1600 SERIES INSTALLATION & OPERATING INSTRUCTIONS

Dynapar, Veeder Root, and Eagle Signal Brands:

Sales, Repair, and Application Support:
1675 Delany Rd.
Gurnee, IL. 60031
847-662-4150 Sales/Order Entry Fax
847-782-5277 Applications Support Fax
800-873-8731 Sales/Order Entry
800-234-8731 Applications Support

NorthStar Brand:

Sales, Repair, and Application Support:
1675 Delany Rd.
Gurnee, IL. 60031
847-782-5288 Sales/Order Entry Fax
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800-326-6216 Applications Support

Partlow, West, Rustrak, and LFE Brands:

Sales, Repair, and Application Support:
1675 Delany Rd.
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847-662-4150 Sales/Order Entry Fax
847-782-5277 Applications Support Fax
800-873-8731 Sales/Order Entry
800-866-6659 Applications Support

Please disregard all phone numbers and addresses in this manual. The phone numbers and address on this page are the correct phone number and addresses to use for sales, repair, and application support.

WEST 1600 THREE MODE TEMPERATURE CONTROLLER

INSTALLATION & OPERATING INSTRUCTIONS

TABLE OF CONTENTS PAGE

UNPACKING THE INSTRUMENT

Carefully unpack your 1600 Series instrument from the shipping carton, and inspect it for shipping damages. Check the contents of the shipping carton against the packing slip. IMMEDIATELY REPORT ANY DAMAGES TO THE CARRIER.

IDENTIFICATION OF MODEL NUMBER

The following part number identification table explains the instrument model number on the inside of the control access door. This number can be used to determine those portions of this manual applicable to your instrument.

16 X X - X - XXXX - 9XXX

SERIES

SET POINT/INDICATION

0-Analog/Expanded Deviation
1-Analog/Full Scale
2-Digital/Deviation
3-Digital/Full Scale
4-Digital/Digital

PRIMARY OUTPUT FUNCTION

2-Time Proportioning Relay
6-Current Proportioning
7-Time Proportioning 0-5 VDC (non isolated) Logic Level

ALARM OR COOLING OUTPUT

0-None
1-Deviation High
2-Deviation Low
3-Out of Limits
4-Process
7-Time Proportioning Cooling

RANGE CODE

SPECIAL FEATURE

WARRANTY

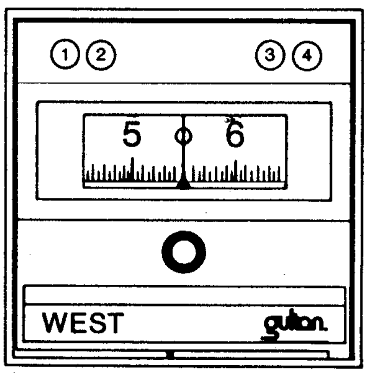
The Company warrants all components of all the 1600 Series to be free from defects in workmanship and material under normal use and service. Equipment returned transportation prepaid to the Company's originating factory within 18 months from the date code stamped on the device and found by the Company's inspection to be defective in workmanship or material will be repaired or replaced, at the Company's option, free of charge and returned prepaid. WITH EXCEPTION OF THE 18 MONTH WARRANTY, SET FORTH ABOVE, THE COMPANY MAKES NO EXPRESS WARRANTIES, NO WARRANTY OF MERCHANTIBILITY AND NO WARRANTIES WHICH EXTEND BEYOND THE DESCRIPTION ON THE FACE HEREOF. In no event will the Company be liable for indirect, special or consequential damages of any nature whatsoever.

The 1600 Series is a complete line of fully adjustable, three-mode (PID) electronic controllers featuring the latest in solid-state design techniques. These controllers are available with five set point/indication configurations, three primary output functions, four alarm output functions and one cooling output function to meet most control requirements. Standard inputs include thermocouple (T/C), current or voltage. Special features include process variable output (0-1mA), remote set point, and multiple unit mounting.

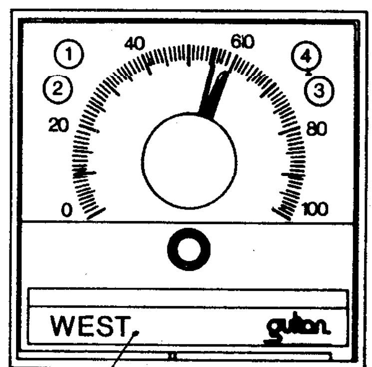
An aluminum case houses the compact plug-in chassis assembly. External wiring is connected to the screw terminals on the rear of the case, which has molded terminal barriers and terminal identification. The case is designed for panel mounting with a U-shaped metal bracket supplied for this purpose.

