INSTRUCTION MANUAL

PART THREE

AERODYNAMIC THERMAL SIMULATION SYSTEM

RELATED REFERENCE MATERIAL

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, Alabama 35812

(Reference: Contract Number NAS8-26416)

R-I CONTROLS DIVISION
RESEARCH INC
BOX 24064 MINNEAPOLIS, MINNESOTA USA 55424
PHONE (612) 941-3300 • TWX 910-576-2837 • TELEX 029-5328

FUNDAMENTALS OF PROPORTIONAL TEMPERATURE CONTROL

RESEARCH INC
BOX 24064 MINNEAPOLIS, MINNESOTA USA 55424

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FOREWORD

Proportional type temperature control is not a new concept; the basic techniques have been applied in laboratories and industrial/production facilities for many years. Technological advances occurring in both research and production have placed newer, more stringent control requirements on these facilities and proportional-type temperature control is becoming more applicable.

Correct utilization of any concept begins with a thorough understanding, or review of what it is, how it works, and how it can best be applied. Technical publications are available that comprehensively describe this type of control, but more publications are written for the more technically astute pupil, and are generally not easily comprehended by the non-technically oriented reader.

The object of this primer is to present the basic fundamentals of proportional control in a technically simplified manner and to provide the reader with a better understanding of how to apply these concepts to his own applications. This primer advances the reader from straight proportional control through fundamentals of more sophisticated rate and reset control.

1. WHAT IS A PROPORTIONAL TEMPERATURE CONTROLLER?

Basically, it is a variable high gain amplifier with a potentiometric measuring circuit on its input. The potentiometric measuring circuit compares the millivoltage output of the control thermocouple with an adjustable "setpoint" or reference millivoltage. Any difference or "error" between these two millivoltage sources is amplified by the high gain amplifier to produce an output signal suitable for driving the other devices in the closed-loop system, such as SCR or IGNITRON-type power controllers. From a functional standpoint, the temperature controller would appear as follows:

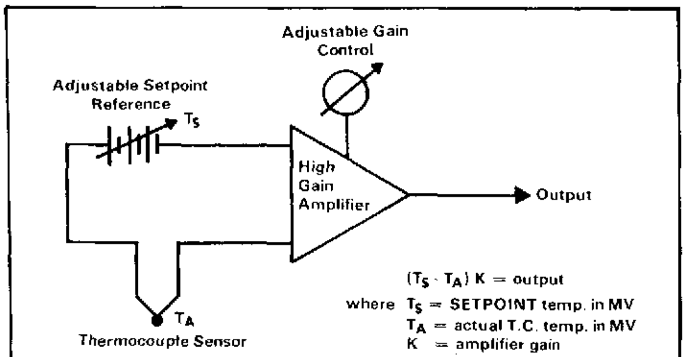


FIGURE 1

For optimum closed loop temperature control, the overall system gain must be matched to the system performance characteristics of each element in the system. Too much gain will cause system instability and too little gain will be characterized by sluggish response. Some of the system elements, such as the thermocouple sensor, power controller and heating element, have fixed gain characteristics which cannot be easily changed after installation. The temperature controller gain, however, can be made adjustable.

The GAIN control determines the magnitude of the minimum error signal required to produce full output, which — in relationship to setpoint — varies with WIDTH of the PROPORTIONAL BAND. The gain control is empirically set by the operator for the narrowest proportional band (highest gain setting) commensurate with system stability; just below the point where thermal oscillations occur. When optimumly set, proportional action begins at the edge of the proportional band where the error signal in microvolts (T_S - T_A) multipled by the new gain setting (K) can no longer produce a full output signal. The controller output becomes the input signal requirement for the final control device, which changes the media temperature accordingly.

The form of this output signal varies from manufacturer to manufacturer and is primarily dependent upon the input signal requirements of the final control device used most frequently with them. Whether this output signal is current rated, voltage rated, biased or unbiased is immaterial with respect to its fundamental operation. This discussion is referenced to a temperature controller having a 0-5 volt output range.

2. The GAIN of the amplifier determines the amount of error signal needed to produce full output of the controller.

Since the temperature controller must at some time be capable of producing a 5 volt output from the small microvolt error signal created between the set-point millivoltage and the thermocouple millivoltage, the maximum GAIN of the amplifier should be between 50,000 and 150,000 — depending upon overall system gain and sensitivity. An amplifier with a maximum gain of 50,000 will produce a 5-volt output with a minimum error signal of $\frac{5v}{50,000}$ or 100 microvolts. Thus, with a maximum gain setting on the controller, any microvoltage error signal obtained between the desired setpoint millivoltage and the thermocouple millivoltage that is equal to **or greater than** 100 microvolts will produce full output from the controller. This 100 microvolt minimum difference signal — when plotted as a locus of points (with respect to time) about the SETPOINT level — defines the MINIMUM PROPORTIONAL BAND of the controller. See Figure 2. Outside of this PROPORTIONAL BAND, the proportional controller will produce full output of 5 volts to the final control element, commanding full power to the heating media. As the temperature increases, the error signal becomes smaller and smaller, and soon reaches the edge of the PROPORTIONAL BAND where the error signal is no longer sufficient to produce full output. From this point on toward SETPOINT, the output of the controller is proportional to the error signal, which reduces the amount of power applied to the heating media.

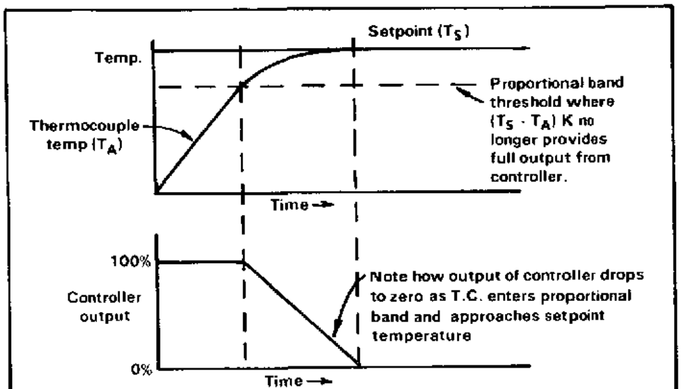
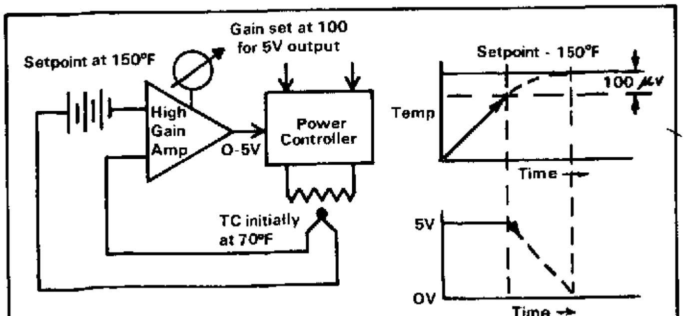


FIGURE 2

3. **PROPORTIONAL BAND, by definition, is the INVERSE FUNCTION OF GAIN.**

In the beginning of this discussion, a temperature controller with a maximum gain setting of 50,000 produced a full 5-volt output signal with an error signal of 100 microvolts. Should the gain be reduced to 25,000 a larger, 200-microvolt error signal would be required to produce full output, which — in terms of time and temperature — would occur further away from SETPOINT. Thus, as the GAIN of the controller decreases, the proportional band of the controller gets larger and, consequently, a larger deviation from SETPOINT would be required to produce a corrective signal to the heating media.



FIGURES 3 & 4

Example: (Refer to figures 3 & 4)

A. Temperature controller has a gain setting corresponding to 100 microvolts (3°F - IRON/CONSTANTAN T.C.)

B. The control thermocouple is at 70°F, the SETPOINT control is turned to 150°F. $(T_S - T_A) = (150°F - 70°F) = 80°F$.

C. 80°F error signal is greater than the minimum required error signal; therefore, the output of the temperature controller would go to maximum, driving full power into the heater.

D. As temperature of the control thermocouple approached the Proportional Band of Control, or point where $(T_S - T_A)K$ will not produce full output, **PROPORTIONAL TEMPERATURE CONTROL BEGINS.** From this point on in toward the SETPOINT, less and less output will be produced, and **IDEALLY** the temperature **RATE** of rise will gradually diminish and the temperature/time curve would asymtotically approach our SETPOINT temperature.

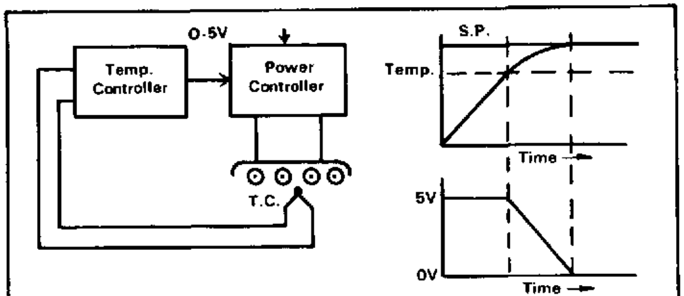


FIGURE 5
IDEAL PROPORTIONAL TEMPERATURE CONTROL (NO THERMAL LOSSES

4. **WHAT ELSE MUST BE CONSIDERED?**

Let's back up one moment in our control loop.

A. We know that the power controller controls power in response to a control signal such that no control signal = no power and full control signal = maximum power.

B. We know that in a manual control system, in order to hold an elevated temperature we must initially apply sufficient power to raise the temperature of our specimen, then **hold** enough power to overcome thermal losses to maintain this temperature.

5. **FROM WHERE DOES THIS POWER CONTROLLER INPUT SIGNAL COME?**

A. Looking back at our basic temperature control loop, one can see that the **only** input signal to the power controller comes from the temperature controller. Thus, somehow the temperature controller must produce this required signal.

Example:

In the previous example, we had an elevated SETPOINT of 150°F. Since thermal losses must exist, let's say that 20% of maximum power is required to overcome thermal losses which corresponds to a requirement of 20% of maximum output from the temperature controller.

This corresponds to 20% of the minimum input error signal. Since 100 microvolts (3°F) is the microvoltage input signal required for full output, 20% of 100 microvolts or 20 microvolts (.6°F) error is required to overcome thermal losses.

B. Thus, with true proportional control, one **never** gets to the desired SETPOINT when thermal losses are present.

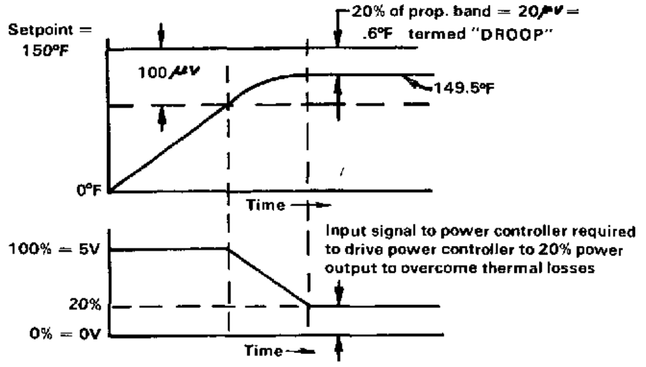


FIGURE 6
IDEAL PROPORTIONAL CONTROL
WITH THERMAL LOSSES

C. For a given SETPOINT temperature, these losses will remain constant; therefore, the **GAIN** of the controller determines how much error signal is necessary to compensate for thermal losses.

The difference between desired temperature and the actual temperature obtained is termed **PROPORTIONAL DROOP.**

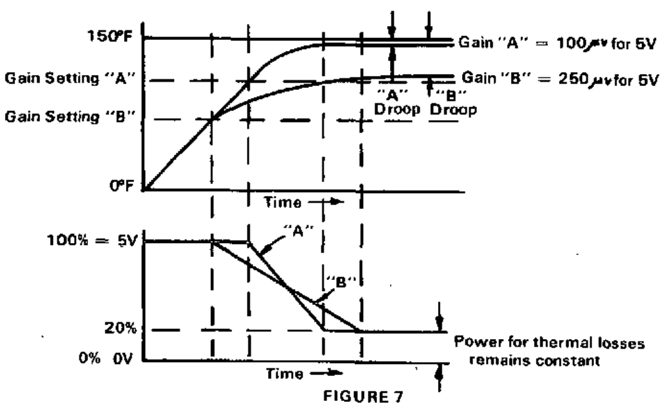


FIGURE 7

6. HOW CAN WE OVERCOME THESE LOSSES AND GET THE DESIRED TEMPERATURE WITHOUT DROOP?

The simplest method is to RESET the SETPOINT temperature to a higher setting. Doing this will also raise the resultant control point, which can be set to the desired temperature. Although this method is commonly used, it is difficult to set accurately without some external means of measuring actual control temperature.

A better method would be to utilize AUTOMATIC RESET, which automatically compensates for thermal losses without changing the SETPOINT command.

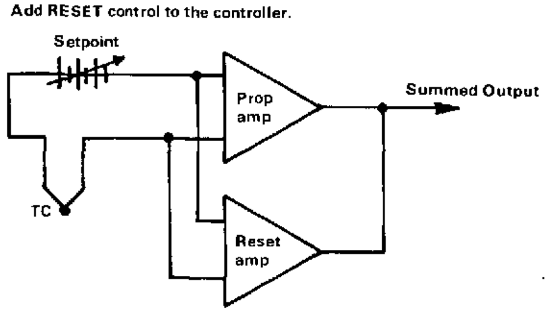


FIGURE 8
PROPORTIONAL TEMPERATURE CONTROLLER
WITH RESET ADDED

7. WHAT DOES RESET ACTION DO?

RESET action senses when the controller begins operating within the proportional band and senses when the control thermocouple reaches the desired setpoint temperature. During this period, it adds (bit by bit) more output to the proportional output. Once the thermocouple is at setpoint temperature, a sufficient amount of additional output has been **added** to the output signal to drive the power controller to the required power output to overcome thermal losses. After reaching SETPOINT, the RESET amplifier will HOLD THE ADDED OUTPUT LEVEL UNTIL CANCELLED BY PROPORTIONAL ACTION.

The RESET circuit is an adjustable rate integrator which when triggered on (at the edge of the proportional band) will generate an output voltage starting at zero and increasing at a pre-determined slope rate. When the thermocouple reaches SETPOINT, the RESET integrator action stops, and it **holds** its output at this level, which when set correctly, will correspond to the amount of output signal the power controller requires to overcome droop.

The amount of RESET action that must be used is dependent upon two basic factors: 1) the time required for the control thermocouple to reach SETPOINT temperature once it has entered the proportional band, and 2) the amount of additional output signal required from RESET action to overcome thermal losses.

Industry has standardized on a somewhat confusing method of describing RESET time, or RESET setting. The amount of RESET action is measured in "repeats per minute," or in other words, the number of times the RESET integrator could integrate between zero and full output (0-5V) within a time span of one minute. With this definition, one can determine the "slope rate" of integrating action, which is actually much more meaningful:

Do not confuse this slope rate definition with the output wave form. The output of the reset integrator does not repeat itself in a sawtooth fashion; it will integrate upwards only once.

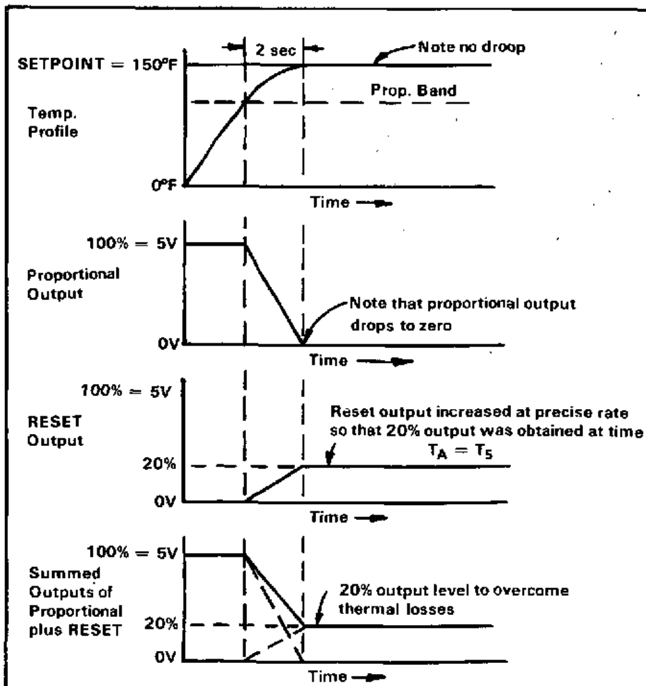


FIGURE 9
ADDING RESET TO A PROPORTIONAL
TEMPERATURE CONTROLLER

Once one has determined the approximate time required for the thermocouple temperature to advance from the edge of the proportional band to the approximate SETPOINT temperature (as shown on Figure 9), and one knows the approximate power required to overcome thermal losses, it is possible to determine the appropriate amount of RESET action required to overcome droop.

Let's assume that in our earlier example shown in Figures 6, 7, 8, and 9, we determined that 2 seconds lapsed between the time the control thermocouple entered the proportional band and when it reached setpoint temperature. We had also determined that a 20% power output level was required to overcome droop.

The RESET integrator must be set so that within this 2 second time period the integrator output will add a 20% output signal to the controller. In terms of "repeats per minute," or slope rate, 20% in 2 seconds is the same as 100% in 10 seconds or a slope rate time of 10 seconds to integrate between 0 and full output of 100%. Thus, a RESET setting of 1 repeat in 10 seconds, is 6 repeats per minute.

This example, of course, is simplified for academic purposes and one usually discovers that it is quite difficult to accurately determine the time element and thermal loss requirement without a few empirical trials. Usually one can determine the time element by observing the output meter on the temperature controller for when the indicator moves from full output to some stabilized point commensurate with thermal losses. The amount of thermal losses can be estimated by operating the system in proportional-only mode at the desired SETPOINT, and reading the OUTPUT meter. Since this meter is easily read in percent of full output, one can interpret this information (along with the time information) in terms of the required RESET setting.

A closed-loop temperature control system should always be set for stabilized operation in proportional mode prior to adding RESET action.

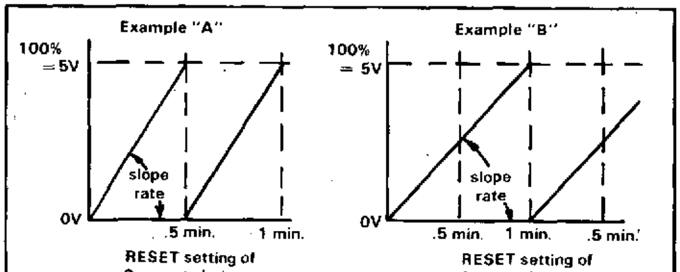


FIGURE 10

8. WHAT CAUSES THERMAL OVERSHOOT?

Up to this point, closed loop temperature control has been discussed with respect to ideal, instantaneously responding systems where no thermal lag is present. In such systems it is possible to operate as described with the overall thermal system quickly reacting to the corrective changes dictated by the temperature controller. Note, however, that all corrective output changes from the proportional amplifier occurred only when the actual temperature (T_A) was within the proportional band of control. Outside of this band, while the thermocouple temperature was approaching SETPOINT, the input to the proportional amplifier was saturated, giving full output since the magnitude of the (T_S - T_A) error signal to the proportional amplifier was greater than that required for full output. During this period of time, the system is actually out of control!

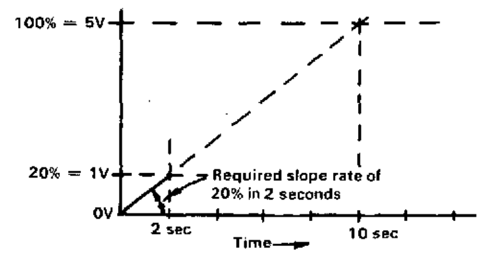


FIGURE 11

In an instantaneously responding system this characteristic is not important, since corrective action can be taken prior to reaching SETPOINT. Consider, however, the resultant operation of such a system where a **time lag** exists between application of power and sensing of power. In the previous example, proportional action began 2 seconds prior to reaching SETPOINT temperature. Upon passing through the edge of the proportional band (T_S - T_A)K became less than 5 volts, causing less power to be delivered from the power controller. Even with less power, the temperature continued to increase, but at a slower rate, until $T_A = T_S$.

If a 5-second time lag existed in this system, where 5 seconds would lapse before the thermocouple could sense a change in power to the heating element, the system would overshoot the desired SETPOINT!

The system is actually controlling the output to the power controller with respect to only one bit of information from the thermocouple, namely, **displacement from SETPOINT**, **(T_S - T_A)** and only when this error is within the proportional band.

Should this information be delayed with respect to corrective action, the thermocouple output will continue to increase at the same rate for 5 seconds after entering the proportional band, resulting in a serious overshoot before the system can respond to the first correction!

9. WHAT CAN BE DONE ABOUT OVERSHOOT?

As pointed out above, Proportional type controllers utilize only one bit of information received from the thermocouple sensor. Actually, several bits of information can be obtained from the thermocouple sensor:

a. Displacement from SETPOINT (T_S - T_A)
b. Edge of proportional band (T_S - T_A)K = 5v.
c. Null - ($T_S = T_A$)
d. Velocity (or Temperature Rise Rate) -

$$\frac{d(T_S - T_A)}{dt}$$

e. Acceleration/Deceleration (or changes in velocity)

$$\frac{d(T_S - T_A)^2}{dt^2}$$

The Proportional Controller utilizes displacement information for control, and the RESET circuit utilizes b and c above for determining turn-on and turn-off times for the integrator.

To prevent thermal overshoot, control action must occur prior to sensor temperature reaching the fixed proportional band, which was set by the operator for stabilized operation about SETPOINT. It is possible to anticipate overshoot in a control system by adding RATE control to the temperature controller.

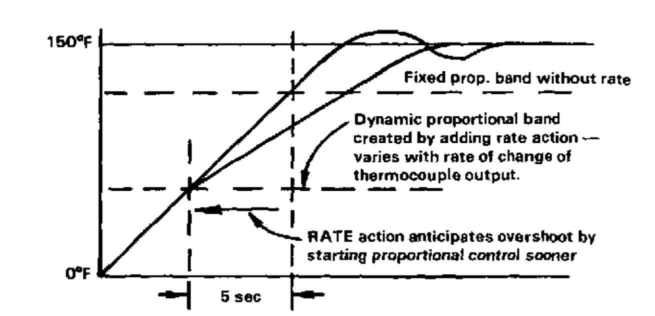


FIGURE 12
HOW WIDENING PROPORTIONAL BAND PROVIDES ANTICIPATION

RATE action is dynamic since the RATE output correction factor is dependent only upon **rate of change** in thermocouple output. When at SETPOINT, where small corrective signals exist to maintain a SETPOINT temperature, effects of RATE action are negligible since no large velocity component is generated.

When optimumly set, RATE action corrects for Thermal lag in the T_A displacement error by advancing the displacement error signal to start displacement control action in **advance** of the fixed proportional band. In effect, it "widens" the proportional band by an amount directly proportional to the velocity & thermal lag time. The result is corrective action permitting maximum allowable rise rates commensurate with the anticipated time lag of the system.

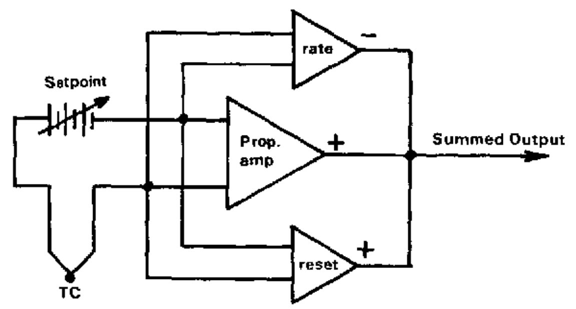


FIGURE 13
TYPICAL TEMPERATURE CONTROLLER WITH RATE AND RESET

Since velocity information is obtainable from the feedback sensor and the thermal time lag of the system is known, it is possible to develop an instantaneous displacement signal which, when properly summed with the lagging T_A displacement signal, corrects for thermal lag. The rate circuit is functionally shown in Figure 13. Velocity information $\frac{d(T_S - T_A)}{dt}$ is applied to the input of the rate amplifier. The gain of the rate amplifier is directly proportional to thermal lag time such that $\frac{d(T_S - T_A)}{dt} K$ = dynamic displacement correction.

10. HOW IS RATE TIME DEFINED AND HOW IS IT EMPLOYED IN A SYSTEM?

RATE time is generally measured in "seconds of anticipation" or its sequel, "seconds of system lag time" and should be added only after initial proportional band (gain) & reset adjustments have been made. Consider the previous example with a 5 second response lag introduced. Refer to Figure 14.

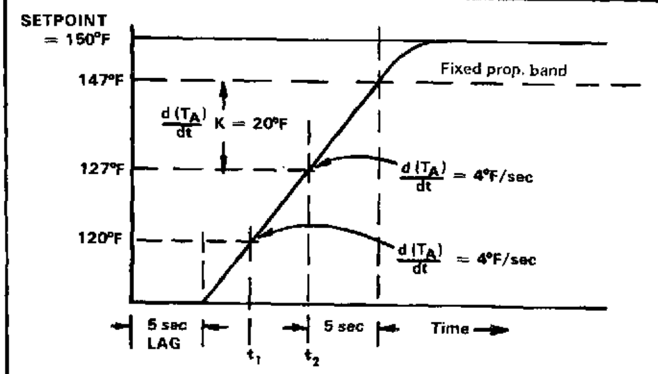


FIGURE 14
RATE ACTION CORRECTS FOR THERMAL OVERSHOOTS THROUGH THERMAL LAG COMPENSATION

A. As per the previous discussion, the fixed proportional band was assumed set for stabilized operation with a 100 uv proportional error signal for 5v output. $(T_S - T_A)$ = 100uv or (150°F - 147°F) = 3°F.

B. The system is energized and a 5 second delay is noted prior to the thermocouple sensing a change in output, therefore 5 seconds is set on the RATE control.

C. Since T_A lags the actual system temperature by 5 seconds, T_A is corrected with respect to this time lag by RATE circuit action.

D. $\frac{d(T_A)}{dt}$ represents the instantaneous thermocouple temperature rise as T_A approaches T_S.

E. $\frac{d(T_A)}{dt}$ is sensed at time t_1 to be 4°F/sec; the RATE circuit multiplies this velocity by the 5 second delay, producing a 20°F corrective signal.

F. The 20°F corrective signal is summed with the lagging T_A signal which at Time t_1 = 120°F.

G. The proportional amplifier looks at the new $T_S - T_A$ - RATE correction error signal and amplifies this error signal accordingly. However (150°F - 120°F - 20°F) is 10°F, which is greater than the 3°F minimum error signal for full output.

H. Since the corrected RATE signal did not cause the resultant error signal to enter the proportional band of control, **no action occurs.**

I. At time t_2 however, $\frac{d(T_A)}{dt}$ is still 4°F/sec., which, when multiplied by the 5 sec. delay time, is still 20°F. and now t_2 = 127°F.

J. (T_S - T_A - RATE correction) = (150° - 127° - 20°F) = 3°F. **NOW corrective RATE action begins to affect system operation.** The corrected error signal now falls at the edge of the PROPORTIONAL BAND, and dynamic proportional action will begin slowing the system thermal rise rate to prevent overshoot.

SUMMARY

In summary, proportional temperature control coupled with a proportional power controller enables precision temperature control by "throttling back" the power applied to the workpiece as the workpiece approaches the desired set point temperature. The temperature controller compares the desired SET POINT temperature with the workpiece thermocouple millivoltage $(T_S - T_A)K$ and amplifies this error difference.

The gain of the amplifier (K) determines the amount of error or difference millivoltage required to provide full output of the controller; any error signal less than this produces proportionally less than full output of the controller. This point determines the outer edge of the PROPORTIONAL BAND.

As the workpiece approaches closer and closer to the desired SET POINT temperature, the output of the controller becomes less and less, until a point is reached where the error or difference signal produces sufficient output from the temperature and power controller to provide sufficient power to overcome THERMAL LOSSES. Thus, when thermal gain equals thermal losses, the temperature of the workpiece stabilizes.

Since an error signal is always required to produce an output on the temperature controller, the point at which the system stabilizes is slightly **less** than the desired SET POINT.* This difference in temperature is termed PROPORTIONAL DROOP.

Droop can be measured on the null indicator of the temperature controller and can be overcome by one of two means:

1) Resetting the SET POINT to some slightly higher setting to achieve the desired control temperature, or

2) Add automatic reset to the controller.

AUTOMATIC RESET eliminates droop by adding an additional output signal to the temperature controller to equal the equivalent error signal required to overcome droop. The amount of RESET signal can be predetermined by the operator by:

1) Noting the percent of output needed to overcome droop by reading the percent of output indicator once the system has stabilized with proportional control, and

2) Determining the time required for the system to stabilize once the temperature controller begins proportional-type control within the proportional band. The operator can determine this easily by timing the output indicator between the time the indicator begins showing less than 100% output, to the time the indicator stabilizes at some point commensurate with thermal losses. During this time period, the RESET integrator must add to the output of the controller the percent of output shown on the percent of output indicator.

*When operating at temperatures above ambient, or in regions where thermal losses occur. When operating at temperatures below ambient, where thermal gains might occur, the system would stabilize at some point slightly **above** set point.

RESET is measured in repeats per minute, or the number of times the reset integrator can integrate between 0 and 100% of full output in one minute. As an example, four (4) repeats per minute would correspond to an integrating rate of 0 to 100% in 15 seconds. If a RESET requirement is 20% in two seconds, the operator would interpret this requirement as 20% in two seconds, which is 100% in 10 seconds, or 6 repeats per minute.

RATE control corrects for OVERSHOOT by adding a corrective signal to the lagging T_A signal. RATE circuitry **anticipates** an overshoot condition by slowing down the controller action with velocity feedback. This is accomplished by sensing the **rate of temperature change** in the control system and introducing a corrective signal to the (T_S - T_A) error signal of the controller. This correction **reduces** the overall gain of the controller which dynamically **widens** the proportional band of control with respect to **rate of temperature change and time lag** in the control system.

This dynamic action causes proportional action to begin **earlier** from the SET POINT than before, causing the system **to anticipate** overshoot by starting proportional action sooner. RATE action is measured **in seconds of anticipation or seconds of thermal lag** and is set to correspond to the thermal response time of the overall system.

The operator can easily approximate the thermal response time of the system prior to closed-loop operation utilizing a simple manually-controlled test. With the system power at zero, the operator notes the workpiece temperature, then applies power to the load. The time interval between applying power and noting a change in workpiece temperature is the response time of the overall system. This response time becomes the RATE setting required to properly anticipate overshoot.

The behavior of every closed-loop system is dependent upon many controllable variables in addition to the ones described in this primer. Thermocouple placement, thermocouple mass, thermal losses and gains also become important factors in correctly applying closed-loop temperature control to a specific application.

The intent of this primer is to acquaint the operator with the fundamentals of closed-loop temperature control, clear up vague understandings, and provide basic control setting guidelines. This information should benefit the operator of any closed-loop operation.

DATA-TRAK
PROGRAMMERS

INSTRUCTION MANUAL

MODEL FGE 5110
DATA-TRAK
PROGRAMMER

Publication Number 200100

RESEARCH INC
BOX 24064 MINNEAPOLIS, MINNESOTA USA 55424

SPECIALISTS IN HIGH-PERFORMANCE PROGRAMMING AND CONTROL INSTRUMENTATION
INFRARED HEATING · AC AND DC POWER CONTROLLERS

PHONE
MINNEAPOLIS
612-941-3300

TWX
910-576-2837

TELEX
029-5328

Model FGE 5110 DATA-TRAK PROGRAMMER INSTRUCTION MANUAL

RECORD OF REVISIONS

REVISION	DESCRIPTION
A-0	Adopted new publications number, previous number
(7/69)	was IM 707-1268. Added Record of Revisions. Revision
	of Schematic KD 33568 changed to C.
A-1	Change written 11/69. Revision C of schematic
	KD33568 omitted at time of printing and Probe
	Guide-Rod Maintenance information is incorrect.
	Changed pages A, 6-5, and sheet 2 of Schematic
	KD33568.
A-2	Reprinted with revisions 5/70. Changed page A.
	Changed option DF/R. Added options - FS51-3, PSC
	Span/Zero, AS51-X. Updated KD33568 to Rev. "D"

Publication Number: 200100

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ILLUSTRATIONS

LIST OF FIGURES

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SECTION 1 INTRODUCTION

1-1 Scope

This manual describes the Model FGE 5110 DATA-TRAK programmer, and provides information for its installation, operation and maintenance.

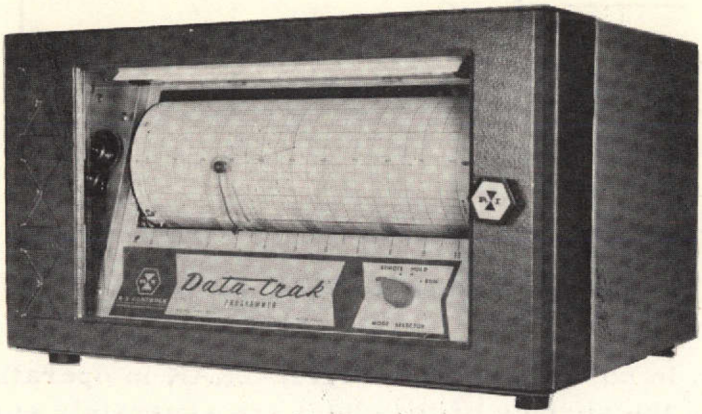


FIGURE 1-1 FGE 5110 DATA-TRAK PROGRAMMER

1-2 General Description of DATA-TRAK Operation

The DATA-TRAK Programmer is an electro-mechanical instrument designed to position the shaft of a rotary output device in accordance with variations in a preplotted program attached to a rotating drum. Several types of output devices may be utilized with the unit, including potentiometers, synchro-transmitters, differential transformers, etc., but, because of its more frequent use, a potentiometer has been selected as a representative output device in the information presented in this manual.

To accomplish its function, the DATA-TRAK employs an electrostatic curve-following system which provides the optimum in programming accuracy and reliability, while enabling the use of easily prepared programs.

A desired program curve is etched in the metalized surface of a special program chart with a sharp stylus. The stylus removes a fine line of metal from along the curve, dividing the surface of the chart into two electrically isolated conductive planes. The chart is then mounted on the outer surface of the program drum, which is subsequently installed in the DATA-TRAK.

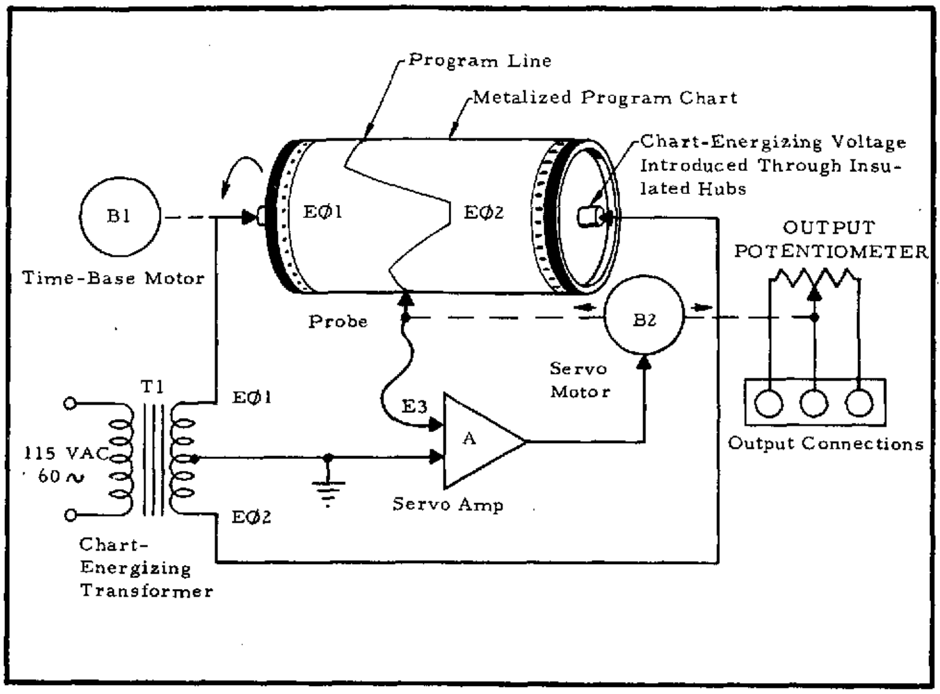


FIGURE 1-2 DATA-TRAK - SIMPLIFIED FUNCTIONAL DRAWING

With the drum in position and the DATA-TRAK in operation, the two isolated planes on the surface of the chart are separately energized by oppositely phased a-c voltages applied through the insulated hubs of the program drum. These voltages, designated E_1 and E_2 inFigure 1-2, establish an electro-static voltage gradient across the gap on the chart created by the program curve. As the drum rotates the chart past the DATA-TRAK's curve-following probe, the probe is driven by the servo-system to continually seek the zero-potential existing at the center of the program curve. The shaft of the output potentiometer is mechanically coupled to the probe through a system of pulleys. Therefore, as the probe is driven to follow the program curve, the position of the wiper on the potentiometer is varied accordingly.

The probe does not actually come in contact with the chart, but picks up a signal from the electrostatic field, which is utilized for positional reference. This "error" signal is designated E_3 inFigure 1-2, and indicates, by its phase and magnitude, the direction and extent of probe displacement from the center of the curve.

When the probe tends to the right of the curve, the error signal reflects the phase of voltage E_2, which, after amplification, causes the servo-motor to drive the probe to the left, back to the center of the curve. Conversely, when the probe tends to the left, the error signal reflects the phase of voltage E_1, which causes the probe to be driven to the right, back to the center of the curve. The speed at which probe corrections are made is proportional to the magnitude of the error signal of either polarity, which, in turn, is proportional to the extent of probe deviation from the center of the curve. Minute deviations cause relatively slow correction rates, which are increased proportionally to maximum as probe deviations widen to equal approximately one percent of the program-chart scale.

1-3 DATA-TRAK SPECIFICATIONS

The DATA-TRAK employs circuitry composed entirely of solid-state components, thus providing the optimum in extended troublefree programming operation. A detailed schematic drawing of the instrument is located at the rear of this manual; the electrical and mechanical specifications are listed in the following table.

TABLE 1-1 SPECIFICATIONS and CHARACTERISTICS

Input Power - - - - - - - - - - - - -	0.5 Ampere at 115 VAC, 60 HZ
Time-Base - - - - - - - - - - - - - -	Adjustable from 3/4 inch per hour to 4 inches per second by gear and/or motor change. Other speeds available by special request.
Time-Base Accuracy - - - - - - - -	1-percent of elapsed time.
Metallized Chart Paper - - - - - -	Research # CMS51
Maximum Follow Rate - - - - - - --	7 inches per second.
Dead Band - - - - - - - - - - - - - -	0.01% of full scale
Repeatability - - - - - - - - - - - - -	0.05% of full scale.
Standard Output Potentiometers	
Type - - - - - - - - - - - - -	3-Turn Spectrol or Helipot
Resistance - - - - - - - - -	1000 ohms, ± 1%
Linearity - - - - - - - - - -	0.2%
(Other resistances and linearities available)	
Quantity - - - - - - - - - -	Provisions have been made for mounting up to four 3-gang output potentiometers in the DATA-TRAK.
Dimensions for rack mounting - - -	10-1/2" high, 19"wide, 15" deep

SECTION 2 INSTALLATION

2-1 General

The DATA-TRAK may either be flush- or face-mounted in an instrument panel, or enclosed in an instrument case for portability (Figure 1-1). Information required for panel-mounting the DATA-TRAK, and for connecting external wiring to the unit for standard operation is provided under the following headings.

2-2 Panel-Mounting the DATA-TRAK

Panel-cut-out dimensions and other pertinent information for either flush- or face-mounting the DATA-TRAK are provided in Figure 2-1.

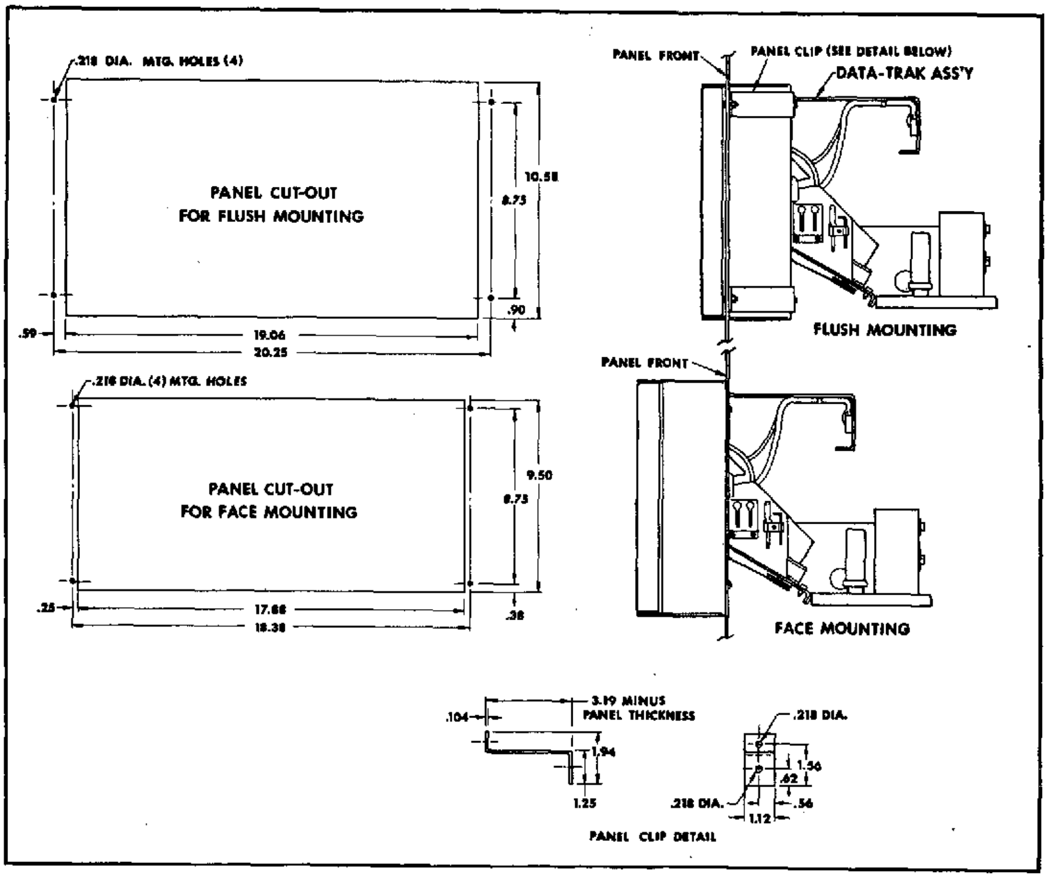
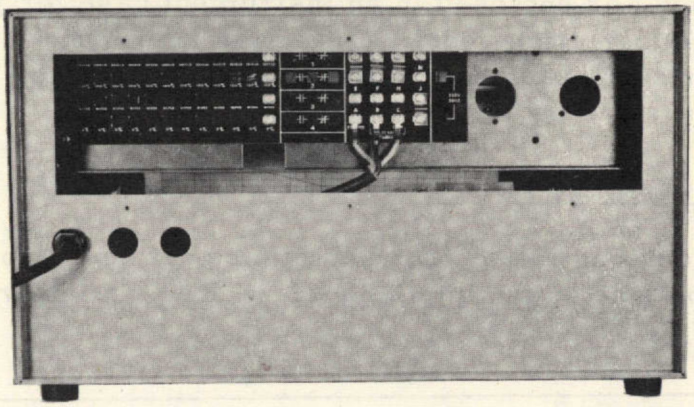


FIGURE 2-1 PANEL-MOUNTING the DATA-TRAK

2-3 DATA-TRAK External-Wiring Connections

All external wiring connects to terminals on the entrance board, which is mounted on a flange located at the rear of the DATA-TRAK assembly (see Figure 2-2). These terminals are accessible from the rear by remains the rear access panel.



NOTE: Entrance board may be reversed for front access.

