SyncroFlo

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Operational Overview and Controls Guide

Standard Two or Three Pump Type VFD Booster Controls with HMI

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BETTER CONTROL THROUGH SYSTEMS ENGINEERING

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I. PUMP SEQUENCING

The controller continuously monitors the pressure of system header with a pressure transmitter and the suction pressure by either a transmitter, switch, or level control by others. Estimated flow rate is calculated based on the differential pressure across the pump headers and the VFD speed. An optional paddle wheel flow sensor may be included to measure flow rate, replacing the estimated flow rate provided the paddle wheel flow sensor is functioning correctly. If the paddle wheel flow sensor fails, the controller will revert to the estimated flow rate. Flow rate (either estimated or measured by paddle wheel) is needed for energy mode, which, if enabled, is used to reduce the system pressure set point at lower flow rates due to lower pipe friction losses.

In automatic operation, the controller will signal the right pump(s) to start or stop based upon the sequencing described herein. It should be noted that all pumps follow the same speed control signal produced by the controller. Upon starting, the pumps will slowly ramp up to the proper speed to avoid overshoot. Once this startup sequence is complete, the pumps will always run at whatever speed is needed to maintain the set point pressure. All pumps are protected by minimum run timers to prevent unnecessary cycling. Whenever a lag pump stops, a momentary drop in system pressure may occur, resulting in the remaining pump(s) to speed up temporarily to compensate. The pumps will stop in the reverse order from which they started.

A minimum run timer auto-adjust feature is available through the human machine interface (HMI). If enabled, the MRT will be automatically adjusted over a range from 30 seconds to 5 minutes. The function keeps the MRT as short as possible (30 seconds), unless any particular motor sees more than 3 starts in a 20 minute period. If a motor does see excessive starts, the MRT will automatically be increased by 1 minute. Conversely, if there are not excessive starts of any motor during the period, the MRT will automatically be decreased. If the function is disabled, the system will operate with a fixed MRT as set by the operator.

A weekly exerciser is provided that will run each pump in AUTO for one minute individually.

Please note that many of the set points described below are adjustable through the human machine interface. This is described in greater detail in both the Appendix 1 - Set Points section of this manual and the HMI manual.

A. Restart Sequencing

Anytime the system is reset from a complete alarm shutdown or after power is restored, pump sequencing is modified to help prevent water hammer. The lead pump will start on low system pressure as normal. However, there is a 10-second interval before each lag pump may start.

B. Lead Pump Sequencing

The lead pump will start when system pressure drops several pounds below the desired system

pressure (system pressure set point - pressure sequencing deadband) after a two second delay. If system pressure drops to the low system pressure set point, the lead pump will start after a one second delay.

Through the HMI, the operator may choose to enable lead pump shut down or have the lead pump run continuously. If enabled, the lead pump will stop if no other pump is running, the lead pump minimum run time has expired, system demand/flow rate is very low (less than 10 gpm), and system pressure is within two pounds of the set point. As an alternate, if high suction pressure occurs (as measured by either a pressure transmitter or switch), the lead pump will stop.

If lead pump shut down is enabled and a HydroCumulator is supplied with the system, the operator may choose to charge the HydroCumulator and system up to an additional 10 psig before allowing the lead pump to stop. This will occur after the above-mentioned low demand conditions are met and will stop if system demand increases. This feature can be used to help conserve energy by allowing the HydroCumulator to meet system demand while the lead pump remains off longer.

In addition, the operator may set a lead pump shutdown/run schedule through the HMI (24 hour per weekday or weekend). The high suction pressure shutdown feature is independent of this schedule and will allow the system to shut down anytime high suction occurs.

C. Lag Pump Sequencing

If the capacity of the lead pump is exceeded, the lag pump will start after an adjustable time delay. A lag pump can start on low system pressure, high power usage, or high flow (if an optional paddle wheel flow sensor is included or estimated flow rate sequencing is enabled). If the capacity of the lead pump and lag pump is exceeded, the second lag pump (on three pump systems) will start. For pressure sequencing, the lag pump(s) will also start if *both* of the following conditions occur:

1) System pressure drops several pounds below the desired system pressure (similar to the lead pump)

and

2) The VFD speed is equal to or greater than the lag pump start speed.

