How to Exceed the ASHRAE 90.1 Energy Code for Service Water Booster Systems and the Importance of Bladder Tanks in Commercial Buildings

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ASHRAE Standard 90.1 is a Department of Energy baseline energy code for commercial buildings. The energy code includes requirements for HVAC systems, lighting, pumps and pumping systems. The 2010 version of ASHRAE 90.1 added a section for service water booster pump systems (Section 10.4.2) with the following three requirements:

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

b) *No device(s) shall be installed for the purpose of reducing the pressure of all of the water supplied by any booster system, except for safety devices.*

c) *No booster system pumps shall operate when there is no service water flow.*

Important Note: This is the entire section pertaining to service water boosters. There are only three requirements, a, b and c.

10.4.2 a)

The first requirement addresses sensor placement. The intent of this requirement is to reduce pump energy at flow rates lower than design. Pipes are sized for high flow requirements which result in lower head losses at non-peak hours. In most cases, the critical fixture is located at the farthest distance from the pump system and the pressure required at that point is typically 30-40 psi. If a constant pressure is maintained at the pump system discharge, this can result in a pressure well above 30-40 psi at the critical fixture location which is in excess of what's really required. If the pressure sensor is installed at the critical fixture location, the pump system can be set up to maintain 30-40 psi at that remote location which will result in additional energy savings.

Consider the pump performance curve shown in **Figure 1** as an example. The design condition for this pump is 180 gpm at 202 feet of head. With a fixed speed PRV based system, the brake horsepower at 40 gpm (22% of design flow) would be 8.2 (Point **A**). If the pump were to be set up to maintain a constant pressure of 202 feet (87.4 psi boost), the pump speed would be reduced to 78% and the brake horsepower would drop to 4.3 (Point **B**). Simply utilizing variable speed pumps with a constant pressure control mode can reduce the power by over 84% in this case. But the Energy Code doesn't stop there. If a remote pressure transmitter is mounted (or pump control software is used to simulate a remote sensor) the pump head can be reduced to 173 feet, a reduction of 14.5% in this example. The pump speed will be reduced to 72% with a corresponding brake horsepower of 3.5 (Point **C**). This represents an additional brake horsepower reduction of 18.6% over a constant pressure variable speed system.

