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OWNER'S MANUAL
SERIES P3
Pump Controller

1.0 DESCRIPTION

1.1 General:

SERIES P3 triplex pump controllers are designed to control the operation of three pumps (or valves or other devices) in response to a rising or falling liquid level while also providing a continuous measurement of the level of the liquid. Each SERIES P3 controller consists of two electrically connected units:

1. A differential pressure transducer. This unit senses the head of the column of liquid and converts it into a proportional electrical signal.

2. An electronic circuit board. This unit provides the electrical excitation for the transducer and converts the signal into an appropriately scaled and offset voltage or current. Adjustable reference signals corresponding to the liquid levels at which the pumps are to start and stop, and alarms (if present) are to be actuated, are also generated and set on the circuit board. The opening and closing of on board solid state relays, at these set levels, controls the power line operated devices (pump motors, motor starters, valves, alarms, etc.).

The circuit boards of SERIES P3 controllers are factory wired for either "pump down" (P3D) or "pump up" (P3U) service. In "pump down" controllers the three operated devices (e.g., the pump motors) are individually energized (started, turned-on) when the liquid rises to each of their preset high levels, and are de-energized (stopped, turned-off), either together or individually, when the liquid falls to the preset low level. In "pump up" controllers the operated devices are energized at the preset low levels and de-energized when the liquid rises to the preset high level.

The transducer and the circuit board are connected via a cable which is permanently affixed to the transducer. The transducer is referenced to the pressure of the atmosphere through a high density polyethylene tube contained within the cable jacket.

In addition to these two basic units, specific models may be equipped with factory installed analog or digital metering devices. The circuit board may be an open, stand alone unit, or it may be mounted in a NEMA rated electrical enclosure. The meter, if present, may be mounted on the circuit board itself, on the cover of an electrical enclosure, behind a window in the cover of the enclosure, or otherwise.

Since there are many specific variations in this series of devices, not all portions of this manual will apply to all models. It should be obvious which portions are not pertinent to any specific configuration.

1.2 Transducer:

The transducer senses liquid level by its associated hydrostatic pressure. The effective pressure acting on the transducer is the difference between the total pressure at its sensing port and the pressure of the atmosphere to which it is vented. The effective pressure is equal to the product of the height and density of the liquid above the transducer sensing port. To the extent that the density is constant, the pressure sensed by the transducer is affected only by the height of the liquid above it.

The pressure responsive member of the transducer is a phosphor bronze bellows. The wall thickness of the bellows and its number of convolutions are chosen to suit the transducer's rated head range. Offset transducers, used for example to monitor the level in elevated tanks, are constructed with two tandem mounted bellows although only the primary bellows is acted on by the pressure. Some offset transducers are further stiffened by the addition of an internal spring.

The compression of the bellows by the external pressure is converted to a proportional electrical signal by means of a magnetostrictive displacement sensing element mounted within it. In offset transducers the displacement sensing element is mounted inside the secondary bellows. Immunity from overpressure is obtained by limiting the bellows compression with a rigid internal stop.

The displacement sensing element within the bellows is in the form of a double helical spring of magnetostrictive wire on which are wound two insulated copper wire solenoids. The spring itself comprises the primary of a transformer, the copper windings being the secondary. Primary current in the form of short duration pulses of alternating polarity is provided by the electronic circuit board via the green and white conductors within the cable. Corresponding secondary pulses having a peak magnitude that reflects the amount of bellows compression are returned via the red and black conductors.

The pressure transducer capsule consisting of the bellows and its displacement sensing element is encased in either a PVC or stainless steel, tubular housing, The cable exits the case through an elastomeric (generally neoprene) strain relief. The internal space where the cable conductors and vent tube are connected to the capsule is sealed with an epoxy encapsulant.

Various pressure end or cable end constructional details and/or accessories may be fitted to the basic transducer casing. These include bumpers, weights and threaded couplings for conduit or piping. The bellows in some transducers is isolated from contact with the liquid by means of a relatively inert silicone gel. A disc having several small holes may cover the pressure port of some transducers. This provides mechanical protection for the gel and prevents large particles of debris from entering the transducer.

