BOILERS: Renovate or replace

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This article explores the issues associated with leveraging a necessary O&M expenditure in order to improve efficiency, sustainability, and performance.

As buildings, systems, and equipment age, facilities engineering groups frequently are faced with the need to replace equipment that has reached the end of its useful service life. Given tight operating budgets and constricted timelines, often driven by an imminent failure, it's common for the engineering group to approach a trusted contractor to obtain a price to replace current equipment with equivalent capacity. Thus, projects frequently are handled on a design-build basis using the installing contractor's engineering expertise, but only to the extent necessary for code compliance.

While expedient, this approach often represents a lost opportunity.

Editor's note

In a series of Sellers' previous blog posts at www.csemag.com/blog, he has written about the efforts of the Marina's engineering team as they implement the Marriott MRCx and MCCx concepts in their facility. MRCx and MCCx are Marriott's internal brand of retro and ongoing commissioning. Embracing these concepts has allowed the Marina engineering team to reduce the facility's utility consumption at the rate of 5% to 6% per year. Other organizations implementing similar measures have seen similar benefits.

- Equivalent capacity may not be the right capacity: Loads change and older equipment may no longer match the existing load profile. It may have even been oversized in the first place. A mismatch between maximum capacity and equipment turn-down capability vs. the real-time-load profile can represent efficiency losses, which also can shorten equipment life and increase maintenance due to frequent cycling.
- Cost premiums for improved efficiency or performance are incremental costs: These projects represent mandatory replacement of equipment that no longer functions; only the difference in cost associated with improving efficiency, performance, sustainability, and/or operability need to be justified by the savings they represent. This is different from a project that must justify the entire cost of replacing equipment based on the improvements in cash flow or savings it will generate.

If these opportunities are not recognized and explored as a part of the replacement effort, then they are likely lost until the next time the equipment needs to be replaced, which can be decades down the road. Leveraging the replacement project as a chance to make other improvements can have a positive impact on cash flow, which can be quite significant when compounded over the equipment life.

Project background

At the San Diego Marriott Hotel and Marina (Figure 1), an engineering team is in the process of replacing boilers in the South Tower. The key points of the Marina project are as follows.

- The existing equipment is at the end of its service life, and the maintenance costs continue to escalate.
- The existing equipment serves domestic hot-water loads, reheat-loads, and space-heating loads.
- Reliable operation of the equipment is critical to the facility's core mission (guest satisfaction) on a number of fronts.
- The replacement budget took years for approval and was based on contractor quotes to replace existing capacity with equivalent capacity.
- The proposed replacement system would consist of eight modular boilers with a guaranteed efficiency of 85%, piped in a primary/secondary arrangement. The current arrangement is variable flow primary only.
- Current energy code requirements drive the replacement equipment to a higher efficiency level than the existing equipment; representing a viable payback on a necessary cost of doing business.
- The newer modular equipment will cost less to maintain, which will improve the payback.

Listening to the building

Having experienced some success in listening to their building, the team decided to employ similar techniques to verify the capacity requirement for the new boilers. This was accomplished by looking at trend data from the existing boiler gas meters. In Figure 2, the analysis reveals useful information:

- The peak load on the system has more to do with the domestic hot water load than the local climate.
- One of the proposed eight modular boilers will likely carry the load in warm weather with an additional boiler required to peak.
- Two modular boilers will likely carry the base-load in cold weather with three or four required to peak.

The analysis led the staff to conclude that six boilers will provide sufficient capacity and adequate redundancy. Since the budget was based on an eight-boiler installation, eliminating two boilers, their related pumps, controls, piping power, and flue connections freed up money for other features or enhancements.

Targeting extra dollars

Discovering extra dollars in the budget opened new enhancement opportunities for the Marina team. Proposed enhancements include the following:

Control system enhancements

A major project facing the Marina team is the migration of the 1980s vintage control system to a current technology platform. Some of the freed-up funds will be used to ensure that the control systems provided for the project are integrated with the new control platform and include the points necessary to operate, maintain, and control the new equipment. The funds will also help the Marina team document the control work for the boiler project and train the operating team on the new controls.

