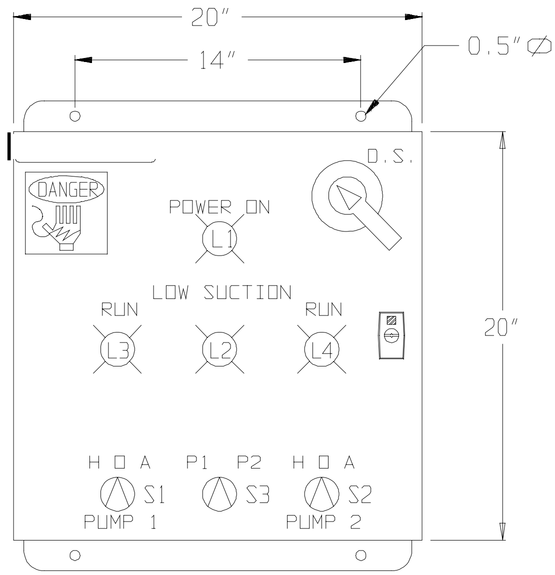
# CHAPTER 7: Control Panels

## SECTION I: OVERVIEW

### Controls

- The controls for Armstrong Booster Systems consist of an electric circuit which operates the starters of the motors. The panel is supplied by the same power source as the booster motors. The controls are housed in a NEMA rated enclosure and are composed of a series of monitoring, control, and logic components.
- Understanding the circuit schematic can make life much easier in the field when starting up, fine-tuning, and maintaining a booster system. Often, problems which arise in the operation or start up of a booster system are linked to the controls even though the problems may seem to be with the motors and pumps, or the piping and valves of the system.




NEMA 1 ENCLOSURE
DIMENSIONS MAY VARY

### Safety

- Because of the high voltages required by the motors, safety cannot be emphasized enough in making adjustments to the controls.
- ***The Bad News****:* Some of the wires inside the panel are live, even when the panel door is open. Always consult the instructions on the inside of the panel door or this manual if you are unsure of the proper safety procedures.
- ***The Good News****:* The circuits will not store latent charge when the panel power is off since there are no capacitors in any of the circuits. Result: No nasty shocks from residual charges stored in the circuits.

**Schematics**

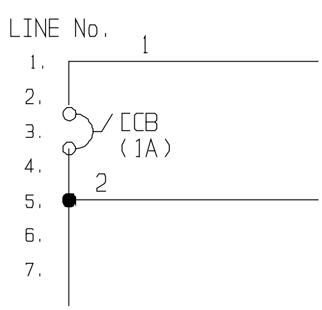
- Schematics for electric circuits can be confusing. With this in mind, this handbook was composed to remove the guesswork by using block diagrams to explain the schematic symbols.
- Two important terms need to be understood at this point. Electricians use the terms “open” and “closed” circuit. **OPEN** means there is a break in the circuit preventing current flow. **CLOSED** means the circuit is continuous and unbroken allowing current flow.
- These definitions lead to a basic rule:

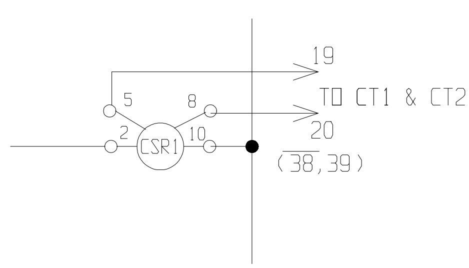
> ***OPEN = OFF (no current flow/cold wire)***
>
> ***CLOSED = ON (current flow/hot wire)***

- Components of circuits such as switches and relays are often spoken of in relation to these terms. A **Normally Open** component in its usual state breaks a circuit preventing current flow. A **Normally Closed** component in its usual state keeps a circuit continuous allowing current to flow. Schematic symbols for a component indicate whether it is normally open or normally closed.

> ***Note: The normal state refers to the position of the component (either open or closed) as that component would be in the DE-ENERGIZED, DE-PRESSURIZED state. To clarify, all pressure switches appear as they would with zero pressure, and motor overloads appear as open (even though during normal operation, these components are closed!).***

- Another important element of the schematic is the list of reference numbers printed vertically on the left hand side of the diagram. These numbers are location references for contactor and relay coils. You will see that to the right of each contactor and relay coil is a list of numbers in brackets. These numbers give the location of the switches actuated by the coils on the diagram. **These are not to be confused with terminal numbers which either appear as labels on arrows or are enclosed in boxes on the schematic.**
- To locate the switch actuated by the coil:
    a) Read the numbers to the right of the coil.
    b) Go to the corresponding numbers on the left side of the schematic.
    c) Search the schematic to the right of the reference number horizontally until the switch is located.