Each transducer is marked, on the case, on the cable end disc, on the coupling, or on some other appropriate surface, with a serial number and range. Except for offset transducers in which the zero offset pressure can be altered from its factory setting, there are no adjustments or repairs that can be performed in the field on any transducer.

Unless the transducer is installed in an environment known to promote fouling or corrosion, no periodic inspection or cleaning is required, nor is it recommended since installed transducers are generally extremely reliable devices being most prone to damage during handling.

1.3 Circuit Board:

The electronic circuits for exciting the transducer, processing its return signal, establishing the set point reference levels and operating the output relays are contained on a glass-epoxy printed circuit board. All external connections are made via screw terminals on back barrier terminal blocks. Separate blocks are used for input power (120 VAC-60 Hz), the transducer, output voltage or current, and for the relays. Both sides of the circuit board are coated with an acrylic conformal coating. Each circuit board is marked with a serial number, generally near the lower right corner. If, as is most usual, the board has been calibrated at the factory with an associated transducer, it will bear the same serial number as the transducer.

The circuit itself is comprised of five functionally distinct sections:

1. Pulse generator.
2. Signal conditioner.
3. Set point comparators.
4. Control interface.
5. Power supply.

The *pulse generating* section drives the transducer with short duration, alternating polarity current pulses at power line frequency. The signal returned from the transducer is similar in shape and duration to the energizing current waveform. The peak value of these pulses is between approximately 0.8 and 1.5 volts depending on the liquid level. The first stages of the *signal conditioning* section capture these signal peaks and convert them to a DC voltage. This voltage *is* subsequently offset and scaled to meet the desired output format, e.g., 0-1 V, 1-5 V. The fully conditioned signal, representing the level of liquid measured by the transducer, appears at the "OUTPUT" terminals of the circuit board. Current output formats, e.g., 4-20 mA are provided by a supplementary circuit board having a voltage to current conversion stage.

The conditioned transducer signal is compared with adjustable DC reference voltages in the *set point comparator* section of the circuit. Each control function, e.g., LEAD ON, LAG ON, OFF, HIGH ALARM, etc., has its own reference setting potentiometer and its own comparator circuit. A slide switch for each control function allows its reference level, rather than the actual level, to appear at the "OUTPUT" terminals while it is being set. Each of the ON comparators is latched in the "on" state by an OFF comparator. This keeps each pump running, after it has been started, until the liquid level (by the action of the pump) falls to the OFF level in P3D controllers or rises to the OFF level in P3U controllers.

As each comparator determines whether the transducer signal is higher or lower than its reference voltage, it acts to open or close an associated solid state relay in the *control interface* section of the circuit. Each controlled device has its own relay (pump motor, alarm, etc.). Standard relays are used to control power line operated devices rated up to 4 A at 24-280 VAC. Some circuit boards may be equipped with DC relays or logic level devices either for switching DC loads or to interface with computers, programmable controllers, telephone dialers or other electronic devices. An LED next to each relay indicates its status; the LED is lit when the relay is closed. External connections to the relay "contacts" are made via screw terminals on terminal blocks identified by their markings. No electrical connection exists between relays nor between operated devices and the electronic sections of the circuit board since all of the relays are internally optically isolated.

The *power supply* section develops the regulated DC voltages required to operate the signal conditioning and comparator circuits. A single step down transformer operates both the *pulse generating* and *power supply* sections of the circuit.

Some P3 controllers have additional logic circuitry to automatically alternate the starting sequences of the three pumps each time the 1-0FF level is reached. An LED indicates which pump is, or will be the lead pump. Some controllers have 10 second delays between start up of pumps following the return of power after a power failure. Some controllers allow each pump to be manually started by the momentary closure of on-board or remotely connected "PUSH TO TEST" switches.