Variable speed distribution pumping

Operating experience revealed that only one of the existing distribution pumps is required to meet the load. The original 1980s system was designed to operate as a variable flow system by using two-way valves at the loads to push the pumps up their curves. This was a common approach during the 1980s, when 40-hp variable speed drives cost more than $40,000 and were as big as a motor control center.

Since then, the price and size of a variable speed drive has dropped significantly. The operating team found that only one drive is required to capture the added benefits of reducing pump speed with load, rather than throttling represented by the "push them up their curves" approach. Thus, the team is considering a variable speed drive and related controls for one of the distribution pumps, which is anticipated to deliver

Figure 1. *The San Diego Marriott Hotel and Marina, home of the boiler replacement project discussed in this article. The South Tower is the high rise on the right side of the picture.* *Photo: San Diego Marriott Hotel and Marina*

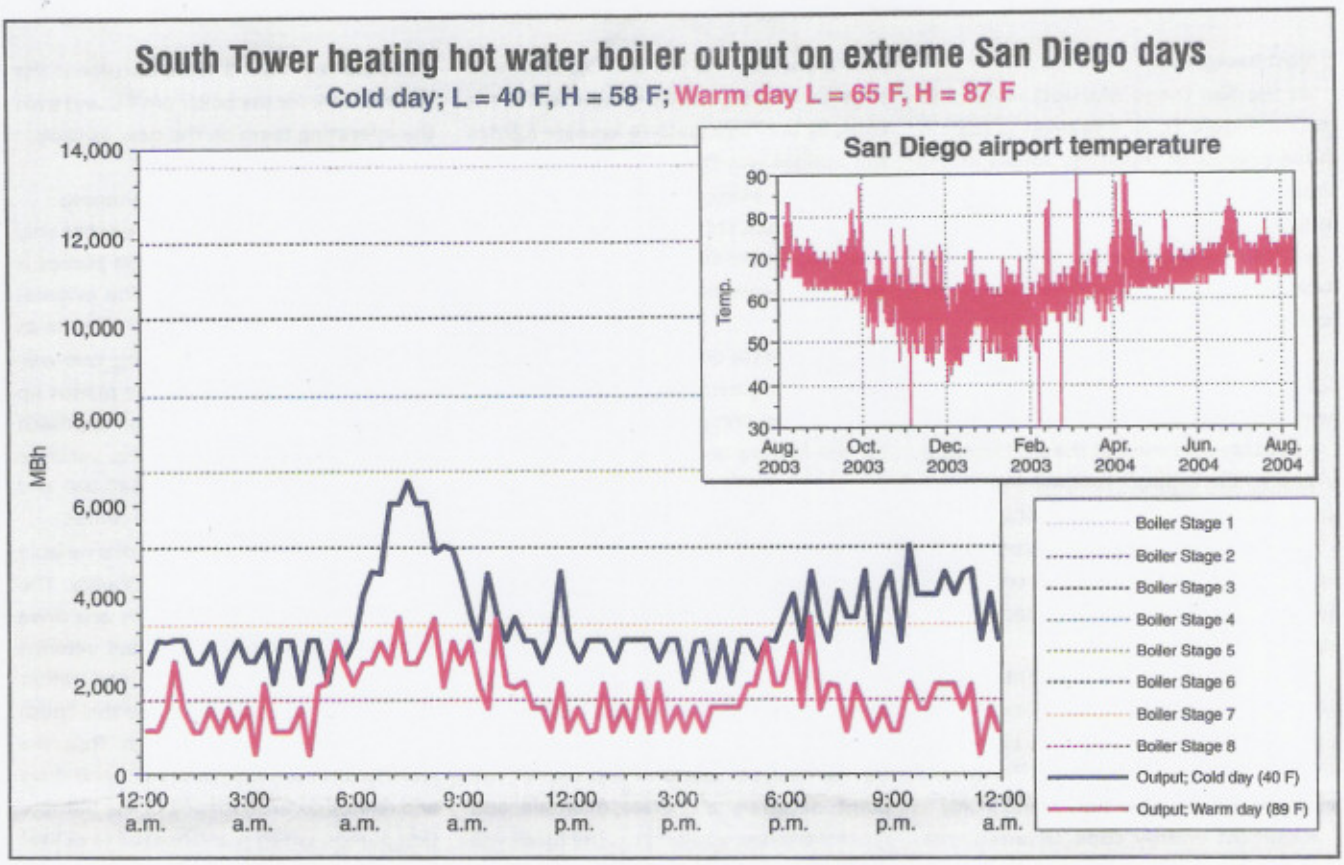

Figure 2. *Measured existing South Tower boiler output on extreme days: The peaks between 6:00 and 9:00 am and then again between 4:30 and 7:00 pm are related to the domestic hot water loads served by heat exchangers from the heating hot water system.*
Source: David Sellers

more than $7,000 in electrical savings by allowing the variable speed pump to be the lead pump. They will operate a constant speed pump only if the variable speed pump fails for some reason.

Condensing boilers

At first look, the upgrade to a condensing boiler that delivers efficiencies in the 90% to 98% range appears to be a simple decision. After all, why would the Marriott hotel not want to spend money for condensing boilers with potential to double the gas savings?