INSTRUMENT DESCRIPTION

SET POINT/INDICATION IDENTIFICATION CODES

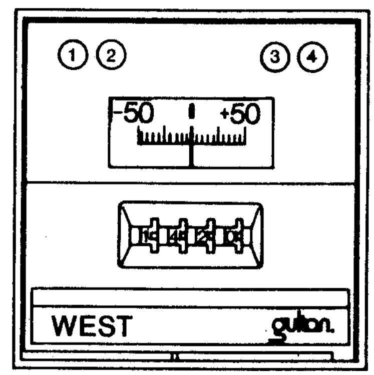


16 [0] X - X

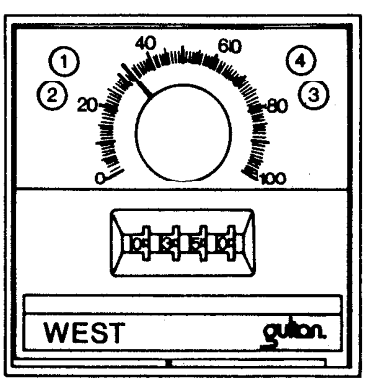


16 [1] X - X

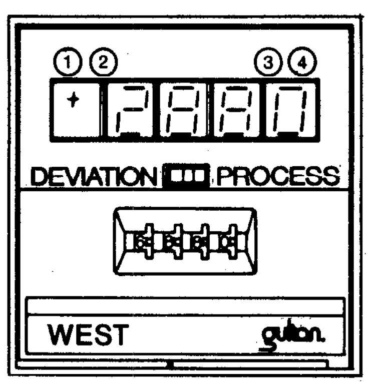
CONTROL ACCESS DOOR



16 [2] X - X



16 [3] X - X



16 [4] X - X

LIGHT SEQUENCE

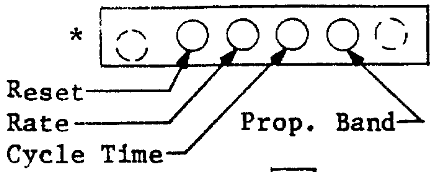
Models 16x6 - X

1 GRN-pwr "ON" (not used-1646-X)
2 not used
3 not used
4 RED-Alarm or cooling output "ON"

All other Models

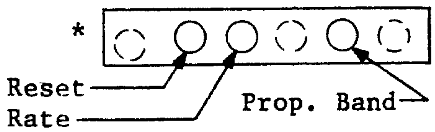
1 RED-primary output "ON"
2 GRN-primary output "OFF"
3 not used
4 RED-Alarm or cooling output "ON"

16 x [2] - x:

* 

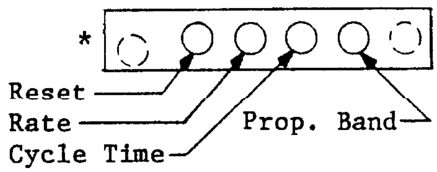
This code number identifies an instrument with a primary output that is time proportioning relay output. The adjustments associated with this feature are shown at the left. See SPECIFICATIONS and TUNING PROCEDURES for additional information.

16 x [6] - x:

* 

This code number identifies an instrument with a primary output that is 4-20mA. The adjustments associated with this feature are shown at the left. See SPECIFICATIONS and TUNING PROCEDURES for additional information.

16 x [7] - x:

* 

This code number identifies an instrument with a primary output that is a 0-5 VDC logic level for switching solid state relays. The adjustments associated with this feature are shown at the left. See SPECIFICATIONS and TUNING PROCEDURES for additional information.

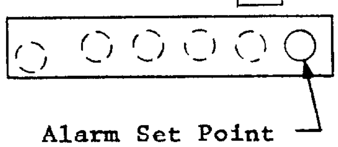
ALARM OR COOLING OUTPUT IDENTIFICATION CODE

16 x x - [0] :

* 

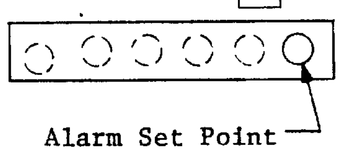
This code number identifies an instrument that has no alarm or cooling output.

16 x x - [1] :

* 

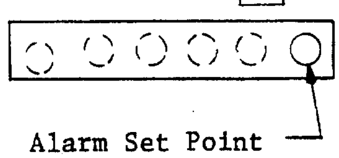
This code number identifies an instrument that has an ON/OFF relay deviation high alarm output. The relay will pull in when the process variable is above the alarm set point. The alarm set point will "track" the primary set point. The adjustments associated with this feature are shown at the left. See SPECIFICATIONS and TUNING PROCEDURES for additional information.

16 x x - [2] :

* 

This code number identifies an instrument that has an ON/OFF relay deviation low alarm output. The relay will pull in when the process variable is below the alarm set point. The alarm set point will "track" the primary set point. The adjustments associated with this feature are shown at the left. See SPECIFICATIONS and TUNING PROCEDURES for additional information.

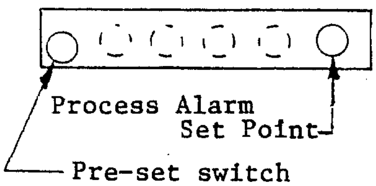
16 x x - [3] :

* 

This code number identifies an instrument that has an ON/OFF relay out of limits alarm output. The relay will pull in when the process variable is either above or below (out of limits) the alarm set point. The alarm set point will track the primary set point. The adjustments associated with this feature are shown at the left. See SPECIFICATIONS and TUNING PROCEDURES for additional information.

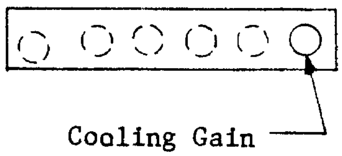
* Located under control access door.

16 x x - 4 :



This code number identifies an instrument that has an ON/OFF relay process high alarm output. The relay will pull in when the process variable is above the alarm set point which is independently adjustable from the primary set point. The adjustments associated with this feature are shown at the left. See SPECIFICATIONS and TUNING PROCEDURES for additional information.

16 x x - 7 :



This code number identifies an instrument that has a TIME PROPORTIONING relay cooling output. This relay will begin to time proportion "on" when the process variable is above the primary set point. The primary output time proportions "on" when the process variable is below the set point. The adjustments associated with this feature are shown at the left. See SPECIFICATIONS and TUNING PROCEDURES for additional information.

* Located under control access door.