2.0 INSTALLATION

2.1 Transducer:

NOTE - PRESSURE TRANSDUCERS ARE PRECISION INSTRUMENTS AND MUST BE HANDLED WITH CARE. IN PARTICULAR THEY SHOULD BE PROTECTED FROM SHARP BLOWS ON THE SIDE OF THE CASE. SUCH SHOCKS CAN CAUSE THE BELLOWS TO STRETCH, THEREBY REDUCING THE ZERO PRESSURE OFFSET MARGIN THAT IS BUILT INTO THE TRANSDUCER. REPEATED OR SEVERE BLOWS CAN OBLITERATE THIS OFFSET CAUSING THE TRANSDUCER TO ACT ERRATICALLY AT LOW HEADS OR EVEN REVERSE ITS NORMAL ACTION AND SHOW A DECREASE IN OUTPUT SIGNAL WITH INCREASING PRESSURE. KEEPING THE PROTECTIVE SLEEVE ON THE TRANSDUCER AS LONG AS POSSIBLE DURING THE MECHANICAL ASPECTS OF THE TRANSDUCER INSTALLATION CAN HELP PREVENT SUCH DAMAGE.

Since the transducer senses the liquid head above its pressure port it must be located at or below the lowest level to be monitored. This is true whether the transducer is submerged within the liquid or is mounted outside with its pressure port piped to the containing vessel. Locating the transducer somewhat below the lowest anticipated level keeps it under a positive pressure and improves its stability. In submerged installations this practice also avoids wet/dry cycling and reduces the opportunity for fouling and corrosion.

In the simplest submerged type of installation, the transducer is freely suspended by its cable. In small bore standpipes and wells, or locations without bottom access, this may be the only practical manner of installation. The transducer depth is controlled by measurement and marking the cable, e.g., with tape, as required. If the transducer has not been factory equipped with a weight, a short section of pipe slipped over the cable and resting on the transducer will help keep the cable straight and avoid flotation tendencies.

Generally, the transducer should be located in a relatively still area where there are no dynamic pressure components. It should not be located adjacent to inlets or outlets nor in turbulent, high velocity or vortex areas. If such conditions can not be avoided, a stilling well is recommended, with the transducer rigidly mounted to avoid impact and cable fatigue.

Rigidly mounting the transducer provides greater control of its exact depth location, lateral position and orientation. In shallow or other easily accessible locations the transducer may be clamped to a wall or bottom of the vessel using standard pipe hangers, preferably cushioned or plastic types.

Submersible transducers equipped with cable end couplings having ½" NPT threads are generally supported by rigid conduit. Teflon tape or thread sealants are recommended since they reduce the tightening torque required.

TIGHTENING TORQUE MUST BE APPLIED ONLY ON THE HEXAGONAL WRENCHING SURFACE ADJACENT TO THE THREADED JOINT.

DO NOT USE A PIPE WRENCH OR PIPE VISE TO HOLD THE TRANSDUCER CASE!

DO NOT APPLY TORQUE ON A PRESSURE END FITTING IN ORDER TO TIGHTEN A CABLE END COUPLING!

Use only clean conduit. Protect the vent tube in the cable with tape or other effective means to prevent it from being clogged with dirt from inside the conduit. Cut off the end if it should appear that debris or water has entered the tube. Thread the cable through the conduit carefully, all the while protecting the transducer, since it is during this phase of the installation that the transducer is most prone to damage. Keep the protective sleeve on the transducer until the installation is complete.

In some applications it may not be desirable or even possible to directly submerge the transducer. Size, thermal or chemical incompatibility, frequent equipment dismantling or wash down may make it preferable to use a piped connection to the transducer pressure port. This is the only way to install offset transducers which cannot be submersed. Transducers in PVC cases that are factory equipped with pressure end couplings have standard NPT threads. Standard compression fittings for 3/16 OD tubing usually have matching straight threads. Teflon tape or thread sealants are recommended for all threads. Since they reduce the tightening torque required to obtain leak tight joints. O-Rings can also be used with shouldered straight thread fittings.