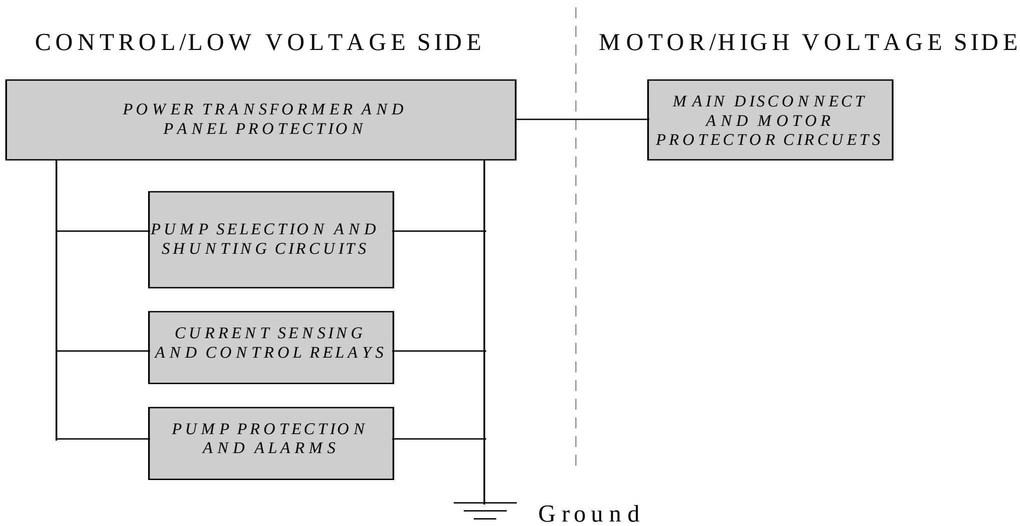


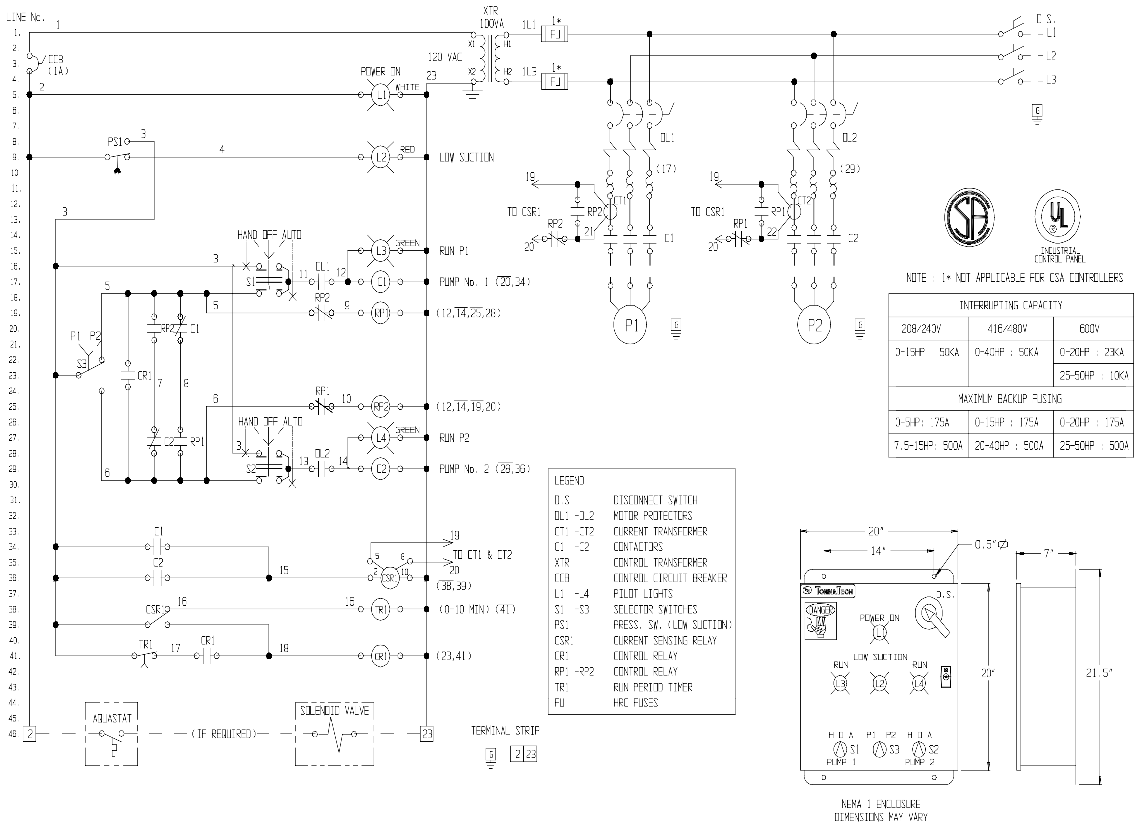
- Lastly, please note that all schematics shown in this handbook are for a three phase Duplex Booster System. These provide examples you can adapt as required when reading schematics in the field.

**The Basic Control Panel Circuit**
Every control panel for Armstrong Booster Systems can be broken down to the following components plus the additional options selected by the customer:

a) Main Disconnect and Motor Protector Circuits
b) Power Transformers and Panel Protection Circuits
c) Pump Selection and Shunting Circuits
d) Current Sensing and Control Relays
e) Pump Protection Circuits and Alarms

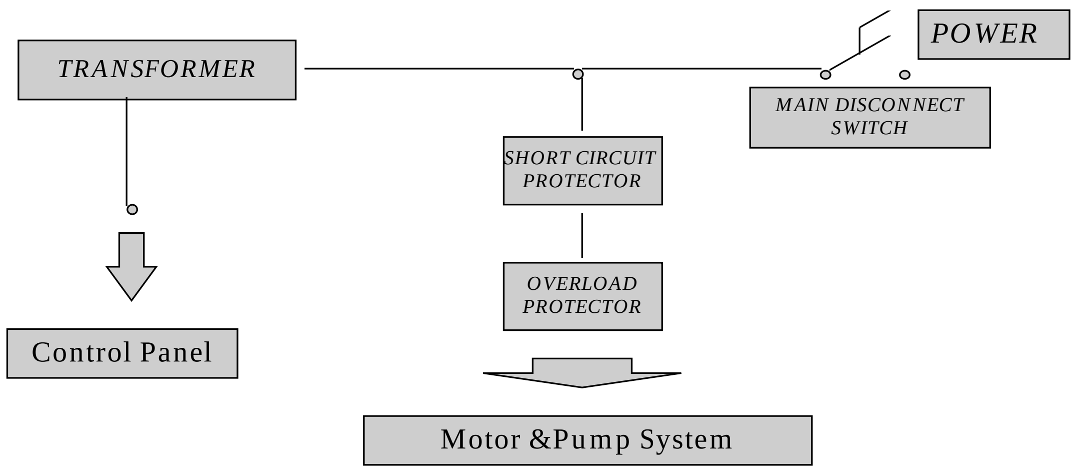



***Block Diagram of Complete Control Circuit***




***The block diagram on the previous page depicts this schematic. As each component is discussed, refer back to this schematic to identify where each element is located.***

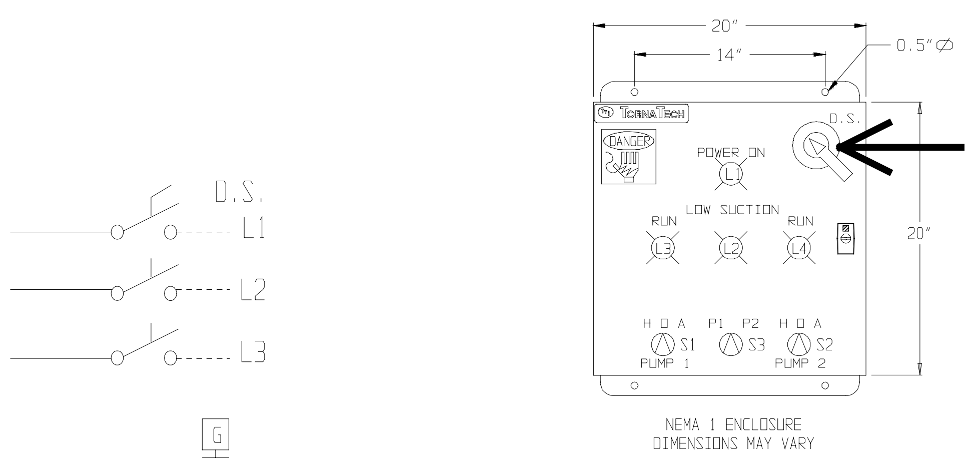
## SECTION II: MAIN DISCONNECT and MOTOR PROTECTOR CIRCUITS




