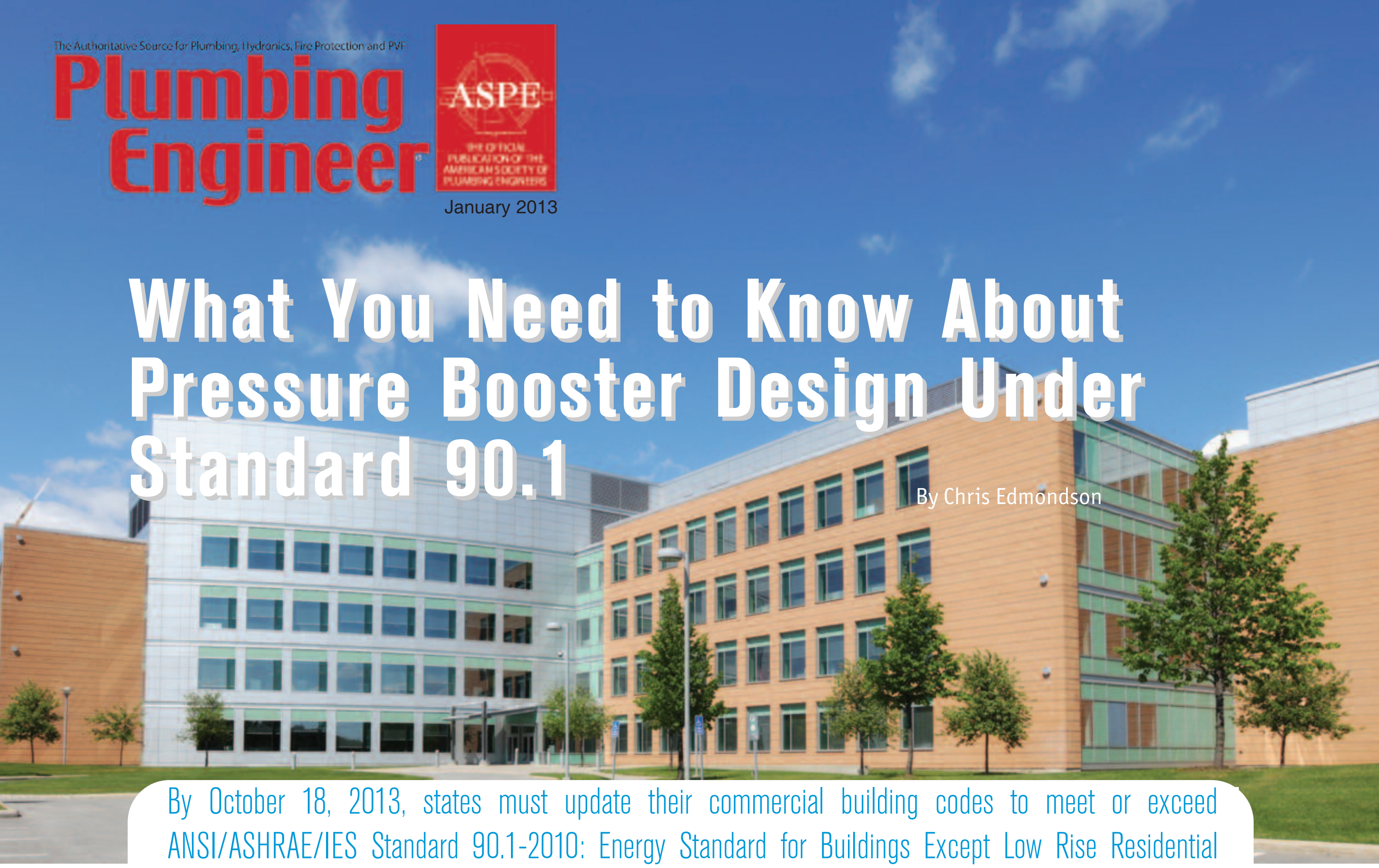

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Plumbing Engineer
ASPE
THE OFFICIAL PUBLICATION OF THE AMERICAN SOCIETY OF PLUMBING ENGINEERS
January 2013

What You Need to Know About Pressure Booster Design Under Standard 90.1

By Chris Edmondson

By October 18, 2013, states must update their commercial building codes to meet or exceed ANSI/ASHRAE/IES Standard 90.1-2010: Energy Standard for Buildings Except Low Rise Residential Buildings or request an extension of deadline.