Please note that the speed consideration for starting the lag pump can be effectively disabled by setting a low speed requirement (equal to minimum speed). Thus, the VFD speed would always be satisfactory and the lag pump(s) would simply sequence on low pressure. A relatively high value for this set point is recommended however, to ensure any running pump is near capacity before starting another pump.

The lag pump(s) will run for at least the duration of the minimum run time and then stop as demand recedes.

Via the HMI, the operator has the option to lock out the second lag pump on a triplex package and the lag pump on a duplex package. The lockout applies to both automatic and hand

operation of a pump. If automatic alternation is enabled, each may pump still serve as the lead pump.

D. Sequence Alternation

The pumps will switch starting positions each time the lead pump either runs for 24 hours or has a non-alarm shutdown. They will also alternate starting positions if the lead pump has over 50 more hours of run time than the next pump in the sequence (if enabled through the HMI). If the lead pump is running at the time of alternation, it will continue to run for 10 seconds more with the new lead pump to help prevent water hammer.

II. SPEED CONTROL

A. Automatic PID Speed Control

In this mode, the booster system will automatically maintain desired system pressure. The controller uses the system pressure measurement from the system pressure transmitter and a proportional, integral, and derivative (PID) algorithm to maintain system pressure. As the pressure in the pipe decreases, the pump speed will increase until the pressure is returned to its set point value. If the pressure begins to rise above the set point, the pump speed will decrease until the set point is reached.

Both the system pressure set point (SP) and process variable (PV - measured system pressure) are used to determine the speed of the pump(s). The controller uses a proportional, integral, and derivative (PID) algorithm to respond to changes in system pressure. All of the PID tuning constants are adjustable through the HMI. Proper settings ensure accurate and timely system response without overshoot or hunting. Any changes made in the field should be done so carefully and notes should be taken.

The larger the difference between PV and SP, the quicker the correction in speed. This effect is provided by the proportional part of the PID speed control algorithm. The integral part of the PID algorithm allows the controller to correct the speed based on the time accumulated difference between the PV and SP. The integral term is effective for closing in on the set point when the process is already very close to the set point and the proportional gain has little effect. For example, if the set point is 12 PSI and the PV is hovering at 11.5 PSI, the longer the PV remains at 11.5, the faster the speed of the pump will be increased. The derivative part of the PID algorithm allows the controller to anticipate a sudden surge in the system by correcting the speed based on the rate at which the process variable is changing. If the PV suddenly increases in a very short time, the derivative term will make a large correction in the speed to compensate. If the derivative gain is set too high, the system will oscillate (hunt), so it is generally best to keep the gain constant low for the derivative term.

There are minimum and maximum speed limits that can be set so that the pump is never operated above or below certain speeds. These values are set through the HMI.

B. Manual Speed Control

If the system pressure transmitter fails or the operator chooses, the controller will output a constant speed value to the drive, which can be adjusted by the operator using the HMI.

C. Energy Mode

In accordance with ASHRAE 90.1, two energy modes are offered that allow the system pressure set point to lower during periods of low demand and conserve energy. Due to lower system friction losses at reduced flow, less pressure is required from the booster package at low flow.

Flow rate (either estimated or measured by paddle wheel) is required for energy mode. Estimated flow rate is calculated based on the differential pressure across the pump headers and the VFD speed. An optional paddle wheel flow sensor may be included to measure flow rate, replacing the estimated flow rate provided the paddle wheel flow sensor is functioning correctly. If the paddle wheel flow sensor fails, the controller will revert to the estimated flow rate.

Via the HMI, the operator has the option to enable either energy mode continuously (always on), during designated hours only, or never (always off, in which case the normal system pressure set point is always followed). Only one energy mode can be selected, automatic or manual.

