

# Design Envelope Booster

## Sequence of operation

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## GENERAL

The packaged domestic water booster system is controlled by a dedicated panel, which contains the electric power distribution switchgear and a PLC based controller.

Pumps are sequenced on and off and their speed adjusted up and down, operating in parallel at the same speed, to maintain a constant system pressure (at discharge or remote) while satisfying varying flow demands, using minimum energy.

The operation Modes include Soft Fill, Normal, Remote Sensor, No Flow Shutdown, Pressure Setback and Emergency Power.

The panel operates packages with or without a standby pump, and the Number of Pumps can be 2, 3, 4 or 5 for all duty pumps packages, and 3, 4 or 5 for packages with a standby pump. i.e., the maximum number of pumps is 5 in all cases.

Every 24 hours of operating time, which is adjustable using the Lead Pump Switch Timer, the controller automatically alternates the lead pump and sequencing order between all pumps, including the standby pump, if present.

The panel has a Programmable Logic Controller (PLC) which is configured, monitored and operated via Armstrong branded HMIs.

The PLC has a single program which can be configured to run all pump combinations.

The PLC small communicates with the pump Variable frequency drives (VFDs) via Modbus RTU serial communication using the integrated FieldBus port or the FieldBus card. The program uses the drive feedback speed for all calculations.

The panel is able to provide optional BMS/BAS communication via Modbus RTU, Lonworks, BACnet (MS/TP) or BACnet (IP/ENET) protocols.

For Normal operation, all VFDs are required to be set in auto mode from their Local Control Panel (LCP) and each pump is required to be set in Auto mode from the booster HMI.

The running pump(s) speed is PID controlled in all modes of operation.

Password protected set up screens: The set up screens are password protected to reduce tampering in the field. Two (2) levels of password protection are provided. Level 1 allows the user to change the operating parameters and restore them to the factory defaults, but not save as factory defaults. Level 2 allows qualified personnel to change the operating and system parameters and allows restoring or saving the factory defaults.

**Parameter definition:** (min, max, default) or (selection 1, selection 2, selection n) default.

### NOTE:

Pressure units default to psi, but users can also select bar, kPa, ft and m.

### Factory adjustable settings

- Number of pumps (2, 5, based on package configuration)
- Standby pump (YES or NO, NO)
- Level switch 1 (ENABLE or DISABLE, DISABLE)
- Level switch 2 (ENABLE or DISABLE, DISABLE)
- Drive type (FC102 or ECM, FC102)
- Motor frequency (50 or 60, 60) Hz
- Lead pump switch time (1, 168, 24) hours of lead pump operation time
- Pump rated power (0.7, 45.0 based on package configuration) kW
- (Pressure) Units (psi, ft, kPa, m, bar) psi
- Suction pressure sensor (ENABLE or DISABLE, ENABLE)
- Suction pressure sensor Range (0, 3200, 300) psi
- Discharge pressure sensor (ENABLE or DISABLE, ENABLE)
- Discharge pressure sensor Range (0, 3200, 300) psi
- Remote pressure sensor (ENABLE or DISABLE, DISABLE)
- Remote pressure sensor range (0, 3200, 300) psi
- Local discharge pressure setpoint (0, max working pressure, based on order) psi.
- Remote discharge pressure setpoint (0, max working pressure, based on order) psi. It appears only if the Remote sensor is enabled.
- System discharge pressure setpoint (it's one of the previous two (depending on which sensor is selected as Control sensor) or one of six the Alternate discharge pressure setpoints (depending on PLC digital input selection))
- (Choose) Control sensor (LOCAL or REMOTE, LOCAL)
- **Update limits** or **Auto set pressure limits** updates (sets up) all pressure limits and No flow shutdown boost pressure proportionally to the System discharge pressure setpoint.
- High suction pressure Limit (low suction pressure shutdown + 5, max working pressure, System discharge pressure setpoint - 10) psi. It is updated (setup) by pressing **Update limits**. High suction pressure limit (ENABLE or DISABLE, DISABLE).
- Low suction pressure limit (0, System pressure setpoint, 5)

