Laboratories for the 21st Century: An Introduction to Low-Energy Design

As a building type, the laboratory demands our attention: what the cathedral was to the 14th century, the train station was to the 19th century, and the office building was to the 20th century, the laboratory is to the 21st century. That is, it is the building type that embodies, in both program and technology, the spirit and culture of our age and attracts some of the greatest intellectual and economic resources of our society.

Unfortunately, a laboratory is also a prodigious consumer of natural resources. For example, laboratories typically consume 5 to 10 times more energy per square foot than do office buildings. And some specialty laboratories, such as cleanrooms and labs with large process loads, can consume as much as 100 times the energy of a similarly sized institutional or commercial structure.

The challenge for architects, engineers, and other building professionals is to design and construct the next generation of laboratories with energy efficiency, renewable energy sources, and sustainable construction practices in mind. And to do so while maintaining — and even advancing — high contemporary standards of comfort, health, and safety.

If we are successful, the benefits will be significant. Assuming that half of all American laboratories can reduce their energy use by 30%, the U.S. Environmental Protection Agency (EPA) estimates that the nation could reduce its annual energy consumption by 84 trillion Btu. This is equivalent to the energy consumed by 840,000 households. An improvement of this magnitude would save $1.25 billion annually and decrease carbon dioxide emissions by 19 million tons — equal to the environmental effects of removing 1.3 million cars from U.S. highways or preventing 56 million trees from being harvested.

Zimmer Gunsul Frasca/Strode Eckert Photo/PIX03536

Daylighting enhances the scientists' work space at the Fred Hutchinson Cancer Research Center in Seattle, Washington.

With these benefits in mind, this publication describes some energy-efficient strategies for designing and equipping the laboratories of the 21st century. It introduces the basic issues associated with energy consumption in the laboratory and summarizes key opportunities to improve or optimize energy performance during each phase of the design and acquisition process. Both standard and advanced new technologies and practices are included.

United States
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PROGRAM

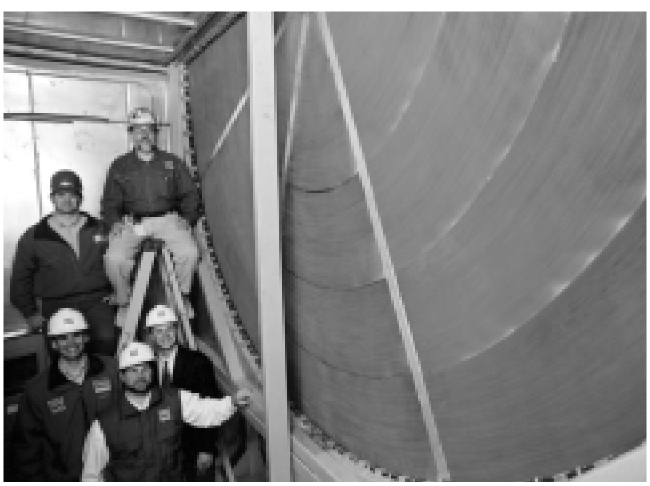
The Energy Challenge

The basic energy challenge confronting laboratory designers is the high cost of conditioning the large volume of ventilation air needed to meet safety requirements and building codes. Unlike office buildings, which are typically designed around a ventilation standard of 20 cubic feet per minute (cfm) per person of outside air — equal to about one air change per hour (ACH) or less — lab modules normally require 100% outside air — often at exchange rates between 6 and 10 ACH — to meet the aggressive exhaust requirements of fume hoods.[1] And in some laboratory designs, ventilation rates are arbitrarily set at levels from 15 to 25 ACH, whether or not there is a need for such a high rate.

Because of these requirements, many best practices for energy-efficient laboratories attempt to reduce the amount of energy required to condition ventilation air. Fortunately, opportunities to do this arise at each phase of the design and construction process. For example, during the planning and programming phase, it is advisable to zone lab modules based on classification-driven ventilation requirements. During building design, the development of clear, flexible distribution plans should be stressed. And during the selection of mechanical systems, energy-efficient technologies such as variable-air-volume (VAV) fume hoods and heat recovery systems should be considered.

As a result of the disproportionate influence of airflow on laboratory energy consumption, many traditional energy-saving measures, such as increasing wall and roof insulation or orientation, might not have a significant effect on energy efficiency. Other strategies, such as using high-performance windows, need to be studied on a case-by-case basis. The bottom line is that design professionals cannot rely on intuition and rules of thumb developed for other building types when planning and implementing energy-efficient strategies for laboratories.

