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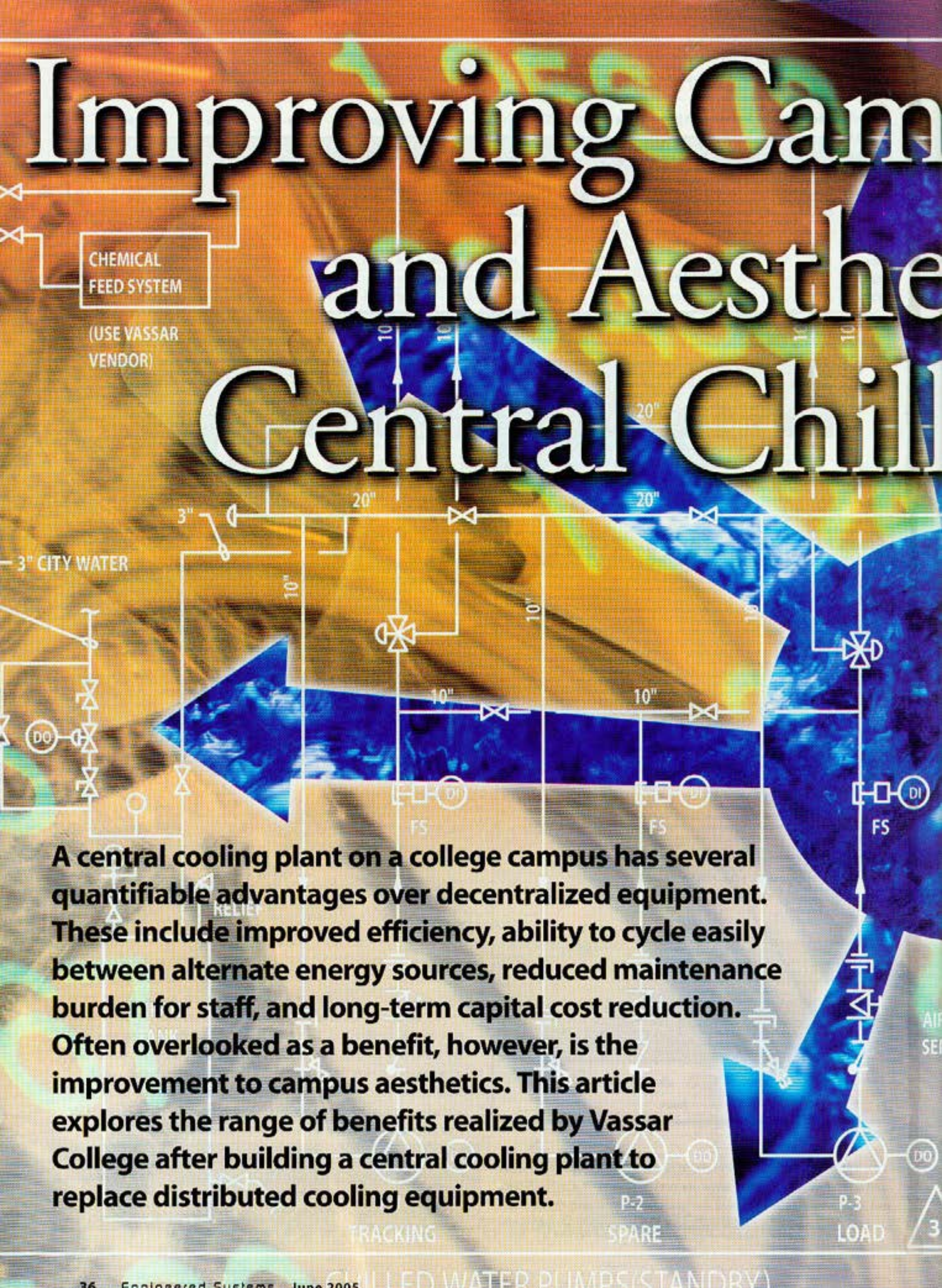
CAMPUS Beautification

One college's central plant project makes both the grounds and the system more attractive.

