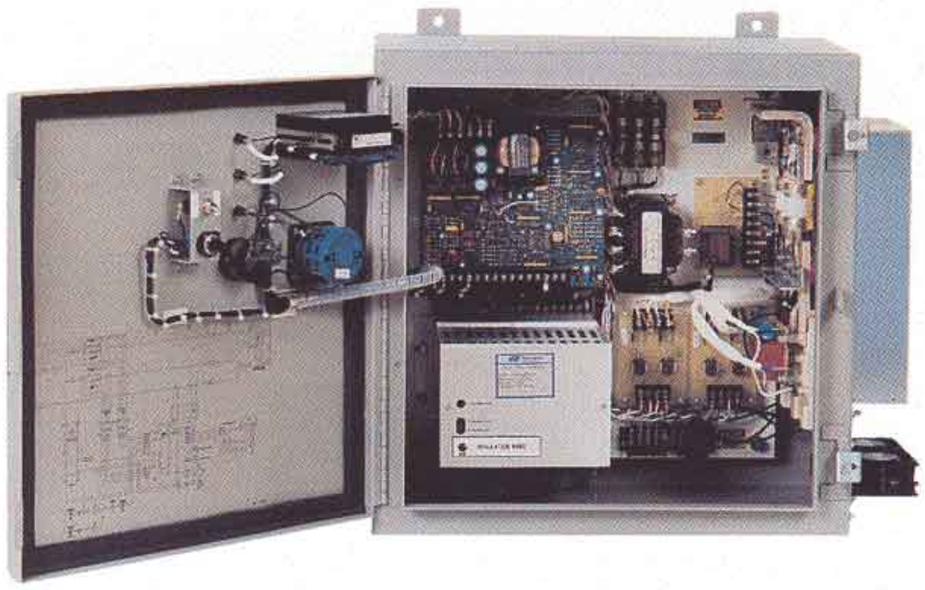
POWER CONTROL PRODUCTS

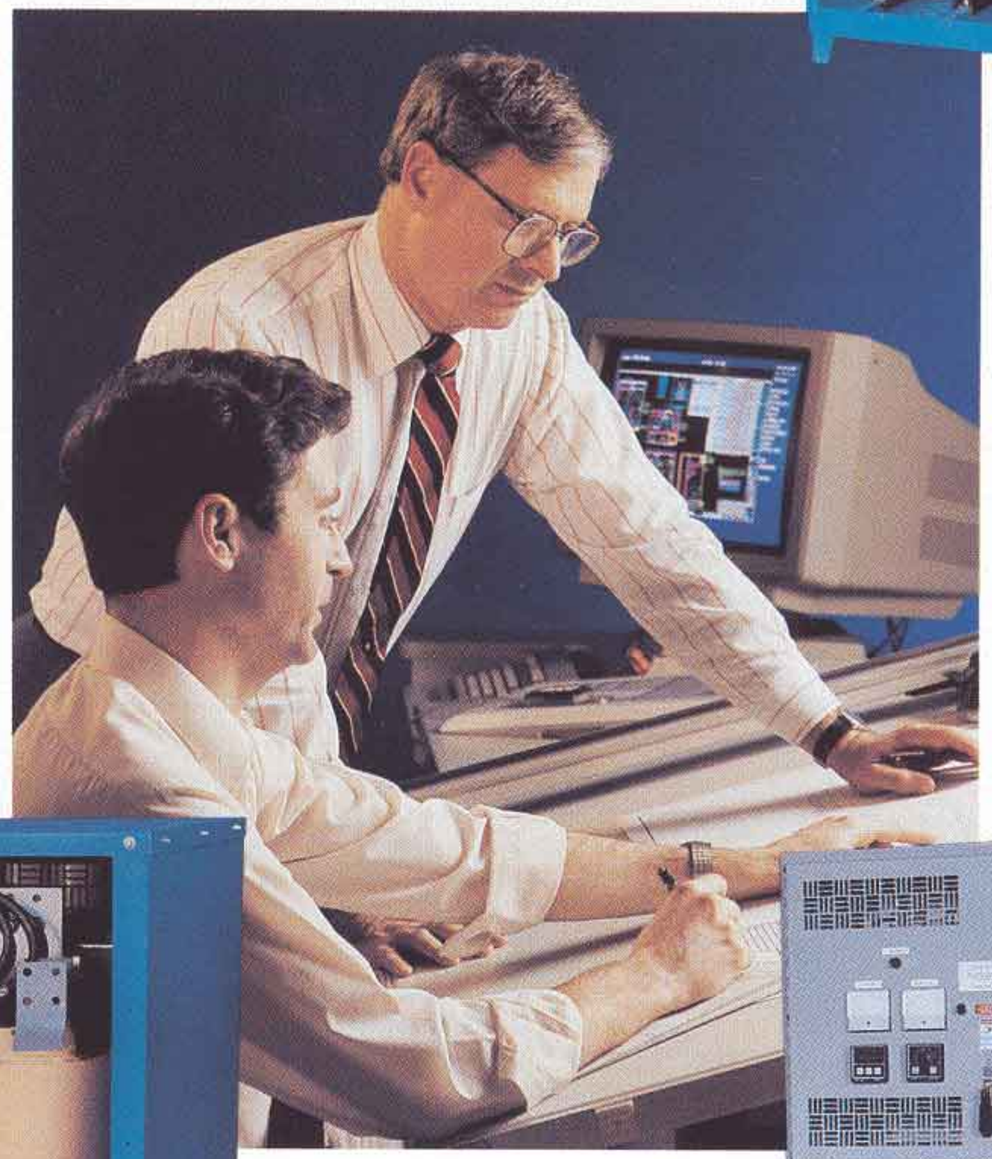
FOR INDUSTRIAL HEATING

Spang Power Electronics



NEMA 12 SCR Power Control Panel

12 Pulse Plasma Arc
Power Supply



150 KVA Multi-tapped
Silicon Carbide Transformer

2 Zone Silicon Carbide
Power Supply

Multi-Zone SCR Power Center

Spang Power Electronics

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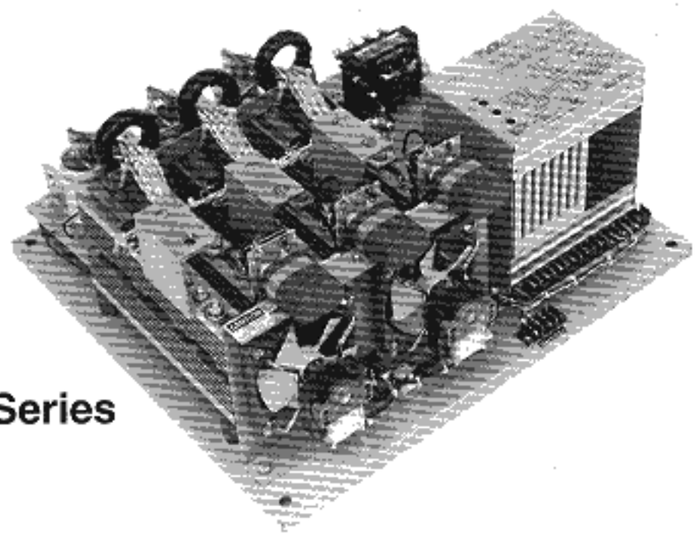
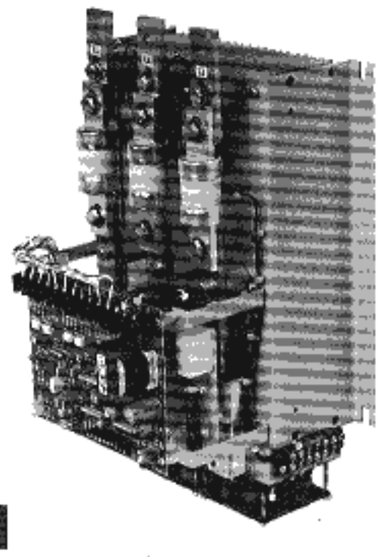
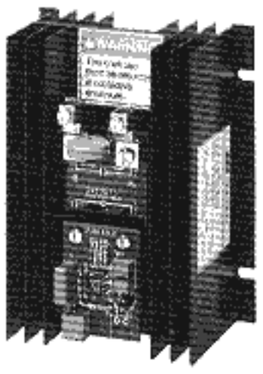
SCR POWER CONTROL UNITS



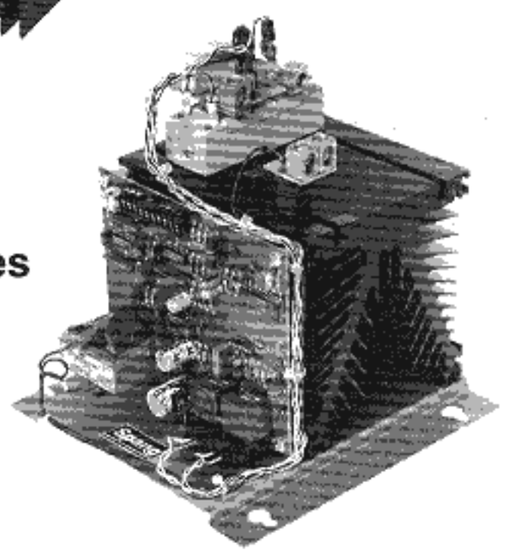
B-Series



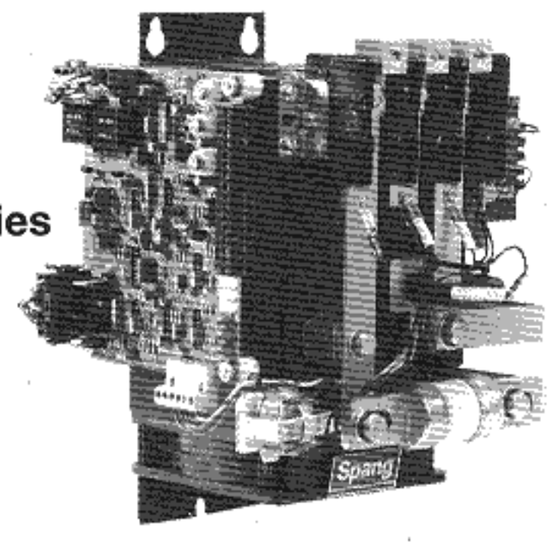
C-Series



550-Series



650-Series



750-Series

SPANG SCR Power Control Units incorporate the latest advances in semiconductors, cooling methods and solid-state firing circuitry for control of power from 1 kw to the megawatt range. Convection ratings to 50 kva, forced air-cooled to 1,200 kva, and water-cooled through 2,000 kva are available.

Options: Include watt regulation, current limit, overcurrent shutdown, and special enclosures.

• Single phase and three phase SCR Power Control Units with Phase Angle Control are used primarily to control dynamic resistive or transformer-coupled loads. They have exceptional stability, reliability and versatility.

• Single phase and three phase SCR Power Control Units using Synchronous (Zero Crossover) Control are used primarily to control static loads such as resistive heating elements which are not affected by age or drastic change in resistance versus temperature.

• Series 650 Thyristor Power Control Units are compact, economical styles for proportional control of single phase AC or DC power to 50kw. They are specially designed for industrial heating applications.

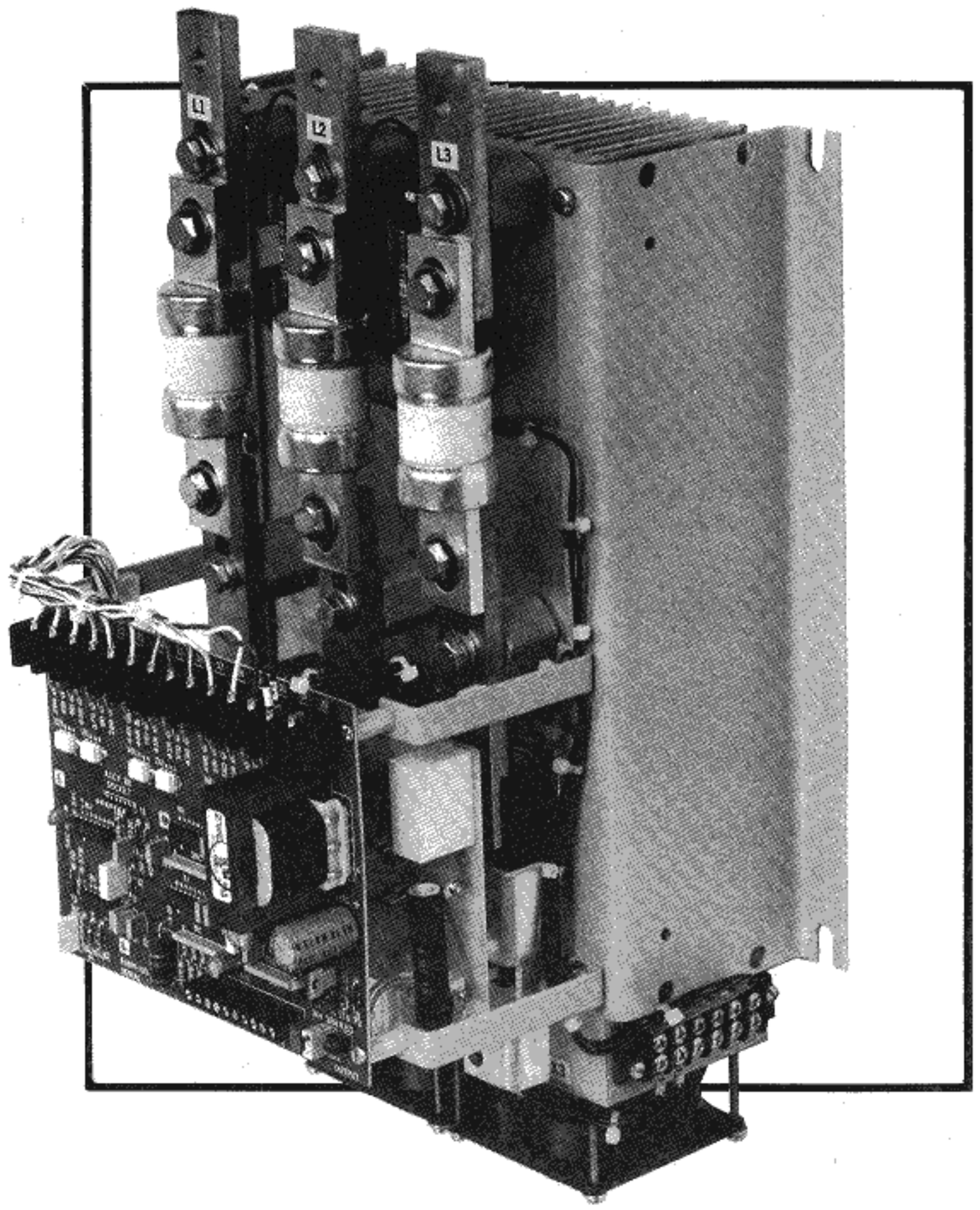
SELECTION GUIDE[1]

Element Type	Resistance Characteristics	Recommended Equipment[2]
Iron-Chromium Aluminum Alloy	5% increase from cold to hot	Phase angle or synchronous (zero crossover) SCR Power Control unit[3]
80 - 20 Nickel Chromium	6% increase from cold to hot	As above except with current limit or over-sized for cold resistance
35 - 20 Nickel Chromium	24% increase from cold to hot	
Silicon Carbide	Decreases to 80% of rated at 1200°F then increases to rated at 2000°F. Resistance can increase up to 4 X over useful lifetime.	6 SCR Phase Angle Power Control Unit with transformer inrush protection and current limit needing multi-tapped transformer.
Molybdenum	20 X increase from cold to hot	6 SCR Phase Angle Power Control Unit with transformer inrush protection and current line leading transformer
Molybdenum Disilicide		
Graphite	20 X increase from cold to hot	
Tungsten	20 X increase from cold to hot	
Quartz		
a. Tungsten	See above listing for Tungsten	See above listing for Tungsten
b. Nichrome	See above listing for Nichrome	See above listing for Nichrome
Infra-Red		
a. Tungsten	See above listing for Tungsten	See above listing for Tungsten
b. Nichrome	See above listing for Nichrome	See above listing for Nichrome

NOTES: 1. For computer information on SCR power controller selection see pages 63-70.
2. Primary overcurrent and disconnect devices, such as fused disconnect switch or a circuit breaker, should be used in all applications.
3. A transformer may be required if the element is working below line voltage.

Spang Power Electronics

THREE PHASE Zero Crossover and Phase Angle Control SCR POWER CONTROLLERS C-SERIES



The C-Series SCR Power Controllers are available either with phase angle or zero crossover firing control of the SCRs. Phase angle controllers are normally applied to control dynamic resistive or transformer-coupled heating element loads.

Zero crossover fired power controllers are primarily used to control static loads, such as resistive heating elements, which are not affected by age or drastic change in resistance versus temperature.

STANDARD FEATURES

- 40% smaller than conventional designs
- Electrically isolated heatsinks
- Easy mounting - Easy service access
- Quick-change I^2T fusing system
- Completely self-contained - No separate control voltage required for standard voltages
- Accepts all standard control signals
- Silver plated all copper bus bar
- Gate signal lockout
- Standard ratings designed for 50° C maximum ambient
- Immunity to line distortion
- Stepless control for proportional electric power

Introduction

The C-Series - a new generation of Spang SCR Power Controllers answers the demand for a smaller, lighter, more cost-efficient unit capable of delivering peak performance under tough industrial conditions.

The C-Series combines large scale integration (LSI) and power semiconductor technology with computer-optimized heat sink design and packaging techniques. This combination reduces size and weight without sacrificing the dependability that is traditional for Spang Power Electronics products.

SCR triggering is precise. The CMOS and digital logic circuits built into the firing control are unaffected by power line distortions such as harmonics, sags, and surges.

General Description - Phase Angle Control

The C-Series Phase Angle Control uses a six (6) SCR configuration composed of two (2) SCRs, connected inverse parallel in each line to the load (Figure 1). Three phase loads may be either Delta or Wye connected.

In Phase Angle Control, the SCR is gated every cycle. Power control is accomplished by delaying SCR gating until some time after the voltage crosses zero. By varying this delay, the time the SCR is allowed to conduct is varied, as is the output.

Advantages

- Conventional voltmeters and ammeters can be used for instrumentation over 0 to 100% voltage range.
- Infinitely variable output.
- Operation into dynamic loads (i.e., transformers).

Specifications for Phase Angle Control

Input Voltage: Ratings are provided for 120, 240, and 480 volt three phase. Other input voltages are available with the addition of an optional transformer. Consult factory.

Input Frequency: All units operate on 50 hertz or 60 hertz.

Ambient: All ratings are designed for 50° C maximum operating temperature. For operation at higher temperature (to 65° C maximum) some derating is necessary. Please consult factory.

Input Signals: Accepts all standard control signals and a manual potentiometer. See control connections chart.

Adjustments: High resolution 20 turn potentiometers are provided for all adjustments.

A. Gain adjustments provide full output for 50% to 200% standard control signal.
B. Bias adjustments for manual control 100% output.

Voltage Protection: Transient voltage suppression is provided by an R-C Snubber Network and Metal Oxide Varistors (MOVs), which clamp high voltage spikes to within the PRV rating of the semiconductors (1200 PRV).

Reference Supply: A 12 volt DC regulated reference supply is available from the firing circuit for connection to a remote potentiometer, from which the power controller can be operated manually. This supply is regulated to within ±½% for line voltage variations. Maximum current rating from this reference source is 10 milliamperes.

Cooling: The 40 amp current size is convection cooled. Larger sizes are forced-air cooled by integral cooling fans. Bimetallic temperature switches are supplied on all forced-air cooled units with one Normally Open (NO) contact wired to the terminal block. As an alternative, Normally Closed (NC) are available on request.

Soft Start: An integral soft start ramp is provided on all C-Series Phase Angle fired units. Upon initial energization, gate firing is inhibited for a short time to all units for circuit stabilization. After this time, the SCR is ramped in response to the input control signal. The Transformer Inrush Protection (TIP) feature allows smooth, reliable control into the primary of a transformer, eliminating nuisance fuse blowing due to high inrush currents which can occur if power is applied too rapidly to a transformer.

Options Available

1. Current Limit — Senses the RMS current and limits output. Current limit adjustment is from 5% to over 100% of rating by a potentiometer on the firing circuit.

2. Voltage Regulation — Adds RMS voltage feedback to the standard model. Voltage regulation is ± 1% for line voltage excursions of + 10%, -15% of nominal. This option also improves control linearity to ± 1% from 0 to 100% output.

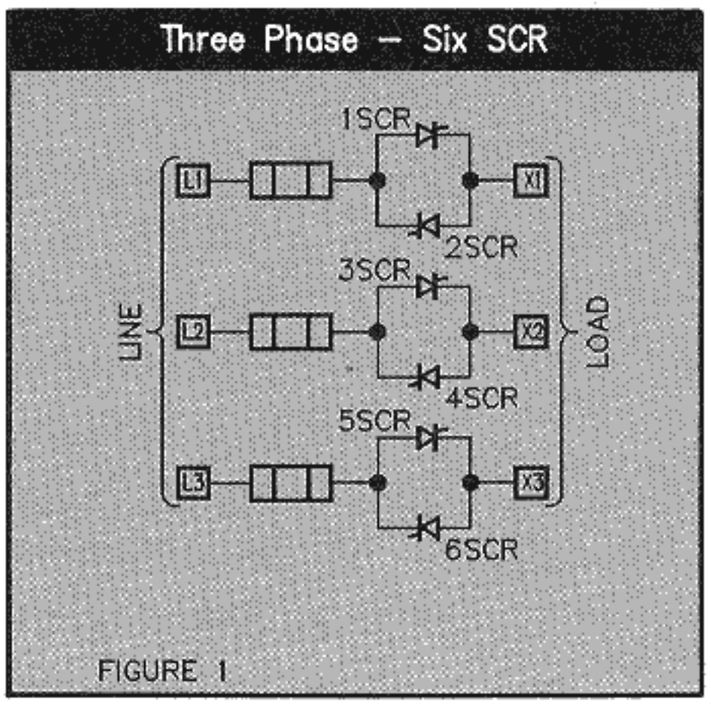
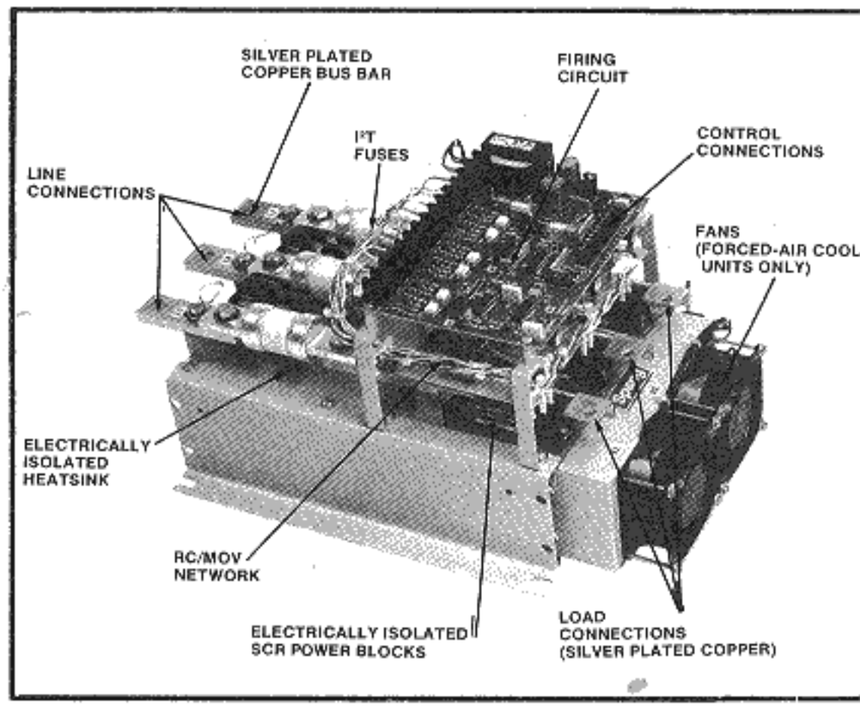


FIGURE 1



General Description Zero Crossover Control

The C-Series Zero Crossover Fired SCR Power Controller is available in two configurations: three-leg six (6) SCR and two-leg four (4) SCR. Two-leg control uses two SCRs connected inverse parallel in two of the three lines to the load (Figure 2 & 3). The six SCR three-leg uses two SCRs connected inverse parallel in each line of the load (Figure 4). Two-leg uses fewer power components and is more economical. Three phase loads may be either Delta or Wye connected. If control is required to a four wire grounded neutral Wye load, the six SCR configuration is required.

In zero crossover control, the SCRs are always gated at the moment the sine wave crosses zero and the anode is driven positive. Complete cycles of power are delivered at a time. Power control is achieved by having the SCRs ON for some cycles and OFF others. The ratio of the number of cycles ON to the number of cycles OFF is varied to proportion the power delivered to the load.

Advantages

- Conventional voltmeters and ammeters can be used for instrumentation at 50% to 100% voltage range.
- Infinitely variable output.
- Elimination of RFI.
- Power is evenly distributed over time.
- Variable ratio cycling rate provides the smoothest power distribution over time.

Specifications for Zero Crossover Control

Input Voltage: Ratings are provided for 120, 240, and 480 volt three phase. Other input voltages are available with the addition of an optional transformer. Consult factory.

Input Frequency: All units operate on 50 hertz or 60 hertz.

Ambient: All ratings are designed for 50° C maximum operating temperature. For operation at higher temperatures (to 65° C maximum), some derating is necessary. Please consult factory.

Input Signals: Accepts all standard control signals and a manual potentiometer. See control connections chart.

Adjustments: High resolution, 20 turn potentiometers are provided for all adjustments.

A. Gain adjustments provide full output for 50% to 200% standard control signal.
B. Bias adjustment for manual control to 100% output.

Voltage Protection: Transient voltage suppression is provided by an R-C snubber network and metal oxide varistor which clamps high voltage spikes to within the PRV rating of the semiconductors (1200 PRV).

Reference Supply: A 12 volt DC regulated reference supply is available from the firing circuit for connection to a remote potentiometer, from which the power controller can be operated manually. This supply is regulated to within ± ½% for line voltage variations. Maximum current rating from this reference source is 10 milliamperes.

Cooling: Current sizes 40 and 60 amperes two-leg and 40 amperes six SCR three-leg are convection cooled. Larger current sizes are forced-air cooled by integral cooling fans. Bimetallic temperature switches are supplied on all forced-air cooled units with one Normally Open (NO) contact wired to the terminal block. As an alternative, Normally Closed (NC) are available on request.

Options Available

1. Current Limit — Senses the RMS current and limits output. Current limit adjustment is from 5% to over 100% of rating by a potentiometer on the firing circuit.

2. Voltage Regulation — Adds RMS voltage feedback to the standard model. Voltage regulation is ± 1% for line voltage excursions of + 10%, -15% of nominal. This option also improves control linearity to ± 1% from 0 to 100% output.

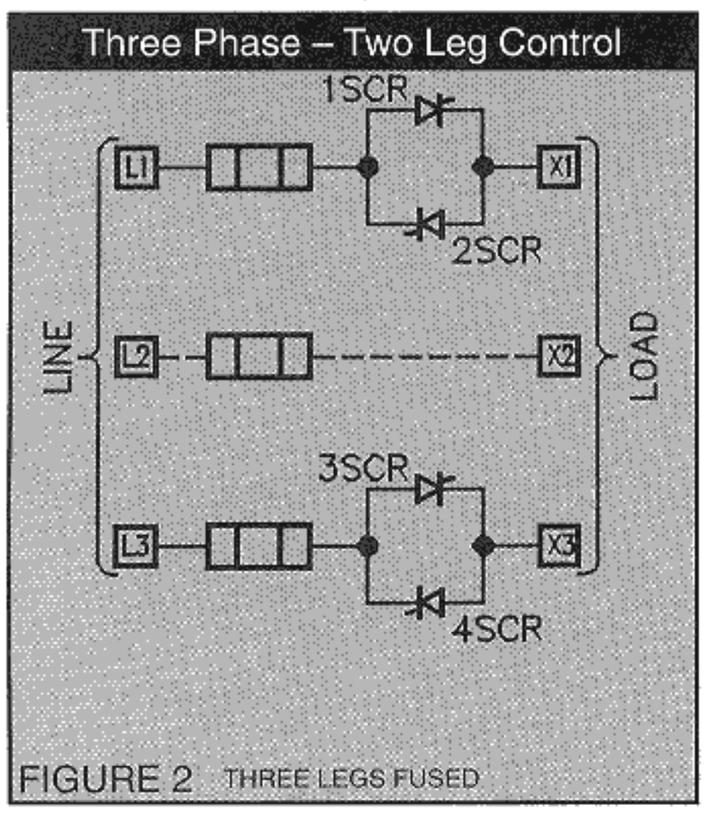


FIGURE 2 THREE LEGS FUSED

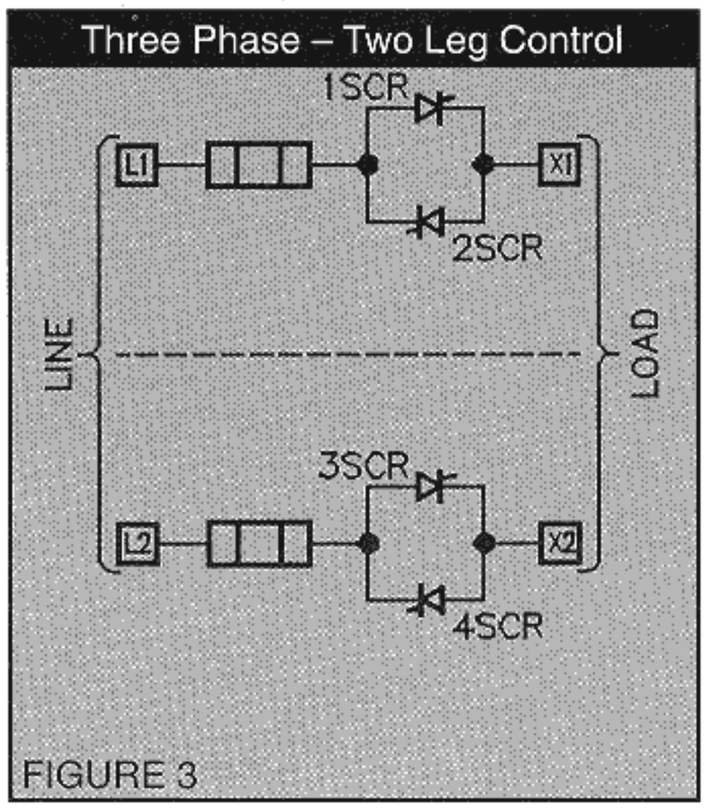


FIGURE 3

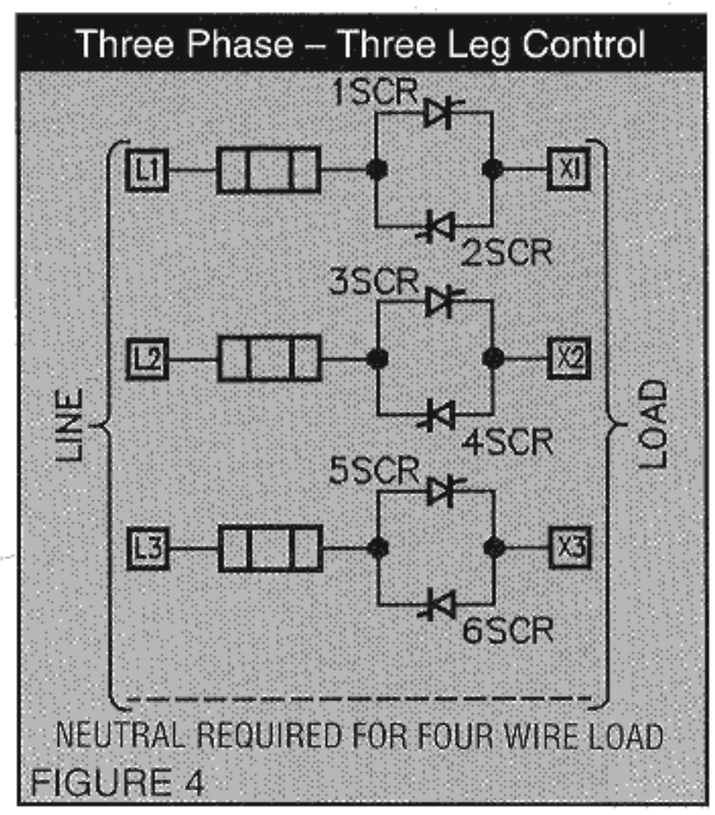


FIGURE 4

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Ordering Information

PART NUMBER CODE

M - Zero Crossover Firing (2-Leg Control, 3-Legs Fused)
N - Zero Crossover Firing (6 SCR 3-Leg 3 Wire Wye or Delta Load)
L - Zero Crossover Firing (2-Leg Control, 2-Legs Fused)
J - Zero Crossover Firing (6 SCR 3-Leg 4 Wire Wye Load)
F - Phase Angie Firing (6 SCR)

E: 120V Line
C: 208V Line
D: 240V Line
J: 277V Line
F: 380V Line
G: 480V Line
H: 575V Line

5: Enclosed Chassis
6: NEMA 12 Enclosure
8: Bezel Mount for NEMA 12 Mounting

0: Basic Unit
1: N.O. Temp Switch*
2: N.C. Temp. Switch*

Size Code

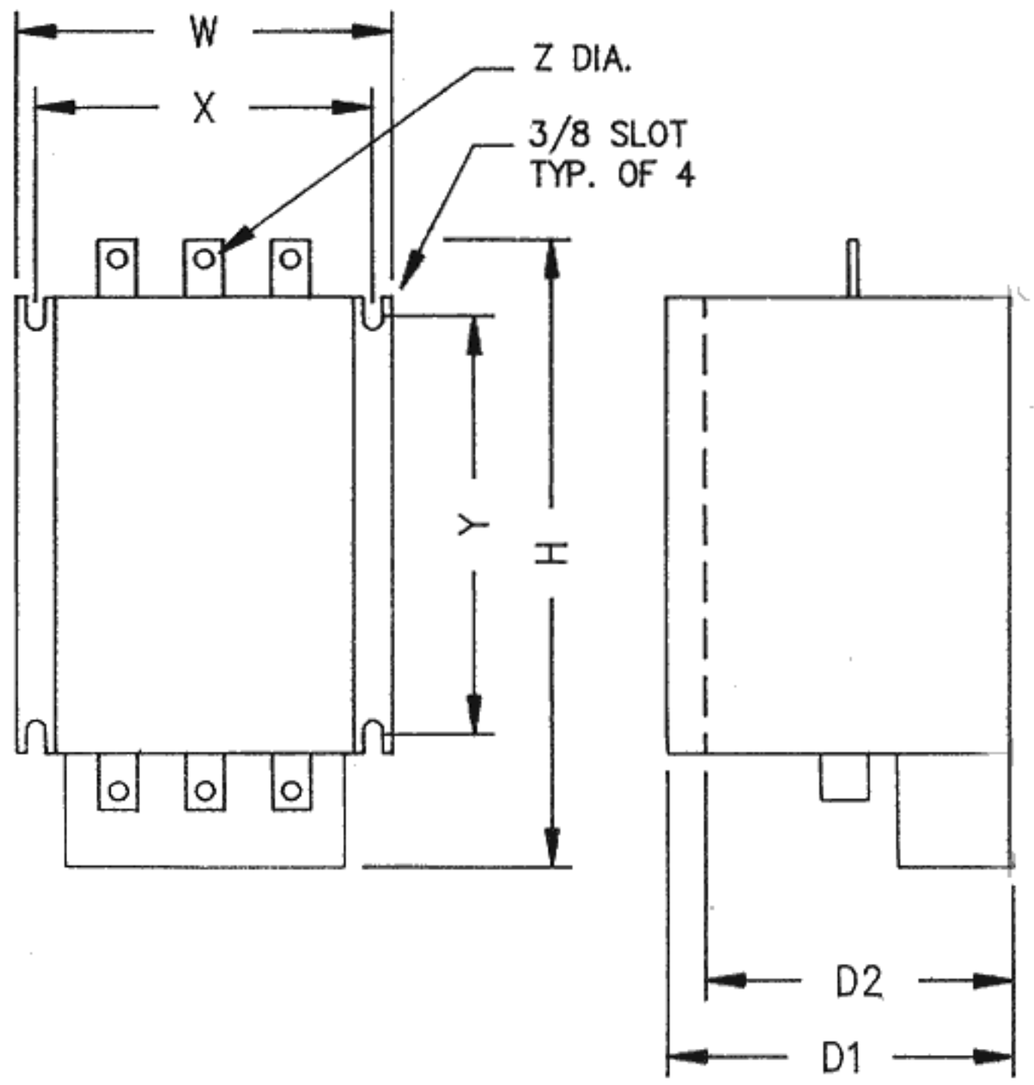
C _ _ - - _ **O**

6: 50 Hz
7: 60 Hz

A: Basic Unit (No Options)
B: Current Limit

2: Basic Unit
8: Voltage Regulation

A: Phase Angle
O: Zero Crossover



Line and Load Lugs Not Included – Order Below

* Forced-air cooled units only not applicable to convection cooled units.

Ratings and Chassis Dimensions

Size Code	Current Rating AC Amps	KVA Rating 120V	240V	480V	H	W	D1	D2	X	Y	Z
400	40	8.3	16.6	33.3	14 3/8	9 7/8	9 1/8	8 7/8	9	11 1/8	5/16
* 600	60	12.5	25.0	50.0	16 3/8	9 7/8	9 1/8	8 7/8	9	11 1/8	5/16
101	100	20.8	41.5	83.1	16 3/8	9 7/8	9 1/8	8 7/8	9	11 1/8	5/16
151	150	31	62	125	16 3/8	9 7/8	9 1/8	8 7/8	9	11 1/8	5/16
251	250	52	104	208	21	12 7/8	10 1/4	10	12	13 1/4	9/16
351	350	73	145	290	21	12 7/8	10 1/4	10	12	13 1/4	9/16

* LC Series 60 Amp – 14 3/8" H

Size	H	W	D
400 thru 151	26	18	14
251 thru 351	32	18	14

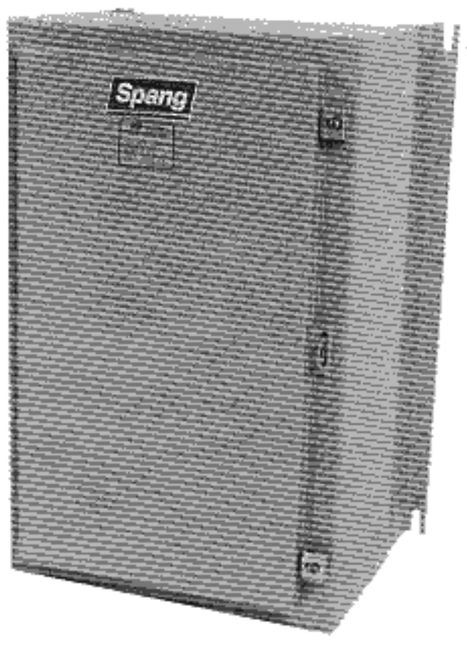
Control Connections

Control Signal	Input Control Terminal Points	Input Impedance
0–5ma 2–12ma 4–20ma 10–50ma 0–10v	1(+)-5(–) 2(+)-5(–) 3(+)-5(–) 4(+)-5(–) 7(+)-5(–)	1000 ohms 400 ohms 250 ohms 100 ohms 200K ohms
Contact Closure	8 and 7	Close Contact to turn PCU on
Manual Control Ends of Pot Slider of Pot	6 and 8 7	Connect a 10K ohm 2 Watt Potentiometer
Lockout (External shutdown contact	6 and 10	Close Contact to turn PCU off

Line and Load Lugs

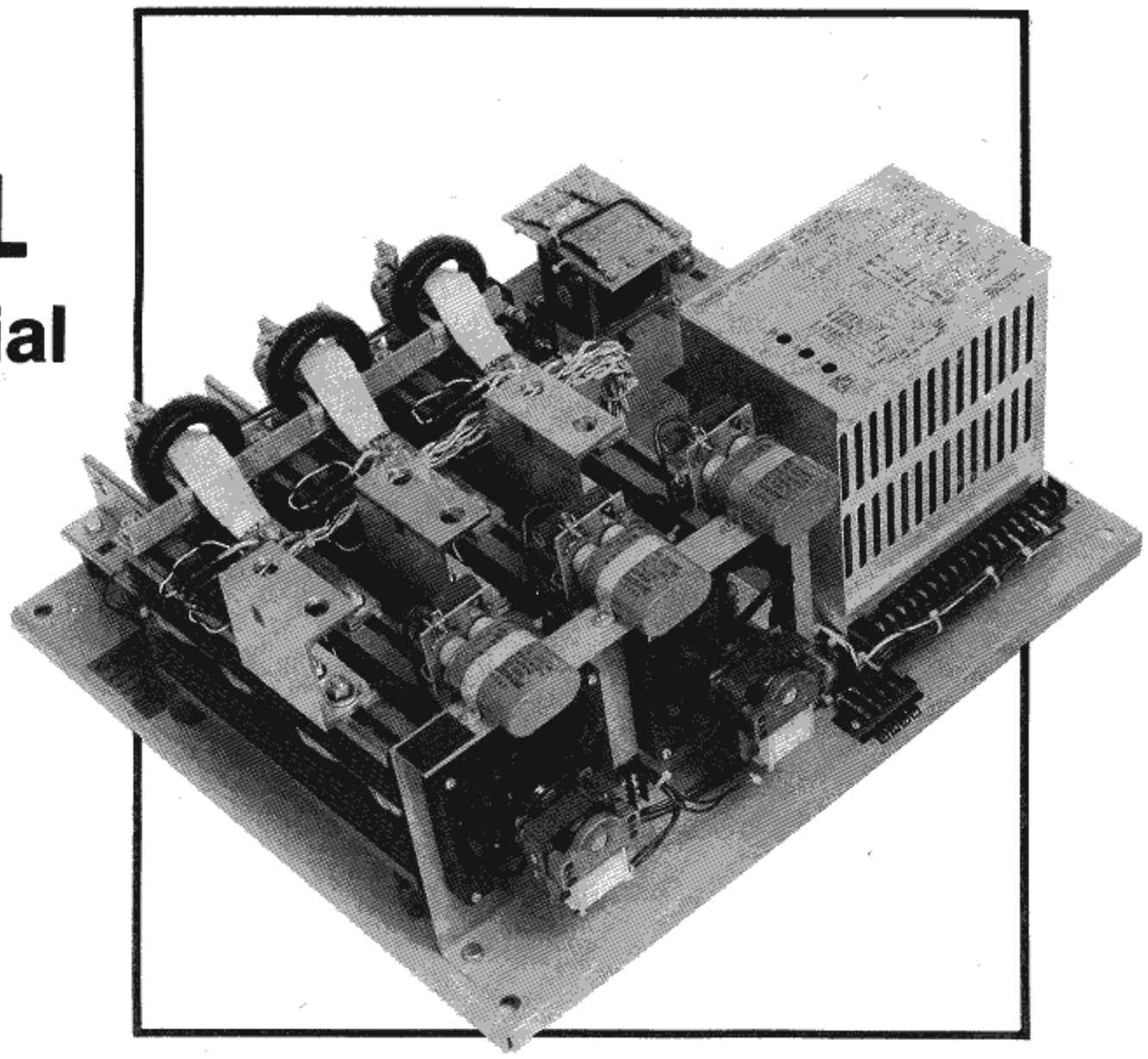
Size Code	Current Rating AC Amps	Wire Size	Catalog Number
400	40	#1/0–14 AWG	TERMKIT – 3 PH100A
600	60	#1/0–14 AWG	TERMKIT – 3 PH100A
101	100	#1/0–14 AWG	TERMKIT – 3 PH100A
151	150	250 MCM – 6 AWG	TERMKIT – 3 PH200A
251	250	350 MCM – 6 AWG	TERMKIT – 3 PH350
351	350	350 MCM – 6 AWG	TERMKIT – 3 PH350

**NEMA 12 enclosures are available. For the above current sizes, dimensions (inches) are as follows:



Spang Power Electronics

Phase Angle Control THREE PHASE SCR POWER CONTROL UNITS - for Industrial Control Applications B-SERIES



SPANG Power Control Units for three phase applications are available either with phase angle control or with synchronous firing control of SCRs. Synchronous firing PCUs are normally applied to control static loads, such as resistive heating elements (nichrome), which are not affected by age or drastic change in resistance versus temperature.

This bulletin describes phase angle PCUs used primarily to control dynamic resistive, or transformer-coupled loads.

