CONTROL CONCEPTS

MODEL 1600-PM6

INSTALLATION & MAINTENANCE MANUAL

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WARNING: The Control Concepts, Inc. power controllers use power thyristors to switch voltage to the connected load. Line voltage must be assumed at the output terminals at all times, even when the control signal has been removed and the load voltage appears to be off. It has been mandated by the National Electrical Code and the Occupational Safety and Heath Act of 1970 that a physical disconnect be opened ahead of all remotely actuated controls before performing any maintenance work on the controller or its connected load.

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DESCRIPTION

The model 1600-PM6 SCR Power Controller (6-Pak) consists of a fan cooled heat sink with up to 6 SCR modules. These modules can be configured as:

6 single-phase, zero-cross controllers
6 single-phase, phase-angle controllers
Three 2-leg, zero-cross, three-phase controllers
Two 3-leg, zero-cross, three-phase controllers, or any combination thereof.

The SCR modules are available with current ratings from 10 to 70 amps and voltages from 120 to 480 for phase-angle operation or 120 to 575 for zero cross operation. Various circuit cards, described in the firing circuit specification section, are available which can control the load power proportional to a command signal.

SPECIFICATIONS

Dielectric Strength input/output/base	2500V(RMS)
Insulation Resistance	10^{10} ohms
Max capacitance input output	8pf
dv/dt rating	200V/usec
Operating Voltage	+10%,-50%

Current Rating		
Continuous RMS in Amps (A)	Surge Peak 1 cycle	RMS 1 Second
10	120	22
20	250	40
30	625	80
40	1000	150
70	1000	150

Input Characteristics		
	DC Models 1651-VV-AA	AC Models 1651A-VV-AA
Control Range	3.5 - 32 Vdc	90 - 280 V(RMS)
Max Turn-On Volts	3.5 Vdc	90 V(RMS)
Max Turn-Off Volts	1.0 Vdc	10 V(RMS)
Min Input Impedance	1500 Ohms	60K Ohms

AC/DC INPUTS

Zero-cross SCR modules, depending upon the model, can be controlled by applying either a DC or an AC command signal directly to the SCR module.

SCR modules type 1651-VV-AA are DC controlled. Voltages from 3 to 32 Vdc will cause the SCR module to turn on. Voltages lower than 1 Vdc will cause the SCR module to turn off. Input load is 3.4mA @ 5Vdc and 20mA @ 20Vdc.

SCR modules type 1651A-VV-AA can be turned on by applying an AC voltage from 90 to 280 V(RMS). Voltages lower than 10V(RMS) will cause the SCR module to turn off. Input load is; 2mA @ 120 Vac, 4mA @ 240Vac.

NOTE: The AC control voltage must generally be switched by mechanical contacts.

Solid state switches are sometimes used to control the AC signal to the SCR module. When off, they typically have a small leakage current sufficient to cause the SCR module to remain turned on. In cases where solid state switches are used, it is recommended that the model 1026-FC be installed to provide positive ON-OFF operation of the SCR. (See 1026-FC in the firing circuit specifications section.)

BASIC CONTROL MODES

The power delivered to a load may be proportioned by SCR power controllers using either the *phase-angle* or the *zero-cross* control mode. Each control mode has its own specific advantages and disadvantages and each application should be reviewed to determine the mode of control most compatible with your application.

PHASE-ANGLE:

In phase-angle control, each SCR of the back-to-back pair is turned on for a variable portion of the half-cycle that it conducts (Figure 2). Power is regulated by advancing or delaying the point at which the SCR is turned ON within each half cycle. Light dimmers are an example of phase-angle control.

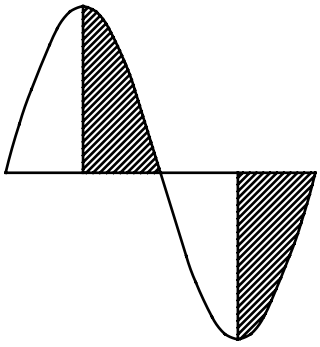


Figure 1. AC Supply.

SCR "ON" time, shown by the shaded area, is varied to apply the desired load power.

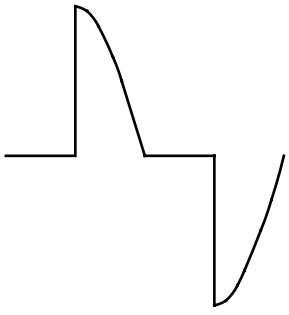


Figure 2. Phase-Angle Waveforms.

Phase-angle control provides a very fine resolution of power and is used to control fast responding loads such as tungsten-filament lamps or loads in which the resistance changes as a function of temperature. Phase-angle control is required if the load is transformer-coupled or inductive.

Phase-angle controllers are typically more expensive than zero-cross controllers because the phase-angle circuit requires more sophistication than does a zero-cross circuit. Phase-angle control of three-phase power requires SCR's in all three legs and is appreciably more expensive than zero-cross control which only requires SCR's in two of the three legs.

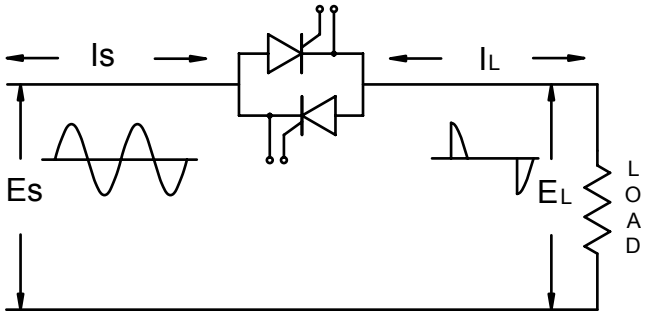


Figure 3. Phase-Angle control at 50% power.

PHASE-ANGLE CIRCUITS

Description:
Only single-phase phase angle controllers are available for use with the '6·Pak' assembly. The model 1022 and 1025 circuits provide phase-angle control of single-phase loads. Three-single phase SCR modules can be connected inside delta to obtain three phase control.

The 1022 and 1025 circuits are powered by 24Vac. They also use the 24Vac signal as a reference to determine the point within each half cycle that the SCRs are turned on, therefore the transformer used to supply the 24Vac must be connected to the same supply used to power the load. Multiple 1022 circuits can be powered by a common transformer providing all the 1022 circuits are on the same phase.