1 The 100% outside air requirement is set to avoid problems of cross-contamination that might arise if air were recirculated.



Bill Branson, NIH/PIX03683

A mammoth heat recovery wheel is employed at the Louis Stokes Laboratories at the National Institutes of Health in Bethesda, Maryland.

Dave Parsons, NREL/PIX04860

The cleanroom in this modern laboratory employs energy-efficient ventilating equipment.

In comparison to other institutional and commercial buildings, laboratories may also have unusually high plug loads — the energy required to run equipment such as computers, centrifuges, and spectroscopes. Whereas office buildings often have connected plug loads of about 0.5 to 1 watt per square foot, laboratories have loads that can range from 2 to 20 watts per square foot. Fortunately, laboratories also usually have a high "diversity factor," which means that most equipment operates only intermittently.

Nevertheless, the effect of plug loads on mechanical system design can be pronounced. Generally, the ventilation rate required for fume-hood exhaust exceeds the rate needed for cooling. But during peak plug loads, internal sources of heat gain from equipment can be more than 10 watts per square foot. At that point, the air supply rate needed to counteract peak heat gain is sometimes greater than the rate required for exhaust. Because of the variability of these requirements, in recent years many large, energy-efficient laboratories have favored the use of VAV supply and hood exhaust systems.

Of course, not all laboratories are the same. Some university labs are intended primarily for instruction, while those on commercial or industrial campuses are used largely for research and development. There are chemical, biological, and physical labs, each having distinct requirements and activities. And within these categories, laboratories are assigned different occupancy classifications depending upon their use and degree of

Warren Gretz, NREL/PIX01014

An award-winning national testing facility in Colorado was designed to reduce energy use by 60% to 70% with high-efficiency lighting; advanced heating, ventilating, and cooling equipment; and many passive solar features.

hazard. The fume hood density in a facility is also an important parameter of building energy performance.

To complicate matters further, most laboratories also include support spaces such as conference rooms, libraries, and office suites with significantly less stringent heating, ventilating, and air-conditioning (HVAC) requirements than those of the labs. On the one hand, this integration of dissimilar types of spaces often increases the potential for energy waste. On the other hand, a clear understanding of the distinct mechanical needs of these diverse spaces can help designers segregate — and efficiently provide for — different building zones.

With these special challenges in mind, the opportunities presented here must be considered and adjusted in light of the special needs and circumstances of each laboratory design project.

The Opportunities

As in any building project, an energy-sensitive design process for laboratories must be supported by a high degree of communication among the design team professionals. Energy-efficient design is invariably integrated design. Among other things, this means that the implications of design decisions on the performance of the whole building are understood and evaluated at each step of the process by the entire team. For simplicity, the opportunities described here are organized according to a sequence of steps in the design process. But they should be pursued as part of an iterative, cross-disciplinary effort in which each phase of the process influences and informs the others.

It is important to note that energy efficiency is just one piece of a larger commitment to sustainable design, which includes site optimization, water conservation, the use of environmentally preferable materials, and concern for the quality of the indoor environment. All laboratory design decisions should be evaluated in the context and spirit of "reduce, reuse, recycle," a phrase that defines contemporary sustainable practices.

Planning and Programming

During planning and programming, important decisions are made that will have a fundamental impact on the energy efficiency of the laboratory. These are some of the key recommendations for this phase of the design:

- **Emphasize the use of life-cycle cost analysis as a basis for energy investment decisions.**

Many sophisticated building planners routinely request life-cycle cost analyses of primary building systems, although the implications of base-case assumptions, such as the length of the cycle, are not yet fully understood. For example, although in some labs a constant volume (CV) air-supply system may have the best 5-year life-cycle value because of its relatively low initial cost, VAV systems usually have the lowest life-cycle cost in large labs when considered in life cycles of 10 years or more.

- **Establish energy efficiency and the use of renewable energy sources as fundamental project goals.**

When possible, set quantitative energy performance goals in terms of Btu consumed, dollars saved, or pollution avoided. As part of this exercise, propose a mechanism by which energy use will be benchmarked and savings calculated during design. This might involve mandating the use of certain software tools and the establishment of consistent base-case assumptions about use, occupancy, or equipment. Include this information in a

Warren Gretz, NREL/PIX04715

Daylighting from clerestories and small, stacked windows illuminate the office space in this lab building; the towers help distribute heated or cooled air.

written design-intent document that can guide a commissioning or quality assurance process. This document will also reinforce institutional and team memory during the long planning and construction horizons that are typical for laboratories.