STANDARD FEATURES

- Electronic design with active integrated circuit networks
- LED indication of proper phase rotation
- Phase lock loop for firing pulse synchronization
- Firing modules consisting of plug-in printed circuit cards
- Six SCR full converter or three SCR semi-converter configurations
- Standard ratings designed for 50° C maximum ambient
- Stepless control for proportional electric power
- Immunity to line distortions and fluctuations

General Description

The phase angle firing circuit used in the SPANG Power Control Units is a new field-proven design incorporating modern electronic hardware for producing electrical pulses to the gates of the SCRs. Built into the devices are CMOS integrated circuits (both analog and digital), operational amplifiers and phase lock loop circuitry, all of which assure that power line distortions (harmonics, sags, surges, etc.) will not affect the firing of the SCRs. These Power Control Units have exceptional stability, reliability, and versatility, plus the availability of options which can be tailored to specific applications. The modular firing circuit package contains three plug-in printed circuit cards with all the electronic circuitry required to perform the control function of any application.

Spang Power Electronics manufactures a three phase, phase angle fired power control unit with six SCR full converter configurations. The full converter uses two (2) SCRs connected inverse parallel in each line to the load (Figure 1).

Advantages of Phase Angle Firing:

- Conventional voltmeters and ammeters can be used for instrumentation over 0 to 100% voltage range.
- Infinitely variable output.
- Operation into dynamic loads (i.e., transformers).

Specifications for Phase Angle Control

Input Voltage: Ratings are provided for 480, 240, and 208 volt, three phase, 60 hertz lines.

Ambient: All ratings are designed for 50°C maximum operating temperature. For operation at higher temperatures (to 65°C maximum), some derating is necessary; please consult factory.

Input Signals: 0-5, 1-5, 2-12, 4-20, 10-50ma inputs or a manual potentiometer (all standard temperature controller outputs). See Control Connections.

Adjustments: a. Gain adjustments provide full output for 50% to 200% standard control signal.

b. Bias adjustment for manual control to 100% output.

Voltage Protection: a. Transient voltage suppression is provided by metal oxide varistors (MOVs) which clamp high voltage spikes to within the PRV rating of the semiconductors.

b. Standard PRV ratings for 480 volt units are 1200 volts for 240 and 208 volt units are 800 volts. Higher PRV ratings are available for specialized applications.

Reference Supply: A 12 volt DC regulated reference supply is available from the firing circuit for connection to a remote potentiometer, from which the Power Control Unit can be controlled manually. This supply is regulated to within ± 1/2% for line voltage variations. Maximum current rating from this reference source is 10 milliamperes.

Cooling: a. Current sizes 15 and 30 amperes are convection cooled.

b. Current sizes from 60 to 1300 amperes are forced-air colled by integral cooling fans. Bimetallic temperature switches are supplied on all forced-air cooled units with one normally open contact wired to a terminal block from each SCR heat sink. As an alternate, normally closed contacts are available on request.

Options Available

1. Current Limit senses RMS current in all three lines (phases) and limits output to the highest of the three. Current limit adjustment is from 5% to over 100% of rating by a potentiometer in the firing circuit.

2. Voltage Regulation adds RMS voltage feedback to the standard model. Voltage regulation is ±1% for line voltage excursions of +10%, −15% of nominal. This option also improves control linearity to ±1% from 0 to 100% output.

3. Current Regulation compensates for both line and load fluctuations and provides a constant RMS current proportional to the control signal. Current regulation is ±1% of set point.

4. Watt Regulation is accomplished by addition of voltage and current feedback into a three phase watt transducer. Output wattage can be regulated to ±1% of set point. Common applications are in control of silicon carbide heating loads.

5. Overcurrent Shutdown is an electronic turn-off of the gate firing pulses within 8.33 milliseconds (1/2 cycle at 60 Hz) by sensing an overcurrent condition and applying the shut-off signal to the firing circuit. For most applications where this is to be used (e.g., protection against short circuits or load faults) external current limiting impedance must be added to insure protection of the power SCRs. Consult the factory for advice on this coordination.

6. NEMA 1 Wall Mounted Enclosures are available for housing the respective Power Control Units. The enclosure features #14 gauge steel construction finished with ASA-61 light gray enamel. Ventilation is provided through expanded metal openings at the bottom and sides of the enclosure. Conduit entrance can be through the top, bottom or lower sides as required. The access door is hinged with a locking handle.

7. Combinations of the above listed options — Refer to page 10 for possible option combinations and corresponding ordering part number.

8. Special Options Custom options such as pilot lights, meters, circuit breaker additions, water cooling, separate firing circuit assembly, and others are available. Please contact the factory for description, pricing, and advice on your custom requirements.

Schematic Drawings of Power Control Units

Three Phase – Six SCR (Full converter)

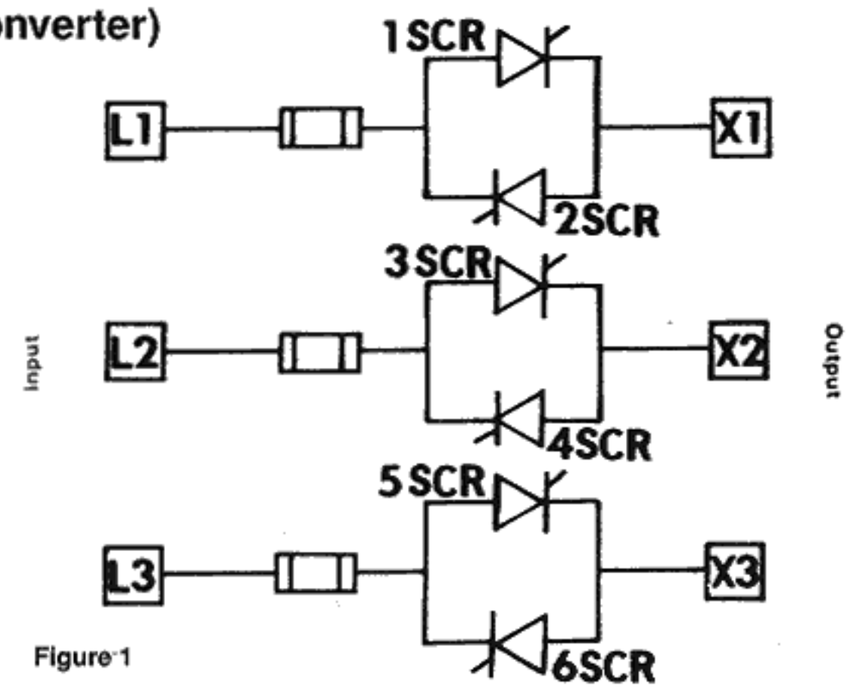


Figure 1

Electrical Features

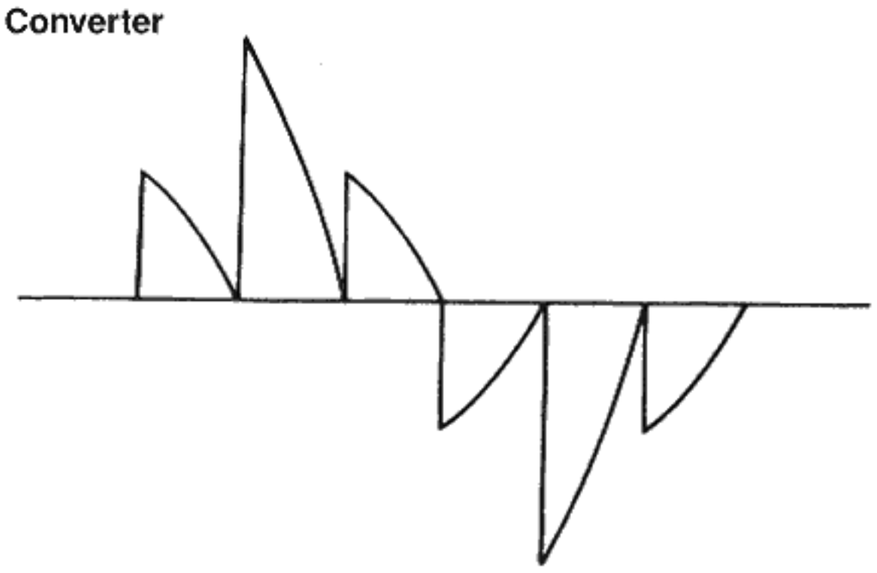
1. Upon initial circuit energization, there is a 4 second dead time for circuit stabilization during which time the SCR gate pulses are inhibited
2. The firing circuit inherently includes a 3-4 seond built-in soft start and Transformer Inrush Protection (TIP) feature.
3. The time response and ramp eliminates output overshoot, preventing damaging excessive currents into dynamic loads on either start-up or response to step function control signals.
4. Firing pulses between phases and complementary pairs are balanced within ±2 electrical degrees.
5. Output control parameters of current, voltage, or power are tightly regulated and linearly responsive to input signal (±1%) with use of feedback options.
6. Gate output pulses from the firing circuit are inhibited during power start-up (turn-on), momentary power interruption and reversed phase sequence.
7. The firing circuit provides a high frequency pulse train with a rise time of 300 nanoseconds to the SCR gates.

Mechanical Features

1. The unit uses a plug-in card rack assembly with three plug-in printed circuit cards and one receptacle board.
2. Electrical connections are made on screw-type terminal blocks.
3. Card pullers (extractors) are provided as an inherent feature on each plug-in board.
4. Bias, Gain, and Current Limit adjustments are accomplished through standard 20 turn potentiometers easily accessible through the top cover plate.
5. Information for input/output connections, control adjustments and input impedance are readily available on the top cover plate.
6. Diagnostic proper phase rotation is indicated with a light emitting diode (LED).

Phase Angle Firing Control

Three Phase – Full Converter



Contol Connections

DC Control Signal	Input Control Terminal Points	Input Impedance
0-5 ma	1 (+)-5 (–)	1000 ohms
2-12 ma	2 (+)-5 (–)	400 ohms
4-20 ma	3 (+)-5 (–)	250 ohms
10-50 ma	4 (+)-5 (–)	100 ohms
0-10 v	7 (+)-5 (–)	200K ohms
Contact Closure	6 and 7	
Manual Control:		
Ends of Pot	6 and 8	Connect a 10k ohms
Slider of Pot	7	2 watt potentiometer.
Lockout (External shutdown contact)	6 and 17	

Ordering Information

3 Phase Power Control Units — AC Output

F.: 6 SCR full converter

E: 120V Line
C: 208V Line
D: 240V Line
J: 277V Line
F: 380V Line
G: 480V Line
H: 575V Line

0: Basic Unit
1: N.O. Temp. Switch
2: N.C. Temp. Switch

5: Open Chassis
6: NEMA I enclosure**

Size Code

B — **O**

6: 50 Hz
7: 60 Hz

2: Basic unit
*4: Overcurrent shut down (OC)
*6: Watt regulation (WR)
*7: OC & WR
8: Voltage regulation (VR)
*9: VR & OC
A: Current regulation (CR)
*B: CR & OC
C: Voltage limit (VL)
*D: VL & OC

A: Basic unit (no options)
B: Current limit (CL)

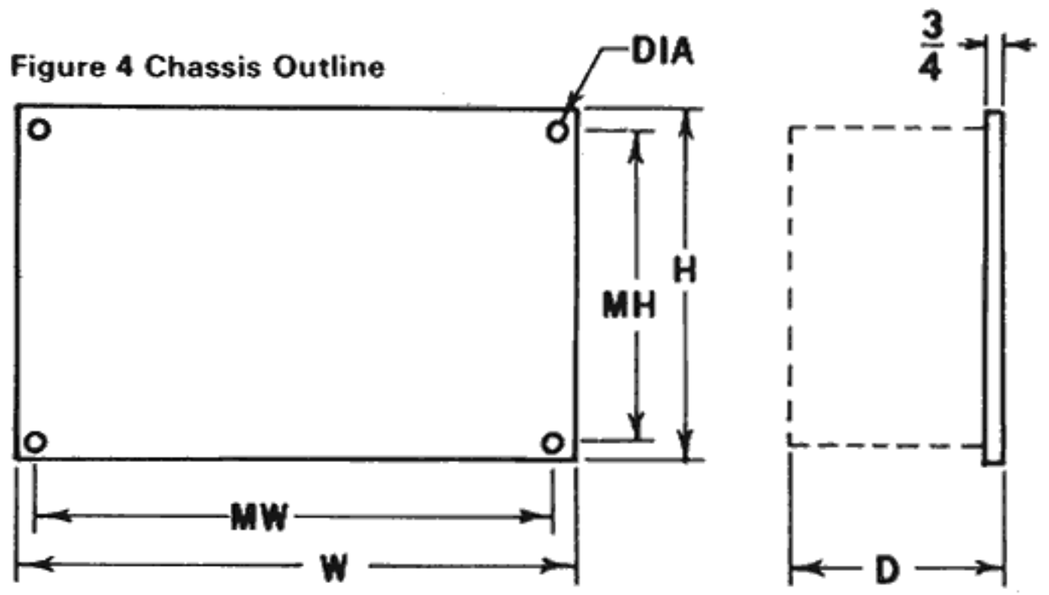
*PCUs with these options must be tailored to individual requirements; consult factory before ordering. An additional 10" is required in height dimension for both chassis and NEMA I enclosures.

Instruction and operating manuals are provided on each Power Control Unit order. When multiple manual copies are required, they can be supplied at extra cost.

Terminal Locations

Control terminals are at lower right of all units. Power terminals are located with line terminals at the top left, and load terminals at the lower left.

Figure 4 Chassis Outline



Ratings and Chassis Dimensions (inches)

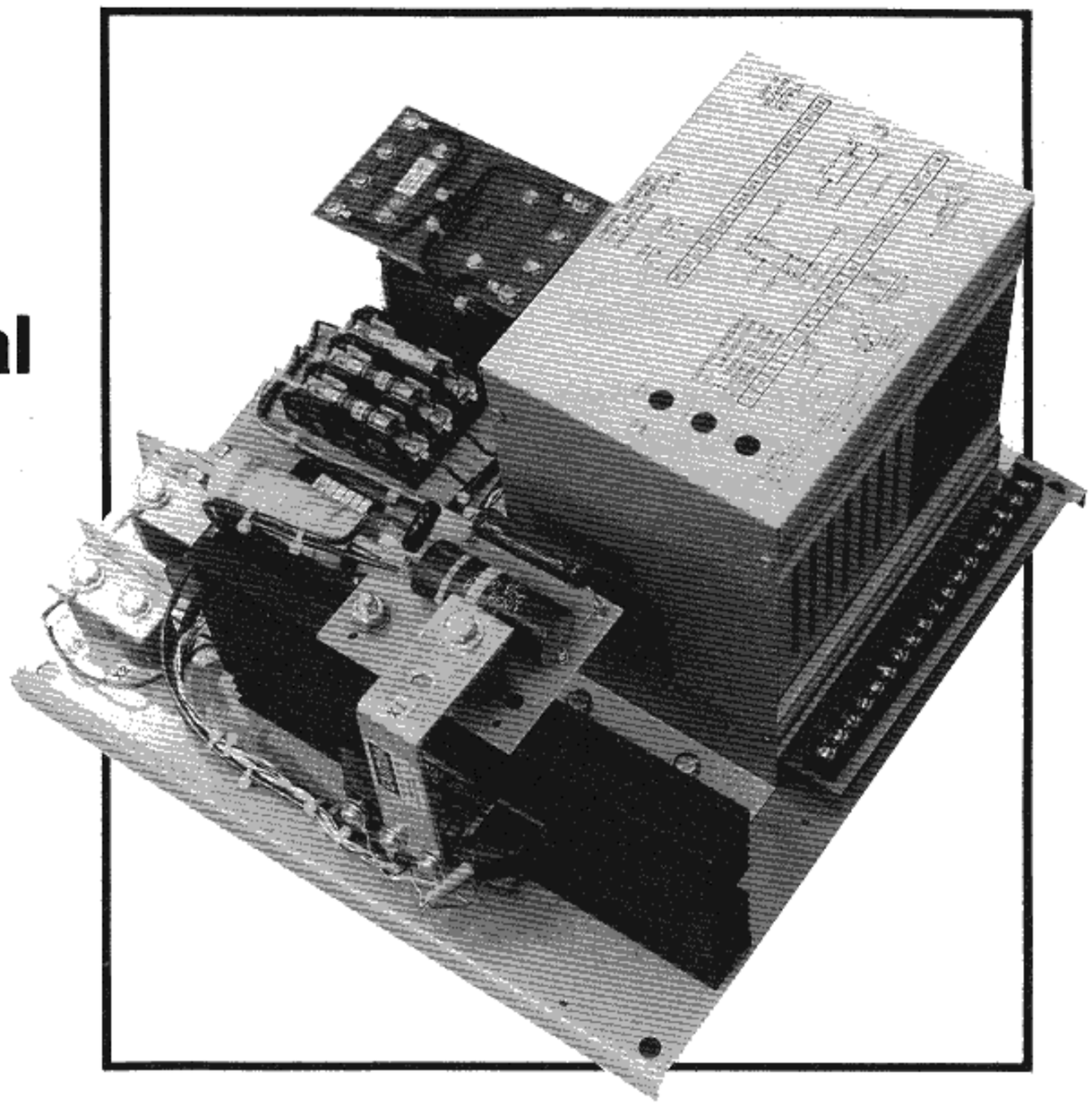
Size Code	Current Rating AC Amps	KVA Rating 208V	240V	480V	Refer to Figure 4 H	W	D	MH	MW	DIA
1508	15	5.4	6.24	12.5	16	14	10	15	13	⅜
3008	30	10.8	12.5	25.0	16	14	10	15	13	⅜
6008	60	21.6	25.0	50.0	18	14	10	17	13	⅜
9008	90	32.4	37.4	75.0	18	14	10	17	13	⅜
1118	110	39.6	45.7	91.4	20	22	12	18½	20½	½
1518	150	54	62	125	20	22	12	18½	20½	½
2518	250	90	104	208	20	22	12	18½	20½	½
3518	350	125	145	290	20	22	12	18½	20½	½
4518	450	162	187	374	20	22	12	18½	20½	½
6018	600	216	250	500	20	24	12	18½	22½	½
8018	800	288	332	665	26	36	15	24½	34½	½
1028	1000	360	416	832	26	36	15	24½	34½	½
1328	1300	468	540	1080	42	37	24	40½	35½	½

****NEMA 1 enclosures are available. For the above current sizes, dimensions (inches) are as follows:**

Size	H	W	D
1508 thru 9008	26	17	12
1118 thru 1518	30	25	14
2518 thru 6018	42	27	14
8018 thru 1028	52	39	16
1328***	76	44	30

***This size uses a free standing, floor mounted cabinet; all others are wall mounted.

Phase Angle Control SINGLE PHASE SCR POWER CONTROL UNITS - for Industrial Control Applications



SPANG Power Control Units for single phase applications are available either with phase angle control or with synchronous firing control of the SCRs. Synchronous firing PCUs are normally applied to control static loads, such as resistive heating elements (nichrome), which are not affected by age or drastic change in resistance versus temperature.

This bulletin describes phase angle PCUs used primarily to control dynamic resistive, or transformer-coupled loads.

STANDARD FEATURES

- Electronic design with active integrated circuit networks
- Phase lock loop for firing pulse synchronization
- Standard ratings designed for 50° C maximum ambient
- Stepless control for proportional electric power
- Immunity to line distortions and fluctuations

General Description

The phase angle firing circuit, used in the SPANG Power Control Units, is a new field-proven design incorporating modern electronic hardware for producing electrical pulses to the gates of the SCRs. Built into the devices are CMOS integrated circuits (both analog and digital), operational amplifiers and phase lock loop circuitry, all of which assure that power line distortions (harmonics, sags, surges, etc.) will not affect the firing of the SCRs. These Power Control Units have exceptional stability, reliability, and versatility, plus the availability of options which can be tailored to specific applications.

The SPANG Single Phase Phase-Angle fired PCU uses two SCRs connected inverse parallel in one of the two lines to the load. The other line is connected directly to the load (see Figure 1).

Advantages of Phase Angle Firing:

- Conventional voltmeters and ammeters can be used for instrumentation over 0 to 100% voltage range.
- Infinitely variable output.
- Operation into dynamic loads (i.e., transformers).

Specifications for Phase Angle Control

Input Voltage: Ratings are provided for 480, 240, and 120 volt, single phase, 60 hertz lines.

Ambient: All ratings are designed for 50°C maximum operating temperature. For operation at higher temperatures (to 65°C maximum), some derating is necessary; please consult factory.

Input Signals: 0-5, 1-5, 2-12, 4-20, 10-50ma inputs or a manual potentiometer (all standard temperature controller outputs). See Control Connections.

Adjustments: a. Gain adjustments provide full output for 50% to 200% standard control signal.
b. Bias adjustment for manual control to 100% output.

Voltage Protection: a. Transient voltage suppression is provided by metal oxide varistors (MOVs) which clamp high voltage spikes to within the PRV rating of the semiconductors.

b. Standard PRV ratings:
480 volt units – 1200 volts
240 volt units – 800 volts
120 volt units – 400 volts
Higher PRV ratings are available for specialized applications.

Reference Supply: A 10-12 volt DC regulated reference supply is available from the firing circuit for connection to a remote potentiometer, from which the Power Control Unit can be controlled manually. This supply is regulated to within $\pm 1/2\%$ for line voltage variations. Maximum current rating from this reference source is 10 milliamperes.

Cooling: a. Current sizes 15, 30 and 60 amperes are convection cooled.

b. Current sizes from 110 to 600 amperes are forced-air cooled by integral cooling fans. Bimetallic temperature switches are supplied on all forced-air cooled units with one NO contact wired to a terminal block from each SCR heat sink. As an alternate, normally closed contacts are available on request.

Options Available

1. **Current Limit** senses RMS current and limits output. Current limit adjustment is from 5% to over 100% of rating by a potentiometer in the firing circuit.

2. **Voltage Regulation** adds RMS voltage feedback to the standard model. Voltage regulation is ±1% for line voltage excursions of +10%, −15% of nominal. This option also improves control linearity to ±1% from 0 to 100% output.

3. **Current Regulation** compensates for both line and load fluctuations and provides a constant RMS current proportional to the control signal. Current regulation is ±1% of set point.

4. **Watt Regulation** is accomplished by addition of voltage and current feedback into a watt transducer. Output wattage can be regulated to ±1% of set point. Common applications are in control of silicon carbide heating loads.

5. **Fast Gate Shut-Off** is an electronic turn-off of the gate firing pulses within 8.33 milliseconds (1/2 cycle at 60 Hz) by sensing an overcurrent condition and applying the shut-off signal to the firing circuit. For most applications where this is to be used (e.g., protection against short circuits or load faults) external current limiting impedance must be added to insure protection of the power SCRs. Consult the factory for advice on this coordination.

6. **NEMA 1 Wall Mounted Enclosures** are available for housing the respective Power Control Units. The enclosure features #14 gauge steel construction finished with ASA-61 light gray enamel. Ventilation is provided through expanded metal openings at the bottom and sides of the enclosure. Conduit entrance can be through the top, bottom or lower sides as required. The access door is hinged with a locking handle.

7. **Combinations of the above listed options** — Refer to page 14 for possible option combinations and corresponding ordering part number.

8. **Special Options** — Custom options such as pilot lights, meters, circuit breaker additions, water cooling, separate firing circuit assembly, and others are available. Please contact the factory for description, pricing, and advice on your custom requirements.

Schematic Drawing

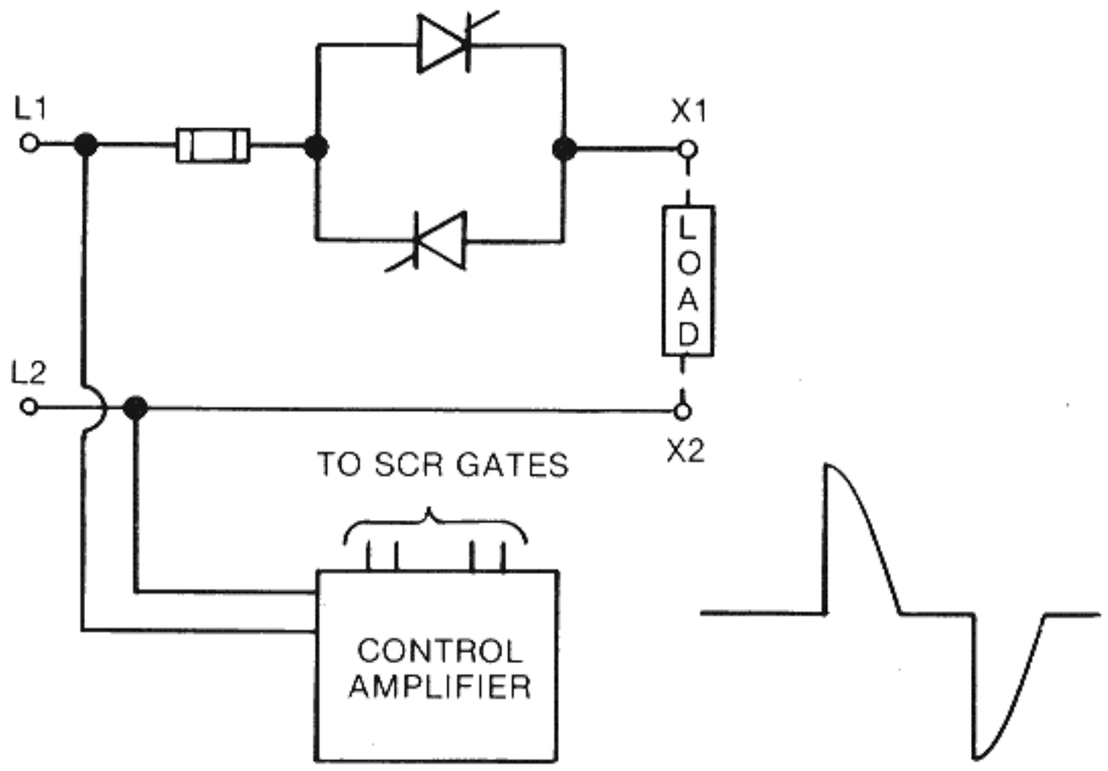


Fig. 1 Single Phase Converter & Waveform

Control Connections

DC Control Signal	Input Control Terminal Points	Input Impedance
0-5 ma	1 (+)-5 (−)	1000 ohms
2-12 ma	2 (+)-5 (−)	400 ohms
4-20 ma	3 (+)-5 (−)	250 ohms
10-50 ma	4 (+)-5 (−)	100 ohms
0-10 v	7 (+)-5 (−)	200K ohms
Contact Closure	6 and 7	
Manual Control:		
Ends of Pot	6 and 8	Connect a 10K ohm
Slider of Pot	7	2 watt potentiometer
Lockout (External shutdown contact)	6 and 17	

Electrical Features

1. Upon initial energization, there is a 4 second dead time for circuit stabilization during which time the SCR gate pulses are inhibited.
2. The firing circuit inherently includes a 3-4 second built-in soft start and Transformer Inrush Protection (TIP) feature.
3. The time response and ramp eliminates output overshoot, preventing damaging excessive currents into dynamic loads on either start-up or response to step function control signals.
4. Firing pulses between complementary pairs are balanced within ±2 electrical degrees.
5. Output control parameters of current, voltage, or power are tightly regulated and linearly responsive to input signal (±1%) with use of feedback options.
6. Gate output pulses from the firing circuit are inhibited during power start-up (turn-on) and momentary power interruption.
7. The firing circuit provides a high frequency pulse train with a rise time of 300 nanoseconds to the SCR gates.

Mechanical Features

1. The unit uses a plug-in card rack assembly with three plug-in printed circuit cards and one receptacle board (HB).
2. Card pullers (extractors) are provided as an inherent feature on each plug-in board (HB).
3. Bias, Gain, and Current Limit adjustments are accomplished through standard 20 turn potentiometers.
4. Information for input/output connections, control adjustments and input impedance are readily available on the top cover plate (HB).
5. Electrical control connections are made on screw-type terminal blocks.
6. Forced air cooling provided on 110 ampere sizes and above.
7. Isolated semiconductor power blocks are used on smaller current ratings.

Ordering Information

Single Phase Power Control Units — AC Output

H: Modular firing circuit

E: 120V Line
C: 208V Line
D: 240V Line
J: 277V Line
F: 380V Line
G: 480V Line
H: 575V Line

0: Basic Unit
1: N.O. Temp. Switch
2: N.C. Temp. Switch

5: Open Chassis
6: NEMA I enclosure**

Size Code

B — — — — **O**

1: 50 Hz
2: 60 Hz

2: Basic unit
*4: Overcurrent shut down (OC)
*6: Watt regulation (WR)
*7: OC & WR
8: Voltage regulation (VR)
*9: VR & OC
A: Current regulation (CR)
*B: CR & OC
C: Voltage limit (VL)
*D: VL & OC

A: Basic unit (no options)
B: Current limit (CL)

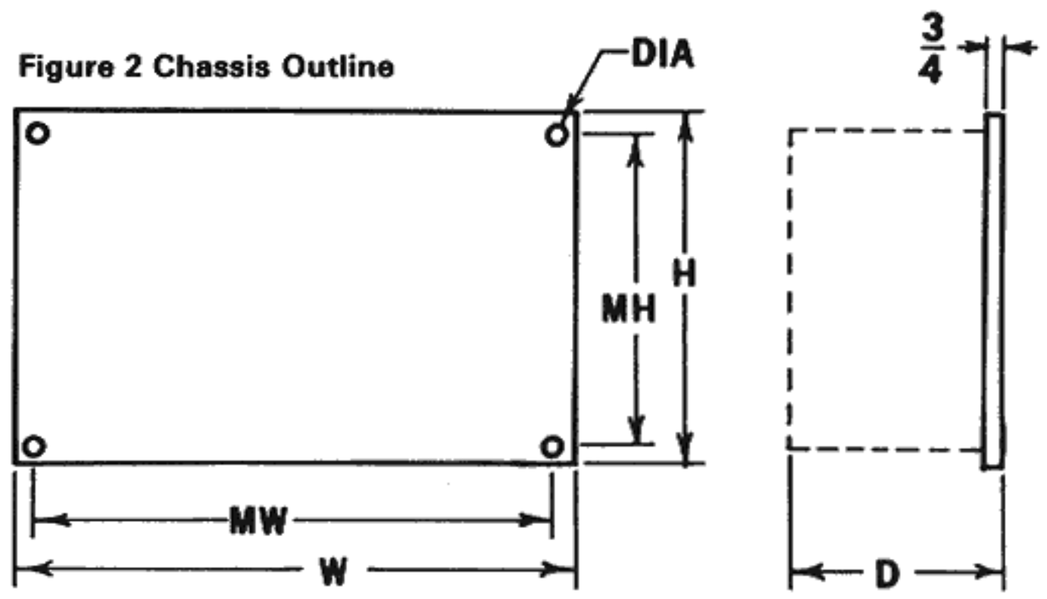
*PCUs with these options must be tailored to individual requirements; consult factory before ordering. An additional 8″ is required in height dimension for both chassis and NEMA 1 enclosures.

Instruction and operating manuals are provided on each Power Control Unit order. When multiple manual copies are required, they can be supplied at extra cost.

Terminal Locations

Control terminals are at lower right of all units. Power terminals are located with line terminals at the top left, and load terminals at the lower left.

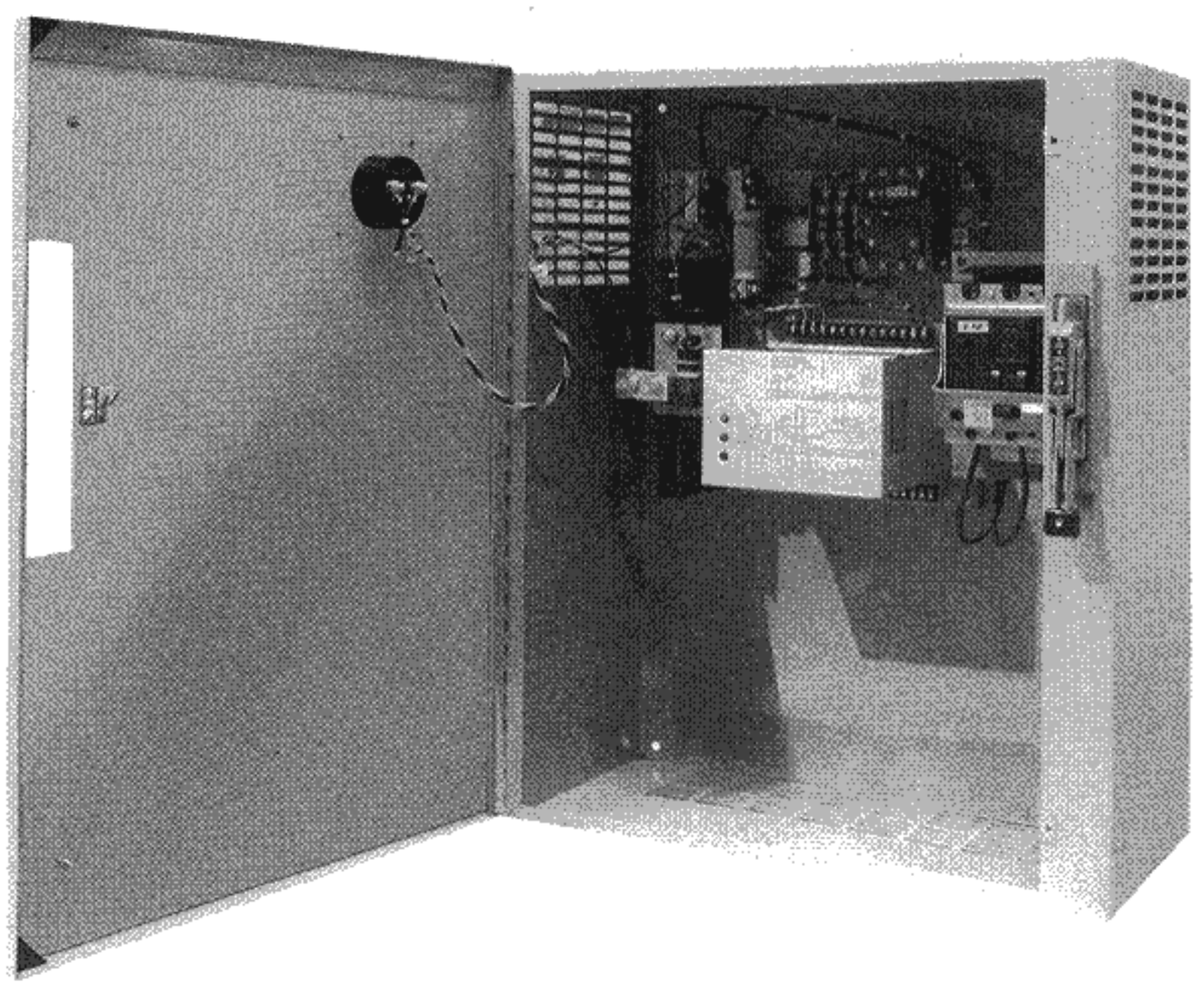
Figure 2 Chassis Outline



Ratings and Chassis Dimensions (inches)										
Size Code	Current Rating AC Amps	KVA Rating 120V	240V	480V	Refer to Figure 2 H	W	D	MH	MW	Dia.
1508	15	1.8	3.6	7.2	14	12	10	13	11	3/8
3008	30	3.6	7.2	14.4	14	12	10	13	11	3/8
6008	60	7.2	14.4	28.8	14	14	10	13	13	3/8
1118	110	13.2	26.4	53	14	14	10	13	13	3/8
1718	175	21	42	84	16	15	10	15	14	3/8
2518	250	30	60	120	20	15	12	18½	13½	½
4018	400	48	96	192	20	15	12	18½	13½	½
5018	500	60	120	240	20	15	12	18½	13½	½
6018	600	72	144	288	20	15	12	18½	13½	½

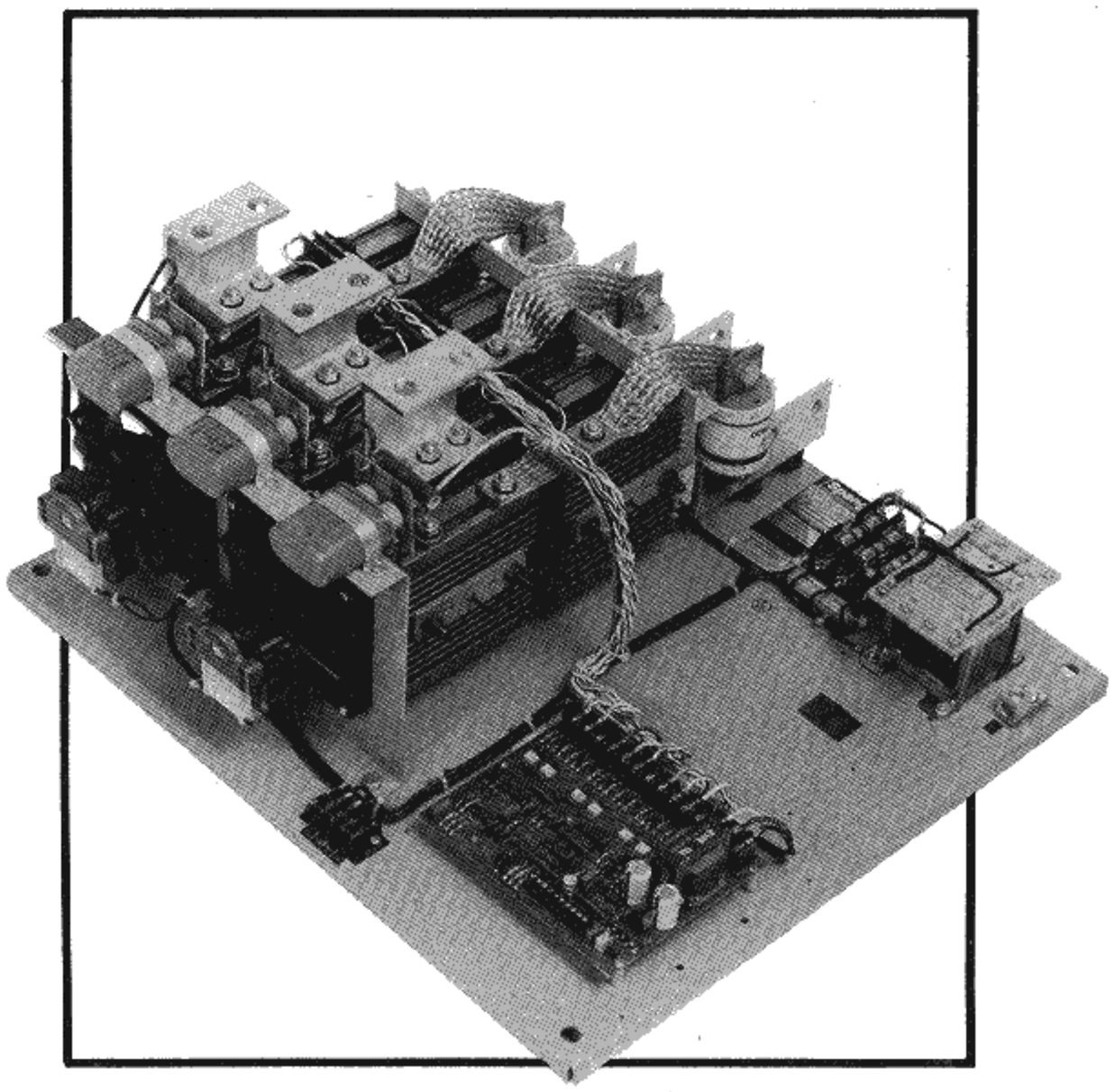
****NEMA 1 enclosures are available. For the above current sizes, dimensions (inches) are as follows:**

Size	H	W	D
1508 thru 3008	22	15	12
6008 thru 1118	26	17	12
1718	30	18	14
2518 thru 6018	42	18	14



Spang Power Electronics

Synchronous Control SINGLE AND THREE PHASE SCR POWER CONTROL UNITS - for Industrial Heating Applications



SPANG Power Control Units are available either with phase angle control or with synchronous firing control of the SCRs. Phase angle PCUs are normally applied to control dynamic resistive, or transformer-coupled heating element loads.

This bulletin describes synchronous firing PCUs used primarily to control static loads, such as resistive heating elements (nichrome), which are not affected by age or drastic change in resistance versus temperature.

STANDARD FEATURES

- 3 Ø conventional 3 leg control and economical 2 leg control
- Fused third leg on 2 leg control
- LED indication of proper phase rotation on 3 phase units
- Variable ratio synchronous control
- Stepless control for proportional electric power
- Units accept all standard control signals
- Electronic design with active integrated circuit networks
- Phase lock loop for firing pulse synchronization
- Immunity to line distortions and fluctuations
- Standard ratings designed for 50° C maximum ambient
- LED indication of firing

General Description

SPANG manufactures three types of synchronous Power Control Units: (a) a single phase version uses two SCRs connected inverse parallel in one line, and the other line is connected directly to the load (Figure 3); (b) the three phase version is designed in two types: two and three leg control (Figures 1 and 2).

Three leg control uses an SCR and a diode connected inverse parallel in each line to the load, (Figure 1). Two leg control uses two (2) SCRs connected inverse parallel in two of the three lines to the load, (Figure 2). Two leg control uses fewer power components and is more economical. Three phase loads may be either three wire Delta or Wye connected. If control is required to a four wire grounded neutral Wye load, it is recommended to use a three leg, six SCR Power Control Unit. These are available upon request.

Advantages of Variable Frequency Synchronous Firing:

- Conventional voltmeters and ammeters can be used for instrumentation at 50% to 100% voltage range.
- Infinitely variable output.
- Elimination of RFI.
- Power is distributed evenly over time.

Theory of Variable Frequency Synchronous Control

Synchronous firing control of thyristors is important for many types of heating and static contactor applications. Other names by which it is known are: Zero Voltage Firing, Zero Angle Firing, Burst Firing, Zero Point Switching, and RFI-less Control. With synchronous firing, the SCRs are used as switches that turn on and off at zero voltage crossover to control complete cycles of power; hence, the voltage being applied to the load is either zero or full line value (Figure 4). With SPANG variable frequency control, power is proportioned by controlling the cycles of power ON versus the cycles of power OFF at a variable ratio. Control is accomplished at a cycling rate which achieves the smoothest, most continuous required output power. For example, very low output is 1 cycle ON and 100 cycles OFF (Figure 4). A slightly greater control signal gives 1 cycle ON and 30 cycles OFF. Power output of 50% typically provides control of 1 cycle ON and 1 cycle OFF. Greater percentage power output is achieved typically as 3 cycles ON and 2 cycles OFF (60% power) or 6 cycles ON and 1 cycle OFF (86% power). Full output is continuous conduction. For this type of control, a variable time base is used instead of a constant fixed time base for the cycle ON-OFF switching.

Specifications for Synchronous Control

Input Voltage: Ratings are provided for 575, 480, 380, 277, 240, 208, and 120 volt, single or three phase, 50 or 60 Hertz lines.

Ambient: All ratings are designed for 50˚C maximum operating temperature. For operation at higher temperatures (to 65˚C maximum), some derating is necessary; please consult factory.

Input Signals: 0-5, 1-5, 2-12, 4-20, 10-50ma inputs or a manual potentiometer (all standard temperature controller outputs). See chart.

Adjustments: a. Gain adjustments provide full output for 50% to 200% standard control signal.

b. Bias adjustment for manual control to 100% output.

Linearity: Output versus control signal is ±10% full scale. For ±1% see regulation options.

Voltage Protection: a. Transient voltage suppression is provided by metal oxide varistors (MOVs) which clamp high voltage spikes to within the PRV rating of the semiconductors.

b. Standard PRV ratings:
Units 380 volts & above – 1200 volts
Units 277 volts & below – 800 volts
Higher PRV ratings are available for specialized applications.

Reference Supply: A 15 volt DC regulated reference supply is available from the firing circuit for connection to a remote potentiometer, from which the Power Control Unit can be controlled manually. This supply is regulated to within ±1/2% for line voltage variations. Maximum current rating from this reference source is 20 milliamperes.

Cooling: a. Current sizes 15, 30, and 60 amperes single phase, 15 and 30 amperes three phase are convection cooled.

b. Larger current sizes are forced-air cooled by integral cooling fans. Bimetallic temperature switches are supplied on all forced-air cooled units with one normally open (NO) contact wired to a terminal block from each SCR heat sink. As an alternate, normally closed (NC) are available on request.

Options Available

Current Limit senses the RMS current and limits the output to an average value over a varying period of time.

Voltage Limit senses the RMS voltage and limits the output to an average value over a varying period of time. Voltage limit adjustment is from 50% to 100% of the line voltage by a potentiometer in the firing circuit.