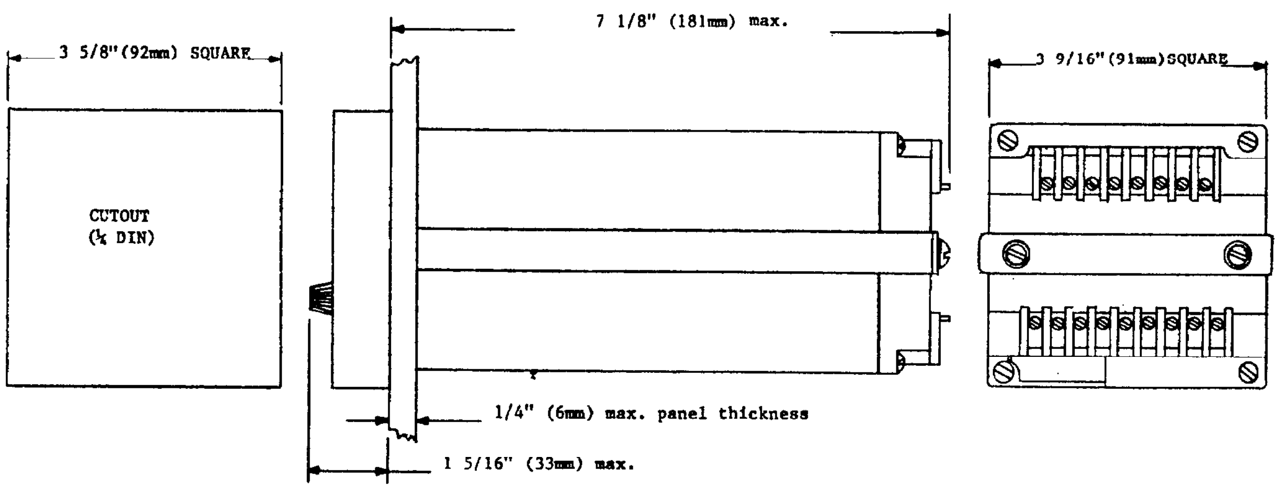
MOUNTING INSTRUCTIONS

LOCATION:

1. Select a location for the instrument where it will not be subjected to excessive shock, vibration, dirt, moisture or oil seepage.
2. The ambient temperature where the instrument is located should be between $0^{\circ}C$ to $55^{\circ}C$ ($32^{\circ}F$ to $131^{\circ}F$). 0-$50^{\circ}C$ for digital indicating controllers.
3. Minimum practical center distance between instruments (without multiple mounting feature) in panel mounting is 101MM.

INSTALLATION

1. Cut panel hole to dimensions shown below.
2. Remove U-shaped mounting bracket by removing the two screws at the back of the instrument.
3. Insert instrument housing into panel cut out and replace U-shaped bracket. Replace mounting screws at the back of the housing and tighten until the instrument is rigidly mounted. DO NOT OVERTIGHTEN.



WIRING INSTRUCTIONS

ALL WIRING MUST COMPLY WITH NATIONAL ELECTRIC CODE, REGULATIONS AND ORDINANCES. Typical wiring connections are shown starting on Page 8.

POWER WIRING

1. Input line voltage must be 120 or 240 Vac + 10% to -15% at 50/60 Hz.
2. Connect the line voltage to the terminals marked 120 and LN (120Vac) or 240 and LN (240 Vac).
3. A good earth ground should be connected to the terminals marked ground (⏚).

INPUT WIRING:

1. DO NOT RUN SENSOR OR OTHER LOW VOLTAGE LEAD WIRES IN A CONDUIT WITH POWER LINE WIRING.
2. Observe correct polarity when connecting thermocouple lead wires. Red is ALWAYS negative.
   Use only the same type thermocouple extension wire as the type of the thermocouple.
3. With 2-wire RTD input, minimize lead wire resistance, since it adds directly to sensor resistance. With 3-wire RTD sensor, make resistance of all three lead wires equal for optimum compensation.

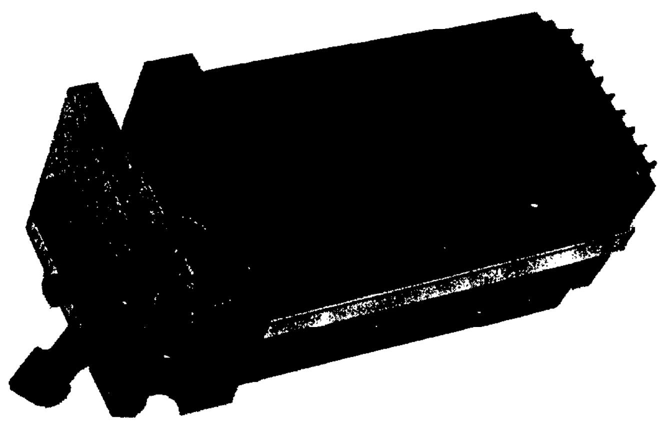
OUTPUT WIRING:

1. Line voltage output options wiring may be run with the power wiring.

REMOVING INSTRUMENT FROM HOUSING

The instrument is held in its plug-in housing by a cam action lever-latch. To remove the instrument depress the lever handle in the lower right hand corner to unlatch and swing the lever outwards 90 degrees. The lever cam action will move the instrument out about 1/4 inch. Do not force lever beyond 90 degrees or cam latch may shear off.

Use lever to pull instrument out until it can be grasped by hand and completely removed.



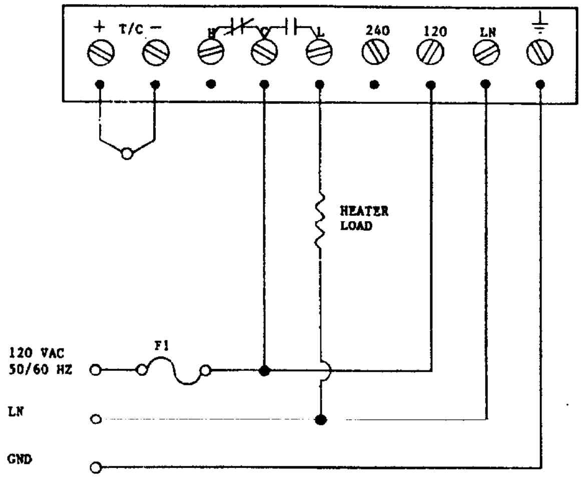
WIRING DIAGRAM IDENTIFICATION TABLE.

