GRUNDFOS
ECADEMY

DIAPHRAGM TANKS
FOR VFD BOOSTER SYSTEMS

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Learning outcome

After this course, you should be able to:

Understand how the use of diaphragm tanks will reduce variable speed pump energy consumption and increase pump component lifetime.

Understand how the use of diaphragm tanks can increase comfort for the consumer.

Understand how inertia affects motor starting.

Using diaphragm tanks to save pump energy

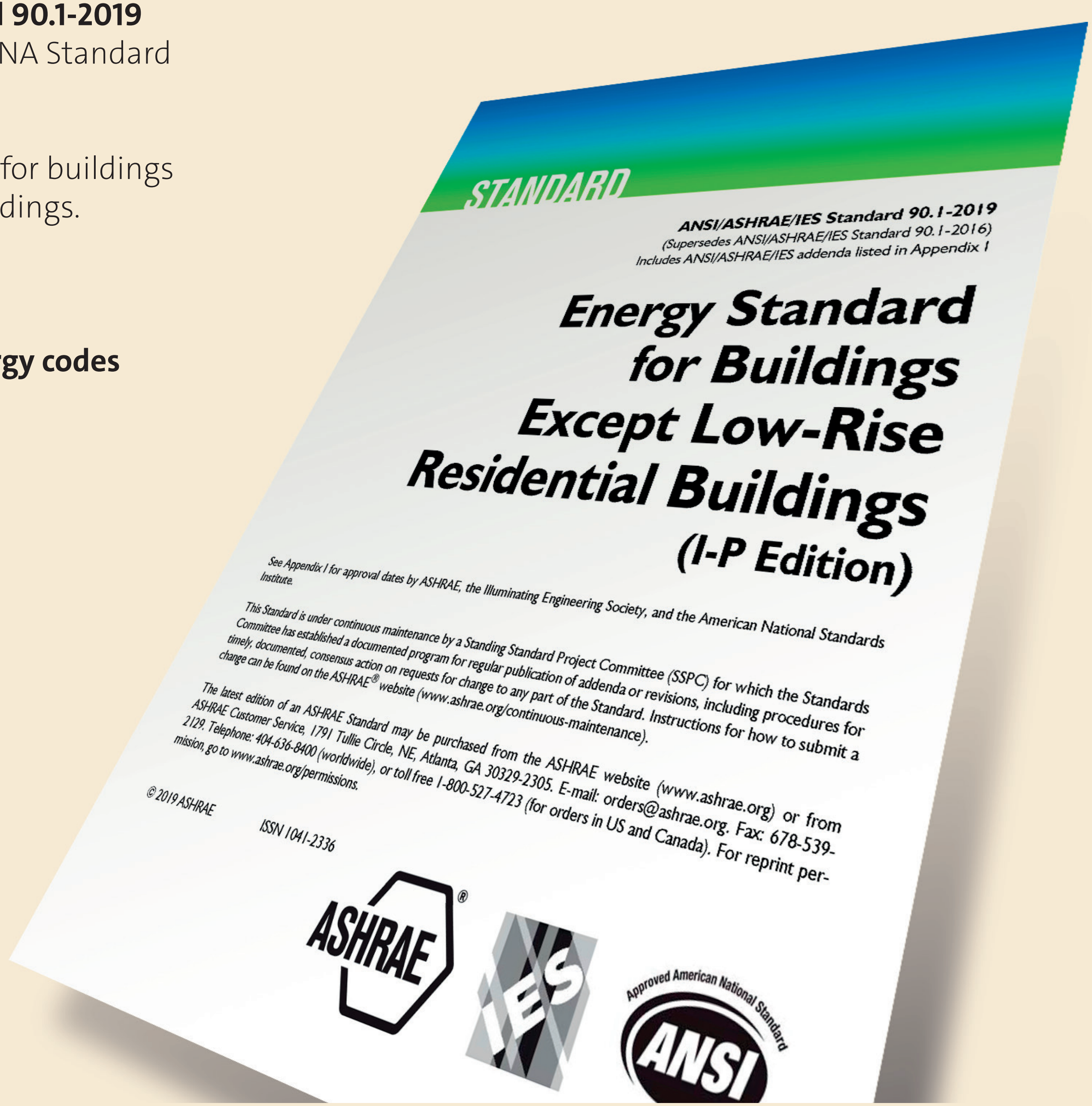
ASHRAE Standard 90.1

ANSI/ASHRAE/IESNA Standard 90.1-2019
(Supersedes ANSI/ASHRAE/IESNA Standard 90.1-2016)

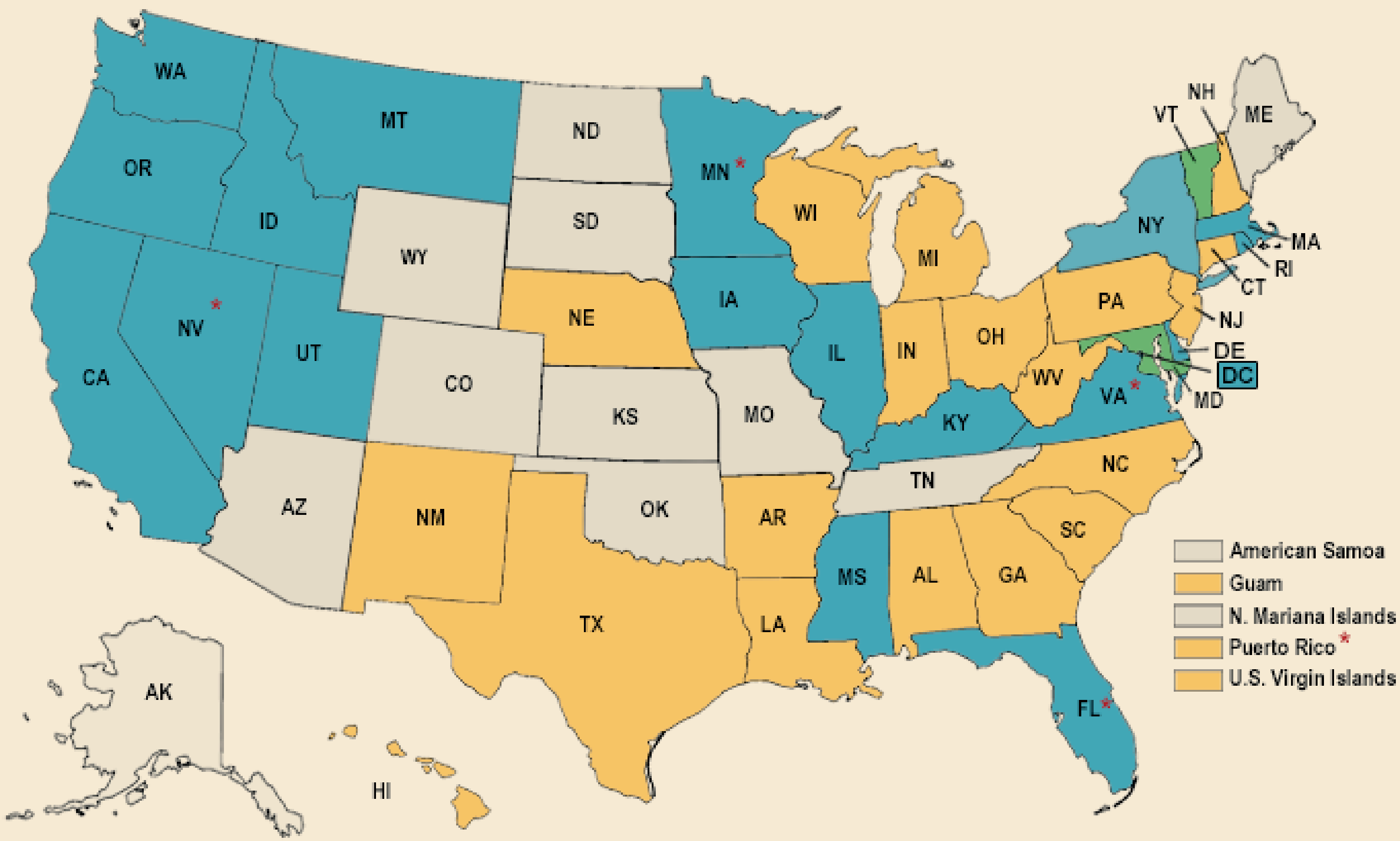
ASHRAE is an energy standard for buildings except low-rise residential buildings.