COLLEGE & UNIVERSITY ISSUE / CHILLERS / BOILERS / LAB VENTILATION

Improving Cam and Aesthe Central Chill



A central cooling plant on a college campus has several quantifiable advantages over decentralized equipment. These include improved efficiency, ability to cycle easily between alternate energy sources, reduced maintenance burden for staff, and long-term capital cost reduction. Often overlooked as a benefit, however, is the improvement to campus aesthetics. This article explores the range of benefits realized by Vassar College after building a central cooling plant to replace distributed cooling equipment.

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BY CHARLES C. COPELAND, P.E.

Founded in 1861, Vassar College is located on a 1,000 acre landscaped campus, 70 miles north of New York City in the scenic Hudson River Valley. Like many college campuses that have evolved over decades, Vassar has numerous buildings of various architectural styles. A few buildings were constructed with A/C, others have had A/C equipment added, and some have never been air conditioned. Most of the A/C equipment added over the years consists of modest packaged cooling systems or window units, located for ease of installation rather than appearance. This decentralized equipment placed a significant maintenance burden on the campus buildings and grounds staff, and it incurred greater electrical operating cost as compared to a larger state-of-the-art central system. Perhaps most significant for the stately and tree-lined Vassar campus was the existing equipment's adverse effect on campus aesthetics, both visual and aural.

BACKGROUND

In 1996, Vassar College commissioned Aramark, together with Vassar's in-house engineering staff, to prepare a utility master plan for the campus A/C system. This master plan analyzed the present and future cooling requirements of 39 buildings on the main campus totaling 1,392,000 sq ft. Most of the A/C needs identified were for comfort cooling, although a few buildings such as Olmstead (biology), Loeb (art gallery), the libraries, and the computer center required more rigorous temperature conditions for specialized programs.

When the master plan was prepared, the total capacity of the HVAC systems on the Vassar campus was approximately 2,000 tons, of which 40% consisted of smaller unitary package systems or window units. There were eight chiller plants, all using electric drive chillers, serving 14 buildings. The largest plant in Olmstead contained a single 570-ton chiller while the smallest had a 25-ton chiller serving the Shiva Theater. Most of these units, along with their ancillary equipment, were well over 20 years old and some used the outmoded and ozone-unfriendly refrigerant R-11. The two roof-mounted cooling towers on Olmstead and College Center were noisy and unattractive.

The master plan concluded that a central chilled water plant and distribution system would best meet the long-term cooling needs of the campus, including future additional A/C requirements for new or renovated academic buildings and dormitories. The master plan suggested, and the college agreed, that the central plant should use a combination of electricity and fossil fuels such as gas or oil to allow flexibility in energy use.

Goldman Copeland Associates, P.C., (GCA), an engineering

Typical view of equipment outside campus buildings. Each building at Vassar had its own equipment, increasing costs and maintenance.

firm with extensive expertise in chiller plants and hydronic distribution systems, was selected for the project and began design of the central chilled water plant and distribution system in 2000. A significant part of the initial planning effort was to confirm the loads and requirements of each building and to identify the new and existing buildings to be air conditioned in the future. The initial assessments were refined during the engineering design phase.

During the design phase, GCA coordinated a design team that included civil and structural engineers, two architects, and an acoustical consultant. Both in-house and outside peer review of some aspects of the project design were employed.

TECHNICAL DESIGN ISSUES

Plant location. One of the first design challenges was deciding where to locate the new main chiller plant. The utility master plan report had designated an unused portion of the old boiler plant as the chiller plant location, with the cooling tower to be located across a nearby stream. This site would then have centralized the steam and cooling utility services in one location. However, initial equipment layouts indicated that a new chiller plant — with chillers, pumps, piping, and future expansion requirements — would not fit in the available space. Additionally, over the last few decades, this central area of the campus has been developed for college programs, with part of the original boiler plant building becoming a theater and a cultural center. Siting a cooling tower in this area presented noise and aesthetics issues.

After analyzing the rest of the campus for possible locations, GCA and Vassar decided to locate the plant near the Buildings and Grounds facility on the southern periphery of the campus. Although the distance from this site to the campus buildings is considerably greater than from the boiler plant location, a new structure that would exactly meet the space requirements of the current plant and expand to allow for chiller plant growth offered a decided advantage. In addition, the site is remote from main campus activities, reducing the impact of noise associated with operation of a mechanical plant.

