Photo 1: BACnet integration of building and central plant equipment communicate over campus network at the new Student Service Center, Montgomery College, Takoma Park/Silver Spring Campus, Takoma Park, Md.

BACnet® on Campus

By J. Michael Whitcomb, P.E., Member ASHRAE

The story of BACnet at Montgomery College reflects the evolving nature of energy management and the building automation controls industry. While the transition from springs, diaphragms, and mercury switches to networked direct digital control (DDC) has been remarkable, the groundswell response to BACnet has revolutionized the building automation industry.

Background

Montgomery College, located in Montgomery County, Md., just north of Washington, D.C., is a community college that offers a broad curriculum to 60,000 credit and noncredit students, offering day, evening and weekend activities. It is an intensely used community resource. We have approximately 2 million gross square feet of space, in 43 buildings, on three campuses and spend approximately 6.1 million utility dollars annually. Our friend and neighbor nearby in Gaithersburg, Md., is the National Institute of Standards and Technology (NIST), Building and Fire Research Laboratory.

The Rockville Campus, built in the early and mid-1960s, included a medium temperature hot water central plant and distribution system with decentralized time clocks and pneumatic building controls. The central plant even had a

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pneumatic/electric network between the plant and nearby buildings that could remotely monitor and adjust adjacent building HVAC systems. *Photo 2,* shows the College's first attempt at an operator workstation (OWS) graphical user interface (GUI).

Each building on the Rockville campus had hot water converters, decentralized chillers and cooling towers with manually selectable, pneumatically actuated summer/winter changeover. The late 1960s saw the redevelopment of the Takoma Park/Silver Spring campus, which included self contained packaged terminal air conditioners (PTAC) and rooftop mounted packaged DX constant volume systems with "black box" electrical controls.

The College built its newest campus in Germantown, Md., in the late 1970s and responded to that decade's energy crisis by designing their buildings with what were then state-of-the-art technologies. Included were exterior envelope insulation systems, large overhangs for passive solar control, double pane operable windows for natural ventilation and daylighting, roof daylight monitors, efficient lighting systems, water source heat pump loops with thermal storage tanks, and centrifugal chillers providing cooling to the building's central core. Large rooftop-mounted flat plate solar thermal arrays and underground thermal storage tanks with backup electrical boilers provided heat to the heat pumps, heated domestic hot water and the swimming pool. Controls consisted of time clocks and electrical controls. College-wide, controls were a mixture of non-DDC technologies and manufacturers, which were competitively procured and serviced by College operations and maintenance (O&M) staff and various controls contractors.

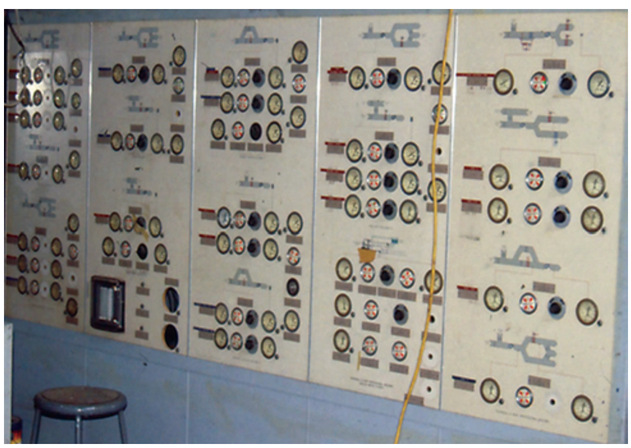

Photo 2: 1960s vintage central plant networked pneumatic operator workstation graphical user interface.

Introduction of DDC

Direct digital controls were introduced incrementally in the latter half of the 1980s. Whole building installations began in the early 1990s with the construction of major new and renovated buildings and central chilled water and hot water plants on the Rockville and Germantown Campuses. The central chilled water plants with ice storage, ammonia rotary screw chillers, and engine-driven chillers with heat recovery used the digital capabilities of the computer to orchestrate energy and demand management automation sequences not possible with previous technology. *Figure 1* shows the chilling equipment in our central plants integrated through the DDC system.

