Foreword

Most chiller based systems save energy when compared to packaged cooling equipment, but they waste a substantial amount of energy compared to their optimized state of operation.

On an annual basis, cooling plants based on constant speed chillers, constant speed chilled water and condenser water pumps and two speed cooling tower fans, and controlled by “normal” control system sequences of operation can use two to three times the energy of comparable cooling plants when equipped with variable speed chillers, variable speed chilled water and condenser water pumps and variable speed cooling tower fans, **IF** those plants are controlled to take advantage of that high efficiency equipment.

We have seen many cases where the individual pieces of equipment are great, but the control strategies that tie them all together defy common sense, thus energy savings are minimal. If you incorporate control routines that actually determine the requirements for water temperature and flow based on the needs of the actual cooling loads, and then reset the chillers and pumping systems based on the actual needs of those end use loads, you can reduce energy consumption in a dramatic manner.

A few examples follow:

These plants were all built using “Variable Speed Everything” design strategies, along with control routines that evaluate the cooling loads and reset the plant variables as required to just meet those needs, with minimal energy waste.

University of Southern California Main Campus Plant
Energy use reduction of 49% compared to previous plants and control strategies.

Arden Realty 5200 West Century
Energy use reduction of greater than 50% compared to previous plant and control strategies.

Transwestern Commercial Services, Irvine Center Towers
Energy use reduction of 48% compared to previous plant and control strategies, but with much higher occupancy, so actual savings are greater.

Transwestern Commercial Services, 2040 Main Street
Energy use reduction of 20% at high loads and 74% at low loads compared to previous plant and control strategies. (no annual savings data yet, recent installation)

The Macerich Company, Queens Center Mall, NYC
Energy use reduction of greater than 50% compared to previous plant and control strategies.

Southwest Value Partners, 600 B Street
Total building energy use reduction of 39%, equates to probable energy use reduction of greater than 60% compared to previous plant and control strategies.

Southwest Value Partners, 525 B Street
Energy use reduction of greater than 40% by converting a 35 year old chiller and the auxiliaries to variable speed and incorporating proper control strategies.

Potential For Improvement is Substantial

We typically see annual chiller plant energy reductions of 30% to 50% compared to the existing systems, with many facilities exhibiting efficiency gains above 50%.

The design strategies we use have been developed by spending literally thousands of hours working in the field, hands on, with some of the best Chief Engineers in the Country. We have taken that hands-on experience, rounded it out with forty-plus years of chiller plant and control system design experience, and honed our design strategies to their current level of excellence.

The two most recent Arden mid-rise facilities that incorporated our design and control system strategies are operating at $1.45 per square foot and $1.75 per square foot, respectively. This equates to $0.55 to $0.80 per square foot lower operating costs than the typical mid rise facility that we are aware of in Southern California.

Tenant Complaints Reduced

In each of the facilities where our design strategies have been implemented, the tenant complaints have been reduced in a dramatic fashion, sometimes dropping from 15 to 25 calls per day down to 3 to 5 calls per week.

By using common sense to conserve energy, you can actually improve comfort.

The rest of this write up describes our design strategy for chiller plants and a short description of our control system design strategies, as well as providing a slightly more detailed look at several projects that have incorporated our design strategies.

Chiller Plant Design Philosophy

First, we determine the approximate cooling load profile for the facility or complex, then we work with the owners to determine a suitable mix of equipment that will best comply with their short and long term needs.

A proper hydraulic design must be developed that minimizes pump energy waste. We have been using the "Primary-Only-Variable-Flow" (POVF) design strategy for the past 8 years very successfully. It tends to minimize both operator interface requirements, as well as energy consumption, while reducing construction costs.

We have also successfully converted primary-secondary pumping systems to more energy efficient Variable Primary, Variable Secondary pumping systems with the addition of VFD's on the primary pumps and a pair of temperature sensors and some associated control logic for the control of the primary pump speed.

We have also been using variable flow on the condenser water systems on all of our projects, and the energy savings have been very dramatic.

After we have a solid direction for the design of the plant, we contact the local utility to determine if there are energy efficiency incentives available that will help to offset the cost of the upgrade.

Once the main equipment and designs have been solidified, we would develop a detailed control system design and sequence of operation. The basis for our sequences follows for your review.

