The R.W. Johnson Pharmaceutical Research Institute

Summary

The Pharmaceutical Research Institute in La Jolla, California, is a 123,000-square-foot laboratory and office building completed in 1999. Among the energy efficiency measures included in the building are systems for limiting energy waste associated with its 92 fume hoods and its air handling, space conditioning, and lighting systems. As a result, smaller-than-usual chillers and fans were employed, which both saved on first costs and will lower energy bills over the life of the building. Despite employing the most energy-efficient motors and other equipment available, the building cost only 1 percent more than other new laboratory/office facilities built to the minimum requirements of California’s Title 24 energy standards.

Johnson & Johnson has over 250 business campuses worldwide, and the company has made a commitment to aggressively pursue energy efficiency wherever it makes sense. All new J&J buildings are subject to the company’s “New Facilities Design Criteria.” Design teams are required to adopt the energy efficiency measures specified or make a persuasive case for exceptions.

This “design for the long term” philosophy was successfully employed in the design and construction of the Pharmaceutical Research Institute facility. In addition to housing state-of-the-art biological and chemical laboratories, the building is quite comfortable and attractive. It thus serves as a catalyst in recruiting new scientific talent.
Introduction

The R. W. Johnson Pharmaceutical Research Institute (PRI), owned by Johnson & Johnson (J&J) and located in La Jolla, California, is a state-of-the-art, 123,000-square-foot research and office facility completed in 1999 (Figure 1). Only a mile from the Pacific Ocean, the building functions well, provides a comfortable working environment for hundreds of biologists and chemists, and is aesthetically appealing. However, its energy bills are a fraction of what a standard structure built to meet California’s Title 24 Energy Efficiency Standards would be, yet it cost no more than ordinary structures of its kind to build.

J&J, which operates more than 250 facilities the world over, has a strong corporate commitment to building structures that are energy efficient, long-lasting, and inexpensive to maintain. Accordingly, the company has developed an energy efficiency document titled “New Facility Design Criteria.” Expressed in an easy-to-use spreadsheet, the design criteria address all energy-relevant elements of new building design in careful detail. Architectural and engineering firms that produce facilities for J&J are

Figure 1: The PRI facility exterior

The front exterior of the PRI facility balances functionality and aesthetics with elements that convey a sense of permanence, such as beautiful stone facades.
charged with developing building designs that are consistent with the “New Facility Design Criteria”—or to make a case for specific exceptions. The default is to do things in accordance with J&J’s doctrine.

At the beginning of the building design process, the team hired by J&J specified a number of features typical of standard practice, speculatively developed research and development buildings in the fast-growing industrial area of La Jolla. However, when they found that J&J “is in it for the long term,” as Thornton Lewis, J&J’s project manager, puts it, “The design firm became very positive about adopting our long-term view.”

The long-term view involved careful computer modeling of the entire structure and weighting each building system element, both as a whole and in part, for lifetime cost. The result is a facility that employs premium efficiency motors, energy efficient lighting, a zoning strategy that limits single-pass ventilation to only laboratory areas that really need it, occupancy sensors for lights and fume hoods, and a host of other energy-saving strategies. Since the above measures lower space conditioning energy needs, much smaller than usual HVAC equipment is employed, and the money saved substantially offsets additional expenses for the other energy efficiency measures.

Scientists and office personnel, as well as the person who was slated to become head of maintenance of the new structure, were part of the design process from the beginning (Figure 2, next page). This element of stakeholder buy-in contributed substantially to producing a facility that capably meets users’ needs. Further, the commissioning process—begun five months prior to occupancy as systems came on line—ensured that glitches were handled well before they became real problems and that training of the maintenance team was thorough.

The building achieves annual savings of $536,000 on its energy bill, compared to the amount a standard laboratory would expect to pay. According to a model used to estimate energy performance of new buildings employed by the local utility, San Diego Gas and Electric (SDG&E), a standard building would have used $1,432,000 per year, 37 percent more than...
The building program called for space to accommodate about 250 occupants, with the vast majority being scientists. The facility needed to support the wide variety of the scientists’ experiments, many of which take place over an extended period and cannot be interrupted. The desire of

the J&J building. Based upon its exemplary energy performance, the building owners were awarded $143,000 for their inventiveness from SDG&E.

The Building Program

The PRI laboratory and office facility project was conceived by J&J to replace a leased facility in the area that was used as a biology lab for the previous 10 years. With the lease coming to an end, as well as a need to expand the facility to accommodate more chemists and biologists, J&J decided to build a new facility designed from the ground up to best meet present and future needs (Figures 3 and 4). J&J started planning the project in November of 1996, with the goal of moving workers into a fully functional facility in mid-1999.

Improved maintainability was achieved by involving the PRI maintenance team in the design of key building systems. Pictured is facilities manager Steve Schuetzle.

Figure 2: PRI maintenance team involved in the design process from the beginning
Figure 3: Overhangs and setbacks reduce solar gain
A climate-responsive building envelope reduces the need for heating and cooling at PRI.

Figure 4: An inviting and efficient facility
Natural and artificial light work together to illuminate the PRI lobby.
The desire of many scientists to work at any hour of the day or night required building systems designed to accommodate diverse usage patterns.

Clearly, the laboratory spaces had to be the dominant feature of the building from both the standpoint of space planning and building system design. The program called for 92, 8-foot-wide fume hoods to be installed to support scientific research (Figure 5). The energy use and complexity of the mechanical systems to support the hoods was a priority building system the design team needed to accommodate.

The differing safety requirements for chemists and biologists also were a major consideration. Chemists tend to deal with harsher chemicals and thus prefer smaller, enclosed laboratory spaces that serve as a barrier to help contain fumes from their experiments. The biologists, on the other hand, do not usually work with extremely hazardous materials. They prefer to work in more open spaces.

The project was also subject to some strict constraints on the form of the building. Because of local building codes, there was a height limit imposed...
for the building. Code mandated that no part of the building could extend more than 30 feet above grade level. This was particularly troublesome for a laboratory building because traditional fume hood exhaust stacks rise 6 to 8 feet above the roofline in order to safely eject fumes away from the building. Subtracting the stack height from the 30-foot allowance left an insufficient amount of floor-to-floor height for a two-story structure, which was a strongly favored building configuration.

The project also had other issues to deal with. In particular, the cost and availability of potable water in San Diego was a concern—even though water is available, conservation is a big issue in San Diego. J&J wanted to be a good citizen when dealing with water issues, so company officials made a commitment to consider using municipal reclaimed water and water from building condensate whenever it could be justified. Thus, they were able to save about 10 percent on water costs, and at the same time demonstrate their commitment to environmental stewardship.