- **Conduct a project-specific codes and standards review with energy considerations in mind.**

Make sure you understand the difference between a code and a standard. A code has the force of law behind it, while a standard is simply a guideline unless it has been adopted as a code by the authority having jurisdiction. Ventilation codes and standards vary markedly according to the occupancy classification. A less stringent classification can reduce energy consumption by allowing lower air-change rates to be used, or permitting air recirculation within a space rather than requiring 100% outside air at all times. With health and safety as paramount considerations, refine your programmatic needs to determine whether a cluster of lab modules can be built to a less stringent classification.

- **Understand the energy consumption implications of narrow operating ranges.**

Although some experiments and equipment require a high level of thermal and humidity control, many do not. In some instances, owners or their representatives mandate an extremely narrow range without appreciating its operating cost penalty. For instance, maintaining an exceedingly tight relative humidity (RH) range consumes a large amount of energy and requires extra cooling and reheating coils in the air-supply system that would not otherwise be needed.

Davis Brody Bond, LLP/PIX03473

Interior, Brown University GeoChemistry Laboratory, Providence, Rhode Island; design by Davis Brody Bond, LLP.

- **Catalogue the energy efficiency and renewable energy opportunities for non-lab spaces in the building.**

Because designers often focus on the laboratory layout, they sometimes overlook excellent opportunities to save energy in other zones of the building. For example, daylighting for offices, meeting rooms, and library spaces should definitely be considered. Consider using photovoltaics for applications such as remote building signs, parking lot lights, and recharging uninterruptible, battery-powered supplies.

- **Segregate energy-intensive process operations tasks with mini-environments.**

Whenever possible, anticipate future needs and provide for HVAC-intensive zoning. In particular, to save energy, segregate areas that require very tightly controlled temperature and humidity conditions from spaces that are simply providing human comfort. Consider stipulating the use of "mini-environments" to isolate energy-intensive operations, such as providing highly filtered air in small, containerized volumes.

Designing

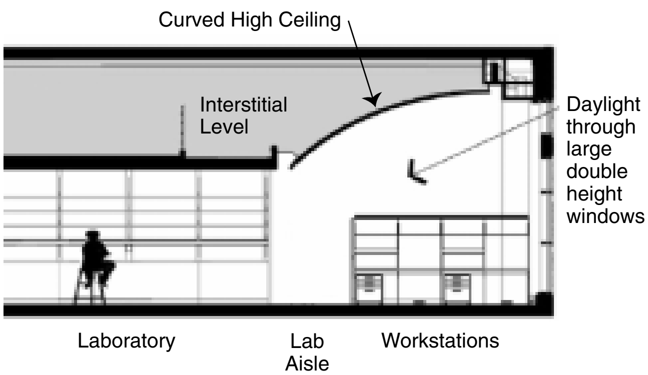
During the design phase of a project, criteria established in the planning and programming phase are translated into actual forms. Many decisions are made about elements that have a significant impact on energy consumption, such as adjacencies, building sections, service routes, and building envelope design. These are some key recommendations for this phase:

- **Select architectural and engineering professionals with laboratory experience and a proven record of sustainable design.**

Be sure to select design professionals familiar with the unique challenges associated with lab design. Laboratory design requires experience. It is not for the faint of heart or the mechanically disinterested. Look for architects and engineers who can demonstrate that they have experience in the interactive design process.

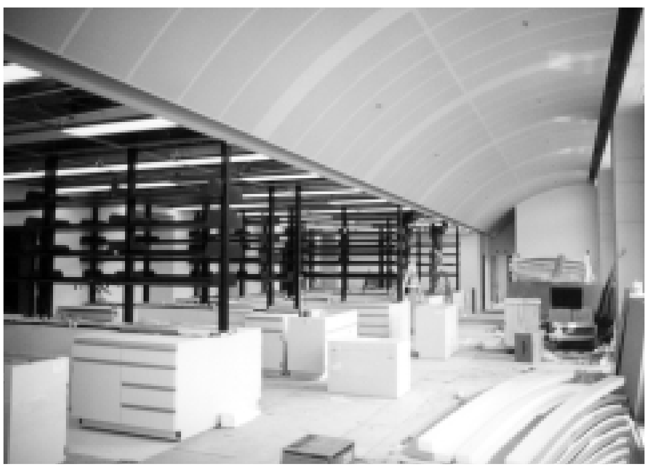
- **Pursue a whole-building approach to design.**

Creating a high-performance building requires an interactive, "whole-building approach" to the design process. In a whole-building approach, all design and construction team members should be able to both appreciate and integrate a wide range of building performance factors. These factors include first costs, life-cycle costs, quality-of-life issues, flexibility, productivity, energy efficiency, aesthetics, and environmental impacts. The



HLM Architects/02877404m

A section cut through the interstitial space and laboratory module of the Louis Stokes Laboratories at the National Insititutes of Health in Bethesda, Maryland; design by HLM Architects.



