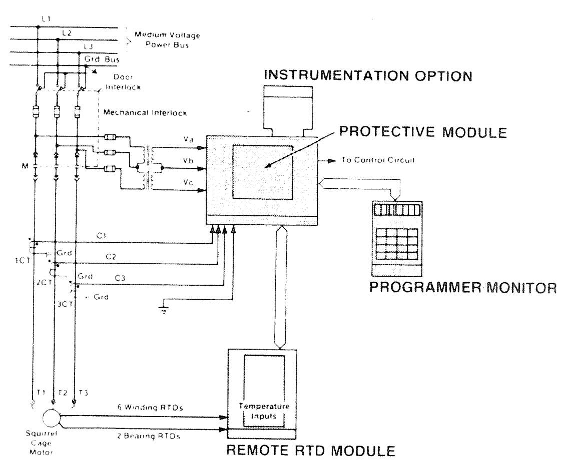
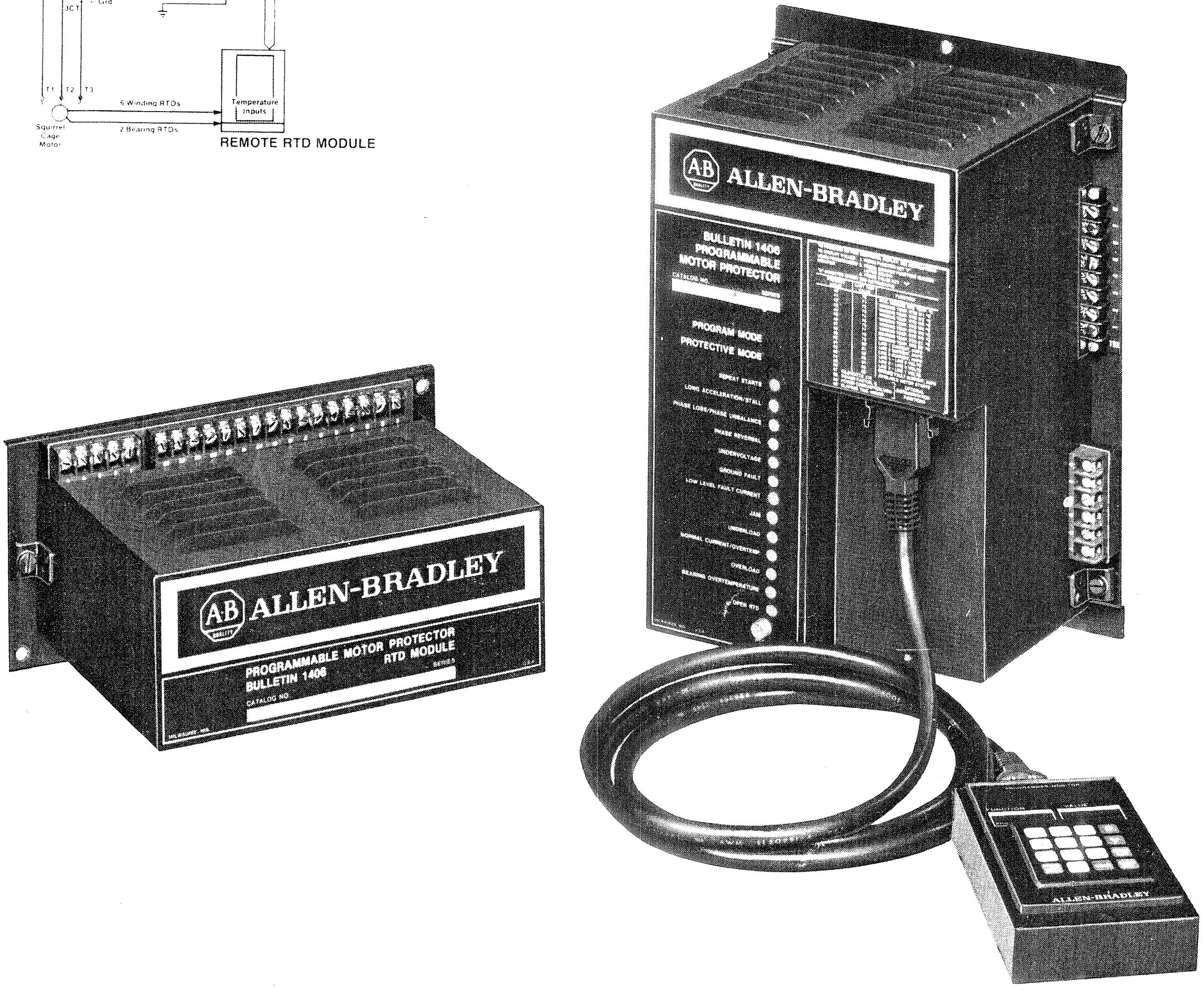
ALLEN-BRADLEY BULLETIN 1406
PROGRAMMABLE MOTOR PROTECTOR – USER'S MANUAL





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Section 1
SCOPE

1.0 Introduction

The Bulletin 1406 Programmable Motor Protector was developed to provide sophisticated, coordinated motor protection and monitoring of motors. Typically, these motors are medium voltage or large low voltage 3-phase induction motors.

The Programmable Motor Protector (PMP) is a modular protective system that consists of three basic modules:

- **Protective Module**
- **Programmer / Monitor**
- **Remote RTD Module**

The **Protective Module** is the main module of the system. It performs most of the information processing required.

The **Programmer / Monitor** serves as the user interface to allow entry of specific motor application data.

The remote Resistance Temperature Detector **(RTD) Module** serves as a remote temperature data gathering panel. It samples temperature data and communicates it to the main Protective Module.

1.1 User's Manual Configuration

The User's Manual is organized to facilitate the first time user of the Programmable Motor Protector. The information is presented in an order that a user would require to apply the device. The following is a breakdown of the information:

Section 2 - consists of a general system overview.

Section 3 - contains information on receiving, storage, and inspection.

Section 4 - is a detailed discussion of the system configuration and description of operation.

Section 5 - contains installation information including hardware, electrical data, grounding considerations and wiring.

Section 6 - contains the system operation from the user's perspective including readouts, keyboard, status indication, error codes,etc. It also discusses loading data, data verification, mode selection, and system checkout.

Section 7 - includes programming information that serves several functions. It covers each harmful motor condition the PMP monitors and serves as a mini-tutorial on motor protection. Also, it defines the harmful condition, discusses how the PMP detects it, identifies the dynamic range in settings and provides some guidelines for making settings.

Section 8 - presents some of the most common overload curves. These curves can be useful in laying out a coordination sequence between the protective device fuses and other protective devices.

Section 9 - is a section on troubleshooting.

Section 10 - is a section on renewal parts.

Section 11- is a section on typical specifications.

Section 2
OVERVIEW

2.0 Description

The Programmable Motor Protector (PMP) system combines sophisticated, comprehensive and coordinated motor protection into a modular system. It is intended for protection of large expensive motors or motors that are critical to a system or process. Typically, these motors are medium voltage (2300 to 7200 volts) or large low voltage (200 HP or larger) motors.

This multifunction protective relay operates as an information processing system. It takes inputs from line voltage, current, ground fault sensor, and temperature information from Remote RTDs and compares this information to expected preprogrammed motor performance.

The PMP is a modular device consisting of three modules:

- Protective Module
- Programmer / Monitor
- Remote RTD Module

Refer to Figure 1.

2.1 Protective Module

The Protective Module is the main module of the system. It receives inputs from the potential transformers, current transformers, and temperature data from the Remote RTD Module. These inputs represent a portion of real time motor data coming into the device for processing. With all these inputs, the Protective Module examines incoming motor data and compares it to user preprogrammed limits. The module then determines if the motor should be taken off line. It provides alarm and trip signals, plus visually indicates the abnormality.

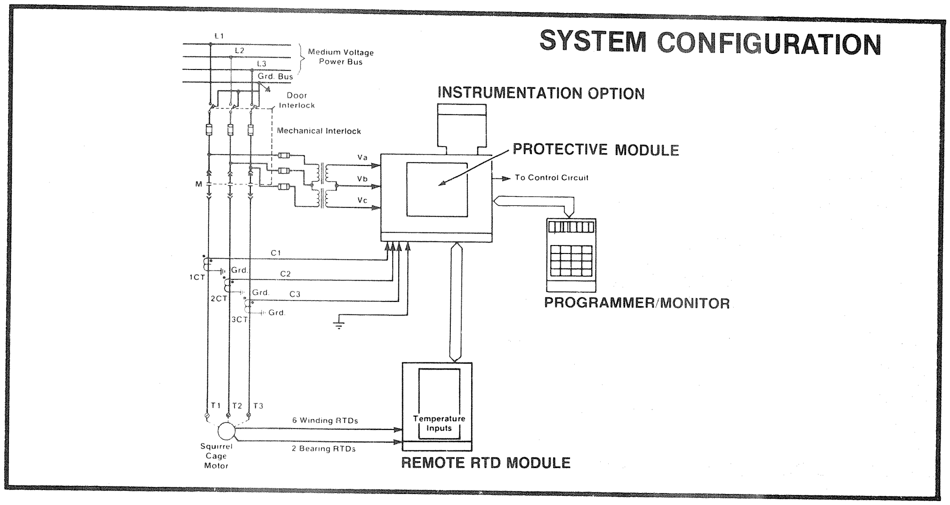


Figure 1.

If a motor parameter is approaching a value that is near the trip value, the PMP changes the state of the alarm contacts. When the parameter reaches the trip point, the trip contacts change state.

The Protective Module has an annunciator package that operates in conjunction with the alarm and trip relays. When a parameter goes into an alarm condition, the appropriate LED will flash. In a trip condition, the LED remains constantly lit.

The harmful conditions detected and annunciated by the PMP are:

- Repeat Starts
- Long Acceleration/Stall
- Phase Loss/Unbalance
- Phase Reversal
- Undervoltage
- Ground Fault
- Low Level Fault
- Jam
- Underload
- Normal Current/Overtemp
- Overload
- Bearing Overtemp

Each of the above conditions will be covered in detail in Section 7.

2.2 Programmer / Monitor

The Programmer / Monitor serves as the user interface for the PMP. It has a twofold purpose:

1. To enter user data into the Protective Module.
2. To allow the user to read out pertinent data.

The data entered by the user to protect the motor consists of expected motor parameters such as:

- Volts
- Amperes (Full Load)
- Amperes (Locked Rotor)
- Number of RTDs
- Safe Stall Time
- Accel Time
- % Phase Unbalance
- Ground Fault
- Low Level Fault
- Jam
- Ultimate Current Trip
- Alarm Temperatures
- Trip Temperatures

The above values are used by the Protective Module to construct a thermal model of the motor. Section 7 discusses the above in detail as well as presenting some guidelines for user settings.

2.3 Remote Resistance Temperature Detector (RTD) Module

The remote RTD Module serves as a remote temperature data gathering panel. This module scans eight RTDs (two bearing and six winding). It takes the analog signal, digitizes it, performs a linearization function (to compensate for the non-linear RTD characteristic) and communicates these temperature values to the Protective Module. It performs the temperature data acquisition and coordination on demand from the Protective Module.

The remote RTD Module can be mounted at or near the terminal box of the motor. It communicates temperature information over three twisted shielded pair of wires.

2.4 Instrumentation Option

The Instrumentation Option card is an internal expansion card that allows the PMP to utilize the voltage and current information present in the Protective Module.

This card performs the necessary data processing required for calculating:

- Elapsed Running Time
- Power Consumption (Totalized)
- Power Factor (Lead/Lag)
- Power

This information can be utilized to schedule loads, maintenance, and diagnostics.

Section 3

RECEIVING / INSPECTION

3.0 Receiving / Inspection

All Bulletin 1406 Programmable Motor Protectors are functionally tested and burned in before shipment. Each module is packed and shipped separately.

Unpack each carton carefully. Make sure that the component received is the one that was ordered. Check for damage that may have occurred during shipping. All claims for damage must be made to the carrier as soon as possible after receipt of shipment.

3.1 Storage

If it is necessary to store equipment for any length of time, follow these recommendations:

Temperature - The ambient temperature should not be less than -20°C or greater than + 120°C.

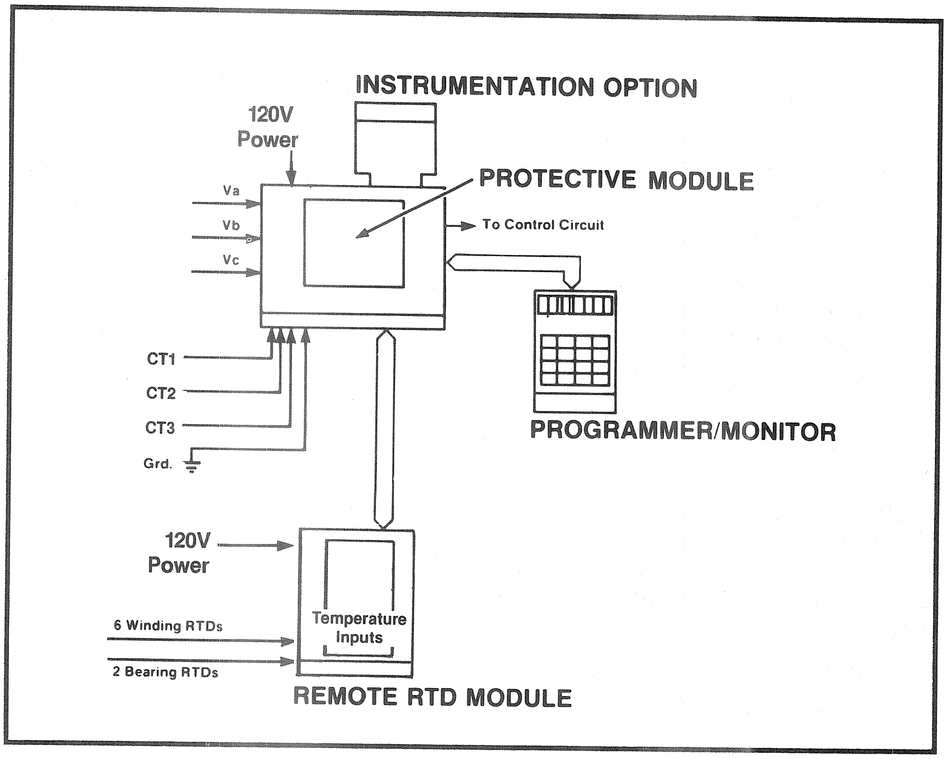
Humidity - If the storage area is damp and/or cool, it is important to dry the unit out in a warm dry environment prior to use. Also, clean all circuit board connections to help provide integrity of the electrical connections.

Dirt - Cover equipment with heavy duty plastic or similar material to help prevent the accumulation of dirt on the equipment.

NOTE - For storage in harsh or caustic environments,etc. - Consult local Allen-Bradley representative.