Refer to instrument model number on the inside of control access door. For example, the wiring diagram for 1612-0 is A and the wiring diagram for 1612-1 is AA.

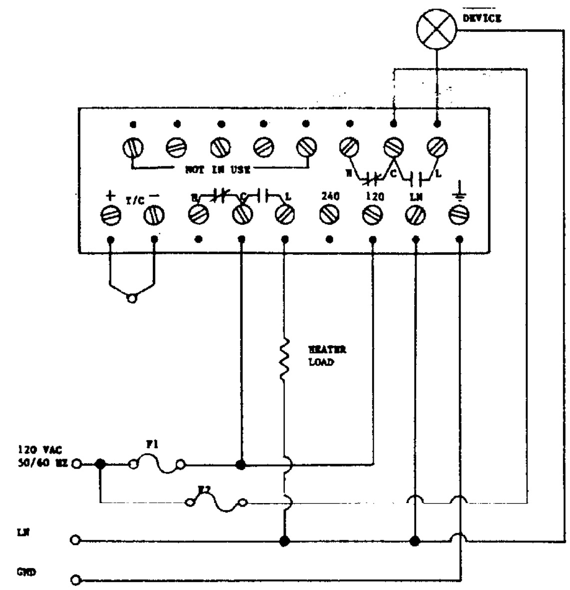
ALARM OR COOLING OUTPUT

PRIMARY OUTPUT

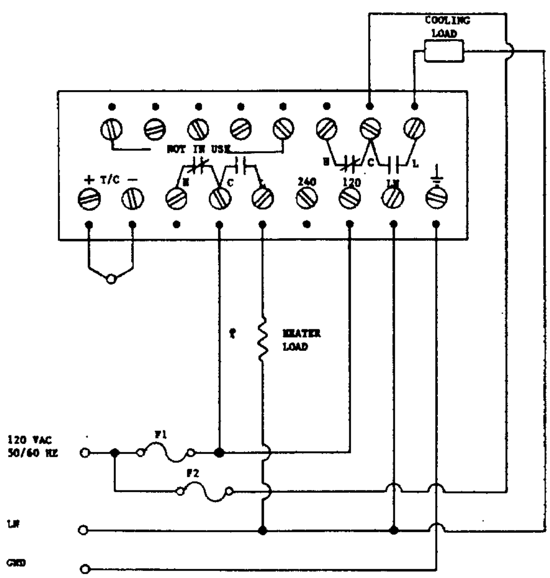
	-0	-1	-2	-3	-4	-7
16x2	A	AA	AA	AA	AA	AAA
16x6	D	DD	DD	DD	DD	DDD
16x7	F	FF	FF	FF	FF	FFF



WIRING DIAGRAM A FOR MODELS 16x2-0



WIRING DIAGRAM AA FOR MODELS 16x2 WITH AUXILIARY OUTPUT -1, -2, -3 OR -4

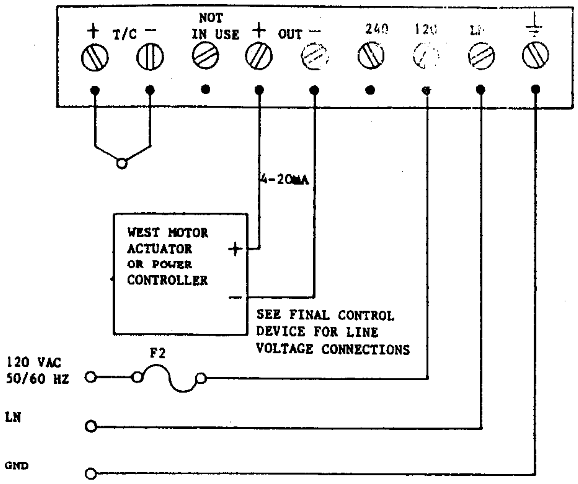


WIRING DIAGRAM AAA FOR MODEL 16x2-7

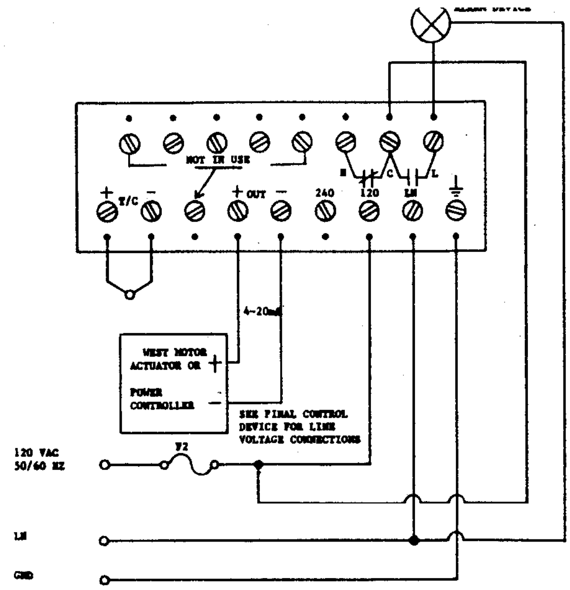
NOTES:

