# Optimizing Building Controls During Commissioning

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Building owners, contractors, design engineers, and commissioning teams expend huge efforts (and project resources) on verifying component compatibility with control specifications, basic on/off control features, and performance at peak design conditions. However, these systems often are not optimized for a typical operating condition. In a health-care facility, optimizing building controls is the leading opportunity for reducing energy expenditures.*

Specific best practices and lessons learned from the recently completed $1 billion expansion project by Memorial Hermann Healthcare System in the Houston metropolitan area (see the section "Case Study") highlight the following key HVAC and building control features that are required (but not often delivered) at occupancy:

- Simplified HVAC system component time of day (TOD) occupancy scheduling via graphical templates.
- Intuitive air-handler cold deck discharge temperature reset schedules or more complex dynamic programs for constant changes based on outside air and/or system load conditions. Care must be given when establishing reset triggers. Poorly chosen parameters will lead to an atypical zone driving the reset parameter to a minimum or maximum value and, therefore, negate any possible energy savings.
- Air terminal reheat flow control sequence templates with preestablished (default) dead bands and seasonal lockout triggers to minimize the occurrence of simultaneous heating/cooling.
- Administrative and support service area night setback strategies for air terminal units and air handlers.
- Basic totalizing central plant HVAC distribution metering to segregate, log, and diagnose consumption patterns via appropri-

*Although this article focuses on health-care buildings, the concepts apply to other building types.

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Memorial Hermann-Texas Medical Center Campus is a 2.4 million ft$^2$ Level 1 Trauma Center, and home of Life Flight Operations.

ate trends while using preestablished, yet customizable trend log templates resident in the building control system (BCS).

- Common diagnostic exception report templates to quickly query the BCS for overridden and out of range/failed data points (versus the laborious task of reviewing multi-thousand system points daily).

These focus areas clearly follow the conclusions and recommendations required to optimize a hospital's HVAC energy expenditures.[1-3]

When commissioning and verifying key testing, adjusting and balancing (TAB) outcomes for building systems, it is mandatory as a best practice to ensure that the previously mentioned control features are fully functional via trend graphs and statistical sampling of field equipment. More importantly, these tools should be resident in the BCS operator interface and subsequent dashboards established for continuous monitoring.

These dashboards should contain the main setpoints and operating conditions of key systems and energy cost driver components such as air distribution, reheat, chillers, and cooling towers. This allows the facility operators to have a quick reference point for verification that the systems are operating within intended parameters.

We suggest that while specifications may include phrases such as "shall be capable of" and "shall operate over the full range of," these are not the ultimate parameters for components such as local thermostats and operator overrides of critical flows, static pressure, and other HVAC features after occupancy.

The human comfort temperature/humidity ranges are well documented in our industry.[4] Therefore, we need to ask "do the majority of hospital patient rooms, common areas, and procedure rooms really require a 20 degree range of local control?" Adequate dead bands designed to limit simultaneous heating and cooling (in all seasons) should be a default setting with air terminal controllers. The commissioning and controls teams should choose to deviate from this key energy optimization feature only in the small percentage of hospital spaces that truly require localized temperature variation.

Commissioning and recommissioning expenditures must be used to set up the HVAC controls in a health-care facility for optimization over both most likely seasonal swings (based upon latitude), as well as to confirm the design team's peak performance parameters.

To maximize the return on commissioning expenditures, consider focusing the commissioning team's scope on thoroughly reviewing key submittals and pre-functional checklists only for large, critical equipment and a sampling of other equipment less prone to defects. If discrepancies are found in the percentage reviewed, the remainder of the submittals or equipment must be reviewed. This cost should be funded by the contractor (and enforced by the project team).

Reducing the commissioning emphasis in these areas frees up additional effort (and commissioning fees) that are available for review of the HVAC system function as a whole. Therefore, additional focus is available to review and adjust the system when the spaces are fully occupied, which is important because the equipment often performs differently after occupancy.