FIGURE 2-2 DATA-TRAK ENTRANCE BOARD

Standard external-wiring connections are described under the following headings; wiring for special run-control functions is described in Section 5.

2-3-1 A-C Input Connections

A 3-wire appliance cord is utilized to energize the DATA-TRAK with operating voltage. The wires of this cord connect to terminals of the entrance board as follows:

STANDARD		220VAC 50Hz OPTION
A-C High	Terminal B	As indicated on entrance board
A-C Common	Terminal C	
Ground	Terminal A	

2-3-2 Potentiometer-Cable Connections

Wiring from up to twelve output potentiometers may be connected to the terminals of the entrance board. The numbering sequence of the output potentiometers, and the system by which their terminals are wired to the entrance board are shown in Figure 2-3. (If more than one 3-gang potentiometer is utilized, the additional terminals required are wired in like manner.)

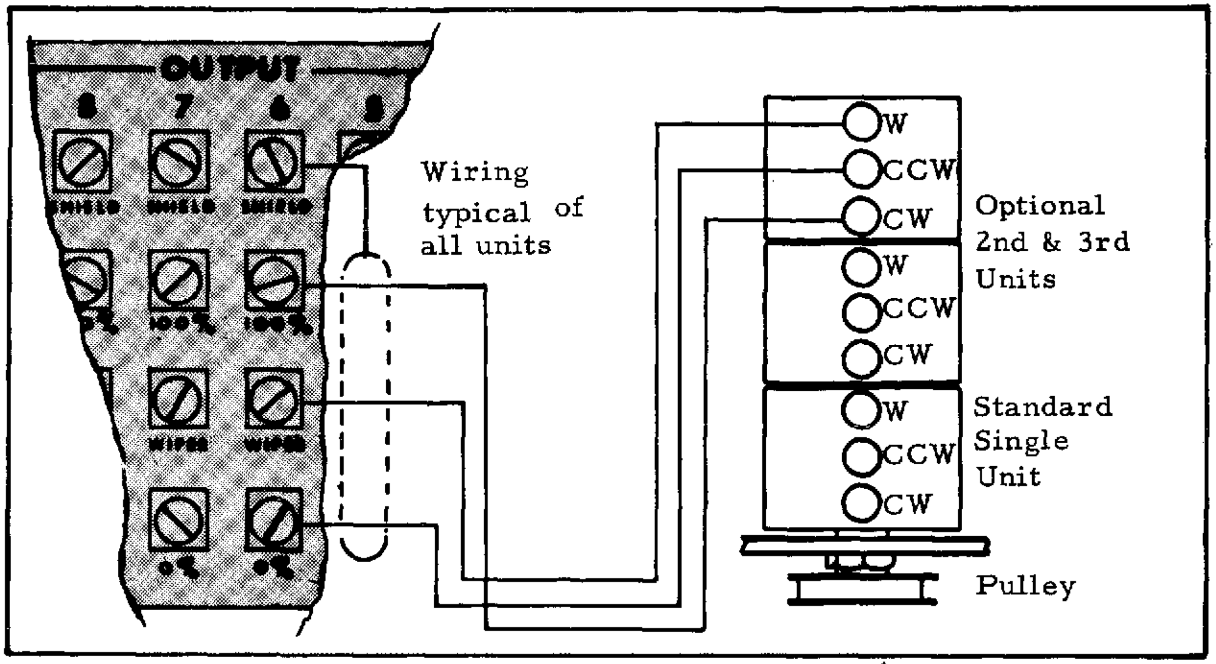


FIGURE 2-3 POTENTIOMETER CABLE CONNECTIONS

2-3-3 PROGRAM FUNCTION SWITCHES Connections (Optional)

Wiring from contacts of relays actuated at selected points in the program is terminated at terminals of the entrance board as shown in Figure 2-4. The manner in which external wiring is connected to these terminals to initiate or terminate selected external functions is left to the choice of the customer. This optional feature is fully described in Section 8.

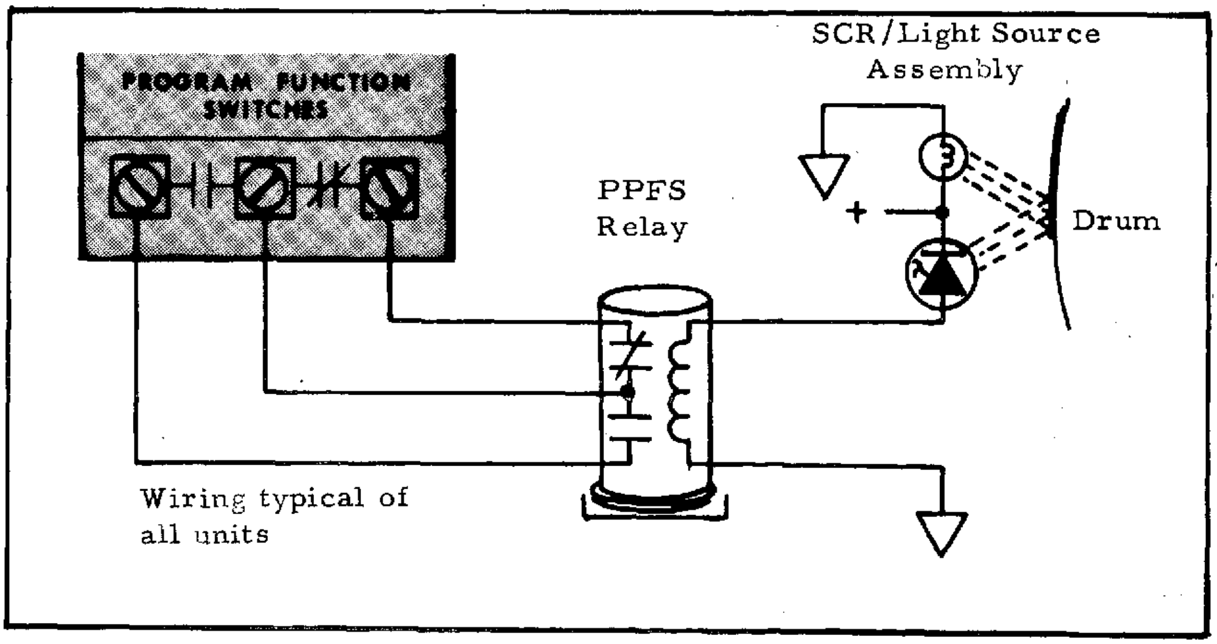


FIGURE 2-4 PROGRAM-FUNCTION-SWITCH RELAY WIRING

3-1 General

Operating controls, and indicators for monitoring the status of the DATA-TRAK are listed and described under the following headings.

3-2 MODE SELECTOR Switch

This 4-position rotary switch (S1 on the DATA-TRAK schematic drawing) is the only control mounted on the front panel of the DATA-TRAK. The function of the switch in each of its four positions is as follows:

1) OFF - Deenergizes all circuits in the DATA-TRAK.

2) REMOTE - Energizes the servo-circuits, but establishes drum-rotation as a function of external run-controls (see information in Section 5).

3) HOLD - With drum initially rotating under either remote or local control, switching to HOLD position deenergizes the a-c drum motor, and discharges a surge of d-c current through its windings (see note below) to provide instantaneous braking. (The servo-circuits remain energized during a HOLD interval.)

4) RUN - Energizes the drum-drive motor to initiate a programming operation, or to restart from HOLD condition. Also applies power to a half-wave rectifier circuit which charges a capacitor with drum-braking current in preparation for a HOLD initiation.

NOTE

Cramer time-base motors do not require current braking, therefore, motor-brake-capacitor C5 (see schematic) is not installed in DATA-TRAK's utilizing these units.

3-3 GAIN Control

This 1-turn trimpot is mounted on the servo-amplifier printed-circuit board; it provides a means for adjusting the band-of-proportional-control by increasing or decreasing the sensitivity of the amplifier (see information under Heading 4-10).

3-4 DRUM-LIMIT Switch

This microswitch is actuated at any arbitrary point within a drum-revolution by appropriately attaching a trip-tab to the scaled edge of the drum, as shown in Figure 4-3.

When actuated, the switch deenergizes the drum-drive motor and applies d-c braking current to its windings to terminate a programming operation. (The trip-tab must be manually rotated past the switch by grasping the edges of the drum and turning it against the slip-clutch before operation can be resumed.)

3-5 Auxiliary Switch

This microswitch is actuated at arbitrary points within a drum-revolution by appropriately attaching one or more auxiliary trip-tabs on the scaled-edge of the drum, as shown in Figure 4-3. Wiring for its single-pole double-throw contacts is terminated at the entrance board, (see DATA-TRAK schematic) to facilitate external connection for such optional functions as:

1) Energizing or deenergizing external circuits at precise points in the program.

2) Stepping an external drum-revolution counter during continuous-rotation applications.

Refer to Section 5 for detailed external-hookup information.

3-6 Percent-of-Run Indicator

A pointer is attached to the inner-right-hand frame, adjacent to the scaled edge of the program drum, and in line with the center of the program probe. As the drum rotates, a coarse percent-of-run time is indicated by the scale division directly opposite the stationary pointer.

3-7 Percent-of-Scale Indicator

A pointer attached to the probe-carriage, in conjunction with the scale provided on the front panel of the DATA-TRAK, is utilized as a coarse indicator of probe position on the program chart. (Tapped holes have been provided at either end of the standard scale to enable installation of special scales.)

SECTION 4 PRE-OPERATION SET-UP PROCEDURES

4-1 General

This section of the manual describes the procedures required to set up the DATA-TRAK for standard operations. Preparations for special applications are described in Section 5.

4-2 Program Preparation*

In the following information, it is assumed that the system to be programmed by the DATA-TRAK is capable of controlling variations in a selected parameter (load, pressure, temperature, etc.) over a range to be represented by from zero to 100 percent on the program chart; and further, that the variations are proportionally controlled in response to a signal which may be varied from minimum to maximum by the output potentiometer.

4-2-1 Program Sheet Layout

The program sheet (see Figure 4-1) is scaled to provide reference line for both "X" and "Y" coordinates. The "Y" axis is scaled from zero to 100 percent in 1/2% steps, representing the relative range of variability of a selected parameter.

The "X" axis has reference lines spaced at 1/4 inch intervals, representing divisions of time within a selected time-base.

The time-base of a program is arbitrarily determined by selection among various combinations of change-gears to be utilized with a particular drum-drive motor and gear train. This must be done before plotting a program curve to establish the relative value of the time-divisions on the sheet.

For example, if it is desired to plot a program which is to run for four and one-half hours, each of the 54 time-divisions on the chart will represent 5 minutes (270 minutes/54 time-divisions).

With the time-base known, and assuming that the desired variations of the selected parameter have been established with respect to time, the program curve may be plotted directly on the program sheet as described under the following Heading.

* For strip-chart and programmable-function-switch program preparation, see information in Section 8.

4-2-2 Plotting the Program Curve

Place the program sheet on a smooth clean surface in a manner which positions the zero-line of the "Y" axis vertically and toward the left hand of the viewer, as shown in Figure 4-1, A. In this position, the bottom edge of the chart is the program starting point and the top edge is the ending point.

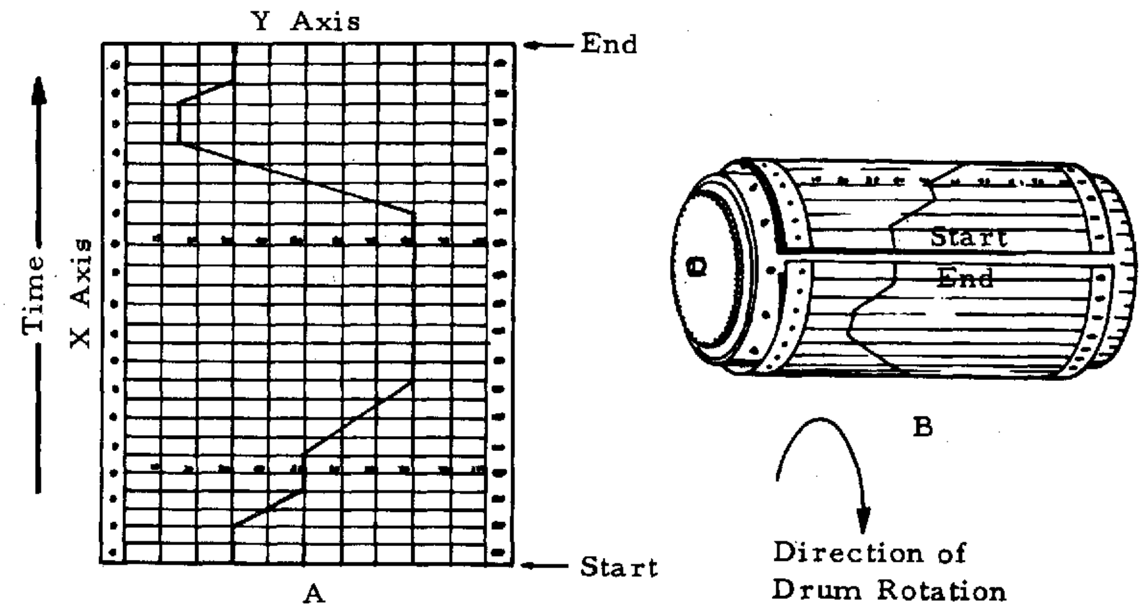


FIGURE 4-1 PROGRAM CHART PREPARATION

The program should be plotted in a manner which initiates and terminates the curve at identical levels on the "Y" axis if continuous rotation is anticipated (see Figure 4-1, B). The curve is drawn with the aid of standard drafting triangles, curves, and a needle-point stylus (part #PS53), progressing time-wise from bottom to top of chart.

4-2-3 Checking the Program Curve

As previously stated, after a program curve has been etched on the chart, the metallized surfaces on either side of the curve should be electrically isolated from one another. This can usually be ascertained by visual inspection; flecks of metal that may not have been removed from the gap created by the program curve show up quite readily with the program held to a light sources as the backing is transluscent.

If desired, an ohmmeter may be utilized to check for the necessary infinite resistance between the two surfaces. However, due to the low conductivity of the carbon combined with the zinc-oxide coating, a careful visual inspection is recommended for all programs.

4-3 Change-Gear Selection

Proper selection of change-gears for a desired chart speed is accomplished with the aid of the chart in Table 4-1. The chart is divided into two sections by a relatively heavy vertical line; the right-hand section lists speed-ranges involving the high-speed gear train, and the left-hand section lists those for the slow-speed gear train. The double columns for each of the speed-ranges (from I through XI on the bottom of the chart) are headed by a numbered box which designates the rpm of an associated motor. With the particular motor and gear-train installed in the DATA-TRAK known, it is only necessary to go down the appropriate double-column until the desired chart speed is found, and then trace directly across the chart to the extreme left-hand column, which lists the proper change-gear combination for the selected speed. Chart speed is shown both in time-per-inch, and in time-per-drum-revolution.

TABLE 4-1 CHANGE-GEAR SELECTION CHART

FGE 5110 CHART SPEEDS																							
MOTOR SPEED (RPM)		1/8		1/4		1/2		1		2		4		10		60		4		10		60	
GEAR TRAIN		SLOW SPEED																HIGH SPEED					
CHANGE GEARS		INCH/DAY	DAYS/REV	INCH/DAY	DAYS/REV	INCH/DAY	DAYS/REV	INCH/HR	HRS/REV	INCH/HR	HRS/REV	INCH/HR	HRS/REV	INCH/HR	HRS/REV	INCH/MIN	MIN/REV	INCH/MIN	MIN/REV	INCH/MIN	MIN/REV	INCH/SEC	SECS/REV
LETTER PAIR	TEETH																						
C/H	16/64	1 1/8	12	2 1/4	6	4 1/2	3	3/8	36	3/4	18	1 1/2	9	3 3/4	3 6/10	3/8	36	1	13 1/2	2 1/2	5 4/10	1/4	54
A/B	15/50	1 7/20	10	2 7/10	5	5 2/5	2 1/2	9/20	30	9/10	15	1 8/10	7 1/2	4 1/2	3	9/20	30	1 1/6	11 1/4	3	4 1/2	3/10	45
J/N	24/72	1 1/2	9	3	4 1/2	6	2 1/4	1/2	27	1	13 1/2	2	6 3/4	5	2 7/10	1/2	27	1 1/3	10 1/8	3 1/3	4 1/20	1/3	40 1/2
K/M	32/64	2 1/4	6	4 1/2	3	9	1 1/2	3/4	18	1 1/2	9	3	4 1/2	7 1/2	1 8/10	3/4	18	2	6 3/4	5	2 7/10	1/2	27
D/G	30/50	2 7/10	5	5 2/5	2 1/2	10 4/5	1 1/4	27/30	15	1 8/10	7 1/2	3 3/5	3 3/4	9	1 1/2	9/10	15	2 2/5	5 5/8	5 5/8	2 2/5	5/9	22 1/2
E/F	32/48	3	4 1/2	6	2 1/4	12	1 1/8	1	13 1/2	2	6 3/4	4	3 3/8	10	1 7/20	1	13 1/2	2 2/3	5 1/16	6 2/3	2 1/40	2/3	20 1/4
L/L	48/48	4 1/2	3	9	1 1/2	18	3/4	1 1/2	9	3	4 1/2	6	2 1/4	15	9/10	1 1/2	9	4	3 3/8	10	1 7/20	1	13 1/2
F/E	48/32	6 3/4	2	13 1/2	1	27	1/2	2 1/4	6	4 1/2	3	9	1 1/2	22 1/2	6/10	2 1/4	6	6	2 1/4	15	9/10	1 1/2	9
G/D	50/30	7 1/2	1 4/5	15	9/10	30	9/20	2 1/2	5 2/5	5	2 7/10	10	1 7/20	25	27/50	2 1/2	5 4/10	6 2/3	2 1/40	16 2/3	81/100	1 2/3	8 1/10
M/K	64/32	9	1 1/2	18	3/4	36	3/8	3	4 1/2	6	2 1/4	12	1 1/8	30	9/20	3	4 1/2	8	1 11/16	20	27/40	2	6 3/4
N/J	72/24	13 1/2	1	27	1/2	54	1/4	4 1/2	3	9	1 1/2	18	3/4	45	3/10	4 1/2	3	12	1 1/8	30	9/20	3	4 1/2
B/A	50/15	15	9/10	30	9/20	60	9/40	5	2 7/10	10	1 7/20	20	27/40	50	27/100	5	2 7/10	13 1/3	1 1/80	33 1/3	81/200	3 1/3	4 1/20
H/C	64/16	18	3/4	36	3/8	72	3/16	6	2 1/4	12	1 1/8	24	9/16	60	9/40	6	2 1/4	16	27/32	40	27/81	4	3 3/8
SPEED RANGE		VIII		IX		X		XI		I		II		III		IV		V		VI		VII	

ORDERING INFORMATION: CALL OUT MODEL FGE 5110-SS-60-CH (SS = GEAR TRAIN; CH = GEAR SET; 60 = DRUM MOTOR)

As indicated on the chart, each set of change-gears (except LL) are utilized to provide two chart speeds with each of the motor/gear-train combinations. This depends on their relative position in the drum-drive assembly, as described under the following Heading.

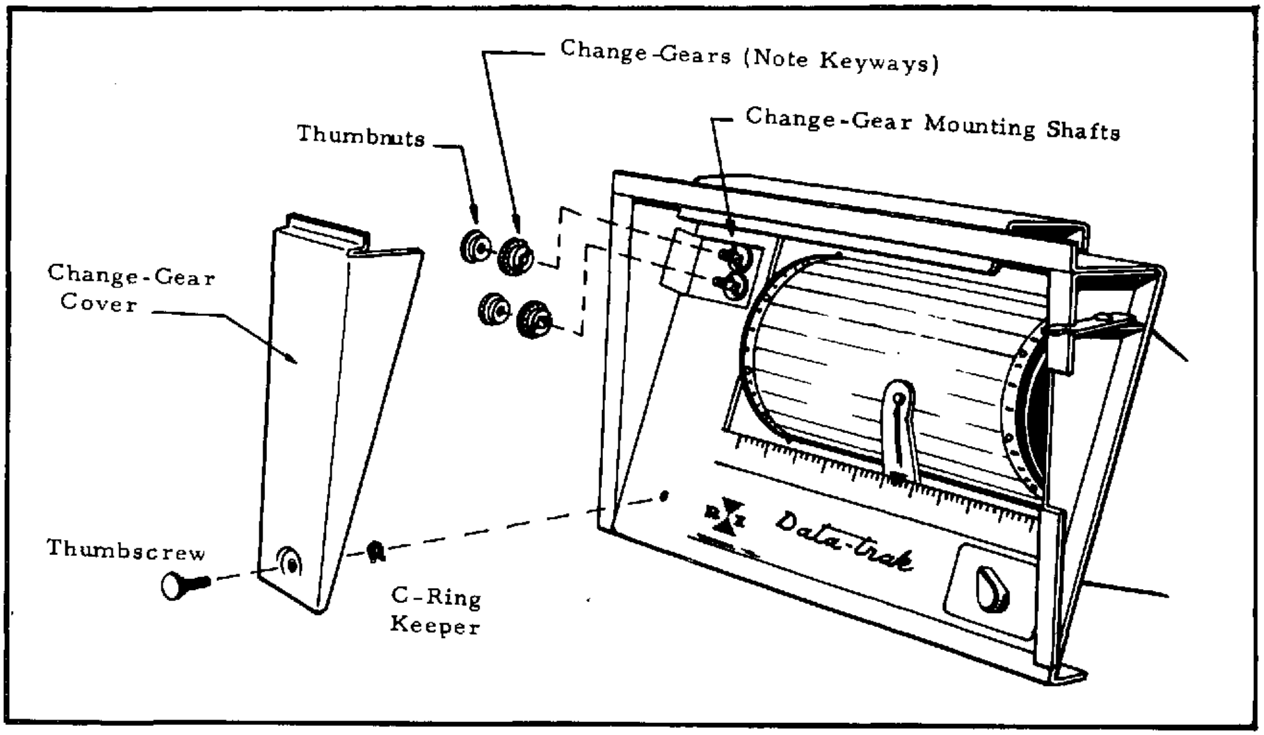


FIGURE 4-2 CHANGE-GEAR ACCESS and MOUNTING POSITIONS

4-4 Installing Change-Gears

The change-gear mounting-shafts are located under the removable cover on the face of the DATA-TRAK electro-mechanical assembly, as shown in Figure 4-2.

The two mounting-shafts are vertically aligned, therefore, to provide easy mounting reference, the combination of change-gears letters for the various speed selections are also vertically aligned in the right-hand column of Table 4-1. To illustrate, the gear represented by the upper letter in a combination must be mounted on the upper change-gear shaft, and the gear represented by the lower letter must be mounted on the lower shaft to obtain an indicated speed. (Mounting the smaller of the two gears of any combination on the upper shaft results in the slower of two possible speeds.)

After removing the thumb-screw which secures the cover to the face of the DATA-TRAK, installation of change-gears is accomplished as follows:

1) Remove the knurled thumb-nuts from each of the two shafts, and slip off the change-gears to be replaced.

2) Install the selected change-gears on the upper and lower shafts as indicated for the desired speed.

3) Secure the gears to the shafts with the thumb-nuts, ensuring that the teeth of the gears are meshed, and that the keyed hubs on the shafts are properly engaged with the keyways on the backs of the gears.

4) Re-cover the assembly to complete the installation.

4-5 Detaching Program Drum

The program drum must be detached from the DATA-TRAK before the program chart can be properly attached to its outer surface; this is accomplished as follows:

1) Unlatch the DATA-TRAK door and swing the hinged electro-mechanical assembly out of the cabinet.

2) Grasp the left-hand edge of the drum (as seen from the rear) with fingertips, and pivot it free from its latching mechanism.

3) Holding both ends of the drum securely, free it from the assembly by lifting outward and to the left.

4-6 Mounting Chart on Program Drum

The starting point of the program (refer to Figure 4-1) can be aligned (approximately) with the zero-percent-of-run indication on the scale inscribed around one end of the drum. The chart must then be wrapped around the outer surface of the drum in a direction opposite to drum-rotation, taking care to properly engage the drum-sprockets with the holes in the edges of the chart. The elongated holes must be engaged with the sprockets on the scaled (right-hand) end of the drum.

The chart has been accurately cut to a length of 13.5 inches, and its opposite ends will meet squarely, forming a precise butt-joint which must be taped together to secure the chart to the drum. (The tape does not interfere with probe signal pickup).

After taping the chart to the drum, six chart-energizing insert pins must be installed in the drum through the holes at the edges of the chart. There are three pins for each edge of the chart; two must be inserted, one on either side of the butt joint, and the third must be inserted approximately half-way around the circumference of the drum.

4-7 Attaching Trip-Tabs to Program Drum

The Drum-Limit and Auxiliary microswitches are positioned approximately 3.5 major drum-scale divisions from the tip of the curve-following probe, in the direction of drum rotation. Therefore, to properly stop with a selected point in the program curve directly under the probe, the Drum-Limit trip-tab must be attached to the drum in a position which leads the selected stopping point by 3.5 major scale-divisions, as shown in Figure 4-3. The same is true for the Auxiliary trip-tab, which must lead the point in the program where it is desired to initiate special external functions, such as described in Section 5.

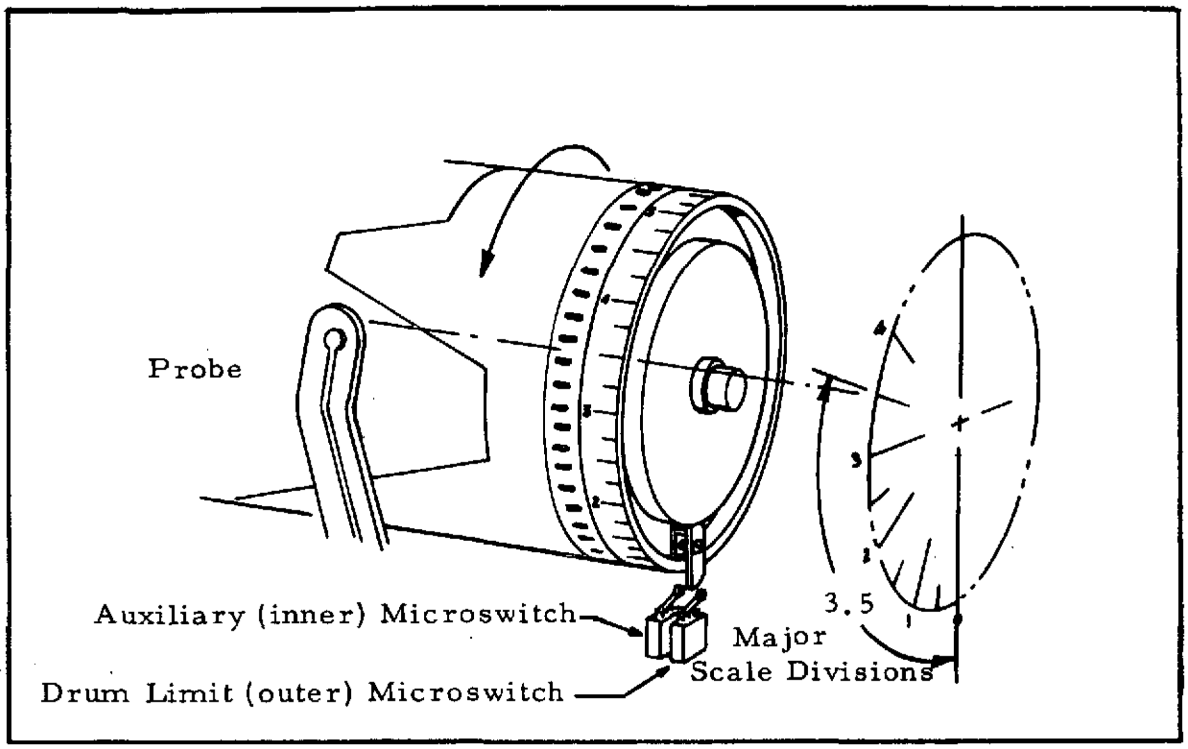


FIGURE 4-3 ATTACHING TRIP TABS ON DRUM

The trip-tabs are inserted in the slot on the scaled end of the drum as shown in 4-3; tightening the screw in the tab assembly provides a compression fit which locks the unit in place. The straight trip-tab actuates the outer (drum-limit) microswitch; the double-angled tab actuates the inner (auxiliary) microswitch.

4-8 Installing Program Drum in DATA-TRAK

Lift the program drum from the work surface with fingertips, grasping it securely by the rim at either end. Engage the geared end of the drum in the DATA-TRAK first; then pivot the free end into position snapping it in place. Swing the DATA-TRAK assembly back into its housing, where it will automatically latch closed.

4-9 Initiating a Programming Operation

With the DATA-TRAK prepared for operation, switch the MODE-SELECTOR to HOLD position.

After the probe has been driven to the center of the program curve by the servo circuits, the MODE-SELECTOR may be switched to RUN. The programming operation will then run to completion, requiring no further operator intervention unless the conditions described under the following Heading are noted.

4-10 GAIN Control Adjustment

If, after drum-rotation is initiated, the probe appears sluggish in following the program curve, or, if oscillation is apparent, maladjustment of the GAIN control is indicated. The setting of the GAIN control establishes the width of the band-of-proportional-control. This control band may be defined as that distance the probe may deviate from the center of the program-curve before maximum corrective torque is produced by the servo-motor.

Since mechanical circuitry cannot respond as rapidly as its electronic counterpart, setting the GAIN control too high will cause probe-overshoot, which, if pronounced, will result in oscillation. Setting the control too low decreases overall system response, causing the probe to lag behind the curve during program intervals demanding rapid follow rates.

Proper setting of the GAIN control matches the electronic response to the mechanical response of the system, resulting in smooth, precise curve-following within the design limits of the instrument.

To adjust the response of the DATA-TRAK, swing out the electro-mechanical assembly from its housing. Then, with the unit in operation, turn the GAIN adjusting trimpot clockwise until probe oscillation is noted; then turn the screw counter-clockwise just enough to damp out the oscillations.

After this adjustment has been accomplished for an individual DATA-TRAK, the GAIN control should require no further attention unless the mechanical load on the servo-system is altered by either the addition of one or more potentiometers, or by slippage in the pulley-drive system. (See information under Heading 6-4 for drivecable retensioning procedures).

NOTE

If oscillations cannot be induced by adjustment of the GAIN trimpot, and hence, the response of the DATA-TRAK cannot be adjusted for optimum performance, improper spacing of the DATA-TRAK probe is indicated. Refer to Heading 6-8 for probe-spacing procedure.

SECTION 5 STANDARD and SPECIAL RUN-CONTROL WIRING

5-1 General

To enable a variety of special run-control applications, all control wiring is connected to the CONTROLS section of the entrance board where jumper-wires may be added or removed, and external wires connected as required for particular special functions.

Standard wiring of the terminals and two alternate wiring methods are shown in Figure 5-1 and described under the following headings.

5-2 Standard Wiring

For clarity, the terminals are not shown in their normal sequential order in Figure 5-1. Also, the internal DATA-TRAK wiring and components are shown but once since it is identical in each of the two additional examples.

It can be seen from the wiring illustrated in example A, that the servo-circuits are energized when the MODE-SELECTOR switch is in any position except OFF, but, to energize the Drum-Drive Motor, it is necessary that the MODE-SELECTOR be in RUN position, and the Drum-Limit switch be in normally closed condition. With the Drum-Drive motor energized, power is also applied to the half-wave rectifier circuit, where d-c current is stored in capacitor C5 * in preparation for dynamic braking of the motor at a subsequent stop. A stop may be initiated by either of the following means:

1) Manually switching the MODE-SELECTOR from RUN to HOLD. This action disrupts a-c voltage to the motor, and connects capacitor C5 into the circuit. The d-c current stored in the capacitor during a RUN is discharged through the motor windings, causing it to instantly stop. (Note that servo-circuits remain energized during a HOLD).

2) Actuation of the Drum-Limit switch by a trip-tab mounted on the program drum; this action causes results identical to those caused by manually switching the MODE-SELECTOR for RUN to HOLD. The significance of the Drum-Limit switch is that a run may be automatically terminated by its actuation at an arbitrary point in the program, thereby eliminating the necessity of operator intervertion. Normally, the trip-tab is positioned on the drum to terminate operation after one complete program cycle.

External wiring of the Auxiliary switch, which is optional with the customer, is discussed under Heading 5-4.

*Capacitor C5 is not used with Cramer motors

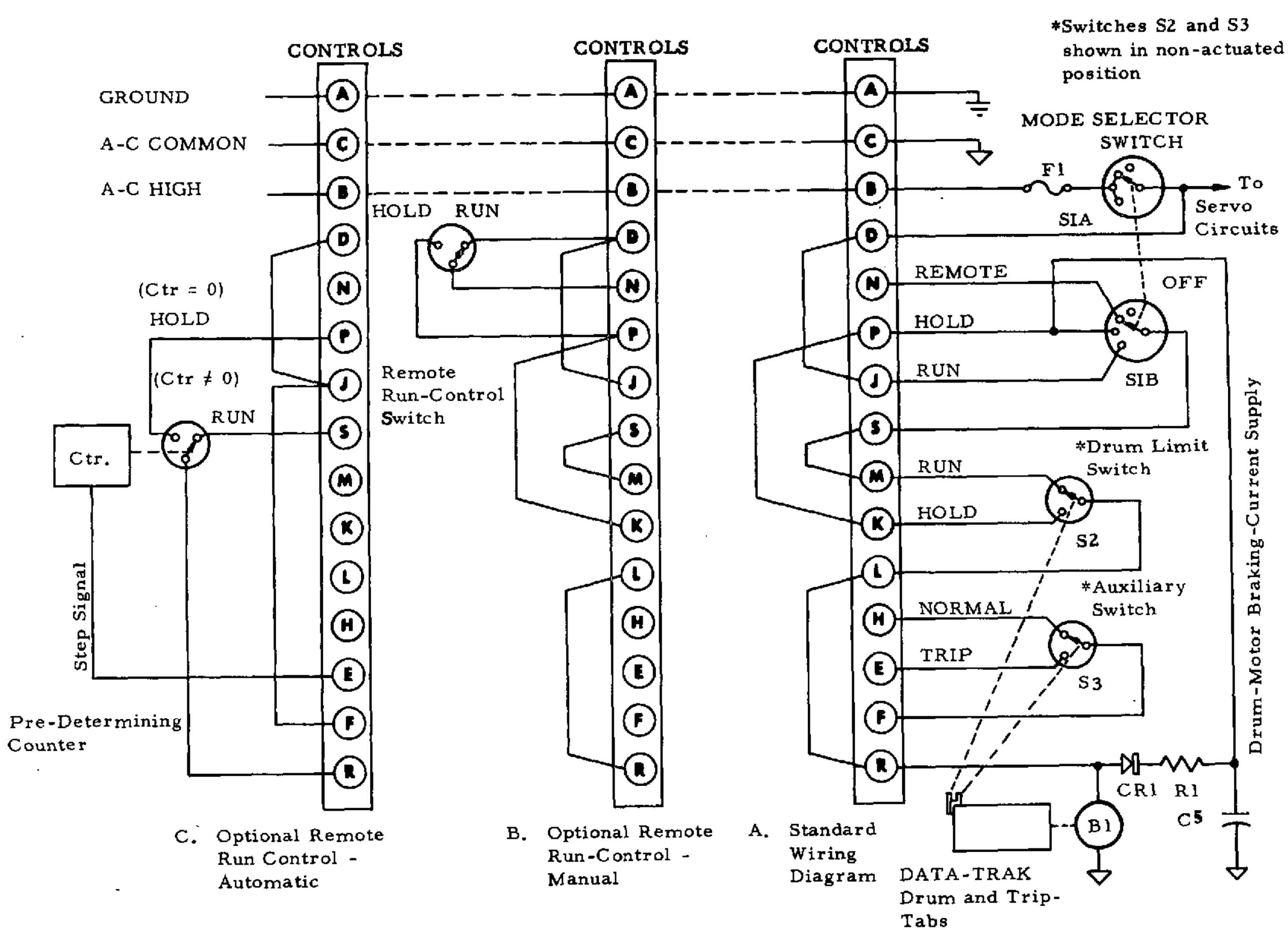


FIGURE 5-1 MODEL 5110 DATA-TRAK STANDARD/SPECIAL RUN-CONTROL WIRING DIAGRAM

5-3 Remote Run-Control Switch

Example B in Figure 5-1 illustrates the manner in which an external remote-control switch may be connected to the DATA-TRAK. No changes in the standard wiring of the terminals are required for this application; just connect three wires from the external switch to the terminals as shown in the figure. The remote-control switch will be enabled to initiate a RUN or HOLD only when the MODE-SELECTOR is switched to REMOTE; either drum-motor a-c energizing current or d-c braking current will then be allowed to pass through the remote switch, through the REMOTE contacts of the MODE-SELECTOR, and on through the Drum-Limit switch to the drum-drive motor.

The function of the Drum-Limit switch in this application is identical to that described under Heading 5-2.

5-4 Remote Program - Cycle Control

For applications requiring continuous drum-rotation for a predetermined number of program cycles, the run-control circuits of the DATA-TRAK may be connected to an external predetermining counter as shown in example C in Figure 5-1.

During operation, the program drum will continuously rotate until the counter has been stepped to zero from an arbitrary number set up in its register. At this time, a single-pole double-throw switch (or series of switches) will be actuated to deenergize the drum-drive motor, and discharge the d-c braking current through its windings. The stepping of the counter is accomplished by means of the Auxiliary switch, which is actuated by its trip-tab to energize the stepping coil of the counter once for each drum revolution.

5-5 Summary

The examples shown in Figure 5-1 are not intended to represent all possible external connections for special functions, but are merely presented as a basis for a clear understanding of the circuitry involved. A number of additional optional applications of the run-control circuitry are listed below and on the following page.

1) A remote run-control switch may be connected to the circuitry of example C exactly as shown in example B. This will enable both remote run- and program-cycle control.

2) to enable unlimited, continuous drum revolution, no rewiring is required; simply remove the drum-limit trip-tab from the program drum.

3) Any timing device capable of operating a single-pole double-throw switch may be substituted for the pre-determining counter shown in example C, freeing the auxiliary switch for other functions such as energizing or deenergizing various external circuits at precise points in the program.

4) If two auxiliary switches are required for an operation in unlimited or predetermined program-cycle applications, the Drum-Limit switch may be utilized along with the standard Auxiliary switch for this purpose. Three jumpers must be removed from the entrance board (from "S" to "M", from "P" to "K", and from "L" to "R") as they are in example C of Figure 5-1. External wiring may then be connected to terminals "M", "L", and "K" in a manner appropriate for the particular function desired. If this is done, a jumper must be installed between terminals "S" and "R" to enable the drum-drive circuits.

6-1 General

Although minimum maintenance is required for the DATA-TRAK, it must be accomplished at regular intervals to ensure trouble-free operation. The frequency at which the following procedures are to be performed will be determined by the environmental conditions under which the unit is operated.

6-2 Cleaning

The entire unit must be periodically vacuum-cleaned to prevent accumulations of dust. (Since the door of the DATA-TRAK housing is equipped with a dust-seal, keeping it closed as much as possible will minimize dust penetration).

6-3 Lubrication

6-3-1 Gear Train

With the exception of the change-gears, which require only to be kept free of dust, all gears in the gear-train must be wiped clean and lightly regreased at regular intervals.

6-3-2 Motors

Bodine, Cramer, and Globe motors are utilized with the DATA-TRAK for probe- and drum-drive. All motors are sealed units, requiring no additional lubrication.

6-4 Drive-Cable Adjustments and Restringing Procedures

6-4-1 Tension Adjustment

Under normal conditions, the drive-cable will remain serviceable indefinitely, requiring only retensioning from time to time if slippage is indicated by the necessity of frequent potentiometer alignment (see Heading 6-5). Retensioning is accomplished by loosening the lock-screw on the tension-adjust pulley (see Figure 6-1), and sliding the unit to left (as seen from rear of chassis) just enough to take up excessive slack, and then relocking it in position.

6-4-2 Restringing the Drive-Cable

If it becomes necessary to replace the drive-cable refer to Figure 6-1, and proceed as follows:

1. Loosen the two set-screws in the potentiometer pulley and remove the unit from the potentiometer shaft.

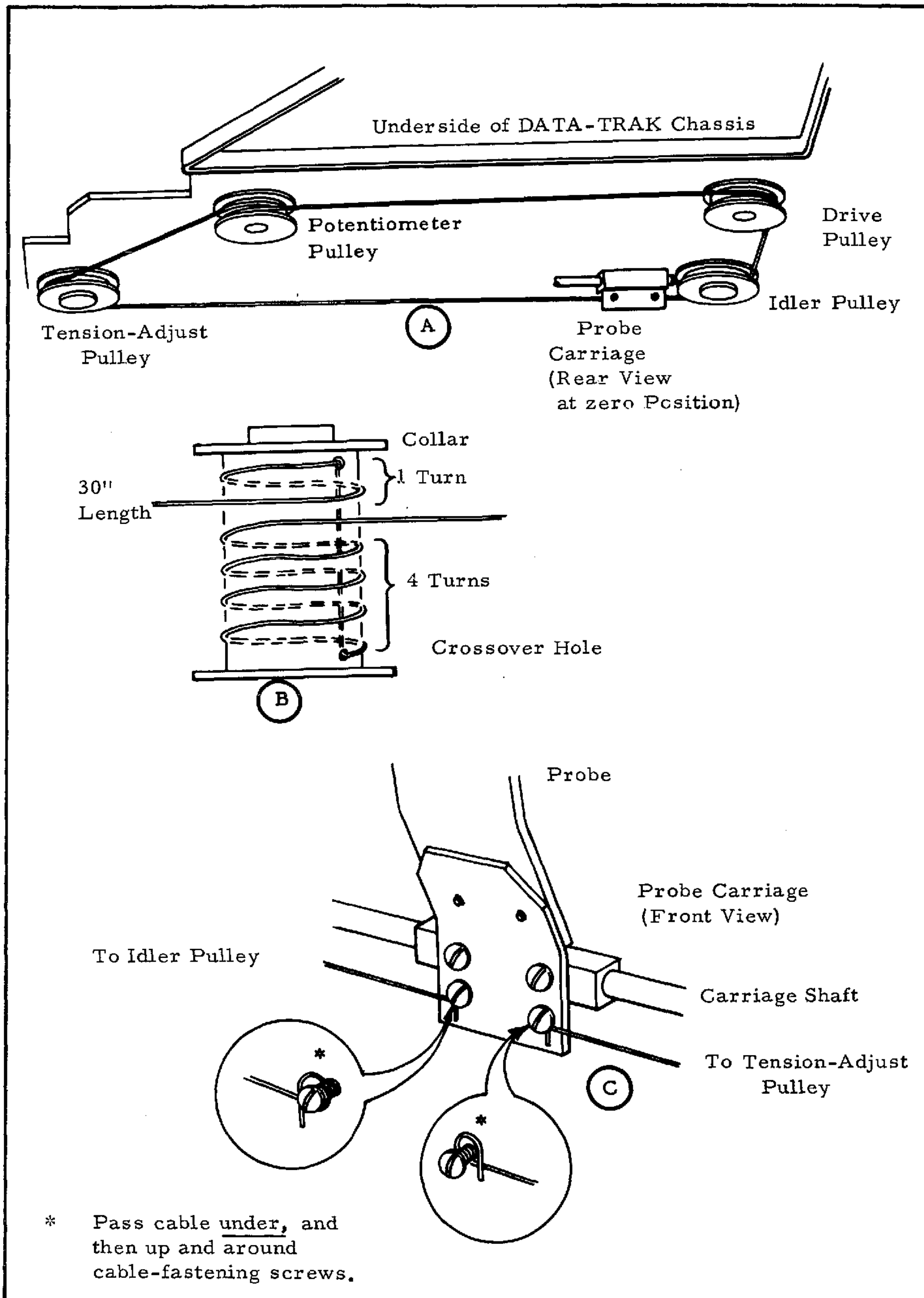


FIGURE 6-1 DRIVE-CABLE WIRING SYSTEM

2. Insert one end of the new 90-inch* length of "cat-gut" cable (Research part #PC 5110-90) through the crossover holes in the pulley.