Design professionals who are aware of this rather pivotal change will surely wonder what this means in terms of HVAC design, lighting, building envelope, etc. However, few plumbing engineers realize the significant impact that this requirement will have on pressure booster design. You may be surprised to learn that these new requirements, imposed per ruling by the U.S. Department of Energy (DOE), effectively put an end to constant-speed pressure boosting. You may also be surprised to learn that the way we are currently designing variable-speed pressure boosters will not meet the new requirements.

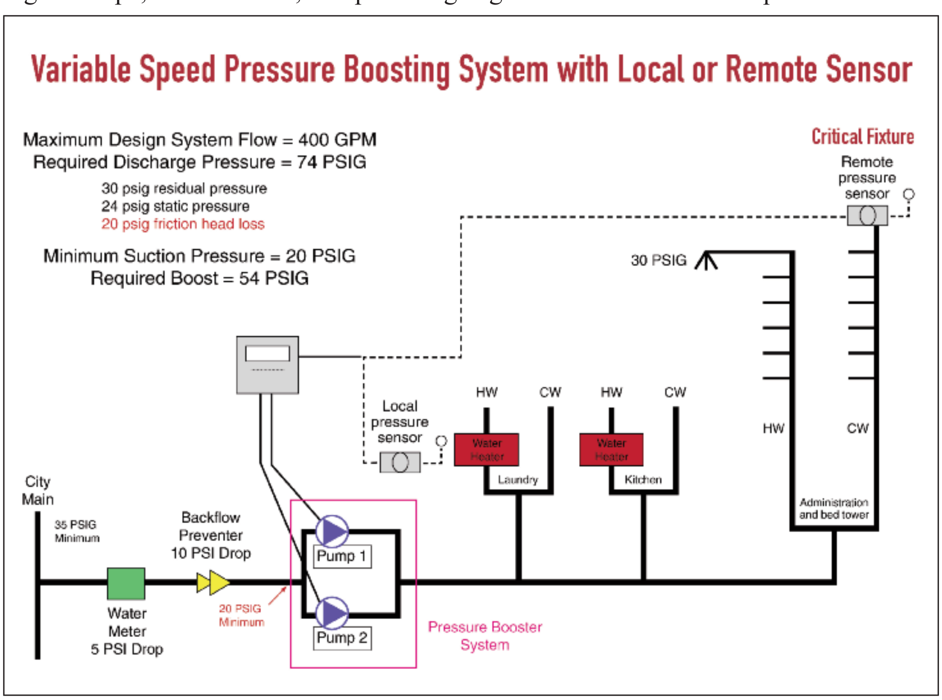

Figure 1 Variable-Speed Pressure Boosting System with Local or Remote Sensor

These changes are literally months away, and in some states they are already in effect under current state energy codes. Other states will be forced to adopt these changes by October 18 or else formally request an extension. To determine the precise requirements for any given state, you can go to the International Code Council website (iccsafe.org). This article focuses on the specific changes outlined in ASHRAE 90.1-2010 that impact pressure booster design.

Death to Constant Speed

The specific changes to service water pressure booster systems, as outlined in ASHRAE 90.1-2010 Chapter 10, Section 10.4 are as follows:

• One or more pressure sensors shall be used to vary the pump speed and/or start and stop the pumps. The sensors shall be located near the critical fixtures that determine the pressure required, or logic shall be employed that adjusts the set point to simulate the operation of a remote sensor.

• No device shall be installed for the purpose of reducing the pressure of all of the water supplied by any booster system pump or booster system, except for safety devices.

• No booster system pumps shall operate when there is no service water flow.