Multiple 1025-FC circuits controlled by a common 4/20mA supply must not be powered by a common transformer.

The 1022-FC and 1025-FC circuits are similar, except the 1022 circuit accepts voltage or potentiometer command signals and the 1025 circuit accepts mA command signals.

SINGLE-PHASE LOAD CONNECTIONS

The connections for phase-angle and zero-cross are the same, the only difference between the two is the manner in which the SCR's are controlled.

BASIC CONTROL MODES (Continued)

ZERO-CROSS:

The term *zero-cross* or *synchronous*, when describing the operation of an SCR, is derived from the fact that the SCR is turned on only when the instantaneous value of the sinusoidal waveform is zero. In zero-cross operation, power is applied for a specific number of continuous cycles and then removed for a specific number of cycles to achieve the desired load power in the same manner as power would be controlled with a mechanical switching device. Also, the frequency of the on-off cycles can be extremely fast because there is no limit to the number of switching operations the SCR can perform.

Zero-cross controllers can provide two rather distinctively different types of control.

Time proportioning control is accomplished with a fixed (constant) time base, therefore the total of power **ON** and **OFF** time is always equal to a fixed value. For example, if the time base is ten seconds and the desired power is 50%, then power is **ON** for 5 seconds and **OFF** for 5 seconds. If the desired power were 25% then power is **ON** for 2.5 seconds and **OFF** for 7.5 seconds.

The disadvantage of time proportioning, particularly as the time base is increased, is that the load temperature varies considerably between the on-off cycles. This can shorten the life of heater elements and decrease the ability to obtain precise process control. It can also cause line voltage variations that can affect lighting other equipment.

Distributive zero-cross control does not use a fixed or constant time base as is used in time proportioning. It is somewhat less expensive and provides a much faster cycle rate, giving better controllability and longer heater life. The technique used by Control Concepts applies load power for 3 electrical cycles and removes load power for 3 electrical cycles at 50% power. At lower power requirements the controller will apply power for 3 electrical cycles and is then off for the appropriate number of electrical cycles. For example, at 25% power the controller is on for 3 electrical cycles and off for 9 electrical cycles, or on for 3 electrical cycles out of 12. At higher power levels the controller is off for three electrical cycles and on for the appropriate number of electrical cycles. For example at 75% power the controller is on for 9 electrical cycles and off for 3 electrical cycles.

The Control Concepts distributive control technique combines power pulses of short duration to obtain the exact power level proportional to the command or set point signal. For example, 60% power is achieved by combining two power pulses. The first power pulse consists of 4 on cycles and 3 off cycles; the second power pulse consists of 5 on cycles and 3 off cycles, providing a total of 9 on cycles during 15 cycles. Of course, such rapid, short bursts of power would be impossible with mechanical contactors. Zero-cross control is typically less expensive than phase-angle control and generates fewer harmonics. However, zero-cross can only be used to control power to resistive loads that do not change appreciably with temperature or time and which are direct-coupled (no transformer between the SCR controller and the load).

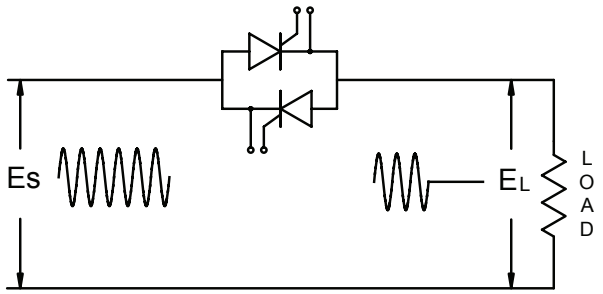


Figure 4. Zero-Cross at 50% power.

ZERO-CROSS - CIRCUITS

Description:

The zero-cross circuits described in the following sections accept standard industrial process signals and apply ON-OFF signals to the SCR module such that the load power is linear with respect to the command signal. The SCR modules used for zero-cross operation provide electrical isolation between their control signal inputs and the line and load voltages, and provide the logic to determine the zero-cross-over of the sinusoidal wave applied to them.

In single-phase control, the circuit card is mounted on the SCR module, and electrical connections are made through the mounting screws.

In three phase control the circuit card is mounted on one SCR module and the ON-OFF signal from the circuit card is connected to the inputs of the other SCR modules. Two-leg, zero-cross is the most common technique for controlling the power to three-phase delta or 3 wire `wye' loads. In this technique, an SCR module is placed in series with two of the three supply leads (Figure 5 & Figure 11). Three-leg control can control power to delta loads and 3-wireloads (Figure 6 & Figure 12) inside delta control (Figure 7).

Although single-phase, 2-leg and 3-leg control all use only one circuit card, it is necessary to identify which type of control is being used such that the proper electrical connections, and parts are supplied.

3 PHASE APPLICATIONS

ZERO-CROSS CONTROL

Two leg control:

This approach uses a pair of back-to-back SCR's in two of the supply leads to the load (Figure 5). If all of the SCR's are off, no power can be applied to the load. The two leg control can be used on either "wye" or "delta" loads, however, it cannot be used to control four wire loads. The primary advantages of the zero-cross control technique are lower cost and extremely low RFI.

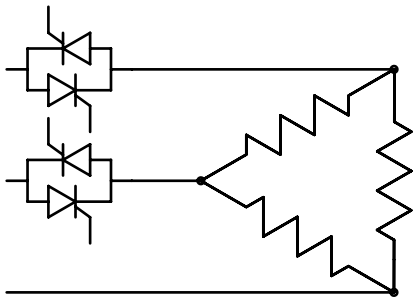


Figure 5. 2-Leg Zero-Cross.

Three leg control:

Some installations require that all three legs of the load be controlled and therefore back-to-back SCR's are placed in all three supply leads. The cost advantage of zero-cross control is reduced with 3-leg control because of the added SCR's and heat sink costs, however, the circuit cost is less than an equivalent phase-angle controller and the advantage of low RFI is retained.

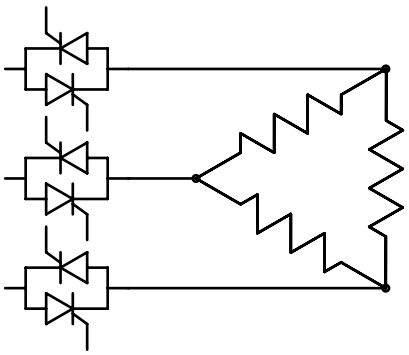


Figure 6. 3-Leg Zero-Cross.