3. Draw the cable through the crossover holes in a manner which leaves a 30-inch length extending from the top crossover hole (nearest the pulley mounting collar).

4. Wrap the 30-inch length counterclockwise around the pulley one full turn; then, holding the looped end in position with left thumb, wrap the opposite end clockwise around the pulley four full turns. The cable is now wound on the pulley as shown in Figure 6-1B and may be secured in this position, for the present, with a strip of masking tape. If more than one potentiometer pulley is used, each pulley will be wrapped in like manner.

5. Turn the shaft of the potentiometer fully counterclockwise, then remount the pulley with crossover holes facing to the rear of the chassis (toward the viewer).

6. Loosen the cable-fastening screws on the probe carriage and slide the unit to its zero-position against the "C" ring stops on the carriage shaft, and secure it in this position with a strip of masking tape.

7. Loosen the lock-screw in the tension-adjust pulley and slide the unit fully to the right (inward), leaving it unlocked for the present.

8. Loop the shortest end of the cable from the potentiometer pulley one half-turn around the tension adjust pulley; then secure the end of the cable under the left-hand cable-fastening screw on the probe carriage as shown in Figure 6-1C.

9. Loop the opposite end of the cable one full turn around the motor pulley, and then a half-turn around the idler pulley before securing it under the right-hand cable-fastening screw on the probe carriage, as shown in Figure 6-1C.

10. Cut off excess cable extending from the probe carriage and remove the tape from the potentiometer pulley and the probe carriage. If a small amount of slack exists in the pulley system, proper cable tension may be obtained by sliding the previously loosened tension-adjust pulley outward, toward the left, and locking it in position.

11. If the potentiometer shaft inadvertently shifted from its full counter-clockwise position during the stringing procedure, it may be re-oriented with the probe-zero position as described under the following Heading.

* See NOTE on following page.

NOTE

If a DATA-TRAK is equipped with more than a single 3-gang potentiometer, each additional pulley will require the length of the cable to be increased by 21-1/4 inches. When ordering replacement cable, specify complete length.

6-5 Potentiometer Alignment

To provide agreement between a desired program and the relative position of the wiper on the output potentiometer, the potentiometer shaft must be at its counterclockwise limit when the probe is at zero position on the program chart.

Misalignment (or a faulty potentiometer) is indicated if an ohmmeter reading of more than 2.5 ohms is obtained between the wiper and the counterclockwise terminal of a standard 1000 ohms potentiometer when the probe is positioned at zero on the program chart.

CAUTION

Use only high impedance ohmmeter to check potentiometer resistance; low impedance meters can cause potentiometer burn-out.

Re-alignment is accomplished as follows:

1. Set the probe at zero position on the chart.

2. Loosen the set-screws in the potentiometer pulley, and holding the unit securely, rotate the potentiometer shaft fully counterclockwise with a screwdriver inserted in its slotted end; then resecure the pulley, taking care not to disturb the position of the shaft.

6-6 Removal of Gear-Train and Time-Base-Motor Assembly

The gear-train and time-base-motor assembly may be removed from the DATA-TRAK for replacement by first removing the change-gears under the front cover, and then loosening the three retaining screws pointed out in Figure 6-2.

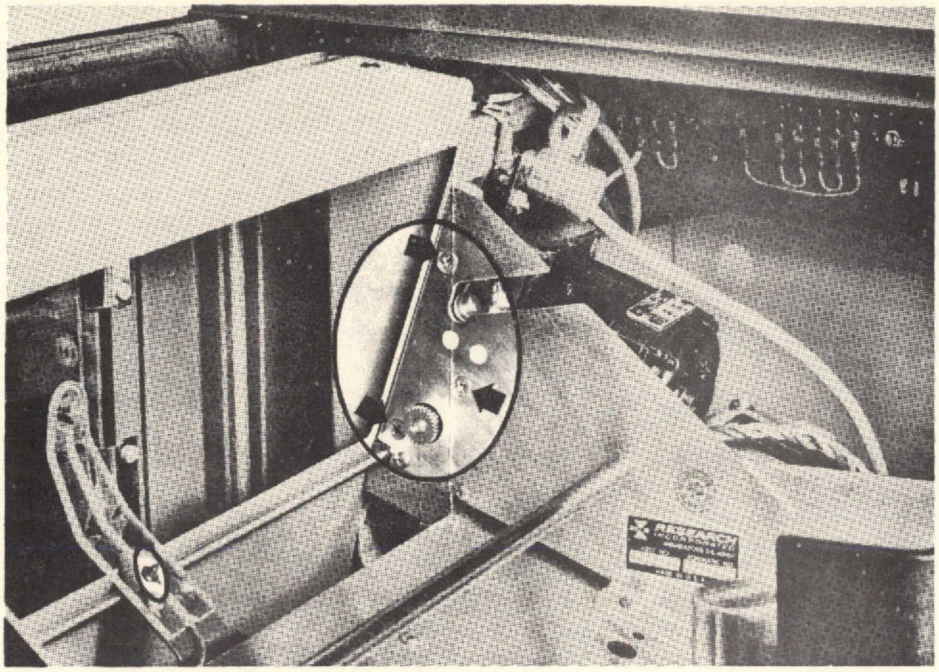


FIGURE 6-2 VIEW OF PROGRAM CARRIAGE WITH PROGRAM DRUM REMOVED

6-7 Probe Guide-Rod Maintenance

To assure the optimum in performance from the DATA-TRAKs curve-following probe, the probe guide-rod to which the probe is affixed and upon which it travels, should be inspected regularly for accumulation of oil deposited by the OILITE bearing.

If accumulations of oil are present, clean the rod with a high grade cleaning solvent and wipe thoroughly clean.

NOTE

DO NOT use any form of petroleum product as a lubricant.

6-8 Probe Spacing

For optimum performance from the DATA-TRAK, the spacing between the probe and the drum must be such that optimum accuracy may be obtained by adjustment of the GAIN control (See Heading 4-10). Due to differences inherent in the electronics of the amplifiers, an exact spacing specification cannot be obtained and the best spacing will vary from unit to unit. In most cases, optimum performance is obtained with a spacing of .04 to .06 inches. Therefore, to readjust the spacing, a combination of readjustment of spacing followed by GAIN adjustment is necessary.

The spacing of the probe is adjusted by the teflon screw located near the base of the probe, slightly above and centered between the two screws visible in Figure 6-2 above. This screw is either a self-locking type or is held in place by a locking nut. Clockwise rotation of the screw decreases the spacing.

SECTION 7: TROUBLESHOOTING

7-1 GENERAL

The DATA-TRAK has been designed to provide the optimum in trouble-free programming operation. The electronic circuitry is simple and straight-forward, and with the aid of the DATA-TRAK schematic diagram on which pertinent quiescent voltage-levels are noted, little difficulty should be experienced in isolating any trouble that may develop. Some of the more common troubles are listed below: Waveforms, voltage and resistance readings follow.

TROUBLE	PROBABLE CAUSE	REMEDY OR CHECK
1. Drum does not rotate when switched to run.	a. Drum not properly seated (drive gears not engaged).	a. Reseat drum, ensuring proper meshing ing of gears.
	b. Change gears loose, or cocked on keys of drive shafts.	b. Ensure that teeth of gears are meshed and keyed hubs on shafts are properly engaged with keyways in backs of gears; then tighten thumb-nuts securely.
	c. Drum-limit switch is actuated by trip-tab.	c. Manually rotate drum to position trip-tab past drum-limit switch.
2. Probe does not follow program curve.		
SYMPTOMS		
a. Probe remains stationary regardless of position on chart.	a. Shorted program curve.	a. Check for short in curve as described under Heading 4-2-3; re-etch faulty portion of curve.
b. Probe drifts in area to left (right) of program line	b. Left-(right) hand chart-energizing circuit shorted to ground.	b. Trace out left-(right-) hand chart energizing circuit and eliminate shorted condition.
c. Probe drives to, and remains at left (right) edge	c. Left-(right-) hand chart-energizing circuit open.	c. Ensure that chart energizing insert pins are installed in the left (right) edge of program drum, and that they are making proper contact with the chart-energizing hub clips.

TROUBLE	PROBABLE CAUSE	REMEDY OR CHECK
d. Probe drifts erratically over entire surface of chart, irrespective of program line.	d. Loss of energizing voltage to both sides of program chart.	d. Ensure that chart-energizing insert pins have been installed in both edges of the program drum, and are making proper contact with the metallized surface of the program chart.
3. Dead Probe	a. Shorted Program	a. Chart resistance (left to right) should be 1 meg ohm minimum. Redraw the curve if less.
	b. No AC power to the chart.	b. Check for 40 VAC present at the power supply. Transformer T1 secondary, current limiting resistors R2 & R3, and capacitor C4.
	c. Probe shorted.	c. Check the resistance between the shield and conductor of the microdot cable. Should be 10 meg ohm minimum. If less, replace cable.
	d. Probe open.	d. Check the microdot cable for an open, replace if bad.
	e. Bad servo amplifier.	e. Check transistors. Replace the amplifier board if bad.
	f. Bad servo motor	f. Check for open or short in the motor windings. Replace motor if bad.
	g. Bad power supply.	g. Check voltage levels of power supply.
4. Probe Erratic	a. Ungrounded probe head.	a. Resistance of the probe head to the cable connector shield should be less than 0.1 ohm. Replace if bad.

TROUBLE	PROBABLE CAUSE	REMEDY OR CHECK
	b. Bad servo amp.	b. Check transistors. Replace the board if bad.
5. Probe Oscillates	a. Probe is too close to the chart.	a. Check for a .030" to .050" gap. Readjust if necessary and reset the gain control.
	b. Gain on servo amplifier is too high.	b. Adjust the gain control for the best sensitivity without oscillations.
6. Probe drives to one end of the chart.	a. AC open to one side of the chart.	a. Check for proper voltages at the chart, current limiting resistors R2 & R3, or the power supply transformer T1.
	b. Shorted program	b. Check the chart resistance left to right. Should be 1 meg ohm minimum. Redraw the curve if less.

7-2 RESISTANCE AND VOLTAGE CHECKS

Reference Schematic KD33568B for the following resistance measurements to ground. Equipment needed VOM (Triplett) or equivalent 20,000 ohms/volt meter.

7-2-1 RESISTANCE CHECKS

For the following readings adjust the gain control for maximum (fully clockwise). Select the meter scale of X 1K ohms.

Minus lead on Ground		Positive Lead on Ground	
Probe	Reading	Probe	Reading
Base Q1		Base Q1	40 K
Base Q3	3400	Base Q3	50 K
Q4	4000	Q4	20 K
Q5	15 K	Q5	12 K
Q6	6 K	Q6	35 K
Q7	20 K	Q7	7 K
Q8	1.2 K	Q8	1.2 K
Q9	1.2 K	Q9	1.2 K
P1A	Short	V1A	Short
L		L	9 K
X	200	X	200
Y	15 K	Y	17 K
Z	15 K	Z	15 K
Cathode CR1	4.2 K	Cathode CR1	3 K

7-2-2 VOLTAGE CHECKS

From	To		
Junction CR 12 & 13 (-)	Junction CR10 & 11 (+)	=	32 VDC
Cathode CR1 (+)	Ground (-)	=	15 VDC
Drum Feed D1	Ground	=	40 VAC
Drum Feed D2	Ground	=	40 VAC
Drum Feed D1	Drum Feed D2	=	85 VAC

The following measurements are to common at NULL

LOCATION	READING
Base Q3	+1.2 VDC
Emitter Q3	0 VDC
Base Q4	+2.0 VDC
R14 to R17	+14.5 VDC to 15.5 VDC
Emitter Q4	+1.5 VDC
Collector Q5	0 VDC
Base Q5	+25.0 VDC
CR1	+15 VDC
C9	+20 to 25 VDC
Base Q6	+1 VDC
Base Q7	-1 VDC
Collector Q8	+16 VDC
Base Q8	+0.4 VDC
Base Q9	-0.4 VDC
Collector Q9	-16 VDC

The following illustrations reference the above component locations

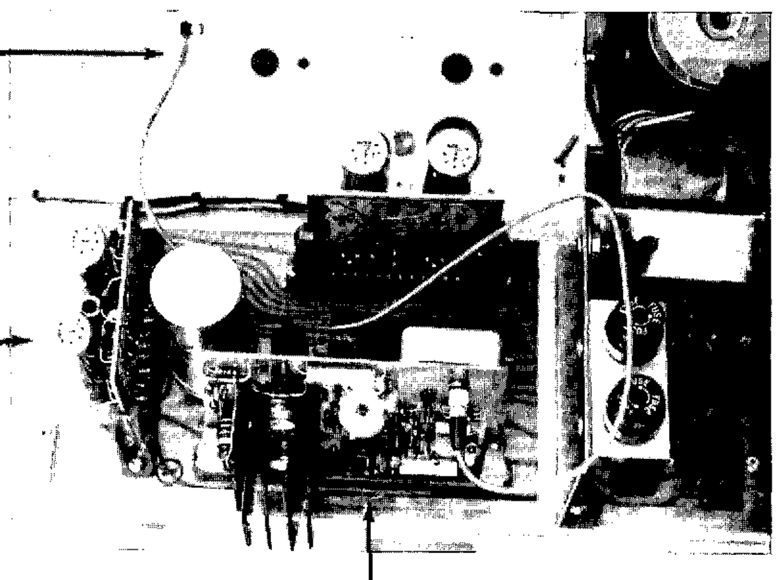


Fig. 7-1: MASTER BOARD ASSEMBLY

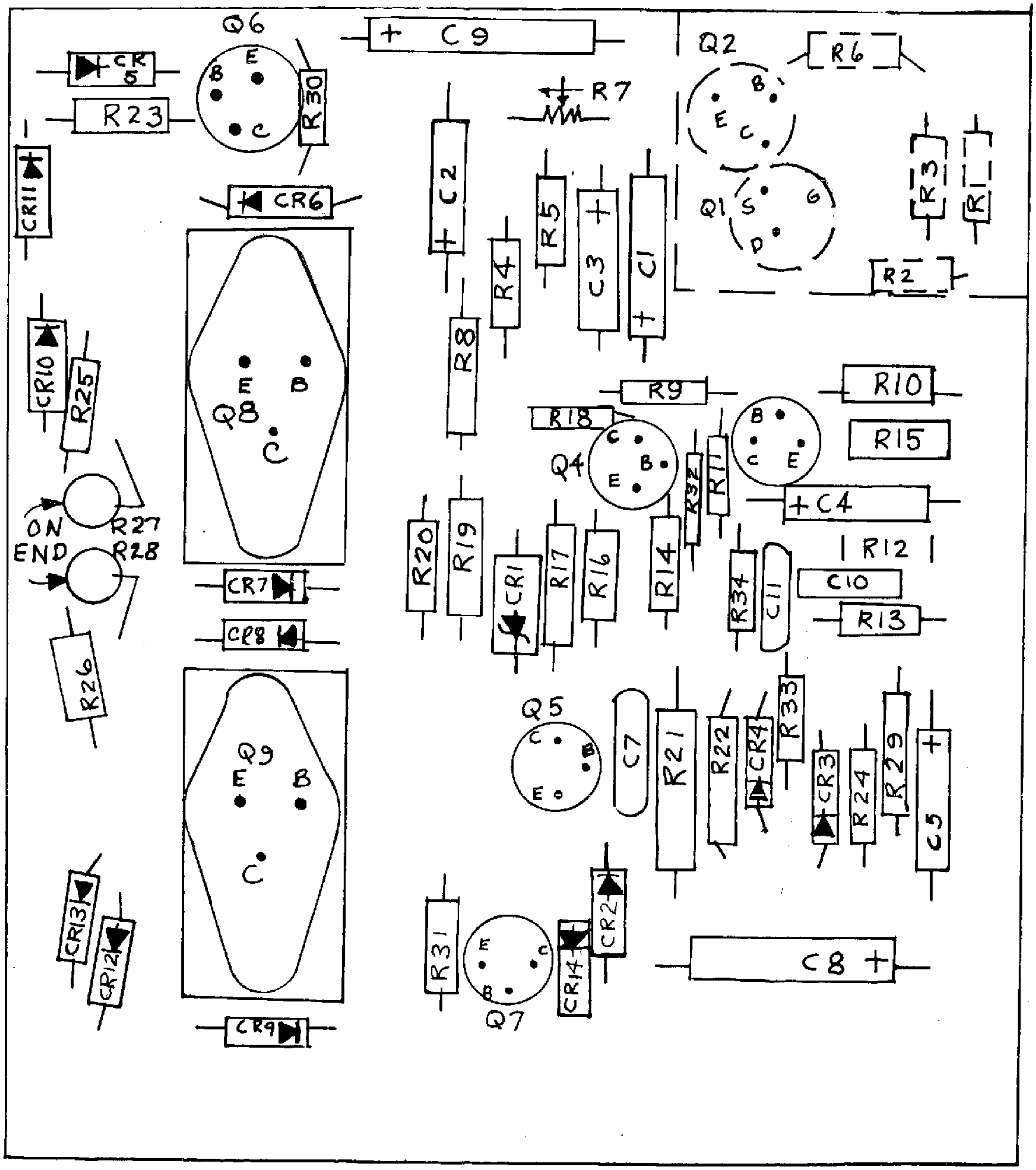
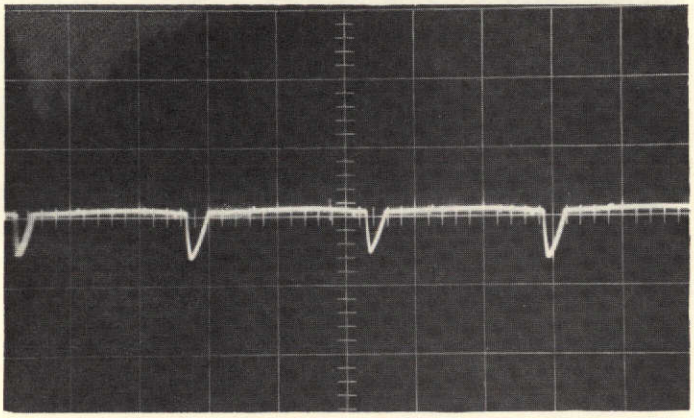


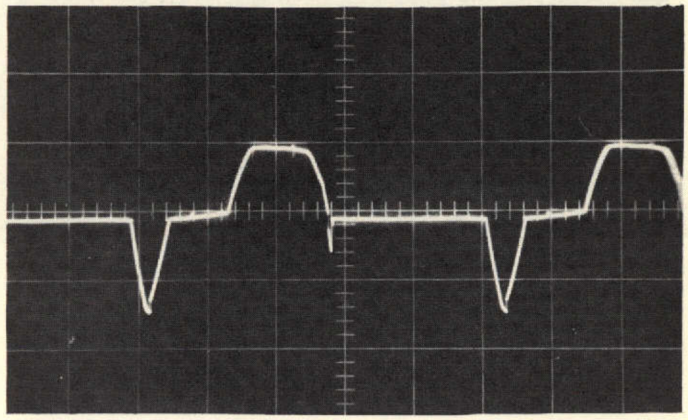
Fig. 7-2: PROBE AMPLIFIER BOARD ASSEMBLY LAYOUT

7-3 WAVEFORMS

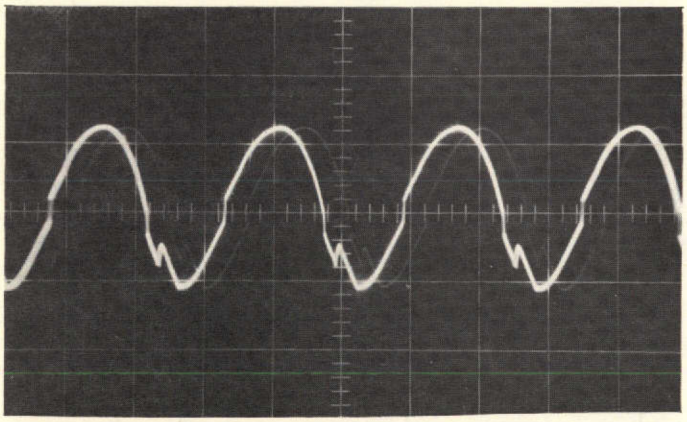
The following amplifier voltage waveforms were taken using a 5 millisecond per centimeter time base. Oscilloscope set up instructions are given below each waveform.



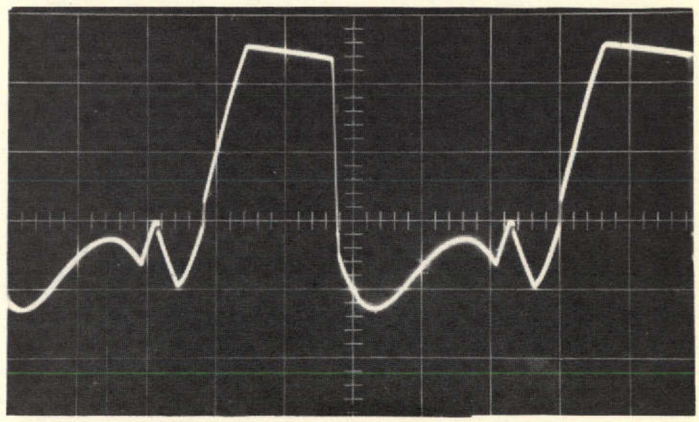
1 V/CM
Collector Q3 Null



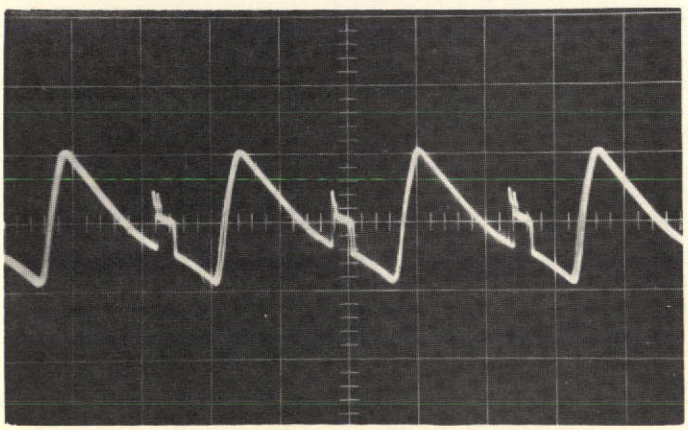
1V/CM
Collector Q3 Probe Offset



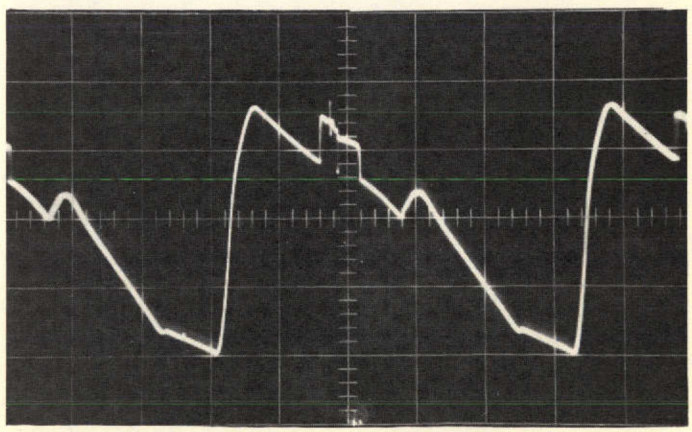
5 V/CM
Collector Q5 Null



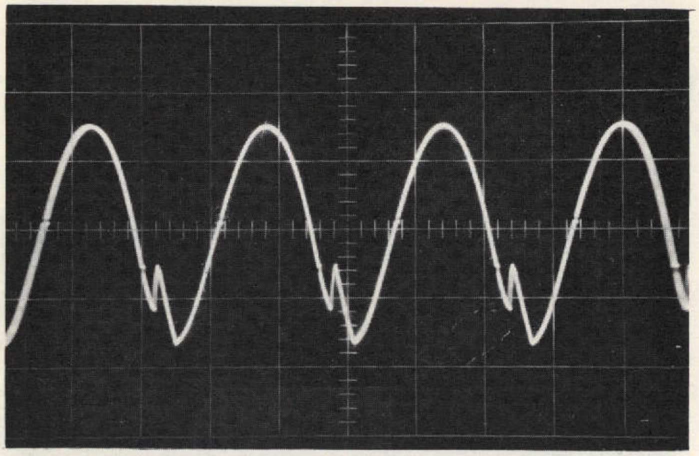
5 V/CM
Collector Q5 Probe Offset



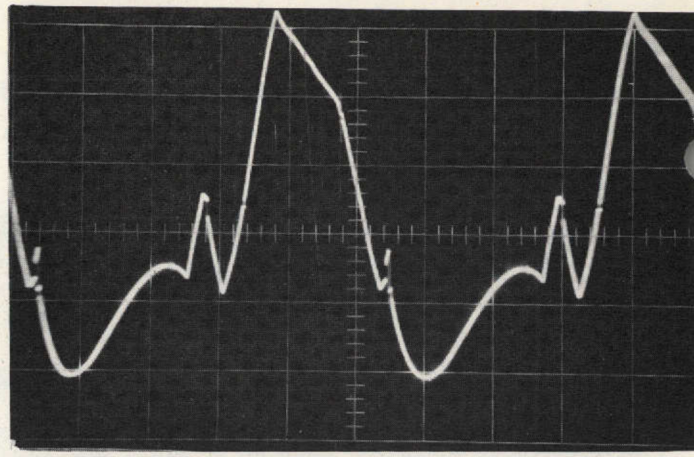
1 V/CM
Collector Q4 Null



1 V/CM
Collector Q4 Probe Offset



5 V/CM
Collector Q8 Null



5 V/CM
Collector Q8 Probe Offset

7-4 MOTOR WINDINGS

Shown in the figures below are the various motor winding layouts and respective resistance (DC).

SERVO MOTORS

DRIVE MOTORS

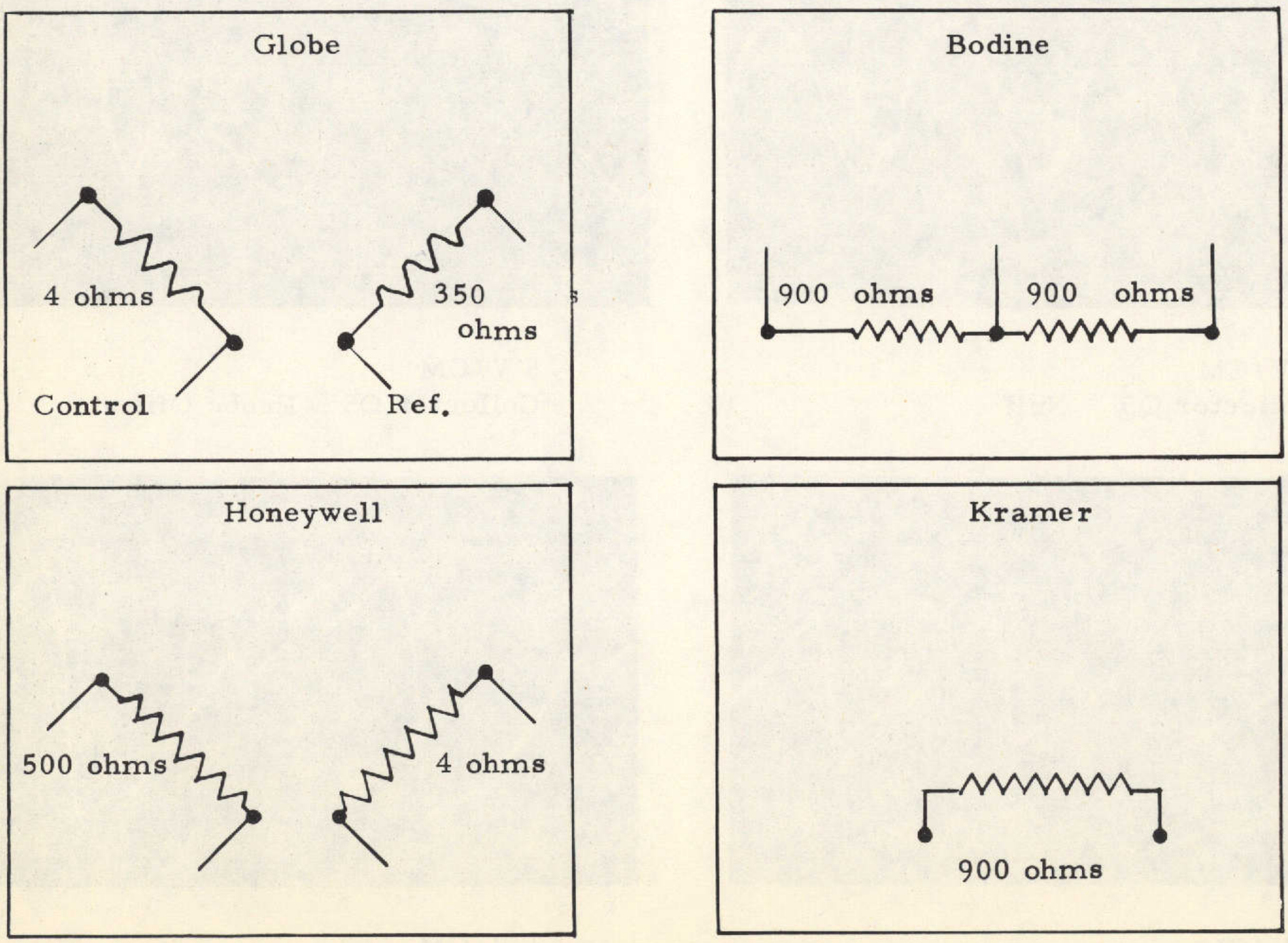


Fig. 7-4

7-5 OPTIONAL FEATURES VOLTAGE AND RESISTANCE CHECKS

The following voltage and resistance checks are for the PHOTO FUNCTION SWITCH (PFS) option. Both sets of checks are to be made with the relays pulled out of the card.

VOLTAGE CHECKS

These checks are to be made with the negative probe on common.

LOCATION (+)	READING
Junction CR9 & CR10	23 VDC
Junction CR6 & CR7	32 VDC
Junction CR5 & CR8	25 VDC
Junction CR3 & R1	20 VDC

RESISTANCE CHECKS

Pull the PFS card out. Common is Pin A and S on the card

LOCATION	READING (- to common)	READING (+ to common)
B	30K	2K
C	20K	Infinity
D	30K	2K
E	Infinity	Infinity
F	Infinity	Infinity
H	Infinity	Infinity
J	20K	40K
L	NC	NC
M	Infinity	Infinity
N	Infinity	Infinity
P	Infinity	Infinity
R	20K	Infinity

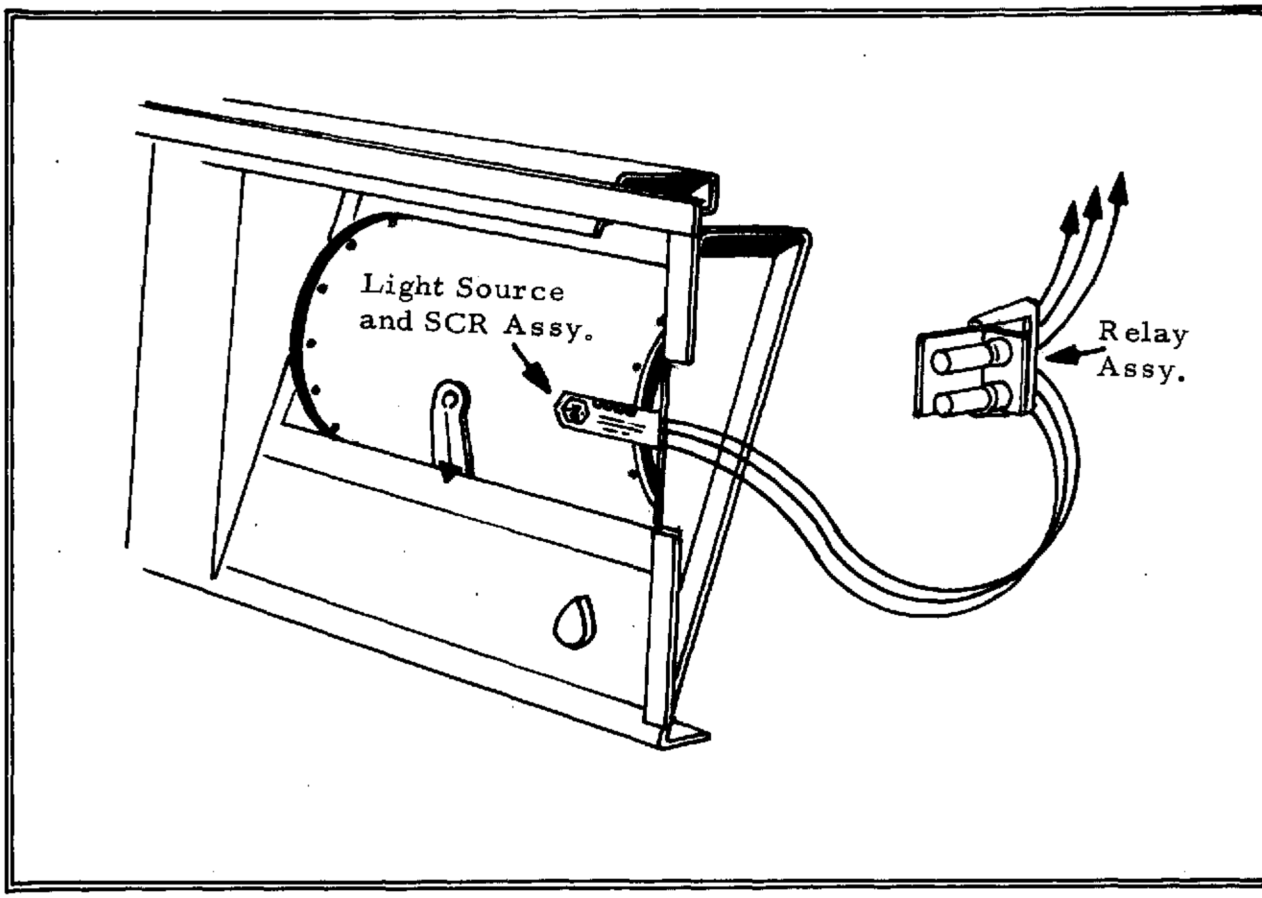
SECTION 8 OPTIONAL FEATURES

NOTE

The following text and illustrations describe the optional features which may be installed on the instrument for which this instructional manual is provided.

PROGRAMMABLE PHOTO FUNCTION SWITCH

The programmable photo function switch (PPFS) option enables the Model 5110 DATA-TRAK Programmer capabilities to be extended to include programmed on/off control of customer-selected external functions. The DATA-TRAK may be equipped with up to four (4) function switches. The number of switches supplied is indicated on the cover of the switch assembly.



The PPFS is comprised of two assemblies: (1) light-activated SCR and light-source assembly, and (2) an amplifier and relay assembly. In operation, light from the light source is reflected by the program sheet and sensed by the light-activated SCR. The SCR is held just below conduction level by the gate resistance. When the photocell senses an increase in reflected light, the corresponding relay is actuated. Programming of the function switch consists of brightening the portion of the program which passes under the SCR. The brightened area (PPFS actuation period) must be as wide as illustrated on the cover of the SCR and light-source assembly and at least

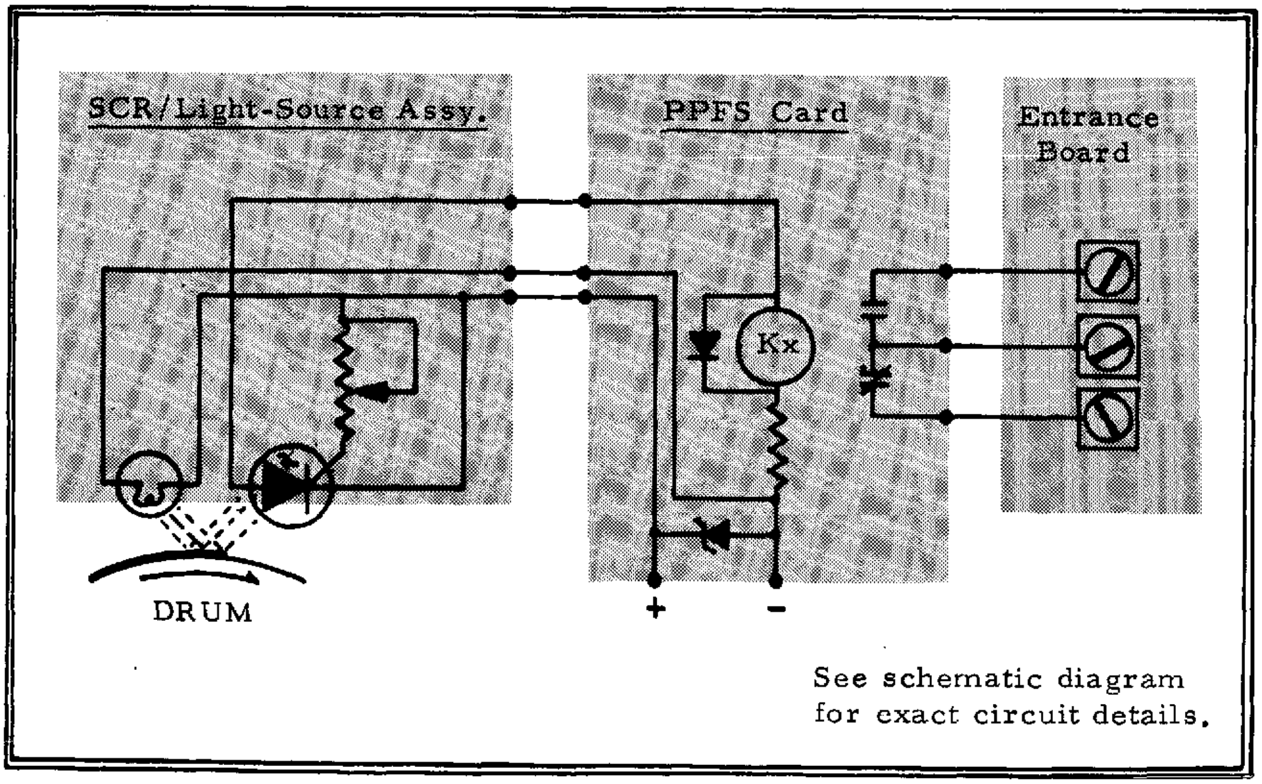
1/32 inch in length.* A roll of aluminized tape at the correct width is initially supplied with the unit for programming. The tape is the most convenient method of programming as it is easily applied and removed.

The SCR and light-source assembly is located one inch above (opposite direction of drum rotation) the probe tip. Therefore, when preparing the program, the initiation and termination points of the PPFS "on" period must be offset one inch to compensate for this physical configuration. That is, when plotting the program curve as outlined in the manual, ** the PPFS "on" period must begin and end one inch above the actual "on" and "off" points (in time) on the program curve. To aid in accurately programming the PPFS, each channel's SCR gate resistor may be adjusted individually by utilizing the alignment screw at each channel.

The photocell and light-source assembly is factory adjusted for optimum sensitivity. It should not require readjustment in the field unless a component is replaced on the assembly or the assembly is removed or its mounting is physically disturbed. If readjustment is necessary, proceed as outlined on the following page.

FUNCTIONAL DIAGRAM

Programmable Photo Function Switch

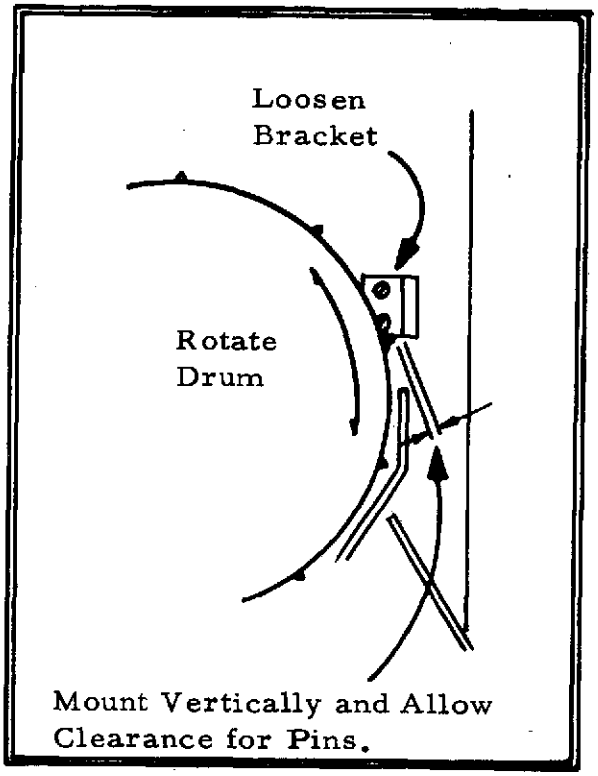


*16 On/Off functions per inch-Maximum.

**NOTE-If tape crosses program line, aluminized surface of tape must also be etched to maintain isolation of planes.

PPFS ALIGNMENT PROCEDURES

Mechanical and electrical alignment is accomplished as follows:



Mechanical

1. Remove change gears and loosen bracket.

2. Position unit as low as possible but allow clearance for pins on drum (Rotate drum to assure clearance).

3. Align unit vertically and re-tighten bracket.

4. Realign electrically after mechanical realignment.

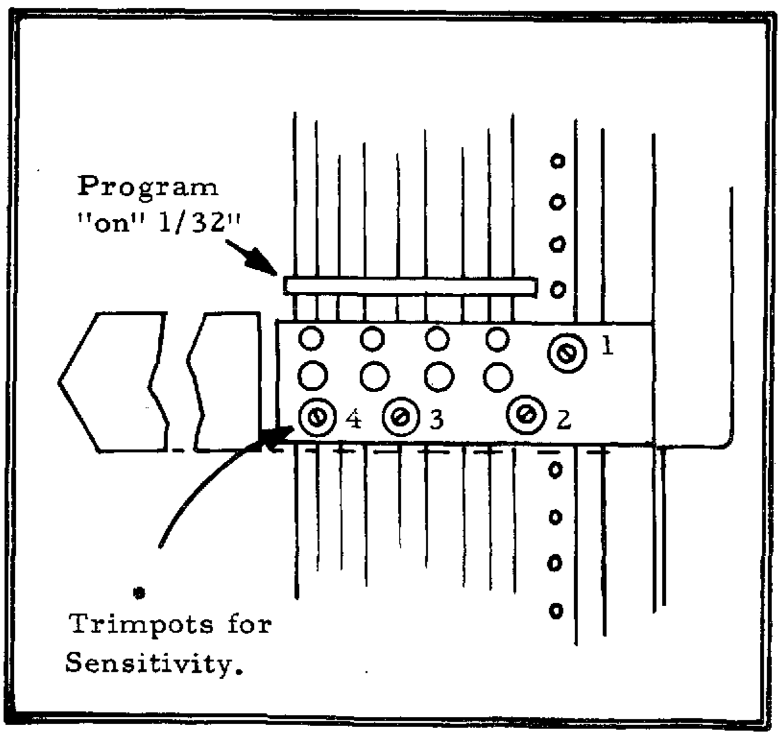
Electrical

1. Remove change gears and PPFS cover. Energize DATA-TRAK.

2. Program "on" time of 1/32" width. Set all trimpots to maximum ccw.

3. Monitor PPFS contacts with ohmmeter. Increase setting cw until actuated by "on" strip.

4. Repeat at each channel.



TB5197 TIME-BASE OPTION

The DATA-TRAK programmer may be equipped with a special Model 5197 - time base. If designated 5197 in the model number, please disregard all information in the manual pertaining to the standard time-base gear train and change gears.