Common Sense Control Strategies

We use "Common Sense" reset strategies. If the facility cooling load is getting larger, we increase the chilled water system differential pressure setpoint to increase the chilled water flow rate, and then we decrease the chilled water supply temperature setpoint to provide colder water to the loads.

If the floor or zone cooling load is increasing, we increase the AHU static pressure setpoint to provide a greater air flow rate, and then we decrease the AHU supply air temperature setpoint to provide colder air to the loads. If the facility, floor or zone cooling loads are getting smaller, we do just the opposite.

A more detailed discussion follows:

1) Provide new central plant optimization software and hardware.

    a) Reset the chilled water differential pressure setpoint.

        i) Reset the chilled water distribution system differential pressure setpoint based on the cooling load of the facility using worst case air handler control logic, and the direction of the cooling load as indicators.

            (1) The Worst Case Air Handler (WCAH) value shall be monitored by the DDC Controls system.

                (a) We monitor several variables on each AHU, and use our control algorithms to determine which AHU has the greatest need for cooling.

                (b) If the value of the worst case air handler (WCAH) is increasing, this indicates that the cooling requirement is also increasing. Since the requirement for cooling is increasing, the differential pressure setpoint shall be increased by the control system, based on several variables. As the differential pressure setpoint is increased, the chilled water flow rate shall increase to satisfy the cooling coil demand.

                (c) If the value of the worst case air handler (WCAH) is decreasing, this indicates that the requirement for cooling is also decreasing and/or the air handling units have the load under control, and not as much cooling capacity is required. Since less cooling capacity is required, the differential pressure setpoint shall be decreased by the control system. As the differential pressure setpoint is decreased, the chilled water flow rate shall decrease to satisfy the reduced cooling coil demand.

b) Reset the chilled water supply temperature setpoint.

i) Reset the chilled water supply temperature setpoint based on the cooling load of the facility, using WCAH control logic. Coordinate this reset strategy with the differential pressure setpoint reset strategy.

(1) Cooling loads that are increasing can be satisfied using either more chilled water, colder chilled water, or a combination of more chilled water and colder chilled water.

(2) When a variable speed centrifugal chiller is installed, its' energy efficiency improves substantially when warmer chilled water is provided to the cooling loads. However, if the water temperature gets too high, the chilled water pumping energy penalty can become burdensome.

(3) For this reason, we employ a strategy that provides additional differential pressure to increase the flow as loads increase, and also reduces the chilled water temperature as loads continue to increase.

(4) The reasons that we first meet demand with additional chilled water flow, instead of colder chilled water are two-fold.

(a) When a cooling load is increasing, we want to get it under control quickly, and not allow it to wander too far from setpoint, lest comfort conditions (or process loads) suffer. The easiest, quickest way to do this is to increase the chilled water flow rate – this has an immediate effect on cooling coil capacity, since the chilled water flow rate can be increased as quickly as the differential pressure is increased by the chilled water pumps. If we want to meet the increased loads by dropping the chilled water supply temperature, it can take 15 to 20 minutes for the colder chilled water to reach the coils. On larger systems and under light loads and low flow rates, there might be a 45 minute delay between the time the water changes temperature and the time that colder water reaches the loads. During this time, the loads may have further increased, and even colder water may be required. When the colder water reaches the coils, it may be too cold, and then the valves will start to close, creating a control system cycle.

(b) The second reason for first using more water, then reducing the chilled water supply temperature to meet the cooling loads is the chiller-related energy as described earlier. Variable speed centrifugal chillers can consume as little as 0.20 kW per ton, when the loads are light and the chilled water supply temperature is high and the condenser water supply temperature is low. We want to stay relatively warm on the chilled water supply temperature, compared to using a "normal" constant speed chiller, so if we have to spend 10 kW extra on the chilled water pumps to provide higher chilled water flow to save 30 kW on the chiller by increasing the chilled water supply temperature, that is a cost effective option.

(5) Since the differential pressure setpoint and chilled water supply temperature setpoint are both being controlled based on the WCAH value, there is the potential for system

cycling and swings if this strategy is not properly implemented. We know how to implement these complimentary strategies to obtain excellent energy conservation results.

c) Reset the condenser water supply temperature setpoint

i) Reset the condenser water supply temperature setpoint based on the cooling load of the chillers and the energy efficiency of the cooling tower fan equipment.

(1) When loads are light and ambient conditions are cool and relatively dry, the cooling towers can be used to reduce chiller energy by dropping the condenser water temperature in a cost effective manner.