PHASE-ANGLE CONTROL

Phase-angle control requires that all three legs of the load be controlled and therefore back-to-back SCR's are placed in all three supply leads. The cost is higher with Phase-angle, 3-leg control because of the higher cost of the Phase-angle SCR modules, and the complexity of the control circuitry. The advantage is being able to control transformer coupled loads as well as inductive loads Another advantage to phase-angle control is being able to use them with 4-wire wye loads. (Contact factory for information)

SIX SCR INSIDE DELTA CONROL

Three phase inside delta control is essentially three single-phase controllers operating from the same command or set point. Typically a six SCR controller can be configured to operate inside delta. It is also possible, of course, to configure three single phase controllers controlled by the same command signal. Because the current in each phase is 57.74% of the line current, smaller and less expensive controllers can be used for inside delta control.

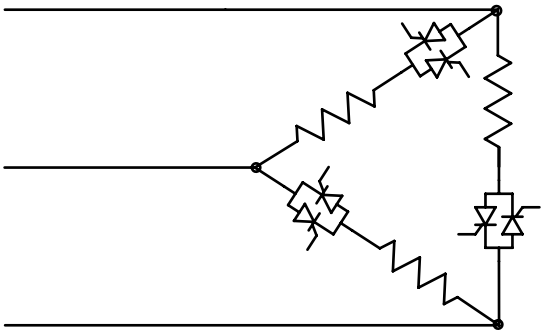
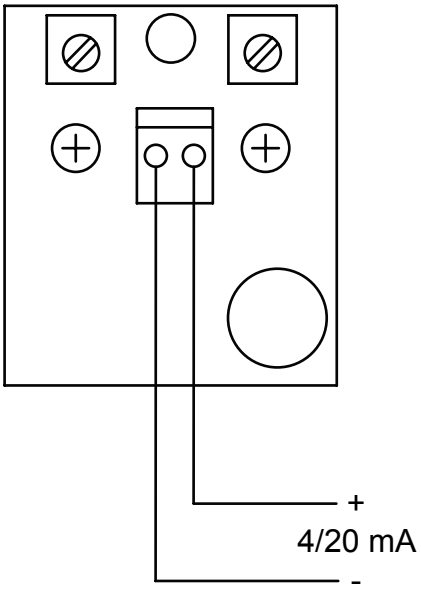


Figure 7. Six SCR inside-delta control Zero-Cross or Phase-Angle.

Caution: If inside delta control is desired in the primary of a three-phase transformer, a six SCR controller must be used, and the secondary of the transformer must also be a delta. *(Three single phase controllers cannot be used in inside delta configuration to operate a three-phase transformer)*. Please consult factory for information about this type of application.

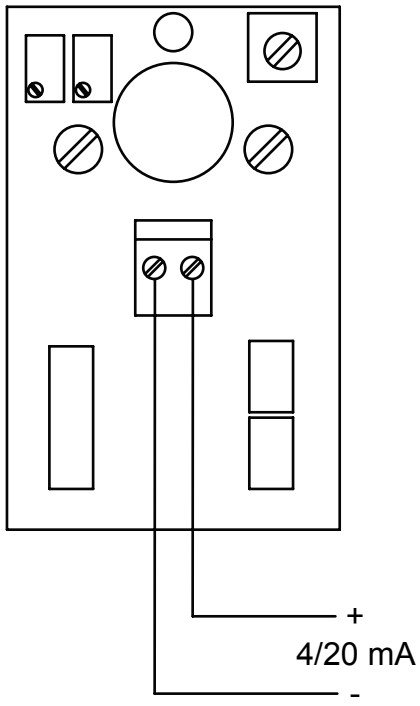
FIRING CIRCUITS

1020-FC (Zero Cross)



Command signal:	4/20mA
Input impedance:	7 volt maximum
Control range:	0 to 100%
Zero and Span adjustment:	+10% typical
Control mode:	Distributive zero-cross; single or three-phase
Operating voltage:	+10% to -50% of nominal voltage 50/60 Hertz
Features:	Circuit powered by 4/20mA signal

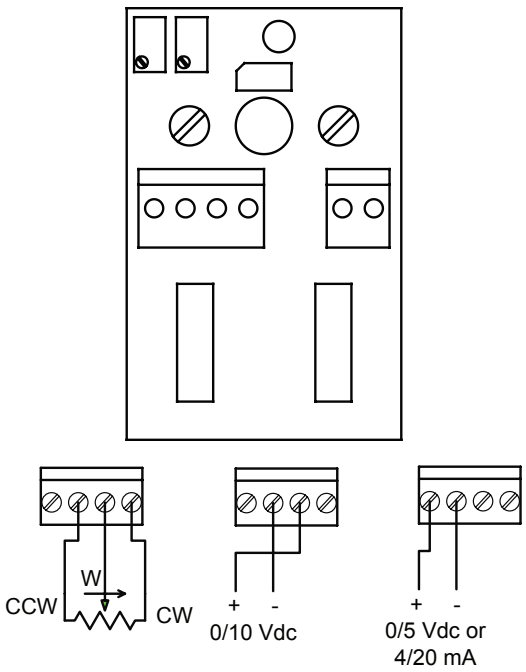
1023-FC (Zero Cross)



Command Signal	4/20mA
Input impedance	Series circuit consisting of a diode, a 7.5 volt zener and a 200 ohm resistor. @ 4mA input, voltage required is 8.8 volts, @ 20mA, voltage required is ~2 volts.
Control range	0 to 100%
Zero and span adjustments	+20%
Control mode	Time proportioning, cycle time is field adjustable from 1 to 10 seconds.
Operating voltage	+10% to -50%
Features	Circuit is powered by 4/20mA signal

FIRING CIRCUITS (Continued)

1021A-FC (Zero Cross)



Command Signal	Input Impedance
0/5Vdc	100K
0/10 Vdc	200K
4/20mA	300 Ohms
Potentiometer	200K

(1K to 20K. Circuit supplies 10Vdc to Pot)

(Model 1021-4/20mA)