DOE baseline for building energy codes

- Commercial buildings
- Includes HVAC, lighting, and pressure boosting systems



Status of state energy code adoption



2 ASHRAE 90.1-2013/2015 IECC, equivalent, or more energy efficient

19 ASHRAE 90.1 - 2010/2012 IECC, equivalent, or more energy efficient

22 ASHRAE 90.1 - 2007/2009 IECC, equivalent, or more energy efficient

13 Older or less energy efficient than ASHRAE 90.1 - 2007/2009 IECC, or no statewide code.

* Adopted new Code to be effective at a later date

As of March 2015

What's relevant to pressure boosters?

ASHRAE Standard 90.1 (2010 or later)

Section 10.4.2
Requirements for service water pressure booster systems are as follows:

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

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

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

No flow shut down

Low/no-flow shutdown

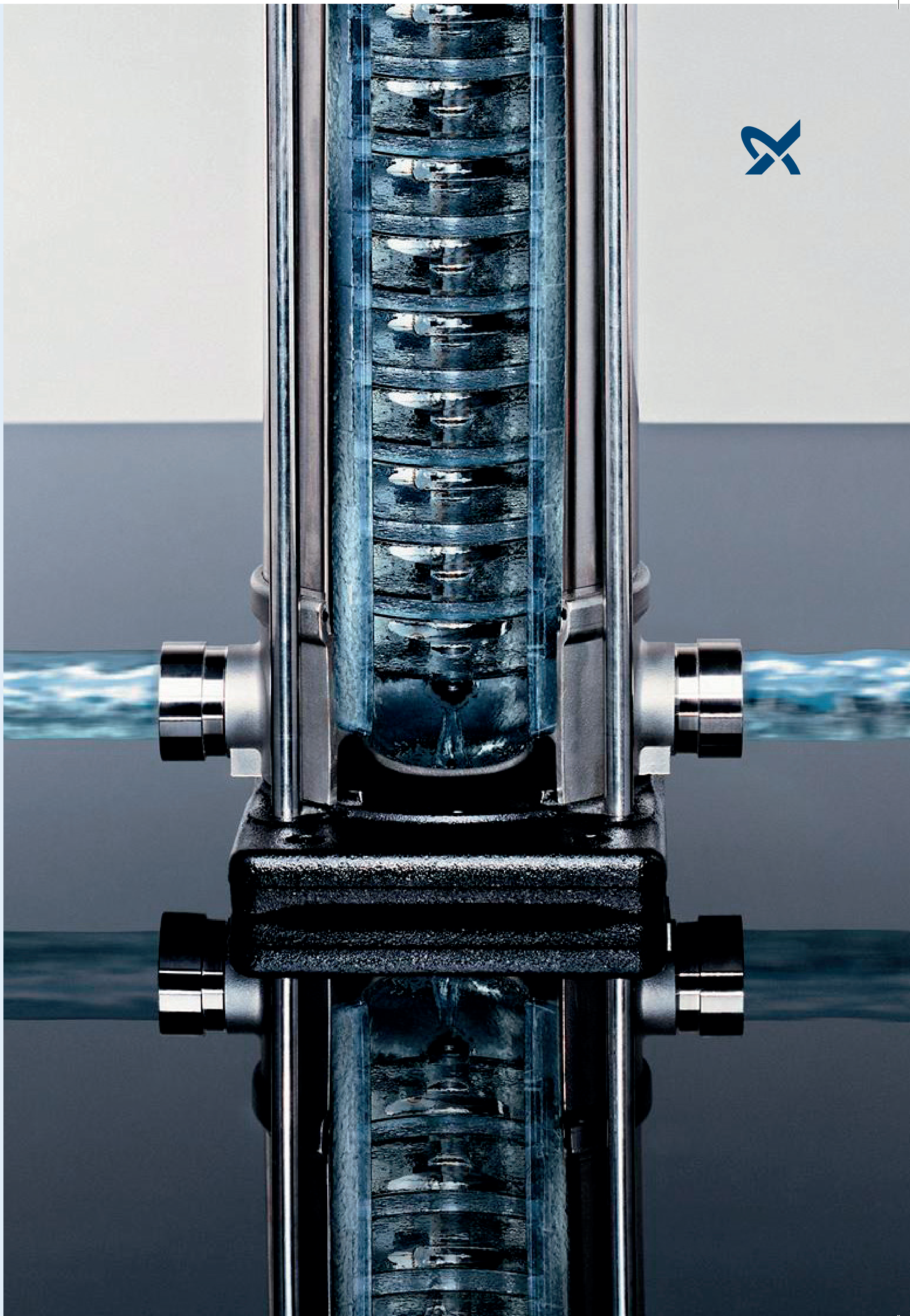
Section 10.4.2
No booster system pumps should operate when there is no service water flow.

Why is this recommended?

- To save energy

Other benefits:

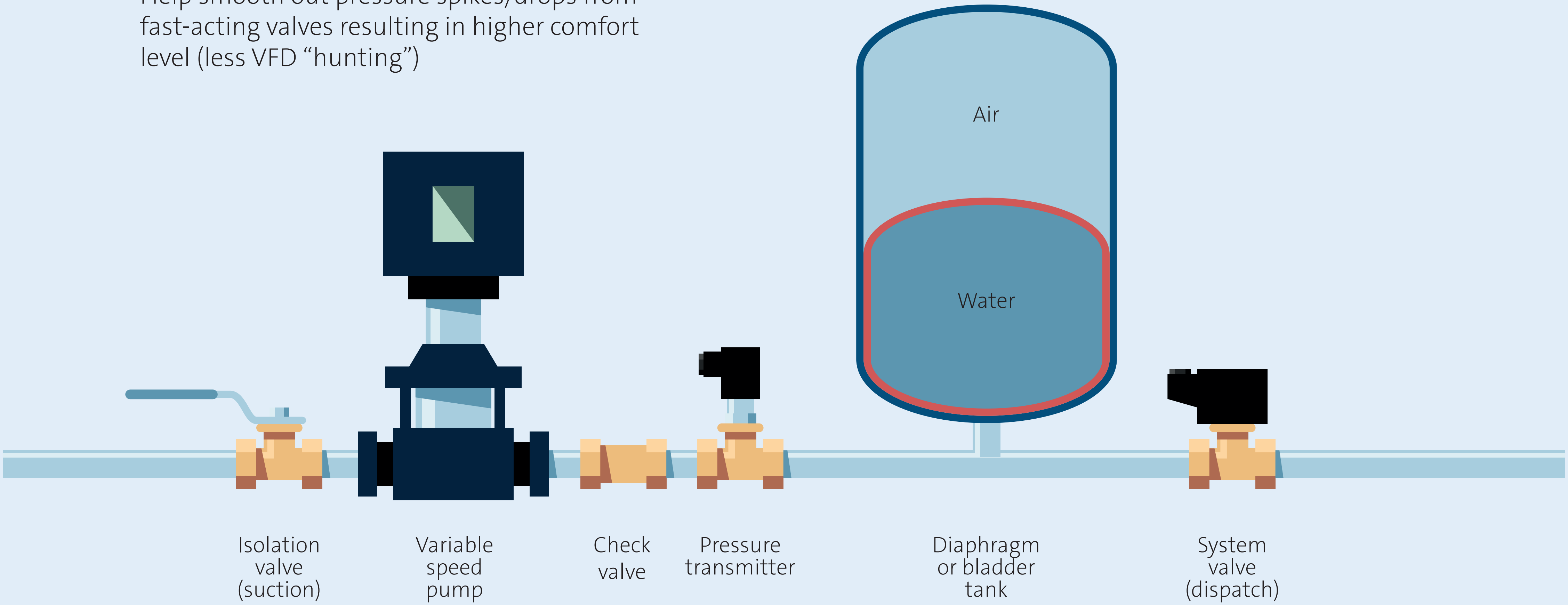
- Avoid heating up the water
- Increase pump component lifetime (shaft seals and so on)



Low-flow operation – Variable speed pump

Purpose of diaphragm/bladder tank:

- Store a small amount of water enabling pump shutdowns
- Help smooth out pressure spikes/drops from fast-acting valves resulting in higher comfort level (less VFD “hunting”)



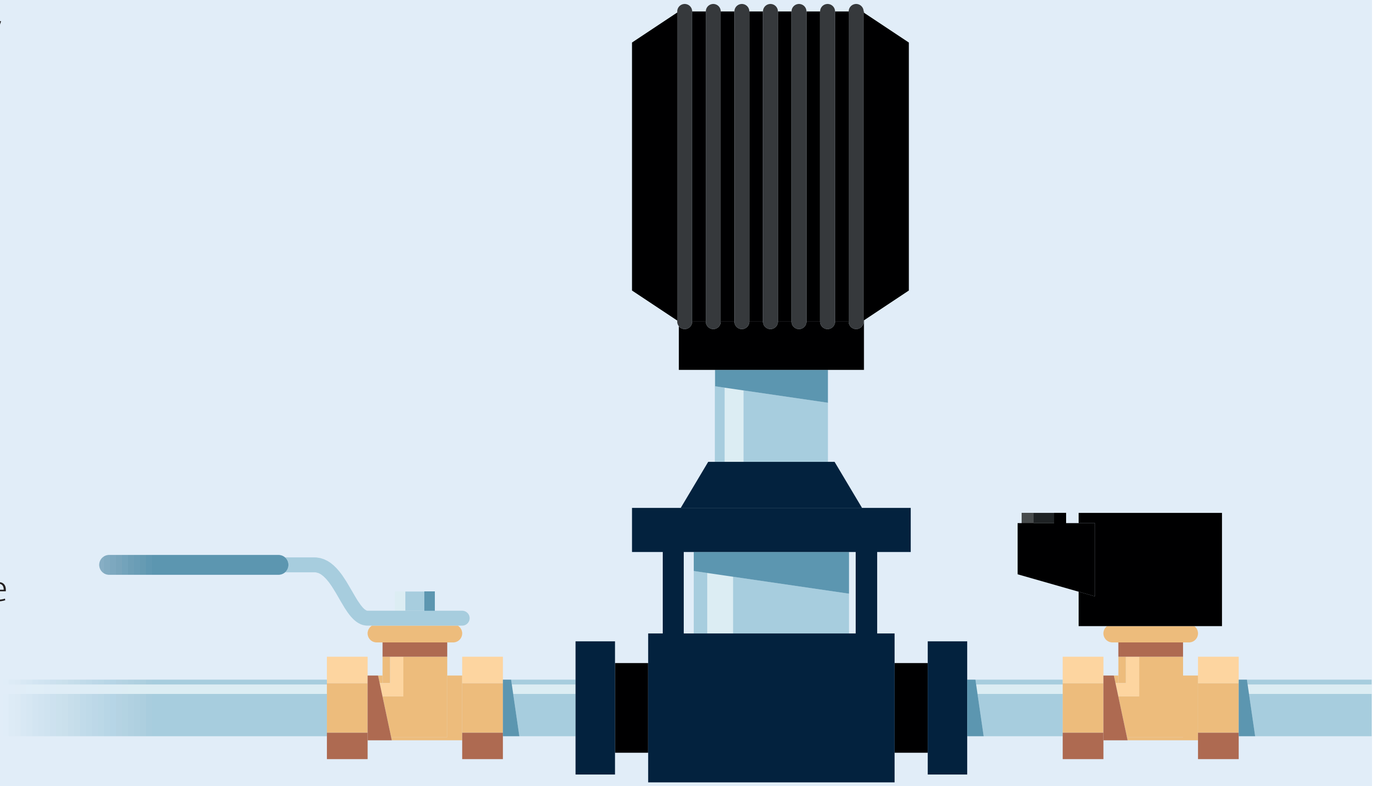
Low-flow operation – Variable speed pump

What about systems that do not use bladder tanks?

A tankless system must encounter a zero-flow condition to switch off a pump in order to maintain the system setpoint.

This has several consequences:

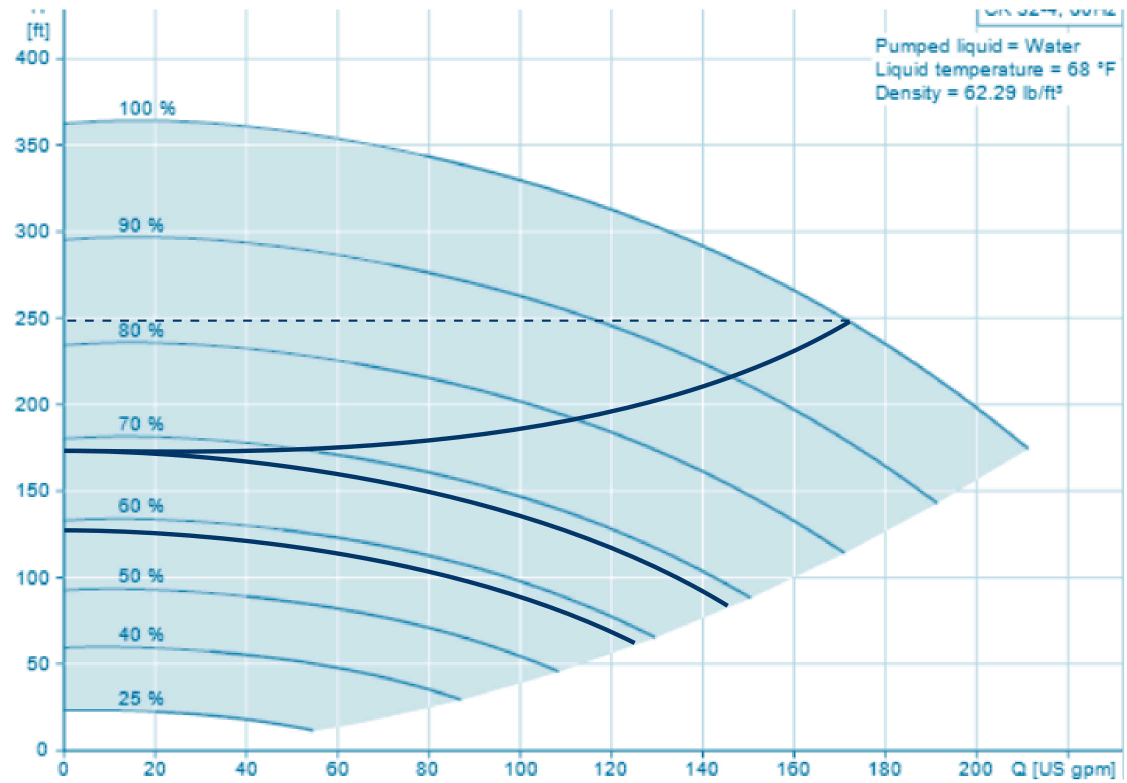
- Wasted energy
- Shortened shaft seal life, as liquid heats up around seal faces, resulting in poorer lubricating properties, even at low speeds
- Liquid in the pump has potential to increase in temperature, as well as potential for bacterial growth (even worse when submersible pumps/motors are used)



Low-flow operation

Without the use of a bladder tank, many tankless systems detect zero-flow conditions based on drives running at a minimum frequency for a set period.

Some systems utilize temperature measuring devices for low-flow detection.



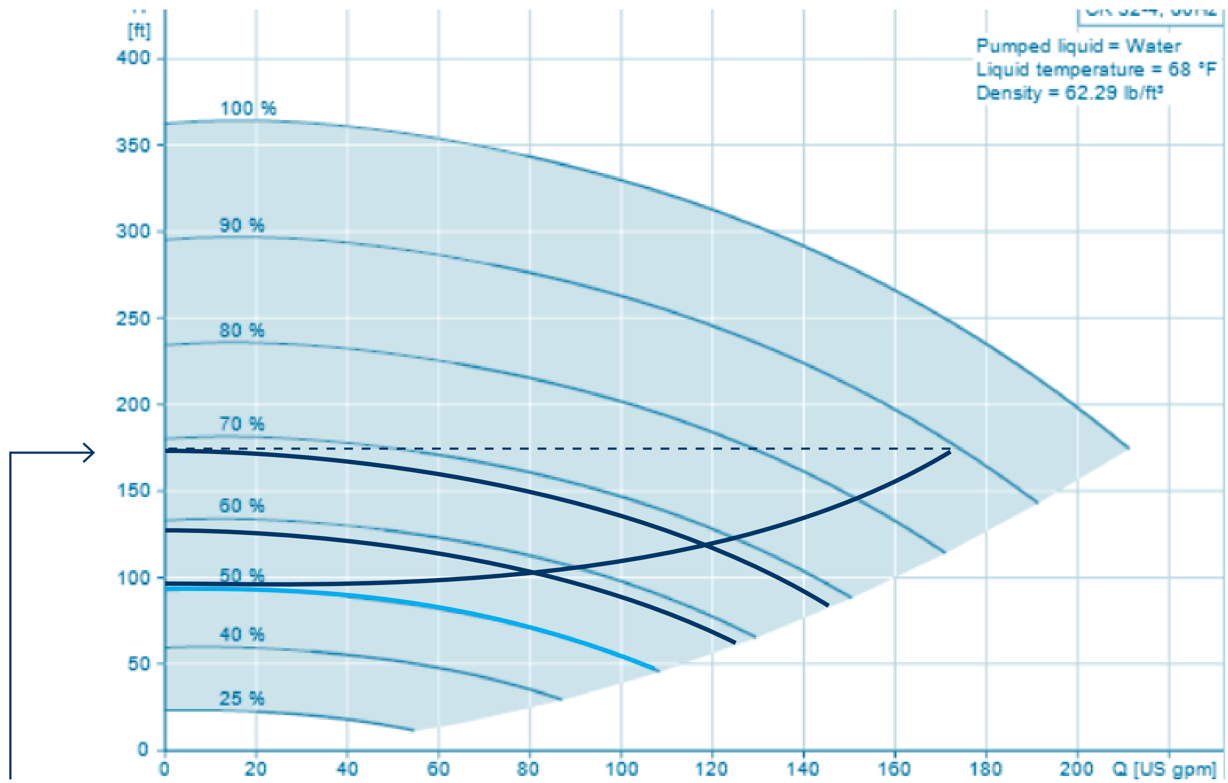
Min. boost required: 170’

Low-flow operation

What if the inlet pressure changes or is higher than expected?

Be aware of frequency-based no-flow shutdowns.

Can result in inconsistent pressure, wasted energy, pumps may run constantly against a closed valve, adding heat to the liquid, poor seal lubrication, shortened pump component lifetime.