Voltage Regulation adds RMS voltage feedback to the standard model. Voltage regulation is ±1% for line voltage excursions of +10%, -15% of nominal. This option also improves control linearity to ±1% from 0 to 100% output.

Current Regulation compensates for both line and load fluctuations and provides an output current proportional to the control signal. Current regulation is ±1% of full scale.

NEMA 1 Wall Mounted Enclosures are available for housing the respective Power Control Units. The enclosure features #14 gauge steel construction finished with ASA-61 light gray enamel. Ventilation is provided through expanded metal openings at the bottom and sides of the enclosure. Conduit entrance can be through the top, bottom or lower sides as required. The access door is hinged with a locking handle.

Schematic Drawings of Power Control Units

Three Phase - Three Leg Control

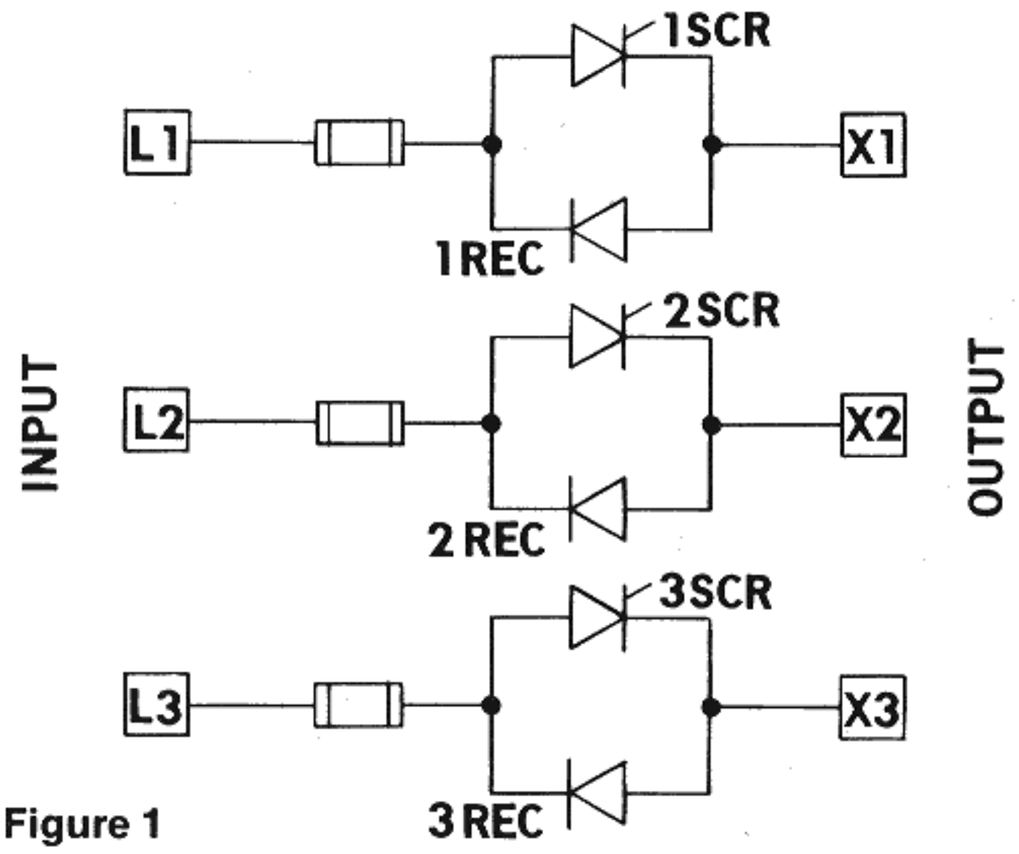


Figure 1

Three Phase - Two Leg Control

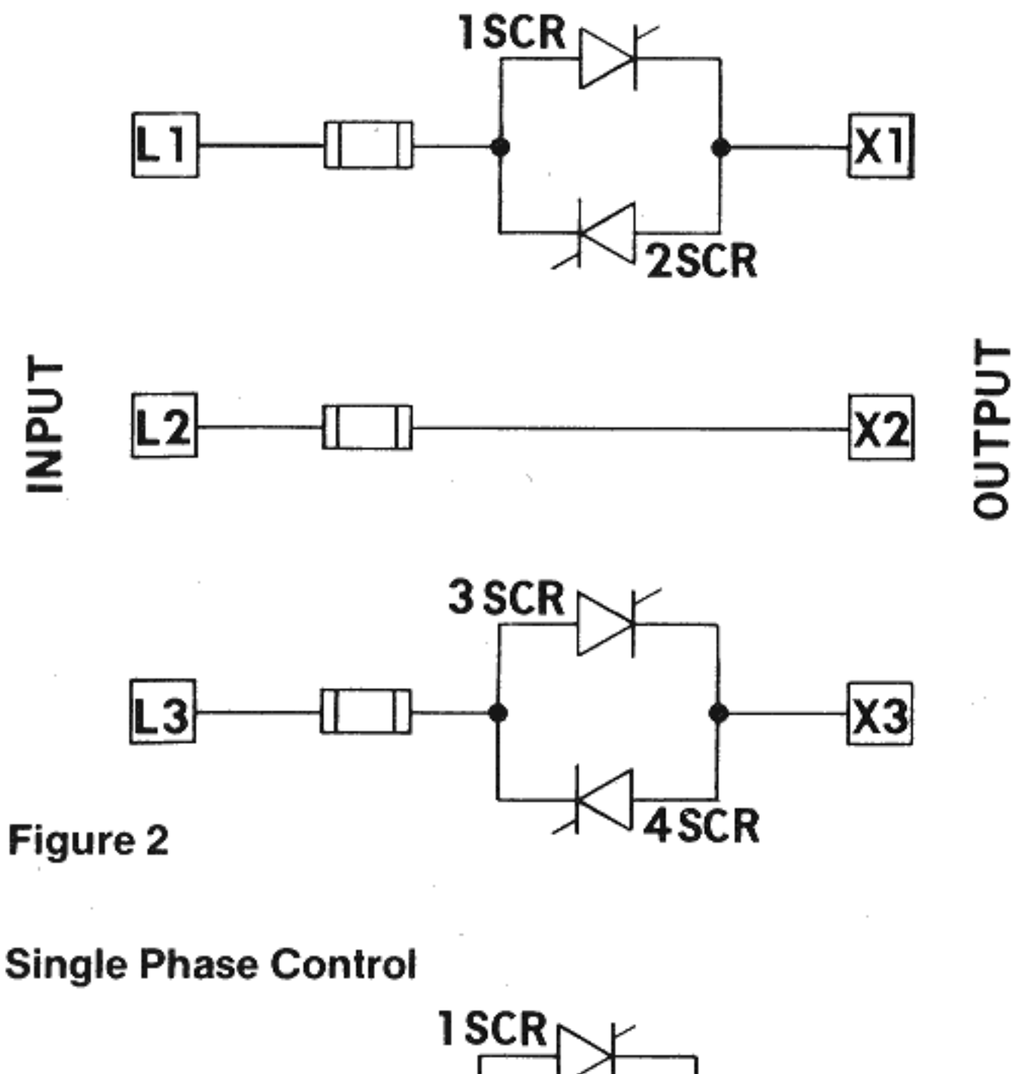


Figure 2

Single Phase Control

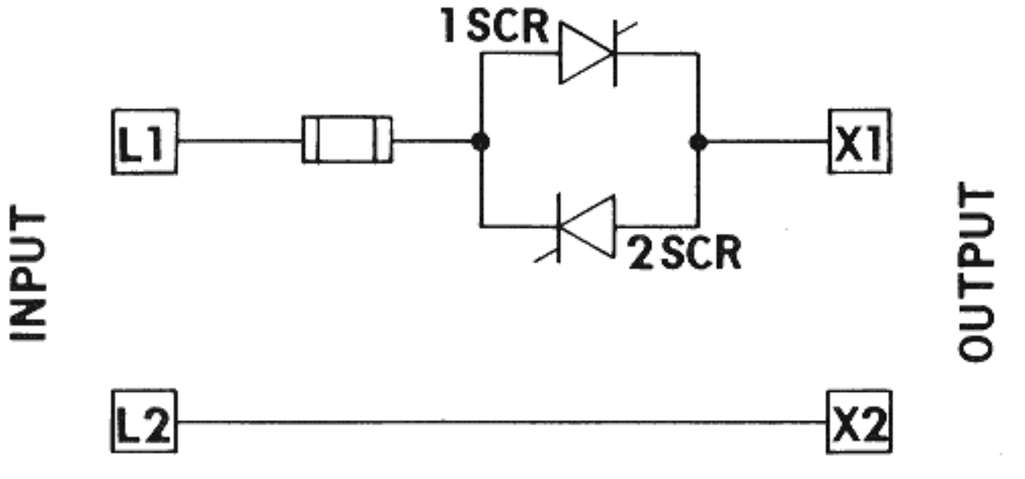
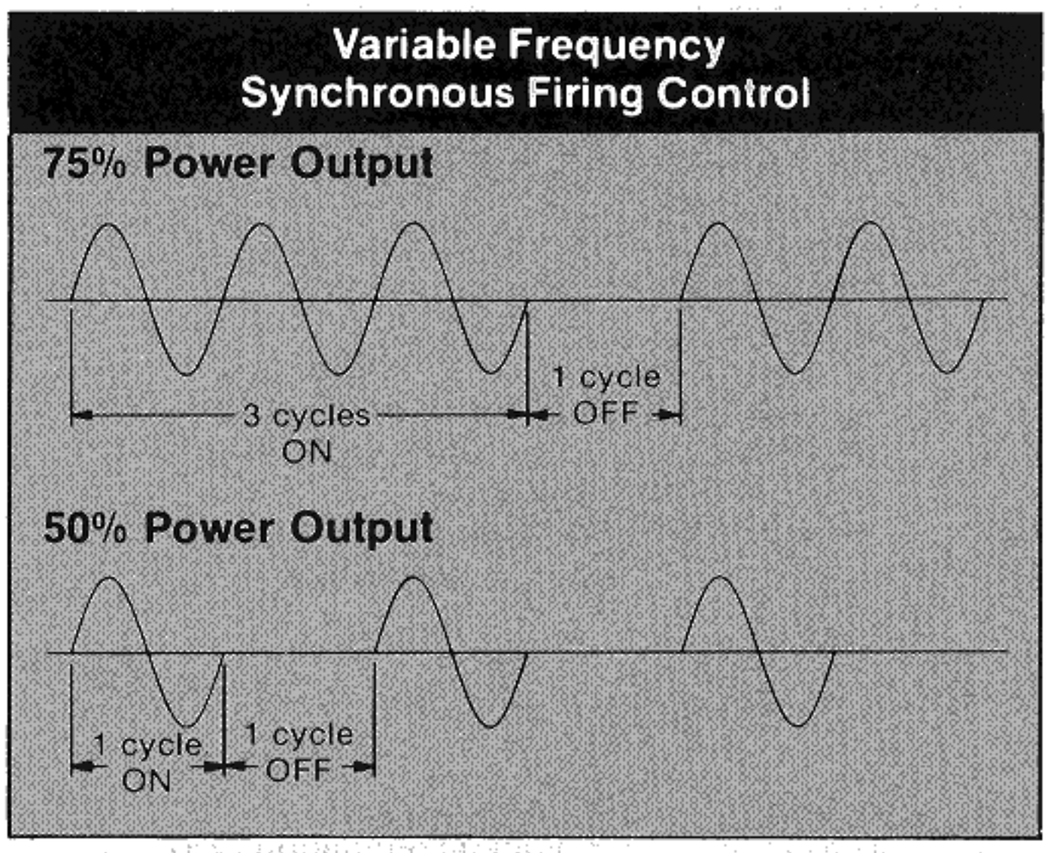


Figure 3

Figure 4



Control Connections		
DC Control Signal	Input Control Terminal Points	Input Impedance
0-5 ma	1 (+)-5 (-)	1000 ohms
2-12 ma	2 (+)-5 (-)	400 ohms
4-20 ma	3 (+)-5 (-)	250 ohms
10-50 ma	4 (+)-5 (-)	100 ohms
0-10 v	7 (+)-5 (-)	200K ohms
Contact Closure	6 and 7	
Manual Control:		
Ends of Pot	6 and 8	Connect a 10K ohm
Slider of Pot	7	2 watt potentiometer.
Lockout (External shudown contact)	6 and 10	

Mechanical Features

1. LED indication of firing provided.
2. Electrical control connections are made on screw-type terminal blocks.
3. Isolated semiconductor power blocks are used on smaller current ratings.
4. Bias, gain and limit adjustments are accomplished through standard 20 turn potentiometers.
5. Rugged metal backplate with all components easily accessible.

Electrical Features

1. Control from 0 to 100% of line voltage.
2. LED indication of phase sequence and phase loss on three phase units with an electrical lockout during abnormal conditions.
3. All three lines are fused on 2-leg synchronous units.

Ordering Information

Part Number Code

J: Synchronous Firing (3-Leg 6 SCR Control, 3 Phase, 4 Wire Wye Load)
K: Synchronous Firing (3-Leg Control and Single Phase)
L: Synchronous Firing (2-Leg Control)
N: Synchronous Firing (3-Leg 6 SCR Control, 3 Phase, 3 Wire Load)

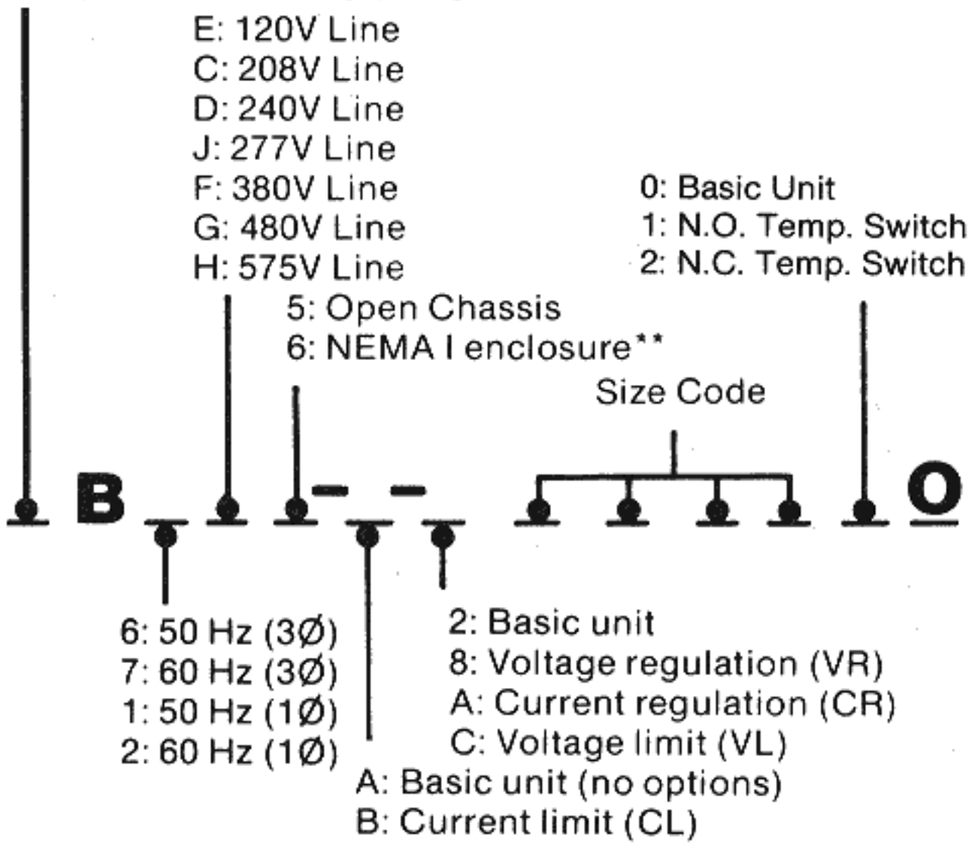
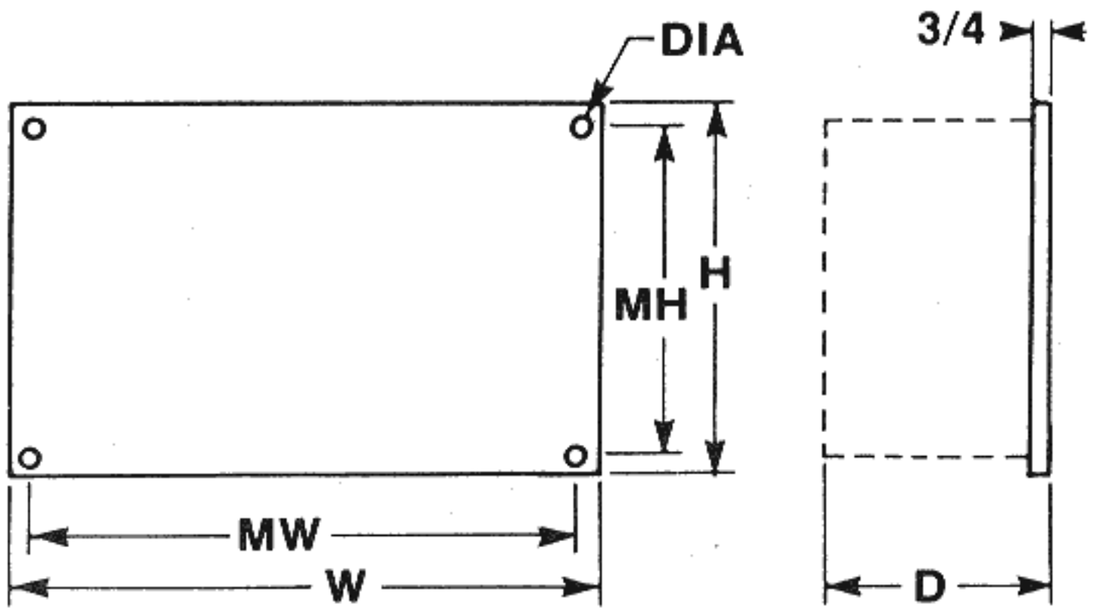


Figure 5 Chassis Outline



Instruction and operating manuals are provided on each Power Control Unit order. When multiple manual copies are required, they can be supplied at extra cost.

Terminal Locations
Control terminals are at lower right of all units. Power terminals are located with line terminals at the top left, and load terminals at the lower left.

3Ø Ratings and Chassis Dimensions (inches)

Size Code	Current Rating AC Amps	KVA Rating 208V	240V	480V	Refer to Figure 5 H	W	D	MH	MW	DIA
1500	15	5.4	6.24	12.5	16	14	10	15	13	⅜
3000	30	10.8	12.5	25.0	16	14	10	15	13	⅜
6000	60	21.6	25.0	50.0	18	14	10	17	13	⅜
9000	90	32.4	37.4	75.0	18	14	10	17	13	⅜
1110	110	39.6	45.7	91.4	20	22	12	18½	20½	½
1510	150	54	62	125	20	22	12	18½	20½	½
2510	250	90	104	208	20	22	12	18½	20½	½
3510	350	125	145	290	20	22	12	18½	20½	½
4510	450	162	187	374	20	22	12	18½	20½	½
6010	600	216	250	500	20	24	12	18½	22½	½
8010	800	288	332	665	26	36	15	24½	34½	½
1020	1000	360	416	832	26	36	15	24½	34½	½
1320	1300	468	540	1080	42	37	24	40½	35½	½

****3φ NEMA 1 enclosures are available. For the above current sizes, dimensions (inches) are as follows:**

Size	H	W	D
1500 thru 9000	26	17	12
1110 thru 1510	30	25	14
2510 thru 6010	42	27	14
8010 thru 1020	52	39	16
1320***	76	44	30

***This size uses a free standing, floor mounted cabinet; all others are wall mounted.

1Ø Ratings and Chassis Dimensions (inches)

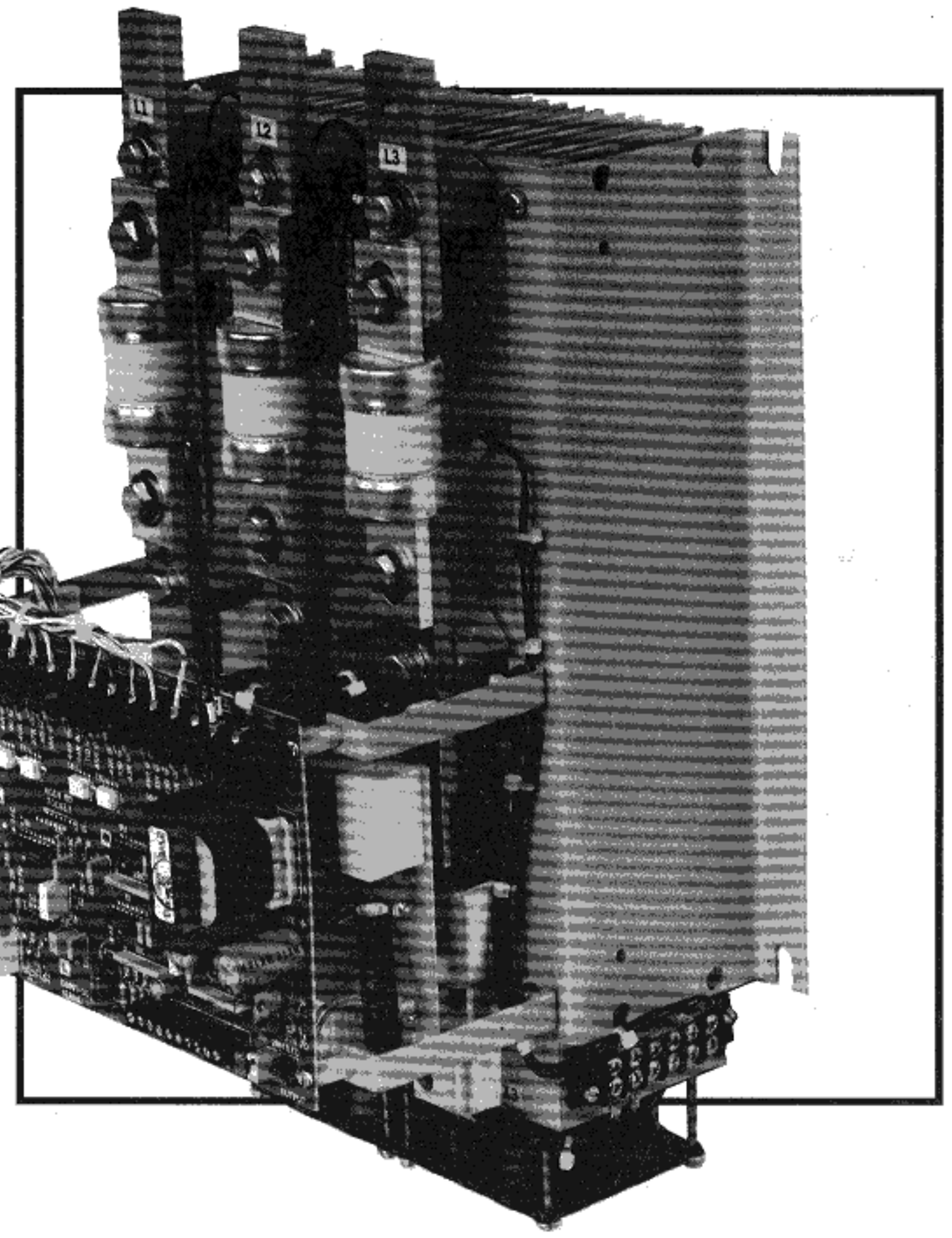
Size Code	Current Rating AC Amps	KVA Rating 120V	240V	480V	Refer to Figure 5 H	W	D	MH	MW	DIA
1500	15	1.8	3.6	7.2	14	12	10	13	11	⅜
3000	30	3.6	7.2	14.4	14	12	10	13	11	⅜
6000	60	7.2	14.4	28.8	14	14	10	13	13	⅜
1110	110	13.2	26.4	53	14	14	10	13	13	⅜
1710	175	21	42	84	16	15	10	15	14	⅜
2510	250	30	60	120	20	15	12	18½	13½	½
4010	400	48	96	192	20	15	12	18½	13½	½
5010	500	60	120	240	20	15	12	18½	13½	½
6010	600	72	144	288	20	15	12	18½	13½	½

****1φ NEMA 1 enclosures are available. For the above current sizes, dimensions (inches) are as follows:**

Size	H	W	D
1500 thru 3000	22	15	12
6000 thru 1110	26	17	12
1710	30	18	14
2510 thru 6010	42	18	14

Spang Power Electronics

Zero Crossover SCR POWER CONTROLLERS For Transformer Coupled Loads TC-SERIES



The Series TC SCR Power Controllers are designed specifically for transformer coupled loads (typically for resistance heating applications). The series TC controllers are two-leg, zero crossover fired units incorporating a control SCR and resistor to limit any transformer saturation current.

STANDARD FEATURES

- Small, compact design
- Electrically isolated heatsinks
- Easy mounting and service
- Eliminates RFI
- Accepts all standard control signals
- Silver plated all-copper bus bar
- Designed for 50°C ambient
- I^2t fusing system

General Description

The Series TC-SCR Power Controllers incorporate a two-leg, four (4) SCR design with two SCRs connected inverse parallel in two of the three lines connected to the load. In zero crossover control, the SCRs are always gated at the moment the sine wave crosses zero delivering complete cycles of power to the load. Power control is achieved by time proportioning full cycle control.

Input Voltages:

Ratings are available for 120, 240 and 480 volt, three phase. Other voltages are available upon request.

Input Frequency:

All units operate on 50 or 60 hertz.

Ambient:

All units are designed for 50°C maximum.

Input Signals:

All units accept: 0-5 ma, 2-12 ma, 4-20 ma, 10-50 ma, 0-10v.

Adjustments:

Gain and bias adjustments are provided.

Voltage Protection:

Transient voltage suppression is provided by an R-C snubber network and metal oxide varistor.

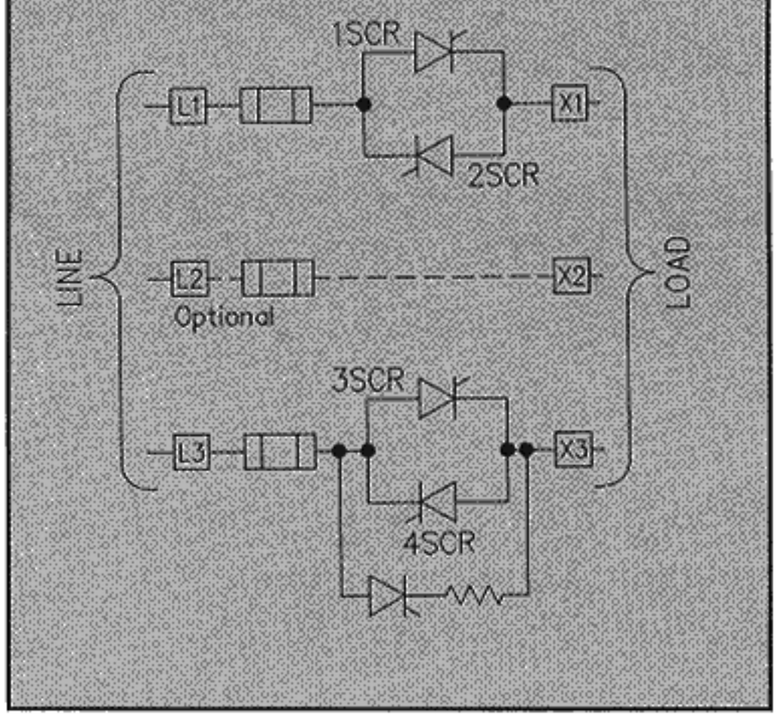
Cooling:

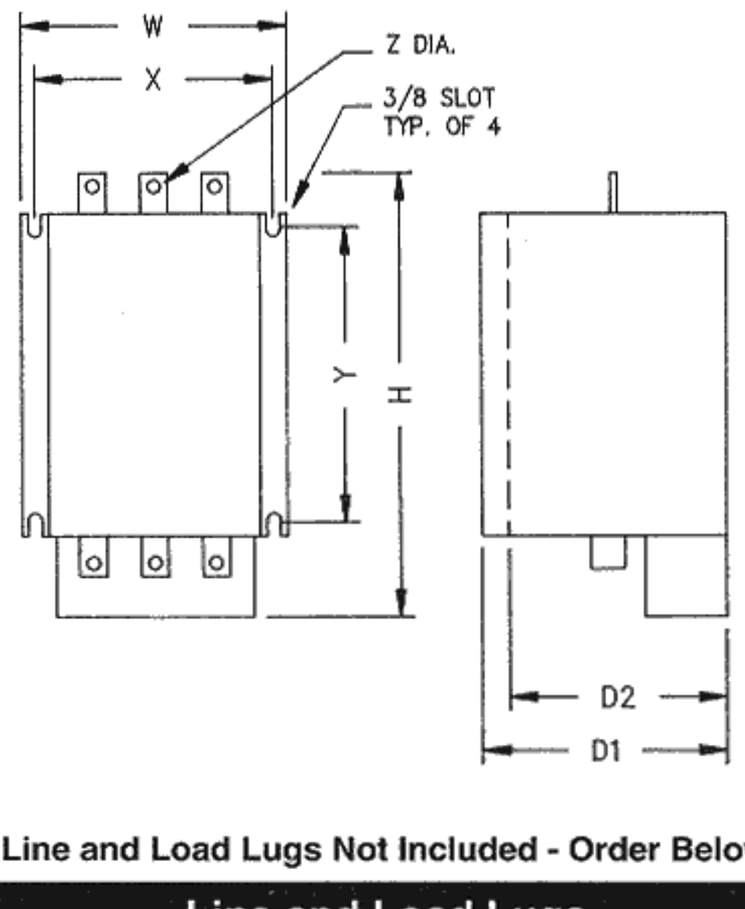
Current rating 40 and 60 amperes are convection cooled. Large ratings are force air cooled.

Types of Loads:

Delta or wye, 3 wire, connections.

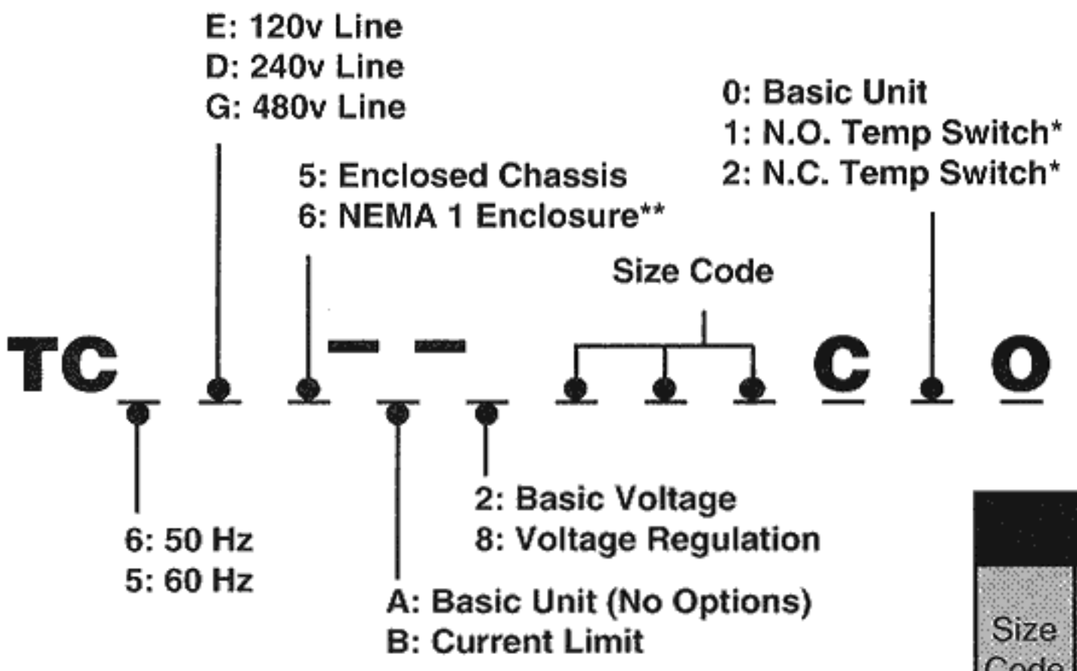
Three Phase - Two-Leg Control





Ordering Information

PART NUMBER CODE



* Forced air-cooled units only, not applicable to convection-cooled units

** NEMA 1 enclosures are available. For the above current sizes, dimensions (inches) are as follows:

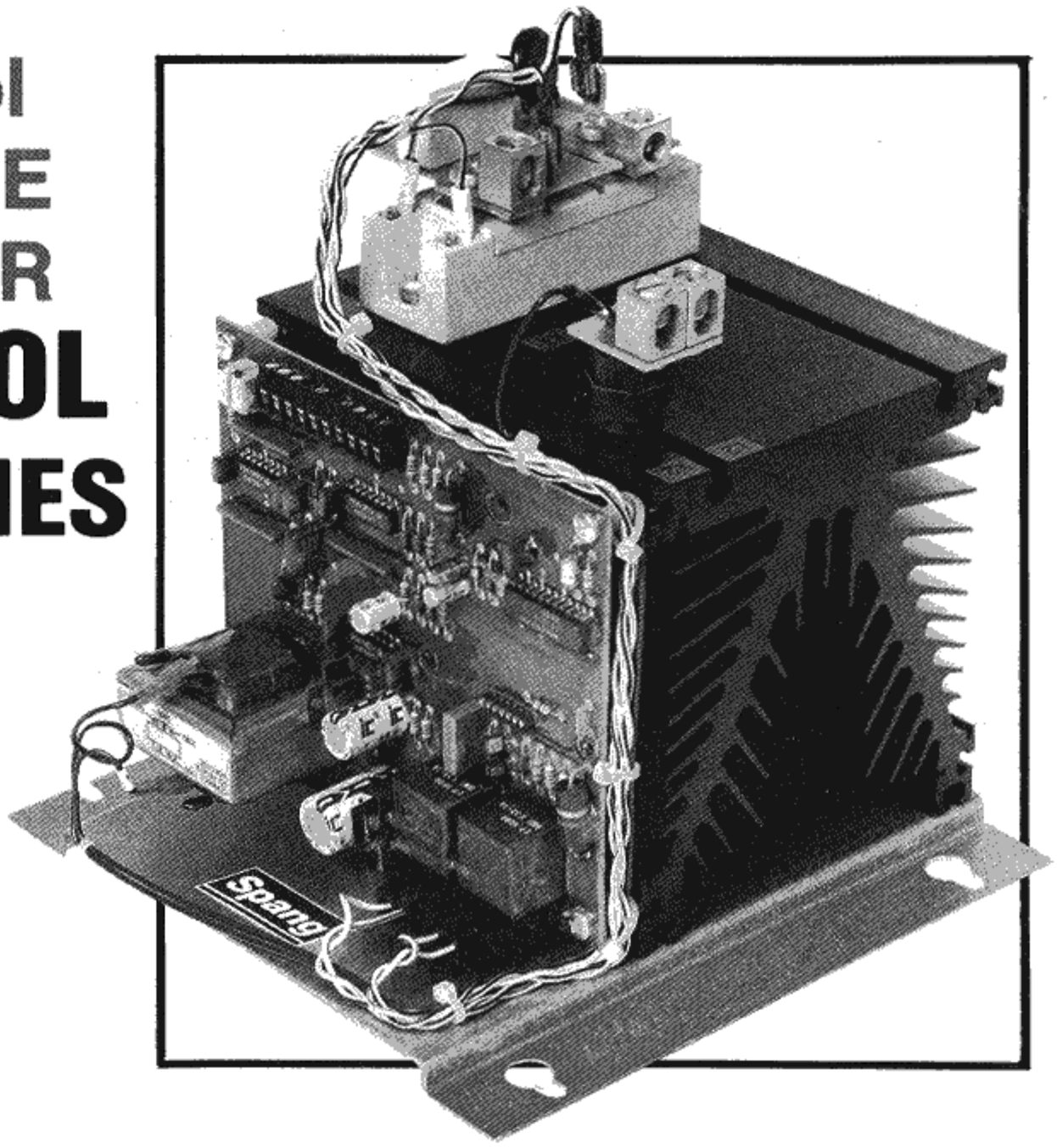
Line and Load Lugs Not Included - Order Below

Line and Load Lugs			
Size Code	Current Rating AC Amps	Wire Size	Catalog Number
400	40	#1/0-14 AWG	TERMKIT - 3 PH100A
600	60	#1/0-14 AWG	TERMKIT - 3 PH100A
101	100	#1/0-14 AWG	TERMKIT - 3 PH100A
151	150	250 MCM - 6 AWG	TERMKIT - 3 PH200A
251	250	350 MCM - 6 AWG	TERMKIT - 3 PH350
351	350	450 MCM - 6 AWG	TERMKIT - 3 PH350

Size	H	W	D
400 thru 151	26	18	14
251 thru 351	32	18	14

Ratings and Chassis Dimensions												
Size Code	Current Rating AC Amps	kva Rating 120v	240v	480v	H	W	D1	D2	X	Y	Z
400	40	8.3	16.6	33.3	14 3/8	9 7/8	9 1/8	8 7/8	9	11 1/8	5/16
600	60	12.5	25.0	50.0	16 3/8	9 7/8	9 1/8	8 7/8	9	11 1/8	5/16
101	100	20.8	41.5	83.1	16 3/8	9 7/8	9 1/8	8 7/8	9	11 1/8	5/16
151	150	31	62	125	16 3/8	9 7/8	9 1/8	8 7/8	9	11 1/8	5/16
251	250	52	104	208	21	12 7/8	10 1/4	10	12	13 1/4	9/16
351	350	73	145	290	21	12 7/8	10 1/4	10	12	13 1/4	9/16

Phase Angle Control DEFINITE PURPOSE SINGLE PHASE SCR POWER CONTROL UNITS - 651 SERIES



Compact, Economical Proportional Control of Single Phase AC Power

Primarily used to control dynamic resistive, or transformer-coupled loads:

- **Small Electric Furnaces**
- **Electric Ovens and Heaters**
- **Vibratory Feeders**
- **Extrusion and Forming Equipment**

STANDARD FEATURES

- Electronic design utilizing Large Scale Integration
- Phase lock loop for firing pulse synchronization
- Standard ratings designed for 50° C maximum ambient
- Stepless control for proportional electric power
- Immunity to line distortions and fluctuations
- Accepts all standard control signals
- All ratings are convection cooled
- Electrically isolated heatsinks
- Pulse transformer gate isolation

General Description

The 651 Series are definite purpose SCR Power Control Units, offering economical phase angle power control in a compact package. The latest advances in integrated circuit technology and power semiconductors have made this possible while maintaining the high quality and reliability that are traditional for Spang Power Electronics products.

The firing circuit utilizes CMOS integrated circuits and digital logic to ensure immunity from power line distortions. Large Scale Integration (LSI) allows for a compact design with improved reliability.

All units in the 651 Series utilize isolated semiconductor power modules. The power module contains two SCRs connected in inverse parallel to control one line of a single phase load. The other line is connected directly through to the load.

These definite purpose units offer the most frequently used options, current limit and voltage regulation. These are available factory installed or in easy-to-add kit form. Where more elaborate control or higher current ratings are required, our GB and HB series units described on pages 11-14 should be considered.

Also available from Spang Power Electronics is a complete line of SCR Power Control Units offering phase angle and synchronous (zero voltage) control in both three phase and single phase configurations.

Advantages of Phase Angle Firing:

- Conventional voltmeters and ammeters can be used for instrumentation over 0 to 100% voltage range.
- Infinitely variable output.
- Operation into dynamic loads (i.e., transformers).

Specifications for Phase Angle Control

Input Voltage: The 651 Series units are available in two voltage ranges of 120 through 277 volts or 380 through 575 volts. They are shipped connected for the most popular voltages of 240 or 480 volts. Other voltages may be selected by simply moving a plug-in jumper. On the 277 volt units, input voltages of 120VAC, 208VAC, 240VAC or 277VAC may be selected. On the 575 volt unit, input voltages of 380VAC, 416VAC, 480VAC and 575VAC are available.

Input Frequency: All units are shipped connected for 60 Hertz operation. Conversion to 50 Hertz is achieved by simply removing a jumper.

Connections: U.L. listed compression terminals are provided for both power and control connections.

Ambient: All ratings are designed for 50°C maximum operating temperature. For operation at higher temperatures (to 65°C maximum), some derating is necessary; please consult factory.

Input Signals: 0-5, 1-5, 2-12, 4-20, 10-50ma inputs or a manual potentiometer (all standard temperature controller outputs) or a manual potentiometer. See Control Connections.

Adjustments: High resolution, 20 turn potentiometers are provided for all adjustments.

a. Gain adjustments provide full output for 50% to 200% standard control signal.

b. Bias adjustment for manual control to 100% output.

Voltage Protection:

a. Transient voltage suppression is provided by an R-C snubber network and metal oxide varistor (MOV) which clamps high voltage spikes to within the PRV rating of the semiconductors.

b.Standard PRV ratings:
380-575 volt units -1200 units
120-277 volt units - 800 volts

Reference Supply: A 12 volt DC regulated reference supply is available from the firing circuit for connection to a remote potentiometer, from which the Power Control Unit can be controlled manually. This supply is regulated to within ±1/2% for line voltage variations. Maximum current rating from this reference source is 10 milliamperes.

Cooling: The 651 Series Power Control Units are convection cooled. Use of isolated power modules provides electrical isolation of the heatsinks.

TIP (Soft Start): An integral soft start ramp is provided on all 651 Series units. Upon initial energization, gate firing is inhibited for a short dead time to allow for circuit stabilization. After this time the SCR output is ramped in response to the input control signal. The Transformer Inrush Protection (TIP) feature allows smooth, reliable control into the primary of a transformer, thus eliminating inrush currents which can occur if power is applied too rapidly to a tranformer.

Options Available

The most frequently used options are available for the 651 Series Power Control Units. These plug-in options can be supplied factory installed or in kit form easily added to an existing unit in the field.

The field installable kits include a plug-in option board, current or voltage transformers and complete installation instructions. They can easily be installed in just a few minutes. The option kits provide for faster delivery and reduced equipment costs. In addition, they allow the user to reduce inventory costs by stocking the basic units and option kits separately, combining them as required for the specific application.

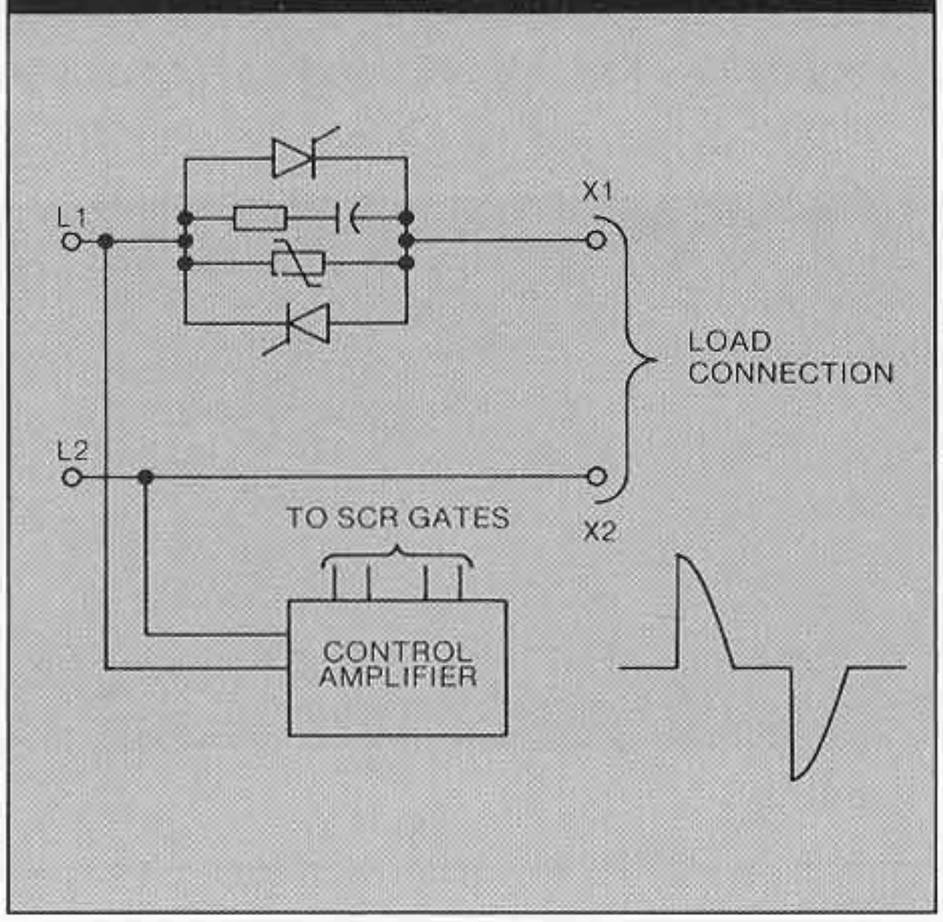
For added convenience the options can be provided factory installed at a nominal extra charge.