Control range 0 to 100%

Zero and Span adjustment ±10%

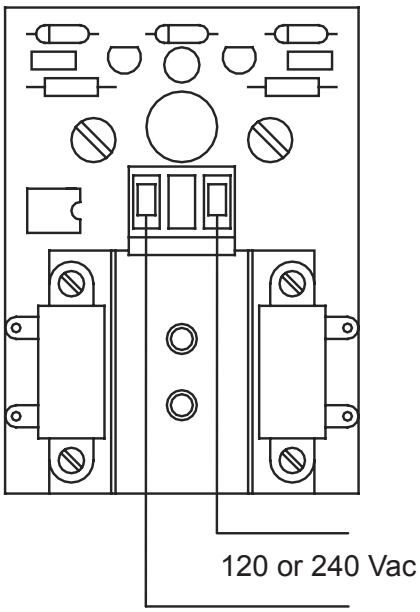
Operating voltage +10,-20% 50/60 Hertz

Control Mode Distributive zero-cross; Single or three-phase

Features: Line voltage compensation.

NOTE:
Multiple 1021A-4/20mA controllers may be powered from a common 24 volt transformer provided that the following conditions are met:
The transformer must be connected to the same two phases used to power the controller and its load.
The minus or return of the mA command must be com mon or the commands must be electrically isolated.
Multiple power controllers cannot be controlled with a common milliamp signal by connecting the ports in series.

1026-FC (Zero Cross)

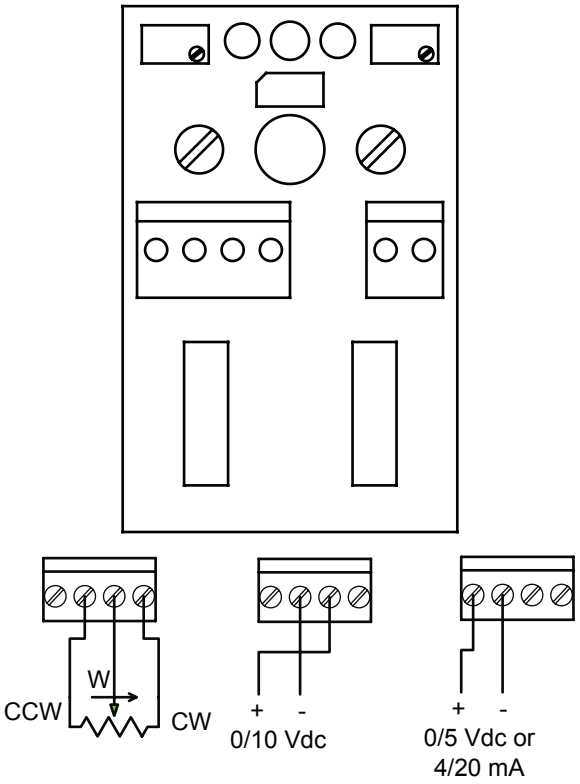


Model Number	Command Signal	Input Impedance
1026-120-FC	120Vac ±20%	2000 ohms
1026-240-FC	240Vac ±20%	4000 ohms

The 1026 circuit accepts ON-OFF 120 or 240 Vac control signals from solid state switching devices and is used to operate DC (type D) input SCR modules. The circuit provides the proper loading for triacs and other solid state switching devices to insure proper turn-on of the solid state switch and to insure that leakage from the solid state switch does not cause false operation of the SCR module.

FIRING CIRCUITS (Continued)

1022-FC (Phase Angle)

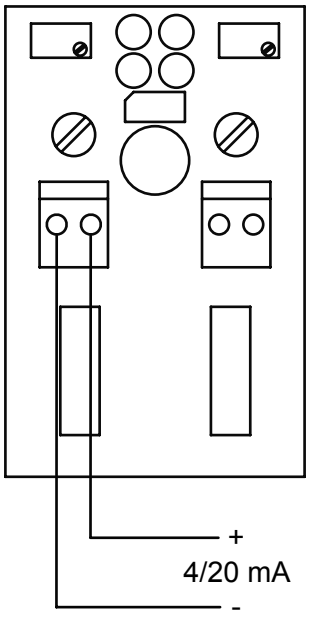


Command signal	Input Impedance
0-5Vdc,	100K
0-10Vdc	200K
Potentiometer	200K

(1k recommended, 20k permissible.)
Note: Circuit provides 10Vdc to potentiometer.

Control range:	5 to 97% .025% to 94% power
Zero and Span adjustment:	±20% of span.
Operating voltage:	+10% to -20% of nominal, 50/60 Hz.
Circuit power	24Vac ±20%, 50/60 Hertz
Linearity:	The RMS load voltage is linear within 2% of the command signal.
Features:	Soft start and missing cycle detection. Line voltage compensation.

1025-FC (Phase Angle)



Command Signal:	4/20mA (35mA max.)
Input Impedance:	200 ohms.
Control range:	5 to 97% voltage. 0.25% to 94% of power.
Zero and Span adjustment:	±20% of span.
Operating Voltage:	+10% to - 20% of nominal, 50/60 Hertz.
Circuit power	24Vac ±20%, 50/60 Hertz
Linearity:	The RMS load voltage is linear within 2% of the command signal.
Features:	Soft start and missing cycle detection. Line voltage compensation.

NOTE:
Multiple 1025 controllers may be powered from a common 24 volt transformer provided the following conditions:

- The transformer must be connected to the same two phases used to power the controller and its load.
- The minus or return of the mA command must be common or the commands must be electrically isolated.
- Multiple power controllers cannot be controlled with a common milliamp signal by connecting the ports in series.