The Design Process

The design of the PRI facility exemplifies the practical application of an integrated design process. Maximizing energy efficiency of the building as a whole—as opposed to focusing on the efficiency of individual building systems—was a goal established early on in the project.

Johnson & Johnson has had a formal energy program in place since 1972. Conceived during the Arab oil embargo, J&J’s cumulative energy design wisdom is collected in a best practices document that offers recommended energy design guidelines for all major building systems. This repository of design wisdom has been continually refined and updated over the years, and the cost-effectiveness of most of its recommendations is time-tested and well documented.

Although it may sound restrictive, J&J’s best practices document still leaves plenty of freedom for the design team. “We establish guidelines, as opposed to rigorous requirements,” notes John Mohn III, PE, J&J’s site project manager. J&J does not force design professionals to implement every item in the best practices document, although it is the design team’s
responsibility to make the case that a particular item is NOT cost-effective or should not be implemented for other reasons.

J&J also approaches cost-effectiveness questions from the standpoint of life-cycle cost, instead of merely the simple payback for a particular building upgrade. Because J&J plans to stay in business for a long time—and because it will be its own tenant at the PRI facility for the foreseeable future—company officials base their decisions on the total benefit offered by particular energy upgrades, not just how quickly they recover their incremental investment.

The design team was selected based upon proven track records of delivering efficient design solutions for high technology buildings. The architectural firm for the project, Carrier Johnson of San Diego, was selected in mid-1997. Carrier Johnson, in turn, brought in Bechard Long Associates of San Diego to provide mechanical, electrical, plumbing, and HVAC control system design services.

To get the design process off to a good start, J&J met with the PRI design team early in the schematic design phase to conduct an initial screening of each item in the J&J design guidelines. Using rule-of-thumb analysis, they were able to get a preliminary indication of which measures would pay off and which ones could not be justified. “We eventually ended up with three categories of measures,” notes Lewis. “There were a number of no-brainer measures that we absolutely planned to implement, and then there was a second group of measures that appeared to be cost-effective, but which would require more detailed analysis to make an informed decision. Finally, there were those that did not stand up to even the first-cut screening, and were clearly not cost-effective for this facility.” High efficiency illumination sources and indirect lighting fixtures were among the first of the no-brainer items, which also included premium efficiency motors, primary and secondary chilled water pumping systems, and enthalpy-controlled air-side economizers. The list of measures that required further study, however, was more extensive. Some of the measures that were studied in greater detail included:
Purchasing electric power at primary voltage (12,000 volts)

Single- versus dual-glazed windows and low-emissivity glazing.

Thermal energy storage

Air distribution: 100 percent outside air for lab spaces only, or for the entire facility?

Variable-speed drives on pump and fan motors

Most of these measures were evaluated with a computer-based energy model of the proposed facility. The mechanical engineers for the project developed an energy model to quantify the benefits of the proposed efficiency measures. This model allowed J&J to accurately assess how certain measures, such as dual-pane glazing, might reduce heating and cooling loads and therefore the size of HVAC equipment installed to serve those loads.

J&J also takes a real-world approach to accounting for facility operating costs. Whereas many organizations allocate energy and maintenance costs from separate budgets and have difficulty dealing with measures that save in one category but cost more in the other, J&J budgets the two together. This allows them to account for, as an example, the fact that T5 lamps provide energy savings and good light quality but cost more than common T8 lamps. Many organizations—school districts are an example—shy away from implementing energy efficiency measures that may result in increased maintenance costs, even if net operating cost savings result, because they will not have a sufficient maintenance budget for upkeep of the systems. By taking a look at the big picture, J&J is able to succeed at reducing total operational costs, as opposed to energy costs alone.

As the project team created their first schematic design package, they aimed at meeting rigid, low-budget criteria. J&J found that some budget-driven building features were not consistent with their best practices.
The early design schematic included the following energy-inefficient features:

- Incandescent lights in some spaces
- Single pane windows
- Chillers with standard efficiency, part-load performance.
- “Energy efficient” instead of “premium efficiency” motors
- Multiple motors on cooling tower fans in lieu of variable speed drives

J&J officials concluded that many of these features were standard practice for similar buildings in the area. San Diego is a hotbed of the burgeoning biotechnology industry, and La Jolla is considered to be a “Park Avenue” address for biotech start-up companies. Such companies are usually funded by venture capital and have a high mortality rate that is largely tied to whether they can successfully bring a product to market or obtain meaningful patents before the funding runs out. Thanks to these financial and temporal demons, most start-ups lease their office space on the basis of low cost and immediate availability as opposed to long-term efficiency. Thus, it follows that most research-oriented buildings for lease around the PRI site are developed to cater to short-term needs and don’t include many efficiency features. Once J&J’s long-term energy conservation mindset was known, the design effort focused on energy-efficient, low maintenance options.

Most architects and engineers are used to translating their clients’ (sometimes unrealistic) wishes into workable designs. In this case, the design team was constantly challenged to produce “life-cycle effective” designs by a savvy client with a wealth of corporate expertise.

J&J officials met with the design team to let them know that J&J is “in it for the long term” and that they were sincere in their desire to follow the corporate best practices to the greatest practical extent. With this affirmation from the client, the design team went back to the boards to produce an award-winning, energy-efficient building.
J&J was diligent throughout the design process to ensure that the design was as good as it could be. Through each step of the design process, and in cooperation with end users and the design and construction team, officials asked themselves again and again:

- Do our best practices requirements make sense?
- Do we meet the requirements?
- Are we over- or under-designed?
- Are there any new opportunities?
- What are the costs and benefits of the alternatives?

With J&J’s support and through the skill of the design team, the final design achieved an impressive level of efficiency and did so within the overall project budget. With the construction manager brought on board in the third quarter of 1997, J&J broke ground on the PRI in the first quarter of 1998. About a year later, building systems were commissioned as they came on line.

Rudolph & Sletten (of Foster City, California, and San Diego), general contractor on the PRI project, teamed up with the engineer to implement a fully documented commissioning procedure in which each building system was rigorously tested by itself under all sequences of operation. Once all systems were shown to properly function individually, the facility was subjected to a 72-hour functional test with all building systems in operation. With the deficiencies addressed and the project completed, PRI employees moved in over Memorial Day in 1999.