Section 4

SYSTEM CONFIGURATION AND DESCRIPTION OF OPERATION



4.0 Introduction

This section of the PMP User's Manual contains the following information:

1. How the PMP is configured.
2. Hardware definition in terms of inputs and outputs.
3. Description of System Data Flow and Communication to outline how data is brought in and processed.
4. System description of operation to assist the user in understanding on how to use the device.

4.1 Protective Module

Inputs:

The Protective Module has three internal current transformers for line current inputs. These inputs are connected to the user's line current transformers (CT-1-3). These current transformers should have a 5-Ampere secondary and be sized so that the motor full load current is between 40 and 80 percent of the transformer primary rating.

There are also three internal potential transformers in the Protective Module for line voltage input. These inputs should be connected to the secondaries of the user's line voltage potential transformers. These voltage inputs are required for any instrumentation or prestart line voltage protection. However, the PMP will function without them.

The user's potential transformers can be either two transformers connected in open delta or three transformers connected in wye or delta. They should be sized to provide line voltage to 120 volts AC.

For ground fault protection, the PMP requires a zero sequence ground fault transformer as an input. The user supplied ground fault transformer should have a secondary current of 5-Amperes. For protection of motors whose acceleration time is longer than the safe stall time, a zero speed switch is required as an input. This input senses that the rotor of the motor has begun to accelerate. (Indicating a "locked rotor" condition no longer exists). This input is wired to provide 120 volts AC to the Protective Module when the R.P.M. exceeds a predetermined level (set at zero speed switch).

If an overload or any other harmful motor condition detected causes the PMP to trip, the device will require resetting. There are two ways to reset the PMP, local and remote.

Local- A local reset can be performed by depressing the reset button on the Protective Module.

Remote- A remote reset can be used by having a user supplied momentary contact (N.O.) push button. This push button is wired to provide 120 volts AC to the reset terminals of the Protective Module.

There are two remaining inputs to the Protective Module. They are the serial communications port from the Programmer output and the serial communications port from the remote RTD Module output.

Outputs:

There are several outputs on the Protective Module (in addition to the two serial communication ports) to the other modules. They are the alarm relay, the trip relay, and the annunciator LEDs.

Alarm Relay - The alarm relay contacts change state when the

Protective Module senses that a motor parameter has reached an alarm condition. This relay provides (2) Form C contacts out.

Trip Relay - The trip relay contacts change state when a motor parameter reaches a programmed trip point. This relay also provides (2) Form C contacts out.

The Protective Module also has an annunciator panel. This panel consists of (15) annunciator LEDs located on front of the Protective Module. These LEDs indicate which abnormal condition caused the trip to occur.

4.2 Programmer / Monitor

The Programmer / Monitor slaves power from the internal power supply of the Protective Module through the interconnect cable.

Inputs:

The Programmer / Monitor serves as the user interface for the PMP system. Inputs to the Programmer / Monitor are entered by keystrokes on the keyboard. The keyboard consists of two types of keys:

- Command Keys (Blue)
- Value Keys (White)

The command keys instruct the PMP to change modes, enter data, select funtions, etc. The value keys (0-9) are used to input the variables required by the PMP system to protect the motor.

Outputs:

The output of the Programmer / Monitor (as previously mentioned) is a serial communications port which is an input to the Protective Module.

4.3 Remote RTD Module

Inputs:

The inputs to the RTD Module consist of RTD temperature inputs. There are six winding RTD and two bearing RTD inputs.

The RTD Module is capable of accepting several different types of RTDs. However, all six of the winding RTDs must be one type and the two bearing RTDs must be of one type. But the winding RTDs can be different than the bearing RTDs.

Briefly, the RTD Module accepts eight RTD inputs. It selects each RTD, examines the analog value, digitizes it, performs a linearization function (to compensate for a non-linear RTD characteristic) and communicates it to the Protective Module.

Outputs:

The output of the RTD Module is a serial communications port that connects to the Protective Module.

The RTD Module (usually mounted at or near the motor) can be mounted up to 4000-feet from the Protective Module.

4.4 Instrumentation Option

This option is an internal expansion card that allows the calculation of metering functions.

4.5 System Data Flow and Communication

The PMP system functions by gathering real time motor data and comparing it to user entered set points.

Simply stated, the user enters specific application information into the system via the Programmer. Real time motor data is present at the RTD and Protective Module inputs.

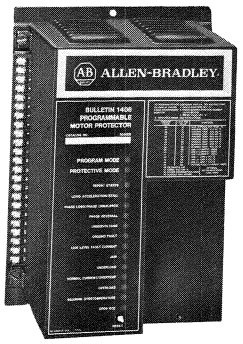
As the PMP advances through its program it sends a message to the RTD Module. The RTD Module converts and transmits back the temperature value of RTD#1. The PMP compares this data to its user entered value. The program then examines temperatures associated with RTD#2 through #8. This temperature data is also fed into the algorithm for the overload calculation.

The PMP also checks the voltages and currents in a similar manner. In addition, it uses this information to protect against the other harmful conditions.

Section 5
INSTALLATION

5.0 Protective Module

The Protective Module is to be located in the low voltage compartment of a medium voltage controller or low voltage controller. It has a 3-point mounting plate for versatility. All wiring enters and exits via the side mounted terminal strips.



CAUTION– Be sure the line disconnect switch is open when working near the voltage inputs. There will be 120 Volts present when the disconnect is closed.

Electrical Data:

Device Power – The Protective Module requires 110/120 Volts AC, 50/60 Hz for device power. This input will present a 40VA burden to the AC supply. Connections are made to terminals 5 and 6 on terminal strip TB-3 (lower R.H. side of the Protective Module). Refer to the Wiring Diagram on Page 5-6 for all terminations.

CAUTION– Do not disconnect any of the current transformer (CT) inputs when there is current present. This will cause a high voltage to appear on the secondary leads of the user supplied CTs.

Current Transformer Inputs – The secondary windings of the user supplied CTs must have 5-Ampere secondaries. They must be sized so that the motor's Full Load Current (FLC) is between 40-80 percent of the CT primary rating. The internal CTs of the Protective Module present a 0.5VA burden to the user's CTs with a 5-Ampere secondary current. These input connections are made to the upper R.H. side of the Protective Module via terminal strip TB-2 (terminals 3-8).

NOTE – When using the Instrumentation Option, be sure to use current transformers with a phase shift of less than 1° from primary to secondary. Failure to do so will degrade the accuracy of the power related functions.

Voltage Inputs – The internal potential transformers (PTs) of the PMP require that the user supplied PTs transform line voltage down to 120 volts AC. The user's PTs can be either two transformers connected in open delta or three transformers connected in either wye or delta. The internal PTs present a 0.2VA burden to the 120 volt secondaries of the user's PTs.

NOTE – When using the Instrumentation Option, be sure to use PTs with a phase shift of less than 1° from primary to secondary. These inputs connect to terminals 1, 2 and 3 of TB-3. Failure to do so will degrade the accuracy of the power related functions.

Ground Fault Inputs – The user supplied ground fault transformer (zero sequence transformer) should be designed to have a 5-Ampere secondary current. The internal ground fault transformer presents a 0.5VA burden to the user's ground fault transformer secondary at 5-Ampere secondary current. This input connects to terminals 1 and 2 of TB-2.

Communications Port - Remote RTD Module – This connection establishes communications between the Protective Module and the Remote RTD Module.

These connections are made on terminals 1-6 on terminal strip TB-1 as shown in Figure 1. The wiring used for this connection is three twisted shielded pair.

The remote RTD Module can be mounted up to 4000-feet from the Protective Module.

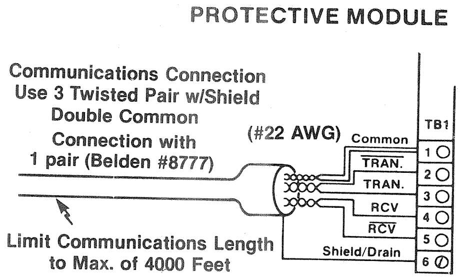


Figure 1.

Acceleration Sensor Input – The acceleration sensor input or zero speed switch is wired to the Protective Module. It is wired to indicate that 0 Volts corresponds to a stall condition and 120 Volts corresponds to a non-stall or rotary input. This input will present a 1.2VA burden to the 120 Volt AC circuit. Any voltage greater than 40 Volts AC will activate the input.

Remote Reset Input – The remote reset input is connected to a normally open momentary contact push button that will reset the device at 120 Volts AC. This remote reset will present a 0.8VA burden to the 120 Volt circuit.

Grounding Considerations

For proper operation of the PMP, the following grounding considerations must be taken into account. There are two grounds on the Protective Module.

The first one is a general purpose ground which is used in conjunction with input power. This terminal (#4) should be connected to earth ground.

The second ground is associated with the communications link between the Protective Module and the remote RTD Module and Programmer/Monitor.

In some cases the "earth ground" is not a pure homogeneous plane and the ground is electrically very noisey. This electrical noise contributes to signal communication degradation.

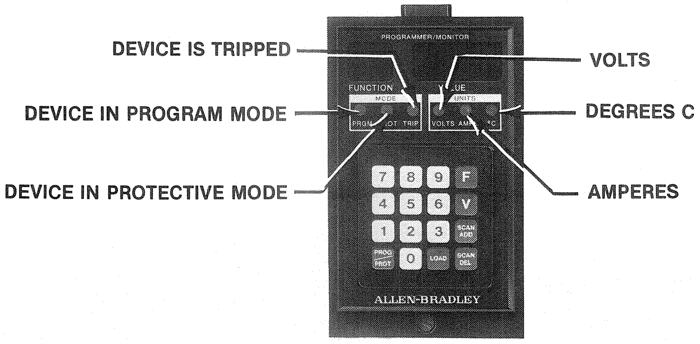
If this is the case in your particular application, then the ground associated with the communications link terminal #9 must be connected to a more solid ground.

If the installation ground at the power connection is a relatively homogeneous solid ground, terminal #9 on TB-1 may be wired to terminal #4 on TB-3 and terminal #4 wired to cabinet ground.

General Wiring Guidelines

Follow the National Electrical Code (NEC) and local codes when wiring the Protective Module, 120 Volt power, acceleration sensor input, remote reset, alarm and trip output relays, and current and potential transformers.

For extremely electrically noisey installations where electromagnetic noise coupled into the system may degrade the signal, it is important to twist the leads at approximately 12 turns/foot. This helps reduce the coupled magnetic noise.



PROGRAMMER/MONITOR

5.1 Programmer / Monitor

The Programmer / Monitor can be hand held, mounted within the Protective Module or mounted on the cabinet door of the enclosure. Use the following procedures described for installation

If the Programmer / Monitor is to be mounted on the Protective Module use the following procedure and refer to Figure 2.

1. Locate the Programmer / Monitor over the cavity on the lower R.H. side of the Protective Module.
2. Align the device connector with the connector in the Protective Module.
3. Insert the Programmer / Monitor and lock in place with the spring screw located in the base of the device.

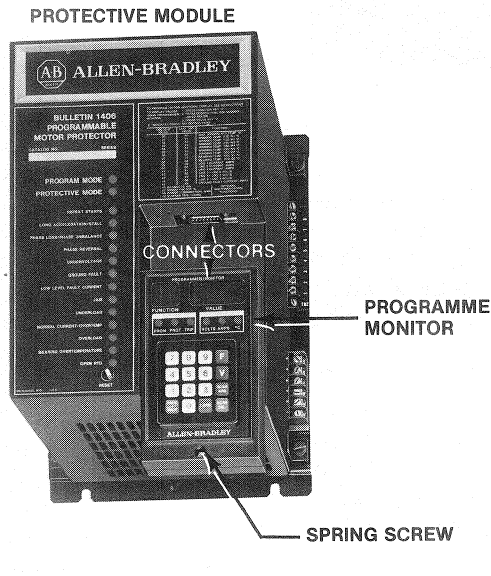


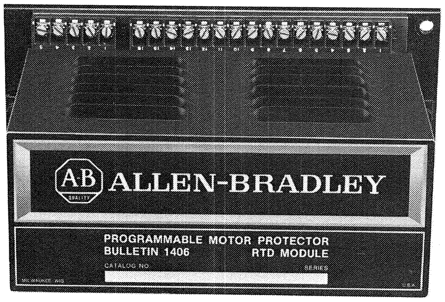
Figure 2.

If the Programmer / Monitor is to be mounted in the cabinet door, follow the instructions outlined in Publication 1406-2.2.

When using the Programmer / Monitor in the hand held configuration, use the 6.7-ft. interconnect cable (Catalog No. 1741-C1). See Publication MC-279 for procedure. If the device is to be mounted further than 6.7-ft. cable, refer to local Allen-Bradley representative.

The Programmer / Monitor requires no other connections and is ready to use.

5.2 Remote RTD Module



The remote RTD Module is normally located at or near the motor. This is to facilitate user "field" wiring. It allows all RTD connections to be made at the RTD Module. The RTD Module is then wired to the Protective Module by three twisted shielded pairs.

Mounting – The RTD Module is mounted in an enclosure by means of its 2-point mounting plate. All connections are made on either side of the mounting plate.

> **CAUTION-** When the remote RTD Module is used, always open the disconnect switch when servicing any part of the PMP system. This is necessary to protect the user in the event one of the motor windings shorts to one of the RTD leads. If that occurred, the internal power supply could be floating on the line voltage and present a hazardous condition to the user.

Electrical Data:

Device Power – The remote RTD Module requires 110/120 Volts AC 50/60 Hz for device power. This device will present a 15VA burden on the 120 Volt AC supply. The connections for device power are located on the upper L.H. side of the unit at TB-3.

Inputs – The RTD module has eight inputs. Six inputs are from the winding and two inputs are from the bearing. The PMP is designed to accomodate three-wire RTDs, so each RTD input requires three connections. The input connections for the RTDs are located on terminal strip TB-2 and TB-4.

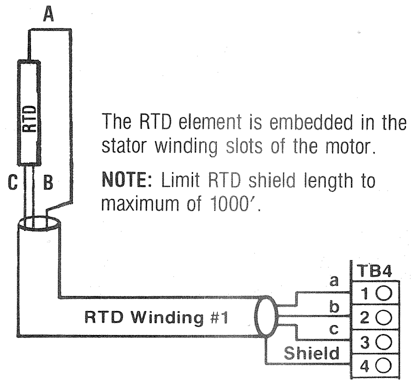
Refer to the wiring diagram on page 5-6.

Grounding and Shielding Techniques for RTDs – The RTD consists of a sensing element and three wires.

The shields of each RTD entering the remote RTD Module are internally commoned. Terminal #4 on TB-4 should be connected to terminal #3 on TB-3 if the earth ground #3 on TB-3 is a solid ground. If this is not the case, then terminal #4 on TB-4 should be connected to a more solid ground.

NOTE – If two-wire RTDs are used it is important to run a third wire back to the RTD. This allows the RTD Module to compensate for the resistance of the RTD wires.