INSTALLATION DRAWINGS

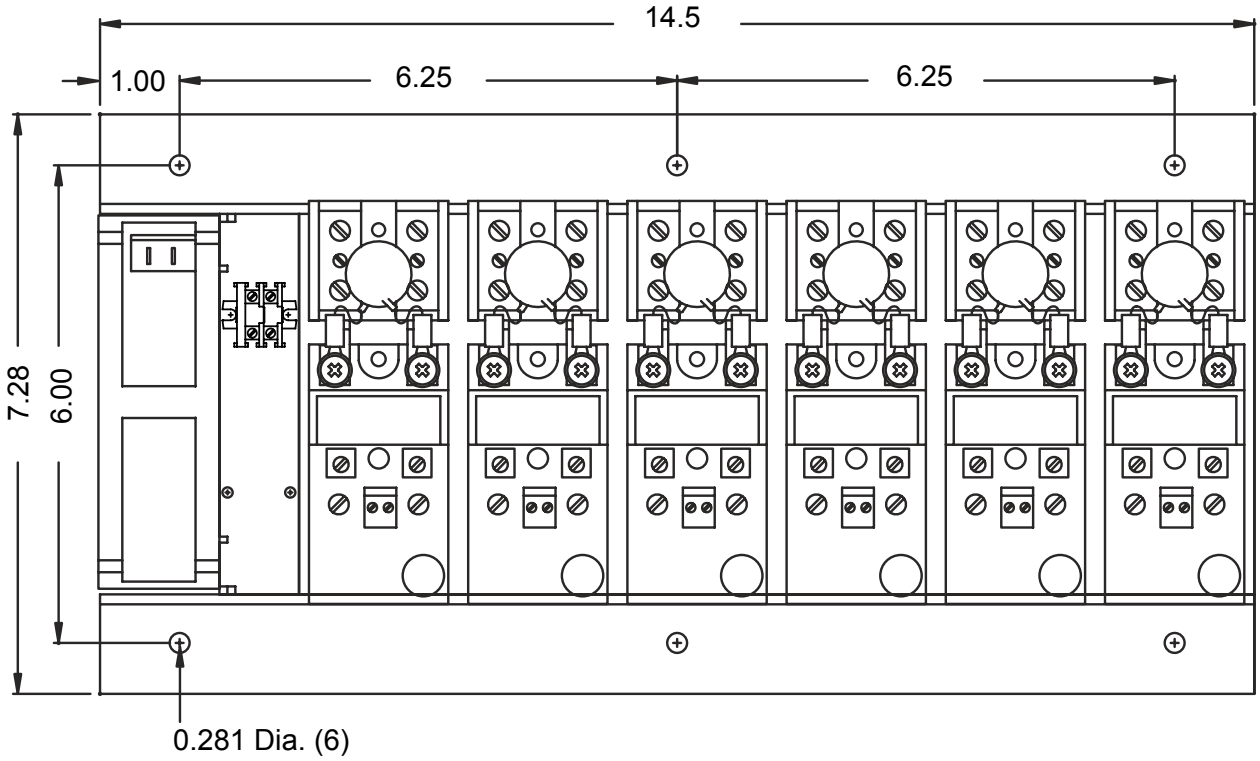


Figure 8. Top view of typical model 1600-PM6-01 controller.

Note: The fan must be wired separately to a 120Vac source (or 240Vac, if a 240 volt fan has been installed.) The thermostatic switch is a normally closed temperature operated switch whose contacts open when the heatsink reaches 87°C. The t-switch may be wired to operate a contactor or other device which can remove power from the controller and load.

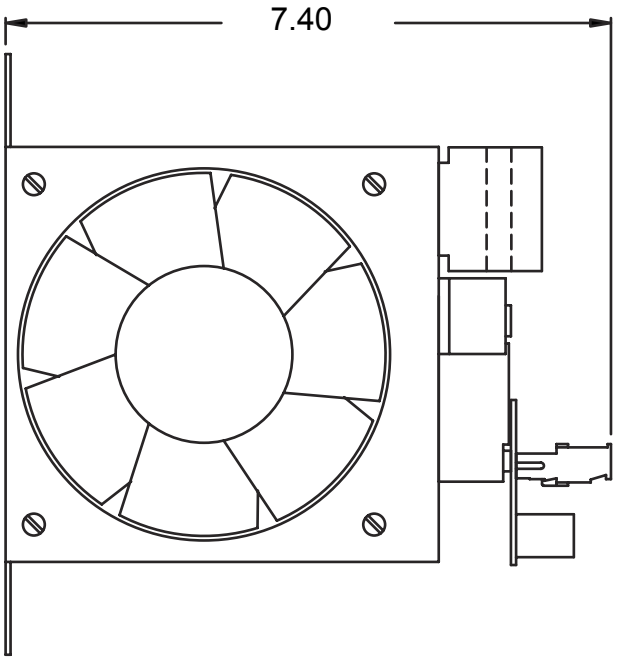


Figure 9. End view of typical model 1600-PM6-01 controller.

Recommended tightening torque for green connector: 	
Wire Size (AWG)	Torque
12 to 26GA	**5.0 in-lbs**

Recommended tightening torque usd connectors: 	
Wire Size (AWG)	Torque
14 - 10 GA	**35 in-lbs**
8 GA	**40 in-lbs**
4 - 6 GA	**45 in-lbs**
2 - 3 GA	**50 in-lbs**