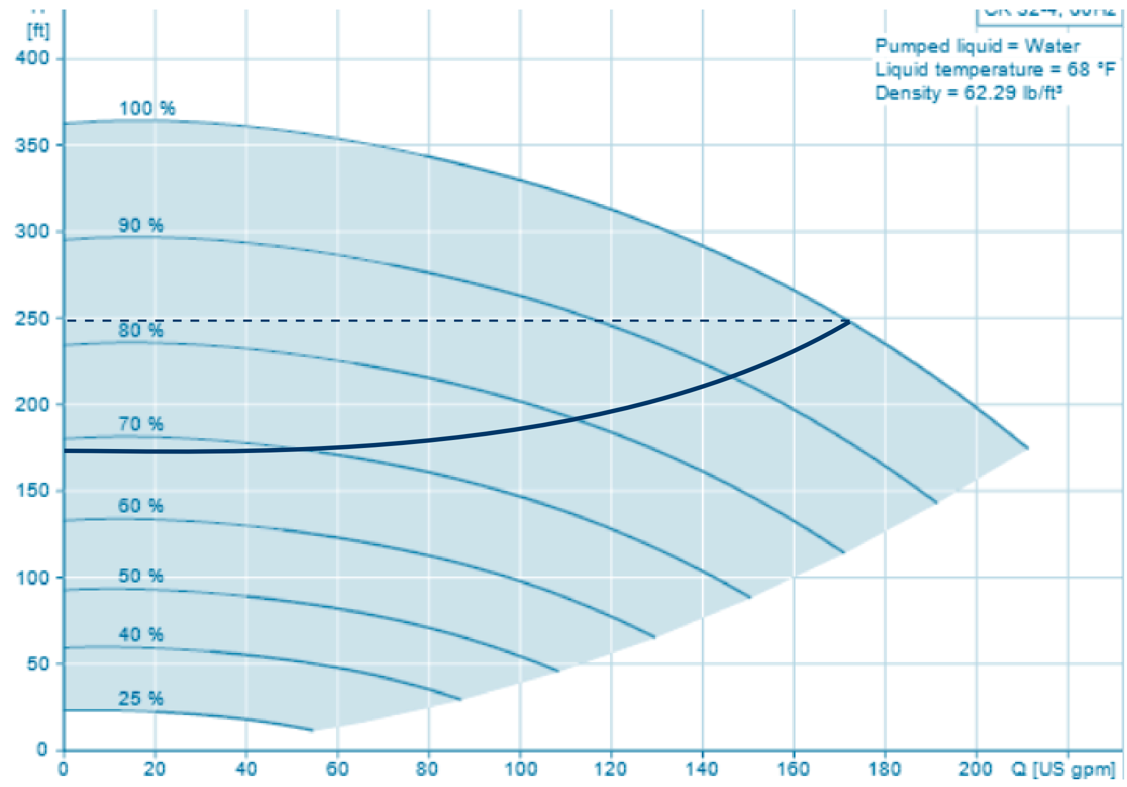


New min. boost required: 100’

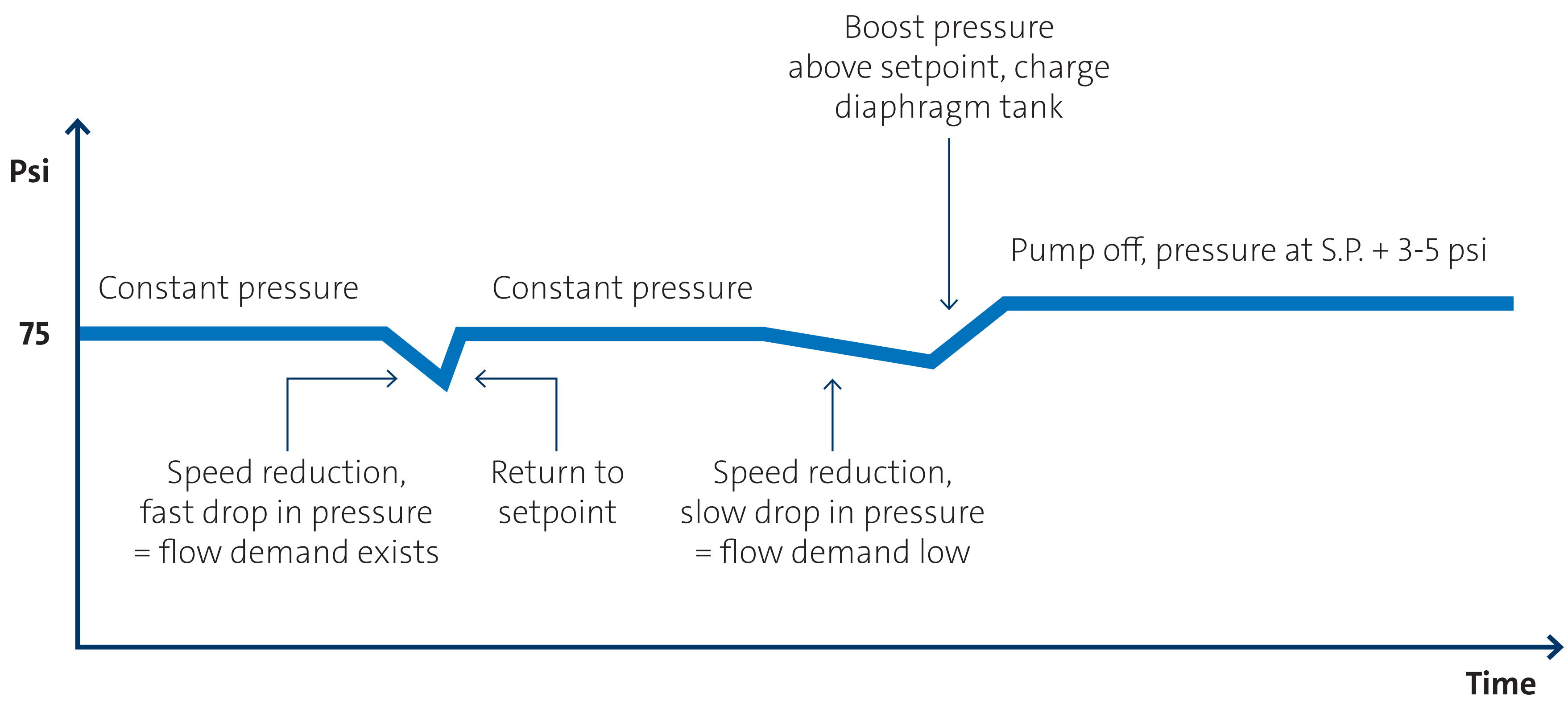
Low-flow operation

Try to utilize low-flow detection before pump runs against a closed valve.

How? Use a flow switch, flow sensor or intelligent pump logic.