Ease of operation. Since Vassar College personnel had no prior experience operating a sophisticated central chiller plant, one of Vassar's mandates was that the plant be simple to operate, not require

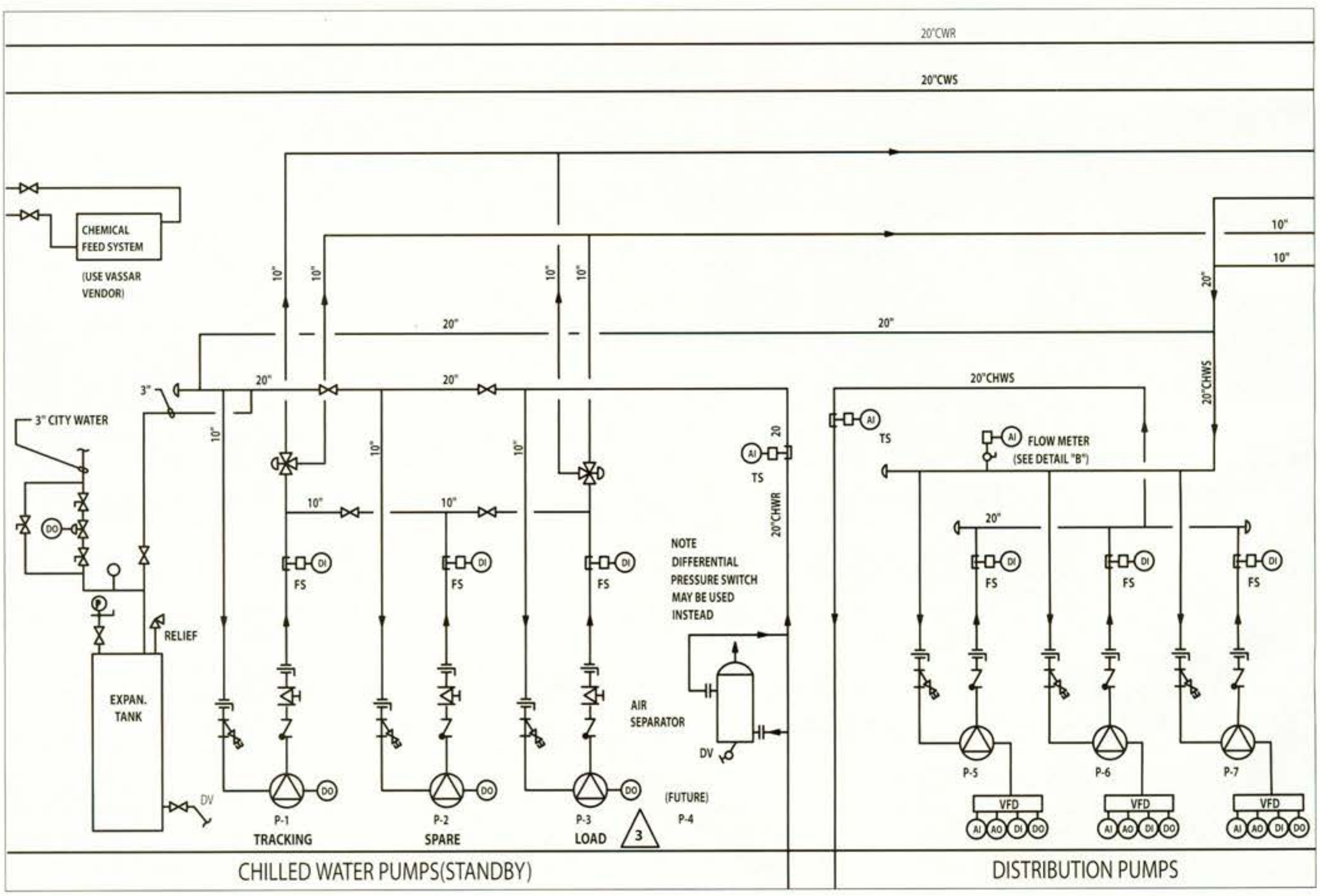

FIGURE 1. Selective chiller loading piping schematic.

Prior to construction, equipment blocked the view of the buildings on the Vassar campus, affecting aesthetics, both visual and aural.

additional operating staff, and possibly even be capable of functioning unattended for long periods. This suggested a straightforward pumping system. A primary/secondary/tertiary campus chilled water distribution system with automatic controls was used rather than a varying primary flow that requires more operator vigilance. In addition, the manufacturer recommends constant chilled or condenser water flow for the gas-fired absorption chiller. Under this approach, a constant flow primary system maintains chilled water flow to the chillers, while secondary pumps within the plant provide varying flow to campus buildings. Tertiary pumps in each major building — many of which were already installed — provide local circulation.