Each 651 Series unit will accept one plug-in option board with either one, or a combination of the options listed below:

1. Current Limit senses RMS current and limits output. Current limit adjustment is from 5% to over 100% of rating by a potentiometer on the option card.

2. Voltage Regulation adds RMS voltage feedback to the standard model. Voltage regulation is ±1% for line voltage excursions of +10%, -15% of nominal. This option also improves control linearity to ±1% from 0 to 100% output.

Schematic Drawing

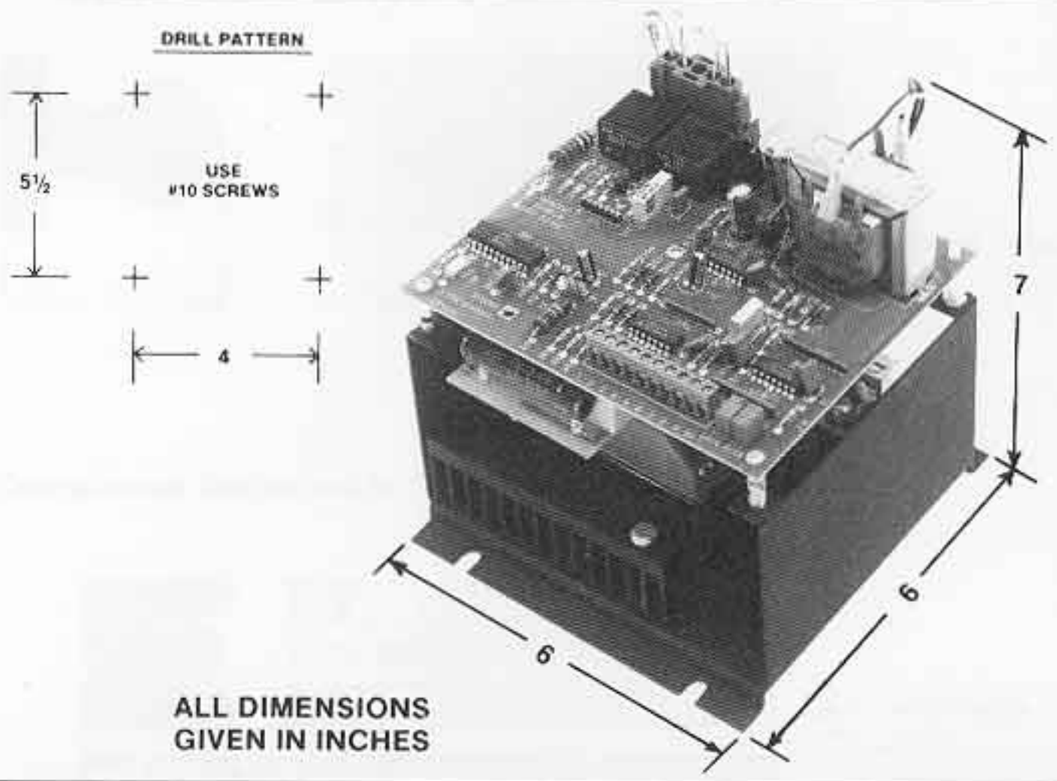


Control Connections

DC Control Signal	Input Control Terminal Points	Input Impedance
0-5 ma 2-12 ma 4-20 ma 10-50 ma 0-10 v	1 (+)-5 (-) 2 (+)-5 (-) 3 (+)-5 (-) 4 (+)-5 (-) 7 (+)-5 (-)	1000 ohms 400 ohms 250 ohms 100 ohms 200K ohms
Contact Closure	6 and 7	Close Contact to turn PCU on
Manual Control: Ends of Pot Slider of Pot	 6 and 8 7	 Connect a 10K ohm 2 watt potentiometer
Lockout (External shutdown contact)	8 and 10	Close Contact to turn PCU off

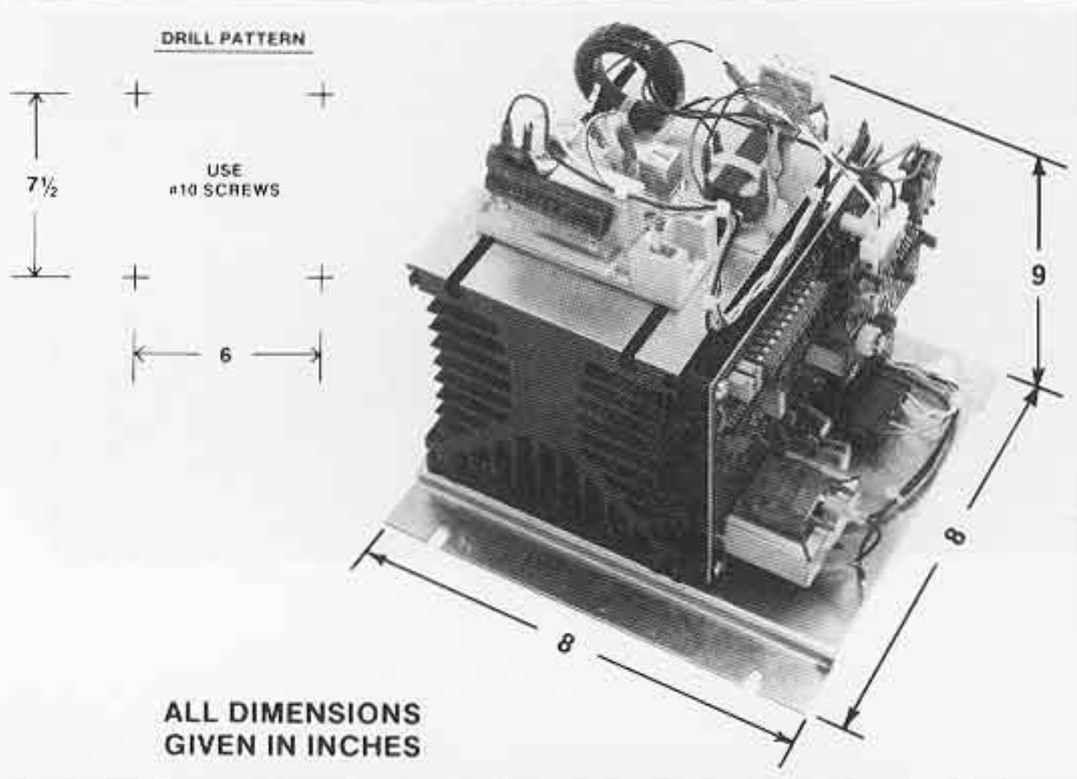
PHYSICAL DIMENSIONS

15 To 40 Amp



ALL DIMENSIONS GIVEN IN INCHES

60 To 110 Amp



ALL DIMENSIONS GIVEN IN INCHES

ORDERING INFORMATION

Amp Rating	CATALOG NUMBER		OPTIONS
	120-277 VAC	380-575 VAC	
15	651-277-15-00	651-575-15-00	To order options with the PCU replace last two digits with code shown for desired option.
40	651-277-40-00	651-575-40-00	
60	651-277-60-00	651-575-60-00	
80	651-277-80-00	651-575-80-00	
110	651-277-110-00	651-575-110-00	Option and Fusing Kits are also available separately. Please refer to next page.

Option	Factory Installed	Field Installable
Current Limit	1A	1K
Voltage Regulation	2A	2K
Current Limit and Voltage Regulation	3A	3K

Field Installable Options

The option kits allow for field installation of current limit or voltage regulation. Kits include the plug-in accessory board and current or voltage transformers as required.

PCU Amp Rating	Catalog Number		
	Current Limit	Voltage Regulation	Current Limit And Voltage Regulation
15	651-CL-15	651-VR	651-CLVR-15
40	651-CL-40	651-VR	651-CLVR-40
60	651-CL-60	651-VR	651-CLVR-60
80	651-CL-80	651-VR	651-CLVR-80
110	651-CL-110	651-VR	651-CLVR-110

Fuse Kits

Each Fuse Kit includes one I^2t current limiting fuse, fuse holder and wiring lugs. The Catalog Number is determined as follows:

650—FA1—_____ - _____

PCU Current rating _____ ┘ └ _____ Maximum voltage (except for 650-FA1-15)

Catalog Number	Fig.	A	B	C
650-FA1-15	2	N/A	N/A	N/A
650-FA1-40-277	1	5	1¾	1¾
650-FA1-40-575	1	5¾	1¾	1¾
650-FA1-60-277	1	5¾	1¾	1¾
650-FA1-60-575	1	5¾	1¾	1¾
650-FA1-80-277	1	5¾	1¾	1¾
650-FA1-80-575	1	5¾	1¾	2⅛
650-FA1-110-277	1	5¾	1¾	1¾
650-FA1-110-575	1	5¾	1¾	2⅛

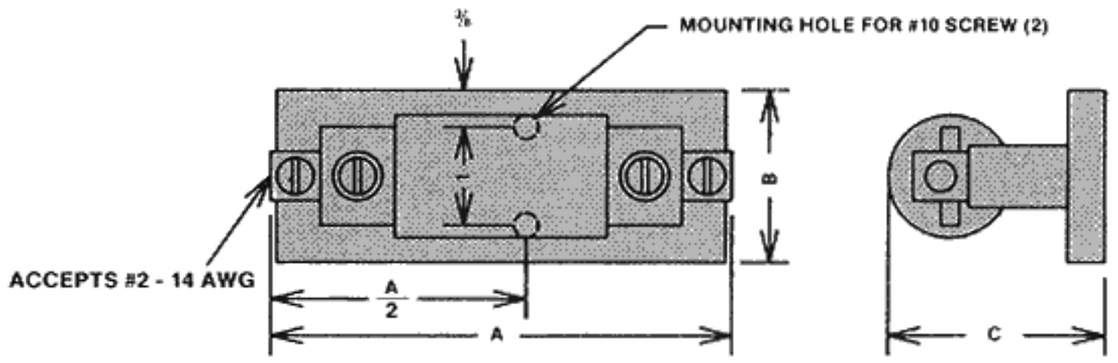


FIG. 1

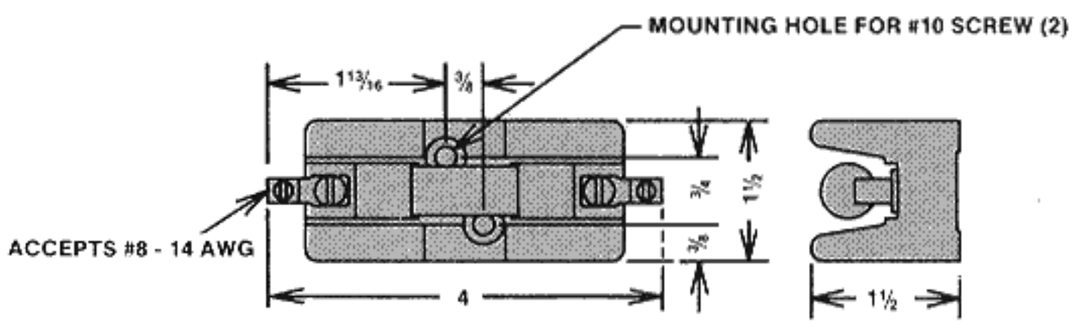
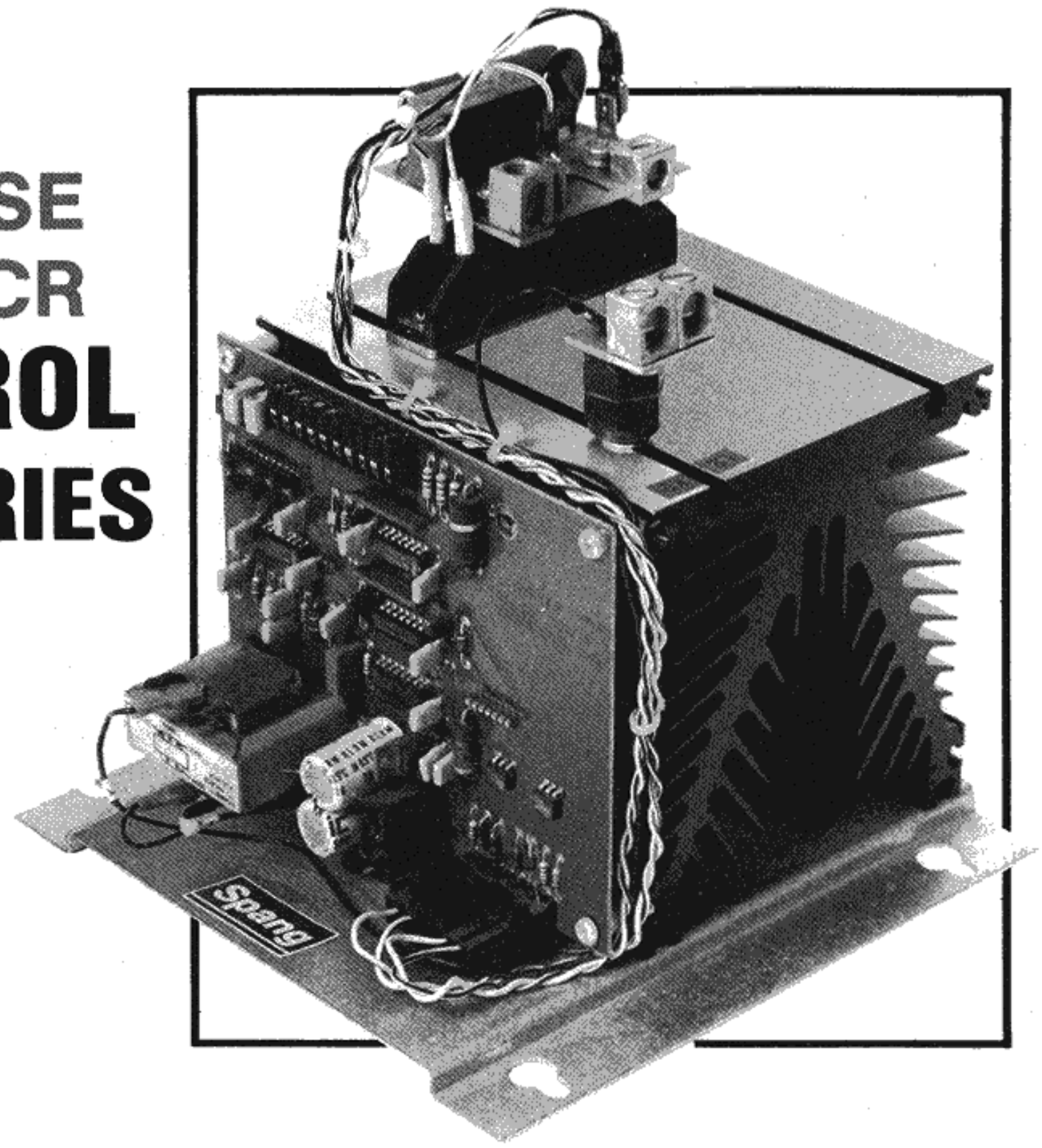


FIG. 2

Synchronous DEFINITE PURPOSE SINGLE PHASE SCR POWER CONTROL UNITS - 652 SERIES



Compact, Economical Proportional Control of Single Phase AC Power

Primarily used to control static resistive, non-inductive loads:

- **Small Electric Furnaces**
- **Electric Ovens and Heaters**
- **Extrusion and Forming Equipment**

- Variable ratio synchronous firing
- Standard ratings designed for 50° C maximum ambient
- Stepless control for proportional electric power
- Immunity to line distortions and fluctuations
- Accepts all standard control signals
- All ratings are convection cooled
- Electrically isolated heatsinks
- Optically isolated gate circuit

General Description

The 652 Series are definite purpose SCR Power Control Units, offering economical synchronous power control in a compact package. The latest advances in integrated circuit technology and power semiconductors have made this possible while maintaining the high quality and reliability that are traditional for Spang Power Electronics products.

The firing circuit utilizes CMOS integrated circuits and digital logic to ensure immunity from power line distortions.

All units in the 652 Series utilize isolated semiconductor power modules. The power module contains two SCRs connected in inverse parallel to control one line of a single phase load. The other line is connected directly through to the load.

These definite purpose units offer the most frequently used options, current limit and voltage regulation. These are available factory installed or in easy-to-add kit form. Where more elaborate control or higher current ratings are required, our KB series units described on pages 15-18 should be considered.

Also available from Spang Power Electronics is a complete line of SCR Power Control Units offering phase angle and synchronous (zero voltage) control in both three phase and single phase configurations.

Advantages of Variable Frequency Synchronous Firing:

- Conventional voltmeters and ammeters can be used for instrumentation at 50% to 100% voltage range.
- Infinitely variable output.
- Elimination of RFI.
- Power is distributed evenly over time.
- Variable ratio cycling rate provides smoothest most even power distribution over time.

Specifications for Synchronous Control

Input Voltage: The 652 Series units are available in two voltage ranges of 120 through 277 volts or 380 through 575 volts. They are shipped connected for the most popular voltages of 240 or 480 volts. Other voltages may be selected by simply moving a plug-in jumper. On the 277 volt unit input voltages of 120VAC, 208VAC, 240VAC or 277VAC may be selected. On the 575 volt unit input voltages of 380VAC, 416VAC, 480VAC and 575VAC are available.

Input Frequency: All units operate on 50 Hertz or 60 Hertz.

Connections: U.L. listed compression terminals are provided for both power and control connections.

Ambient: All ratings are designed for 50° C maximum operating temperature. For operation at higher temperatures (to 65° C maximum), some derating is necessary; please consult factory.

Input Signals: 0-5, 1-5, 2-12, 4-20, 10-50ma inputs (all standard temperature controller outputs) or a manual potentiometer. See Control Connections.

Adjustments: High resolution, 20 turn pentiometers are provided for all adjustments.

a. Gain adjustments provide full output for 50% to 200% standard control signal.

b. Bias adjustment for manual control to 100% output.

Voltage Protection:

a. Transient voltage suppression is provided by an R-C snubber network and metal oxide varistor (MOV) which clamps high voltage spikes to within the PRV rating of the semiconductors.

b. Standard PRV ratings:
380-575 volt units – 1200 volts
120-277 volt units – 800 volts

Reference Supply: A 12 volt DC regulated reference supply is available from the firing circuit for connection to a remote potentiometer, from which the Power Control Unit can be controlled manually. This supply is regulated to within ±½% for line voltage variations. Maximum current rating from this reference source is 10 milliamperes.

Cooling: The 652 Series Power Control Units are convection cooled. Use of isolated power modules provides electrical isolation of the heatsinks.

Options Available

The most frequently used options are available for the 652 Series Power Control Units. These plug-in options can be supplied factory installed or in kit form easily added to an existing unit in the field.

The field installable kits include a plug-in option board, current or voltage transformers and complete installation instructions. They can easily be installed in just a few minutes. The option kits provide for faster delivery and reduced equipment costs. In addition, they allow the user to reduce inventory costs by stocking the basic units and option kits separately, combining them as required for the specific application.

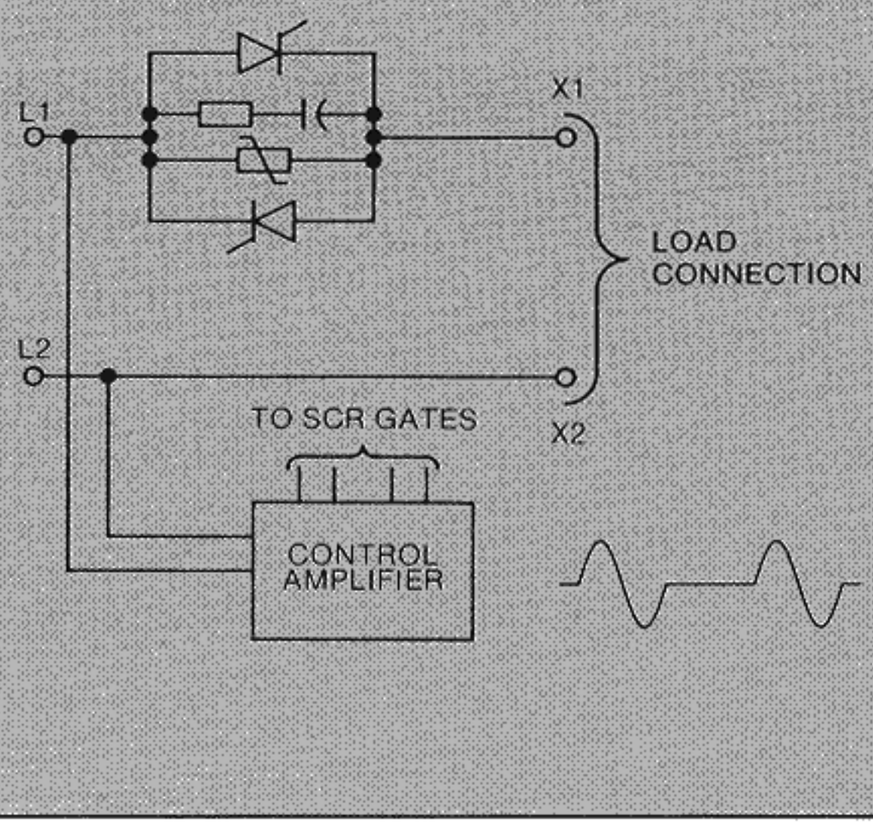
For added convenience the options can be provided factory installed at a nominal extra charge.

Each 652 Series unit will accept one plug-in option board with either one, or a combination of the options listed below:

1. Current Limit senses RMS current and limits output. Current limit adjustment is from 5% to over 100% of rating by a potentiometer on the option card.

2. Voltage Regulation adds RMS voltage feedback to the standard model. Voltage regulation is ±1% for line voltage excursions of +10%, −15% of nominal. This option also improves control linearity to ±1% from 0 to 100% output.

Schematic Drawing

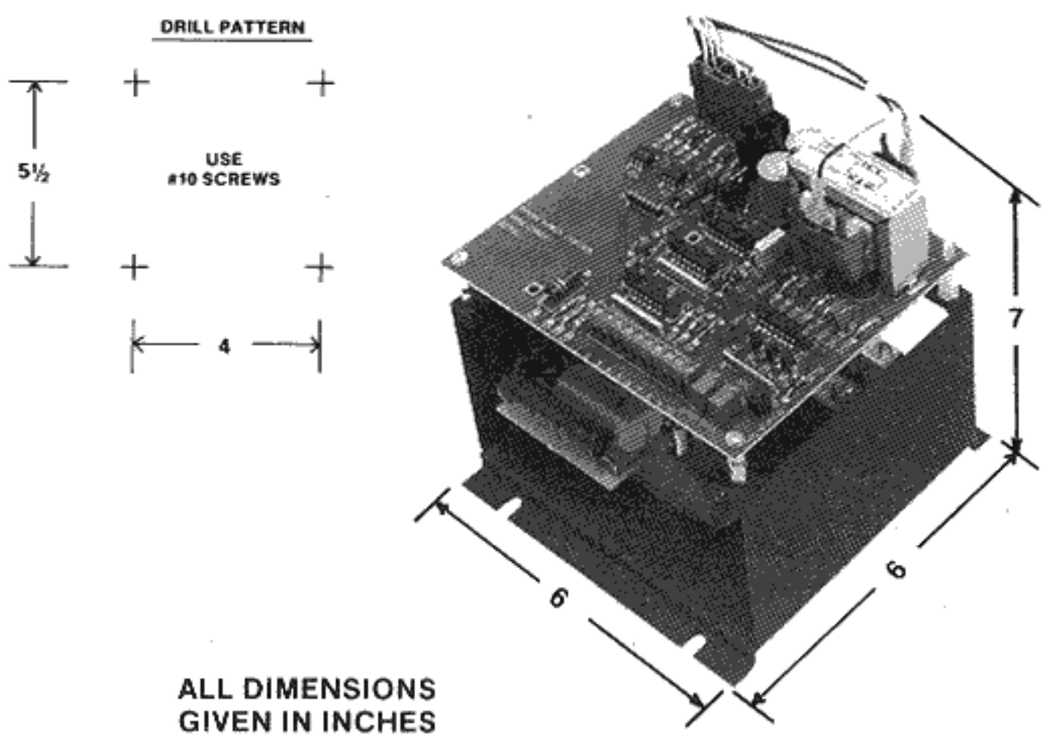


Control Connections

DC Control Signal	Input Control Terminal Points	Input Impedance
0-5 ma 2-12 ma 4-20 ma 10-50 ma 0-10 v	1 (+)-5 (−) 2 (+)-5 (−) 3 (+)-5 (−) 4 (+)-5 (−) 7 (+)-5 (−)	1000 ohms 400 ohms 250 ohms 100 ohms 200K ohms
Contact Closure	6 and 7	Close Contact to turn PCU on
Manual Control: Ends of Pot Slider of Pot	 6 and 8 7	 Connect a 10K ohm 2 watt potentiometer
Lockout (External shutdown contact)	6 and 10	Close Contact to turn PCU off

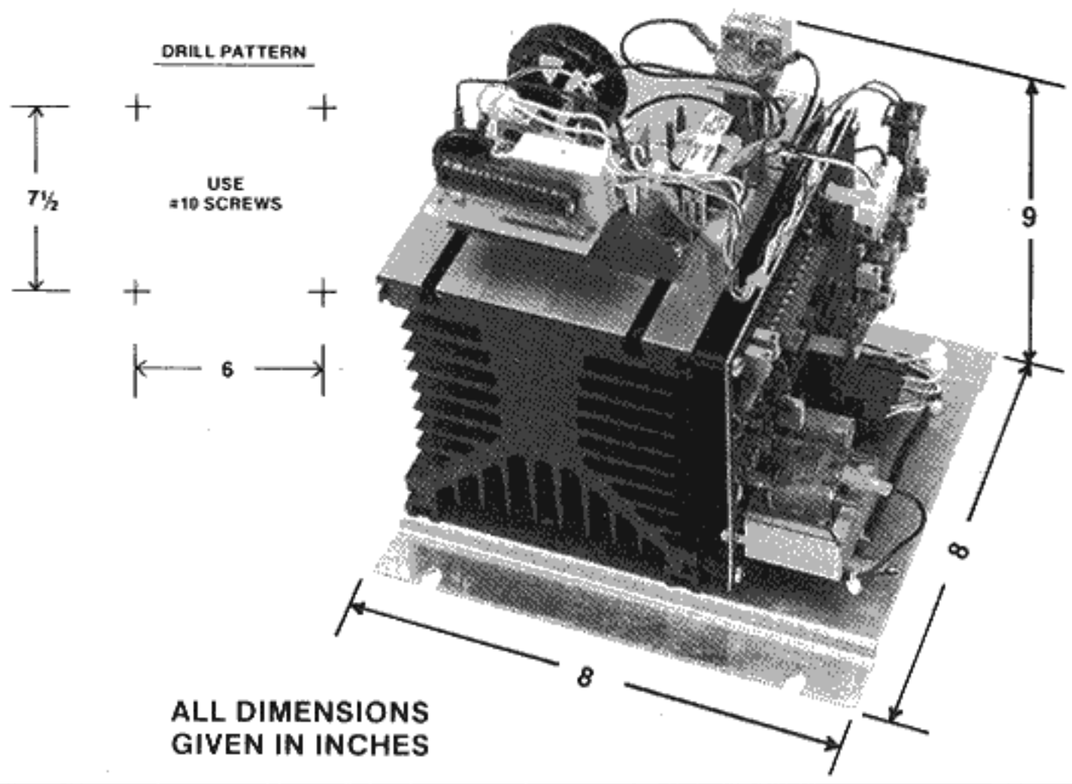
PHYSICAL DIMENSIONS

15 To 40 Amp



ALL DIMENSIONS GIVEN IN INCHES

60 To 110 Amp



ALL DIMENSIONS GIVEN IN INCHES

ORDERING INFORMATION

Amp Rating	CATALOG NUMBER 120-277 VAC	CATALOG NUMBER 380-575 VAC	OPTIONS
15	652-277-15-00	652-575-15-00	To order options with the PCU replace last two digits with code shown for desired option.
40	652-277-40-00	652-575-40-00	
60	652-277-60-00	652-575-60-00	
80	652-277-80-00	652-575-80-00	
110	652-277-110-00	652-575-110-00	

Option	Factory Installed	Field Installable
Current Limit	1A	1K
Voltage Regulation	2A	2K
Current Limit and Voltage Regulation	3A	3K

Option and Fusing Kits are also available separately. Please refer to next page.

Field Installable Options

The option kits allow for field installation of current limit or voltage regulation. Kits include the plug-in accessory board and current or voltage transformers as required.

PCU Amp Rating	Catalog Number		
	Current Limit	Voltage Regulation	Current Limit And Voltage Regulation
15	652-CL-15	652-VR	652-CLVR-15
40	652-CL-40	652-VR	652-CLVR-40
60	652-CL-60	652-VR	652-CLVR-60
80	652-CL-80	652-VR	652-CLVR-80
110	652-CL-110	652-VR	652-CLVR-110

Fuse Kits

Each Fuse Kit includes one I^2t current limiting fuse, fuse holder and wiring lugs. The Catalog Number is determined as follows:

650—FA1—_____ - _____

PCU Current rating _____ ┘ └ _____ Maximum voltage (except for 650-FA1-15)

Catalog Number	Fig.	A	B	C
650-FA1-15	2	N/A	N/A	N/A
650-FA1-40-277	1	5	1¾	1¾
650-FA1-40-575	1	5¾	1¾	1¾
650-FA1-60-277	1	5¾	1¾	1¾
650-FA1-60-575	1	5¾	1¾	1¾
650-FA1-80-277	1	5¾	1¾	1¾
650-FA1-80-575	1	5¾	1¾	2⅛
650-FA1-110-277	1	5¾	1¾	1¾
650-FA1-110-575	1	5¾	1¾	2⅛

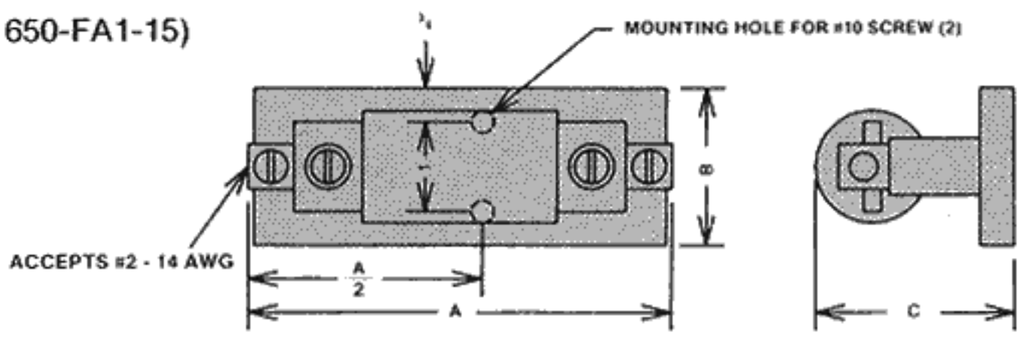


FIG. 1

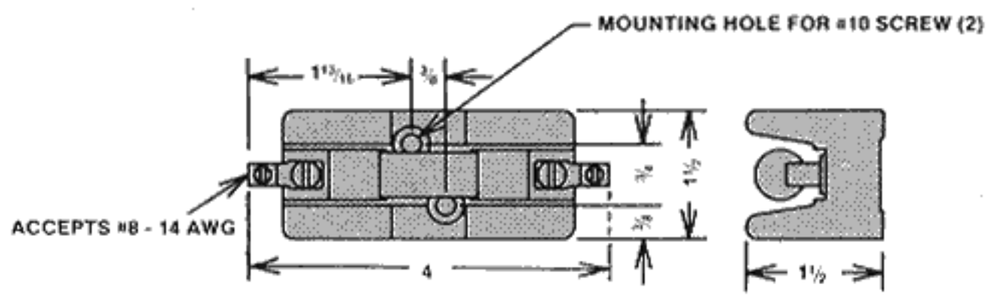
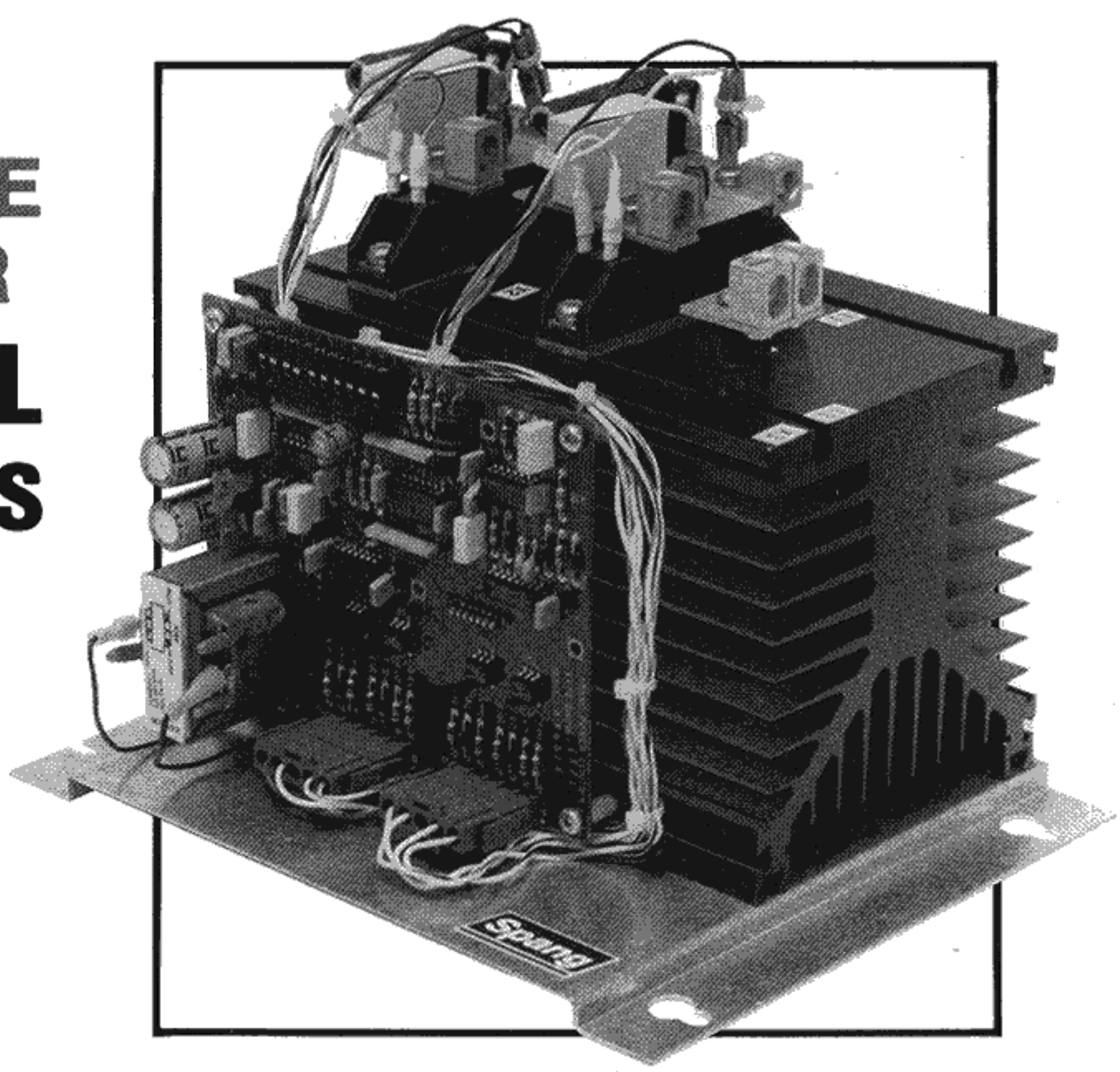


FIG. 2

Spang Power Electronics

Synchronous DEFINITE PURPOSE THREE PHASE SCR POWER CONTROL UNITS - 654 SERIES



Compact, Economical Proportional Control of Three Phase AC Power

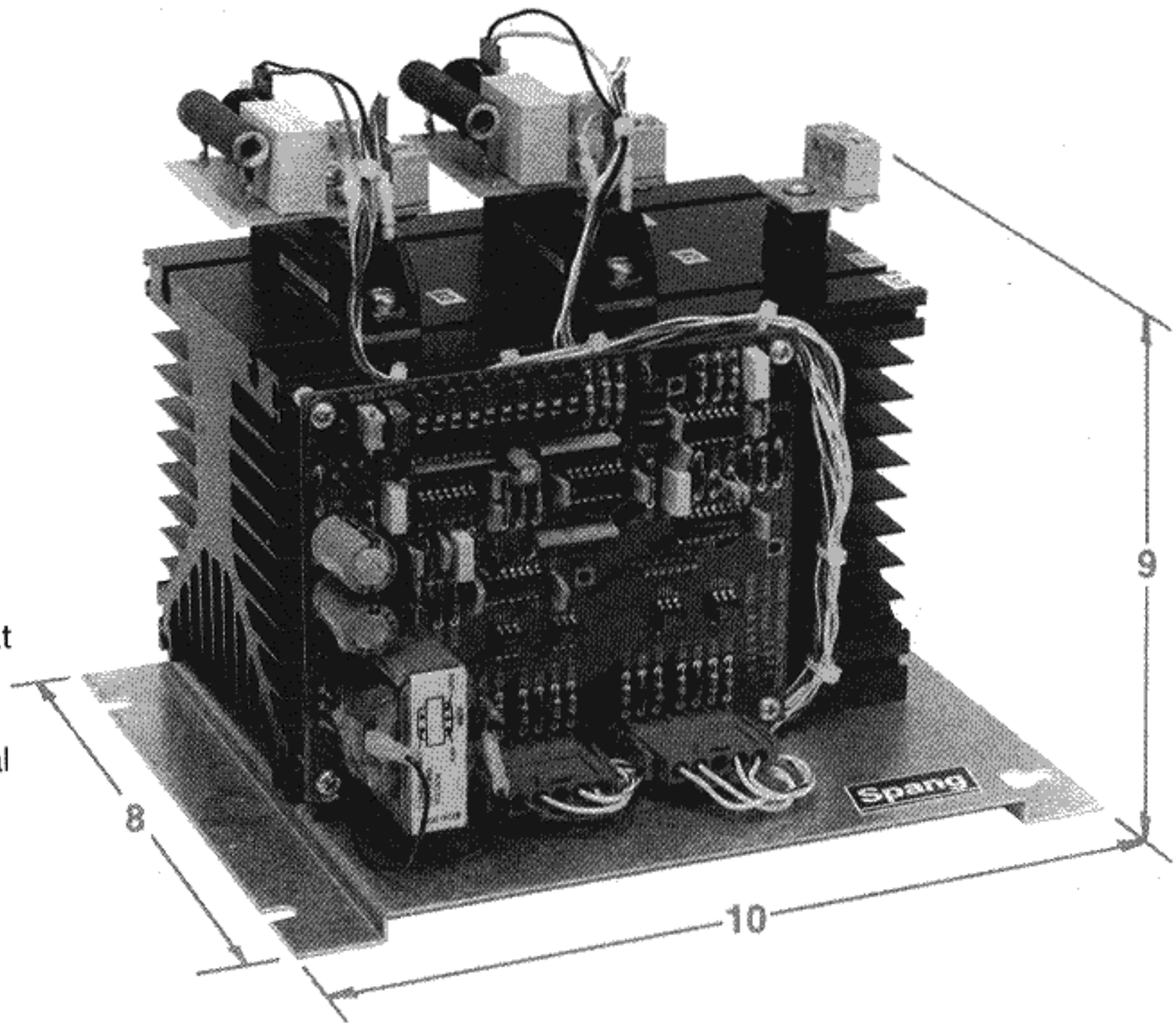
Primarily used to control static resistive, non-inductive loads:

- **Small Electric Furnaces**
- **Electric Ovens and Heaters**
- **Extrusion and Forming Equipment**

STANDARD FEATURES

- Variable ratio synchronous firing
- Standard ratings designed for 50° C maximum ambient
- Stepless control for proportional electric power
- Immunity to line distortions and fluctuations
- Accepts all standard control signals
- All ratings are convection cooled
- Electrically isolated heatsinks
- Optically isolated gate circuit

Synchronous
DEFINITE PURPOSE
THREE PHASE SCR
POWER CONTROL UNITS - 654 SERIES



The 654 Series are definite purpose SCR Power Control Units, offering economical synchronous power control in a compact package. The latest advances in integrated circuit technology and power semiconductors have made this possible while maintaining the high quality and reliability that are traditional for Spang Power Electronics products.

The firing circuit utilizes CMOS integrated circuits and digital logic to ensure immunity from power line distortions.

All units in the 654 Series utilize two isolated semiconductor power modules. The power modules each contain two SCRs connected in inverse parallel to control two lines of a three phase load. The other line is connected directly to the load.

These definite purpose units offer the most frequently used options, current limit and voltage regulation. These are available factory installed or in easy-to-add kit form. Where more elaborate control or higher current ratings are required, our KB and LB series units should be considered.

Also available from Spang Power Electronics is a complete line of SCR Power Control Units offering phase angle and synchronous (zero voltage) control in both three phase and single phase configurations.

Advantages of Variable Frequency Synchronous Firing:

- Conventional voltmeters and ammeters can be used for instrumentation at 50% to 100% voltage range.
- Infinitely variable output.
- Elimination of RFI.
- Power is distributed evenly over time.
- Variable ratio cycling rate provides smoothest most even power distribution over time.

Specifications for Synchronous Control

Input Voltages: The 654 Series units are available in two voltage ranges of 120 through 277 volts or 380 through 575 volts. They are shipped connected for the most popular voltages of 240 or 480 volts. Other voltages may be selected by simply moving a plug-in jumper. On the 277 volt unit input voltages of 120VAC, 208VAC, 240VAC or 277VAC may be selected. On the 575 volt unit input voltages of 380VAC, 416VAC, 480VAC and 575VAC are available.

Input Frequency: All units operate on 50 Hertz or 60 Hertz.

Connections: U.L. listed compression terminals are provided for both power and control connections.

Ambient: All ratings are designed for 50° C maximum operating temperature. For operation at higher temperatures (to 65° C maximum), some derating is necessary; please consult factory.

Input Signals: Accepts all standard control signals and a manual potentiometer. See control connection chart.

Adjustments: High resolution, 20 turn potentiometers are provided for all adjustments.

a. Gain adjustments provide full output for 50% to 200% standard control signal.

b. Bias adjustment for manual control to 100% output.

Voltage Protection:

a. Transient voltage suppression is provided by an R-C snubber network and metal oxide varistor (MOV) which clamps high voltage spikes to within the PRV rating of the semiconductors.

b. Standard PRV ratings:
380-575 volt units — 1200 volts
120-277 volt units — 800 volts

Reference Supply: A 12 Volt DC regulated reference supply is available from the firing circuit for connection to a remote potentiometer, from which the Power Control Unit can be controlled manually. This supply is regulated to within ±½% for line voltage variations. Maximum current rating from this reference source is 10 milliamperes.

Cooling: The 654 Series Power Control Units are convection cooled. Use of isolated power modules provides electrical isolation of the heatsinks.

Options Available

The most frequently used options are available for the 654 Series Power Control Units. These plug-in options can be supplied factory installed or in kit form easily added to an existing unit in the field.

The field installable kits includes a plug-in option board, current or voltage transformers and complete installation instructions. They can easily be installed in just a few minutes. The option kits provide for faster delivery and reduced equipment costs. In addition, they allow the user to reduce inventory costs by stocking the basic units and option kits separately, combining them as required for the specific application.

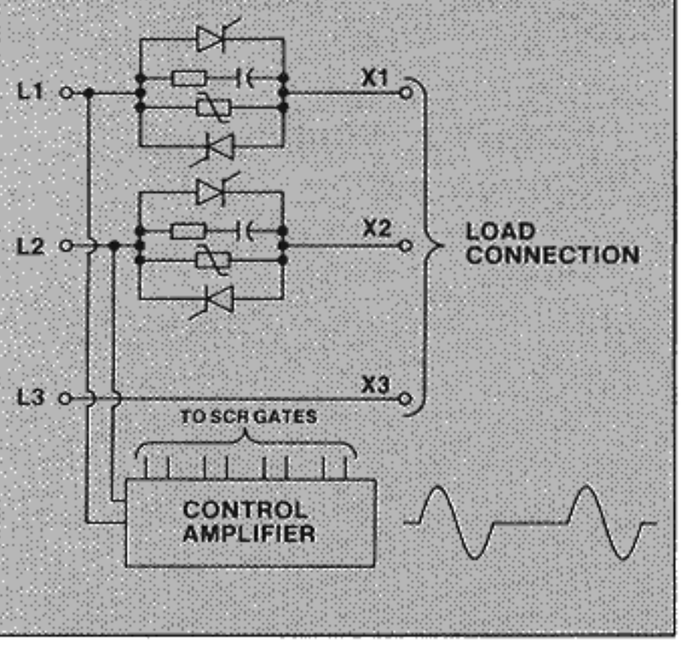
For added convenience the options can be provided factory installed at a nominal extra charge.