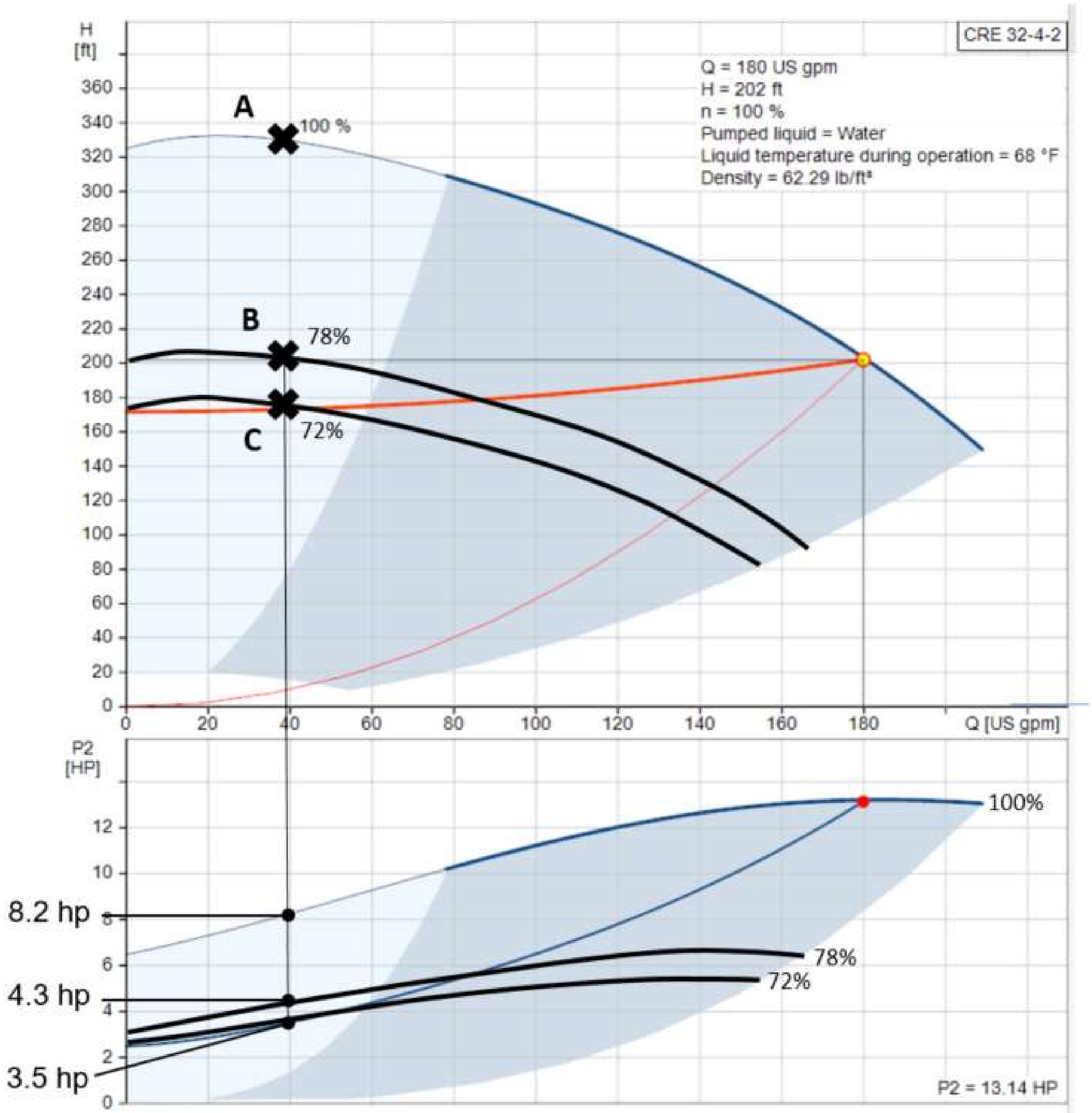


Figure 1

10.4.2 b)

The second requirement prohibits the use of pressure regulator valves (PRVs) to **reduce** the supply pressure to the building. Variable speed control is the most common method to meet this requirement and some have interpreted the code as requiring **constant pressure**. Nowhere does the code state constant pressure is required for service water boosters. Again, the intent of the code is to discourage the use of PRVs to control the pressure which results in wasted energy. Technically you can meet the requirements of 10.4.2 b) by using fixed speed pumps. Due to the misinterpretation of the code, the use of bladder tanks has been discouraged. Some people have argued that there can be no water exchange in and out of the bladder, therefore making the tank a location of stagnant water because there is no change in pressure. In this next section, we will address whether or not this is true.

Note: Although we will use the term *bladder i*n this document, this is inclusive of *diaphragm* type tanks as well as they serve the same function.

10.4.2 c)

This third part simply states that no pumps shall operate when there is no service water flow. In other words, when nobody's using water, turn the pumps off! What about very little water flow? There are many scenarios where there is a very small, yet unintended, water demand such as a leaky toilet, a water faucet not fully shut off or leaks in an irrigation piping system. These very low flow situations should be considered when attempting to optimize pump energy consumption in commercial buildings.

Now back to the Bladder tank

How important is a bladder tank on a domestic water supply pump system?

The key to fully understanding this question requires an understanding of how water is used over the course of 24 hours of operation. Domestic water use in commercial buildings has a somewhat predictable flow rate at different times of the day. See **Figure 2**

