Case Study

By Peter Coffey
VACUUBRAND, INC.

Problem-Focused Science Demands Building Adaptability

SUMMARY:

Scientific and budget priorities are changing faster and faster. It is critical that buildings that are designed today are not technically obsolete while there is still a lot of life left in the physical structure. This case study describes how the University of Notre Dame prioritized adaptability measures in its new multidisciplinary research building design, and how VACUU·LAN® local vacuum networks supported its overall goal of making the building adaptable over time

BACKGROUND:

Dr. Brian Baker, the chair of Notre Dame's Department of Chemistry and Biochemistry recently made the comment that "You can't do anything these days without working with someone else, and usually in a very different discipline." In today's multidisciplinary science buildings, research and, more recently, teaching approaches to science are increasingly problem-focused, not discipline-focused. This means science buildings often incorporate multiple disciplines, from chemistry and biology to engineering and computational work. As the problems studied change, the buildings themselves have to adapt so the problem-focused team has the facilities it needs. This is a big departure from the past where science buildings were designed around the needs of a specific discipline that was expected to be unchanged for the life of the building.

Figure 1: University of Notre Dame, McCourtney Hall.

Notre Dame committed some years ago to expand its scientific program to enhance its capabilities in analytical sciences and engineering, chemical and biomolecular engineering, and drug discovery. The goal was to enrich the university's contribution to research in fields like brain injuries, clean water, cancer treatment, sustainable energy and climate change.

To do that, they needed to mount interdisciplinary programs and expand Notre Dame's capacity for cutting edge research. That required both a new facility and the recruitment of new research faculty. The challenge was to build facilities that would help in the recruitment of scientists for the envisioned research areas, but without the knowledge of the exact uses that would be made of the facilities. The building would have to adapt to the needs of new faculty within months of occupancy. And because the research would be organized around problems, rather than disciplines, the problems studied would change over time, requiring the building to adapt to the needs of changing research teams over the long term as well. Importantly, the university wanted to design a building that serves those unspecified future needs without burdening the building's cost with a lot of "just-in-case" utility infrastructure that might never be used.

CONCEPT FOR A PROBLEM-BASED RESEARCH BUILDING

Notre Dame decided to develop a new East Campus Research Complex. The planning team envisioned "research neighborhoods" that would co-locate scientists with overlapping interests, such as polymer chemists who are developing new polymers with the engineering groups that will test these new materials in real-world applications.

The first building in this new East Campus Research Complex was designated "McCourtney Hall of Molecular Science and Engineering." The name brings science and engineering together, and the reference to "molecular science," which occurs at the boundary between biology and chemistry, indicates the range of disciplines that would

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be active in the building. McCourtney Hall was completed in 2016 as a 219,500 GSF building, with 100,000 SF of open lab and team spaces. Some of the lab space would be assigned to faculty who would be relocated from elsewhere on campus, but 40% of the new lab space was reserved as shell space to be built out later when the support needs of recruited faculty were clear.

The university wanted a building in which any type of lab could go on any floor, and in which open labs would encourage interaction as well as providing flexible use of the space. Given those goals, mobile casework made the most sense, with overhead delivery of utilities, and a mix of central and local utilities. Floor plans were designed with flex space that could be easily allocated to lab or support use, depending on the science requirements. Ductwork for supply air and exhaust was sized and manifolded to maximize the number of fume hoods possible on each floor if needed in the future, for example, to support chemistry or chemical engineering.

HOW TO HANDLE LAB VACUUM SUPPLY?

Figure 2: Local vacuum network pump under a fume hood.

As Notre Dame considered its plans for lab vacuum, it had to confront its experience with the central vacuum system in another research building on campus. After aspirated solvents had twice damaged the central pumps, with repair costs each time of about $25,000, the central vacuum there was shut down completely in 2012 after the third instance. Under the circumstances, the chemistry department had the scientists buy individual pumps, as needed. This hit departmental budgets, but also meant that the school was faced with the challenge of maintenance on a mixed lot of pumps all over the building.

Based on the experience elsewhere on campus, it was clear that central vacuum was a non-starter at McCourtney. The architects for the project had prior experience with local vacuum networks at other institutions, and suggested that Notre Dame consider that technology.

Local vacuum networks are a modular approach for supplying vacuum to lab benches, fume hoods and biosafety cabinets. Instead of a building-wide system, vacuum networks are installed only where vacuum is known to be needed. If a lab is intended to be used as a (dry) computational lab, no vacuum is installed. If the lab's function is converted to a wet lab in the future, vacuum can be installed readily at that time.