Frank Kutlak, NIH/PIX03716

A typical perimeter workstation area at Louis Stokes Laboratories.

fundamental challenge of whole-building design is to understand that all building systems are interdependent.

The first step in this direction can be to invite clients, team members, and other stakeholders to a design charrette. A charrette is a focused, collaborative brainstorming session held at the beginning of the project. During a design charrette, all participants are encouraged to address design problems and opportunities on a cross-disciplinary basis.

- **Insist on the clarity and convenience of mechanical systems distribution.**

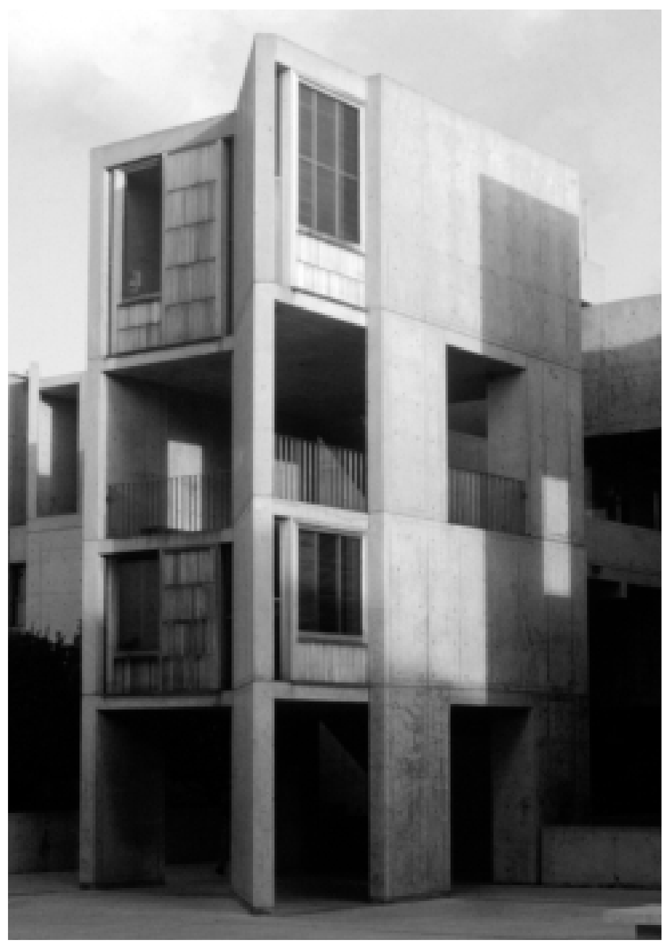
In laboratory design there is ample room for architectural expression, but that should not be achieved by compromising the clarity and convenience of HVAC distribution in the building plan. Efficient air distribution is important, because undersized or convoluted duct runs can increase the resistance to airflow and unnecessarily increase the fan energy required to distribute the supply air.

In practical terms, this means that locating HVAC service chases and access corridors cannot be an afterthought; instead, this must be a fundamental planning element in laboratory design. First-cost increases required by rational lab module planning and elaborated building cross-sections are often more than justified by the resulting improvements in energy efficiency, flexibility, and maintenance on a reasonable life-cycle basis.

Among HVAC planning strategies with significant architectural and formal implications are the use of double-loaded utility corridors, the insertion of partial or complete interstitial spaces and — in the case of some retrofits — the addition of exostitial volume on the building perimeter.

- **Try to isolate office and noncritical support spaces from lab modules and, when feasible, cascade airflow from offices to labs.**

Different scientists have different preferences for the location of office and support space, and these often depend on the nature of the research being conducted. In some cases, users prefer work desks immediately adjacent



Donald Prowler/PIX03472

A study carrel pavilion in the courtyard of the Salk Institute in La Jolla, California; design by Louis I Kahn, Architect.

