# User Guide

1/4 HP to 2 HP
Adjustable Voltage DC Drive

# Focus 1

CONTROL TECHNIQUES WORLDWIDE

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359 Lang Boulevard, Building B
Grand Island, New York 14072  USA
(716) 774-1193 • Fax: (716) 774-8327

*Division of Emerson Electric Co.*

FOCUS1/UG
February 1997

Printed in USA

The drive stop and start inputs should not be relied upon alone to ensure the safety of personnel. If a safety hazard could arise from the unexpected starting of the drive, a further interlock mechanism should be provided to prevent the motor from running except when it is safe to do so.

The manufacturer accepts no liability for any consequences resulting from inappropriate, negligent or incorrect installation or adjustment of the optional operating parameters of the equipment, or from mismatching of the drive to the motor.

The contents of this guide are believed to be correct at the time of printing. In the interests of a commitment to a policy of continuous development and improvement, the manufacturer reserves the right to change the specification of the product or its performance or the contents of the User's Guide without notice.



**WARRANTY**

Control Techniques Drives (CT) warrants to the buyer who purchases for use and not for resale that the equipment described in this manual is sold in accordance with CT's published warranty statement (document # GEN-030) and CT's published terms and conditions (document # GEN-031). Copies of these documents may be obtained from any Drive Center listed below.

For product technical support and/ or copies of this User guide, please contact the Drive Center nearest you:

**CALIFORNIA**
ADI/Control Techniques Drives
San Francisco Drive Center
2512 Tripaldi Way
Hayward, CA 94545
Phone: 510-264-4940
Fax: 510-264-4949

**ILLINOIS**
Control Techniques Drives
Chicago Drive Center
95 Brandon Drive
Glendale Heights, IL 60139
Phone: 708-893-5249
Fax: 708-893-4156

**OHIO**
Control Techniques Drives
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1125 Petersburg Road
Hebron, KY 41048
Phone: 606-689-4900
Fax: 606-689-5344

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Charlotte, NC 28208
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Toronto Drive Center
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Markham, ON Canada L3P 3J3
Phone: 905-475-4699
Fax: 905-475-4694

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**AMERICAS' SERVICE CENTER**
Control Techniques Drives
359 Lang Boulevard, Building B
Grand Island, NY 14072
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# TABLE OF CONTENTS

# LIST OF ILLUSTRATIONS





# LIST OF TABLES

# SECTION 1
# SAFETY

This section outlines procedures necessary to insure safe operation of any AC or DC drive. For further information, contact the Service Department at the address shown on the inside back cover of this manual.

## 1.1 GENERAL SAFETY PRECAUTIONS

**WARNING**

**THIS CONTROL AND ASSOCIATED MOTOR CONTAINS HAZARDOUS VOLTAGES AND ROTATING MECHANICAL PARTS. EQUIPMENT DAMAGE OR PERSONAL INJURY CAN RESULT IF THE FOLLOWING GUIDELINES ARE NOT OBSERVED.**

1. Only qualified personnel familiar with this equipment and the information supplied with it should be permitted to install, operate, troubleshoot or repair the apparatus. A qualified person must be previously trained in the following procedures:
   a) Energizing, de-energizing, clearing, grounding and tagging circuits and equipment in accordance with established safety practices.
   b) Caring and using protective equipment such as rubber gloves, hard hat, safety glasses or face shields, flash clothing, etc., in accordance with established safety practices.
   c) Rendering First Aid
2. Installation of the equipment must be done in accordance with the National Electrical Code and any other state or local codes. Proper grounding, conductor sizing and short circuit protection must be installed for safe operation.
3. During normal operation, keep all covers in place and cabinet doors shut.
4. When performing visual inspections and maintenance, be sure the incoming AC power is turned off and locked out. The drive and motor will have hazardous voltages present until the AC power is turned off. The drive contactor does not remove hazardous voltages when it is opened.
5. When it is necessary to make measurements with the power turned on, do not touch any electrical connection points. Remove all jewelry from wrists and fingers. Make sure test equipment is in good, safe operating condition.
6. While servicing with the power on, stand on some type of insulation, being sure you are not grounded.
7. Follow the instructions given in this manual carefully and observe all warning and caution notices.

## 1.2 INSTALLATION SAFETY

When moving this control and associated motor into the installation position, do any required lifting only with adequate equipment and trained personnel. Eyebolts or lifting hooks, when supplied, are intended for lifting the product only and must not be used to lift additional weight. Improper lifting can cause equipment damage or personal injury.

**WARNING**

**HAZARDOUS VOLTAGES MAY BE PRESENT ON EXTERNAL SURFACES OF UNGROUNDED CONTROLS. THIS CAN RESULT IN PERSONAL INJURY OR EQUIPMENT DAMAGE.**

**IF THE DRIVE CABINET OR OPEN CHASSIS UNIT IS MOUNTED SUCH THAT IT IS NOT GROUNDED, A GROUND WIRE MUST BE CONNECTED TO THE PANEL OR ENCLOSURE FRAME FOR PERSONNEL SAFETY. ALSO ANY MOTOR FRAME, TRANSFORMER ENCLOSURE AND OPERATOR STATION MUST BE CONNECTED TO EARTH GROUND. CONSULT THE NATIONAL ELECTRICAL CODE AND OTHER LOCAL CODES FOR SPECIFIC EQUIPMENT GROUNDING REQUIREMENTS.**

**PROTECTIVE GUARDS MUST BE INSTALLED AROUND ALL EXPOSED ROTATING PARTS.**

**CAUTION**

**Drilling or punching can create loose metal chips. This can result in shorts or grounds that can damage the equipment.**

If it is necessary to drill or punch holes in the equipment enclosures for conduit entry, be sure that metal chips do not enter the circuits.

Circuits shown on the drawings that require shielded cable are sensitive to pick-up from other electrical circuits. Examples include wiring from the tachometer and from the speed setting device. Erratic or improper operation of the equipment is likely if the following precautions are not observed:

1. Where shielded cable is required, use 2- or 3- conductor twisted and shielded cable with the shield either connected as shown in the drawings, or “floating”, if so specified. If the shield is to be connected, do so only at the specified terminal in the drive unit. Do not connect at a remote location.
2. Shielded cables outside the drive enclosure should be run in separate steel conduit, and should not be mixed in with other circuits that are not wired with shielded cable.
3. Inside the drive equipment, whenever possible, avoid running the shielded cable close to other circuits. Avoid long parallel runs to other non-shielded circuits, and cross other cable bundles at right angles.



Do not connect any external circuits to the drive or its associated equipment other than those shown on the diagrams supplied. Connection of external devices to the tachometer or speed setting device can significantly affect drive performance.

**CAUTION**

**Meggering circuits connected to the drive can cause damage to electronic components. Do not megger or hi-pot this equipment. Use a battery operated Volt-Ohm-Meter (VOM) to check for shorts, opens or mis-wiring.**

**Connection of unsuppressed inductive devices to the drive power feed or control circuits can cause mis-operation and possible component damage to the equipment.**

**Do not connect power factor correction capacitors with this equipment, as this may cause high voltages that can damage the drive.**

## 1.3 Start-up Safety

Detailed startup procedures are described in the Operation and Startup Section of this manual. Before and during startup, it is imperative that all of the following safety procedures be observed.

**WARNING**

**AC POWER MUST BE DISCONNECTED FROM THE DRIVE CABINET TO ELIMINATE THE HAZARD OF SHOCK BEFORE IT IS SAFE TO TOUCH ANY OF THE INTERNAL PARTS OF THE DRIVE. CIRCUITS MAY BE AT LINE POTENTIAL WHETHER THE ENCLOSED DRIVE IS OPEN OR CLOSED. USE EXTREME CAUTION.**

**ALSO, HAZARDOUS VOLTAGES ARE PRESENT ON THE MOTOR UNTIL ALL POWER TO THE CONTROL IS DISCONNECTED.**

**TURN OFF AND LOCK-OUT ALL POWER TO THE CONTROL BEFORE TOUCHING ANY INTERNAL CIRCUITS ON THE MOTOR.**

1. The use of unauthorized parts in the repair of this equipment or tampering by unqualified personnel will result in dangerous conditions which can cause equipment damage or personal injury. Follow all safety precautions contained in this manual and all safety warning labels on the product.
2. Loose rotating parts can cause personal injury or equipment damage.

Before starting the motor, remove all unused shaft keys and any other loose parts on the motor or the rotating mechanical load. Be sure all covers and protective devices are in place. Refer to the instruction manual supplied with the motor for further information and precautions.

3. When using an oscilloscope to make measurements in the power circuits, use the connections shown in Figure 1-1 and the procedures described in step 4. Failure to follow this procedure could result in the case of the oscilloscope being at line potential. Only qualified personnel should be allowed to use the oscilloscope and other test equipment.
4. Referring to Figure 1-1, set the oscilloscope to add channels A & B, and invert channel B. Before making measurements, connect both probes together and set the “zero” line.

This connection allows the oscilloscope case to be connected to ground for safe operation.

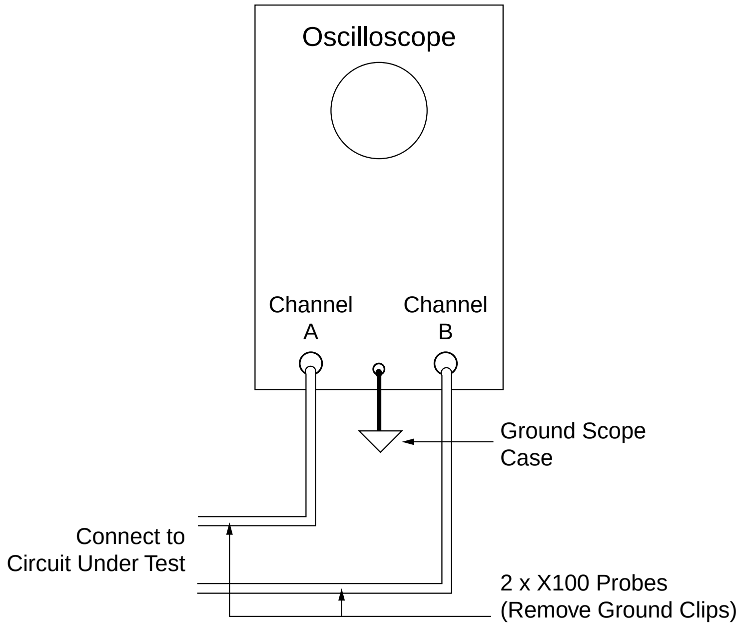



**Figure 1-1.**
*Oscilloscope Connections*



# SECTION 2
# GENERAL INFORMATION

## 2.1 INTRODUCTION

This instruction manual contains installation information, operating instructions, and troubleshooting procedures for this adjustable voltage DC drive. It also includes a complete description of the control with detailed product specifications and a complete description of all customer selectable functions and customer installable option kits.

For most drive applications, the information contained in this instruction manual will completely describe all drive system set-up and operating procedures. It should also provide all the information required by the customer to install and maintain the control. In a few applications, additional drive system set-up and operating information may be required. This information will generally be furnished in the form of system schematic and system interconnection diagrams. An overall Systems Installation Manual may also be furnished.

This instruction manual should be read in its entirety before beginning installation and before performing any start-up or maintenance on the drive system.

**NOTE**

The information in this manual applies to both the panel mount and enclosure mount controls except where specifically stated otherwise.

## 2.2 GENERAL DESCRIPTION

The control is a high performance DC drive. It contains all the required circuitry to control the speed of, or to control the current supplied to, small horsepower shunt wound or permanent magnet DC motors. It includes many standard features that are available only as options on other single phase DC drives. This allows the control to be used in custom engineered applications as well as standard speed regulated applications.

The DC motor speed is controlled by varying the DC voltage applied to the motor armature, or the motor torque is controlled by varying the current applied to the motor armature.

Single phase AC input power is converted to variable voltage DC output power by the control. In speed regulated applications, the DC output voltage varies as a function of an input reference voltage. Typically, the input reference voltage is provided by an operator adjustable potentiometer. Changing the potentiometer setting (reference) results in a motor speed change. In torque regulated applications, the DC output current varies as a function of an input reference voltage. Changing the torque reference changes the current supplied to the motor and results in a change in motor torque output.

The control is designed to handle most single phase drive applications without the need for costly, time-consuming engineering.

Simple jumper programming allows for maximum versatility in the drive. Functions such as input voltage selection (120/240 VAC), armature voltage selection (Low - 90 VDC, High - 180 VDC), motor current range (High, Medium, and Low), and speed/current regulation are achieved by customer selection of the jumper positions. Refer to Section 4 for details on all jumper programming. Each control is also provided with standard adjustments for maximum/minimum speed and IR compensation.

A panel mounted and an enclosure mounted model are available, both of which can handle the entire 1/4 to 2 HP range of applications. The enclosure mounted model is provided with a rugged dust and oil-tight enclosure with a smart, modern design that adds eye appeal to the customer's machine. A NEMA 4/12 conversion kit is also available for the enclosure.

## 2.3 TYPICAL PACKAGING

The panel mounted control is suitable for sub-panel mounting inside a customer supplied control enclosure (See Figure 2-1).

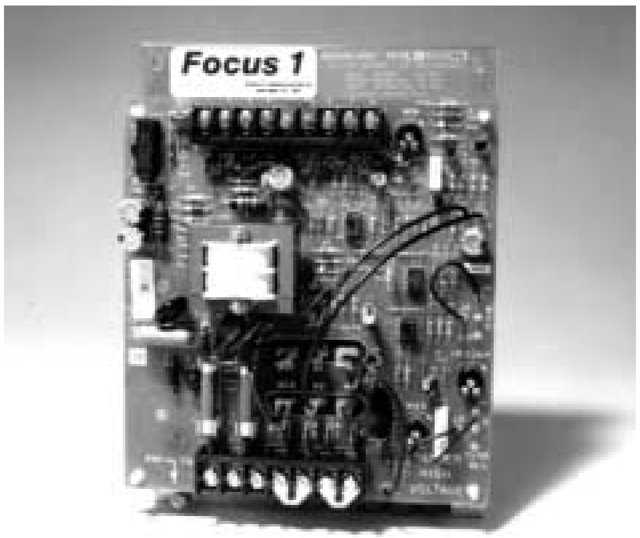



**Figure 2-1.**
*Panel Mounted Control*

The enclosure mounted control is furnished in a NEMA 1 enclosure that precludes the entry of dust and oil droplets into the electronic hardware. The enclosure is intended for use in general purpose environments.

A NEMA 4/12 conversion kit is available for the enclosure. It includes a cover gasket and protective boots for the potentiometer and switches.



The enclosure package consists of two halves of a shell which are taken apart by removing the four mounting screws in the corners of the cover. As shown in Figure 2-2, the inside of the cover contains the switches and heatsink. The inside of the base contains the PC board, the functions of which are described in detail in Sections 4 and 5.

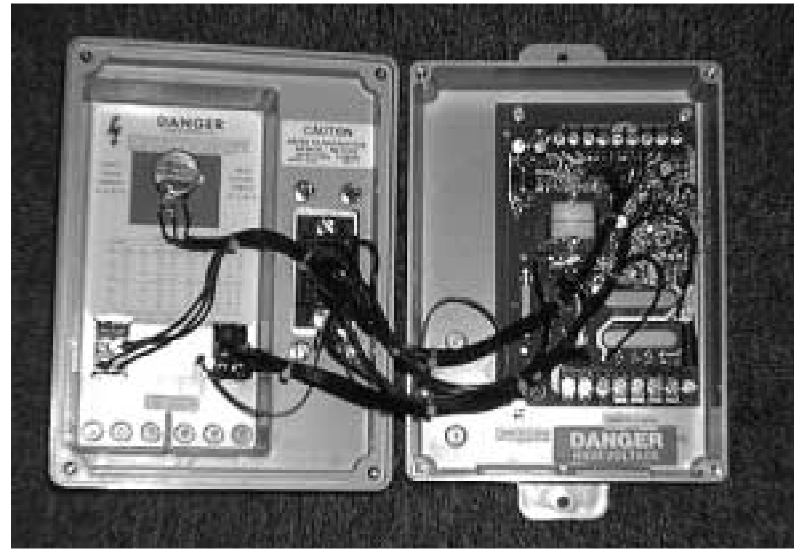



**Figure 2-2.**
*Enclosure Mounted Control*

## 2.4 EQUIPMENT IDENTIFICATION

It is important to identify the control completely and accurately whenever ordering spare parts or requesting assistance in service.