Each 654 Series unit will accept one plug-in option board with either one, or a combination of the options listed below:

1. **Current Limit** senses RMS current and limits output. Current limit adjustment is from 5% to over 100% of rating by a potentiometer on the option card.

2. **Voltage Regulation** adds RMS voltage feedback to the standard model. Voltage regulation is ±1% for line voltage excursions of +10%, -15% of nominal. This option also improves control linearity to ±1% from 0 to 100% output.

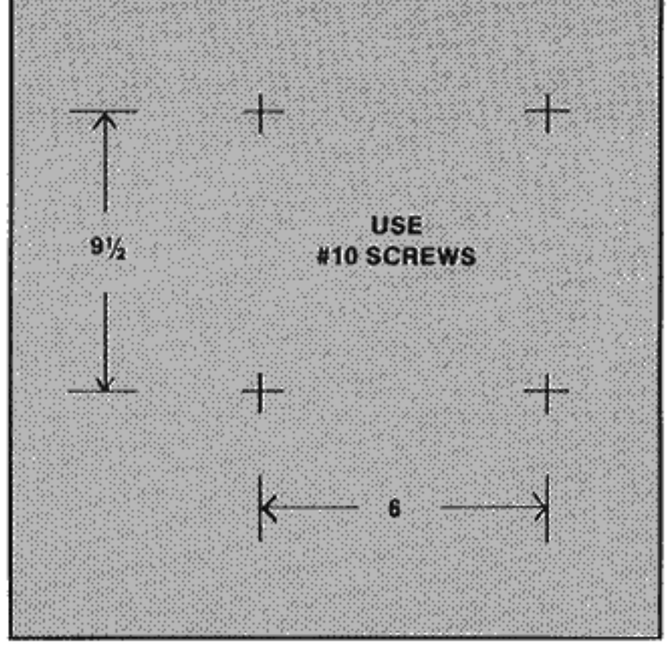
SCHEMATIC



CONTROL CONNECTORS

DC Control Signal	Input Control Terminal Points	Input Impedance
0-5 ma 2-12 ma 4-20 ma 10-50 ma 0-10 v	1 (+)-5 (-) 2 (+)-5 (-) 3 (+)-5 (-) 4 (+)-5 (-) 7 (+)-5 (-)	1000 ohms 400 ohms 250 ohms 100 ohms 200K ohms
Contact Closure	6 and 7	Close Contact to turn PCU on
Manual Control: Ends of Pot Slider of Pot	 6 and 8 7	 Connect a 10K ohm 2 watt potentiometer
Lockout (External shutdown contact)	6 and 10	Close Contact to turn PCU off

DRILL PATTERN



ORDERING INFORMATION

Amp Rating	CATALOG NUMBER 120-277 VAC	CATALOG NUMBER 380-575 VAC
50	654-277-50-00	654-575-50-00
75	654-277-75-00	654-575-75-00

OPTIONS

To order options with the PCU replace **last two digits** with code shown for desired option.

Option	Factory Installed	Field Installable
Current Limit	1A	1K
Voltage Regulation	2A	2K
Current Limit and Voltage Regulation	3A	3K

Option and Fusing Kits are also available separately. Please refer to next page.

Field Installable Options

The option kits allow for field installation of current limit or voltage regulations. Kits include the plug-in accessory board and current or voltage transformers as required.

PCU Amp Rating	Catalog Number		
	Current Limit	Voltage Regulation	Current Limit And Voltage Regulation
50	652-CL-60	652-VR	652-CLVR-60
75	652-CL-80	652-VR	652-CLVR-80

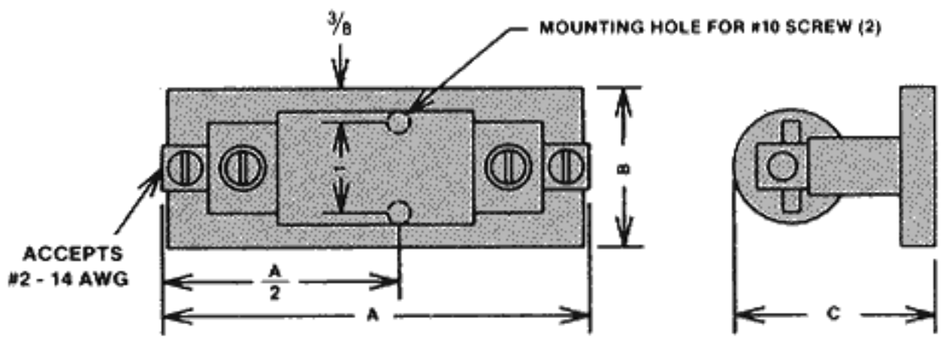
Fuse Kits

Each fuse kit includes one I^2t current limiting fuse, fuse holder and wiring lugs. The Catalog Number is determined as follows:

650—FA1—_____ - _____

Current rating_____ ____ Maximum voltage

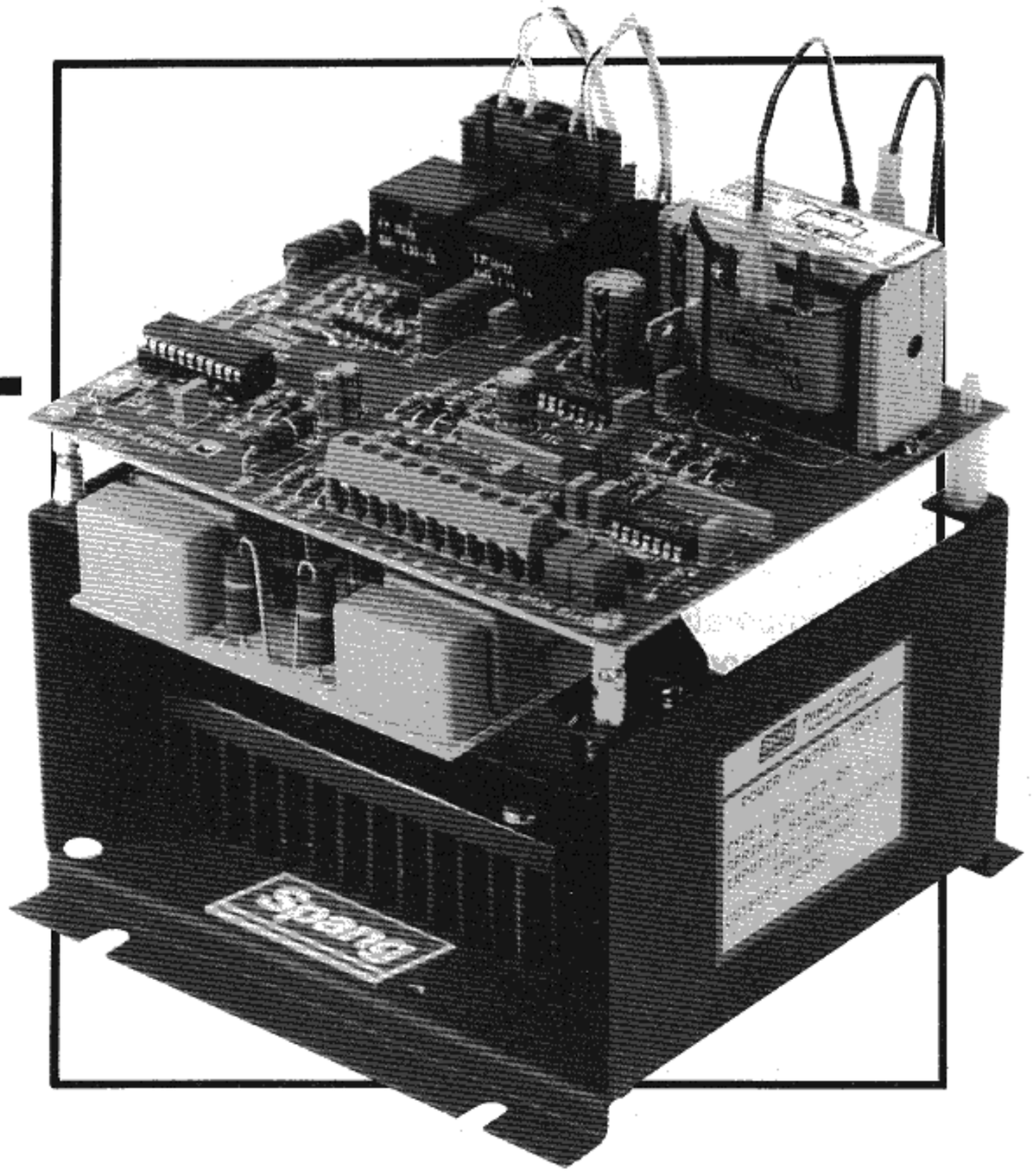
Catalog Number	PCU Amps	A	B	C
650-FA1-60-277	50	5¾	1¾	1¾
650-FA1-60-575		5¾	1¾	1¾
650-FA1-80-277	75	5¾	1¾	1¾
650-FA1-80-575		5¾	1¾	2⅛



NOTE: One kit is required for each phase to be fused.

Spang Power Electronics

Phase Angle Control DEFINITE PURPOSE SINGLE PHASE SCR DC POWER CONTROL UNITS - 653 SERIES



Compact, Economical Proportional Control of Single Phase DC Power

For control of static resistive or inductive loads:

- **Saturable Reactor Driver**
- **Generator Field Control**
- **Eddy Current Brakes**
- **Eddy Current Clutches**
- **Small Electromagnets**

STANDARD FEATURES

- Electronic design utilizing Large Scale Integration
- Phase lock loop for firing pulse synchronization
- Stepless control for proportional electric power
- Immunity to line distortions and fluctuations
- Electrically isolated heatsinks
- Pulse transformer gate isolation
- Accepts all standard control signals

Specifications

Output Rating: 20 amperes DC average at full output voltage.

Input Voltage: All units are shipped connected for 240VAC input. 120VAC, 208VAC, or 277VAC may be selected by moving a plug-in jumper.

Input Frequency: All units are shipped connected for 60 Hertz operation. Conversion to 50 Hertz is achieved by simply removing a jumper.

Connections: UL listed compression terminals are provided for both power and control connections.

Ambient: All ratings are designed for 50°C maximum operating temperature. For operation at higher temperatures (to 65°C maximum), some derating is necessary; please consult factory.

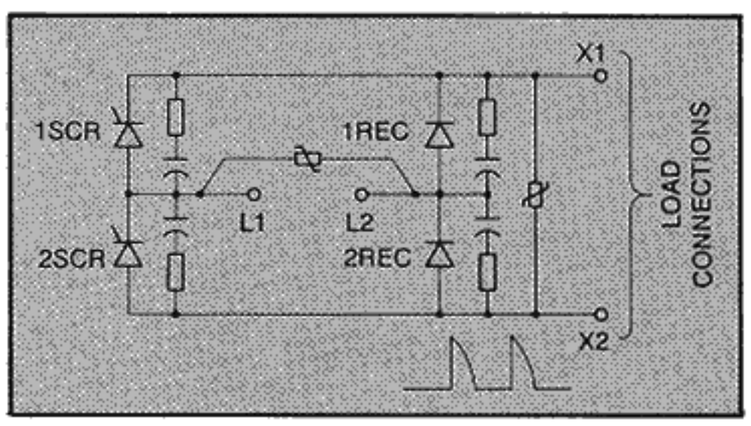
Input Signals: 0-5, 1-5, 2-12, 4-20, 10-50ma inputs or a manual potentiometer (see chart).

Adjustments: High resolution, 20 turn potentiometers are provided for all adjustments.

a. Gain adjustments provide full output for 50% to 200% standard control signal.

b. Bias adjustment for manual control to 100% output.

Voltage Protection: Transient voltage suppression is provided by an R-C snubber network and a metal oxide varistor (MOV) which clamps high voltage spikes to within the standard 1200 volt PRV rating of the semiconductors.



Reference Supply: A 12 volt DC regulated reference supply is available from the firing circuit for connection to a remote potentiometer from which the unit can be controlled manually. This supply is regulated to within ±½% for line voltage variations. Maximum current rating from this reference source is 10 milliamperes.

Cooling: All units are convection cooled with electrically isolated heatsinks. Optional fan kit is available.

Soft Start: An integral soft start ramp is provided on all units. Upon initial energization, gate firing is inhibited for a short dead time to allow for circuit stabilization. After this time the SCR output is ramped in response to the input control signal.

Special Applications and Options

I²t Fusing: Fuse kit 650-FA1-40-277 connected in series with either L1 or L2 protects the SCRs and diodes from current surges.

Forced Air Cooling: Fan kit 11596-0006 mounted below the power control unit to provide forced air cooling increases the unit's output to 30 amperes DC.

Voltage Regulation and Current Limit: RMS voltage regulation of load voltage controlled by a saturable reactor and rms current limit of the load current requires the following:

CONTROL CONNECTIONS

DC CONTROL SIGNAL	INPUT CONTROL TERMINAL POINTS	INPUT IMPEDANCE
0-5 ma 2-12 ma 4-20 ma 10-50 ma 0-10 v	1 (+) 5 (-) 2 (+) 5 (-) 3 (+) 5 (-) 4 (+) 5 (-) 7 (+) 5 (-)	1000 ohms 400 ohms 250 ohms 100 ohms 200K ohms
Contact Closure	6 and 7	Close Contact to turn PCU ON
Manual Control: Ends of Pot Slider of Pot	 6 and 8 7	 Connect to a 10K ohm 2 Watt Potentiometer
Lockout (External shutdown contact)	8 and 10	Close Contact to turn PCU OFF

a. 11719-0106 accessory card mounted to the unit's control amplifier.

b. E7036 voltage feedback transformer connected to the voltage being regulated and plugged into the accessory card.

c. 650-CT-15 current limiting CT plugged into the accessory card.

d. Three turns of feedback from the 5 ampere secondary of a CT measuring load current placed through the 650-CT-15 current limiting CT.

Current Limit: RMS current limiting of the actual load current of the saturable reactor in a driver application requires the following:

a. 11719-0101 accessory card mounted on the unit's control amplifier.

b. 650-CT-15 current limiting CT plugged into the accessory card.

c. Three turns of feedback from the 5 ampere secondary of a CT measuring load current placed through the 650-CT-15 current limiting CT.

d. To provide RMS current limit of the actual driver output current, place the line current to either L1 or L2 through the window of the 650-CT-15 current limiting CT one time.

Ordering Information

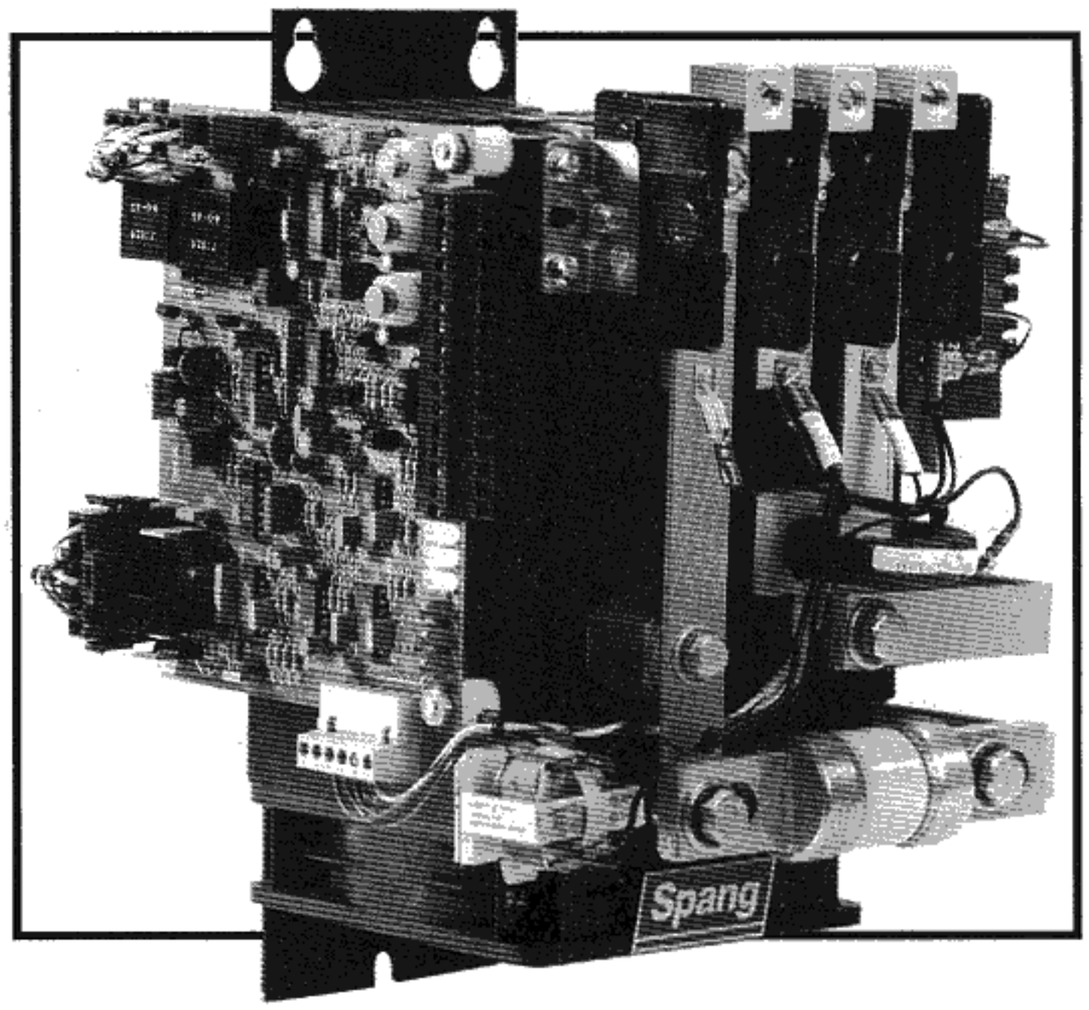
Model No.: 653-277-20
Current Rating: 20 Amps
Input Voltage: 120-277 VAC

PHYSICAL DIMENSIONS

15 To 40 Amp

Spang Power Electronics

Phase Angle Control SINGLE PHASE SCR POWER CONTROL UNITS-75I SERIES



Compact, Economical Proportional Control of Single Phase AC Power

Primarily used to control dynamic resistive, or transformer-coupled loads in:

- **Electric Furnaces**
- **Electric Ovens and Heaters**
- **Vibratory Feeders**
- **Extrusion and Forming Equipment**

STANDARD FEATURES

- Electronic design utilizing large scale integration and digital logic
- Four modes of regulation - voltage, current, power or open loop
- Four modes of limiting - voltage, current, power or none
- Diagnostic indication of lockout, limit, and gate signal
- East mounting - Easy service access
- Quick-change I^2t fusing system
- Completely self-contained - No separate voltage required for standard voltages
- Accepts all standard control signals
- Silver plated all-copper bus bar
- Gate signal lockout
- Standard ratings designed for 50°C maximum ambient
- Immunity to line distortion
- Stepless control for proportional electric power

General Description

The 751 Series are general purpose single phase SCR Power Control Units, offering economical phase angle power control in a compact package. The latest advances in integrated circuit technology and power semiconductors have made this possible while maintaining high quality and reliability.

The firing circuit utilizes BIPOLAR integrated circuits and digital logic to ensure immunity from power line distortions. State of the art Large Scale Integration (LSI) allows for a compact design with improved reliability.

All units in the 751 Series utilize isolated power modules. The power module contains two SCRs connected in inverse parallel to control one line of a single phase load. The other line is connected directly through the load.

These general purpose units offer all of the most frequently used options as standard equipment. The features that are an integral part of this unit are:

1) Four different modes of regulation - voltage, current, power, or open loop
2) Four different modes of limiting - voltage, current, power, or none
3) Visual indication of firing, limiting, and inhibit
4) Semiconductor fusing
5) Two-piece terminal blocks located on top of the unit for easy installation and service
6) Internal transducers for monitoring voltage, current and power
7) Current source transducers (1ma) for increased accuracy
8) Convenient mounting of unit and power connecting
9) Integral CT and PT for regulation
10) Accepts feedback signal from user-supplied current and potential transformers if desired

These features allow the user to customize the PCU to suit the load or process right on site. Additionally, it allows the user the flexibility to change his process at any time in the future without purchasing different hardware.

Advantages of Phase Angle Firing:

- Conventional voltmeters and ammeters can be used for instrumentation over 0 to 100% voltage range.
- Infinitely variable output.
- Operation into dynamic loads (i.e., transformers).

Specifications for Phase Angle Control

Input Voltage: The 751 series units are available in three voltage ranges of 120/208/277, 240/480, or 380/415/575 volts. Specific voltages within the range may be selected by simply moving a plug-in jumper on the power supply board and the voltage feedback transformer.

Input Frequency: All units are capable of either 50Hz or 60 Hz operation without modification or adjustment.

Connections: UL listed compression terminals are provided for both power and control connections.

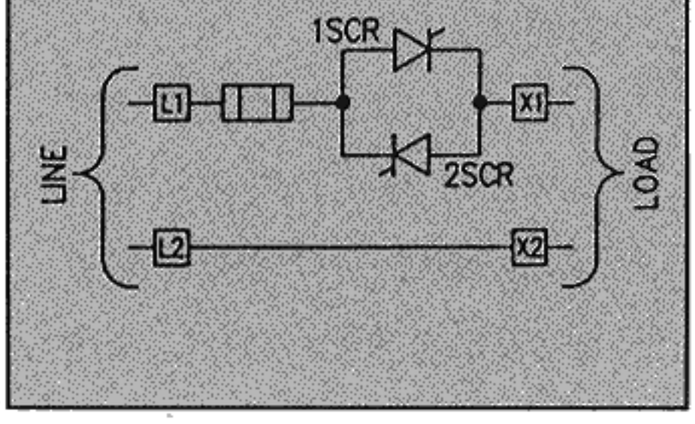
Ambient: All ratings are designed for 50°C maximum operating temperature. For operation at higher temperatures (to 65°C maximum), some derating is necessary; please consult factory.

Input Signals: 0-5, 2-12, 4-20, 10-50 ma inputs (all standard temperature controller outputs) or a manual potentiometer. See chart on page 42.

Adjustments: High resolution, 20 turn potentiometers are provided for all adjustments.

a. Gain adjustments provide full output for 50% to 200% standard control signal.
b. Bias adjustment for manual control to 100% output.

Single Phase Schematic



Voltage protection:

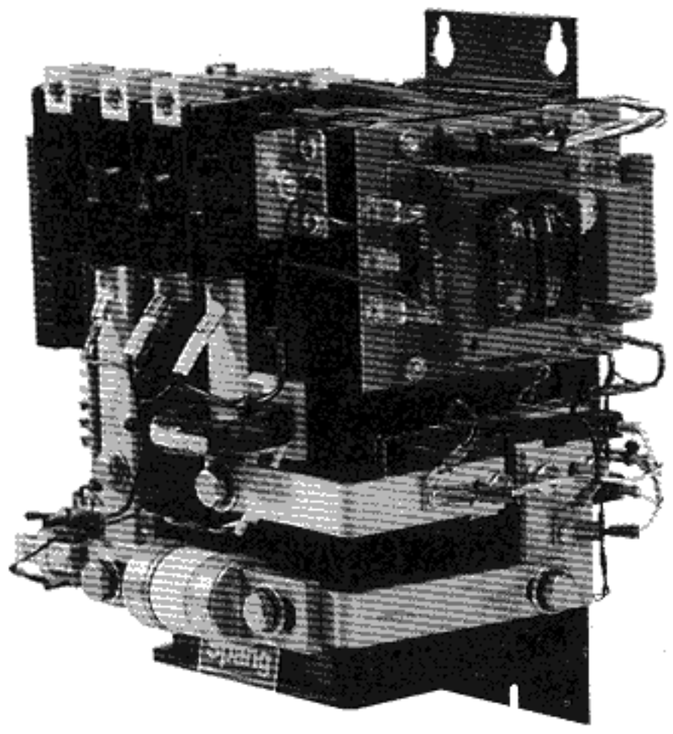
a. Transient voltage suppression is provided by an R-C snubber network and metal oxide varistor (MOV) which clamps high voltage spikes to within the PRV rating of the semiconductors.

b. Standard PRV rating:
120-575 volt units - 1200 volts

Reference supply: A 12VDC regulated reference supply is available from the firing circuit for connection to a remote potentiometer, from which the Power Control Unit can be controlled manually. This supply is regulated to within ± ½% for line voltage variations. Maximum current rating from this reference source is 10 milliamperes.

Cooling: The 50 amp current size is convection cooled. Larger sizes are forced-air cooled by integral cooling fans.

TIP (Soft Start): An integral soft start ramp is provided on all 751 Series units. Upon initial energization, gate firing is inhibited for a short dead time to allow for circuit stabilization. After this time the SCR output is ramped in response to the input control signal. The Transformer Inrush Protection (TIP) feature allows smooth, reliable control into the primary of a transformer, thus eliminating nuisance fuse blowing due to high inrush currents which can occur if power is applied too rapidly to a transformer.



Limits and Regulation

The 751 Series provides a choice of three types of limit control and three modes of regulation as standard equipment. Each type is easily field-selectable by simply moving the appropriate shunt on the control amplifier circuit board. Any combination of regulation or limit is possible, including no limit and open loop.

Limits

1. Current limit - senses rms current and limits output. Current limit adjustment is from 5% to over 100% of rating by a potentiometer on the firing circuit.

2. Voltage limit - senses rms voltage and limits output. Voltage limit adjustment is from 5% to over 100% of rating by a potentiometer on the firing circuit.

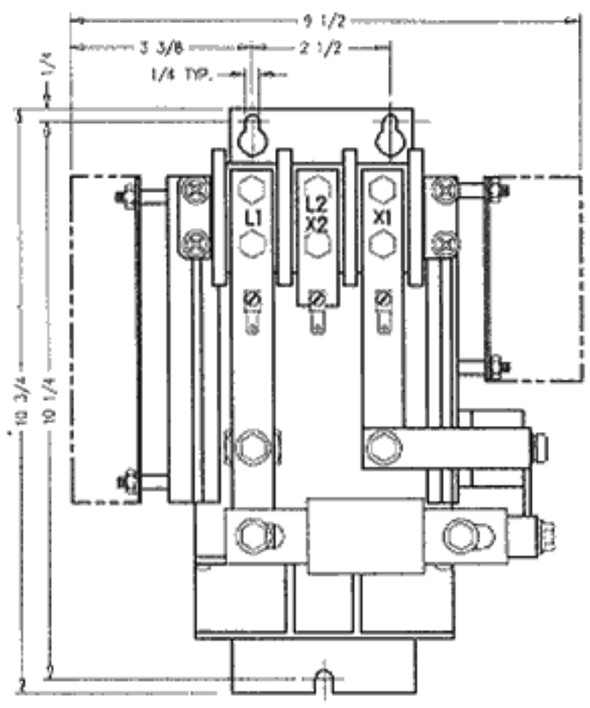
3. Watt limit - senses both rms current and voltage to limit the output kva to a preset value. Watt limit adjustment is from 5% to 100% of rating by a potentiometer on the firing circuit.

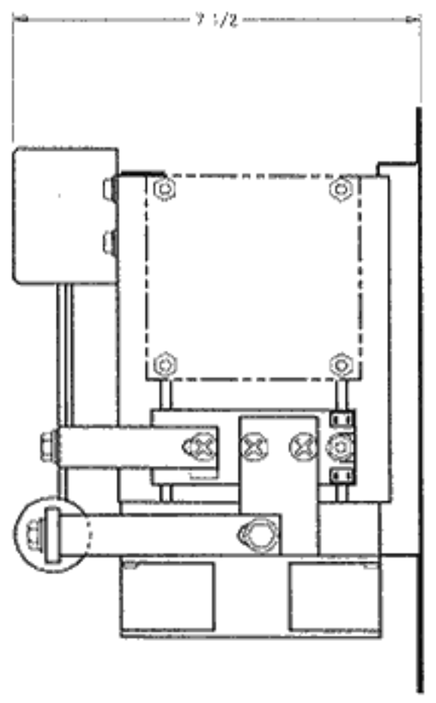
Regulation

1. Voltage regulation - maintains output voltage to ±1% for line voltage fluctuations of +10% to -15% of nominal and provides an rms output voltage that is linear to the control signal within ±1% from 0 to 100% output.

2. Current regulation - compensates for both line and load fluctuations and provides constant rms current proportional to the control signal. Current regulation is ±1% of setpoint.

3. Watt regulation - regulates output kilowatts to within ±1% of the setpoint.





Spang Power Electronics

Indication

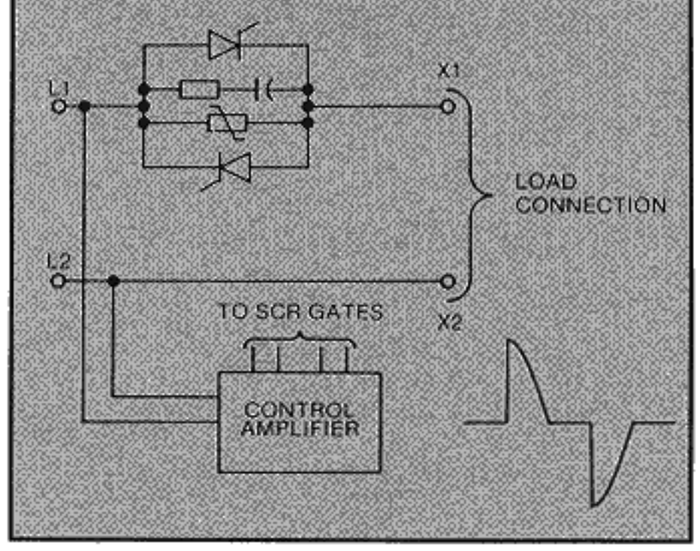
Three LED indicators are located on the side of the circuit board above the gain, bias, and limit potentiometers. These LEDs indicate the status of the SCR unit by giving a visual indication of the operation.

LED1 is a bicolor device that shows if the SCR unit output is being limited. Normally this device should show a green indication - no limiting action is taking place (the control signal is less than the setpoint of the limit). A yellow or orange color indicates that the firing angle is beginning to be limited (the control signal is approaching the setpoint of the limit.) A red color indicates that the unit is hard into a limit (the control signal is far greater than the setpoint of the limit).

LED2 is a bicolor device that shows a normal operating condition when green or an intentional disabling of the SCR gates. This "lockout" condition is present when Terminals 3 and 4 of the TB1 are shorted together and the LED2 glows red. LED2 also glows red on initial power up of the unit and then changes to green after 1.5 to 2 seconds.

LED3 is a bicolor device that indicates the presence of a gate signal to the SCRs. At any firing angle this LED will glow orange if gate signals are being sent to the SCRs. This indication allows for an easy bias adjustment by just observing this LED while adjusting the potentiometer.

Schematic Drawing



Control Connections

DC Control Signal	Input Control Terminal Points	Shunt Position	Input Impedance
0-5 mA	5(+) 6(-)	5 mA	1000 ohms
2-12 mA	5(+) 6(-)	12 mA	400 ohms
4-20 mA	5(+) 6(-)	20 mA	250 ohms
10-50 mA	5(+) 6(-)	50 mA	100 ohms
0-10 v or Manual	9(+) 10(-)	Manual	200K ohms
Contact Closure	8 and 9		Close contact to turn PCU on
Manual Controls: Ends of pot Slider of pot	 8 and 10 9	Manual	 Connect a 10K ohm, 2 watt potentiometer
Lockout (external shutdown contact)	3 and 4		Close contact to turn PCU off
Watt transducer output (0-1mA)	11 and 10		
Voltage transducer output (0-1mA)	13 and 14		
Current transducer output (0-1mA)	15 and 16		

Amp Rate	Catalog Number		
	120-208-277 VAC	204-480 VAC	380-415-575 VAC
50	751-277-50	751-480-50	751-575-50
100	751-277-100	751-480-100	751-575-100
175	751-277-175	751-480-175	751-575-175

SOLID-STATE CONTACTOR SSC100

The SSC100 is a solid-state contactor designed to control resistive heating elements and as a replacement for electro-mechanical contactors and mercury relays on directly connected resistive loads. These devices provide the same features as a relay with several important advantages:

- The SSC100 is capable of millions of operating cycles since they contain no moving parts to wear out. Semiconductor switching eliminates mechanical contacts which can chatter, bounce, or become damaged by arcing.
- The SSC100 produces no RFI, harmonics, or other electrical noise. ON and OFF switching always takes place at the zero crossing of the voltage cycle.
- The SSC100 provides a much finer resolution of control. Because of the extremely fast switching of the semiconductors, operation is not limited by a mechanical response time.
- The SSC100 contains no mercury or other environmentally hazardous components . For safety, the SSC100s heatsink is electrically isolated and all electrically hot components are covered and protected.

Specifications:

Output Rating: 277VAC @ 100 amperes maximum. Output voltage can be any AC voltage equal to or less than rated voltage.

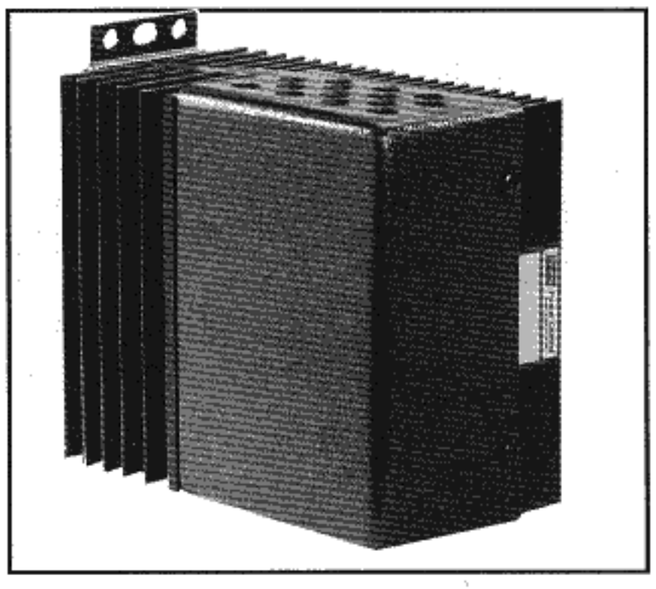
Input Voltage: 277VAC maximum. Input voltage can be any AC voltage equal to or less than rated voltage.

Input Frequency: 50 or 60Hz.

Control Signal: 120VAC, 60Hz, 50Hz available.

Connections: UL listed compression terminals are provided for both power and control connections.

Voltage Protection: Transient voltage protection is provided by an integral R-C snubber network and a metal oxide varistor (MOV) which clamps voltage spikes to within the standard PRV rating of the semiconductors.



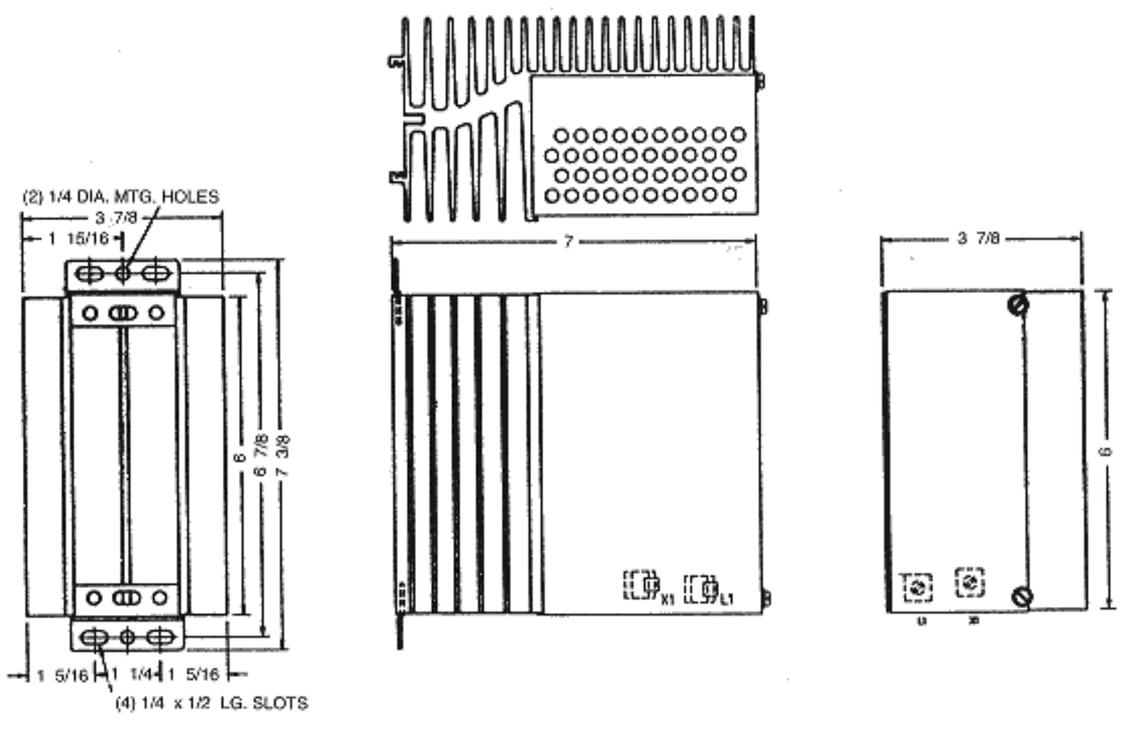
I²t Fusing: An integral I²t fuse is included to protect the SCR from current surges. Fuse rating: 150 amperes.

Ambient Temperature: 45°C for vertical mounting in a ventilated enclosure.

Mounting Position: Vertical only.

Cooling: Convection cooled with electrically isolated heatsinks.

Load: Single phase resistive. Three phase wye or delta connected load with a neutral line are controlled using three (3) SSC100s. Delta connected loads without a neutral are controlled with two (2) SSC100s.



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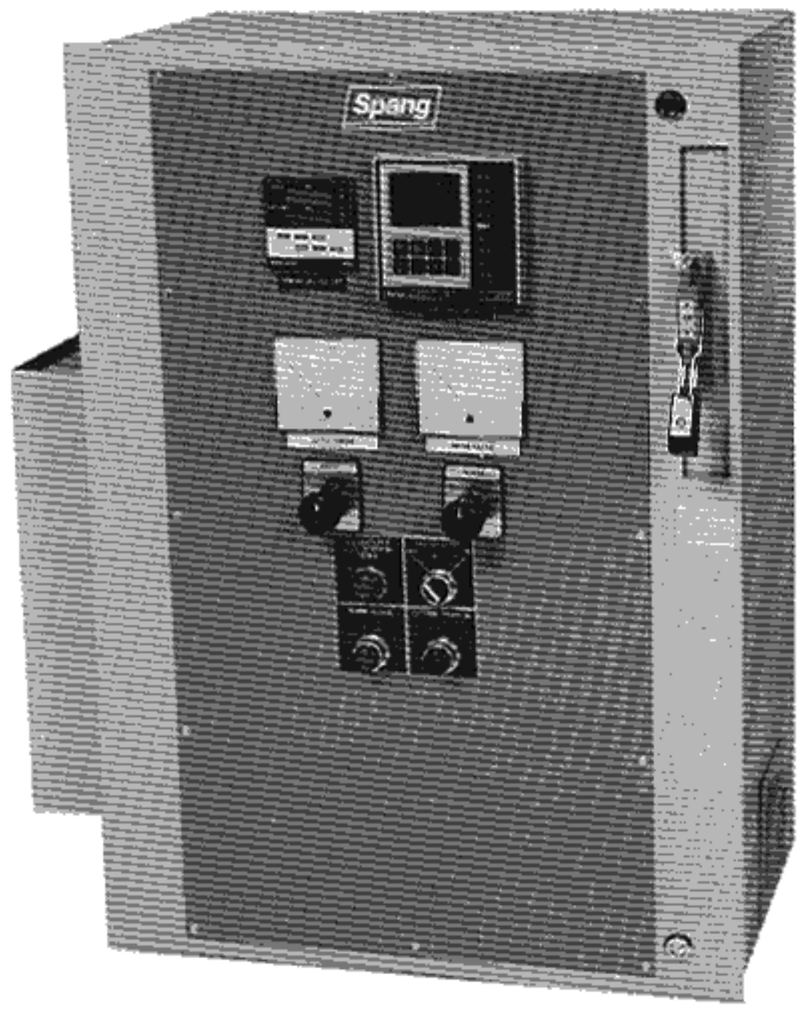
SCR TEMPERATURE AND POWER CONTROL PANELS



C-Series Power Panel

These rugged, solid-state control panels are designed for use in any process heating application where precise temperature and power control are required. Every unit is prewired, pretested and completely self-contained. Connection of the line, load and thermocouple leads is all that is necessary to get into operation. A wide range of options are available to equip the panel with the level of control and instrumentation to match the heating load and process requirements.