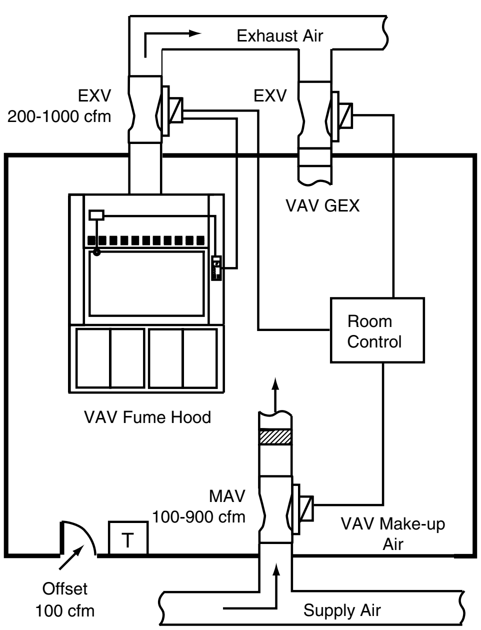
to their lab benches; in other cases, separation from the lab proper is acceptable and even preferable. When possible, attempt to mechanically isolate offices and support facilities from the lab module to reduce the building's HVAC requirements.

At the world-famous Salk Institute in the benign climate of La Jolla, California, architect Louis I Kahn detached the study carrels of the scientists from their benches by means of an open-area corridor. This reduces the volume of space that needs to be served by 100% outside air and decreases the energy required for conditioning and distribution. It also permits scientists to reflect on their work in bright, naturally lit environments enlivened by natural views and ventilation.

- **Plan architectural adjacencies with mechanical system requirements in mind.**

Determine the feasibility of HVAC strategies that may have adjacency implications. For example, labs for handling hazardous or toxic (a.k.a. "dirty") operations are negatively pressurized, while labs for handling precious or delicate (a.k.a. "clean") operations are positively pressurized. Under some conditions, exhaust air from clean labs can be used as supply air for dirty labs. But this would be feasible only if the labs are so designed from the outset.

The proximity of supply and exhaust air streams can also be a major organizing factor. In general, it is best to separate supply and exhaust air to avoid cross-contamination. But there are cases in which energy can



Phoenix Controls Corporation/02877403m

Sash-sensing, pressure-independent air valves, and volumetric room flow controls are used in this variable-air-volume HVAC system.

be recovered from exhaust air if the two streams are brought to a central point before separation. Examples of such systems include regenerative heat (enthalpy) wheels, heat pipes, and fixed-plate heat exchangers. It is best to determine the viability of these systems early in the design phase, in close collaboration with engineering and safety professionals.

- **Don't forget about people!**

In our well-meaning quest for the optimal lab module design, fume hood isolation, and mechanical room layout, we sometimes overlook the more pedestrian needs of scientists. In many labs, researchers can benefit greatly from the use of natural light for ambient illumination, exterior views, and individually controlled task lights. In office zones, daylighting, which provides a major opportunity for energy savings, can displace or reduce the need for artificial illumination.

Be sure to include appropriate controls to dim or shut off lights. And, particularly in facilities with diverse loads, include occupancy sensors to control lights, computers, and, in some cases, fume hoods, as appropriate.

Engineering

In energy-efficient laboratory design, it is critically important for the engineering design team to provide input to the architectural design team from the very outset. If this is not done, opportunities to integrate efficiency measures into the building can be lost as the design progresses. But even after a building is planned and its architectural schematics completed, many important engineering decisions remain. These are some key recommendations for the engineering phase:

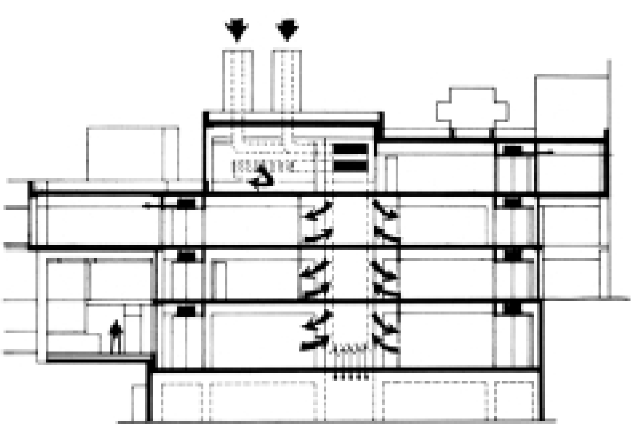
- **Be sure to right-size equipment.**

Engineers may have a tendency to oversize central mechanical heating and cooling equipment in the belief that providing a significant margin of error builds in flexibility and reliability, reduces the likelihood of litigation, and improves comfort. But in fact, oversizing increases energy consumption, hurts life-cycle economics, and can actually diminish comfort. All too often, the call for flexibility is an excuse for insufficient planning.