Automatic Energy Mode

The Darcy-Weisbach equation relates pipe friction to flow rate per the following:

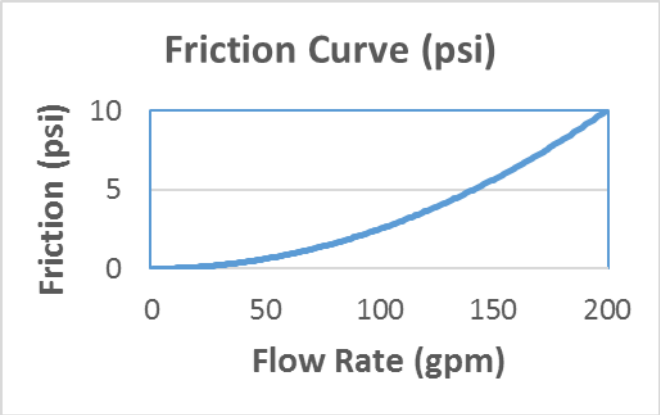
$H_f = F_d*(L/D)*(U^2/2G)$

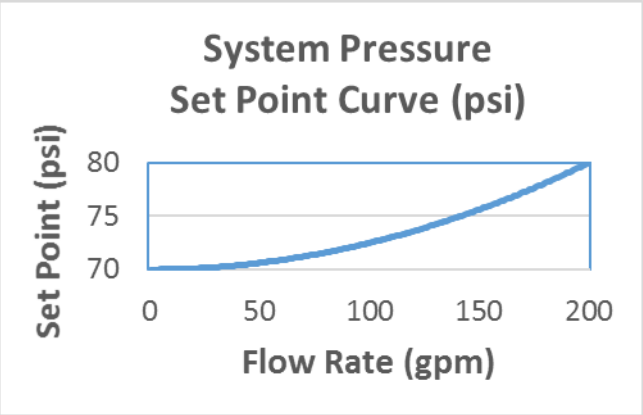
Where
H_f = head loss due to friction (ft)
F_d = Darcy friction factor (dimensionless constant)
L = length of pipe (ft)
D = hydraulic diameter of pipe (ft)
U^2 = flow rate (ft/sec in pipe size diameter D above)
G = local acceleration due to gravity

The formula simplifies to H_f = constant * gpm^2 and is the basis for automatic energy mode. Set points for system duty friction (H_f) and system duty flow rate (U or gpm) allow calculation of the constant for the particular installation.

As an example, the friction curve on the left below shows data for a system duty of 200 gpm

with 10 psi of losses at duty flow. The friction curve follows the formula above. The curve on the right shows the system pressure set point curve across the system duty flow range in automatic energy mode with a normal system pressure set point of 80 psi.





As shown on the curves above, automatic energy mode reduces the system pressure set point across the system design flow rate. Pipe friction is very small at low flow rates and rapidly increases as flow nears the system design flow rate. At very low flow, the system pressure set point is the normal system pressure set point minus the friction set point required at full system design flow (as system flow rate reduces to zero, so does the piping friction). At very low flow, virtually none of the friction accounted for during full design flow occurs so the required system pressure can be lowered correspondingly. At full system design flow, the entire system duty friction will be required to deliver pressure at the furthest fixture so the normal system pressure set point will be maintained. Any flow beyond the system design flow will also maintain the normal system pressure set point. The system pressure set point is calculated based on the system duty flow rate and system duty friction set points entered via the HMI.

Manual Energy Mode

If manual energy mode is enabled, at low system demand the normal system set point will be reduced by the amount entered on the HMI. With only the lead pump running, when system demand recedes to less than the ON set point for the duration of the adjustable time delay, manual energy mode will turn on. When system demand exceeds the OFF set point (5 gpm greater than the ON set point) or if a lag pump starts, manual energy mode will turn off and the normal system pressure set point will be used to control system pressure. Manual energy mode is intended only for small flows within the lead pump's capacity (maximum on set point is 50 gpm).

III. OPERATOR CONTROLS

The primary controls interface is the HMI, which allows access to the pump operation touch keys, status of the system, alarms, set points, and all transmitter measurements. The HMI is

described in detail in the HMI manual.