1. SELECT PROPER TERMINAL IF 240 VAC IS USED RATHER THAN 120 VAC.

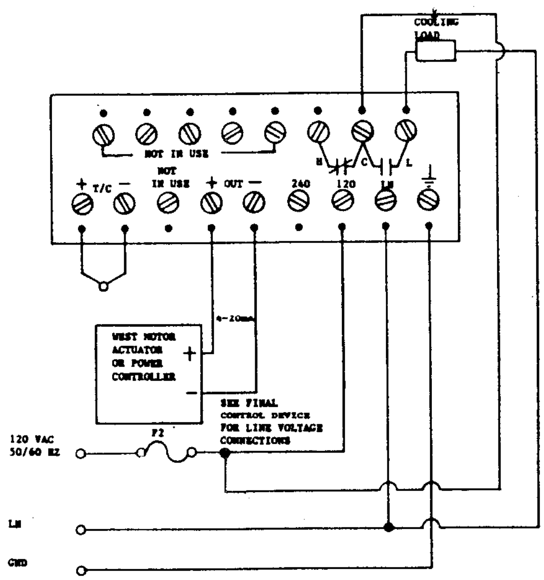
2. FUSE RATINGS:
   F1: 10A @ 120 VAC/5A @ 240 VAC (RESISTIVE LOAD)
   F2: 5A @ 120 VAC/2.5A @ 240 VAC (RESISTIVE LOAD)



WIRING DIAGRAM D FOR MODELS 16x6-0



WIRING DIAGRAM DD FOR MODELS 16x6 WITH AUXILIARY OUTPUTS -1, -2, -3 OR -4

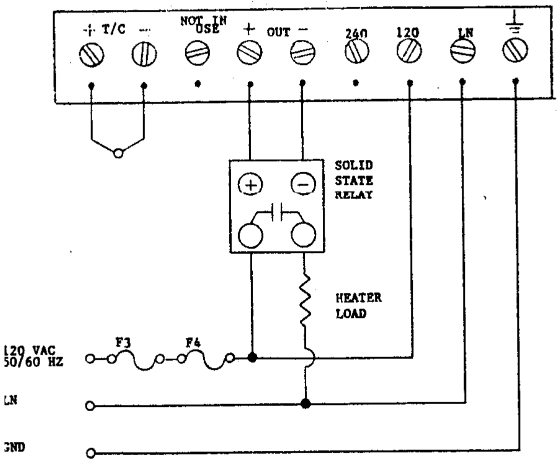


WIRING DIAGRAM DDD FOR MODEL 16x6-7

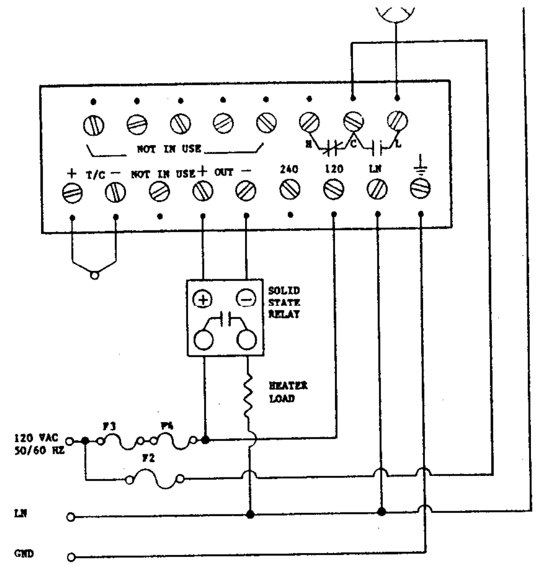
NOTES:

1. SELECT PROPER TERMINAL IF 240 VAC IS USED RATHER THAN 120 VAC.

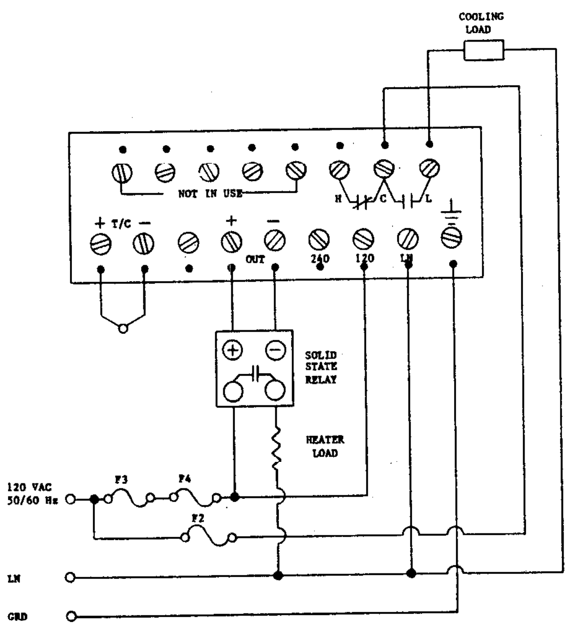
2. FUSE RATINGS:
   F1: 10A @ 120 VAC/5A @ 240 VAC (RESISTIVE LOAD)
   F2: 5A @ 120 VAC/2.5A @ 240 VAC (RESISTIVE LOAD)



WIRING DIAGRAM F FOR MODELS 16x7-0



WIRING DIAGRAM FF FOR MODELS 16x7 WITH AUXILIARY OUTPUTS -1, -2, -3 OR -4



WIRING DIAGRAM FFF FOR MODEL 16x7-7

NOTES:

1. SELECT PROPER TERMINAL IF 240 VAC IS USED RATHER THAN 120 VAC.

2. FUSE RATINGS:
   F1: 10A @ 120 VAC/5A @ 240 VAC (RESISTIVE LOAD)
   F2: 5A @ 120 VAC/2.5A @ 240 VAC (RESISTIVE LOAD)

INPUT SPAN

Thermocouple: 8 mV minimum, 60 mV maximum span with cold junction compensation. Total resistance of thermocouple and leadwire up to 100 ohms without affecting accuracy. Thermocouple break protection (TCBP) standard.