This is also the ideal time to optimize the field-determined setpoints for differential pressures on pumping systems and static pressure setpoints for air handlers. This is best completed after TAB and occupancy.

In summary, commissioning agents often spend limited project dollars triple checking the obvious component level items, rather than focusing on key energy cost drivers (systems) that directly impact a hospital's future energy expenditures.

Parallel with commissioning and recommissioning efforts, the owner must dedicate resources and ensure a senior level focus on maintaining energy optimization efforts. Memorial Hermann (see "Case Study" in the next section) refined this focus by:

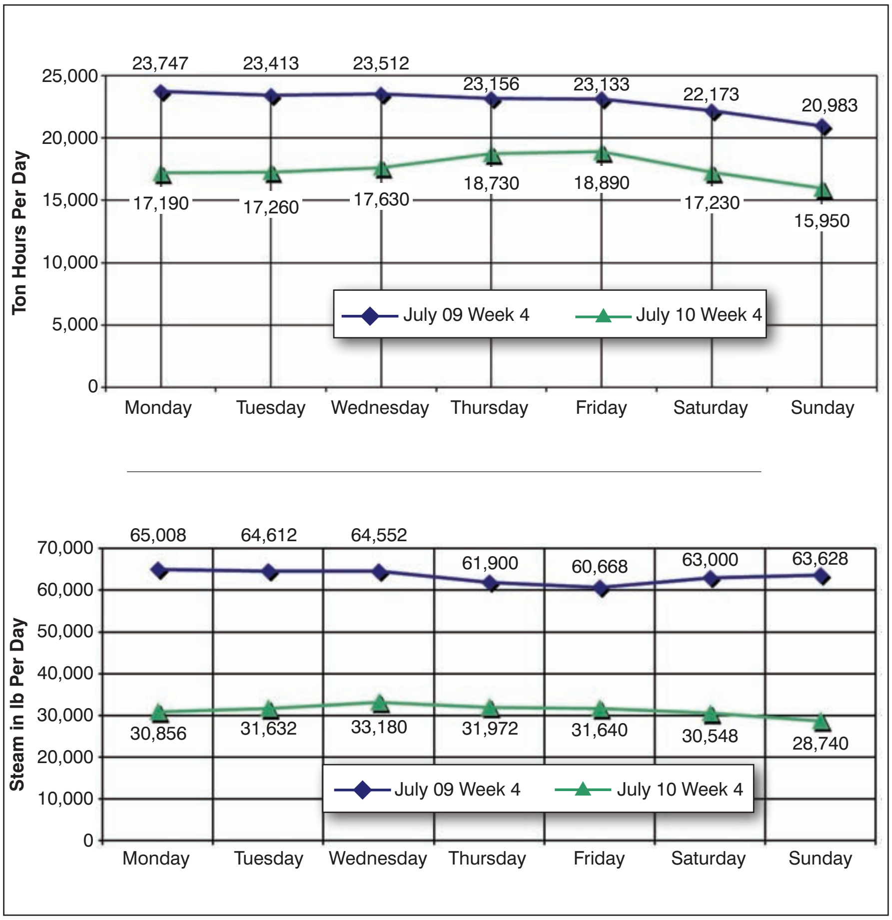


**Figure 1a (top):** District energy hospital facility ton hours/week over week. **Figure 1b (bottom):** District energy hospital facility steam/week over week.

- Internal benchmarking of each campus with its peers and external benchmarking with the ENERGY STAR Portfolio Manager. This has been accomplished with both in-house personnel and outside consultants when required.
- Holding regular energy meetings at each facility to review current trends, rankings, and next steps (goal setting) for optimization that are specific to that location.
- Training staff on intended design operation of systems, and dedicating time for operator focus on energy management responsibilities.
- Providing staff feedback on how their specific actions affect the facility's energy use using regular reporting of the facility's year over year consumption. (The figures in this article were originally produced for this purpose.)