A small oil-free pump is put in the lab, in the casework or under the fume hoods, for example, and chemical-resistant fluoropolymer tubing is run to where ever vacuum is needed in the lab. With this approach, vacuum is installed lab by lab, so it can scale to the demands of the building, but also be put in later in the spaces reserved for later build-out. Previous experience at Notre Dame indicated that a careless operator in one location could compromise the vacuum supply for the entire building. With local vacuum networks, the vacuum in each lab is isolated from the vacuum in the other labs. This not only protects against the loss of a building-wide utility, it also protects against the scientific risk of cross-contamination between labs through the vacuum lines.

As exemplified by Notre Dame's prior experience with central vacuum systems, service demands and maintenance costs are critical concerns when evaluating vacuum system options. Local vacuum networks utilize pumps and vacuum lines that have no metal exposed to the corrosive effects of lab chemicals. Further, the dry pumps contain no oil that can be degraded by exposure to solvent vapors, so service is minimal despite the use of multiple pumps distributed around the building.

Upon examination by the spokesmen for the scientists at Notre Dame, the chemistry department head saw the value of the deeper vacuum at the benches and fume hoods. That could potentially eliminate the space demands and equipment costs of lots of dedicated pumps. Both the scientists and facility personnel saw the benefits of a distributed, corrosion resistant system after their prior experience elsewhere on campus. And the fact that the life science labs could have a different vacuum supply that fit their needs while the chemists got what they needed meant that the solution could work for everyone.

It turned out that the installed cost of the local vacuum networks was comparable to the cost of central vacuum, and had the advantage that investment in vacuum supply for the reserved shell space could be deferred until the needs there were clear.

Beyond the comparable capital costs and the improved flexibility, the local vacuum approach

produces vacuum on demand, so there are material energy savings compared with central vacuum supply. Pumps are oil-free with no metal exposed to corrosive vapors, so service intervals are normally about 15,000 operating hours. For a utility used intermittently in the labs, that means several years between service stops, and service that can be done on-site one lab at a time. If back-up supply is needed for critical operations during service, which takes about 2 hours, a service pump can be kept in maintenance stock and switched in to replace the installed pumps in about 15 minutes. The vacuum provided by the networks also saves on equipment costs, since the chemists – who typically need deeper, more stable vacuum – can use the networks for most of their work instead of having to buy dedicated pumps. All of these advantages supported the university's decision to rely on the VACUU·LAN® local vacuum networks instead of the traditional fixed vacuum system.

Twenty-eight VACUU·LAN® network pumps were installed to provide vacuum at nearly 300 workstations in McCourtney Hall. The pumps create vacuum of 2 Torr – about 29.8 in. Hg – at bench and fume hood ports; this is about 2 orders of magnitude deeper than vacuum typical of central supply. The tubing can be plumbed through ceiling drops with quick-connect fittings, so it was compatible with the flexible layout planned for McCourtney.

Figure 4: Vacuum network tubing (white) plumbed through ceiling tile.

LOCAL VACUUM NETWORKS: EARLY RESULTS

Once the installation was complete, 12 of the 28 pumps were metered for 6 weeks to confirm the anticipated energy savings from the variable speed, on-demand pumps. This chart shows the weekly usage in each of 12 labs over 6 weeks. You can see a lot of variability lab to lab. One lab (B45), for example, had a very vacuum-intensive project in week two, but very little other vacuum usage. Labs 221 and 223 have a pretty low but steady utilization. Lab 310 also had one week in which use spiked, while several of the labs used vacuum very little over the test period. When the pumps are not actively used, they are on standby drawing only 4 watts to monitor demand, so you can see that the energy demand is trivial in those labs with low vacuum use in this period.

