

AQUA PHASE

PUMP CONVERTER




***THE POWER BEHIND
THE PUMP!***

**AP Series Variable Frequency Drives
Operation & Installation Manual**









SAFETY MESSAGES AND WARNINGS

To ensure safe and reliable operation of the AquaPhase AP Series pump converter, it is important to carefully read this manual, and to read and observe all warning labels attached to the drive before installing the equipment. Please follow all instructions exactly, and keep this manual with the equipment at all times for quick and easy reference.

Definitions of Warning Signs and Symbols

-  **CAUTION:** Indicates a potentially hazardous situation that could result in injury or damage to the product.
-  **WARNING:** Indicates a potentially hazardous situation that could result in serious injury or death.
-  **HIGH VOLTAGE:** Indicates high voltage. The voltage associated with the procedures or operations referenced could result in serious injury or death. Use caution and follow instructions carefully.

READ THESE WARNINGS BEFORE INSTALLING OR OPERATING THE EQUIPMENT!

-  **WARNING:** Risk of electric shock. More than one disconnect switch is required to de-energize the equipment before servicing.
-  **WARNING:** Risk of electric shock. De-energize the unit by disconnecting all incoming sources of power, then wait 30 minutes for internal charges to dissipate before servicing the equipment.
-  **HIGH VOLTAGE:** This equipment is connected to line voltages that can create a potentially hazardous situation. Electric shock could result in serious injury or death. This device should be installed only by trained, licensed and qualified personnel. Follow instructions carefully and observe all warnings.
-  **WARNING:** This equipment should be installed and serviced by qualified personnel familiar with the type of equipment and experienced in working with dangerous voltages.
-  **WARNING:** Installation of this equipment must comply with the National Electrical Code (NEC) and all applicable local codes. Failure to observe and comply with these codes could result in risk of electric shock, fire or damage to the equipment.
-  **WARNING:** Control Terminals COM, NO, NC, the remote notification terminals, are rated at 240V. While it is recommended that the circuit attached to these terminals use a non-lethal voltage, it is possible that they are connected to a circuit with up to 240V. Disconnect power to these terminals before servicing the equipment.
-  **CAUTION:** The AUX1 and AUX2 terminals are galvanically isolated, with approximately 5V potential between them. DO NOT apply a voltage to the terminals. Use dry contacts only.
-  **CAUTION:** Circuit breakers or fuses, proper ground circuits, disconnects and other safety equipment and their proper installation are not provided by Phase Technologies, LLC, and are the responsibility of the end user.

- ⚠ CAUTION:** Long leads between the unit and the motor with an unfiltered PWM voltage can lead to dangerous voltage rise from reflected harmonics. Very long leads, such as in deep well submersible pump applications, may require the use of a sine wave filter to remove most of the harmonics from the waveform. Consult the factory or a knowledgeable source on drive filters if your application has more than 50 feet between the drive and the motor.
- ⚠ CAUTION:** Failure to maintain adequate clearance may lead to overheating of the unit and cause damage or fire.
- ⚠ WARNING:** Suitable for use in a circuit capable of delivering not more than 5 kA RMS symmetrical amperes, 240 V maximum for all models with 240V class input (refer to model nomenclature).
- ⚠ WARNING:** Suitable for use in a circuit capable of delivering not more than 5 kA RMS symmetrical amperes, 480 V maximum for all models with 480V class input (refer to model nomenclature).
- ⚠ WARNING:** Wire used within the motor circuit and all field wiring terminals must be rated at least 75 C.
- ⚠ WARNING:** Use wire size suitable for Class 1 circuits.
- ⚠ WARNING:** Input power connections should be made by a qualified electrician into a nominal 240V circuit for models with 240V input, or a nominal 480V circuit for models with 480V input, with adequate current carrying capacity. Branch circuit protection to the drive should be provided by appropriate size fuses or a 2 pole, linked circuit breaker. Circuit breaker and fuse ratings for each model are listed in Table 3-3.
- ⚠ WARNING:** These devices are equipped with integral solid state short circuit protection. Integral solid state short circuit protection does not provide branch circuit protection. Branch circuit protection must be provided in accordance with the National Electrical Code and any additional local codes.
- ⚠ CAUTION:** Use 600 V vinyl-sheathed wire or equivalent. The voltage drop of the leads needs to be considered in determining wire size. Voltage drop is dependent on wire length and gauge. Use Copper Or Aluminum Conductors.
- ⚠ CAUTION:** Wires fastened to the terminal blocks shall be secured by tightening the terminal screws to a torque value listed in Table 3-2.
- ⚠ CAUTION:** The input wire gauge must be sized to accommodate the single-phase input current, which will be significantly larger than the three-phase output current to the load.
- ⚠ CAUTION:** The maximum wire gauge for the input terminals is listed in Table 3-2.
- ⚠ CAUTION:** Never allow bare wire to contact the metal surfaces.
- ⚠ CAUTION:** Never connect AC main power to the output terminals U/T1, V/T2, and W/T3.

- ⚠ WARNING:** Under certain conditions, the motor may automatically restart after a trip has stopped it. Make sure power to the drive has been disconnected before approaching or servicing the equipment. Otherwise, serious injury may occur.
- ⚠ CAUTION:** The AUX1 and AUX2 terminals are galvanically isolated, with approximately 5V potential between them. DO NOT apply a voltage to the terminals. Use dry contacts only.
- ⚠ CAUTION:** Before applying power to the main input terminals of the unit, make certain that at least one of the switches or jumpers connected to AUX1 or AUX2 is open. Otherwise, the motor load will start as soon as the drive is energized.
- ⚠ WARNING:** On models equipped with keypad and display, the default mode when the unit is energized is AUTO. If the AUX1 and AUX2 terminals are closed when the unit is energized, the motor will start. Make sure either AUX1 or AUX2 terminals are open before energizing the input. Refer to the section on Keypad and Display for instructions on operating the keypad.
- ⚠ CAUTION:** The AC motor load must be connected directly to the output terminals of the converter. Do not install relays or disconnect switches between the converter and the motor load.
- ⚠ CAUTION:** Before the motor is connected to the output terminals, check all output lines for line-to-ground faults using a megger. There is a direct path through the drive circuitry for ground fault currents that can be triggered when power is applied to the input terminals, even though the output switches are not activated. These currents can cause serious damage to drive circuitry and are not covered under warranty.
- ⚠ CAUTION:** When equipped with the optional keypad and display, the rotary switch on the Control Terminal Panel is disabled. Do not attempt to set motor protection trip settings with the rotary switch when the keypad and display is present.
- ⚠ CAUTION:** Before touching any printed circuit board, place a hand on a bare metal surface of the unit to discharge any static electricity. Electrostatic discharge (ESD) can damage printed circuits and their components.
- ⚠ CAUTION:** Upon initial start-up, the keypad will default to AUTO mode. The motor load will automatically run if both AUX1 and AUX2 remote switches are closed. To stop the motor, push MAN (manual) or OFF, or open AUX1 or AUX2. The RUN and STOP keys only work when in MAN mode.
- ⚠ CAUTION:** Operating the system in MAN mode on the keypad overrides signals from the pressures switches. Operating the system in this mode may lead to dangerous pressures in closed plumbing systems

TABLE OF CONTENTS

Safety Messages and Warnings	i
Contact Information	vi
Section 1 Introduction	1-1
1.1 AP Series Design.....	1-1
1.2 Model Nomenclature.....	1-2
1.3 Base Models and Ratings.....	1-3
1.4 Dimensions and Weights.....	1-4
Section 2 System Configuration	2-1
2.1 System Configuration Settings.....	2-3
Section 3 Installation	3-1
3.1 Mounting.....	3-1
3.2 Dimensional Drawings.....	3-2
3.3 General Wiring Considerations.....	3-8
3.4 Control Terminals.....	3-10
Section 4 Operation	4-1
4.1 Motor Overload Protection.....	4-1
4.2 Setting System Configuration.....	4-2
4.3 Using the Keypad and Display.....	4-4
4.4 Power-Up Procedures.....	4-11
Section 5: Adjustable Parameters	5-1
5.1 Start-Up and Shut-Down Ramp Times.....	5-1
5.2 Controlling Motor Speed With Analog Input.....	5-3
5.3 Changing Parameter Values.....	5-5
Section 6: Constant Pressure Systems	6-1
6.1 Control Principles of Constant Pressure Systems.....	6-1
6.2 Digital Constant Pressure Systems.....	6-3
6.3 Analog Constant Pressure Systems.....	6-6
6.4 Pre-Charge Mode.....	6-10
6.5 Duplex Systems.....	6-11
Section 7: Troubleshooting	7-1
7.1 Status Indicators and Fault Codes.....	7-1
7.2 Routine Inspection and Maintenance.....	7-5
Section 8: Limited Warranty	8-1

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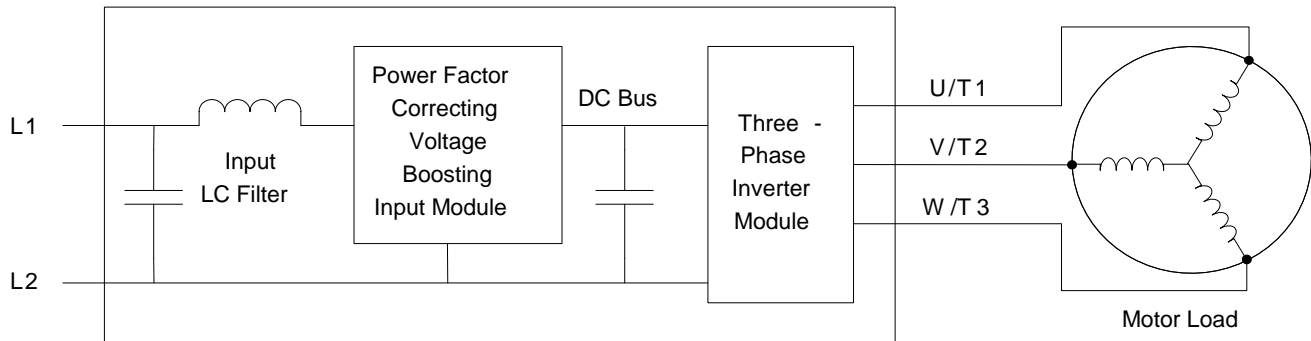
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Version 1.8

AP Series pump converters are inverter-based devices that convert single-phase input to three-phase variable frequency output to provide speed control for three-phase AC motors.

Figure 1-1 AP Series Block Diagram



1.1 AP Series Design

The simplified block diagram below demonstrates how the AP Series drive converts the incoming AC power to DC, then utilizes an inverter module to generate variable voltage and frequency output to control the speed of the motor.

Rectifier Input

The single-phase input rectifier stage consists of a diode rectifier, IGBT chopper module and an inductor. This input module employs electronic power factor correction, drawing the input current as a sine-wave, eliminating the current distortion and line harmonics associated with a diode rectifier bridge. The input module can also boost the DC bus voltage, which allows the inverter module to produce an output voltage much higher than the input voltage. The AP Series includes models with either 240V or 480V input. A 240V class model requires nominal 240VAC input, and a 480V model requires nominal 480VAC input. In order to avoid overloading the input module, the converter output should be de-rated linearly as the input voltage decreases.

Low Input Harmonics

All models of the AP Series employ electronic power factor correction on the input module. Electronic power factor correction allows the drive to draw the input current as a sine wave, greatly reducing the current distortion and line harmonics associated with a diode bridge rectifier. Because of its favorable harmonic profile, input line reactors and harmonic filters are NOT REQUIRED on the input of an AP Series drive. Installations in many cases will comply with IEEE 519, the international standard for allowable harmonic distortion on utility mains.

Voltage Boosting

Unlike a diode bridge rectifier, the input module is capable of significantly boosting the voltage on the DC bus. In fact, the output voltage can be more than doubled from the input voltage. The AP Series includes models rated either 240V or 480V input. A 240V class model requires nominal 240VAC input, and a 480V model requires nominal 480VAC input.

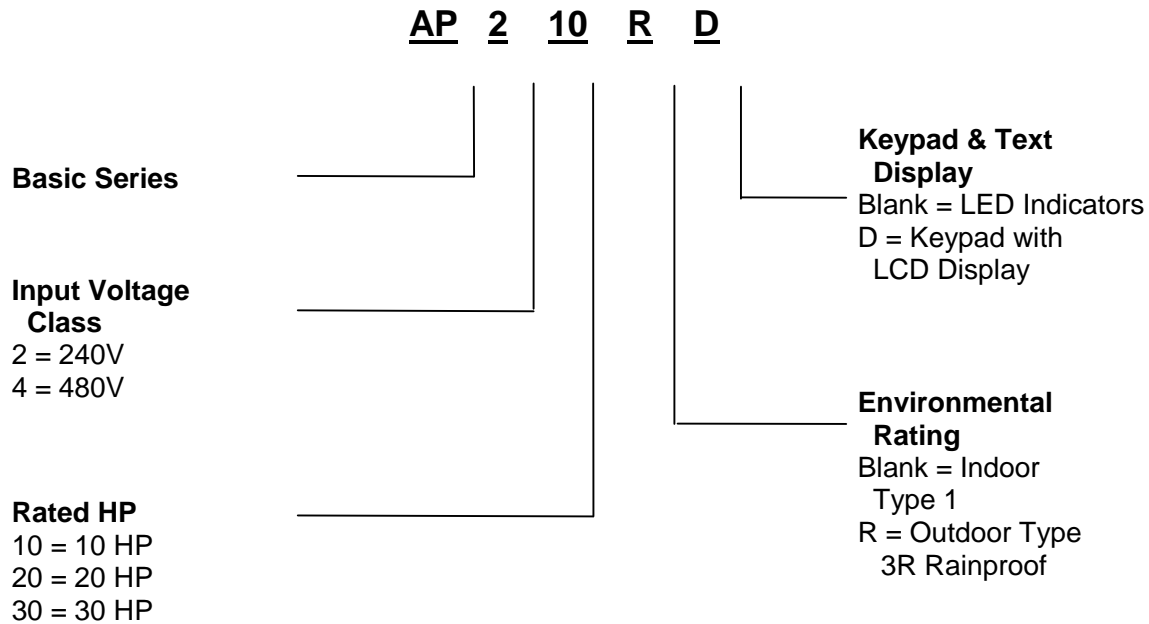
Inverter Output

The AquaPhase output is three-phase, pulse width modulated (PWM), variable voltage and frequency. All models have a 480V output, thus allowing 240V input models to convert the incoming single-phase 240VAC to three-phase 480VAC output. The AP Series employs either v/f control or sensorless vector control for outstanding low-speed performance and speed control.

⚠ CAUTION: The AC motor load must be connected directly to the output terminals of the drive. Do not install relays or disconnect switches between the drive and the motor load.

Fuses or motor overload devices as required by NEC and local safety codes may be installed between the drive and the motor, however the AP Series is equipped with adjustable solid state motor overload protection.

1.2 Model Nomenclature



1.3 Base Models and Ratings

Table 1-1 Base Models and Ratings

240V Input Models			
Model	AP210	AP220	AP230
Rated Input Voltage	1-phase, 240VAC, 50/60 Hz		
Rated Input Current (A)	58	100	139
Rated Output Voltage	3-phase, 380-480VAC, 50/60 Hz		
Rated Output Current (A)	18	31	46
Rated output KVA (480V)	15	26	38
Rated output KW (480V)	11.4	21	31
Carrier Frequency	5.2 kHz	2 kHz	2 kHz

480V Input Models			
Model	AP410	AP420	AP430
Rated Input Voltage	1-phase, 480VAC, 50/60 Hz		
Rated Input Current (A)	29	50	69
Rated Output Voltage	3-phase, 440-480VAC, 50/60 Hz		
Rated Output Current (A)	18	31	46
Rated output KVA (480V)	15	26	38
Rated output KW (480V)	11.4	21	31
Carrier Frequency	5.2 kHz	2 kHz	2 kHz

1.4 Dimensions and Weights

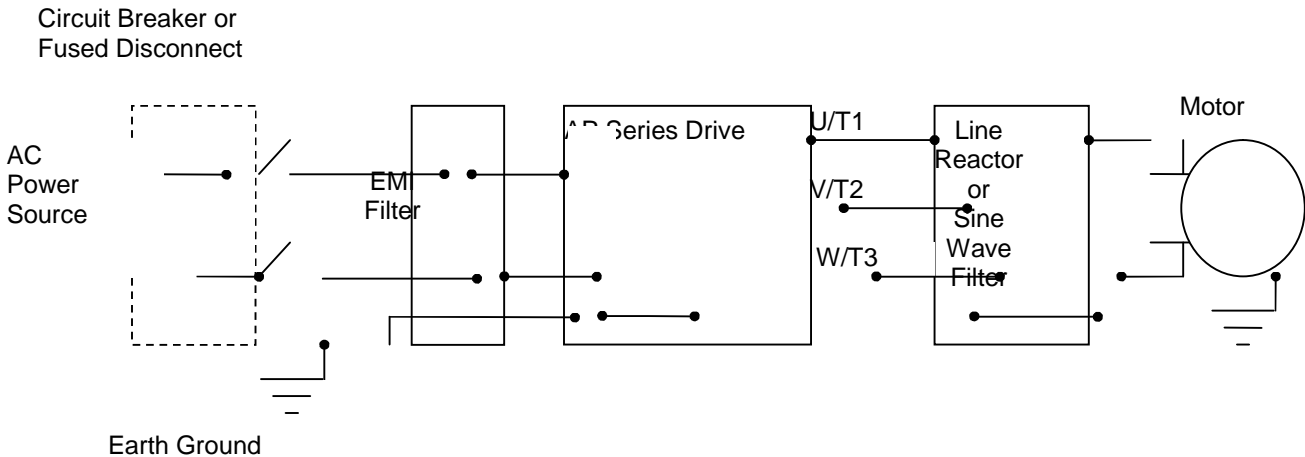
Table 1-2 Dimensions and Weights

Model	Height (in.)	Width (in.)	Depth (in.)	Weight (lb.)
AP210 or AP410	17.3	12.4	12.4	65
AP210R or AP410R	22.7	12.4	16.4	74
AP220 or AP420	23.2	18.9	14.6	110
AP220R or AP420R	27.7	18.9	20.7	125
AP230 or AP430	25.5	20.2	14.6	149
AP230R or AP430R	30	20.2	20.4	165

When used in a typical motor application, the AP Series may require the installation of several additional components. Figure 2-1 below illustrates a motor load application with components that may be required. Please remember to follow all applicable NEC and local codes to ensure safety and compliance.

⚠ CAUTION: Circuit breakers or fuses, proper ground circuits, disconnects and other safety equipment and their proper installation are not provided by Phase Technologies, LLC, and are the responsibility of the end user.

Figure 2-1 System Configuration



Because AP Series converters have an actively controlled, power factor corrected input module, input line reactors and harmonic filters are not required. The input current is drawn in a sine wave, resulting in very low input current harmonics. Most other VFDs utilize a diode bridge rectifier which induces high levels of distortion in the input current. An AP Series installation in many cases will comply with IEE519, the international standard for allowable limits on distortion of AC power mains.

Under certain conditions such as large power supply capacity or abrupt power supply changes, general purpose VFDs may also require an AC reactor on the input side to prevent large peak current flows that can destroy their input diode rectifier. An AP Series converter with its actively controlled input module does not create these high peak currents and is therefore not susceptible to damage under these conditions. An input line reactor is not recommended.


Mitigating Electromagnetic Interference (EMI)

Devices that utilize power switching electronics, such as AquaPhase AP Series drives, produce high frequency emissions commonly known as electromagnetic interference (EMI). These emissions can be conducted on power cables or emitted (radiated) through the air. Conducted and emitted noise can sometimes interfere with radio signals or sensitive electronic equipment near the installation. The use of shielded cables and rigid metal conduit on the input lines on both input and output lines between the converter and the motor is recommended to help reduce EMI. An EMI Filter on the input lines helps reduce the radiated and emitted noise that can feed back from the converter to the source power. Contact the factory for assistance in choosing an EMI filter.

Output Filters

Some installations may require a load reactor, dV/dT filter or sine wave filter between the drive and the motor. **Output filters are necessary when motor leads exceed 50 ft.** Without filters, long leads allow reflected harmonics to create dangerous voltage spikes that can exceed the insulation rating of the motor cables and windings. Over time, these voltage spikes will degrade the insulation and result in motor faults.

A filter reduces harmonics in the PWM output voltage, smoothing the waveforms to reduce vibration in the motor. Filters also reduce common mode currents in the motor windings that can discharge through motor bearings, causing pitting and premature motor failure.

 **CAUTION:** Long leads between the unit and the motor with an unfiltered PWM voltage can lead to dangerous voltage rise from reflected harmonics. Very long leads, such as in deep well submersible pump applications, may require the use of a sine wave filter to remove most of the harmonics from the waveform. Consult the factory or a knowledgeable source on drive filters if your application has more than 50 feet between the converter and the motor.

2.1 System Configuration Settings

An AquaPhase converter is capable of operating several types of systems, including:

- Simple ON/OFF motor control from the keypad or remote switches
- Variable speed based on analog input signals
- Digital constant pressure water systems
- Analog constant pressure water systems

The AquaPhase firmware interprets input signals and other data differently, depending upon the type of system being operated. It is therefore important to select the appropriate system configuration setting either through the Programmable Parameters on the keypad, or by DIP switch settings on the main control board.

Detailed information on setting System Configuration can be found in Section 4.2, *Setting System Configuration*.