## Case Study

As an owner/operator with more than 6.5 million ft$^2$ (603 870 m$^2$) of hospital facilities in the metropolitan Houston area, Memorial Hermann's focus on addressing energy optimization since 2008 has resulted in decreasing overall energy consumption (Btu/ft$^2$ [J/m$^2$]) by greater than 11% at its 13 hospital facility portfolio. Those facilities specifically targeted by this multidisciplinary test and tune initiative have reduced consumption by as much as 35%.

Our first large-scale effort at commissioning and retrocommissioning at Memorial Hermann is similar to that described by Brambley and Katipamula.[5] Typical focus areas were water and airside re-balancing, controls optimization strategy implementation, and sensor calibration and replacement. In addition, three of the existing facilities required emissions-mandated capital expenditures for new condensing heating boilers, which dramatically improved energy efficiencies. The results of these efforts also were reflected and accounted for in the external benchmarking process through the ENERGY STAR Portfolio Manager, which tracks historical changes in both facility and portfolio outcomes.

One example of a commissioning project is a recently completed specialty hospital that is provided with chilled water and steam services from a central utility district. During its first year of operation, benchmarking ranked it as the least energy-efficient facility in Memorial Hermann's portfolio. Although this project was methodically commissioned, schedule constraints created by a mid-project doubling in size resulted in a challenging start-up period.

Through a methodical and selective recommissioning effort, many BCS and operational items were optimized, resulting in stable operation and greatly reduced energy use versus the first year of operation. This hospital has experienced a greater than 23% reduction in chilled water consumption while using 50% less steam during recent summer periods as compared to the same period in 2009 (*Figure 1*, Page 24). Conversely, during identical winter periods the facility used 65% less chilled water and 37% less steam (*Figure 2*).

For the year, this hospital used 23% less chilled water for the period from September 2009 to September 2010 while experiencing a 44% reduction in steam consumption during the same period (*Figure 3*). Although we did not attempt to normalize the comparison for year over year weather data (heating degree-days/cooling degree-days), clearly this facility has been optimized given these dramatic changes.

The team implemented several key HVAC optimization strategies including reset schedules for air-handler discharge air temperature, air-handler static pressure, water side pressure differentials, and reheat loop temperatures. Temperature settings in common areas were set at pre-established parameters and programmed via the BCS while patient areas requiring individual control were set up to enable minimal localized adjustment capability with larger dead bands. It appears that the largest gain in efficiency resulted from re-balancing terminal unit minimum airflows to the lowest (prudent) code allowable level based on air change rates and outside air quantities as calculated by the design team.

Operating room temperature and flow reset schedules, previously an untouchable topic, did not initially function as designed with an occupancy sensor trigger. After implementing control algorithms that evaluated space temperature, outside air conditions, humidity, and time of day, the resultant operating room setbacks successfully achieved their goal of reducing both airflow and corresponding reduc-