The panel mounted controls include a product nameplate located along the top edge of the panel as shown in Figure 2-1. The product nameplate should appear similar to the sample nameplate shown in Figure 2-3. Record the part number (P/N), revision level (REV), and date for future reference in the front of this manual.

The enclosure mounted controls include a product nameplate located on the bottom edge of the cover as shown in Figure 2-4. The product nameplate should appear similar to the sample nameplate shown in Figure 2-5. Record the part number (P/N), revision level (REV), and date for future reference in the front of this manual.

If the control is part of an engineered drive system, the system cabinet will also include a product nameplate. Record the part number (P/N), and serial number (S/N) of the engineered system and include this information with the information on the individual controls whenever contacting the factory.

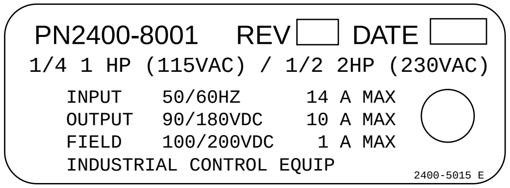



**Figure 2-3.**
*Typical Panel Mount Product Nameplate*

**Figure 2-4.**
*Enclosure Mount Control Product Nameplate Location*

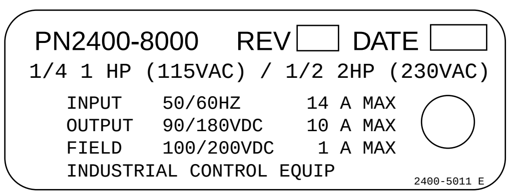



**Figure 2-5.**
*Typical Enclosure Mount Product Nameplate*



# SECTION 3
# CONTROL SPECIFICATIONS AND FEATURES

## 3.1 EQUIPMENT RATINGS

Both the panel and enclosure mounted controls can be programmed for 120VAC input (1/4-1HP) or for 240VAC input (1/2-2HP). Table 3-1 summarizes the horsepower outputs available in each programming mode.

**Table 3-1**
*Control Rating Table*

| ** \AC INPUT | | | DC ARMATURE OUTPUT | | DC FIELD OUTPUT | |
|---|---|---|---|---|---|---|
| VOLTS | AMPS | HP | VOLTS | AMPS* | VOLTS | AMPS* |
| | 3.6 | 1/4 | 90 | 2.6 | 100 | 1 |
| 120 | 5.2 | 1/3 | 90 | 3.7 | 100 | 1 |
| VAC | 7.7 | 1/2 | 90 | 5.5 | 100 | 1 |
| 50/60 | 10.5 | 3/4 | 90 | 7.5 | 100 | 1 |
| Hz | 14 | 1 | 90 | 10 | 100 | 1 |
| | 3.6 | 1/2 | 180 | 2.6 | 200 | 1 |
| 240 | 5.2 | 3/4 | 180 | 3.7 | 200 | 1 |
| VAC | 7.7 | 1 | 180 | 5.5 | 200 | 1 |
| 50/60 | 10.5 | 1-1/2 | 180 | 7.5 | 200 | 1 |
| Hz | 14 | 2 | 180 | 10 | 200 | 1 |

** These are typical motor current ratings. See motor nameplate for exact current ratings.*
*** The input voltage and current (amp) values are approximate. Actual values may vary depending on input voltage, input line impedance, and actual motor efficiency. A fused AC line disconnect or circuit breaker is required by the National Electrical Code. This AC line disconnect or circuit breaker must be installed ahead of the control.*

**NOTE**

The following data is equally applicable to both the panel and enclosure mount controls unless specifically stated otherwise.

## 3.2 SERVICE CONDITIONS

ENCLOSURE: ......................................Chassis (panel mount)
.....................................................NEMA 1 TENV (enclosure mount)

HORSEPOWER RATINGS:
Input Power:
120VAC, 1 phase, 50/60 Hz: ............1/4-1 HP
240VAC, 1 phase, 50/60 Hz : ..........1/2-2 HP

LINE VOLTAGE VARIATION: ...............±10%

LINE FREQUENCY VARIATION: ...........48 - 62Hz

FIELD SUPPLY: ................................1 amp

MAXIMUM ALTITUDE
(WITHOUT DERATING): ........................3,300 feet above sea level

AMBIENT TEMPERATURE: ................0°C to 55°C (32°F to 131°F) (panel mount)
0°C to 40°C (32°F to 104°F) (enclosure mount)

SPACE REQUIREMENT FOR
PANEL MOUNT IN TOTALLY
ENCLOSED NON-VENTILATED............20" x 20" x 8" or
(TENV) ENCLOSURE: ...........................24" x 20" x 6"

AC LINE FUSES: ..................................15A, 250V

## 3.3 PERFORMANCE SPECIFICATIONS

SERVICE FACTOR:................................1.0 maximum rating

SPEED REGULATION:
For a 95% Load Change
Using Armature Voltage
Feedback with IR Compensation: .....±1% of maximum speed

For All Other Variables
(Voltage Regulated): ..........................Changes up to 15% of top speed can result from temperature, voltage, frequency variations and drift.

OVERLOAD CAPACITY
(as a percent of maximum rating):..........150% for one minute

ACCELERATION TIME (Fixed):...............2 to 3 seconds



EFFICIENCY:
Control Only (Minimum).....................98%
Motor and Control (Typical) ...............86%

CURRENT LIMIT (Fixed):........................150% of selected rating

## 3.4 OPERATOR FUNCTIONS

SPEED ADJUSTMENT:..........................Standard

POWER ON/OFF, START/STOP:
Panel Mount: ....................................Customer supplied
Enclosure Mount:..............................Standard

FORWARD/REVERSE:...........................Optional

## 3.5 POTENTIOMETER ADJUSTMENTS

The standard control includes three (3) customer adjustable potentiometers which are located on the printed circuit board. These potentiometers have been preset. However, for proper operation in some applications, minor readjustments may be necessary during drive installation and startup.

MAXIMUM SPEED: .......................... 70 to 115% of rated speed
MINIMUM SPEED: ........................... 0 to 30% of maximum speed
IR COMPENSATION: ....................... 0 to 20% of rated voltage at rated current

## 3.6 CUSTOMER PROGRAMMABLE SELECTIONS (JUMPERS)

MODE OF CONTROL: ......................Speed or torque regulation
OPERATING VOLTAGE: ....................120 or 240 VAC
CURRENT LIMIT LEVEL:...................High, Medium, or Low

## 3.7 STANDARD FEATURES

- Compact and lightweight:
  —Panel mount control only 3 pounds
  —Enclosure mount control only 4 pounds
- Control relay providing momentary Start/Stop operation. Control cannot restart without pushing Start button if AC power is momentarily disconnected and restored.
- Current limiting to protect drive from overloads. Automatically adjusts to 150% of selected current rating.
- Continuous full rated torque over a 30:1 speed range.
- Run LED (light emitting diode) indicator light.
- Zener regulated control power supply provides compensation for line voltage fluctuation.

- Integrated circuit operational amplifier for high gain, fast response, and excellent linearity.
- Full wave encapsulated SCR bridge power cube.
- Varistor transient voltage protection providing trouble - free operation.
- UL and cUL listed.

## 3.8 PRE-ENGINEERED MODIFICATION KITS

The control can be purchased alone or with a selected group of pre-engineered modification kits. These kits allow the customer to create a custom engineered control to meet individual specific requirements. Each modification kit is individually packaged, identified, and includes all mounting hardware, wire, terminals, cable ties, labels and instructions. Paragraphs 3.8.1 through 3.8.5 provide a brief description of the modification kits currently available:

**CAUTION**

**These modification kits are the only kits designed for use with this control. Any modifications other than those specified by ICD Drives, Inc., voids all warranties, stated or implied.**

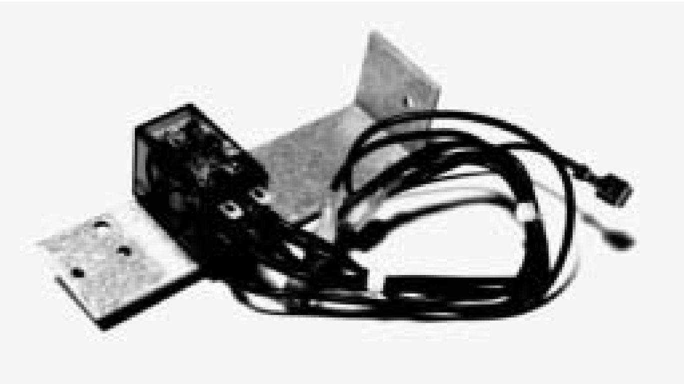


**Figure 3-1.**
*"M" Contactor Kit*

### 3.8.1 "M" Contactor Kit

This kit shown in Figure 3-1, includes a magnetic contactor which can be mounted inside the enclosed control or directly on the chassis mount unit. This contactor provides a positive disconnect of the motor armature when the control is stopped, preventing motor turnover in case the SCRs should false fire. Note that this kit may be required by local and/or national electrical codes.



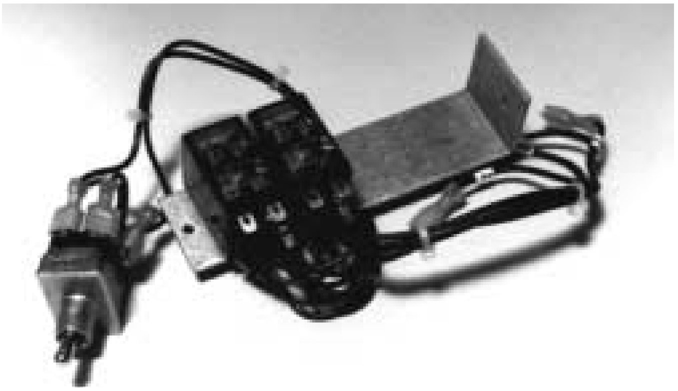


**Figure 3-2.**
*Magnetic Reversing Kit*

### 3.8.2 Magnetic Reversing Kit

This kit, shown in Figure 3-2, includes forward and reverse contactors which can be mounted inside the enclosed control or on the chassis mount unit. Also provided is a forward/reverse toggle switch for selecting the direction of motor rotation. The electrical code requirements for an "M" contactor are also satisfied since the forward and reverse contactors disconnect the motor armature from the control when the motor is stopped. This switch may be mounted in the cover of the enclosed control or in the customer's operator control panel. Note that this kit provides no anti-plugging protection. The motor must be allowed to reach a complete stop before starting in opposite rotation. When anti-plugging protection is required, use the Focus 2 Control.

### 3.8.3 NEMA 4/12 Conversion Kit

The standard enclosed control is provided in a TENV enclosure rated NEMA 1. For protection from a more rigorous industrial environment, the NEMA 4/12 Kit may be used. This kit converts the standard enclosure into one which meets NEMA 4 or 12 requirements. It includes a gasket which provides a tight seal around the enclosure cover, switch boots which seal the operator control switches and a shaft sealing nut for the potentiometer.

**Figure 3-3.**
*Dynamic Braking Kit*

### 3.8.4 Dynamic Braking Kit

These kits, an example of which is shown in Figure 3-3, are for use with either the "M" Contactor Kit or the Magnetic Reversing Kit. Dynamic braking provides rapid motor stopping by automatically connecting a resistor across the armature of the motor to absorb the energy produced by the coasting motor ( now acting as a generator) and bringing it to a stop quickly. Note that the dynamic brake is not a holding (fail-safe) brake. The standard dynamic brake resistors have been sized for use with DC motors that have no appreciable load inertia connected to the shaft and have start/stop cycles no more frequent than the following:

Fractional HP: 1 stop per 70 seconds

Integral HP: 3 quick stops with 7 minutes before the next stop.

### 3.8.5 Spare Parts Kit

For most customers, this kit provides all the spare parts ever required. The kit contains three complete sets of fuses (quantity 6 fuses) and an SCR power cube. You may use this spare parts kit with either panel or enclosure mount controls.



# SECTION 4
# INSTALLATION

## 4.1 SAFETY WARNINGS

Improper installation or operation of this control may cause injury to personnel or damage to equipment. Read the operating instructions. The control and its associated motors and operator control devices must be installed and grounded in accordance with all local codes and the National Electrical Code (NEC). To reduce the potential for electric shock, disconnect all power sources before initiating any maintenance or repairs. Keep fingers and foreign objects away from ventilation and other openings. Keep air passages clear. Potentially lethal voltages exist within the control unit and connections. Use extreme caution during installation and start-up.

## 4.2 INITIAL CHECKS

Before installing the control, check the unit for physical damage sustained during shipment. If damaged, file claim with shipper and return for repair following procedures outlined on the back cover. Remove all shipping restraints and padding. Check nameplate data for conformance with the AC power source and motor.

## 4.3 CONTROL JUMPER PROGRAMMING

Prior to installing the control, the jumpers must be programmed for all of the following:

1. Using either the speed or torque regulated mode of operation.
2. Using the correct AC line voltage.
3. Matching the control to the motor being used.

These programming jumpers, labeled JA, JB, and J1 through J3 on the PC board, are jumper wires that are connected to terminal pins as described in paragraphs 4.3.1 through 4.3.3. All of these jumpers are illustrated in Figure 4-1.

These jumpers perform the following functions:

JA & JB - Transformer Programming Jumper - programs unit for correct AC input voltage.

J1 - Mode of Operation Jumper - programs unit as a speed or torque control.

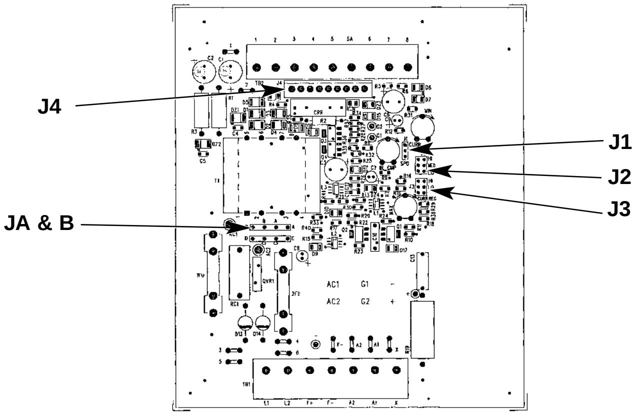
J2 - Current Feedback Jumper - programs current limit level for the motor being used.

J3 - Voltage Feedback Jumper - programs voltage feedback for motor with 90 VDC or 180 VDC armature or eliminates voltage feedback if unit is used as a torque control.

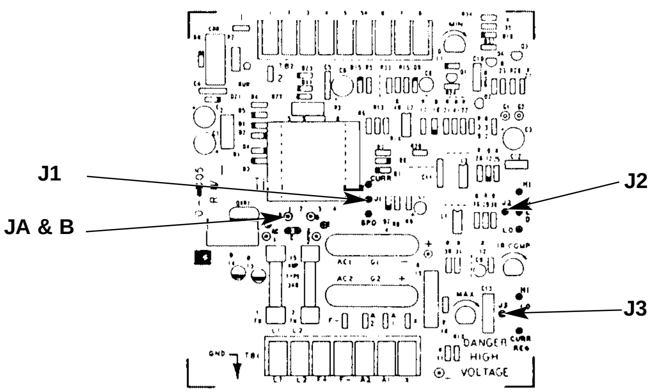
Refer to Table 4-1 for determining the correct jumper connections. After the jumper programming is completed, the jumper positions can be recorded for future reference on the Customer Jumper Programming Chart, Table 9-2.