When all was said and done, the PRI building’s impressive list of energy efficiency and water conservation features resulted in an annual savings of more than a half million dollars. This translates into:

- Enough electricity to power 680 homes
- Enough natural gas to heat 950 homes
Reduced power plant emissions of 4.8 tons of nitrogen oxides per year, 2.1 tons of sulfur oxides per year, and 4,318 tons of carbon dioxide per year

Overview of the PRI Facility’s Energy Efficiency Features

Energy-conscious design principles were applied to nearly all of the building systems at the PRI facility. The design wisdom embodied in J&J’s best practices and in its corporate expertise includes the following elements:

Reduce loads first. Before any HVAC system efficiency measures are considered, J&J first works hard to reduce HVAC loads through application of internal and external load reduction measures. These include efficient lighting, high performance glazing, occupancy sensors, sash position sensors on fume hoods, and appropriate insulation. In particular, the company desires measures that not only save energy by themselves but that also result in downstream savings.

Improve systems efficiency next. With heating and cooling loads reduced, the design process then focuses on efficient strategies for delivering heating and cooling to the building. Systems efficiency measures include low-pressure ductwork, variable speed drives, premium efficiency motors on fans, and advanced controls. Rather than oversize the HVAC systems so that they never work too hard to provide comfort, J&J advocates “right sizing” systems so that they provide efficient operation during three seasons, and occasionally operate flat-out to meet peak loads in the heat of summer. This reduces the size and cost of HVAC equipment, producing dollar savings that can be spent on more efficient equipment.

Improve plant efficiency last. With loads minimized and efficient systems in place, the crosshairs target the efficiency of plant equipment. As a result of the good work done in previous steps, high efficiency chillers and boilers can be purchased for little or no incremental cost when compared to oversized, average efficiency models.

Following is an overview of the most notable features of the building systems.
Building envelope. The building is constructed of steel framing and curtain wall (Figure 6). The walls are insulated only to the prescriptive levels required by Title 24 for the San Diego climate—R-11 for walls and R-19 for the roof. Though higher insulation levels were evaluated, they did not provide much energy savings in the mild La Jolla climate. A white reflective cap sheet was installed on the roof, which both reduces the overall cooling load for the facility and extends roof life because of the reduced roof temperature. This measure had no incremental cost associated with it; it was simply a matter of selecting a material that was light and reflective.

The team evaluated dual-pane glazing—as an upgrade for the entire project—but found the measure was too expensive relative to the savings it would provide. In a late-night project meeting, J&J realized that dual glazing was not an all-or-nothing proposition. The engineers suggested glazing options for different orientations of the building and for offices with exposures in several directions. As a result, a revised analysis was prepared that addressed glazing issues on each facade of the building. This led J&J to the decision to use dual-pane glazing on the east facade in order to control morning sunlight and single-pane glazing on the other facades.

Interior lighting systems. Like most buildings that reach an exemplary level of energy efficiency, the PRI facility features a highly efficient interior lighting system. This is a critical component of the whole building’s efficiency, for two reasons:

Figure 6: The PRI facility rear exterior
The back of the PRI facility. The walls and roof are insulated to conform to Title 24’s provisions. Higher levels of insulation were deemed unnecessary in La Jolla’s mild climate.
1. Lighting energy use is huge. Lighting is the single largest energy end use in most commercial buildings (though perhaps not for a laboratory facility), accounting for anywhere between 25 and 50 percent of overall energy use. In addition, even though T8 lamps and electronic ballasts are standard practice for new lighting designs in California today, there are still opportunities to significantly improve lighting efficiency through a combination of good design and efficient technology. Even though California’s 1998 Title 24 lighting efficiency standards are already fairly stringent, they can still be beat by 30 percent or more, which may translate into a load reduction of 0.30 to 0.50 watts per square foot.

2. Lighting efficiency leads to downstream savings. The ample load reductions that result from efficient lighting lead to reduced cooling loads as well. As a result of reduced cooling and airflow requirements, a series of “downstream” savings are generated, including smaller ductwork, piping, air-handling units, and chillers. All of these downstream efficiency gains translate into reduced operating cost, as well as construction cost savings for the smaller systems.

The interior lighting system at the PRI facility is designed around high-quality fluorescent sources that are applied to balance efficiency with visual comfort. Pendant-mounted, indirect fixtures using T5 lamps and electronic ballasts are used in most office spaces (Figure 7) in order to provide a uniform, glare-free environment. By bouncing light off the ceiling instead of shining it directly into the workspace, a uniform level of illumination is achieved instead of the checkerboard of bright and dark spots that typically result from direct lighting. Bouncing light off the ceiling also diffuses it effectively, reducing glare on computer screens.

T5 lamps are quite intense when compared to other linear fluorescent sources and consequently have enough punch to illuminate a space with fewer fixtures than a system designed around T8 lamp technology. Even though T5 fixtures are more expensive than similar configuration T8 models, in most cases the reduced number of fixtures offsets much of this extra cost.
Traditional T8 lamps and electronic ballasts are employed in non-office spaces. Compact fluorescent lamps installed in recessed fixtures are used in some spaces as well. J&J proudly reports that, except for what is contained in some specialized laboratory equipment, there is not a single incandescent lamp used in the PRI facility.

Other noteworthy features of the lighting system include occupancy sensors throughout the building and the use of radioactive (tritium) exit signs that glow without a wired power source (Figure 8, next page). One maintenance worker noted that the energy savings for the exit signs are almost inconsequential compared to the maintenance savings associated with not having to replace ever-failing lamps.

Whereas using occupancy sensors in small, enclosed spaces is quite common in buildings today, J&J aggressively went after additional savings by installing these devices in open office spaces, as well as in the usual private offices, restrooms, and conference rooms. They report that the sensors can work well in open spaces as long as the right technology is specified. Key design features that need to be matched include passive...
infrared, ultrasonic, or dual-technology sensors; configuration view angle (the pattern that the sensor can “see”); and sensor placement (Figure 9).

J&J also addressed the efficiency of lighting at individual workstations by providing T8 or T5 lamps for all task lighting.

**HVAC Systems**

Even though San Diego has a mild climate, heating or cooling is still needed every month of the year. This is particularly true for a lab facility that must be kept within a relatively narrow band of temperature and relative humidity for experimental procedures.

Every laboratory in the building is designed as a “once-through” system that brings in 100 percent outside air, runs it through the building to heat or cool it, and then exhausts it all (Figure 10). This causes a lot of conditioned air to be exhausted out of the building instead of being recirculated, resulting in increased heating and cooling energy and higher energy cost. In response to this, J&J decided to install a once-through system to serve laboratory spaces and a recirculating system for office and administrative spaces. This design minimizes energy waste by tailoring ventilation rates according to the use of each space.

Most of the building is designed around single-duct variable air volume (VAV) air handling systems, featuring central chilled water and hot water...
Using occupancy sensors in open spaces provides substantial energy savings

Multiple, ceiling-mounted sensors with overlapping areas of coverage make it possible to effectively control lighting in open spaces, such as this laboratory.