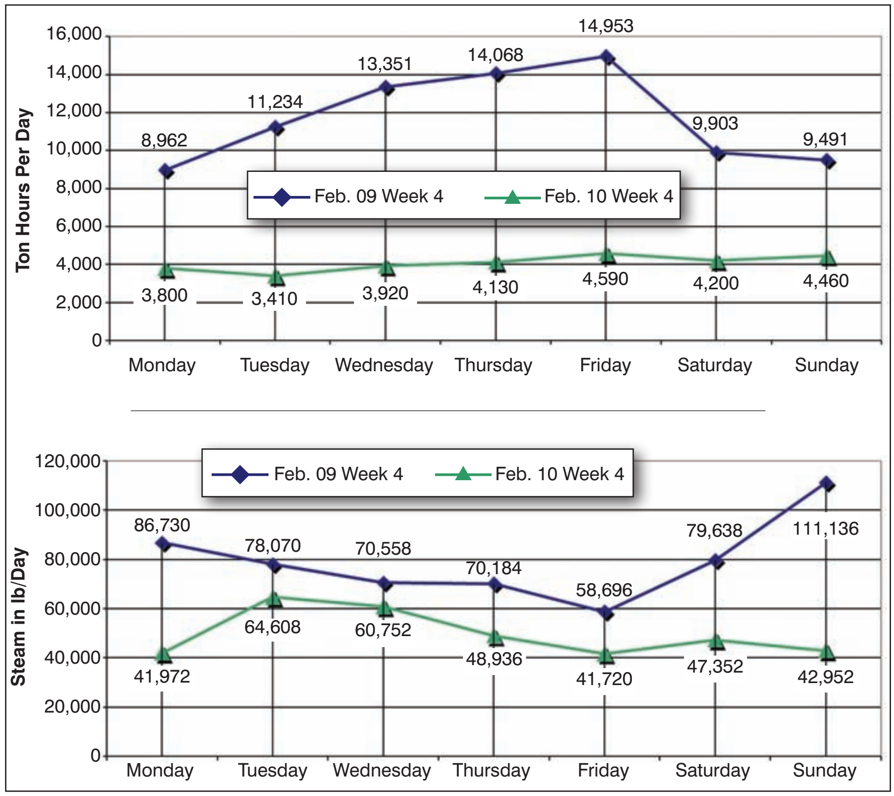


**Figure 2a (top):** District energy hospital facility ton hours/week over week. **Figure 2b (bottom):** District energy hospital facility steam/week over week.

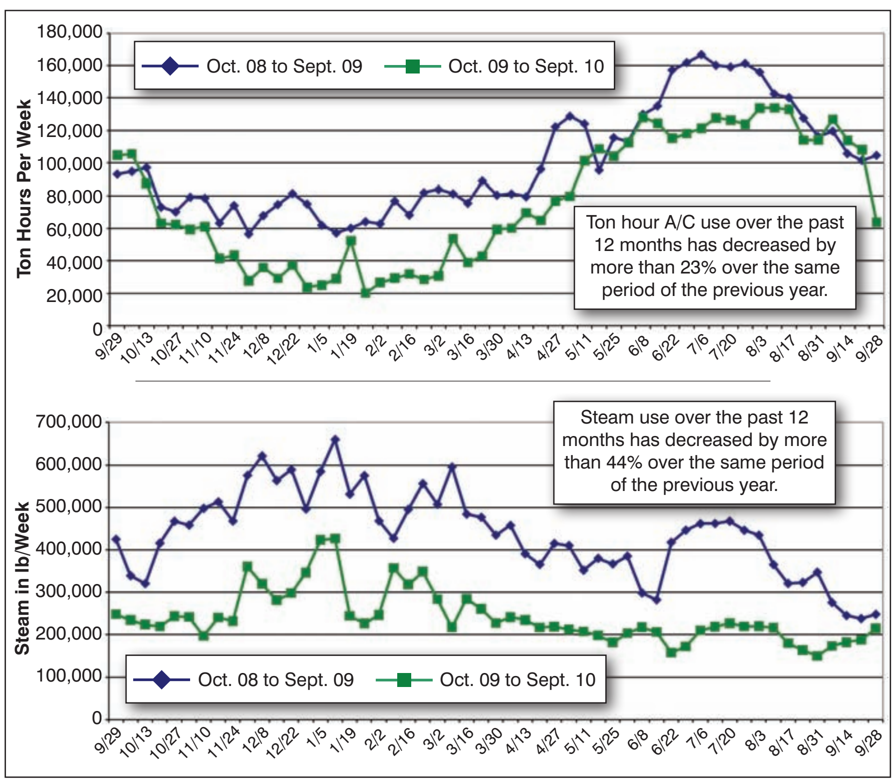


**Figure 3a (top):** District energy hospital facility ton hours/Oct. 09 to Sept. 10 over Oct. 08 to Sept. 09. **Figure 3b (bottom):** District energy hospital facility steam/ Oct. 09 to Sept. 10 over Oct. 08 to Sept. 09.

tions in both heating and cooling loads during unoccupied hours of operation (nights/weekends).