TIGHTENING TORQUE MUST BE APPLIED ON THE FLATTED OR HEXAGONAL WRENCHING SURFACE AT THE PRESSURE END ONLY.

DO NOT USE A PIPE WRENCH OR PIPE VISE TO HOLD THE TRANSDUCER CASE!

DO NOT APPLY TORQUE ON A CABLE END COUPLING IN ORDER TO TIGHTEN A PRESSURE PORT FITTING!

The threads in Delrin end plugs provide good sealing without the need for excessive tightening. The transducer case can be hand held while the fitting is being installed.

It is recommended that the transducer be assembled to the system through a union or similar fitting in order to avoid twisting the cable during installation or removal. Offset transducers need no union since they are constructed of two units held together by a coupling nut. This nut should be loosened before attachment of the threaded portion to the piping to avoid twisting the cable. The nut should then be tightened firmly but gently. A shut off valve between the transducer and the system is recommended for all piped installations, following standard practice with other pressure measuring instruments.

2.2 Cable:

The cable connected to the transducer contains a high density polyethylene vent tube to provide automatic compensation for barometric pressure variations. For proper operation it is important that this tube not be obstructed nor punctured. The cable should not be kinked, crushed, nor sharply bent, nor should the free end be allowed to get wet. The cable should not be installed nor stored adjacent to, or in contact with, surfaces above 70°C (158°F).

In the event that the cable attached to the transducer is found to be too long, it may be cut to the required length. The cable sheath should be removed carefully to avoid cutting through the insulation of the individual conductors or damaging the vent tube.

If the cable is found to be too short, additional cable may be connected to the existing cable, either in a running splice or in a suitable junction box. If the splice is in a clean, dry location vented to the atmosphere, the vent tube may be terminated and exposed at the junction; otherwise a leak proof coupling must be made to a similar tube in the added cable or to some comparable venting means. Helpful information and hardware for such instances are available from the factory. The red and black conductors must be continued as a shielded pair. The shield (or drain wire if present) in the extension cable should be connected to the drain wire in the existing cable and this connection should be insulated from all of the other conductors. The shield is to be connected to the black wire only at the circuit board terminal.

2.3 Circuit Board:

Circuit boards may be mounted in any position. Units with analog meters have the meter zero set for vertical mounting. Orientation of units with meters is obvious. Circuit boards are equipped with either mounting brackets or stand-off spacers. The spacers will pass #8 screws; the brackets will pass #10 screws. It is expected that the circuit board will be mounted in an electrical enclosure appropriate for the environment at its location.

NOTE: Since the cable vent tube generally terminates inside the enclosure it is important that the air pressure inside the enclosure follows the outside atmospheric pressure. Normally this is accomplished automatically through the electrical fitting holes or through the conduits carrying the power lines or output leads. If liquid tight fittings are used, or if the enclosure or substantial portions of the conduit leading to it might be subjected to rapid temperature changes, for example, as by exposure to the sun, it may be necessary to drill a small (approx. 1/8" diameter) vent hole through the back or bottom of the enclosure to ensure proper pressure equalization.

2.4 Electrical Connections:

All electrical connections are to be made using the screw terminals on the back barrier terminal blocks located along the edges of the circuit board. The connections are indicated in the accompanying diagram and explained below.

Input power (105-130 VAC 60 Hz) is connected to the terminals marked, "120V-60 Hz". The bare ends of connecting wires, approximately 0.4" long, may be simply slipped under the wire clamping plates and the screws then tightened. Lugs may be used if desired. Spade lugs are more convenient since ring lugs require the complete removal of the screw/clamp plate assembly.

The conductors in the transducer cable are attached to the terminals marked, "B" (Black wire), "R" (Red), "G" (Green) and "W" (White). The bare drain wire for the shield should be connected to the black wire at the "B" terminal.