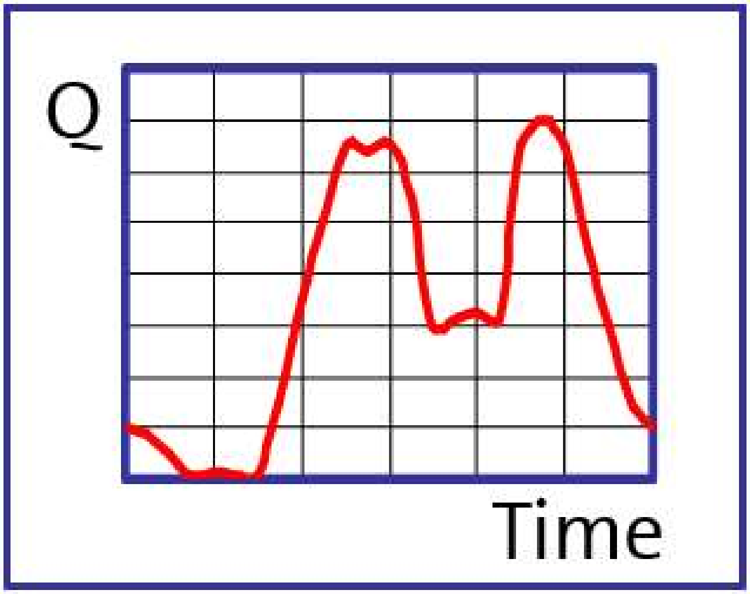


Figure 2 – Typical Domestic Water 24hr Flow Profile

The building function plays a role in how water is used along with times of occupancy and the ancillary functions the building may have. For example, an office building that has occupancy 12 hours a day can expect low or no domestic water flow the other 12 hours of the day. In this example, the low or no flow time is half of the day and if there is a low flow condition that happens during this time, bladder tanks along with intelligent pump control that takes advantage of bladder tank storage, can save operating costs. The Grundfos CU352 controller in Hydro MPC BoosterpaQ systems has a Low Flow Stop Function that will determine when there is a low flow (adjustable) and operate in a more efficient method of operation. (See **Appendix A** for more details of CU352 Low Flow Stop Function) This energy saving method of operation has proven to save up to 68% in energy costs compared to continuous pump operation in low flow conditions. **See Figure 3**