The specific speed of the special time-base, in inches/hour and hour/revolution, can be found on the tables below:

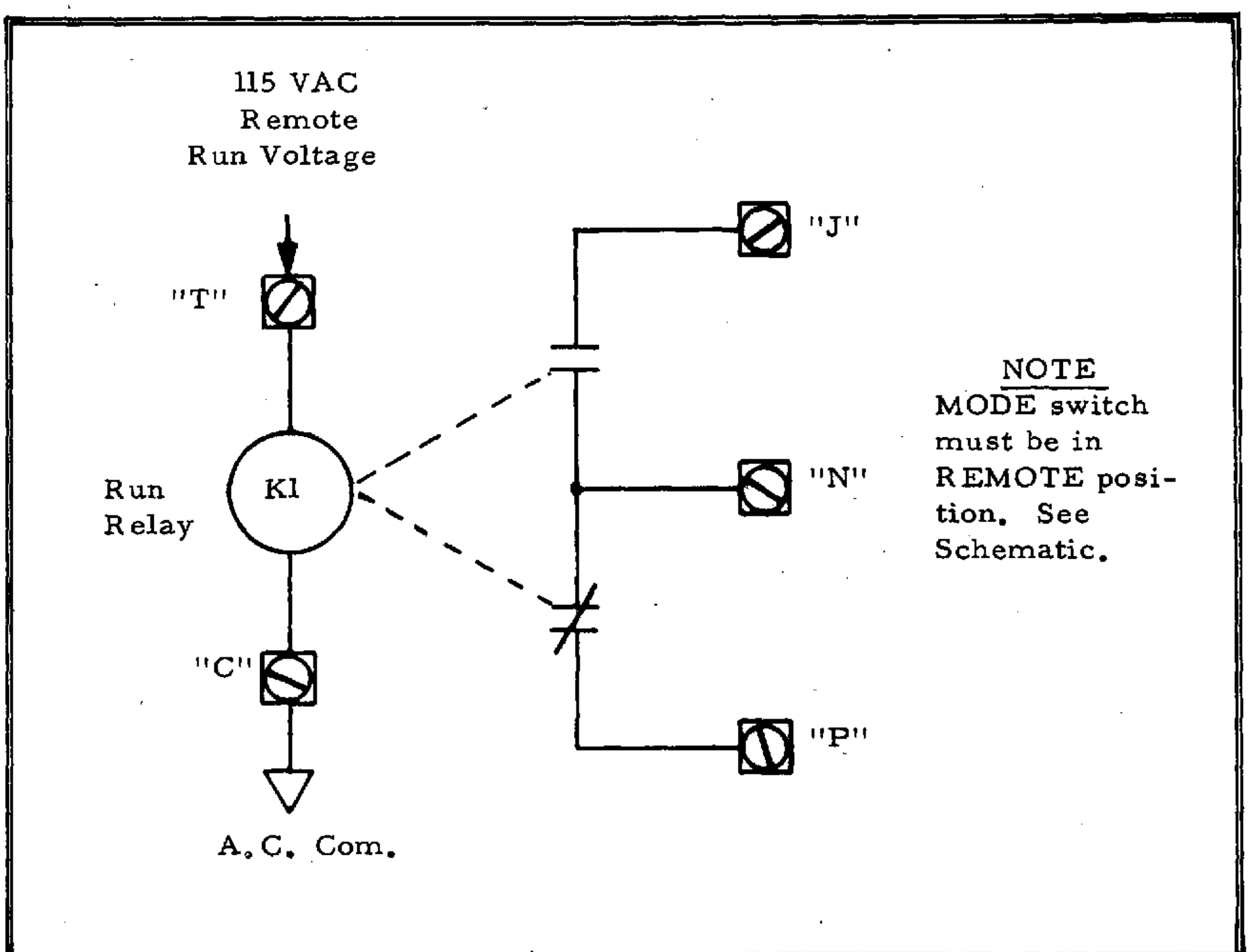
TIME BASE MODELS

MODEL NO.	PROGRAM SPEED	
	in. /sec	sec/rev
5197-1	1-1/8	12
5197-2	[illegible] DISCONTINUED	[illegible]
5197-3	[illegible]	[illegible]
5197-4	3/10	45
5197-5	9/40	60
5197-6	3/16	72
5197-7	3/20	90
5197-8	9/80	120
5197-9	3/40	180
5197-10	3/64	288
5197-11	3/80	360
	in. /min	min/rev
5197-12	1-1/2	9
5197-13	1-1/8	12
5197-14	9/10	15
5197-15	3/4	18
5197-16	6/10	22-1/2
5197-17	9/16	24
5197-18	9/20	30
5197-19	3/8	36
5197-20	3/10	45
5197-21	9/32	48

MODEL NO.	PROGRAM SPEED	
	in. /hr	hr/rev
5197-22	13-1/2	1
5197-23	11-1/4	1-1/5
5197-24	9	1-1/2
5197-25	6-3/4	2
5197-26	5-5/8	2-2/5
5197-27	4-1/2	3
5197-28	3-3/8	4
5197-29	3	4-1/2
5197-30	2-13/16	4-8/10
5197-31	2-1/4	6
5197-32	1-1/2	9
5197-33	1-1/8	12
5197-34	3/4	18
5197-35	9/16	24
5197-36	3/8	36
5197-37	9/32	48
5197-38	1/4	54
	in. /day	day/rev
5197-39	4-1/2	3
5197-40	2-1/4	6
5197-41	1-1/2	9
5197-42	1-1/8	12

REMOTE RUN-CONTROL OPTION

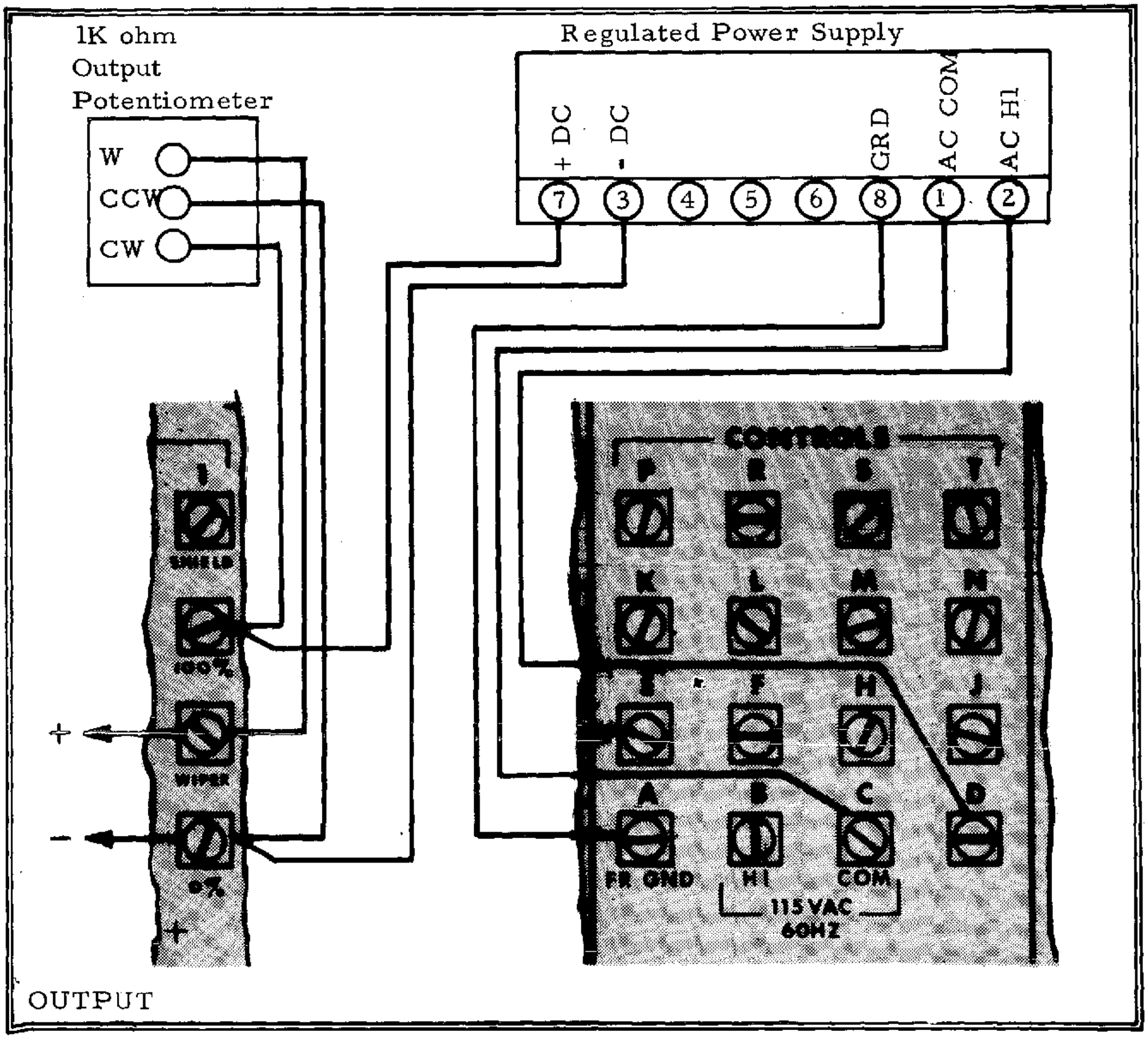
The DATA-TRAK may (generally in system applications) be equipped with a remote run-control relay. This option functions identically to the remote run-control switch described under Heading 5-3 and illustrated by example "B" in Figure 5-1. To operate under the control of the relay, the DATA-TRAK's MODE switch must be in the REMOTE position. Under these conditions, the DATA-TRAK will go into run when 115 VAC is applied to terminal "T" of the entrance board.



REGULATED POWER SUPPLY OPTION

The DATA-TRAK may be equipped with an optional REGULATED POWER SUPPLY output. This option provides a linear output voltage ranging from zero to +10 VDC (other ranges available). The output of the RPS is wired to the normal output connections of the DATA-TRAK; as shown below.

As the curve-following probe of the DATA-TRAK tracks back and forth to follow the program, the wiper of the 1K output potentiometer is varied accordingly; delivering to the load from zero to 100% of the voltage applied to the output potentiometer.



ALARM SWITCH OPTION

The AS51 option expands the DATA-TRAK's capabilities to allow the operator to program momentary contact-transfer of a switch at a preselected level of programmed output. A notched cam and switch assembly is mounted on the DATA-TRAK's swing-out assembly. This assembly is installed in the same fashion as the output device and the cams are pulley-driven by the probe cable (see photo).

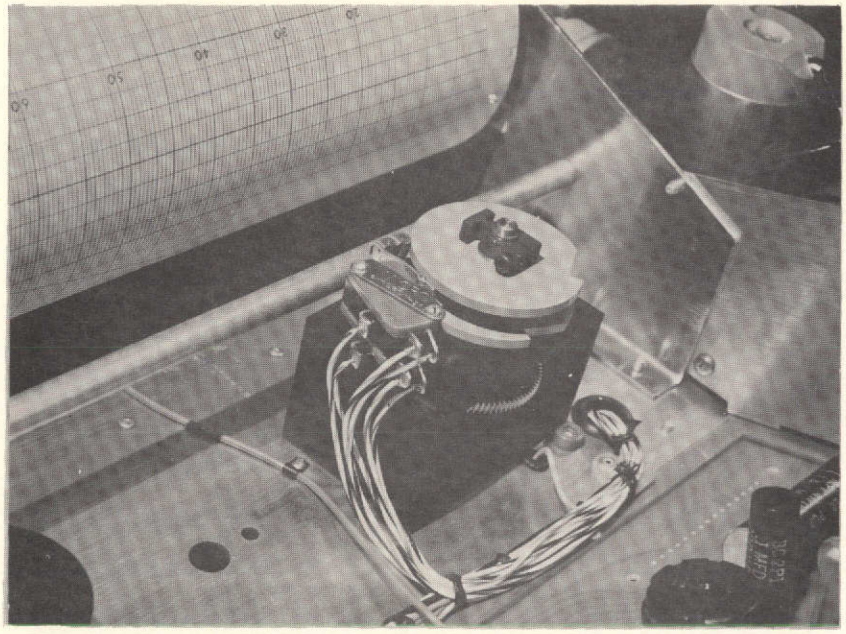


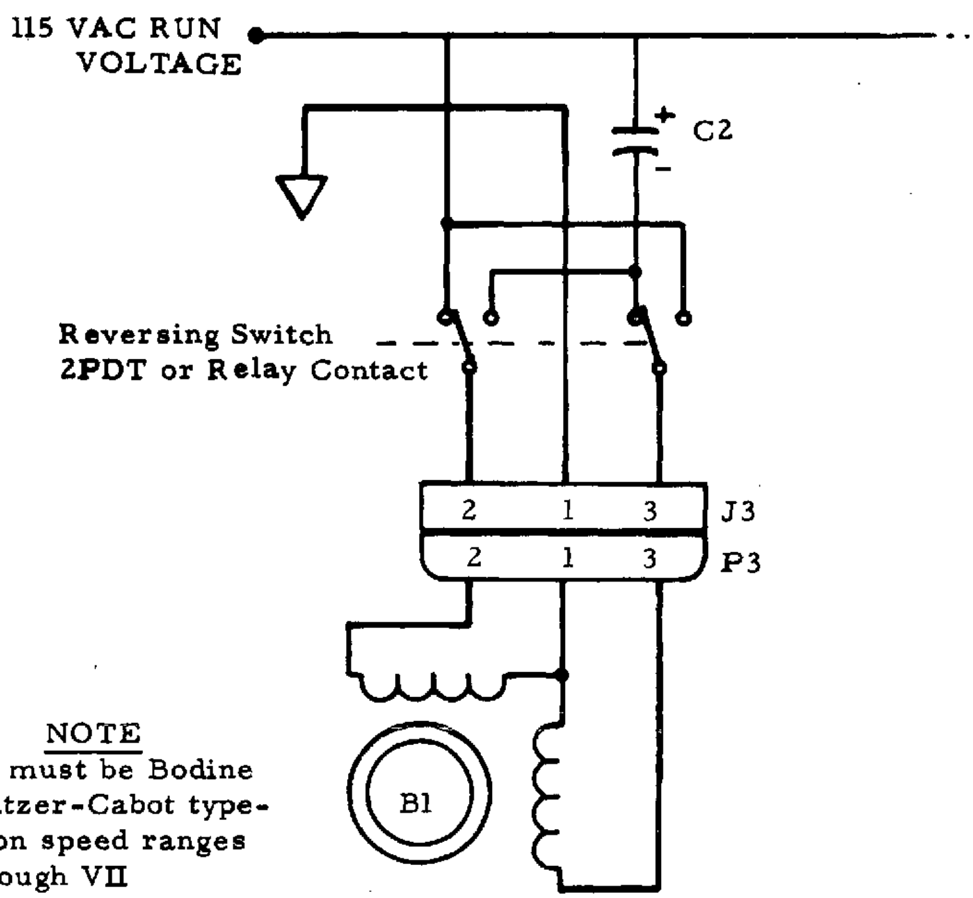
FIGURE 1 AS51-X ASSEMBLY MOUNTED

As the probe tracks back and forth to follow the program curve, the cams are rotated accordingly. As previously mentioned, the cams are notched, and when the notch passes beneath the actuating arm of the switch, the contacts of the switch transfer. The cam may be set (by loosening a set screw on the cam assembly and rotating the cam) to actuate the switch at any desired level of programmed output (probe position).

The contacts of the switches are wired to the terminals designated LIMIT ALARM SWITCH on the DATA-TRAK entrance board. Maximum current which may be passed through these contacts is 5 amperes at 115 VAC (2 amperes at 230 VAC). The switches are numbered from bottom to top as designated on the entrance board.

DRUM FORWARD/REVERSE SWITCH OPTION

The DATA-TRAK programmer may be equipped with a DRUM FORWARD/REVERSE switch to enable selection of either forward or reverse rotation of the program drum. If provided, the switch will be located directly to the left of the MODE SELECTOR switch on the front panel of the DATA-TRAK; the manner in which its contacts are wired to reverse the phasing of the time-base motor is illustrated below.



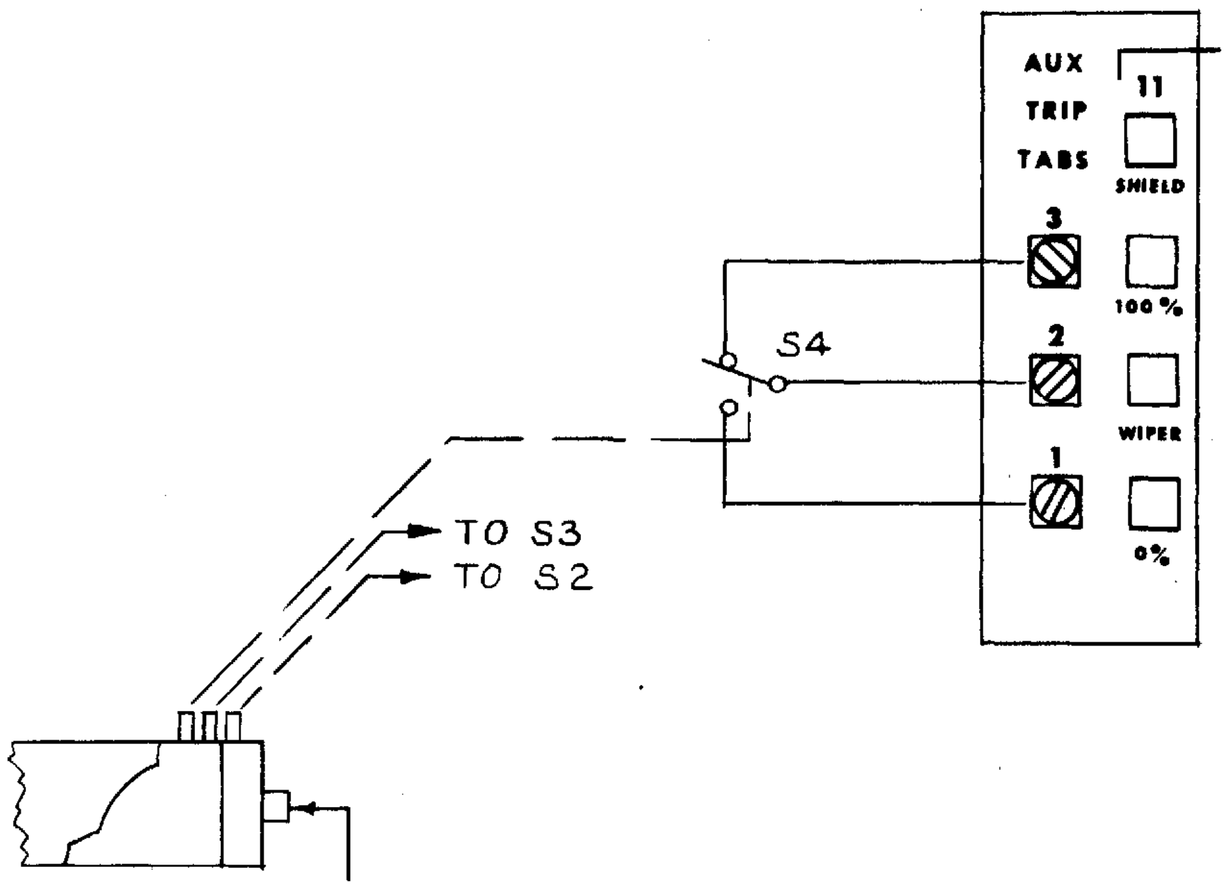
NOTE
Motor must be Bodine or Holtzer-Cabot type-Used on speed ranges III through VII

RPM Motors

P1----BLUE
P2----RED
P3----BLACK

THIRD MICRO SWITCH ADDITION

The DATA-TRAK Programmer may be equipped with a third auxilliary micro switch. The switch will be installed next to the two original micro switches and is actuated by a third trip tab.

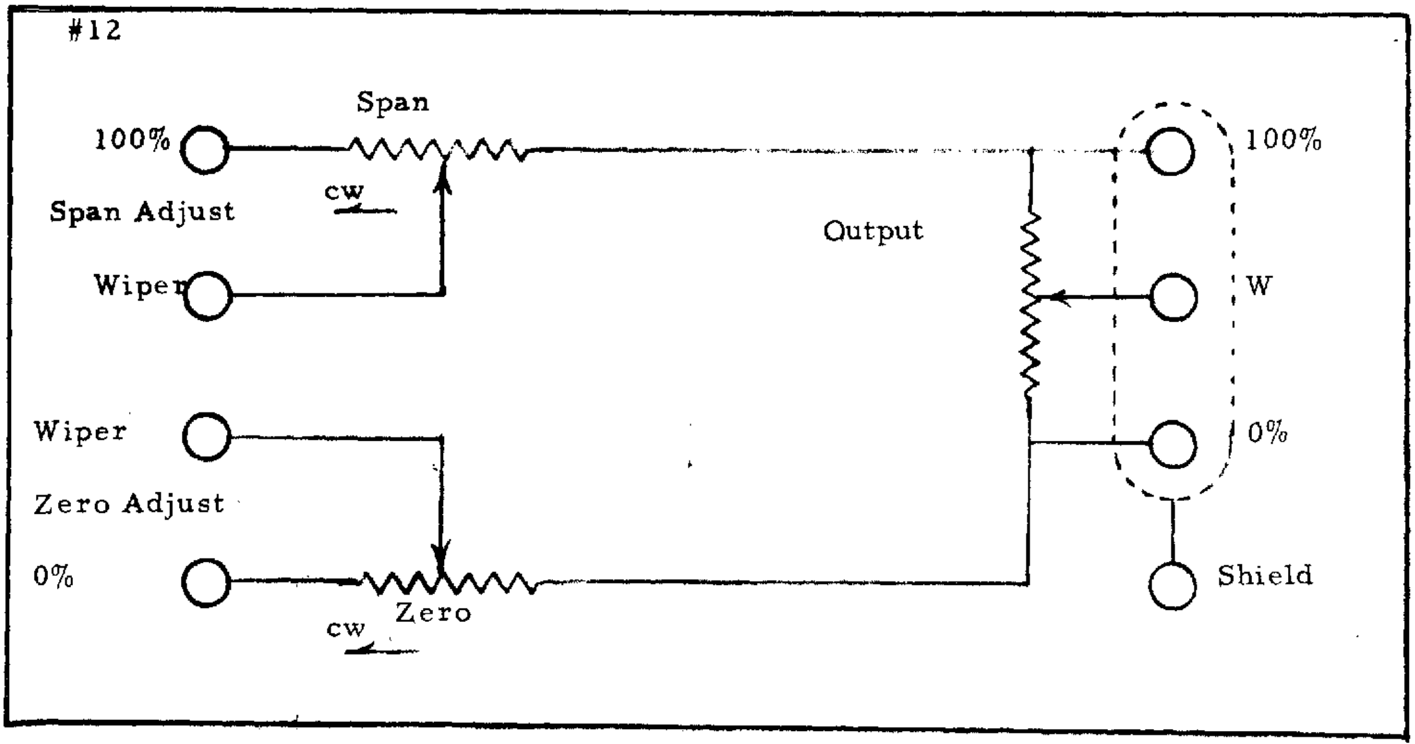


5110 DATA-TRAK SPAN/ZERO MODIFICATIONS

The instrument for which this instruction manual is provided may differ from standard with respect to the output potentiometer connections. The output potentiometer may be augmented by the addition of two trimpots designated SPAN and ZERO. Refer to the schematic below for exact output potentiometer configuration and value.

The trimpots will be located behind the swing out chassis on a bracket near the top right side of the cabinet.

SCHEMATIC DIAGRAM
SPAN/ZERO MODIFICATION



POTENTIOMETER VALUES

R Span	R Output	R Zero

5110 DATA-TRAK PRESET COUNTER (PSC) OPTION

The instrument for which this manual is provided may be equipped with a preset counter to enable the program drum to be automatically stopped after a predetermined number of revolutions.

To preset a desired number of drum revolutions, depress the button next to the counter register and rotate the red plastic shield upward. Set up the desired number of revolutions on the setting register and close the red plastic shield.

When placed in operation, the DATA-TRAK drum will continue rotating until the accumulated count in the counter register is equal to the preset count in the setting register, at which time rotation of the drum will be automatically stopped.

When equipped with the PSC, the DATA-TRAKs drum-limit switch S2 is removed from the circuit. A jumper is installed between terminals "R" and "S" of the entrance board when the RDB option is provided.

To (effectively) remove the PSC from the circuit, dial in some arbitrary count and remove the S3 trip tab.

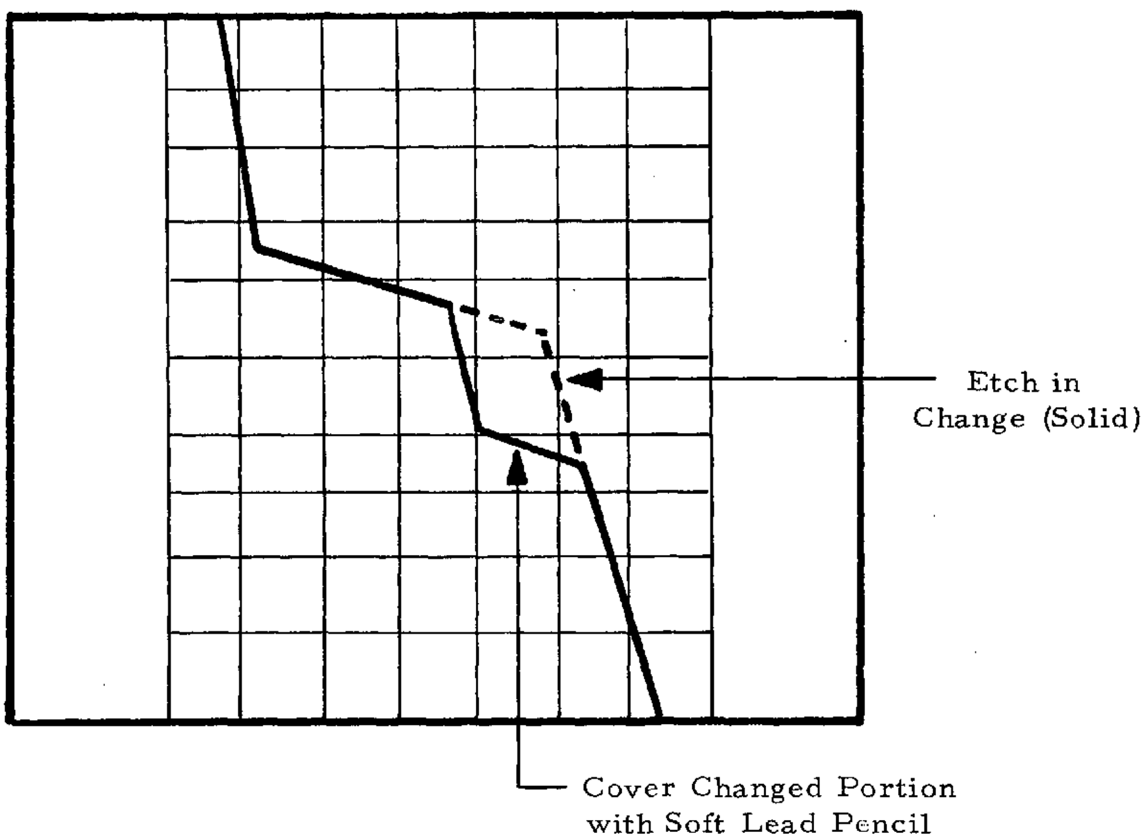
SECTION 9

ADDENDUMS

ADDENDUM FGE DATA-TRAKs

It is possible to make a temporary change in an existing program without changing the chart. This can be done by using a soft lead pencil to cover the portion of the program to be changed and etch in the desired change. Reference the sketch below.

Once the program has been resolved, it is recommended that it be transferred to a new chart.

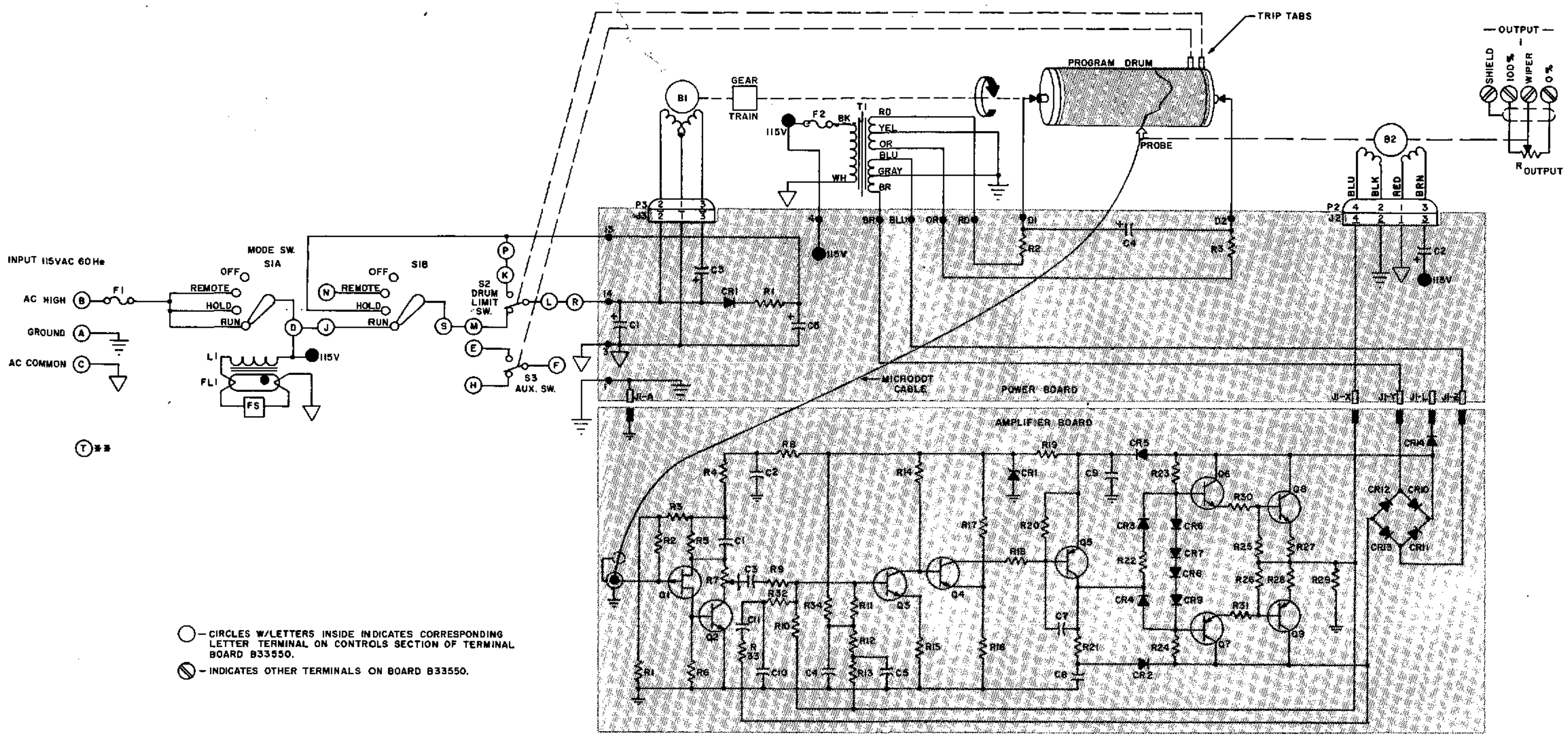


SECTION 10

SCHEMATICS

FOLDOUT FRAME

REV.	DESCRIPTION	DRAFT	DATE
A	R3 WAS 100K ON AMP PCB	RL	11/9/67
B	R2 & 3 ON POWER BOARD WERE 100K, ADDED R'OUTPUT NOTE F1 WAS 1/2 AMP SLO-BLO 3AG LITTLEFUSE	RL	12/8/67
C	ADDED C2 TO PPFS OPTION	BL	5/14/69
D	REVERSED WIRING CONNECTIONS ON 4,10 & 60 RPM PIN 2 & PIN 3	EAG	2-19-70
E	PPFS CARD - ADDED R5, 6, 7, 8, C3, 4, 5, 6 1N5357 WAS ZS20B	RMF	5-20-71



○ – CIRCLES W/LETTERS INSIDE INDICATES CORRESPONDING LETTER TERMINAL ON CONTROLS SECTION OF TERMINAL BOARD B33550.

⊘ – INDICATES OTHER TERMINALS ON BOARD B33550.

FINAL, CASE, & CHASSIS ASSEMBLY
R OUTPUT – RESISTANCE & LINEARITY DETERMINED BY APPLICATION.
FUSE F2 -SLO-BLO, 1/2 AMP, LITTLEFUSE, 3AG
TRANSFORMER, T1 — A32269
BALLAST, L1 — GE, 890435
STARTER, FS — GE, FS-5
FLUORESCENT TUBE, FL1 — SYL, F6T5 CW
MOTOR, B1 — BODINE OR CRAMER, SYNCHRONOUS
MOTOR, B2 — GLOBE, 150 RPM
MICRODOT CABLE — 50-3804
SWITCH, S1 — A17688
S2,3 — MICROSWITCH, V3-601
FUSE F1, SLO-BLO, 3/4 AMP, LITTLEFUSE, 3AG

POWER BOARD ASSEMBLY D33544
CAPACITOR, C1 — 1 MFD, 200V
C2 — 1.5 MFD, 400V
C3 — 1 MFD, 600V
C4 — .01 MFD, 600V
* C5 — 40-40 MFD, 450V
DIODE, CR1 — D156
RESISTOR, R1 — 100Ω, 1/2 W, 10%
R2,3 — 27 KΩ, 1/2 W, 10%

* NOT USED W/CRAMER MOTOR.
** USED W/REMOTE RUN RELAY OPTION.

AMPLIFIER BOARD ASSEMBLY B31504
POTENTIOMETER, R7 — 20 KΩ, MTC24L1
TRANSISTOR, Q1 — U112
Q2,3,4 — 2N3565
Q5,7 — 2N3644
Q6 — 2N3643
Q8 — 2N3054
Q9 — 2N3741
ZENER DIODE, CR1 — 1D15B
DIODE, CR2,3,4,5,6,7,8,9,14 — D142
CR10,11,12,13 — D152
CAPACITOR, C1,4,5 — 40 MFD, 10V
C2 — 22 MFD, 15V
C3 — 1.0 MFD, 35V
C7 — .001 MFD, 1KV
C8,9 — 78 MFD, 50V
C10,11 — .01 MFD, C. DISC
RESISTOR, R1,34 — 470KΩ, 1/4W, 10%
R2 — 100 MEGΩ, 1/4 W, 10%
R 6,32 — 100KΩ, 1/4 W, 10%
R4 — 1.5 KΩ, 1/4W, 10%
R5,11 — 27KΩ, 1/4 W, 10%
R8 — 3.3KΩ, 1/2 W, 10%
R9,23,24,3 — 33KΩ, 1/4W, 10%
R10,33 — 10 MEGΩ, 1/4W, 10%
R12,25,26 — 1 KΩ, 1/4W, 10%
R13 — 22KΩ, 1/4W, 10%
R14 — 27 KΩ, 1/4 W, 10%
R15,30,31 — 100Ω, 1/4W, 10%
R16 — 470Ω, 1/4W, 10%
R17 — 4.7 KΩ, 1/4W, 10%
R18,20 — 10 KΩ, 1/4W, 10%
R19 — 1 KΩ, 1/2W, 10%
R21 — 2.2KΩ, 1 W, 10%
R27,28 — 4.7Ω, 1 W, 10%
R29 — 220Ω, 1/2W, 10%
R22 — 2.2 KΩ, 1/2 W, 10%

WIRING CONNECTIONS— P3					
R.P.M.	CYCLES	MFG.	PIN 1	PIN 2	PIN 3
4	60	BODINE	BLUE	RED.	BLACK
10	60	BODINE	BLUE	RED	BLACK
60	60	BODINE	BLUE	RED	BLACK
4	50	BODINE	BLUE	RED	BLACK
10	50	BODINE	BLUE	RED	BLACK
60	50	BODINE	BLUE	RED	BLACK
ALL	50-60	CRAMER	BLACK	BLACK	

NOTE:

3	6	9	12
2	5	8	11
1	4	7	10

WITH DOOR OPEN & CHASSIS SWUNG OUT, THE ORDER OF THE R' OUTPUT POTENTIOMETERS –IS ALWAYS– BOTTOM TO TOP & LEFT TO RIGHT.

INVENTORY	USED ON	ASSEMBLY
3D107	5110	D31112

DRAFTSMAN RL 6/29/67 — CHECKED — APPROVED

K = 10³ M = 10⁶ — CONNECTION — NO CONNECTION

UNLESS OTHERWISE INDICATED
- RESISTANCE IN OHMS ± 10% 1/2 WATT
- CAPACITANCE IN MFD ± 20%
- INDUCTANCE IN HENRIES
- USE 60/40 ROSIN CORE SOLDER
- USE NO CORROSIVE FLUX

INVENTORY 3D747

TITLE: SCHEMATIC—FGE 5110 DATA-TRAK

NUMBER: KD33568 — REV. E — SHEET 1 OF 2

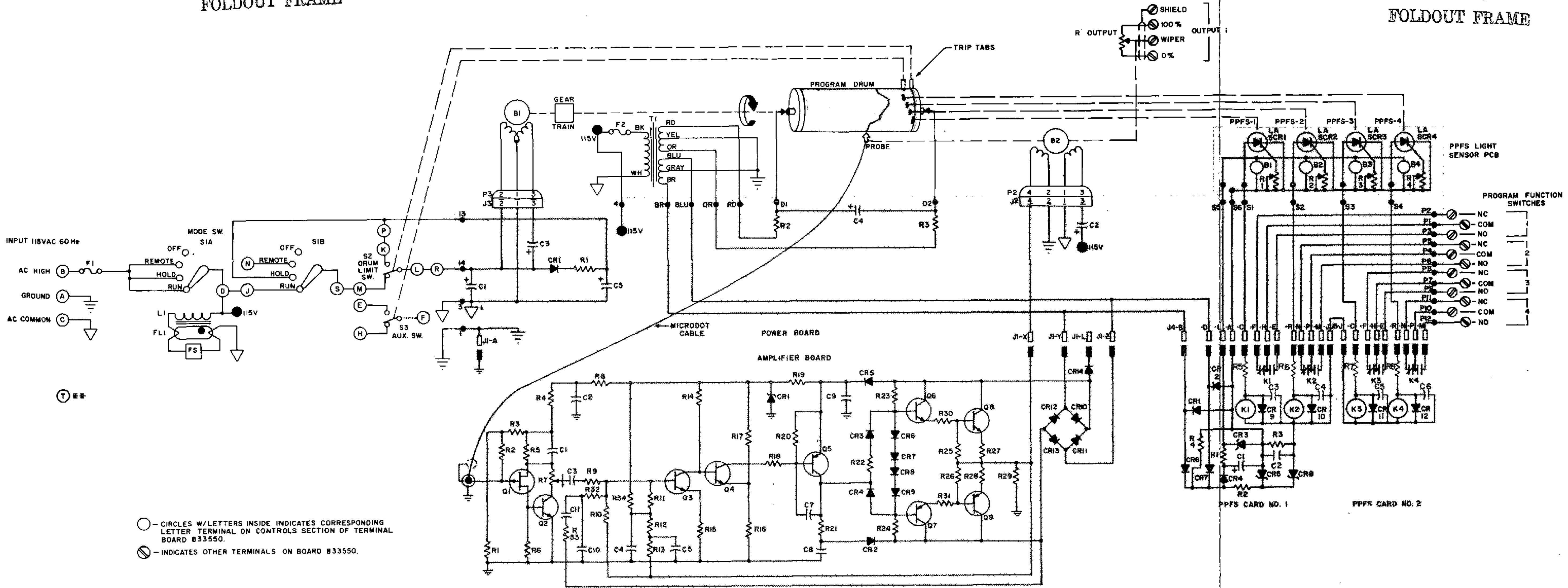
RESEARCH INCORPORATED MINNEAPOLIS, MINNESOTA

FOLDOUT FRAME

REV.	DESCRIPTION	DRAFT	DATE
	SEE SHEET 1		

2

FOLDOUT FRAME



FINAL, CASE, & CHASSIS ASSEMBLY

R OUTPUT - RESISTANCE & LINEARITY DETERMINED BY APPLICATION.

- FUSE F2 - SLO-BLO, 1/2 AMP, LITTLEFUSE, 3AG
- TRANSFORMER, T1 — A32269
- BALLAST, L1 — GE, 89G435
- STARTER, FS — GE, FS-5
- FLUORESCENT TUBE, FL1 — SYL, F8T5 CW
- MOTOR, B1 — BODINE OR CRAMER, SYNCHRONOUS
- MOTOR, B2 — GLOBE, 150 RPM
- MICRODOT CABLE — 50-3804
- SWITCH, S1 — A17688
- S2,3 — MICROSWITCH, V3-601
- FUSE F1, SLO-BLO, 3/4 AMP, LITTLEFUSE, 3AG

POWER BOARD ASSEMBLY D33544

- CAPACITOR, C1 — 1 MFD, 200V
- C2 — 1.5 MFD, 400V
- C3 — 1 MFD, 600V
- C4 — .01 MFD, 600V
- * C5 — 40-40 MFD, 450V
- DIODE, CR1 — D156
- RESISTOR, R1 — 100Ω, 1/2 W, 10%
- R2,3 — 27 KΩ, 1/2 W, 10%

* NOT USED W/CRAMER MOTOR.

USED W/REMOTE RUN RELAY OPTION.

AMPLIFIER BOARD ASSEMBLY B31504

- POTENTIOMETER, R7 — 20KΩ, MTC24L1
- TRANSISTOR, Q1 — U112
- Q2,3,4 — 2N3565
- Q5,7 — 2N3644
- Q6 — 2N3643
- Q8 — 2N3054
- Q9 — 2N3741
- ZENER DIODE, CR1 — 1D15B
- DIODE, CR2,3,4,5,6,7,8,9,14 — D142
- CR10,11,12,13 — D152
- CAPACITOR, C1, 4, 5 — 40 MFD, 10V
- C2 — 22 MFD, 15V
- C3 — 1.0 MFD, 35V
- C7 — .001 MFD, 1KV
- C8,9 — 78 MFD, 50V
- C10,11 — .01 MFD, C. DISC
- RESISTOR, R1, 34 — 470KΩ, 1/4W, 10%
- R2 — 100 MEGΩ, 1/4 W, 10%
- R 6, 32 — 100KΩ, 1/4 W, 10%
- R4 — 1.5 KΩ, 1/4W, 10%
- R5, 11 — 27 KΩ, 1/4W, 10%
- R8 — 3.3 KΩ, 1/2 W, 10%
- R9, 23, 24, 3 — 33KΩ, 1/4W, 10%
- R10, 33 — 10 MEGΩ, 1/4W, 10%
- R12, 25, 26 — 1 KΩ, 1/4W, 10%
- R13 — 22KΩ, 1/4W, 10%
- R14 — 27 KΩ, 1/4 W, 10%
- R15, 30, 31 — 100Ω, 1/4W, 10%
- R16 — 470Ω, 1/4W, 10%
- R17 — 4.7 KΩ, 1/4W, 10%
- R18, 20 — 10 KΩ, 1/4W, 10%
- R19 — 1 KΩ, 1/2W, 10%
- R21 — 2.2KΩ, 1W, 10%
- R27, 28 — 4.7Ω, 1W, 10%
- R29 — 220Ω, 1/2W, 10%
- R22 — 2.2KΩ, 1/2 W, 10%

OPTION

PPFS LIGHT SENSOR PCB ASSEMBLY
B32936

- LASR1, 2, 3, 4 — 3P 30
- LAMP, B1, 2, 3, 4 — BRITE-EYE, NO. 62
- POT., R1, 2, 3, 4 — HELI-POT, 62P-200 K

PPFS CARD ASSEMBLY
B32573

- CONNECTOR, J4, 5 — AMPHENOL, 143-15-03-110)
- RELAY, K1, 2, 3, 4 — P&B, PW5LS
- DIODE, CR1, 2, 4, 6, 7 — D142
- DIODE, CR9, 10, 11, 12 — 1N34
- ZENER DIODE, CR3 — 1N5357
- CR5 — 1N4752
- CR8 — 1N4731
- CAPACITOR, C1, 3, 4, 5, 6 — 78 MFD, 50 V
- RESISTOR, R2 — 470Ω, 1/2 W, 10%
- R3 — 47 KΩ, 1/2 W, 10%
- R1 — BROWN DEVIL, 8 W, 5%
- FOR MODEL PPFS-1 — 700Ω
- PPFS-2 — 400Ω
- PPFS-3 — 250Ω
- PPFS-4 — 200Ω
- R4 — [illegible], 1/2 W, 10%
- R5, 6, 7, 8, — 1K, 1/4W, [illegible]
- CAPACITOR, C2 — .01 MFD 50 V

REMOTE RUN CIRCUIT
A27315

- RELAY, K1 — P&B, KRP11AG

PRESET COUNTER
F30021

- COUNTER — HECON, FA043 50

WIRING CONNECTIONS — P3					
RPM	CYCLES	MFG.	PIN 1	PIN 2	PIN 3
4	60	BODINE	BLUE	RED	BLACK
10	60	BODINE	BLUE	RED	BLACK
60	60	BODINE	BLUE	RED	BLACK
4	50	BODINE	BLUE	RED	BLACK
10	50	BODINE	BLUE	RED	BLACK
60	50	BODINE	BLUE	RED	BLACK
ALL	50-60	CRAMER	BLACK	BLACK	

NOTE

3	6	9	12
2	5	8	11
1	4	7	10

WITH DOOR OPEN & CHASSIS SWUNG OUT THE ORDER OF THE R OUTPUT POTENTIOMETERS IS ALWAYS BOTTOM TO TOP & LEFT TO RIGHT.