Early integration for monitoring and control was through hardwired points, separate independent computer hardware and software devices, and occasionally through expensive proprietary and rarely reliable integration devices. Network communications were through low-speed twisted-pair cables, pulled through conduits that followed the central plant distribution system to each building, while remote communication access was through dial-up modems.

Controls were specified, furnished, installed, and maintained by a single, sole source vendor, using proprietary products. Normally, public institutions such as the College require competitive procurement of goods and services. However, in the early days several factors drove us toward sole source procurement.

First, the College was trying to successfully introduce a new and complex technology while minimizing disruption and ensuring ownership by the O&M staff. Unlike some larger institutions who manage controls with a separate controls group, we chose to manage our controls with the people who are directly responsible for answering the hot and cold calls, the O&M staff. The O&M staff was trained on a standard platform using standard tools while their capabilities were supplemented by service agreements with the vendor. Expansion of the proprietary DDC into other buildings not scheduled for renovation was coordinated with the vendor by the O&M staff and funded from their operating budgets.

Second, since our campuses were small, and we had central plant distribution systems thermally communicating with our buildings, it was necessary to have the ability to communicate with the building systems from the central plant. Controls at the time lacked a common communications protocol, and if you wanted to use different vendors, you either wrote your own software drivers as Mike Newman and his controls group did at Cornell University or you hardwired monitoring and control points between systems. Neither of these options was desirable so we stayed with sole source controls.

In the latter part of the 1990s, the College partnered with NIST by pproviding access to our DDC systems and assisting in downloading actual system trend data that was used to test their algorithms for rule-based fault detection and diagnostics (FDD). Faults were examined and verified in the field and repairs were made as necessary. Although those first algorithms were external to the controls system, later work would embed the algorithms directly into control devices. This was the first time that we used the computer capabilities beyond the traditional controls model and it opened our eyes to some of the untapped opportunities of this computer resource.