**WARNING**

**EQUIPMENT DAMAGE AND/OR PERSONAL INJURY MAY RESULT IF ANY JUMPER PROGRAMMING IS ATTEMPTED WHILE THE CONTROL IS OPERATIONAL. ALWAYS LOCK OUT POWER AT THE REMOTE DISCONNECT BEFORE CHANGING ANY JUMPER POSITIONS.**




**Enclosure Mount PC Board**




**Panel Mount PC Board**

**Figure 4-1.**
*Panel and Enclosure Mount PC Board Jumper Locations*



## 4.3.1 Mode of Control Selection

The first step in programming the control is to determine if the unit is going to be used as a speed or torque control. When used as a speed control, the potentiometer sets the motor RPM, and the motor produces only the torque necessary to drive the load. This type control is used in most applications. If, however, the unit is connected as a torque control (used mainly on surface winders), the potentiometer sets the motor torque, and the motor will run at an RPM determined by the torque-speed characteristics of the driven load.

A. If the unit is to control speed:
   1. Place J1 in the "SPD" position.
B. If the unit is to control torque (current):
   1. Place J1 in the "CURR" position.
   2. Place J3 in the "CURR REG" position.

**CAUTION**

**When using the unit as a torque control, observe the following precautions: (1) If load torque is removed or reduced to a level below the torque setting, motor RPM could increase to dangerous levels. For this reason, protection against overspeeding is recommended. (2) If load torque exceeds control torque setting, motor will stall. Leaving motor in a stalled condition for extended periods can cause motor overheating and winding insulation damage.**

## 4.3.2 Operating Voltage Selection

The next step in programming the control is determining what AC input voltage is required. This is determined by the motor being used. If the motor is rated 1/4 to 1 horsepower and has a 90VDC armature with either a 100VDC or permanent magnet field, then 120VAC input power is required. If the motor is rated 1/2 to 2 HP and has a 180VDC armature with either a 200VDC or permanent magnet field, then a 240VAC input source is required. Other motors can not be used with this control. Refer to the motor nameplate for this information.

A. If the control is operating on 120VAC input and 0-90VDC output:
   1. Connect jumper "A" to the "E" position and jumper "B" to the "D" position.
   2. Place J3 in the "LO" position, if not already placed in the "CURR REG" position.
B. If the control is operating on 240VAC input and 0-180VDC output:
   1. Connect jumper "A" to the "C" position and jumper "B" to the "C" position.
   2. Place J3 in the "HI" position, if not already placed in the "CURR REG" position.

**WARNING**

**NEVER ATTEMPT TO CONVERT THE CONTROL TO ANY OPERATING VOLTAGE OTHER THAN 120VAC INPUT/0 -90VDC OUTPUT OR 240VAC INPUT/0 - 180 VDC OUTPUT. ANY SUCH ATTEMPTED CONVERSION CAN CAUSE EQUIPMENT DAMAGE AND POSSIBLE PERSONAL INJURY.**

## 4.3.3 Current Limit Level Selection

The control is designed to control motors rated for 1/4 to 2 HP which have a wide range of current ratings. Because of this, the current limit setting and IR compensation adjustment ranges must be matched to the motor current rating using jumper J2. The control can be programmed for low, medium or high current limit level as follows:

A. Refer to the motor nameplate for the horsepower rating and the DC armature voltage and current (amps).

B. Use this data to determine the proper position of J2 ("LO", "MED" or "HI") from Table 4-1.

**Table 4-1.**
*Jumper Programming*

| AC INPUT ** | | | DC ARMATURE OUTPUT | | DC FIELD OUTPUT | | TRANSFORMER PROGRAMMING | SPEED MODE*** (SPEED CONTROL) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| VOLTS | AMPS | HP | VOLTS | AMPS* | VOLTS | AMPS* | JUMPERS | J1 | J2 | J3 |
| 120 | 3.6 | 1/4 | 90 | 2.6 | 100 | 1 | A-E; B-D | Spd | Lo | Lo |
| VAC | 5.2 | 1/3 | 90 | 3.7 | 100 | 1 | A-E; B-D | Spd | Lo | Lo |
| 1Ø | 7.7 | 1/2 | 90 | 5.5 | 100 | 1 | A-E; B-D | Spd | Lo | Lo |
| 50/60 | 10.5 | 3/4 | 90 | 7.5 | 100 | 1 | A-E; B-D | Spd | Med | Lo |
| Hz | 14 | 1 | 90 | 10.0 | 100 | 1 | A-E; B-D | Spd | Hi | Lo |
| 240 | 3.6 | 1/2 | 180 | 2.6 | 200 | 1 | A-C; B-C | Spd | Lo | Hi |
| VAC | 5.2 | 3/4 | 180 | 3.7 | 200 | 1 | A-C; B-C | Spd | Lo | Hi |
| 1Ø | 7.7 | 1 | 180 | 5.5 | 200 | 1 | A-C; B-C | Spd | Lo | Hi |
| 50/60 | 10.5 | 1-1/2 | 180 | 7.5 | 200 | 1 | A-C; B-C | Spd | Med | Hi |
| Hz | 14 | 2 | 180 | 10 | 200 | 1 | A-C; B-C | Spd | Hi | Hi |

* *These are typical motor current ratings - See motor nameplate for exact current ratings.*

** *The input voltage and current (amp) values are approximate. Actual values may vary depending on input voltage, input line impedance, and actual motor efficiency.*

*** *These are standard connections for speed control. For torque mode (current control) if desired, reposition J1 to curr position and J3 to curr reg position. Position the J2 jumper for the correct motor used.*



## 4.4 DETERMINING THE CONTROL LOCATION

The control is suitable for most well-ventilated factory areas where industrial equipment is installed. Locations subject to steam vapors, excessive moisture, oil vapors, flammable or combustible vapors, chemical fumes, corrosive gases or liquids, excessive dirt, dust or lint should be avoided unless an appropriate enclosure has been supplied or a clean air supply is provided to the enclosure. The location should be dry and the ambient temperature should not exceed 55°C for a panel mount or 40°C for an enclosed unit. If the mounting location is subject to vibration, the unit should be shock mounted.

If the enclosure is force ventilated, avoid, wherever possible, an environment having a high foreign matter content as this requires frequent filter changes or the installation of micron-filters. Should the control enclosure require cleaning on the inside, a low pressure vacuum cleaner is recommended. Do not use an air hose because of the possibility of oil vapor in the compressed air and the high air pressure.

## 4.5 INSTALLING PANEL MOUNT CONTROLS

The panel mount control is suitable for mounting in a user's enclosure where internal temperature will not exceed 55°C. The following procedure is recommended. Mount the panel vertically against the mounting surface. Dimensions are shown in Figure 9-1.

**CAUTION**

**Never operate the control for an extended time on its back. Doing this may cause the heat from the heat sink to penetrate the control logic wiring.**

## 4.6 INSTALLING ENCLOSED CONTROLS

Enclosed controls are suitable for wall mounting in an ambient atmosphere between 0°C and 40°C. Mount the control to provide access to the front panel. See Figure 9-1 for dimensions.

**CAUTION**

**The non-metallic enclosure does not provide grounding between conduit connections. Use grounding type bushings and jumper wires. In making conduit connections, the hub must be assembled to the conduit before it is connected to the enclosure.**

## 4.7 POWER WIRING

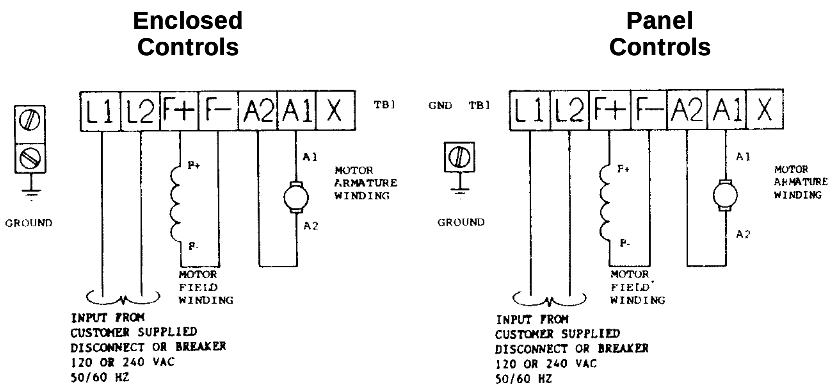



**Figure 4-2.**
*Connection of AC Power and Motor Leads to Panel and Enclosure Mount Controls*

Throughout the following discussion, reference to Figure 4-2 and to the connection and schematic diagrams shown as Figures 9-2, 9-3, 9-8 and 9-9 in Section 9 is recommended.

### 4.7.1 Incoming Power Requirements

A remote fused AC line disconnect or circuit breaker is required by the National Electrical Code. This AC line disconnect or circuit breaker must be installed in the incoming AC power line to the control. Refer to Table 3-1.

The control will operate from typical AC power lines. The line should be monitored with an oscilloscope to insure that transients do not exceed limitations as listed below:

1. Repetitive line spikes of less than 10 microseconds must not exceed the following magnitude.

   120 Volt Programming 200V Peak

   240 Volt Programming 400V Peak
2. Non-repetitive transients must not exceed 25 watt seconds of energy. Transients of excessive magnitude or time duration can damage dv/dt networks or surge suppressors.
3. Line notches must not exceed 300 microseconds in duration. An abnormal line condition can reflect itself as an intermittent power unit fault. High amplitude spikes or excessive notch conditions in the applied power could result in a power unit failure.



The control is designed to accept single phase AC line voltage. See Table 3-1 for drive input and output ratings. When using single phase power, connect the incoming lines to terminals L1 and L2 of terminal block TB1. TB1 is located at the bottom edge of the PC board as shown in Figure 4-1. Either incoming line can be connected to either of the L1 and L2 terminals.

**WARNING**

**CONNECTING THE INPUT AC POWER LEADS TO ANY TERMINALS ON TB1 OTHER THAN L1 OR L2 WILL CAUSE AN IMMEDIATE FAILURE OF THE CONTROL.**

**CAUTION**

**The voltage of the incoming line to the control must be 240 VAC ±10%, 50/60Hz ±2 Hz, or 120 VAC ±10%, 50/60 Hz ±2 Hz, depending on the jumper programming described in Paragraph 4-3. If the incoming line voltage and/or frequency is out of this tolerance, the control will fail to operate.**

### 4.7.2 Output Power Ranges

Table 4-1 lists the AC line voltages, line currents (amps), DC armature output currents (amps), and DC field output currents (amps) for various motor horsepower ratings. The AC line amps (RMS) should be used to size the wire for both the armature output and the AC line input connections. The field current is less than one (1) ampere for each of the motors listed. The wire for field connections can be sized accordingly.

**NOTE**

Overload protection must be provided per National Electrical Code article 430, Section C.

### 4.7.3 Output Terminal Installation Checks

It is imperative that the control be connected to earth ground for the safety of the operating personnel. On panel mount controls, this ground is provided by a panel-installed screw. This screw is below the GND ( ) label marked on the lower left corner of the PC board. On enclosed controls, this ground is provided by a lug mounted in the lower left corner of the PC board to the left of TB1.

**CAUTION**

**No points in the control circuitry, including common, should be connected to earth ground unless specifically shown on the supplied wiring diagrams. No grounding connections should be made on the terminal block. Improper connections to ground, including speed potentiometer connections, will result in control failure.**

Before making the AC line input connections, the following readings across terminals A1, A2, F+, F-, and GND should be verified. All of these terminals except GND are located on TB1. The GND terminal is located as described earlier in this paragraph.

**NOTE**

If TB1 has terminals F1 and F2 instead of F+ and F-, the F1 and F2 terminals correspond, respectively, to F+ and F-.

In making the readings listed in the following table, use a volt-ohm-milliammeter such as a Simpson 260, Triplett 630, or equivalent.

**WARNING**

**DO NOT USE A VACUUM TUBE VOLTMETER OR OTHER SIMILAR TYPE OF METER THAT REQUIRES AC POWER FOR OPERATION.**

Using red as the positive lead, make the following checks.

| CHECKS | | RANGE OF |
|---|---|---|
| Red + | Black - | Acceptable Readings |
| A2 | A1 | 1-4 ohms |
| F+ | F- | 100-700 ohms* |
| F+,F-,A1,A2 | GND | Infinite |

** Provided motor has wound field.*

If any of the above checks are not within the indicated range, verify all connections and recheck.

As a recommended safety practice, use an isolation transformer to reduce the possibilities of ground paths.



### 4.7.4 Output Power Connections

The DC motor connects to terminals A1 and A2 of TB1 as shown in Figures 4-2, 9-8 and 9-9. The pre-installed links between terminals A1 and X and between A2 and F- are not removed unless the optional armature contactor or reversing kits are being installed. Refer to Figures 9-4 through 9-7 and to specific instructions provided with these kits for armature contactor or reversing kit installation information.

Terminals F+ and F- on TB1 are for the customer-supplied shunt field connections as shown in Figures 4-2, 9-8 and 9-9. The shunt field will be at 100 VDC field voltage when the control is operated at 120 VAC and 200 VDC field voltage when the control is operated at 240 VAC. The motor shunt field supply is rated at 1 amp.

**NOTE**

Terminals F+ and F- are not used with permanent magnet motors.

If, with the motor connected, the wrong rotational direction is observed, the rotational problem can be corrected in any of three (3) possible ways:

1. Exchanging the A1 and A2 output leads to the motor.
2. Exchanging the shunt field F+ and F- leads on shunt wound motors only.
3. Changing the position of the Forward/Reverse switch, if this option kit is being used.

**CAUTION**

**The motor must be completely stopped before it is started in opposite rotation. Attempting to reverse the motor direction while it is still rotating can cause equipment damage.**

Note that exchanging the incoming power leads to terminals L1 and L2 will not affect the direction of motor rotation.

## 4.8 PANEL MOUNT CONTROL LOGIC AND SIGNAL WIRING

The local On/Off and Start/Stop controls required for panel mount drives are customer supplied. A unidirectional speed potentiometer is supplied loosely with the control. Forward/Reverse operation can be accomplished through the use of the optional Magnetic Revising Kit.

The On/Off switch is installed by the customer in the incoming L1 - L2 line to the control.

The panel mount control circuitry allows the customer to wire the Start/Stop logic with the supplied unidirectional potentiometer with or without a Forward/Reverse switch. The Start/Stop, Forward/Reverse, and potentiometer controls are wired into terminal block TB2, located at the top edge of the PC board as shown in Figure 4-1. The basic Start/Stop and potentiometer connections are shown in Figure 4-3. If Forward/Reverse switch wiring is desired, refer to Figure 9-6.

**NOTE**

Faston contacts "1" and "2" on the panel mount controls, shown in Figure 4-1, are used only with the optional armature contactor and reversing kits.

It is recommended that shielded wire be used for reference, and other signal wire connections. Belden #83394 (2 conductor) and Belden #83395 (3 conductor) shielded wire (or equivalent) is recommended. The shields should be taped off at the remote end. At the drive control, the shields should be connected to circuit common, TB-2 terminal #8. Additional consideration is recommended to route this wiring away from high current lines (i.e., AC lines and armature wiring).

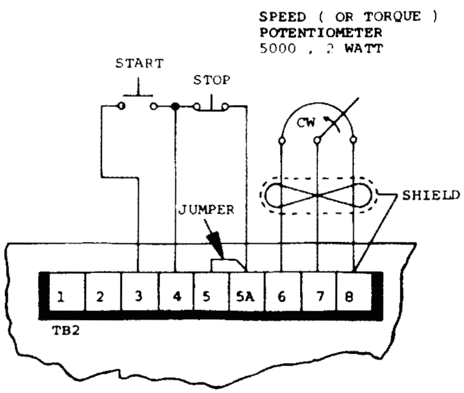



**Figure 4-3.**
*Panel Mount Start/Stop and Potentiometer Connections*

**CAUTION**

**As shown in Figure 4-3, a jumper or a motor thermal overload switch must be installed between terminals TB2-5 and -5A on panel mount controls. If this is not done, the control will not operate. In the event that a motor thermal contact is not desired, a terminal jumper has been supplied loosely with the control.**



## 4.9 ENCLOSURE MOUNT CONTROL LOGIC AND SIGNAL WIRING

The local On/Off, Start/Stop and speed potentiometer controls associated with enclosure mount drives are pre-installed on the enclosure cover. A Forward/Reverse switch, installable on the enclosure cover, is available as an option kit. The On/Off switch is wired into the 1FU and 2FU fuses on the top cover.