3.1 Mounting

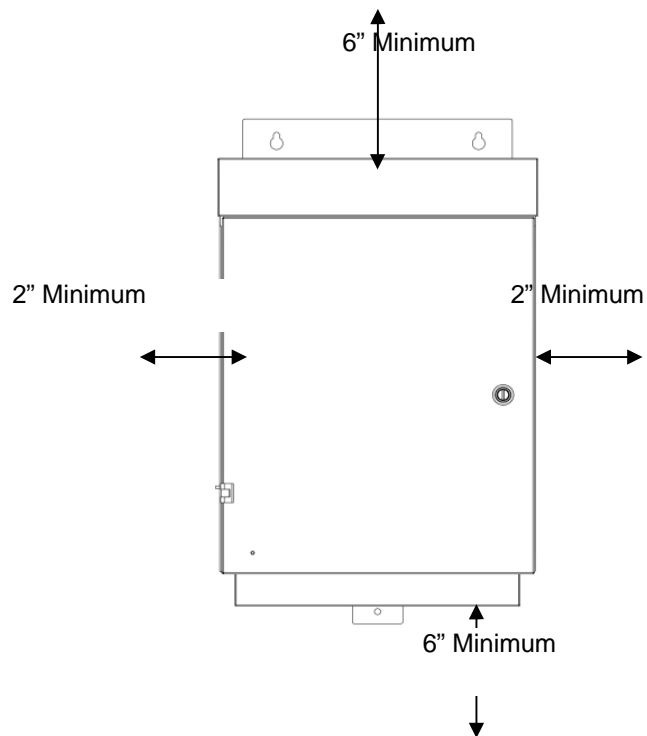
The AP Series converter is designed for wall mounting. Secure the unit to a sturdy, vertical surface capable of bearing the weight of the system. Fasten the unit to the wall using screws or bolts of an appropriate size through the holes on the mounting brackets.

In order to allow for proper cooling and air circulation around the enclosure, maintain minimum clearance of 2 inches on the sides and 6 inches on top and bottom.

AP Series converters are cooled by fans with ventilation openings on the top and bottom of the enclosure.

Figure 3-1 Minimum Clearance

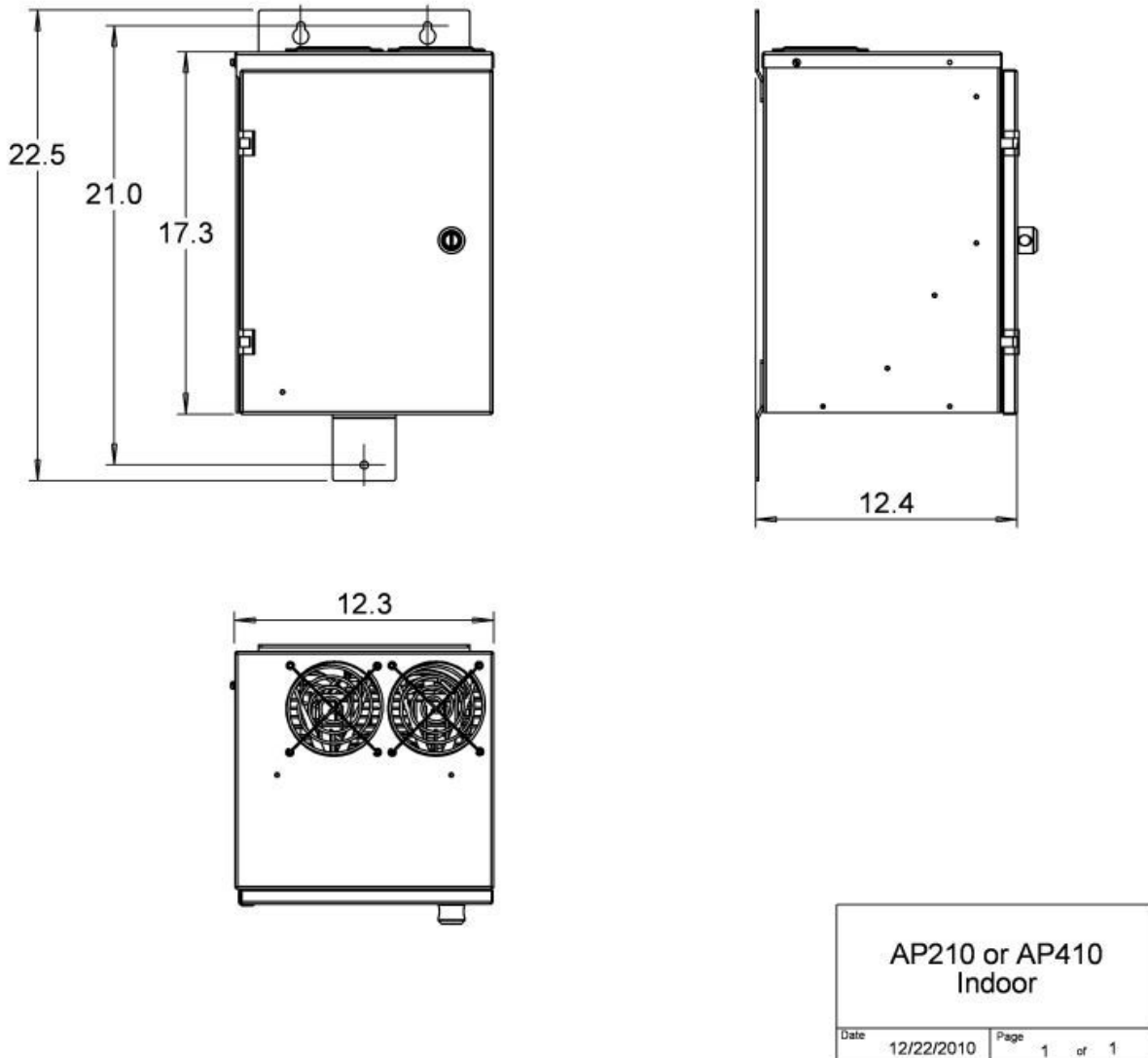
⚠ CAUTION: Failure to maintain adequate clearance may lead to overheating of the unit and cause damage or fire.



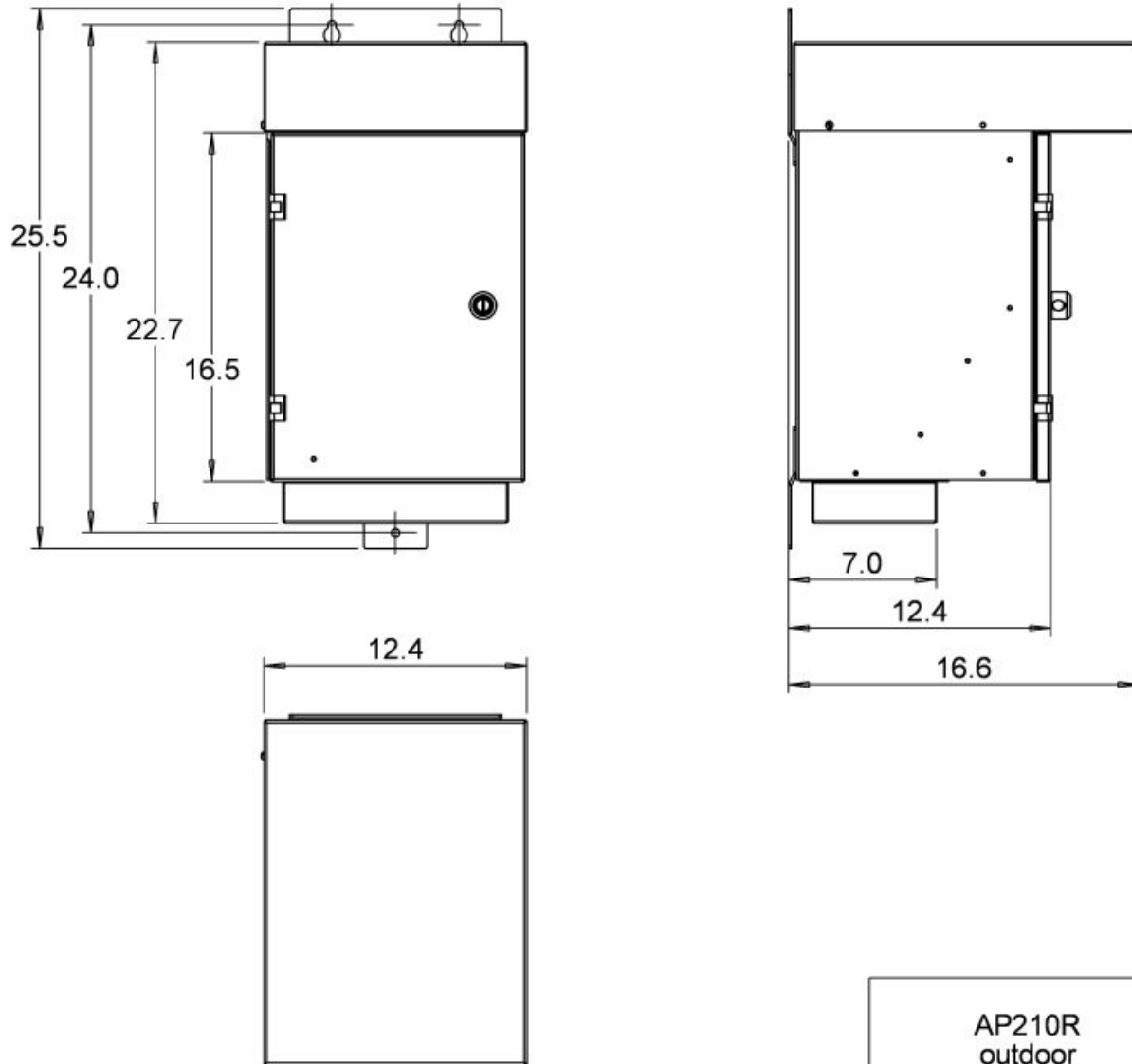
3.2 Dimensional Drawings

Locate the drawing of your AP Series model in Figure 3-2, Dimensional Drawings for assistance in determining hole mounting location and clearance.

Figure 3-2 Dimensional Drawings

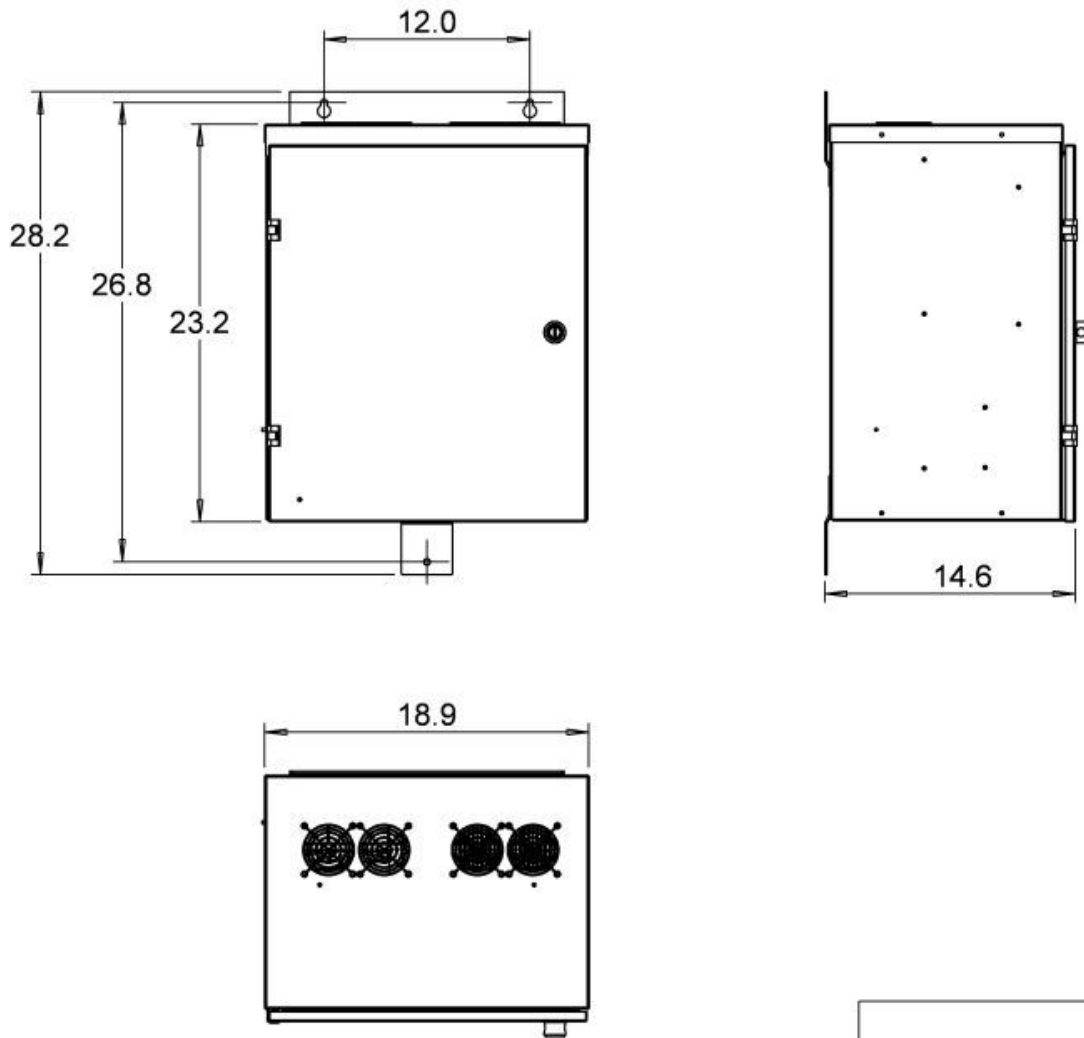


Dimensional Drawings Continued...



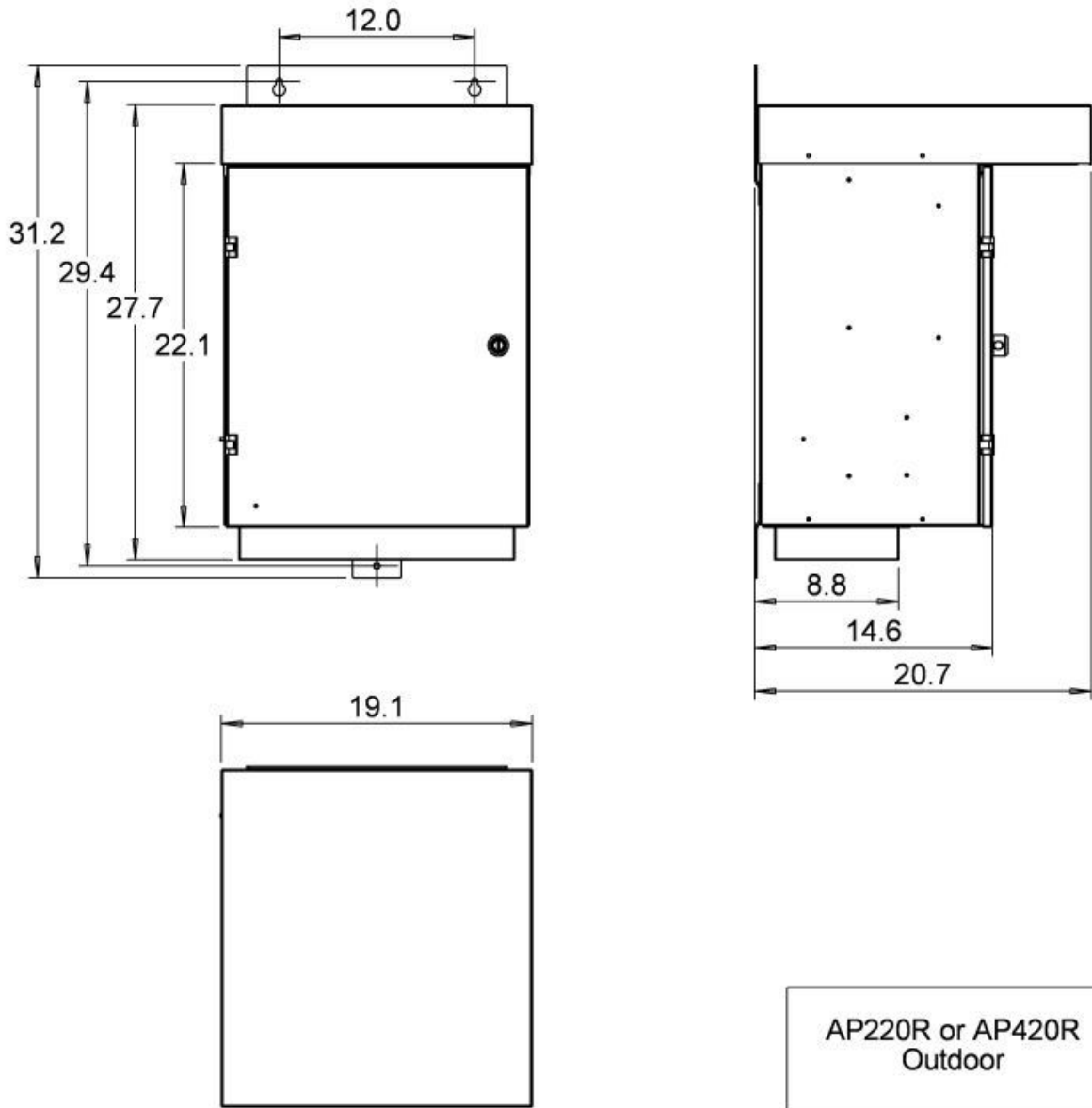
AP210R outdoor	
Date	12/22/2010
Page	1 of 1

Dimensional Drawings Continued...



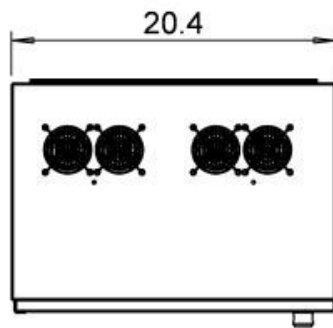
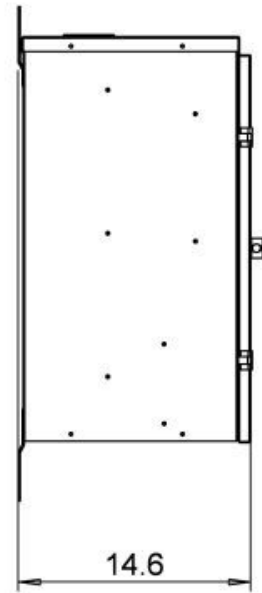
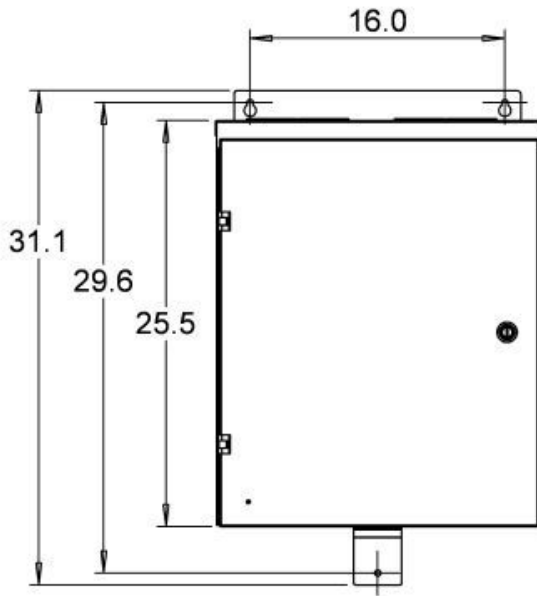
AP220 or AP420 Indoor	
Date	12/22/2010
Page	1 of 1

Dimensional Drawings Continued...



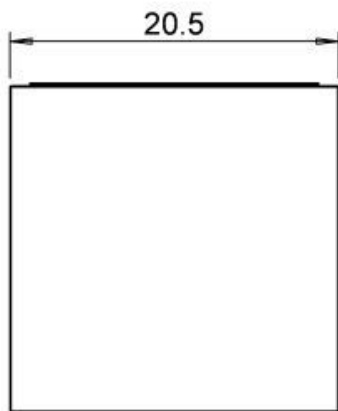
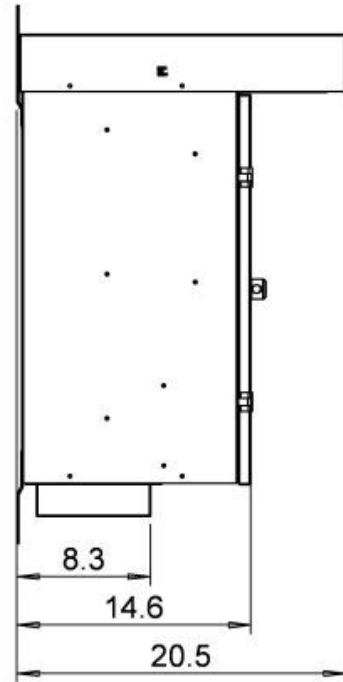
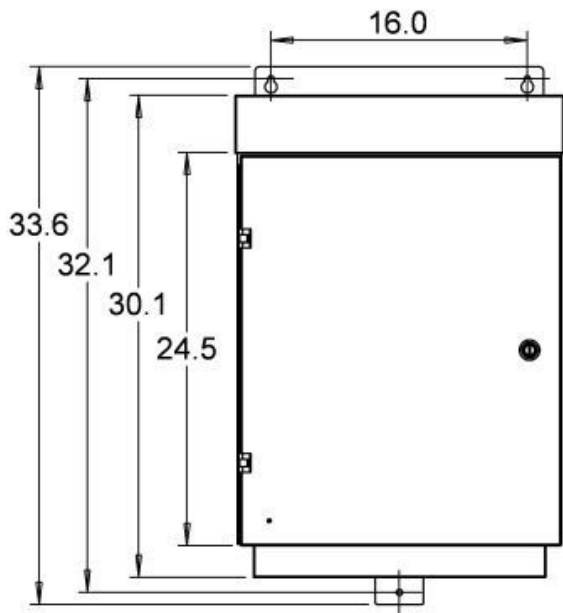
AP220R or AP420R Outdoor		
Date	12/22/2010	Page 1 of 1

Dimensional Drawings Continued...



AP230 or AP430 Indoor	
Date	12/22/2010
Page	1 of 1

Dimensional Drawings Continued...