Introduction of BACnet

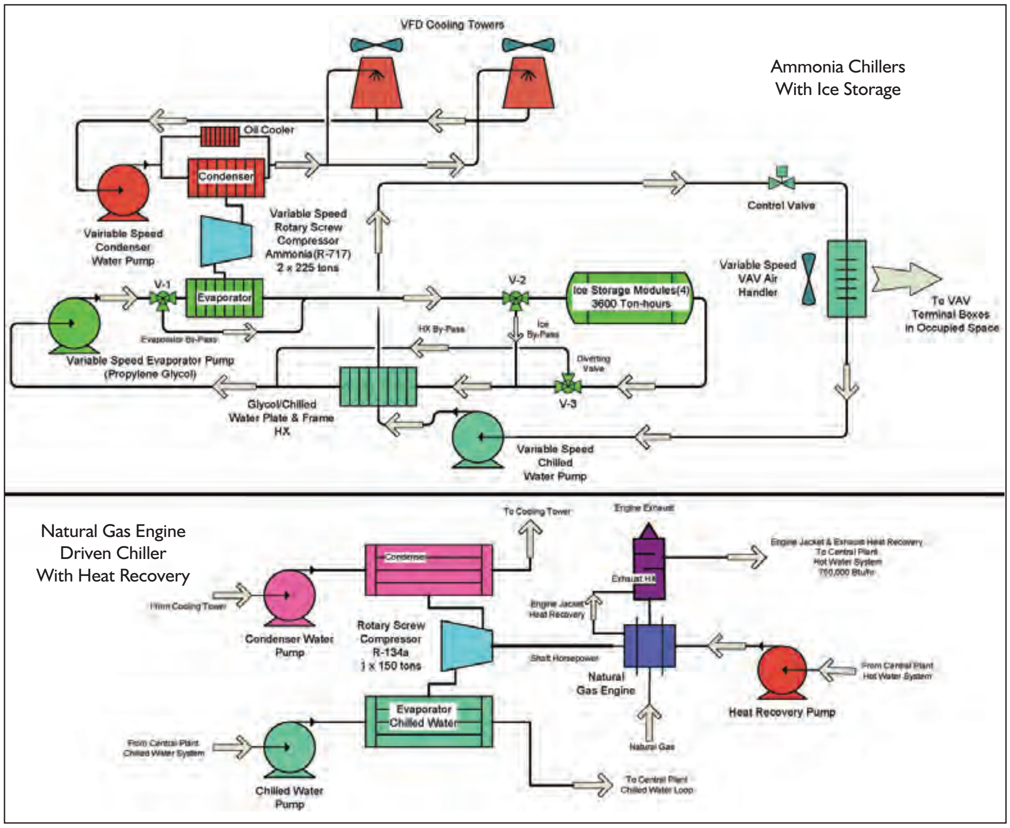

Figure 1: Typical college central plant energy and demand management equipment requires DDC integration for proper sequence of operation.

Our partnership with NIST lead us to Steve Bushby, one of the early leaders in the development of BACnet, and through him we met Mike Newman from Cornell University. As it turns out, Mike is the guy who started the BACnet ball rolling in ASHRAE and chaired the committee during its initial development. These interactions influenced the College's decision to embrace BACnet technology.

Some manufacturers quickly responded to ANSI/ASHRAE Standard 135, *BACnet®—A Data Communication Protocol for Building Automation and Control Networks*, and began to introduce BACnet products, opening the door to a diversified competitive controls solution. In 2000 we were able to identify three manufacturers with local representation capable of providing BACnet equipment. As a demonstration and to better understand BACnet, we installed separate BACnet controls on three identical retrofit rooftop air handlers serving an open laboratory space and competitively selected one of the vendors to provide controls for the supporting hot water and chilled water hydronic systems. We also connected a newly renovated building fire alarm control panel (FACP) to the system via a BACnet interface provided by the FACP vendor. Traditionally, we would have hardwired dry contacts between the FACP and BAS to provide non-life-safety notification to the O&M staff that some activity was occurring in their fire alarm system.

To further investigate BACnet capabilities we required the vendors to share a single OWS which was networked to their controllers via the Montgomery College Wide Area Network (MC WAN). Each vendor was required to develop graphics and demonstrate integrated operations of their controlled equipment and the controlled equipment of the other vendors. This allowed the various stakeholders, O&M, facility managers, information technology staff, and other interested parties to test-drive a real-world BACnet installation. For example, while troubleshooting a communications failure we were able to prove BACnet network conformance by stringing a twisted-pair communication line across the roof from Vendor A's building controller, connecting it to Vendor B's MS/TP network and watching the Vendor A's BACnet points appear on the OWS. We also used one vendor's scheduling graphics to control all of the equipment schedules because the O&M staff preferred the look and feel of that vendor's graphic display. This demonstration project was successful in that it allowed us in the early days to experience many levels of interaction and helped us develop guidelines for our design teams, information technology staff, and O&M. It was also shortly after this that I joined the BACnet standard committee (SSPC 135) as a user representative and began to get involved with committee activities.

BACnet in New Construction

The introduction of BACnet was timely because the early 2000s saw plans for the largest expansion in the College's history with the construction of four major buildings and two central hot water and chilled water plants on the Takoma Park/Silver Spring campus. BACnet was specified for the controls and three fully compliant manufacturers with local representation were listed as acceptable bidders. We were unable to list our legacy controls vendor because they did not have a compliant product.

The 98,000 gross square feet, four-story Health Sciences Center (HSC), which specializes in training health professionals, was our first BACnet-compliant building. It is a high performance building with a 35 kW solar photovoltaic array, commissioned in 2004. This building not only was a success-