***Block Diagram of Main Disconnect and Motor Protector Circuits***

### Main Disconnect Switch

- The main disconnect is the main power switch for the entire booster system.
- **All Panel and Motor servicing should be performed with the main disconnect in the OFF position. Setting the HAND-OFF-AUTO (H-O-A) switches to the OFF position does not disconnect power from the controls.**
- The main disconnect switch releases the control panel, motors, and pumps from the power supply. As a safety feature, the panel door cannot be opened without first switching to the open (OFF) position.
- The main disconnect dial/switch is located at the top right hand corner of the panel.
- **Warning: Though the open panel is not live, the wires entering the panel to the disconnect at the top of the panel are LIVE. DO NOT TOUCH.**

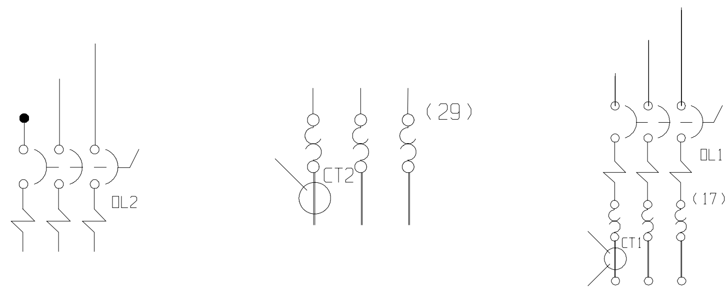



***Schematic of Disconnect Switch. The location of the switch on the panel is indicated by the arrow.***

## Motor Protector Circuits

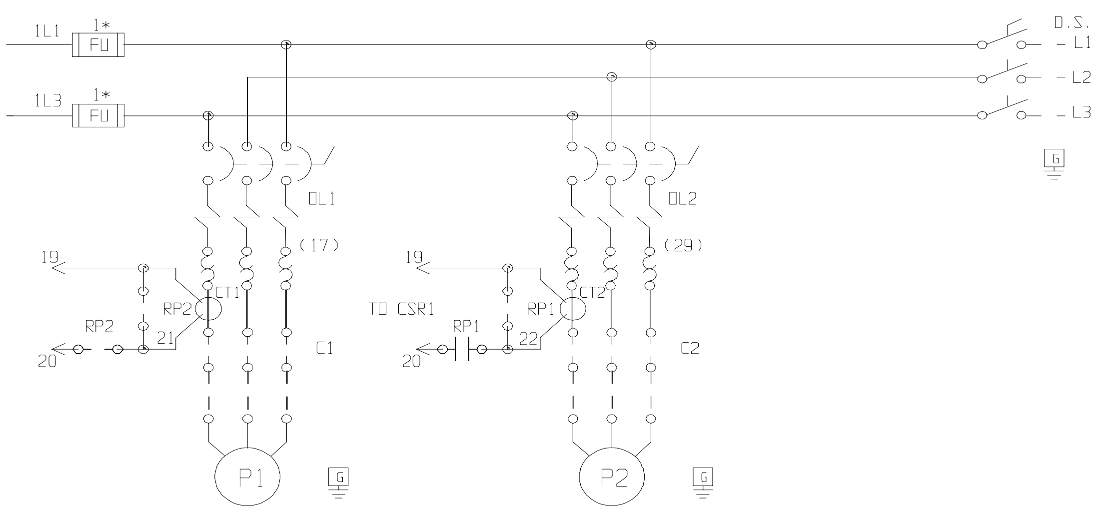
Every panel houses a protection circuit for the motors. These circuits consist of two basic components:

a) Short Circuit Protector: This is a quick-trip breaker which protects the motor from potentially damaging current surges. Typically, the short circuit protector will trip on 13 times the full load amps of the motor (maximum motor current rating).
b) Overload Protector: This bi-metal trip device is heat sensitive and will trip if the current to the motor exceeds the motor current rating for more than a given period of time.



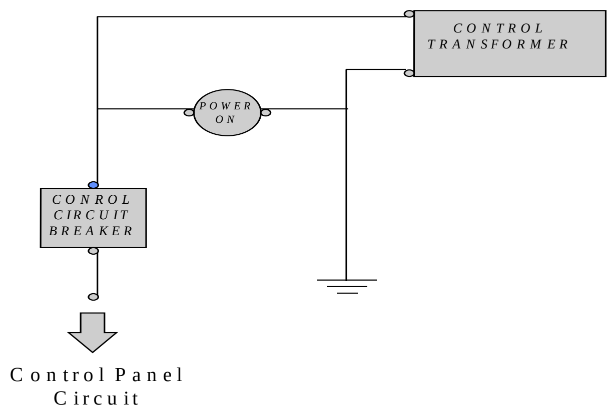

***The short circuit protector (left) and overload protector (middle) combine to form a complete motor protector circuit (right)****. Within the controller, these components are integrated into a single component called an overload relay. The device has a setting for the maximum allowable amperage, and a two push button circuit breaker (pushing in the red button opens the circuit / pushing in the white button closes the circuit).*

- These circuits are separated from the actual motor starter by a set of contacts which turn individual pumps on and off as required by the flow demand conditions. The logic for pump switching is contained in the pump shunting circuit and relays discussed in Sections IV and V. A schematic showing the main disconnect and motor protection circuits is shown below.




***Main Disconnect and Motor Protection Circuit. Note that the lower segment of the diagram (marked "P1" and "P2") represents the motors and their respective starters.***

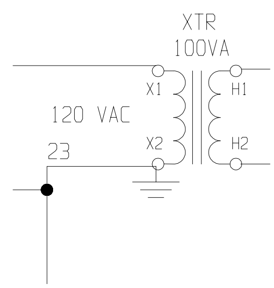
## SECTION III: POWER TRANSFORMERS and PANEL PROTECTION CIRCUITS




***Block Diagram of Power Transformer and Panel Protection Circuit***

### Control Transformers

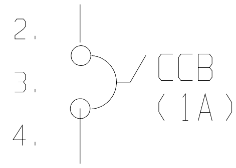
- The control transformer separates the motor side (high voltage) from the control side (low voltage) of the booster system.
- The control transformer steps down the voltage to the control panel. Though the motor may use three phase 208V to 600V power, the control portion of the panel always runs on single phase 115V power. The transformer takes care of this voltage conversion.