On the main screen of the HMI, the operator has open access to pump selector switches and an alarm silence/reset push button (the alarm silence/reset push button is also on the alarm status screen). These devices are described below:

A. Pump Selector Switch

The pump selector switch is on the HMI. Each pump button must be pushed for half a second to take affect. A "HELP" button in the upper right corner also gives instructions.

"HAND" - Use for manual operation only - to start up, restart and reset, or test each pump. No pump should run in this position without supervision.

"OFF" - Pump will not run at all. Use during start up, restart and reset, or when a pump is down for service.

"AUTO" - Automatic position for each pump, which allows the controller to have full control over the pumps operation.

B. Alarm Silence/Reset Push Button

Push once to silence the alarm horn, wait five seconds and push a second time to reset the system from alarm mode back to normal automatic operation. The system will not reset unless the original cause of the alarm(s) has been corrected or removed.

This button can also be used to defeat the minimum run time of the pumps and allow the lag pumps to turn off if they are not required to be running. This is a useful feature when testing or monitoring the system.

C. Alarm Horn

The horn sounds when an alarm condition occurs. It has a medium volume that is not adjustable. Its piercing sound can be easily heard in mechanical rooms.

IV. ALARMS

Several of the alarms described below feature adjustable set points. These can be adjusted using the HMI. This is described in greater detail in both the Appendix 1 - Set Points section of this manual and the HMI manual. Please note that each of the alarms described below, except as noted, will activate the alarm horn, post a scrolling alarm message on each screen of the HMI, and post an alarm status on the HMI.

A. Low Suction Pressure \ Level Alarm

If the low suction device (pressure switch, pressure transmitter, or level switch) signals a loss of supply water pressure for 10 seconds (default), all pumps will be locked off. This alarm and the system will be disabled in case of a suction pressure transmitter failure.

The operator may select either manual reset or limited automatic reset of this alarm through the HMI. The procedure for manual resetting is described below. The limited automatic reset feature allows the controller to reset this alarm automatically up to three times in an hour after the low suction condition signal has cleared for one minute. If the alarm occurs four times in an hour, the automatic reset feature will be canceled, and the alarm will require manual resetting.

B. Low System Pressure Alarm

If system pressure drops to or below the low system pressure set point for 30 seconds (default), this alarm will activate. System performance will not be affected by this alarm. It is used to alert the operator that a problem occurred. This alarm will be disabled in case of a system pressure transmitter failure. The alarm requires manual resetting as described below.

C. Low Low System Pressure Alarm

Via the HMI, the operator can enable or disable this alarm. If enabled and system pressure drops to or below the low low system pressure set point for 60 seconds (default) with a pump running, this alarm will activate. This alarm will shut down the pumps and prevent operation until the alarm has been manually reset as described below. The pressure set point is differential from the normal set point pressure and can be set as low as equivalent to 5 psig. For example, if the normal system pressure set point is 80 psig, the low low system pressure set point can be set at 75 psid (for an alarm at 5 psig). This alarm will be disabled in case of a system pressure transmitter failure.

Enabling or disabling this alarm creates a log in the event history on the HMI. It is also logged to the SDHC card in the HMI (if logging is enabled), which is explained further in the HMI manual.

D. High Flow Rate Alarm (optional)

If a paddle wheel flow sensor is installed, this alarm can be enabled that will cause the pump(s) to shut down if the flow rate is (nominal 20%) over the running pump(s) duty flow rate. This alarm stops the pumps from operating and requires a manual reset as described below.

E. High System Pressure Alarm

If system pressure rises above the high system pressure set point for 5 seconds (default), this alarm will activate and lockout the pumps. This alarm will be disabled in case of a system pressure transmitter failure.

The operator may select either manual reset or limited automatic reset of this alarm through the HMI. The procedure for manual resetting is described below. The limited automatic reset feature allows the controller to reset this alarm automatically three times in an hour after system pressure drops to the pressure sequencing set point. If the alarm occurs four times in an hour, the automatic reset feature will be canceled and the alarm will require manual resetting.