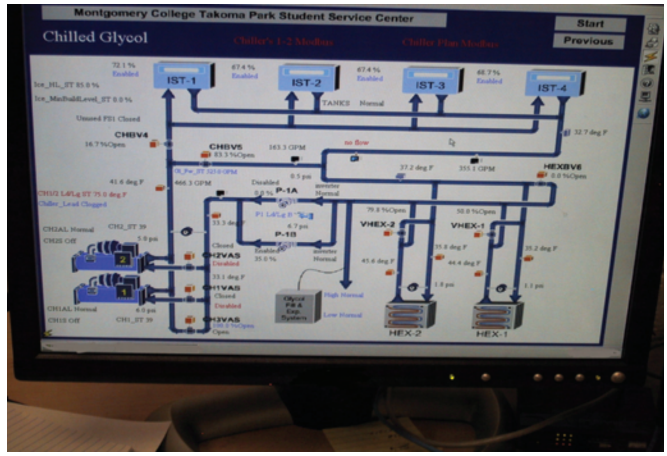

Photo 3 (left): Typical ammonia refrigeration chiller assembly, l-r, variable frequency drive (VFD), plate and frame evaporator, refrigerant vent system, and rotary screw ammonia chiller with integrated control panel. Photo 4 (right): Typical central plant graphical depiction showing glycol system with chillers, ice storage modules, piping, heat exchangers, pumps, and accessories. Compare this to Photo 2.

ful BACnet installation, but it introduced remote Web access through a Web server and, although not BACnet, a completely digital security system with CCTV recorders and centralized swipe card door access.

We got our information technology (IT) department's attention when we requested Internet Protocol (IP) access to the MC WAN and enough bandwidth to stream camera video across the campus to our security office. Shortly thereafter, IT developed a virtual local area network (VLAN) called Montgomery College Facilities Network (MC FNET) with sufficient fiber optics, dedicated only for facilities systems.

Although we attempted to integrate all of the building controls using BACnet, some equipment such as variable frequency drives (VFD) used a different protocol. Integration of the different protocols requires translation devices that increase system complexity and introduces challenges to proper commissioning and operations. Fortunately, BACnet is now readily available on most equipment, which eases the integration effort.

The College and its controls contractor again partnered with NIST, which resulted in their researchers embedding rule-based FDD algorithms directly into our controlled devices. The fault reports identified several anomalies that allowed the O&M staff to fine tune their system. Hopefully, NIST's work will result in future FDD capabilities similar to the "light on the dashboard" annunciation in automobiles.

The next building was the 111,000 gross square feet, three-story Student Services Center (SSC), see *Photo 1*, which provides space for student service functions, has a cafeteria, a central chilled water and hot water plant in the basement, and was commissioned in 2006. The central plant that serves the East Campus includes ice thermal storage with ammonia VFD refrigeration chillers, a natural gas engine-driven chiller with heat recovery, variable speed pumping, high performance condensing boilers, and energy consumption measuring equipment. The building is served by variable air volume (VAV) air-handling systems with occupancy sensor-controlled terminal devices and lighting systems. Compared to our last central plant installed 10 years earlier, the change in technology is amazing. Whereas, the older plant was hardwired, this plant is almost completely networked using BACnet or other communications protocols. *Photo 3* is a picture of our typical central plant rotary screw ammonia chiller while *Photo 4* shows our typical central plant graphical user interface representation.

The control system in the SSC was competitively bid and a different manufacturer than the one used in the HSC building was awarded the contract. We installed a central operations office adjacent to the new central plant with additional computers and monitors to serve as a centralized campus monitoring area. Using BACnet we have the ability to integrate one vendor's objects with another vendor's GUI, which provides efficiency and flexibility in monitoring and control. Although we have the capability to configure a master supervisory GUI, we have found it simpler to require vendors to provide certain standard graphics. Our O&M staff is then able to manage the multiple vendor systems because of the similar presentation and function.

BACnet Influence

Since the initial introduction of our small demonstration project we standardized upon BACnet, developed guidelines and specifications and have installed approximately 850,000 gross square feet of new BACnet controls such that BACnet now represents 40% of our controlled building square footage. We are excited about two new laboratory buildings, the 141,000 gross square feet, Rockville Science Center scheduled for construction starting late 2008 and the 127,000 gross square feet Germantown Bioscience Center, scheduled for construction late 2010. Both buildings will be LEED® Gold Certified and use BACnet to integrate fume hoods, building HVAC, and basement satellite central plants.