***Control Transformer. The left side is the low voltage side providing power to the panel. The right side is the high voltage supply which powers the motors.***

### Control Circuit Breakers

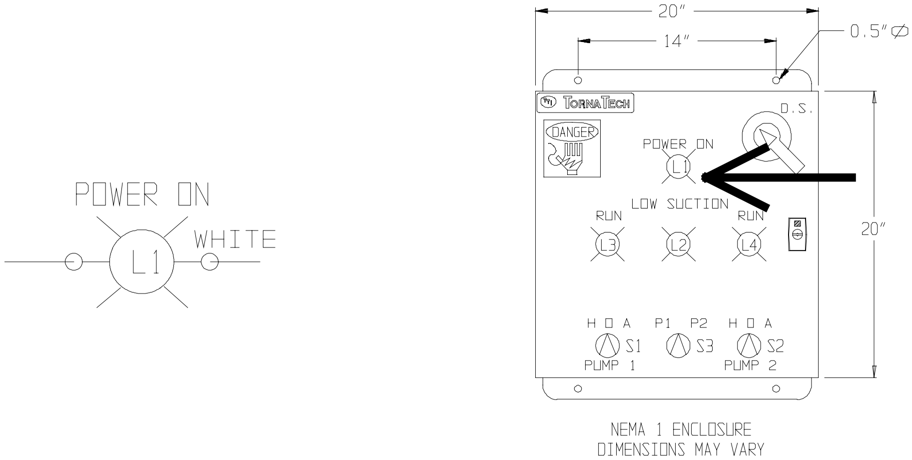
- A control circuit breaker protects the more sensitive components (relays and contacts) from being damaged by current surges.
- This standard circuit breaker trips at 0.5 amps to 3.0 amps depending on the system's combined horsepower.




***The control circuit breaker prevents current overloads in the controls' sensitive components.***

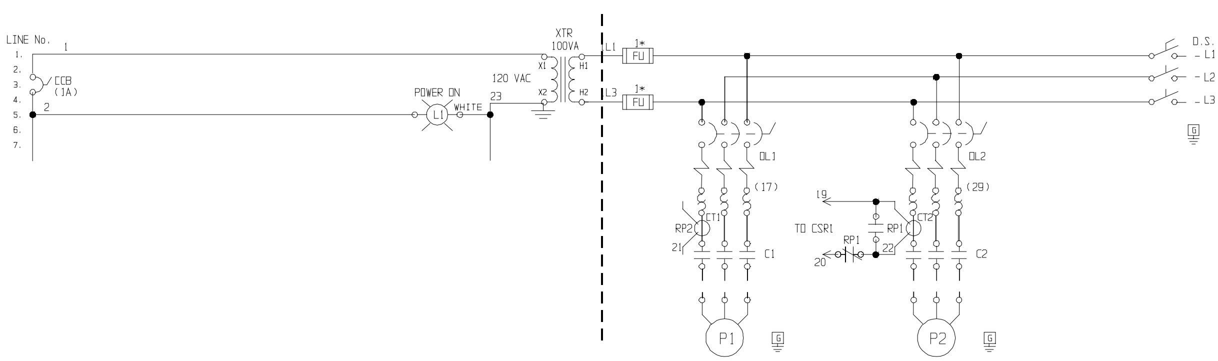
**Power On Pilot Light**

- A pilot light indicates that power is being supplied to the controls. Provided that the control circuit breaker is closed, this pilot should be lit.



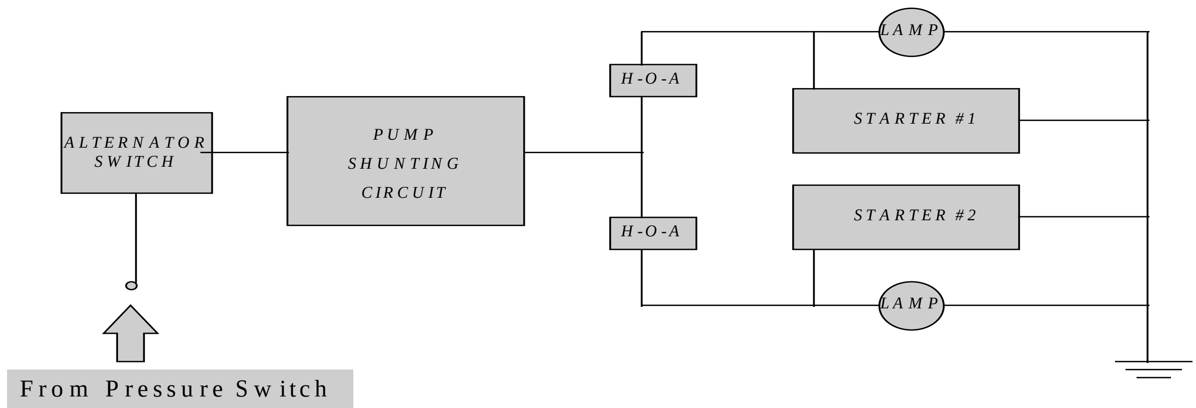

***The Power On pilot light informs the controls operator that the panel is live.***

- We now are able to discuss the fundemental panel protection and motor protection circuits. On the schematic, the main power source is supplied at the right of the disconnect switch. This power supplies the motors via the motor protector circuit and is stepped down to the panel voltage via the transformer. This is the junction that separates the high voltage (motor) side from the low voltage (control) side of the control panel.
- The control circuit breaker then protects the controls from current surges. All things being normal, the panel is supplied with power lighting the Power On pilot light. This circuit can be seen below.




***Control Protection, Transformer and Motor Protector Circuits. The portion of the schematic on the left side of the dashed line was discussed in this section.***

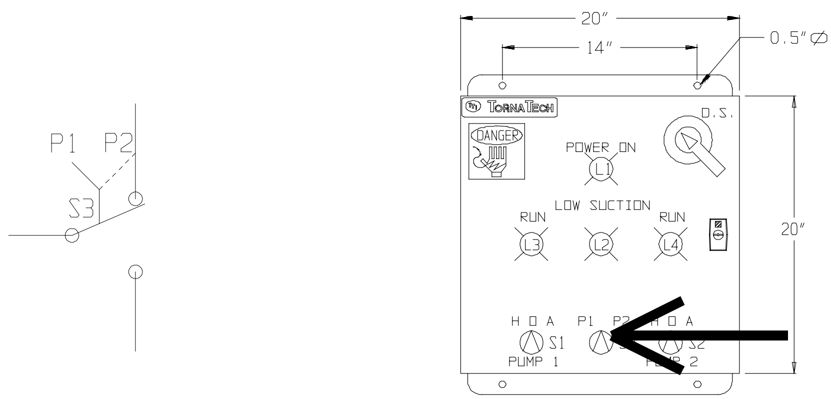
## SECTION IV: PUMP SELECTION and SHUNTING CIRCUITS




***Block Diagram of Pump Selection and Shunting Circuits***

### Manual Alternator Switches

- Manual alternator switches are standard for 50-50 capacity split Duplex systems and for the two lag pumps in the Triplex systems. The switch allows selection of which pump is the lead pump. This allows the operator of the system to equalize wear on the motors and pumps by periodically changing the alternator setting.
- The switch is a standard selector switch (marked either “P1-P2” or “P2-P3”) located at the bottom center of the panel.