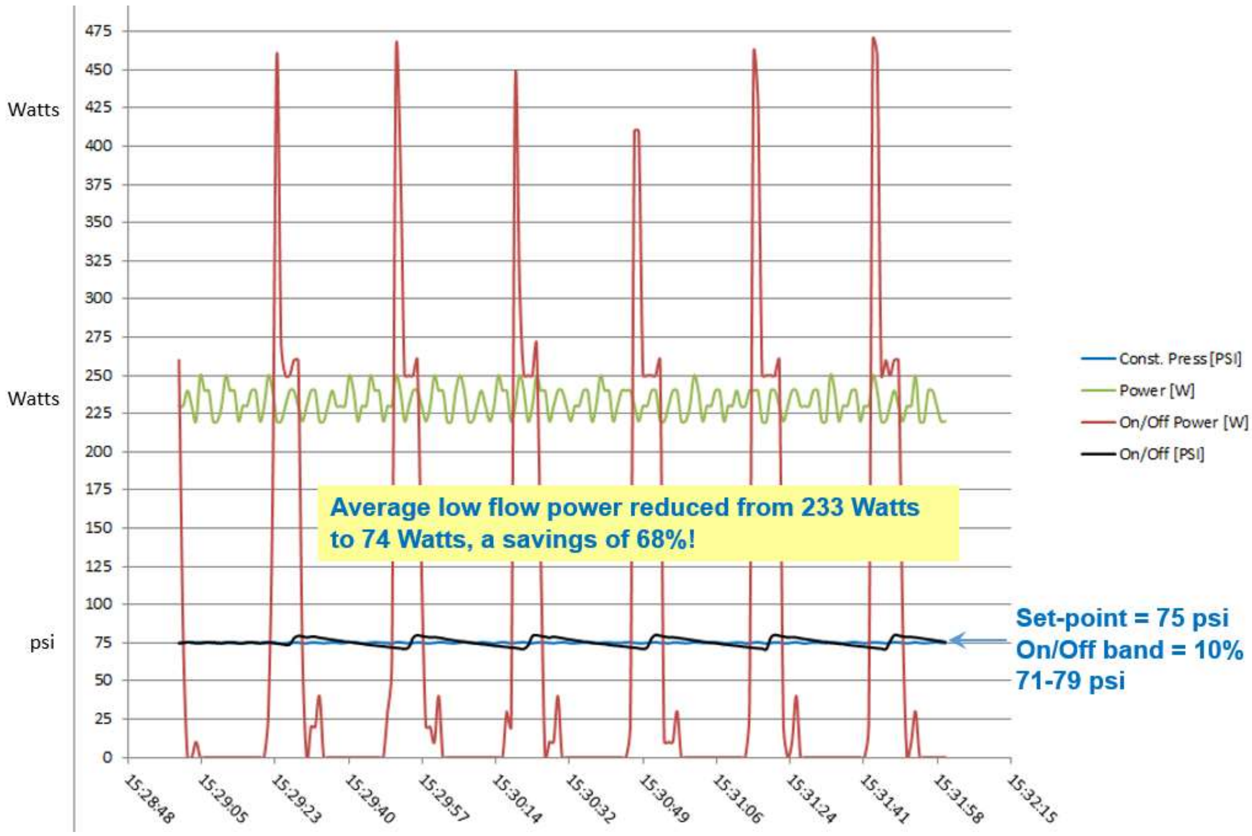


Figure 3

Data log results at low flow – On/off vs. Continuous run

ASHRAE 90.1 Section 10.4.2 c) states that the pumps or pump system shall not operate when there is no service water flow. Intelligent controls can **exceed** this requirement by acting not just on zero flow rates, but when flow rates are low which will lead to a much more efficient method of operation. This more efficient method of operation uses tank storage. When low flow is detected, the pump will speed up, filling the bladder with water and will switch off when the pressure reaches the stop pressure (Setpoint + ½ X Start/stop band or 79 psi in the example shown in **Figure 3**). When the pressure drops to the start pressure (Setpoint – ½ X Start/stop band or 71 psi shown in Figure 3) and the flow is still LOW, the pump will increase speed again and re-charge the tank to the stop pressure. The pump will repeat this process while the flow remains low. The result of this is improved operational efficiency for the pump system and it eliminates the chance of water heating up in the pump and piping system. The bladder tank rotates its stored water each cycle as the pump switches on and off. It is more practical to design for low flow than zero flow especially if optimizing energy consumption is desired.

It is important to note that pump systems that require zero flow before switching off can heat up water when there is very little water flow, such as leaky toilets, leaks in irrigation piping or water faucets not fully shut off. In these low flow conditions, the pump is usually operating at lower speeds churning water within the pump casing and subsequently increasing the temperature of the water. This condition, decreased pump speed and higher water temperature, has poorer lubricating properties on the pumps seal faces and can reduce the lifetime of these parts. This can also create an environment for bacteria growth and legionella in the pump and pipe system.

It is important to understand this, a variable speed constant pressure system that does not use a bladder tank must encounter a ZERO flow condition before the pump can be switched off. For example, say you have a nominal 150 gpm pump running variable speed, maintaining a discharge pressure of 100 psi at a flow rate of only 5 gpm. Without a bladder tank, this pump will simply operate at that low flow continuously, potentially all through the night with no complaints from the consumers. During this time, any attempt at stopping the pump will result in the pressure dropping well below 100 psi. Without a bladder tank, the only time this pump could actually switch off without a drop in discharge pressure would be zero gpm. A system that utilizes a bladder tank will be able to stop during the night, and as shown in figure 3, can save up to 68% in energy consumption in addition to exchanging the water stored in the bladder tank.

Other benefits of bladder tanks

Many domestic water systems have fast acting valves such as toilet flush valves. The bladder tank can support these abrupt increases of water flow and allow time for VFD controlled pumps to smoothly react to these sudden flow requirements. The bladder will have an immediate effect on these sudden changes and acts as a shock absorber resulting in a more stable supply pressure. Again, during this process, the water in the bladder is exchanged even though the change in pressure might be only 1-2 psi. Pumps and pump systems without bladder tanks can have difficulty in maintaining steady pressure when fast acting valves are present. If several flush valves suddenly open, the discharge pressure can drop quickly which will result in a sudden pump “ramp up’ in speed to avoid low discharge pressure. These overshoots can result in pressure spikes and/or water hammer that can be severe enough to cause excessive noise in buildings and even pipe breakage. During these sudden flow increases, the water stored in the bladder rushes out into the piping allowing the variable speed controls to softly return the discharge pressure to the set-point. With variable flow applications, bladder tanks provide cushion to the pipe system that gives the controller reaction time to adjust pump speed without pressure hunting and pressure spikes.