OPTIONS AVAILABLE:

- SCR Power Controller, Single or Three Phase; Zero Crossover; Phase Angle
- Main input circuit breaker with door interlock; 120 volt shunt trip; undervoltage release; auxilary contacts; alarm contacts
- Temperature controller
- Overtemperature controller
- Ammeter, load or primary phase selector switch
- Voltmeter, load or primary phase selector switch
- Kilowatt hour meter
- Chart recorder
- Power on/off push button
- Reset push button
- Auto/manual switch
- Local/remote switch
- Control relay
- Manual potentiometer
- Power “ON” pilot light
- Indicator lights—alarm, overtemperature, etc.
- Control transformer
- Enclosure — NEMA 1; NEMA 12

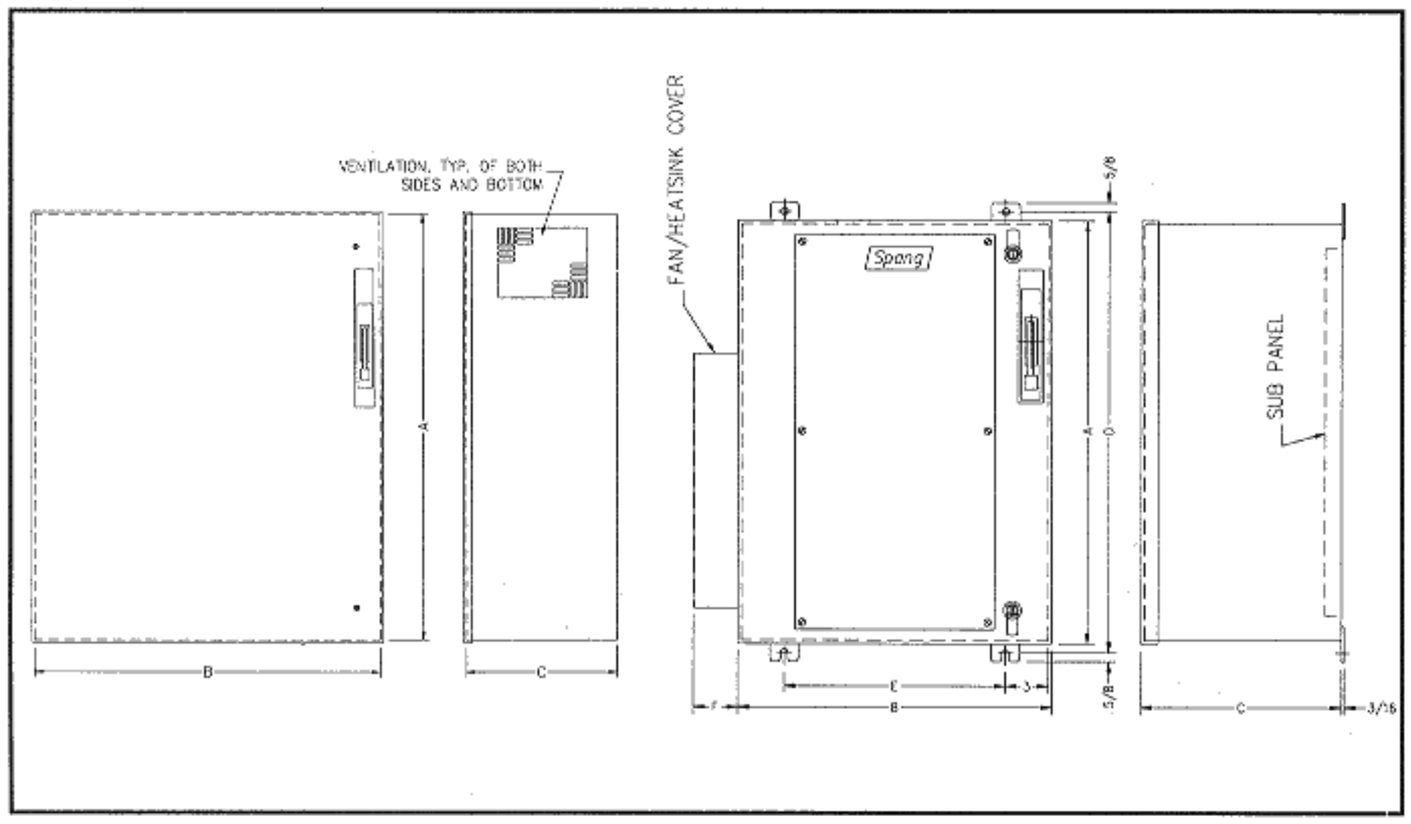
B-Series Power Panel

Three Phase Rating and Enclosure Dimensions						
Current Rating AC Amps	kva Rating			A (H)	B (W)	C (D)
	208v	240v	480v			
15	5.4	6.24	12.5	40	26	14
30	10.8	12.5	25	40	26	14
60	21.6	25	50	40	26	14
90	32.4	37.4	75	40	26	14
110	39.6	45.7	91.4	40	32	14
150	54	62	125	40	32	14
250	90	104	208	40	32	14
350	125	145	290	40	32	14
450	162	187	374	40	32	14

Single Phase Rating and Enclosure Dimensions						
Current Rating AC Amps	kva Rating			A (H)	B (W)	C (D)
	120v	240v	480v			
15	1.8	3.6	7.2	30	24	12
30	3.6	7.2	14.4	30	24	12
60	7.2	14.4	28.8	30	24	12
110	13.2	26.4	53	30	24	12
175	21	42	84	40	26	14
250	30	60	120	40	26	14
400	48	96	192	40	26	14
500	60	120	240	40	26	14
600	72	144	288	40	26	14

B-SERIES NEMA 1

B-SERIES NEMA 1



NEMA 1 ENCLOSURE

NEMA 12 ENCLOSURE

Ratings and Enclosure Dimensions									
Current Rating AC Amps	kva Rating			A (H)	B (W)	C (D)	D	E	F
	120v	240v	480v						
40	8.3	16.6	33.3	30	22	14	31¼	15½	3¾
60	12.5	25	50	30	22	14	31¼	15½	3¾
100	20.8	41.5	83.1	30	22	14	31¼	15½	3¾
150	31	62	125	30	22	14	31¼	15½	3¾
250	52	104	208	40	28	18	41¼	21½	3
350	73	145	290	40	28	18	41¼	21½	3

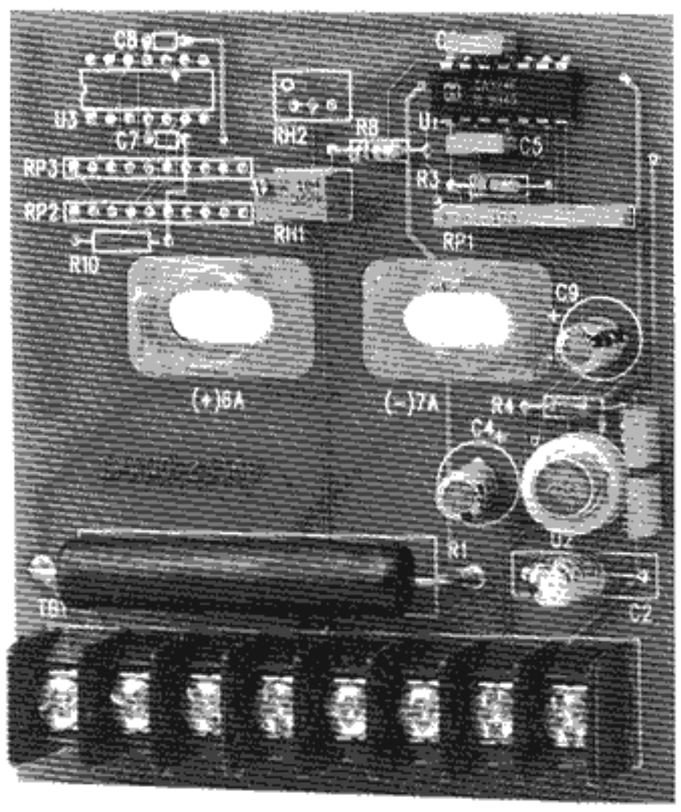
C-SERIES NEMA 12

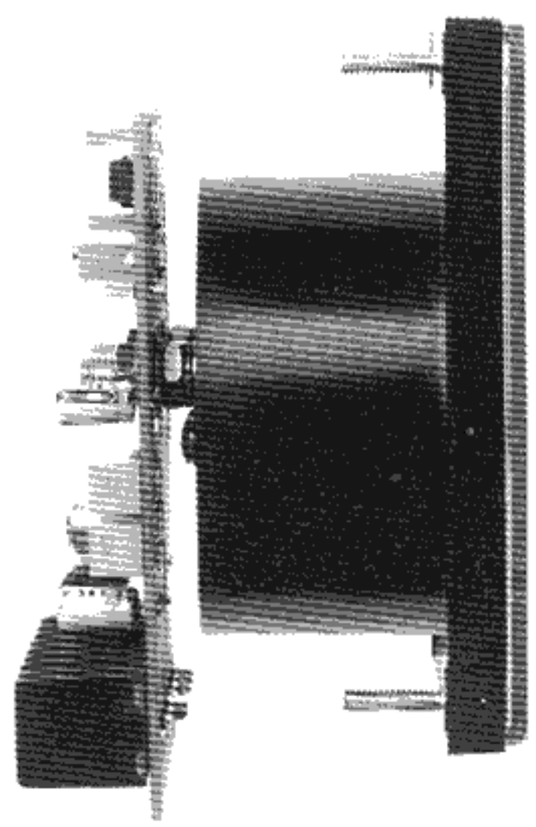
Note: Standard dimensions may change with addition of optional equipment

Spang Power Electronics

TRANSDUCER DAMPENING CIRCUIT BOARD

Type E7279





General Description

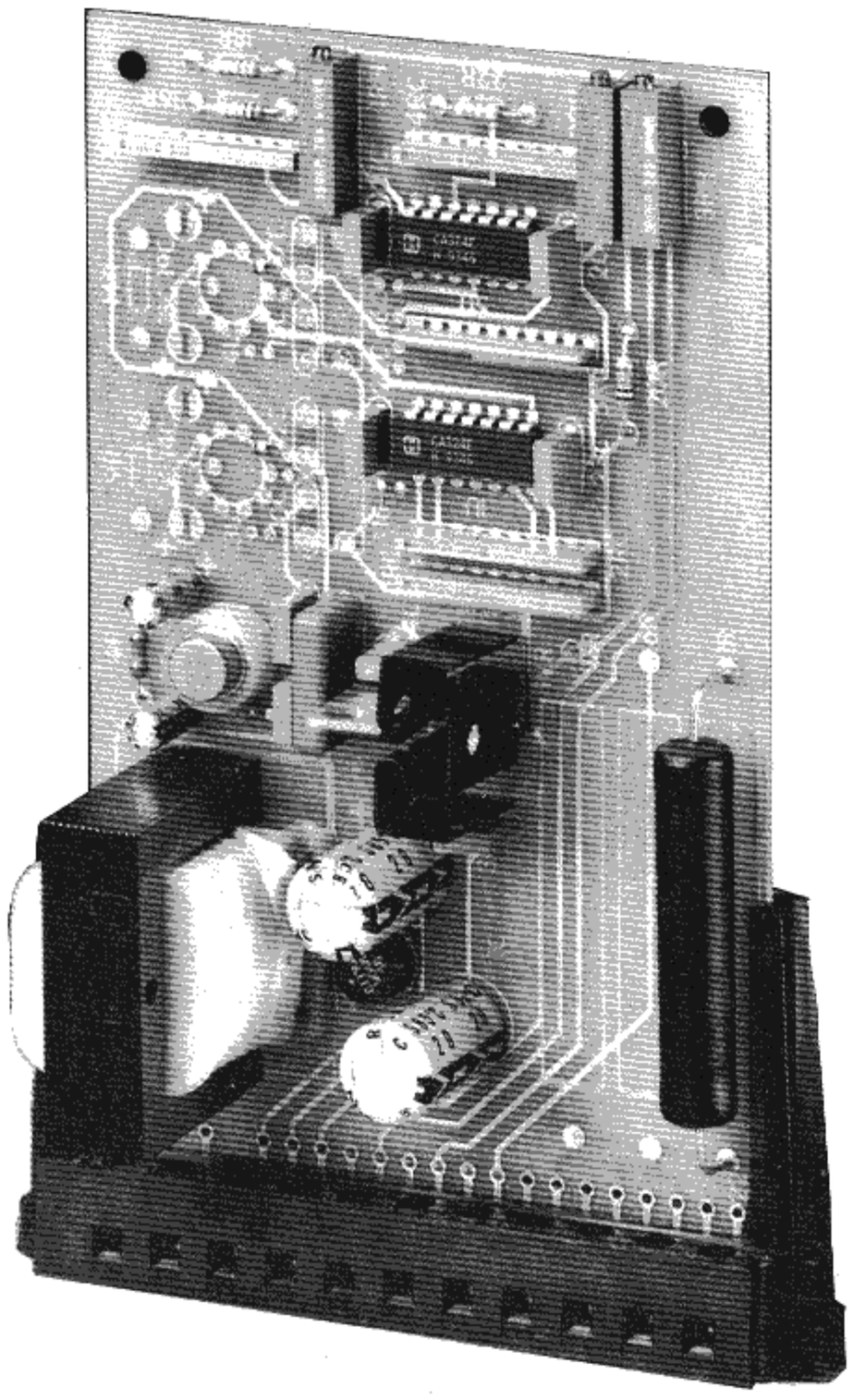
The E7279 transducer dampening circuit board eliminates the bouncing of analog meter needles associated with zero crossover power controllers operating at less than full output. The fluctuating meter needle makes it very difficult to obtain an accurate output reading. The E7279 incorporates a circuit to convert an AC signal into a true RMS DC signal. This signal is a true representation of the actual voltage or current being measured. The converted signal eliminates the fluctuations of the needle, and allows an easy and accurate reading.

Specifications

Models of the E7279 are available to accept either a current or voltage input and provide a 0-5 VDC output. An optional 0-1 mA output signal is also available on some models. A current input requires the use of a 5 Amp current transformer (P/N 71242). A voltage input requires the use of a potential transformer which provides isolation and supplies 5 volts output at full scale (P/N 71434).

Mounting and Installation

The E7279 requires a supply of + and - 12 volt DC. This may be found on the power controller. The dampening board fits directly onto the threaded stud terminals of most standard panel meters but they must have a meter movement of 0-5 VDC. No special mounting provisions or interconnecting wiring is needed between the circuit board and the meter. The input leads on the power controller are the only connections required.



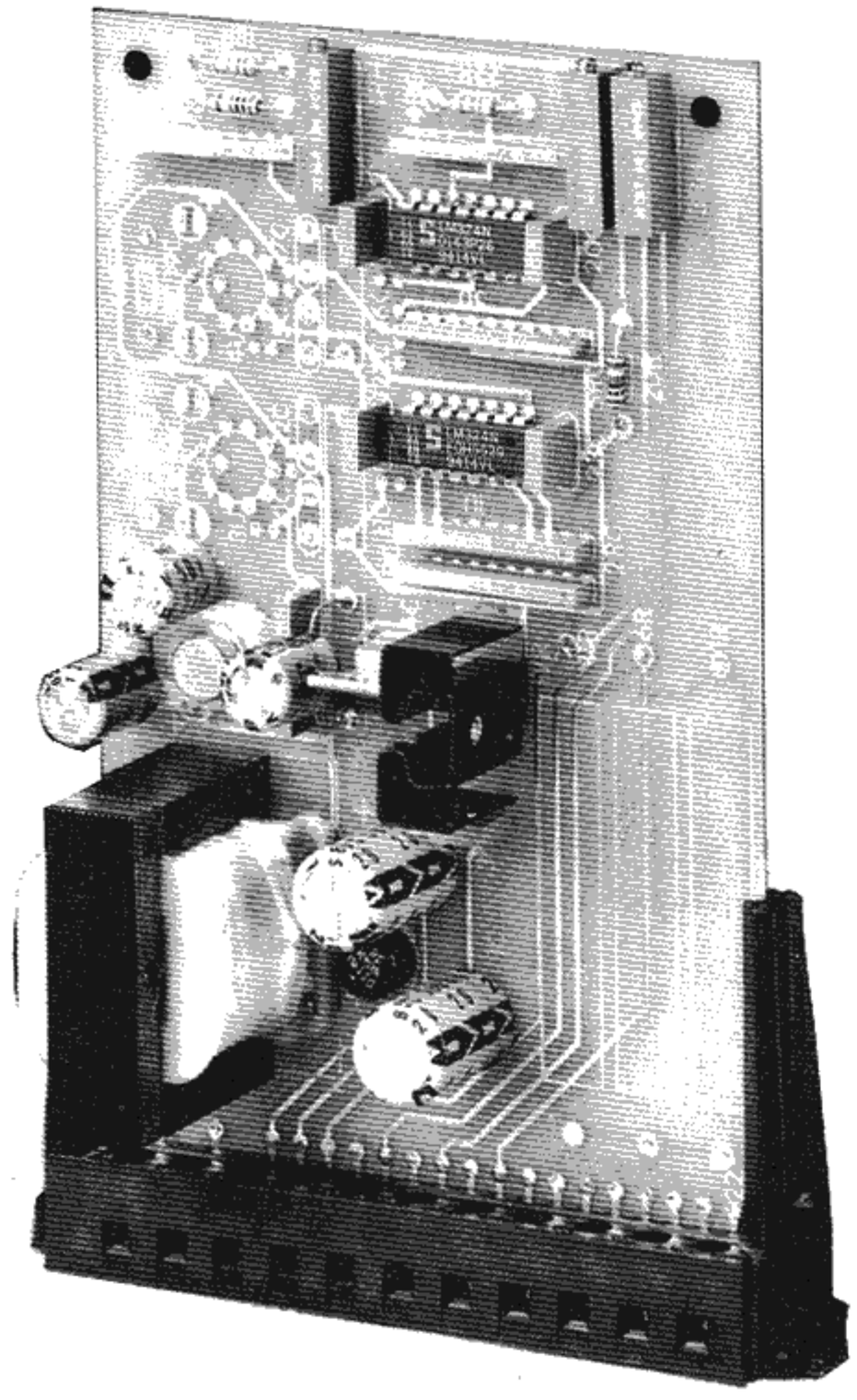
CURRENT TRANSDUCER

Specifications

Phase:	Single or Three (sinusoidal or nonsinusoidal waveforms)
Current Signal Input:	0-5 Amps from optional Current Transformer C.T. burden: .1Ω
Output Voltage:	0-10 VDC in 2000Ω load impedance or greater
Output Current:	
Single Phase:	0-1 MADC into 10,000Ω maximum load impedance for 0 to rated input current 4-20 MADC into 500Ω maximum load impedance for 0 to rated input current
Three Phase:	4-20 MADC into 500Ω maximum load impedance for 0 to rated input current
Accuracy:	1% of full scale
Output Ripple:	50 mV Max.
Step Response:	
Phase Angle:	100 mS for a 10 to 90% change
Zero Crossover:	500 mS for a 10 to 90% change
Repeatability:	Better than .1% of full scale
Calibration Adjustment:	± 25 %
Power Required:	120 VAC, 50/60 Hertz
Temperature Range:	0 to 50˚C
Size:	6.25˝ x 3.581˝ x .97˝

General Description

The current transducer senses current signals of 0 to 5 amps from an optional current transformer and converts the AC signal into a true RMS DC signal. This converted signal is a true representation of the AC current being delivered to the load and is accurate within 1%. The current transducer accepts either sinusoidal or nonsinusoidal waveforms. Output current is available in either 0-1 mA or 4-20 mA.



VOLTAGE TRANSDUCER

Specifications

Phase:	Single or Three (sinusoidal or nonsinusoidal waveforms)
Input Voltage:	0-5 VAC*
Output Voltage:	0-10 VDC in 2000Ω minimum load impedance
Output Current:	
Single Phase:	0-1 MADC into 10,000Ω maximum load impedance for 0 to rated input voltage
	4-20 MADC into 500Ω maximum load impedance for 0 to rated input voltage
Three Phase:	4-20 MADC into 500Ω maximum load impedance for 0 to rated input voltage
Accuracy:	1% of full scale
Output Ripple:	50 mV Max.
Step Response:	
Phase Angle:	100 mS for a 10 to 90% change
Zero Crossover:	500 mS for a 10 to 90% change
Repeatability:	Better than .1% of full scale
Calibration Adjustment:	± 25 %
Power Required:	120 VAC, 50/60 Hertz
Temperature Range:	0 to 50°C
Size:	6.25″ x 3.581″ x .97″

Option:

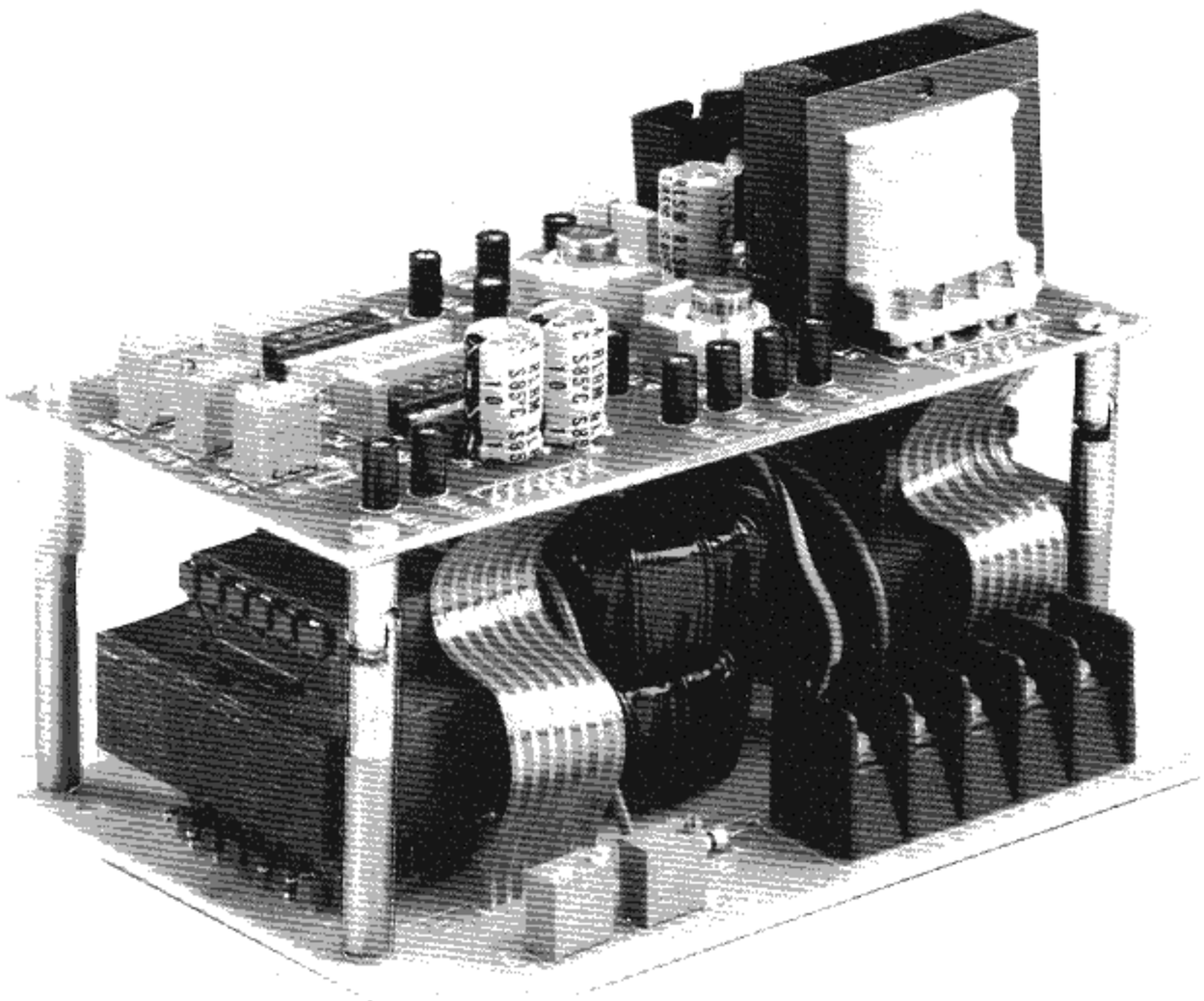
*An input voltage of 120, 208, 240, 277, 380, 416, 480, or 575 RMS VAC can be accepted with use of a potential transformer which can supply 5 volts output at full scale. (Spang P/N 71434).

General Description

The voltage transducer accepts a voltage input of 0-5 VAC and converts the AC signal into a true RMS DC signal. This converted signal is a true representation of the voltage and is accurate within 1%. The voltage transducer accepts both sinusoidal and nonsinusoidal waveforms. Output voltage is available in 0-10 VDC and output current is available in either 0-1 mA or 4-20 mA.

Spang Power Electronics

WATT TRANSDUCER



General Description

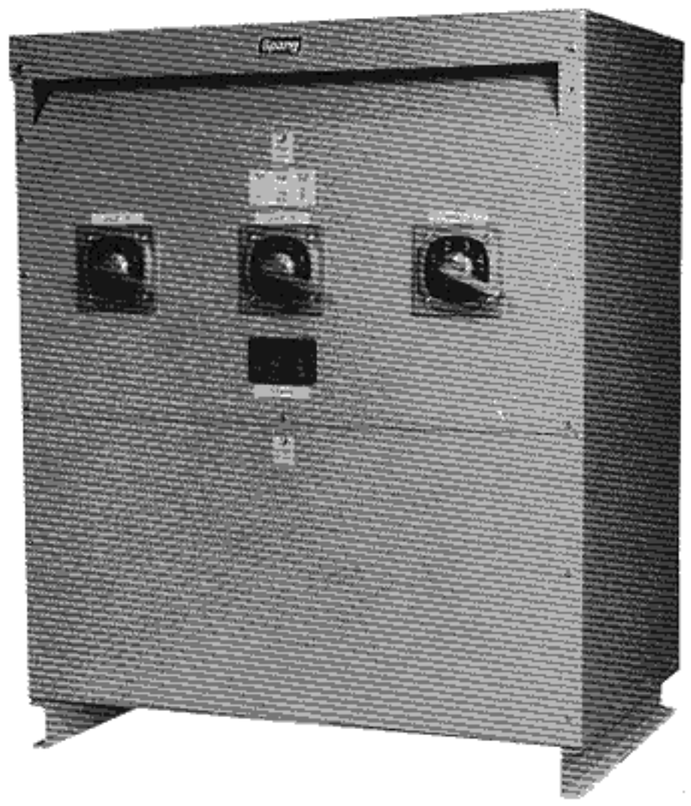
The watt transducer senses voltage and current on single or three phase AC power lines and provides an output proportional to the total power consumed by the load. The three phase watt transducer is designed to operate on three wire or balanced four-wire systems. The watt transducer accepts either sinusoidal or nonsinusoidal waveforms. It converts an AC signal into a true RMS DC signal. This signal is a true representation of the power being delivered to the load and is accurate within 1%.

Specifications

Phase:	Single or Three (sinusoidal or nonsinusoidal waveforms)
Voltage Signal Input:	60, 120, 240, 380, 480 or 600 RMS AC
Current Input:	5 Amp from optional Current Transformer
Voltage Output: Only available on Model E6691-XX17	0-2 VDC for regulation (unfiltered)
Current Output:	0-1 MADC full scale standard output (10KΩ maximum load impedance)
	4-20 MADC full scale optional output (500Ω maximum load impedance)
Accuracy:	±1% full scale
Output Ripple:	50 mV Max.
Step Response:	
Phase Angle:	Approximately 30 mS for a 10 to 90% change
Zero Crossover:	Approximately .8 seconds for a 10 to 90% change
Repeatability:	Better than .1% of full scale
Calibration Adjustment:	± 25 %
Power Supply Required:	120 VAC, 50/60 Hertz
Temperature Range:	0 to 60˚C
Size:	5.25˝ x 3.75˝ x 3.625˝

Spang Power Electronics

FURNACE TRANSFORMERS



☐ Furnace Transformers

- **Silicon Carbide**
- **Molybdenum**
- **Graphite**
- **Salt Bath**

☐ Scott Connected Transformers

☐ Saturable Core Reactors

STANDARD FEATURES

- Single and Three Phase styles through 10,000 kva
- 220°C insulation System
- Designs for 80°C through 150°C temperature rise available
- Low loss grain oriented core construction
- Copper and aluminum conductor designs
- Core and coil or enclosed units available
- 50 hertz, 60 hertz, and 50/60 hertz designs available

SPANG offers a full line of Dry Type Specialty Transformers designed to provide the voltage matching capability and ratings required by a variety of heating elements.

Silicon Carbide Heating Elements

Silicon carbide heating elements change resistance with age. Over the useable life span of the element, resistance can increase as much as four times. In order to deliver full power to the elements over the resistance range, a means of increasing voltage over a two-to-one range must be provided. Multi-Tapped Furnace Transformers provide this voltage matching capability.

A typical multi-tapped transformer for manual or contactor control might have six (6) coarse and six (6) fine taps to provide a two-to-one output voltage range with 36 steps, each rated at full load kva.

When coupled with proportional power controllers such as Silicon Controlled Rectifier (SCRs) or Saturable Core Reactors, the fine taps can be eliminated. With the SCR proportional control device, five (5) coarse taps provide infinite voltage control over the entire two-to-one range with a high power factor (0.80 or better).

The transformer and taps are designed to deliver full rated power over the operating range. A sixth reduced power tap is provided at 70% of the lowest full power tap voltage for use in start-up and reduced power holding conditions. The transformer is designed for primary proportional control with saturation and losses controlled by use of high quality, grain oriented core steel.

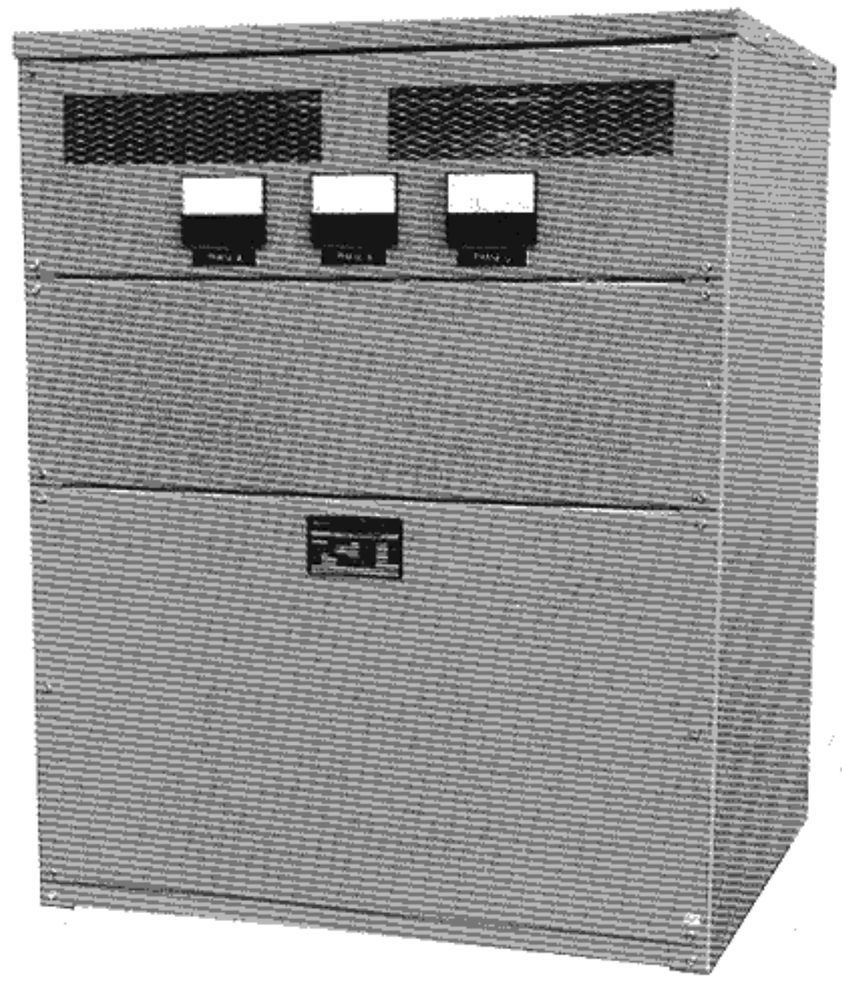
Molybdenum and Graphite Heating Elements

Molybdenum and graphite elements generally are operated at lower voltages (approximately 50 volts) and associated higher currents. These elements change resistance with temperature. At room temperature their resistance can be as low as 5% of the nominal resistance seen at operating temperatures.

For contactor or manually controlled heating applications, reduced voltage taps are required to avoid overloading the system during the cold element's low resistance stage. For furnaces up to 500 kw, the secondary taps are typically selected at one third, two thirds and full operating voltage. For larger furnaces, finer taps may be desired, such as one quarter increments of operating voltage. Since the current will be higher than nominal when each voltage is first applied, some oversizing of the electrical system, including the transformer, is desirable. For finer control, additional taps may be specified.

SCR control and saturable core reactors offer proportional power control which allows use of a less complicated transformer and simplifies furnace operation. By using a SPANG SCR Power Control Unit with RMS Current Limit and soft start ramp of several seconds, it is possible to bring the furnace up quickly and safely without secondary taps.

Spang Power Electronics Furnace Transformers are available in Single Phase, Three Phase and Scott Connected designs. They can be provided as core/coil units or in a variety of enclosures. Accessories such as tap switches and meters are available. Complete power centers can also be provided including SPANG SCR Power Control Units.



300 kva for Graphite — with Ammeters

TO ORDER, SPECIFY:

- Load kw
- Heating element type
- Input voltage - phase and frequency
- Output voltages desired or "nominal" voltage required when elements are new and at operating temperature
- Output configuration - single phase, two phase, three phase (3, 4, or 6 wire)
- Temperature rise - 80°C, 115°C or 150°C
- Enclosure
- Other features and accessories

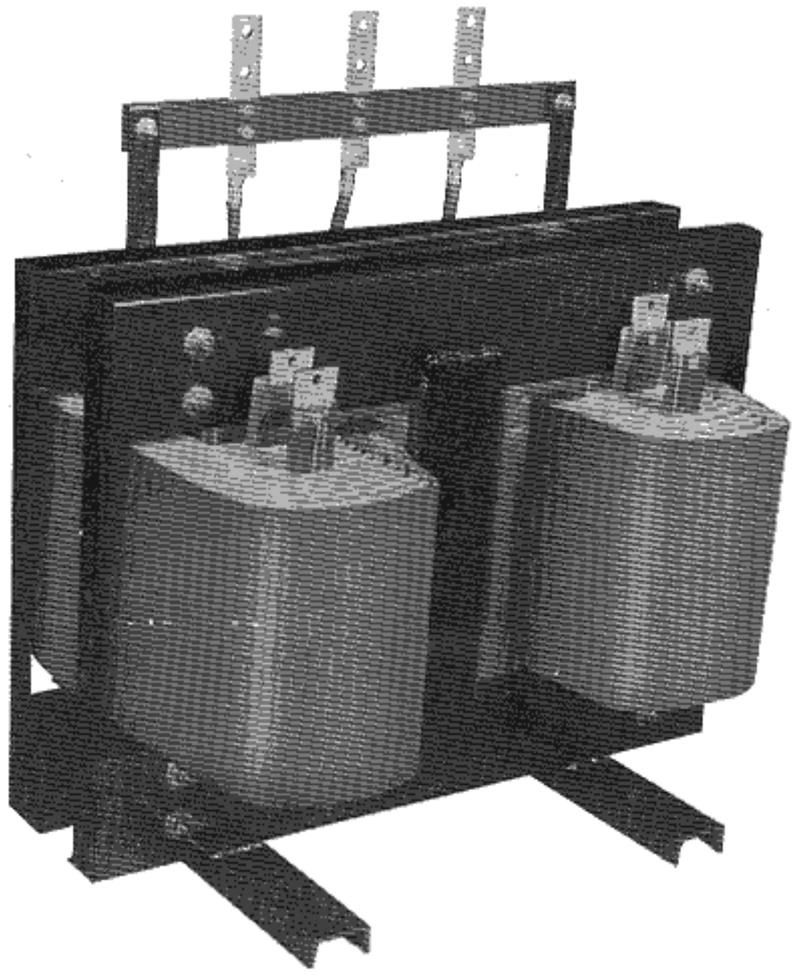
Scott Connected Transformers—Phase Changers

The majority of electric power is distributed with a three phase network. For two phase loads, particularly existing machinery, balancing a two phase (or two single phase) load on a three phase line requires a three phase to two, phase transformer.

Spang Power Electronics Scott Connected Transformers (phase changers) offer a wide range of three-to-two phase transformation. They provide two phase outputs while drawing balanced power from a three phase input. They can be designed for special purposes such as furnace and glass melting applications.

TO ORDER, SPECIFY:

- Load kva
- Input voltage, phase and frequency
- Output voltage, two phase (3,4, or 5 wire)
- Temperature rise - 80°C, 115°C, or 150°C
- Enclosure • Other features and accessories

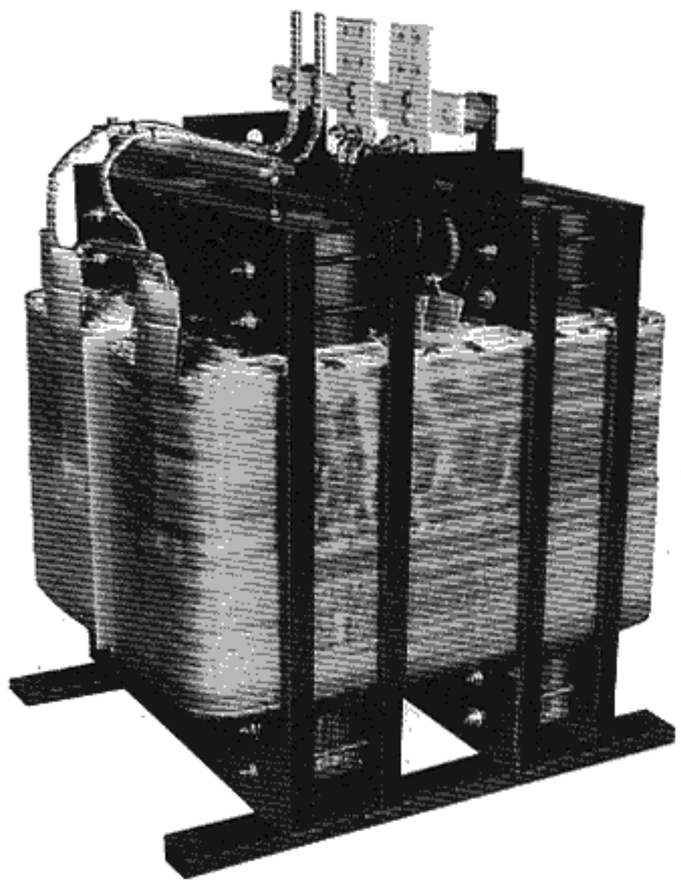


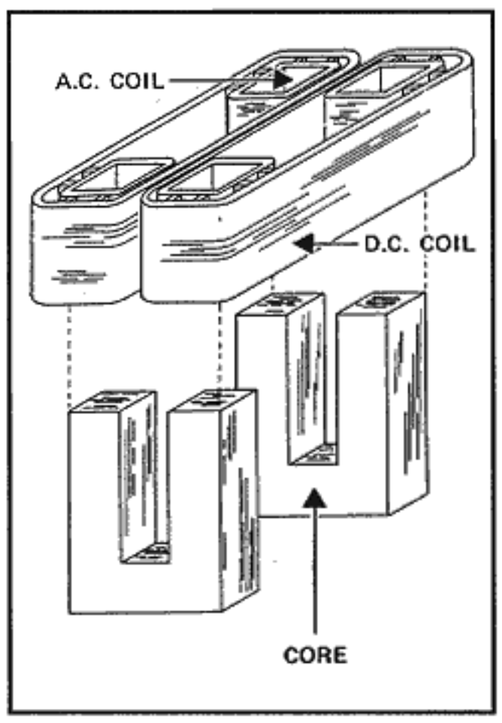
Saturable Core Reactors

A saturable core reactor is a magnetic device used for proportional control of AC power to resistive heating elements.

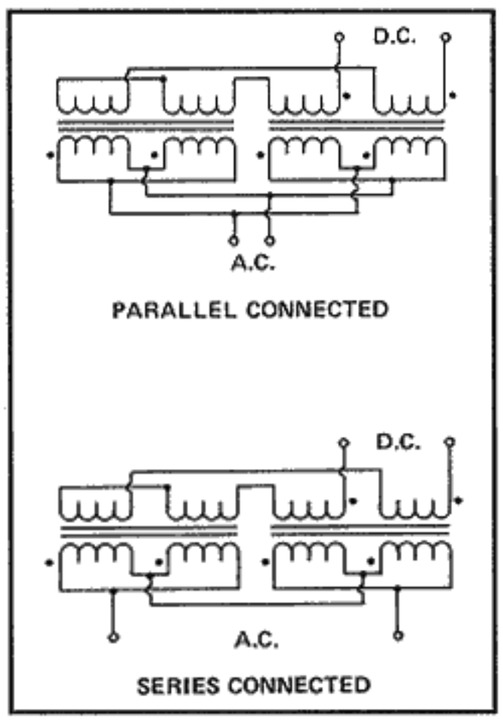
Spang Power Electronics Saturable Core Reactors provide this control in a stepless and smooth manner, and only small amounts of DC control power are required. The source of DC power is usually a magnetic amplifier or a silicon controlled rectifier driver (see pg. 33).

A SPANG Saturable Core Reactor operates as a variable impedance controlled by a direct current within the limits of the design voltage and load. With zero DC control current, the reactor is at high impedence and limits load current to 5% of rated. With 100% control current the impedance is reduced allowing rated AC current to the load. With rated AC supply voltage and matched load at unity power factor, the above characteristics can be expressed as: "a zero to 100% change in DC control will provide a load voltage change of approximately 5% to 95% of supply voltage."





Core and Coil Construction

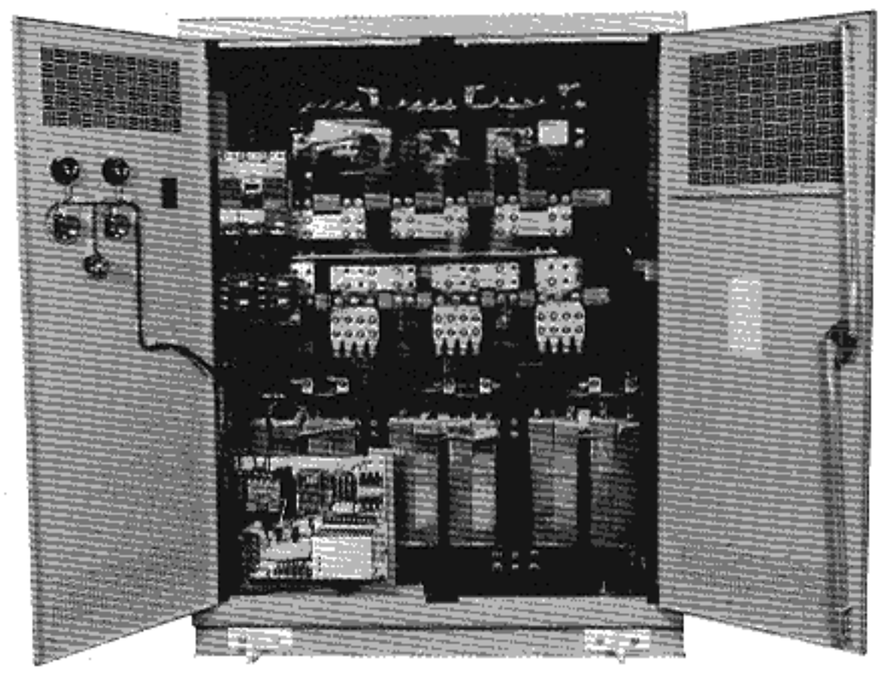


Wiring Diagram

The construction is basically similar to that of two transformers in one structure. The AC windings are on each leg, connected in parallel. They are connected in a bucking configuration so that the AC voltages induced in the DC winding will cancel out. The DC winding encompasses both cores of the structure. With this type of construction, the entire core carries both AC and DC flux, and the mutual inductance of the coils is maximum.

Saturable Reactor Control Systems

Spang Power Electonics offers complete control systems, factory wired and tested to meet customer specifications. This can include the saturable reactors, driver, transformers, and control equipment with metering. The control cabinet can be adjacent to, or remote from, the reactor.



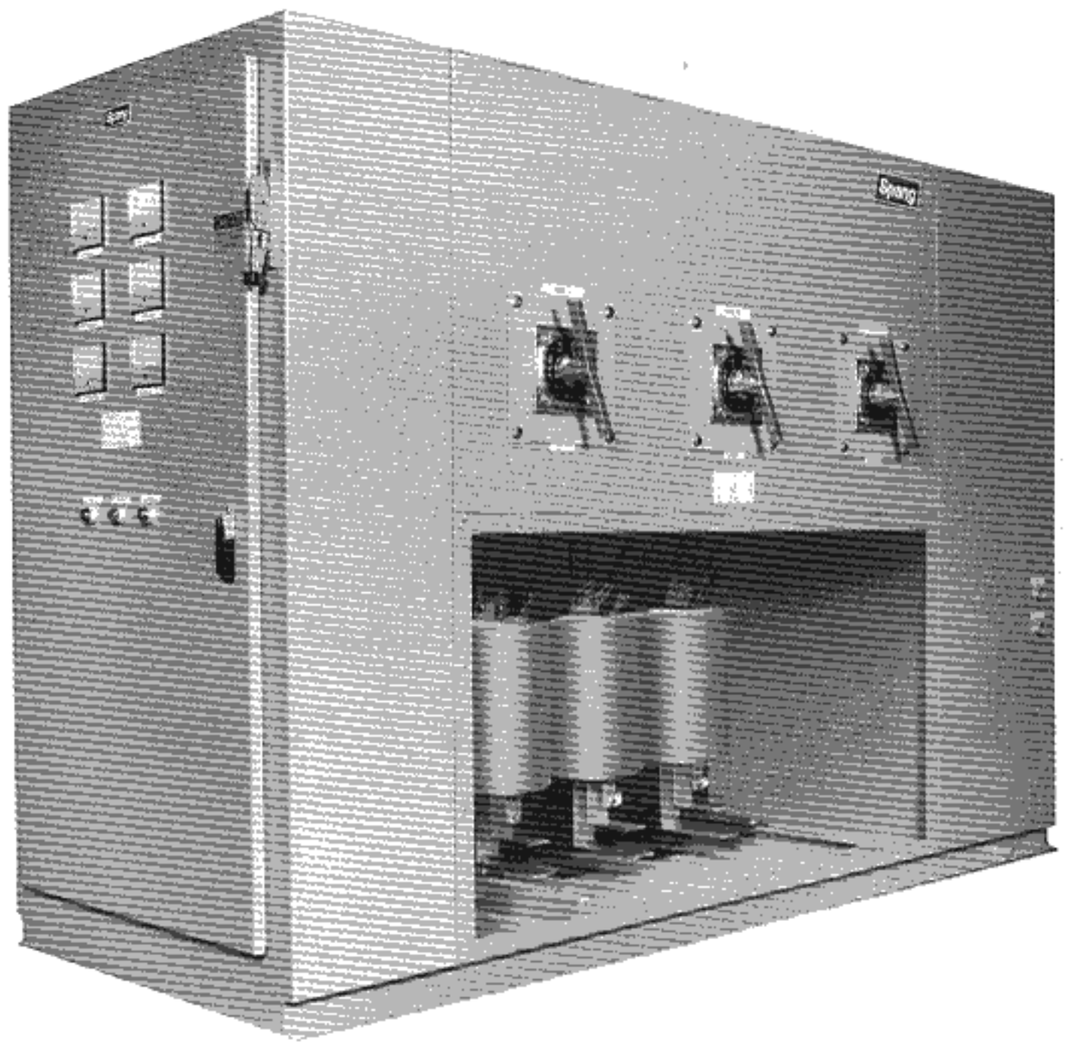
TO ORDER, SPECIFY:

- Load kva
- Voltage - normally same as line volts
- Frequency
- Phase
- Load power factor
- DC control voltage

Spang Power Electronics

SILICON CARBIDE POWER CENTERS

The Leading Choice for Process Heating Control of Silicon Carbide Elements



STANDARD FEATURES

- Solid State Reliability
- Extended Heating Element Life
- Low Installation Cost
- Low Operating Cost
- Optimum Utilization of Electric Power
- Modular Construction Adaptable to Multiple Zone Control

The SPANG SC Power Center maximizes the useful life of silicon carbide heating elements.