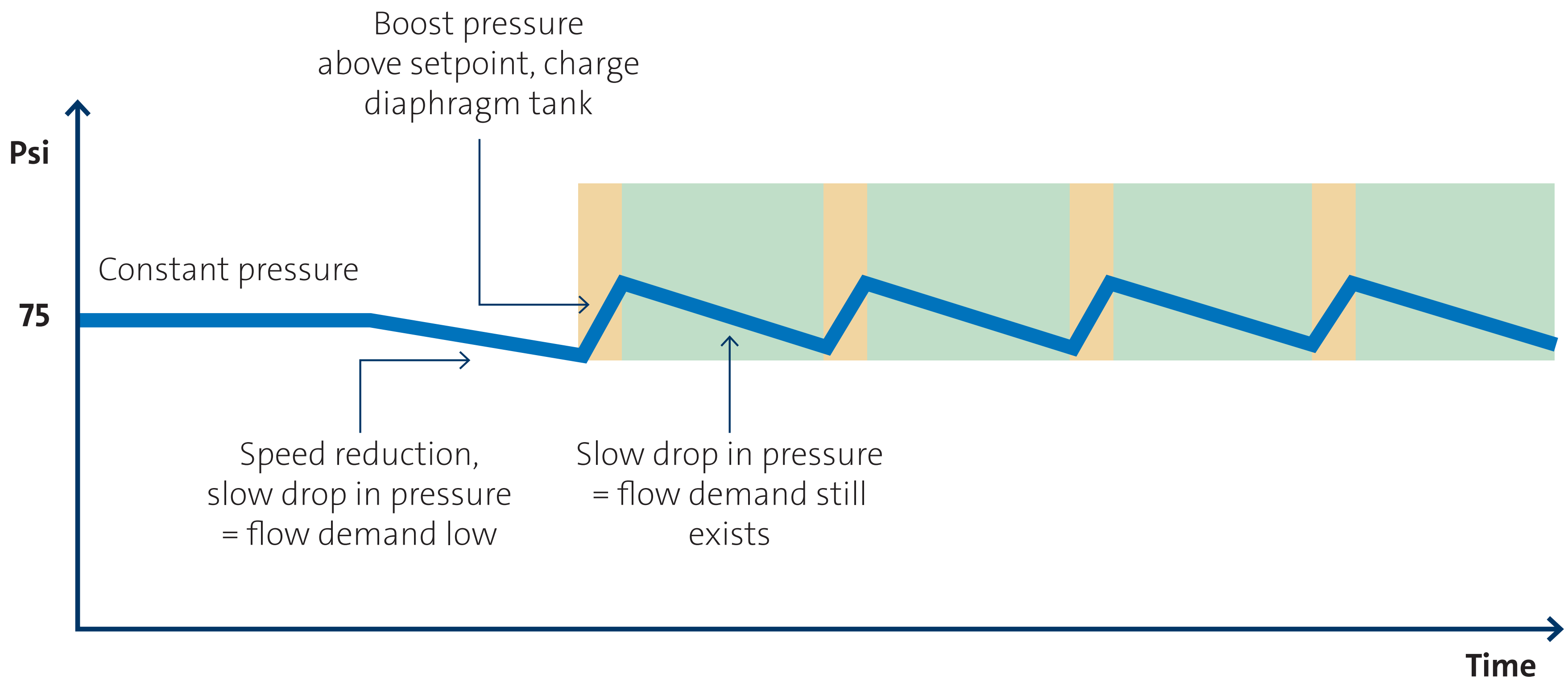


Low-flow operation – Variable speed pump



Low-flow operation – Variable speed pump

Energy savings with on/off operation



Low-flow operation – Variable speed pump

The best way to demonstrate the potential energy savings is to get actual data from an actual pumping system.

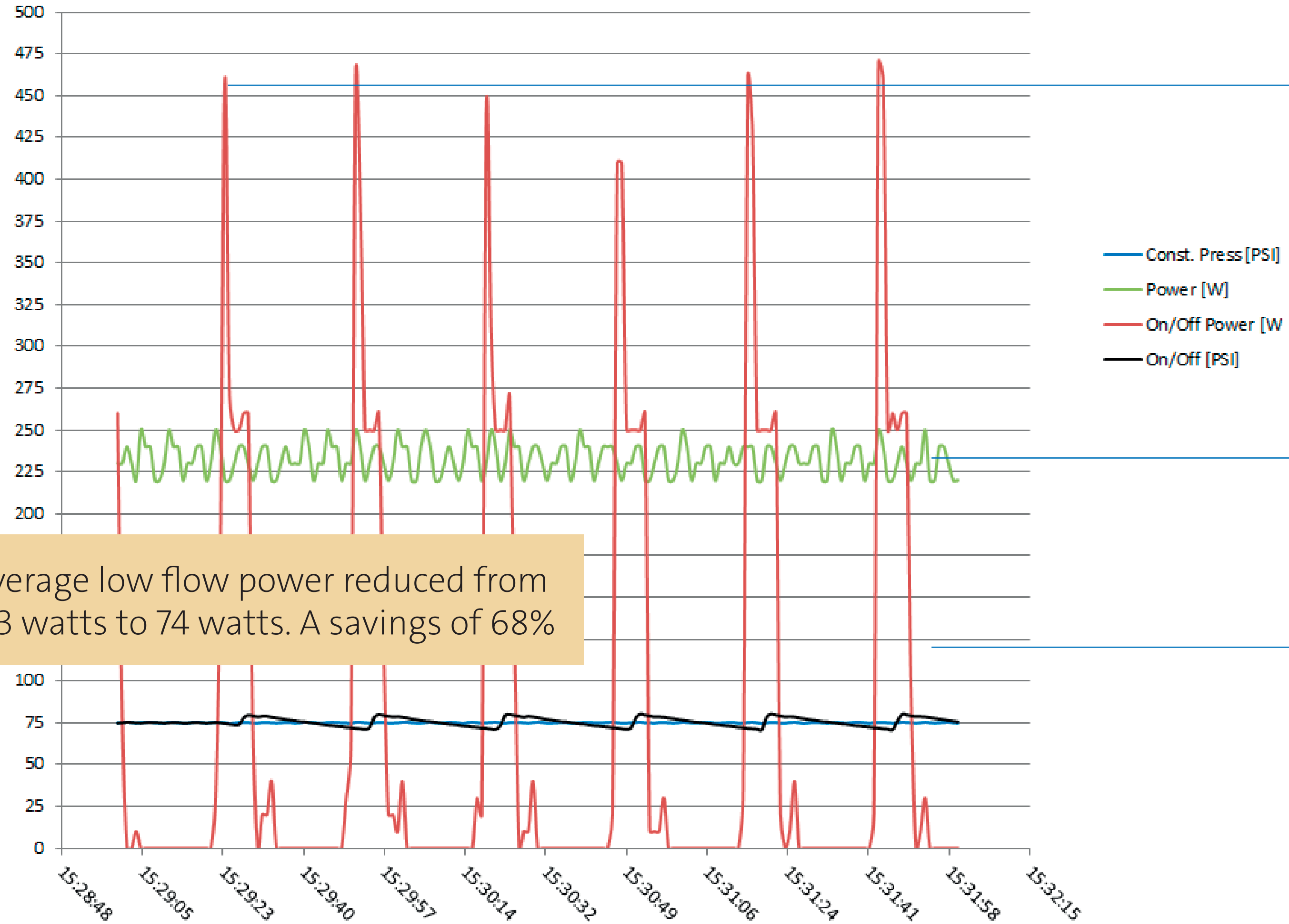
The following information is from a small-pressure boosting system:

- Pump type: Vertical multistage
- Motor size: 1.5 hp
- Pump inertia: 0.003 lb-ft2
- Nominal flow: 25 gpm
- System setpoint: 75 psig
- Diaphragm tank size: 4.4 gallon
- Tank pre-charge: 50 psig

Low flow settings:

- Low flow detection: 2 gpm
- Pump start pressure: 71 psig
- Pump stop pressure: 79 psig

Energy comparison at 2 gpm, on/off vs. continuous run



More power to boost tank, for a very short period of time

Avg. continuous power at 233 watts

Average low flow power reduced from 233 watts to 74 watts. A savings of 68%

Setpoint = 75 psi
On/off band = 5%
71-79 psi, starts
27 seconds apart

Motor starts per hour

That's a lot of "short cycling", isn't that bad for motors?

That all depends on the load being started.

Allowable motor starts per hour is a function of the inertial load to be turned.

When a motor starts, the starting current (aka inrush current) can be 5-10 times full load current.

The higher the inertia, the longer it takes to get the motor to running speed.