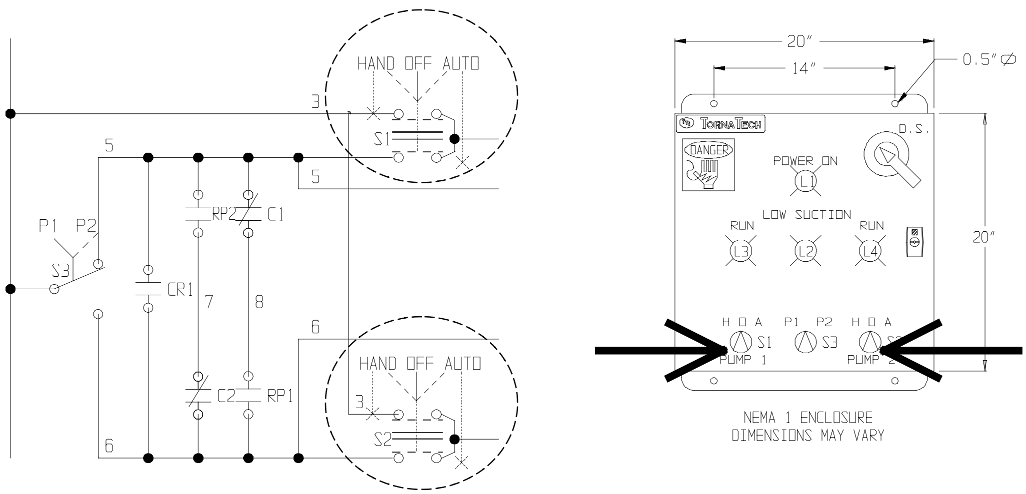

***Manual alternator switch determines which pump leads.***

### Automatic Alternator Switches

- Automatic alternator switches are optional on units requiring alternation of the lead or lag pumps. The switch serves the same purpose as the manual selector switch.
- The switch is designed to alternate on every no-flow condition and on shutoff of one pump after a full flow condition.

**Pump Shunting Circuits**

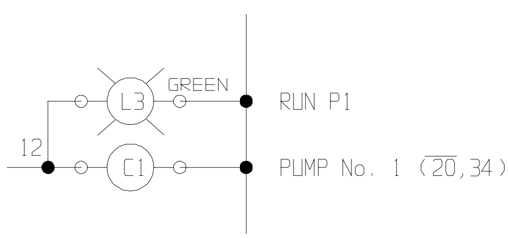
- The shunting circuit controls the turn-on and shut-off of pumps in the Duplex and Triplex booster systems. This circuit contains the logic which sequences the booster system.
- The shunting circuit is governed by the readings of one or more current sensing relays (see Section V on current sensing relays). The current sensing relay causes control relays to open and close contacts in this circuit. This action starts and stops the motors in response to the flow demand.
- The circuit is only activated when all the pumps of the booster system are set to the AUTO position on their respective H-O-A switches.




***Pump Shunting Circuit holds key to pump sequencing. The circuit is only activated when the pumps are placed in the AUTO position.***

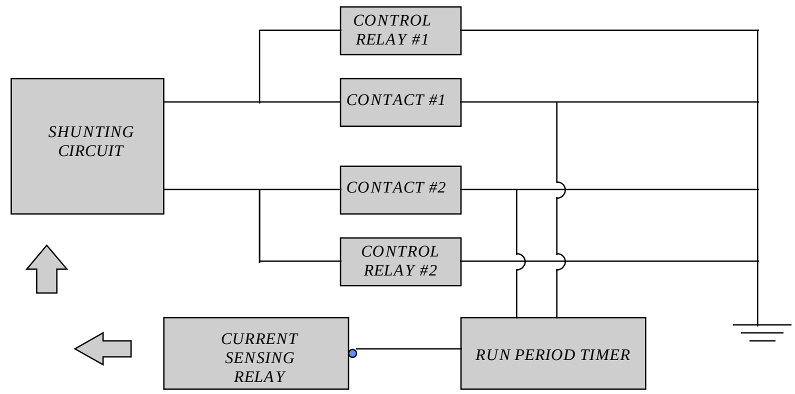
**Pump Run Indicators and Motor Contactors**

- Pump run indicator lamps (Pilot Lights) are placed in parallel with the contactor coil for each motor. The contactor coil actuates a contact located between the motor protector circuit and the motor to close. The closed contact supplies power to the motor and starts the pump running.
- This connection also lights the pump run lamp on the panel allowing the operator to know the status of each pump of the system.




***Pump run indicator and contact coil in parallel. The coil closes contacts starting a motor.***

## SECTION V:  CURRENT SENSING and CONTROL RELAYS




***Current Sensing and Control Relays***

### Current Sensing Transformers

- One leg of each motor lead is passed through a current transformer coil. These coils measure the current drawn by each motor, indirectly measuring the GPM flow through each pump.
- The current sensing relays supplied by the current transformers are factory set to an upper and lower current threshold. When the current exceeds the upper threshold, an additional pump is turned on to cope with the increased flow. Likewise, when the current drops below the lower threshold, a pump is shut down to conserve energy.
- The upper threshold controls the turn-on of the next pump and is adjusted by the dial marked “Threshold” on the current sensing relay.
- The lower threshold controls the shut-off of a running pump. It is set as a percentage of the upper threshold using the dial marked “Hysteresis” on the current sensing relay.


***Current Sensing Relay. In combination with a control relay, the CSR activates a current transformer in the starter (part of the contact arrangement) to start the motor. The numbers 19 and 20 marking the arrows indicate a connection to the matching numbers on the motor lead.***

> *TIP: The number of current sensing relays in a system can be determined by the formula:*
>
> **DUPLEX: ONE RELAY + ONE RELAY PER STEP OF SEQUENCING**
> **TRIPLEX: TWO RELAYS + ONE RELAY PER STEP OF SEQUENCING**

*EXAMPLE*: A Duplex System on 33-67 capacity split supplies a peak demand of 300GPM. The system is designed for conventional sequencing (i.e. The lead pump runs constantly. The lag pump turns on and off as the flow demand requires). The motors are 5 and 10 hp and run on a 208V supply voltage. At full flow, the lead pump draws 50 amps.