- psi. It is updated (setup) by pressing **Update limits**.
- High discharge pressure limit (low system pressure + 5, max working pressure, System discharge pressure setpoint + 15) psi. It is updated (setup) by pressing **Update limits**. High discharge pressure limit (ENABLE or DISABLE, DISABLE).
  - Discharge High Alarm Auto/Manual Reset (Manual or Auto, Auto).
  - Discharge High Alarm Delay (1,15,10) sec
  - Emergency power mode low discharge pressure limit (0, System Discharge Pressure Setpoint \* 0.5, System discharge pressure setpoint \* 0.2). It is updated (setup) by pressing **Update limits**.
  - Factory high system shutdown pressure (0, 3276.7,200) psi. It is Maximum Working Pressure based on package configuration.
  - Low discharge pressure limit (0, System discharge pressure setpoint \* 0.8, pressure setback at start \* 0.8) psi. It is updated (setup) by pressing **Update limits**.
  - Number of alternate discharge setpoints (0, 6, 0)
  - Alternate discharge pressure setpoint 1 to 6 (0, max working pressure, system discharge pressure setpoint) psi.
  - Emergency power mode (ENABLE or DISABLE, DISABLE)
  - Number of running pumps in emergency (0,5,1)
  - EOC (End of Curve) protection (ENABLE or DISABLE, DISABLE)
  - EOC (End of Curve) Head coefficient (0, 100, 90)% of Local discharge pressure
  - Aquastat protection (ENABLE or DISABLE, DISABLE)
  - Airlock protection (ENABLE or DISABLE, DISABLE)
  - Airlock shutdown pump power setpoint (0 to 30, 15) % Pump rated power
  - Airlock shutdown delay (0, 600, 20) sec
  - Pump stage on speed (33, 100, 100) % speed
  - Pump stage off by selector (speed, power, speed or power, speed and power), default is speed or power
  - Pump stage off speed (33, 98, 70) % speed
  - Pump stage off power (70, 200, 90) % power (See normal mode for description)
  - Pump stage on delay (0,999,10) seconds
  - Pump stage off delay (0,999,30) seconds
  - Soft fill mode (DISABLE or ENABLE, ENABLE).
  - Soft fill pressure setpoint (20, 100, 30) % of System discharge pressure setpoint
  - Soft fill Ramp time (0,999,120) seconds
  - No flow shutdown (DISABLE or ENABLE, ENABLE).
  - No flow shutdown delay (0,999,300) seconds
  - No flow shutdown speed/power (POWER or SPEED, POWER)
  - No flow shutdown speed/power (0, 100, 95) % Power/speed
  - No flow shutdown wait time (0,999,60) seconds
  - No flow shutdown set speed (0, 100, 70) % speed
  - No flow shutdown boost pressure (0, max working pressure - System discharge pressure Setpoint, 5) psi. It is updated (setup) by pressing **Update limits** after Pressure units are selected. Setup is 5 psi or 11 ft or 35kPa or 3.5m or 0.34bar.
  - Pump minimum speed setpoint (0, 98, 40) % speed
  - Pump maximum speed setpoint (0, 100, 100) % speed
  - Pump ramp (5, 15, 15) seconds
  - Pump default speed (0, 100, 70)% when all discharge sensors fail and the aquastat is enabled
  - Pump motor rated RPM (0, 9999, 3600) rpm
  - PLC PID proportional gain (1, 99, 10) %/sec
  - PLC PID speed up limit (0.2, 99.9, 1.0) %/sec
  - PLC PID speed down limit (0.2, 99.9, 3.0) %/sec
  - Pressure setback (ENABLE or DISABLE, ENABLE)
  - Pressure setback setpoint (80, 100, 85) % of System discharge Pressure setpoint
  - Pressure setback control mode (LINEAR or QUADRATIC, QUADRATIC)
  - BAS Interface setup: Protocol (Modbus or Lonworks or BACnet MSTP or BACnet IP or none, none), Node (1 to 128, 1), Baud (9600 to 115200, 19200)
  - FieldBus setup: Source (Fbus2, Fieldbus Card, Fbus2)
  - Pump Model (Current Pump Model).
  - Design flow (number). It is the (Maximum) Design flow of the Booster system.
  - Design flow unit ((US GPM, UK GPM, m<sup>3</sup>/hour, l/sec), US GPM).
  - (Display) flow units ((US GPM, UK GPM, m<sup>3</sup>/hour, l/sec), US GPM) – Not Important, setup by a customer.
  - Flow offset (0.75, 1.2, 1.0) adjust the calculated flow to the measured flow.

## OPERATION

On startup and after any power outage, the system starts in Soft Fill Mode, and in Normal Mode when restarting from No Flow Shutdown.

## MODES

### Soft fill mode

This can be enabled or disabled, with enabled as default. When the booster is powered up, the lead pump starts. The System Discharge Pressure Setpoint increases in a linear ramp, starting at the Soft Fill pressure Setpoint or the real discharge pressure whatever is higher at a rate of  $((\text{System Discharge Pressure Setpoint} - \text{Soft Fill Pressure Setpoint}) / \text{Soft Fill Ramp Time})$ , until the pressure reaches the System Pressure Setpoint or the Pressure Setback Setpoint (if Pressure Setback Mode is enabled), then the booster switches to Normal Mode.