The Start/Stop logic is pre-wired as shown in Figure 6-3. See Figure 4-1 for contact locations on the PC board. If required, install the motor thermal overload switch between contacts "4" and"5". Simply cut the wire to splice in this contact as shown in Figures 9-3, 9-5, 9-7 and 9-9. If a Forward/Reverse switch is desired, wire it as shown in Figure 9-7.

## 4.10 INSTALLING MODIFICATIONS

When modifications are shipped loose as kits for field installation, each kit is individually packaged, identified, and includes all mounting hardware, wire, terminals, cable ties, labels and instructions. Figures 9-4 through 9-7 can be used as a guide in connecting these kits to the control. Refer to paragraph 3.8 for a listing of the modification kits.

# SECTION 5
# OPERATION & STARTUP PROCEDURE

## 5.1 INTRODUCTION

This section describes the startup procedure for the control and the adjustment of potentiometers that may be necessary for the application.

Read this section thoroughly to develop an understanding of the operation and logic incorporated into the control.

## 5.2 START-UP PROCEDURE

To insure maximum efficiency with a minimum amount of delay in production, factory start-up assistance by a factory engineer is available. Contact the factory to make arrangements.

**CAUTION**

**The following start-up instructions are intended only as a guide and should be clearly understood by the responsible installation personnel before proceeding with them.**

### 5.2.1 Pre-Start Equipment Checks

Before starting the control, all of the following pre-start conditions must be met.

1. Insure that the control has been properly programmed for 120VAC or 240VAC operation as described in Paragraph 4.3.1.
2. Check that all the jumpers have been set correctly as described in Paragraph 4.3.
3. Complete all the wiring procedures described in Paragraphs 4.7, 4.8, and 4.9.

After all of the above pre-start conditions have been satisfied, proceed to the start-up procedure described below. This start-up procedure is equally applicable for the panel and enclosure mount controls.

### 5.2.2 Operation and Adjustment

1. Turn the speed potentiometer extreme counterclockwise. Insure that the remote disconnect is admitting AC power to the control.
2. Set the On/Off switch to the ON position. This will apply power to the control, but it will not start the motor. The run LED indicator light on the main control board will be off.
3. Set the Start/Stop switch to the START position to start the motor. The run LED indicator light will illuminate.

**NOTE**

On the enclosure mount controls, the provided Start/Stop switch will spring back to a middle position after it has been placed in the START position and released. This switch must be momentarily held in the START position to start the motor.

Adjust the speed potentiometer slowly clockwise until rotation begins. If the motor rotates in the wrong direction, simply place the On/Off switch in the OFF position, place the Start/Stop switch in the STOP position, lock out power at the remote disconnect, and exchange the A1 and A2 output leads to the motor. On shunt wound motors, exchange the shunt field F+ and F- leads.

**CAUTION**

**If backward rotation of the motor could damage the driven machine, then direction of motor rotation should be determined before connecting the motor shaft to the load.**

If the drive trips off, the motor will coast to a stop or fail to start. A drive trip off is usually caused by incorrect wiring. It also can be caused by either (1) a faulty motor or (2) a malfunctioning drive. Proceed to Basic Troubleshooting (Section 7, Paragraph 7.4)

4. With the motor rotating, adjust the speed potentiometer up and down. Check that the motor follows the speed reference.
5. The control can be stopped in one of two (2) ways as follows:
   A. A coast stop is initiated by either placing the Start/Stop switch in the STOP position or by removing the AC power at the local On/Off switch or at the remote disconnect. Once AC power is removed and then restored, the Start/Stop switch must be momentarily set to the START position to restart the motor.
   B. A faster coast stop can be accomplished by installing the dynamic braking kit. The armature contactor kit or reversing kit is required in this application. Refer to Figures 9-4 through 9-7 and the instruction sheets provided with the individual kits for installation information.
6. Three (3) customer adjustable potentiometers are located on the PC board as shown in Figure 4-1. These potentiometers have been preset. However, for proper operation in some applications, minor readjustments may be necessary.

   Before making final adjustments, allow the motor to warm up for at least 15 minutes. With the control driving a motor, do not exceed ten (10) degrees of potentiometer rotation per second. Clockwise adjustment will cause an increase in the adjustment parameter.



**WARNING**

**DO NOT ALLOW THE ADJUSTING SCREW DRIVER TO TOUCH ANYTHING OTHER THAN THE POTENTIOMETER WHILE THE CONTROL IS OPERATIVE. USE ONLY AN INSULATED SCREWDRIVER TO MINIMIZE THE HAZARDS OF ELECTRIC SHOCK.**

Steps A and B describe, respectively, the potentiometer adjustment procedure for operation in the speed or torque (current) mode of control.

A. Adjustment Procedure for Operation in the Speed Mode:

(1) Maximum Speed Adjustment—

(a.) Run the motor with the load applied.

(b.) Turn the speed potentiometer on the operator control panel fully clockwise.

(c.) Adjust the potentiometer on the Main PC Board marked "MAX" to set the maximum motor speed. This may be adjusted from approximately 70 - 115% of motor base speed. DO NOT EXCEED THE MOTOR NAMEPLATE MAXIMUM SPEED RATING.

(d.) Using a hand held tachometer or by visually observing machine operation, adjust "MAX" to the desired maximum setting.

(2) Minimum Speed Adjustment —

(a.) Turn the speed potentiometer on the operator control panel fully counterclockwise.

(b.) Adjust the potentiometer on main PC board marked "MIN" to desired lowest motor speed setting. This adjustment may be set at 0 - 30% of the maximum speed setting.

(3) IR Compensation Adjustment—

(a.) IR Compensation is provided to overcome the motor's natural tendency to slow down as the load increases. If the motor slows down excessively as it is loaded, the potentiometer marked "IR COMP" should be adjusted clockwise.

(b.) If the IR compensation is adjusted too far clockwise, the motor will begin to oscillate in speed or "hunt." If this pulsing of speed occurs, adjust the IR Compensation counterclockwise until the motor speed stabilizes.

B. Adjustment Procedure for Operation in the Torque (Current) Mode:

(1) Turn the potentiometers on the main PC board marked "MAX", "MIN", and "IR COMP" fully counterclockwise.

(2) Start motor and turn torque potentiometer on operator control panel fully counterclockwise.

(3) Adjust the potentiometer on the main PC board marked "MIN" to a minimum torque level if desired.

(4) Leave potentiometers marked "MAX" and "IR COMP" turned fully counterclockwise.

7. After Steps A and B above are done, the potentiometer in the operator control panel may be used to adjust either:
   A. Motor speed from the minimum to maximum speed setting if control is in the speed regulation mode, or
   B. Motor torque level from the minimum torque setting to the maximum torque level for the current range selected if the control has been set up as a torque control.
8. If a Forward/Reverse switch is being used, flip it several times to verify that the motor follows direction change commands. The motor must be completely stopped before each flip of the switch.

**CAUTION**

**Attempting to reverse the motor direction while it is still rotating can cause equipment damage.**



# SECTION 6
# FUNCTIONAL DESCRIPTION

This section describes, in detail, the following circuits included in the control:

1. Power Bridge and Field Supply
2. Start/Stop Logic
3. Regulator Circuitry
4. Power Supplies

Throughout this section, reference to the schematic diagrams in Figures 9-8 and 9-9 is recommended.

## 6.1 Power Bridge and Field Supply

Throughout this paragraph, refer to Figure 6-1.

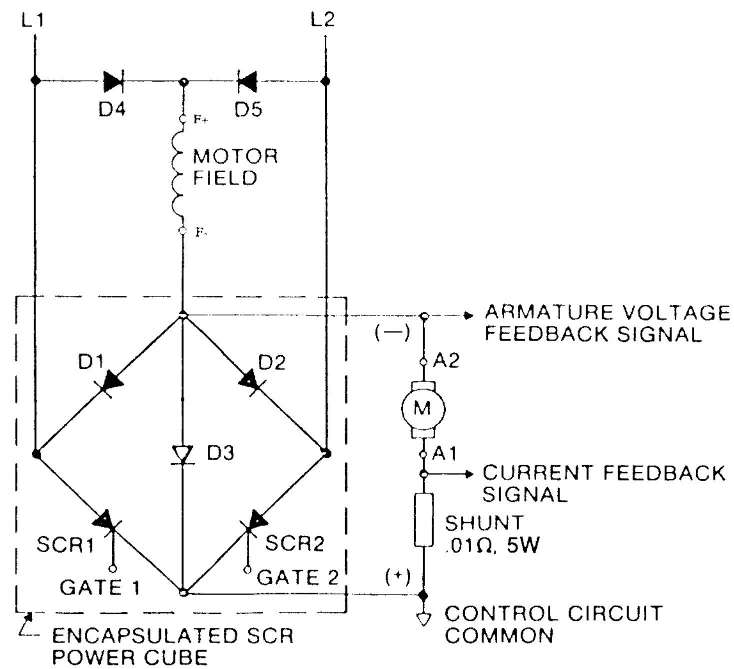



**Figure 6-1.**
*Power Bridge Assembly*

**NOTE**

Component designations in Figure 6-1, such as "D1" and "D2", are for reference purposes only. They do not correspond to actual component designations on the control.

The power bridge supplied in the control consists of an encapsulated SCR power cube containing two (2) SCRs and three (3) diodes. The basic operation consists of the following sequence.

When L1 is more positive with respect to L2, SCR1 is gated "on" at a particular phase angle commanded by the drive regulator circuitry. Current then flows from L1, through SCR1, the shunt resistor, the drive motor, diode D2, and back to L2. When L2 is more positive with respect to L1, SCR2 is gated "on". Current flows from L2, through SCR2, the shunt resistor, the drive motor, and back to L1 through diode D1. This results in a positive current flow through the motor.

Diode D3 is called a "free wheeling" diode which insures continuity of the load current when the previously "fired" SCR becomes reverse biased. This diode also helps the SCR return to its blocking state.

Three functional details are shown in Figure 6-1 as follows:

1. Armature Voltage Feedback Signal - This signal is used in determining when the correct drive operating speed (voltage) is reached as required by the operator speed potentiometer.
2. Current Feedback Signal - This signal provides current information to the drive inner current loop.
3. Control Circuit Common - This is tied to the positive terminal of the power bridge.

**CAUTION**

**The control circuit common is floating and must never be tied to earth ground. Attempting this will cause equipment damage or failure.**

Figure 6-1 also shows the motor shunt field supply. Diodes D1, D2, D4 and D5 form a single phase full wave uncontrolled rectifier bridge. This bridge produces a 200 VDC field voltage when operated at 240 VAC and a 100VDC field voltage when operated at 120 VAC. The motor shunt field supply rating is 1 amp.

## 6.2 START/STOP LOGIC

The standard start/stop logic is shown in Figures 6-2 and 6-3.

When the START button is momentarily activated, a 24VDC signal is supplied to Control Run Relay CRR. This energizes CRR, which closes a normally open contact and seals in CRR. When this occurs, 24 VDC will then be present on the signal labeled +24 VDC RUN. This voltage is then directed to two (2) places as follows:

1. Speed Potentiometer Voltage Supply - The Run LED lights and a 10 volt reference appears at the top of the speed potentiometer. This voltage is zener regulated and protects the 24 volt supply if a potentiometer wire is shorted to common.



2. Transistor Clamp Circuit - This releases the gate drives whenever the drive is in the start mode. This circuit provides three (3) important functions: (1) it prevents misfiring of the SCRs when power is first applied to the drive, (2) it provides positive gate pulse suppression in the stop mode, and (3) it resets the inner current loop upon drive stop.

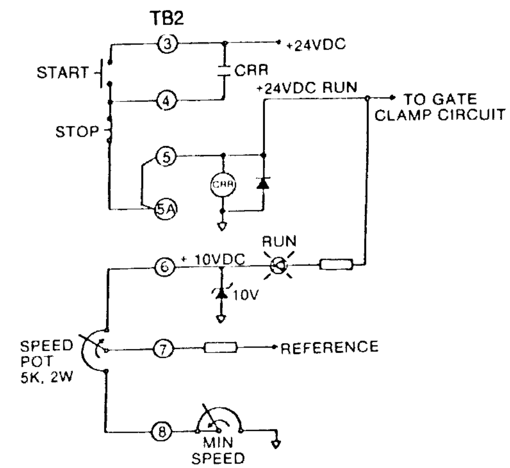



**Figure 6-2.**
*Panel Mount Start/Stop Logic*

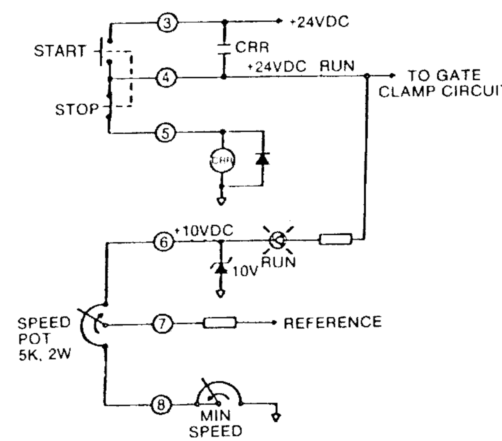



**Figure 6-3.**
*Enclosure Mount Start/Stop Logic*
*(see Figure 4-1 for contact locations on PC board)*

## 6.3 REGULATOR CIRCUITRY

Throughout this paragraph, refer to Figure 6-4.

The multi-loop regulator circuitry consists of an inner current loop and an outer voltage (speed) loop.

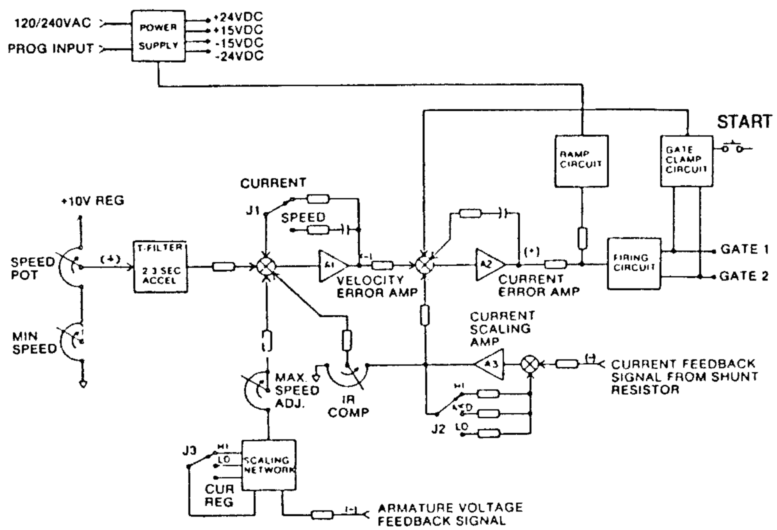



**Figure 6-4.**
*Control Circuit Block Diagram*

The inner loop current error amplifier is a proportional plus integral controller having an integrating time constant of about 10 milliseconds. This amplifier receives a current reference from the outer loop velocity error amplifier and a current feedback voltage. This feedback voltage is derived from the current scaling amplifier. This inverting type scaling amplifier has an adjustable gain which allows the customer to adapt the maximum current level of the drive to the motor.

One other input to the inner current loop, only present in the stop mode, resets the current error amplifier. The current error amplifier output is a positive voltage with an amplitude such that, when fed to the firing circuit, produces gate pulses. These gate pulses are at a phase angle that produces the armature current requested by the velocity error amplifier.