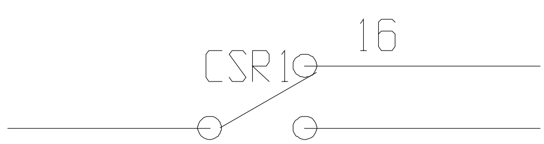
The system has one current sensing relay. The current sensing relay turn-on threshold would be set to 50 amps. This would cause the lag pump to turn on when the lead pump draws 50 amps.

The shutoff threshold would be set to about 60 amps. This would cause the lag pump to shut off when *both motors together* draw 60 amps. The "Hysteresis" setting would be 20%. Reason: 20% of 50 amps is 10 amps. Fifty amps (upper threshold) plus 10 amps gives a shutoff threshold of 60 amps.

Why is the shutoff threshold set higher than the turn-on threshold? This is because two motors working at the same flow rate as one motor alone will draw more amps.

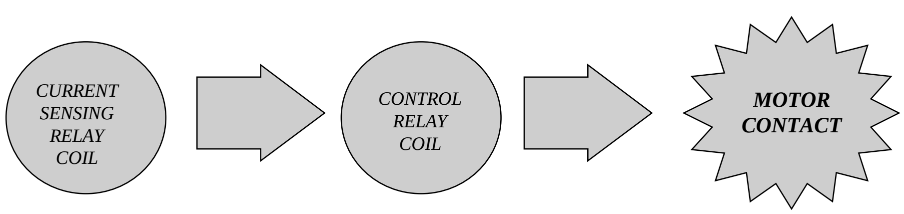
**Current Sensing Relay Switches**

- Every time a current sensing relay coil reads a threshold current, it actuates a current sensing relay switch to either open or closed (depending on whether the switch is normally open or normally closed).



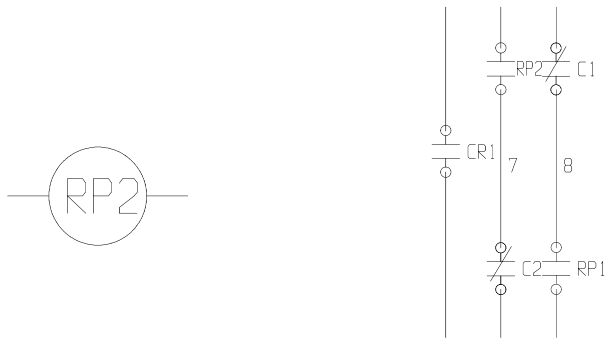

***Current sensing relay switch closes actuating a control relay to start or shut down a motor.***

- As the relay coil requires, this relay switch will open or close causing one of the following to happen:
  a) The switch closes causing a control relay to turn on a pump..
  b) The switch opens starting the countdown on the minimum run timer. When the timer runs down, a control relay turns the pump off.



**Control Relays**

- A control relay coil is actuated by the closing of a current sensing relay switch.
- The control relay in turn actuates a contact to close starting a motor.
- This coil, once activated will not deactivate with the opening of the current sensing relay switch. Instead, a minimum run timer holds the circuit closed until the timer has run down.
- This feature prevents cycling of pumps during near-threshold flow conditions.

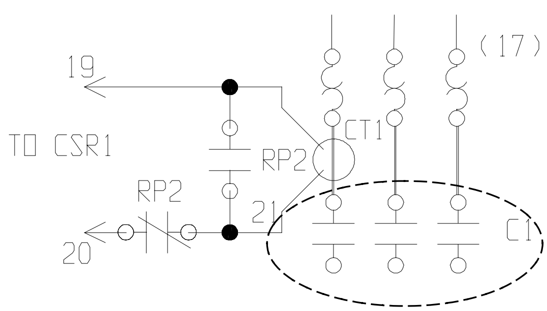



***Control Relay Coil actuates the motor starter contacts inside the shunting circuit.***

**Contacts**

- A contact corresponding to each control relay is located in the pump shunting circuit. The contact reacts to the coil in turn actuating the motor contactors and will do one of the following:

a) Turn on a new pump and shut the running pump off.
b) Turn on a new pump and leave the running pump on.
c) Shut off the running pump after the set time.



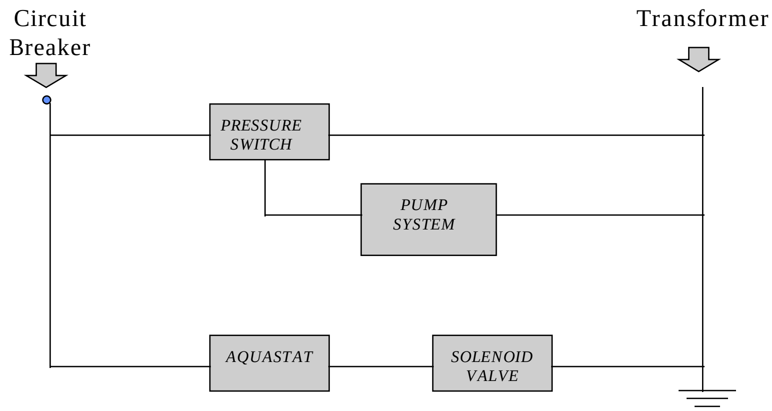

***Contacts (RP2) close to start the motor running or open to shut one down.***
***This action opens or closes the motor contactors (C1).***

**Minimum Run Timer**

- A minimum run timer for each current sensing relay ensures that pumps do not cycle damaging the motors.
- The timer is started when the current sensing relay opens. The timer keeps the control relay energized and the corresponding contact closed. The result is that instead of the pump corresponding to the control relay turning off, the pump keeps running for the designated time period. After this time, the connection is opened and the pump turns off.
- For example, if the timer is set for 5 minutes, and a pump is turned on, it will stay on for at least five minutes. Cycling of the pump can only occur at five minute intervals preventing cycling damage to the motor and pump.