AP230R or AP430R Outdoor	
Date	12/22/2010
Page	1 of 1

3.3 General Wiring Considerations

Installations must comply with all NEC and local electrical code requirements. Please follow all warnings and directions below:













-  **WARNING:** Suitable for use in a circuit capable of delivering not more than 5 kA RMS symmetrical amperes, 240 V maximum for all models with 240V class input (refer to model nomenclature).
-  **WARNING:** Suitable for use in a circuit capable of delivering not more than 5 kA RMS symmetrical amperes, 480 V maximum for all models with 480V class input (refer to model nomenclature).
-  **WARNING:** Wire used within the motor circuit and all field wiring terminals must be rated at least 75° C.
-  **WARNING:** Use wire size suitable for Class 1 circuits.
-  **WARNING:** Input power connections should be made by a qualified electrician into a nominal 240V circuit for models with 240V input, or a nominal 480V circuit for models with 480V input, with adequate current carrying capacity. Branch circuit protection to the drive should be provided by appropriate size fuses or a 2 pole, linked circuit breaker. Circuit breaker and fuse ratings for each model are listed in Table 3-3.
-  **WARNING:** These devices are equipped with integral solid state short circuit protection. Integral solid state short circuit protection does not provide branch circuit protection. Branch circuit protection must be provided in accordance with the National Electrical Code and any additional local codes.
-  **CAUTION:** Use 600 V vinyl-sheathed wire or equivalent. The voltage drop of the leads needs to be considered in determining wire size. Voltage drop is dependent on wire length and gauge. Use Copper Or Aluminum Conductors.
-  **CAUTION:** Wires fastened to the terminal blocks shall be secured by tightening the terminal screws to a torque value listed in Table 3-2.
-  **CAUTION:** The input wire gauge must be sized to accommodate the single-phase input current, which will be significantly larger than the three-phase output current to the load.
-  **CAUTION:** Maximum wire gauge for the input terminals is listed in Table 3-2.
-  **CAUTION:** Never allow bare wire to contact the metal surfaces.
-  **CAUTION:** Never connect AC main power to the output terminals U/T1, V/T2, and W/T3.

Table 3-1 Power Terminal Descriptions

Terminal Name	Description
L1, L2	Input power terminals for single-phase input
U/T1, V/T2, W/T3	Output power terminals for three-phase output
GND	Earth safety ground

Table 3-2 Field Wiring Power Terminal Specifications

Model	AP410	AP210	AP420
Input Power Terminals			
Tightening torque	20 in. lb.	20 in. lb.	2/0 - #6 AWG 120 in. lb. ----- #8 AWG 40 in. lb. ----- #10- #14 AWG 35 in. lb.
Wire size	#4 - #12 AWG Al ----- #4 - #18 AWG Cu	#4 - #12 AWG Al ----- #4 - #18 AWG Cu	#4 - #12 AWG Al ----- #4 - #18 AWG Cu
Output Power Terminals			
Tightening torque	20 in. lb.	20 in. lb.	20 in. lb.
Wire size	#4 - #12 AWG Al ----- #4 - #18 AWG Cu	#4 - #12 AWG Al ----- #4 - #18 AWG Cu	#4 - #12 AWG Al ----- #4 - #18 AWG Cu

Table 3-2 Field Wiring Power Terminal Specifications continued...

Model	AP220	AP430	AP230
Input Power Terminals			
Tightening torque	2/0 - #6 AWG 120 in. lb. ----- #8 AWG 40 in. lb. ----- #10- #14 AWG 35 in. lb.	2/0 - #6 AWG 120 in. lb. ----- #8 AWG 40 in. lb. ----- #10- #14 AWG 35 in. lb.	2/0 - #6 AWG 120 in. lb. ----- #8 AWG 40 in. lb. ----- #10- #14 AWG 35 in. lb.
Wire size	2/0- #14 AWG	2/0- #14 AWG	2/0- #14 AWG
Output Power Terminals			
Tightening torque	20 in. lb.	20 in. lb.	20 in. lb.
Wire size	#4 - #12 AWG Al ----- #4 - #18 AWG Cu	#4 - #12 AWG Al ----- #4 - #18 AWG Cu	#4 - #12 AWG Al ----- #4 - #18 AWG Cu

Table 3-3 Input Circuit Breaker and Fuse Ratings

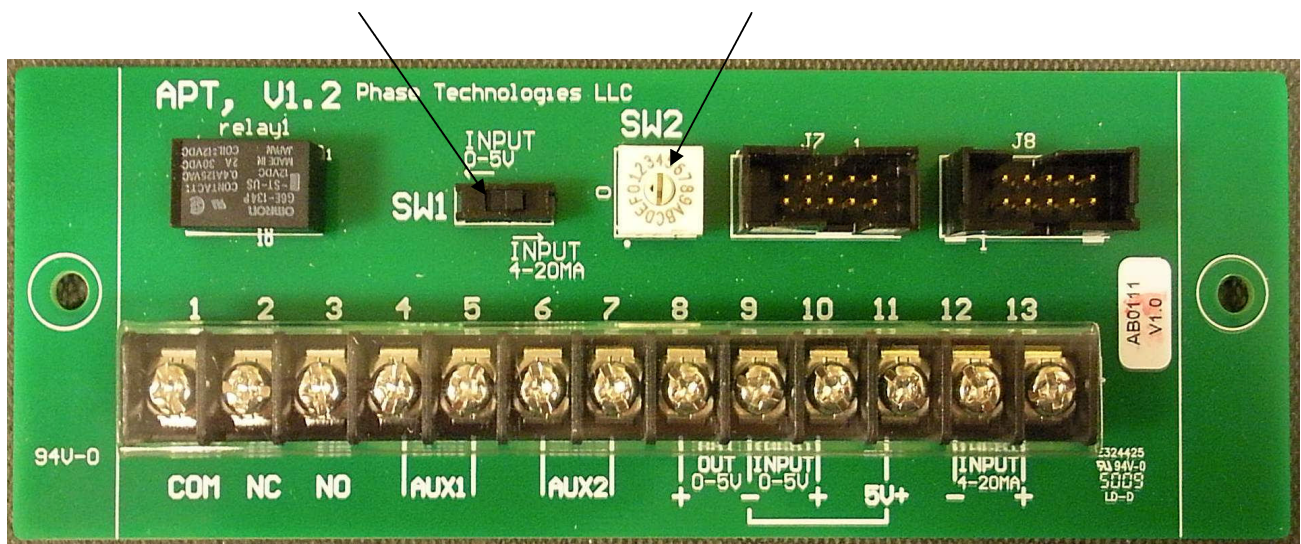
Model	AP410	AP210	AP420	AP220	AP430	AP230
Maximum fuse rating, Class J	40A, 600V	80A, 240V	70A, 600V	125A, 240V	90A, 600V	175A, 240V
Maximum circuit breaker rating, amps	40A, 480V	80A, 240V	70A, 480V	125A, 240V	90A, 480V	175A, 240V

3.4 Control Terminals

Figure 3-3 Control Terminal Panel

2-position switch to select either voltage or current analog input.

Rotary switch to set motor trip settings on models without optional keypad. Also locks and unlocks keypad. A setting of "0" locks the keypad.



An AP Series converter is equipped with Control Terminals that allow a number of control functions, including remote ON/OFF control, analog input signals, analog output signals, remote notification and operation of constant pressure water systems.

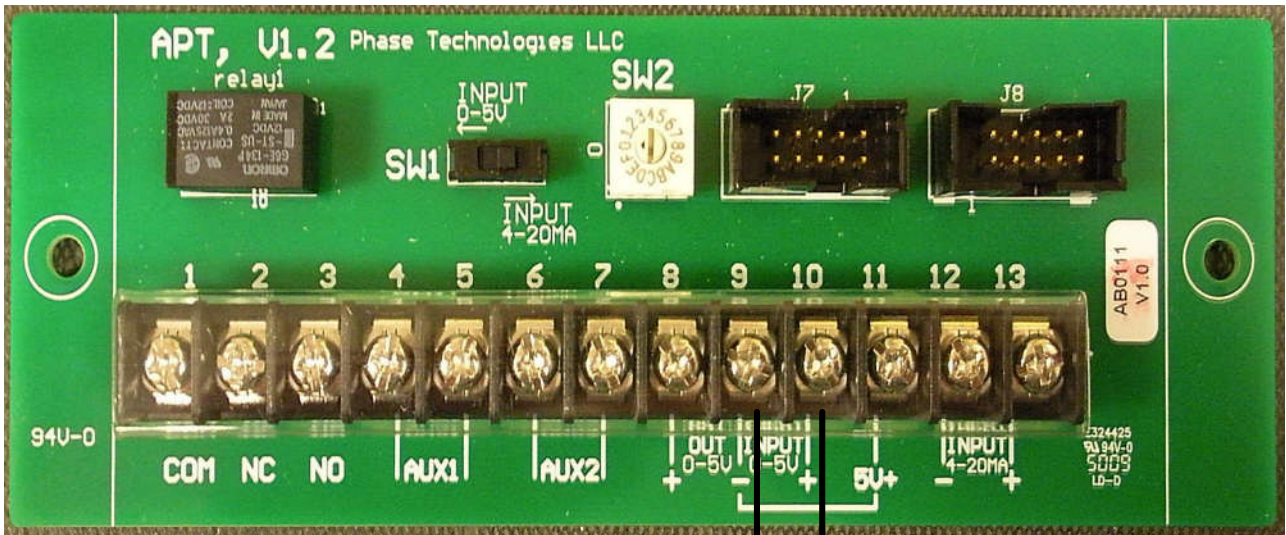
⚠ WARNING: The remote notification Control Terminals COM, NO, NC, are rated at 240V. While it is recommended that the circuit attached to these terminals use a non-hazardous voltage, it is possible that they are connected to a circuit with up to 240V. Disconnect power to these terminals before servicing the equipment.

⚠ CAUTION: The AUX1 and AUX2 terminals are galvanically isolated, with approximately 5V potential between them. DO NOT apply a voltage to the terminals. Use dry contacts only.

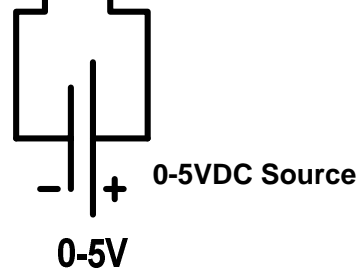
Table 3-4 Control Terminal Ratings and Descriptions

Terminal	Description	Rating	Comments
COM	Common	240V, 1A	Common terminal for use with either NC or NO terminal
NC	Normally Closed	240V, 1A	Normally closed remote notification terminal. Connection between NC and COM terminal will close when unit is off or fails.
NO	Normally Open	240V, 1A	Normally open remote notification terminal. Connection between NO and COM terminal will open when unit is off or fails.
AUX1	Auxiliary 1	< 5 volts, galvanically isolated	Remote ON/OFF terminal 1. Dry contact closure between the terminals will start the drive and connected load. Both AUX1 and AUX2 must be closed for the motor to run. In a digital CP system, the primary pressure switch is attached to AUX1.
AUX2	Auxiliary 2	< 5 volts, galvanically isolated	Remote ON/OFF terminal 2. Dry contact closure between the terminals will start the drive and connected load. Both AUX1 and AUX2 must be closed for the motor to run. In digital and analog CP systems, the emergency over-pressure limit switch is attached to AUX2.
OUT 0-5V	0-5VDC Analog Output	0-5 VDC	Analog output. Factory default for motor torque. Other outputs available. The negative terminal is shared with the negative terminal for 5VDC input.
INPUT 0-5V	0-5VDC Analog Input	0-5 VDC	Analog input to control motor speed. Use 2-position switch above terminals to select 0-5VDC input. Analog input must be activated with keypad. Refer to Section 5.2, <i>Controlling Motor Speed with Analog Input</i> for detailed instructions. The negative terminal is shared with the negative connection for 5VDC output. See Figure 3.4 or Figure 3.5 for a connection diagram.
5V+, -	5VDC Power Supply	5VDC	5VDC supply to provide power to analog voltage transducers. Connect the positive lead to the terminal labeled 5V+ . Connect the negative lead to the – terminal shared with OUT 0-5V and INPUT 0-5V . See Figure 3.5.
INPUT 4-20mA	4-20mA Analog Input	4-20 mA	Analog transducer input to control motor speed. Use 2-position switch above terminals to select 4-20mA input. Analog input must be activated with keypad. Refer to Section 5.2, <i>Controlling Motor Speed with Analog Input</i> for detailed instructions. See Figure 3.6 for a connection diagram.

Figure 3.4 Connection Diagram for External 0-5VDC Source to Analog Input



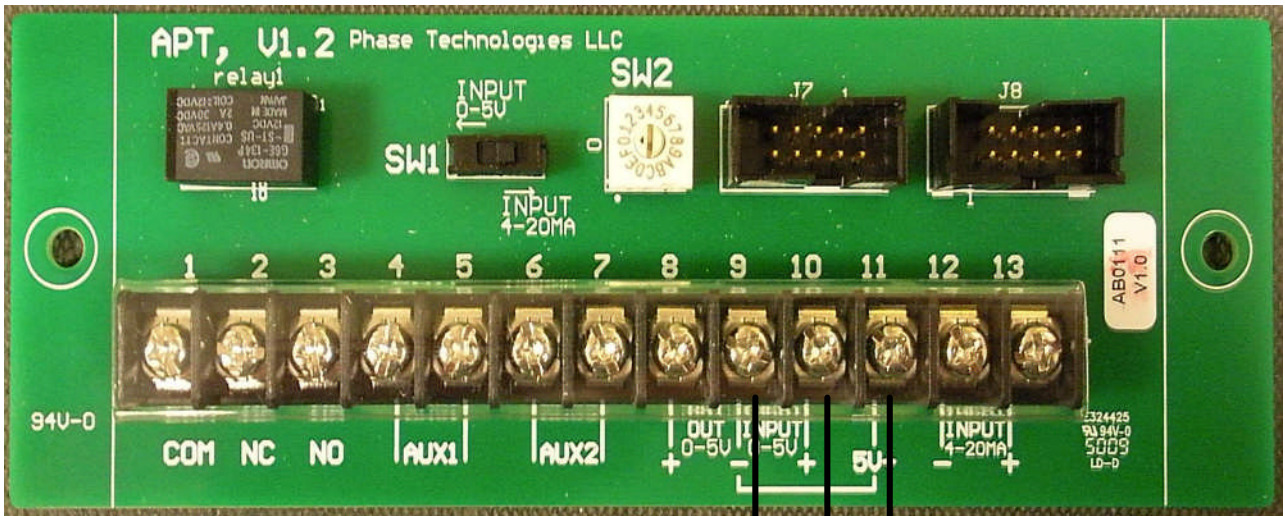
⚠ CAUTION: This connection diagram is for an external 0-5 VDC source, generally used to control motor speed.



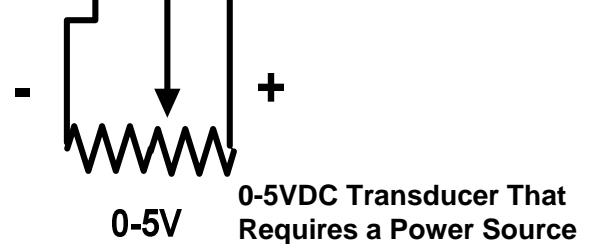
Follow these steps to connect a 0-5 VDC source to analog input:

1. Connect the negative lead of the source to terminal # 9, the shared **OUT/INPUT 0-5V-** terminal
2. Connect the positive lead of the source to terminal # 10, the **INPUT 0-5V+** terminal

Figure 3.5 Connection Diagram for 0-5VDC Transducer to Analog Input



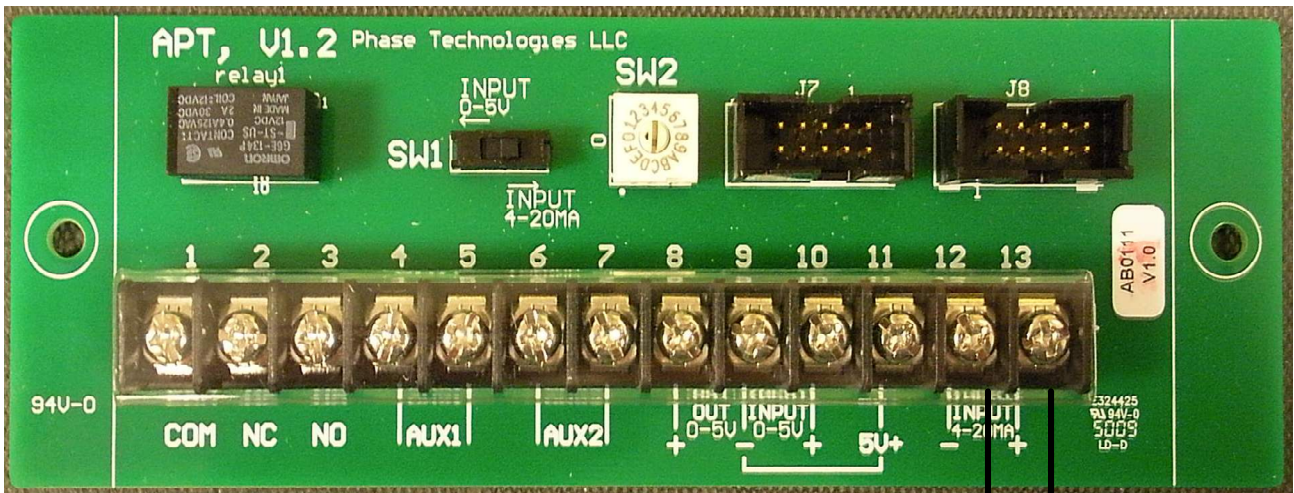
CAUTION: This connection diagram is for a 0-5 VDC transducer that requires an external power source. Circuits in the AP Series drive provide the 0-5 VDC power source.



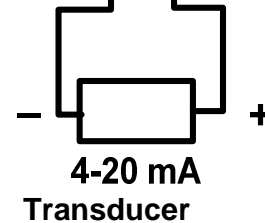
Follow these steps to connect a 0-5 VDC transducer to analog input:

1. Connect the negative lead of the transducer to terminal # 9, the shared
2. **OUT/INPUT 0-5V-** terminal
3. Connect the analog output lead of the transducer to terminal # 10, the
4. **INPUT 0-5V+** terminal

Figure 3.6 Connections for 4-20 mA Analog Transducer



⚠ CAUTION: 4-20mA signal can only be provided by an analog transducer. Do not provide a 4-20mA signal with external power supply. Power for the 4-20 mA transducer is provided by internal circuits in the AP Series drive.



Follow these steps to connect a 4-20 mA transducer:

1. Connect the negative lead of the transducer to terminal # 12, the **INPUT 0-20mA-** terminal
2. Connect the positive lead of the transducer to terminal # 13, the **INPUT 4-20 mA+** terminal

Operation of an AP Series converter is simple and straightforward after completion of physical installation and wiring. Before operating the motor load, several basic settings and procedures must be completed. If desired, extensive features for special operating conditions and for protection of the motor load are available through the keypad.

A power-up test should be performed before the unit and its load are placed in service. Refer to Section 4.4, *Power-Up Procedures*. Before initial power up, it is advisable to become familiar with setting motor overload protection, setting system configuration, and with basic operation of the optional keypad and display (base models are not equipped with keypad and display).

4.1 Motor Overload Protection

AP Series converters are equipped with adjustable solid state motor overload protection. Protection is based on a Class 10 trip curve. On models without the optional keypad, motor protection trip settings are selected with the rotary switch located on the Control Terminal Panel (See Figure 3-3, *Control Terminal Panel* and Figure 4-1, *Location of Rotary Switch*). When equipped with the keypad, motor overload settings are selected by navigating to the appropriate menu item using the keypad and display. Refer to Section 5.3, *Changing Parameter Values* for detailed instructions.

Setting Motor Overload Protection With the Rotary Switch

Motor overload trip settings in amperage are selected by the rotary switch in models without a keypad and display. A motor overload fault will be indicated by colored LEDs on the control printed wiring board behind the clear plastic panel. Refer to Table 7-1, *Fault Codes* to identify the LED combination. The unit will not automatically restart after a fault from output current too high. Power must be cycled OFF/ON to reset the unit. Automatic restarts after a fault can be programmed only when the unit is equipped with the optional keypad and display.

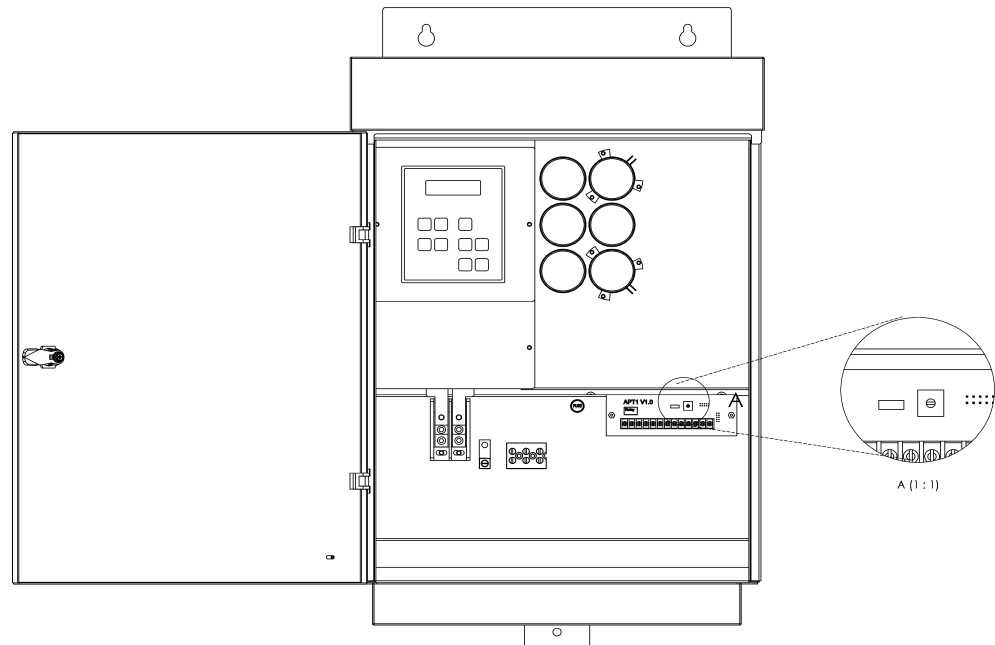
⚠ CAUTION: When equipped with the optional keypad and display, the rotary switch on the Control Terminal Panel is disabled. Do not attempt to set motor protection trip settings with the rotary switch when the keypad and display is present.