For best performance, the RTD wires should be run back to the RTD Module using three conductor cable with shield (Alpha #2403 or equivalent). Figure 3 shows typical wiring for RTD #1 to terminal TB-4.



The RTD element is embedded in the stator winding slots of the motor.

NOTE: Limit RTD shield length to maximum of 1000′.

Figure 3.

Outputs – The output of the RTD Module is the communications port and can be referred to as an input/output or I/O. Under direction and control of the Protective Module, the I/O is the path for the temperature data to flow from the RTD Module to the Protective Module. The five connections for this pathway are on TB-1. (See Figure 4). The communications path requires three twisted shielded pairs of wires. BELDEN #8777 or similar should be used. This connection is to be limited to 4000-feet maximum. One pair of the twisted shielded pairs shall be a common connection as shown in Figure 4.

NOTE – It is important for these connections to be made correctly for proper communication between the remote RTD Module and the Protective Module.

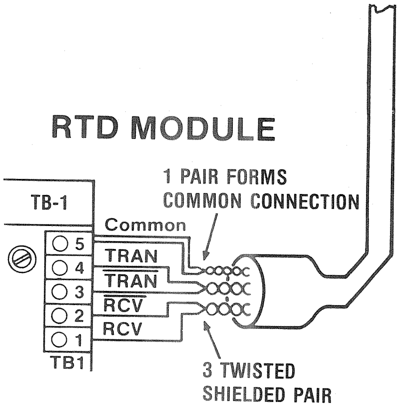


Figure 4.

RTD Selection

The RTD Module allows the user to select the winding and bearing types desired.

The conversion from one RTD type to another is accomplished by the following procedure.

Remove the cover of the RTD Module. There are two DIP switch blocks located on the inside of the module. One block is for setting the winding RTD and the other is for setting the bearing RTD. Each block has four switches, one for each type of RTD.

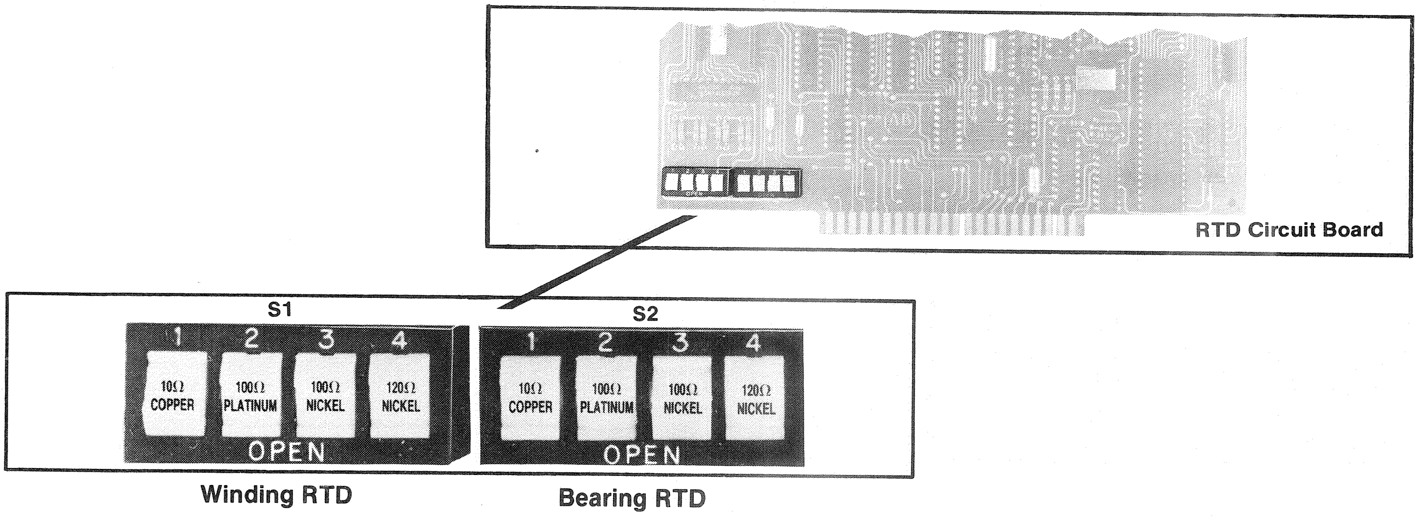
To set up the RTD Module, select the block of switches (either bearing or winding) and depress the appropriate DIP switch.

NOTE- Make sure only one switch in each block is closed.

After the RTD types have been selected, the number of winding and bearing RTDs are programmed into the Protective Module. If only three winding RTDs are to be monitored, they must be connected to the three lower RTD winding connection ports.

(RTD Winding #1)
(RTD Winding #2)
(RTD Winding #3)

The same applies to the bearing RTDs.



5.3 Instrumentation Option

The instrumentation option is a printed circuit card that allows the PMP to calculate the metering functions. This card contains all the hardware and software required for these functions.

There is no field set up or wiring for the instrumentation option. It is installed in the third card rail (See Figure 5) on the mother board within the Protective Module.

Procedure:

1. Remove the four screws holding the cover of the Protective Module to its base.
2. Take the instrumentation card as in Figure 6 and locate as shown with components facing the right.
3. Push connector into the card rail until it seats firmly.
4. Replace the cover screws.

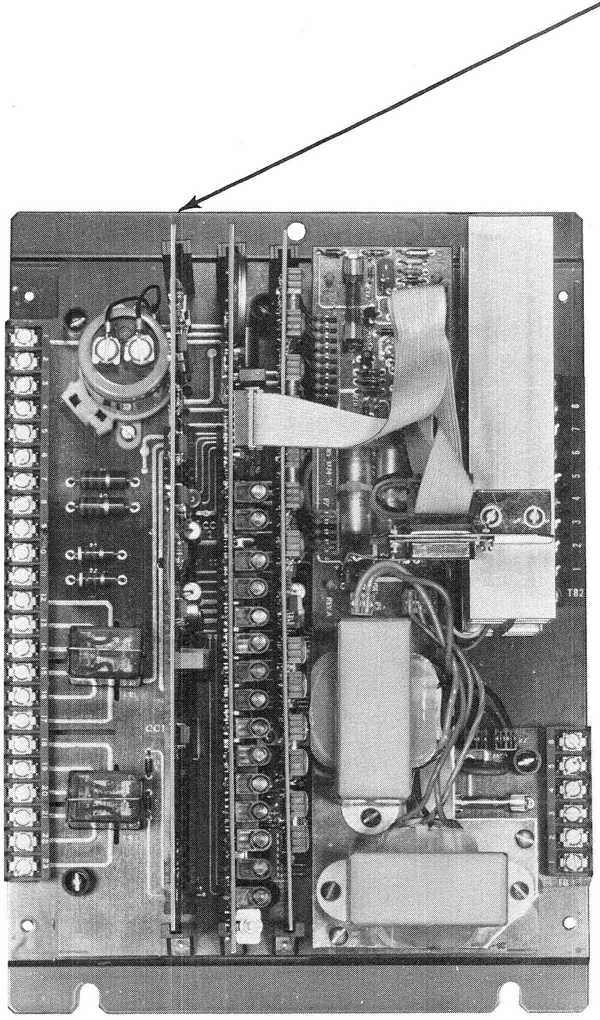


Figure 5.

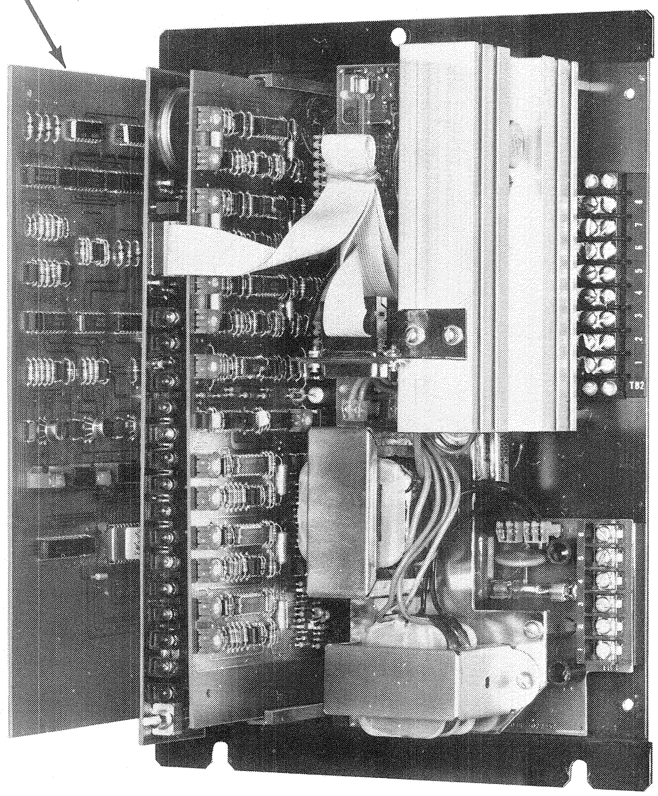
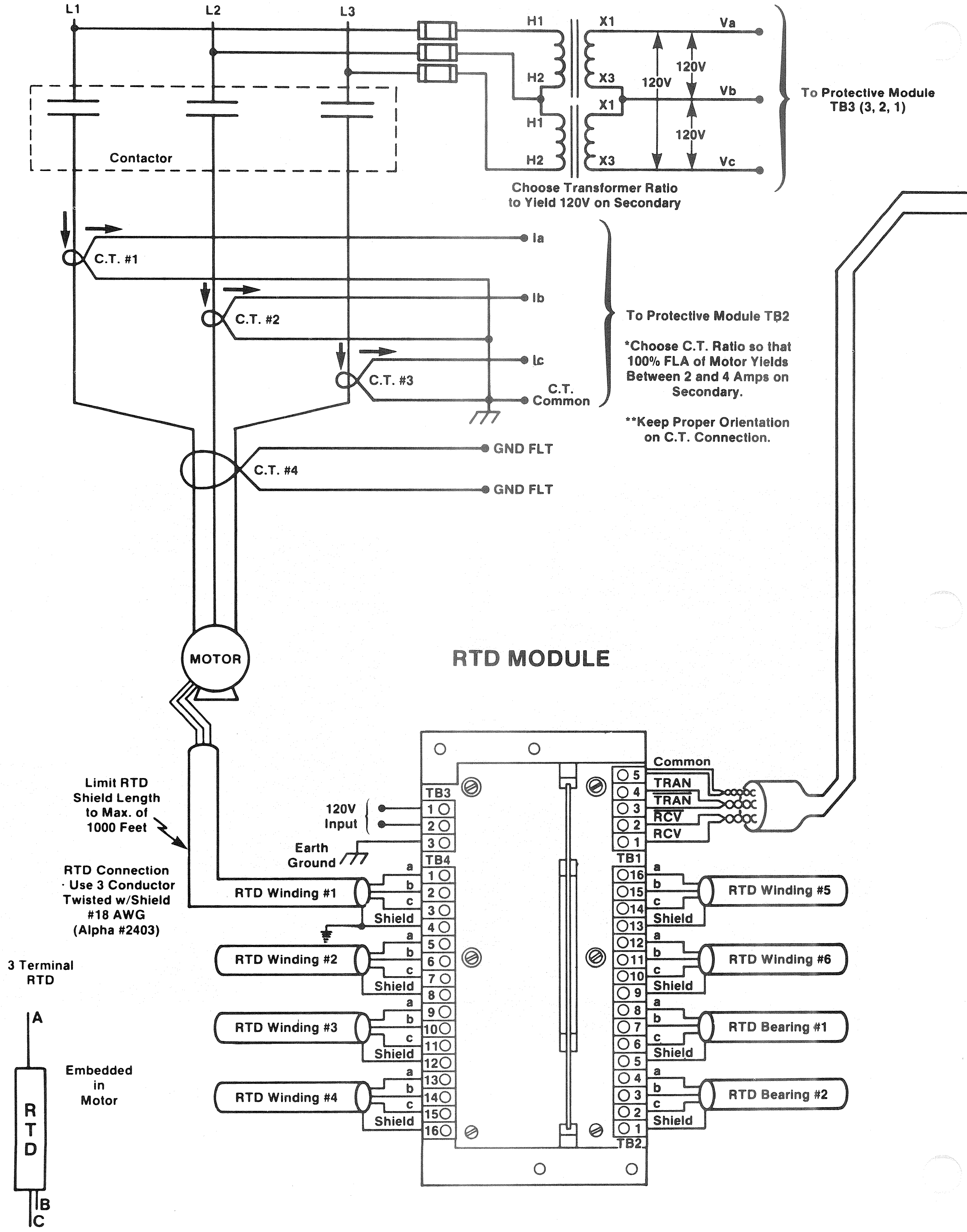
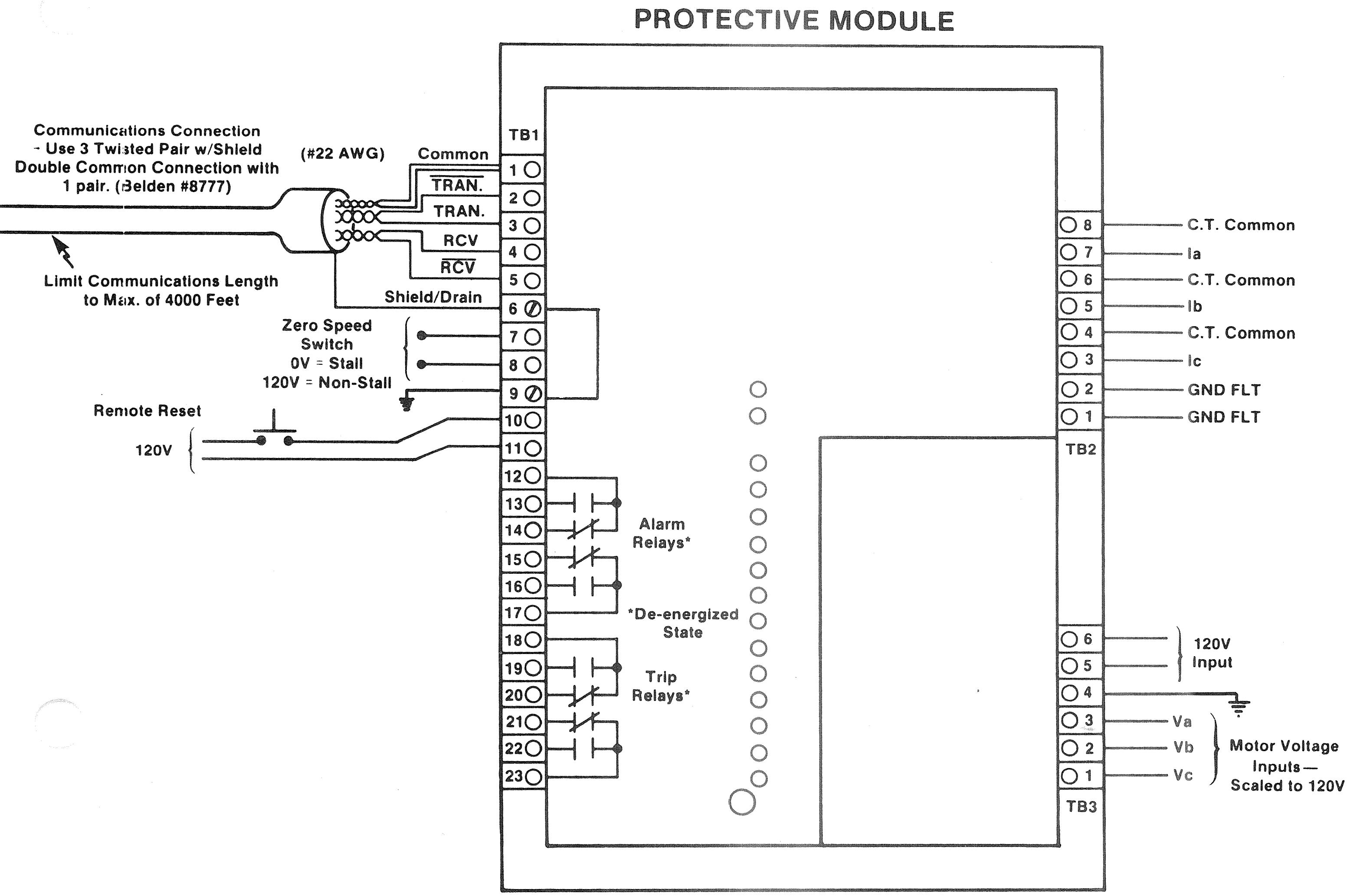


Figure 6.