(2) Variable speed centrifugal chillers can be very efficient when the chilled water supply temperature is high, or the condenser water supply temperature is low, or a combination of both of these conditions.

2) Provide new Air Handling Unit (AHU) optimization software and hardware.

a) Reset the discharge static pressure setpoint based on the load of the AHU, using the direction and magnitude of the return air temperature as the indicator of load.

i) If the return air temperature is increasing, this indicates that the cooling load is also increasing. Since the cooling load is increasing, the static pressure setpoint shall be increased by the control system. As the static pressure setpoint is increased, the supply air flow rate shall increase to satisfy the cooling demand in the spaces.

ii) If the return air temperature is decreasing, this indicates that the cooling load is also decreasing. Since the cooling load is decreasing, the static pressure setpoint shall be decreased by the control system, so that less static has to be wasted across the VAV boxes. As the static pressure setpoint is decreased, the supply air flow rate shall decrease to just satisfy the cooling demand in the spaces.

b) Reset the cold deck temperature setpoint based on the load of the AHU, using the direction and magnitude of the AHU fan speed as the indicator of load.

i) If the fan speed is increasing, this indicates that the cooling load is also increasing. Since the cooling load is increasing, the supply air temperature setpoint shall be decreased by the control system. As the supply air temperature setpoint is decreased, the cooling capacity delivered to the spaces shall increase to satisfy the cooling demand in the spaces.

ii) If the fan speed is decreasing, this indicates that the cooling load is also decreasing, or the AHU has the loads under control. Since the cooling load is decreasing or the loads are under control, the supply air temperature setpoint shall be increased by the control system. As the supply air temperature setpoint is increased, the cooling capacity delivered to the spaces shall decrease to just satisfy the cooling demand in the spaces.

iii) Higher supply air temperatures accomplish two things within reason.

(1) The higher supply air temperature requires less chilled water, and warmer chilled water, so central plant energy is saved on the pumps and the chiller.

(2) A higher supply air temperature will reduce the amount of dehumidification load that must be served. This reduces the overall load on the system, saving more energy.

(3) There are practical limitations to using higher supply air temperatures – if the supply air temperature is too high, the amount of extra fan energy expended to deliver the greater volumes of air required to meet the occupant needs can outweigh the savings in the chiller plant, so this must be controlled. Noise and "drafts" can also cause tenant issues if too much air is being circulated, so this must be avoided.

c) Implement demand limitation sequences of operation, to allow reductions in power and energy waste on unit startup, during the day and as commanded by the operating staff.

i) By limiting fan speeds during various portions of the day, energy waste can be avoided.

d) Implement a cooling load based coasting cycle routine for the central plant and AHU's to allow the use of the "flywheel effect" and reduce cooling demands prior to shutting off the air handling units. The coasting cycle will utilize the magnitude of the return air temperature as the indicator of load.

i) When the coasting cycle is enabled, the fan speed and cooling output from the AHU will be limited to conserve resources.

ii) Depending upon the conditions in the spaces, this routine may start to reduce capacity and fan energy anywhere from 30 minutes to 60 minutes prior to the end of scheduled occupancy times.

Variable Speed Chiller Plant Experience

Our Award-Winning VSD chiller based systems cool over 10,000,000 square feet of facilities, with several million more SF of facilities either being implemented, or being budgeted for future installation at this point in time.

In the recent past, we have given training seminars to ASHRAE and the Association of Energy Engineers groups of engineers totaling approximately 150 engineers on the topic of VSD chiller plant designs.

Recent Energy Awards

In 2000, one of our VSD chiller plant based projects (a 480,000 SF project for Arden Realty) was awarded the **National Energy Efficient Office Building of the Year** by Energy User News

In 2003, our VFD chiller plant projects won six local and regional (Western United States) Energy Efficiency Awards from ASHRAE for owners whose projects were capital constrained. We worked with the Owners engineering teams to develop creative solutions that also reduced energy consumption and operating costs dramatically.

We have been the Mechanical Engineer for every major Arden Realty chiller plant project for the past 7 years. We have helped them win **three National Energy Awards** from the **Environmental Protection Agency** for their portfolio.

Our project at the 340,000 SF 600 B Street for Southwest Value Partners in San Diego reduced overall facility energy consumption by 39%, resulting in a 2.2 year simple payback period on a $1,400,000 project, and was an ASHRAE dual award winner.