The rotary switch is labeled with an alpha/numeric index. Corresponding current values for a given letter or number on the switch can be found in Table 4-1, which is also located on the Control Terminal Panel. For example, position C on the rotary switch might equal a trip setting of 16 amps. Motor overload settings are always Trip Class 10. A small screw driver is required to set the rotary switch.

Table 4-1 Motor Overload Ampere Settings for Rotary Switch

Rotary Switch Position	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
Amps, 10 HP models	2	4	6	7	8	9	10	11	12	13	14	15	16	17	18	20
Amps, 20 HP models	10	11	12	13	14	15	16	18	20	22	24	26	28	30	31	33
Amps, 30 HP models	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48

Figure 4-1 Location of Rotary Switch



Setting Motor Overload Protection with Optional Keypad

⚠ CAUTION: When equipped with the optional keypad, the rotary switch on the Control Terminal Panel is disabled. Do not attempt to set motor protection trip settings with the rotary switch.

To set motor overload protection with the keypad, navigate to the Main Menu item **CHANGE PARAMETER VALUES > OVERCURRENT LIMIT**. Refer to Section 5.3, *Changing Parameter Values* for detailed instructions.

4.2 Setting System Configuration

An AquaPhase converter is capable of operating several types of systems, including constant pressure water systems, variable speed systems based on analog inputs, and simple ON/OFF control from remote switches. The system configuration must be selected for proper operation of the different types of systems.

When equipped with the keypad and display, system configuration is set by navigating to the keypad Main Menu item **CHANGE PARAMETER VALUES > SYSTEM CONFIG**. Refer to Section 5.3, *Changing Parameter Values* for detailed instructions.

Setting System Configuration on Models Without Keypad and Display

For models without the keypad and display, only two types of system configuration can be selected—simple ON/OFF motor control through the AUX1 and AUX2 Control Terminals, or a digital constant pressure water system. These two system configurations are selected with a DIP switch on the main control printed wiring board located behind the clear plastic panel. See Figure 4-2 for help in locating the DIP switch array. To set the system configuration on models without the keypad, follow these steps:

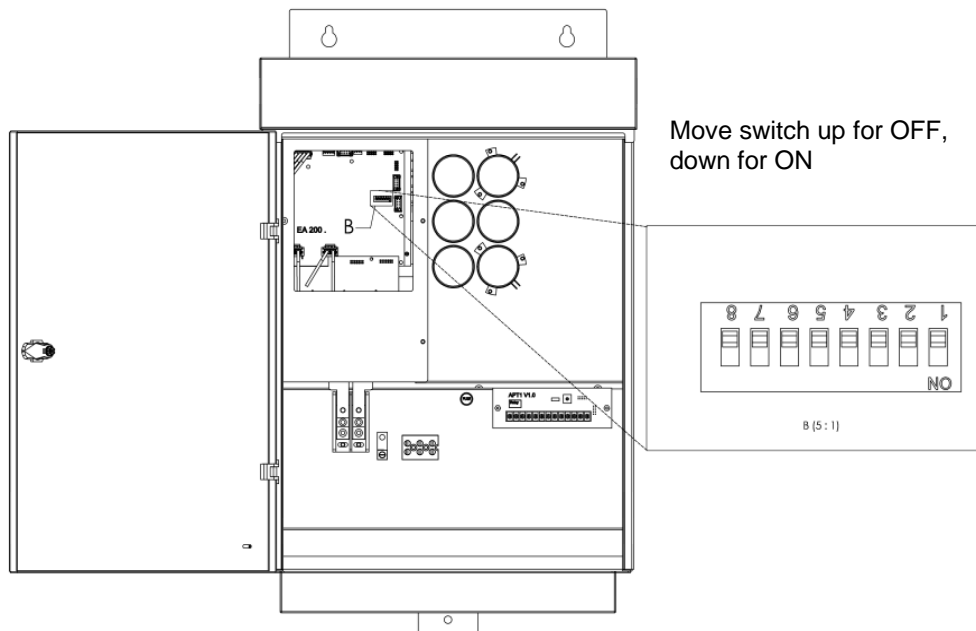
⚠ WARNING: Risk of electric shock. De-energize the unit by disconnecting all incoming sources of power, then wait 30 minutes for internal charges to dissipate before servicing the equipment.

⚠ WARNING: Risk of electric shock. More than one disconnect switch is required to de-energize the equipment before servicing.

⚠ CAUTION: Before touching any printed circuit board, place a hand on a bare metal surface of the unit to discharge any static electricity. Electrostatic discharge (ESD) can damage printed circuits and their components.

1. Disconnect all input power sources from the unit and wait for internal charges to dissipate.
2. Remove the screws that secure the plastic panel to gain access to the main control printed wiring board.
3. Locate the array of DIP switches on the board and select the appropriate position for DIP switch 8:
 - a. OFF = simple ON/OFF control through AUX1/AUX2
 - b. ON = digital constant pressure water system
4. Replace the plastic panel before energizing the unit.

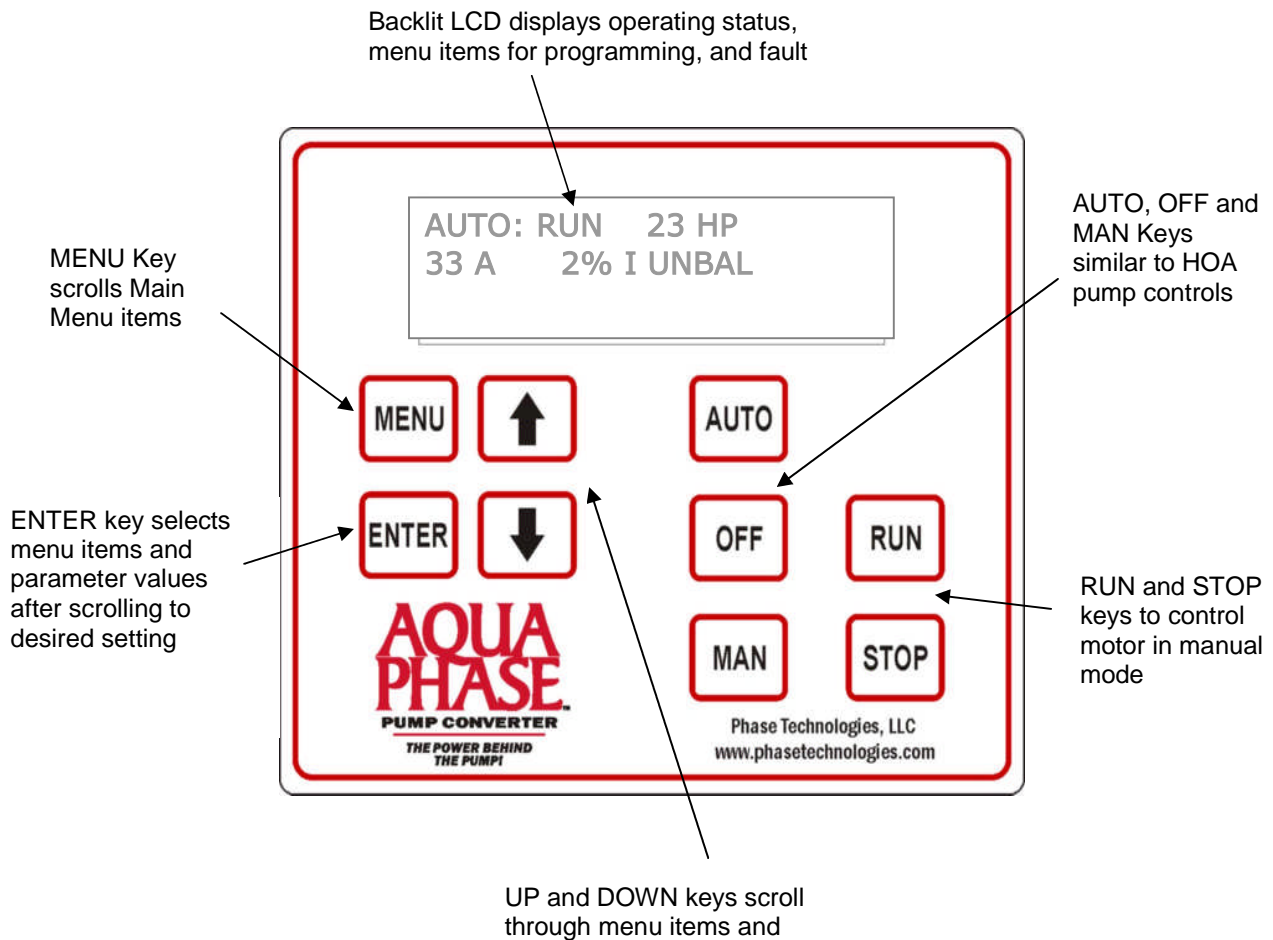
Figure 4-2 Location of DIP Switches



4.3 Using the Keypad and Display

When equipped with the optional keypad and display, the AP Series converter is capable of many advanced, easy to use features that allow the user to protect the motor load from damage, monitor load conditions, log motor run time, trouble shoot the system and more. This powerful tool is easy to use and understand, with 32 character text messages and an intuitive interface specifically tailored for pumping applications.

Figure 4-3 Optional Keypad & Text Display



IMPORTANT! The AquaPhase must be in the OFF mode in order to make changes to the programmable parameters. Press the OFF key before making any changes to the parameters.

Auto-Dimming Display

The backlit LCD display is designed to enter a sleep mode and dim the display after 5 minutes of inactivity on the keypad. The display can be awakened by touching any key on the keypad. When the display is in sleep mode, touching any key results only in awakening the display. Specific key function will not return until the display is lit.

Locking the Keypad and Display

The keypad and display functionality can be locked to prevent inadvertent or unauthorized manipulation of the operating parameters of the drive. When the keypad is locked, none of the parameters can be changed or edited. Navigation with the keypad to read measured values, read the clock, read the fault log and read the settings of the adjustable parameters is still possible when the keypad is locked.

To lock and unlock the keypad, use the rotary switch located on the Control Terminal panel. See Figure 4-1 for assistance in locating the rotary switch. Select the “0” position on the rotary switch to lock the keypad. Any other position is unlocked. A small screw driver is necessary to set the rotary switch.



Default Display Mode

After two minutes of keypad inactivity, the display will revert to the default display mode, which indicates either AUTO, MANUAL, or OFF mode and the status of the AUX1 and AUX2 remote switch circuits. The default display also indicates the output horsepower (HP), output current in amps (A) and output percent current unbalance (% IMBAL).

Keypad Display Start-up Messages

Several messages will appear on the display when the unit is initially energized. When the unit has completed its start-up routine, the default display indicating the status of the OFF, AUTO, MAN mode will appear. Start-up display messages are detailed in Table 4-2 below.

Table 4-2 Display Start-up Messages

DISPLAY MESSAGE	DESCRIPTION
NO COMMUNICATION	Power is on but communication with control board has not been established
INITIALIZING PLEASE WAIT	Keypad is communicating with the main controller
STARTING V1.X	Displays the firmware version loaded in the PIC controller
AUTO	 CAUTION: Upon initial start-up, the keypad will default to AUTO mode. The motor load will automatically run if both AUX1 and AUX2 remote switches are closed. To stop the motor, push MAN (manual) or OFF, or open AUX1 or AUX2. The RUN and STOP keys only work when in MAN mode
MANUAL	Unit is in MANUAL mode. Activate MANUAL mode by pushing the MAN key. In MANUAL mode the motor load is controlled by using the RUN and STOP keys, which will override the AUX1 and AUX2 remote switches.  CAUTION: Operating the system in MAN mode on the keypad overrides signals from the pressures switches. Operating the system in this mode may lead to dangerous pressures in closed plumbing systems
OFF	Pressing the OFF key will stop the motor load. To start the motor, revert to either AUTO mode or MANUAL mode. Certain faults can also be cleared by pressing the OFF key.

Main Menu

Main Menu items are accessed by pressing MENU on the keypad. Press MENU to scroll through the Main Menu items. Press ENTER to view or edit a Main Menu item.

Figure 4-4 Navigating Main Menu Items

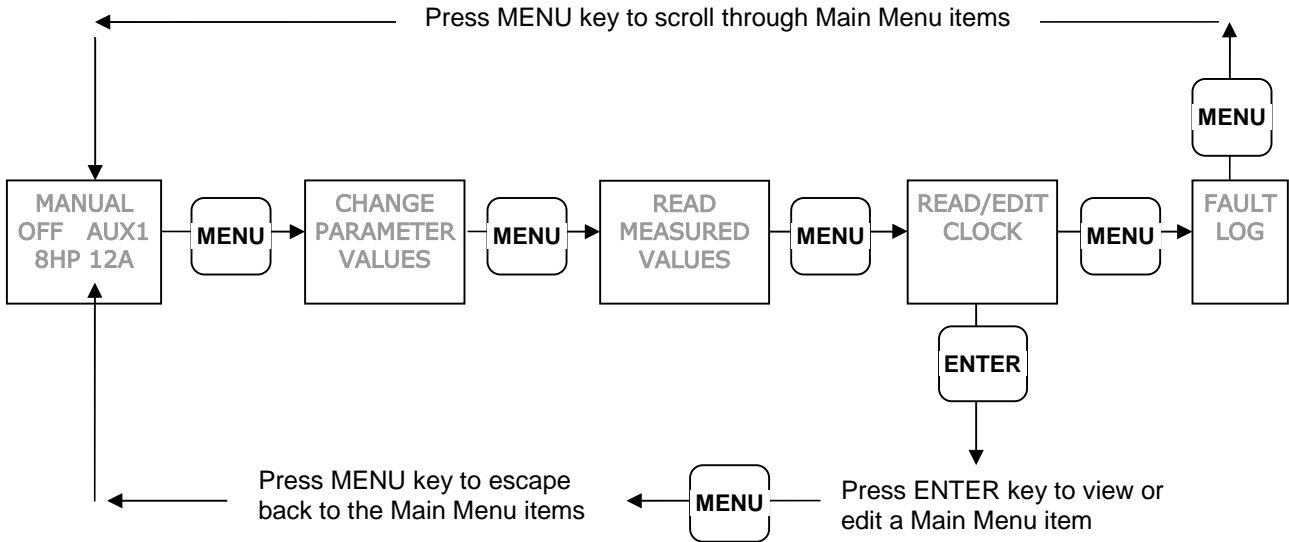


Table 4-3 Main Menu Items

DISPLAY MESSAGE	DESCRIPTION
MANUAL/OFF/AUTO AUX1 AUX2 HP, A, % I UNBAL	Display indicates either AUTO, MANUAL, or OFF mode, the status of the AUX1 and AUX2 remote switch circuits, output HP, output current and % current unbalance. This is the default display mode. After 2 minutes of keypad inactivity, the display will revert to this mode.
CHANGE PARAMETER VALUES	Allows the user to set values for functions such as motor overload amp settings, low current to detect dry well condition, time to restart after a fault, etc.
READ MEASURED VALUES	Displays measured values such as output current, input voltage, load power factor, etc.
READ/EDIT CLOCK	Records motor run time and drive on time
FAULT LOG	Records the number of times a particular fault has occurred

Reading Measured Values

When equipped with the optional keypad and display, the AP Series drive can display a variety of measured values related to the performance of the drive and its load, such as currents, horsepower, and power factor. To read measured values:

1. Press the MENU key to scroll through menu items until **READ MEASURED VALUES** appears on the display.
2. Press ENTER to access this menu item.
3. Use the up and down arrow keys to scroll through the various values that you wish to read.

Figure 4-5 Read Measured Values

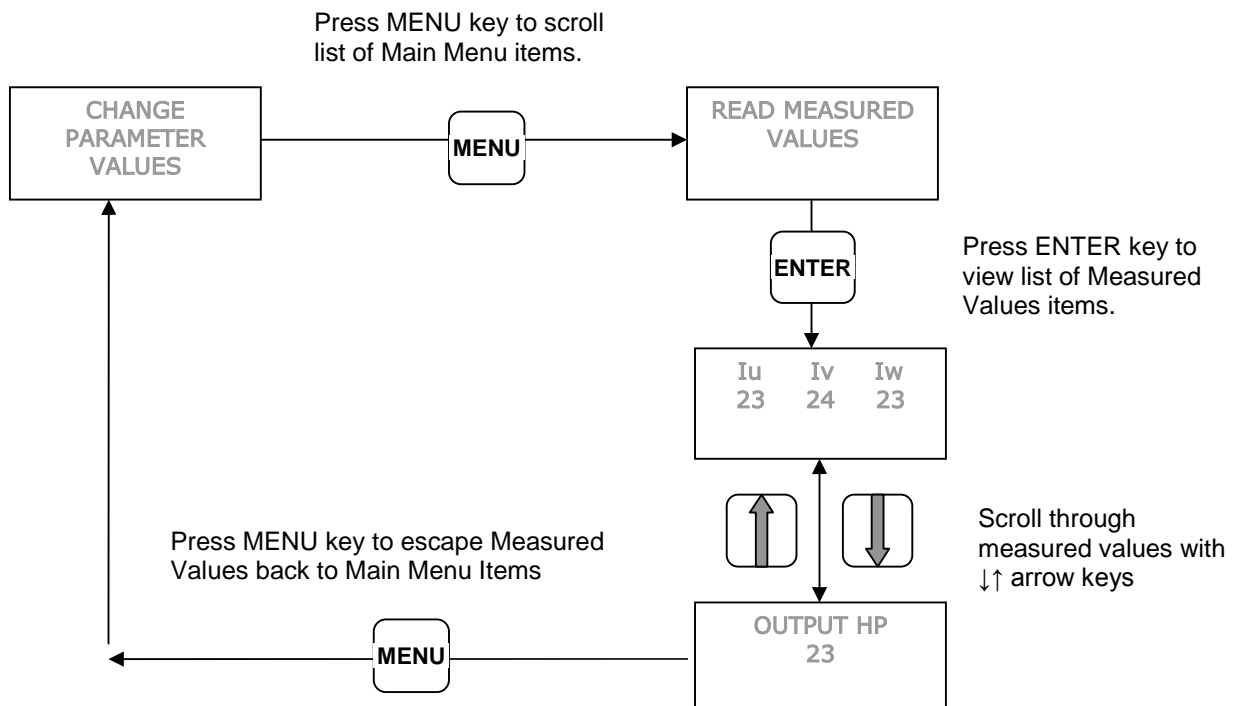


Table 4-4 Measured Values

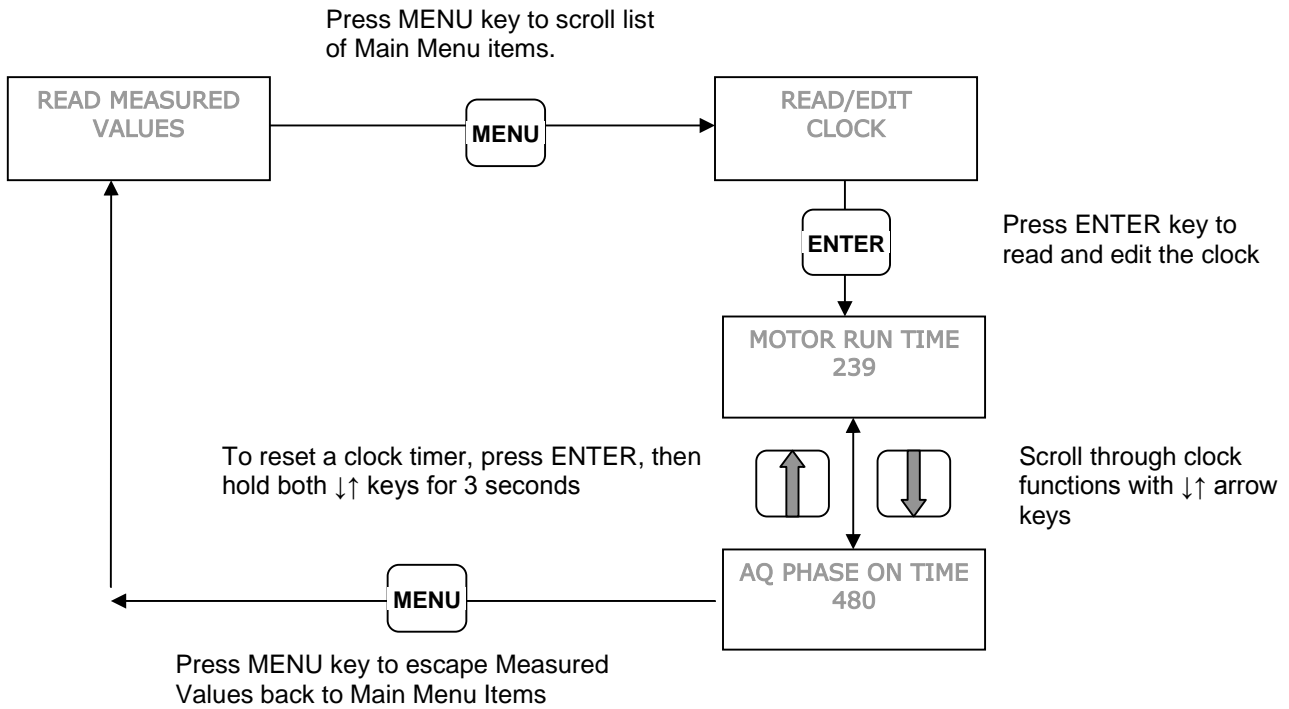
DISPLAY MESSAGE	DESCRIPTION OF MEASURED VALUE
Iu I _v I _w	Three-phase currents on the output
OUTPUT HP	Output measured in horse power
OUTPUT KWATTS	Output measured in kilowatts
OUTPUT KVA	Output measured in KVA
OUTPUT PF	Power factor of the motor load
BUS CAP VOLTAGE	Voltage of the DC bus
INPUT VOLTAGE	Input voltage AC
INPUT CURRENT	Input current in amps
AUX1 AUX2	ON/OFF status of the remote switch circuits AUX1 and AUX2
FREQUENCY	Frequency of output voltage controlling motor speed