"Right-sizing" is by far the better strategy. Among other attributes, right-sizing respects the principle of diversity, that is, the assumption that all the laboratory's equipment is unlikely to be operating at rated capacity simultaneously. While single-room labs should always be sized for full 100% capacity, studies and practical experience have shown that, in large laboratories with many fume hoods, about 30% to 70% of the hoods are either

Davis Brody Bond, LLP/PIX03477

A side exterior view of the State University of New York (SUNY) Binghampton Science Complex; design by Davis Brody Bond, LLP.



Davis Brody Bond, LLP/02877402m

A section cut through the SUNY Binghampton Science Complex, showing clear HVAC distribution logic; design by Davis Brody Bond, LLP.

closed or only partially in use at any one time, yielding an overall diversity factor of approximately 50%.

- **Select equipment with part-load operation and variable conditions in mind.**

Because many labs have a highly variable HVAC demand, take part-load performance into consideration when designing and specifying equipment. For example, some chillers have significantly higher efficiencies when operating at or near peak output than when operating at partial output. With this in mind, engineers can size chillers in incremental modules that activate singly or in tandem to meet variable loads while continuing to run at maximum efficiencies. Similarly, as a sizing strategy, instead of specifying two identical chillers, consider installing two chillers of unequal size that provide more flexibility in matching variable loads. Still another option is to choose variable-load equipment, such as screw chillers, specifically engineered for high part-load efficiency.

On the heating side, specify module boilers to meet part-load requirements and to improve overall system reliability. Other devices that can be operated by adjusting them according to demand and occupancy include VAV supply and fume-hood exhaust systems and variable frequency drives (VFDs) on pumps and fans. Because fan horsepower varies directly with the cube of the airflow, relatively small reductions in airflow rates can substantially reduce motor and energy requirements. Using VAV systems reduces the volume of outside air that needs to be conditioned, saving a substantial amount of energy.

- **Specify premium high-efficiency equipment.**

Because laboratories are energy intensive, investments in high-efficiency HVAC equipment today invariably pay off tomorrow. This has been found to be true for a wide range of economic assumptions and climatic conditions. In particular, it is cost effective to specify chillers with low kW/ton profiles in the expected range of operation, low face-velocity coils and filters, and efficient motors and pumps.

Davis Brody Bond, LLP/PIX03476

Laboratory interior, Corning Glass Works, Corning, New York; design by Davis Brody Bond, LLP.

As much as possible, avoid the use of reheat coils. While reheat systems may be inexpensive to install, cooling air only to reheat it is inherently inefficient. A better approach to variable load control is to vary the volume of air provided by using VAV supply and exhaust systems. A dedicated cooling coil allows additional cooling to be added as needed.

- **Carefully consider the number, size, location, and type of fume hoods; each one uses as much energy as an entire house.**

Design systems that permit hoods to be moved as required. Many laboratories that are starved for air because of additional hoods in some modules have underused hoods in other modules. (Some are even used to store lunches!)

To ensure the isolation of chemicals, standard practice is to specify minimum incoming face velocities at the hood opening when it is operating. Depending on room distribution arrangements and circulation patterns, face velocities in the 60 to 110 fpm range are believed to provide acceptably safe operating conditions.

When hood sashes are fully or partially retracted, acceptable face velocities can be achieved at dramatically reduced airflow rates. In the past, constant-volume fume hoods did not adjust exhaust rates under these circumstances. Today, VAV fume hoods can automatically reduce the amount of exhaust air while maintaining acceptable face velocities. The VAV hoods have become standard practice for energy-efficient operation. Note that, when VAV fume hoods are installed, a VAV control system must also be installed to modulate the building supply and exhaust systems.

Currently under development are technologies that will provide acceptable fume hood isolation while dramatically reducing required face velocities. When fully commercialized, these high-containment, laminar flow, CV hoods may be viable alternatives to today's generation of high-performance VAV equipment.

- **Stress low-pressure drop design.**

The energy needed to blow air or pump water is largely determined by the resistance to flow, or pressure drop. At the beginning of the design process, set a system-wide maximum pressure drop target and pursue strategies that help to meet this goal. For example, consider specifying slightly oversized supply ducts and pipes that both reduce pressure drop and anticipate future needs. Avoid devices that create large, and often unnecessary, drops such as balance valves and fittings.

For similar reasons, use low face-velocity coils and filters. In particular, always use high-efficiency particulate (HEPA) filters with the lowest pressure drop available.