F. Pressure Transmitter Out of Range Alarms

The correct output range of the pressure transmitter(s) is 1 - 6 kHz. The pressure transmitter failed low alarm will activate if the controller receives an abnormally low signal for 2 seconds. The pressure transmitter failed high alarm will activate if the controller receives an abnormally high signal for 8 seconds. The system will run at the manual speed set point if the system pressure transmitter fails. If a suction pressure transmitter is included and fails, the system will be disabled. These alarms will automatically reset when the transmitter operates in its correct range.

G. Individual Drive Fault Alarms

If a fault occurs in the drive when it is being called to run, the VFD failure alarm will be activated. This alarm will stop the pump with the failed drive and start the next available pump if it is not currently running.

The operator may select either manual reset or limited automatic reset of these alarms through the HMI. The procedure for manual resetting is described below. The limited automatic reset feature allows the controller to reset this alarm automatically three times in an hour after the fault signal clears for 15 seconds. If the alarm occurs four times in an hour, the automatic reset feature will be canceled, and the alarm will require manual resetting.

H. Irregular Power Alarm (optional)

If a power monitor is included with this system, it will protect the system from an abnormal main power condition. If irregular power is sensed, the system will shut down all motors until normal power has been restored for 10 seconds.

I. Surge Protective Device (SPD) Failure (optional)

If a SPD is included with this system, it will help protect the system from power surges within its operational specifications. The controller monitors the condition of the suppression element and will indicate an alarm if the SPD can no longer provide surge protection and needs to be replaced.

J. Paddle Wheel Flow Sensor Failure (optional)

If a flow sensor is provided, this alarm will occur if during the time span of three first lag pump starts there are no pulses measured from the flow sensor. If this happens, the system will automatically switch to estimated flow rate. This alarm will automatically reset once the

controller receives a pulse signal from the sensor.

K. Power Failure Alarm

Each time the PLC is powered up, this alarm will occur. The previously described restart delay helps prevent water hammer as pumps are brought back online.

L. Manually Resetting Alarms

The reset push button can be found on the main screen of the HMI and also the alarm status screen. Before resetting an alarm, the alarm horn must first be silenced by pressing the alarm silence / reset push button. Five seconds after silencing the alarm horn, the system can be reset (provided the original reason for the alarm has been corrected).

M. Event History

This feature displays the last 200 events that have occurred on the system with record 0 being the most recent. An event is when any alarm occurs or the operator attempts to reset an alarm with the alarm reset push button. For each event record, the following information is provided:

1) Alarm Name
2) Date
3) Time
4) Flow Rate (estimated or measured)
5) Suction Pressure (psig)
5) System Pressure (psig)
6) System Pressure Set Point (psig)
7) VFD Speed Command Signal
8) Individual VFD Amps / Run Indication

Please refer to the Human machine interface Manual for further details.

V. PROTECTION DEVICES

A. Operator Safety

The enclosure features door-interlocking motor disconnecting devices or a main disconnect (disconnect switch or circuit breaker), to prevent opening the panel while the motors are running. To open the control panel, turn off each of the motor disconnecting devices. Please note, control power may still be present while the enclosure is open. In addition, high voltage may still exist in the panel. Circuit breakers are provided on the primary and secondary of the control power transformer.

B. Motor Protection

Anytime a motor protection device trips, the cause of the problem should be determined before returning the motor to service. Each motor will be protected against overload and short circuit current by one of the following devices:

Fuses

Dual-element fuses are provided for over-current protection.

Circuit Breakers

If a circuit breaker should trip due to over-current, the handle will turn to the "TRIP" position. To reset the circuit breaker, turn the handle to the "OFF" position and then back to "ON".

C. Control Circuit Protection

The control power transformer is sized according to the consumption of power of the controls. Circuit breakers that are sized according to N.E.C. requirements for transformers protect the primary and secondary circuits.

D. Pump Over-Temperature Protection

Each pump is fitted with a temperature purge valve. If the water in a pump becomes too hot (at low flow), the valve will open. The hot water is then dumped to drain, allowing cool water to enter the pump from the suction side. Once the pump is cool again, the temperature purge valve will close.