The reason is because the high efficiencies delivered by condensing boilers come with a drawback (see Figure 3). Condensing boilers deliver their high levels of efficiencies by condensing water out of the flue gas; condensing the water vapor liberates roughly 1,000 Btu/lb vs. the 1 Btu/lb liberated by cooling it 1 F. Typically, a modular condensing boiler array can further leverage the efficiency benefits of a condensing boiler. The array can stage strategies that operate multiple boilers at part load, where they have a "sweet spot" in terms of the efficiency they deliver.

Important to capturing this massive increase is to cool the flue gas to a point where condensation can occur. In the case of a gas-fired process, this is in the range of 130 to 140 F, which means that the boiler entering water temperatures needs to be relatively low for a condensing boiler to achieve maximum efficiency.

For the South Tower system at the Marina, running below a supply temperature of 140 F is challenging. The limitation is the supply water temperature range required by the domestic water heat exchangers to deliver domestic water—120 to 130 F.

Thus, it would seem that the upgrade would have little, if any, benefit because the South Tower system could not operate at a temperature low enough to leverage the efficiency.

However, the primary/secondary configuration proposed for the new system (with a minor modification) opens the door to a solution. Some of the key points of the solution are:

- Adding a three-way valve blending high-temperature water from the boiler (primary) loop with the return water from the distribution (secondary) loop will allow the distribution loop to be operated at a lower temperature than the boiler loop.
- Connecting the domestic hot water heat exchangers directly to the boiler loop would allow them to be served by water at the temperature they require, while the other loads on the distribution