ELECTRICAL CONNECTIONS

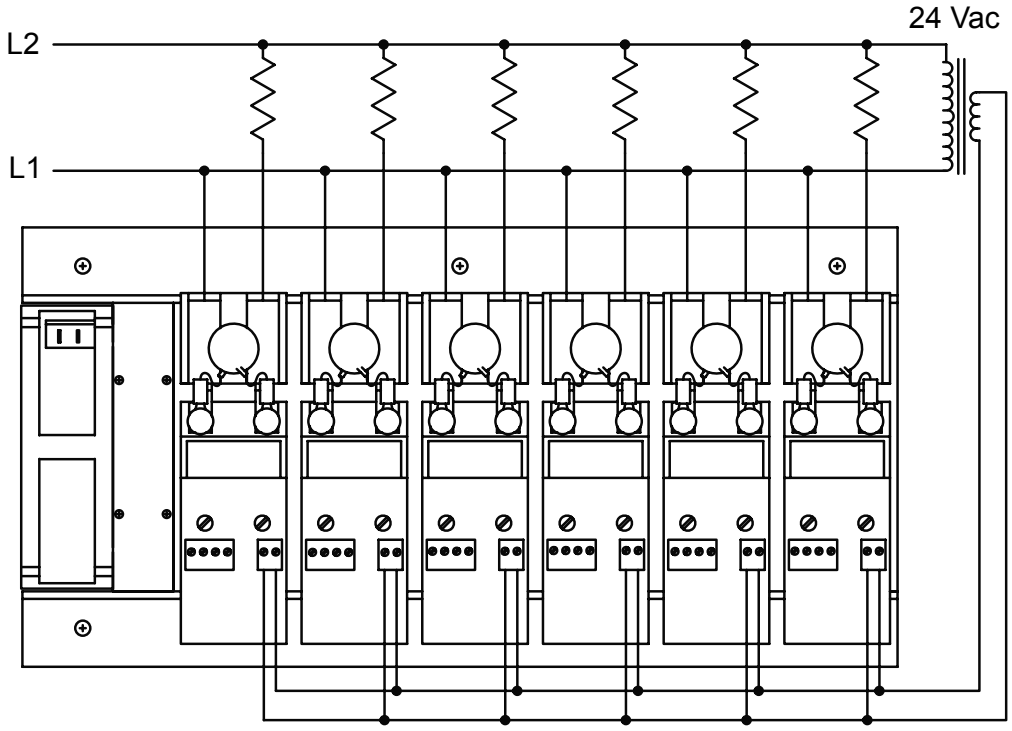


Figure 10. Single Phase electrical connection.
Zero-Cross or Phase-Angle.

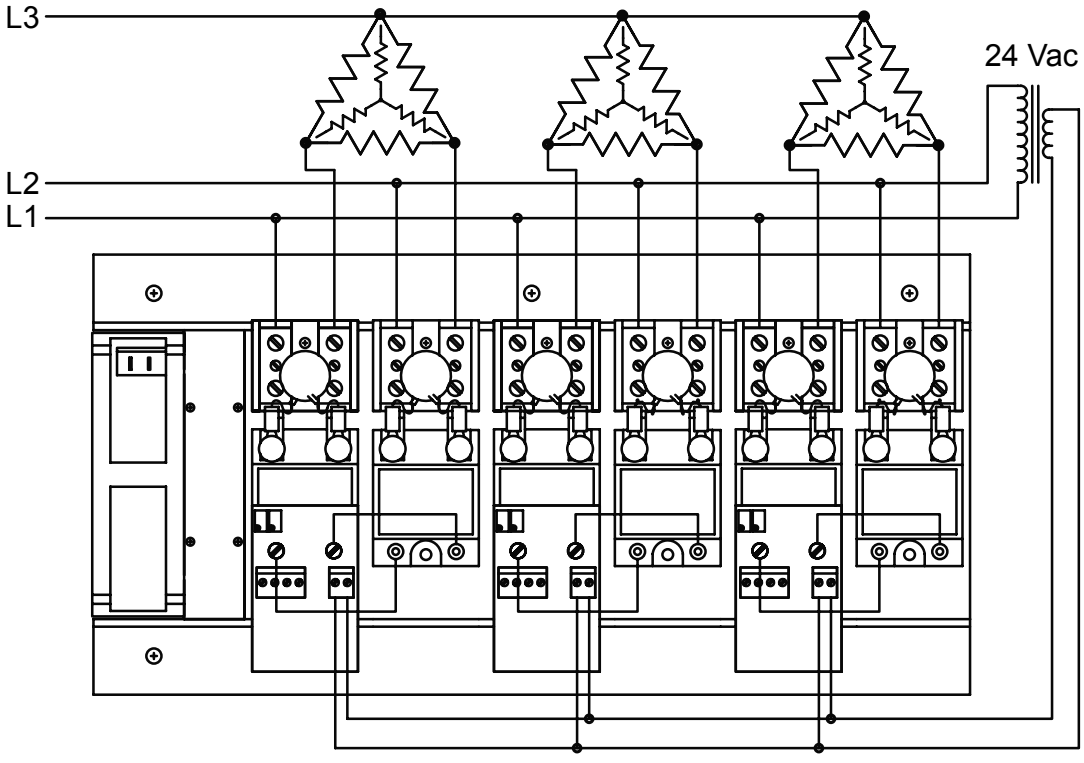


Figure 11. 2-Leg DELTA/wye electrical connections.
Zero-Cross only.

ELECTRICAL CONNECTIONS (Continued)

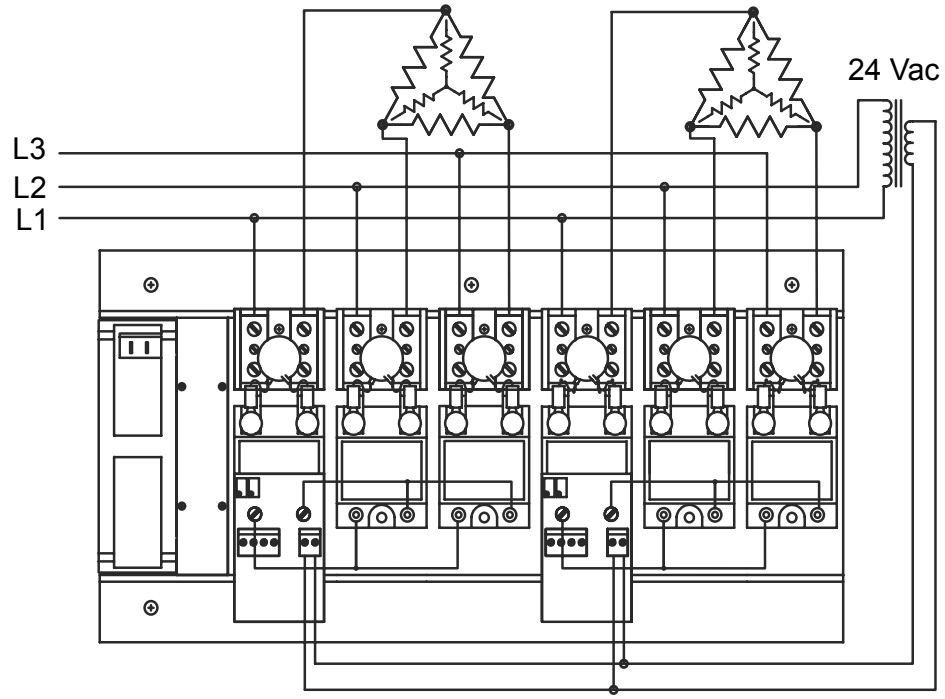


Figure 12. 3-Leg DELTA/wye electrical connections.
Zero-Cross only.