Common myths about bladder tanks

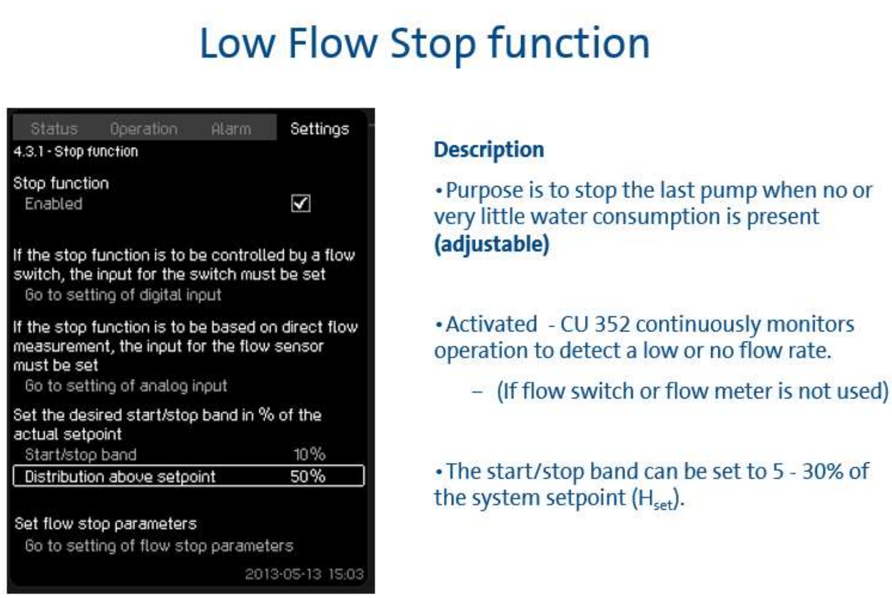
A common myth centered around the need for a bladder tank on variable speed booster systems is that the system discharge pressure is constant, resulting in no water exchange in and out of the bladder tank. This really can only be true if there is a continuous water flow at the same rate 24 hours a day. Typical domestic water pressure boosting applications are the opposite of this with substantial variation in water flow and many hours where no service water is needed. It should be evident by now that with intelligent pump control and the use of a bladder tank that this myth is simply not true.

So how do Grundfos systems exceed the requirements of ASHRAE 90.1 for service water boosters?

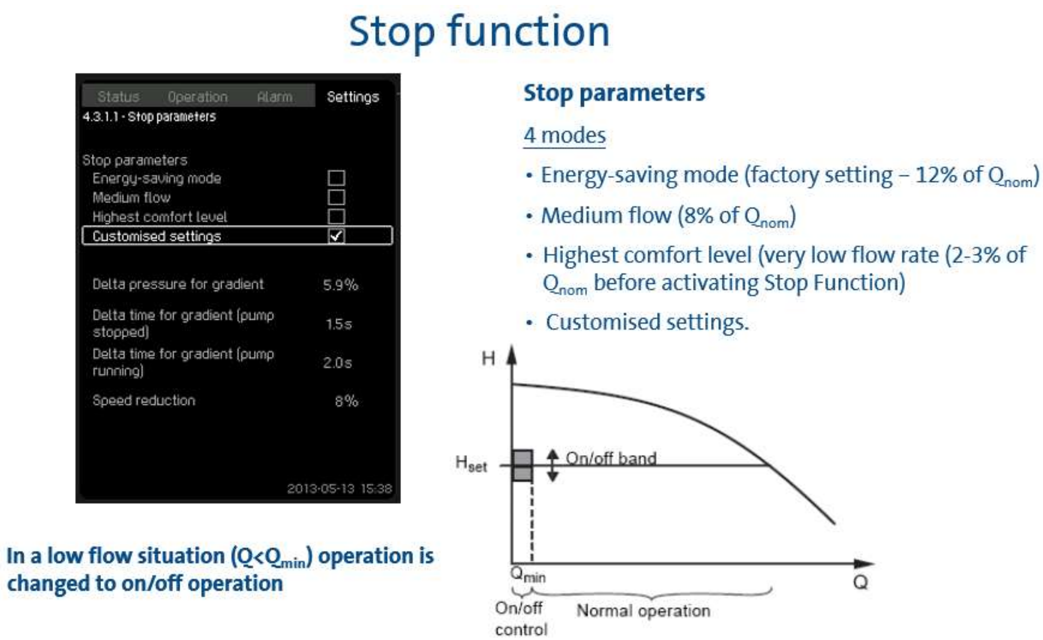
Grundfos pumps used in service water applications have **low** flow detection rather than **no** flow detection. **Figure 3** shows an example of a pump system operating at a continuous flow of 2 gpm. Many variable speed booster systems installed today will keep the pump in operation at this low flow rate, especially those systems that do not use bladder tanks. A Grundfos system will switch to a start/stop mode during this time to save pump energy which exceeds the intent of the code. The code simply requires pumps to be switched off when there is no service water flow but the code is unclear as to how to handle leaks. Leaks can lead to additional pump energy and Grundfos has addressed this with intelligent pump control.