3D107	5110	D31112
INVENTORY		
	USED ON	ASSEMBLY

DRAFTSMAN: RL 6/29/67
CHECKED:
APPROVED:

CONNECTION / NO CONNECTION

UNLESS OTHERWISE INDICATED
- RESISTANCE IN OHMS ± 10% ½ WATT
- CAPACITANCE IN MFD ± 20%
- INDUCTANCE IN HENRIES
- USE 60/40 ROSIN CORE SOLDER
- USE NO CORROSIVE FLUX

INVENTORY
3D747

TITLE: SCHEMATIC—FGE 5110 DATA-TRAK

NUMBER: KD33568 — REV. E

SHEET 2 OF 2

RESEARCH INCORPORATED MINNEAPOLIS, MINNESOTA

RECOMMENDED SPARE PARTS LIST

Model FGE 5110 Data-Trak Programmer	33568	1267 A
TITLE	NUMBER	REV

ITEM	DESCRIPTION	PART NO.	INVENTORY	QUANTITY 1	2	3	4	↓
1	Fuse - F2 (1/2 Amp SLQ-BLO)	Littlefuse 3 AG	17A100			X		
2	Contact Pin Assembly (Note: six spares provided initially)	A26071	18A134				X	
3	Drive Cable (Cat Gut)	Squire Co.	10A100	X				
4	Probe Assembly	B16344	19A102	X				
5	Probe Amplifier Assembly	B31504	3B608	X				
6	Aux. Switch Trip Tab	A18962	18A125	X				
7	Drum Limit Switch Trip Tab	A18963	18A126	X				
8	Output Potentiometer (Standard)	Spectral Model 850	6B101	X				
8A	Output Potentiometer (Special)							
	NOTE: Specify Valve, linearity							
	tolerances, etc.							
9	Optional - PPFS Unit							
9A	Bulf B1 - B4 (Cal Glo)	Brite Eye No. 62	11A136		X			
9B	SCR--LA SCR1--LA SCR4 (Solid-State	3P30	16A189	X				
	Prod. Inc.)							
10	Fuse - F1 (3/4 Amp SLO-BLO)	Littlefuse 3AG	17A157			X		

ORDERING INFORMATION

1) For ordering information and latest prices, contact your local representative or the RESEARCH, Incorporated factory in Minneapolis, Minnesota.

2) When ordering spare parts, please include references both to this parts list number and revision level, plus, the Model Number and Serial Number of the instrument for which these parts are being ordered.

TWX	PHONE MINNEAPOLIS	TELEX
910-576-2837	612-941-3300	029-5328

R·I CONTROLS
A DIVISION OF RESEARCH, INCORPORATED
BOX 24064 MINNEAPOLIS, MINNESOTA USA 55424

INSTRUCTION MANUAL

THERMAC Series 6000

Temperature Controller

Model 624A

The options indicated below have been included in this unit.

- [ ] Multi-Range Card
- [ ] Span Zero
- [ ] Rate/Reset
- [ ] Special Output

Publication Number 200300

RESEARCH INC
BOX 24064 MINNEAPOLIS, MINNESOTA USA 55424
PHONE (612) 941-3300 • TWX 910-576-2837 • TELEX 029-5328

Model 624A THERMAC

Temperature Controller

INSTRUCTION MANUAL

RECORD OF REVISIONS

REVISION	DESCRIPTION
A-O	Manual reprinted with revisions 11/69
	Changed pages 3-2, 6-3 and the title page.
	Added the RECORD OF REVISIONS (page A)
	Changed the publication number from IM 624
	& 624A-D30-569 to 200300
A-1	Manual printed with revisions 5/70
	Changed pages A and 3-3
A-2	Manual reprinted with revisions 8/70
	Changed pages A, 1-1, 1-8, 1-5, 3-1, 3-2, 3-3, 4-2,
	4-4, 4-5, 4-6, 4-7, 5-5, 5-6, 6-2, 6-3, Spare Parts
	Lists, KD33680 to Rev. X, KC34364 to Rev. E
B-O	Revised Edition 12/70
B-1	Manual reprinted with revisions 8/71. Changed pages
	A, 6-2, and 6-3.

Publication Number: 200300

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SECTION 3 OPERATING CONTROLS AND INDICATORS

SECTION 4 NORMAL OPERATING PROCEDURES

SECTION 5
TEMPERATURE CONTROL CIRCUITS
D30 OPERATING PRINCIPLES

SECTION 6
GENERAL MAINTENANCE AND CALIBRATION PROCEDURES

SECTION 7 SCHEMATICS

SECTION 1 INTRODUCTION

1-1 SCOPE

This manual describes the 624A Temperature Controller and provides information for its installation, operation and maintenance.

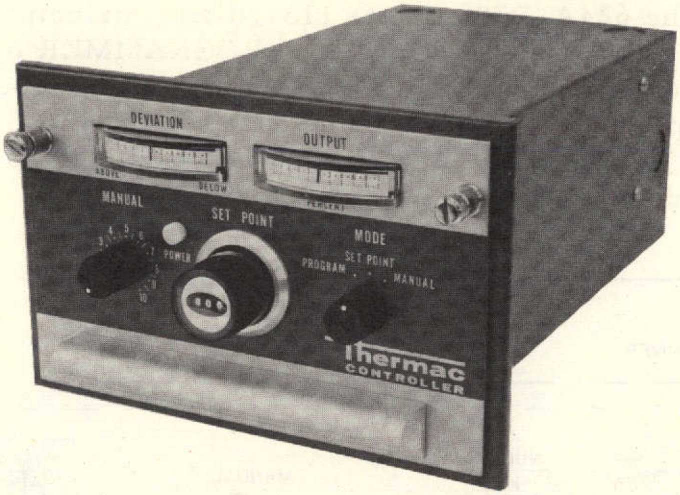


Figure 1-1 Model 624A Temperature Controller

1-2 GENERAL DESCRIPTION

The 624A is a primary control instrument utilized with RESEARCH, INCORPORATED closed-loop control systems. Its completely solid-state design provides both the optimum in precision process control, and extended trouble-free operation.

The instrument can be utilized with any process-control system in which changes in the controlled variable (temperature, power, displacement, etc.) can be effected by changes in the magnitude of an electrical control signal generated by the D30, and, in which the changes in the controlled variable can be sensed by an electrical transducer.

When operated in conjunction with a proportional power controller, a heating device and a thermocouple, the instrument provides the means for establishing and automatically maintaining the temperature of a workpiece at any desired set-point level within the operating range of the system or, when utilized with an external programming device, to vary the controlled temperature according to an arbitrary pre-determined program.

In addition to SET POINT and PROGRAMMER CONTROL modes, the 624A-D30 may be operated in MANUAL mode to enable control of the voltage applied to the external heating device to be solely a function of the selected setting of the MANUAL control dial, irrespective of workpiece or oven temperature.

1-3 FUNCTION OPERATION

The 624A-D30 utilizes closed-loop principles in controlling temperature in either SET POINT or PROGRAMMER operating modes; open-loop control is utilized in MANUAL operating mode. Principles of closed-loop control, and the manner in which closed-loop control is accomplished are illustrated in Figure 1-2 and described under the following headings.

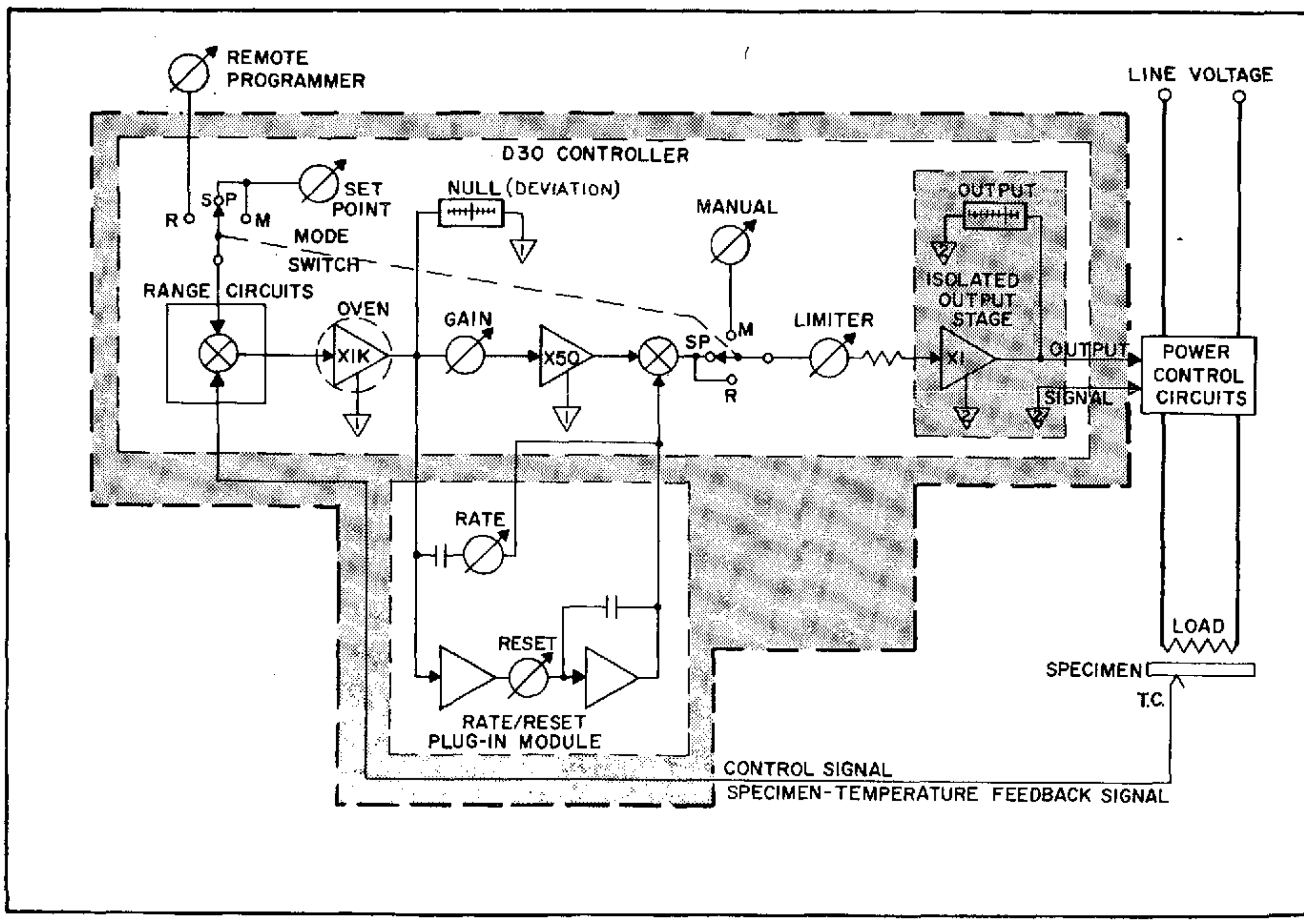


Figure 1-2 Functional Block Diagram 624A-D30

The manner in which the magnitude of the DC control signal, (and hence the temperature of a workpiece or oven) is controlled, is described under the following headings.

1-3-1 Set Point Operating Mode

In SET POINT operation, a thermocouple, affixed to the surface of the workpiece (or located within an oven), generates a feedback millivoltage which represents workpiece temperature. This signal is summed with a set-point command millivoltage in the range card circuitry of the unit. With the workpiece temperature equal to the set-point level, the command and feedback millivoltages cancel each other and zero error voltage is applied to the input of the amplifier circuits. The amplifier circuits, in turn, transmit a zero-magnitude control signal to the external power controller firing circuit, thus preventing additional application of voltage to the heater.

Any tendency of the workpiece temperature to cool below the setpoint command level causes a proportional decrease in feedback millivoltage. The feedback millivoltage no longer completely cancels the command millivoltage and an error voltage (usually in the micro-volt region) appears at the input of the amplifier circuits. The error voltage is amplified and its polarity reversed to become the control signal applied to the power controller firing circuit which applies a proportional amount of voltage to the heaters. This increase in thermocouple output which brings the controller back to NULL or zero output.

The extent to which the workpiece temperature may deviate below the command level before the unit applies maximum corrective signal to the external power controller is defined as the "band of proportional control". The width of the proportional band is adjustable by a GAIN control to provide stable system operation under various conditions of heater and workpiece thermal response.

Due to workpiece or oven heat losses, the controlled temperature will always settle out somewhat below the set-point level with proportional control only. This inherent temperature error (termed temperature-droop) may be cancelled out by manually resetting the SET POINT dial to a higher setting such that the temperature will droop exactly to the desired temperature. Instruments equipped with optional rate/reset circuitry do not require manual resetting of the SET POINT control to achieve a zero-error (no droop) condition. Reset action is accomplished automatically be integrating out a signal until NULL is achieved.

The rate circuit on the optional rate/reset printed circuit card provides derivative action to the controller. It detects a rate-of-change of error signal (control signal) and adds a signal to either aid or oppose the control signal. The circuit anticipates the temperature approach to the set-point and cuts back the control signal to minimize overshoot. Additionally, if the specimen temperature is deviating away from set-point, the rate circuit will generate a signal of appropriate polarity (either additive or subtractive to the control signal) to either increase or decrease signal output and return the specimen to set-point temperature. The rate circuit functions ONLY when the error signal is CHANGING in magnitude, and the polarity and magnitude of the rate signal is determined by the direction and rate-of-change of error signal (respectively).

1-3-2 Programmer Operating Mode

In the remote programmer mode of operation, the output potentiometer of an external programming device (such as a RESEARCH, INCORPORATED DATA-TRAK) is switched in to substitute for the SET POINT control in the unit. Operation in this mode is identical to set-point operation except that, rather than being maintained at a static set-point level, the command temperature is varied as a function of time, according to a pre-plotted program chart mounted in the programming device.

1-3-3 Manual Operating Mode

In the MANUAL mode of operation, closed-loop control is not utilized; the temperature command and feedback signals exercise no authority over the magnitude of the control signal, and the control signal becomes solely a function of the zero-to-maximum setting of the MANUAL control dial.

1-4 MODULAR SUB-ASSEMBLIES

The main sub-assemblies to the 624A-D30 controller (some with additional plug-in modules) are called out in Figure 1-3 below and described under the headings which follow.

1-4-1 624A Case

The unit consists of a case, complete with transformers for driving the modular plug-in D30 assembly, and wire harnesses for connecting the plug-in unit to the transformers and to barrier strips provided at the rear of the case for external connections. The schematic diagram illustrates the wiring within the case. With the D30 plug-in unit installed, all external wiring connections will terminate at the barrier strips at the back of the unit. Knock-outs are provided on the case for wire penetration and conduit mounting.

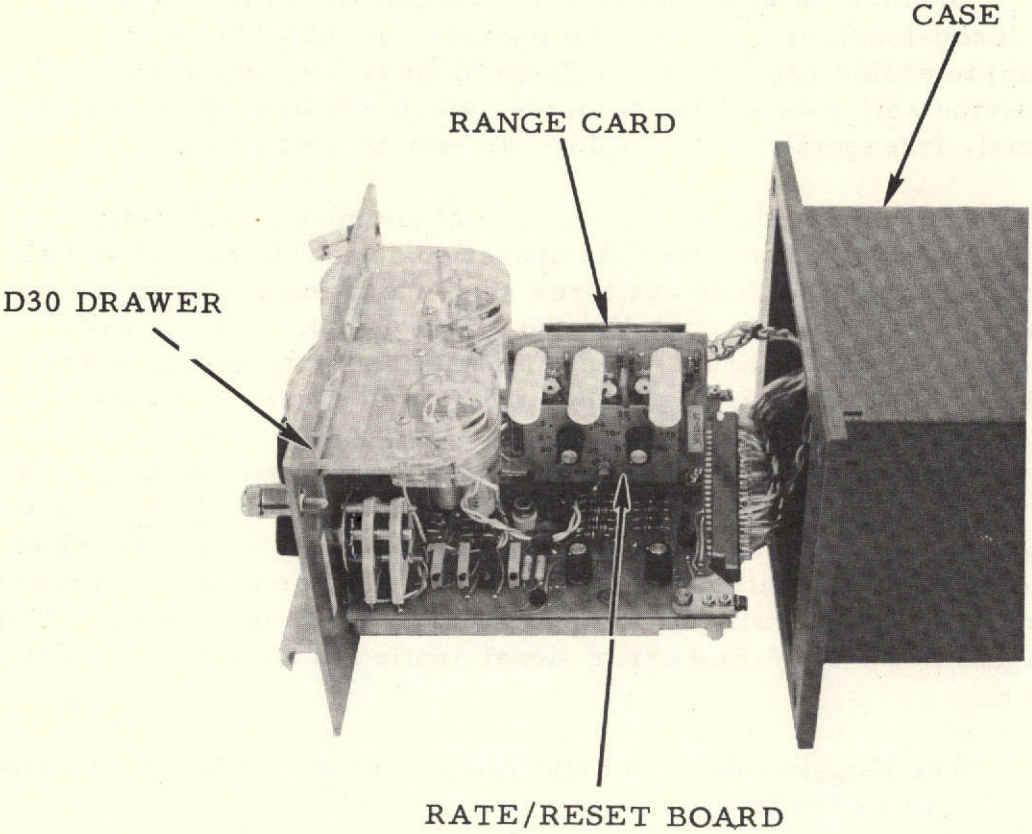


Figure 1-3 Main Modular Sub-Assemblies

The unit measures approximately 6 inches high, 9 inches wide and 12 inches deep. Exact dimensions are provided in Figure 2-1, as well as information pertinent to panel-mounting the unit. The unit is provided with rubber feet for "test bench" use and may be provided with a handle if so designated by the customer at the time of purchase.

1-4-2 D30 Control Module

The D30 controller is the primary control module manufactured by RESEARCH, INCORPORATED in the THERMAC Series 6000 line of controllers. It is a drawer-type control module designed for use in either the 624A or 625 Frame of this series of controllers.

When operated in conjunction with a proportional power controller, a heating device, and a thermocouple, the D30 provides the means for establishing and automatically maintaining the temperature of a workpiece at any desired set-point level within the operating range of the system; or, when utilized with an external programming device, to vary the controlled temperature according to an arbitrary, pre-determined program.

In addition to SET POINT and PROGRAMMER control modes (closed-loop), the D30 may be operated in MANUAL mode (open loop) to enable proportional voltage to be applied to the external heating device solely as a function of the selected setting of the MANUAL control dial, irrespective of workpiece or oven temperature.

The electronics of the D30 are of completely solid-state design, utilizing integrated-circuit, operational amplifiers as the main active components. The D30 has three such operational amplifiers, with straight DC coupling to amplify the error signal. The first of these operational amplifiers is oven temperature-controlled to minimize drift. The controller has an overall gain in excess of 50,000.

Meters are provided to monitor the error signal (DEVIATION) and control signal (OUTPUT). The error signal is the difference between command millivoltage (established in the precision resistor network of the range card by the setting of the SET POINT dial or REMOTE programmer) and the feedback millivoltage generated by the thermocouple. The output signal is the amplified error signal applied to the external power controller.

The plug-in rate/reset and range card modules are described under the following headings.

1-4-2-1 Rate/Reset Module (Option RR)

The rate/reset module is a plug-in option which may be added to the controller at any time. These circuits are designed to increase system stability and controlling accuracy by eliminating some problems inherent with proportional control only. Refer to Heading 1-3-1 for a description of the function of these circuits.

1-4-2-2 Range Card Module Options

The range card module is a plug-in unit. Each "range" is a precision-resistor, voltage-divider network. In each range circuit, a command millivoltage (determined by the selected setting of the SET POINT control or remote programmer potentiometer) is summed in a series-opposition fashion with the feedback millivoltage generated by a thermocouple attached to an external specimen. The difference between these two signals is the error signal applied to the amplifier circuits. The resistors in each range must be specially selected for the type of thermocouple to be employed and/or the millivoltage range of the feedback signal.

Zener-diode-regulated reference voltage is applied to the range card from the reference-voltage supply on the D30. The range card precisely divides the reference voltage to establish the range of the SET POINT potentiometer such that its zero and span voltages correspond to the curve of voltage generated by a particular thermocouple or power transducer from the minimum to maximum levels of a specific range.

Automatic thermocouple-cold-junction temperature compensation is provided in most range card modules by resistance spool D (see schematic). A standard range card is referenced to 75°F if its temperature range is designated in °F; if its temperature range is designated in °C, it is referenced to 25°C. All temperature range cards are equipped with a fail-safe resistor (R_{fs}) which causes the output signal of the THERMAC to be driven fully negative if the thermocouple circuit opens or presents a high resistance.

NOTE

> The fail-safe resistor will cause an undesirable offset in the potentiometric measuring circuits of the range card if the resistance value of the thermocouple circuit exceeds 100 ohms. Therefore, the 10 megohm resistor, (R_{fs}) must be removed if such high-resistance circuits are to be utilized with the D30.

There are three basic types of range cards which are available for use with the D30. Described under each of the following headings is one of the three basic types. Special range cards are available on request.

1-4-2-2-1 Standard Range Cards

The standard range card is a single-range unit with the resistor spools calculated for a particular thermocouple, temperature range, and/or millivoltage span.

1-4-2-2-2 Multi-Range Range Cards (Option RC)

The multi-range range cards may be supplied in one of two configurations. One has provisions for three ranges, the other has provisions for five ranges. A switch is provided on the module to select the range to be used.

Both the three-range and the five-range models have provisions for either two thermocouples or one thermocouple and one millivoltage feedback. Therefore, in the multi-range range cards, the customer has options of up to five total ranges and two types of feedback.

1-4-2-2-3 Span/Zero Range Cards (Option SZ)

The span/zero range card is a single-range unit selected for a particular span of millivoltage feedback (for example 0 - 50 MV). The precision resistor network of the span/zero range card is augmented by the addition of two potentiometers designated SPAN and ZERO. These potentiometers enable the operator to increase or decrease the span of the range card by up to 50% or 100% (specified at time of purchase) and to shift the zero of the range card over 50% or 100% of its span (also specified at the time of purchase).

1-5 SPECIAL OUTPUT-SIGNAL PARAMETERS

If the customer requires an output signal which differs from the standard ±5 VDC signal generated by the D30, a special amplifier module is connected in series with the output signal from the D30 to convert the standard signal to the signal required by the customer. This module will be located at the rear of the 624A case. The +15 VDC and -15 VDC potentials shown on the schematic diagram of the 624A case are utilized to supply this external module.

1-6 SPECIFICATIONS

General specifications are listed below for the D30 and the optional rate and reset circuitry.

1-6-1 Temperature Controller (D30)

Output Signal	0 ±5 VDC (0 ±1.0 MA into 5K ohm load
Ambient Operating Range	0 - 50°C
Input (Plug-in Cards)	Thermocouple or MV source
Indication and Measuring Accuracy	±0.25% or 15 uv (whichever is greater)
Control Repeatability	0.1% (0 - 2000°F CR/AL Range)
Control Sensitivity	5 microvolts
Common Mode Rejection	120 db at 60 Hz, 130 db at DC
Peak Common-Mode EMF	150 V
Stabilization Time	2.5 minutes
Drift	±30 uv over 72 hours
Gain	50,000
Response	100 milliseconds
Set Point Control	Utilizes 1000-part logging dial with load
Proportional Band Range	100 uv 2.5 mv (4°F to 275°F K)

Output Signal Limiter	30% to 100% (positive-going signal only)
Operating Modes	MANUAL (open loop) SET POINT (closed loop) REMOTE (Programmed from remote DATA-TRAK or equivalent 100 ohm setpoint potentiometer)
Power Requirements	120 VAC, 60 Hz, 0.5 ampere
Ambient Temperature Effect	Change of ambient from 25°C to 50°C causes a maximum change ±30uv in control point.
Line Voltage Effects	±10% change in line voltage causes no more than ±5 uv shift in control point.

1-6-2 Optional Plug-In Rate/Reset Cards

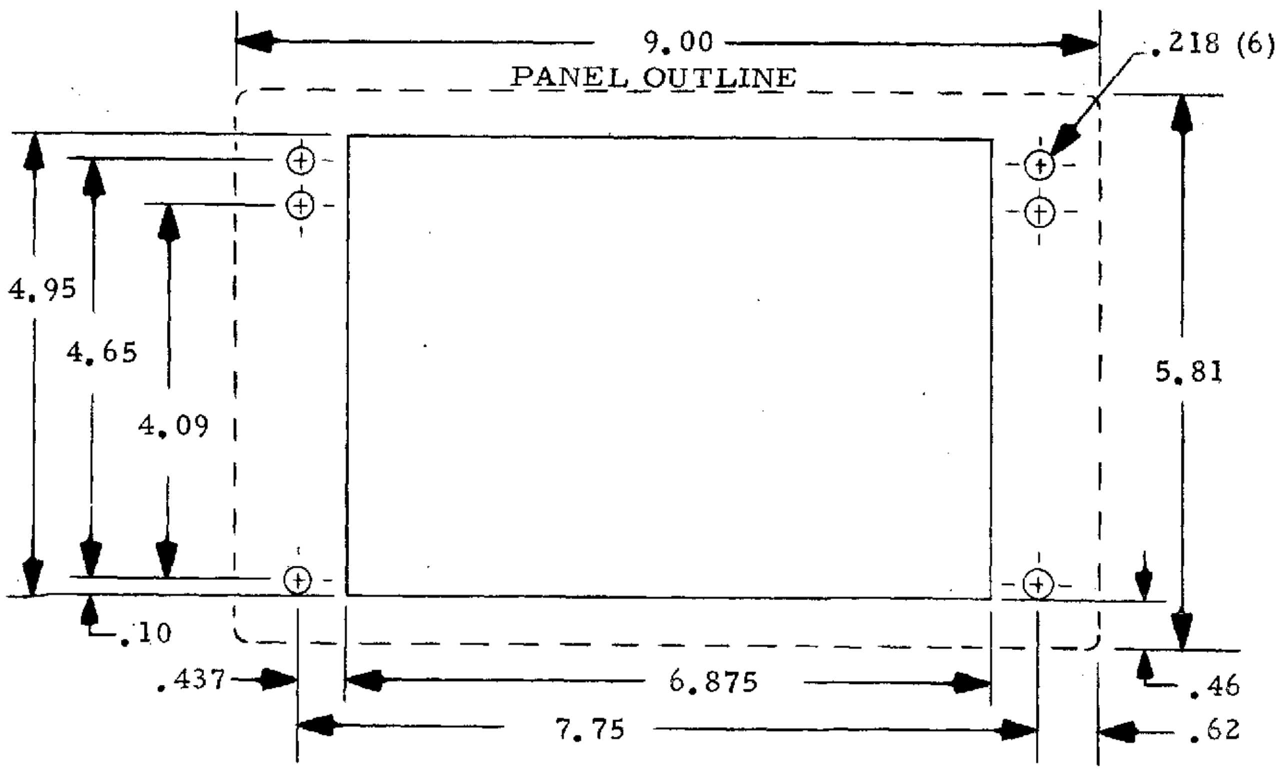
Rate Time	0 - 90 minutes
Reset Adjustment	0.02 to 30 repeats per minute
Anti-Reset Windup	Inhibits reset action at edge of proportional band.

2-1 GENERAL

Installation of the instrument consists of connecting line and signal wiring as described under Heading 2-3. If it is desired to panel-mount the unit rather than to utilize it as a portable instrument, proceed as outlined under the following heading. Before attempting installation, it is recommended that the operator read the balance of this manual to asure a full understanding of the operation and physical configuration of the unit.

2-2 PANEL-MOUNTING THE 624A-D30 SERIES

The instrument must be mounted in a 12-gauge, or heavier, panel to prevent distortion of the panel due to the weight of the instrument. Cut-out dimensions and other pertinent information for panel-mounting are provided in Figure 2-1.



(12.0 inches deep)

Figure 2-1 Mounting Dimensions for the 624A-D30 Series

Panel-mounting is most easily accomplished by first removing the electronics assembly from within the instrument case, and then replacing it after the case has been secured to the panel.

To remove the electronics assembly, loosen the two captive thumbscrews on the front panel of the unit and draw the drawer (D30) out until the stops are reached. Unplug the plug-in range card (see Figure 1-3) or disconnect range-card leads (thermocouple extension wires). Then carefully withdraw the assembly from the case.

If a carrying handle or rubber feet have been provided, these items must be removed from the instrument case before installing it in the panel. In addition, the rear cover of the case should be removed to expose the entrance panel, and "knock-outs" at points selected for external-wiring entrance should be removed prior to installation. The instrument case may be slipped into the cutout opening from the front side of the panel, and secured in position with 10-32 hardware through the four holes provided in the mounting flange on the front of the case.

Replace the electronics assembly in the instrument case to complete the panel-mounting procedure. Connection of external wiring is next accomplished as described under the following headings.

2-3 MECHANICAL ADJUSTMENTS AND WIRING CONNECTIONS

In either panel-mounting or in preparing the instrument for portable use, the plug-in electronics assembly should be withdrawn from the instrument case before removing "knock-outs" from selected external-wiring entrance holes.

2-3-1 Line-Voltage Connection

AC line voltage connects to terminals 7 (AC neutral) and 8 (AC high) on barrier strip E2. A third wire from either building- or power-source ground should be connected to terminal 9.

2-3-2 Output Signal Connections

The output signal from the D30 controller is available at terminal 2 (-) and terminal 4 (+) of barrier strip E2. By referring to the schematic of the 624A case, it will be apparent that the positive signal is first present at Pin 1 of the barrier strip and is applied to pin 4 via jumpers to pins 3 and 4. These jumpers are provided for insertion of under- and over-temp contacts as well as series connection of optional signal amplifiers (see Headings 1-5 and 2-3-6).

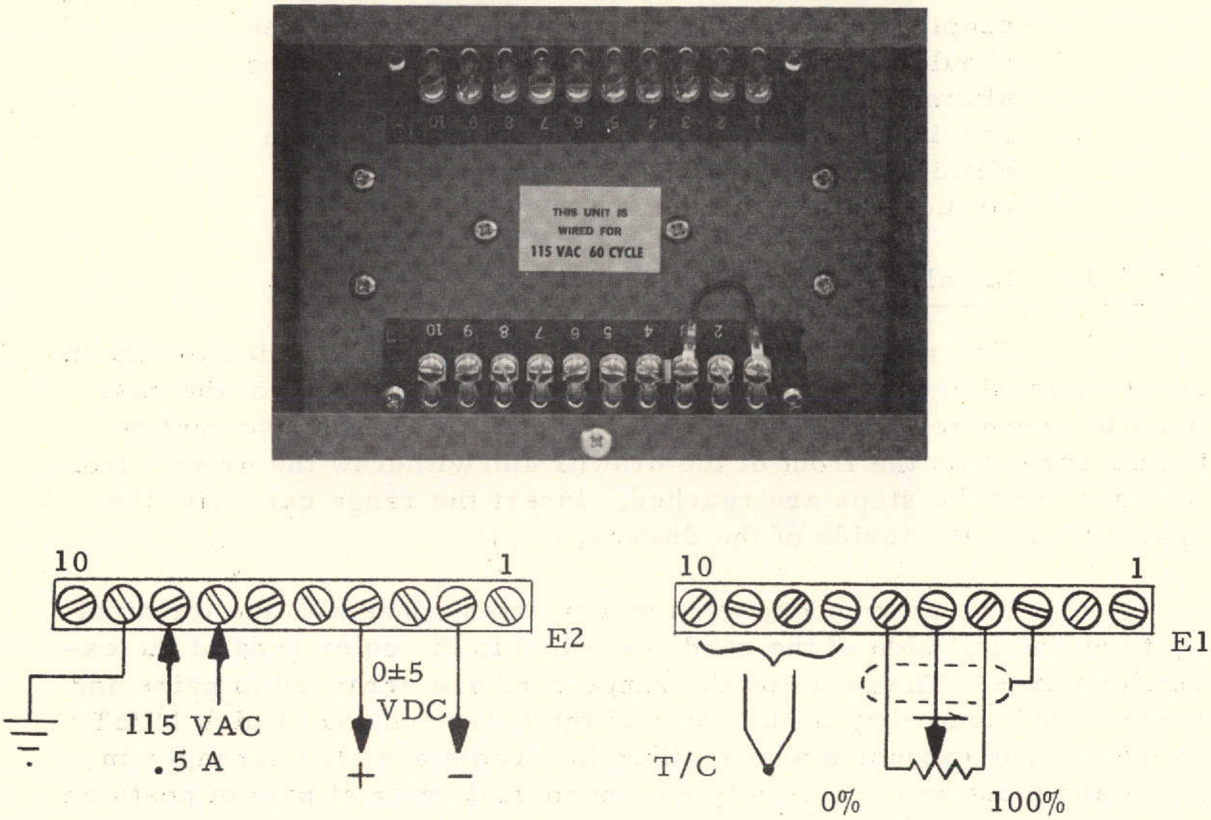


Figure 2-2 External-Wiring Connections

2-3-3 Thermocouple Connections

Thermocouple or thermocouple-extension wires connect to terminals of barrier strip E1 according to type. The location of barrier strip E1 is shown in Figure 2-2; the terminals to which the positive and negative leads of specific thermocouples connect will depend upon the extension wire configuration which carries the feedback millivoltage from this barrier strip to the range card (see information under next heading). A table listing the standard configuration of thermocouple extension wire to barrier strip E1 is provided on the schematic diagram of the frame. This configuration is subject to change, however, for the reasons outlined under the Heading 2-3-3-1.

NOTE

Since this unit has been designed for the optimun in response (100 ms), with the best practical series-mode noise rejection, some applications may require special consideration. When a T/C wire is lying in a high-density electrical field, or the specimen is located a considerable distance from the controller, it is recommended that a twisted thermocouple wire be used. If possible, the specimen should be grounded. If the specimen is floating, attempt to bring the T/C wire away from the specimen at a 90° angle. These practices can eliminate much series-mode noise which may be induced into the thermocouple loop.

2-3-3-1 Installing Range Card Module

The range-card module is a plug-in unit to which the thermocouple extension wires from the barrier strip at the rear of the case must be connected. To install a range card, loosen the two captive thumb-screws on the front of the drawer and withdraw the drawer from the case until the stops are reached. Insert the range card with the spools toward the inside of the drawer.

The thermocouple extension wires connect to the terminal posts on the foil side of the card according to the color code of the extension wires. The posts on the range card are arranged in pairs and color-coded according to the color of the extension wire which MUST be used. The extension wires within the frame are also arranged in pairs and must be connected to the appropriate pair of pair of posts on the range card. If necessary, make a continuity check of the extension wire to determine what terminals on the barrier strip at the rear of the case correspond to what input on the range card to assure proper connection of wiring from the T/C junction to the proper pair of range-card terminals.

Listed in Table 2-1 are the most common thermocouples and the color code and polarity for the extensions wires. Also provided is a curve relating SET POINT Dial Divisions versus Temperature (or Millivoltage) of the range card (see Heading 3-2-3).

TABLE 2-1
THERMOCOUPLE EXTENSION WIRE COLOR CODE

THERMOCOUPLE	T/C SYMBOL	COLOR CODE + LEAD	- LEAD
Chromel/Alumel	K	Dark Blue (Chromel)	Red (Alumel)
Copper/Constantan	T	Dark Blue (Chromel)	Red (Const.)
Iron/Constantan	J or Y	White (Iron)	Red (Const.)
Chromel/Constantan	E	Dark Blue (Chromel)	Red (Const.)
Platinum 10% Rhodium/Platinum	S	Dark Blue (Pt., 10% Rh.)	Light Blue (Platinum)
Platinum 13% Rhodium/Platinum	R	Dark Blue (Pt., 13% Rh.)	Light Blue (Platinum
Millivoltage	MV	Dark Blue	Light Blue

2-3-4 Power-Transducer Connections (Optional)

If optional closed-loop power control is to be utilized instead of, or in conjunction with, temperature control, the power-transducer leads connect to terminals on barrier strip E1 as follows: Positive Lead, Terminal 9 (dark blue); negative lead, terminal 10 (light blue).

2-3-5 External-Programmer-Connections (Remote Set Point)

An external programmer (or a remote set-point potentiometer) may be utilized in conjunction with the instrument by connecting its output potentiometer (100 ohm unit) to terminals of barrier strip E1 as follows:

Potentiometer Leads	E1 Terminals
Clockwise (100%)	4
Counterclockwise (0%)	6
Wiper	5
Shield	3

2-3-6 Remote-Run/High-Low Limit Connections

As mentioned under Heading 2-3-2, jumpers are provided in series with the positive output signal line. These jumpers have been provided to enable series wiring of an external set of contacts for external control of the removal or application of control signal. This external device may range from a remote-run switch or relay, to a safety interlock such as a high-low limit meter. In order for the unit to operate these terminals must be shorted together (assuming output signal connections to terminal 4).

2-3-7 Installing Rate/Reset Module

The rate/reset module may be added to the D30 drawer at any time. The unit is a plug-in module with no "hard" wiring. To add the rate/reset module, loosen the two captive thumb screws on the front panel of the drawer and withdraw the drawer from the electronics assembly until the stops are reached. Insert the module such that the RATE and RESET controls are directly over the % VOLTAGE LIMITING and GAIN controls on the D30 main board (see Figure 1-3).

SECTION 3 OPERATING CONTROLS AND INDICATORS

3-1 GENERAL

Operating controls and indicators for monitoring the status of the instrument are listed and described under the following heading, their physical locations are called out in Figures 3-1 and 3-2.

3-2 FRONT-PANEL CONTROLS AND INDICATORS

This group of controls and indicators is located on the front panel of the D30 control module as called out in Figure 3-1. The individual controls and indicators are described under Headings 3-2-1 through 3-2-6.

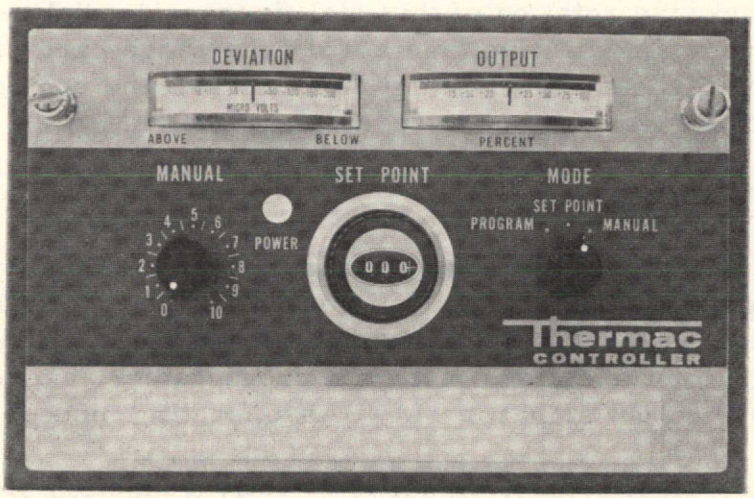


Figure 3-1 Front-Panel Controls and Indicators

3-2-1 POWER Indicator

This white indicator is lighted whenever line voltage is applied to the unit.

3-2-2 MODE Switch

This switch enables selection among the D30 control modules' operating modes: SET POINT, PROGRAMMER or MANUAL. In Set Point or Programmer operating modes, a potentiometer dictates the level of common millivoltage established in the range card circuits of the D30. These modes are closed-loop operation. In MANUAL mode, the control signal out of the D30 to the power control circuits is strictly a function of the zero-to-maximum setting of the MANUAL dial; the feedback signal and/or command millivoltage exercise no control over the D30 output signal (see Heading 4-3-1).

3-2-3 SET POINT Control

This three-place, turns-counting dial provides the means for establishing the command millivoltage across the range circuits of the D30 range card. A curve relating SET POINT dial settings to temperature and/or feedback millivoltage points in the selected range is provided with this manual.

Clockwise rotation of this dial (increasing dial settings) increases the command millivoltage across the range card, requiring ever-increasing feedback millivoltage to "null" out the controller and reduce its control signal output to zero.

3-2-4 MANUAL Control

This control is utilized in manual operating mode only, to govern the magnitude of control signal applied to the external power control circuits irrespective of workpiece conditions. Neither the SET POINT control, nor the optional external programmer, exercise any control over D30 output signal in MANUAL operating mode.

The output control signal is strictly a function of the zero-to-maximum setting of the MANUAL control potentiometer in MANUAL mode. Clockwise rotation of the MANUAL control will cause the output control signal to range from zero to +5 VDC maximum (unless the maximum level of control signal has been limited by utilizing the % VOLTAGE LIMITING Control - see Heading 3-3-2).

3-2-5 DEVIATION Indicator

The DEVIATION indicator scale is calibrated zero ±200 microvolts. With the DEVIATION meter centered at zero (null) on the scale, the feedback millivoltage is equal to the command millivoltage in the controller's range circuits. Deflection of the indicator to the left from null (minus direction) or to the right from null (positive direction) indicates that the feedback millivoltage is respectively higher than, or lower than, command millivoltage, and that a control signal is being generated in the D30 proportional circuits.

Full scale on the deviation meter represents the following degrees F and C. Due to the nonlinearity of thermocouples, this is presented for use as a guide at 75°F.

THERMOCOUPLE	°F	°C
S	62°	34°
R	62°	35°
J	7°	4°
T	9°	5°
K	9°	5°

The DEVIATION indicator, along with the SET POINT dial, may also be utilized to indicate feedback millivoltage (the temperature of a workpiece or oven) when operating in open-loop manual mode (see information under Heading 4-3-1).

3-2-6 OUTPUT Indicator

The OUTPUT indicator scale is scaled zero to ±100%. It indicates output control signal out of the D30 control module drawer into the power control firing circuit (0 ±5 VDC or ±1 MADC into 5 K ohm load).

3-3 SUB-PANEL CONTROLS

This group of controls and indicators is located behind the front panel of the D30 drawer. Access to these controls is achieved by loosening the two captive thumb screws on the front panel, and drawing the panel assembly forward by pulling on the single handle across the bottom of the unit. Exercise reasonable caution when drawing the unit out on the slides to avoid damaging the wiring and/or slide assembly.

The individual controls in this group are utilized to set the D30 up for operation with a particular feedback signal and operating range, and to adjust the instrument for optimum controlling accuracy.

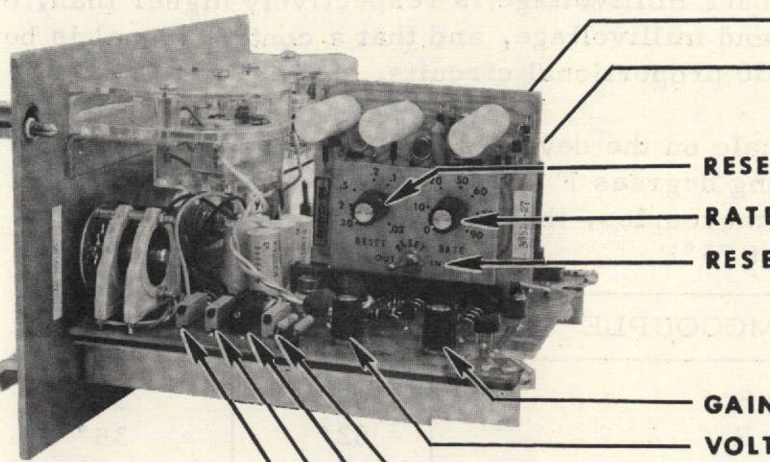


Figure 3-2 Standard Sub-Panel Controls

3-3-1 GAIN Control

This control provides the means for adjusting the gain of the D30 proportional circuitry. The gain of the D30 is defined as the level to which feedback millivoltage may deviate from command millivoltage before maximum output signal (±5 VDC) is obtained. This is also referred to as the band of proportional control.