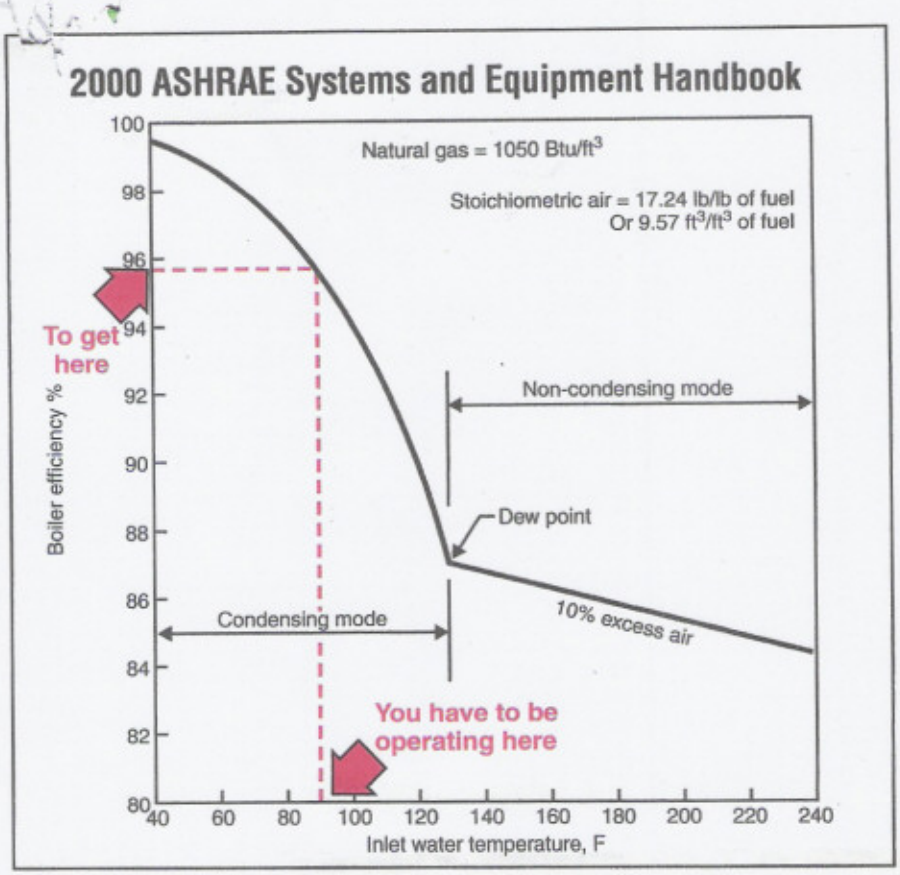

Figure 3. *Boiler efficiency versus entering water temperature. Note that the water has to be cold enough to cause moisture in the flue gasses to condense for condensing boilers to achieve maximum rated efficiency. Source: 2000 ASHRAE Systems and Equipment Handbook*

system are served by lower temperature water.

- Since the base-load during warm weather (when lower distribution loop temperatures are viable) is in the range of the capacity of one or two modular boilers, all of the benefits of condensing boiler operation could be realized by providing one or two condensing boilers and the remaining boilers of the conventional design.

Presently, our analysis indicates that it should be possible to configure the South Tower system to accomplish all of the listed goals.

At a minimum, the new boilers can be installed in a manner that allows the desired improvements to be added via subsequent energy conservation projects. The key to success is developing the proposed system configuration now while providing the necessary connection points with taps and valves for the future. Watch the Field Guide for Engineers blog to monitor progress as I work with the team to explore the options.

Tying it all together

The Marina project is more complex than originally envisioned. The added complexity can open the door to confusion and misleading pricing as contractors are asked to provide competitive bids for a project that has specific goals in mind, but no support in the form of detailed engineering documents.

Recognizing this, the Marriott team leveraged their relationship with their commissioning consultant and contractor. Specifically, the team chose to work with contractors that had previously delivered solid work on turnkey, design-build projects for them in the past. In order to eliminate misunderstandings, the team worked with their commissioning consultant to develop an outline scope of work that included the following fundamental items:

- System diagrams depicting the current system configuration and the modifications required to achieve the fundamental goal of the project—replace aging equipment—while paving the way for future enhancements
- Specifications tied to their efficiency goals, Marriott standard design guidelines, and Marriott MRCx and MCCx standards for commissioning, efficiency, operability, documentation, and training.
- Specifications outlining the minimum level of interface to the control system enhancement project that is already underway.
- Point lists describing all of the data points required to control, operate, and maintain the system, including sensor accuracy requirements and trending requirements.
- An outline of narrative control sequences, describing how the system will function including normal operation; operation when all proposed enhancements are implemented; and operation under extreme conditions and in a number of failure modes.

The bottom line is that by taking a lifecycle perspective and listening to the building, the Marina team discovered that a "cost of doing business" project was actually a resource conservation project. This led to potential optimization of the replacement dollars to deliver additional benefits that will reduce the hotel's environmental impact while maintaining its trademark guest satisfaction

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Sellers is a member of Consulting-Specifying Engineer's editorial advisory board. His background includes more than 30 years of experience with commissioning, design engineering, facilities engineering, mechanical and control system contracting, and project engineering in a wide array of facilities. Sellers also provides technical training and develops technical guidelines on retrocommissioning and commissioning field techniques and engineering fundamentals in a number of venues. This article was developed in collaboration with the Building Commissioning Assn.