- **Take advantage of the unique conditioning approaches offered by your climate and location.**

Climate and location are important considerations when conditioning air. For example, in dry climates, like those of the Southwest, it is possible to use evaporative cooling in its various forms. In this process, moisture evaporated in a low-humidity air stream lowers the sensible, or dry-bulb, temperature of the air while keeping the total energy content, or enthalpy, of the air constant. Also called "adiabatic" or "free" cooling, this effect can be harvested by employing cooling-tower economizers or by applying direct or indirect evaporative cooling cycles.

- **Separate low- and high-temperature cooling loops.**

In some laboratories, chilled water is required for both air-conditioning and process cooling. However, the temperature requirements of these applications are often quite different. Typically, 45°F water might be needed as part of an air-conditioning cycle to provide adequate dehumidification, while 60°F water might suffice for a process cooling need. Because most chillers work more efficiently when producing higher temperature fluid, install a dedicated chiller to meet process requirements rather than tempering cold water produced from a single, low-temperature source. If the process cooling temperature can be modified, it might be possible to provide water with a cooling tower year-round at a significant savings in both first costs and operating costs.

- **Consider energy recovery from exhaust air or process cooling water, when this is permitted.**

In some laboratories, concerns about cross-contamination limit opportunities to recover energy from exhaust air and other fluid streams. But there are still many circumstances in which it is possible to recover sensible, and in some cases, latent energy using heat pipes, run-around coils, regenerative enthalpy wheels, and other devices. Give special consideration to reusing air from office and support spaces to reduce the need for mechanical cooling in adjacent laboratories.

- **Incorporate energy monitoring and control systems with direct digital controls.**

An energy monitoring and control system (EMCS) that incorporates direct digital control (DDC) is a key element of an energy-efficient research laboratory. DDCs replace conventional pneumatic or electromechanical HVAC operating systems with equipment capable of performing not only control functions but also energy management and system diagnostic functions within a centralized computer network.

If properly designed, installed, and maintained, an EMCS supports the efficient operation of the facility by monitoring, controlling, and tracking energy consumption. In particular, be sure to meter HVAC, plug, and lighting loads separately. Additional meters should be considered on large loads such as chillers.

Traditionally, EMCSs have been supplied to facilities by manufacturers with little input from design team engineers. We recommend that energy engineers take a more proactive role in EMCS development — from the selection of preferred sequences of operation to the specification of sensors and operators.

Commissioning, Operating and Maintaining

Even the most carefully designed and built project can fall far short of its performance goals if the building is not properly commissioned, operated, and maintained (CO&M). This means that concerns for CO&M must be incorporated into all phases of the design process. Commissioning a facility begins with a design-intent document that includes an outline of a comprehensive commissioning plan. A realistic description of the capabilities and funding level of building support personnel should be included in the project description. And, with the participation of O&M personnel on the project review team, CO&M concerns should be reviewed during the design and engineering phase of each project. These are some recommendations for CO&M:

- **Require whole-building commissioning.**

More so than most other building types, laboratories are complex; each is a uniquely crafted machine that must function superbly from the first day of operation. For this reason, it is essential that laboratories receive comprehensive, third-party, whole-building commissioning. Though a tradition of testing and balancing (TAB) has long been a part of the laboratory preoccupancy protocol, commissioning extends this process. Among other features, an effective whole-building commissioning process begins at a project's inception and records — and subsequently verifies — all system performance expectations.

As part of a comprehensive process, the designated commissioning agent should provide the user with a specific guide to the building. This document summarizes all building performance expectations and describes how the building systems should be maintained and operated to meet those expectations.

- **Benchmark, monitor, and report annually on building energy performance.**

Too often, building operations are noticed only when something is broken, or when it's too cold or too hot. A process of continuous commissioning should be put in place. Managers should plan and budget for consistent, regular reports on building comfort and energy consumption statistics. Without the benefit of a dependable benchmark, it is impossible to determine when energy consumption increases unnecessarily or the building's performance in general falters and requires attention.

In many cases, for example, submetering is relatively easy and inexpensive to do during construction and more costly to do as a retrofit. But obtaining more data does not necessarily mean having better information. Carefully balance the need for targeted figures with the problems that can ensue from a glut of numbers flowing from excessively monitored equipment.

Powering

Many laboratories are located on large university or corporate campuses. Increasingly, these complexes are investigating the economic viability of on-site electric power generation or load-leveling options such as cogeneration or off-peak thermal energy storage. Both small and large projects can benefit from the application of distributed technologies, such as natural-gas-powered fuel cells. In some climates and utility districts, solar thermal or photovoltaic energy systems are also cost effective. These are some recommendations for powering a laboratory:

U.S. Environmental Protection Agency/PIX03531

An artist's rendition of the EPA National Computer Center in Research Triangle Park, North Carolina; the building will include a 100-kW roof-integrated PV system for electricity generation.