Within the band of proportional control, as feedback millivoltage deviates from command millivoltage, the D30 applies proportional control signal with respect to feedback millivoltage polarity. The upper edge of the proportional band is the point at which the D30 is applying maximum corrective signal (+5 VDC) to the power control circuits (full power out).

Clockwise rotation of the GAIN control increases the gain of the proportional circuitry and narrows the proportional band. The tighter the proportional band, the more responsive the controller will be to shifts in the level of feedback signal. For optimum controlling accuracy during operation, this control should be set for minimum proportional band consistent with system stability. If the gain of the

D30 is set too high, minor shifts in the feedback millivoltage will cause maximum corrective signal (and hence maximum power) to be applied, possibly causing unstable system operation.

3-3-2 % VOLTAGE LIMITING Control

This control enables limiting of the maximum amount of control signal which may be applied by the D30 to the power controller without affecting the gain of the unit. The control functions in any operating mode (set point, programmer, or manual) and effectively limits the amount of power which may be applied to the load by the power control circuits (see Heading 4-3).

With this control set fully CCW (at dial setting 0), the output signal of the D30 may increase to the full +5 VDC level (no limiting). Clockwise rotation of this control reduces the level to which the output control signal may increase in the positive direction (increases the amount of limiting action).

In a temperature control application, workpiece temperature rise-rate, which is a function of limiter setting, is reduced when utilizing limiting action. That is, if the output control signal of the D30 cannot go fully positive, the power controller cannot apply full power to the load. The increased life of heating elements when operating at less than their maximum rated voltage, is worthwhile consideration for establishing a limiting level.

The control and circuit have no effect on signals in the negative-going direction. That is, if the feedback signal deviates out of the proportional band in the positive direction (indicating specimen exceeds SET POINT setting), the output signal will deviate fully negative regardless of the setting of the % VOLTAGE LIMITING control. The OUTPUT meter will deviate fully negative; however, power will be removed from the load as soon as the signal reaches zero.

3-4 OPTIONAL RATE/RESET MODULE OPERATING CONTROLS

The rate/reset module is a plug-in option. The circuits on this module aid in controlling stability and accuracy. The controls located on this module are listed and described under the following headings.

3-4-1 RATE Control

This control is utilized to adjust the amount of rate action added to proportional control. Rate action aids controlling stability by preventing sudden shifts in the controlled temperature above or below the set point level (velocity and/or rate-of-change errors). The rate signal is generated whenever the error signal is changing in magnitude. When the error signal is constant, the rate signal is not generated.

The signal out of the rate circuit is summed with the amplified error signal (control signal) at the output to the 2nd amplifier stage. The polarity of the rate signal will be such that it will oppose the change in command signal magnitude depending upon the direction of change in error signal. That is, if the error signal is approaching command level (set point), the polarity of the rate signal will be such that it opposes the command signal, preventing overshoot (either positive-going or negative-going). If the error signal is deviating away from command level, the signal out of the rate circuit will oppose the change in control signal magnitude out of the D30, preventing sudden shifts away from set point.

The RATE control dictates the magnitude of rate signal which will be added to oppose the change in control signal magnitude as a function of the rate-of-change of error signal within the proportional band (see Heading 3-3-1). The RATE dial is calibrated 0 - 90 in a clockwise direction. This scaling correlates to the time in minutes that it would take the error signal to deviate from zero (set point) to the edge of the proportional band (or from the edge of the proportional band to zero) at a given rate-of-change.

The selected dial setting for the RATE control will dictate what rate-of-change of error signal will cause the rate circuit to generate full rate signal out. For example, with the RATE control set at six, an error signal which is changing at such a rate that it would go from zero to the edge of the proportional band (or from the edge of the proportional band to zero) in six minutes will cause the rate circuit to generate full output rate signal. If the error signal is changing at a rate which is slower than that selected by the RATE dial setting, the rate circuit will generate a signal which is proportionally lower than that level of signal generated by a rate-of-change which is equal to or greater than the selected RATE control setting.

Primarily, the rate circuit was designed to compensate for thermal lag in a system. That is, systems where immediate changes in power input do not result in immediate changes in heat input to the specimen. This "thermal lag" is normally caused by heating elements which continue to emanate heat after power is removed. On slow responding systems, where the thermal lag is extensive, the higher RATE control settings (CW direction) will probably be more applicable; on fast responding systems, where thermal lag is minimal, the lower RATE control settings (CCW direction) will probably work better. On many fast-responding systems, rate signal may not be necessary at all, and, in fact, rate may be detrimental to system stability. The RATE control should be left fully CCW in these instances.

3-4-2 RESET Control

The reset circuit on the optional rate/reset plug-in module generates a signal which is additive to the control signal when the controller is operating within the proportional band (see Heading 3-3-1). In a temperature control system, with proportional control alone, the specimen temperature will always settle out somewhat below the set point level. This inherent "temperature droop" occurs as the specimen nears set point and the control signal out of the D30 has almost been reduced to zero. At this point, heat-loss factors of the specimen are exactly equal to heat input factors and the specimen has not yet reached set point.

The reset circuit is an integrating amplifier which monitors the error signal. As soon as this signal begins to reduce (indicating the specimen temperature has entered the proportional band), the reset circuit begins integrating out an increasing signal.

This signal continues to build in magnitude until no error signal is detected (indicating feedback millivoltage and command millivoltage are equal).

When the controller "nulls" out, the control signal applied by the D30 to the external power controller is generated solely by the reset circuit, and its magnitude is dictated by the level the reset signal had achieved when the controller nulled. At this point, the specimen is at set point, the heat-loss factors are equal to the heat-input factors, and a constant level of power is being applied to the load.

The RESET control controls the integration time of the reset amplifier. The control is scaled from .02 to 30 in a counterclockwise (CCW) direction. These increments correlate to the number of times the reset amplifier could integrate from zero to full output (+5 VDC) in one minute. Hence, at the lower settings the reset signal will be added more slowly than at the higher settings. As long as the error signal remains within the limits of the proportional band, the reset circuit will remain active. Any shift of either error signal or command signal which does not drive the error-signal magnitude out beyond the edge of the proportional band, will cause the reset circuit to begin integrating; either increasing the output signal or reducing the output signal. As soon as the reset signal reaches the proper magnitude for feedback to null the controller, the circuit ceases integrating, and holds output constant.

If, while the system is operating under the control of the reset signal, the command or feedback signals should vary such that the error signal deviates beyond the edge of the proportional band, the reset amplifier will be de-energized and full controller output will be generated by the proportional control circuits. The reset amplifier will begin integration again as soon as the error signal returns to within the limits of the proportional band. The circuit which causes this action is termed the "anti-reset wind-up".

The anti-reset wind-up circuit is standard in all RESEARCH, INC. rate/reset circuits. "Reset wind-up" is defined as "the condition where a controller is applying full power to the load due to integration of the reset signal up to full output". On some controllers, positive reset signal is generated whenever there is an error signal, and on a slow responding system, the specimen can overshoot before the reset signal is removed or begins negative integration. The anti-reset wind-up circuit in the D30 rate/reset circuits prevent this condition.

Reset wind-up can occur in the D30 when the specimen is unable to attain set point but the error signal achieves the lower limit of the proportional band. In this case, the reset circuit will be activated and the signal will wind up to full controller output (+5 VDC) and the system will run at full power until something causes a change in either feedback signal or command signal to drive the error signal out of the proportional band and initiate the anti-reset wind-up circuit.

3-4-3 RESET IN/OUT Switch

The RESET IN/OUT switch is utilized to remove the reset signal for both calibration and stability on a system. Since the reset signal increases the gain of the D30, and can cause some instability even at the lowest settings, it may be necessary to remove the reset signal from some units; given a particular combination of controlled variable and controller response.

3-5 OPTIONAL RANGE CARDS OPERATING CONTROLS

The controls described under the following headings are provided with the optional multi-range or span/zero range cards.

3-5-1 RANGE Switch

The RANGE switch allows the operator to select the precision-resistor network which is to be connected to the input posts on the range card. On range cards utilizing two different types of inputs (thermocouples) the RANGE switch also selects which pair of input posts are to be connected into the precision resistor networks (selects input and range). Refer to Headings 4-6 and 4-18.

3-5-2 SPAN Control

The SPAN control is provided on the optional span/zero range card. The span/zero range card is selected for a particular millivoltage-range feedback signal (see Heading 1-4-2-2-3).

The SPAN control is a logging-type duo-dial of one-thousand places. Adjustment of this control enables the operator to calibrate the range card such that the maximum millivoltage feedback signal anticipated will correlate to 999 dial divisions on the SET POINT dial on the front panel of the D30. The SPAN control may be functional for ±50% or ±100% span of the millivoltage range selected at the time of purchase. For example, on a 0 - 50 millivolt range card with a 50% span, the amount of feedback signal necessary to null the controller with a SET POINT dial setting of 999 can be adjusted from 25 millivolts to 75 millivolts by utilizing the SPAN control.

Refer to Heading 4-7 for detailed instructions concerning set-up and calibration procedures for the SPAN control.

3-5-3 ZERO Control

The ZERO control is functionally identical to the SPAN control (see preceding heading) with the exception that it functions at the low end of the millivoltage range selected at the time of purchase, and is utilized to calibrate for 000 dial divisions on the SET POINT dial on the front of the unit. Like the SPAN control, the ZERO control may be ordered with a range of either ±50% or ±100% of span millivoltage.

Refer to Heading 4-7 for detailed information concerning set-up and calibration of this control.

3-6 BALANCE 1, 2 and 3 POTENTIOMETERS

These potentiometers, located on the D30 main board directly behind the MODE switch, are utilized in calibration of the proportional amplifier circuits. Refer to Section 6 for calibration procedures.

3-7 CALIBRATION SWITCH

This switch, located on the D30 main board directly behind the MANUAL control, is utilized in calibration of the proportional amplifier circuits. It should never be placed in the CAL position unless the unit is undergoing calibration. Refer to Section 6 for calibration procedures.

SECTION 4 NORMAL OPERATING PROCEDURES

4-1 GENERAL

This section of the manual provides information for placing the 624A-D30 in operation in each of its operating modes: MANUAL, SET POINT, and PROGRAMMER. The 624A-D30 is most commonly utilized in a closed-loop temperature-control process. Therefore, the information presented in this section of the manual is based on the operation of the instrument in such an application.

4-2 PRE-OPERATING CHECKOUT

Prior to operation of the 624A-D30, the following conditions should be insured:

1) All interwiring connections proper and secure.

2) Workpiece at a sufficiently safe distance from all high voltage points.

3) Continuity of the thermocouple, and its bonding to the workpiece, checked.

4) Polarity of thermocouple connections to the D30 double-checked.

5) Thermocouple extension wire isolated as far as possible from line and load wiring.

If the unit is being utilized with a RESEARCH, INC. power controller, before placing the unit in operation, refer to the appropriate heading in the Power Controller Instruction Manual and select the proper operating mode for the firing circuit, depending upon the specific type of load to which the instrument is connected.

CAUTION: DO THIS BEFORE APPLYING LINE VOLTAGE TO THE UNIT.

4-3 MANUAL OPERATING PROCEDURE

In MANUAL operating mode, the value of the voltage delivered to the heating device is solely a function of the selected setting of the MANUAL control, provided the power control circuit does not incorporate current-limiting circuitry, or the current-limiter adjust and/or the % VOLTAGE LIMITING controls are positioned for minimum (zero) limiting action.

If the % VOLTAGE LIMITING control of the D30 is utilized, load power will increase with clockwise rotation of the MANUAL dial until the selected limiting level is reached. Further increase in control signal is then inhibited to prevent further increase in load voltage.

The procedure for placing the unit in operation in MANUAL mode is as follows:

1) Position MODE switch to MANUAL

2) Rotate MANUAL control fully counterclockwise.

3) If the power control circuits incorporate current-limiting circuitry, and limiting action is not desired, set the current-limiter control for zero limiting. If current limiting is desired, set the control for maximum limiting action.

4) If voltage limiting is not desired, rotate the % VOLTAGE LIMITING control fully counterclockwise. If voltage limiting is desired, rotate the % VOLTAGE LIMITING control fully clockwise.

5) Apply line voltage to the instrument.

6) If limiting is not utilized, MANUAL control of power delivered to the load may be commenced from this point with no further adjustments. If limiting is to be utilized, final adjustment is accomplished as outlined in Step 7.

7) Rotate the MANUAL control fully clockwise. Rotate the applicable limiter adjust (CCW for % VOLTAGE LIMITING) until the selected maximum (load voltage or load current) is obtained, thus completing the procedure.

4-3-1 Determining Workpiece Temperature (Feedback Level) in MANUAL Operation

Although workpiece or oven temperature is not directly controlled in MANUAL operating mode, its level can be determined (if within the specified range(s) of the instrument) by adjusting the

SET POINT dial until the DEVIATION meter is at midscale zero. Although the SET POINT control exercises no authority over output in MANUAL mode, it may be utilized to balance out the temperature feedback millivoltage from the thermocouple. The dial setting of the SET POINT control after this balance has been achieved may then be correlated with a point of the SET POINT Dial Divisions vs. Temperature (millivoltage) curve to determine the temperature of the workpiece or oven.

4-4 SET POINT OPERATING PROCEDURES

NOTE

> The first stage integrated circuit amplifier is oven temperature controlled for low-drift characteristics. Allow 2.5 minutes warm-up time before making any precise settings or adjustments.

The value of voltage (control signal out) delivered to the heating element in SET POINT operating mode is a function of any error existing between workpiece or oven temperature, and the set point command level.

If limiting is to be utilized (either current or voltage), the instrument must first be set up for manual operation and adjusted for the desired level of limiting as described under Heading 4-3, and then set up for set point operation as follows:

1) De-energize the instrument.

2) Set the following controls as indicated:

    a. MODE switch in SET POINT position.

    b. If the instrument is equipped with optional rate/reset circuitry, set both the RATE and RESET controls to their zero settings. Put RESET IN/OUT switch to OUT.

    c. Set the GAIN control full CCW.

3) Apply line voltage to the instrument.

4) Allow 2.5-minute warm-up period.

The instrument is now prepared to be adjusted to a closed-loop temperature control process, which is accomplished as described under the following headings.

4-4-1 Adjusting the Instrument to a Process

A closed-loop temperature control process is initiated, after accomplishing the steps under Heading 4-4, by rotating the SET POINT dial to a setting corresponding to the desired temperature level (refer to SET POINT Dial-Divisions vs. Temperature curve for proper dial setting).

After establishing the set point command level, the GAIN control must be adjusted for proper temperature-control operation. If the instrument is equipped with the optional rate-reset circuits, rate and reset action may be added to proportional control after the GAIN adjustment has been accomplished.

The optimum settings of the GAIN, RESET and RATE controls depend on the electrical and thermal characteristics of the components which comprise the system. The more important factors which affect temperature control operation are listed below:

A. Workpiece color, mass, losses, and specific heat.

B. Ambient temperature

C. Heater response, loss and capacity.

D. Thermocouple mass, position and bonding to the workpiece.

E. Power controller response and capacity.

In view of the numerous variables involved, a general, rather than a specific, adjustment procedure for each of these controls is provided under the following headings, in the order in which they should be performed.

4-4-1-1 Adjusting the GAIN Control

The GAIN control setting establishes the level to which error signal magnitude may deviate from null before the unit is delivering full signal to the load. The GAIN control setting should be increased clockwise (the proportional band tightened) to a point where system oscillations occur in response to small shifts in command (set point) level. The control setting must then be reduced counterclockwise (proportional band widened) until oscillations cease.

When a workpiece has settled out as close as possible to set point level with minimum gain, the GAIN control setting should be increased while observing the DEVIATION meter. On initial "settle-out" the DEVIATION meter should be reading in the positive direction (to the right) indicating the specimen has not achieved the set point level and a "temperature-droop" condition exists (see Heading 1-3-2). The GAIN control setting should now be increased in the clockwise (toward 10) direction in small increments, allowing the DEVIATION indicator to settle out after each increase. After one of these adjustments, the system may go into oscillation (indicated by oscillations of the DEVIATION meter). Should this occur, the setting of the GAIN control should be reduced in a counterclockwise direction (proportional band widened) until system oscillations cease. Figure 4-1 shows typical temperature-versus-time histories for three GAIN control settings.

If the unit is not equipped with a rate/reset module, refer to Heading 3-2-5 to determine the amount of droop. If this temperature differential between set point and specimen temperature is unacceptable, the SET POINT control setting may be increased to compensate for the droop. If temperature is being programmed, the droop (if significant) must be compensated for in the program. However, if the unit is equipped with a rate/reset module, the droop need not be compensated for by resetting of the SET POINT control.

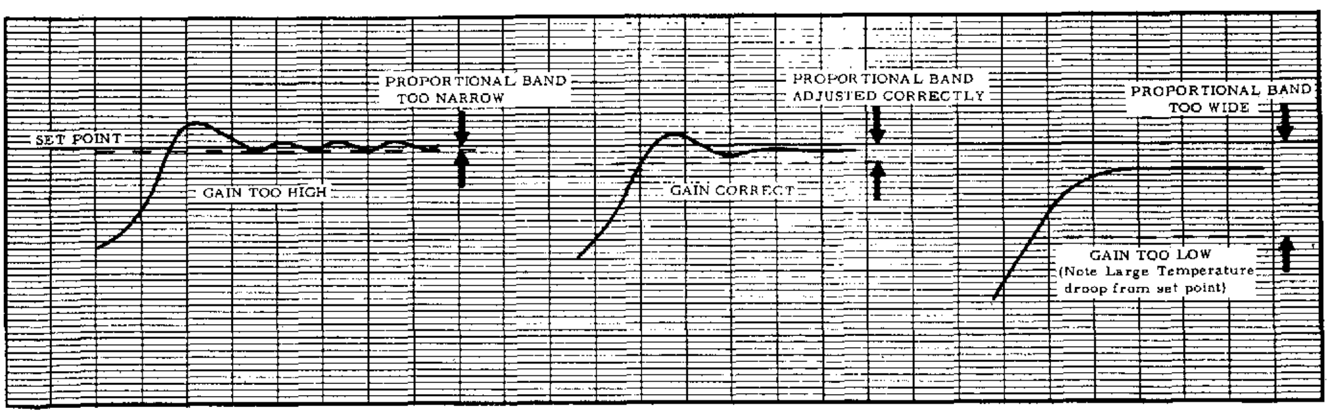


Figure 4-1 Gain Control Adjustments

Once the DEVIATION indicator has settled out after widening of the proportional band (again, somewhat to the right, above "null"), reset signal may be added to the proportional signal to bring the workpiece exactly to set point (null). Refer to the information under the following heading for adjustment of the RESET control.

4-4-1-2 Adjusting the RESET Control

Reset signal may be added to proportional control after the set point has been selected and the GAIN control adjusted as outlined under the preceding headings.

To initially introduce reset action, place the RESET control at the lowest (.02) setting (fully clockwise) so the reset signal will be added at its slowest rise-rate. It is not recommended that reset signal be added at the faster times (repeats-per-minute) until the operator has had some experience as to the effect of reset signal rise-rate on system stability. Generally, reset may be added at the faster rates on the slower responding systems and specimens, whereas on the faster responding systems and specimens, the faster reset rise-rates may result in system oscillations and/or overshoot.

Most high-response systems (such as those utilizing radiant heating) do not normally require much reset, since the high response allows a band of proportional control of only a few degrees Fahrenheit. Slow response ovens and the like, however, generally demand wider bands of proportional control to provide stable system operation. Wider bands proportionally increase temperature droop, which must then be cancelled out by automatic reset action if accurate temperature control is to be achieved (see Heading 3-4-2).

With the unit stabilized under proportional control as described under the preceding heading, and the RESET control at its lowest (CW) setting, switch the RESET IN/OUT switch to the IN position. Observe the DEVIATION indicator for a decrease in the indicated droop error (a deviation of the Indicator toward the left to null). SLOWLY, rotate the RESET control counterclockwise a small increment (toward the higher dial settings), and observe the DEVIATION indicator for reset action and an indication of rise-rate.

When the DEVIATION indicator nulls out at zero, increase the setting of the SET POINT dial and again observe the DEVIATION indicator and/or specimen for reset action and any overshoot. If there is no overshoot and the specimen is responding too slowly, increase the setting of the RESET control (CCW) another increment toward a higher dial setting, and again shift the SET POINT control to increase the command level. At some point, some overshoot and/or oscillation should be noted. The RESET control setting must then be decreased (turned clockwise to lower dial setting) until just a very small amount of overshoot and/or oscillation occurs with repeated shifts upward in command level. It may be necessary to widen the proportional band (reduce GAIN control setting) with the addition of reset signal. Figure 4-2 shows typical temperature-versus-time histories for three RESET control settings.

Reset action is automatically inhibited outside the proportional band of control by a special anti-reset circuit to prevent an initial temperature overshoot after a shift in command point greater than the width of the proportional band.

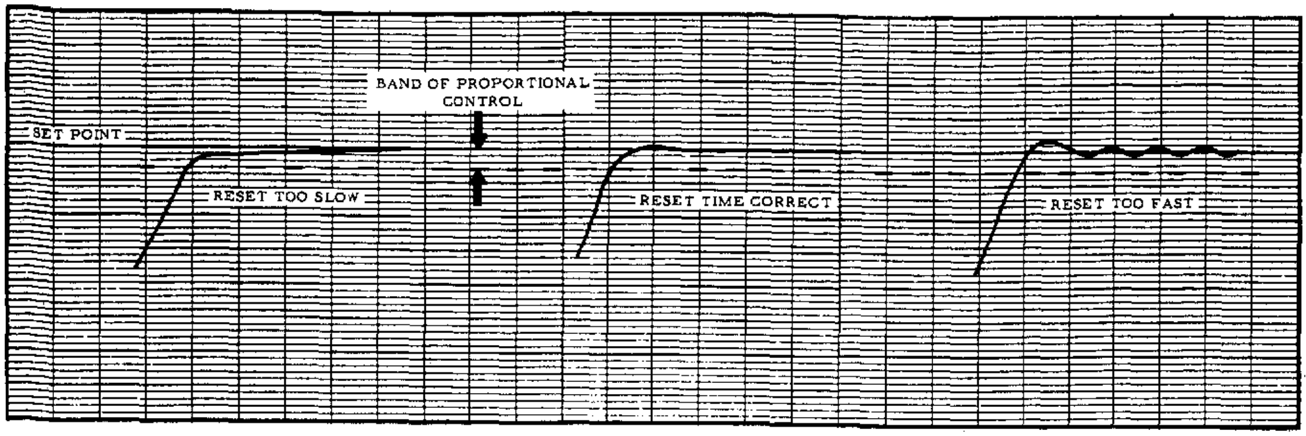


Figure 4-2 Adding Reset Action to Proportional Control

If a satisfactory setting of the RESET control cannot be achieved without unacceptable overshoot or, if even without reset, the system is subject to unacceptable overshoot, rate action may be required to stabilize the system. If rate action is required, place the RESET IN/OUT switch to OUT and proceed as outlined under the following heading. When rate action is required, the sequence of control adjustment must be GAIN, RATE and then RESET.

4-4-1-3 Adjusting the RATE Control

Rate action may be added to proportional control or proportional-plus-reset control to improve system responsiveness and to prevent overshoot. Some systems cannot tolerate rate action, being inherently too responsive and/or unstable. On the other hand, some systems have satisfactory response without rate action, being stable enough and responsive enough to achieve set point without rate action. If rate action cannot be tolerated or is unnecessary, the RATE control should be left fully at zero.

To introduce rate action, slowly rotate the RATE control clockwise up from its zero position while at a control point, until system oscillation occurs. Excessive rate action is characterized by system oscillations of a higher frequency than those produced by excessive proportional control (gain) action. When system oscillations begin, reduce the setting of the RATE control until oscillations cease.

When the system has stabilized after oscillation, shift the setting of the SET POINT control and observe the results on the

DEVIATION meter. If the RATE control is too high, the DEVIATION indicator will indicate a "hunting" action characterized by a series of jerky movements of the pointer as it enters the null area. If rate action is not sufficient, the DEVIATION indicator will indicate overshoot by large deviations to the left. Figure 4-3 shows typical temperature-versus-time for three RATE control settings.

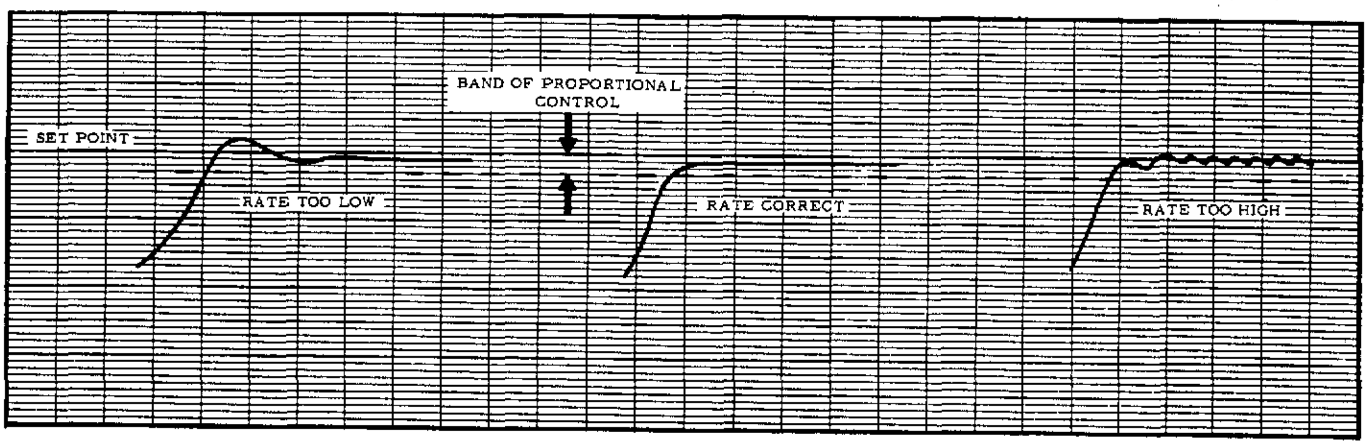


Figure 4-3 Adding Rate Action to Proportional Control

Rate action may be increased as long as overshoot decreases with small shifts in command (set point) level. When the best setting of the RATE control has been achieved, refer to Heading 4-4-1-2 and, if necessary, adjust the RESET control.

Occasionally, the amount of extraneous signal pickup in a system will not permit the use of rate action since this action greatly amplifies noise. This problem can usually be overcome by grounding the specimen and the controller, and by twisting the thermocouple leads and keeping them well away from the power wiring.

4-5 PROGRAMMER OPERATING PROCEDURE

Assuming that an external programming device has been connected to the instrument, as described in Section 2, the following procedure should be followed to adjust the unit for programmer operating mode:

1) If limiting is to be utilized (either voltage or current), initially place the instrument in MANUAL mode and adjust for desired limiting level (see Heading 4-3).

2) Place the instrument in SET POINT operating mode and adjust GAIN, RESET, and RATE controls as described under Heading 4-4.

3) Place the MODE switch in PROGRAMMER mode, and initiate programming operation.

It is recommended that when establishing the settings of the GAIN, RESET and RATE controls in SET POINT, prior to Programming (Step 2), these settings be established at the high-temperature level of the program.

4-6 CHANGING RANGES WHILE OPERATING

Changing the setting of the RANGE switch on multi-range cards while at a control point may result in an upset of control unless the % VOLTAGE LIMITING control is utilized to stabilize output until the set point is re-established (see Heading 4-8). If the switch is inadvertently transferred to an open input or unused switch position, the thermocouple fail-safe resistor (Rfs) will be connected to the input, shutting the unit off.

4-7 OPERATION WITH SPAN/ZERO RANGE CARDS

A Span/zero range card is designed for versatile use with most millivolt transducers utilizing copper leads (see Headings 1-4-2-2-3, 3-5-2, and 3-5-3). It cannot, however, be used in conjunction with a thermocouple since no automatic temperature compensation is provided, due to the adjustable zero reference feature. Additionally, no fail-safe circuitry is provided in this range card since most millivolt transducers used with this type of range card have high-impedance outputs which are adversely affected by the fail-safe circuitry.

This card is designed to provide the operator with a flexible means of matching the dial divisions of the SET POINT control with the expected millivoltage difference between the lowest and highest millivoltage output of the transducer for a particular application. The ZERO control enables the operator to match the lowest end of the SET POINT control (000 DD) with the lowest expected millivoltage output of the transducer. The SPAN control enables the operator to match the highest end of the SET POINT control (999 DD) with the highest expected millivoltage output of the transducer.

The information provided under the following headings describes the procedure for calibrating a span/zero range card for a particular millivoltage range feedback signal. If an adjustable millivoltage source is available, utilize the information provided under

Heading 4-7-1 and 4-7-2. If such millivoltage source is not available, utilize the procedure provided under Heading 4-7-3.

CAUTION

> While calibrating a span/zero range card, disconnect the controller from its load or place the MODE switch in MANUAL position and reduce the MANUAL control to its zero setting.

4-7-1 Adjusting the ZERO Control

To adjust the ZERO control, set the SET POINT control at 000 dial divisions and apply a feedback millivoltage of the lowest magnitude anticipated to the power transducer feedback connections (see Heading 2-3-4). Energize the controller (see CAUTION note under preceding heading) and adjust the ZERO control on the range card for a "null" indication on the DEVIATION meter.

4-7-2 Adjusting the SPAN Control

To adjust the SPAN control, set the SET POINT control to 999 dial divisions and connect a millivoltage signal of the maximum magnitude anticipated to the power transducer connections (see Heading 2-3-4). Energize the controller (see CAUTION note under Heading 4-7) and adjust the SPAN control for a "null" reading on the DEVIATION meter. Recheck the setting of the ZERO control.

4-7-3 Using the SPAN DIAL DIVISIONS vs. SPAN MILLIVOLTAGE and ZERO DIAL DIVISIONS vs. ZERO SUPPRESSION Curves

Both SPAN and ZERO controls have logging-type duo-dials of 1000 places, enabling accurate positioning of the associated potentiometers. The span setting is a slightly non-linear function; however, a SPAN DIAL DIVISIONS vs. SPAN MILLIVOLTAGE CURVE is provided, which enables the operator to determine the required SPAN control DD setting required for a particular MV span. The ZERO control varies the zero position as a linear function of the SPAN control setting, with each ZERO control DD corresponding to 0.2% of the particular span MV.

To set up a span/zero range card for optimum operation, first determine the difference between the highest and lowest millivoltage output levels expected to be generated by the transducer during the operation. This difference millivoltage determines the span required; refer to the SPAN DD vs. SPAN MV graph to determine the necessary SPAN control DD corresponding to the span millivoltage. Secondly, determine the millivoltage difference between the lowest anticipated transducer millivoltage output and the lowest millivolt value of the range card (design zero value). Express this millivoltage difference with a plus value of transducer millivoltage output if above the design value, a minus value if below the design zero value. To express the difference in ZERO control dial divisions, divide this millivoltage difference by 0.2% of the span millivoltage determined above, since each ZERO control DD corresponds to 0.2% of the span MV. Add these dial divisions to 500 DD for positive difference, and subtract from 500 DD for negative difference from design zero value.

EXAMPLE:

PROBLEM: A transducer produces a linear output proportional to E • I cos θ; where E is load voltage, I is load current, and θ is phase angle between E and I (Formula for real power).

It is desired to control power by either SET POINT control or remote programmer between 20 and 80 KVA. According to the particular transducer data, this corresponds to a transducer output varying between 10 and 40 millivolts. The controller has 0 - 50 MV, ±50% span, ±100% zero span/zero range card installed.

SOLUTION:

SPAN SETTING:

1. Difference between 10 and 40 MV = 30 MV (SPAN)
2. Corresponding SPAN control DD for 30 MV = 292 DD (from graph).
3. Position and lock SPAN control at 292 DD.

ZERO SETTING:

1. Difference between 10 MV and 0 MV = 10 MV (positive.)
2. $\frac{\text{Zero difference}}{0.2\text{T Span MV}} = \frac{+10 \text{ MV}}{0.002 \times 30 \text{ MV}} = \frac{10}{0.06} =$ 167 DD
3. 500 DD + 167 DD = 667 DD
4. Position and lock ZERO control at 667 DD.

With the range card set as shown above, the SET POINT control will correspond to 20 KVA at SET POINT DD = 000; 80 KVA at

SET POINT DD = 999. Thus, each SET POINT control DD corresponds to

$$\frac{80 \text{ KVA} - 20 \text{ KVA}}{1000} = 60 \text{ watts}$$

4-8 USING THE % VOLTAGE LIMITING CONTROL TO STABILIZE OUTPUT

In addition to functioning as a straight voltage limiter as described under Headings 3-3-2 and 4-3, the % VOLTAGE LIMITING control may be utilized to stabilize controller output while changing modes or switching ranges. This is accomplished by limiting to the desired level in MANUAL mode with the MANUAL control at 10 (fully clockwise).

For example, if operating in set point and it is desired to switch modes or change ranges with minimal upset, turn the % VOLTAGE LIMITING control clockwise until the OUTPUT meter begins to indicate a drop in output signal due to limiting. Set the control as close as possible to the desired stabilized output level and turn the MANUAL control fully clockwise. Switching the MODE switch to MANUAL will cause the controller to hold signal level and, hence, load voltage (not necessarily specimen temperature) constant at the limited level. Ranges may now be changed and set points re-established or manual control assumed, without undue disruption of control.

SECTION 5
TEMPERATURE CONTROL CIRCUITS
D30 OPERATING PRINCIPLES

5-1 GENERAL

The function of the circuits of the D30 module is to compare a feedback signal with a command signal and to generate a signal which is proportional in magnitude to any existing differential (error). Additionally, the signal generated by the D30 must reflect by polarity whether the feedback signal is higher than, or lower than, the command signal. This section of the manual provides a general description of how the D30 accomplishes its function.

To provide ease in maintenance and modification, and increased flexibility of application, all signal circuitry is logically divided with respect to function and mounted on individual plug-in sub-assemblies. These major sub-assemblies include a main board consisting of the basic proportional amplifier circuits and power-supply circuits, a potentiometric input-measuring range card, and an optional signal conditioning rate reset module.

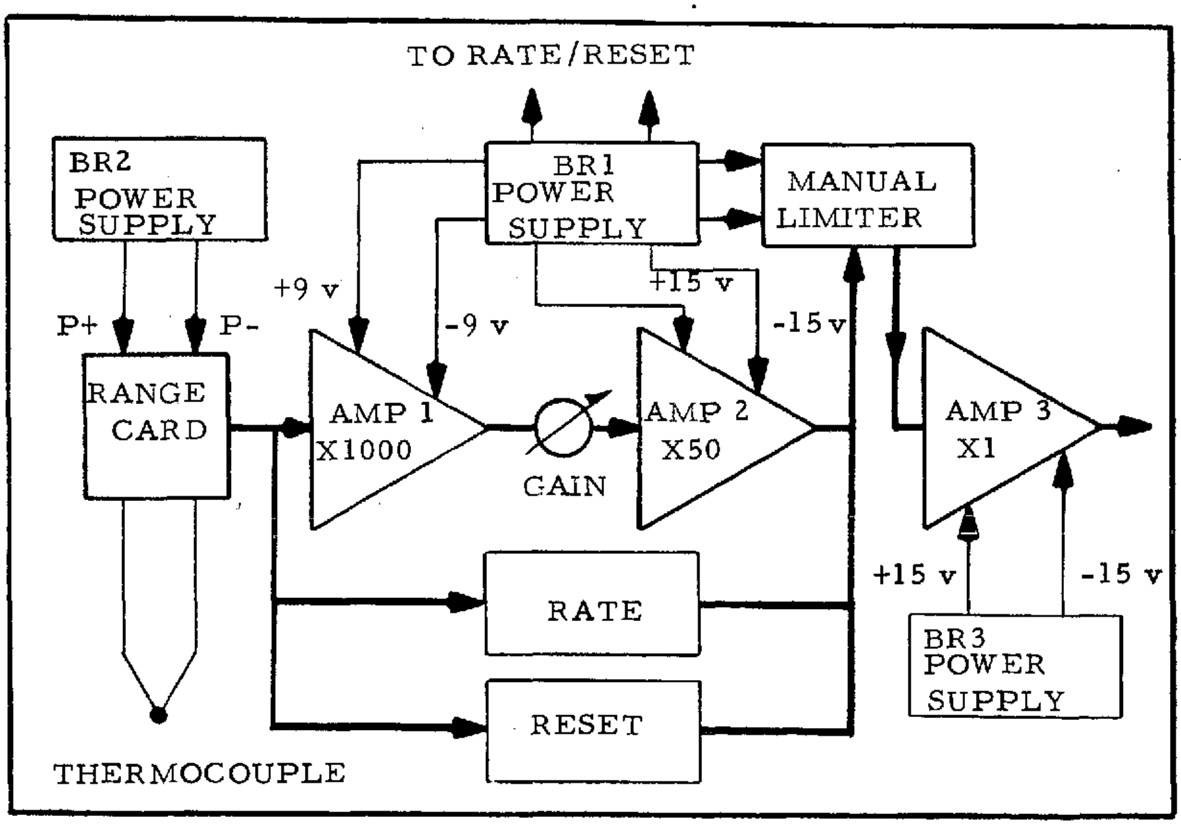


Figure 5-1 Block Diagram of D30 Circuitry

Each of the primary circuits is discussed individually under one of the following headings. It is recommended that the appropriate schematic diagram be folded out for reference while reading the following discussions. The various circuits to be discussed are illustrated in Figure 5-1 in block form with functional interconnection.

5-2 POWER SUPPLY CIRCUITS

The D30 has three separate power supply circuits, each of which is discussed individually under one of the following headings. Each of the supplies is identified by the alpha-numeric designation utilized on the schematic to identify the integrated circuit bridge rectifier which converts the AC input to DC (e.g., BR1, BR2, and BR3). Before discussing the individual supplies, one point should be considered concerning the three supplies collectively--Isolation.

Isolation is critically important in this unit for common mode noise rejection. Therefore, the power supply which drives the final amplifier stage (BR3-circuit) is isolated from the balance of the D30 circuits and is referenced to circuit common of the external power controller (common notation ▽2 on the schematic diagram). Consequently, the balance of the D30 circuits (with common notation of ▽1 on the schematic diagram) will be "floating" and will assume the common potential of the only external connection to these circuits--the thermocouple (or other feedback source).

CAUTION

> If the thermocouple is floating at a high potential, common ▽1 will also be floating at this same potential. If possible, the specimen should be grounded to prevent this condition and, additionally, to help eliminate as much common mode noise as possible.

In any event, never connect a common ▽1 point to an external circuit.

5-2-1 The BR1-Circuit Supply

The BR1 supply is the primary power supply for the D30. It is the supply referenced to common ▽1 as described under the preceding heading and drives all circuits except the isolated output stage and range card.

An external isolation transformer with dual secondary windings steps down the 115 VAC supply voltage to 24 VAC and 40 VAC secondary voltage.

The 40 VAC secondary is center-tapped and the center tap is circuit common ▽1 . The opposite ends of this secondary (20 VAC each) are applied to BR1 bridge. The DC output of the bridge is filtered and regulated by zener diodes to +15 VDC and -15 VDC potential to drive the second amplifier stage, the manual control and limiter circuits, and the optional rate/reset circuits. The +15 VDC and -15 VDC is again zener-regulated by temperature-compensating diodes to +9 VDC and -9 VDC potentials to drive the first amplifier stage.

The 24 VAC secondary of the supply transformer for BR1 is utilized by the miniature oven which holds the first amplifier at 80°C for stability.

5-2-2 The BR2-Circuit Supply (Range Card Supply)

As indicated by the heading, the BR2 supply is applied to the range card circuits and is utilized to establish the command millivoltage (set point).

An external isolation transformer steps down the 115 VAC supply voltage to a 47 VAC secondary voltage. This transformer is shielded, with the primary shield at frame ground and the secondary shield at BR2 negative potential.

The 47 VAC secondary voltage is rectified by BR2, filtered, zener regulated, and applied to a bridge configuration circuit where it is again zener regulated. The bridge circuit is designed to balance the dynamic impedance of the zener diode within the bridge to remove any AC ripple. The output of the bridge circuit is then trimmed by R8 to supply 1.003 VDC at 2.5 milliamperes to the range card (P+ and P-). All range cards are shunted to 396 ohms to provide a constant load and thus assure interchangeability of range cards.

The circuit is a highly isolated, double-zener regulated, temperature-compensated supply which is connected only to the range cards.

5-2-3 The BR3-Circuit Supply (Output Stage)

As indicated by the heading, the BR3 supply is utilized to supply the isolated output amplifier only (circuit common ▽2).

An external transformer steps down the 115 VAC supply voltage to a 40 VAC secondary voltage. This secondary is center-tapped and the center tap is circuit common ▽2 . The opposite ends of this secondary (20 VAC each) are applied to BR3 bridge. The DC output of the bridge is filtered and regulated by zener diodes to +15 VDC and -15 VDC which supplies the third amplifier (output) stage.

5-3 POTENTIOMETRIC INPUT MEASURING CIRCUITS

The range card module, and the precision resistors and other components on it comprise the potentiometric input measuring circuits of the D30. These circuits are enclosed by a guard which, along with the resistors and capacitors on the input of the first amplifier of the D30, provides a common-mode rejection equal to 120 db.

Zener diode regulated reference voltage is applied to the range card from the BR2 reference voltage supply (see Heading 5-2-2). The range card precisely divides the reference voltage to establish the range of the SET POINT potentiometer such that its zero and span (maximum) voltages correspond to the curve of voltage generated by a particular thermocouple from the minimum to maximum levels of a specific temperature range.

In addition to the standard range cards, other optional modules are available to enable the SET POINT dial to be directly calibrated, in terms of temperature-versus-dial settings, over its entire span for any thermocouple type and temperature range. Also, for applications where it is desired to control heater power rather than workpiece temperature in closed-loop operation, power range cards are available to correlate the span of the SET POINT dial to the range of a selected power transducer (millivoltage).

Automatic thermocouple cold junction temperature compensation is provided in most range card modules by resistance spool D. A standard range card is referenced to 75°F if its temperature range is designated in °F; if its temperature range is designated in °C, it is referenced to 25°C. All temperature range cards are equipped with a fail-safe resistor (R_{fs}) which causes the output signal of the D30 to be driven fully negative (-5 VDC) if the thermocouple circuit opens or presents a high resistance.

NOTE

> The fail-safe resistor will cause an undesirable offset in the potentiometric measuring circuits if the thermocouple circuit exceeds 100 ohms. Therefore, the 10-megohm resistor, (R_{fs}) must be removed if such high-resistance circuits are to be utilized with the unit.

The potentiometric measuring circuits provide a means for comparing the relative electrical magnitude of the temperature command and temperature feedback signals, and producing a DC output signal which is proportional to any difference existing between them. The magnitude of the command signal is established in the range card by the position of either the wiper on the SET POINT potentiometer, or the wiper on the remote programmer's output potentiometer, depending on the position of the MODE switch. With this switch in PROGRAMmer position, the remote programmer's output potentiometer is switched in to substitute for the SET POINT potentiometer; with the switch in either SET POINT or MANUAL position, the SET POINT potentiometer controls the magnitude of the command signal.

It should be noted at this time that the MODE switch consists of three sections: Sections S1A and S1B are utilized for switching between the SET POINT and REMOTE PROGRAMMER potentiometers, Section S1C disconnects the proportional amplifiers when the switch is in MANUAL position and switches the input of the output (third) amplifier to manual control.