Silicon carbide heating elements change resistance with both temperature and age. From room temperature to normal operating temperature, the element passes through a negative resistance region where its resistance decreases before increasing to the operating value. At its lowest point, the element's resistance can be as much as 20 percent below nominal.

Aging is proportional to the watt density and environment to which the element is subjected. Over the life span of the element, its resistance can increase as much as four times. Due to these inherent characteristics, silicon carbide heating elements require special consideration in power supply design.

The SPANG SC Power Center protects the element in the negative resistance region.

Its RMS current limit responds to the actual heating current, prolonging element life by limiting excessive watt densities. The three phase SC Power Center senses all three lines and limits the highest current, preventing element fatigue in unbalanced systems.

The SPANG SC Power Center compensates for aging elements.

As the element ages, higher voltages are required to deliver full power. The SC Power Center provides this **Extended Full Power Voltage Range** while maintaining maximum efficiency and high power factor. A special multi-tapped transformer design allows full power operation over a two to one voltage range.

The SPANG SC Power Center is designed for reliable operation and long life.

Drawing upon years of experience in power control, and specifically power control for silicon carbide, SPANG has engineered the SC Power Center for maximum reliability. Every component is selected and designed with the particular requirements of silicon carbide in mind.

The SCR Power Control Unit (PCU) features a solid state firing circuit utilizing an Active Filter and CMOS Digital Circuitry for high Noise Immunity. SCR firing coordination is guaranteed through use of Phase Locked Loop technology. Rapid SCR turn-on is assured by 20 kHz Pulse Train firing for protection against di/dt failures.

A Phase Loss Detection circuit continuously monitors the incoming power. Should a power disruption occur, the firing circuit is inhibited, thus preventing SCR misfiring and nuisance fuse blowing.

When the disruption passes, operation returns to normal without loss of fuses. An Integral Ramp Circuit brings the Power Control Unit on in about 3 seconds, minimizing transformer in-rush currents.

The RMS current limit not only protects the heating element, but also provides overcurrent protection for the SC Power Center itself. For maximum reliability into unbalanced loads, the three phase SC Power Center is equipped with a SPANG 6 SCR Power Control Unit.

The SPANG Multi-Tapped Furnace Transformer is specially designed for primary SCR control of power for silicon carbide heating elements. Transformer saturation and losses are controlled by use of high quality, grain oriented core steel. The transformer is air-cooled, utilizing a Class H220°C Insulating System. Designed for a low 115°C Temperature Rise over a 40°C ambient, it provides long life and a liberal safety margin. **The SPANG SC Power Center substantially reduces installation and operating costs.**

The SPANG SCR Power Control Unit utilizes silicon controlled rectifiers for power proportioning. Solid State SCR control provides maximum efficiency with lower losses than saturable reactors. Unlike contactors, there are no moving parts to wear out or replace. Maintenance and downtime costs are reduced.

The Multi-Tapped Furnace Transformer is designed to maximize efficiency and power factor. The low 115°C temperature rise attests to the high efficiency of the transformer. The multi-tapped secondary allows full power to be delivered over a two-to-one voltage range while maintaining a high power factor of 0.80 or better at full power outlet. Compared to 0.50 and lower power factors of other approaches, the SPANG design can result in substantial installation and operation savings. Substation and power feed sizes can be reduced by up to 50 percent. Utility rate savings, due to lower demand, accumulate substantially with every hour of operation.

The SC Power Center is a complete system, pre-wired and pretested. Costly field installation and start-up time are kept to a minimum. Since it is a complete system, the SPANG SC Power Center is easier to specify and use. Hidden costs, such as those associated with purchasing and assembling separate components, are eliminated.

Power Center Components

1. Input circuit breaker, with: shunt trip coil (120VAC). Safety handle mechanism.
2. SPANG SCR Power Control Unit with:Transformer Inrush Protection (soft start).
   RMS current limit feature. Solid state firing circuit. Plug-in printed circuit boards. Transient voltage protection. Phase loss protection on 3 phase units. Fast acting current limit fuses.
3. SPANG Silicon-Carbide Power Transformer, with: 115°C Temperature rise. 220°C UL listed insulation system
4. Metering:
   Load ammeter (one per phase).
   Load voltmeter (one per phase).

Standard Control Features

- Primary circuit breaker mechanically interlocked with access door.
- Shunt trip coil on primary circuit breaker can be used for over-temperature protection.
- Adjustable current limit, 25 to 100%.
- "Power on" indicator light.
- Power center will accept outputs from all standard temperature controllers.

Package Features

- Free-standing, ventilated NEMA 1 enclosure of 11 gauge steel construction.
- Durable industrial finish on all metal surfaces.
- Front control compartment with hinged access door.
- Easily accessible terminals for line and load connections.
- Lifting provisions.

Options Available

- Watt regulation control for improved element protection.
- Secondary tap switch with interlock.
- NEMA 12 enclosure.
- Forced ventilation.
- Temperature controller.
- High limit controller.
- Electronic overcurrent shutdown
- Under voltage release on breaker in lieu of shunt trip.

SC Power Centers—Standard Sizes

SERIES SCP48—480 Volt, 3 Phase, 60 Hertz input (note 1)

MODEL NO.	LOAD KW (note 2)	STANDARD NOMINAL OUTPUT VOLTAGES (note 3, 4)
SCP48-040	40	60
-050	50	85
-060	60	120
-075	75	170
-100	100	240
-125	125	
-165	165	
-225	225	
-235	235	
-270	270	
-300	300	
-340	340	
-400	400	
-450	450	
-525	525	

SERIES SCS48—480 Volt, 1 Phase, 60 Hertz input (note 1)

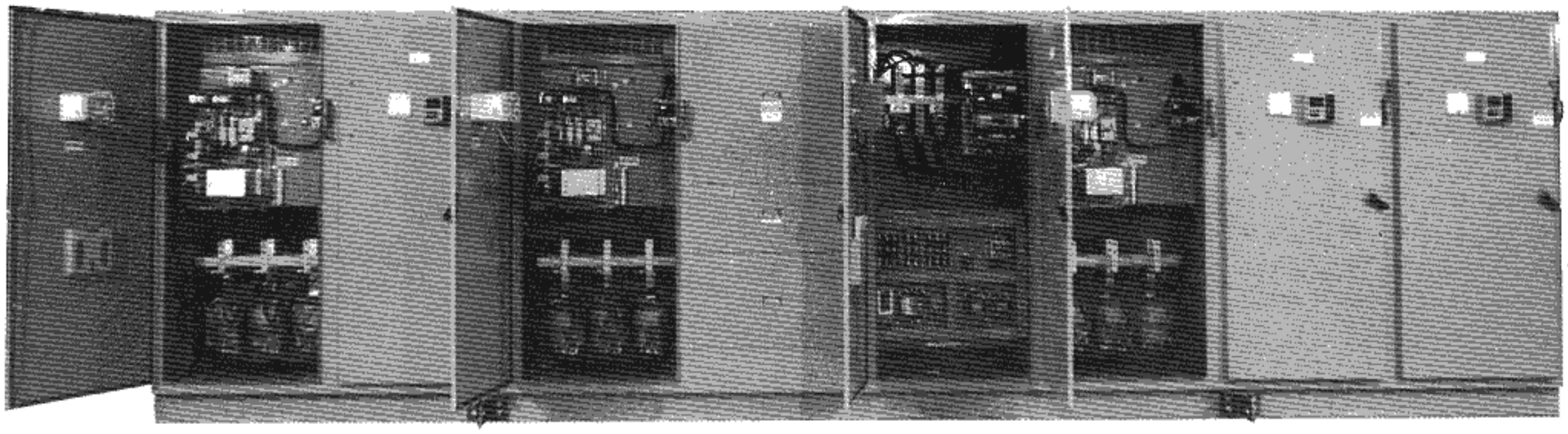
MODEL NO.	LOAD KW (note 2)	STANDARD NOMINAL OUTPUT VOLTAGES (note 3)
SCS48-020	20	60
-030	30	85
-035	35	120
-040	40	170
-065	65	240
-120	120	
-150	150	
-175	175	
-190	190	

Notes:

1. Other input voltages available.
2. Ratings listed have been chosen to maximize KW vs. dollar value. Other sizes available upon special request.
3. Nominal voltage is chosen from those listed. Specify when ordering. Full power is available from nominal to twice nominal voltage in five taps. A sixth, reduced power tap, is provided at approximately 70% of nominal. Other voltages available upon special request.
4. Output voltages are transformer coil voltages. Three phase units may be connected in three single phases, delta or wye. Specify when ordering. When wye connected, the line-to-line output voltage is $\sqrt{3}$ times the coil voltage.

Spang Power Electronics

AC POWER CENTERS



Sealed NEMA 12 Multi-Zone Power Center for high temperature requirements

SPANG AC Power Centers are packaged control systems designed to match the characteristics of specific heating elements and process requirements. Available in both single and multiple zone configurations, these power centers are easily customized and equipped with the level of control, instrumentation and indication needed. Where required, SPANG dry-type transformers can be included for load matching either as an integral component or for remote mounting.

STANDARD FEATURES

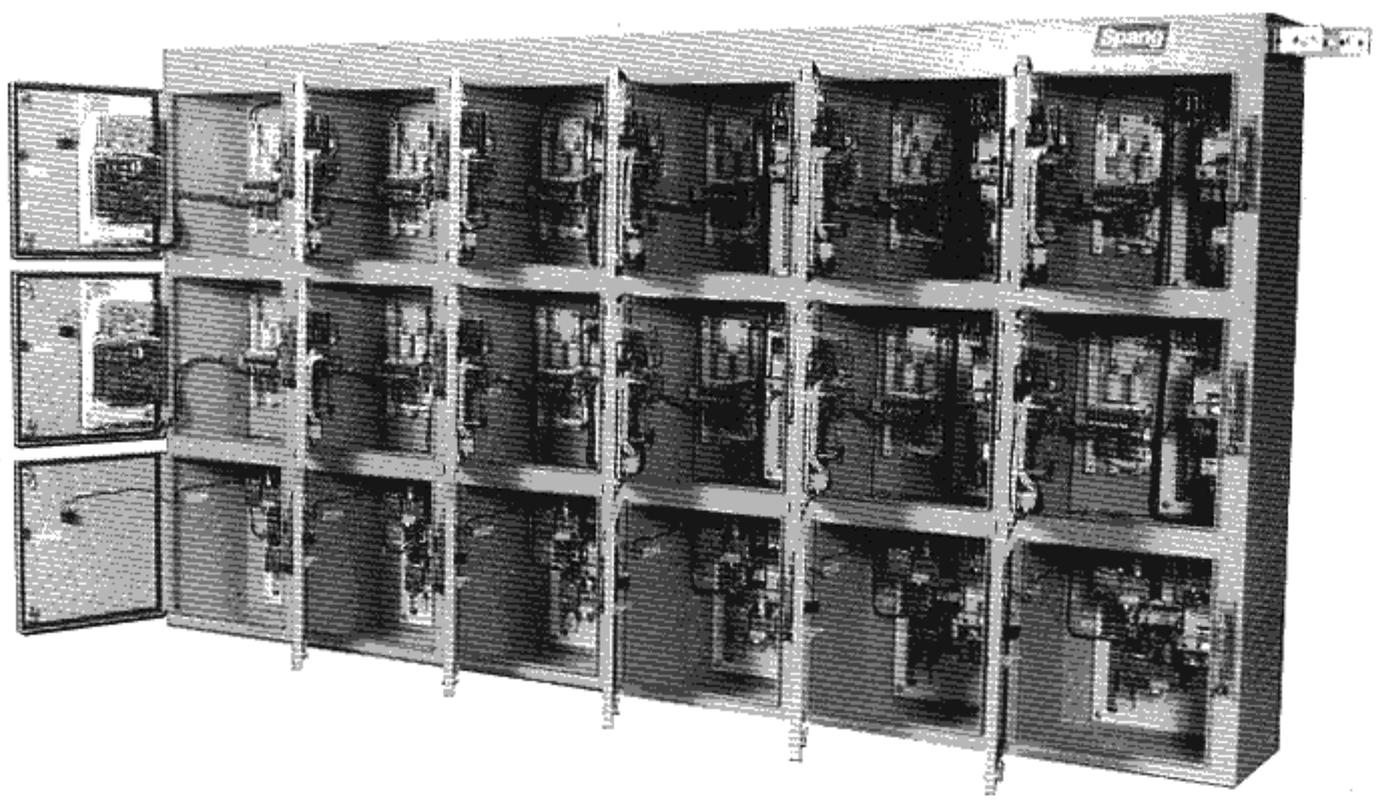
SPANG Power Centers provide packaged power for easy application to your electric heating need. These centers feature:

- Modular construction adaptable to multiple zone control.
- Modular and construction for placement near your element loads. No need for long runs of bus bar or heavy cable.
- Centralized temperature indication and instrumentation in a remote cabinet or can be included as part of the Power Package.
- Proper matching of the element to the power source. No mismatching of transformer and power controller.
- Maximum utilization of power controller (no need for vernier taps on silicon carbide transformers).
- Simplified installation; need only to connect line source and load.
- Unitized cabinets; no need for separate enclosures for transformers and controllers.
- Accepts any current output from your preferred temperature indicator/controller.
- Proportional regulated control provides precise temperature regulation in accordance with your temperature controllers signal.
- Line/Load isolation through use of isolation transformers.
- Transformer Inrush Protection (T.I.P.) on all SCR Power Controllers operating into power transformers.
- Current Limiting protection on all SCR Power Controllers, operating into changing loads.
- Choice of synchronous firing, phase angle firing, or automatic power factor firing Silicon Controlled Rectifier (SCR) Power Controllers or Saturable Reactor with SCR driver power controllers.
- Choice of single phase, three phase or two phase control to match your element loads.

Power Centers for Nichrome Elements

Nichrome heating elements represent a nearly pure resistive load displaying relatively little change in resistance with age or temperature. Typically, the change is on the order of 5 to 25%, depending on the alloy, from cold to operating temperature. Also, nichrome elements are often designed to operate from line voltages. Consequently, there is no need for a power transformer.

Power modulation in these systems is generally accomplished through zero crossover fired SCR Power Controllers. The controllers are either sized to handle the higher current of the elements cold resistance or equipped with current limiting circuitry. Where voltage-matching transformers are required, components and firing circuitry are configured to optimize size, cost, and controllability of the system.



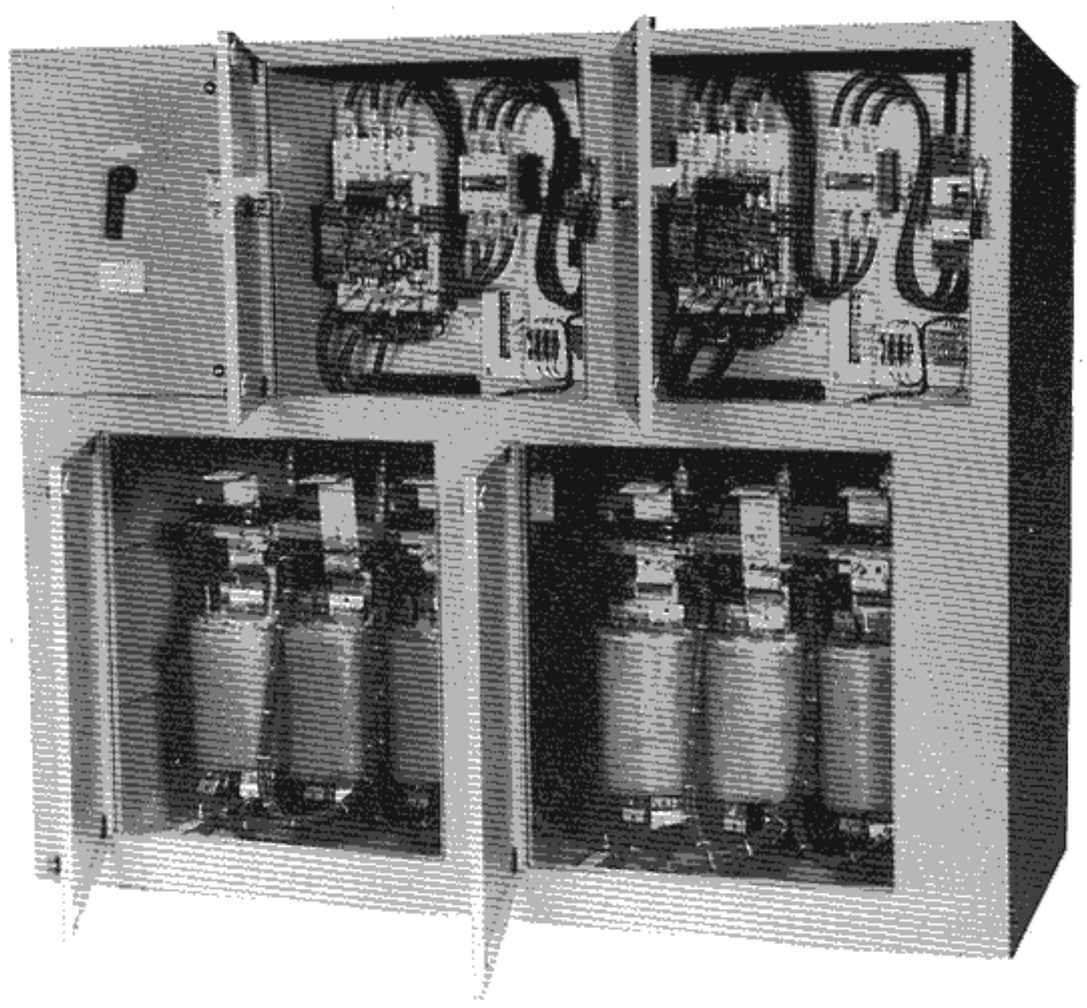
Options:
- Temperature indicator/controller.
- Temperature recording.
- Power transformer.

TO ORDER, SPECIFY:
- Input voltage, frequency and phase.
- Load kw, voltage and current.
- Desired options or special features.

Power Centers for Molybdenum Elements

Molybdenum elements exhibit a dramatic change in resistance with temperature. Typically, the resistance may increase as much as 20 times from cold to operating temperatures. In addition, molybdenum elements generally operate at low voltage (around 35 to 50 volts). SPANG Power Centers for molybdenum applications incorporate RMS current limiting circuitry and a soft-start ramp on the SCR Power Controller.

SPANG Power Centers for molybdenum applications incorporate a step-down transformer to match the incoming line voltage to the element's operating voltage and a phase angle fired SCR Power Controller with RMS current limit and soft-start ramp circuitry to prevent excessively high start-up currents.



Options:
- Temperature indicator/controller.
- Temperature recording.

TO ORDER, SPECIFY:
- Input voltage, frequency and phase.
- Load kw, voltage and current.
- Desired options or special features.

Power Centers for Tungsten Elements

Tungsten elements have a cold to operating temperature resistance change similar to that of molybdenum. Power Centers for the elements provide the same RMS current limit and soft-start circuitry to eliminate low-temperature current surges. Although tungsten elements may be designed for use at line voltage, a step-down transformer can be included for those applications where the element's operating voltage is lower than the line.

Options:

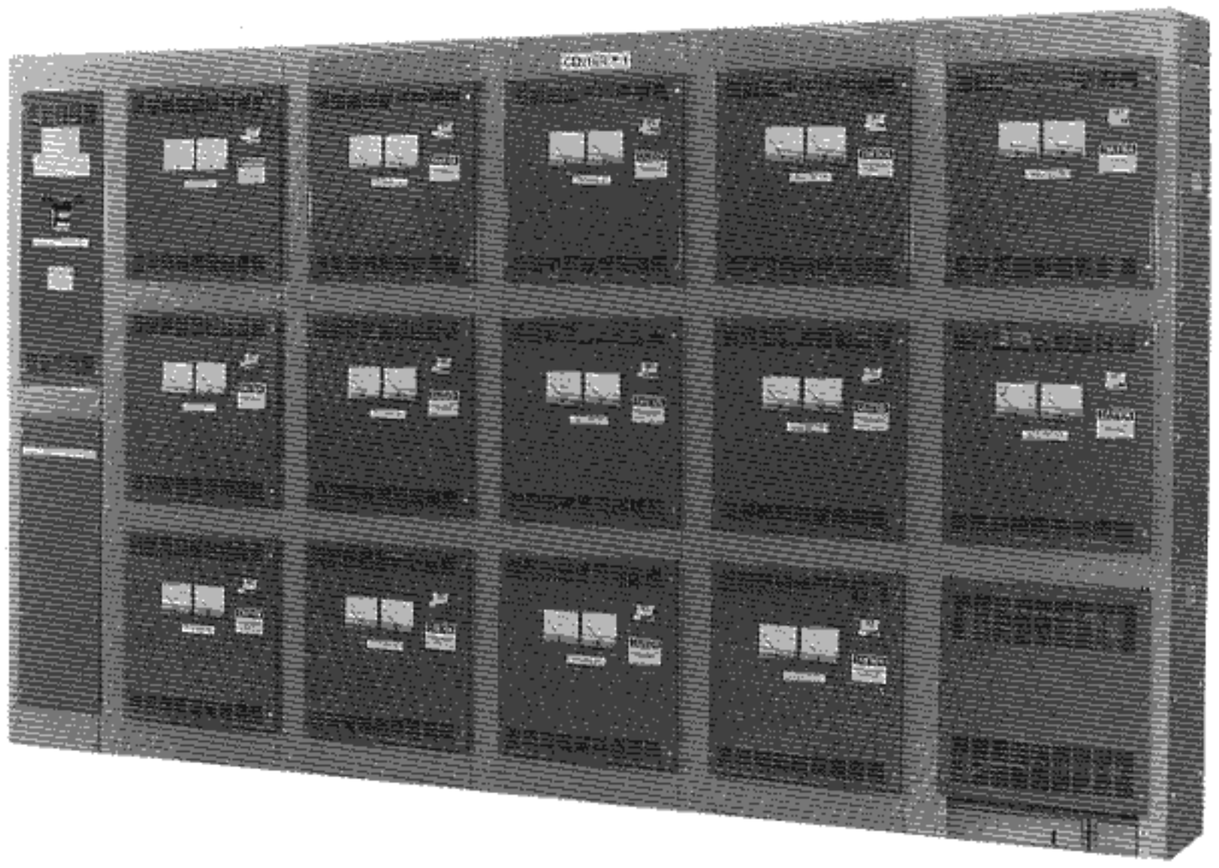
- Temperature indicator/controller.
- Temperature recording.
- SPANG Step-Down Power Transformer.

TO ORDER, SPECIFY:

- Input voltage, frequency and phase.
- Load kw, voltage and current.
- Desired options or special features.

Power Centers for Infra-Red Elements

Infra-red heating elements are generally designed for line voltage and available with either tungsten or nichrome filaments. Each filament type requires different features in the power controller to operate reliably. Power supplies for tungsten elements must be designed with currently limiting start-up circuitry and longer ramp time. Nichrome filament power controllers are usually oversized to compensate for cold resistance in-rush current.



Options:

- Temperature indicator/controller.
- Temperature recording.

TO ORDER, SPECIFY:

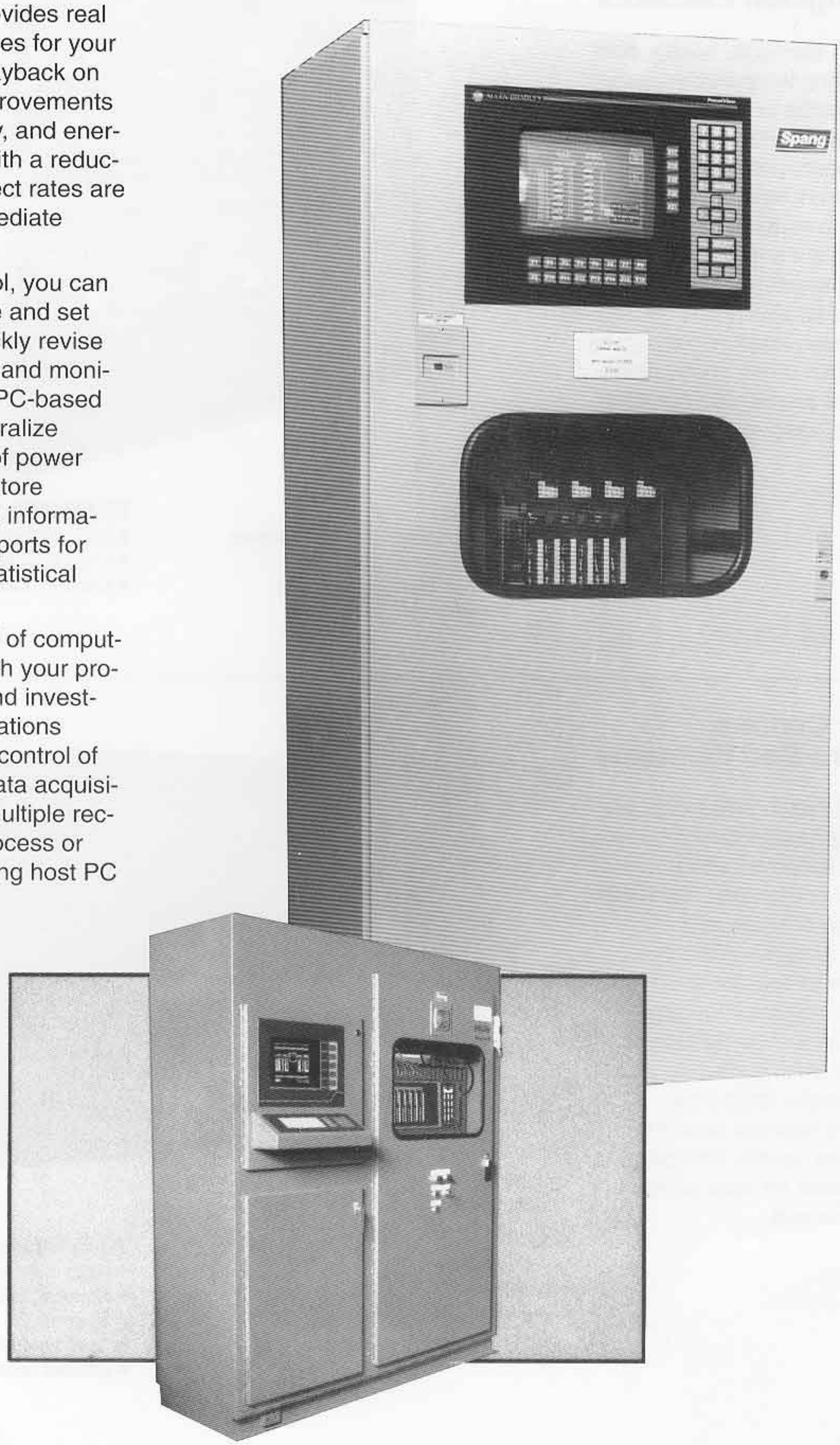
- Input voltage, frequency and phase.
- Nominal load voltage. Load kw, voltage current.
- Load type (tungsten or nichrome).
- Desired options or special features.

Computer Control

Computer control provides real bottom-line advantages for your operation and fast payback on your investment. Improvements in productivity, quality, and energy efficiency along with a reduction in waste and reject rates are just a few of the immediate benefits.

With computer control, you can automatically retrieve and set process profiles, quickly revise process parameters, and monitor real-time data. A PC-based system can also centralize control of a number of power centers, collect and store process performance information, and generate reports for trend analysis and statistical process control.

SPANG offers a level of computer integration to match your process requirements and investment plans. Configurations range from PLCs for control of logic functions and data acquisition of individual or multiple rectifiers to complete process or batch automation using host PC networks.

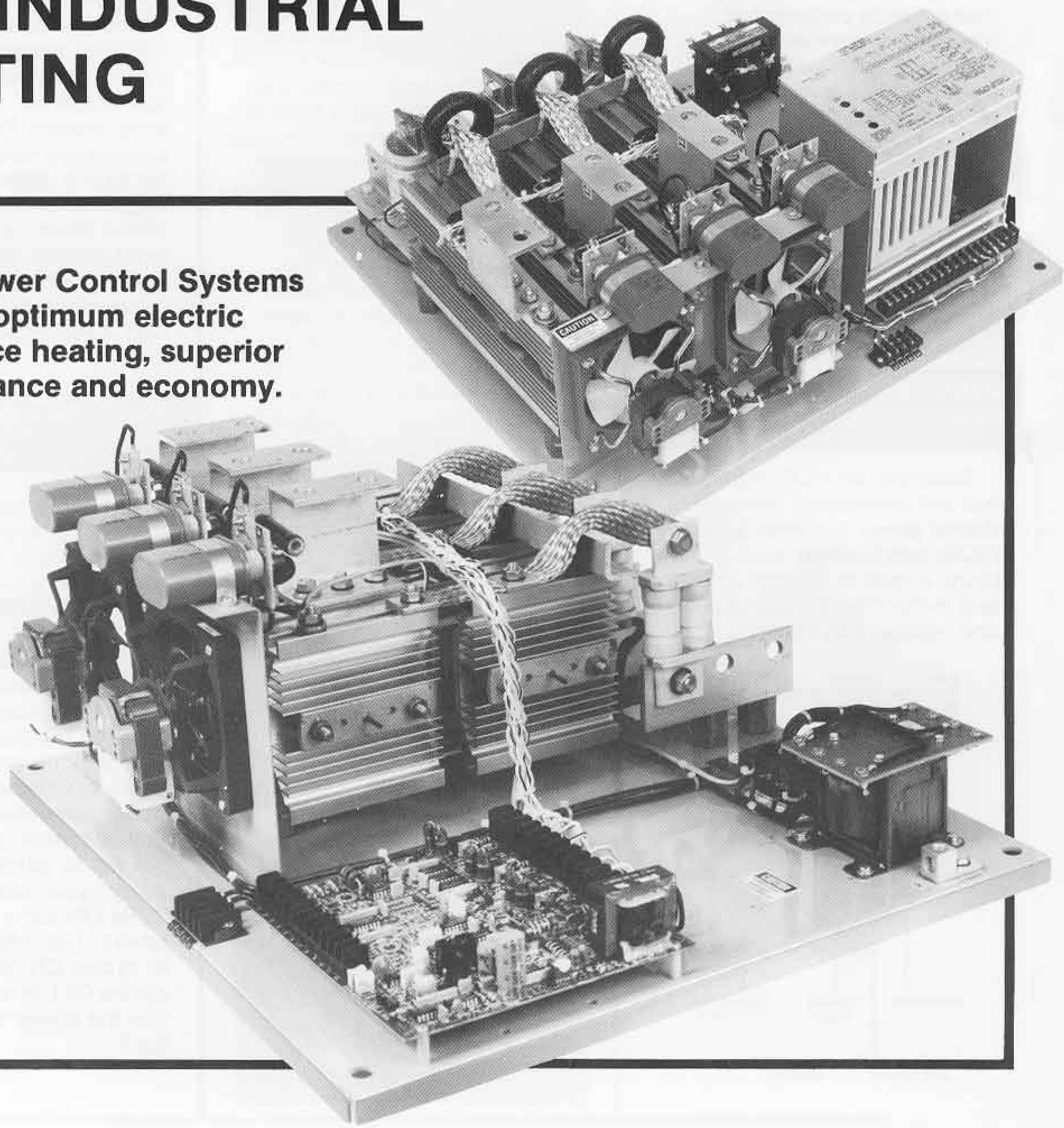


Spang Power Electronics

Guide To Selecting

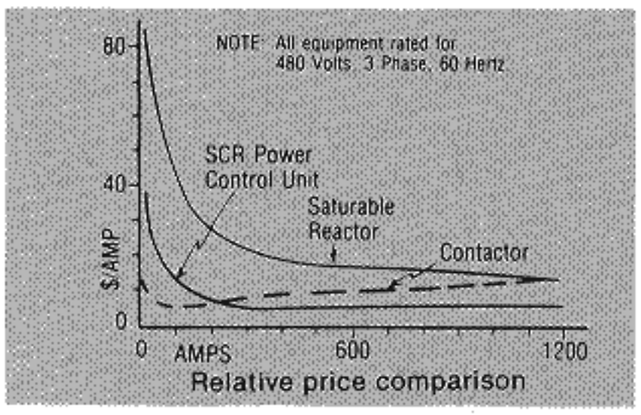
SCR POWER CONTROLLERS FOR INDUSTRIAL HEATING

SCR Power Control Systems provide optimum electric resistance heating, superior performance and economy.



The control of electric power for resistance heating may be accomplished in a variety of ways. The type of power control equipment used is basically a choice involving cost, reliability and performance.

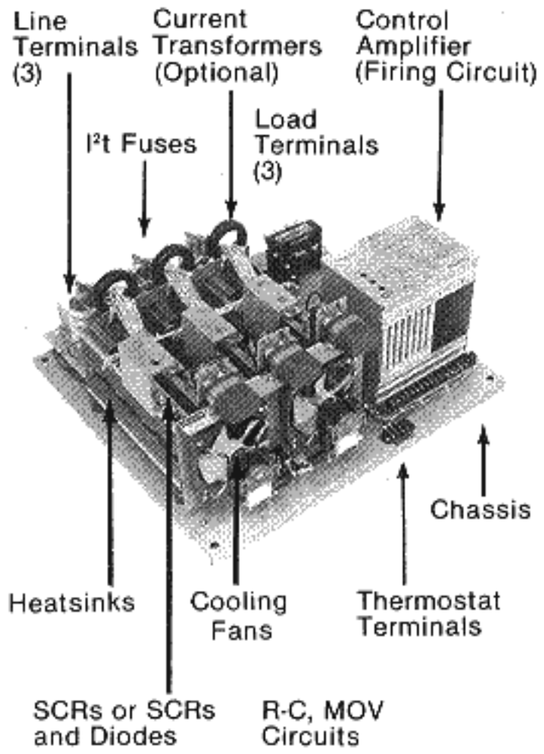
Silicon Controlled Rectifiers (SCRs) provide a relatively economical means of power control. SCR power control units cost less and are more efficient than saturable core reactors. Compared to contactors, SCRs offer a finer degree of control and do not suffer from the maintenance problems of mechanical devices. Properly applied, a well designed SCR power control unit provides high efficiency and reliability.



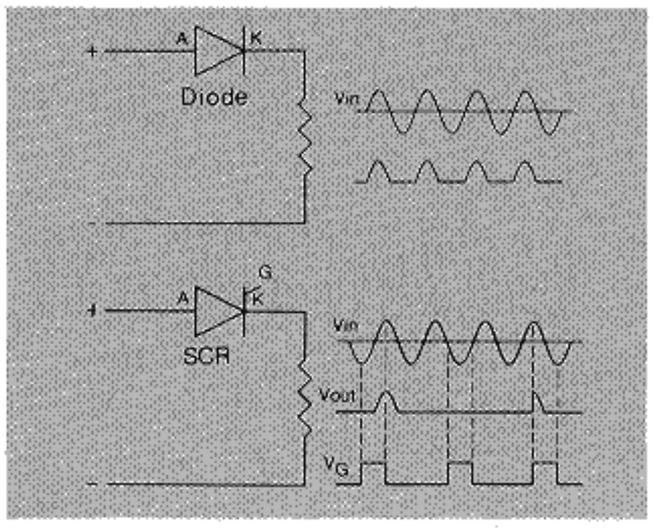
Relative price comparison

DESCRIPTION OF SCR POWER CONTROL UNIT

Basically, an SCR power control unit consists of semiconductor power handling devices (SCRs and Diodes), control logic (firing circuit or control amplifier) and protective devices (fuses and voltage suppressors).



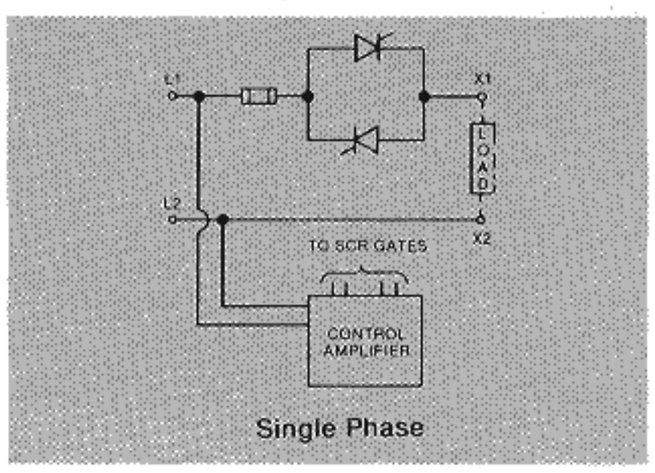
An SCR, like a DIODE, will only allow current flow in one direction, when the voltage across it is such that the anode (A) is positive with respect to the cathode (K). Unlike a diode, an SCR can be controlled.



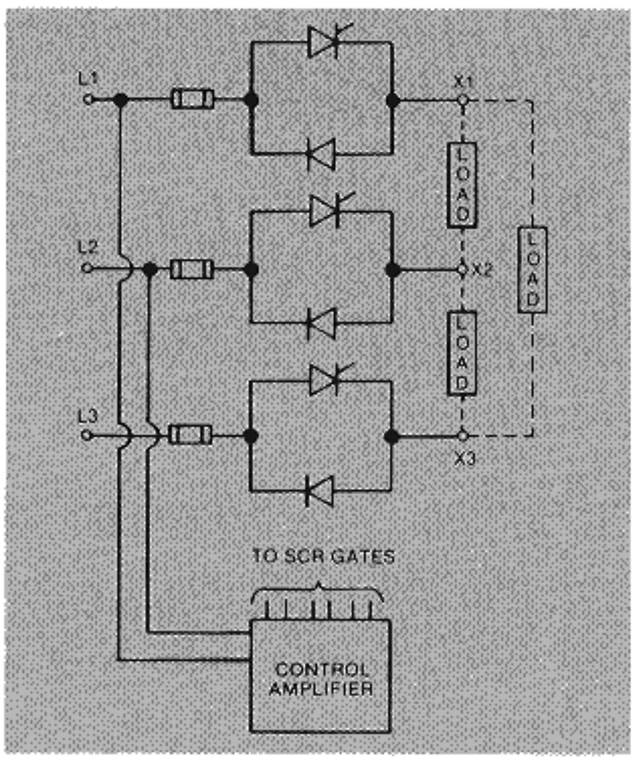
In addition to an anode and cathode, an SCR has a third terminal called the gate (G). In order for current flow to be initiated, the gate must be driven positive with respect to the cathode at the same time the anode is positive with respect to the cathode. Once conduction is started, current flow will continue as long as a minimum (or holding current) is drawn from anode to cathode. Therefore, once conduction is triggered by a pulse on the gate circuit, the SCR will continue to conduct until the current tries to reverse at the end of the half cycle or is otherwise reversed or interrupted.

The output of the SCR can be controlled by selectively gating the SCR in time.

By connecting two SCRs in opposite directions, it is possible to control both half cycles of the AC power. In some three phase configurations, diodes can be used in conjunction with SCRs to obtain full wave control.



Single Phase



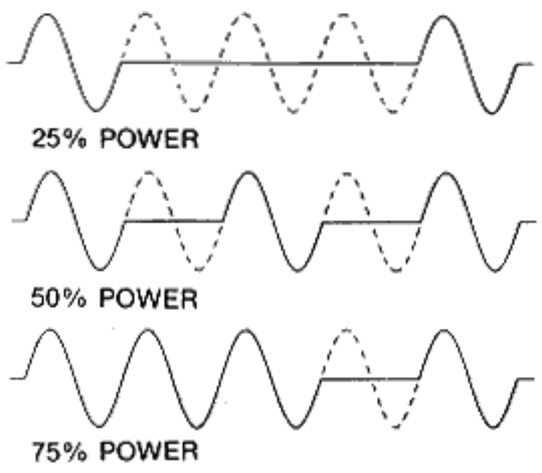
The Control Amplifier or FIRING CIRCUIT accepts a control signal from a potentiometer, temperature controller, computer or other source. Detecting the incoming line voltage, it then fires the SCR's gates in the correct sequence and time to provide output power in response to the input control signal. The firing circuit may also accept various feedback signals to regulate or limit output power, voltage or current.

TYPES OF CONTROL

Two major types of SCR control are commonly used for electric resistance heating:

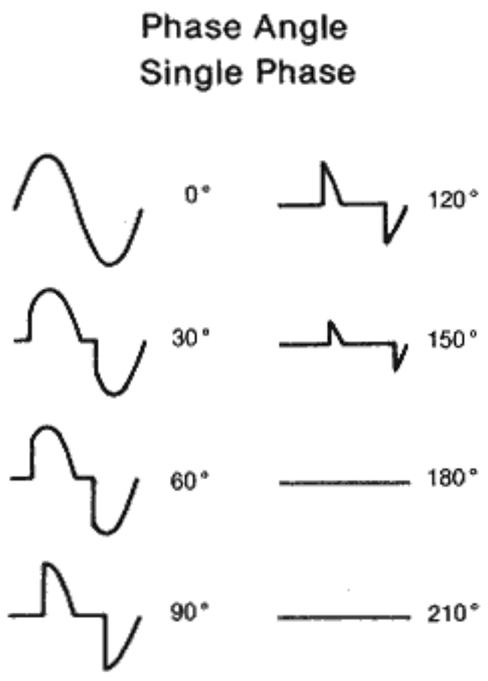
A. SYNCHRONOUS

In SYNCHRONOUS, (or zero voltage crossover) control, the SCRs are always gated at the moment the sine wave crosses zero and the anode is driven positive. Complete cycles of power are delivered at a time. Power control is not accomplished by gating the SCRs every cycle, but by having the SCRs ON some cycles and OFF others. The ratio of the number of cycles ON to the number of cycles OFF is varied to proportion the power delivered to the load.



B. PHASE ANGLE

In PHASE ANGLE control, the SCR is gated every cycle. Power control is accomplished by delaying SCR gating until some time after the voltage crosses zero. By varying this delay (measured in electrical degrees), the time the SCR is allowed to conduct is varied, as is the output power.



Typical Output Waveforms of Load Voltages at Various Delay Angles

C. COMPARISON OF PHASE ANGLE VS. SYNCHRONOUS

SYNCHRONOUS control has the advantage of producing no Radio Frequency Interference (RFI) since, turning on at zero, there are no abrupt changes in current or associated fields. Contactors and PHASE ANGLE controlled SCRs do turn on at points other than zero on the sine wave and the abrupt change in currents can produce RFI. However, proper installation can minimize the effect by routing power feeds away from sensitive equipment, routing power wires together to cancel antennae effect and using ferrous conduit and enclosures to contain the fields.

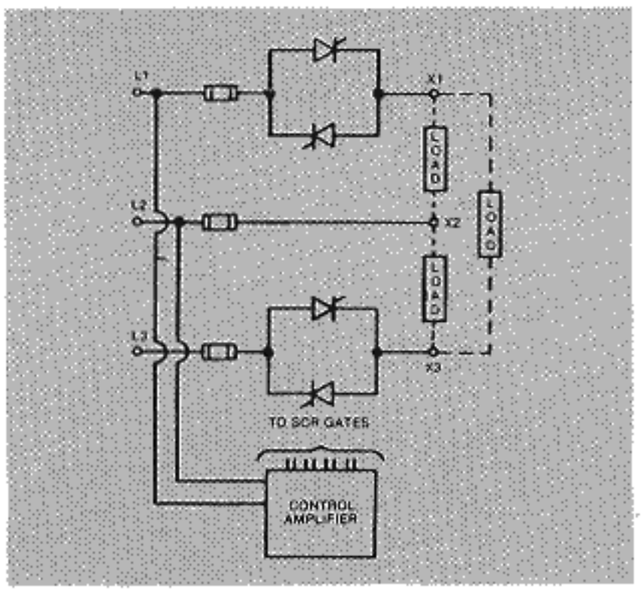
PHASE ANGLE control has the advantage of proportioning every cycle. This "subcycle" control allows voltage to be gradually applied to the load. When feeding the primary of a transformer (or other inductive load), this is very important. A PHASE ANGLE unit can be gradually turned on, providing a soft start to eliminate transformer inrush. SYNCHRONOUS control must deliver a full cycle of voltage which can result in high inrush currents and may lead to transformer saturation and fuse blowing.

CONFIGURATIONS

Although most single phase SCR Power Control Units utilize two inverse parallel SCRs, various configurations are used on three phase units. Waveforms of the various outputs are presented after the following discussion.