The focus of all of these projects has been **COST-EFFECTIVE** energy efficiency improvements. We do not blindly pursue efficiency at the expense of the limited budgets that most of our projects have been straddled with.

Some Building and Project Descriptions

600 B Street, San Diego, CA

General/Background

The building is a 24 story, 380,000 GSF (334,000 Net SF) Class A commercial office facility located in San Diego. It is fully occupied from 8:00 AM to 6:00 PM and partially occupied from 4:00 AM to 8:00 AM, as several of the tenants are stockbrokers and arrive early. The 25 year old high rise facility suffered from unreliable cooling equipment, high operating and maintenance costs, and substantial tenant complaint problems, especially on low load days when the VAV boxes would throttle back, and the static pressure would climb into the range of 2.5" to 3".

There were two 500 ton electric chillers with constant speed chilled water and condenser water pumps and two single speed cooling tower fans. Three-way constant flow chilled water cooling coil control valves were found on nine out of the twenty-four AHU's. The AHU's were equipped with forward curved fans with no volume control equipment installed – they "rode the fan curve", which generated very high system static pressures as the load dropped off and the VAV boxes throttled back.

Using 55°F supply air temperature, the fans were unable to meet the design cooling loads on many of the floors. The systems were designed before the advent of personal computers and copiers for every 10th person. Occupant densities have also increased, so the cooling loads are higher than they were when the system was designed. We evaluated replacing the cooling coils with larger coils to meet the higher tenant cooling loads, but determined that we could gain approximately 29% more cooling capacity from the existing cooling coils by supplying them with 38°F chilled water in lieu of the design of 45°F water, so we selected our new chiller with 38°F chilled water supply capabilities.

Even with the old chillers at full load, there was inadequate capacity to satisfy the tenants. The condenser water supply temperature to the chillers would exceed 90°F on humid days, sapping capacity from the chillers, and causing excessive energy use. Further, as zones opened in attempt to satisfy the space conditions, the fan systems would run down their curves as the supply air temperature crept above the design point and the static pressure dropped off to near 0.5". The system was drafty on hot days and noisy on cold days.

The goals of the project were to improve tenant comfort, improve IAQ, reduce energy consumption, and reduce maintenance costs to the greatest extent possible.

The project that was undertaken was to replace one of the 500 ton chillers with a new 650 ton variable speed drive chiller capable of delivering 38°F chilled water supply temperature. Other modifications included replacing the cooling towers with "oversized" cooling towers, replacing the chilled water and condenser water pumps, and equipping the chilled and condenser water pumps, and cooling tower fans with variable speed drives. The piping system was converted to "Primary-Only-Variable-Flow" operation by replacing the three-way valves at the AHU's with two way valves and adding a minimum flow-controlled bypass loop in the chiller plant to maintain adequate flow through the chillers under light loads. We installed variable speed drives on the floor by floor AHU's to gain energy savings, and quiet the system down, reducing tenant complaints.

To allow faster resetting of the HVAC system variables and maximizing the potential for savings, 25% of the VAV terminal controllers in the building were switched from pneumatic control to DDC zone terminal control and the information from the zones was used to reset the static pressure setpoint for the AHU's, as well as the supply air temperature.

Energy Efficiency

We have reduced overall energy consumption in this facility (measured at the utility meter) by approximately 39%, with a slight increase in occupancy. This can be seen in the graphic showing the four year, month by month energy consumption of the facility.

The old HVAC system operated at between 1.8 and 3.5 kWh per ton-hour of cooling delivered, since everything was constant speed and constant flow. The chillers by themselves operated at between 0.8 and 1.9 kWh per ton-hour. The energy consumption of the entire retrofitted HVAC system operates at an average of approximately 0.95 kWh per ton-hour of cooling delivered on an annual basis. The chiller plant efficiency has averaged 0.55 kWh per ton-hour, and the chiller alone has averaged 0.37 kWh per ton-hour. This efficiency figure is based on two years worth of monitored data, with calculations made every 5 minutes. This energy efficiency is surprisingly good considering that the building is not equipped with any form of an outdoor air economizer system.