Figure 5: Local vacuum network ports mounted to casework

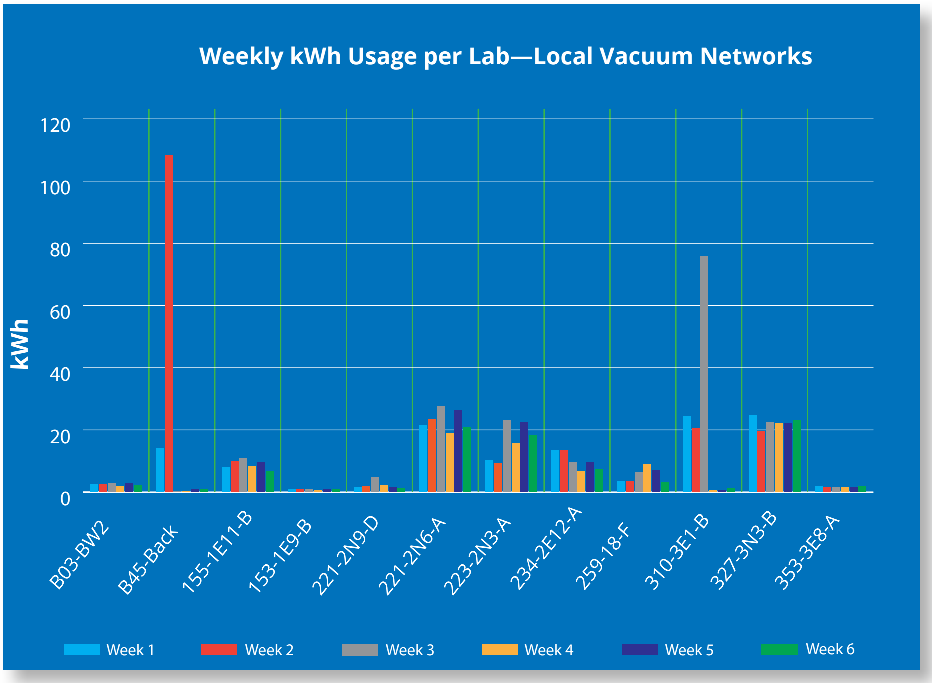

Figure 3: Weekly kWh usage per lab

Across all 12 labs, the weekly average electrical demand ranged from as low as 8 kW-hr/week to as much as 18 kW-hr/week. Over the course of the entire test period, the average was 11 kW-hr/week per lab to support 10-11 users *(see Figure 6)*.

It's important to recall that this vacuum is deep enough that it replaces both central vacuum supply, and much of the need for dedicated vacuum pumps for applications that need deeper vacuum than central vacuum can supply. Energy use is so little because the local networks' variable speed pumps can turn-down to close to zero pumping speeds when there is little demand, and no pumping when vacuum is not needed. So besides the adaptability that was the main reason for the use of local vacuum network, the energy use over the life of the building is expected to be much lower than if a central system had been installed.

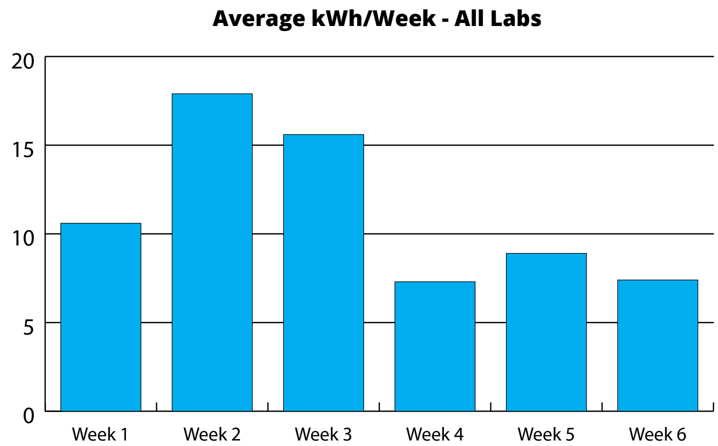

Figure 6: Average kWh per week for all labs

Recruitment of the new researchers at Notre Dame has gone well, so that a quarter of the space reserved for new hires was already in the process of build-out within a year of initial occupancy. The modular design approach to the building overall, and the vacuum systems in particular, has enabled the university to quickly fit out this space to the needs of the new principal investigators that have responded to the university's expanded research initiative.

VACUUM UTILITY FOR PROBLEM-BASED SCIENCE BUILDINGS

Modular vacuum, as at Notre Dame, can offer a lot of benefits.

- **It eliminates inflexible**, **building-wide piping systems** and replaces them with local systems, which can speed up installation and simplify scheduling.
- **The in-lab systems can support phased project work** – not just in new buildings but in phased renovations as well.
- **The local vacuum networks offer technical advantages** to the scientists the building serves, so they contribute to scientific performance as well as adaptability goals for the building.
- **Long-term operating cost savings** are provided by the systems' low energy demand and infrequent service needs.
- **Systems can be modified** over the life of the building, if needed, without the costs of gut renovations typical of a fixed, building-wide vacuum installation.

When designing multidisciplinary science and engineering buildings for adaptability over decades, VACUU·LAN® local vacuum networks can be an important part of the plan.

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VACUUBRAND, INC. | 11 Bokum Road | Essex, CT 06426 | 888-882-6730
info@vacuubrand.net | www.vacuubrand.com | www.vacuu-lan.com