The outer loop velocity error amplifier is also a proportional integral controller. Its integrating time constant is about 0.22 seconds. There are three inputs to this amplifier.

The first of these is the speed command. This command is the voltage at the wiper of the operator speed potentiometer passed through a T-filter which provides a 2-3 second acceleration time.



The second input is the armature voltage feedback. The feedback level is adjustable to allow the customer to set the maximum motor speed to the application requirement. The feedback level is also scaled by jumper programming for a 180VDC motor (240VAC input), 90VDC motor (120VAC input) and is shorted out when the drive is used as a current regulator.

The third input to this amplifier is the IR compensation input. It is used to compensate for the IR losses in the motor. It should also be noted that this amplifier can be changed (by jumper programming) to have approximately a gain of one, when the drive is to be used as a current regulator.

The firing circuit consists of three parts: (1) a timing ramp circuit (2) a comparator circuit, and (3) a gated 555 oscillator. The timing ramp is produced by allowing a capacitor to charge to 10 volts in 8.3 msec. This capacitor is reset to zero volts at every zero crossing. This ramp voltage is then compared to the output voltage of the current error amplifier. When the ramp voltage exceeds the current error voltage, the comparator then toggles to +15 volts. The 15-volt signal enables the 555 oscillator, producing a train of firing pulses to the SCRs about 40 m sec wide and 800 m sec apart.

## 6.4 POWER SUPPLIES

Four (4) power supplies are available. These supplies are +24VDC and +15VDC. The power supply transformer is rated at 6VA. The transformer input is jumper programmable on the PC board for 240VAC or 120VAC input voltages.

# SECTION 7
# MAINTENANCE AND TROUBLESHOOTING

## 7.1 IMPORTANT SAFEGUARDS

All work on the drive should be performed by personnel familiar with it and its application. Before performing any maintenance or troubleshooting, read the instructions and consult the system diagrams.

**WARNING**

**MAKE SURE THAT ALL POWER SOURCES HAVE BEEN DISCONNECTED BEFORE MAKING CONNECTIONS OR TOUCHING INTERNAL PARTS. LETHAL VOLTAGES EXIST INSIDE THE CONTROL ANYTIME INPUT POWER IS APPLIED, EVEN IF THE DRIVE IS IN A STOP MODE. A TURNING MOTOR GENERATES VOLTAGE IN THE DRIVE EVEN IF THE AC LINE IS DISCONNECTED. EXERCISE CAUTION WHEN MAKING ADJUSTMENTS. WITH THE CONTROL DRIVING A MOTOR, DO NOT EXCEED TEN (10) DEGREES OF POTENTIOMETER ROTATION PER SECOND. NEVER INSTALL OR REMOVE THE PC BOARD WITH POWER APPLIED TO THE CONTROL.**

## 7.2 ROUTINE MAINTENANCE

Only minor adjustments should be necessary on initial startup, depending on the application. In addition, some common sense maintenance needs to be followed.

KEEP IT CLEAN: The control should be kept free of dust, dirt, oil, caustic atmosphere and excessive moisture.

KEEP IT COOL: The control should be located away from machines having a high ambient temperature. On panel mount controls, air flow across heatsinks must not be restricted by other equipment within the enclosure.

KEEP CONNECTIONS TIGHT: The equipment should be kept away from high vibration areas that could loosen connections or cause chafing of wires. All interconnections should be retightened at time of initial startup and at least every six months.

**WARNING**

**THE DC MOTOR MAY BE AT LINE VOLTAGE EVEN WHEN IT IS NOT IN OPERATION. THEREFORE, NEVER ATTEMPT TO INSPECT, TOUCH OR REMOVE ANY INTERNAL PART OF THE DC MOTOR (SUCH AS THE BRUSHES) WITHOUT FIRST MAKING SURE THAT ALL AC POWER TO THE CONTROL AS WELL AS THE DC POWER TO THE MOTOR HAS BEEN DISCONNECTED.**

The motor should be inspected at regular intervals and the following checks must be made:

A. See that both the inside and outside of the motor are not excessively dirty. This can cause added motor heating, and therefore, can shorten motor life.

B. If a motor blower is used, make sure that the air passages are clean and the impeller is free to rotate. If air filters are used, they should be cleaned at regular intervals or replaced if they are disposable. Any reduction in cooling air will increase motor heating.

C. Inspect the commutator and brushes. Replace the brushes if needed. Make sure that the proper brush grade is used.

D. The motor bearing should be greased per the manufacturer's instructions as to type of grease and maintenance frequency. Over greasing can cause excessive bearing heating and failure. Consult the instructions supplied with the motor for more details.

## 7.3 TROUBLESHOOTING OVERVIEW

Fast and effective troubleshooting requires well-trained personnel supplied with the necessary test instruments as well as a sufficient stock of recommended spare parts. Capable electronic technicians who have received training in the control operation and who are familiar with the application are well qualified to service this equipment.

### 7.3.1 Suggested Training

A. Study the system instruction manual and control drawings.

B. Obtain practical experience during the system installation and in future servicing.

C. Train in the use of test instruments.

### 7.3.2 Maintenance Records

It is strongly recommended that the user keeps records of downtime, symptoms, results of various checks, meter readings, etc. Such records will often help a service engineer locate the problem in the minimum time should such services be required.

### 7.3.3 General Troubleshooting

The most frequent causes of drive failure are:

A. Interconnect wire discontinuity, caused by a broken wire or loose connection.

B. Circuit grounding within the interconnections or the power wiring.

C. Mechanical failure at the motor.



DO NOT make adjustments or replace components before checking all wiring. Also monitor all indicator lights before proceeding with troubleshooting checks, and check for blown fuses.

It should be noted that modern solid state electronic circuitry is highly reliable. Often problems which appear to be electrical are actually mechanical. It is advised that the motor be checked in the event of any drive problems. Refer to the motor owner's manual for maintenance and repair procedures.

### 7.3.4 Notes for a Troubleshooting Technician

A minimum knowledge of system operation is required, but it is necessary to be able to read the system schematics and connection diagrams.

An oscilloscope (Tektronix 214 or equivalent) may be needed to locate problem areas and to make adjustments. However, the majority of problems can be solved by using a multimeter and by parts substitution.

Multimeters having a sensitivity of 1000 ohms per volt on DC or more are recommended, such as a Triplett Model 630, a Simpson Model 260, or equivalent.

**WARNING**

**WHEN A TEST INSTRUMENT IS BEING USED, CARE MUST BE TAKEN TO INSURE THAT ITS CHASSIS IS NOT GROUNDED EITHER BY A GROUNDING PLUG CONNECTION OR BY ITS CASE BEING IN CONTACT WITH A GROUNDED SURFACE. EXTREME CARE MUST BE TAKEN WHEN USING THE OSCILLOSCOPE SINCE ITS CHASSIS WILL BE ELECTRICALLY HOT TO GROUND WHEN CONNECTED TO THE CONTROL SYSTEM.**

## 7.4 BASIC TROUBLESHOOTING

This paragraph contains a basic list of symptoms of an improperly functioning control. Included in the list are possible causes and corrective measures for each symptom described.

**WARNING**

**BEFORE PROCEEDING WITH ANY MAINTENANCE OR TROUBLESHOOTING ACTIVITY, ALL POWER SOURCES MUST BE DISCONNECTED AS DESCRIBED IN PARAGRAPH 7.1.**

**CONTROL APPEARS TO BE DEAD:**

A. ON PANEL MOUNT CONTROLS: Terminals TB2-5 and -5A are not jumpered together - install either a motor thermal overload switch or a terminal jumper (supplied loosely with control).

B. No AC power - apply AC power.

C. Blown line fuses - replace line fuses.

D. Loose connections - turn off AC power and tighten connections.

E. Control incorrectly wired - recheck all wiring.

F. Defective power module, Start/Stop switch, component on regulator PC board, or relay - replace bad components as required.

G. Speed potentiometer set to zero - slowly advance from zero to begin motor rotation.

LINE FUSES BLOW OR MAIN CIRCUIT BREAKER TRIPS WHEN APPLYING AC POWER:

A. Power module, field supply diode or suppressor shorted, or a short to ground is present - locate and remove short.

B. Control is wired to AC voltage exceeding control rating - rewire control to proper AC voltage or use step-down transformer.

FUSES BLOW WHEN SPEED POTENTIOMETER IS ADVANCED FROM ZERO:

A. Motor is overloaded - reduce load as required.

B. Motor is defective - consult motor instruction manual and repair or replace motor as required.

ACCEL/DECEL RAMP IS MUCH LONGER THAN EXPECTED:

A. Motor overloaded/overhauling - reduce load or apply optional braking kit.

MOTOR DOES NOT REACH FULL SPEED:

A. Motor is overloaded - correct overload condition.

B. Maximum Speed potentiometer (MAX) is set too low - adjust MAX potentiometer clockwise.

C. Low AC line voltage (more than 10% below nominal) - check AC line voltage and correct.

D. Current limit level jumper (J2) in wrong position - reprogram as described in Paragraph 4.3.3.

E. Feedback jumper (J3) in wrong position - reprogram as described in Paragraph 4.3.

F. Speed/Torque jumper (J1) in wrong position - reprogram as described in Paragraph 4.3.1.

G. Defective power module - replace as required.

H. Motor brushes worn — replace as specified in motor instruction manual.



MOTOR RUNS IN WRONG DIRECTION:

A. The A1 and A2 output leads to the motor are incorrectly wired - exchange these leads.

B. On shunt wound motors only, the shunt field F+ and F- leads are incorrectly wired - exchange these leads.

C. The Forward/Reverse switch (if used) is in the wrong position - change this position.

**CAUTION**

**The motor must be completely stopped before it is started in opposite rotation. Attempting to reverse the motor direction while it is still rotating can cause equipment damage.**

MOTOR DOES NOT MAINTAIN SPEED UNDER LOAD:

A. IR COMP potentiometer is set too low - adjust clockwise as described in Paragraph 5.2.2.

B. Motor is overloaded - correct overload condition.

C. Speed/Torque jumper (J1) in wrong position - reprogram as described in Paragraph 4.3.1.

D. Defective component on regulator PC board - replace as required.

E. Current limit level jumper (J2) in wrong position - reprogram as described in Paragraph 4.3.3.

F. Motor brushes worn - replace as specified in motor instruction manual.

MOTOR IS UNSTABLE OR OSCILLATES:

A. IR COMP potentiometer set too high - adjust IR COMP potentiometer counterclockwise until the motor speed stabilizes without oscillating.

B. Defective motor - consult motor instruction manual and repair or replace as required.

C. Load is loosely coupled to motor or misaligned - check and correct load coupling.

D. Loose wire connections - tighten connections (to motor).

E. Defective component on regulator PC board - replace as required.

MOTOR DOES NOT COME TO FULL STOP:

A. Minimum speed potentiometer (MIN) is set too high - readjust as described in Paragraph 5.2.2.

B. Defective speed potentiometer, component on regulator PC board, Start/Stop switch, or power module - replace as required.

# SECTION 8
# ORDERING SPARE PARTS

For both panel mount and enclosure mount controls, spare parts kit #2400-9901 provides all the spare parts ever required for most customers. This kit contains the following components:

| COMPONENT | QUANTITY | DESIGNATION | PART NUMBER |
|---|---|---|---|
| Power Cube, 230V | 1 | | 3720-004 |
| Fuse, 15A, 250VAC | 6 | 1FU, 2FU | 3705-032 |
| Heat Sink Compound | 1 | | 3464-003 |

The power cube is part of the panel and enclosure mount assemblies. Fuses 1FU and 2FU are part of the enclosure mount assembly, but are PC board components on the panel mount control. If a more sophisticated level of troubleshooting is required, the following part numbers are listed for reference.

**PANEL MOUNT CONTROLS (P/N 2400-8001W) ASSEMBLY COMPONENTS**

| COMPONENT | QUANTITY | DESIGNATION | PART NUMBER |
|---|---|---|---|
| Speed Potentiometer 5K, 2W | 1 | | 3533-0502 |
| Push-On Knob for Speed Potentiometer | 1 | | 3549-002 |
| PC Board Assembly | 1 | | 2400-4005 |

**ENCLOSURE MOUNT CONTROLS (P/N 2400-8000W) ASSEMBLY COMPONENTS**

| COMPONENT | QUANTITY | DESIGNATION | PART NUMBER |
|---|---|---|---|
| Molded Gray Top Cover | 1 | | 2400-5032 |
| Shoulder Screws for Top Cover | 4 | | 4069-83263 |
| “O” rings for screws | 4 | | 568-006 |
| Switch, Toggle | 1 | “ON/OFF” | 3550-004 |
| Switch, Toggle | 1 | “START/STOP” | 3550-005 |
| Push-on Knob for Speed Potentiometer | 1 | | 3549-002 |
| Molded Gray Enclosure Bottom | 1 | | 2400-5031 |
| PC Board Assembly | 1 | | 2400-4100 |

**PANEL AND ENCLOSURE MOUNT CONTROLS PC BOARD COMPONENTS**

| COMPONENT | QUANTITY | DESIGNATION | PART NUMBER |
|---|---|---|---|
| <u>Capacitors - Consult Factory with the Value and Board Designation</u> | | | |
| Diodes: 1A, 200V | 6 | D1-D5, D8 | 1N4003 |
| 10mA, 75V | 9 | D6,D7,D9-D12, D15-D17 | 1N914 |
| 3A, 600V | 2 | D13, D14 | 4020-D030X06 |
| LED | 1 | "RUN" | 4030-500 |
| Diodes, Zener: 15V | 2 | DZ1,DZ2 | 1N4744A |
| 10V | 1 | DZ3 | 1N4740A |
| 12V | 1 | DZ4 | 1N4742A |
| Operational Amplifier | 2 | L1, L2 | 4041-0358 |
| Timing Circuit | 1 | L3 | 4041-0555 |
| Potentiometers : 5K | 2 | "MIN", "IR COMP" | 3545-053 |
| 500K | 1 | "MAX" | 3545-055 |
| R-C Network: | | | |
| 0.1 mF, 47 ohm | 1 | RC1 | 3084-118 |
| Relay | 1 | CRR | 3520-240 |
| <u>Resistors - Consult Factory with Value and Board designation.</u> | | | |
| Resistor, Shunt: | | | |
| .01 ohms, 3W, 5% | 1 | R19 | 0916-8R01-005 |
| Terminal blocks: 7-position | 1 | TB1 | 3792-1607 |
| 9-position | 1 | TB2 | 3792-1509 |
| Transformer | 1 | T1 | 3082-436 |
| Transistors | 4 | Q1-Q4 | 0991-003N |
| Varistor | 1 | QVR1 | 4017-2515 |



# SECTION 9
# SUPPLEMENTARY TECHNICAL INFORMATION

**Table 9-1**

*Control Standard Connection Scheme*

*Terminal Blocks TB1 and TB2*

TB1 (PANEL AND ENCLOSURE MOUNT CONTROLS)

| | |
|---|---|
| L1, L2 | Incoming AC power |
| F+, F- | Shunt field connections |
| A1, A2 | DC Motor connections |
| X | Connected by link to A1 (also, F- is connected by link to A2). Do not remove either link unless the optional armature contactor or reversing kits are being installed. |

**NOTE**

If TB1 has terminals F1 and F2 instead of F+ and F-, the F1 and F2 terminals correspond respectively, to F+ and F-.