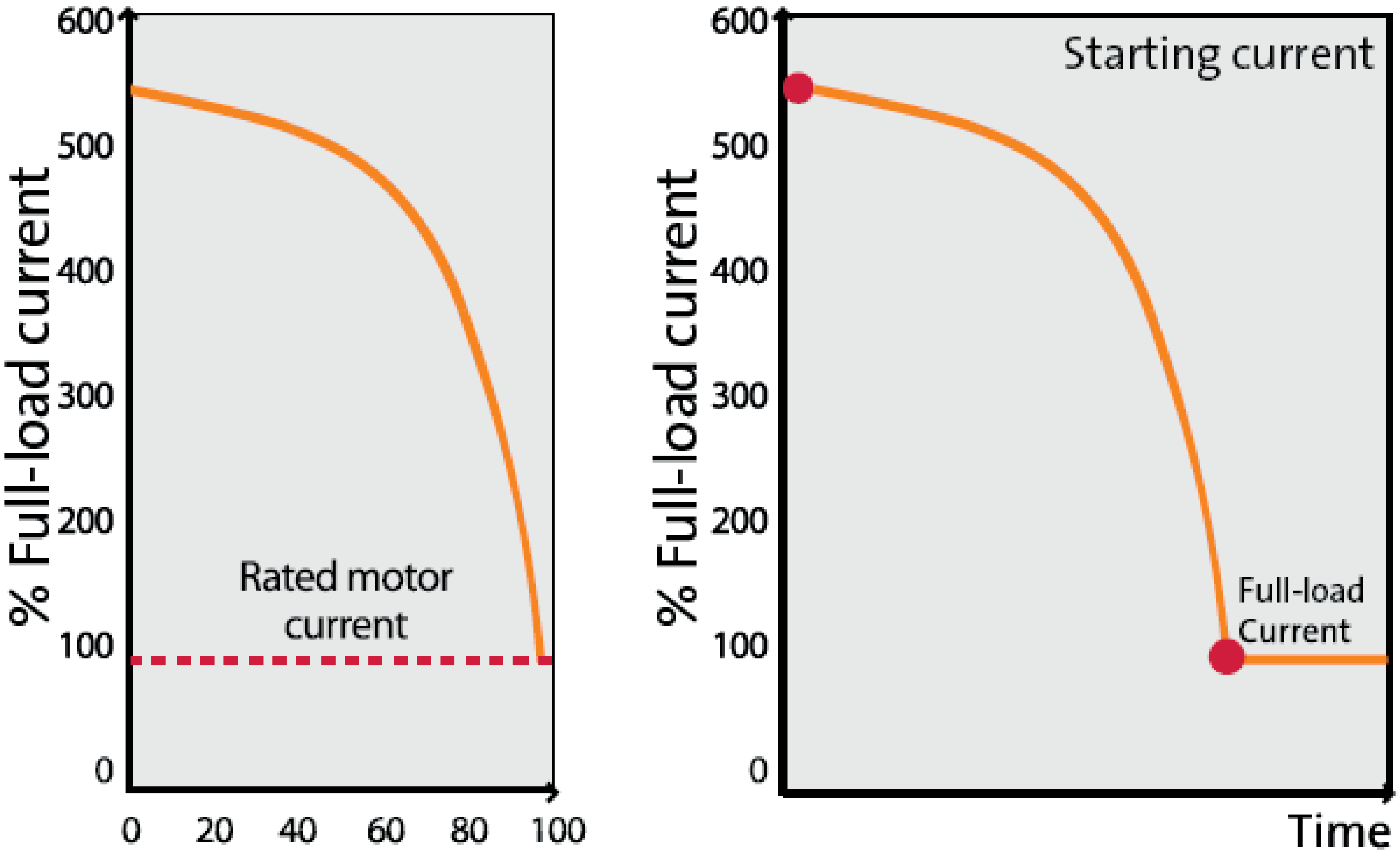
Since current is high for longer periods of time on high-inertia loads, more heat is generated during starting.