WIRING DIAGRAM




PROTECTIVE MODULE
Communications Connection
- Use 3 Twisted Pair w/Shield
Double Common Connection with
1 pair. (Belden #8777)
(#22 AWG)
Common
TRAN.
TRAN.
RCV
RCV
Shield/Drain
Limit Communications Length
to Max. of 4000 Feet
Zero Speed
Switch
0V = Stall
120V = Non-Stall
Remote Reset
120V
TB1
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
Alarm
Relays*
*De-energized
State
Trip
Relays*
TB2
8 C.T. Common
7 Ia
6 C.T. Common
5 Ib
4 C.T. Common
3 Ic
2 GND FLT
1 GND FLT
TB3
6
5
120V
Input
4
3 Va
2 Vb
1 Vc
Motor Voltage
Inputs—
Scaled to 120V

Section 6
SYSTEM OPERATION – USER PERSPECTIVE

6.0 Description

This section consists of two parts: Programming and Monitoring.

The programming section will go through the operation of the keyboard, displays, function number listing, and error code listing.

The monitoring section will cover the reading out of motor data, both actual real time data and last trip motor data. This section will also discuss the scan list.

6.1 Programming

Shown in Figure 1 is the face of the Programmer/Monitor. There is a two-digit display for function numbers and a four-digit display for values.

The function number is used to select the desired parameter or variable. The value is the value of the parameter corresponding to the function number.

The user need not select every function. If there are functions that are not required, a zero must be inserted in place of a value for that function.

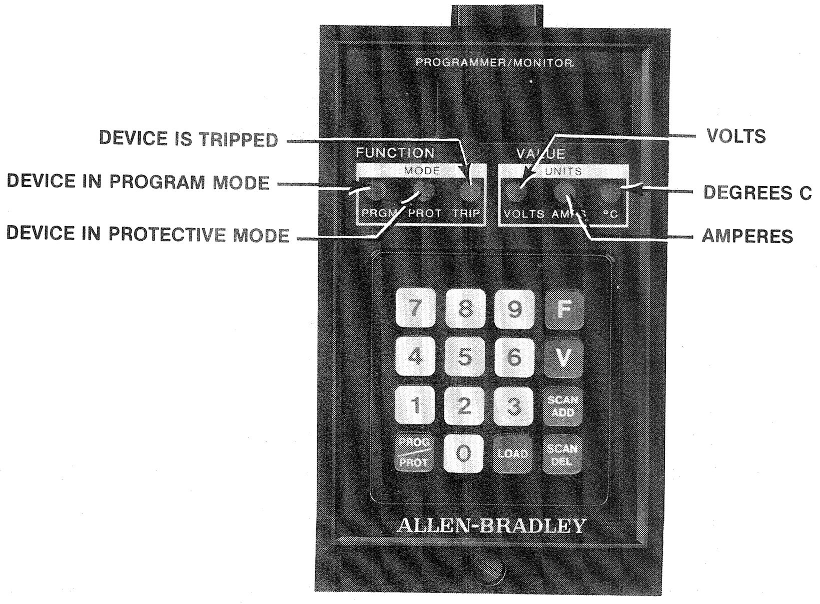
Programming Procedure

Function numbers 1 through 30 are assigned to those variables that are required by the Programmable Motor Protector system. These functions must be programmed before the motor can be protected.

The procedure for programming the Protective Module is as follows:

1. Depress the function key ("F") on the keyboard. This will instruct the system that any digits to follow are function number digits. It will also put a zero in the function number display and clear the value display.
2. Enter the function number with the digit keys. Enter the most significant digit first. The digits will "walk" across the function number display as they are entered. If you make a mistake return to step 1.
3. Depress the value key ("V") on the keyboard. This will cause the system to check for a valid function number. If the function number is valid, the currently programmed value for the displayed function number will appear in the value display.

   If the function number is invalid, an error code will appear in the value display. When a valid function is entered, depressing the value key will also instruct the system that any digits to follow are value digits.
4. Enter the desired value with the digit keys. Enter the most significant digit first. The digits will "walk" across the value display as they are entered. The value must be within the limits for the selected function number. If you make a mistake simply return to step 3 and continue from there.
5. Once the function number and the value have been entered, verify that they are correct. Then depress the LOAD key on the keyboard. This will cause the unit to verify that the function number is a function that can be programmed and that the value entered is within the limits for that function. If those conditions are met, a load response (-L-) will appear in the value display and the programmed data will be stored in the Protective Module. If the conditions are not met, an error code will be displayed and the entered data will be ignored.



PROGRAMMER/MONITOR

Figure 1.

6.2 Function Numbers- The following is a function number listing of the user entries for the PMP.

The left hand column is the function number, the middle column the description, and the right hand column defines the limits for that function.

These functions allow the PMP to tailor its algorithm to your specific application. These functions and their ranges will be described in detail in Chapter 7.

USER ENTRIES		
Function No.	Description	Limits
1	Current transformer primary rating in amperes	25-1500
2	Full load current in amperes	15-800
3	Locked rotor current in amperes	30-9999
4	Line voltage in volts (phase to phase)	208-7200 – 0 disables
5	Number of winding RTDs	1-6 – 0 disables
6	Number of bearing RTDs	1-2 – 0 disables
7	Allowable stall time in seconds at + 40° C at locked rotor amperes	1-30
8	Allowable acceleration time in seconds at + 40° C at locked rotor amperes	1-60
9	Allowable number of starts/specified time increment	1-10 – 0 disables
10	Time increment for repeat start protection in hours	1-16
11	Phase unbalance trip-current as a percent of FLA	5-30 – 0 disables
12	Phase reversal protection	1 enables – 0 disables
13	Undervoltage trip as a percent of line voltage	75-95 – 0 disables
14	Undervoltage trip time delay in seconds	1-10 – 0 disables
15	Ground fault transformer primary rating in amperes	5-1000 – 0 disables
16	Ground fault alarm current in amperes	1-25 – 0 disables
17	Ground fault trip current in amperes	1-25 – 0 disables
18	Ground fault trip delay in milliseconds (10 millisecond increments)	10-1000 0 disables
19	Low level fault trip current as a multiple of FLA	5-15 – 0 disables
20	Jam trip current as a multiple of FLA	2-10 – 0 disables
21	Excessive fault trip-inhibit	1 enables – 0 disables
22	Underload trip current as a percent of FLA	50-90 – 0 disables
23	Underload trip time delay in seconds	1-10 – 0 disables
24	Ultimate trip current as a percent of FLA	100-125
25	Winding alarm temperature in degrees C	20-180
26	Winding trip temperature in degrees C	20-180
27	Bearing alarm temperature in degrees C	20-180
28	Bearing trip temperature in degrees C	20-180
29	Reset condition	1 automatic – 2 manual
30	Access code	1-9999 – 0 disables
31	Watchdog timer failure counter ①	0 clears counter
32	Scan List (Use Scan Add or Scan Delete keys to enter data)	40-60 – 99 does all
33	Scan time/function in seconds (Use Scan Add or Scan Delete key to enter data)	3-10 – 0 suspends

① Indicates the number of times device has deviated from its program (due to failure etc.)

6.3 Error Code Listing- To aid the user in programming, the PMP system utilizes several error codes that correspond to user prompts in case of error. The use of error codes assist the user in learning how to use the system. The table to the right is a list of error codes and their meaning.

6.4 Mode Change- The PMP system has two different operating modes; the program mode and the protective mode. All programming must take place in the program mode. While the device is in the program mode, the outputs are in the trip state and the motor is not protected.

When the device is in the protective mode, the motor is being protected and the outputs assume the appropriate state. No programming can take place when the device is in the protective mode. The "PRGM/PROT" key allows the user to toggle between the two modes.

When the device is in the program mode and the "PRGM/PROT" key is depressed, the system checks to verify that every function has been programmed. It then checks that the proper coordination exists between various programmed parameters (alarm levels less than or equal to trip levels, etc.).

If the above check is true, the device will then change to the protective mode. If the check is false, the appropriate error message will be displayed and the mode will not change.

When the device is in the protective mode and a mode change is attempted, the device checks to see if the access code feature was enabled. If the access code was not enabled, the device will change to the program mode. If the access code was enabled, the mode will not change. The following procedure must be used for changing the protective mode to the program mode:

1. Depress function key ("F").
2. Enter function number for access code, function 30.
3. Depress the value key ("V"). This will cause a prompt for the access code to appear in the value display. The prompt will be four dashes in the display.
4. Enter the correct access code. (The access code is programmed by the user when in the program mode).
5. Depress the "PRGM/PROT" key. If the correct code was entered, the device will enter the program mode. If the code was incorrect, an error code will appear in the value display and the mode will not change.

PROGRAMMABLE MOTOR PROTECTOR ERROR CODES

Error Code	Description
E-LO	Value below minimum limit
E-HI	Value above maximum limit
E-1	Invalid function number
E-2	Load attempt while in protective mode
E-3	Non-loadable function number
E-4	Non-disableable function number
E-5	Non-scannable function number
E-6	Invalid entry attempted for scan time
E-7	Invalid characters in value display when "load" or "scan" entry attempted
E-8	Invalid function number in function display when "scan" add/delete" attempt made
E-9	Option card not installed
E-10	Locked rotor amps less than full load amps
E-11	Alarm level greater than associated trip level
E-12	Acceleration time less than stall time
E-13	Invalid access code
E-14	Undefined "value" data - data > 9999 or data < -999
E-15	Invalid user entry table ①
E-16	Function number not verified after invalid user entry table
E-17	Invalid last-trip table

"9999" in value display indicates an overflow condition

"-999" in value display for RTD temperature indicates an open RTD

① Check and reload each user entry. Depress mode key. E-16 will appear in the value display and function # in the function display. If this function # is not verified, push value key and associated value (for the function #) will appear in the value display. If value is correct, push load key. Repeat procedure until entire scan entry table is verified.

6.5 Monitoring- This section consists of two parts:

- Real time motor data monitoring
- Reading out last trip motor data

In addition to the protective functions, the PMP system allows the user to read out real time motor data. This motor operating data consists of information such as: winding RTD temperatures, line currents, ground fault current, etc.

A function number that is different from the Programming function number exists for each parameter of motor operating data.

Function numbers 40 through 60 are used to access values of the current motor data parameters such as line current or line voltage. However, functions 57 through 60 can only be accessed if the optional instrumentation card is installed in the Protective Module. Follow steps 1 through 3 described in the Programming section to read out the current value of the selected function.

A function number listing and description for reading out real time motor operating data is shown to the right.

Function No. Instantaneous Value	Description
40	Maximum winding RTD temperature in degrees C
41	Winding temperature RTDW1 in degrees C
42	Winding temperature RTDW2 in degrees C
43	Winding temperature RTDW3 in degrees C
44	Winding temperature RTDW4 in degrees C
45	Winding temperature RTDW5 in degrees C
46	Winding temperature RTDW6 in degrees C
47	Bearing temperature RTDB1 in degrees C
48	Bearing temperature RTDB2 in degrees C
49	Line 1 current in amperes
50	Line 2 current in amperes
51	Line 3 current in amperes
52	Line 1 - Line 2 volts
53	Line 2 - Line 3 volts
54	Line 3- Line 1 volts
55	Ground fault current in amperes
56	Available motor starts
57	Optional function (Kilowatts)
58	Optional function (Power factor in percent)
59	Optional function (Megawatt-hours running)
60	Optional function (Elapsed running time in hours)

6.6 Trip Reset Conditions- The conditions under which the Protective Module can be reset from a trip condition provides a high level of protection for the motor installation.

For those functions that are to be manually reset, the reset button located on the device or the remote reset button, if installed by user is utilized.

The reset button must make a transition from a non-depressed to a depressed conditon in order to be recognized. Neither the local nor the remote reset buttons has any effect when the unit is not tripped. The remote reset can only be used to reset those functions that can be programmed for automatic reset.

Before any reset, either manual or automatic is recognized, all of the protective functions, except "Open RTD" must be clear of any alarm indication.

The various trip conditions are separated into three different categories according to how they can be reset. The following conditions are always manual reset:

1. Low-level fault
2. Jam
3. Phase Reversal
4. Underload
5. Bearing overtemperature
6. Ground fault
7. Repeat Starts
8. Phase Loss/Unbalance (motor running)
9. Undervoltage (motor running)

The following conditions may be programmed by the user for either manual or automatic reset:

1. Overload
2. Long acceleration/stall
3. Normal current /overtemperature

The following conditions are always automatic reset:

1. Phase loss/unbalance(motor not running)
2. Undervoltage(motor not running)

6.7 Scan List- The PMP can also be used to display the real time operating motor data automatically. This is done by putting the desired functions on the scan list.

The motor data parameters, functions 40 through 60, can be individually added or deleted from the scan list. The functions on the list and their associated values are sequentially selected and displayed for a short period of time so they can be continuously monitored.

The scan list can be reviewed and function numbers added to and deleted from the list in a manner similar to the procedure for programming the system variables. The procedure is as follows:

1. Depress the function key ("F").
2. Enter the function number for the scan list (function #32)
3. Depress the value key ("V"). This will cause the first function number on the scan list to be displayed in the value display. Depressing the value key again will cause the next function number on the scan list to be displayed. The value key can be

repeated as many times as desired. When the end of the list (or if there are no functions on the list) is reached an end-of-list symbol (--) will be displayed. Depressing the value key again will display the first function on the list again.