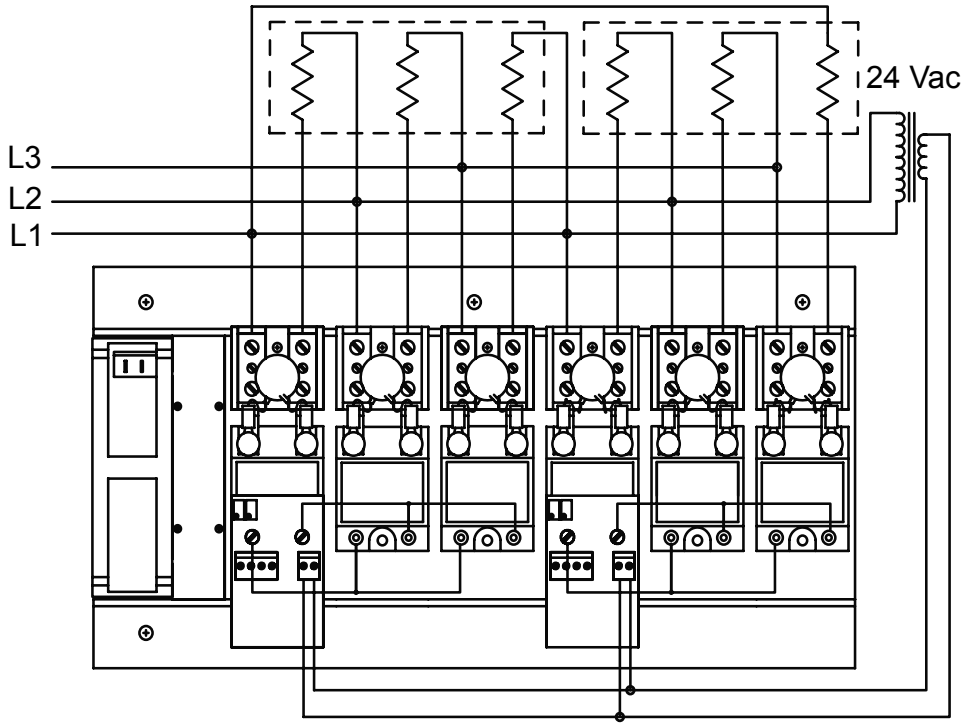


Figure 13. Inside delta electrical connection.
Zero-Cross only.

ELECTRICAL CONNECTIONS (Continued)

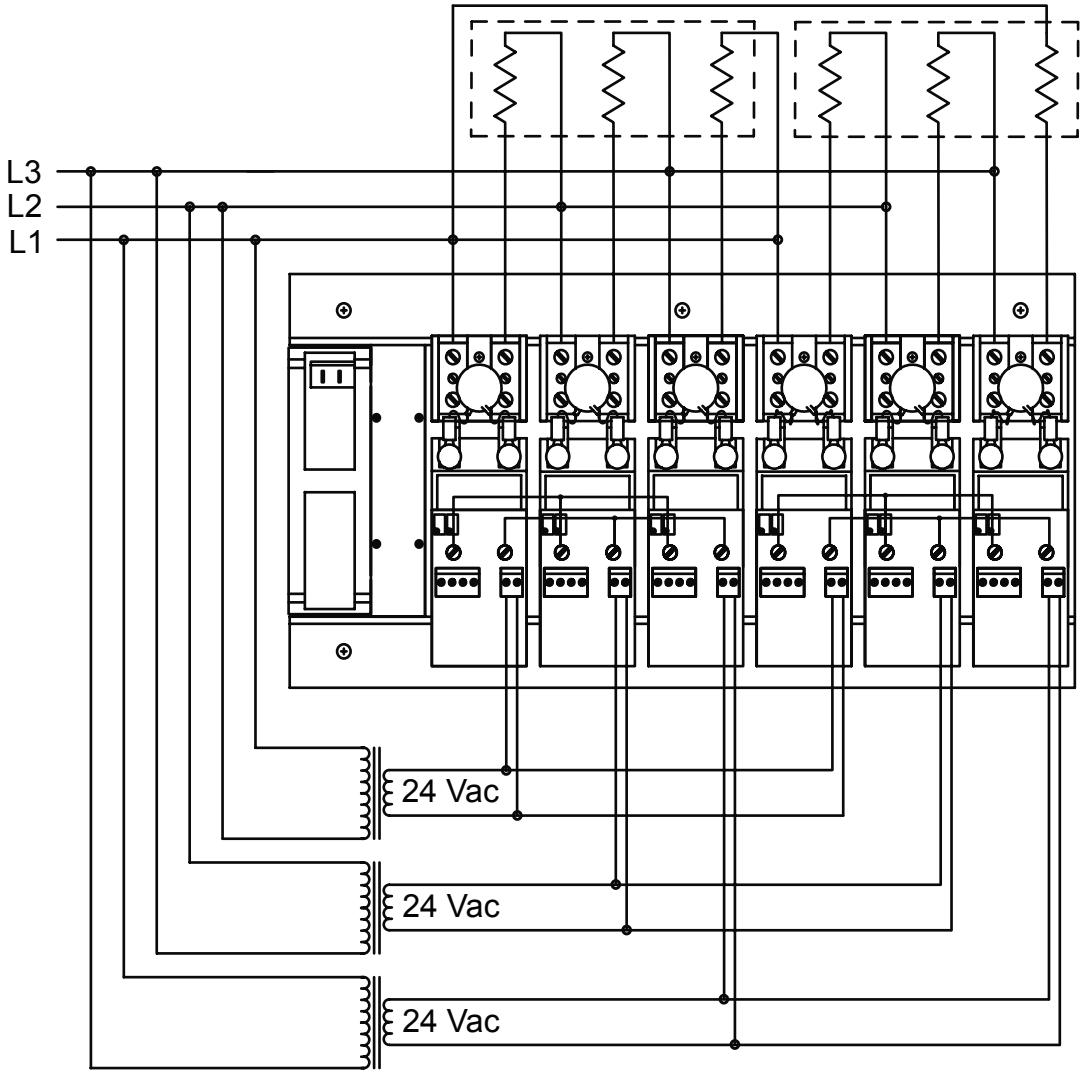


Figure 14. Inside delta electrical connection.
Phase-Angle only.

REPLACEMENT PARTS

Spare parts are available with same day shipment from Control Concepts. If it is desired to maintain spare parts, it is recommended that one SCR module and one circuit be maintained as a spare for each type used.