During Soft Fill Mode, Low System Pressure Alarm & Shutdown and EOC Protection are disabled.

### Normal Mode:

In Normal Mode the booster system adjusts the pump(s) speed and adds or sheds pumps to maintain system pressure at the active setpoint.

When the system is switched on the lead pump is started. The program stages on a new pump, when the existing pump(s) are all running at same speed and have/has reached its Maximum Speed Setpoint or any pump has reached the pumps motor nameplate power for the Stage On Delay Time. All pumps runs at same speed except during a pump ramp time. Speed is not increased if any running pump nameplate power is reached (next pump starts).

The program switches off a pump, after the Stage Off Delay time if the pumps speed is less than the Stage Off Speed and/or disconnection of one pump will cause the remaining pump(s) power to be less than the Pump(s) Stage Off Power. The speed or power condition also can be disabled. (The stage off selector settings: Speed, Power, Speed or Power, Speed and Power)

The program continues to regulate the pressure until there is no demand, as defined by the No Flow Shutdown Mode, if enabled, and the booster pumps are stopped. When the pressure drops 5 psi below the Active Discharge Pressure Setpoint, the lead pump is started again in Normal Mode.

Alternation of the Lead pump takes place after the adjustable Lead Pump Switch Time operation period. Automatic alterna-

tion changes the lead pump to the last lag and the first lag becomes the lead, and so on through any additional pumps. If the first lag pump is off at the time of alternation, it starts and ramps up speed to that of the lead pump and then the lead pump is staged off (after it has completed its pump Stage Off Delay time). If the system includes an optional standby pump, the controller exercises the standby pump as a part of the system and all pumps run equally.

Activation of any of the Alternate Setpoint digital inputs 1 to 6 (4, 5 and 6 are not available when aquastat, and float switches 1 and 2 respectively are connected) changes the System Discharge Setpoint to the corresponding Alternate Setpoint. This option is available with Local and Remote System Control Sensor selections, and with Pressure Setback. If more than one Alternate Setpoint digital input is active the one with the lowest index is used.

### Remote Sensor Mode

This can be enabled or disabled, with disabled as the default. The booster system runs as per normal mode with the exception that the booster maintains the System Discharge Pressure Setpoint based on the remote sensor value and Remote Pressure Setpoint and Pressure Setback Mode is disabled. Upon indication that there is a remote sensor failure, the system automatically disables the Remote Sensor Mode, provide an alarm indicating a remote sensor failure and switch to the Local Pressure Setpoint as the basis for the System Discharge Pressure Setpoint. If the local and remote sensors fail simultaneously (or not enabled) and the aquastat is enabled, then all available pumps run at the adjustable Default Speed (70.0 %).

### No Flow Shutdown Mode

This can be enabled or disabled, with enabled as the default. If the booster is running on the lead pump only and at or below No-Flow Shutdown Set Speed or Power (field selectable, default: power, 70%), for longer than the No Flow Shutdown Delay Time (default is 300s), the pump speed and discharge pressure values are stored, the speed is reduced by 5% and the No-Flow Wait Timer (default is 60s) is started. If until the wait timer expires the pressure doesn't fall by more than 2 psi, then the controller assumes there is no-flow demand, otherwise it returns immediately to Normal mode. When the no-flow condition is met, the pressure is increased by the No-Flow Shutdown Pressure Boost (default is 5 psi) and the lead pump is shutdown after Pressure Boost is met or Boost time of 2 minutes has passed. When the pressure drops 5 psi below the Active Discharge Pressure Setpoint, the lead pump is started in Normal Mode.

### Pressure Setback Mode

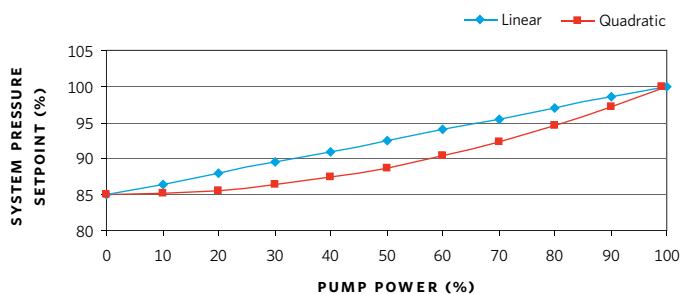
Pressure setback mode can be enabled (default) or disabled.