Other technical design features include:

Selective loading. Vassar expressed an interest in maximizing the use of either the gas or electric chiller based on utility rates when the campus cooling load causes both chillers to come on-line. In response, GCA designed a piping arrangement that permits what it calls "selective chiller loading." Although it is possible to stage chiller operation through chilled water temperature setpoints and extract most of the capacity of either chiller, selective chiller loading maximizes the cooling load from either the gas or electric chiller. As shown in Figure 1, the main 20-in. distribution return pipe routes chilled water to the load pump first and to the tracking pump second. The load pump then sends site return chilled water through a three-way valve, which directs flow to either the gas-fired or the electric chiller and heavily loads the selected chiller. The tracking pump, through a three-way valve, directs mostly plant return chilled water to the other chiller.

Variable-speed pumping. The variable-speed pumping package consists of integrated pump controllers that control chilled water distribution between the plant and the buildings. Matching flow to temperature requirements saves electrical energy. This system includes programmable logic pump and zone valve controllers, VSDs, and remote sensor/transmitters.

Off-season cooling. A plate-and-frame heat exchanger was included to permit off-season cooling, which is especially effective

Improving Campus Economics

in this cooler Hudson Valley climate. When weather conditions are right, the evaporative action of the cooling tower produces cool water in the condenser water circuit. The plate-and-frame equipment provides very efficient heat exchange between cool condenser water and the circulating chilled water, reducing the need to run mechanical cooling.

BMS. The campus BMS links all control operations in the existing buildings with the new plant allowing good communication with the operations staff. All alarms and warnings are sent to the main BMS computer and can signal staff through pagers.

Distribution piping. While steel pipe is used through building walls and inside structures, PVC plastic chilled water underground piping provided a corrosion-resistant, low-cost conduit for the chilled water throughout the site. The piping layout was coordinated with the many other buried services such as steam, water, drainage, and electric power, which are inevitable on existing campuses. The piping is adequate for 3,000 tons of cooling at up to 12°F degrees of temperature rise (44° to 56°). Since the ground temperature is in the 50° to 55° range, all year round, the return pipe could have been left uninsulated. However, the incremental cost for the insulation was so modest that Vassar decided to insulate the return pipe as well.

Vassar is justly proud of its attractive campus, which is also an arboretum with more than 200 varieties of trees. Preservation of the specimen trees during installation of the chilled water distribution piping was a major concern. Vassar employs a full-time arborist who identified the important trees and designated how close the various pipe trenches could be dug. Fortunately, much of the site distribution piping could be routed below sidewalks and walkways that were, in some cases, scheduled for replacement.

Noise reduction. In keeping with peaceful atmosphere of the campus, it was important to keep mechanical noise associated with the chiller plant to a minimum. An acoustical consultant provided recommendations to keep the sound within acceptable criteria. Quiet operation was accomplished by carefully selecting the cooling tower based on noise criteria and by using VSDs for the tower fan motors to reduce noise during off-hours (at reduced cooling load) when it is most noticeable due to lower background ambient sound.

Electric power. There are two electrical distribution loops serving the campus. Vassar is phasing out use of the older 4,160V loop and increasing use of the newer 13.8KV loop. GCA performed an analysis of the 13.8KV electrical loop to determine spare capacity and ability to support the new central chiller plant. A new 2,000KVA 13,800/480V step-down transformer was installed to provide electric power for the new plant equipment. The 13.8KV primary was connected to the campus loop through the 15KV pad-mounted switchgear. A new motor control center distributes the 480V secondary power to the equipment.

Natural gas. Survey of the existing campus gas distribution piping and discussions with the utility company resulted in a new gas service being brought in for the chiller plant.

ADVANTAGES OF THE CENTRAL CHILLER PLANT FOR VASSAR

Improved campus aesthetics and reduced objectionable noise. As the design was evolving, Vassar administration was already planning removal of most of the old cooling equipment from the academic buildings. One of the more important campus buildings, Blodgett Hall, a science building, had an air cooled chiller, transformer, and emergency generator right in front of the building. Upon completion of the new central chilled water distribution system, the chiller was removed, the transformer installed below grade, and the emergency generator relocated, significantly improving the appearance of the building.