***Timing Relay holds the contact for a set period of time in order t o prevent pump cycling.***

## SECTION VI: PUMP PROTECTION




***Block Diagram of Pump Protection Circuit***

### Low Suction Pressure Warning

- A pressure switch protects the pumps from the effects of low suction pressure. If the suction pressure feeding the system drops below a minimum threshold the low suction pressure switch will open, shutting all pumps down.
- The minimum suction pressure cut-out is factory set to 5 psi but may be adjusted, though this is strongly advised against.
- The low suction switch will turn all pumps off and light the low suction lamp warning.
- The pressure switch has two settings:

  a) Cut-out value: This opens the contacts shutting down the pumps (set at 5 psi). On the switch itself, this setting is adjusted by turning the top screw. The actual setting is read on the scale on the side of the switch.
  b) Cut-in value: This is adjusted relative to the cut-in value using the "Differential" setting. (Cut-out value + Differential Setting = Cut-in Value) The differential is set after the cut-out value has been set, and should be set to its minimum to begin adjustments. After the cut-out has been set, turn the bottom screw to the letter corresponding to the desired differential. (Factory set to 5 psi above the cut-out pressure.)

- **Warning: If the low suction pressure switch is set too close to the minimum NPSH, pump cycling will occur. If the situation is not corrected, damage to the motor starters can be expected. The same problem will occur if the "Differential" setting is too low.**

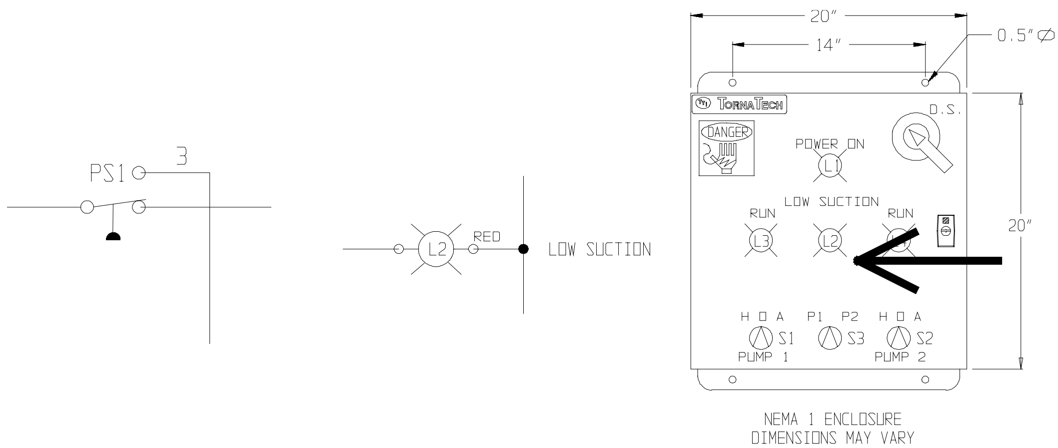


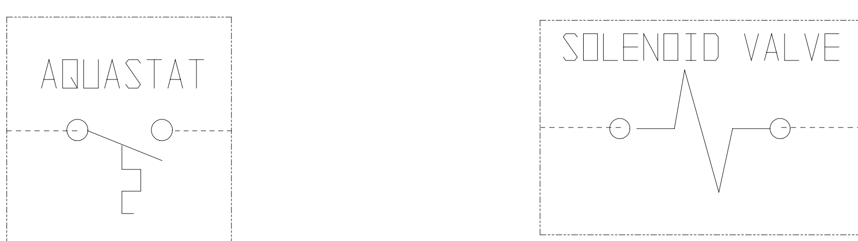

***Fig.# 21: Low suction pressure switch shuts down system and warns by lighting pilot.***

### High and Low System Pressure Warnings

- Two further pressure switches with warning pilots are available as options (see Section VII of this chapter).
- These switches are also factory set and can be complimented by corresponding low and high system pressure warning lamps.

### Aquastats and Solenoid Valves

- During normal operation, a steady flow of water through the pumps carries away the waste heat they generate. Because of this, high temperatures are occasionally generated during periods of low flow. High temperature water can affect the performance of and even damage the pumps.
- An aquastat is available as an option and is installed on the suction header to measure the temperature of the water in booster system.
- The aquastat is set for a certain temperature (120°F) at which it actuates a solenoid valve located on the side of the control panel. This valve opens bleeding the potentially harmful hot water.
- In No-Flow Shutdown Systems (Option X), the aquastat is used to trigger a pressure switch which shuts down the system. In this case, no solenoid valve is required since the aquastat is set to a much lower temperature (90°F).




***Aquastat and Solenoid valve act together to bleed high temperature water from the pumps.***
***On No-Flow shutdown systems, the solenoid valve is not necessary since***
***the pumps shut down long before high temperatures are generated.***

## SECTION VII: OPTIONS

### No-Flow Shut-down

- No-Flow Shut-down (Option X) is an energy saver option, and requires a drawdown tank.
- Though this incurs an initial cost, on systems where no flow conditions occur for several hours a day (i.e. office buildings, etc.), the energy savings can be dramatic. Typically, the option pays for itself within the first two years of operation.
- The No-Flow Shut-down option uses an aquastat to trigger the shutdown. The aquastat is set from its usual 120°F to 90°F. This typically shuts the system down after about three minutes of a no demand condition. No solenoid bleed valve is required since the system shuts down well below the usual 120°F threshold.
- The aquastat may need resetting depending on the ambient water temperature of the particular location. **Check the troubleshooting guide or instructional video before resetting the aquastat.**
- The drawdown tank maintains system pressure and handles leak loads while the pumps are not running. A “call on” pressure switch triggers the lead pump to turn on when a demand is placed on the system.

### Enclosures

- Though the NEMA 1 Enclosure is Standard for Armstrong Booster Systems, a wide range of indoor and outdoor enclosures of varying protection ratings are available as options.
- Be sure the enclosure suits the needs of the customer by refering to the listing of NEMA, CSA, and UL standard codes for control panel enclosures on page 40 of this handbook.

### Alarms

A variety of alarm options are available. All are visible warning lamps and may be complimented as required by Option H, the audible alarm buzzer (linked in parallel) with the standard alarm lamp. The following alarms are offered:

a) High System Pressure: This option (Option K) is simply a pressure switch with indicator lamp on a bypass circuit much like the low suction pressure alarm. This alarm is accompanied by a system shutoff and a manual reset button on the panel door.
b) Low System Pressure: Two different low system pressure alarms are available. **Be sure to quote the correct option on orders.** Option AD will shutdown on the low system pressure condition. Option Q will turn on another pump to compensate for the low pressure. This pump will remain engaged until the reset button is pushed. Both options have manual resets.
c) High Suction Pressure: Option G is also a bypass type pressure switch which will shut the system down on high suction pressure readings. This option has automatic reset when the suction pressure drops below the set threshold pressure.
d) Low Suction Level Shutdown: Option AE
e) Motor Overload Lamps: Option D is mounted on the motors themselves. The lamps will light if the motor current level exceeds the set overload current.