4. To add or delete a function number from the list, enter the desired function number. It will appear in the value display.
5. Depress either the "Scan Add" or "Scan Delete" key, whichever is desired. If the function number is a scannable function, it will be added/deleted from the scan list and a scan response (-S-) will appear in the value display. If the function number in not scannable (not within the allowable function number range), an error will appear in the value display.
6. To add/delete another function to the list, refer back to step 4.
7. All of the scannable functions can be added to or deleted from the list at the same time by entering 99 for the function number in step 4.

In addition to selecting the functions that are on the scan list, the length of time each will be displayed should be programmed. The procedure is as follows:

1. Depress the function key ("F").
2. Enter the function number for scan time/function (function 33).
3. Depress the value key ("V").This will cause the currently programmed display time to be displayed in the value display.
4. Enter the desired scan time. The time must be zero or 3 through 10. A value of 3 to 10 will cause the scan function to be displayed for that number of seconds. An entry of zero will suspend operation of the scan function without changing the contents of the scan list.

The scan list and the scan time/function may be altered in either program or protective mode.

Motor Operating Data	
Function No. Last-trip Value	Description
70	Maximum winding RTD temperature in degrees C
71	Winding temperature RTDW1 in degrees C
72	Winding temperature RTDW2 in degrees C
73	Winding temperature RTDW3 in degrees C
74	Winding temperature RTDW4 in degrees C
75	Winding temperature RTDW5 in degrees C
76	Winding temperature RTDW6 in degrees C
77	Bearing temperature RTDB1 in degrees C
78	Bearing temperature RTDB2 in degrees C
79	Line 1 current in amperes
80	Line 2 current in amperes
81	Line 3 current in amperes
82	Line 1 - Line 2 volts
83	Line 2 - Line 3 volts
84	Line 3- Line 1 volts
85	Ground fault current in amperes
86	Available motor starts

6.8 Reading Out Last Trip Motor Data- Function numbers 70 through 86 are used to access the values of various motor data parameters at the time the last trip occurred. Follow steps 1 through 3 described in the programming section to read the desired values.

6.9 Protective Module Malfunction- The Protective Module performs a self-check at power-up, and once every second during normal operation. If a malfunction is detected, the output relays go into the trip state, the Programming Module will not respond to any keyboard inputs (and the value display will say "HELP"), and an internally located LED will illuminate.

The self-check tests the system RAM, system EPROM, A/D converter, +5 volt DC supply, and +/- 12 volt DC supply.

Section 7
PROGRAMMING APPLICATION DATA

7.0 Programming Application Data (Motor Protection Tutorial)

This section contains information on all the harmful motor conditions the PMP monitors. It discusses each condition individually, plus describes how the PMP detects it, identifies the dynamic range and provides some guidelines for settings.

The PMP system provides thirteen different protective functions. These functions are designed so that the user can implement a coordinated protective scheme. Because some of the various protective functions are more rapidly changing than others, the monitoring of these functions is scheduled within the main program.

For example, the Low Level Fault condition is a very rapidly changing condition, therefore it is examined every 10 milliseconds, Whereas the Underload which by comparison is a slower changing condition is examined every 500 milliseconds.

The PMP system allows the user to create an operating envelope for motor operation. If the limits established by the user are exceeded it results in the alarm or trip relays activating.

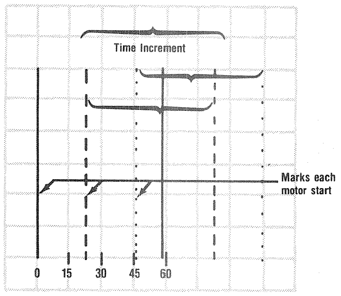
7.1 Repeat Starts Protection

Each time an AC induction motor is started a certain amount of heat is generated in the motor. By allowing an excessive number of starts, damage can occur in the rotor due to the heating effects.

The Repeat Starts feature allows the user to specify a number of starts per time increment. Each time the motor is started, a timer begins keeping the elapsed time and the starts counter keeps track of the number of motor starts. A "sliding window" is created which allows the number of starts and elapsed time to be updated.

The PMP will not permit more starts per time increment than programmed. The trip relay contacts will change state if the programmed data is exceeded. There is no alarm condition for repeat starts. The alarm occurs every time the trip occurs. Alarm and trip protection occur simultaneously.

The chart in Figure 1 shows how the Repeat Start feature functions. There are two inputs, the time increment and number of starts allowed within the time increment.



Two squares = 15 minute time period

Figure 1.

For example:

At two starts/hr., the PMP would trip on the third start attempt at the 45 minute mark and allow another start at 60 minutes.

At three starts/hr., the PMP allows the third and final start (for the first hr.)

At four starts /hr., at 45 minutes the user has one available start left.

At one start/hr, the PMP will trip at 22 minutes and allow another start at 60 minutes.

By entering Function number 56 (Motor Operating Data) the PMP will display the number of available starts left.

Range:

Allowable Number of starts - (1-10) Function #9 , 0-disables the function.

Time Increment - (1-16) Function #10 Hours.

Guidelines for Setting- The NEMA Standards are quite specific for motor design in terms of starting duty. The Standard outlines one cold start and coast to stop followed by one hot start. This standard, while governing certain parameters in motor design, does not take the actual application into account.

For example, if the motor is underloaded or unloaded, the number of tolerable repeated starts/time increment is greater than if the motor is fully loaded. The user must consider their specific application using the NEMA Standard as a basis as well as consult the motor manufacturer.

7.2 Long Acceleration/Stall Protection

The Long Acceleration/Stall condition occurs when a start cycle exceeds the present thermal capacity of the motor. The danger to the motor is excessive rotor heating can occur due to the length of the start.

However, there are cases where the allowable acceleration time of a motor is greater than its safe stall time. Even though a locked rotor current is seen during starting, the rotor is beginning to rotate. Not all of this "locked rotor energy" is going into the rotor as heat. (See Figure 2 below).

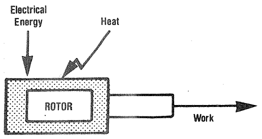


Figure 2.

Some of the electrical energy is being converted to work. Consequently, an acceleration time greater than the safe stall time is possible. However, it is imperative that the "overload algorithm" reflect this. For these applications a zero speed switch contact must be input to the PMP. This signal adjusts the algorithms characteristic to reflect this case.

This protection function is part of the overall overload algorithm and will be discussed later (Function #8).

Guidelines for Setting- Since the Long Acceleration/Stall function is built into the overload calculation, many of the inputs such as full load current (FLC), safe stall time, etc. are used to construct the thermal model of the motor. The setting for this condition is the allowable acceleration time specified by the motor manufacturer. This time must be greater than or equal to the safe stall time.

7.3 Phase Loss/Unbalance

The Phase Loss/Unbalance algorithm is implemented as two separate functions.

The Phase Loss protection is always enabled since proper motor operation necessitates all three phase voltages be present.

The Phase Unbalance protection can be disabled or set to the appropriate setting by the user.

Prestart Line Protection Using Potential Transformers (PTs)- Prestart line protection against phase loss can be provided by sensing the voltage inputs via user supplied PTs. If PTs are not used, there is no prestart line protection, but there is post start protection provided by current inputs from current transformers (CTs).

When using voltage inputs for phase loss detection, a trip condition will automatically reset when the phase loss is corrected. However, once the motor is started (current in the motor circuit established) a trip as a result of phase loss must be manually reset. Refer to the following chart.

PHASE LOSS DETECTION	
Prestart	Post start
Voltage detection if using PTs-	Current detection with or without PT-
Auto Reset	Manual Reset

The Phase Unbalance protection can be disabled by the user or can be programmed for an allowable unbalance magnitude at FLC.

The PMP calculates Phase Unbalance using the following NEMA definition:

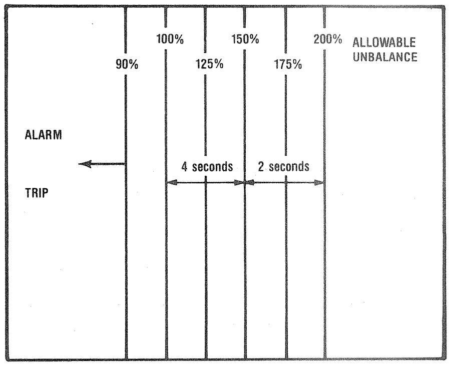
$$\% \text{ Unbalance} = \frac{\left|(I_{\text{Line}} - I_{\text{Ave}})\right|_{\max}}{I_{\text{Ave}}} \times 100$$

Since an unloaded or underloaded motor can tolerate more unbalance than a fully loaded motor the PMP automatically re-adjusts this calculation based on motor loading. The trip times are as follows:

% Unbalance is greater than 150% of the allowable unbalance-Time Delay = 2 seconds

% Unbalance is less than or equal to 150% of the allowable unbalance-Time Delay = 4 seconds

The alarm relay changes state at 90% of the allowable unbalance. This is summarized in the following chart.



Guidelines for Setting- A small voltage unbalance can cause a large current unbalance. This current unbalance causes excessive heating in the rotor. The reason for the PMP's phase unbalance calculation is for the user to create a maximum tolerable phase unbalance at full load.

A minor percentage of voltage unbalance can be reflected as a 6-10 times percent of current unbalance. Therefore, it is important to select a setting for current unbalance that is commensurate with the motor and its application.

7.4 Phase Reversal Protection

The Phase Reversal Protection can be enabled or disabled by the user. If it is enabled, prestart phase sequence is checked by using the user supplied potential transformers (PTs). Regardless of the PTs usage once current is flowing in the motor circuit, the current is used as a basis for the phase reversal protection as shown in the following table.

PHASE REVERSAL DETECTION	
Prestart	Post Start
Only if PTs used	Always uses current as input

Whenever an improper phase sequence is detected, an instantaneous alarm and trip will occur.

7.5 Undervoltage Protection

The Undervoltage Protection can either be enabled or disabled by the user. If the Undervoltage Protection is programmed by the user, the average line to line voltage is computed and used to calculate the percent of undervoltage. This function automatically disables itself if the line to line voltage is less than 70% of the rated voltage.

If an undervoltage condition occurs that is less than or equal to the programmed trip point for a period of time that is greater than or equal to the programmed delay time, an alarm and trip will occur simultaneously.

A balanced three phase undervoltage condition will provide a balanced three phase current increase. This overcurrent produces excessive heat in the rotor and stator.

Guidelines for Setting- The PMP provides undervoltage protection by allowing the user to set the undervoltage trip point and the time delay for that point. The dynamic range is shown in the following table.

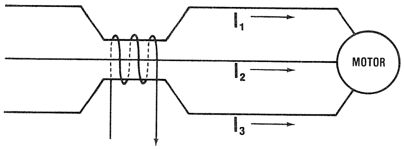
Undervoltage trip point as percent of line volts	75% - 95% 0 - disables
Undervoltage trip time delay in seconds	1 - 10 0 - disables no delay

To determine the setting of the undervoltage trip point the user must examine their electrical distribution system, application and motor. Most trip settings will fall between 75 and 95% of line voltage, typically 80%.

The time delay for undervoltage trip also depends on motor application. Undervoltage dips of 5-15 cycles (60 Hz) normally do not harm induction motors. Generally, the time delays programmed should be on the order of 2-3 seconds.

7.6 Ground Fault Protection

The following is a partial diagram of a motor circuit.



For a system with no ground fault, $I_1 = I_2 = I_3$. By using a zero sequence "doughnut" transformer, it is possible to measure the ground fault current. This is the ground fault sensing configuration utilized by the PMP system.

The ground fault protection can be programmed for a specific alarm level and a specific trip level.

By using the user supplied zero sequence transformer, ground fault alarm occurs whenever the magnitude of the sensed ground fault current is greater than or equal to the alarm level setting. The alarm output will occur instantaneously. When the ground fault current exceeds the trip level for a period of time that is greater than or equal to the programmed trip time delay, a trip will occur. The following is a range of settings.

Gndflt xfmr primary rating in Amperes	5 - 1000 0 - disables
Gndflt alarm current in Amperes	1 - 25 0 - disables
Gndflt trip current in Amperes	1 - 25 0 - disables
Gndflt trip delay in ms (10ms. incrmt)	10 - 1000 0 - disables no delay

Guidelines for Setting- Most high impedance grounded systems use a lower setting for ground fault current while the lower impedance more solidly grounded systems use a higher setting for ground fault. Typically, the ground fault current setting is approximately 10% FLC or less.

Note- The ground fault protection in these ranges does not provide protection for personnel.

7.7 Low Level Fault Protection

The purpose of Low Level Fault Protection is to allow the user to program alarm and trip protection. It provides protection if current flowing in the motor circuit is in the range of 5-15 times the FLC rating of the motor. This condition would normally occur if there is some type of fault in the motor circuit.

If the Low Level Fault Protection is enabled, it will alarm and trip when the current flowing is greater than or equal to the programmed trip level. Alarm and trip protection occur simultaneously.

This function can be disabled beyond the trip point by using the Excessive Fault Trip Inhibit feature. Refer to Excessive Fault Inhibit.

The reason for this feature is that using the contactor to interrupt a fault current to save the fuses may not be beneficial. Since this fault current is flowing and a finite period of time is required to drop out the contactor, damage has already occurred in the fuses.

Range of Settings

Function #19 - Programmed as a multiple of FLC 5-15 times.
0 - disables the function

Guidelines for Setting- The Low Level Fault setting should be low enough to protect the motor from serious damage. But high enough over locked rotor current to allow a motor to start. The Low Level Fault function is typically used in conjunction with switch gear.

Excessive Fault Inhibit- The Excessive Fault Inhibit feature should be enabled whenever the load break device is not rated to interrupt currents greater than six times FLC using this feature. If the current exceeds the six times FLC, the device will be prevented from tripping and the line fuses or breaker will interrupt the current. An alarm output will occur even if the trip is inhibited. This feature affects the protection for Low Level Fault, Jam, and Ground Fault. Below are the guidelines for Class I and Class II systems.

Class I systems do not contain a high current inhibit circuit and are intended for use with medium voltage controllers or shunt-trip circuit breakers.

Class II systems provide a high current inhibit circuit to protect motor controllers. This circuit will inhibit the controller from opening the circuit when the fault current exceeds the interrupting capacity of the controller.

7.8 Jam Protection

The reason for the PMP Jam protection is to protect the motor against overcurrent due to a jam condition.

This functions the same as the Low Level Fault protection except that this protection is locked out during starting. This allows the user to set the jam levels as low as 200% FLC. The range of settings for this function is 2-10 times FLC, 0 - disables.

Guidelines for Setting- The settings for Jam detection depend on the individual application. Some motor applications attain a 200% FLC for a short period of time. This would cause nuisance tripping.