Reading and Editing the Clock

When equipped with the optional keypad and display, AP Series converters record the motor run time in hours, and the time the drive has been energized. There are two clocks for each function, one which can be reset, and one permanent. To view and reset the clock:

1. Press the MENU key to scroll through menu items until **READ/EDIT CLOCK** appears on the display.
2. Press ENTER to enter this menu item.
3. Use the up and down arrows to scroll through the clock functions.
4. To reset a clock timer, press ENTER, then hold both ↓↑ arrow keys down for 3 seconds

Figure 4-6 Read/Edit Clock



To reset a clock timer, press ENTER, then hold both ↓↑ arrow keys down for 3 seconds

Table 4-5 Clock Timers

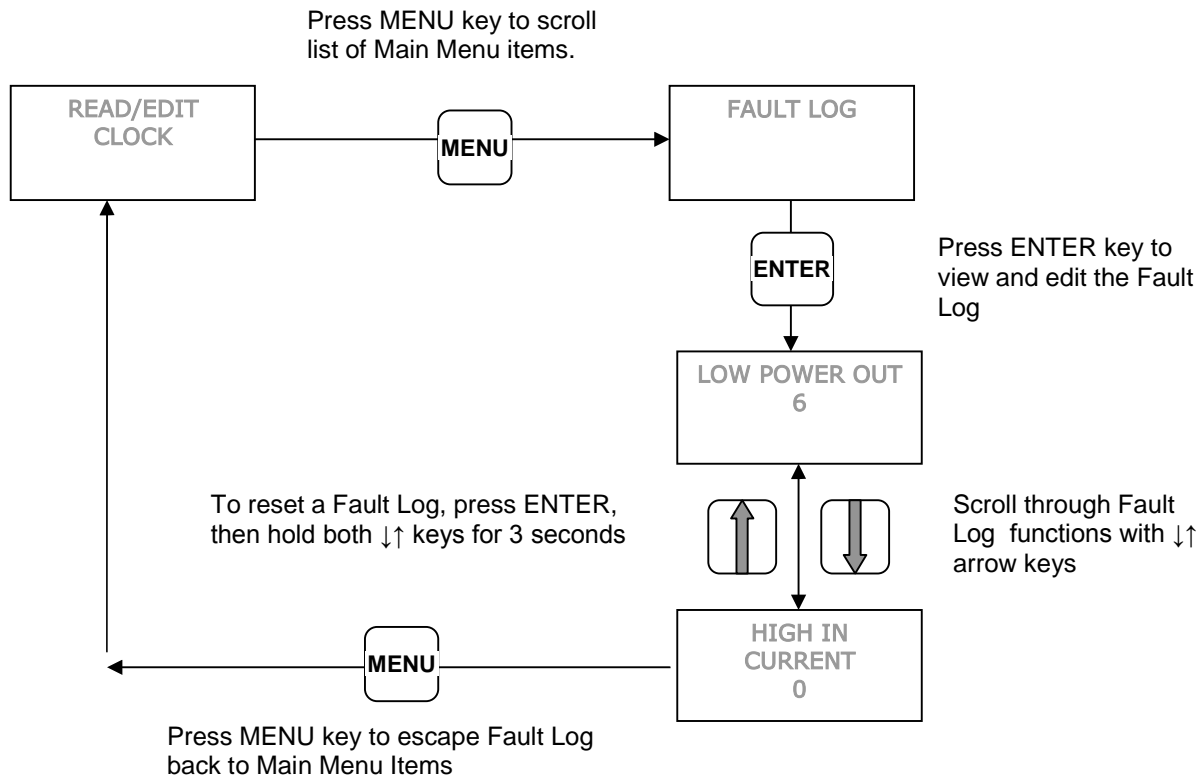
TIMER	DESCRIPTION
MOTOR RUN TIME	Logs motor run time in hours. To reset, press ENTER, then both arrow keys for 3 seconds.
AQ PHASE ON TIME	Logs time in hours the AP Series unit is energized To reset, press ENTER, then both arrow keys for 3 seconds.
ALL MOTOR HOURS	Logs total motor run time. Not resettable.
ALL AP HOURS	Logs total time the AP Series unit is energized. Not resettable.

Fault Log

AquaPhase converters record the number of times a particular fault has occurred. For instance, in a remote well pump application, it might be useful to know how many times the unit has tripped due to dry well since the last visit to the site. To view the Fault Log:

1. Press the MENU key to scroll through menu items until **FAULT LOG** appears on the display.
2. Press ENTER to access this menu item.
3. Use the up and down arrows to scroll through the fault functions.
4. The fault will appear on the first row of the display, followed by the number of times that fault has occurred.
5. To reset a fault log, press ENTER, then hold both ↓↑ arrow keys down for 3 seconds. Resetting a fault log also restarts the counter for number of automatic restarts allowed for that fault. Number of restarts allowed is selected through the keypad menu, **CHANGE PARAMETER VALUES**.

Figure 4-7 Fault Log




See Section 7.1 *Status Indicators and Fault Codes* for a complete listing of fault codes.

4.4 Power-Up Procedures

It is always advisable to check the operating status of the converter and its load before commencing regular operation. After the system is properly installed and connected to input power, follow the power-up procedures in this section.


Verify the following:


1. The unit is securely attached to the proper mounting surface
2. The unit's input terminals are connected to an appropriate power source

 **CAUTION:** Before the motor is connected to the output terminals, check all output lines for line-to-ground faults using a megger. There is a direct path through the drive circuitry for ground fault currents that can be triggered when power is applied to the input terminals, even though the output switches are not activated. These currents can cause serious damage to drive circuitry and are not covered under warranty.

3. An appropriately rated motor is connected to the output terminals
4. The motor is secured and properly mounted


Power-up Procedure for Base Models without Keypad and Display

 **WARNING:** Before applying power to the input terminals of the unit, make certain that at least one of the switches or jumpers connected to AUX1 or AUX2 is open. Otherwise, the motor load will start as soon as the unit is energized.


 **CAUTION:** The AUX1 and AUX2 terminals are galvanically isolated, with approximately 5V potential between them. DO NOT apply a voltage to the terminals. Use dry contacts only.

1. On models without a keypad and display, the motor will not run unless there is a contact closure between the terminals of both AUX1 and AUX2.
2. Connect a remote ON/OFF switch to AUX1 terminals. An additional remote switch or jumper wire may be connected to the AUX2 terminals.
3. If a digital constant pressure water system will be operated, the System Configuration must be changed by setting DIP switch 8 to the ON position. See Section 4.2, *Setting System Configuration* for details. Refer to Section 6, *Constant Pressure Systems*, for instructions on setting up and operating a digital CP system.
4. Set the appropriate motor overload current setting on the rotary dial located on the Control Terminal panel. See Section 4.1, *Motor Overload Protection, Table 4-1*, for the amp values of each switch position.
5. Apply power to the input terminals of the unit by turning on the input circuit breaker or disconnect switch.
6. Confirm that the Status LED on the main printed wiring board behind the clear panel is steady green
7. Close the remote switch connected to AUX1 and/or AUX2 to start the motor.
8. The motor will start with an acceleration ramp time of 0-30 Hz in one second, then 30-60 Hz in eight seconds. See Section 5.1, *Start-Up and Shut-Down Ramp Times*, to change the ramp time and profile.
9. Confirm that the motor rotation is correct. Swapping any two of the output leads will reverse the motor rotation.

Power-up Procedure for Models with Keypad and Display

 **WARNING!** On models equipped with keypad and display, the default mode when the unit is energized is AUTO. If the AUX1 and AUX2 terminals are closed when the unit is energized, the motor will start. Make sure either AUX1 or AUX2 terminals are open before energizing the input, or push the OFF key as soon as the unit has initialized. Refer to Section 4.3, *Using the Keypad and Display*, for instructions on operating the keypad.

1. If remote or automatic ON/OFF function is required, connect remote switch leads to the AUX1 terminals. An additional remote switch or jumper wire may be connected to the AUX2 terminals.
2. If a Constant Pressure (CP) water system will be operated, connect the pressure sensors to the appropriate Control Terminals. See Section 6, *Constant Pressure Systems* for details.
3. Apply power to the input terminals of the drive by turning on the input circuit breaker or disconnect switch.
4. The LCD text display will scroll through several start-up sequence messages.
5. In order to prevent the motor from running at start-up, immediately after initialization, press the OFF key.
6. Confirm that the unit has properly energized, and the display indicates the OFF mode.
7. Using the keypad and display, navigate to the Main Menu item, **CHANGE PARAMETER VALUES**, to set the following parameters (see Table 5-1, *Adjustable Parameters*, for details):
 - **SYSTEM CONFIG** This parameter is critical to the operation of the system. The default setting is for simple ON/OFF operation.
 - **RATED HORSEPOWER** Enter the nameplate HP of the motor load. This parameter helps control deceleration and is critical to proper operation of CP water systems.
 - **OVERCURRENT LMT** This parameter sets the motor overload protection.
8. Push MAN on the keypad for manual mode, then push RUN to start the motor. In manual mode, the RUN key will override an open AUX terminal. Push the STOP key to stop the motor in manual mode.

 **CAUTION:** In manual mode, pushing the RUN key will override all external control signals, including constant pressure sensors. Dangerous pressure rise in closed plumbing systems is possible.

9. The motor will start with the default acceleration ramp time of 0-30 Hz in one second, then 30-60 Hz in eight seconds.
10. Confirm that the motor rotation is correct. Swapping any two of the output leads will reverse the motor rotation.
11. After initial power-up, use the keypad and display to navigate to **CHANGE PARAMETER VALUES** to set any other adjustable parameters you wish to be different from the factory defaults.

AquaPhase converters are equipped with advanced features to fit a wide range of applications. However, unlike most VFDs that are designed for industrial automation, the AquaPhase user interface is tailored specifically for pumping applications, making it simple and intuitive to use.

IMPORTANT! The AquaPhase must be in the OFF mode in order to make changes to the programmable parameters. Press the OFF key before making any changes to the parameters.

The keypad and display is required to adjust all but a few of the parameters, but in most cases, the factory default settings will provide trouble-free operation.

5.1 Start-Up and Shut-Down Ramp Times

Start-up and shut-down ramp times specify the time required to go from Minimum Frequency to the maximum frequency allowed or vice versa. Ramp times and profiles are adjustable when the unit is equipped with the optional keypad and text display. Units without the keypad and display have limited options for ramp times, and the maximum frequency is set at 60 Hz.

Minimum Frequency

Most submersible pump motor manufacturers require the motor to reach 30 Hz within one second in order to protect the motor bearings from damage. Because the AP Series is frequently used for pumping applications, it has a minimum frequency feature that limits the time the motor runs below the minimum frequency to one second. For example, when the minimum frequency is set to 30 Hz, the motor speed will ramp to 30 Hz in one second, then ramp to the maximum frequency in the default setting of 8 seconds, or in a time set through the adjustable parameter, **START UP RAMP**. This is depicted in Figure 5-1. **The factory default setting for minimum frequency is 30 Hz.**

When the minimum frequency is set to 0, the motor will ramp from stop to the maximum frequency in 8 seconds in a linear fashion as depicted in Figure 5-2. Start and stop ramp times and maximum frequency are not programmable in models without the keypad and display option.

Setting the Minimum Frequency with Keypad

To set the minimum frequency, navigate to the keypad Main Menu item **CHANGE PARAMETER VALUES > MINIMUM FREQ > 30 Hz**. When this parameter is set to 0 Hz, ramp times will be linear, as depicted in Figure 5-2.

Figure 5-1 Default Start-Up and Shut-Down Ramp Time

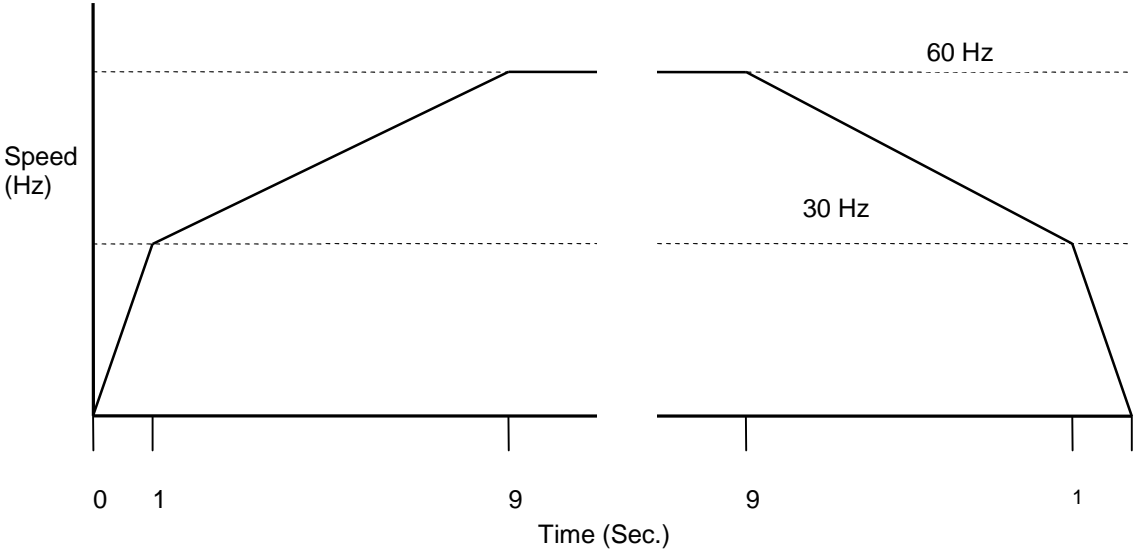
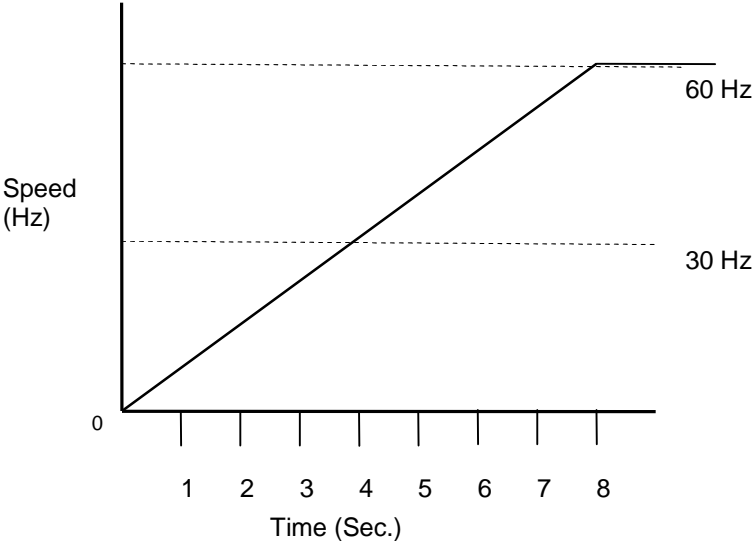




Figure 5-2 Start-Up Ramp with Minimum Frequency 0 Hz




Setting Minimum Frequency without Keypad

When the unit is not equipped with the optional keypad and display, there are two choices for minimum frequency, 0 Hz or 30 Hz. These values are set with a DIP switch on the main control printed wiring board located behind the clear plastic panel. See Figure 4-2, *Location of DIP Switches*, for help in locating the DIP switches. Follow these instructions to set the minimum frequency in models without the keypad:

 **WARNING:** Risk of electric shock. De-energize the unit by disconnecting all incoming sources of power, then wait 30 minutes for internal charges to dissipate before servicing the equipment.

 **WARNING:** Risk of electric shock. More than one disconnect switch is required to de-energize the equipment before servicing.

 **CAUTION:** Before touching any printed circuit board, place a hand on a bare metal surface of the unit to discharge any static electricity. Electrostatic discharge (ESD) can damage printed circuits and their components.

1. Disconnect all input power sources from the unit and wait for internal charges to dissipate.
2. Remove the screws that secure the clear plastic panel to gain access to the main control printed wiring board.
3. Locate the array of DIP switches on the board and move DIP switch 7 to the desired location (OFF = 0 Hz, ON = 30 Hz).
4. Replace the clear plastic panel before energizing the unit.

Shut-down Ramp Time and Regenerative Power

When a motor is decelerated faster than the friction of the motor and its load would passively slow the motor, the potential for regenerative power (regen) exists. During regen, the inertia of the load on the motor shaft causes the motor to generate power, rather than consume it. This regenerative power can cause voltage to rise on the DC bus, tripping out the drive. Most drives require the addition of a braking resistor to handle regen.

AP Series converters are designed to sense regen and automatically extend shutdown time to avoid a voltage rise on the DC bus. This avoids nuisance tripping and expensive braking resistors common to other drives.

When shut-down ramp time is programmed, one must consider the potential for regenerative power caused by a braking motor. Setting a ramp time that is too short may lead to regen. Regen is not common in most pumping applications, however motors operating beam pumps (pump jacks) commonly experience regen.

5.2 Controlling Motor Speed with Analog Input

AquaPhase AP Series converters are equipped with analog inputs that allow an external signal of 0-5VDC to control motor speed. A 4-20mA transducer can also control motor speed. The terminals for these signals are located on the Control Terminal panel. Refer to Table 3-4, *Control Terminal Ratings and Descriptions* for more information on terminal location and rating. **Speed control through the analog input is available only when the unit is equipped with the optional keypad and display.** The system configuration must be set through the parameter, **SYSTEM CONFIG**, for analog input to control motor speed.

Adjustable Parameters

Analog Speed Control Set-up Procedures:

1. Select either 0-5VDC or 4-20mA on the 2 position switch above the Control Terminals
2. Connect the analog input to the appropriate Control Terminals, either **INPUT 0-5V** or **INPUT 4-20mA**

⚠ CAUTION: 4-20mA signal can only be provided by an analog transducer. Do not provide a 4-20mA signal with external power supply. Power for the 4-20 mA transducer is provided by internal circuits in the AquaPhase.

3. Navigate through the keypad Main Menu item **CHANGE PARAMETER VALUES > SYSTEM CONFIG**. Select **1** to set the system configuration for analog speed control
4. Set the keypad to AUTO mode to operate the system

Analog Input and Minimum Frequency

The analog input signal will control motor speed only between the minimum frequency and the maximum frequency. The motor speed will not be allowed to fall below the minimum frequency, regardless of the signal on the analog input. **The minimum frequency must be set to 0 Hz for the analog signal to control speed between stop and maximum frequency.**

When controlled by analog input, the motor speed will be determined by the ratio of the input signal to the maximum value for that signal. For example, if the Maximum Frequency is set at 60 Hz and Minimum Frequency is set at 0 Hz, an analog signal of 2 VDC would result in a speed of 24 Hz. Remember that if Minimum Frequency is at the default 30 Hz, any signal that calls for speed below Minimum Frequency will be ignored, and the speed will remain at 30 Hz until the signal exceeds 2.5 VDC. The formula for calculating speed is illustrated in Figure 5.3 below.

Figure 5.3 0-5 VDC Analog Input Speed Calculation


Where *Hz max* equals the maximum frequency, *VDC in* equals the analog input signal in volts DC (VDC).

$$\text{Speed (Hz)} = \text{max Hz} \quad \times \quad \left(\frac{\text{VDC in}}{5 \text{ VDC}} \right)$$

$$\text{Speed (Hz)} = 60 \text{ Hz} \quad \times \quad \left(\frac{2}{5} \right)$$

$$\text{Speed (Hz)} = 24 \text{ Hz}$$

5.3 Changing Parameter Values

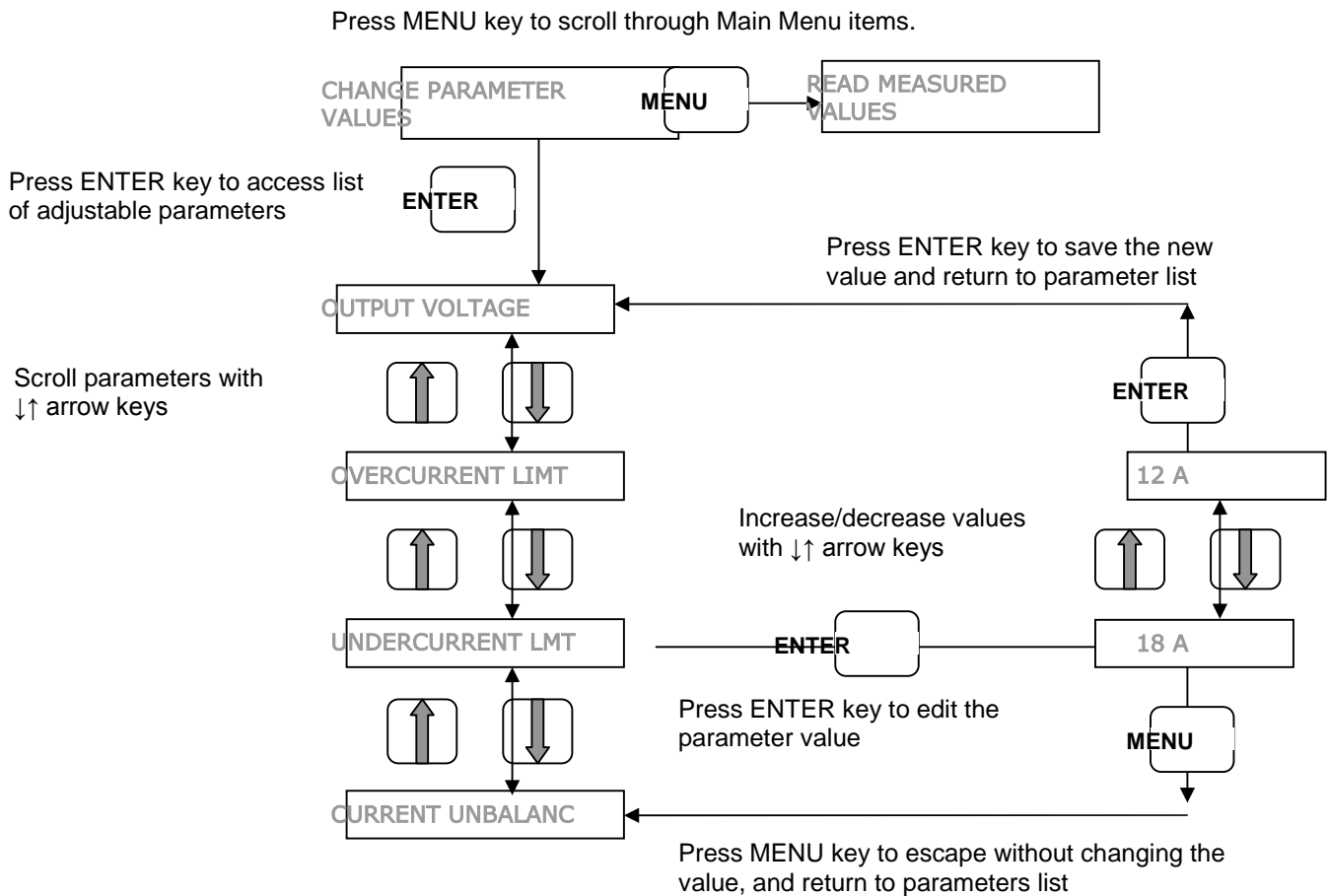
 **WARNING:** When the converter is set to automatically restart after a trip or fault, the main output terminals can energize and the load can start without warning, exposing the user to risk of serious injury. Make certain the input is de-energized or controls to the load are OFF before approaching the equipment. The unit can be programmed to automatically restart after certain faults. The factory default for number of automatic restarts allowed after a fault is zero. Use caution if automatic restart is allowed for any fault.