Controllers having voltage outputs can supply up to 5 mA to their connected loads. Standard units are rated as follows:

P3 – lA	0-1 volt	200 ohm minimum load resistance
P3 –1B	0-5 volt	1000 ohm minimum load resistance

The output voltage appears across the terminals marked, “-OUTPUT+" and has the polarity indicated. Some units have an additional pair of output terminals marked, "-METER+" to allow a separate, dedicated connection of a voltmeter in parallel with the device connected to the “-OUTPUT+" terminals.

Some units have an on-board +5 volt regulated power supply for use in powering an LCD digital instrument. In some units this is brought out to a separate terminal marked "5 V". The negative "-METER+" terminal is used for both the signal ground and the power supply ground. If the meter is to be located remote from the circuit board it is recommended that separate ground wires be brought back from the meter to this terminal.

Some SERIES P3 controllers provide current outputs from a supplementary circuit board. This board has its own input power (105-130 VAC 60 Hz) terminals and receives its input signals from the "OUTPUT" terminals of the main circuit board via its "INPUT" terminals. Standard units have 4-20 mA outputs with maximum load resistance capabilities as follows:

P3 -1C 4-20 mA 350 ohm maximum load resistance
P3 -1D 4-20 mA 600 ohm maximum load resistance
P3 -1E 4-20 mA 1000 ohm maximum load resistance

The output current is taken from the terminals marked, "-OUTPUT+" with the polarity indicated. An additional pair of output terminals marked, "-METER+" allows the dedicated connection of a milliammeter. Since these terminal pairs are connected in series on the circuit board there will be no current output unless each pair is connected to a closed circuit. Thus there will be no indication on the meter unless a load resistance within the rated range is connected to the "-OUTPUT+" terminals. Similarly, there will be no current through the load unless a meter (or other device having an internal resistance small enough, such that when added to the resistance of the output load, the sum does not exceed the rated maximum} is connected to the "-METER+" terminals. In the event that a milliammeter is used without any other load, a resistor having the rated maximum resistance or less must be connected across the "-OUTPUT+" terminals.

Although the circuit will perform satisfactorily at any total load resistance down to zero ohms (both pairs of terminals short circuited), it is better if the combined resistances connected to the two pair of terminals is near the maximum rated value. This will decrease the power dissipated in the output amplifier, allowing it to run cooler with a longer, more stable life (especially if the circuit board is operated under high ambient temperature condiditions). Units having current outputs are generally shipped with a small resistor connected across the output terminals to facilitate testing during installation. This resistor must be removed when the output is connected to its load.

Units having a current output and a factory installed LCD digital instrument also have a shunt resistor connected across the terminals marked "-METER+". This converts the instrument, which is basically a millivoltmeter, into a milliammeter of the appropriate range.

NOTE: DO NOT CONNECT ANY OTHER DEVICE, RESISTOR OR JUMPER ACROSS THE "-METER+" TERMINALS ON UNITS EQUIPPED WITH MILLIAMMETERS.

The devices being controlled at the set levels are connected in series with their respective power sources and the appropriate relay terminals on the circuit board. The terminals for the solid state relays (SSRs) which control the operation of the pumps (or valves, etc.) are on the terminal blocks marked, "SSR-l", "SSR-2", "SSR-3". If the unit includes alarm functions the additional terminal blocks will be marked, "ALARM" or "HIGH" or "LOW" as appropriate. AC SSRs can be used on any 60 Hz voltage source from 24 to 280 volts without regard for grounding or phasing. The terminals of DC SSRs and other DC output devices are marked with the required polarity. In general, SSRs should not be connected in series with each other but may be used in this manner in certain instances. Consult the factory if the application requires such connections.

The relays for controlling alarms are often specified as normally open (NO) or normally closed (NC). Regardless of whether the unit is wired for pump-up or pump-down service, all relays operate as follows:

A NO relay closes when the level rises to the set point.

A NC relay closes when the level falls to the set point.

When no power is applied to the circuit board, all relays, both NO and NC, are open.

High voltage transients on the power line can sometimes cause unwanted turn-on of SSRs and in extreme cases, even damage. A properly rated varistor (MOV) may be required in such electrical environments. (Consult the factory for MOV or additional relay snubber recommendations if problems are encountered with specific line/load conditions.)