VI. PROGRAMMABLE CONTROLLER

The controller features both non-adjustable and adjustable timers. The adjustable timers can be changed using the HMI. Please refer to the Human machine interface Manual for instructions on how to do this. A listing of the set points for all timers is provided in Appendix 1 - Set Points.

A. Status LEDs

The status of the PC can be determined by observing the LEDs on the face of the PC. To do this, the control panel door must be opened and the control circuits must be energized. The function of each LED is described below.
POWER - This LED should be illuminated continuously if control power is on.

RUN - This LED should be illuminated during normal operation. If this LED is off, make sure the switch under the small door to the left of the HMI connection is in the RUN position.

ERR / ERROR - If this LED is flashing, then a program error is indicated. If it stays on

continuously, a processor error is indicated. If turning power off and on cannot clear either of these errors, consult the factory.

ALM / BATT – This LED will illuminate if the PLC battery is low and needs replacing.

IN / OUT - Individually numbered red LEDs turn on when their corresponding INput or OUTput point is on.

B. Program Changes

SyncroFlo will do all programming for the PC. Every phase of the program will have been tested with the entire machine at the factory. Final adjustments are made at start-up by factory trained personnel. If a program change is required, it will be made by SyncroFlo and transmitted to the field via a program loader or chip. SyncroFlo keeps a copy of the program at the factory so that any changes can be made and transmitted immediately.

C. Maintenance

The PC requires no routine maintenance. The program is stored on an EEPROM chip so that it will not be lost due to loss of power no matter how long the power is off.

A periodic check of the PC status lights will be sufficient to check for correct operation. The power and run status LEDs should always be on when control power is available. Testing all control functions to see if the PC performs as described can check the inputs and outputs. Remember that when an input or output contact is on, its status LED will be on.

D. Repairs

It is unlikely that a problem will develop with the PC itself. If a problem seems to be evident, call the factory for assistance. If it is determined that a problem does exist, a new unit can usually be shipped in 24 hours. Please note that if, for example, lightning struck the control panel and destroyed the PC, the pumps can still be run in the hand position while repairs are underway.

VII. GENERAL MAINTENANCE INDICATION

The HMI has several maintenance indicator banners the run across the bottom of each screen on the HMI. As described in the HMI manual, for each drive the following parameters are monitored: inrush current limiting circuit (0-100 %), control circuit capacitor (0 – 100 %), and cooling fan speed (OK/Low). For the first two parameters, a value of 10 % or below indicates the drive will require servicing soon by qualified personnel. If a low drive cooling fan speed is indicated, the drive fan should either be cleaned or replaced by qualified personnel. For each of the conditions above, the indicator banner will run within 20 minutes from onset of the condition. In addition, every 90 – 180 days (adjustable via the HMI) a banner will indicate the filter pads for the main control panel fan(s) and exhaust(s) require cleaning or replacing.

Finally, if the observed holiday schedule is used for either the lead pump stop or energy mode schedules, a reminder banner will appear on December 15th each year to update the settings for the next year. Setting and using the observed holiday schedule is described in the HMI manual. Press the reset push button to clear the banners. In the case of the VFD parameter banners, the banner cannot be cleared until the VFD has been serviced.

VIII. REMOTE INDICATION

Normally open dry contacts (close when condition is true or active) are provided for indication of the low low system pressure alarm (if enabled), high system pressure alarm, low suction pressure / level or suction transmitter alarm, if any pump is disabled, and one general contact that indicates any of the following service conditions:

A) Low System Pressure Alarm (package still operational)
B) Any VFD Preventive Maintenance Required:
    a. Low Fan Speed
    b. Low Inrush Current Limiting Circuit
    c. Low Control Circuit Capacitor
C) Any Pump Service Interval Expired (if enabled)
D) Panel Air Filter Pads or External VFD Filter Grate Inspection Interval Expired
E) System Pressure Transmitter Failure
F) Surge Protective Device Failure (if provided)
G) Paddle Wheel Flow Sensor Failure (if provided)

An optional BACnet MS/TP, BACnet IP, LonWorks, Modbus 485 Slave RTU, or Modbus TCP gateway may also be provided for remote monitoring by the building automation system.