### Automatic Alternation

- Automatic pump alternation (Option I) is available on a 24 hour/7 day per week time clock, or automatically after every full demand and no-flow condition.
- Instructions for programming the timer are included inside the panel door with every order on this option. The timer controls a relay which toggles the pump alternation switch at the time set on the clock (daily or weekly).

**HydroSaver Sequencing**

- The HydroSaver Sequencing options (Option S, T, and U) require the addition of an extra control relay per stage of sequencing. Though there is a cost for this option, this cost is often offset within the first two years of operation in energy savings.
- Option S adds three step sequencing to a Duplex system typically using a 33-67 capacity split between the two pumps. The arrangement leads to the following pump run conditions depending on the demand flow:

  - Step 1: Pump 1 running, Pump 2 off (33% capacity)
  - Step 2: Pump 1 off, Pump2 running (67% capacity)
  - Step 3: Pump 1 and Pump 2 Running (full capacity)

- Option T adds four step sequencing to a Triplex system using a 20-40-40 capacity split between the three pumps. The arrangement yields the following pump configurations subject to demand conditions:

  - Step 1: Pump 1 running, Pumps 2 and 3 off (20% capacity)
  - Step 2: Pump 2 running, Pumps 1 and 3 off (40% capacity)
  - Step 3: Pumps 2 and 3 running, Pump 1 off (80% capacity)
  - Step 4: Pumps 1, 2, and 3 running (full capacity)

- Option U takes full advantage of the Triplex 20-40-40 capacity split by breaking the supplied flow into five steps:

  - Step 1: Pump 1 running, Pumps 2 and 3 off (20% capacity)
  - Step 2: Pump 2 running, Pumps 1 and 3 off (40% capacity)
  - Step 3: Pumps 1 and 2 running, Pump 3 off (60% capacity)
  - Step 4: Pumps 2 and 3 running, Pump 1 off (80% capacity)
  - Step 5: Pumps 1, 2, and 3 running (full capacity)

**NEMA 1**
*General Purpose - Indoor*
Intended for indoor use. Provides protection from accidental contact of personnel with enclosed equipment. Standard Armstrong enclosure.

**NEMA 2**
*Dripproof - Indoor*
Intended for indoor use. Protects equipment from falling dirt and falling non-corrosive liquids.

**NEMA 3**
*Dust, Rain, and Sleet resistant - Outdoor*
Intended for outdoor use. Protects enclosed equipment from wind-blown dust and water. Limited resistance to snow, sleet, and ice. (NOT SLEET PROOF)

**NEMA 3R**
*Rainproof / Sleet-resistant - Outdoor*
Same as NEMA 3 with added resistance to rain and snow.

**NEMA 4**
*Water/Dust-tight - Indoor/Outdoor*
Intended for indoor/outdoor service. Protects equipment from splashing, seeping, falling, or hose-directed water and from severe external condensation. Limited resistance to snow, sleet, and ice.

**NEMA 4X**
*Water/Dust-tight - Indoor/Outdoor Corrosion Resistant*
Same provisions as NEMA 4 with the addition of resistance to corrosion.

**NEMA 12**
*Indoor Industrial - Dust and Drip-tight*
Intended for indoor use. Protects equipment from fibers, flyings, lint, dust and dirt, and light splashing, seepage, dripping and external condensation of noncorrosive liquids.

**NEMA 13**
*Indoor Industrial -Dust and Drip-tight*
Intended for housing pilot devices such as limit switches, foot switches, pushbuttons, selector switches, pilot lights, etc. and to protect these devices from lint and dust, seepage, external condensation, and spraying of water, oil or coolant.

**CSA 1**
*Indoor*
General purpose enclosure providing protection from accidental contact of personnel with enclosed equipment.

**CSA 2**
*Drip Resistant - Indoor*
Enclosure constructed to provide a degree of protection from dripping and light splashing of non-corrosive liquids and falling dirt.

**CSA 3**
*Rain-resistant - Indoor/Outdoor*
Indoor/Outdoor enclosure constructed to provide a degree of protection from rain, snow, and windblown dust. Undamaged by external ice formation.

**CSA 3R**
*Rainproof - Indoor/Outdoor*
Same as CSA 3 with higher resistance to rain and snow. Also undamaged by external ice formation.

**CSA 4**
*Rainproof - Indoor/Outdoor*
Indoor/Outdoor enclosure constructed to provide a degree of protection from rain, snow, windblown dust, splashing and hose-directed water. Also undamaged by external ice formation.

**CSA 4X**
*Corrosion-resistant - Indoor/Outdoor*
Same as CSA 4 enclosure with added resistance to corrosion.

**CSA 12**
*Indoor Industrial*
Constructed so as to provide a degree of protection from circulating dust, lint fibers, and flyings; dripping and light splashing of noncorosive liquids; not provided with knockouts.

**CSA 13**
*Indoor Industrtial*
Constructed so as to provide a degree of protection against circulating dust, lint fibers, and flyings; seepage and spraying of noncorrosive liquids including oils and coolants.

**UL 50/UL 508 Type 1**
*Indoor*
Indoor enclosure providing a degree of protection from contact with enclosed equipment and from limited amounts of falling dirt.

**UL 50/UL 508 Type 2**
*Water-resistant - Indoor*
Enclosure resistant to limited amounts of falling water and dirt.

**UL 50/UL 508 Type 3**
*Outdoor*
Outdoor enclosure providing a degree of protection from windblown dust, rain, and sleet. Undamaged by external ice formation.

**UL 50/UL 508 Type 3R**
*Rain-resistant - Outdoor*
Same as UL 50/UL 508 Type 3 also providing a degree of protection from falling rain and sleet.

**UL 50/UL 508 Type 4**
*Indoor/Outdoor*
Indoor/Outdoor enclosure providing protection from splashing or hose-directed water, rain and windblown dust. Undamaged by the formation of ice on the enclosure.

**UL 50/UL 508 Type 4X**
*Indoor/Outdoor*
Indoor/Outdoor enclosure same as Type 4 with added resistance to corrosion.

**UL 50/UL 508 Type 12**
*Indoor Industrial*
Indoor enclosure providing a degree of protection from dust, falling dirt, and dripping non-corrosive liquids.

**UL 50/UL 508 Type 13**
*Indoor Industrial*
Indoor enclosure providing a degree of protection form dust and spraying of water, oil and non-corrosive coolants.