TB2 (PANEL MOUNT CONTROLS ONLY)

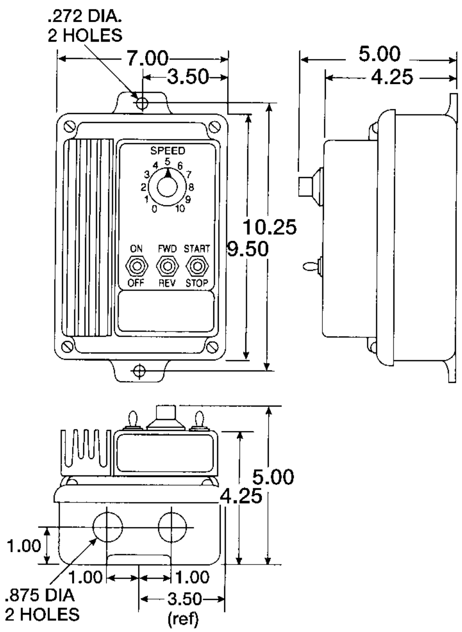
| | |
|---|---|
| 1,2 | Terminals for optional reversing kit toggle switch. Also, TB2-1 is jumpered to TB2-5 when armature contactor kit is used. |
| 3, 4 | N.O. Start contact |
| 4, 5A | N.C. Stop contact |
| 5, 5A | N.C. Motor thermal contact, (if required). Jumper TB2-5 to -5A if thermal contact is not used. |
| 6 | CW side of speed potentiometer |
| 7 | Wiper contact of speed potentiometer |
| 8 | CCW side of speed potentiometer (Min Speed) |

**Table 9-2**

*Customer Jumper Programming Chart (filled out by customer)*

| JUMPER GROUP | POSITION AT STARTUP |
|---|---|
| J1 | |
| J2 | |
| J3 | |
| JA& B | |

ENCLOSURE MOUNT CONTROLS




ALL DIMENSIONS
ARE IN INCHES

PANEL MOUNT CONTROLS

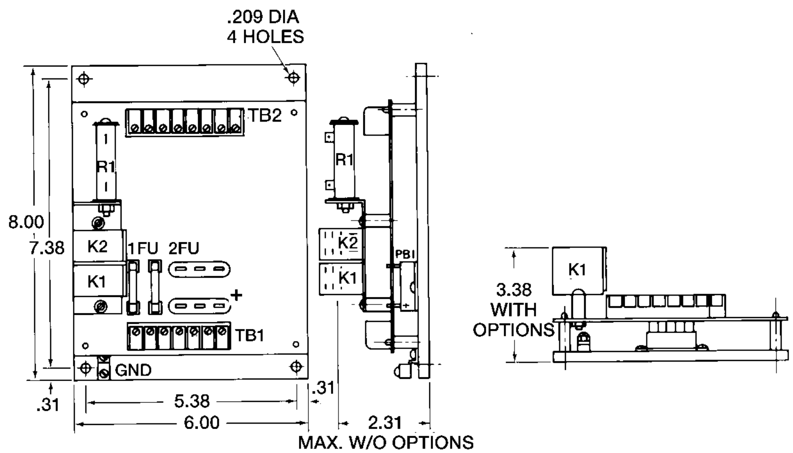



**Figure 9-1.**
*Outline and Mounting*
*Dimensions for Panel Mount and Enclosure Mount Controls*



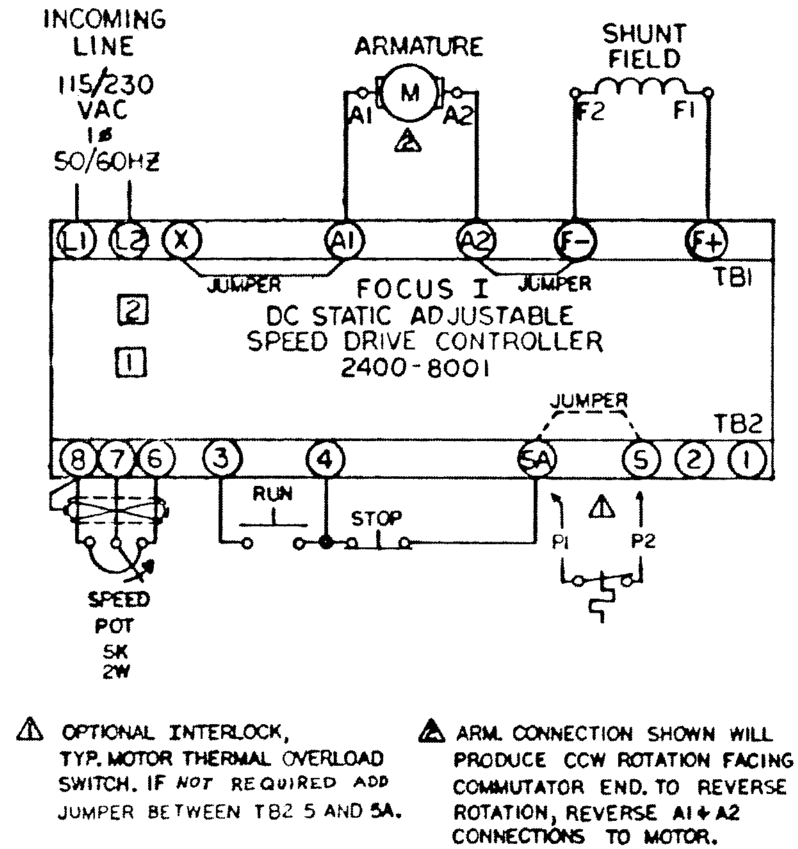
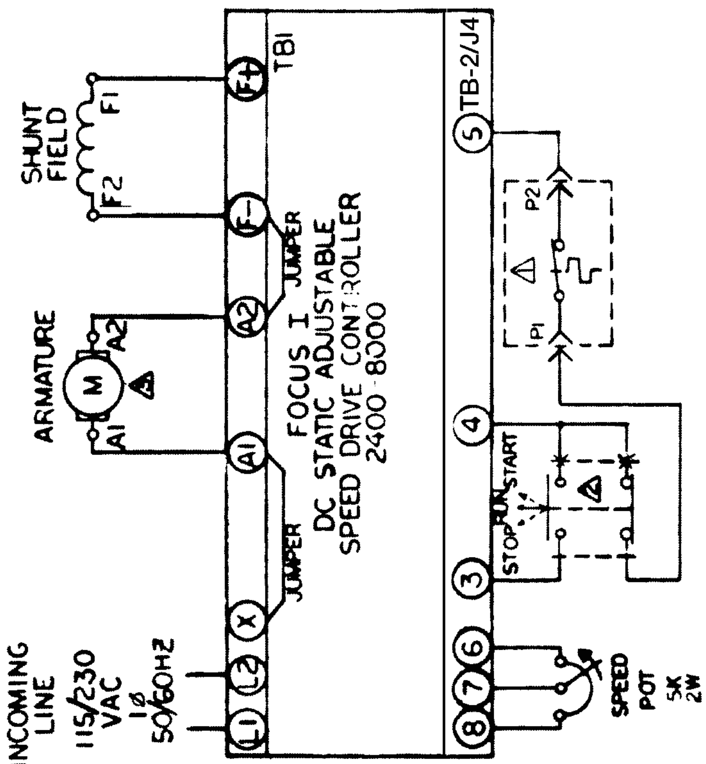


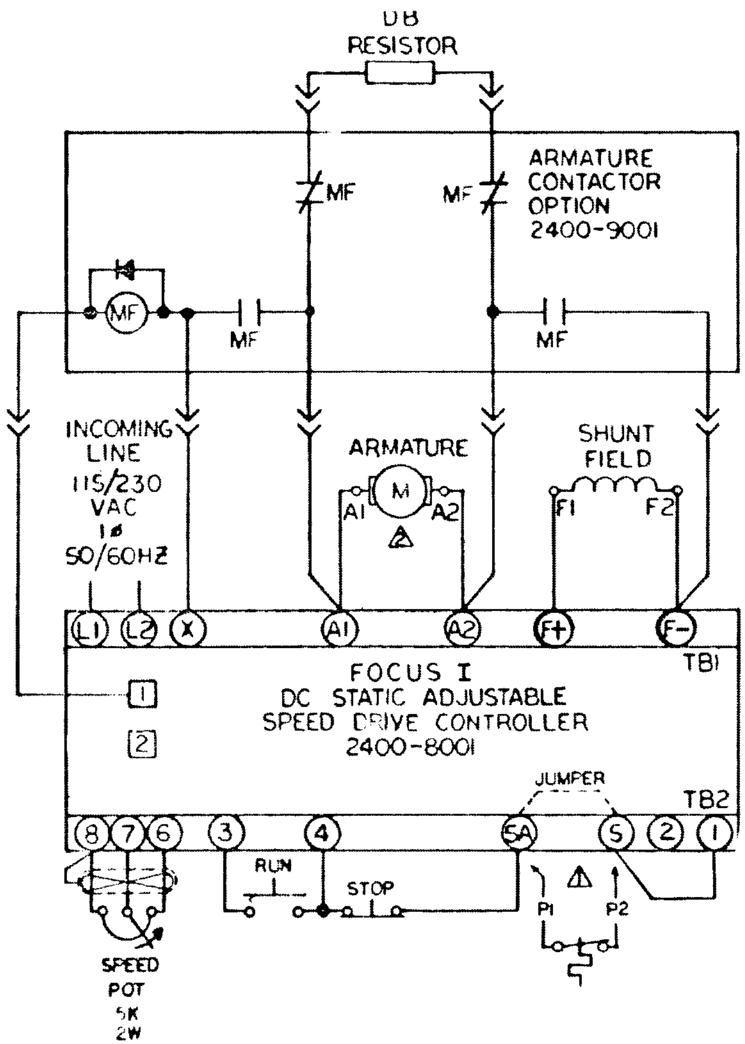

**Figure 9-2.**
*Connection Diagram for Panel Mount Controls*
*2400-1002-I (Rev. B)*




1. OPTIONAL INTERLOCK, TYP. MOTOR THERMAL OVERLOAD SWITCH, IF REQUIRED.
2. STOP AND RUN POSITION MAINTAINED; START POSITION MOMENTARY.
3. ARM. CONNECTION SHOWN WILL PRODUCE CCW ROTATION FACING COMMUTATOR END. TO REVERSE ROTATION, REVERSE A1 & A2 CONNECTIONS TO MOTOR.

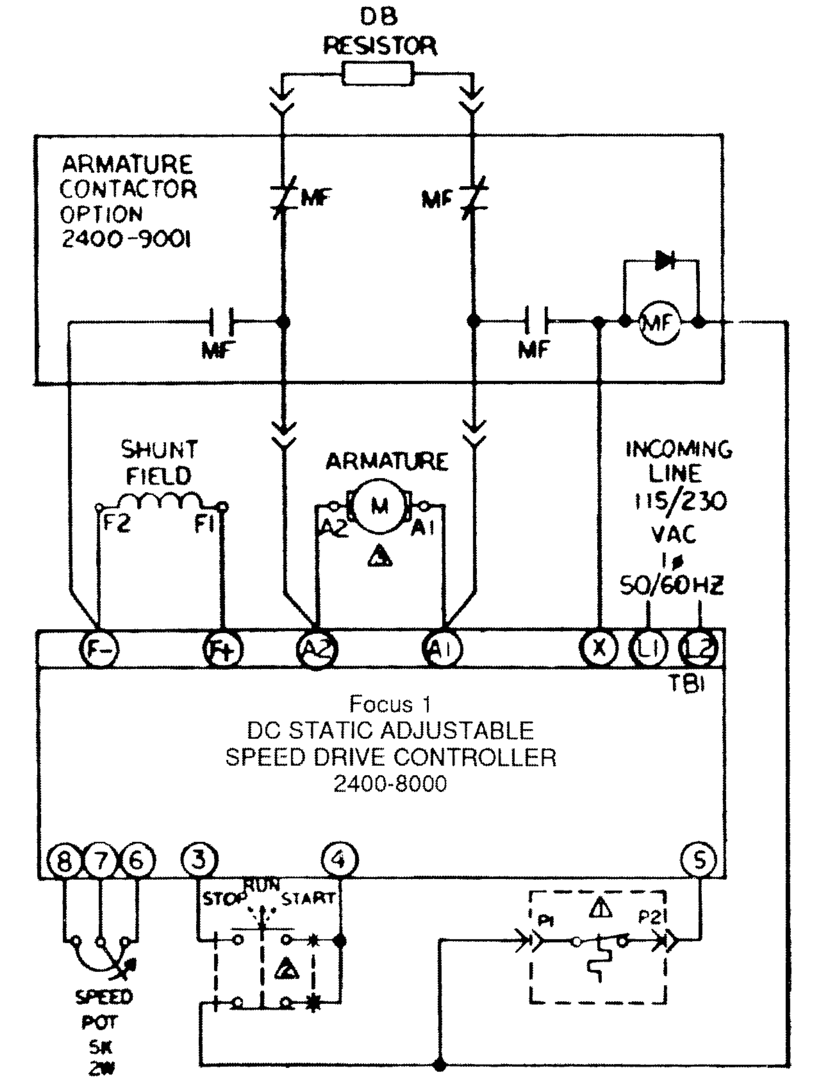
**Figure 9-3.**
*Connection Diagram for Enclosed Controls, 2400-1000-I (Rev. A)*






1. OPTIONAL INTERLOCK, TYP. MOTOR THERMAL OVERLOAD SWITCH. IF NOT REQUIRED ADD JUMPER BETWEEN TB2 5 AND 5A.
2. ARM CONNECTION SHOWN WILL PRODUCE CCW ROTATION FACING COMMUTATOR END. TO REVERSE ROTATION, REVERSE A1 & A2 CONNECTIONS TO MOTOR.

**Figure 9-4.**
*Panel Mount Control with Armature Contactor and Dynamic Braking, 2400-1003-I (Rev. B)*



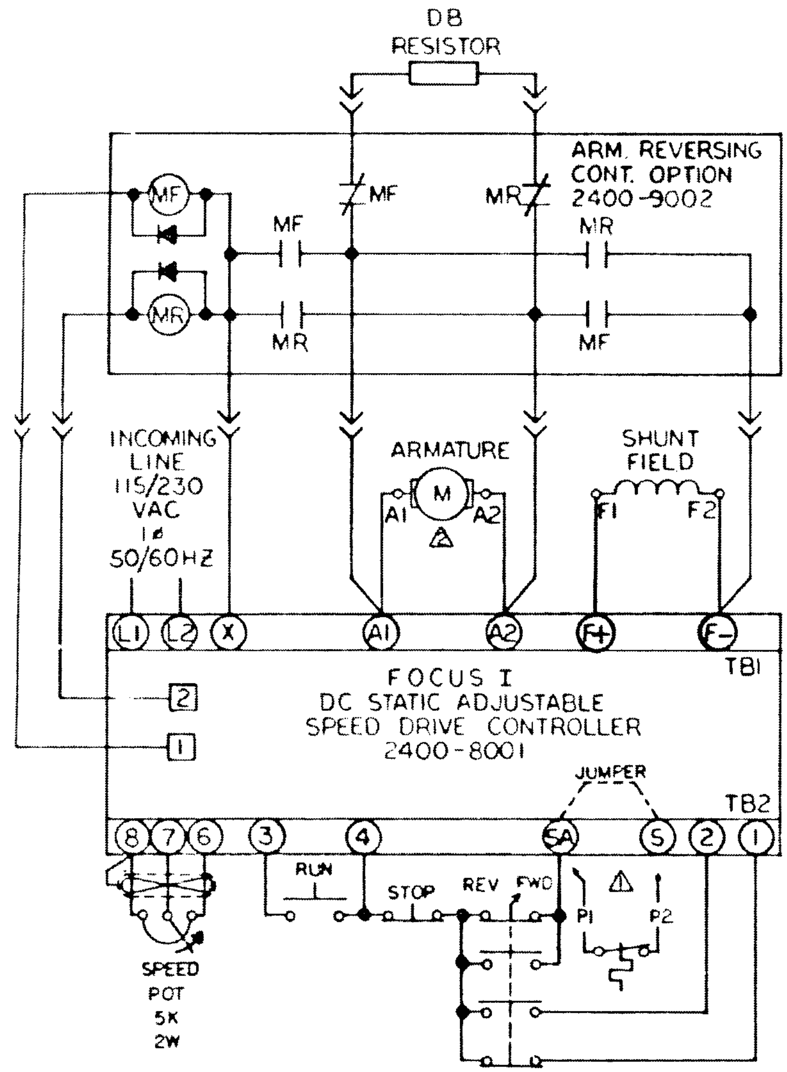

1 OPTIONAL INTERLOCK, TYP. MOTOR THERMAL OVERLOAD SWITCH, IF REQUIRED

2 STOP AND RUN POSITION MAINTAINED, START POSITION MOMENTARY.

3 ARM CONNECTION SHOWN WILL PRODUCE CCW ROTATION FACING COMMUTATOR END. TO REVERSE ROTATION, REVERSE A1 + A2 CONNECTIONS TO MOTOR

**Figure 9-5.**
*Enclosed Control with Armature Contactor and Dynamic Braking, 2400-1001-I, (Rev. A)*






1 OPTIONAL INTERLOCK, TYP. MOTOR THERMAL OVERLOAD SWITCH. IF NOT REQUIRED ADD JUMPER BETWEEN TB2 5 AND 5A

2 ARM. CONNECTION SHOWN FOR CCW ROTATION FACING COMMUTATOR END. FOR CW ROTATION,(WITH FWD/REV SWITCH IN FWD. POSITION), TO REVERSE SEQUENCE, REVERSE A1 + A2 CONNECTIONS TO MOTOR.