However, typically a 200% FLC would be a good starting point for jam detection. Refinements to these settings can be made as the user gains experience on the application.

7.9 Underload Protection

This feature allows the user to provide a degree of protection to the application in case the Drive System fails. This includes belts, pulleys, gears, etc. If the current falls below 25% FLC this feature is inhibited.

The Underload protection provided by the PMP allows the user to program the trip settings. This provides indication if the average motor current is less than or equal to the time delay (also programmable).

Range of Settings- Function#22,23	
Underload trip current as a % of FLA	50-90 0-disables
Underload trip time in seconds	1-10 0-disables no delay

Guidelines for Setting- The setting for Underload protection is also based on the application. The first concern to be determined would be the No Load Current to the motor. If a pulley, belt , etc. fails the motor current will drop somewhere around this value. User experience will determine the final set point.

7.10 Normal Current / Overtemp

The use of this function requires the utilization of the RTD Module for temperature input. This function is primarily an indication of blocked ventilation or high ambient temperature.

An alarm or trip will occur if the motor current is less than or equal to the FLC and the maximum winding RTD temperature is greater than or equal to the programmed winding alarm or trip temperature.

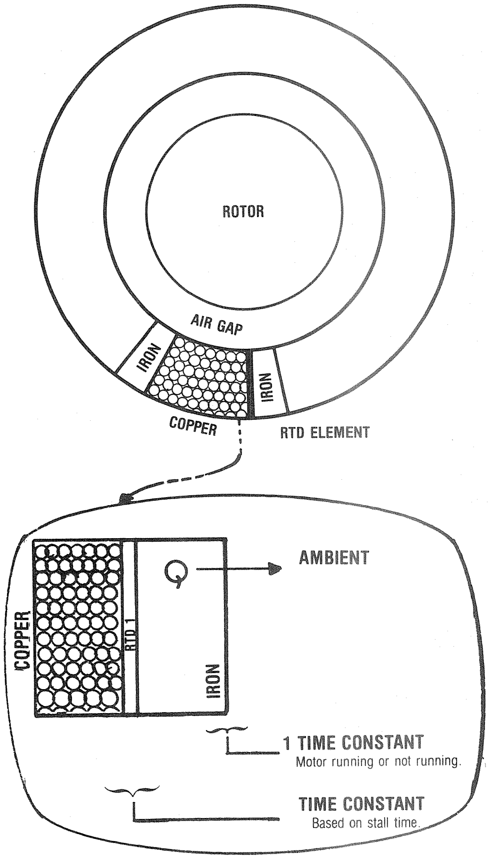
The inputs to this algorithm are from FLC and the maximum RTD winding temperature. There are two inputs for RTD temperatures as follows:

Winding alarm temp. in °C	20-180
Winding trip temp. in °C	20-180

7.11 Overload Protection

The Overload algorithm is the most complex in the PMP. It utilizes temperature inputs from the stator windings and motor data information to determine if an overload condition is occurring.

The Overload algorithm utilizes a two time constant motor heating model. Referring to the following diagram, it allows the simulation of heating capacity in the copper windings, the heat flow from the copper windings and winding insulation/iron frame interface and the heat flow from the iron/frame to the ambient.



Algorithm calculates copper temperature and iron temperature. Models thermal heat transfer from copper to iron and iron to air.

This also allows the PMP to differentiate between a running overload and an overload due to an excessive start.

Heat is generated in the copper via the electrical energy conducted into the stator windings. This heat is stored in the windings and is also transferred to the iron via the copper insulation interface separating them. The RTD senses this insulation interface. The algorithm uses the interface temperature to calculate the copper temperature and iron temperature for all the motor operating conditions ,i.e., starting, running, stalling, etc. The heat is then transferred from the iron to ambient.

Of the two thermal time constants that govern the overload (1) is for heat transfer from copper to iron and (1) is for transfer from iron to air.

If there is not an RTD Module present in the system or it is not operating correctly, the iron/ frame temperature is calculated. The thermal time constant for heat transfer from copper to the iron/ frame/insulation is estimated. It is based on the stall time of the motor and a default value for the time constant for heat transfer from the iron/frame/insulation temperature to ambient used.

This default will assume one value if there is motor current present (motor running) and a larger value if there is no motor current (motor not running). The two different values are used to reflect the different heat transfer rates that occur as a result of windage cooling.

The temperature is calculated using the magnitude of the motor current and the above assumptions. If the remote RTD Module is present and operating, the temperature input from the sensor in the motor will provide the iron/ frame/insulation temperature. Therefore, the time constant for heat transfer from the iron/frame/ insulation temperature to ambient temperature is sensed directly with the RTDs.

The copper winding temperature is calculated by combining the iron/ frame/insulation temperature (either calculated or measured), the magnitude of the motor current and the thermal capacity of the copper (based on allowable stall time of the motor). If either the copper winding temperature or the iron/ frame/insulation temperature exceeds its associated programmed operating temperature, an overload alarm and trip will occur.

7.12 Bearing Overtemperature

This function requires the use of the remote RTD Module. It is designed to provide indication that the temperature of either bearing is over the limit.

When the temperature of the bearing is greater than or equal to the programmed alarm or trip level the appropriate alarm or trip will occur. The dynamic range of temperature sensing is between + 20°C and + 180°C.

Guidelines for Setting- Experience will dictate the setting for bearing overtemperature. Typically, the application would be analyzed for a period of time to determine the operating temperature. Alarm and trip settings would then be set just above the operating temperature.

7.13 Alarm and Trip Set Points for all Functions- The only alarm settings the user can set are for ground fault, winding RTD temperature and bearing RTD temperature This enables the alarm contact to initiate an orderly shutdown of the process. A recommended starting point for the programmable alarm settings would be a 10-15° C in temperatures and a 15-25% on all other parameters.

7.14 Automatic vs. Manual Reset- As stated earlier, the PMP can programmed for automatic or manual reset on the following functions:

1. Overload
2. Long Acceleration/Stall
3. Normal Current/Overtemp

Paragraph 430-43 of the NEC states: "A motor that can restart automatically after shutdown shall not be installed if its automatic restarting can result in injury to personnel".

In these cases the user should opt for manual reset of these functions. In remote locations where personnel protection is not required, an automatic reset can be used. Refer to local codes for selection.

7.15 Instrumentation Functions

Elapsed Running Time- This time is displayed in hours rolls over after 9999 hours.

Power- Power is calculated by the PMP using a modified 3-wattmeter method. The power is calculated in Kilowatts.

Power Factor (P.F.)- The P.F. is obtained by dividing the measured power by the measured average KVA and multiplied by 100.

The P.F. is expressed in percent. A negative sign on the display indicates a lagging P.F. and no sign indicates a leading P.F. At no current the P.F. is displayed as 100%.

Megawatt Hours - Running- This function computes the energy consumed by the motor and expresses it in megawatt hours. When the maximum count of 9999 megawatt hours is exceeded the display rolls over and starts over at zero.

Section 8

TYPICAL OVERLOAD CURVES

8.0 Typical Overload Curves

The PMP system allows the user to "configure" their own set of overload curves based on certain inputs. This section of the manual will present some typical overload curves that were generated based on known inputs.

The overload curves are divided into two categories:

- Motor overload curves without RTDs
- Motor overload curves with RTDs

It is important to note that the curves presented are based on data that is outlined below. They do not necessarily reflect the trip curves for the user unless the user selects the same data.

8.1 Overload Curves without RTDs

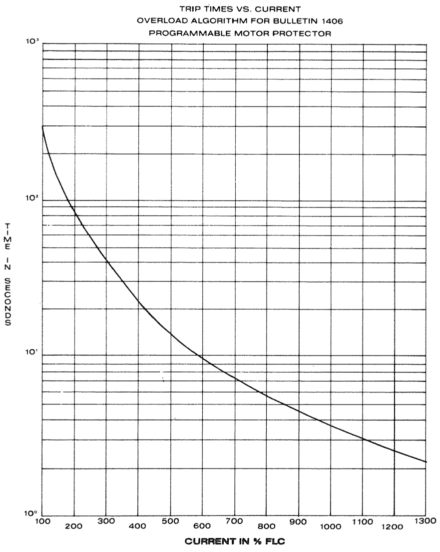
These curves are generated by the overload algorithm for the PMP. The data that helps construct the curve consists of ultimate trip current, full load current, locked rotor current, stall time and acceleration time.

The following three curves are based on the following data for each curve at +40° C.

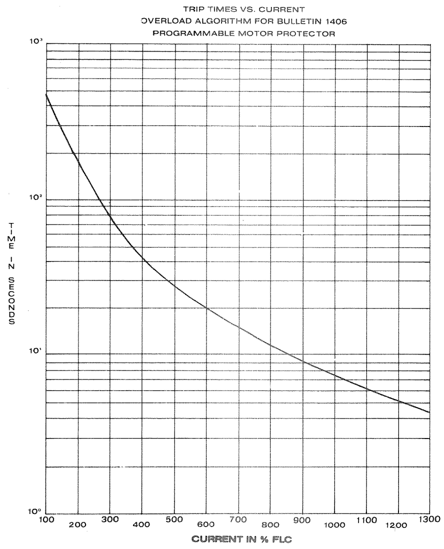
This is a simulation with no RTDs present.

The ultimate trip current (normal) is: 1.00.

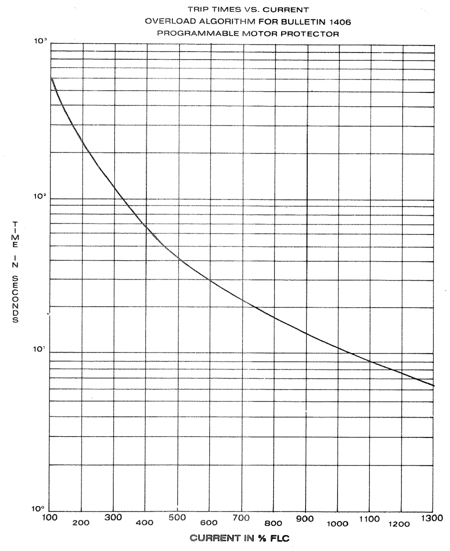
The locked rotor stall current (normalized) is: 6.0.



The safe stall time is: 10



The safe stall time is: 20



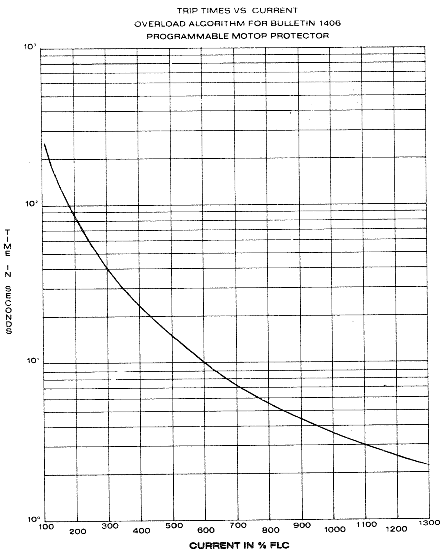
The safe stall time is: 30

The next set of overload curves is the same except that the ultimate trip current is changed from 1.0 to 1.15 which corresponds to a 1.15 Service Factor (S.F.) motor at + 40° C.

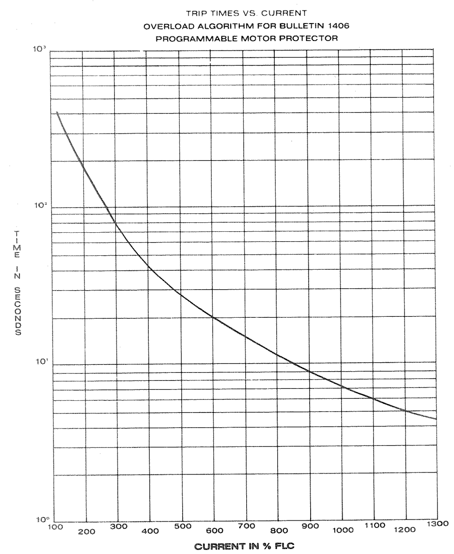
Note that the curves stop before intersecting the "y" coordinate (time). The curve actually stops at 114% Full Load Current (FLC).

For example, if the motor was drawing 114% FLC the overload would not trip. The reason is the motor can run indefinitely at 114% FLC if it is a 1.15 S.F. motor.

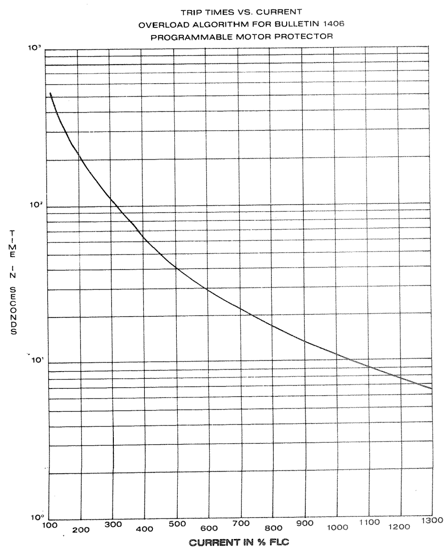
Even though the overload does not trip at 114% FLC the algorithm is still updating the copper and iron temperatures. So if the current does exceed the ultimate trip level an overload trip will take with less delay than if it was operating at 100% prior to the current exceeding the ultimate trip level of 115%.



The safe stall time is: 10



The safe stall time is: 20



The safe stall time is: 30

8.2 Overload Curves with RTDs

The next set of overload curves is an attempt to convey the characteristics when RTDs are used. However, they will not reflect what is actually taking place with the overload algorithm, since the simulation does not provide for RTD feedback. These inputs provide the PMP a measure of the thermal capacity of the motor.

For example, if a 150% overload is injected into a 1.0 S.F. motor, the trip time not only depends on the algorithm (which is based on current inputs), but also the feedback from the RTDs. The RTD shows what is actually happening thermally.

For this reason curves presented in this section serve as an illustration only and cannot be accurately used as overload curves for low level overloads.

The characteristics will change in an actual application since the RTD temperature is dynamic. Whereas in the simulation the temperature is stated at + 40° C and held constant. In the actual application, the RTD temperature would increase.

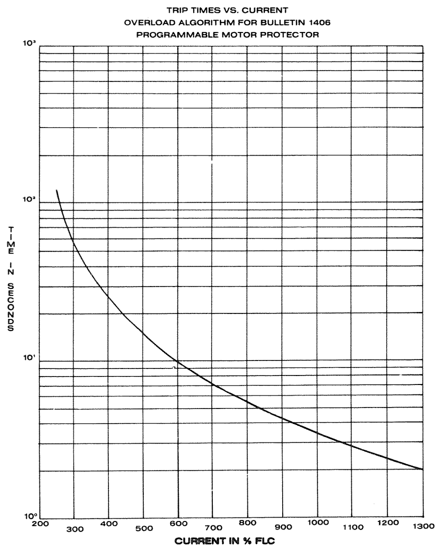
The RTD's effect on the curve is more pronounced at 100-300% FLC as opposed to higher current. The reason is the trip time involved is very short, i.e., the RTD could not react fast enough for a trip.