SET POINT RESOLUTION

Analog (expanded deviation):............ ±0.1%: 8 inches scale length
Analog (full scale):.................... ±0.1%: 4.7 inches scale length
Digital:............................... 1^o

INDICATOR ACCURACY

Analog (expanded deviation):............ ± 1% of span
Analog (full scale):.................... ± 2% of span
Digital (deviation meter):.............. ± 1% of span
Digital (process readout):.............. ± 1 digit

Note: Indication accuracy includes indicator accuracy plus set point accuracy. For digital readout instruments add electronic linearizer conformity error.

OUTPUT FUNCTION

Primary

Time proportioning relay................ cycle time adjustable 2-60 seconds
Current proportioning................... 4-20 mA into 800 ohms max.
Time proportioning (5 VDC logic)........ cycle time adjustable 2-60 seconds

Alarm or Cooling

Deviation High relay:................... adjustable +1/2% to +25% of span
Deviation Low relay:.................... adjustable - 1/2% to -25% of span
Out of Limits relay:.................... adjustable ± 1/2% to ±25% of span
Process relay:.......................... adjustable 0 - 100% of span
Time prop. cool gain:................... adjustable from 0.025 to 1.0 relative to heating gain

RATING

Relay (primary): ------------------------ 10A/5A @ 120/240 VAC (Resistive)
" (alarm or cooling): ---------------- 5A/2.5A @ 120/240 VAC (Resistive)
5 VDC logic level: ----------------------- "ON" voltage - 5 V min., 7 V max.
"OFF" voltage - 0.3 V max.
Load resistance - 500 ohms min.

Current:Proportioning:

Letter Code	Output	Maximum Load	Output Resistance
A	4-20 MA	0-800	---
B	2-10 MA	0-1600	---
C	1-5 MA	0-3200	---
D	0-10 MA	0-1600	---
E	1-5 Volt DC	25KΩ to ∞	250
F	0-5 Volt DC	25KΩ to ∞	250
G	2-10 Volt DC	50KΩ to ∞	500

CONTROL ADJUSTMENTS

Proportional Band (gain):............... adjustable 3 to 40% of span

Integral (automatic reset):............. adjustable .06 repeats/minute (15 minutes) to 6 repeats/minute (0.15 minutes)

Rate (derivative):...................... adjustable 0 to 5 minutes

PERFORMANCE

Accuracy (Set Point)

Reference: ------------------------------ ±0.5% of span over the central 80% of span at reference conditions.

Rated: ---------------------------------- ±1.0% typical of span over the central 80% of span at rated conditions.

Repeatability: --------------------------- ±0.1% of span

Conformity error

Electronic linearizer: ------------------ ±0.3% of span

Digital set point: ---------------------- ±0.5% of span

Stability:

Temperature: ---------------------------- ±5 microvolts/°C (maximum)
±2 microvolt/°C (typical)
(input OP amp only)

Line Voltage: --------------------------- ±0.1% of span with change of +10% to -15% @ 120/240 VAC @ 50/60 Hz.

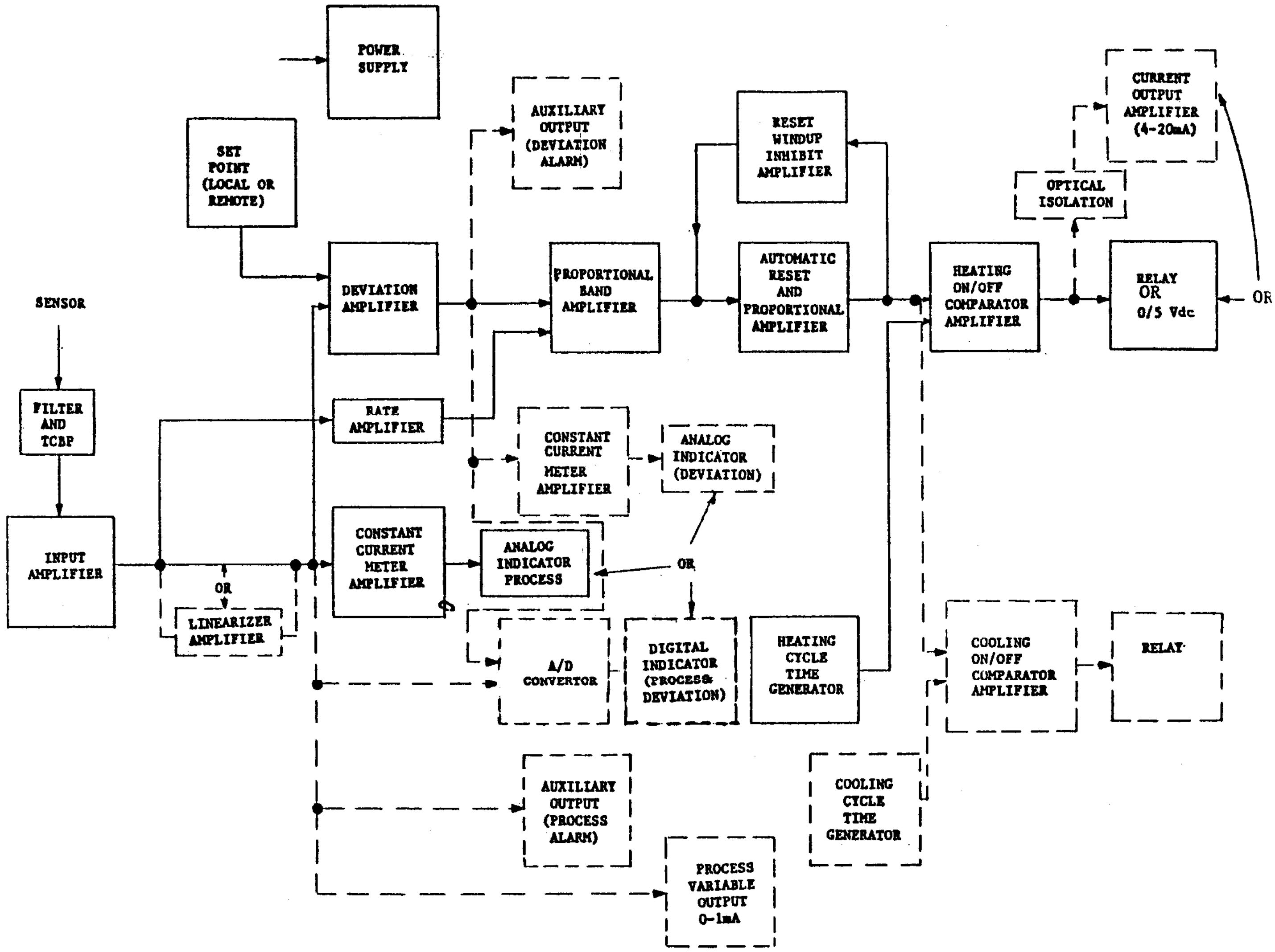
Common mode rejection: ------------------- 120 db up to 240 VAC ±1% @ 50/60 Hz;