Referring to the schematic drawings, it can be seen that even though the SET POINT potentiometer is switched in to control the magnitude of the temperature command signal during a manual operation, the command signal exercises no authority over the D30's output control signal since the input of the output amplifier is switched to manual control, and the magnitude of the output control signal is solely a function of the selected setting of the MANUAL control dial. The SET POINT potentiometer is switched in only to enable its use, along with the temperature feedback signal and DEVIATION meter, for temperature indicating purposes during a manual operation, as described under Heading 4-3-1.

5-3-1 Input Measuring Principles

Referring to the simplified drawing of the potentiometric measuring circuits in Figure 5-2, any electrical difference existing between the command millivoltage Ec and the feedback millivoltage E_{tc} will cause a proportional DC signal to exist at the input of the first amplifier of the D30. The polarity of the error signal is determined by the relative magnitude of the command and feedback signals. A negative difference signal exists when the command signal is greater than the feedback signal, indicating specimen temperature is below set point.

The magnitude of the command signal Ec is dictated by the setting of the set point. When the feedback signal exceeds this command signal, polarity is reversed and a positive difference signal exists, indicating specimen temperature exceeds set point. When there is no difference (error) signal, a null condition exists, indicating the specimen is at set point.

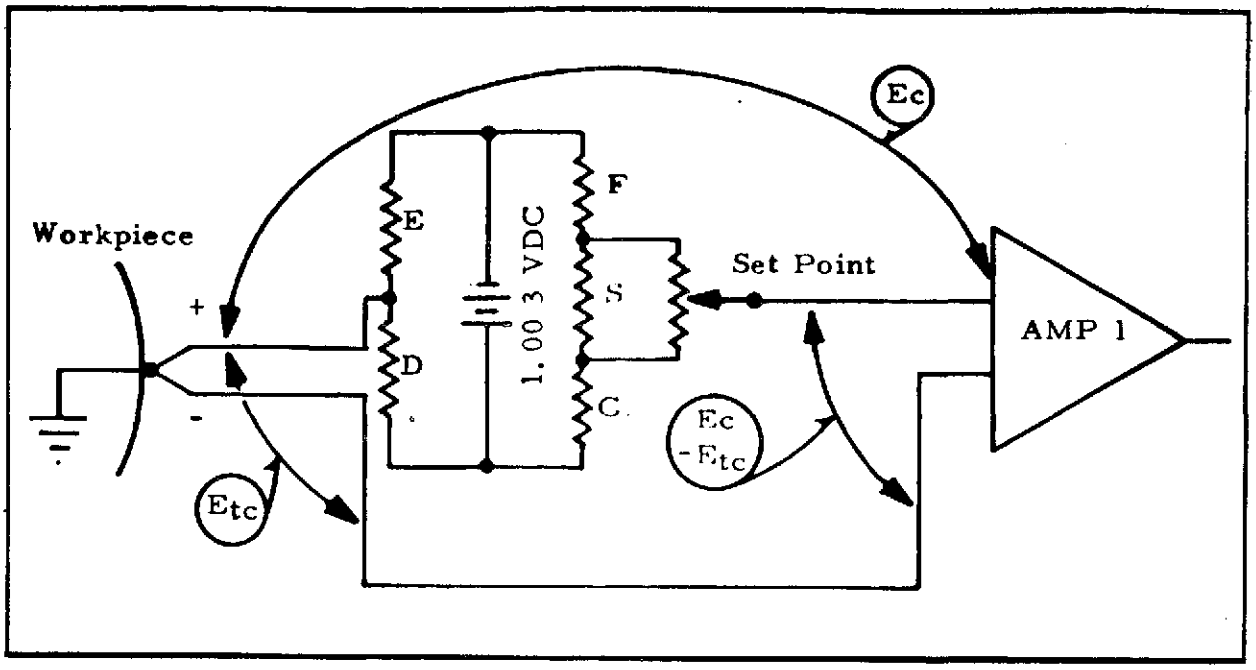


Figure 5-2 Potentiometric Measuring Circuits Simplified

Precision, ratio-matched, D-E resistors provide automatic thermocouple cold junction compensation in temperature range cards. To eliminate the inconvenience of external ice bath temperature reference, automatic cold junction compensation can be produced electrically. The standard reference supply maintains a constant known millivoltage across the set point potentiometer, but the known millivoltage produced by an ice bath reference thermocouple is replaced by the millivoltage across temperature compensating resistor "D". This resistor, composed of nickel wire which has a positive temperature coefficient, is calculated in ratio with the gain of the thermocouple type at 75°F (or 25°C), which is considered the mean ambient temperature of the cold junction. Resistor "E" is of much higher resistance, is composed of manganin wire, selected for its stable temperature characteristics. Resistor "D" and "E" must be ratio-matched. Standard temperature vs. millivolt tables referenced to 75°F (25°C) are used.

5-4 PROPORTIONAL AMPLIFIER CIRCUITS

The function of the proportional amplifier circuits of the D30 is to amplify the error voltage generated in the range circuits into a DC control signal of useable magnitude (from signals in the microvolt region to ±5 VDC at full gain). The overall gain of the unit is 50,000.

There are three DC coupled amplifiers in the proportional amplifier circuits. The first of these (AMP 1) has a gain of X1000 and is oven temperature-regulated at 80°C to minimize drift. The second stage (AMP 2) has a gain of X50. The third stage (AMP 3) has a gain of X1 and is isolated from the balance of the D30 circuits.

The error voltage generated in the range circuits is amplified 1000 times by the first stage. The output of this amplifier is connected to the negative input of the DEVIATION meter. (The positive input is at common.) Therefore, the DEVIATION meter will indicate the magnitude and polarity of the command millivoltage relative to the feedback millivoltage after amplification; the DEVIATION meter will deviate upscale when command exceeds feedback (negative error signal) and a downscale when feedback exceeds command (positive error signal).

The error signal is applied to a voltage-divider network consisting, in part, of the GAIN control potentiometer. The wiper of this potentiometer selects a portion of the error signal and applies it to the negative input of the second amplifier where this attenuated error signal is amplified 50 times and its polarity reversed. By reversing the polarity at this stage, a <u>negative</u> error voltage from the range circuits (indicating specimen temperature is below set point) is amplified and converted into a proportional <u>positive</u> control signal.

Note that the gain of the individual amplifiers is not varied, but rather, the input signal to the second state is attenuated. The magnitude of either positive or negative error voltage necessary to generate full ±5 VDC output is established by the setting of the GAIN control. The range between these upper and lower limits is defined as the "band of proportional control". Within these limits, output signal is proportional to error voltage and the polarity is the <u>opposite</u> of error voltage polarity.

The output of the second stage is passed through the manual control and limiter circuits (see Heading 5-5) and is applied to the input of the third stage (AMP 3). This third stage is "floating" until the negative output signal line is connected to an external circuit. In the 624A-D30, this third stage is referenced to the external signal-circuit common. This third-stage amplifier is for isolation only as is an X1 circuit.

The amplifiers utilized in the D30 are integrated circuit operational amplifiers. The information provided under the following heading may be helpful in understanding the operation of these units.

5-4-1 Operational Amplifier Characteristics

The amplifiers utilized in the D30 are differential input, DC amplifiers with an open-loop gain of approximately 30,000. Resistance is utilized on the input and feedback to establish the desired closed-loop gain. For example, AMP 1 (see schematic) has an input resistance of 2 K ohms and a feedback resistance of 2 Megohms. Feedback resistance is divided by input resistance to establish the value of closed-loop gain

$$\text{e.g.} \quad \frac{2 \times 10^6}{2 \times 10^3} = 10^3 = 1000.$$

The AC gain of the amplifiers is reduced to a minimum (for noise rejection) by connecting capacitors across the inputs and from the inputs to common.

As indicated in the preceding sentence, each amplifier has two inputs: an inverting input and a noninverting input. The inverting input is identified by a negative (-) symbol and the noninverting input is identified by a positive (+) symbol.

All operation amplifiers have some inherent DC offset. The balance-adjusting potentiometer associated with each amplifier is utilized to reduce this inherent offset to a minimum.

5-5 THE LIMITER AND MANUAL CONTROL CIRCUITS

Referring to the schematic diagram of the D30, it will be apparent that with the MODE switch in either SET POINT or PROGRAM, the output of AMP 2 is applied to AMP 3 through S1C and Q1. Transistor Q1 is connected as an emitter-follower. Therefore, the potential at the emitter of Q1 can only go as far positive as the potential at its collector, regardless of the potential of the signal at its base.

The potential at the collector of Q1 is established by the selected setting of the % VOLTAGE LIMITING control potentiometer. By reducing the potential at the collector of Q1, we limit the amount of positive control signal which can be applied by the D30 to its load. The circuit has no control over the negative-going signals. This circuit functions regardless of the setting of the MODE switch.

When the MODE switch is in the MANUAL position, the potential at the base of Q1 is supplied by the wiper of the MANUAL control potentiometer. This potentiometer is connected in a voltage divider network between +15 VDC and -15 VDC of the BR1 supply.

5-6 RATE CIRCUIT

The function of the rate circuit is to monitor the error signal and to add a signal to the command signal of appropriate polarity and magnitude to, primarily, prevent overshoot of specimen temperature (see Heading 3-4-1). A functional diagram of the rate circuit, including its interconnection to the proportional amplifier circuits, is provided below.

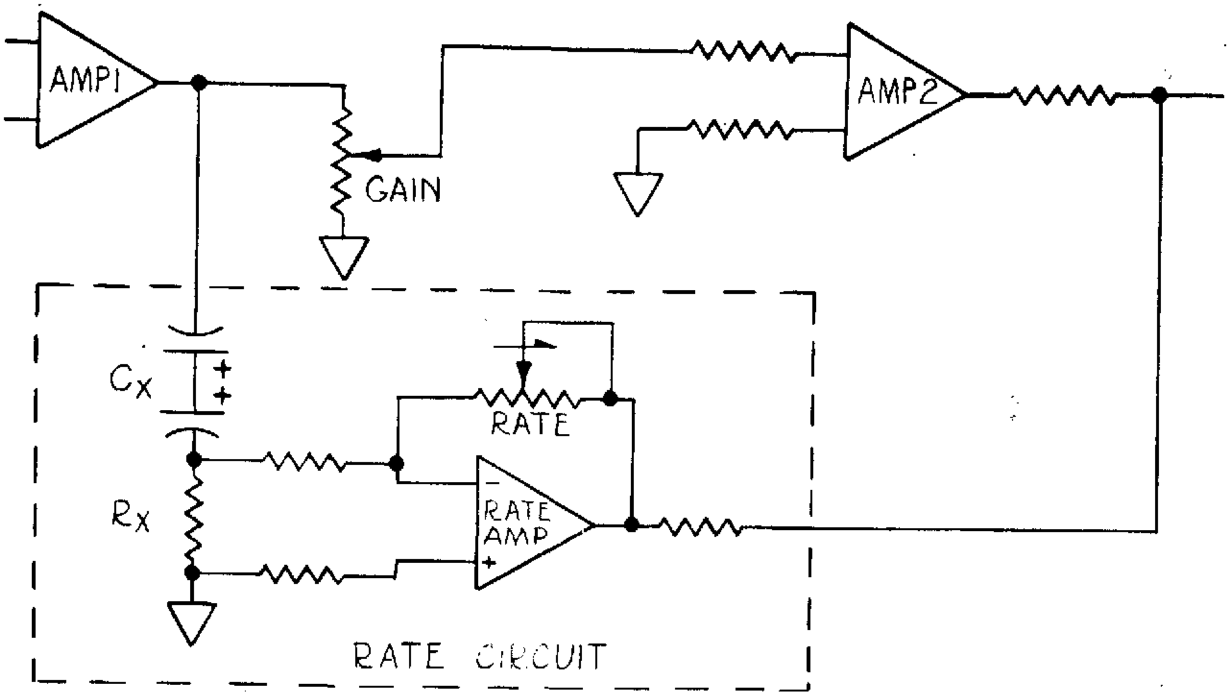


Figure 5-3 Functional Diagram of the Rate Circuit

The input to the Rate circuits is basically a differentiator consisting of R_x and C_x (R10, C3 and C4 on the schematic diagram). The error signal at the output of Amp 1 is applied to this differentiator and also displayed on the DEVIATION Meter. Whenever this signal is changing, current will flow through R_x due to the charging and/or discharging of C_x. The direction of this current flow will dictate the polarity of the signal at the inverting input to the Rate amplifier.

If the error signal is approaching set point from below, the rate signal will be positive and the error signal will be negative (although changing in a positive direction). Amp 2 inverts the negative error signal into a positive control signal. The Rate Amplifier inverts the positive rate signal to a negative rate signal which is summed at the output of Amp 2. The effect of summing the positive control signal with the negative Rate signal is to anticipate the temperature approach to set point and cut back controller output in proportion to the magnitude of the rate signal.

The Rate control determines the gain of the Rate amplifier which, in turn, determines how much rate signal is to be summed with the proportional control.

5-7 RESET CIRCUIT

The function of the Reset circuit is to eliminate the condition inherent with proportional control known as "temperature droop" (see Heading 3-4-2). The circuit, and its interconnection to the proportional control circuits, is functionally illustrated in Figure 5-4 and described in the text that follows.

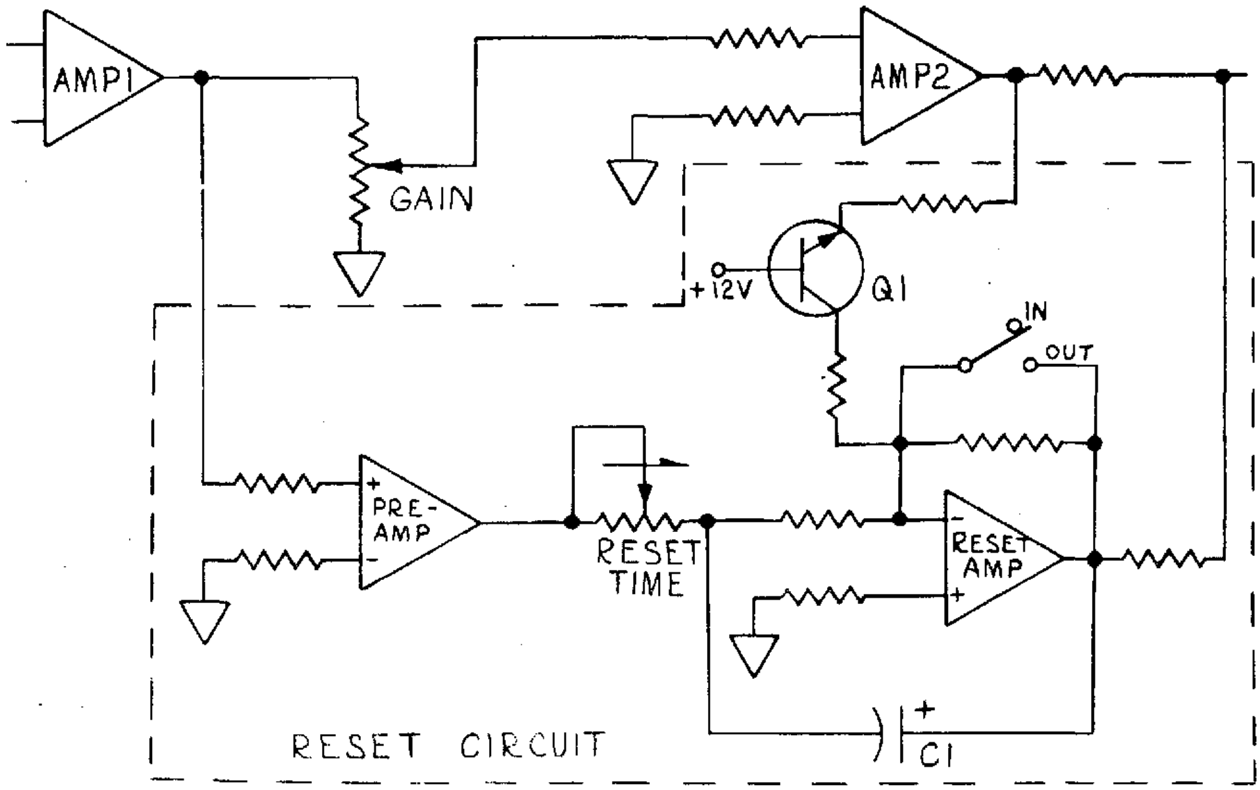


Figure 5-4 Functional Diagram of the Reset Circuit

When the command signal exceeds the feedback signal and the unit is calling for power, the output of Amp 1 is negative. This negative voltage is applied to the non-inverting input of the reset pre-amp. The amplified negative output is applied to the inverting input of the Reset Amp which is connected as an integrator. Capacitor C1 charges linearly at a rate determined by the setting of the Reset time potentiometer. This signal is summed with the proportional signal at the output of Amp 2 and raises controller output, resulting in a decrease in error signal. When the feedback signal equals the command signal, the input to the Reset Amp is zero and C1 ceases charging and the controller output is held constant. Any error signal, indicating a shift of specimen temperature from set point, will result in a consequent linear charge or discharge of C1, integrating the output in the appropriate direction.

To disable the Reset circuit, switch the Reset IN/OUT switch to the OUT position, which shorts the Reset capacitor.

Transistor Q1 is biased such that when the controller is out of the proportional band it causes the output of the Reset Amp to go negative, effectively disabling it.

SECTION 6
GENERAL MAINTENANCE AND CALIBRATION PROCEDURES

6-1 GENERAL MAINTENANCE

The 624-D30 is designed to provide reliable service over extended periods of time with a minimum of maintenance. Primarily, maintenance will consist of keeping the instrument free from accumulations of dust and periodically checking the DC balance of the D30.

All calibration procedures can be accomplished "on-line" without removing the controller from its case or disconnecting signal lines. The required test equipment is limited to a relatively sensitive (capable of reading ±0.05 VDC) high impedance voltmeter.

6-2 D30 CALIBRATION

Calibration of the D30 control module consists of balancing the three integrated circuit operational amplifiers of the proportional amplifier (main board) circuits, and, the operational amplifier of the reset circuit on the optional rate/reset module (if used).

6-2-1 Calibration of the Proportional Amplifier

To calibrate the proportional amplifier circuits, proceed as follows:

Initial Set-Up (POWER OFF)

1) Loosen the two captive thumbscrews on the front of the drawer and draw the drawer forward on its slides and carefully allow unit to tip down. Exercise reasonable caution to prevent damage to the slide and/or wiring.

2) Remove the rate/reset module and set the following controls as indicated:

   MODE Switch.................SET POINT
   CALibrate Switch.............CAL
   GAIN Control................ 10 (fully CW)
   % VOLTAGE LIMITING Control.. 0 (fully CCW)

   The setting of all other controls is arbitrary at this point.

3) Connect a DC voltmeter capable of accurately reading ±0.20 VDC or less to pins P (+) and D (-) of the rate/reset module jack J12.

4) Energize the unit and allow at least 2.5 minutes warm-up time. During this time, check (by touch) to assure that the oven containing amplifier #1 is heating. This is the yellow unit on the D30 circuit board.

Calibration

1) Adjust the BALANCE 1 (coarse) potentiometer first and then 1A (fine) for a "null" on the DEVIATION meter.

2) Adjust the BALANCE 2 potentiometer for a reading of zero (±0.20) VDC on the voltmeter.

3) Adjust the BALANCE 3 potentiometer for a "null" on the OUTPUT meter.

This completes the calibration of the proportional amplifier circuits.

6-2-2 Calibration of Reset Amplifier

The operational amplifiers in the reset circuit are checked as follows:

Initial Set-Up

1) Check the calibration of the proportional amplifier circuits as outlined under Heading 6-2-1.

2) Replace rate/reset module and set the following controls as indicated:

MODE Switch	SET POINT
CALibrate Switch	CAL position
GAIN Control	0 (fully CCW)
% VOLTAGE LIMITING Control	0 (fully CCW)
RATE Control	0 (fully CCW)
RESET IN/OUT Switch	OUT
RESET Control	30 (fully CCW)

The setting of all other controls is arbitrary at this point.

3) Check balance #3 for null(on OUTPUT meter). A slight adjustment might be necessary.

4) Short out the thermocouple input pins on the range card and switch CAL switch out of the CAL position.

5) Adjust the SET POINT control until a "null" is achieved on the DEVIATION Meter (at SET POINT dial setting which corresponds to room ambient on the range card curve).

Operational Check

1) Slightly increase the setting of the SET POINT control, until the DEVIATION meter reads approx. +. 4.

2) Switch RESET in, the OUTPUT meter should indicate increasing output signal.

3) Decrease SET POINT setting until DEVIATION meter centers. (OUTPUT meter will remain positive).

4) Slightly decrease the setting of the SET POINT control.

5) The OUTPUT Meter should indicate the control signal decaying to a zero reading.

6-2-3 Calibration of the Common Mode Stage

This is a factory setting and recommended changes are to be made only in case of parts replacement.

1) Short the input on the range card.

2) Connect 115 VAC between T/C input and ground (2(P10-P).

3) Connect an oscilloscope to the output of the D30 drawer, pins R & P of P10.

4) Adjust R41 for minimum DC on the output.

5) Adjust R40 for minimum AC on the output.

6) Repeat Steps 4 and 5

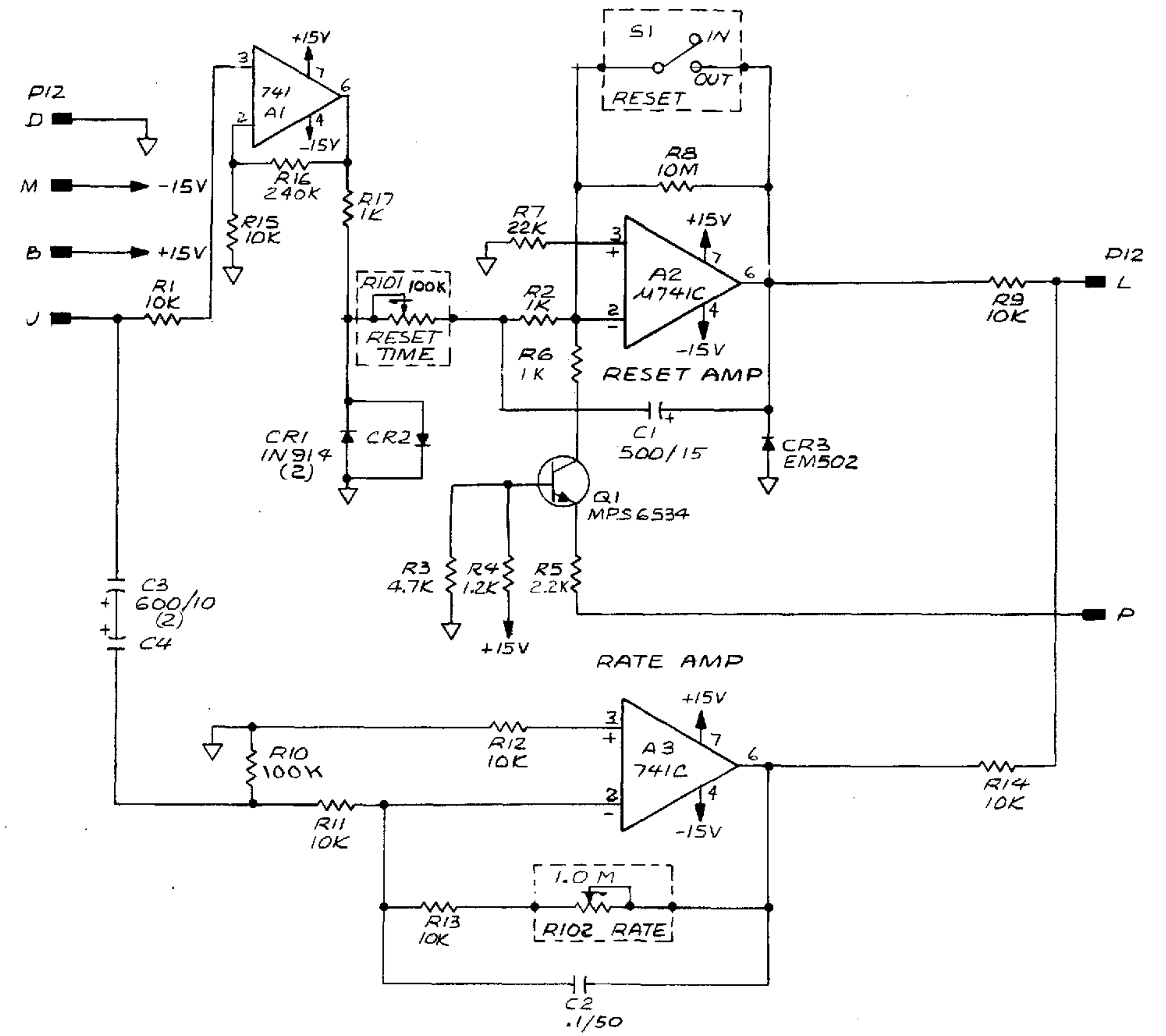
7) AC on the output should be no more than 0. 5 VPP

1 2

FOLDOUT FRAME

REVISIONS			
SYM.	DESCRIPTION	DRAFT.	DATE
D	REDESIGNED	RMF	9-21-70

FOLDOUT FRAME



SEE SCH. D33680 FOR PIN REFERENCE

INVENTORY	USED ON	ASSEMBLY
3D810	THERMAC 6000	B33665
3D808	THERMAC SERIES 6000	B33665

DRAFTSMAN RMF 9-21-70 · CHECKED · APPROVED ARM 4-17-70

K = 10^3 · M = 10^6 · CONNECTION · NO CONNECTION

UNLESS OTHERWISE INDICATED
- RESISTANCE IN OHMS ± 10% 1/4 WATT
- CAPACITANCE IN MFD ± 20%
- INDUCTANCE IN HENRIES
- USE 60/40 ROSIN CORE SOLDER
- USE NO CORROSIVE FLUX

INVENTORY 3D849

TITLE: SCHEMATIC, RATE RESET PLUG-IN PCB OPTION

NUMBER KC34353 REV D

SHEET 1 OF 1

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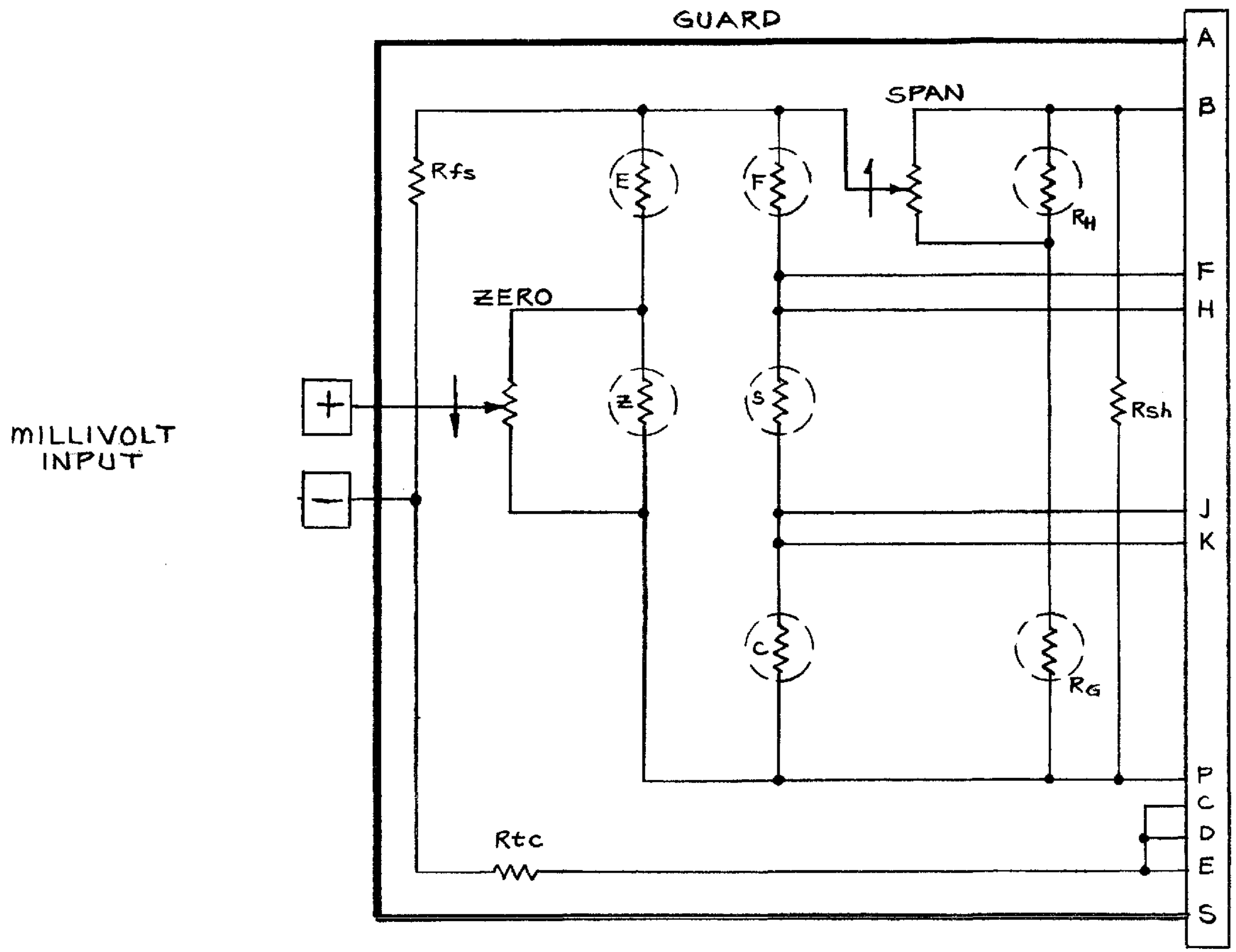
FOLDOUT FRAME

REVISIONS					
SYM.	ZONE	DESCRIPTION	DRAFT.	CHECK.	DATE
A		CHANGED ROTATION OF ZERO POT.	AKB		5-7-68
B		REVERSED R_H & R_G	JON		12-27-68



3D810	THERMAC 6000	B35135
3D808	THERMAC 6000	B35135
INVENTORY	USED ON	ASSEMBLY

DRAFTSMAN RL 4/4/68
CHECKED
APPROVED

K = 10^3 M = 10^6
CONNECTION NO CONNECTION

UNLESS OTHERWISE INDICATED
- RESISTANCE IN OHMS ± 10% ½ WATT
- CAPACITANCE IN MFD ± 20%
- INDUCTANCE IN HENRIES
- USE 60/40 ROSIN CORE SOLDER
- USE NO CORROSIVE FLUX

MODEL

TITLE SCHEMATIC – SPAN – ZERO RANGE CARD

INVENTORY NO. 3D830

NUMBER KB35133 REV. B

SHT. OF

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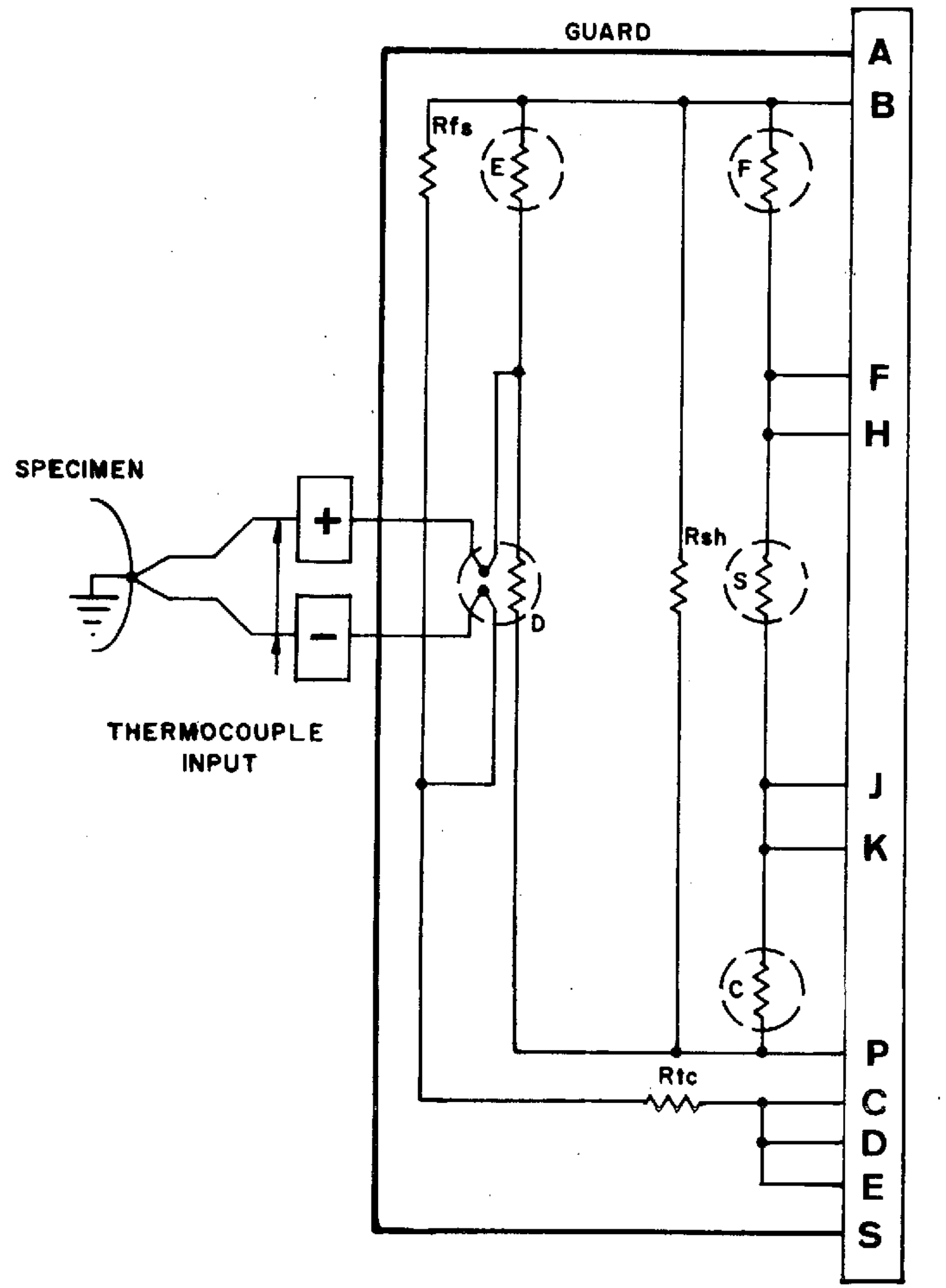
FOLDOUT FRAME 1

FOLDOUT FRAME 2

REVISIONS

SYM	ZONE	DESCRIPTION	DRAFT	CHECK	DATE
A		REMOVED Cg1,2	RL		12/9/67



THERMOCOUPLE RANGE CARD

3D810	THERMAC 6000	B33156-1
3D808	THERMAC 6000	B33156-1
3D810	THERMAC 6000	A33644
3D810	THERMAC 6000	A33644
INVENTORY	USED ON	ASSEMBLY

RL 12/9/67

UNLESS OTHERWISE INDICATED

[redacted]

INVENTORY 3D814

SCHEMATIC – SINGLE RANGE CARD

KB34354 A

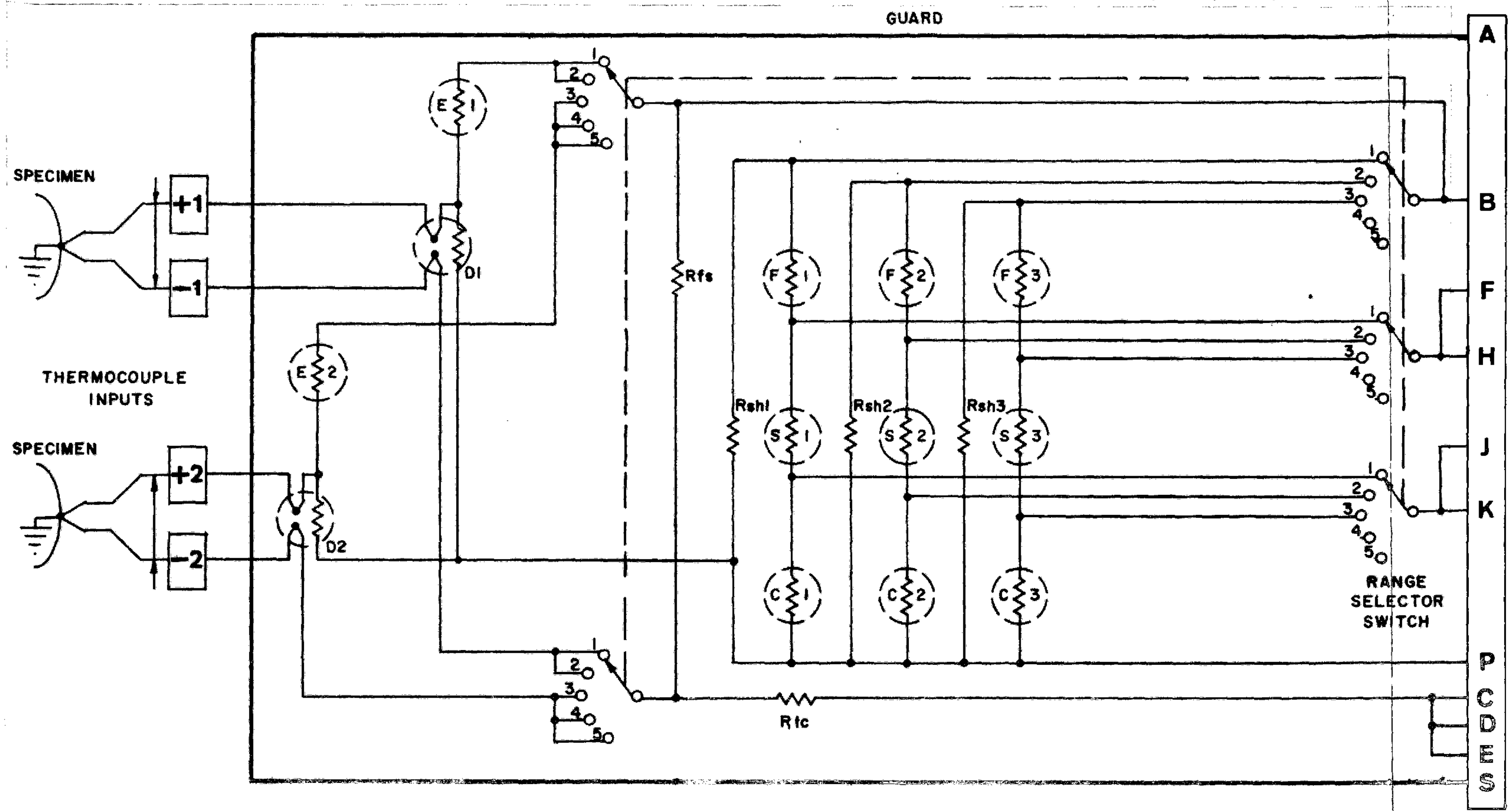
1 OF 1

CONTROLS DIVISION • RESEARCH, INCORPORATED • MINNEAPOLIS 24, MINNESOTA

FOLDOUT FRAME 1

REVISIONS					
SYM.	ZONE	DESCRIPTION	DRAFT.	CHECK.	DATE
B		ADDED No's ON INPUTS	RL		4/23/68

FOLDOUT FRAME 2



RANGE AND/OR THERMOCOUPLE CHANGE CARD

3D810	THERMAC 6000	B33156
3D808	THERMAC 6000	B33156
INVENTORY	USED ON	ASSEMBLY

DRAFTSMAN RL 12/9/67
CHECKED
APPROVED

K = 10^3 M = 10^6
CONNECTION NO CONNECTION

UNLESS OTHERWISE INDICATED
- RESISTANCE IN OHMS ± 10% ½ WATT
- CAPACITANCE IN MFD ± 20%
- INDUCTANCE IN HENRIES
- USE 60/40 ROSIN CORE SOLDER
- USE NO CORROSIVE FLUX

MODEL 3D823

TITLE SCHEMATIC - 3 RANGE CARD

NUMBER B34355 REV. B

SHT. 1 OF 1

CONTROLS DIVISION • RESEARCH, INCORPORATED • MINNEAPOLIS 24, MINNESOTA

FOLDOUT FRAME 1

FOLDOUT FRAME 2

REVISIONS					
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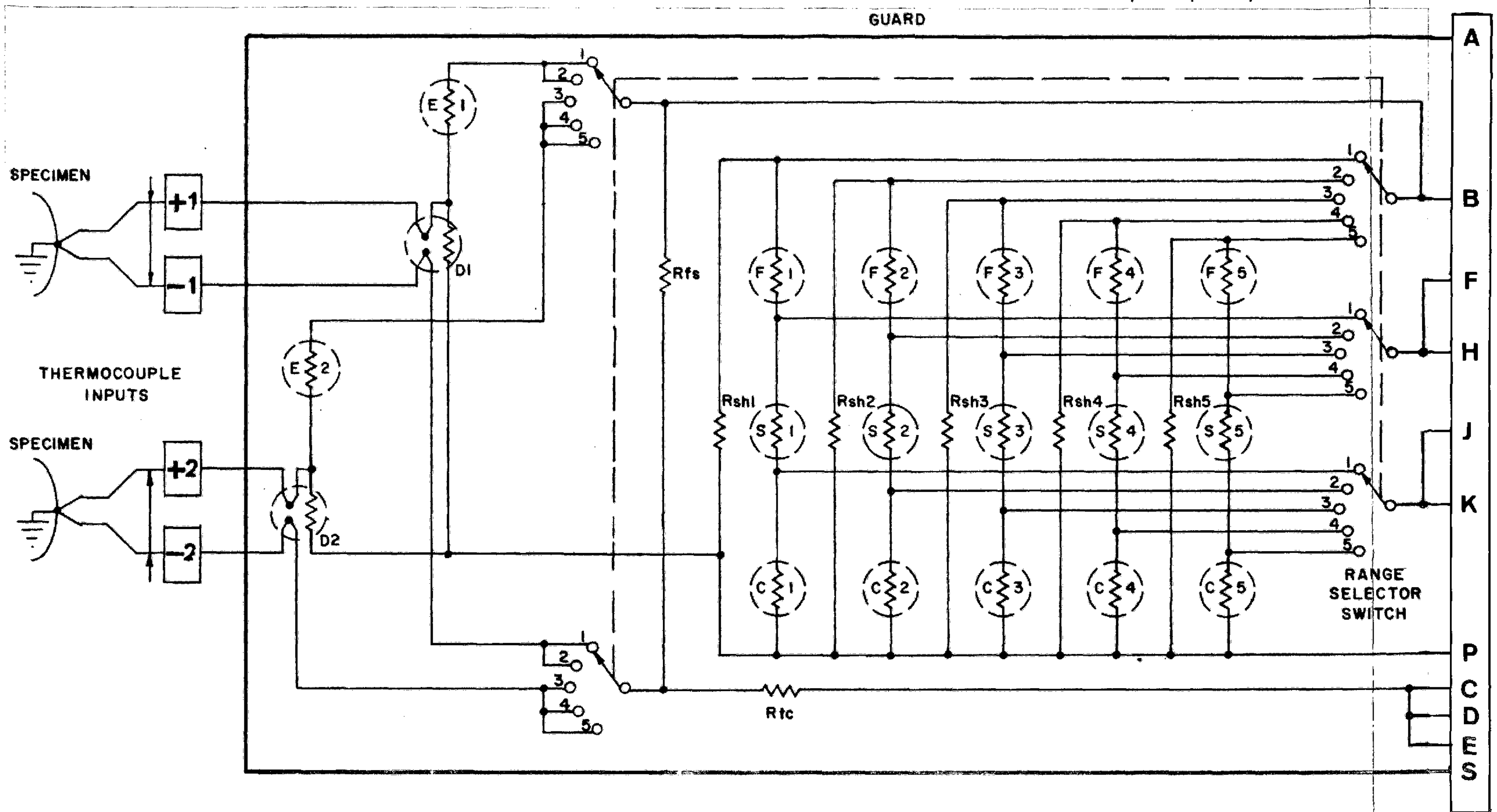
[illegible]		[illegible] INPUTS	RL		9/23/68



RANGE AND/OR THERMOCOUPLE CHANGE CARD

3D810	THERMAC 6000	B33156
3D808	THERMAC 6000	B33156
INVENTORY	USED ON	ASSEMBLY

DRAFTSMAN RL 12/5/67

CHECKED

APPROVED

K = 10^3 M = 10^6

CONNECTION NO CONNECTION

UNLESS OTHERWISE INDICATED
- RESISTANCE IN OHMS ± 10% ½ WATT
- CAPACITANCE IN MFD ± 20%
- INDUCTANCE IN HENRIES
- USE 60/40 ROSIN CORE SOLDER
- USE NO CORROSIVE FLUX

MODEL 3D824

TITLE SCHEMATIC-5 RANGE CARD

NUMBER KB34356 REV. B

SHT. 1 OF 1

CONTROLS DIVISION • RESEARCH, INCORPORATED • MINNEAPOLIS 24, MINNESOTA

RECOMMENDED SPARE PARTS LIST

TITLE	NUMBER	REV
D 30 DRAWER	KD33680	X

ITEM	DESCRIPTION	PART NO.	INVENTORY	QUANTITY 1	2	3	4	↓
1	Amplifier 1 (Selected)	U5B7741 393	16A198	X				
2	Amplifier 2, 3	U5B7741 393	16B241	X				
3	Oven for AMP 1	4 STI	16A200	X				
4	Bridge BR 1, 2, 3,	VE28	16B201	X				
5	Transistor Q 1, 2	MPS6531	16A206	X				
6	Transistor Q 3	MPS6534	16A211	X				
7	Zener Diode CR 1, 2, 7, 8	IN4744A	16A202	X				
8	Zener Diode CR 3, 4, 6	IN935	16A147	X				
9	Zener Diode CR 5	OM4749	16A203	X				
10	Digital Potentiometer	A36732	6A204	X				
11	Meter - DEVIATION	A38759-1	25B134	X				
12	Meter - OUTPUT	A38759-2	25B100	X				

ORDERING INFORMATION

1) For ordering information and latest prices, contact your local representative or the RESEARCH, Incorporated factory in Minneapolis, Minnesota.