**Figure 9-6.**
*Panel Mount Control with Reversing and Dynamic Braking, 2400-1005-I ( Rev. B)*

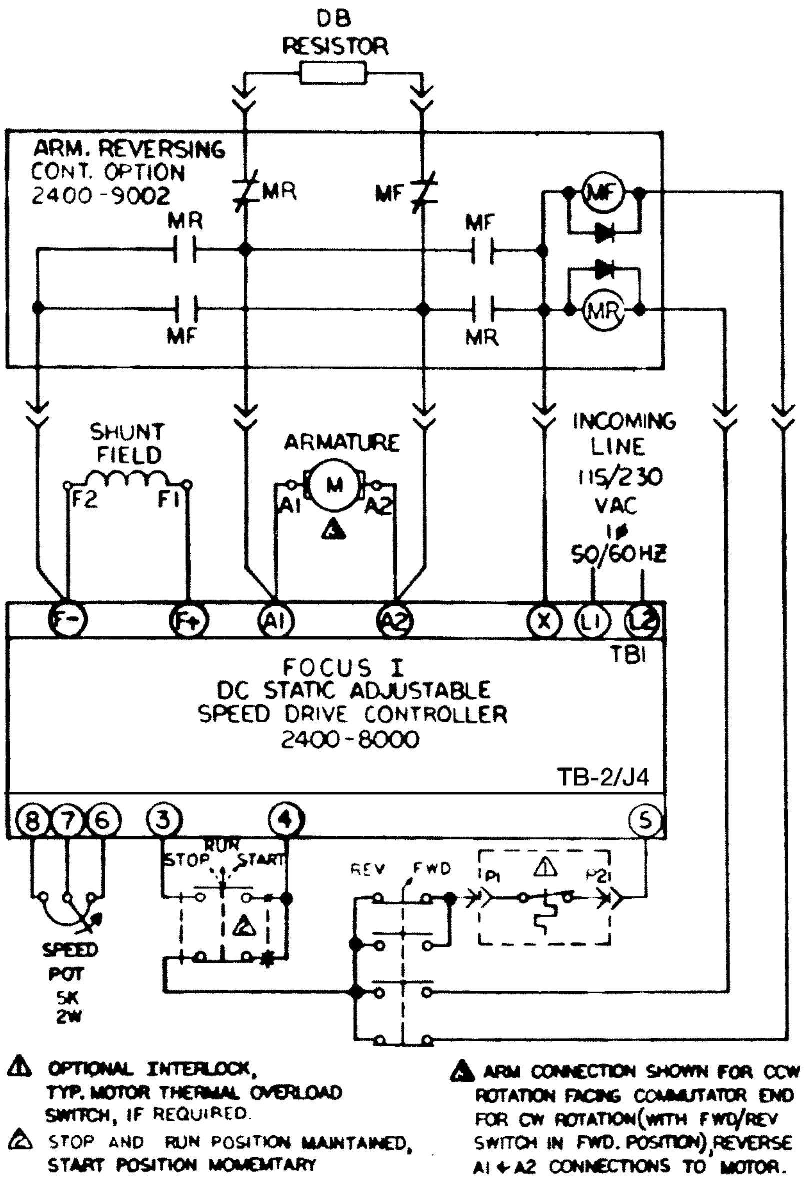



**Figure 9-7.**
*Enclosed Control with Reversing and Dynamic Braking,*
*2400-1004-I ( Rev. A)*



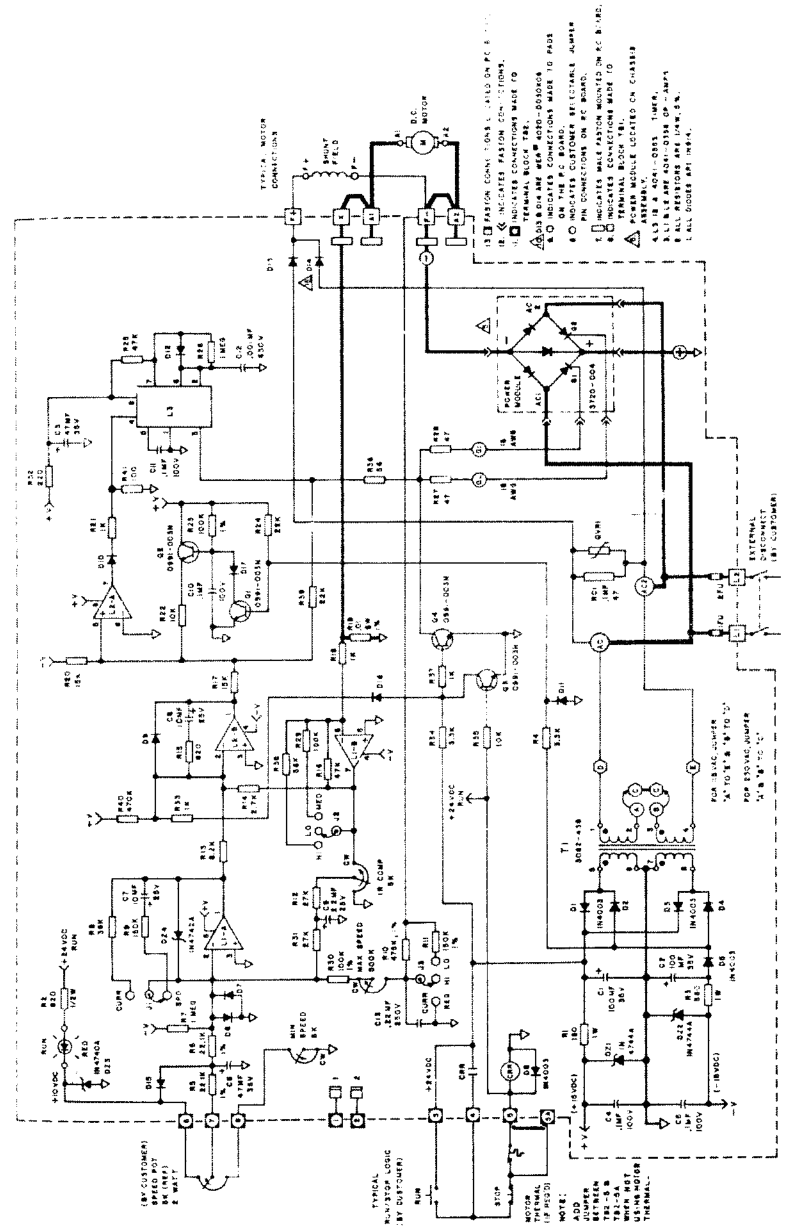


**Figure 9-8.**
*Schematic Diagram, Panel Mount Control,*
*2400-1005, (Rev. D)*

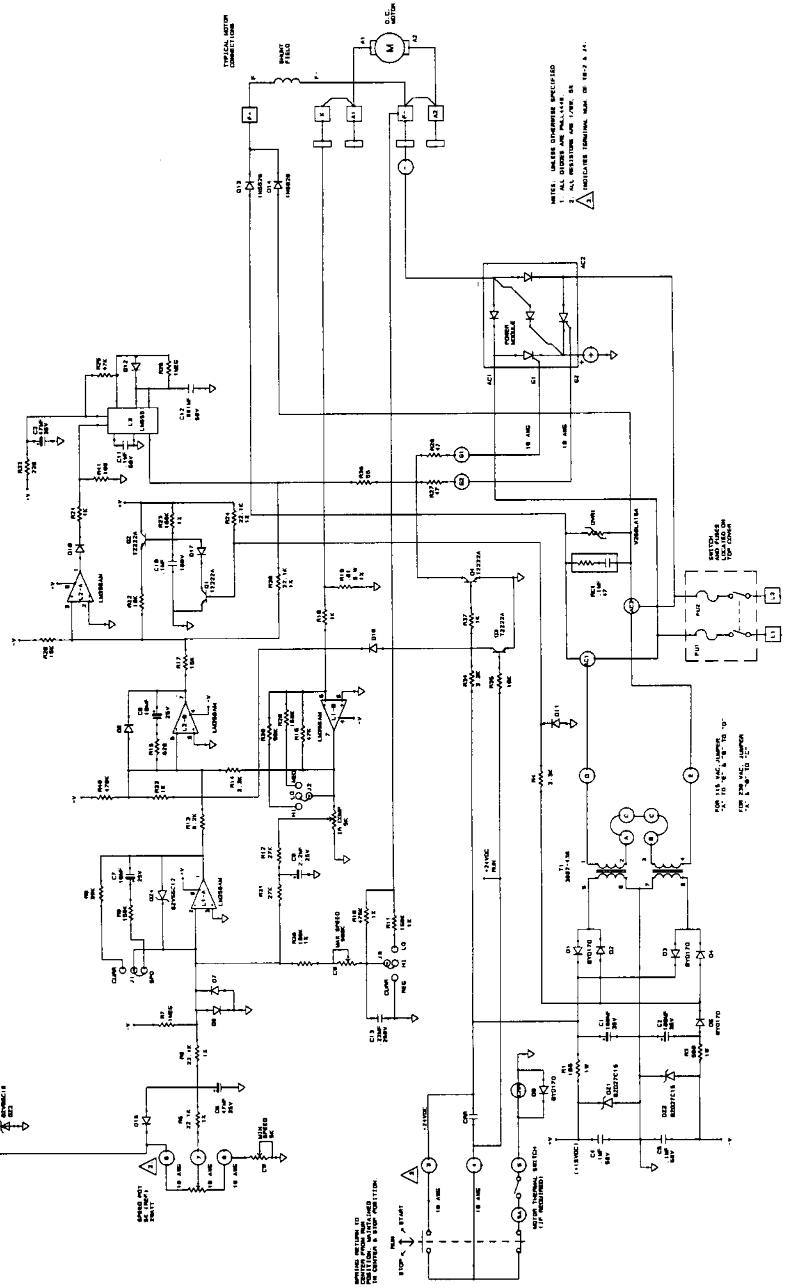


**Figure 9-9.**
*Schematic Diagram, Enclosure Mount Control, 2400-1501-I, (Rev. -)*



# SECTION 10
# BASIC APPLICATION INFORMATION

## 10.1 BASIC MECHANICS

Two (2) basic mechanical parameters, torque and horsepower, must be completely understood to properly apply DC drives.

### 10.1.1 Torque

Torque is a force applied that tends to produce rotation. Torque (force) without rotation is called static torque, since no motion is produced.

Torque is measured in lb-in or lb-ft. It is the product of the force in pounds (lb) x the distance in inches (in) or feet (ft) from the center of the point of apparent rotation. Figure 10-1 shows 120 lb-in (12 inches x 10 lb) or 10 lb-ft of torque.

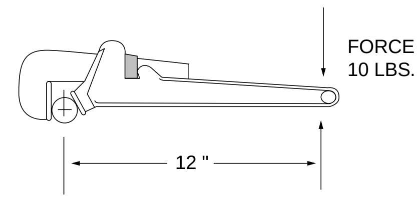



**Figure 10-1.**
*Example of 10 lb-ft Applied Torque*

Because most power transmission is based upon rotating elements, torque is important as a measurement of the effort required to produce work.

### 10.1.2 Horsepower

Horsepower is a measure of the rate at which work is being done. When a force is applied in a manner that produces motion, work can be measured. One (1) horsepower (HP) is defined as the force required to lift 33,000 lbs. one foot in one minute.

## 10.2 TORQUE VS. HORSEPOWER

A simple formula exists that relates torque and horsepower to each other. This formula is:

$$\text{Horsepower} = \frac{\text{Torque (lb-ft)} \times \text{Speed (RPM)}}{5250}$$

## 10.3 MATCHING THE DRIVE TO THE MACHINE

The application of an adjustable speed drive to a machine is a mechanical, rather than an electrical problem. When applying the drive, the speed, torque, and horsepower characteristics developed at the motor shaft must be considered. These must meet or exceed the torque and horsepower requirements of the machine being driven.

The torque requirements of a machine fall into three major categories:

1. Breakaway torque
2. Accelerating torque
3. Running Torque

### 10.3.1 Breakaway Torque

Breakaway torque is the torque required to start a machine in motion. It is almost always greater than the torque required to maintain motion (running torque). In some applications, breakaway torque is a very important parameter that cannot be neglected.

### 10.3.2 Accelerating Torque

This is the torque required to bring the machine to operating speed within a given time. With most machines, the load is largely friction and a standard drive rating may have adequate torque for satisfactory acceleration. However, certain machines classified as “high inertia” with flywheels, bull gears or other large rotating masses may require drive selection based upon the power required to accelerate the load within a given time.

### 10.3.3 Running Torque

This is the torque required to maintain machine motion after it accelerates to the desired operating speed. Running torque is usually a combination of the torque required to push, pull, compress, stretch or process the material plus the torque required to overcome frictional forces and windage. Running torque may vary as a complex function of operating speed. It is very important to understand the torque requirements of the application before attempting to apply a drive. In general, most applications will fall into one of the following categories:

A. Constant torque

B. Constant horsepower

C. Variable torque



A limited number of machines may have operating characteristics which are a composite of the basic types.

A. Constant Torque - About 90% of all general industrial machines (other than pumps) are constant torque systems. The machine torque requirement is independent of its speed. If the machine speed is doubled, its horsepower requirement doubles. Constant torque is illustrated in Figure 10-2.

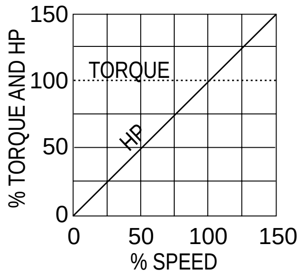



**Figure 10-2. Constant Torque**

B. Constant Horsepower - For machines with constant horsepower loads, the power demand is independent of speed and torque varies inversely with speed. This type is most often found in the machine tool industry and with center driven winders. When drilling, shaping, milling, or turning metal, the loads all tend toward constant horsepower. At low speed there is high torque; at high speed, light torque. A drive must be selected for its highest torque condition which is at the lowest speed. Constant horsepower is illustrated in Figure 10-3.

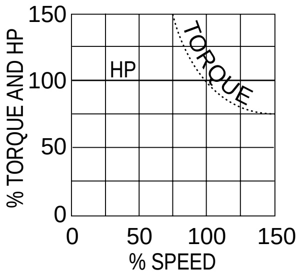



**Figure 10-3. Constant Horsepower**

C. Variable Torque - This type of load is commonly found on centrifugal pump drives and in most fan or blower applications. The torque and horsepower both vary with speed. Variable torque is illustrated in Figure 10-4.

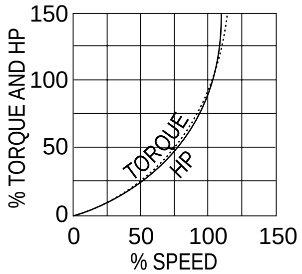



**Figure 10-4. Variable Torque**

# 10.4 DC DRIVE CHARACTERISTICS

## 10.4.1 Constant Torque Applications

Armature voltage controlled DC drives are constant-torque drives. They are capable of providing rated torque at any speed between zero and the base (rated) speed of the motor. Horsepower varies in direct proportion to speed, and 100% rated horsepower is developed only at 100% rated motor speed with rated torque.