Capacity. Because cooling loads do not necessarily peak at the same time (load diversity), the total tonnage of a central cooling plant size can often be less than the combined capacity of the existing individual systems. Goldman Copeland's analysis confirmed that, based on future potential cooling loads, 2,000 tons of chiller capacity could meet the current requirements and the next decade of growth. Modular design of the new plant building allows for the easy addition of another 1,000 tons of capacity to provide for future expansion of the cooling system.

Lowest long-term capital cost. One of the most powerful economic reasons to install central campus cooling systems for a growing campus is reduced long-term capital cost. Load diversity can result in a central plant 35% to 50% smaller than the total of individual building plants. Each decen-

Over the next decade, the load of the new chiller plant is expected to increase along with the energy savings.

tralized plant must meet each building's individual peak load and provide additional capacity in case a chiller fails or under performs. Duplication of equipment in individual buildings is avoided with a central plant and significant floor area in each building is freed up for other uses.

Arguably, with a central plant the capital dollars are paid out at the time of installation, and therefore, there is some lost value of money, compared to installing equipment piecemeal. However, at the rates currently in effect, the interest value of the capital would not double in a period of less than 20 to 25 years. Moreover, the central plant — with its smaller overall pumping capacity, greater efficiency, alternate chiller energy options, and newer state-of-the-art equipment — largely offsets the time value of the investment as described in the next section. Clearly, a central plant conserves institutional capital.

Lower energy costs. Typically, energy costs resulting from a campus central plant are lower than those associated with a distributed chiller system for the following reasons:

- Lower overhead costs than from individual building condenser water pumping and cooling tower operation (Note this is partially offset by the site pumping costs for a central plant.);
- Improved chiller efficiency at all levels of loading compared to the part loading that occurs with individual plants;
- The ability to easily manage alternate chiller energy sources under favorable fuel pricing (such as natural gas vs. electricity); and
- Ease of integrating state of the art cooling technologies from cool storage to highly efficient chillers or even future electrical cogeneration.

At Vassar College, the central plant loading is expected to increase over the next decade. Using an average peak 1,600-ton cooling load over the 10 years, the average savings in energy, including the site pumping costs, over an equivalent 2,400 tons of decentralized equipment is approximately $240,000 per year. In addition to improved efficiency, the savings include reduced summer peak demand charges from use of the gas-fired chiller.

The analysis and preliminary design recommended one 1,000-ton electric chiller and one 1,000-ton gas-fired absorption chiller to permit fuel switching based on market prices. Coincident with the