- **Investigate the application of on-site power generation.**

The process-heat-load requirements of some laboratories make them excellent candidates for on-site electrical generation. In the case of a cogeneration plant, for example, a by-product of the electric generation process is heat, for which there might be an immediate use in a process application. When tied to a utility grid, on-site power generation can also provide redundancy for high-risk applications.

Warren Gretz, NREL/PIX03438

This energy-efficient laboratory building, built in Colorado in the 1990s, faces south and makes use of daylighting, evaporative cooling, and advanced heat recovery systems; the photovoltaic modules on the roof feed electricity into the local grid.

- **Consider using renewable energy.**

The relationship between renewable energy sources and laboratory energy requirements is not an obvious one. The energy needs of laboratories are often focused and intense, while renewable resources — such as solar and wind systems — are often diffuse and intermittent. Nevertheless, on-site harvesting of renewable energy can have positive economic impacts. Examples include using solar thermal collectors at sites where low-cost gas is not available for domestic water heating or process heat, and installing photovoltaic (PV) electricity generation systems in remote areas for applications such as footpath and parking-area lights or as a building component, such as PV roofing materials.

Other potentially viable renewable technologies include daylighting for ambient lighting, ground-source heat pumps for space conditioning, and transpired solar collectors for ventilation-air preheating. To ensure the cost effectiveness of a project, first reduce loads through energy-efficiency and conservation measures before applying renewable energy options.

- **Purchase green power.**

Often, a good strategy that laboratories can use to support the application of renewable energy technologies is to select the "green power" option from local utility providers. Depending on the location of the lab, this power could be generated by small-scale hydropower, wind farms, or PV systems.

Introduction to Low-Energy Design: A Checklist

Planning and Programming:

- ❏ Emphasize life-cycle costs when making energy decisions.
- ❏ Establish energy efficiency and the use of renewables as project goals.
- ❏ Conduct a codes and standards review.
- ❏ Understand the implications of narrow operating ranges.
- ❏ Catalogue opportunities for energy efficiency and renewables in non-lab spaces.
- ❏ Segregate energy-intensive processes by creating mini-environments.

Designing:

- ❏ Select A/E professionals with experience in sustainable lab design.
- ❏ Pursue a whole-building approach.
- ❏ Insist on clarity and convenience in mechanical systems distribution.
- ❏ Try to isolate office and support spaces from lab modules.
- ❏ Plan adjacencies by considering mechanical system requirements.
- ❏ Don’t forget about people!

Engineering:

- ❏ Be sure to right-size equipment.
- ❏ Select equipment by considering part-load and variable operating conditions.
- ❏ Specify premium high-efficiency equipment.
- ❏ Carefully consider the number, size, location, and type of fume hoods.
- ❏ Stress low-pressure-drop design.
- ❏ Take advantage of your unique climate and location.
- ❏ Separate low- and high-temperature cooling loops.
- ❏ Consider using energy recovery systems.
- ❏ Incorporate energy-monitoring and control systems.

Commissioning, Operating and Maintaining:

- ❏ Require whole-building commissioning.
- ❏ Benchmark, monitor, and report annually on energy performance.

Powering:

- ❏ Investigate the use of on-site power generation.
- ❏ Consider using on-site renewable energy.
- ❏ Purchase green power.

For More Information

With its extensive requirements for environmental systems, flexibility, and growth, energy-efficient laboratory design is a challenge. Unlike other building types, a laboratory has HVAC and energy considerations that cannot be deferred; they must play a key, formative role if the building is to succeed.

This publication should help to sensitize building professionals and their clients to the complex array of issues associated with efficient laboratory design and performance. But it is only an introduction; you will need to consult other resources, such as those listed here, for in-depth information about energy-efficient laboratory design.

The authors are particularly indebted to the *Design Guide for Energy-Efficient Research Laboratories*, prepared by the Lawrence Berkeley National Laboratory Applications Team. It is an excellent resource.

Publications:

- **ASHRAE Handbook – HVAC Applications, Chapter 13, "Laboratories"**
- **NFPA 45, Standard on Fire Protection for Laboratories using Chemicals**
- ***R&D Magazine*, a Cahners Publication**

Web Sites:

- **EPA Laboratories for the 21st Century http://www.epa.gov/labs21century/**
- **LBL Design Guide for Energy-Efficient Research Laboratories http://ateam.lbl.gov/Design-Guide/**

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