Labs typically require two to three times the amount of air as in a standard office building, but none of it is recirculated.
coils, and hot water reheat coils in each zone for individual temperature control. The air handling units were fitted with variable speed drives (VSDs) in order to reduce fan energy use during periods of mild weather.

The mechanical engineer used an energy model to evaluate permutations of chiller quantity, type, and capacity before finally settling on two, 600-ton centrifugal chillers, each fitted with a variable speed drive (Figure 11). Even though installing a VSD on only one chiller could have saved some initial cost, J&J decided to spend the extra money to put VSDs on both chillers. Their rationale was that they wanted the efficiency and control that the VSD affords regardless of which chiller runs at a given time. They recognized that each chiller would need to be periodically taken off-line for service, and they didn’t want to have to juggle maintenance schedules to respond to anticipated cooling requirements. In addition, their approach allows them to alternate which chiller comes on first, resulting in more bal-

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**Figure 11: Centrifugal chiller with variable speed drives**

This 600-ton, VSD-driven centrifugal chiller provides efficient operation under varying load conditions.
anced wear-and-tear on the chillers over time. In practice, the two chillers are alternatively assigned as the “lead” chiller on a weekly basis.

The chillers were also selected to operate reliably with low entering condenser water temperatures. This capability substantially improves chiller efficiency during much of the year. To take full advantage of this feature, the engineers generously sized the two cooling towers (Figure 12), and also specified wetbulb temperature reset controls that measure the outdoor conditions and reset the condenser water temperature downward when conditions permit.

Chilled water is circulated to the air handling units through a variable flow, primary/secondary distribution system, with two-way throttling valves installed on each cooling coil to reduce the flow rate when cooling loads are small. VSDs are installed on the secondary chilled water pumps (Figure 13, next page), saving substantial energy during off-design conditions.

All fan and pump motors are premium efficiency (Figure 14, next page), meaning that they are of the highest efficiency commercially available within each horsepower category. Because electric motors consume many

VSDs are installed on the secondary chilled water pumps, saving substantial energy during off-design conditions.

Figure 12: Induced-draft cooling towers provide efficient heat rejection

Two induced-draft cooling towers provide heat rejection for the chillers. They were generously sized in order to improve chiller operating efficiency over much of the year.
Figure 13: Variable-speed chilled water pumps

Each of the secondary chilled water pumps is fitted with a variable-speed drive, providing substantial energy savings during light load conditions.

Figure 14: Premium efficiency motors

Premium efficiency motors provide additional energy savings when used instead of motors that merely meet the National Electrical Manufacturing Association’s “high efficiency” motor efficiency requirements.
times their purchase price in energy over their lifetimes, J&J feels that it is almost always cost-effective to purchase the highest efficiency available.

To ensure that they were getting the energy performance they paid for, J&J specified that chillers and air handling units would undergo performance testing at their respective points of manufacture, and that J&J would only accept this equipment after its performance was witnessed and documented.

Recognizing the mild nature of the San Diego climate, boilers for space heating were specified to have high efficiency, high turndown burners that can efficiently meet a wide range of heating loads (Figure 15). In addition, flue stack economizers were installed that recover heat from the boiler exhaust air that is then used to preheat makeup water for the boilers.

The control of the HVAC system components is managed by a distributed digital control (DDC) system. The system allows efficient equipment scheduling, as well as a wealth of energy saving sequences of operation such as chilled water temperature reset and static pressure reset for fan systems. J&J evaluated several comparable systems but ultimately decided on the product that offered the greatest compatibility with hardware in other J&J facilities and that their facility engineers were comfortable with using.

Figure 15: High efficiency space heating boilers

High efficiency boilers with flue stack economizers (not visible) minimize energy use for space heating.

Flue stack economizers were installed that recover heat from the boiler exhaust air that is then used to preheat make-up water for the boilers.
To allow the chiller microprocessor-based control panels to communicate with the DDC system that controls other building systems, J&J opted to install communication gateways (Figure 16). These hardware devices allow data sharing between devices that follow disparate communication protocols, enabling enhanced chiller control and better integration with the operation of other building systems.

Digital controls were used throughout the facility, including for the VAV terminals that control the temperature in occupied spaces. Because these distributed microprocessors are networked together, the facilities staff can often troubleshoot comfort complaints from the PC in their office instead of having to go to the physical location of the complaint.

One of the most conspicuous results of involving the maintenance staff in the design of systems that they would eventually service is the amount of open space around mechanical and electrical equipment. For example, adequate clearance is given to easily pull the tube bundle out of each chiller without tearing the room apart (Figure 17), or to set a new motor without dismantling much of the surrounding piping. There is ample space around air handlers to facilitate maintenance. This feature comes with a price tag, though, because space taken up for mechanical and electrical equipment is limited.

**Figure 16: Communication gateways facilitate inter-device communications**

The communication gateway (left) allows the chillers to communicate with the digital control system (right two devices).
rooms means the building gets larger and more expensive. The benefit of substantially enhanced maintainability of the systems, though, was felt to be well worth the effort.

From the standpoint of financial savvy, J&J left its indelible mark in another way. Because of the inherent efficiency of the various HVAC system components—VSD motors, for example, are intrinsically “soft started” and therefore significantly reduce inrush current—J&J was able to justify downsizing the capacity of the emergency generator from 2,000 kilowatts (kW) to 1,500 kW. This resulted in significant cost savings and also reduced space requirements for the generator.

**Laboratory Fume Hoods**

Even though the energy efficiency of laboratory fume hoods is not governed by Title 24, J&J recognized that these were probably the single largest energy users in their proposed building. Fume hoods are directly responsible for a large amount of fan energy, and they are indirectly responsible for vast amounts of heating and cooling energy because of the volume of conditioned air they continually exhaust from the labs. Accordingly, J&J worked hard to make these systems as efficient as possible while maintaining a safe and productive working environment (Figure 18).
J&J involved the scientists who would eventually occupy the PRI facility extensively in the process of evaluating candidate laboratory mechanical systems. In particular, the design team solicited input on the merits of installing variable air volume fume hood controls instead of traditional constant volume controls. Once the scientists learned about the enhanced safety, reduced noise, and impressive energy savings that VAV hood controls can provide, they cautiously endorsed this system but stated, “It had better work.” J&J ultimately opted to install VAV fume hood controls in all chemical fume hoods. Since they first occupied the building in mid-1999, response from the scientists to these advanced fume hoods has been overwhelmingly positive.

After the engineers evaluated the various product offerings on the market, J&J opted to install VAV supply and exhaust valves that provide ultra-fast response to changing conditions in the lab (such as a fume hood sash being abruptly opened or closed). It also issues an audible alarm if safe

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**Figure 18: Laboratory fume hood**

The PRI facility includes 92 fume hoods.
conditions are not being met because of some sort of equipment failure in the hood or downstream in the exhaust system (Figure 19).