Collectively, these three requirements will transition nearly every booster system to variable speed. First, by using the most critical fixture as the sensing point, pressure boosters will be required to vary pump speed over a much wider range. This is a critical departure from most pressure-boosting systems in use today, where the pressure sensor is installed locally in the discharge header of the pumps. The pumps are controlled based on a set point that equals the minimum suction pressure and the required boost. In the example shown in Figure 1, the pumps would have to maintain a discharge pressure of 74 pounds per square inch gauge (psig) in a conventionally controlled system using local sensors at the discharge. However, if the sensors are located at the most critical fixture (or otherwise based on demand) the pumps could vary downward to as low as 54 psig. This represents a dramatic reduction in overall pump speed—in this case a 26 percent reduction as opposed to a 10 percent reduction when sensing at the discharge header.

Table 1 Pressure Booster System Control Strategy Comparison*

Strategy	Operating Costs
Two constant-speed pumps, 50/50 percent split	$6,331/year
Two variable-speed pumps, with local sensor located at discharge header with 50/50 percent split	$4,873/year
Two variable-speed pumps, with remote sensor located at most critical fixture with 50/50 percent split	$3,205/year

*Based on 10-psi variable-suction pressure and 20-psi friction head loss at $0.10 per kWh

Secondly, the very common practice of installing pressure-reducing valves (PRVs) on the pumps shall be prohibited, with the exception of safety valves installed for the purpose of keeping discharge pressures below 80 psig. In other words, you cannot constrict pump flow to keep downstream pressure at a predetermined limit.

Finally, the pumps shall not operate when there is no demand for water. This presents certain challenges with respect to short-cycling when there are minor, intermittent demands. This will be addressed later in the article.

Change Is Good; Saving Energy Is Better

These are major changes, which many in the industry may view as being thrust upon them with little warning or resources for how to make it all work without major increases in installed cost, especially when it comes to demand-based pressure sensing. The idea of wiring remote sensors is not likely to be embraced by many owners, engineers, or contractors, simply due to the labor and expense involved. However, when you closely examine the potential savings for a new demand-based control path when compared to constant-speed systems (and their inherent waste), it becomes apparent that this is a change for the better. It may also be encouraging to learn that hardwiring sensors is not the only available option for demand-based control.

The DOE was not without motive when it made the decision in late 2011 to make Standard 90.1–2010 the commercial building reference standard for state building energy codes. The DOE determined through quantitative analysis that the standard will have a significant impact on building energy consumption— to the tune of approximately 18.2 percent over Standard 90.1-2007. In other words, it just makes sense.

In terms of pressure boosting, you need only to look at the current widespread waste associated with constant-speed pumping to come to terms with why these particular changes belong in the energy codes. Consider the following common characteristics of virtually every constant-speed booster system in service today.

• Oversized pumps: It is a well-accepted fact that engineers tend to err on the side of oversizing pumps. This problem is magnified by the fact that many new buildings have high-efficiency plumbing fixtures, and many state codes are now requiring their use. This decreases the demand for water below what Hunter's curve would indicate, meaning that the vast majority of pressure boosters are already oversized.

• Variable head loss: As flow decreases, friction loss also decreases. Constant-speed pressure boosters do not adjust for these consistently recurrent variable head losses, using far more energy than actually required.

• Pressure-reducing valve losses: Pressure-reducing valves typically have a pressure drop of up to 5–8 psi, which must be taken into account when sizing the pump/motor. Thus, PRVs create a permanent energy burden on pressure-boosting systems. Eliminating PRVs would have a significant impact on the overall energy consumption of pressure booster systems.

• Varying system loads: Booster systems experience widely varying system loads over the course of 24 hours, yet pumps are selected for the peak flow rate—a condition that may occur for only a short period of the day. Thus, for most of the day, pressure boosters are over-pumping.

• Changing suction pressure: Booster systems typically experience a wide variance in suction pressures throughout the day unless the pumps are drawing from a tank. However, systems are designed based on the minimum available suction pressure. Constant-speed systems do not capitalize on intermittent increases in suction pressure, whereas variable-speed pressure boosters will slow down under these conditions.