Normal mode rejection: ------------------- 60 db @ 50/60 Hz

Operating Conditions

Reference: ------------------------------ 25°C± 1°C; 120/240 VAC ±1% @ 50/60 Hz; 10 ohms T/C source resistance; 15% RH

Rated: ---------------------------------- 0-55°C for all non digital readout controller.
0-50°C for all digital readout controller.
120/240 VAC +10%, -15 @ 50/60 Hz, 100 ohms maximum T/C source resistance; 0-70% RH



The power line voltage is stepped down by the power transformer, rectified and filtered to approximately ± 16 Vdc. This unregulated voltage energizes the power supply circuitry which develops the positive and the negative regulated voltages to power the other control circuit functions.

The input amplifier converts the filtered input signal from the sensor to an equivalent process variable signal which drives the meter amplifier for the analog process indicator, the rate amplifier, and the linearizer if the indicator is digital. The output of the linearizer (or the input amplifier if the indicator is analog) drives the process alarm option, the process variable 0-1 mA output, and the digital indicator when the deviation process switch is switched to process The linearizer is included in the instrument when the indicator is digital so that the process signal is converted to a signal that is linearly related to the sensor temperature. This makes the circuit for the digital indicator simpler.

The process variable signal is also one input to the analog deviation amplifier which compares this signal to the set point signal. When the process variable signal differs from the set point signal, the deviation amplifier generates an error signal. This error signal drives the meter amplifier for the analog deviation indicator and is also the input signal to the deviation alarm option and digital indicator when the deviation-process switch is switched to deviation.

This error signal is also one input to the adjustable gain proportional band amplifier. The second input is from the rate amplifier which applies a corrective signal determined by the rate of change of the process variable. The output of the adjustable gain proportional band amplifier is the input signal for the automatic reset and fixed gain proportional band amplifier which produces a corrective signal to reduce the error signal to zero when enabled by the reset windup inhibit amplifier.

The output ot the automatic reset and fixed gain proportional band amplifier is one input to the heating ON/OFF comparator amplifier which drives the output (electro-mechanical relay, 5 Vdc logic level signal, or the current output amplifier through an optical isolator). The other input is the ramp signal from the cycle time generator. From these two inputs, the ON/OFF comparator amplifier generates an ON-OFF periodic signal that has a ratio of "ON" to "OFF" determined by the magnitude of the signal from the automatic reset and proportional band amplifier.

The output of the automatic reset and fixed gain proportional band amplifier and the cooling cycle time generator are inputs to the cooling ON-OFF comparator amplifier which produces an output similar, but inverse, to the heating ON/OFF comparator amplifier. This amplifier drives an electromechanical relay. A cooling gain control allows proportioning the cooling source to the heating source and process.

The alarm output option will accept either the process signal or the error signal as an input. This input signal is compared to the alarm set point and actuates the alarm output relay in response to these inputs. The relay will be energized when the alarm set point has been exceeded for the process alarms, deviation high alarms and out of limit alarm. The relay will be energized when the temperature is below the deviation low alarm or out of limits alarm set points.

TUNING PROCEDURES

Tuning of a PID (proportional, integral, and derivative) controller, such as the 1600 series, MUST NOT be approached casually. These controllers provide a powerful control algorithm for solutions to difficult control problems. Each will compensate for various process parameters. Before attempting to tune your instrument, familiarize yourself with the appropriate portions of the TUNING PROCEDURE.

To properly evaluate system response to the tuning procedure, a recorder MUST be used. Absolute accuracy in the recorder is not necessary since wave shape only will be observed. A West W2155A or equivalent should be used. The recorder input can be paralleled with the controller thermocouple provided that the recorder input is potentiometric.

SET POINT:

Set to desired temperature.

CYCLE TIME:

Adjust to the proper cycle time for the process based upon the system requirements. A short cycle time increases heating element life by reducing thermal shock. A longer cycle time increases mechanical contactor life. A short cycle time should be used for loads which heat and cool rapidly, and conversely, a long cycle time should be used for loads which heat and cool slowly.

There are two basic methods of tuning the controller. The first method characterizes the process by measuring the period of sustained oscillation and calculating the required controller parameters. Procedures 1 and 2 are examples of this method. The second method causes a process upset and monitors the system response on a recorder. The tuning is changed and the process upset is repeated. This procedure is continued until the desired response is obtained. Procedure 3 is a modification of this trial and error method.

TUNING PROCEDURE 1 (Ziegler-Nichol's Closed Loop Method)

Step 1: Initial Adjustments - Proportional band to minimum (CCW); integral (reset) at .06 repeats/minute (CCW); derivative (rate) at 0 minutes (CCW)

Step 2: Bring the process to the approximate desired set point. The process should oscillate. If not, use Procedure 3. If the process does oscillate, slowly decrease the Proportional Band setting (CW) in small increments until a sustained oscillation is achieved (amplitude neither increases nor decreases). Allow sufficient time between increments for the system to react, typically 15-20 minutes.