One interesting feature is an occupancy sensor for each fume hood that senses when somebody is in the vicinity of the hood. When no one is around, the airflow velocity through the hood is reduced from its usual value of about 100 feet per minute (fpm) down to 60 fpm. This reduction saves fan energy, but more importantly reduces the amount of conditioned air that is exhausted out of the building during periods of non-use. When someone approaches the fume hood, the system senses their approach and quickly kicks the face velocity back up to 100 fpm. Because many of J&J’s scientists like to work at odd hours, there is a great diversity in the use of most fume hoods. The usage-based controls capture much of the savings potential of this diversity.

The exhaust and makeup air systems that serve spaces with fume hoods are usually quite large when compared to traditional HVAC systems.

![Figure 19: VAV fume hood controls provide energy savings and enhance safety](image)

This fume hood controller sounds an alarm if it is not performing properly and lets users know if it is operating in standard or standby mode.
because of the large airflow requirements of fume hoods (Figure 20). Installing VAV fume hoods that move less air when they are not used and driving overall exhaust rates down further with the usage-based controls allowed the mechanical engineer to make a case for downsizing other mechanical systems (Figures 21 and 22). Because of the proposed system’s ability to predictably respond to diverse use, J&J was able to install ducts and fans that were about 25 percent smaller than they would be if constant volume controls were installed. This also translated into smaller chillers and boilers because of the reduced amount of conditioned air exhausted from the building. These cost savings were used to offset the higher cost of the VAV hood controls.

As mentioned previously, the PRI facility had a 30-foot height limitation imposed by applicable local building codes. Accordingly, a conventional fume hood exhaust extending 6 to 8 feet above the roofline would have imposed serious limitations on the floor-to-floor heights for the proposed two-story structure. To minimize the amount of vertical height that the exhaust stacks would steal from the building, J&J opted to install high-entrainment exhaust fans (Figure 23). These fans have an innovative

Because of the proposed system’s ability to predictably respond to diverse use, J&J was able to install ducts and fans that were about 25 percent smaller than they would be if constant volume controls were installed.

### Standards for Laboratory Exhaust Systems

There is some confusion about the governing standards for laboratory exhaust systems because a number of organizations publish standards. The most commonly cited standard is ANSI/AIHA Z9.5 (1992), developed by the American National Standards Institute and the Association of Industrial Hygienists of America. Other widely used standards include the Occupational Safety and Health Administration 29 CFR, Part 1910; the National Fire Protection Association Standard 45; and the American Society of Heating, Refrigeration, and Air Conditioning Engineers Standard 110, “Methods of Testing Performance of Laboratory Fume Hoods.” Although there are differences among them, most of the standards are in basic agreement on the following performance requirements:

- Maintain a face velocity of 100 feet per minute with the sash in the open position.
- Maintain a slightly negative pressure in the lab with respect to adjoining corridors and offices to create a secondary containment barrier.
- Maintain a ventilation rate of 12 to 16 air changes per hour while the lab is occupied.
**Figure 20: Typical centrifugal utility fan in fume hood exhaust**

The field-installed components, such as inlet elbows and flexible connectors, in the typical fume hood exhaust system result in a large pressure drop that the fan must overcome in order to produce the necessary exit velocities for the airstream.

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**Figure 21: Schematic of a variable-volume fume hood**

The constant-face-velocity controller gathers information from a velocity sensor positioned inside the fume hood or from a sash position sensor. The sensor feeds information to the controller, which adjusts the damper position to obtain the necessary airflow.
design that produces a “virtual stack” that is much higher than their physical height. They accomplish this by mixing large quantities of outdoor air with the fume-laden effluent from the fume hoods before it is blasted high above the facility. The result is a tight exhaust plume directed away from possible exposure that is quickly diluted by outside air.

Wanting to ensure that this advanced technology performed as published, J&J commissioned Bechard Long and Associates to compile a mathematical model for exhaust plume distribution. The goal was to have concentration of no more than 1 part per million (ppm) in the event of accidental release of a significant amount of chemicals. The highest concentration predicted by the model at building air intakes or at any normally occupied location was about 0.5 ppm—far lower than J&J’s requirement for safety, and proof that the fans perform as promised.

An additional, significant advantage of the fans was that their efficient design led to an approximate 25 percent reduction in installed horsepower when compared to typical fume hood exhaust stacks fitted with utility fans.

**Water Conservation**

Since San Diego has no real potable water resources of its own, the city takes an aggressive stance toward conservation of this precious resource. As one water district authority staff member once put it, “San Diego is at the end of a mighty long straw.” In other words, its water supply comes from distant sources.
J&J implemented a number of water conservation technologies at PRI. These include:

- **Recovering condensate from cooling coils to use as make-up water for the cooling towers.** Even though this measure had a 15-year payback, J&J felt that implementing this measure was consistent with their goal of environmental stewardship.

- **Using reclaimed water for landscape irrigation and other uses** (Figure 24, next page). Using reclaimed water (which is available through a separate municipal water distribution system in the vicinity of PRI) for landscape irrigation and for providing makeup water to the cooling towers gave J&J a two-fold benefit. First, the reclaimed water costs about 10 percent less than regular water. Second, making a commitment to use it may give J&J some beneficial considerations if drought
conditions ever necessitate serious curtailment of water use in the future.

What Didn’t Make the Cut? (And Why?)

Because of the extensive list of energy efficiency features of the PRI facility, it may seem that no reasonable technological stone was left unturned. This is not the case, though; a number of worthwhile design strategies were considered but ultimately omitted for non-energy reasons.

- **Primary vs. secondary service voltage.** The engineering team made an analysis of utility cost saving that would result from installing an electric substation owned by J&J that would allow them to purchase electricity at a lower cost. Even though the potential cost savings were impressive, it was ultimately decided that the reduced maintenance requirements and overall issues of accountability favored buying electricity at the more expensive secondary service voltage. Under the
lower voltage scenario, SDG&E owns and maintains the equipment that steps voltage down from transmission to distribution levels. Since the utility has sole accountability for getting power all the way to the PRI facility service vault, J&J will not have to worry about operating and maintaining an electric substation and can let the utility bring its extensive experience to bear on this essential practice. This is especially important when one considers the substantial financial losses embodied in scientists who cannot work if there is a power interruption.

- **Thermal energy storage.** The economics were favorable for installing a thermal energy storage (TES) system that would inexpensively produce chilled water during non-peak utility cost periods such as the middle of the night. However, the constrained project site made it difficult to find a suitable location for the large chilled water storage tank that would be required. TES was ultimately ruled out because of a lack of available space.

