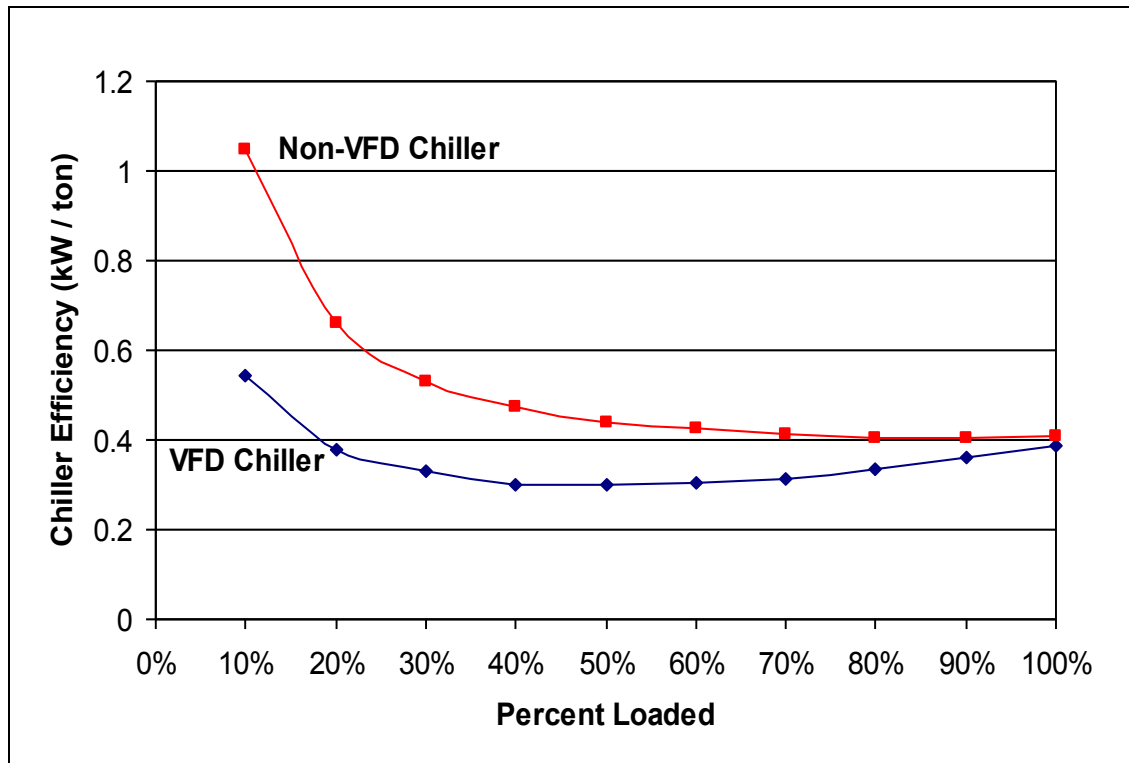
It is common practice to supply redundant air handlers and scrubbers to ensure the highest system reliability. These air handling devices represent a significant portion of the pressure drop in the air side system. If the fans are equipped with VFDs and the units are installed in a parallel configuration that allow all of the air handlers or scrubbers to be run at a reduced speed during normal operation, significant energy savings can be realized.

For example, running three air handlers at 67% capacity rather than just two at 100% capacity reduces the total power required to overcome the internal air handler pressure drop by over 50%. A similar savings occurs with scrubbers, although it will be slightly less due to increased circulation pumping power. Operating all units, including the redundant unit, in parallel has the additional benefit of having the redundant unit as always operational and prepared to provide seamless backup. By running the redundant air handler(s), slightly more maintenance will be required. However, maintenance costs are outweighed by ongoing energy cost savings.

## Chillers, Chilled Water Loop, Cooling Towers

Standard constant speed centrifugal chillers operate most efficiently at or near their design capacity. Depending on the number of paralleled chillers used to meet a cleanroom's peak load, chillers rarely run at peak capacity. Variable frequency drive (VFD, also referred to as variable speed drive) equipped centrifugal chillers are a mature technology to handle part load conditions without a significant efficiency penalty. When equivalent chiller selections (similar condenser and evaporator tubing and configuration) are compared, the VFD chiller usually offers superior part load efficiency.

Figure 1. High Efficiency Centrifugal Chiller Comparison



800 ton chillers operating at 44°F chilled water supply and 65°F condenser water inlet temperatures.

Chillers should be staged to minimize the number of chillers operating at any given time. Barring an unusually advanced and complex pumping system, staging on an additional chiller causes an immediate drop in total plant efficiency as condenser water pumping power and tower fan power jump up. At sub-design conditions, where modern chillers taking advantage of condenser water reset should operate for many hours of the year, a chiller can supply in excess of its nameplate capacity. The controls system should stage chillers such that this extra capacity is used to delay the staging on of an additional chiller with its associated pumping costs.

The chilled water loop components should be designed for a large temperature differential (delta T) to minimize pumping requirements. If a single low temperature loop is used to supply medium temperature loads, such as process equipment cooling water or recirculation sensible cooling, a heat exchanger should be selected that provides a large delta T. Due to the inherent surplus capacity of critical facility cooling plants, low

delta T syndrome (below design temperature chilled water return at design flow) is a significant problem. By carefully selecting all components on the loop to meet or exceed the design delta T, a common problem of having to stage chillers on due to flow requirements rather than load requirements can be avoided.

There are few downsides to having surplus cooling tower capacity installed. In fact, an efficient design will allow all towers, including the redundant unit(s) to be run simultaneously. Running all the cooling towers in parallel maximizes the natural convective cooling and reduces fan power requirements. This strategy requires that the cooling towers utilize variable speed fans and have a suitable flow turndown range. By running the redundant cooling tower(s), slightly more maintenance will be required. However, ongoing energy cost savings outweigh the maintenance costs.

### *Boilers*

The boiler plant should be sized to minimize the energy used by idle boilers. Due to dehumidification reheat loads, it is not uncommon to find boiler plants operating throughout the summer. The fuel costs of maintaining a boiler at operating temperature can be considerable. Ideally, reheat requirements will be eliminated through the use of heat recovery, run around coils, or simply a distribution system that allows for the use of recirculation air for reheat. Such a system approach can allow for the majority (possibly all in very high internal load facilities) of the boiler plant to be shutdown in the heating season. Barring this level of system design, the use of different sized boilers with an intelligent seasonal switchover control is recommended to minimize the idle boiler capacity that is kept fired during low load periods.

### Related Best Practices

Low Pressure Drop Air Systems	Variable Speed Chillers
Recirculation System Types	Cooling Tower and Condenser Water Optimization
Air Change Rates	Variable Speed Pumping
Exhaust Optimization	Dual Temperature Cooling Loops
Fan Filter Efficiency	Control of Chilled Water Systems

### References

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### Resources

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