SPARE FIRING CIRCUITS

If you wish to order replacement or spare circuits, use the 10XX-FC number where 'XX' specifies the type of circuit as described in the model number identification.

NOTE: On 2-leg or 3-leg controllers where two or three SCR modules are controlled by the same firing circuit, the circuit card will be located on the SCR module closest to the fan end of the controller .

SUGGESTED FUSES		
FUSES FOR 120/208/240 VOLT RESISTIVE LOADS		
Controller Current Rating	Bussmann Part Number	Control Concepts Part Number
10	JJN-15	42110-0430-315
20	JJN-25	42110-0430-325
30	JJN-35	42110-0430-335
40	JJN-50	42110-0430-350
70	JJN-90	42110-0430-390
FUSES FOR 480 VOLT RESISTIVE LOADS		
Controller Current Rating	Bussmann Part Number	Control Concepts Part Number
10	JJS-15	42110-0460-315
20	JJS-25	42110-0460-325
30	JJS-35	42110-0460-335
40	JJS-50	42110-0460-350
70	JJS-90	42110-0460-390
FUSES FOR 120/208/240/480 VOLT WITH TRANSFORMER COUPLED LOADS		
Controller Current Rating	Bussmann Part Number	Control Concepts Part Number
30	FWH-35	42220-0450-335
40	FWH-50	42220-0450-350
70	FWH-90	42220-0450-370

MODEL No. IDENTIFICATION

The characteristics of a `6·Pak' are identified by a model number specifying the main frame, followed by a model number for each of the SCR modules, then followed by a model number for each of the circuits used. The location of each of the SCR controllers is identified in order by position, with the first being closest to the fan.

1600-PM6-01/(Q1)165(X)-(VV)-(AA)-USD/(Q2)(XXXX)-FC-(CS)

1600-PM6-01 This identifies the frame. This may be followed by **TS87C.** Which specifies an 87°C thermostatic switch with N.O. contacts, and/or may be followed by **240FAN.** Which indicates that a 240Vac fan has been substituted for the 120Vac fan.

/(Q1) Specifies the quantity of SCR modules
165(X)-(VV)-(AA)-USD

(X) Specifies operating mode
165**1** specifies Zero-Cross operation (3-32Vdc)
165**1A** specifies Zero-Cross operation with 90Vac to 280Vac control.
165**2** specifies Phase-Angle operation

(VV) Specifies Operating (supply) Voltage
12 = 120 Vac
24 = 240 Vac
48 = 480 Vac
57 = 575 Vac

(AA) Specifies controller current
10, 20, 30, 40, 50, 60 or **70** Amps

USD Specifies a box lug terminal block

/(Q2) = Specifies the quantity of firing circuits

(XXXX) Specifies type of control circuits
ZERO-CROSS: **1020**, **1021A**, **& 1021B**
PHASE-ANGLE: **1022**, & **1025**.

(CS) Specifies the command signal

Available Command Signals*	
Model Number	Command
1020, 1025	4/20 mA
1021A, 1021B, 1022	0/5 V, 0/10 V, POT

*Consult factory for more options.

TROUBLESHOOTING

CAUTION: High voltage exists on the line and load terminals of the controllers.
Use extreme caution to avoid electrical shock.

General Comments:
The LED on the circuit board is a valuable troubleshooting aid. On zero-cross controllers it is "ON" when power is applied to the load (SCR module ON). On phase-angle controllers the intensity of the led increases as the magnitude of the command signal increases. The LED can be used to determine that a command signal is applied, if the circuit card is working and that the SCR module should be on.

Common Installation Errors:
Transformer: The primary of the 24 volt transformer may be *incorrectly* connected across either the SCR module, or the load. It should get it's power from the AC supply to which the SCR module and load are connected.

If connected across the SCR module, the controller will "kind of" work. The controller will be unable to reach full power. On zero-cross controllers, the cycle rate will be very slow. On phase-angle controllers the LED intensity will not be constant. If connected across the load, no power is applied to the circuit and the LED will not light.

Potentiometer: The connections to the clockwise, counterclockwise and wiper connections may be *incorrectly* connected to the CW, CCW and W terminals on the circuit. The circuit provides 10Vdc between CW and CCW and if the potentiometer is connected wrong, this voltage may change as the potentiometer is rotated.

NO LOAD POWER

LED "ON"
1. Check fuses.
2. Check electrical continuity.
3. Measure DC voltage across the 2 screws used to mount the circuit to the SCR module. If greater than 3.5 volts, SCR module may have failed. If less than 3.5 volts, the circuit may have failed.

LED "OFF"
1. Check to see the control signal exists and can be varied.
2. Determine that 24 Vdc is applied to the circuits requiring transformer power.
3. On controllers with potentiometer input determine that 10 Vdc exists between the terminals labeled CCW and CW and that the potentiometer wiper is connected to W on the circuit. Also, determine that the voltage from CCW to W can be varied from 0 to 10Vdc as the potentiometer is rotated Clockwise.

LOAD POWER TOO HIGH

LED "ON"
1. Determine that the control signal can be adjusted to zero or minimum value. The control signal input connector can be separated to remove the control signal.
2. On controllers with inputs for potentiometer control, determine that 10Vdc exists between the terminals labeled CCW and CW and that the potentiometer wiper is connected to W on the circuit and that the voltage between CCW and W does vary as the potentiometer is rotated.
3. In 2-leg, three phase control, failure of one SCR module will cause one phase of the load to have full voltage, and the other 2 phases to have 50% voltage.

LED "OFF"
1. SCR module has probably failed in the shorted mode. Remove all power connections and measure across the line load connections with an ohm meter. If resistance is less than 1K the module has failed.
2. It is possible that one of the two SCRs within the module will fail in a manner allowing it to turn on when power is applied resulting in approximately 50% voltage being applied to the load.

REFERENCE MATERIAL

Schematic(s) as required:

Model 1020	-	1000163C
Model 1021A	-	1000359B2
Model 1022	-	1000466_2
Model 1023	-	1000295A2
Model 1025	-	1000324_4
Model 1026	-	1000303C

Instruction manual(s) as required:
Model 1020, 1021A, 1022-1025, 1023, 1026

MANUFACTURED BY

CONTROL CONCEPTS

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