### What Should Have Made the Cut?

Hindsight is 20/20, and after a couple years of operation J&J allows that there are a few features that they wish had been included in the original design.

- **Install a pony chiller to serve light cooling loads.** Even though the two 600-ton centrifugal water chillers are each fitted with variable speed drives that allow them to efficiently serve fairly light cooling loads, there is a small but constant cooling load that is too small for them to serve reliably. The data center requires 20 to 30 tons of air conditioning on a 24/7 basis, and J&J had to install a couple of packaged direct expansion (DX) cooling units to provide reliable cooling for this critical space.

- **Implement deeper tinting in some spaces to improve comfort.** Some perimeter office spaces had substantial glare problems because of direct sunlight entering the space. To ameliorate visual conditions for workers in such spaces, J&J installed a tinted solar control film to reduce the intensity of glare. If they were doing it again, they would...
If they were doing it again, they would have evaluated additional fins or overhangs in the problematic spaces to keep direct beam insolation off the glass in the first place.

- **Upgrade humidification system capacity.** San Diego is a “binary” climate when it comes to humidity. Certain research spaces require that humidity be maintained within reasonable tolerances, and, even though San Diego is temperate and not too dry most of the time, it can at times be quite arid. When Santa Ana winds reverse the coastal flow and bring in hot, dry air from the deserts to the east, the relative humidity can be extremely low. The humidification system at PRI was not furnished with adequate water make up and an additional feed had to be installed.

This is a short list of shortcomings for PRI, in light of the extensive list of project successes. Nonetheless, J&J has learned useful lessons from these minor shortcomings and has modified its best practices process to reflect newly acquired practical wisdom.

**Conclusions**

All modern laboratory buildings are complicated affairs and it’s hard to make them work right under the best of circumstances. The Pharmaceutical Research Institute in La Jolla had to be constructed under a number of particularly stringent environmental constraints. Yet it works well, uses much less energy than similar laboratory facilities, and is easy to maintain. The building’s success depended on a combination of J&J’s design philosophy (reflected in the company’s “New Facilities Design Criteria”), careful modeling of building systems to envision how each works on its own and what its impact is on the others, and a steadfast vision of the need to produce a robust structure that will function well for many decades.

Going with the most efficient equipment possible made sense in almost every case, for it will last longer, use less energy, and allow for HVAC equipment to be smaller and less expensive. “Proper sizing is a key goal,” observes Harry Kauffman, J&J’s corporate energy director, who is responsible for the development of the “New Facilities Design Criteria.” “Most of the time A&E firms use rule-of-thumb estimates for sizing equipment, but modeling actual loads leads to much more accurate sizing.”
Hardheaded cost-benefit studies were applied to every system in the building, but common sense presided over the court of appeals. Most often, common sense focused on the importance of reliability and smooth operation over the long term. For example:

- Both of the two large chillers had VSDs installed to facilitate maintenance and provide flexibility with controls, though cost/benefit analysis did not support this decision.

- A condensate recycling system was installed in spite of showing a 15-year payback because J&J wants to be a good corporate citizen. Using reclaimed water provided cost savings, improved environmental performance, and also reduces the chances that PRI will be shut off in the case of a future water crisis.

The chiller room is oversized and arguably wastes valuable space. But when major equipment must be serviced or replaced, the decision to anticipate the need for extra space will be highly praised.

Making judicious use of practical design criteria, computer modeling, cost benefit analysis, and the like helps in making good decisions on key elements of a building, but that’s only part of the design process. “One hundred percent completion of best practices does not guarantee a cost-effective and energy efficient design,” Kauffman points out. “Parts must be integrated to ensure a successful whole.”

The J&J building in La Jolla is a well-designed whole; it’s an attractive facility, inside and out. It’s also a pleasing and highly functional and comfortable facility to work in. Hence, it constitutes a non-trivial element in J&J’s pursuit of top scientific talent.
Appendix: Details from J&J's New Facility Design Criteria

The following is a reproduction of key elements of J&J's “New Facility Design Criteria,” an in-house publication used in the design and construction of its facilities worldwide, including the La Jolla, California, Pharmaceutical Research Institute, a state-of-the-art, 123,000-square-foot research and office facility completed in 1999.

Johnson-Johnson
New Facility Design Criteria

Instructions
Revised October 1999

The following outlines the design requirements for new facilities that are constructed within the Johnson & Johnson organization. We must strive to design the new facilities to the minimum building loads and properly size the mechanical/electrical systems to meet the needs of energy efficient equipment. Design integration will not only reduce operating costs but will also reduce first cost.

These Design guidelines are divided into three major categories of design:

<table>
<thead>
<tr>
<th>Electrical Design</th>
<th>Facility Design</th>
<th>Mechanical Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting Levels (Green Lights)</td>
<td>Building Envelope</td>
<td>Fan Systems</td>
</tr>
<tr>
<td>Lighting Types (i.e., T-4 and T-8)</td>
<td>Windows and Doors</td>
<td>Motor Challenge</td>
</tr>
<tr>
<td>Lighting Controls</td>
<td>Roof Systems</td>
<td>Electric Motor Management</td>
</tr>
<tr>
<td>Motorizing</td>
<td>Exterior Wall Systems</td>
<td>Motor Efficiencies</td>
</tr>
<tr>
<td>Electrical Purchasing</td>
<td>Critical Factors</td>
<td>Chiller Design Criteria</td>
</tr>
<tr>
<td>Operating Schedule</td>
<td>Office Equipment</td>
<td>Boiler Design Criteria</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Multiannual Factors</td>
<td>Compressor Design Criteria</td>
</tr>
</tbody>
</table>

These design requirements must be incorporated into the facility design in coordination with the Operating Company Project Manager, Johnson & Johnson Worldwide Engineering Project Manager and Design Teams. Recommendations and life cycle cost analysis should meet the financial criteria of a 20% IRR.
Electrical Design

<table>
<thead>
<tr>
<th>Area/Use</th>
<th>Light Level (fc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office (High Contrast - Typical)</td>
<td>20-30-50</td>
</tr>
<tr>
<td>Office (Computer Use - Ambient Level)</td>
<td>20-25-30</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>50-70</td>
</tr>
<tr>
<td>Warehouse</td>
<td>20</td>
</tr>
<tr>
<td>Research</td>
<td>50-100</td>
</tr>
<tr>
<td>Parking Lot</td>
<td>2-3-5</td>
</tr>
<tr>
<td>Hallways (Short Typical Hallway)</td>
<td>5-7.5-10</td>
</tr>
<tr>
<td>Stairways/Corridor (Longer Hallways)</td>
<td>10-20</td>
</tr>
<tr>
<td>Elevators/Restrooms</td>
<td>10-20</td>
</tr>
<tr>
<td>Conference Rooms</td>
<td>30-50</td>
</tr>
<tr>
<td>Lobby</td>
<td>20-30</td>
</tr>
<tr>
<td>Auditoriums</td>
<td>10-20</td>
</tr>
</tbody>
</table>

The following lighting systems are recommended for the listed applications.