The following three curves are based on the following data for each curve at + 40° C.

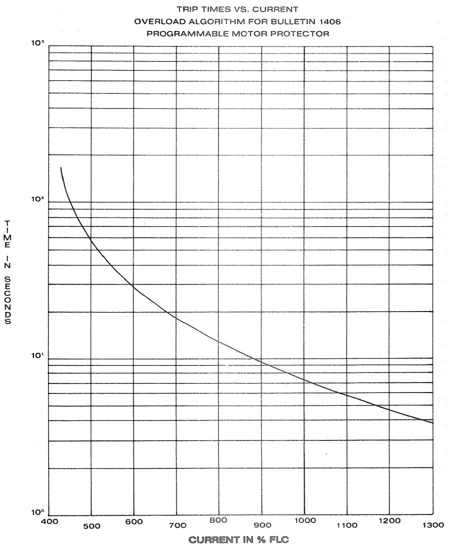
This is a simulation with RTDs present.

The RTD trip temperature is: 130.0.

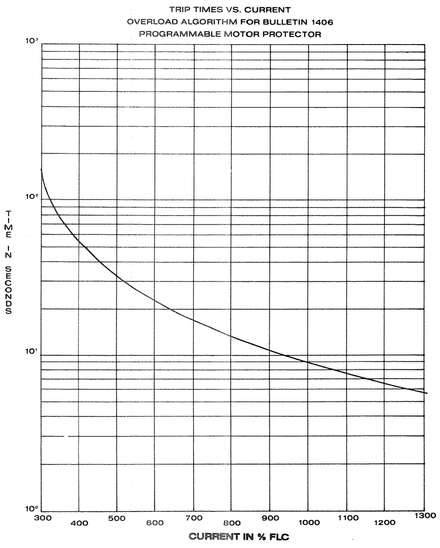
The locked rotor current (normalized) is: 6.0



The safe stall time is: 10



The safe stall time is: 20

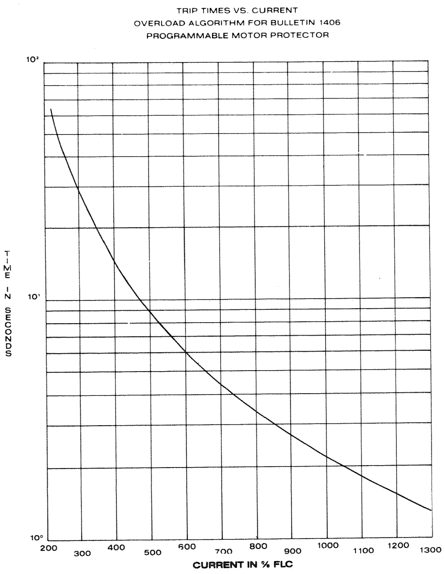


The safe stall time is: 30

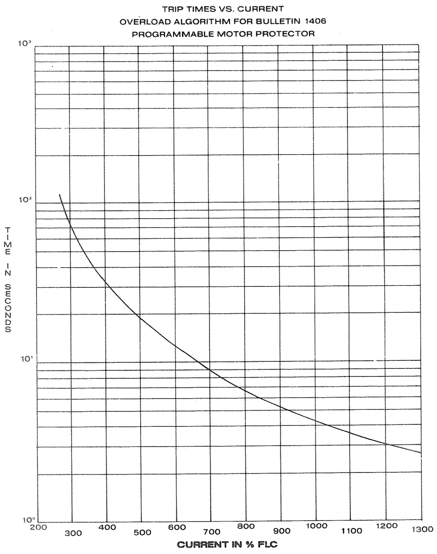
8 TYPICAL OVERLOAD CURVES

The last set of overload curves illustrate the characteristics when the motor windings are heated up.

The following three curves are the same except the data is based on + 90° C RTD temperature.

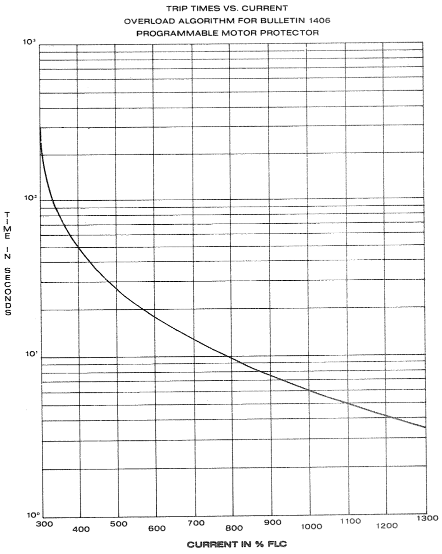


The safe stall time is: 10



The safe stall time is: 20

H - L



The safe stall time is: 30

Section 9

TROUBLESHOOTING

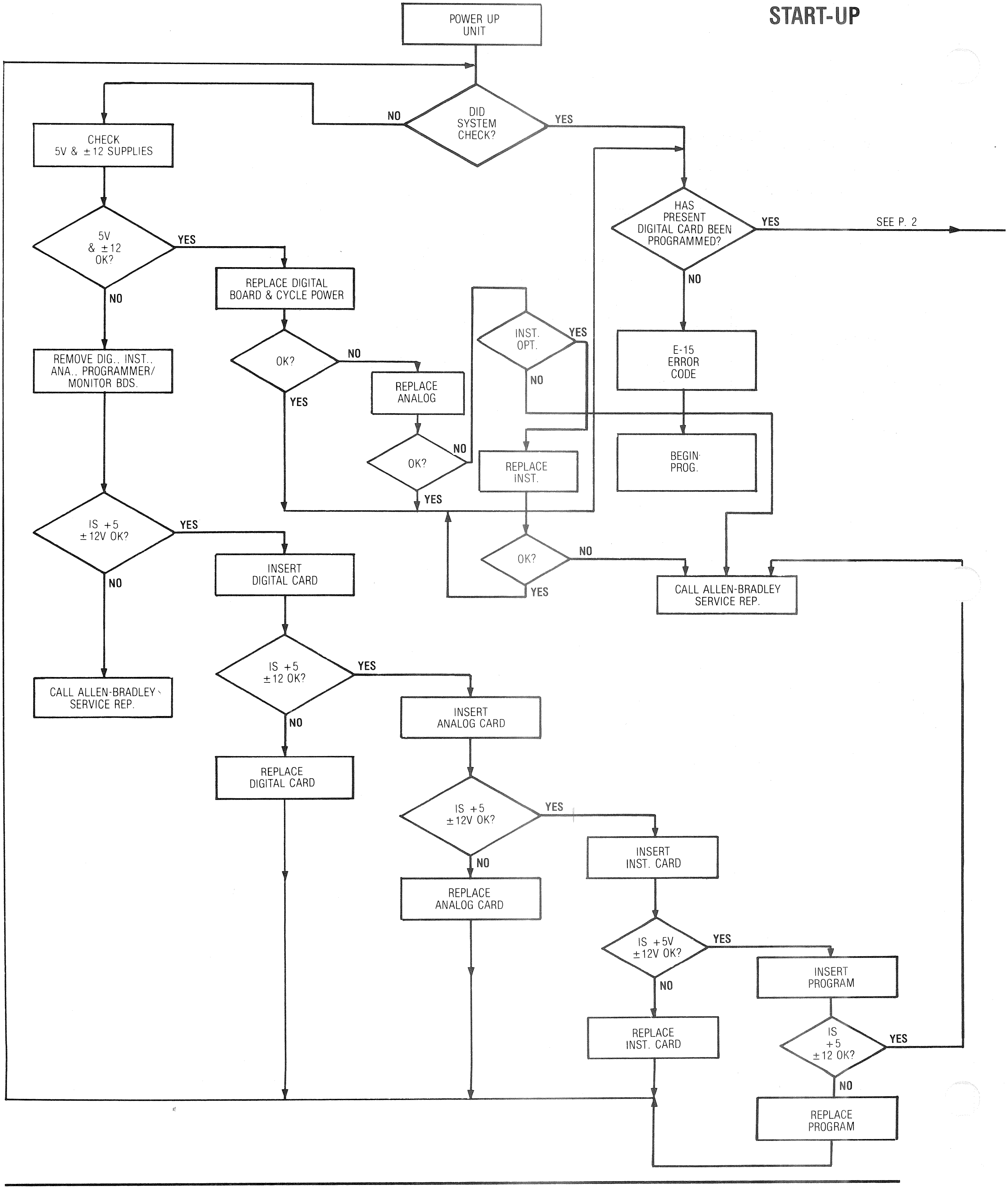
The troubleshooting section of this manual is designed to allow the user to troubleshoot the PMP beyond the module level to the board level. Any troubleshooting procedures more complex that require equipment accuracy must be provided by the factory.

The PMP has some diagnostics already built into the software. For example, on power-up the Protective Module performs a self-check on the random access memory, the ± 12 volt supply, the A/D converter and the EPROM system memory.

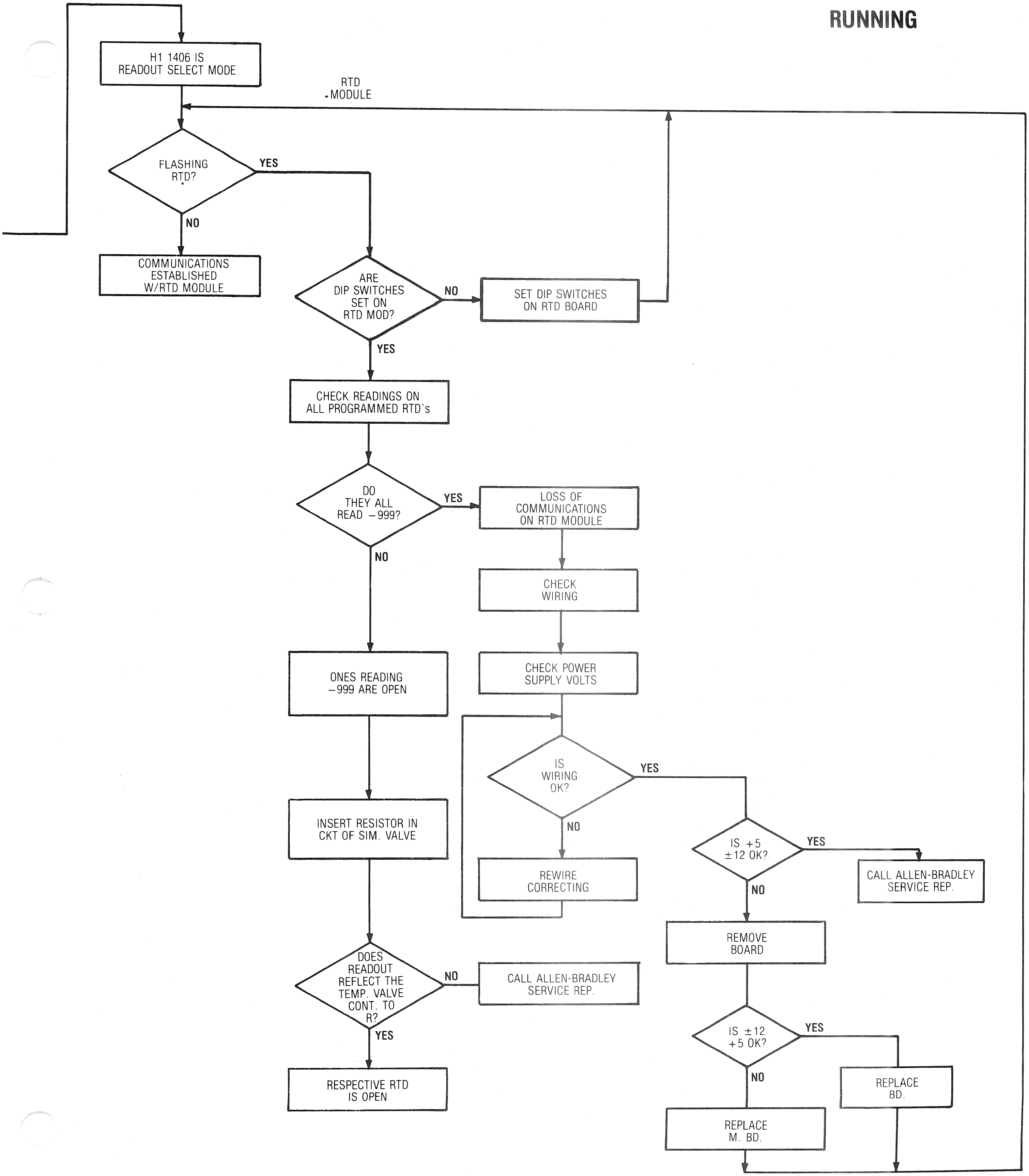
In a similar manner, the remote RTD Module checks (on power-up) the A/D converter, the ram memory, the EPROM as well as the ± 12 volt supply. The following troubleshooting flow chart can be used in conjunction with the internal diagnostics check to determine the status of the system.

The chart on Pages 9-2 and 9-3 is to be used during start-up and also to check out the remote RTD Module.

START-UP


POWER UP UNIT
DID SYSTEM CHECK?
NO
YES
CHECK 5V & ±12 SUPPLIES
5V & ±12 OK?
YES
NO
REPLACE DIGITAL BOARD & CYCLE POWER
HAS PRESENT DIGITAL CARD BEEN PROGRAMMED?
YES
SEE P. 2
NO
REMOVE DIG., INST., ANA., PROGRAMMER/ MONITOR BDS.
OK?
NO
YES
REPLACE ANALOG
OK?
NO
YES
INST. OPT.
YES
NO
REPLACE INST.
OK?
NO
YES
E-15 ERROR CODE
BEGIN PROG.
IS +5 ±12V OK?
YES
NO
INSERT DIGITAL CARD
CALL ALLEN-BRADLEY SERVICE REP.
CALL ALLEN-BRADLEY SERVICE REP.
IS +5 ±12 OK?
YES
NO
INSERT ANALOG CARD
REPLACE DIGITAL CARD
IS +5 ±12V OK?
YES
NO
INSERT INST. CARD
REPLACE ANALOG CARD
IS +5V ±12V OK?
YES
NO
INSERT PROGRAM
REPLACE INST. CARD
IS +5 ±12 OK?
YES
NO
REPLACE PROGRAM

RUNNING


H1 1406 IS READOUT SELECT MODE
RTD MODULE
FLASHING RTD?
YES
NO
COMMUNICATIONS ESTABLISHED W/RTD MODULE
ARE DIP SWITCHES SET ON RTD MOD?
NO
SET DIP SWITCHES ON RTD BOARD
YES
CHECK READINGS ON ALL PROGRAMMED RTD's
DO THEY ALL READ −999?
YES
LOSS OF COMMUNICATIONS ON RTD MODULE
NO
CHECK WIRING
ONES READING −999 ARE OPEN
CHECK POWER SUPPLY VOLTS
IS WIRING OK?
YES
NO
INSERT RESISTOR IN CKT OF SIM. VALVE
IS +5 ±12 OK?
YES
CALL ALLEN-BRADLEY SERVICE REP.
REWIRE CORRECTING
NO
REMOVE BOARD
DOES READOUT REFLECT THE TEMP. VALVE CONT. TO R?
NO
CALL ALLEN-BRADLEY SERVICE REP.
YES
IS ±12 +5 OK?
YES
RESPECTIVE RTD IS OPEN
NO
REPLACE BD.
REPLACE M. BD.