## 10.4.2 Constant Horsepower Applications

A. Armature Controlled DC Drives - Certain applications require constant horsepower over a specified speed range. Since an armature voltage controlled DC drive has constant torque characteristics, the drive must be oversized to handle these applications. A drive required to deliver constant horsepower over a 2:1 speed range has to be rated at twice the required horsepower since it only develops 50% of its rated horsepower at half speed. The horsepower rating required for any constant torque drive operated in a constant horsepower application can be easily calculated as follows. Multiply the desired horsepower by the ratio of the speed range over which horsepower must remain constant. If 5HP is required over a 2:1 range, an armature only controlled drive rated for 10 horsepower (5 HPx 2) would be required.

B. Field Controlled DC Drives - Another characteristic of a shunt-wound DC motor is that a reduction in field voltage to less than the design rating results in an increase in speed for a given armature voltage. It is important to note, however, that this results in a higher armature current for a given motor load. A simple method of accomplishing this is by inserting a resistor in series with the field voltage source. This may be useful for achieving an ideal motor speed for the application. An optional, more sophisticated method uses a variable voltage field regulator. This provides coordinated automatic armature and field voltage control for extended speed range in constant HP applications. The motor is armature voltage controlled for constant torque-variable HP operation to base speed. It is then transferred to field control for constant HP-variable torque operation to maximum speed. This is illustrated in Figure 10-5.

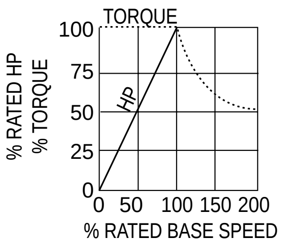



**Figure 10-5.**
*Motor Armature Voltage Control and Field Control*



# 10.5 OTHER MECHANICAL CONSIDERATIONS

## 10.5.1 Constant Torque Speed Range

When a DC drive is operated continuously at low speed and rated torque, motor heating problems may be encountered. At reduced speeds, the motor internal cooling fan is less effective and overheating occurs if the motor remains fully loaded. A typical self ventilated DC motor continuous torque rating as a function of speed is shown in Figure 10-6.

When continuous operation is required at rated torque and reduced speed, supplemental motor ventilation such as a motor mounted blower or separate ventilation duct must be supplied. An oversized motor (one that does not have to produce rated torque) or a totally enclosed non-ventilated (TENV) motor may also be used in these situations.

## 10.5.2 Torque Limitations

Most adjustable speed drives feature a torque limiter to protect the drive and the machine from torque overloads. The torque limiter (current limit) is normally adjustable to 150% of rated torque to allow extra momentary torque for breakaway, acceleration or cyclic overloads. Most drive systems are capable of sustaining the 150% torque overload for 1 minute or less.

## 10.5.3 Duty Cycle

Certain applications may require continuous reversals, long acceleration times at high torque due to inertia loads, frequent high rate acceleration or cyclic overloads. These may result in severe motor heating if not considered in the selection of the drive. Most drives with 150% overload capability operate successfully if there are compensating periods of operation where motor temperatures can be normalized.

## 10.5.4 Overhauling Loads

In some applications, process tension differences, downhill loads, or machine inertia may cause the driven machine to overhaul the drive motor. In these applications, the DC motor must provide holdback torque to brake the load. A regenerative drive is usually required in these applications.

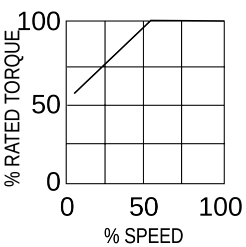



**Figure 10-6.**
*Constant Torque Speed Range*

## 10.6 MOTOR APPLICATION FORMULAS

### 10.6.1 Calculating Horsepower

Once the machine torque requirement is determined, horsepower can be calculated using the formula:

$$HP = \frac{T \times N}{5250}$$

where,

HP = Horsepower

T = Torque, (lb-ft)

N = Base speed of motor (rpm)

If the calculated horsepower falls between standard available motor ratings, select the higher available horsepower rating. It is good practice to allow some margin when selecting the motor horsepower.

For many applications, it is possible to calculate the horsepower required without actually measuring the torque required. The following useful formulas will help:

A. For Conveyors

$$HP\ (Vertical) = \frac{Weight\ (lb) \times Velocity\ (FPM)}{33{,}000}$$

$$HP\ (Horizontal) = \frac{Weight\ (lb) \times Velocity\ (FPM) \times Coef.\ of\ Friction}{33{,}000}$$

B. For Web Transport Systems and Surface Winders

$$HP = \frac{Tension\ (lb) \times Velocity\ (FPM)}{33{,}000}$$

Note that the tension value used in this calculation is the actual web tension for surface winder applications, but it is the tension differential (downstream tension - upstream tension) for sectional drives.

C. Center Winders (Armature Control Only)

$$HP = \frac{Tension\ (lb) \times Line\ Speed\ (FPM) \times Buildup}{33{,}000 \times Taper}$$

D. Center Winders (Field Control)

If Taper x Field Range > Buildup

$$HP = \frac{Tension\ (lb) \times Line\ Speed\ (FPM)}{33{,}000}$$

If Taper x Field Range < Buildup

$$HP = \frac{Tension\ (lb) \times Line\ Speed\ (FPM) \times Buildup}{33{,}000 \times Taper \times Field\ Range}$$



**CAUTION**

**The above formulas for calculating horsepower do not include any allowance for machine function windage or other factors. These factors must be considered when selecting a drive for a machine application.**

E. For Fans and Blowers

$$HP = \frac{CFM \times Pressure\ (lb/ft2)}{33{,}000 \times (Eff.\ of\ Fan)}$$

Effect of speed on HP:

HP = K1 (RPM)3 - Horsepower varies as the 3rd power of speed

T = k1 (RPM)2 Torque varies as the 2nd power of speed

Flow = k3 (RPM) - Flow varies directly as the speed.

$$HP = \frac{CFM \times Pressure\ (lb/In2)}{229 \times (Eff.\ of\ Fan)}$$

$$HP = \frac{CFM \times (Inches\ of\ Water\ Gauge)}{6356 \times (Eff.\ of\ Fan)}$$

F. For Pumps

$$HP = \frac{GPM \times Head\ (Ft) \times (Specific\ Gravity)}{3960 \times (Efficiency\ of\ Pump)}$$

Specific gravity of water = 1.0

1 cu. ft. per sec. = 448 GPM

1 PSI = A head of 2.309 ft. for water weighing

62.36 lbs./ft.3 and 62oF

Displacement pump efficiency:

Displacement pumps may vary between 50% and 80% efficiency, depending on size of pumps.

Centrifugal pump efficiency:

500 to 1000 gal. per min. = 70% to 75%

1000 to 1500 gal. per min. = 75% to 80%

Larger than 1500 gal. per min. = 80% to 85%

### 10.6.2 Inertia ($WK^2$)

The factor $WK^2$ is the weight (lb) of an object multiplied by the square of the radius of gyration (K). The unit measurement of the radius of gyration is expressed in feet.

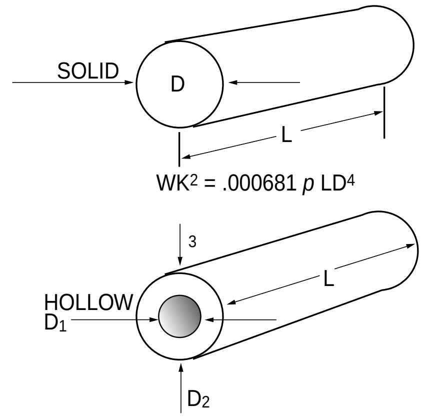
**Table 10-1**
*Inertia of Steel Shafting (per inch of length)*

| DIAM. (IN) | WK2 (=-LB -FT2) | DIAM. (IN) | WK2 (=LB -FT2) |
|---|---|---|---|
| 3/4 | .00006 | 10-1/2 | 2.35 |
| 1 | .0002 | 10-3/4 | 2.58 |
| 1-1/4 | .0005 | 11 | 2.83 |
| 1-1/2 | .001 | 11-1/4 | 3.09 |
| 1-3/4 | .002 | 11-1/2 | 3.38 |
| 2 | .003 | 11-3/4 | 3.68 |
| 2-1/4 | .005 | 12 | 4.00 |
| 2-1/2 | .008 | 12-1/4 | 4.35 |
| 2-3/4 | .011 | 12-1/2 | 4.72 |
| 3 | .016 | 12-3/4 | 5.11 |
| 3-1/2 | 0.029 | 13 | 5.58 |
| 3-3/4 | 0.038 | 13-1/4 | 5.96 |
| 4 | 0.049 | 13-1/2 | 6.42 |
| 4-1/4 | 0.063 | 13-3/4 | 6.91 |
| 4-1/2 | 0.079 | 14 | 7.42 |
| 5 | 0.120 | 14-1/4 | 7.97 |
| 5-1/2 | 0.177 | 14-1/2 | 8.54 |
| 6 | 0.250 | 14-3/4 | 9.15 |
| 6-1/4 | 0.296 | 15 | 9.75 |
| 6-1/2 | 0.345 | 16 | 12.59 |
| 6-3/4 | 0.402 | 17 | 16.04 |
| 7 | 0.464 | 18 | 20.16 |
| 7-1/4 | 0.535 | 19 | 25.03 |
| 7-1/2 | 0.611 | 20 | 30.72 |
| 7-3/4 | 0.699 | 21 | 37.35 |
| 8 | 0.791 | 22 | 44.99 |
| 8-1/4 | 0.895 | 23 | 53.74 |
| 8-1/2 | 1.00 | 24 | 63.71 |
| 8-3/4 | 1.13 | 25 | 75.02 |
| 9 | 1.27 | 26 | 87.76 |
| 9-1/4 | 1.41 | 27 | 102.06 |
| 9-1/2 | 1.55 | 28 | 118.04 |
| 9-3/4 | 1.75 | 29 | 135.83 |
| 10 | 1.93 | 30 | 155.55 |
| 10-1/4 | 2.13 | - | - |



For solid or hollow cylinders, inertia may be calculated by using the equations given here.

The inertia of solid steel shafting per inch of shaft length is given in Table 10-1. To calculate hollow shafts, take the difference between the inertia values for the O.D. and I.D. For shafts of materials other than steel, multiply the value for steel by the appropriate factor given in Table 10-2.



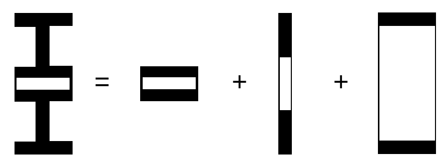

$WK^2 = .000681\ p\ L\ (D_2^4 - D_1^4)$
$WK^2 =$ lb. ft.$^2$
$D_1 D_1 D_1$ and L = in.
$p =$ lb./in.$^3$

$p$ (aluminum) = .0924
$p$ (bronze) = .320
$p$ (cast iron) = .260
$p$ (steel) = .282
$p$ (paper) = .0289

**Table 10-2**
*Density Factors*

| SHAFT MATERIAL | FACTOR |
|---|---|
| Rubber | .121 |
| Nylon | .181 |
| Aluminum | .348 |
| Bronze | 1.135 |
| Cast Iron | .922 |
| Steel | 1.00 |

The inertia of complex, concentric rotating parts may be calculated by breaking the part up into simple rotating cylinders, calculating their inertias and summing their values, as shown in the following diagram.




$$WK^2_{TOT} = WK^2_1 + WK^2_2 + WK^2_3$$

### 10.6.3 WK2 of Rotating Elements

In practical mechanical systems, all the rotating parts do not operate at the same speed. The WK2 of all moving parts operating at each speed must be reduced to an equivalent WK2 at the motor shaft, so that they can all be added together and treated as a unit, as follows:

$$\text{Equivalent WK2} = WK^2 \left(\frac{N}{N_m}\right)^2$$

Where

WK2, = inertia of the moving part
N = speed of the moving part (RPM)
Nm = speed of the driving motor (RPM)

When using speed reducers, and the machine inertia is reflected back to the motor shaft, the equivalent inertia is equal to the machine inertia divided by the square of the drive reduction ratio.

### 10.6.4 WK2 of Linear Motion

Not all driven systems involve rotating motion. The equivalent WK2 of linearily moving parts can also be reduced to the motor shaft speed as follows:

$$\text{Equivalent } WK^2 = \frac{W\,(V)^2}{39.5\,(N_m)^2}$$

Where,

W = weight of load (lb)
V = linear velocity of rack and load or conveyor and load (FPM)
Nm = speed of the driving motor (RPM)

This equation can only be used where the linear speed bears a continuous fixed relationship to the motor speed, such as a conveyor.

## 10.7 ELECTRICAL FORMULAS

Ohms Law:

$$\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}} \qquad \text{Ohms} = \frac{\text{Volts}}{\text{Amperes}}$$

Volts = Amperes x Ohms
Power in DC Circuits:
Watts = Volts X Amperes

$$\text{Horsepower} = \frac{\text{Volts x Amperes}}{746}$$

$$\text{Kilowatts} = \frac{\text{Volts x Amperes}}{1000}$$



$$\text{Kilowatt-Hours} = \frac{\text{Volts x Amperes x Hours}}{1000}$$

Power in AC Circuits:
Kilovolt - Amperes (kVA)

$$\text{kVA (Single-Phase)} = \frac{\text{Volts x Amperes}}{1000}$$

$$\text{kVA (Three-Phase)} = \frac{\text{Volts x Amperes x 1.73}}{1000}$$

Kilowatts (kW)

$$\text{kW (Single-Phase)} = \frac{\text{Volts x Amperes x Power Factor}}{1000}$$

$$\text{kW (Three-Phase)} = \frac{\text{Volts x Amperes x Power Factor x 1.73}}{1000}$$

$$\text{Power Factor} = \frac{\text{Kilowatts}}{\text{Kilovolts x Amperes}}$$

## 10.8 OTHER USEFUL FORMULAS

1KW = 56.88 BTU/MIN
1HP = 0.7457kW
= 550 lb-ft per sec
= 33,000 lb-ft per min
= 2545 BTU per hour

TEMPERATURE CONVERSION

Degrees C = (Degrees F-32) x 5/9
Degrees F = (Degrees C x 9/5) + 32

# APPENDIX A
# GLOSSARY

Constant HP Load - A load requiring high torque at low speeds, low torque at high speeds, and thus constant horsepower at any speed.

Constant Torque Load - A load requiring the same amount of torque at low speed as at high speed. Torque remains constant throughout the speed range, and the horsepower increases and decreases in direct proportion to the speed.

CRR - Control run relay.

Horsepower - A measure of the rate at which work is being done. One (1) horsepower (HP) is defined as the force required to lift 33,000 lbs. one foot in one minute.

IR Compensation - An adjustment that overcomes the natural tendency for a motor to decelerate with increasing load.

LED - Light emitting diode.

Non-Regenerative Drive - One which rotates the DC motor in only one direction to supply rotational energy or torque into the load.

Overhauling Load - A load such as a process tension difference, a downhill load or machine inertia that requires the motor to provide holdback torque to brake the load. A regenerative drive or energy absorber kit is usually required in these applications.

Regenerative Drive - One which can both deliver and remove electrical energy to or from a motor. In this manner, rotational mechanical energy can be supplied to or be removed from a load.

SCR - Silicon controlled rectifier.

TENV - Totally Enclosed Non-Ventilated.

Torque - A force applied that tends to produce rotation. Breakaway torque is the torque required to start a machine in motion. Accelerating torque is the torque required to bring the machine to operating speed within a given time. Running torque is the torque required to maintain machine motion after it accelerates to the desired operating speed.

Variable Torque Load - A load requiring much lower torque at low speeds than at high speeds. Horsepower varies approximately as the cube of the speed, and the torque varies approximately as the square of the speed.