The Change Parameter Values function allows the user to set values for a variety of functions including motor overload settings, number of restarts after a fault, ramp time, maximum frequency, and more. To change parameter values:

1. Press the OFF key on the keypad. Parameter changes can only be made in the OFF mode.
2. Press the MENU key to scroll through menu items until **CHANGE PARAMETER VALUES** appears on the display.
3. Press ENTER to access this menu item.
4. Use the up and down arrows to scroll through the various parameters that you wish to set.
5. When the parameter you want to set appears on the display, press ENTER, then use the up and down arrows to select a new value for that parameter.
6. When the value you want appears on the display, press ENTER to select that value.
7. To escape the parameter without selecting or resetting the value, press the MENU key, which will return you to the list of parameters.

Adjustable Parameters

Figure 5-4 Changing Parameter Values



(See Table 5-1 for a complete list of adjustable parameters and their description)

Restoring Default Settings

To restore **ALL** adjustable parameters to their default value, press and hold the MENU, ENTER, ↓, ↑ keys at once and hold for three seconds.

⚠ CAUTION: Holding all four of these keys down will reset **ALL** programmable parameters to the default value. To reset an individual parameter to its default value, you must refer to Table 5-1, *Adjustable Parameters*, to find the default value for that parameter. Then navigate to that parameter through the **CHANGE PARAMETER VALUES** menu and enter the default value.

Adjustable Parameters

Resetting a Fault Counter

AquaPhase converters can be programmed to automatically restart after certain faults, and the user can also select the number of automatic restarts allowed before the unit will remain OFF after a fault.

To clear the fault counter and start counting the number of faults from zero again, the Fault Log for that particular fault must be cleared. Navigate through the keypad to **FAULT LOG**, navigate to the particular fault log, then reset the counter by pressing ENTER, then holding down both arrow keys for 3 seconds.

Table 5-1 Adjustable Parameters

DISPLAY MESSAGE	DESCRIPTION	DEFAULT/MIN /MAX VALUE
OUTPUT VOLTAGE	Phase-to-phase output voltage, 240V input models	480/360/500
	Phase-to-phase output voltage, 480V input models	480/440/500
OVERCURRENT LIMT	Setting for motor overload protection, Trip Class 10 curve.	AP10: 18/3/20 AP20: 30/3/33 AP30: 46/3/48
UNDERCURRENT LIM	Unit shuts down when output current goes below the set value (dry well protection). To use this function for dry well protection, set MINIMUM POWER to zero.	AP10: 0/0/18 AP20: 0/0/30 AP30: 0/0/46
CURRENT UNBALANC	% current unbalance on output phases, NEMA MG1	100/1/100
MINIMUM FREQ	Minimum output frequency allowed in any steady state condition. System accelerates from zero to this frequency in 1 second and decelerates from this frequency to zero in 1 second. Used to protect the thrust bearing in submersible pumps. A setting of zero disables this feature.	30/0/120
RESTART DELAY 1	Delay in seconds before unit restarts after a trip due to: <ul style="list-style-type: none"> • Over-current due to motor overload Trip Class • Instantaneous over-current 	300/0/9999
RESTART DELAY 2	Delay in seconds before unit restarts after a trip due to: <ul style="list-style-type: none"> • DC bus over voltage • Under current (dry well) • Single-phasing • Current imbalance • Under kW (dry well) 	300/0/9999
RESTARTS UDR CUR	# automatic restarts allowed due to under current trip (see Note 1)	0/0/99
RESTARTS CUR IMB	# automatic restarts allowed due to current imbalance trip (see Note 1)	0/0/99
RESTARTS SING PH	# automatic restarts allowed due to single phasing trip (see Note 1)To disable single phase protection, set number of restarts to 99	0/0/99
RESTARTS CUR OVL	# automatic restarts allowed due to motor overload current trip (see Note 1)	0/0/99

Adjustable Parameters

DISPLAY MESSAGE	DESCRIPTION	DEFAULT/MIN /MAX VALUE
UNDERCUR DELAY	Time in seconds under current is allowed before unit trips	4/0/9999
START UP RAMP	Time in seconds from MIN FREQUENCY to MAX FREQUENCY. Ramp speed is linear	8/1/120
SHUTDOWN RAMP	Time in seconds from MAX FREQUENCY to MIN FREQUENCY. Ramp time is linear. Ramp time will be automatically extended to avoid regen.	8/1/120
MAX FREQUENCY	Maximum frequency allowed, or target frequency at start-up ramp. Motor must be stopped using the OFF key for new max. frequency to take effect.	60/1/120
START UP DELAY	Anti-cycling feature. Delay in seconds before unit restarts after an input power OFF/ON cycle.	0/0/9999
RESTARTS UNDER V	# automatic restarts allowed due to low input voltage trip (see Note 1)	0/0/999
RESTARTS OVER V	# automatic restarts allowed due to high input voltage trip (see Note 1)	0/0/999
RESTART DELAY3	Delay in seconds before unit restarts after a trip due to: <ul style="list-style-type: none"> • Input over voltage • Input under voltage 	300/0/9999
MINIMUM POWER	Unit shuts down when output measured in kW goes below the set value (dry well protection). Generally more accurate than undercurrent. To use this feature for dry well protection, set UNDERCURRENT LIM to zero.	AP10: 0/0/10 AP20: 0/0/20 AP30: 0/0/30
RATED HORSEPOWER	Enter nameplate HP of motor load. Information assists controls during deceleration and is critical for constant pressure (CP) system control.	AP10: 10/0/10 AP20: 20/0/20 AP30: 30/0/30
RESTARTS BUS OV	# automatic restarts allowed due to DC bus overvoltage (see Note 1)	0/0/99
TROUBLESHOOTING	Factory assisted use only. Contact manufacturer.	
CONTRAST LEVEL	Sets contrast level of backlit LCD display	50/0/100
INPUT MODE	Selects the type of transducer connected to the analog input terminals. Options are (0) 0-5VDC and (1) 4-20mA. Note that the switch setting on the Control Terminal printed circuit board must also set for the appropriate input mode.	1/0/1
TRANSDUCER SETPT	As a %. For analog CP system only. This sets the level at which the pressure will be controlled. It is a percentage of the full-scale range of the pressure transducer, i.e. if the setpoint is 50% and the pressure transducer has a full-scale range of 150psi, then the control pressure will be 75psi.	50/0/100
CONTROLLER GAIN	Multiplier for the analog error signal in an analog constant pressure system.	5/0/30
DUPLEX PRES DROP	As a % of the full-scale transducer range. For analog CP system only. Sets the drop in pressure that must occur before the Slave unit is turned on to assist the Master.	5/0/30

Adjustable Parameters

DISPLAY MESSAGE	DESCRIPTION	DEFAULT/MIN /MAX VALUE
T OFF	In seconds. Used to prevent short cycling in CP systems. If the motor was off during the last cycle for a period greater than TOFF, the minimum on time of the motor is T1ON. If the motor was off for a period less than TOFF, the minimum on time of the motor is T2ON. Default values give a minimum cycle time of about 1 minute.	30/0/1000
T1 ON	In seconds. See T OFF above. T1ON should be set to be less than T2ON.	15/0/1000
T2 ON	In seconds. See T OFF above. T1ON should be set to be less than T2ON.	60/0/1000
SHUTOFF PMIN	As a % of RATED HORSEPOWER. Prevents short cycling in CP mode. When power to the motor drops below PMIN times RATED HORSEPOWER, the motor will turn off.	25/0/100
BOOST AMOUNT	As a % of Maximum Frequency for digital CP systems, or as a % of the full-scale transducer pressure range for analog CP systems. In CP systems, this boosts the pressure or motor speed a given %, and for a fixed time of 5 seconds before the motor shuts down.	5/0/100
PRECHARGE FREQ	In Hz. Sets the maximum frequency applied to the motor during the pre-charge interval.	30/0/120
PRECHARGE TIME	In seconds. Sets the maximum time for pre-charge regardless of any sensor inputs. A setting of zero disables the pre-charge mode.	0/0/30000
PRECHRG SETPOINT	As a %. Used only for analog CP systems. Sets pressure as % of transducer full-scale range. Pre-charge will be terminated when pressure reaches this set point. Should be set less than TRANSDUCER SETPT.	20/0/100
DUPLEX CYC TIME	In minutes. In a duplex system this determines the maximum time interval that either the Master unit or the Slave unit will be the primary pump. A setting of zero disables the Duplex mode.	0/0/9999
SYSTEM CONFIG	<p>Sets the system configuration.</p> <ul style="list-style-type: none"> • 0 = On/off control using AUX1 and AUX2. Both AUX1 and AUX2 must have a contact closure for the system to be on. • 1 = Analog control based in the input to the analog input terminals. Motor speed is proportional the analog input. Both AUX1 and AUX2 must have a contact closure for the system to be on. • 2 = Analog constant pressure system. • 3 = Digital constant pressure system. 	0/0/3

Note 1:

To clear the fault counter and start counting the number of faults from zero again, the Fault Log for that particular fault must be cleared. Navigate through the keypad to **FAULT LOG**, navigate to the particular fault log, then reset the counter by pressing ENTER, then holding down both arrow keys for 3 seconds. See Section 4.3 *Fault Log*, for details.

AquaPhase drives can be configured as constant pressure (CP) water systems using either an analog pressure transducer (which we will refer to as an analog constant pressure system) or pressure switches (which we will refer to as a digital constant pressure system). A CP water system includes a pressure tank, a pressure gauge to observe system pressure, and pressure switches or sensors

6.1 Control Principles of Constant Pressure Systems

In a CP system, a target pressure for the system is set either on the switch itself (digital CP) or through the AquaPhase keypad (analog CP). Signals from the sensors interact with firmware in the AquaPhase converter to control the motor speed and maintain a constant water pressure.

In a strict definition of a constant pressure system, the pump would never turn off. If the pressure differential between pump-on and pump-off was actually zero, the noise fluctuations of the transducer output would cause the motor to cycle constantly between the on and off states. For this reason, most applications will want to accept a small differential pressure in the system in order to prevent either continuous running of the motor, or constant on/off cycling of the motor.

Preventing Short Cycling During Low Flow Conditions

When a CP system is in a low flow state, it is desirable to turn the motor off in order to conserve energy and preserve the motor. The adjustable parameters **TOFF**, **T1ON**, **T2ON**, **SHUTOFF PMIN** and **BOOST AMOUNT** control when the motor is turned off, how long it is off and also prevent short cycling of the motor at low water flow rates. More information including default values for these parameters can be found in Table 5-1 *Adjustable Parameters*.

When water flow in the system is low, the pump motor will consume less power than what is required to pump larger flows. When the HP output of the AquaPhase falls below the value of **SHUTOFF PMIN**, the constant pressure control algorithm gives the system a slight boost in pressure before shutting off the motor. The amount of boost is determined by the parameter, **BOOST AMOUNT**.

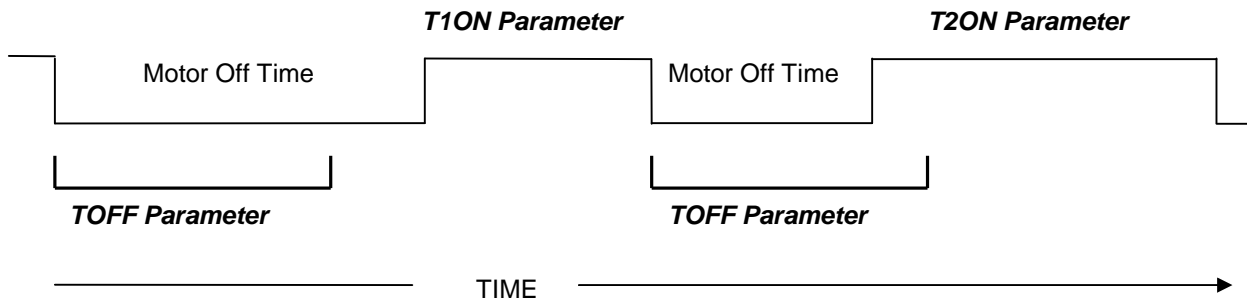
This low power threshold parameter, **SHUTOFF PMIN**, is defined as a per cent of the rated motor HP. It is important to enter the rated HP of the motor load in the adjustable parameter, **RATED HP**, so that the system calculates an accurate **SHUTOFF PMIN**. The default value for **SHUTOFF PMIN** is 25% of the rated motor HP.

The controls also record the length of time the motor remained in the OFF cycle and compare that time to the parameter, **TOFF**. If the motor-off time during the last OFF cycle was greater than the value of **TOFF**, then the minimum motor-on time will be equal to **T1ON**. If the motor-off time was less than **TOFF**, the minimum motor-on time will be equal to **T2ON**.

In other words, the time of the last OFF cycle determines whether the next ON cycle should be relatively long or relatively short. The graphic in Figure 6-1 demonstrates how the system adjusts the motor-on time in response to motor-off time.

As the water flow in the system increases, the HP consumed by the motor will increase, in which case the **T1ON** and **T2ON** settings will be ignored and the motor will remain ON so long as the HP input to the motor remains above the **SHUTOFF PMIN** threshold.

Figure 6-1 Motor-On and Motor-Off Times



Controller Gain and Ramp Time

The stability of the constant pressure system (i.e., its tendency **not** to exhibit pressure oscillations) is determined by parameters set on the AquaPhase keypad, the flow rate of the pump, and the volume of the pressure tank. Stability of a system with a large maximum flow rate and a small pressure tank will be more difficult to control and may require de-tuning the system to accept larger variations in the system pressure and longer response times. Through the keypad, the user can set parameters for **CONTROLLER GAIN**, **START UP RAMP**, and the **SHUTDOWN RAMP**.

Larger values for **CONTROLLER GAIN** give smaller error in the pressure, but also make the system more susceptible to oscillation.

The acceleration and deceleration rates of the motor are controlled by the **STARTUP RAMP** and **SHUTDOWN RAMP** parameters. These parameters affect the response time of the pump to large changes in flow and the tendency of the pump speed to wobble or oscillate at a constant flow rate. Small values of **START UP RAMP** and **SHUTDOWN RAMP** allow the system to correct more rapidly for changes in flow, but also make the system more susceptible to pressure oscillations.

AquaPhase units are shipped with default ramp values of 8 seconds, which will suppress motor speed oscillations. The response time to abrupt changes in flow rate can be reduced by decreasing ramp time. The maximum flow rate of the pump and the size of the pressure tank installed will determine the minimum values that can be used. A system with a high flow rate pump coupled to a small pressure tank will be more difficult to control.

Emergency Over-Pressure Limit Switch

Both digital and analog CP systems require an emergency over-pressure limit switch connected to the AUX2 terminals in case the main pressure control system fails. The emergency over-pressure set-point should be at least 10 PSI higher than the system control pressure to prevent nuisance tripping.

6.2 Digital Constant Pressure Systems


The digital CP system uses a digital pressure switch connected to the AUX1 terminals (see Figures 6-2 and 6-3 for one-line and wiring diagrams). For digital CP systems, the factory default settings will be satisfactory for most CP applications. A digital CP system can be operated by an AquaPhase unit not equipped with the keypad and display, however the adjustable parameters that help to stabilize the system will not be available, and **only pump motors equal to the rated HP of the AquaPhase system may be used in systems without the keypad and display, i.e. 10, 20 and 30 HP motors.** Using other motor sizes will likely result in an unstable system.

Adjusting Parameters in Digital CP Systems

With the optional keypad installed, there are several parameters which can be adjusted to fine tune digital CP systems. These are **STARTUP RAMP**, **SHUTDOWN RAMP**, **MAX FREQUENCY**, **MINIMUM FREQ**, **TOFF**, **T1ON**, **T2ON**, **SHUTOFF PMIN**, and **BOOST AMOUNT**. The use of these parameters has been discussed in the previous section.

Digital Constant Pressure Installation Procedures:

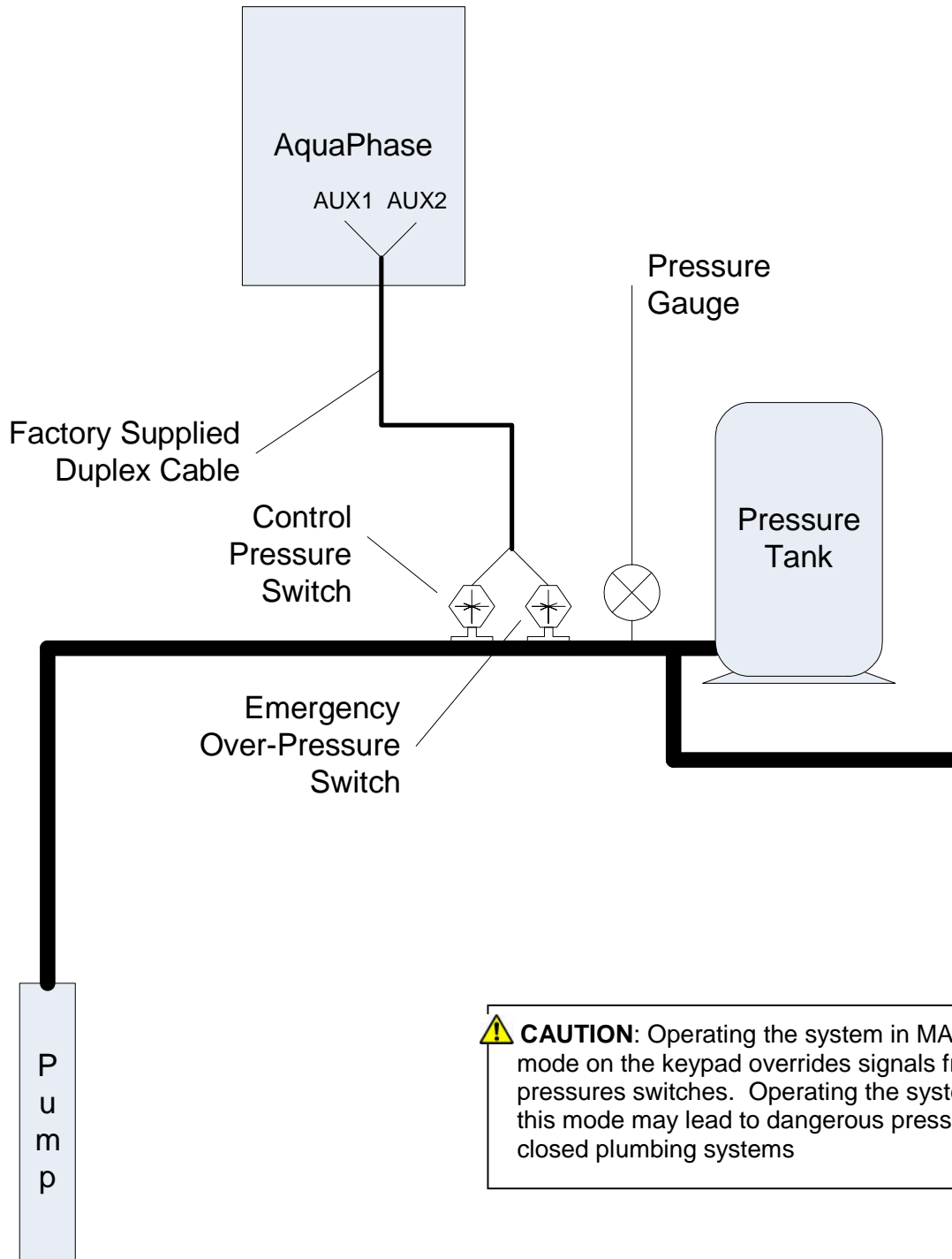
1. Install the digital pressure switches in the water line
2. Remove protective rubber boot from each switch, insert factory provided duplex cable through the boot, and connect a twisted pair of wires to the normally closed (NC) and common (C) terminals of the emergency over-pressure switch

 **CAUTION:** The use of shielded cable is recommended. Regular wire may induce capacitance in the line and corrupt the signals from the pressure switches.