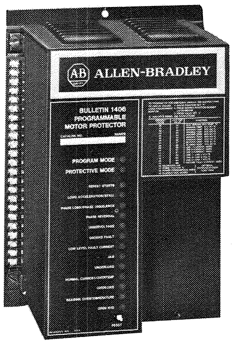
Section 10

RENEWAL PARTS

IMPORTANT- For service requirements other than those described in this manual, contact Allen-Bradley Customer Support Services at a Local Service Center.

DESCRIPTION- The Bulletin 1406 Programmable Motor Protector (PMP) consists of three basic modules:

- Protective Module
- Remote RTD Module
- Programmer/Monitor



CAUTION- Never remove or replace a circuit board while power is applied to the unit.

The following information outlines the procedure for renewal parts replacement designed for the user.

Protective Module- The renewal parts replacement for the Protective Module consists of Circuit Board and Fuse replacement.

Circuit Board Replacement- The Protective Module is constructed of a mother board and three edge connector into which three replacement boards fit. The three boards are the Instrumentation Board, the Digital Board, and the Analog Board.

NOTE- For replacement of the mother board or power supply board, refer to factory.

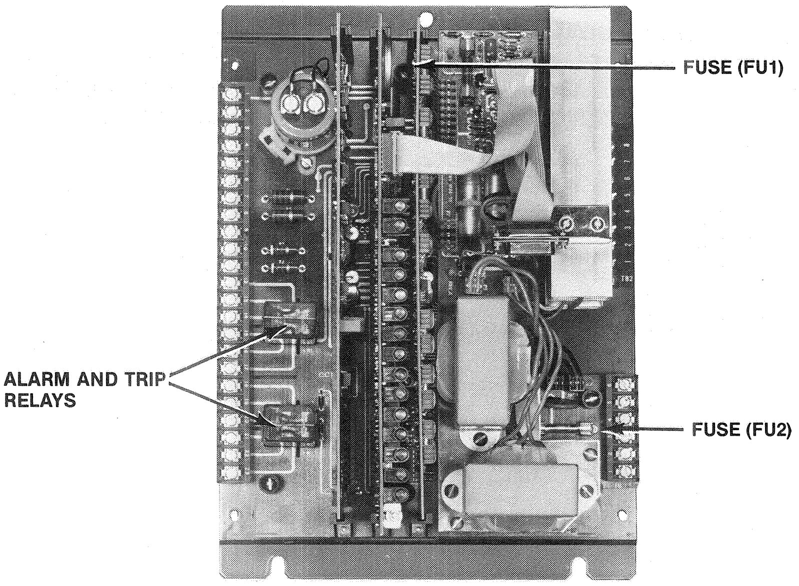


Figure 1. Protective Module with cover removed and circuit boards in place.

Instrumentation Board- This board fits into the first card rack on the left side of the Protective Module. Use the following procedure for replacement:

1. Take the Instrumentation Board and locate with components facing to the right as shown in Figure 2.
2. Push the connector into the card rail until it seats firmly.

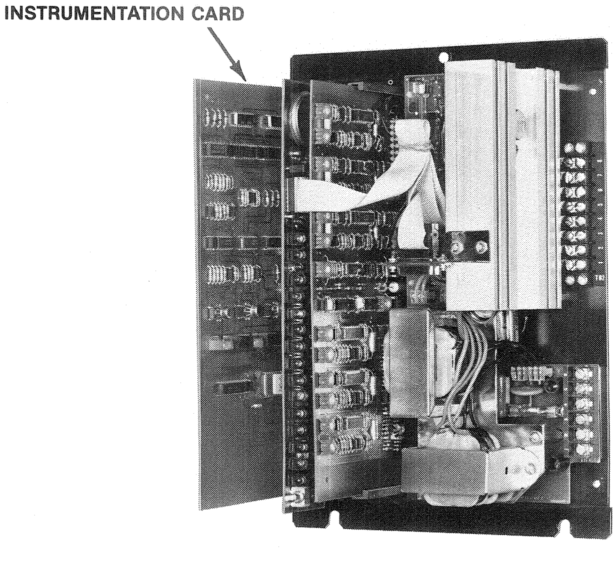


Figure 2. Instrumentation Board

Digital Board- This board is located to the right of the Instrumentation board as shown in Figure 3. To install this board requires the following two steps:

1. The programmer to digital card connector must be pushed on to the digital board. The connector is in the configuration of a dual in-line package. It should be inserted into the socket located on the digital board to the lower left hand of the lithium battery (which is located at the upper left hand of the board). Be sure to orient the connector, so the ribbon is facing the row of LEDs.
2. To install the digital board into the PMP mother board, orient the board so the battery is facing the top of the PMP. The component side must face to the right. Guide the board down the board rail and insert in the connector. Be sure the circuit board is firmly seated into the connector.

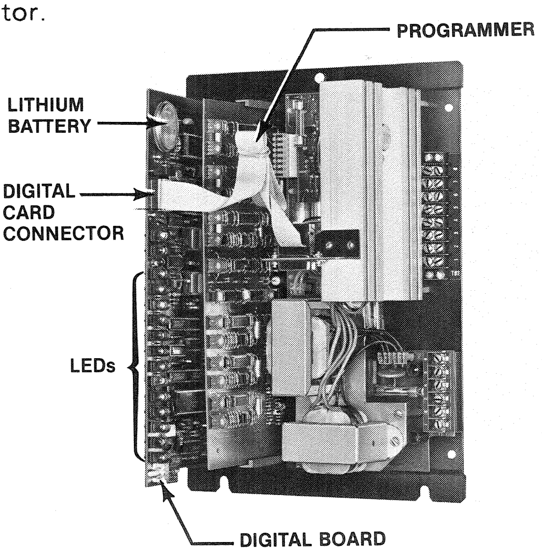


Figure 3. Digital Board

Analog Board- This board is located to the right of the Digital Board as shown in Figure 4. To install the Analog Board use the following procedure:

1. Orient the board so the components are facing to the right. The row of potentiometers on the left hand side of the board should face the front of the Protective Module.
2. Guide the board down the board rails until the edge connector is firmly seated into the connector on the mother board.

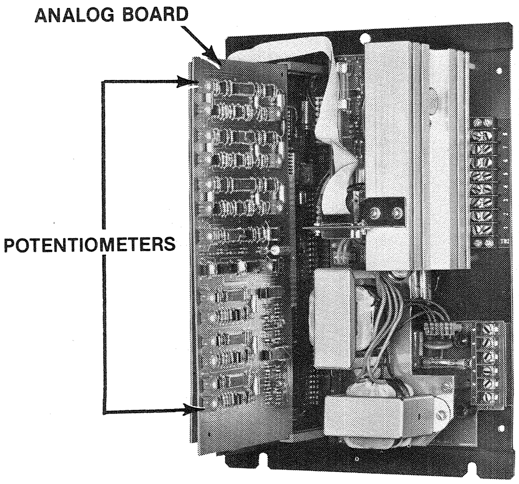


Figure 4. Analog Board

NOTE- All three replacement circuit boards are factory preset and calibrated. They require no field adjustment.

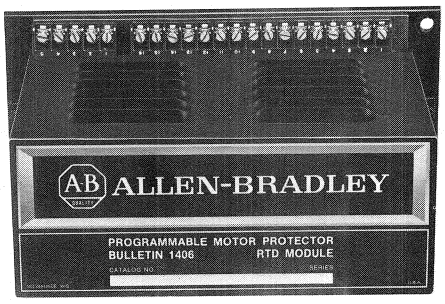
Fuse Replacement- There are two fuses in the Protective Module. They are the Programmer Fuse labeled FU1 and the Line Fuse labeled FU2. These fuses are located in the upper middle section and lower right section of the Protective Module as shown in Figure 1.

NOTE- It is important that the replacement fuses be the same as the factory supplied fuses. Refer to the Renewal Parts List.

Alarm and Trip Relay Replacement - The following procedure outlines the replacement of the Alarm and Trip relays. (Refer to Figure 1).

1. Remove the relay retaining clip.
2. Unplug the existing relay.
3. Locate and plug-in the replacement relay.
4. Replace the relay retaining clip.

Remote RTD Module- The next section contains the service procedure for the RTD Module. It consists of Circuit Board and Fuse replacement.



RTD Module

Circuit Board Replacement- The RTD Module consists of a mother board and RTD Digital Board. Refer to Figure 5. Use the following procedure for board replacement.

For replacement of the mother board, simply remove the (4) screws holding the board to the RTD Module backplate and install the new board.

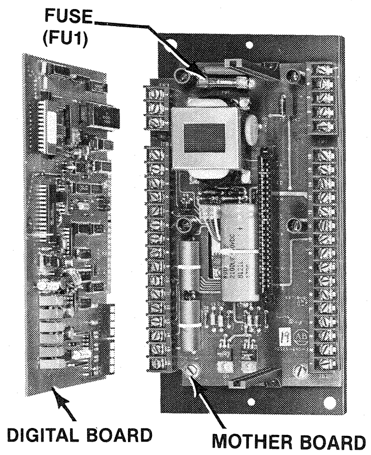


Figure 5. RTD Module with cover removed

To install the RTD Digital Board into the mother board connector assembly:

1. Orient the board so the components are facing to the right as shown in Figure 5. The board is "keyed" so it fits into the mother board only in one manner. This is to prevent against incorrect installation.
2. Guide the board along the board rails and insert into the connector. Be sure the edge connector is firmly seated into the mother board connector.

Fuse Replacement- The Line Fuse labeled FU1 is located at the top of the transformer to the left of the top card rail on the mother board. Refer to Figure 5. Replacement of this fuse should be coordinated with the appropriate part number in the Renewal Parts List.

Programmer/Monitor- Refer to factory for repair and/or replacement.

Renewal Parts- The following table lists the renewal parts for the PMP. Most of the parts and subassemblies can be installed by a qualified user. However, some of the parts and subassemblies require precise calibration and must be installed by a service representative. These parts are noted in the table.

Description	Part Number	Customer Support Services	User
PROTECTIVE MODULE			
Power Supply Board	40385-034-51	X	N/A
Analog Board	40385-016-51	X	X
Digital Board	40385-084-51	X	X
Instrumentation Board	40385-074-51	X	X
Heat Sink Assembly	40385-101-51	X	N/A
Current Transformer Assembly ①	40385-105-51	X ③	N/A
Mother Board Assembly ②	40385-022-52	X ③	N/A
Power Supply Subassembly	40385-100-51	X	N/A
Connector Assembly Prog → Digital Board	40385-069-51	X	X
Fuse FU1 (3/8A-250V)	25176-151-01	X	X
Fuse FU2 (0.6A-250V)	25183-165-02	X	X
Alarm and Trip Relay	24520-005-01	X	X
Retaining Clip	22307-005-01	X	X
RTD MODULE			
Analog Board Assembly	40385-046-51	X	X
Mother Board Assembly	40385-040-52	X	X
Fuse FU1 (0.25A-250V)	25183-165-01	X	X

① Requires mother board from unit being serviced.

② Requires current transformer assembly from unit being serviced.

③ With factory set-up.

Section 11
TYPICAL SPECIFICATIONS

ELECTRICAL DATA

Protective Module

Device Power – 110/120 Volts AC 50/60 Hz, 40 VA (Req'd)

Inputs – 3 Phase line voltage via user supplied potential transformer - 120 Volt secondary.

3 Phase current via user supplied current transformers - 5 Ampere secondary.

Zero sequence ground fault transformer - 5 Ampere secondary.

RTD Module Output (communications port). RS 422 compatible.

Programmer / Monitor Output (communications port). RS 422 compatible.

Acceleration Input - User provides N.O. contact - 120 Volts AC Protective Module - 1.2 VA burden

Remote Reset - User provides N.O. contact - 120 Volts AC Protective Module - 0.8 VA burden

Outputs – Alarm Contacts and Trip Contacts: (2) Form C contacts each.

Ratings:

- 30 Volts DC - 10 Amperes (Resistive)
- 40 Volts AC - 10 Amperes w/P.F. greater than or equal to 0.8
- 120 Volts AC - 10 Amperes w/P.F. greater than or equal to 0.8

LED Annunciator Display
Alarm - LED flashes
Trip - LED stays lit

Programmer/Monitor

Device Power – (Slaved off Protective Module).

Inputs – Keyboard Data Entry.

Outputs – Communications port to Protective Module.

Remote RTD Module

Device Power – 110/120 Volts AC 50/60 Hz, 15 VA (Req'd)

Inputs – (6) 3-wire winding RTDs (2) 3-wire bearing RTDs ①

Accepts RTD Types:

- 10 Ohm Copper
- 100 Ohm Platinum
- 100 Ohm Nickel
- 120 Ohm Nickel

Output – Communications port to Main Protective Module. (Requires 3 twisted shielded pair cable for connections.)

Instrumentation Option

Power.........................(Kilowatts)

Power Factor..........(%) Lead/Lag

Totalized Power........(Megawatt Consumption Hours)

Elapsed Running Time....(Hours)

METERING ACCURACY

Voltage (Volts) – ± 4% of Full Scale ②

Current (Amperes) – ± 4% of Full Scale ③

Temperature (°C) – ± 2% of Full Scale ④

Instrumentation Features

Power (KW) – ± 4% of Full Scale ⑤

Totalized Power (MWHrs) – ± 4% of Full Scale ⑥

Power Factor – ± 10% of Full Scale ⑦

Elapsed Time (Hrs) – ± 0.05% of Full Scale ⑧

ENVIRONMENTAL DATA

Temperature Range
Operating: 0°C to + 55°C
Storage: -20°C to + 80°C

Humidity Range
Operating: 5 - 95%
Storage: 5 - 95%

(non-condensing)

① Winding RTD type may be different than the bearing RTD type.
② Full Scale = 2 x Potential Transformer (PT) primary rating.
③ Full Scale = 1.6 x Current Transformer (CT) primary rating.
④ Full Scale = + 240 °C
⑤ Full Scale = $\frac{(3.2595)\ (\text{PT pri.})\ (\text{CT pri.})}{1000}$
⑥ Full Scale = 9999
⑦ Full Scale = 100
⑧ Full Scale = 9999

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