**Fluorescent Systems:**

- T-8's with electronic ballast (T-5's where/when available)

**Downlights:**

- Compact Fluorescent (Primary)
- Halogen (Secondary for decorative purposes)

**Task Lighting:**

- Compact Fluorescent or
- T-8's with electronic ballast (T-5's where/when available) applications

**High/Low Bay Lighting:**

- High Pressure Sodium or Metal Halide with electronic ballast
Exit Signs
☐ LED (1-2 Watts per fixture)
Comment: 

Controls
Fluorescent Options:
☐ Occupancy sensors:
  - Daytime dimming
  - Timed switching (Timer or EMS)
Comment: 

HID Options:
- Occupancy sensors with bilevel dimming
- Occupancy sensors with electronic ballast
- Panel level dimming system
Comment: 

ELECTRICAL DISTRIBUTION
☐ Provide power at the highest voltage possible
☐ High efficiency, dry transformers
  - K Rated Transformers for non-linear loads
☐ Install power factor correction (capacitors) where utilities penalize for low power factor or where additional capacity is required.
Comment: 

Energy Purchasing - Review availability of market priced electricity and natural gas (deregulation). If not available review utility tariff and opportunities.

OPERATING SCHEDULES
☐ Fine tune operating schedule of equipment (lighting, HVAC, etc.) to match actual occupied hours.
Automatic control: In addition to Stop/Start, other EMS strategies include:
  Optimum Stop/Start, Night Setbacks, Enthalpy Control Reheat Control,
  and any successor technique.
Comment: 

METERING
☐ Primary metering of electric and fuel
☐ Additional metering by subsection or use area
  Suggested areas: manufacturing equipment, chillers, boilers, fans, lighting, compressed air, plug loads, any significant other uses.
☐ Connect metering to EMS or equivalent system for data collection.
Comment: 
Johnson & Johnson

New Facility Design Criteria

Mechanical Design

Fan System

- Outside air intake requirements must be evaluated to optimize systems.
- VAV fan system should utilize variable speed drives. (Note: Motors and drives must be compatible.)
- All office systems use Variable Air Volume with Variable Speed Drives.
- Laboratory systems (if appropriate) use Variable Air Volume with Variable Speed Drives with appropriate hood/slash controls. (NOTE: Need to comply with safety requirements.)
- Manufacturing systems that don't require constant volume use Variable Air Volume with Variable Speed Drives.
- Verify requirements for operation of fan system (i.e., air changes, filtration, etc.)
- Electronic control of air handling units.
- All fan motors to be energy efficient, per the attached minimum efficiency charts.
- For moderate climates, eliminate or reduce the use of reheat for local temperature or humidity control through the use of enhanced central system control.
- For humidity control, evaluate heat pipes or desiccant wheel in place of reheat. (NOTE: Heat pipes can only control down to 40% RH. Use waste heat to regenerate desiccant media where possible.)
- No electric reheat.
- Add air side economizers where appropriate climate conditions exist.
- Control fan systems through building automation systems. - As an alternative, control through a local controller.
- Add dedicated units for areas with specific requirements. (i.e., longer hours of operation, lower or higher temperatures, specific processing equipment, etc.) that would allow you to shut down or set back central systems.

Motor Challenge

The following equipment must be properly sized and specified as energy efficient motors per the attached Motor Efficiency list and evaluated for variable speed drives, 2 speed motors, etc.

- Chilled Water Pumps
- Condenser Water Pumps
- Cooling Tower Fans
- Boiler Feedwater Pumps
- Water Distribution Pumps
- Waste Treatment Pumps
- Process Motors
- Exhaust Fans
- Dust Collectors
- Vacuum Systems
- Air Handling Units
Johnson & Johnson

New Facility Design Criteria

Electric Motor Management Policy

All Motors should be specified as energy efficient and properly sized.

All Motors should be installed on rigid, level bases and properly aligned to

- All Electric motors should be inventoried and tagged.
- An energy efficient motor stock program should be implemented
to guarantee timely replacement of failed motors with energy
efficient motors (on-site or through supplier for guaranteed, quick
deliveries). NOTE: To be classified as energy efficient, motors
must meet the efficient level of NEMA MG-a Table 12-10.
However, motors with higher efficiencies and cost effective are
readily available. The recommended chart (attached) should be
used when specifying energy efficiencies.

- Rewind should be utilized as a last resort only for custom motors
or when timing requires. Rewind specifications should minimize
the efficiency loss.

An on-going preventive/predictive maintenance program should be in place
to include: Lubrication bearing inspection (stethoscope, infrared scanner,
temperature), belt inspection, alignment, motor mount inspection, cleaning,
and overload protection inspection. Frequency will be determined based on
hours of operation and criticality of motors. Additional inspections including
vibration analysis, oil sampling, and disassembly may be necessary for very
critical motors.
**New Facility Design Criteria**

**Recommended Minimum Motor Efficiencies**

Values are for TEFC (Open Drip-proof) Efficiencies should be equal or slightly higher

To be categorized as energy efficient by NEMA Table 12-10, motors can have lower efficiencies. The efficiencies listed below are the recommended minimum efficiencies at 75% loading to optimize your motor systems.