Variable Speed, Low Temperature Air Conversion - We are able to deliver 48°F supply air temperatures to floors that have high loads, meeting tenant needs and reducing supply fan energy consumption, without having spent $45,000 per floor upgrading the cooling coils to meet the higher cooling loads. The supply air temperature setpoint is dropped gradually, so there has never been an issue with condensation on the supply air duct running through the return plenum. Prior to dropping the allowable supply air temperature, a floor was tested by dropping the setpoint from 55°F to 45°F in 30 minutes, and there were no condensation problems. The current time frame to drop to the minimum setpoint is one hour. The fans are now equipped with VSD's for volume/pressure control.

Variable Speed Low Temperature Chiller - The chiller was selected to deliver 38°F water to increase cooling coil capacity without replacing the cooling coils. The 38°F chilled water temperature is rarely used, with most of the operating hours in the 44°F to 55°F range, and higher than this in the winter months or when serving light loads. Because the chilled water supply temperature is reset as well as the condenser water supply temperature, we actually obtain better system efficiency than predicted when using NPLV values for the chiller. Chiller efficiencies in the 0.25 kW per ton range are commonly seen, with best recorded efficiency at 0.15 kW per ton serving a 180 ton load.

Variable Flow Primary Only Chiller Piping – We replaced the three-way valves with two-way throttling type control valves, and added a minimum flow controlled bypass valve and piping in the chiller plant to allow the system flow to be varied over a wide range, reducing pumping energy.

Variable Flow Condenser Water System - The condenser water system operates as a variable flow system. The variable speed drives on the condenser water pumps are controlled to maintain a variable TD across the chiller condenser barrels. Under light loads, the temperature split across the condenser is allowed to rise to increase cooling tower efficiency with a higher entering water temperature. As the load increases, the TD is controlled so that a 10°F split is maintained at full load.

Floating Condenser Water Temperature Control - Variable speed drive centrifugal chillers love to see low entering condenser water temperatures. Many design engineers specify the cooling towers to run at full fan speed to reduce chiller energy consumption any time a variable speed chiller is operational. While this may be a fine strategy when the chiller is fully loaded, our field testing has shown that there is a trade off between cooling tower fan energy and chiller energy, and that under light loads, the cooling tower fans can use more energy than the chiller does if that strategy is employed. We have incorporated cooling tower control sequences that evaluate the ambient conditions, the cooling load and energy being consumed, and limit the cooling tower fan energy so that it cannot overwhelm the chiller energy. The lowest "energy efficient" condenser water temperature to the chiller is provided using this method.

"Oversized" Cooling Tower System - We evaluated different cooling tower sizes, and selected a cooling tower system that is 50% larger than required to meet the specified load. This resulted in a larger cooling tower surface area with a smaller fan in each cooling tower cell. There was a minor cost increase for this change.

"Worst Case Load" Automated System Resets - The DDC system is configured to continually reset each of the following variables based on the loads being served:

- The chilled water supply temperature is reset between 38°F and 60°F.
- The chilled water supply differential pressure is reset between 4 PSID and 25 PSID.
- The condenser water supply temperature is reset between 58°F and 78°F.
- The condenser water differential temperature is reset between 14°F and 10°F.
- The system supply air static pressure setpoint, is reset between 0.50" WC up to a maximum of 1.5" WC.
- The supply air temperature is reset between 48°F and 72°F, based on cooling loads balanced with heating needs.

Operation and Maintenance

The maintenance requirements on the system have been dramatically reduced. The equipment and controls have become a friend to the Chief Engineer and his operators, rather than an enemy. The system anticipates load changes and responds in very short order, almost eliminating Operator interface requirements, and freeing up their time for performing preventive maintenance calls. They no longer spend most of their time responding to equipment failures and comfort calls.

Cost Effectiveness

The incremental cost of the energy efficiency components on this project added approximately $386,000 to the price of the project, but the annual utility cost savings were over $360,000 when compared to previous operation. The energy efficiency aspects of the project earned a utility incentive of approximately $300,000, so the net cost of the efficiency portion of the project was $86,000.

Including the incentive funding, the simple payback period for the energy conservation portion ended up taking 3 months. The total project paid for itself in 2.2 years.

5200 West Century, Los Angeles, CA, Arden Realty

5200 West Century is a 10 story, 321,530 GSF (278,123 Net SF) Class A commercial office facility located near LAX. It is fully occupied from 8:00 AM to 6:00 PM. After 6:00 PM, there are two floors that run until 11:00 PM, with a very high occupant density tenant (over 1,000 people per floor).