High inertia: More heat

Low inertia: Less heat

Allowable starts per hour

Rated motor current during acceleration

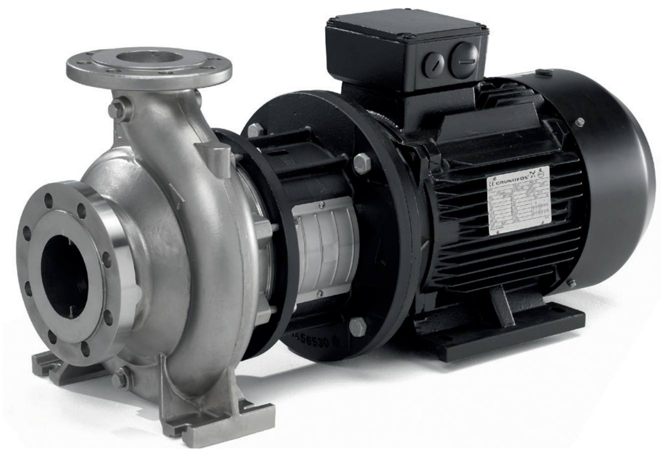


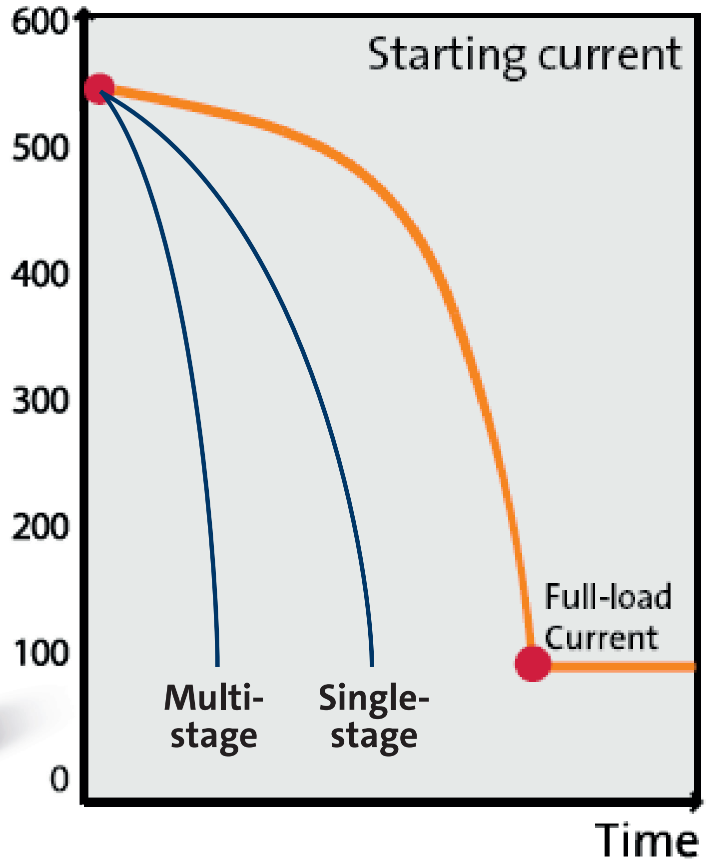
Impact of inertia on starting time

NEMA Guidelines
General purpose

Single stage pumps
Medium to low inertia

Stainless steel multistage pumps
Low Inertia





Inertia comparison

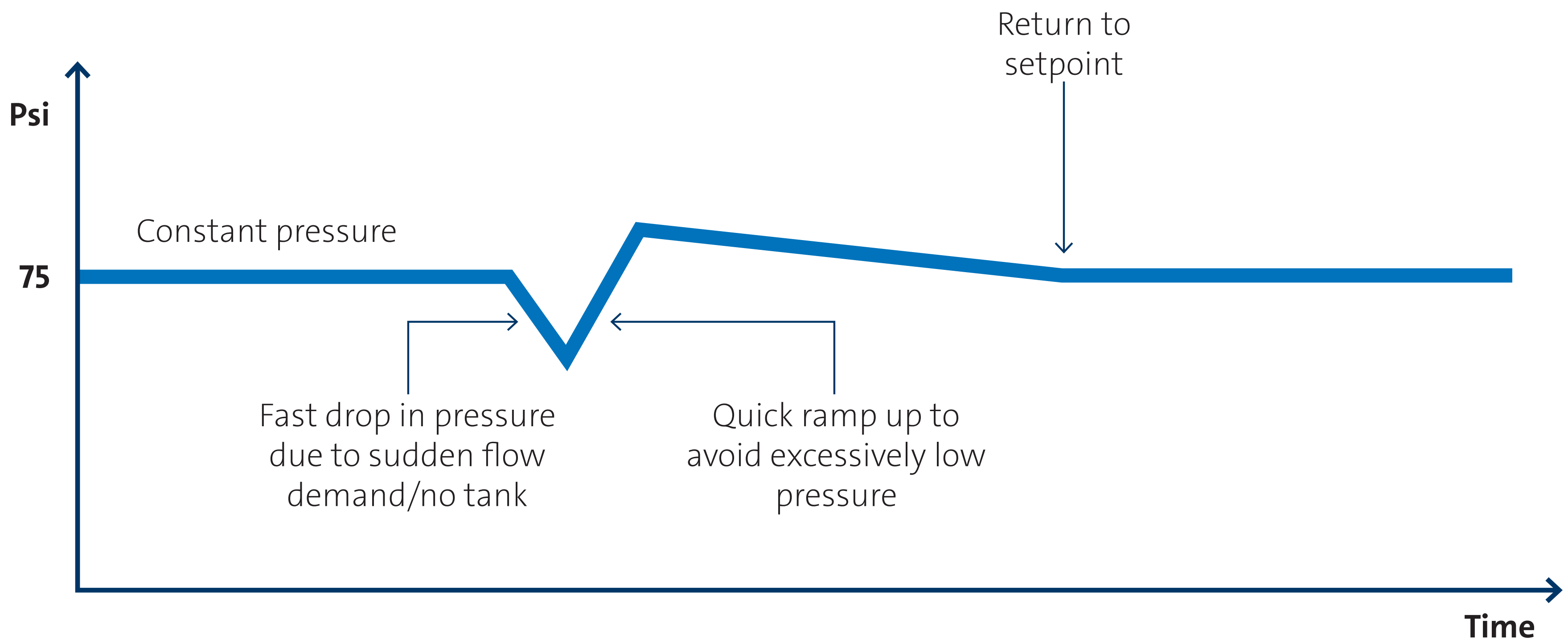
- For the 5hp motor, the vertical multistage pump has 1,425 times less inertia than what NEMA requires for motor design, 107 times less inertia for the 15 horsepower
- The single-stage pump has 30 times less inertia for both motor sizes.
- With such low inertia, the allowable starts per hour for multistage pumps can be much higher than what the typical motor O&M manual suggests
- The allowable starts per hour for a motor should be based on the actual load the motor is connected to - this requires information from the pump manufacturer

	5 hp	15hp
NEMA MG1, Table 12-7	5.7 lb-ft^2	16 lb-ft^2
Single-stage end suction close-coupled	0.19 lb-ft^2	0.52 lb-ft^2
Vertical multistage (stainless steel)	0.004 lb-ft^2	0.15 lb-ft^2
Canned turbine (multistage)	0.34 lb-ft^2	

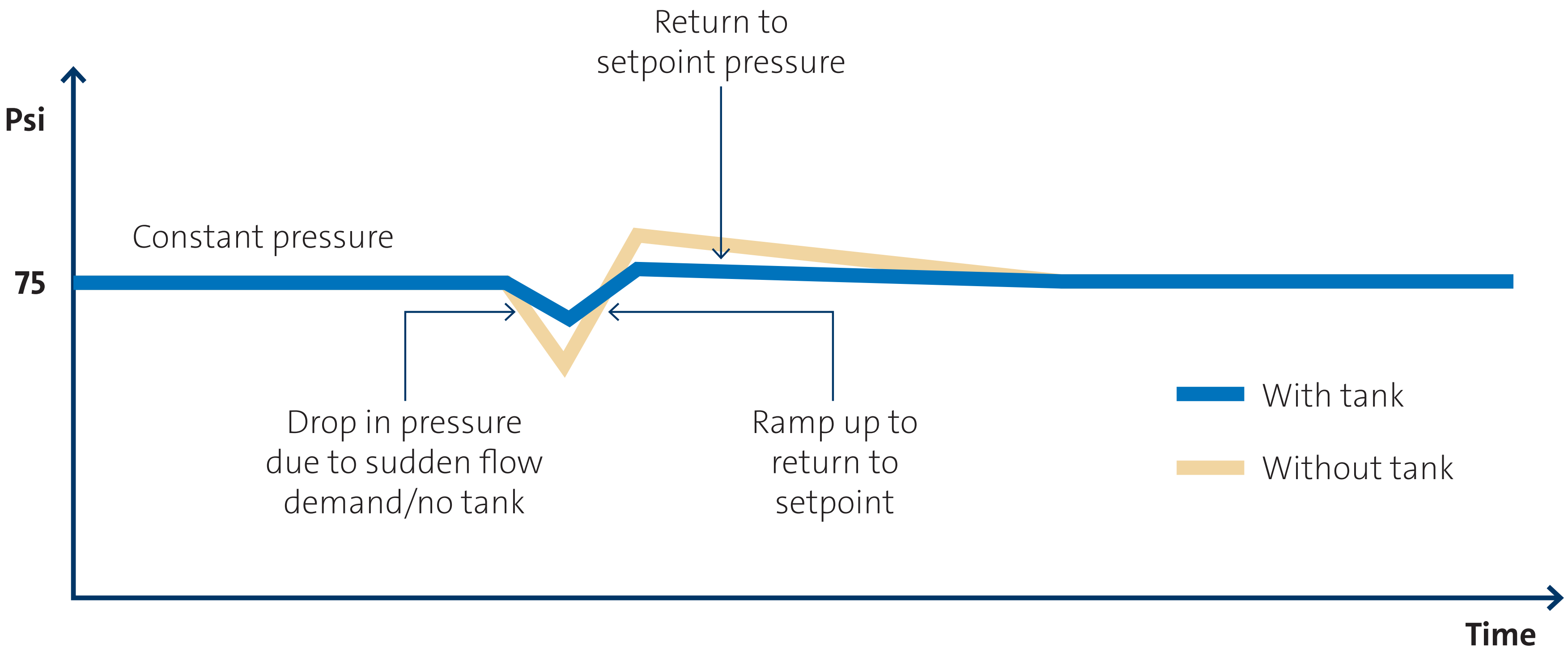
Most importantly, this is all based on across-the-line starting. VFD starting is much more forgiving, peak current is no greater than motor full-load current.

Achieving high comfort levels using diphragm tanks

Constant pressure – Variable speed pump without diaphragm tank



Constant pressure – Variable speed pump with diaphragm tank



Typical diaphragm tanks sizes for variable speed booster systems

Pump nominal flow* [gpm]	Nominal tank volume [gallons]
30	5 - 9
60	8 -18
90	14 -27
150	23 -45
200	30 - 60
300	45 - 90
500	75 - 150

*Nominal flow of each pump, not station flow

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