Applying variable-speed pressure boosting with demand-based control eliminates the waste associated with all of the above scenarios, but how much energy (and money) will it really save? As an example, consider again the system in Figure 1. Changing the sensor location from the discharge header to the remote fixture allows for a pump speed reduction of 26 percent versus 10 percent. This speed reduction translates into some pretty significant monetary savings for owners. If you factor in changing the sensor location along with eliminating PRVs, compensating for varying suction pressure conditions and system loads, then the energy savings can be more dramatic. The following comparison reflects these savings.

This level of operational efficiency delivers an attractive payback, but there are other financial incentives to consider. Utility companies in most if not all states offer attractive rebates, sweetening the pot for the application of variable-speed drives alone. These rebates vary from state to state, but typically deliver a return of approximately $100/horsepower. (More detailed information about state-by-state rebates for VFD applications can be found at dsireusa.org.) Unfortunately, these rebates are frequently underutilized simply because owners and many engineers are unaware they exist. However, the payback is compelling, and it could be argued that engineers have a fiduciary responsibility to present owners with these options and benefits, regardless of impending building codes.

Given these financial incentives, there is little if any justification on the part of the well-informed plumbing engineer not to recommend a system that meets the pressure booster criteria of Standard 90.1-2010 sooner rather than later.

Making It Work

The most energy-efficient pump is the pump that isn't on, which is why Standard 90.1–2010 prohibits the operation of booster system pumps when there is no service water flow. Ascertaining that booster pumps only operate when there is a call for domestic water without short-cycling means two things: (1) an effective demand-based sensing control must be in place and (2) the system must be adequately pressurized during low demand periods to meet minor, intermittent demands, such as the occasional 3 a.m. toilet flush or glass of water.

Addressing the latter prerequisite first, a properly sized hydropneumatic tank is required to prevent short-cycling of the booster system. Hydropneumatic tanks are ASME and non-ASME vessels that hold water and air under pressure. The compressed air creates a cushion that can absorb or apply pressure as needed to provide efficient water supply under low demand conditions without the operation of the pumps. These tanks should be sized based on the length of time the designer theorizes that the booster pumps should remain inoperable in a no-flow condition, the type of building and application, and the tank location in relation to the pressure booster pumps. It is important to remember that if the tank is too small, the booster system will short-cycle, which wastes energy and shortens equipment life. It is a misnomer that variable-speed booster systems can operate effectively without a hydropneumatic tank. Invariably, short-cycling will occur without this low-cost pressurization strategy in place.

Of course, control is key when it comes to efficient variable-speed pressure booster control, which is why Standard 90.1–2010 specifies that the pressure sensor must be located near the critical fixtures or some other logic be applied to simulate operation of a remote sensor. Clearly, many will balk at the idea of hardwiring a remote sensor because of the expense and complexity. Wireless sensors are a possibility, but many, with good reason, will hesitate to use this type of technology because of the reliability and also the expense. What alternatives exist?

Surprisingly, the answer comes down to a basic law of fluid dynamics that every engineer knows well: flow varies as the square root of differential pressure changes. If you know the flow, then the differential pressure changes can also be determined. By sensing the demand (flow) of the pressure booster, the discharge set point can be reset continuously based on demand. This reset is based on the amount of variable head lost in the distribution piping between the booster discharge and the critical fixture. By knowing the demand and variable head loss it is possible to create a virtual remote sensor. This allows the owner to achieve the energy savings of a remote sensor without the added installation cost of mounting and hardwiring a remote sensor.

These control measures can be accomplished in the field or custom designed and special ordered, although design and installation costs, and sometimes reliability, may be a deterrent. However, at least one manufacturer of prepackaged variable-speed booster system includes this built-in logic on their units, already programmed for the given application. In this case, the added cost is all but negligible, and the owner has the peace of mind of single-source accountability.

This is valuable information to have on the eve of the adoption of Standard 90.1–2010 into commercial building codes. But given the potential for savings, the obvious question for engineers and building owners is "Why wait?" ▯

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