We continue to coordinate with our IT department and our typical controls network configuration is shown in *Figure 2*. Now, we integrate lighting controls, fire alarms, variable frequency drives, chiller and boiler control panels, and energy monitoring equipment into our BACnet systems. Since BACnet is readily available, we only specify equipment with BACnet communications interfaces. We try to limit our controls manufacturer to one per building, but in some cases we have several. In these instances, the mix has been in terminal equipment applications, which are all integrated using BACnet. Remote communications using wireless and Web services has long since replaced the telephone modem and has allowed more stake holders access to the system. As previously stated, we work closely with our IT department to ensure that the communications are reliable and secure.

As we introduced BACnet, we soon realized that we needed to provide the facilities organization with a roadmap for management of a diversified controls solution. As part of the College's master planning efforts we developed a controls master plan. This plan includes a survey of existing college buildings, the type and condition of their controls, and a schematic plan for replacement and retrofits. The plan provides guidance to designers through standard controls specifications, controls drawings with narrative and graphical logic diagrams of sequences of operations, typical college controls network arrangements, and system commissioning and documentation requirements. Future work will include input from the O&M staff on training and routine maintenance requirements, as well as formats for standard service contracts.

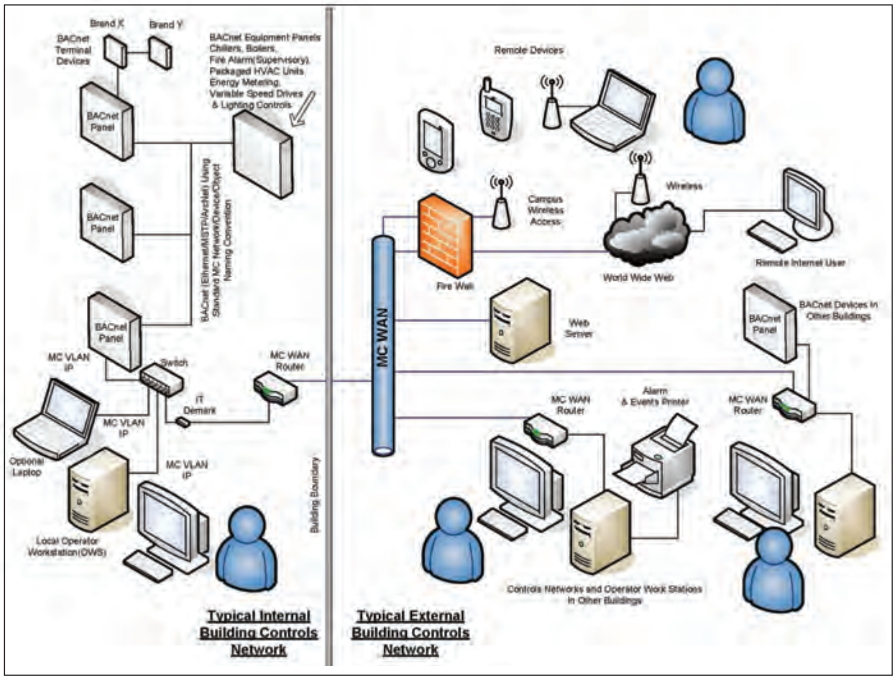

Figure 2: Typical college controls network diagram.

College-wide we have allowed five different BACnet manufacturers. Only three manufacturers are allowed on each campus to reduce complexity while ensuring competition. In each new installation, vendors are required to provide a completely functional stand-alone system including all required software tools to manipulate and operate the system. Once functionality is tested as part of our commissioning process, VLAN IP addresses are assigned, communications are established on our MC WAN and graphics and other tools are mirrored on to other College operator workstations to provide functional flexibility for operations staff. Servers located on the MC WAN also provide Web services to other users such as remote access via the World Wide Web.

BACnet has revolutionized the building automation industry and has become a household name at Montgomery College. The dedicated efforts of the volunteer members of the ASHRAE BACnet Standard committee, who developed the protocol, have provided users like me a much needed tool, which has greatly enhanced our ability to provide a diversified, competitive, and integrated controls solution. Manufacturers, vendors, designers, owners, and operators have responded to BACnet's influence and we are just seeing a glimpse of the benefits and opportunities that are presenting themselves.