A. FOUR SCR OR 2 LEG

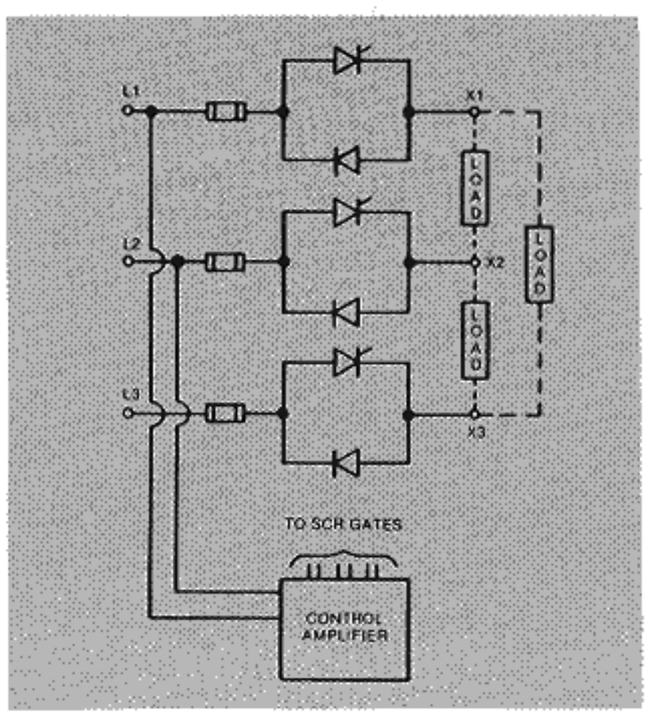
Generally used only on SYNCHRONOUS units, the 2 leg configuration uses four SCRs in inverse parallel sets in two legs or phases. The third phase provides a free return path for power from the controlled phases. This configuration is similar to using a two pole contactor on a three phase load.



This configuration is generally less expensive than controlling all three phases. However, an inherent DC component and the uncontrolled leg may cause problems with certain ground monitor systems and solid state trips on some circuit breakers.

B. 3 SCR — 3 DIODE

This configuration is used on both PHASE ANGLE and SYNCHRONOUS control. With SYNCHRONOUS it is commonly referred to as 3 leg control. For PHASE ANGLE, it is often referred to as a *semiconverter* or *hybrid SCR-Diode* circuit.



Current flow is controlled by an SCR in each phase. Complementary diodes allow this current to flow from the SCR controlling at a given instant, through the load and back to the other phases through the diodes.

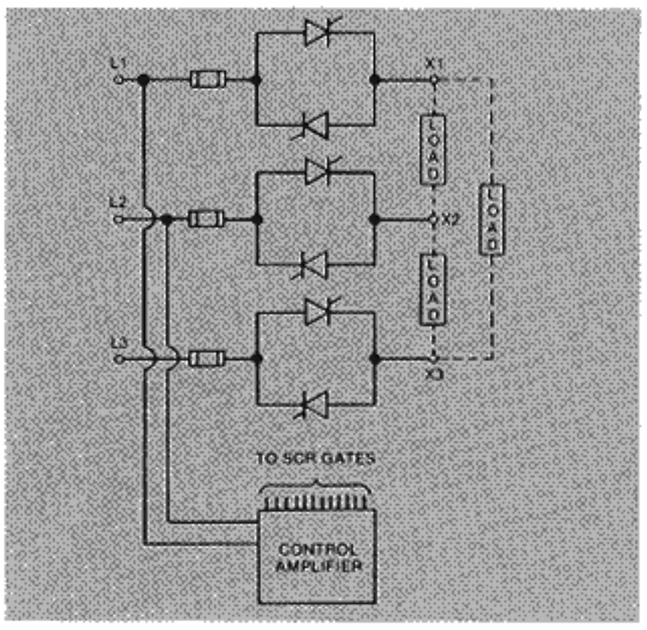
C. 6 SCR

The 6 SCR or *full converter* configuration uses all SCRs for control of the three phases in both directions.

Although generally more sophisticated and more expensive than the previous configurations, 6 SCR control is widely used for certain applications . . .

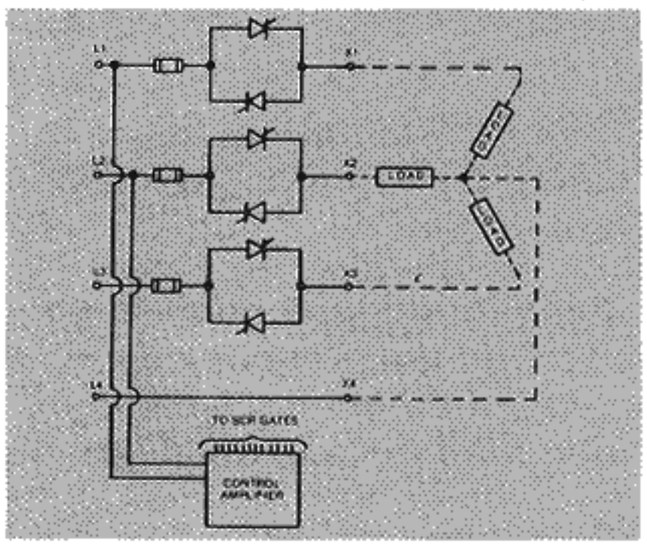
1. TRANSFORMER COUPLED LOADS

In PHASE ANGLE applications where a transformer primary is controlled, 6 SCR offers additional advantages over 3 SCR - 3 Diode control. First, it is more forgiving of drastic load unbalances. Second, should one SCR misfire due to a transient, the 3 SCR - 3 Diode configuration would allow a DC component to pass through the diodes of the other phases. This DC could saturate the transformer resulting in fuse blowing or breaker tripping. In the 6 SCR, this current could not flow unless two or more SCRs misfired, which is much more unlikely to occur.

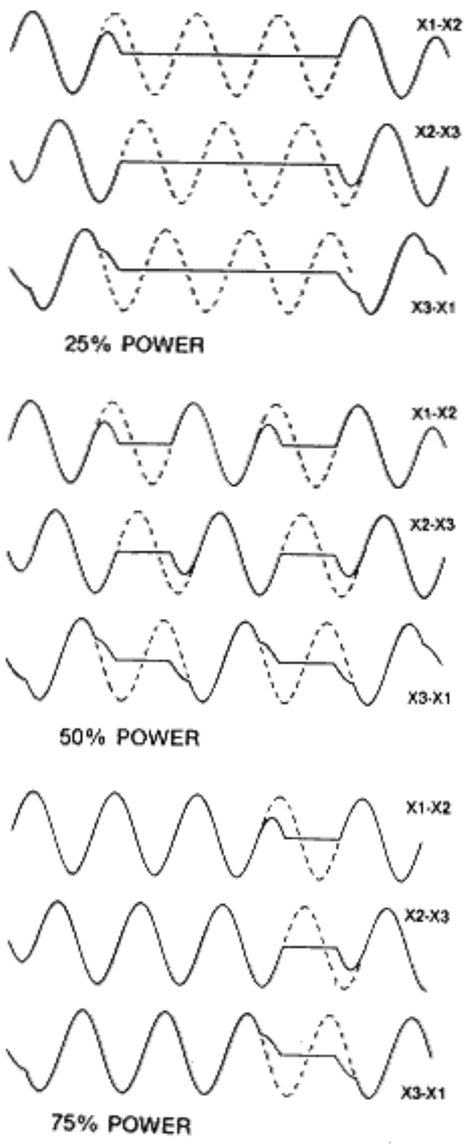


2. FOUR WIRE WYE LOADS

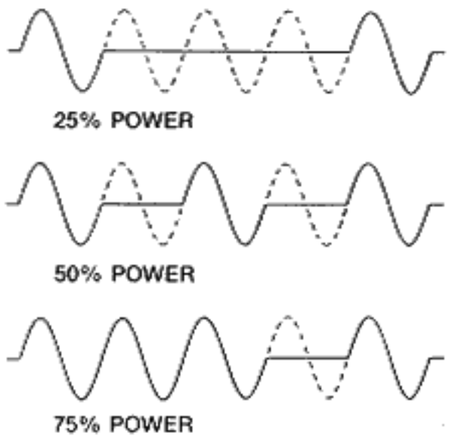
For both SYNCHRONOUS and PHASE ANGLE applications, the 3 SCR- 3 Diode configuration can be used for either delta or wye loads. However, they cannot have a ground or neutral tied back to the source without uncontrolled DC current flowing through the diodes. The 6 SCR configuration does not have this problem as only SCRs are used.



SYNCHRONOUS

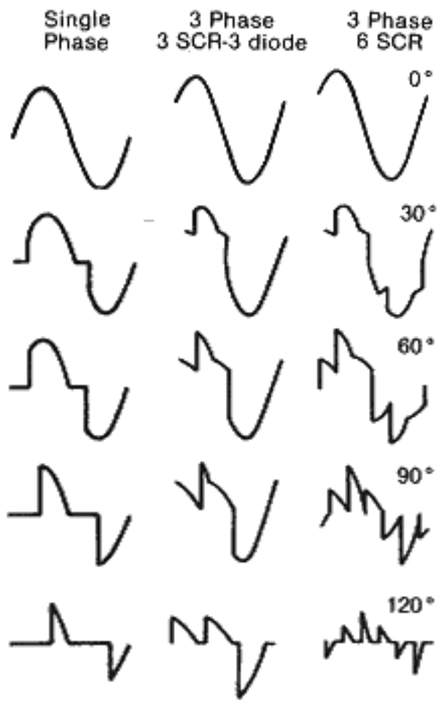


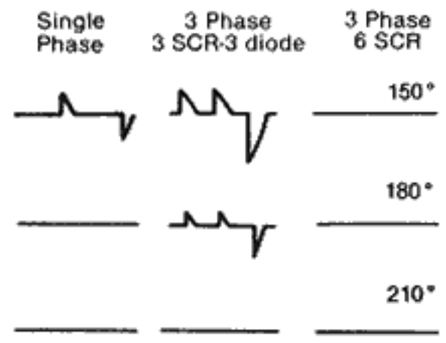
Typical Output Waveforms of Load Voltages for 3 Phase 2 LEG and 3 LEG Control



Typical Output Waveforms of Load Voltages for 1 Phase and 3 Phase 6 SCR Control, Line to Neutral

PHASE ANGLE





Typical Output Waveforms of Load Voltages at Various Delay Angles

POWER FACTOR

Recently there has been increasing concern relating to SCR control and power factor. It should be noted that in both SYNCHRONOUS and PHASE ANGLE firing for resistive loads, the current is in phase with the voltage whenever there is current flow. Even in phase angle control, where the application of voltage and current to the load are delayed each half cycle, once conduction is initiated, the current and voltage delivered are in phase. For this reason, the definition p.f. = COS θ has no real meaning.

The second definition of power factor should then be considered.

$$\text{p.f.} = \frac{\text{KW}}{\text{KVA}}$$

By reading input voltage and current with a voltmeter and ammeter while reading input KW with a wattmeter, it will be found that the ratio of KW to KVA will vary from near zero to unity as the SCR power control unit output is varied from zero to line voltage. As a result, both SYNCHRONOUS and PHASE ANGLE types of control appear to have a variable power factor.

Since we are considering purely resistive loads, the KW delivered is equal to the product of the voltage and current at the load. This fact allows us to better analyze what happens in producing the varying power factor.

Consider the input is 480 volts, single phase and the SCR power control unit is set to deliver 240 volts to a 2.4 ohm

load which is purely resistive.

Load Current is

240 V ÷ 2.4 ohms = 100A

Load KW is

240 V × 100 A = 24 KW

Since for SCR control the current out of the SCR unit must come directly from the input, 100 Amps must be supplied from the 480 Volt line . . .

Input KVA is

480 V × 100 A = 48 KVA

This formula can be generalized and simplified as follows:

$$p.f. = \frac{KW}{KVA} = \frac{V_{out} \times I_{out}}{V_{in} \times I_{in}}$$

As in our example, the current out of the SCR unit must come directly from the SCR input . . .

$$I_{in} = I_{out}$$

and therefore

$$\frac{I_{out}}{I_{in}} = 1$$

thus

$$p.f. = \frac{V_{out}}{V_{in}}$$

From this, we can state that the *apparent power factor* for both SYNCHRONOUS and PHASE ANGLE SCR control varies as the ratio of output voltage to input voltage.

For this reason, it is desirable to run SCR controls as near full line voltage as possible when delivering full power. To accomplish this, stepdown transformers are often used to match the required load voltage. When a stepdown transformer is used, a PHASE ANGLE power control unit is often operated on the transformer primary to take advantage of the lower line currents since SCR power control unit prices are related to current size.

POWER CONTROL SYSTEM SELECTION

The basic problem involved in selecting a power control system for electric resistance heating is three-fold. The first consideration is matching input and output power requirements. Second, the type of control equipment to be used must be decided. The third consideration is matching the power control system to the heating element's resistance characteristics.

Coordinating the power control system with the resistance characteristic of a particular type of heating element requires an understanding of how the element resistance varies with temperatures and age. Some elements vary relatively little and can be controlled with rather simple systems. Others exhibit drastic changes and are best controlled by more sophisticated systems that compensate for this characteristic.

For purposes of our discussion, the elements can be divided into three categories:

A. Elements with relatively stable resistance.
B. Elements that change resistance with age.
C. Elements that change resistance with temperature.

The table on page 70 lists typical characteristics of elements in these categories along with SCR power control system recommendations that have been proven reliable and economical.

A. ELEMENTS WITH RELATIVELY STABLE RESISTANCE.

This category includes iron-chromium-aluminum, 80-20 nickel-chromium and 35-20 nickel-chromium alloy elements. Often referred to as "straight resistance elements", these exhibit relatively little change in resistance with age or temperature. Typically, the change is on the order of 5 to 25 percent resistance increase from room temperature to operating temperature.

The basic equipment required for proportional control is either a phase angle or synchronous power control unit. Most frequently, synchronous firing is chosen due to its lower cost and elimination of radio frequency interference (RFI). Often two leg snychronous can be used on three phase applications in lieu of full three leg control.

Six SCR control must be used with four wire wye loads to eliminate the uncontrolled current path through the neutral and diodes of the 3 SCR- 3 diode configuration or through the neutral and the uncontrolled leg of two leg synchronous units.

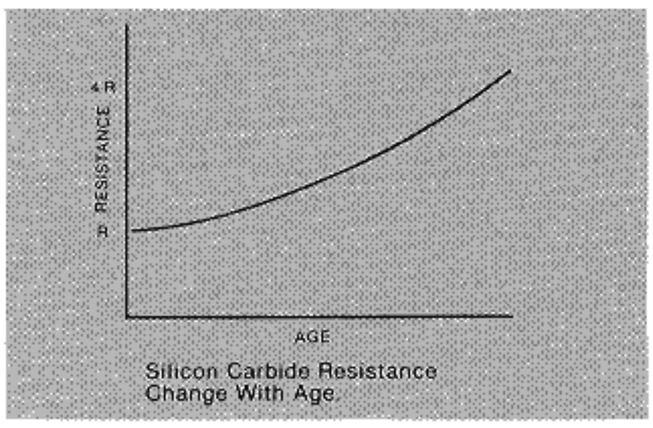
When sizing the power control unit, it is recommended that the element resistance change be considered. Either use a unit rated for the higher current seen at the lower "cold" resistance or one equipped with a current limit option.

Depending on the available incoming voltage and element design voltage, a load matching transformer may be required. For example, if the element design voltage is 120 volts and available power is at 480 volts, a 480 to 120 volt stepdown transformer would be desired. (It would be possible to reduce the voltage by using a voltage limited power control unit, but this would result in poor power utilization and high demand requirements.) If a synchronous power control unit is used, it must be placed on the transformer secondary to avoid transformer inrush currents which may cause nuisance fuse blowing or equipment failure. In some cases it may be more economical to place the power control unit on the transformer primary to take advantage of the lower current rating required. In these cases, a phase angle unit is necessary. It must include a soft start or transformer inrush protection feature which is not available on synchronous units. Six SCR control is recommended for three phase applications to minimize the possibility of transformer saturation associated with unbalanced loading or SCR misfiring.

B. ELEMENTS THAT CHANGE RESISTANCE WITH AGE

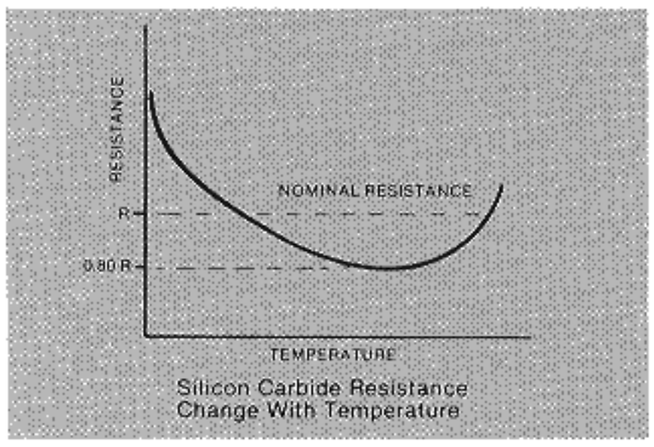
The resistance of the elements in this category increases with age. Generally caused by oxidation, the aging of the element is dependent on many factors including chemical environment (atmosphere) and operating watt densities. In addition to aging, these elements often exhibit a moderate resistance change with temperature.

The most common heating element in this group is silicon carbide. Due to the aging process, the element, by the end of its useful life, may increase resistance to as much as four times that of a new element.



Silicon Carbide Resistance Change With Age.

The element also exhibits a resistance change with temperature. As the element temperature increases, the resistance decreases until at approximately 1200°F it is about 80 percent nominal. Above 1200°F the resistance increases with temperature, reaching the nominal value at about 2000°F.



Silicon Carbide Resistance Change With Temperature

Two approaches to the power control system are widely used. The first uses a phase angle SCR power control unit and multi-tapped transformer. The second uses only a phase angle power control unit and is generally limited to lower power applications.

SCR-Transformer

The SCR-Transformer approach uses a multi-tapped transformer to compensate for element aging with a phase angle SCR power control unit providing proportional control on the transformer primary.

The first transformer tap selected is the "nominal" tap. It is generally specified to the voltage required to get the desired power when the element is new. To maintain rated power over the element's useful life, the formula $KW = \frac{V^2}{R}$ tells us that for the anticipated four fold increase in resistance the voltage will need to double. Additional taps are then specified to cover a range from the nominal voltage to twice the nominal voltage.

The number of taps is chosen to optimize efficiency, power factor and equipment utilization. To allow stepless control throughout the tap range, the power control unit must reduce the transformer secondary voltage to the value of the next lower tap while delivering full power to the load. This is done by reducing the transformer primary voltage the same percentage that the taps are apart. When delivering full power at this reduced voltage, the power factor for the SCR unit is

$$p.f. = \frac{V_{out}}{V_{in}}.$$

With V_t being the voltage of the tap in use and V_{t-1} the voltage of the next lower tap, when the output is reduced by SCR control to V_{t-1}, then

$$p.f. = \frac{V_{out}}{V_{in}} = \frac{V_{t-1}}{V_t}$$

It follows that with an increasing number of taps, power factor will approach unity. A practical limit is reached where the cost of manufacturing the transformer and inconvenience of frequent tap changing become prohibitive. Experience has shown a good compromise to be five full power taps with each tap a fixed percentage of the next higher tap. For five taps this works out to be approximately 84 percent.

$$V_t = 0.84\ V_{t+1}$$

By spacing the taps equal percentages apart, the power factor range is equalized. With five taps, the power factor between taps would range from 0.84 to unity.

The power factor must be considered for equipment sizing. Although rated for a given load KW, the transformer, SCR and source will need to be capable of handling the higher KVA required where

$$p.f. = \frac{KW}{KVA}$$

$$KVA = \frac{KW}{p.f.}$$

for five taps

$$KVA = \frac{KW}{0.84} = 1.2 \times KW.$$

A sixth tap is often added at 70 percent of the nominal voltage to provide reduced power for start-up, dry-out or holding applications.

The SCR power control unit is phase angle controlled. It is operated on the transformer primary for two reasons:

1. The primary is generally higher voltage (i.e., 480 volts) resulting in lower currents than the secondary. SCR power control unit costs are proportional to ampere rating; this lower current generally results in a cost savings.
2. The primary current is consistent throughout the tap range while secondary currents vary inversely with tap voltage. Placing the SCR unit in the primary allows the current limit to be consistent regardless of tap selection.

Six SCR control is recommended for three phase applications to minimize the possibility

of transformer saturation associated with unbalanced loading or SCR misfiring. The SCR unit must be equipped with a soft start (or transformer inrush protection) feature to gradually apply voltage to the transformer at start-up or in response to step increases in the process control signal. This prevents high inrush currents and nuisance fuse blowing.

An RMS current limit option is used on the SCR power control unit. In conjunction with the taps, this feature limits current draw during the negative resistance swing seen as the element heats up and helps limit element watt densities when operating between tap settings. With five full power taps, the watt densities are limited to within 19 percent over the design value.

The system can be further optimized by use of a watt regulation option which linearizes power output with respect to the process control signal. Watt regulation effectively eliminates excessive watt densities. When operating elements near maximum watt rating, this option should be considered.

SCR Only

The second approach to the control of elements like silicon carbide uses only SCR control without the tapped transformer. Although simpler in concept, it has many limitations that must be considered.

In order to utilize the element to its fullest extent, a two to one output voltage range is required to compensate for the four fold increase in resistance. Without the tapped transformer, this is generally accomplished by having the elements and incoming line voltages selected so that the nominal voltage required when the element is new is half the incoming line voltage. This results in the power control unit delivering full power over an output voltage range of half line voltage to full line voltage. The current required is provided to the SCR unit at line voltage. From our previous discussion of SCR power factor

$$\text{p.f.} = \frac{KW}{KVA} = \frac{V_{out} \times I}{V_{in} \times I} = \frac{V_{out}}{V_{in}}$$

With the output voltage half the input when the element is new p.f. = ½ = 0.5.

This power factor requires oversizing the power control unit, feeder lines and power source by up to 100 percent.

The possible initial power control equipment savings is often more than offset by increased installation and operating costs. However, in lower power applications (i.e., below 15 KW) where this load is relatively small compared to total plant loading, this approach may be worth considering.

The effect on power factor can be reduced by not trying to cover the full voltage range required for a four fold resistance change with element aging. This could require more frequent element replacement. Therefore, such reduced voltage range designs are limited to application where the atmosphere is non-oxidizing and the elements are conservatively operated below their maximum watt-density rating.

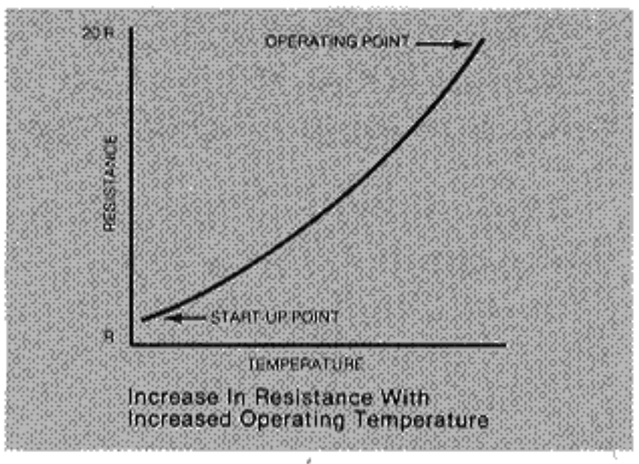
The SCR power control unit used for straight control of silicon carbide elements is a phase angle unit rated for the incoming line voltage and maximum current seen when the elements are new.

Watt regulation is a must in this control scheme. Since there is no tapped transformer to limit output voltage, watt regulation must be relied upon solely for preventing excessive watt densities in the element.

RMS current limit is required primarily to protect the power equipment.

C. ELEMENTS THAT CHANGE RESISTANCE WITH TEMPERATURE

This third category, unlike the preceding two, includes elements which show dramatic resistance change with temperature. Typically, the resistance may increase as much as twenty (20) times from cold to operating temperatures. Although this change is relatively rapid, the potential for high current draw at low temperatures must be considered.



Increase In Resistance With Increased Operating Temperature

Included in this category are elements such as molybdenum, molybdenum-disilicide, graphite and tungsten.

Two major characteristics determine the basic equipment required for controlling these elements. The first is the dramatic resistance change described above. The second is the normally low operating voltage (around 35 to 50 volts). Basic control equipment includes an SCR power control unit and a stepdown transformer.

The power control unit operates on the transformer primary to take advantage of lower primary currents. It is a phase angle fired type with a soft start (transformer inrush protection). Six SCR control is recommended for three phase applications. The use of the RMS current limit option is mandatory. Since the resistance of the heating element when cold is essentially a short circuit, excessively high start-up current would be encountered unless limited by the controller. The power control unit should be turned on gradually for a smooth transition of the element to operating temperature and resistance. This can be accomplished by increasing the

C. ELEMENTS THAT CHANGE RESISTANCE WITH TEMPERATURE *(Cont.)*

soft start time or adding a separate ramp circuit. When coupled with RMS current limit a ramp time of approximately three seconds is generally sufficient.

The transformer used is basically a stepdown transformer for load matching. It should be a high quality unit designed for use with SCR control.

Another group of elements in this category includes Quartz and Infra-red heaters and lamps with tungsten filaments. Often, these are designed to operate at line voltage levels, eliminating the need for a transformer. Also, recent experience has shown that the current limit option may not be necessary for these lamps if the ramp time of the SCR unit is long enough so that the voltage is applied gradually enough to allow element temperature and resistance increase without high current draw. The ramp time should be around three seconds or more. Some SCR power control unit oversizing may be required and can best be determined by experimentation.

SUMMARY

Controls for three basic categories of resistance heating elements have been considered. There may be other types not specifically mentioned. Many can be placed in the three categories based on similar resistance characteristics, while others may require separate design considerations. By properly matching the power control system to the heating element characteristics, the benefits of electric resistance heating can be maximized while obtaining superior performance and economy.

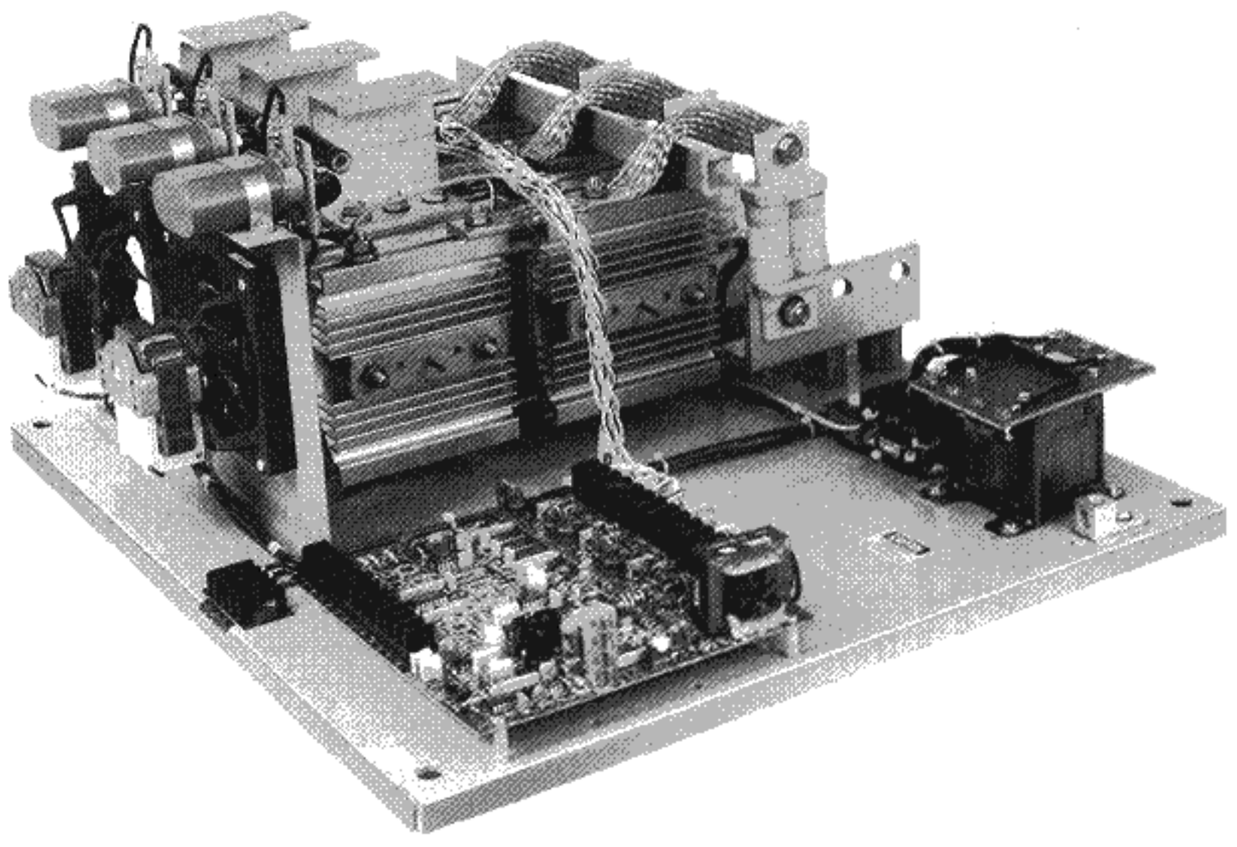
POWER CONTROL COMPARISON CHART

Equipment Features	Tapped Transformer (Alone)	Electro-Mechanical Contactor	Saturable Reactor	SCR Power Control Unit
Type of Control	Fixed Taps	Time Proportioning (On-Off)	Current Proportioning	Voltage Proportioning
Degree of Control	Coarse — Fixed Steps	Coarse — Limited by Mechanical Considerations	Fine — Intinitely Variable	Fine — Infinitely Variable
Means of Control	Transformer Action	Mechanical	Static-Magnetic	Static — Solid State
Construction	Bulky — Rugged	Compact	Bulky — Rugged	Compact
Efficiency	Good	Good	Relatively Low	High
Power Factor	High	High	Relatively Low	Variable with Output
Options (Such as Current Limit and Power Regulation)	Not Available	Time averaged hard to apply. Generally not used.	Wide choice limited by slow response.	Wide choice
Maintenance	Minimal	High	Minimal	Minimal
Problems	Tap repair	Mechanical failures, very coarse control.	Bulky, low efficiency, poor power factor, relatively expensive.	Sophisticated (but reliable)

CONTROL SYSTEM SELECTION GUIDE

Category	Element Type	Resistance Charactertistics	Recommended Equipment[2]
A	Iron-Chromium Aluminum Alloy	5% increase from cold to hot	Phase angle or synchronous[1] SCR power control unit
	80 - 20 Nickel Chromium	6% increase from cold to hot	
	35 - 20 Nickel Chromium	24% increase from cold to hot	As above except with current limit or oversized for cold resistance
B	Silicon Carbide	Decreases to 80% of rated at 1200°F then increases to rated at 2000°F. Resistance can increase up to 4× over useful lifetime.	6 SCR phase angle power control unit with transformer inrush protection and current limit feeding multi-tapped transformer.
C	Molybdenum	20 times increase from cold to hot.	6 SCR phase angle power control unit with transformer inrush protection and current limit feeding transformer.
	Molybdenum Disilicide		
	Graphite	20 times increase from cold to hot.	
	Tungsten	20 times increase from cold to hot.	
	Quartz		See text
	a. Tungsten	See above listing for Tungsten	
	b. Nichrome	See above listing for Nichrome	
	Infra-red		
	a. Tungsten	See above listing for Tungsten	
	b. Nichrome	See above listing for Nichrome	

NOTES: 1. A transformer may be required if the element is working below line voltage.
2. Primary overcurrent and disconnect devices, such as fused disconnect switch or a circuit breaker, should be used in all applications.



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Analysis of Straight SCR Control Versus SCR with Tapped Transformer for Silicon Carbide Elements

The resistance of silicon carbide elements can increase as much as four (4) times the original nominal value over its useful lifetime. In order to get maximum utilization of the element, it is then desirable to design the power supply to compensate for this.

How Much Voltage Range Is Needed?

Power = $w = (v^2/R)$

Let R_N = New element resistance

Let R_A = Aged element resistance

Let v_N = New element voltage required for full power

Let v_A = Aged element voltage required for full power

Then, in order to deliver the same power to the aged element as to the new element:

$(v^2_A/R_A) = (v^2_N/R_N)$

Since the element resistance can increase four (4) times with age,

$R_A = 4R_N$

Therefore:

$(v^2_A/4R_N) = (v^2_N/R_N)$

$4R_N \times (v^2_A/4R_N) = 4R_N \times (v^2_N/R_N)$

$v^2_A = 4v^2_N$

$\sqrt{v^2_A} = \sqrt{4v^2_N}$

$v_A = 2v_N$

This indicates that a two-to-one (2:1) voltage range will maximize the useful life of the silicon carbide element.

Compensation

With SCR control, there are two major approaches in use.

(1) Use straight SCR control (no transformer) with input power at approximately twice that required when the element is new (i.e. $v_A = 2v_N$). Use power or watt regulation to maintain the SCR output to required level.

(2) Use an SCR power control unit and tapped transformer. The secondary taps would cover a 2:1 range to compensate for element aging. The taps also provide a good degree of power limiting, making watt regulation a desirable option instead of a necessity.

Both approaches generally incorporate current limiting to protect against higher current draws during the resistance change occurring with element heat up.

Power Factor

While both approaches provide good control of power to the silicon carbide heating element, they differ greatly in their effect on power factor and feeder equipment sizing.

With increasing penalties charged by power companies for poor power factor, it is desirable to avoid this situation. Poor power factor can also require higher feed equipment ratings, leading to higher cost.

When power factor is considered, a tapped transformer coupled with SCR control becomes more desirable. This becomes even more critical as the total SCR controlled power increases.

Straight SCR Control

Consider a typical SCR control application using straight SCR control (Fig. 1).

The silicon carbide heating element is rated to deliver 12kw at 120 volts. As it ages, it will require twice this, or 240 volts, to obtain full power. The input power, therefore, is at 240 volts.

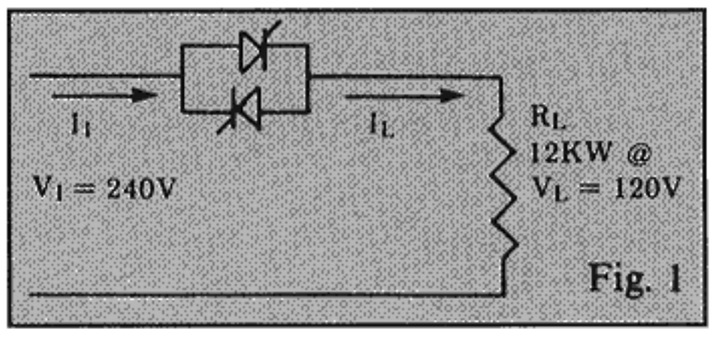


Fig. 1

Since the element can be approximated as purely resistive,

Load Power = $w_L = v_L \times I_L$

$I_L = (w_L/v_L)$ = 12000w/120v =100 amperes

Thus, to deliver 12kw at 120 volts, 100 amperes must be drawn through the SCRs from the 240 volt input line.

Although the *Real Power* (watts) read on w_I going into the unit is 12kw, the total *Apparent Power* (vo!t-amperes) into the unit is not 12 kva.

$vA = v_I I_I$ = 240v x 100A = 24,000 vA

kva = $(v_I I_I/1000)$

= 240v x IOOA/1000 = 24 kva

Power Factor is defined as

P.F. = kw(IN)/kva(IN)

Thus, the Power Factor for this example is: P.F. = 12kw/24 kva = 0.5

Two results of this type of control are:

(1) Depending on the power used, this control system can result in a power factor penalty on the electric bill. The larger the percentage of total plant power represented by this control, the worse the total plant power factor and the higher the operating costs.

(2) The kva requirement must be supplied by the plant system. In this example, 24 kva iA required for a 12kw load. This would mean that the feeder transformer and lines

needed to be sized for 24 kva, *not* 12kw.

A similar 150kw system would require 300 kva to power!

Excessive power can lead to wasted capacity on the plant electrical system. This wasted capacity translates into extra costs.

An interesting relationship between power factor and SCR input and output voltages can be developed for rapid estimation of power factor under most conditions.

Since P.F. = kw(IN)/kva(IN) = kw(OUT)/kva(IN)
= (v_L x I_L /v_I x I_I) and $I_L = I_I$ then
P.F. = ($v_L I_L / v_I I_L$) = (v_L / v_I)

Therefore, the power factor at any point is the ratio of output voltage to input voltage.

SCR—Tapped Transformer Control

Consider a tapped transformer coupled with SCR control to minimize power factor. The transformer is tapped over a 2:1 range with 5 taps. The taps are spaced equal *percentages* apart. Each tap is approximately 84% of the voltage of the next higher tap.

The example is similar to Figure 2. The five power taps are at 120v, 142v, 169v, 202v and 240v.

When the element is new, the 120 volt tap provides 12kw with unity power factor.

$I_L = (w_L/v_L)$ = 12000w/120v = 100A
$I_I = I_L$ x (N_S/N_P)

where (N_S/N_P) is transformer ratio
(N_S/N_P) = (v_S/v_P) = 120v/240v
therefore:
I_I = 100A x ½ = 50 amperes thus
kva(IN) = $v_I I_I$/1000 = 240v x 50A/1000 kva(IN) = 12 kva and
P.F. = kw/kva =12kw/12kva = 1

Next, consider the worse case. That would be drawing full power at the voltage corresponding to the next tap down. That is, using 120 volts on the 142 volt tap.

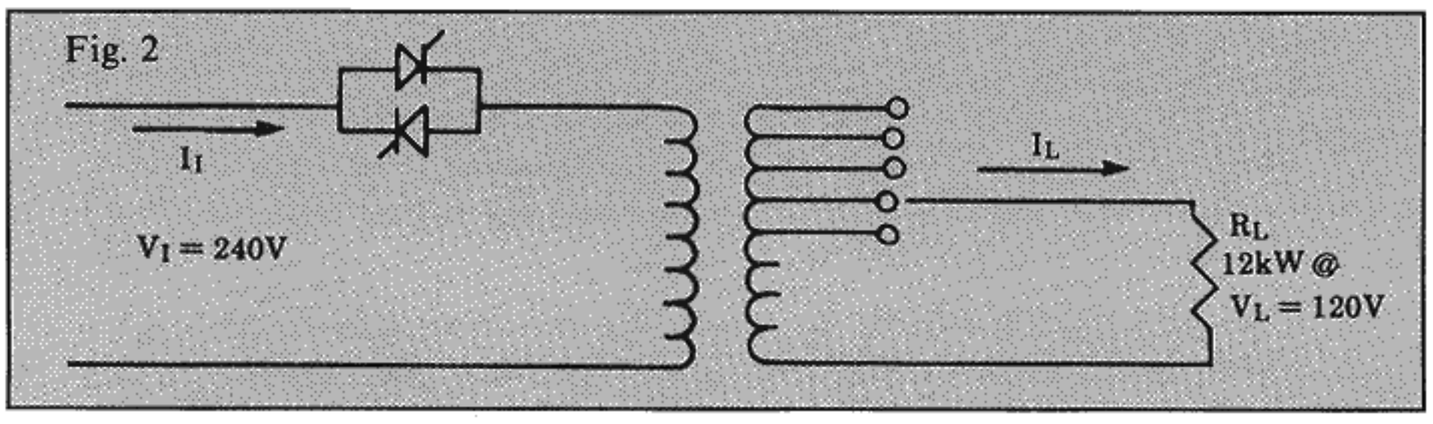
$I_I = (w_L/v_L)$ = 12000w/120v = 100A I_I = I_L x (Ns/Np) now the transformer ratio is (Ns/Np) = (vs/vp) = 142v/240v = 0.59 $I_I = I_L$ x 0.59 = 100 x 0.59 = 59 amperes thus kva (IN) = $v_I I_I$/1000 = 240v x 59A/ 1000 kva (IN) = 14.16 kva and P.F. = kw/kva = 12kw/14.16 kva = 0.84.

Therefore, the transformer allows operation at full power with a 0.84 power factor or better throughout the 2:1 voltage range. This is quite an improvement over the 0.5 power factor of the straight SCR approach described above.

In the worse case, the power factor of 0.84 has less effect in terms of power factor penalty on the electric bill than the 0.5 power factor of straight SCR control. A savings in operating cost results.

Furthermore, the kva requirement supplied by the plant system is less. In the examples; only 14 kva is required with SCR and tapped transformer instead of 24 kva required with straight SCR control or a plant capacity savings of 10 kva!

A similar 150kw system with SCR and tapped transformer control would only require 179 kva instead of 300 kva required for straight SCR control—a plant capacity savings of 121 kva or 40%!



The savings in feed transformers and wiring costs can result in reduced total installation costs.

The savings can mean the difference between using existing power distribution equipment or buying more equipment to meet the capacity requirement!

Summary

The above examples show that savings on operating and installation costs are possible using the SCR-tapped transformer approach to control silicon carbide heating elements.

The actual economy depends on several factors:

(1) How much of total plant loading does the SCR control represent? The greater the percentage the greater the savings.
(2) How high is the local power company's power factor penalty? The higher the penalty the greater the savings.
(3) Is a step-down transformer required even with straight SCR control (i.e. 480v to 240v)? If so, the cost of the tapped transformer can be greatly offset.
(4) What effect do the kva requirements have on plant loading? The SCR-tapped transformer can prevent the need for adding plant capacity and this can mean substantial savings.
(5) Other installation costs such as input wiring, feeder breakers, etc. should be considered. All are related to the input kva requirements. The lower kva required by the SCR-tapped transformer approach means installation savings.

In general, the higher the load kw the greater the savings with use of the SCR-tapped transformer.

When it comes to controlling electric power from the line to your heating load, turn to a specialist, Spang Power Electronics.

We turn out everything from SCR power controllers and transformers to custom engineered AC power centers, in NEMA 1 or NEMA 12, for automatic control of silicon carbide, nichrome, molybdenum, tungsten, graphite, infra-red elements, and other heating loads.

As a one-source supplier, we design and manufacture all major components: transformers, SCR power controls, saturable reactors, sensing and control amplifiers.

From watts to megawatts, you can count on Spang Power Electronics to take total responsibility to custom design and construct the AC process heating system to fit your requirements.

Whatever the element...a Spang power center will take the heat. For additional information contact our power control specialists at our Mentor, Ohio and Sandy Lake offices, or visit our website: www.spangpower.com

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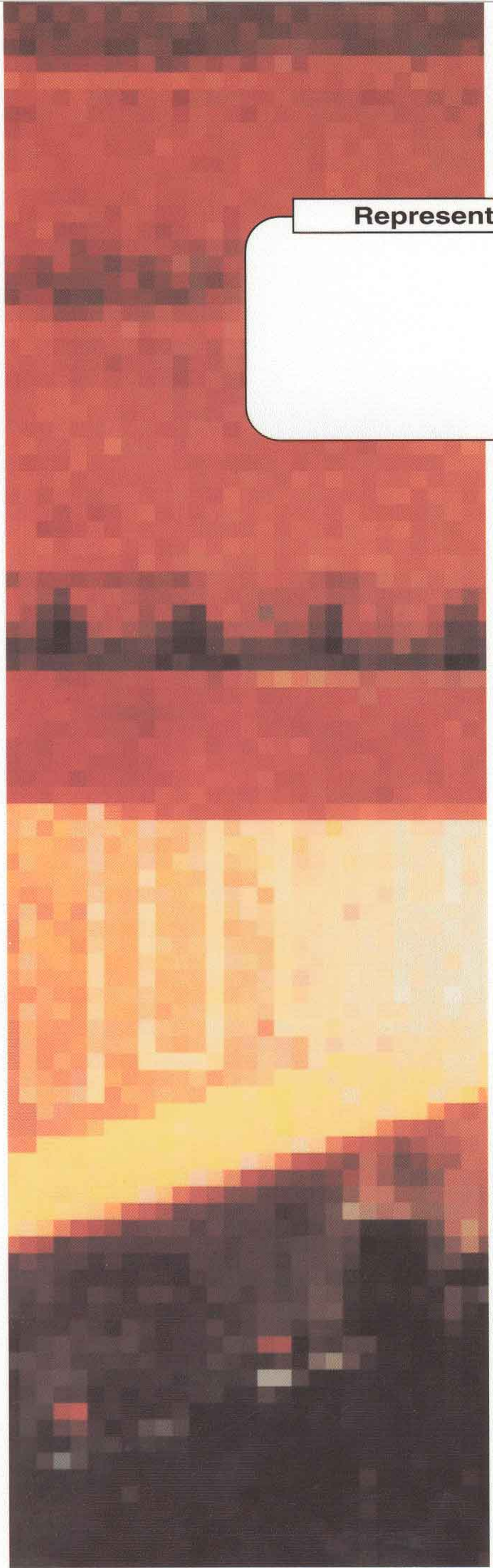

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