Appendix A

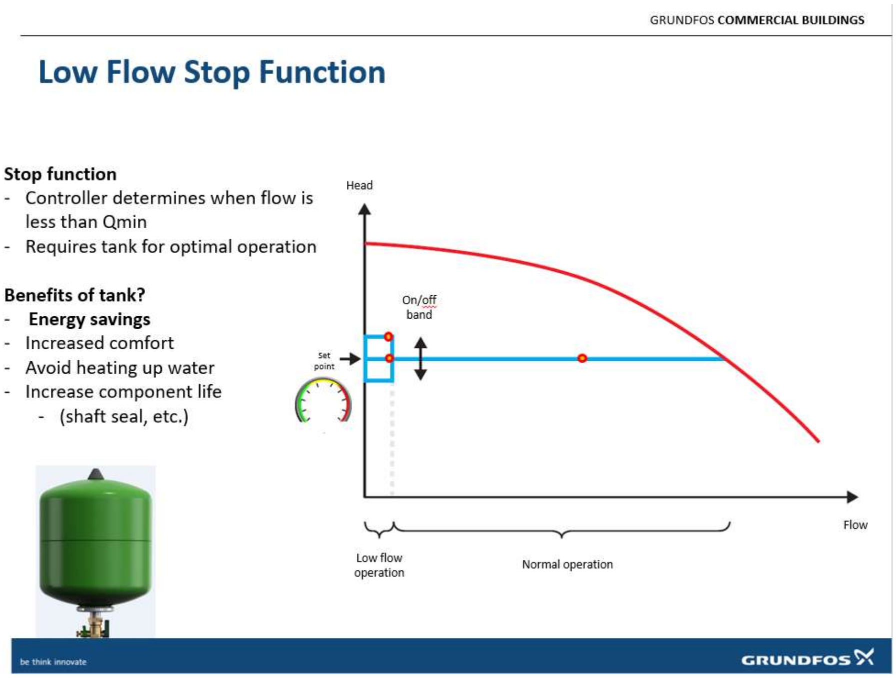
The Low Flow Stop Function is active when there is one pump in operation. The Grundfos CU352 controller has the capability to take an input from a flow switch or use an analog signal from a flow meter to define when to activate the Low Flow Stop Function. If a flow switch or flow meter is not used, the controller will estimate flow and make the determination this way.



Setting within the Low Flow Stop Function include a Start/Stop band and setting for how the Start/Stop band is distributed above and or below set point pressure.



The Grundfos CU352 controller has three pre-configured settings that control when the Low Flow stop limit (Q_{min}) is activated: Energy-saving mode, Medium flow, and Highest comfort level. A Customized setting is also available to exactly define the stop limit. When the controller determines flow is less than the Low Flow Stop Limit (Q_{min}), the controller will increase the speed of the pump to charge the bladder tank until the upper limit of the Start/Stop band is reached, then switches the pump off. The bladder tank, charged to the upper limit of the Start/Stop band, will supply pressurized water until the pressure drops to the lower limit of the Start/Stop band. The controller monitors how fast the pressure drops off and if the controller determines that the actual flow remains less than the Low Flow Stop Limit, the controller will switch on a pump and immediately re-charge the tank again and switch the pump off. This Start/Stop mode of operation will continue until the flow is greater than the Stop Flow Limit (Q_{min}). When flow is greater than Low Flow Stop Limit the controller will switch on the pump and return to normal operation to maintain constant pressure.



What don't some manufacturers tell you?

There are some manufacturers that will not recommend bladder tanks and leave out important information. You need to know that systems without tanks must encounter a zero-flow condition to switch a pump off in order to maintain the system set-point pressure! At low flow rates if there is no bladder tank the set point pressure will immediately drop once the pump is switched off because there is no bladder tank to help maintain the system pressure.

- Results in wasted energy
- Shortened shaft seal life, liquid heats up around seal faces, poorer lubricating properties, even at low speeds
- Liquid in pump has potential to increase in temperature, potential for bacterial growth (even worse when submersible pumps/motors are used)