As a result of the previously referenced testing/tuning, current building energy use has been reduced 15% from its first year of operation and is improving with each period. An unanticipated benefit of the HVAC optimization is that hot and cold calls (i.e., customer work requests) have been virtually eliminated within this facility, resulting in greater patient satisfaction and more efficient use of building operations staff for preventive maintenance activities.

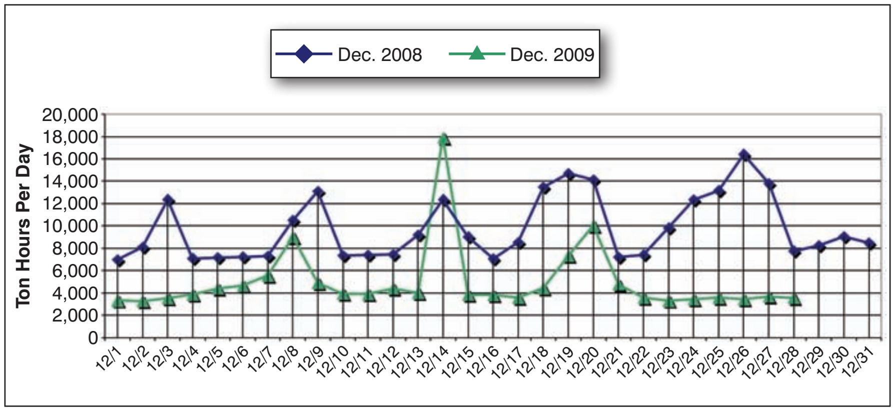


**Figure 4:** District energy hospital facility ton hours/week over week.

The item with the greatest energy impact addressed by the team related to the calibration of the terminal unit sensors, flow calibration, and direct digital control (DDC) system parameters. This correlates with Klaczek, et al., who found that "the great majority of improvements made to the existing HVAC systems have been through the DDC re-calibration parameters."[6]

Process improvements were also implemented regarding HVAC system operations for the maintenance personnel at this facility. Field staff are no longer allowed to make adjustments to the main settings on HVAC equipment without approval from one of two supervisors. This enables the BCS to automatically control the systems in the most efficient manner.

This change was prompted by review of chilled water use trends that displayed a large variation in tonnage that could not be correlated to either a weather or system event. Trending allowed the project team to more quickly notice the issue and correct it. It also allowed the supervisory team to coach their staff on the unintended consequences of making adjustments to system setpoints; i.e., the increase in chilled water consumption would set a new peak, establishing a higher district energy demand charge for the next year (*Figure 4*).

## Conclusions

ASHRAE notes that "the average hospital in North America consumes nearly 250% more energy than the average commercial building."[3] Given this statement and understanding that commissioning is accepted as a standard line item of a healthcare facility project budget, project teams should ensure the targeted expenditure of their efforts maximizes the long-term energy performance of the project. Building owners and project teams should establish energy and benchmark goals in the owner's project requirements at the start of the project.

While overall utility cost per square foot is directly correlated to consumption patterns and commodity cost, benchmarking facilities on total energy consumption and understanding its energy subcategories (cost drivers) is mandatory to ensure wise expenditures of commissioning and test/tune/balance fees.

Utility production and distribution systems should have consumption metering installed and appropriate trends established in the BCS with "dashboard" graphics to facilitate review of key data. Data presented on a current versus prior period comparison must be part of any BCS graphical package using spreadsheet-style functions. The owner and operator can more rapidly observe deviations from prior periods and correct them during start-up and future periods of operation.

Project teams may want to consider allocating project funds for the post-occupancy period, which would provide for additional design team, commissioning and TAB services later in the first year of occupancy. This would facilitate review of key system trends to enable further HVAC system optimization with the building in its fully functional state. Having these key dashboard deliverables fully functional at facility start-up/occupancy will enable owners and commissioning professionals to more quickly discover trends and system deficiencies and provide a financial return from reduced energy expenditure in year one.

## Acknowledgments

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