Pressure setback is the adjustable reduction of the System Discharge Pressure Setpoint. This feature decreases the System Discharge Pressure Setpoint relative (Linear or Quadratic) to the pumps power. When the pumps consume no power, the pressure setpoint is reduced to **Pressure setback setpoint** percent value. When all the pumps run at their rated power, the **System Discharge Pressure Setpoint** is the value inputted in the pressure setup screen.

The **Pressure Setback Control mode** is a **Linear** or **Quadratic** (Default) function.

In next examples **Pressure setback setpoint** is setup to 85.0% (Default).

#### PRESSURE SETBACK



### Emergency Power Mode

This can be enabled or disabled, with disabled as the default. When enabled, upon receiving a signal through the Emergency Power digital input, the system only allows to run up to the Number of Running Pumps in Emergency (default is 1). Auto Alternation and Low Discharge Pressure Shutdown is disabled. Low Discharge Pressure Alarm uses the Low Discharge Pressure Setpoint in Emergency Power Mode. When the emergency input signal is not present, after operating in Emergency Power Mode, the booster system switches to Normal Mode after delay of the pump minimum run time (default is 1 min).

### ALARMS AND PROTECTION

The user is able to silence the audible alarm by pressing the reset button on the HMI. The touchscreen HMI options have an alarm log with a minimum of 100 events with time and date stamp where the oldest entry is deleted and overwritten by newer entries, when entries have met their maximum space allowance.

### End-Of-Curve (EOC) Protection

When the eoc Head becomes less than the Full speed eoc head the next pump is staged on, after the user adjustable Stage on timer. An 'eoc' is displayed in the overview screen when active. eoc Head is defined as the differential pressure, discharge minus suction.

$$\text{EOC Head} < \text{Full speed EOC Head} * (\text{Speed} / \text{Full speed})^2$$

or practical

$$\text{EOC Head} < \text{EOC Head coefficient} * \text{Local discharge setpoint} * (\text{Speed}/\text{Full speed})^2$$

By default eoc Head coefficient is 90.0%.

### Low Suction Level 1 Shutdown Alarm

This is a visual and audible alarm condition and can be enabled or disabled, with disabled as the default. If the Low level switch 1 is connected to the booster controller and enabled, opening the contact of the Level switch 1 will stop the booster set and display the alarm. This alarm is reset automatically when the alarm condition disappears.

### Low Suction Level 2 Shutdown Alarm

This is a visual and audible alarm condition and can be enabled or disabled, with disable as the default. If the Low level switch 2 is connected to the booster controller and enabled, opening the contact of the Level switch 2 will stop the booster set and display the alarm. This alarm is reset automatically when the alarm condition disappears.

### Low Suction Pressure Shutdown Alarm

This is a visual and audible alarm condition and can be enabled or disabled. It is disabled if the Low suction pressure limit is set to zero. When the suction pressure is less than or equal to the setpoint for 10 seconds the booster displays the alarm and shuts down. This is reset automatically when the pressure is 2 psi greater than the setpoint.

### High Suction Pressure Shutdown

This is a visual and audible alarm condition and can be enabled or disabled, with enabled as the default. When the suction pressure is greater than or equal to the High suction pressure Limit for 10 seconds, the booster displays the alarm and shuts down. This is reset automatically when the discharge pressure is 5 psi less than the High suction pressure limit.

### Low Discharge Pressure Shutdown Alarm

This is a visual and audible alarm condition and can be enabled or disabled. It is disabled if the Low discharge pressure limit is

set to zero. When the discharge pressure is less than or equal to the limit for 300 seconds, the booster displays the alarm and shuts down. It has to be reset manually.

It is also temporally disabled if no pump is running and during ramping in the soft fill mode.

### High Discharge Pressure Shutdown Alarm

This is a visual and audible alarm condition and can be enabled or disabled, with enabled as the default. When the discharge pressure is greater than or equal to the High Discharge Pressure Limit for the Discharge High Alarm Delay Time, the booster displays the alarm and shuts down. This reset automatically when Discharge High Alarm Auto/Manual Reset switch is setup in Auto position and the discharge pressure is 5 psi less than the High Discharge Pressure Limit.

### Low Discharge Pressure Alarm In Emergency Mode

This is a visual and audible alarm condition only for Emergency Power mode and is enabled only if Emergency power mode is enabled and Emergency input is on. When the discharge pressure is less than or equal to the Emergency power mode low Discharge pressure limit, the booster displays the alarm and continue to work. This is automatically reset when the discharge pressure is 5 psi greater than the Low system pressure alarm in emergency setpoint.