3. Attach the cable shield to the Control Terminal Ground post located in the AquaPhase enclosure below the Control Terminal strip
4. Connect the emergency over-pressure limit switch to the AUX2 Control Terminals
5. Navigate through the keypad Main Menu item **CHANGE PARAMETER VALUES > SYSTEM CONFIG**. Select **3** to set the system configuration for a digital CP system. For units without the keypad, see Section 4.2, *System Configuration*
6. To set the emergency over-pressure limit switch, remove the rubber boot from the switch, pry the plastic plug from the top of the switch housing to access the pressure adjustment screw. Use an Allen wrench to adjust the pressure setting of the switch – jumper the AUX1 terminals and run the pump in the AUTO mode, and observe the pressure gauge, turning the Allen screw to adjust the pressure shut-off point. **The emergency over-pressure limit switch should be set at least 10 PSI higher than the desired constant pressure set point.**
7. Remove the jumper from AUX1 and connect the remaining twisted pair of wires in the shielded cable to the normally closed (NC) and common (C) terminals of the control pressure switch. Connect the switch to the AUX1 Control Terminals, and adjust the constant pressure set point using the same procedure as the emergency over-pressure limit switch.
8. Set the keypad to AUTO mode to operate the system

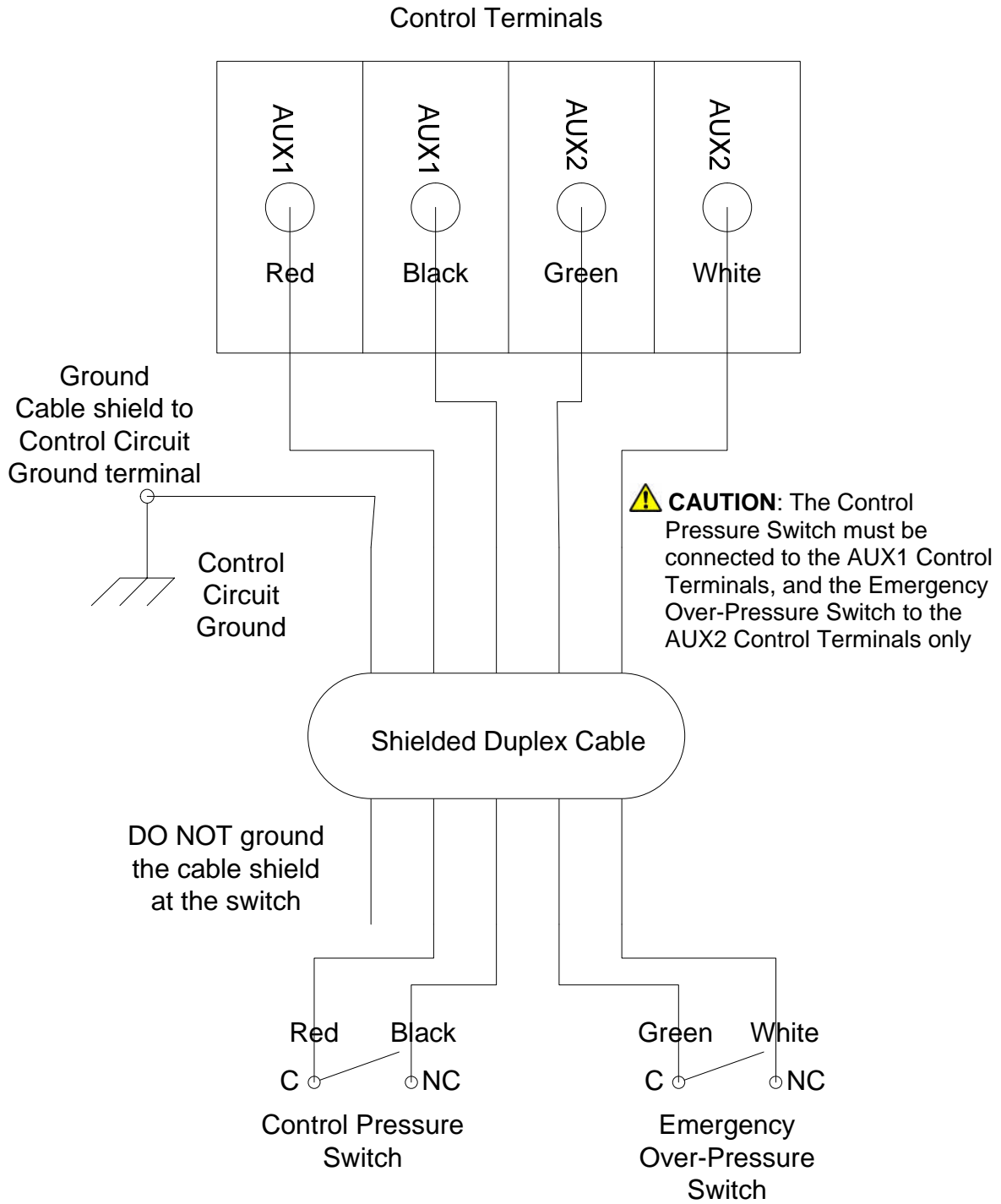
Constant Pressure Systems

Figure 6-2 Digital Constant Pressure One-Line Diagram



Constant Pressure Systems

Figure 6-3 Digital Constant Pressure System Schematic



6.3 Analog Constant Pressure Systems

The analog CP system uses an analog pressure transducer connected to the analog input on the Control Terminals (see Figures 6-4 and 6-5 for one-line and wiring diagrams). **The AquaPhase unit must be equipped with a keypad and display to operate an analog CP system.** Analog CP systems require an analog pressure transducer and a normally-closed emergency over-pressure switch connected to the AUX2 terminals. These are used in conjunction with the internal firmware of the AquaPhase to implement a constant pressure water system.

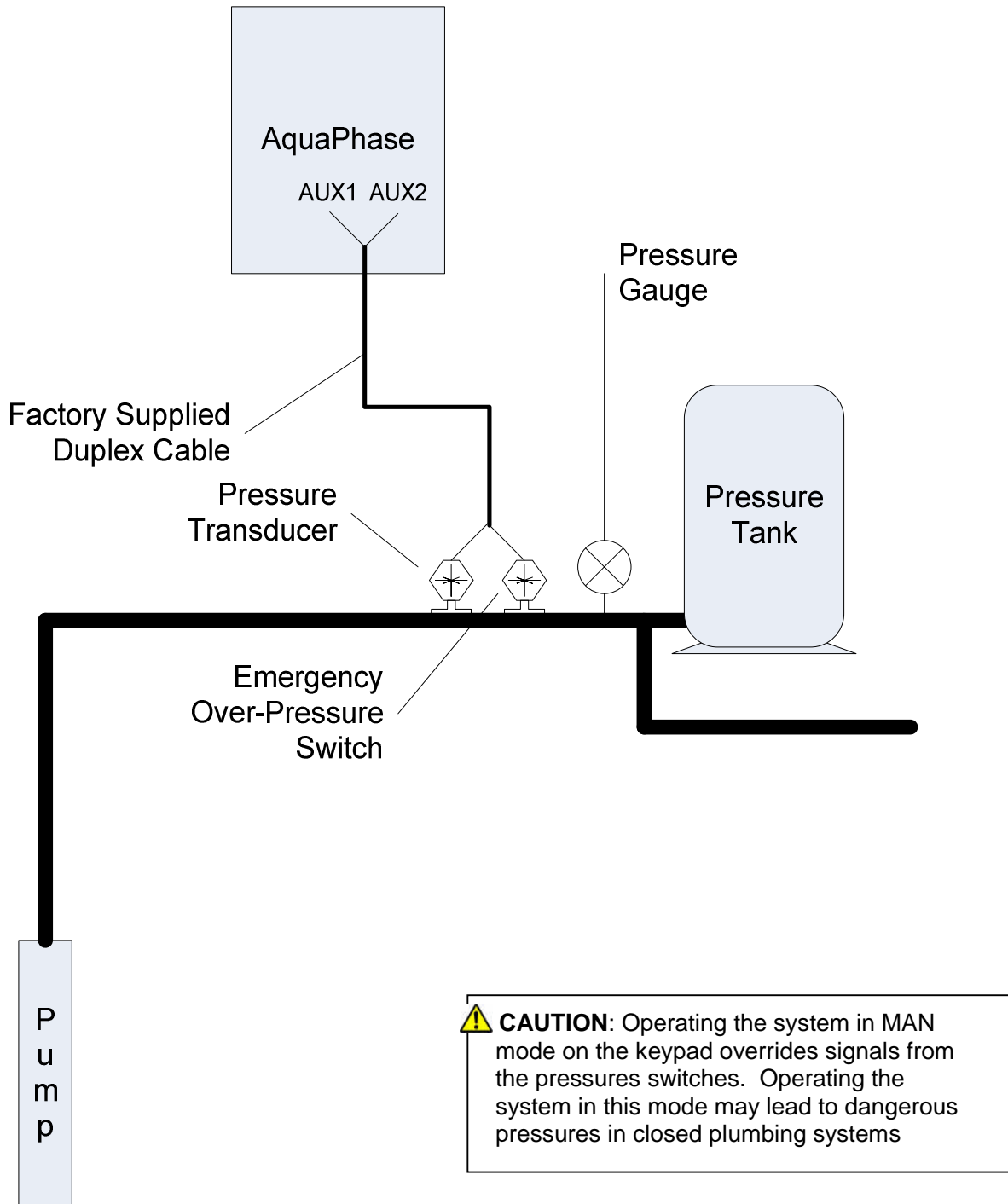
AquaPhase compares the analog signal from the pressure transducer to the parameter **TRANSDUCER SETPT**, and controls the motor speed to maintain constant pressure in the system.

In analog CP systems, the error signal between the pressure transducer and the internal Aqua Phase signal determined by the **TRANSDUCER SETPT** value is multiplied by the **CONTROLLER GAIN**, then this signal is used to determine the motor frequency. If the pressure transducer signal and the internal set-point value were the same, then the motor speed would be zero. High **CONTROLLER GAIN** values give smaller error in the pressure, but also make the system more susceptible to oscillation.

Additional adjustable parameters including **STARTUP RAMP, SHUTDOWN RAMP, MAX FREQUENCY, MINIMUM FREQ, TOFF, T1ON, T2ON, SHUTOFF PMIN CONTROLLER GAIN, and BOOST AMOUNT** help to optimize the performance of the system. The use of these parameters was discussed in the previous section. The unit is shipped with default settings which will work in most applications with no adjustment. As with all systems of this type there are tradeoffs between maintaining a tightly controlled set-point, achieving high motor efficiency and maintaining system stability.

Constant Pressure Systems


Figure 6-4 Analog Constant Pressure One-Line Diagram




Constant Pressure Systems

Analog Constant Pressure Installation Procedures:

1. Install the analog pressure transducer and emergency over-pressure switch in the water line
2. Remove protective rubber boot from the over-pressure switch, insert factory provided duplex cable through the boot, and connect a twisted pair of wires to the normally closed (NC) and common (C) terminals of the emergency over-pressure switch

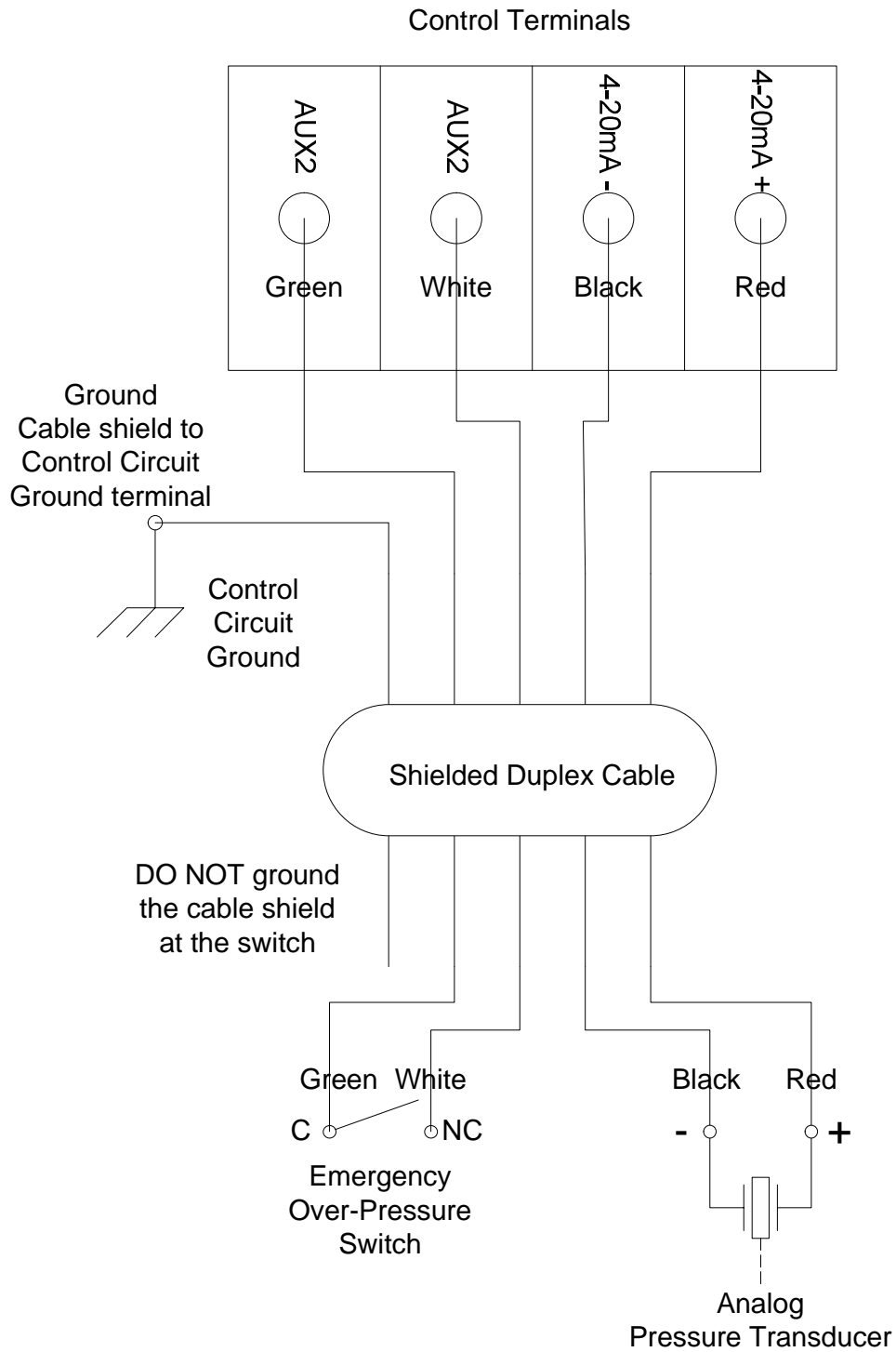
 **CAUTION:** The use of shielded cable is recommended. Regular wire may induce capacitance in the line and corrupt the signals from the pressure switches.

3. Attach the cable shield to the Control Terminal Ground post located in the AquaPhase enclosure below the Control Terminal strip
4. Connect the emergency over-pressure limit switch to the AUX2 Control Terminals
5. Navigate through the keypad Main Menu item **CHANGE PARAMETER VALUES > SYSTEM CONFIG**. Select **2** to set the system configuration for an analog CP system
6. To set the emergency over-pressure limit switch, remove the rubber boot from the switch, pry the plastic plug from the top of the switch housing to access the pressure adjustment screw. Use an Allen wrench to adjust the pressure setting of the switch – jumper the AUX1 terminals and run the pump in the AUTO mode, and observe the pressure gauge, turning the Allen screw to adjust the pressure shut-off point. **The emergency over-pressure limit switch should be set at least 10 PSI higher than the desired constant pressure set point.**
7. Connect the remaining twisted pair of wires to the + and – terminals of the transducer
8. Connect the + terminal of the transducer to the +4-20mA Control Terminal, and the – terminal to the – 4-20mA Control Terminal

 **CAUTION:** It is critical that the + terminal of the transducer is connected to the + terminal of the 4-20mA Control Terminal, and likewise for the – terminals.

9. Set the **TRANSDUCER SETPT** on the keypad (see Section 5.3 *Changing Parameter Values* for details)
10. Set the keypad to AUTO mode to operate the system

Figure 6-5 Analog Pressure System Schematic



6.4 Pre-Charge Mode

When filling a large plumbing system with water, it may be desirable to fill at a slow pump speed so that when the system reaches the full point, water hammer does not cause damage such as sprinkler head blow-off or burst pipes. To achieve this, AquaPhase is equipped with a pre-charge feature.

Both the digital and analog constant pressure systems can implement a low-flow pre-charge of the system plumbing before the pump is allowed to come to full speed. This feature is disabled if the **PRECHARGE TIME** parameter is set to zero. For both types of CP systems, the frequency of the pump will not exceed the value set by the **PRECHARGE FREQ** parameter during the pre-charge interval.

In a digital CP system the pre-charge interval is terminated if either the **PRECHARGE TIME** is exceeded or the control pressure is reached.

An analog CP system has the same features with the added option that the pre-charge interval will terminate when the system pressure exceeds the setting of the **PRECHRG SETPOINT** parameter. In this case, the **PRECHRG SETPOINT** must be lower than the **TRANSDUCER SETP**.

In both CP systems the pre-charge interval happens only once after a power-on reset of the Aqua Phase.

Precharge Mode Setup:

1. Navigate through the keypad menu to **CHANGE PARAMETER VALUES > PRECHARGE FREQ** Enter the Precharge frequency
2. Navigate through the keypad menu to **CHANGE PARAMETER VALUES > PRECHARGE TIME**. Enter the Precharge time in seconds
3. For analog CP systems only, navigate through the keypad menu to **CHANGE PARAMETER VALUES > PRECHRG SETPOINT**. Enter the pre-charge pressure as a % of the transducer full-scale pressure. This value must be lower than the **TRANSDUCER SETPT**
4. Set the keypad to AUTO mode to operate the system


6.5 Duplex Systems

AquaPhase is equipped with a duplex pump feature that allows for integrated control of two AquaPhase drives and two pumps in the same water system. The duplex pump feature will alternate the two pumps on a regular schedule, and can call on the standby pump to bring both pumps online at the same time to maintain pressure in high flow conditions.

In a duplex system, one of the AquaPhase units will operate as a Master and the other will operate as a Slave. **To operate in duplex mode, both Master and Slave must be configured as constant pressure (CP) systems.** Both units also must be configured as the same type of constant pressure (CP) system. See Figure 6-6 and 6-7 for one-line and wiring diagrams of a duplex configuration.

The optional keypad and display is required in the Master unit to operate a duplex system. The Slave unit does not require the keypad and display to operate in a duplex system, but can only be configured as a digital CP system.

The two AquaPhase units are connected by a shielded cable (available from the factory) from the NO/COM Control Terminals of the Master to the AUX2 terminals of the Slave. Because NO/COM Control Terminals are normally used for remote notification, the remote notification feature is not available when AquaPhase is in the duplex mode.

 **CAUTION:** The use of shielded cable is recommended. Regular wire may induce capacitance in the line and corrupt the signals between the units.

The duplex function is enabled when the **DUPLEX CYC TIME** parameter on the Master unit is set to any value greater than zero. Note: this parameter on the Slave unit must be set to zero. The AquaPhase units can be configured as either analog CP or digital CP systems. **It is essential that the control pressure of the Slave unit be higher (at least 3 PSI) than the control pressure of the Master unit, but lower (at least 5 PSI) than the emergency over-pressure set-point of the Master.** If the Slave control pressure and the Master emergency over-pressure set-points are too close, the system will experience nuisance shut down by the over-pressure switch. The Slave unit requires no special configuration, other than ensuring that its control pressure setting meets these criteria.

The duplex timer on the Master unit is initialized during a power-on reset and begins timing the first cycle. The Master unit will operate as the primary pump during the first cycle. After the **DUPLEX CYC TIME** expires for the first cycle, the Slave unit becomes the primary pump for the same amount of time, and then the Master unit again becomes the primary.

If the Master unit is the primary pump and its control pressure device (either switch or transducer) indicates that the Master is not keeping up with the system flow demand, then the Master unit will turn on the Slave unit by closing the relay contacts connected to AUX2 of the Slave. The Slave unit will then remain on until the output power of the Master unit drops below the level determined by the **SHUTOFF PMIN** parameter. At that point the Slave shuts off and the Master is again the only unit running.

When the Slave is the primary pump, the pressure in the system will be slightly higher than the turn-on pressure of the Master unit. If the flow becomes too high for the Slave to maintain the pressure, the Master unit will come on to assist when the pressure has dropped to the turn-on pressure of the Master unit.

Constant Pressure Systems

Precharge in Duplex Mode

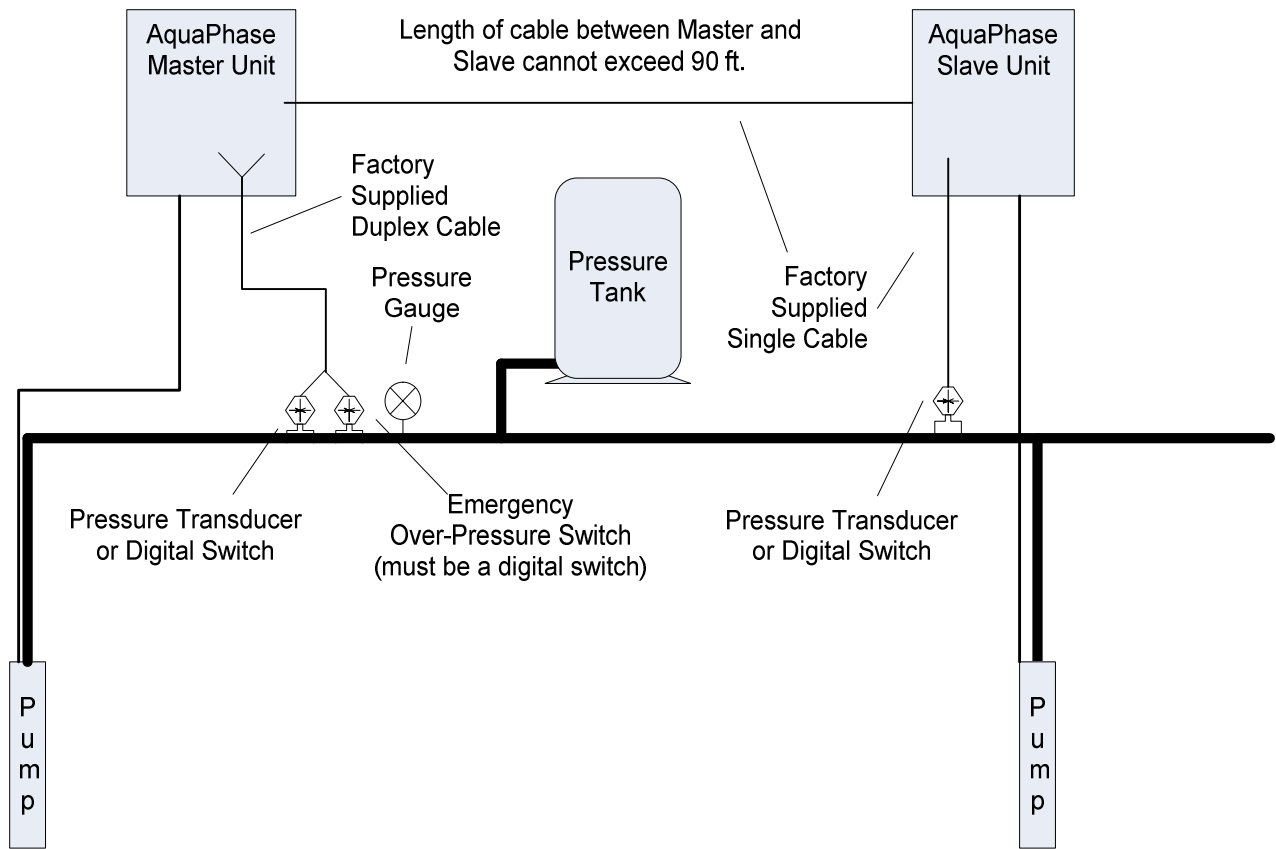
The pre-charge function can be enabled in a duplex system, and as in the case of a single Aqua Phase, pre-charge will happen only once after a power-on reset. Pre-charge is controlled only by the Master unit. The **PRECHARGE TIME** parameter for the Slave unit should remain at zero.