<table>
<thead>
<tr>
<th>HP</th>
<th>US/PR Nominal 1800 RPM % Efficiency</th>
<th>US/PR Nominal 3600 RPM % Efficiency</th>
<th>INTERNATIONAL Nominal 1800 RPM % Efficiency</th>
<th>INTERNATIONAL Nominal 3600 RPM % Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>86.5%</td>
<td>80.0%</td>
<td>0.75</td>
<td>86.5%</td>
</tr>
<tr>
<td>1.5</td>
<td>86.5%</td>
<td>85.5%</td>
<td>1.1</td>
<td>86.5%</td>
</tr>
<tr>
<td>2</td>
<td>86.5%</td>
<td>86.5%</td>
<td>1.5</td>
<td>86.5%</td>
</tr>
<tr>
<td>3</td>
<td>89.5%</td>
<td>88.5%</td>
<td>2.2</td>
<td>89.5%</td>
</tr>
<tr>
<td>5</td>
<td>90.2%</td>
<td>89.5%</td>
<td>3.7</td>
<td>90.2%</td>
</tr>
<tr>
<td>7.5</td>
<td>91.7%</td>
<td>91.7%</td>
<td>5.6</td>
<td>91.7%</td>
</tr>
<tr>
<td>10</td>
<td>91.7%</td>
<td>91.7%</td>
<td>7.5</td>
<td>91.7%</td>
</tr>
<tr>
<td>15</td>
<td>92.4%</td>
<td>91.7%</td>
<td>11.0</td>
<td>92.4%</td>
</tr>
<tr>
<td>20</td>
<td>93.0%</td>
<td>92.4%</td>
<td>15.0</td>
<td>93.0%</td>
</tr>
<tr>
<td>25</td>
<td>93.6%</td>
<td>92.4%</td>
<td>19.0</td>
<td>93.6%</td>
</tr>
<tr>
<td>30</td>
<td>93.6%</td>
<td>92.4%</td>
<td>22.0</td>
<td>93.6%</td>
</tr>
<tr>
<td>40</td>
<td>94.5%</td>
<td>94.5%</td>
<td>30.0</td>
<td>94.5%</td>
</tr>
<tr>
<td>50</td>
<td>94.5%</td>
<td>94.5%</td>
<td>37.0</td>
<td>94.5%</td>
</tr>
<tr>
<td>60</td>
<td>95.0%</td>
<td>95.0%</td>
<td>45.0</td>
<td>95.0%</td>
</tr>
<tr>
<td>75</td>
<td>95.0%</td>
<td>95.0%</td>
<td>56.0</td>
<td>95.0%</td>
</tr>
<tr>
<td>100</td>
<td>95.0%</td>
<td>95.0%</td>
<td>75.0</td>
<td>95.0%</td>
</tr>
</tbody>
</table>
Building Case Study: R.W. Johnson Pharmaceutical Research Institute

Chiller Equipment

EQUIPMENT SELECTION

☐ Chillers must be non-CFC.

☐ Refrigerant monitoring system for chillers located inside an equipment room.

☐ Chillers should be rated at 0.56 kW/Ton (5.3 COP) or better at the predominant operating load. (The best available unit on the market today (2000) has an energy efficiency of .47 kW/Ton.) Cost effective evaluation using life cycle costing (minimum of 5 years) must be made among electric, gas engine or gas or steam absorber based upon energy rates and load profile. A combination of electric and gas chillers may provide the most cost effective system.

☐ Electronic control on individual chillers

☐ Water cooled chillers which are the most efficient.

☐ Energy efficient motor (See minimum efficiency motor list).

☐ Consider installing vibration analysis sensors.

☐ Units must be equipped to monitor and record (kWh, flow and kW/ton as a minimum).

☐ Low voltage soft start (peak demand control).

☐ Self diagnostic control system.

☐ Part load control capability: Variable Speed Drive is the preferred technology on centrifugal chillers, electric control for staging of reciprocating chillers

☐ Energy efficient water towers.

☐ Energy efficient tower fan motors.

☐ Evaluate VSD’s on tower fans (chiller performance must be taken into account since lower condenser water temperatures normally improve chiller performance).

☐ Where package units are required for specific areas (or where a central system is not cost justified), a minimum BPR of 10, energy efficient motors, variable speed drives, economizer and electric controls should be utilized.
Sense space conditions and reset chilled water based upon requirements.

Install smaller dedicated chiller/s for exceptional uses (i.e., longer hours of operation such as weekends, lower temperature requirements, etc.).

For multi-chiller operation, different sized chillers to meet different loads throughout the seasons.

Properly sized chillers to meet the specific facility’s load profile. NOTE: There is a significant energy penalty that is paid for oversizing of chillers especially if no low load control is provided.

For multi-chiller operation, chiller optimization (automated load management: electric automation system that automatically controls operation of chillers based on facility requirements and efficiency of different units and system).

Evaporative cooling in place of mechanical cooling where proper environmental conditions exist (generally dry climate) and internal conditions permit (typically uses less than 1/4 energy required for mechanical cooling). (Energy efficiency motors and synchronous belts should be used to maximize efficiencies).

Evaluate thermal storage for demand reduction (for central and unitary systems). NOTE: The appropriateness of thermal storage is driven by the electric rate structure.

Water side economizer (“free cooling”: plate and frame heat exchanger) for chillers that must operate below 50°F (10°C) outside air.
Air Compressors Equipment

EQUIPMENT SELECTION
- Energy efficient motor (See minimum efficiency list).
- Properly sized, energy efficient compressors.
- Capability to efficiently operate at part load.
- Electronic control for individual compressors.
- Properly sized, energy efficient dryers.
- Properly sized, air receiver (storage tank) at the compressors.

MECHANICAL DESIGN
- Install metering that will allow user to monitor and record energy usage, temperature, pressure, and flow.
- Design at minimum required air pressure only. NOTE: Every 2 psi (.14 bar) drop improves efficiency 1%.
- Evaluate compressed air boosters for higher pressure applications to reduce overall system pressure.
- Consider additional load storage tanks at the point of use to act as demand buffer.
- Energy efficient motor (See minimum efficiency list).
- Properly sized, energy efficient compressors.
- Capability to efficiently operate at part load.
- Evaluate piping system to minimize pressure drops and distribution. NOTE: A looped system is recommended.
- Dedicated compressor for high or low pressure, volume or off hour use.
- For multi-compressor operation, compressed air optimization (not just a lead/lag system) to include demand control, cycling, and off hour shutdown.
Boiler Equipment

EQUIPMENT SELECTION
- Properly sized boilers for the loads with a minimum fuel-steam/hot water efficiency of 85% or above at full load.
- Combustion control system
- Properly sized energy efficient motors (draft fan, feedwater, Dearator-see minimum efficiency chart).
- Provide alternate fuels to utilize the least cost fuel and take advantage of competitive opportunities. (Interruptible gas purchasing)
- Low excess air burner minimum of 10% (2% O2) and 8:1 turndown

MECHANICAL DESIGN
- Appropriate water treatment capability provided (Site specific).
- In line stack monitoring (temperature, excess air, CO, CO2, opacity and NOx), or portable monitoring equipment.
- Install metering that can monitor and record steam/hot water usage.
- Operate equipment to meet requirements only. (set points)
- Stack (flue gas) economizer.
- Automatic blowdown based on total dissolved solids.
- Blowdown heat recovery.
- Variable speed drive feedwater pumps.
- Condensate return system. (high pressure to eliminate latent heat loss)
- Evaluate other sources of reducing water usage through the use of the condensate.
- Consider purging traps (pressure power pumps) in place of condensate receivers.
- Dearator system.
- Utilize dedicated units for higher pressure or off hour or seasonal load requirements.
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