This facility runs at $1.45 per SF.

The building was originally constructed with only 535 square feet per ton of chiller plant capacity and 0.7 CFM per GSF of supply and return fan capability – it was severely short of chiller capacity and circulation air and could not meet tenant loads and comfort conditions when the weather was much above 70°F. The fan systems, chillers and cooling towers would run at their full rated capacity at ambient temperatures in excess of 72°F. Part of the load problem was related to the location of the cooling towers – they were directly in the path of the fresh air inlet to the building, and the cooling tower discharge could be seen to be drawn directly into the fresh air inlet, creating an endless loop of cooling load – the chillers would take the load from the cooling coils, reject the heat to the cooling towers, and a substantial portion of the cooling tower discharge would be drawn back into the cooling coils, to create more load. It is amazing how much load is contained in saturated 90°F air coming out of a cooling tower.

The goals of the project were to improve tenant comfort, improve IAQ, reduce energy consumption, and reduce maintenance costs to the greatest extent possible.

The project that was undertaken was to convert the air distribution system to be low temperature air capable so that the ductwork and fan systems could all be reused, replace one of the 300 ton chillers with a new 500 ton variable speed drive chiller, capable of delivering 34°F chilled water supply temperatures, with no freeze-point depressant in the system. Other modifications included replacing the cooling towers with "oversized" cooling towers, in a location away from the fresh air inlet, replace the chilled water and condenser water pumps with new pumps, equip the chilled water and condenser water pumps and cooling tower fans with variable speed drives. The cooling coils were replaced with larger face area, 8 row, 12 fin per inch coils, and the piping system was converted to "Primary-Only-Variable-Flow" operation, with the chillers in series for added energy efficiency. The economizer system was modified so that the discharge air from the building was not immediately recirculated back into the fresh air inlets. The original design on the economizer system allowed so much recirculation that the inlet air temperature would be 7°F to 10°F above the ambient conditions, effectively eliminating economizer use for much of the year.

It was determined that there was inadequate air delivery capacity and undersized ductwork to meet the loads of the facility, if the supply air temperature was maintained at 55°F. To reduce first cost and operating costs, the airside was converted to operate as a low temperature air system, being capable of delivering 42°F air, should the need arise. With this design, the main air duct risers, and the supply and return fans could all be reused, and have adequate capacity for the loads. Low temperature air is only used on peak load days – the typical supply air temperature varies between 55°F and 65°F.

Energy Efficiency

The system that was replaced operated at between 2 and 4 kWh per ton-hour of cooling delivered, since everything was constant speed and constant flow, and the economizer system was essentially non-functional. The chillers, by them selves, operated at between 0.9 and 1.9 kWh per ton-hour. The energy consumption of the entire new HVAC system operates at an average of less than 0.8 kWh per ton-hour of cooling delivered on an annual basis. The measured system energy efficiency includes the supply and return fans, the chillers, the chilled water pumps, the cooling towers, and the condenser water pumps, in short, every energy consuming device related to the HVAC system.

The chiller plant averages approximately 0.55 kWh per ton hour, including the energy consumed by the chillers, the condenser water pumps, the cooling towers and the chilled water pumps.

Tenant Complaint Reductions

When the building was only 55% occupied, there used to be 15 to 30 tenant comfort related calls per day, we are now down to approximately 5 to 10 calls per week, a reduction of approximately 90%, even though the building is now fully occupied.

Innovation

This project incorporates everything that we could think of for energy efficiency – it is capable of delivering low temperature air when the need arises, it is equipped with variable speed drives on all the new equipment, the chillers are piped in a series configuration, and we installed a VFD chiller that can deliver 34°F water reliably, with no freeze-point depressant, and the refrigerant temperature above 32°F, so there is no danger of freezing the water in the chiller, even if a CHW pump failed at full chiller load.

The DDC system is configured to continually reset every variable, including the chilled water supply temperature (34°F to 60°F reset range) and differential pressure (2 PSID to 20 PSID reset range) – reset based on the cooling loads and energy efficiency, the condenser water supply temperature (60°F to 80°F reset range) – reset based on cooling loads and ambient conditions, the supply air static pressure setpoint, which gets reset between 0.35" WC up to a maximum of 1.5" WC, based on cooling loads, and the supply air temperature, reset between 42°F and 75°F, based on cooling loads and heating needs.