Duplex Mode Setup:

1. Follow the Constant Pressure Installation Procedures in the Section 6.2 or 6.3 to configure the Master and Slave unit as either a digital or analog CP system
2. Install a digital pressure control switch or analog transducer in the water system near the Slave unit
3. Using factory supplied single shielded cable, connect the normally open (NO) and common (COM) Control Terminals of the Master Unit to the AUX2 Control Terminals of the Slave unit
4. If the slave is configured as a digital CP system, connect a pressure switch to the AUX1 Control Terminals, then set the control pressure in the manner described in Section 6.2, *Digital Constant Pressure Systems*
5. If the Slave is configured as an analog CP system, navigate through the keypad to **CHANGE PARAMETER VALUES > TRANSDUCER SETPT** to set the control pressure. The AUX1 terminals must be jumpered for the unit to run.
6. **The Slave control pressure must be at least 3 lb. higher than the Master control pressure set-point, but no less than 5 lb. lower than the emergency over-pressure setting on the Master unit.** If the Slave control pressure and the Master emergency over-pressure set-points are too close, the system will experience nuisance shut down by the over-pressure switch.
7. When the Slave control pressure is set, turn the unit OFF while configuring the Master unit
8. Adjust the emergency over-pressure set-point, then the control pressure set-point on the Master, following the Constant Pressure Installation Procedures in the previous section. **The Master control pressure must be at least 3 PSI lower, and the emergency over-pressure setting no less than 5 lb. higher, than the Slave control pressure set-point.**
9. Navigate through the Master unit keypad menu to **CHANGE PARAMETER VALUES > DUPLEX PRES DROP**. Enter pressure drop (as a % of the full-scale transducer range) that must occur before the Slave is turned on to assist the Master. See Table 5-1, *Adjustable Parameters*, for details.
10. Navigate through the Master unit keypad menu to **CHANGE PARAMETER VALUES > DUPLEX CYC TIME**. Enter the cycle time in minutes.
11. Set the Master unit keypad to AUTO mode to operate the system
12. Energize the Slave unit, and if it is equipped with a keypad, set in AUTO mode to operate the system.

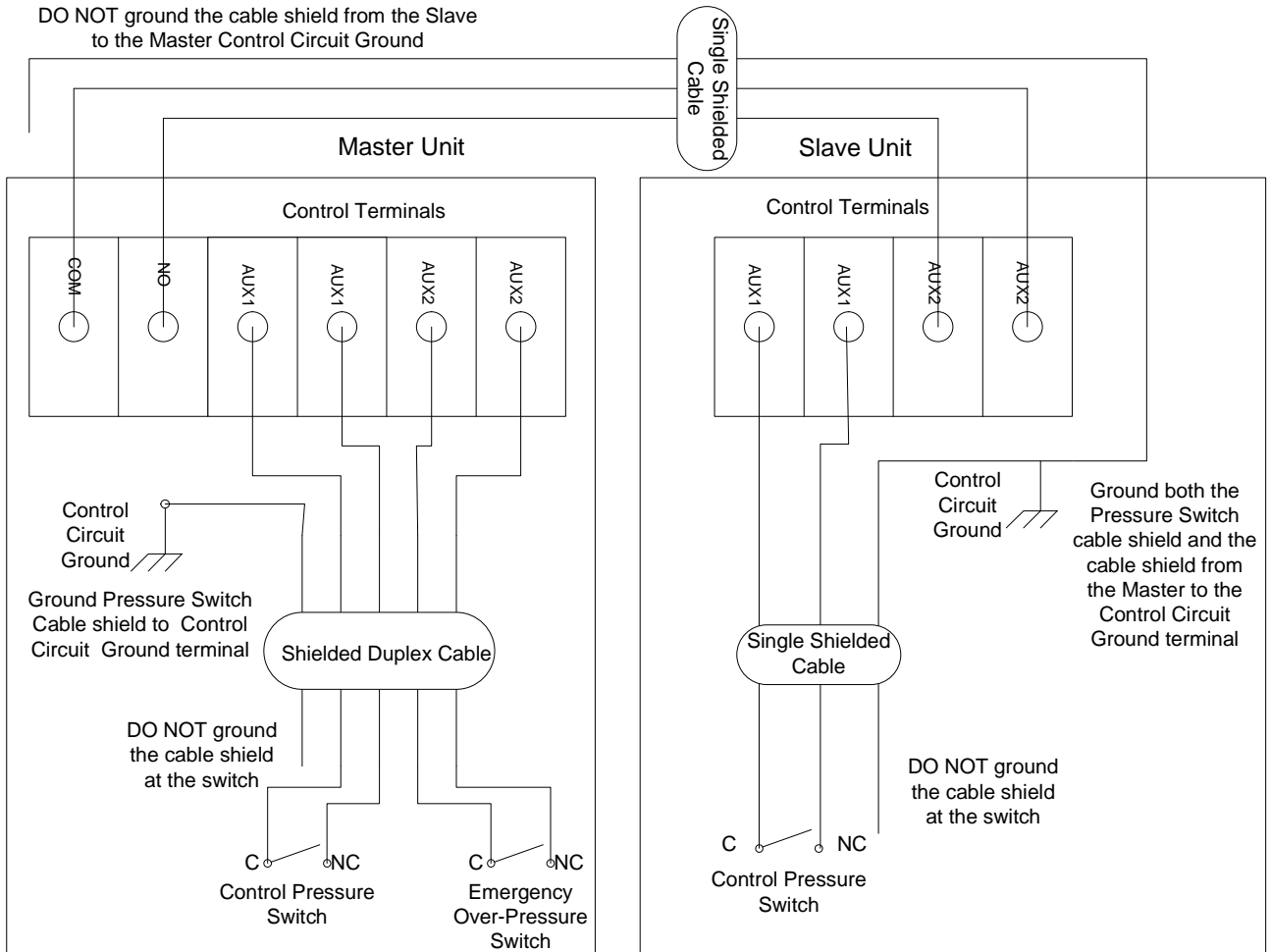
Constant Pressure Systems

Figure 6-6 Duplex Configuration One-Line Diagram



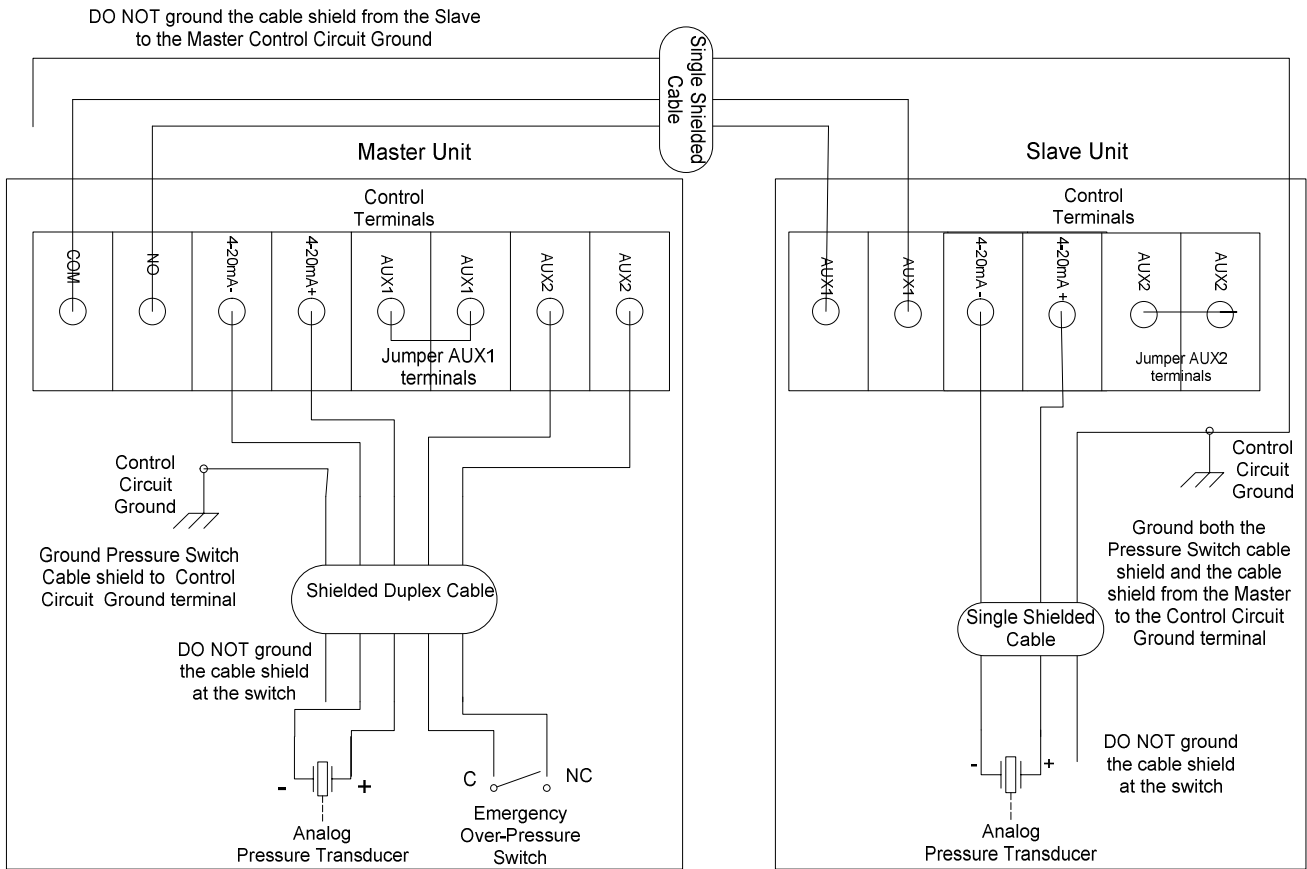
Constant Pressure Systems

**Figure 6-7 Duplex Digital CP Configuration Schematic
(both units configured as digital CP systems)**





Constant Pressure Systems


Figure 6-8 Duplex Analog CP Configuration Schematic (both units configured as analog CP systems)




This section provides information on status indicators that display information about the operating parameters of the system and troubleshooting tips for potential system problems.

 **WARNING!** In some instances, the unit will shut down, then automatically restart when conditions allow. Always disconnect input power from the unit and wait for internal electrical charges to dissipate before performing service on the unit or its connected loads.

 **WARNING:** Risk of electric shock. More than one disconnect switch is required to de-energize the equipment before servicing.

 **WARNING:** Risk of electric shock. De-energize the unit by disconnecting all incoming sources of power, then wait 30 minutes for internal charges to dissipate before servicing the equipment.

 **HIGH VOLTAGE:** This equipment is connected to line voltages that can create a potentially hazardous situation. Electric shock could result in serious injury or death. This device should be installed and serviced only by trained, licensed and qualified personnel. Follow instructions carefully and observe all warnings.

Always check the status LEDs or the LCD display for fault codes if the converter or its load is not operating. Disconnecting the input power will clear any fault code indication, possibly losing valuable information for troubleshooting.


7.1 Status Indicators and Fault Codes

The GREEN, YELLOW, and RED status LEDs are found on the control printed wiring board visible behind the clear plastic panel inside the enclosure. The status lights provide information about the operating status of the unit, indicate fault codes, and provide useful troubleshooting information. A steady GREEN LED on the control printed wiring board indicates that the unit is ON and all systems are normal. When equipped with the optional keypad and display, fault codes are also indicated in 2-row, 32-character text messages.

A fault can be cleared by either cycling the input power OFF/ON, or if the unit is equipped with the keypad and display, by pressing the OFF key. Some faults will always require cycling the input power OFF/ON to clear the fault.

Fault Codes

The converter will display a number of error codes or messages in the event of a fault or shutdown of the drive. For models without the optional keypad and display, there are 3 colored LEDs on the printed circuit board that indicate the fault by flashing different combinations. When equipped with the keypad and display, the display will indicate the fault with a text message. See Table 7-1, *Fault Codes*, for more information on fault codes.

 **WARNING:** Unit may restart automatically without warning after a fault when operating conditions permit. Make certain input power is disconnected before servicing the unit or its connected loads.

Clearing a Fault

Models not equipped with the keypad and display will NOT automatically restart after a fault, and will remain stopped until the input power is cycled OFF/ON to clear the fault and restart the unit.

Troubleshooting

When equipped with the keypad and display, a fault that allows auto restart can be cleared by either pressing the OFF key, or cycling the input power OFF/ON. If the unit is programmed to automatically restart after a particular fault, the display indicates that the unit will restart and will count down the seconds remaining to restart on the display.

Not all faults allow an automatic restart. For example, an OUTPUT FAULT, which indicates the possibility of a short circuit on the output lines, requires a manual reset only by cycling the input power OFF/ON.

For faults that allow an automatic restart, the default number of restarts after a fault is zero. If the end user desires the unit to automatically restart after a fault, the number of restarts allowed and the time between fault and restart must be programmed in the **CHANGE PARAMETER VALUES** for that fault.

Table 7-1 Fault Codes


LED COMBINATION	TEXT MESSAGE	DESCRIPTION / COMMENTS	NOTES
GREEN FLASH RED FLASH	OUTPUT FAULT	Check for short circuit on output lines and load. Contact factory	1
RED FLASH	INPUT FAULT	Contact factory.	1
YELLOW ON	OVER TEMP	Internal temperature of the drive exceeded safe limits. Check fans and ventilation openings for obstruction. Reduce ambient temperature.	2
GREEN FLASH YELLOW FLASH	BUS OVERVOLTAGE	Possibly due to regenerative power from the load. Reduce regen by increasing deceleration time. Go to SHUTDOWN RAMP under CHANGE PARAMETER VALUES menu on the keypad and display, or contact factory.	P, 1
YELLOW FLASH	UNDER CURRENT	Motor current has fallen below the value set in UNDERCURRENT LIM under CHANGE PARAMETER VALUES menu. Commonly used to detect dry well condition.	P, 2
YELLOW ON GREEN ON	SINGLE PHASING	Current unbalance greater than 80%. Check motor load, terminals and leads.	1
GREEN ON RED FLASH	SHORT C1	Possible short on output or internal fault. Check output lines and load for short circuit, or contact factory.	1
RED FLASH YELLOW ON	LOW INPUT VOLT	Input voltage has fallen below a level for safe operation of the drive.	2
GREEN FLASH RED FLASH YELLOW FLASH	OVERCURRENT OUT	Output current has exceeded the value set on rotary switch or with keypad in OVERCURRENT LIMIT under CHANGE PARAMETER VALUES menu. Check status of motor load. If output current limit is increased, make sure it is within the limit of the motor nameplate.	P, 2
RED ON	DEFECTIVE FAN	Usually indicates locked rotor on any fan. Check all fans for normal operation and make sure the impellor rotates freely. Check power leads to fans.	1

Troubleshooting

LED COMBINATION	TEXT MESSAGE	DESCRIPTION / COMMENTS	NOTES
GREEN ON RED ON	CURRENT BALANCE	Motor current unbalance has exceeded the limit set in CURRENT UNBALANC under CHANGE PARAMETER VALUES menu. Check motor load for normal operation, or increase current unbalance limit.	P
GREEN ON YELLOW FLASH	LOW POWER OUT	Real power in kW consumed by the motor load has fallen below the limit set in MINIMUM POWER under CHANGE PARAMETER VALUES menu. Commonly used to detect dry well condition.	P, 2
GREEN FLASH RED ON YELLOW ON	OVERCURRENT IN	Input current has exceeded safe level. Could be due to low input voltage and/or overload on the output. Reduce load and/or output voltage. Go to OUTPUT VOLTAGE under CHANGE PARAMETER VALUES menu.	P, 2
GREEN FLASH YELLOW ON	TEMP SENSE FAULT	Solid state temperature sensor on the heat sink has failed or its cable is disconnected. Contact factory.	1
RED ON GREEN ON YELLOW ON	HIGH INPUT VOLT	Input voltage has exceeded a level for safe operation. Reduce input voltage. General purpose buck/boost transformers are compatible with AP Series drives.	2
GREEN FLASH RED ON	OUTPUT OVERLOAD	Current on output module exceeded safe limit. Check motor overload settings in OVERCURRENT LIMT under CHANGE PARAMETER VALUES menu. Current may have exceeded the maximum motor overload setting.	1

P = Fault may be related to an adjustable parameter. Always check the value of the parameter to eliminate nuisance tripping.

1 = Drive will remain OFF until input power is cycled OFF/ON

2 =  **WARNING:** Unit may restart automatically without warning after a fault when operating conditions permit. Make certain input power is disconnected before servicing the unit or its connected loads.

Fault Log

When equipped with the optional keypad and display, the AP Series converter records the number of times a particular fault has occurred. Refer to Section 4.3, *Using the Keypad and Display*, for details.

Table 7-2 Troubleshooting

PROBLEM	POTENTIAL CAUSE	SOLUTION
Motor not running	Is a fault code indicated?	Based on the fault code, resolve any factors that are likely causing the fault. Clear the fault by pressing the OFF key on the keypad or by cycling input power OFF/ON.
	Are the remote switches AUX1 and AUX2 closed?	Check the status of the switches or jumpers connected to AUX1 and AUX2 on the Control Terminal panel. The LCD display indicates the status of AUX1 and AUX2 in the default display mode. Both AUX1 and AUX2 must be closed for the motor to run in AUTO mode.
	Are the signals to the Control Terminals corrupted?	Shielded cable is required for AUX1/AUX2 switch leads longer than 20 ft. Regular wire will induce capacitance in the line and corrupt control signals.
	Are the signals to the analog inputs on the Control Terminals correct?	Verify 0-5VDC or 4-20mA signals to Control Terminals.
	Is the keypad in MAN>STOP or OFF mode?	The keypad will override signals on the Control Terminals when OFF or MAN>STOP is selected. Keypad must be in AUTO mode for AUX1 and AUX2 to control the motor.
	Is the maximum frequency set at 0 Hz?	Check the maximum frequency by using the keypad to navigate MAIN MENU>CHANGE PARAMETER VALUES>MAX FREQUENCY. Frequency is not programmable on models without the keypad and display.
	Are the input terminals L1 and L2 energized?	Green status LED on the control printed wiring board should be on. If no LEDs are lit on the PWB, check the main input fuses or breaker. Check the fuse on the panel near the Control Terminal.
Motor is turning the wrong direction	Phase sequence on output terminals U/T1, V/T2, W/T3 is out of order	Swap any two of the three motor leads on the output terminals.
Unable to edit programmable parameters with keypad	Keypad is locked.	Keypad can be locked to prevent unauthorized or inadvertent editing of programmable parameters. To lock keypad, turn rotary switch, located on the Control Terminal panel, to position "0". All other rotary switch positions unlock the keypad.

7.2 Routine Inspection and Maintenance

The unit should be inspected and cleaned at least annually, or more frequently if it is located in an excessively warm or dusty environment.

Fans and heatsinks: Excessive dust buildup on the heatsink and cooling fan impellers may lead to overheating. Lightly brush and vacuum clean.

Power terminals: Inspect for loose connections and tighten to specifications in Table 3-2, Field Wiring Power Terminal Specifications.

Capacitors: Check for leakage or deformation.

Overall: Perform a visual inspection checking for things such as discolored wires or terminals, evidence of arcing, loose mounting screws, physical damage to the enclosure, etc.

LIMITED WARRANTY

Phase Technologies equipment is warranted against defects in material and workmanship for a period of one year. This warranty covers both parts and labor for one year from the date of purchase by the original owner. Phase Technologies will repair or replace (at our option), at no charge, any part(s) found to be faulty during the warranty period specified. The warranty repairs must be performed by/at a Phase Technologies Authorized Service Center or at Phase Technologies LLC, Rapid City, SD.

Obligations of the Original Owner

1. The original Bill of Sale must be presented in order to obtain "in-warranty" service.
2. Transportation to Phase Technologies or an Authorized Service Center is the responsibility of the original purchaser. Return transportation is provided by Phase Technologies.
3. Installations must comply with all national and local electrical codes.

Exclusions of the Warranty

This warranty does not cover any of the following: accident, misuse, fire, flood, and other acts of God, nor any contingencies beyond the control of Phase Technologies, LLC, including water damage, incorrect line voltage, improper installation, missing or altered serial numbers, and service performed by an unauthorized facility. Phase Technologies' liability for any damages caused in association with the use of Phase Technologies' equipment shall be limited to the repair or replacement only of the Phase Technologies' equipment. No person, agent, distributor, dealer, or company is authorized to modify, alter, or change the design of this merchandise without express written approval of Phase Technologies, LLC.

INSTALLATIONS MUST COMPLY WITH ALL NATIONAL AND LOCAL ELECTRICAL CODE REQUIREMENTS.