2.5 Adjustments:

Once the electrical connections have been completed, power should be applied to the circuit board to check the operation of the controller, adjust the set points to the desired levels and make any calibration adjustments that may be required.

NOTE: DO NOT APPLY POWER TO THE CONTROLLED DEVICES UNTIL THE OPERATION OF THE CONTROLLER IS CHECKED AND THE SET POINTS ARE ADJUSTED TO THE DESIRED LEVELS.

If the unit has been ordered without its own meter, it will be necessary to connect a voltmeter (units having voltage outputs) or a milliammeter (units having current outputs) of the appropriate range to the "-METER+" or "-OUTPUT+" terminals while making these adjustments.

To adjust the level at which a pump will turn on, locate the reference potentiometer indicated by the legend "LEAD", "LAG" or "LAG-LAG" (or "1-0N", "2-0N", "3-0N") printed on the circuit board. Move the slide switch adjacent to this potentiometer to the right (setting position). Turning the reference potentiometer clockwise will raise the meter reading and turning counter-clockwise will lower the reading. Adjust the reading to the level at which it is desired for each pump to start. After each level is set to its desired value, SLIDE THE SWITCH adjacent to the setting potentiometer TO THE LEFT ("LEVEL" or "DEPTH" position).

To adjust the levels at which the pumps will turn-off, locate the reference potentiometers indicated by the "OFF" legends printed on the circuit board. Move the slide switch adjacent to this potentiometer to the right (setting position). Turning the reference potentiometer clockwise will raise the meter reading and turning counter-clockwise will lower the reading. Adjust the reading to the level at which it is desired for the pumps to stop. SLIDE THE SWITCH TO THE LEFT ("LEVEL" or "DEPTH" position).

In similar fashion set the levels at which the alarms or other controlled devices (if present) are to be operated.

Unless ordered otherwise, the output is set at the factory to be 0.0 V (voltage output units) or 4.0 mA (current output units) when the effective head acting on the transducer is zero. If it is desired to monitor the level from some other reference head, adjust the ZERO potentiometer as required to secure either of these zero output indications.

It may be necessary, as a result of unavoidable rough handling during installation, to reset the ZERO potentiometer. It is recommended that the installed transducer be subjected to several level (pressure) excursions over all or most of its range before deciding that the factory setting needs to be altered.

3.0 CALIBRATION

3.1 Transducer:

Calibration of transducers is limited to adjusting the offset head (corresponding to the elevation of the bottom of the tank} of offset transducers as follows:

The coupling nut should be completely disengaged and the two units separated. The operating plunger may be adjusted upwards or downwards on the threaded stem by gently turning it with a small pin (e.g., a paper clip} inserted in the side hole. The red sealant will not interfere with this adjustment but merely prevents vibration from affecting the selected offset. After the upper unit is in place the nut should then be tightened firmly but gently. In the event the exact offset desired is not obtained by this means finer adjustment may be obtained by adjusting the ZERO control on the circuit board (see below}.

3.2 Circuit Board:

Prior to making any adjustments it is important to understand the functions of the two trimmer potentiometers located on the circuit board.

ZERO This control is used to offset the conditioned signal from the transducer to effectuate a zero output indication when the effective head is either actually zero or at whatever greater head is being used as a measurement reference.

SPAN This control adjusts the amplifier gain such that there is a full scale output indication when the effective head exceeds zero (or other specified reference head} by the specified range of the transducer.

Field calibration is normally limited to minor adjustment of the ZERO control. Adjustment of this control has the same effect as raising or lowering the transducer without affecting any other part of the calibration. If the transducer has been located properly and the readings of the instrument fail to correlate with those from a staff gauge (or other gauge of unquestionable accuracy) the ZERO control may be adjusted to obtain matching readings.

Unless precision level measuring instrumentation is available, no adjustments should be made to the SPAN control. If such calibrations are thought to be necessary it is best to contact the factory for specific instructions.