Cost Effectiveness

This system cost less than any of the alternate systems that were proposed, and offers the greatest energy efficiency and cost effectiveness that could be attained.

The incremental cost of the energy efficiency components on this project added approximately $300,000 to the price of the project, but the annual utility cost savings were over $400,000 when compared to other proposed solutions. The simple payback on the energy efficiency components is less than 1 year. If you look at the overall project, the first cost of this option was approximately $1,100,000 less expensive than alternatives that would have used more energy and required higher maintenance, so the real simple payback period was instantaneous.

Queens Center Mall, Queens, New York, Macerich

This is our latest design, and operates at a best-we've-seen **total** chiller plant energy efficiency of **0.25 kW** per ton during winter, light load operations. Annual total chiller plant energy efficiency, even in muggy NYC conditions has been measured at 0.55 kWh per ton-hour. Total chiller plant energy efficiency includes all of the energy consumed by the chillers, the cooling towers, the condenser water and chilled water pumps – everything in the plant that touches water. Most chillers use twice this amount of energy on their own, without adding in the energy consumption for all of the auxiliary equipment.

Two 1,000 ton chillers that could not meet the cooling loads were replaced by two 1,500 ton VFD chillers that meet the loads. The new 1,500 ton chillers use the same peak power as the old 1,000 ton chillers.

Cooling towers totaling 225 HP for 2,000 tons of heat rejection were replaced by cooling towers totaling 150 HP for 3,000 tons of heat rejection, with VFD's.

The chilled water system is primary-only, variable flow.

The condenser water system is variable flow.

Refined versions of the "Worst Case Load" automatic reset strategies described in the 600 B street section are incorporated at the Queens Center, so we did not want to waste space by repeating all those strategies here.

2040 Main Street, Irvine, CA, Transwestern Commercial Services

We re-used the existing chillers, adding a VFD to an existing 750 ton Trane chiller.

As with our other designs, we converted the system on the 750 ton chiller to primary only, variable flow, and we converted the condenser system on the 750 ton chiller to variable flow as well.

Refined versions of the "Worst Case Load" automatic reset strategies described in the 600 B street section are incorporated at the 2040 Main Street project, so we did not want to waste space by repeating all those strategies here.

The graphs we included from 2040 Main Street show dramatic gains in efficiency across the spectrum. At near full load on the 750 ton chiller, the total plant efficiency is 0.52 kW per ton.

As a bonus to this, the airside reset strategies we have incorporated have reduced the cooling loads to the point that we've allowed them to stop using both chillers at the same time. Previously, it was common to run the 250 ton and 750 ton chillers together all summer long. On Friday, July 22, 2005, a very hot and muggy day, the loads had been reduced to the point that we were only running a 530 ton load at 4:00 PM, typically the peak load of the facility.

At partial loads, (47 tons, 6.3%) the total plant efficiency is 0.42 kW per ton. Using the constant speed 250 ton chiller to serve this same 50 ton load resulted in total plant efficiency of 1.62 kW per ton, so using our large VFD chiller with proper reset strategies allowed an efficiency improvement of 74%.

This project shows that it might not be necessary to replace all of your chillers – we might be able to perform rebuilds and retrofits to existing equipment, and reduce your project cost, while still dramatically reducing your operating costs.

Airside Resets

If you save $900,000 per year in chiller plant utility costs, but have unhappy tenants because the air delivery system is not set up correctly, you have lost, not gained.

Our airside reset strategies, described in more detail elsewhere, have a dramatic effect on reducing tenant complaints as well as energy consumption.

We typically see tenant complaint reductions of between 80% to 95% when our airside reset strategies are employed.

In summary, our reset strategies look at the cooling loads on the floors, and reset the supply air temperature and static pressure setpoints as required to satisfy those loads.

We use "Common Sense" reset strategies. If a cooling load is light, we reduce the static pressure setpoint to reduce energy waste, and to reduce noise across the VAV dampers. We increase the supply air temperature to maintain the circulating air volume so that the tenants can "hear" the air conditioning system and feel psychologically comfortable, and to reduce cold air "dumping" from the diffusers in the spaces, reducing cold calls. Higher loads require a higher static pressure setpoint and lower supply air temperatures, so that is what we deliver.

The comfort targets are made adjustable for each air handling system, so the operators have complete control of the comfort level on their floors.

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