### Factory High Discharge Shutdown Alarm

This is a visual and audible alarm condition and cannot be disabled. When the discharge pressure is greater than or equal to the Factory high system shutdown pressure the booster shuts down. This is reset automatically when the discharge pressure is less than the Factory High system shutdown pressure.

### Sensor Failure Alarm

This is a visual and audible alarm condition to indicate a sensor's signal is out of range. If the local and remote sensors fail simultaneously (or not enabled) and the aquastat is enabled, all the available pumps run at the adjustable Default speed (70.0 %).

### Airlock Alarm

This is a visual and audible alarm condition and can be enabled or disabled, with disabled as default. When any pump speed is faster than 50% and the power it consumes is less than the Airlock power threshold (set to what the pump consumes running at Minimum speed with no flow) for longer than the Airlock Alarm delay. The pump/drive is tagged as 'failed'. The alarm message indicates which pump triggered the alarm.

### Aquastat Alarm

This is a visual and audible alarm condition and is enabled when the Alternate setpoint 4/Aquastat input is configured for Aquastat. The alarm is active when the Aquastat input is open (dry contact) and the booster stops. The alarm is automatically reset when the alarm condition disappears.

## ERROR HANDLING

### Omission of failed or tripped drives

Any drive which fails or trips is omitted from operation.

### Omission of Pumps in the Off position:

Any pump which is in the hand or off position is omitted from operation.

### Back-up of the Remote Sensor

If the signal from the remote sensor falls outside the valid range (below 2 mA/V), the Local discharge sensor is used as Control sensor instead, as described in the Remote sensor mode above.

### Local Discharge Sensor Failure

If the Local discharge sensor is selected as the System control Sensor and it fails, then if the aquastat is enabled all the available pumps run at the adjustable Default speed (70.0%).

If the Local discharge sensor is not selected as the System control sensor then upon this alarm the booster system will continue using the remote sensor for speed control.

## SETUP

### PID Setup

Defaults: Gain is 10%/sec, Speed up limit is 1.0%/sec and Speed down limit is 3.0%/sec.

Increasing the PID Proportional gain increases the reaction speed to discharge pressure changes. Decreasing the value slows down the reaction speed to a discharge pressure deviations from setpoint.

The ramp time in the PLC and the drives should always be 15sec. That allows the actual ramp up time to be controlled by the PID Speed up and Speed down limits. If the Speed up limit = 1.0% then the actual ramp up time =  $100 / \text{Speed up limit} = 100\text{sec}$ .

Example for PID parameters and speed relationship:

If Disch press deviation from setpoint = 15.0 PSI, Gain=10%/sec and Current speed=58.0%, then

Updated pumps speed= Current speed + Disch press deviation \* Gain =  $58.0\% + 15.0 * 10/100 = 58.0\% + 1.5\% = 59.5\%$

But the pumps acceleration rate is limited by the Speed up limit, so if the Speed up limit = 1% then the updated speed is 58.0% + minimum (1.0%, 1.5%) = 59.0% instead of 59.5%.

The update of the pumps speed is done once per second.

### Inputs

- 1 Digital
  - A Remote start (optional)
  - B Emergency power (optional)
  - C Use alternate setpoint 1 (optional)
  - D Use alternate setpoint 2 (optional)
  - E Use alternate setpoint 3 (optional)
  - F Use aquastat (optional)/Alternate setpoint 4 (optional)
  - G Use level switch 1 (optional)/Alternate setpoint 5 (optional)
  - H Use level switch 2 (optional)/Alternate setpoint 6 (optional)
- 2 Analog
  - A Discharge pressure transducer
  - B Suction pressure transducer
  - C Remote pressure transducer (optional)

### Outputs

- 1 Digital
  - A Alarm (optional)
  - B Pump running (optional)
  - C Panel alarm buzzer (optional)
  - D Low suction pressure (optional)
  - E High discharge pressure (optional)
- 2 Analog
  - A Discharge pressure (optional)
  - B Suction pressure (optional)
  - C Boost pressure (optional)

All Analog outputs are scaled as 0 v DC=0 psi and 10 v DC = Factory high discharge shutdown setpoint

### Serial Communications

- 1 Integrated fieldbus port (drives)
  - A Modbus RTU
- 2 Field card (drives - optional backup)
  - A Modbus RTU
- 3 Integrated serial Port (touchscreen HMI)
  - A Modbus RTU
- 4 Serial card (optional BMS/BAS connection)
  - A Modbus RTU
  - B Lonworks
  - C BACnet(MS/TP)
  - D BACnet(IP/ENET)

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