Step 3: Measure the period of sustained oscillation in minutes and read the Proportional Band setting.

Step 4: Increase the Proportional Band setting to 1.6 times the setting for sustained oscillation. The Reset setting in minutes/repeat is 2 divided by the period of sustained oscillation. The Rate setting in minutes is the period of oscillation divided by 8.

The controller is now tuned, and this procedure gives an overshoot with an amplitude decay ratio of 1/4.

TUNING PROCEDURE 2 (Minimum Overshoot Method)

Step 1: Do steps 1, 2, and 3 of Procedure 1.

Step 2: Set Proportional Band to 2.25 times the setting for sustained oscillation. The Reset setting in repeats/minute is 1.67 divided by the oscillation period in minutes. The Rate setting in minutes is 0.19 times the period of sustained oscillation in minutes.

The controller is now tuned.

TUNING PROCEDURE 3

Step 1: Do steps 1, 2, and 3 of Procedure 1.

Step 2: Double the Proportional Band setting of sustained oscillation, and the oscillation will die out. If the process did not oscillate at minimum setting, leave it at that value.

Step 3: Increase the Rate or Derivative setting by a small increment and then change the setpoint by - 5% and observe the process response. The desired response is a compromise between over-shooting the new setpoint and the speed at which the process reaches the new setpoint. Increase the Rate setting by another small increment and change the setpoint by +5% (the original setpoint) and observe the process response. Keep doing this until the desired response is achieved.

Step 4: Slowly increase the Reset Rate setting in small increments until an oscillation is observed, then halve the Reset Rate setting. The oscillation will stop, and the controller is now tuned.

DEVIATION ALARM SET POINT:

A clockwise (CW) rotation of the alarm set point potentiometer increases the separation between the primary set point and the alarm set point. This separation may be above, below or both (out of limits) depending upon the option selected. Each graduation around the alarm set point adjustment represents approximately 10% of the total adjustment, i.e., total adjustment is 25% span, therefore, 2 graduations equals 5% of span (50° on 1000° span). The alarm set point is "blind", however, the proper switch action can be verified by moving the primary set point opposite to the direction of the alarm set point. That is, decrease the primary set point to verify a deviation HIGH alarm output and note the difference between the set point and indicator when the alarm output LED lamp turns on.

PROCESS ALARM SET POINT:

The process alarm set point is continuously adjustable from 0 to 100% of the span of the controller. Clockwise (CW) rotation increases the set point. To set the process alarm set point, set the desired temperature on the primary set point. Push the pre-set switch and slowly adjust the process alarm set point potentiometer until the alarm output relay just pulls in (right RED LED lamp on instrument face will light).

IMPORTANT - Cooling lines should be unrestricted. Check that the shut-off valves are completely open. On initial start-up, the COOLING GAIN potentiometer should be set at the mid-position unless previous experience indicates a different setting. To determine which direction to turn the adjustment potentiometer, observe the action of the RED/GREEN heating LED lamps (left side of instrument face) and the RED cooling LED lamp (right side of instrument face), and the relationship between the indicator and the set point.

INDICATOR MOVES RAPIDLY DOWNSCALE WHEN THE COOLING (right RED LED lamp) FIRST TURNS ON: This indicates that the cooling gain is set too high and the cooling puses are too long. To correct this condition, turn the cooling gain potentiometer counter-clockwise (CCW) in SMALL INCREMENTS and allow sufficient time (typically 15-20 minutes) for the process to stabilize. Continue as needed until correct control action is attained.

INDICATOR IS OVERRIDING THE SET POINT AND THE COOLING (right RED LED lamp) is increasing towards 100% ON. This indicates that there is insufficient cooling to override the heat generated by the process. If the cooling lines are unrestricted, turn the cooling gain potentiometer clockwise (CW) in SMALL INCREMENTS and allow sufficient time (typically 15-20 minutes) for the process to stabilize. Continue as needed until correct control action is attained.

TROUBLESHOOTING

A temperature controller is only one part of a heating system. Its function is to sense temperature at a particular point in the system and, on the basis of what it senses, actuate some other device which changes the quantity of heat flowing into the system. A controller can respond only to what it senses at the particular sensing point. It cannot react to a temperature rise or fall somewhere else in the system until that rise or fall causes a change at the sensing point. Generally, it will have difficulty regulating the system when the heat source is improperly sized. And, most important, it has no way of recognizing whether the temperature at the sensor truly represents the temperature at the work area. Regardless of the capabilities of the controller, it can control no more closely than the design of the system permits.

The temperature controller set point, indicator and LED'S will aid you in determining whether the temperature controller is functioning properly. Generally, the RED LED is on when the output function is energized (see DESCRIPTION). In normal operation the indicator should be within the proportional band of the controller for the set point desired and relatively stable. The following table outlines some typical symptoms and probable causes.

TYPICAL SYMPTOM	PROBABLE CAUSE
LED lamps off.	No power controller. Check all power wiring & connections.
Indicator remains at or near zero.	Open indicator circuit. Replace controller. Shorted T/C lead wire.
Indicator remains upscale.	Open input circuit. Check for burned out T/C, broken wires, etc.
No output, but indicator and LED lamps functioning correctly.	Open circuit in output wiring. Check for broken wires, loose connections, burned out heaters, etc.
Controller and relay/contactor are functioning properly, but process is overheating.	Sensor placement is incorrect or cooling is needed. Check sensor location, type, position in well, etc.
Primary set point LED lamp on wit temperature indicator decreasing.	Reversed thermocouple polarity.