Appendix 1 - Set Points

A. Non-Adjustable Set Points

Reset Delay after Alarm Silence	5 sec.
Lead Pump Start on Normal Sequencing Pressure	2 sec.
Lead Pump Start on Low System Pressure	1 sec.
Pressure Transmitter Failed Low Delay	2 sec.
Pressure Transmitter Failed High Delay	8 sec.
VFD Fault Delay	0 sec.
Surge Protective Device Fault Delay	1 sec.
Manual Energy Mode Off Set Point	On Set Point + 5 gpm

B. Adjustable Set Points

i. Sequencing & Time Delay Set Points

	Default	Range
Low System Press. Alarm Delay	30 sec.	10 - 60 sec.
Low Low Sys. Press. Alarm Delay (if enabled)	60 sec.	30 - 90 sec.
High System Press. Alarm Delay	5 sec.	1 – 30 sec.
Low Suction Press. / Lev. Alarm Delay	10 sec.	0 - 30 sec.
Tank Charge Timer (if shutdown enabled)	30 sec.	0 - 999 sec.
Pump Pressure Start Time Delay	5 sec.	2 - 30 sec.
Lag Pump Power Start Time Delay	2 sec.	2 – 30 sec.
Lag Pump Flow Start Time Delay (if provided)	2 sec.	2 - 30 sec.
Pump Minimum Run Time (Manual or Auto-Adjust Set)	30 sec.	30 - 300 sec.

ii. Pressure Set Points

	Default	Range
Normal System Pressure	(See System Data Sheet)	1 - 999 psig
Pressure Sequencing Deadband	5 psid	1 - 999 psid
Low System Pressure Deadband	10 psid	1 - 999 psid
Low Low Sys. Press. Deadband (if enabled)	25 psid	15 psid – equivalent of 5 psig
High System Pressure Deadband	30 psid	1 - 999 psid
Low Suction Press. Alarm (if available)	5 psig	0.1 - 999 psig
High Suction Press. Stop (if available)	Sys. Pressure + 1	1 - 999 psig

iii. Energy Mode Set Points

	Default	Range
Auto Energy Mode System Duty Flow	(See Sys. Data Sheet)	1 – 9999 gpm
Auto Energy Mode System Friction	10 psig - *	1 – 99 psig

Manual Energy Mode On Delay	30 sec.	15 – 90 sec.
Manual Energy Mode On Set Point	25 gpm	10 – 50 gpm
Manual Energy Mode Normal Set Point Reduction	5 psig	1 – 20 psig

* - Should be verified with the engineer's system design flow friction calculation/estimate

iv. Power Set Points

	Default	Range
Lag 1 On Power	See Factory Default Sticker (inside control panel door)	0 – 999 Hp
Lag 1 Off Power	See Sticker	0 – 999 Hp
Lag 2 On Power (if available)	See Sticker	0 – 999 Hp
Lag 2 Off Power (if available)	See Sticker	0 – 999 Hp

v. Flow Rate Set Points (optional)

	Default	Range
Lag 1 On Flow Rate	One Pump Capacity	0 - 9999 gpm
Lag 1 Off Flow Rate	85% of Pump Cap.	0 - 9999 gpm
Lag 2 On Flow Rate (if available)	200% of Pump Cap.	0 - 9999 gpm
Lag 2 Off Flow Rate (if available)	185% of Pump Cap.	0 - 9999 gpm

vi. Speed Control

	Default	Range
VFD Minimum Speed	30 Hz	15 – 60 Hz
VFD Maximum Speed	60 Hz	15 – 60 Hz
VFD Manual Speed	50 Hz	Min. - Max. Speed
Lag Pump Start Speed	50 Hz	Min. - Max. Speed

vii. PID Set Points

	Default	Range
Proportional Gain	500 %	1 - 32767 %
Integral Time Constant	30 decisec.	0 - 32767 sec./10
Derivative Gain	100 %	1 - 100 %
Derivative Time Constant	5 centisec.	0 - 32767 sec./100