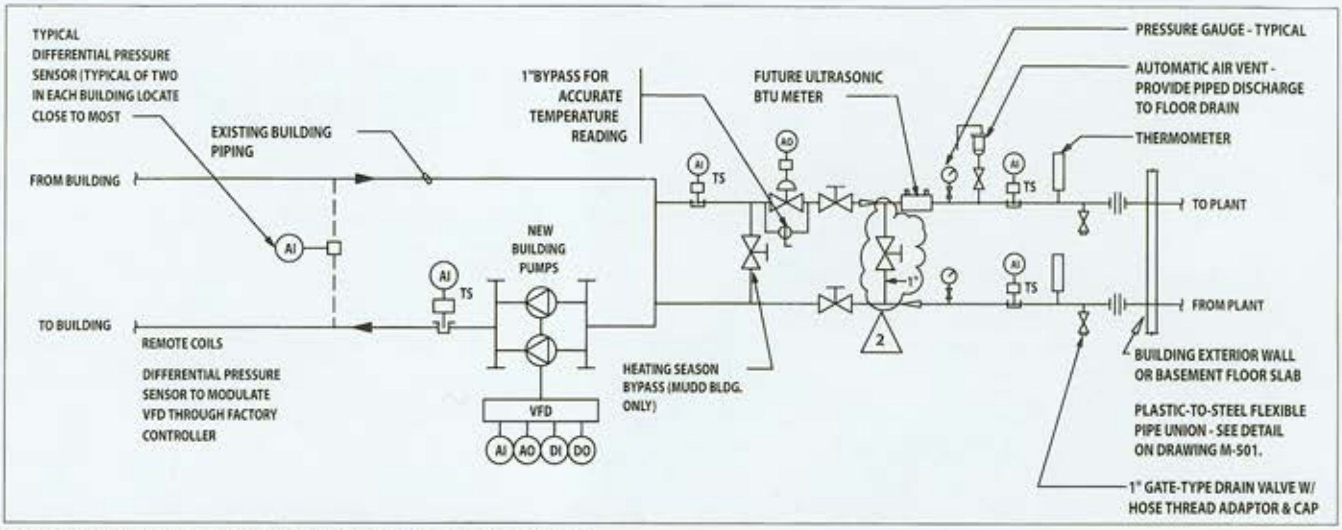

FIGURE 2. Schematic of the typical connections at the building.

report and design phase, New York State's newly deregulated electricity markets created volatile pricing which reinforced the wisdom of this fuel switching decision. At the same time, the New York State Energy Research and Development Authority (NYSERDA) was offering substantial incentives to install non-electric chillers as part of a public policy initiative to reduce the growth of electricity use. Vassar successfully participated in the NYSERSDA program. Two summers of gas-fired chiller operation are required to qualify for the NYSERDA chiller incentive. During this period, monitoring and verification (M&V) is required to validate reduced electrical consumption. M&V requires added equipment including electric meters connected to the chillers and chilled water distribution pumps, temperature and pressure transmitters, and totalized chiller ton-hour production. In order to facilitate remote transmission of this data, GCA created a report format for the BMS vendor to incorporate into their software. All of the information is available on the Internet for processing into the required agency reports.

Simplified, more cost-effective maintenance. Whether maintenance is performed by in-house personnel or by outside service vendors, it costs more to maintain equipment in multiple buildings compared to one central equipment location. According to a maintenance contractor, if all the local building cooling systems at Vassar College, including window units, were included, the average annual maintenance savings with the central plant is approximately $160,000 per year.

Redundancy and flexibility. As noted, most of the Vassar buildings had single chillers or packaged A/C units. When one of these chillers or packaged units malfunctioned, the building or a specific area was without air conditioning. Currently, the new central cooling plant has two chillers of equal size, with backup pumps and related equipment capable of satisfying most of the next five to 10 years of cooling load. Should a major outage occur in the central plant, it would be fairly straightforward to connect a rental chiller into the plant.

Simpler renovations. In response to projected additional cooling loads, 26 taps (valved, capped branch lines) to the chilled water distribution piping were provided near or inside all the main campus buildings that were not connected as a part of this project. Almost all the buildings have one tap (one supply line and one return line) in a single location. Because of its size, the Old Main building received two taps, one at each end. Thus, all the buildings can be easily supplied with chilled water if desired.

Since the plant came online in the spring of 2002, four additional buildings have been connected to the distribution system. Two buildings already had air handlers with cooling coils installed as part of prior renovations anticipating chilled water, one building had air handlers added, and one building was completely rebuilt, except for the façade. In that case, GCA coordinated the connection size and location with the building MEP design engineers. In all cases, cooling was added to the buildings with little increase in cooling related electric load, no increase in noise, and no requirements at the building for heat rejection equipment.

SUMMARY

For all the reasons discussed, Vassar College will enjoy long-term savings from reduced maintenance and energy cost. Even with the new buildings added, cooling load diversity will allow the 2,000 tons of chiller capacity to be sufficient for many years to come. For the long term, the plant can easily accommodate cooling loads associated with major renovation programs and additional buildings. The $575,000 NYSERDA incentive, which depends on actual avoided electricity use, certainly helped to reduce the capital cost. For other colleges and universities considering chiller plants, investigation of these types of government or utility incentive programs is recommended. **ES**

Copeland has 40 years experience in the engineering and design of mechanical and electrical systems for institutional and commercial facilities. His expertise encompasses both new construction and renovation projects, the latter frequently involving historic and land-marked buildings. He is an authority on energy efficiency in buildings and has led numerous study and retrofit design projects in this area. He was recognized with an ASHRAE Energy Award in 1989 for his NYU Medical Center design connecting disparate chillers into a parallel/series chilled water loop. He is an ASHRAE Fellow, a Life Member of ASME, and a LEED® Accredited Professional.