2) When ordering spare parts, please include references both to this parts list number and revision level, plus, the Model Number and Serial Number of the instrument for which these parts are being ordered.

TWX	PHONE MINNEAPOLIS	TELEX
910-576-2837	612-941-3300	029-5328

R·I CONTROLS
A DIVISION OF RESEARCH, INCORPORATED
BOX 24064 MINNEAPOLIS, MINNESOTA USA 55424

RECOMMENDED SPARE PARTS LIST

TITLE	NUMBER	REV
RATE/RESET FOR D30	C34353	D

ITEM	DESCRIPTION	PART NO.	INVENTORY	QUANTITY 1	2	3	4	↓
1	Amplifier 1, 2, 3	741C	16A241	X				
2	Transistor Q1	MPS6534	16A211	X				
3	Capacitor C1 500/15	MTV 500DN15	15A198	X				
4	Capacitor C2, C3 600/10	MTV 600DN10	15A194		X			

ORDERING INFORMATION

1) For ordering information and latest prices, contact your local representative or the RESEARCH, Incorporated factory in Minneapolis, Minnesota.

2) When ordering spare parts, please include references both to this parts list number and revision level, plus, the Model Number and Serial Number of the instrument for which these parts are being ordered.

TWX	PHONE MINNEAPOLIS	TELEX
910-576-2837	612-941-3300	029-5328

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RESEARCH INC

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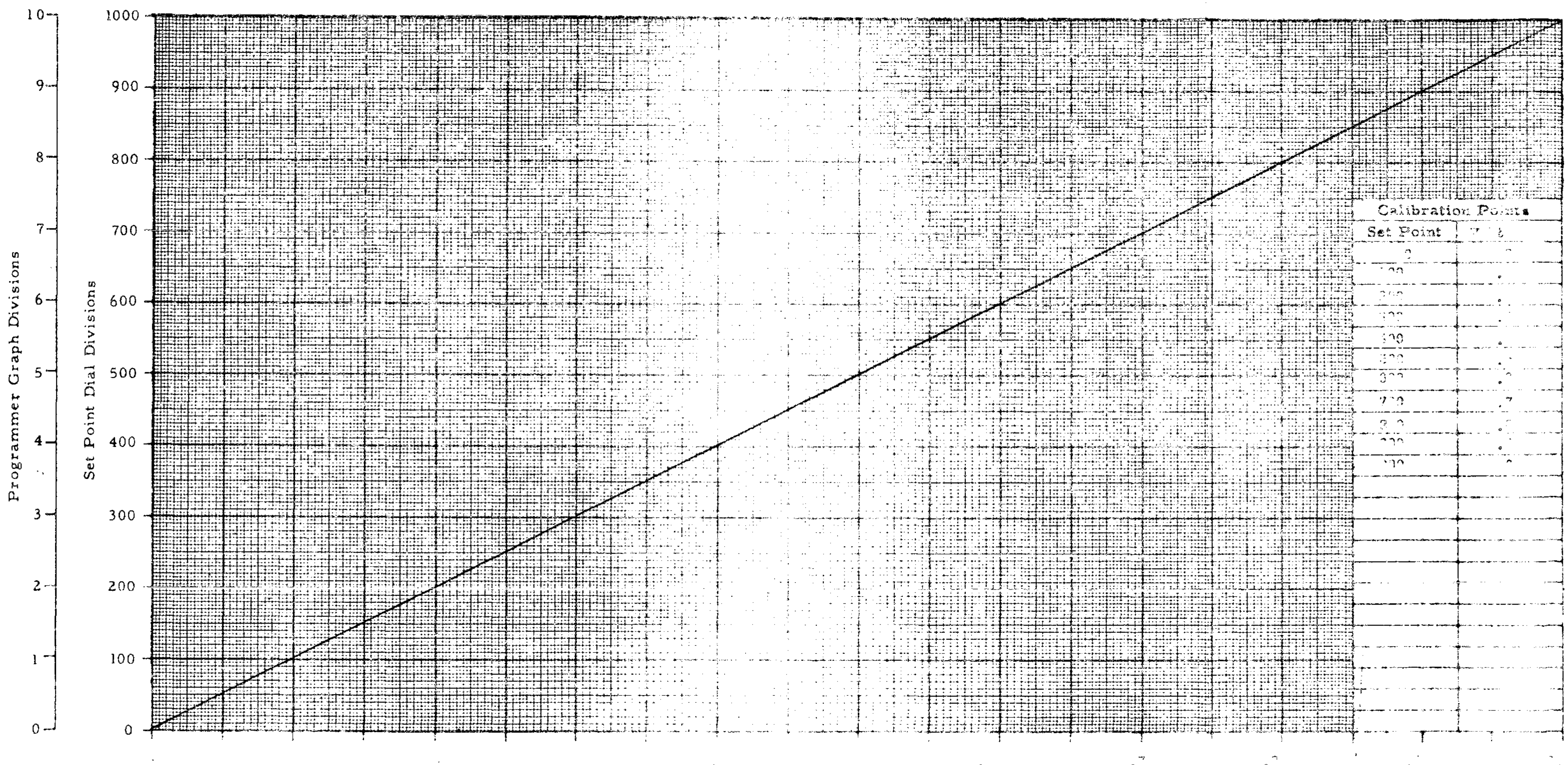
FOLDOUT FRAME 1

FOLDOUT FRAME 2

Curve

[illegible] SET POINT DIAL DIVISIONS
and [illegible] GRAPH DIVISIONS

Range [illegible]

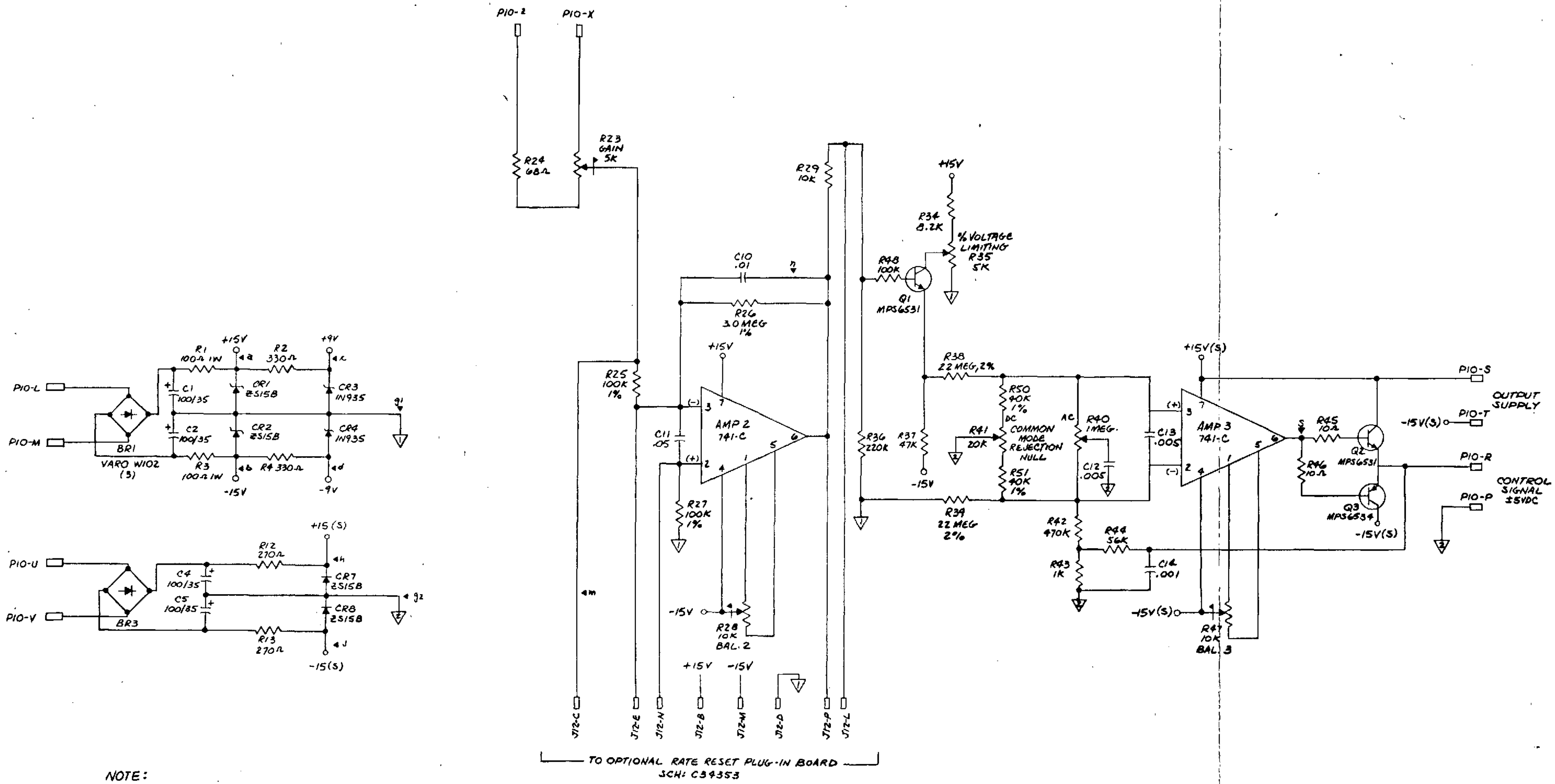


RI-102

FOLDOUT FRAME /

FOLDOUT FRAME 2

REVISIONS			
SYM.	DESCRIPTION	DRAFT.	DATE
A	ADD MSFC CONTRACT NO.	DS	1-17-72



NOTE:

1. ⏚ SEPERATE COMMONS BY NUMBER
2. ▼ INDICATES TEST POINT.
3. UNLESS OTHERWISE INDICATED: RESISTANCE IN OHMS, ±5%, ½W - CAPACITANCE IN MFD ±20%.
4. SEE DWG C41261 FOR P10 CONNECTIONS

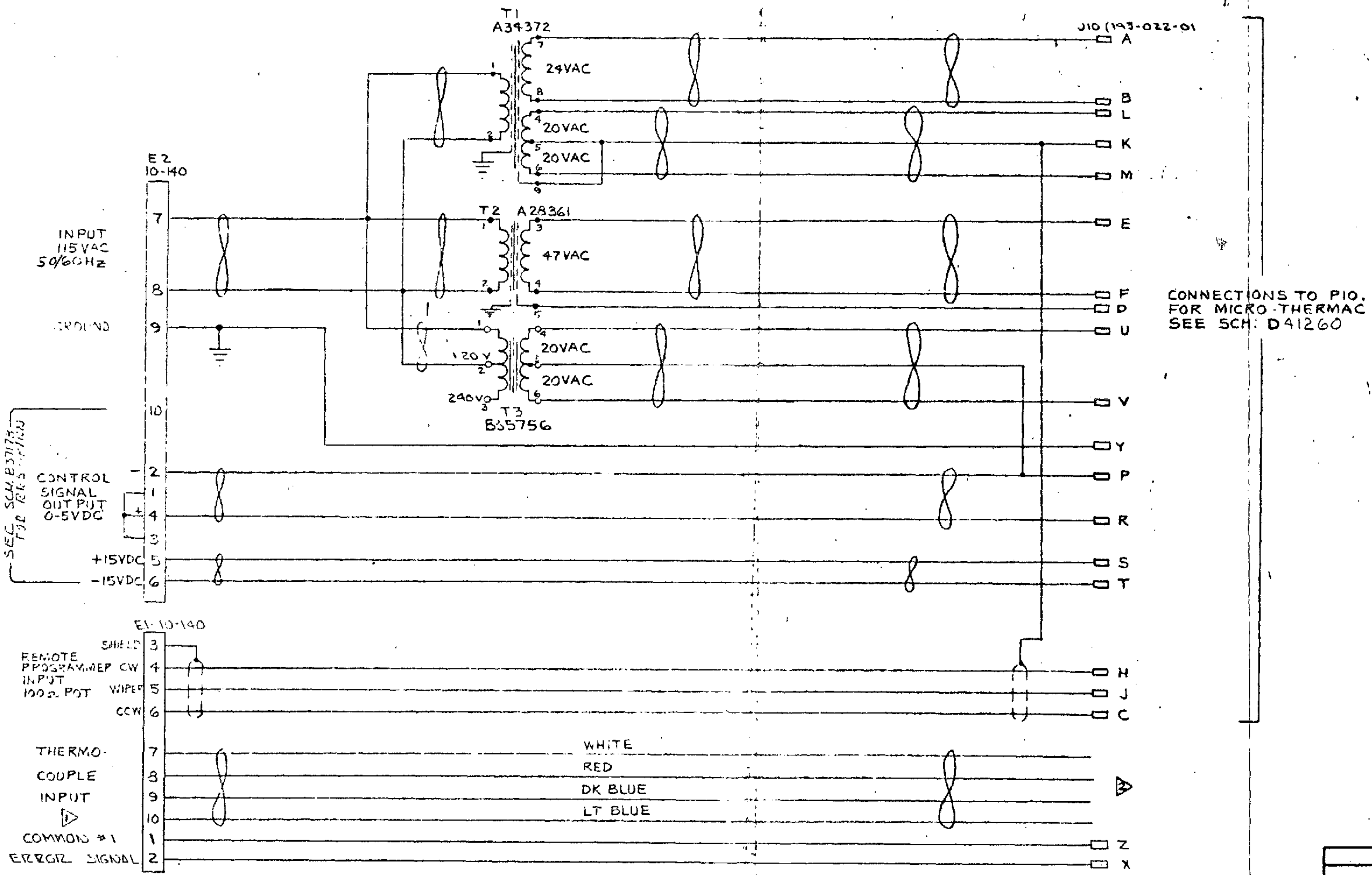
MSFC CONTRACT NAS 8 26416

COR APPROVAL ______ DATE 2/9/72

USED ON	5008 D4339
SCALE	None
TITLE	SCHEMATIC - COOLING CONTROLLER
NUMBER	D41260
REV	A

R·I CONTROLS — A DIVISION OF RESEARCH INCORPORATED, MINNEAPOLIS, MINNESOTA

FOLDOUT FRAME



1. CONNECT THERMOCOUPLE OR MILLIVOLTAGE INPUT TO E1 PER TABLE BELOW.

THERMOCOUPLE TYPE	+ LEAD	- LEAD
CHROMEL/ALUMEL	E1-9	E1-8
COPPER/CONSTANTAN	E1-9	E1-8
IRON/ CONSTANTAN	E1-7	E1-8
PLT/PLT 10% RHD	E1-9	E1-10
PLT/PLT 13% RHD	E1-9	E1-10
CHROMEL/CONSTANTAN	E1-9	E1-8
MILLIVOLTAGE	E1-9	E1-10

2. CONNECT THE THERMOCOUPLE EXTENSION LEADS DIRECTLY TO THE RANGE CARD PINS MARKED + & -.

REVISIONS

RL 12/5/67

SCHEMATIC - 6000 THERMAC 624A SPECIAL

INVENTORY

C41261

R·I CONTROLS

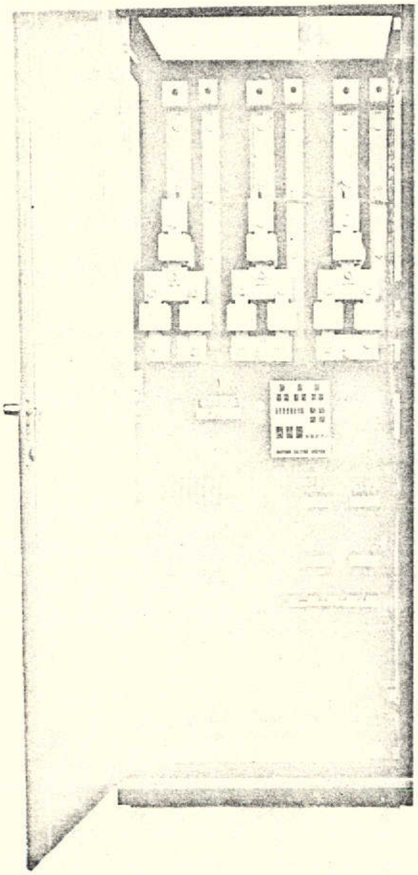
FOLDOUT FRAME

INSTRUCTION MANUAL

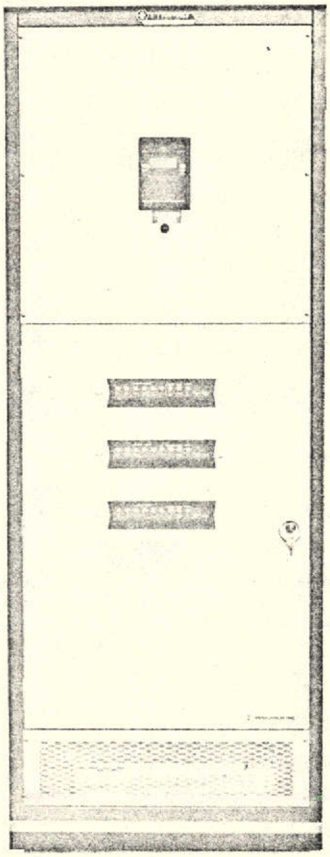
POWER REGULATOR
MODEL HI - D3 - 645

R-I CONTROLS DIVISION
RESEARCH INC
BOX 24064 MINNEAPOLIS, MINNESOTA USA 55424
PHONE (612) 941-3300 • TWX 910-576-2837 • TELEX 029-5328

The Model HI - D3 - 645 utilizes the control logic and SCR driver circuits of a standard NUMERAC NIPC Power Controller. Special fuses and water cooled SCR's are provided for increased load capacity.



Rear View



Front View

The Model HI - D3 - 645 Power Regulator

Carbone-Ferraz Protistor fuses are used for load protection. Fuses F2, F4 and F5 protect the SCR while fuses F1, F3, and F6 protect against ground faults in the load return lines. Overload protection is provided by the main circuit breaker in each power controller cabinet.

Single zone power control cabinets are actually 3 single zone controllers connected in a master-slave configuration. Two of the zones have a special slave logic board that utilizes the distributed zero crossover pulses from the master zone to control their respective SCR's.

The main circuit breaker is equipped with an undervoltage trip circuit. The breaker will trip on an undervoltage condition of 30 to 60% of line voltage. Door interlocks and water flow switches also activate the undervoltage trip circuit when cabinet doors are opened or the 0.5 gallon per minute minimum water flow requirement is not maintained.

Listed below are the special schematics that reflect the changes from a standard NIPC Power Controller to the units supplied.

Schematic C39138 (NIPC Basic) has been replaced by D40642 (NIPC Basic-Single Zone) and by D40643 (NIPC Basic - 3 Zone).

Schematic D38377 (NIPC Master Board) has been replaced by D40873.

Schematic D38290 (NIPC Logic Board) has been replaced by D40871 (NIPC Logic Board-Master) and by D40872 (NIPC Logic Board-Slave).

INSTRUCTION MANUAL

NUMERAC

NIPC Series

Power Controller

The following options have been included in your equipment:

- ☐ Manual Entry (PBE)
- ☐ Enclosure (E)
- ☐ Ammeter (IA)
- ☐ Voltmeter (IV)
- ☐ Wattmeter (IP)
- ☐ Analog Input (AV)

Publication Number 300500

R-I CONTROLS DIVISION
RESEARCH INC
BOX 24064 MINNEAPOLIS, MINNESOTA USA 55424
PHONE (612) 941-3300 • TWX 910-576-2837 • TELEX 029-5328

RECORD OF REVISIONS

REVISION	DESCRIPTION
A-O	Released (January, 1970)
B-O	Released (October, 1970) Mk II Model Revised Edition
B-1	Changed Pages A and 6-12 (June, 1971)

Publication Number:

INTRODUCTION

Scope

This manual contains information pertaining to the NUMERAC NIPC series Power Controller and its options. Sections 1 through 7 contain a description plus installation, operation, and maintenance instructions for the basic NUMERAC NIPC series Power Controller. Section 8 contains the schematic drawings.

Level of Information

Discussions in RESEARCH, INC. instruction manuals concerning principles or theory of operation and maintenance assume that the reader has a basic knowledge of electronics, electronic test equipment, and troubleshooting techniques.

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Section II INSTALLATION

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Section VIII SCHEMATIC DIAGRAMS

1-0 General

The NUMERAC NIPC series power controller is a numerically commanded solid-state AC power controller. It is designed to be a final control element in any process requiring control of electrical power into heater loads. The unit proportions power to the load in response to a 6-bit digital word supplied, primarily, by a computer. Figure 1-1 shows the basic NUMERAC NIPC power controller without any of the available options.

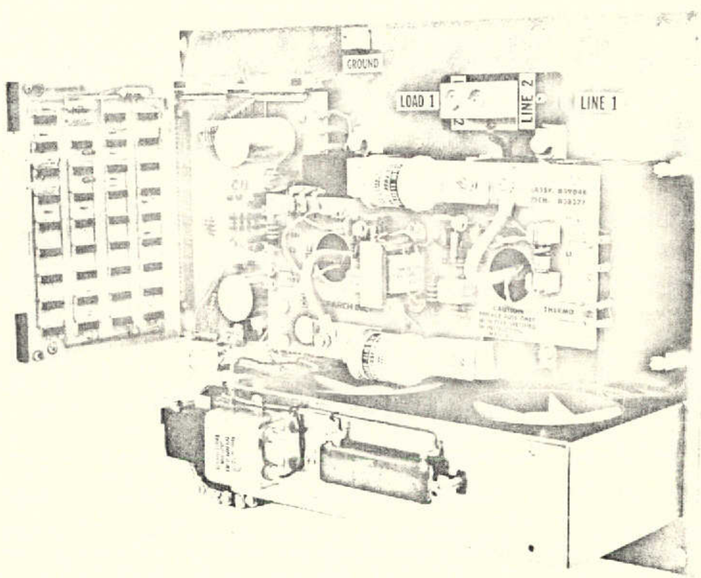


Figure 1-1. NUMERAC NIPC Power Controller

The various options available for the NIPC are covered in the options section at the rear of this manual. They include a complete enclosure, special indicator metering circuits, and options to enable the NIPC to accept inputs other than the computer-supplied 6-bit word.

1-1 Functional

The NIPC proportions AC power to the load in response to the magnitude of the binary input word. Since the NIPC, with its unique zero crossover firing circuit, supplies only full cycles of power to the load, power is proportioned to the load by the ratio of "ON" cycles to "OFF" cycles within a 63-cycle time frame. Figure 1-2 shows this proportioning relationship for 3 different power levels.

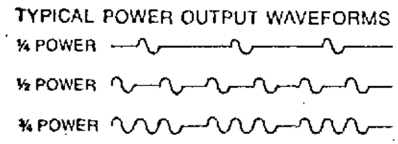


Figure 1-2. Power Proportioning

The NIPC output power level is determined by a 6-bit binary word input. The 6-bit word, primarily supplied to the basic unit by a computer, is a 6-digit number written in 1's and 0's. Each digit from right to left is a sequentially higher order power of 2 and the total value of the input word corresponds directly to the number of applied cycles within each 63-cycle time frame. Thus, when the values of all of the digits shown in Figure 1-3 are added, the number of applied cycles for that particular time frame is 53 (decimal) or 84% of full power.

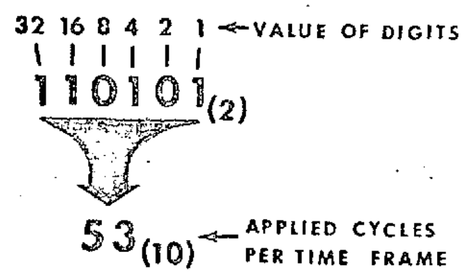


Figure 1-3. Binary Input Word

The binary input word is used because each of its digits can be used to represent the ON or OFF state of electronic switching circuitry. When a particular data bit is active, it means that that digit has the value ascribed to it (2, 4, 8, etc.) and is referred to as "High" or "Logical 1". When a data bit is inactive, it means that the value of that particular digit is 0 and is referred to as "Low" or "Logical 0". The "High" and "Low" states are represented electrically by +5 and 0 volts respectively and are used to determine the state of electronic switching circuitry.

Special circuitry within the NIPC distributes the applied cycles over a 63-cycle time frame for the most uniform and practical power distribution. Assume, for instance, that only 10 cycles out of every 63 were to be applied to the load. Without this unique distribution circuitry, the 10 cycles would be applied in one burst and no power would be applied for the remaining 53 cycles, resulting in non-uniform output. However, the NIPC evenly distributes those 10 cycles over the 63-cycle time frame to provide a more uniform output power level.

1-2 Physical Description

The basic NUMERAC NIPC series power controller consists of four main assemblies: mounting panel assembly, SCR assembly, masterboard assembly, and main logic assembly. Figure 1-4 is an exploded view of the basic NIPC series power controller showing the physical relationship of the 4 main assemblies and identifies the two special card connectors.

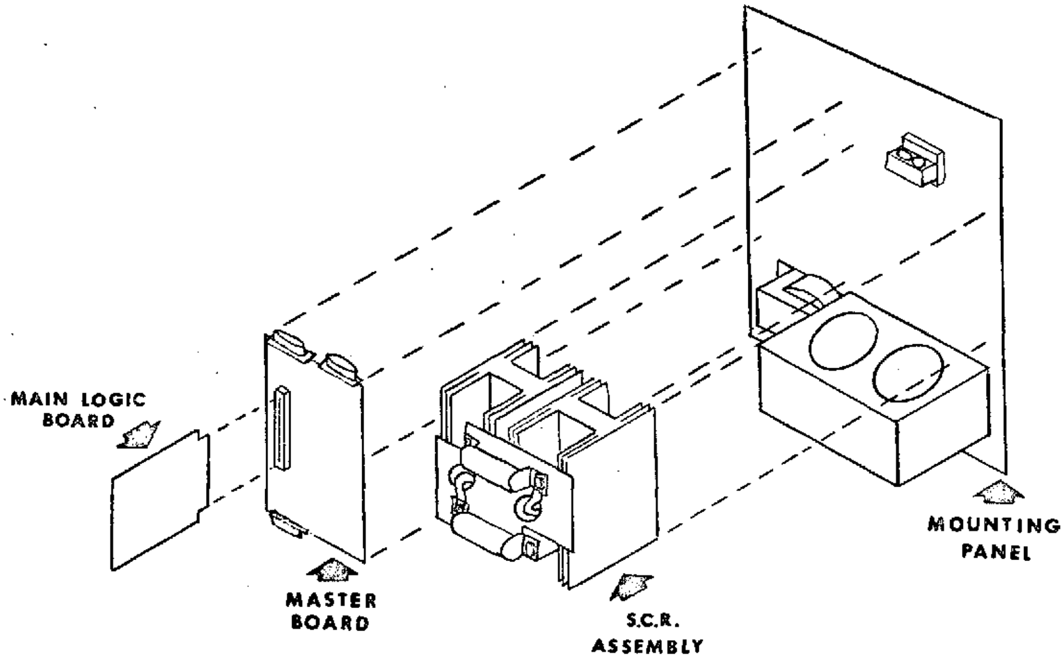


Figure 1-4. NIPC Mechanical Breakdown

1-2-1 Mounting Panel Assembly

The mounting panel assembly consists of a power transformer, a blower (optional), and a DV/DT network mounted on a metal panel. The metal panel is used as a surface on which to mount the rest of the NIPC assemblies and to mount the basic NIPC into an enclosure or on an electronic rack.

1-2-2 SCR Assembly

The SCR assembly consists of the power SCR's, the SCR driver assembly, and the protective fuses mounted on two heat sinks. The entire SCR assembly is mounted above the fans on the mounting panel assembly.

1-2-3 Masterboard Assembly

The masterboard assembly is a solid-state printed circuit board mounted directly on the mounting panel assembly in the upper lefthand corner. It contains the firing circuit, power supplies, two harness connectors, and one printed circuit board connector.

1-2-4 Main Logic Board Assembly

The main logic board assembly is a printed circuit plug-in module which plugs into the connector on the masterboard assembly. It consists of integrated circuitry and contains all of the logic circuitry for the basic NIPC power controller.

1-2-5 Dimensions

The overall dimensions of the NUMERAC NIPC series power controller are shown in Figure 1-5 and its accompanying table.

DIMENSIONS

	INCHES			CENTIMETERS		
	A	B	C	A	B	C
PANEL BOARD	19	15	9	48	38	23
ENCLOSURE	20½	20½	10½	52	52.0	26.7

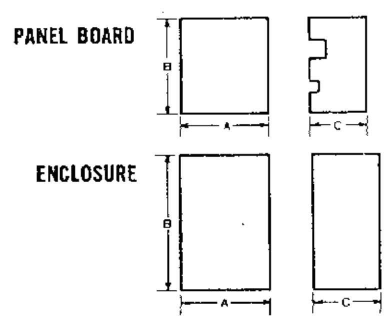


Figure 1-5. Overall Dimensions

1-3 Electrical Description

The following paragraphs describe the electrical characteristics of the NIPC power controller.

1-3-1 Output

The NIPC power controller applies only distributed, full cycles of output power from the input line. The output capacity of the unit depends upon the specific model chosen. Refer to Table 1-1 for the output capacity of the various models.

1-3-2 Input Voltage

NIPC power controllers may be operated at various input voltage levels depending upon the model chosen and the connection of the input transformer voltage taps. Connection of input connection taps is covered in the installation section of this manual. The input power capacities are shown in Table 1-1. The input line frequency may be either 50 or 60 Hz.

TABLE 1-1 NIPC INPUT/OUTPUT CAPACITIES

Resistive Loads		
Model	Output Amperage (Max.)	AC Input Voltages
NIPC-P27	70 amperes	240, 208, 120
NIPC-P214	140 amperes	240, 208, 120
NIPC-P47	70 amperes	480, 380, 277, 240, 208, 120
NIPC-P414	140 amperes	480, 380, 277, 240, 208, 120
Incandescent Loads		
Model	Output Kilowatts (Max.)	AC Input Voltages
NIPC-W27	9.6 KW	240, 208, 120
NIPC-W214	15.3 KW	240, 208, 120
NIPC-W222	24.0 KW	240, 208, 120
NIPC-W233	35.0 KW	240, 208, 120
NIPC-W47	19.2 KW	480, 380, 277, 240, 208, 120
NIPC-W414	30.6 KW	480, 380, 277, 240, 208, 120
NIPC-W422	48.0 KW	480, 380, 277, 240, 208, 120
NIPC-W433	70.0 KW	480, 380, 277, 240, 208, 120

1-3-3 Signal Input

There are ten signal input lines to the basic NUMERAC NIPC power controller. Six lines are for data input, one line for strobing the data bits into the register, two lines for computer UP and computer DOWN function commands, and the last line for stepping the UP/DOWN function at a rate other than the internal clock rate (1-7/8 PPS).

The NIPC uses standard DTL logic levels:

+3 to +5 VDC = HIGH or "Logical 1"

0 VDC to + 0.6 VDC = LOW or "Logical 0"

1-3-4 Range of Control

The range of control of the output power is 0 - 100% in single-cycle increments. The percentage of output power stipulated by the data word input may be computed by dividing the 63-cycle time frame into the decimal value of the data word input. For example:

$$110101_{(2)} = 53_{(10)} = 84\% \text{ of applied power}$$

$$\frac{53}{63} = 84\%$$

2-0 General

This section contains instructions for mounting the unit and wiring the signal, input power and load connections. Read this section carefully before attempting to install the unit.

2-1 Mounting Instructions

The following procedures are mounting instructions for the basic NIPC series power controller. If the enclosure option is to be used, refer to Mounting Instructions for the option "Enclosure" at the rear of this manual. Before attempting to install the unit, refer to the discussion on cooling factors in the next paragraph.

2-1-1 Cooling Considerations

The basic NIPC power controller is air-cooled. In mounting the unit, do not restrict the free flow of air through the unit.

2-1-2 Mounting Instructions

The power controller is designed to be mounted vertically with screws or bolts through the pre-drilled mounting holes. To prepare the mounting surface for mounting, drill four holes to correspond with the mounting holes in the NIPC mounting panel assembly. Refer to Figure 2-1 for the dimensions of the mounting holes.

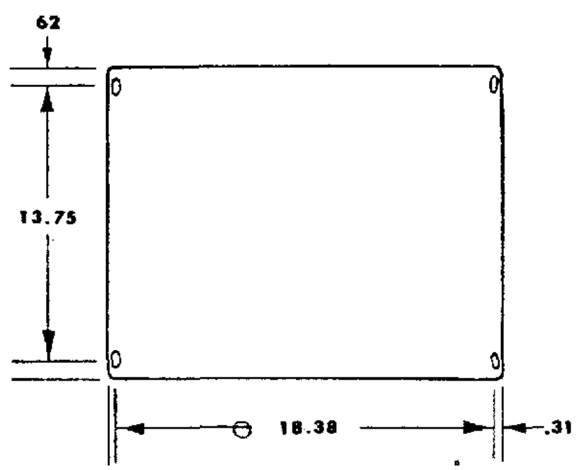


Figure 2-1. Mounting Hole Dimensions

2-2 Load Connections

Before connecting the power controller to the load, the type and size of the load must be considered. If the power controller is to be operated into a resistance-type load, the unit can be operated at its full rated capacity if the load has the appropriate resistance. Compute the minimum load resistance (in ohms) for the rated current output by dividing the input voltage by the current rating of the unit.

For incandescent type loads, refer to Table 1-1 for output KW ratings for each particular model. These KW ratings include allowance for normal cold-lamp inrush current.

Because the NIPC applies only full cycles of power, there are certain inherent problems with operating the unit into a transformer load. If the power controller is to be operated into a transformer load, it is recommended that RESEARCH, INC. be consulted prior to installation of the unit.

2-2-1 Load Connection Procedure

Connect the load wires to the power controller at the two terminals marked LOAD 1 and LOAD 2 on the unit. Figure 2-2 shows the location of the load connections.

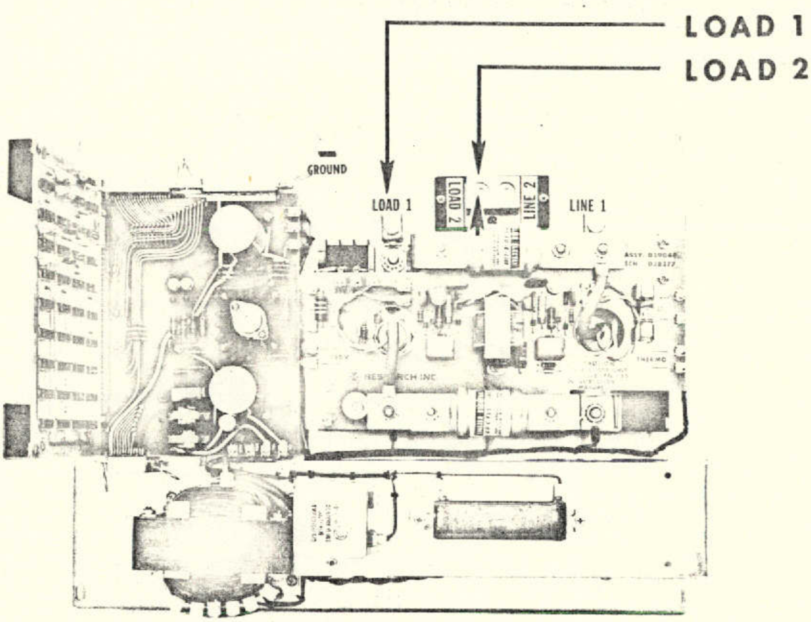


Figure 2-2. Load Connections

The size of the load wire should conform to the local electrical codes for the rated capacity of the unit.

2-3 Input Line Voltage Connections

The input power lines are connected to the terminals marked LINE 1 and LINE 2, shown in Figure 2-3.

The input line should be run through conduit or greenfield and sized according to local codes for the rated capacity of the unit.

Should it be desired to operate the unit at an input voltage other than that specified at the time the unit was ordered, the input power transformer must be rewired for the desired input voltage. The input voltage for factory-wired units is specified on the unit itself.

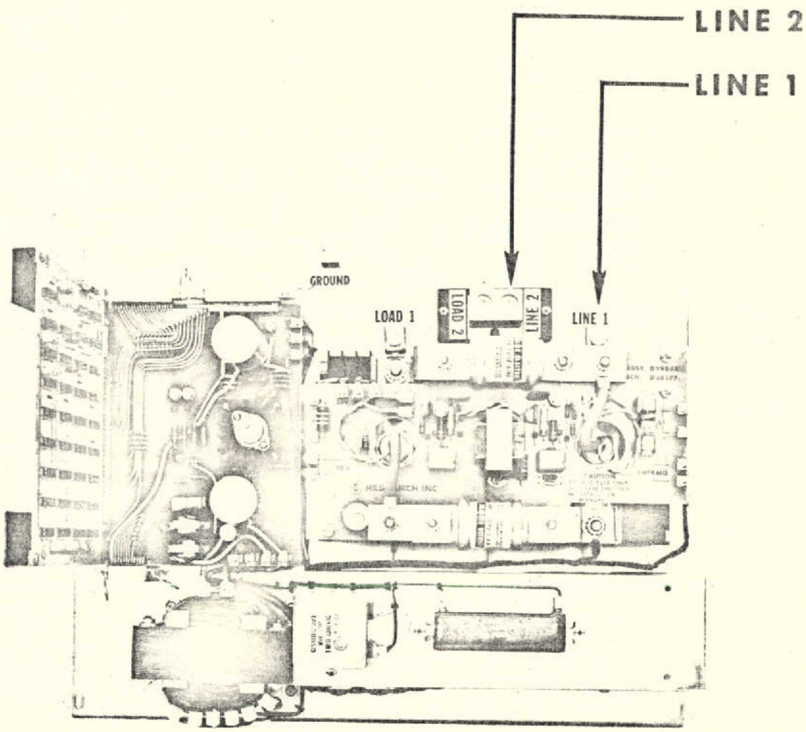


Figure 2-3. Input Line Voltage Connections

2-3-1 Transformer Wiring

Transformer B38364 shown on Schematic C39138 must have its primary voltage tap changed if a change in line voltage is contemplated. See Figure 2-4 for transformer wiring configurations.

CAUTION

The unit must not be operated on a higher line than that for which it was designed. Refer to Table 1-1.

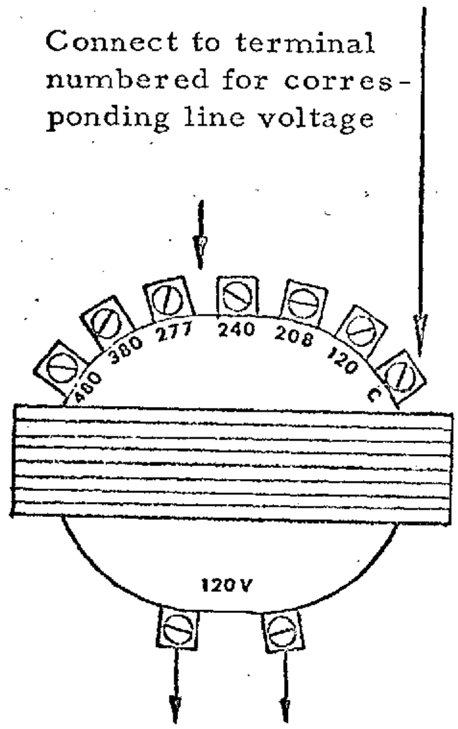


Figure 2-4. Transformer B38364 Wiring Configurations

2-4 Input Signal Connections

Figure 2-5 shows the location of the signal input wiring connectors on the Master board. Connectors J1 and J2 are wired in parallel so that in multi-channel operations, any number of units may be harnessed together with short jumper cables. For example, the cabling would go: Computer to J1, J2 to J1 of next channel, J2 to J1 of next channel, etc., etc.

Connector J3 is used only for connecting the manual entry option (See Section A6-2-2).

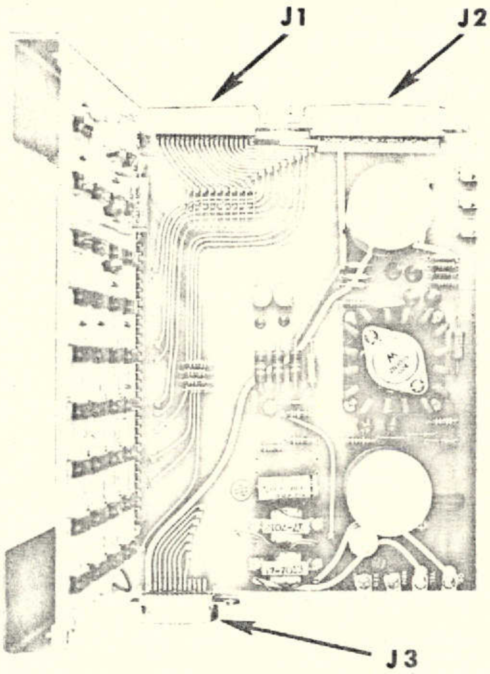


Figure 2-5. Input Signal Connectors

Table 2-1 shows where each signal line terminates and also its function. For multi-channel operation, refer to Section 2-4-1 for further information on channel addressing of strobe pulses.

TABLE 2-1 Input Signal Terminals

Title	Termination on Power Controller (P1 or P2)	Function
CS0 (2^0)	24	6 Bit Binary Word which determines the power output level. (See Section 1-1)
CS1 (2^1)	23	
CS2 (2^2)	22	
CS3 (2^3)	21	
CS4 (2^4)	20	
CS5 (2^5)	19	
Strobe	7 through 16	A +5 VDC pulse applied to any of these terminals, gates the binary word input into the register.
Computer Up	18	A logic zero applied here enables the input register to count up in binary steps.
Computer Down	17	A logic zero applied here enables the input register to count down in binary steps.
Computer Step	25	+ 5 VDC clock pulses from computer determines how fast the Up/Down Counter operates. (The Jumper, shown on Schematic D38290, must be moved to the dotted line position for computer control.)

2-4-1 Strobe Addressing for Multi-Channel Systems

Figure 2-6 illustrates a channel address strobing code for use in multi-channel operation. It can be used for addressing strobe pulses to a maximum of 31 channels utilizing 10 parallel signal lines. Its use requires the removal (clipping out) of diodes on the Master board of each individual power controller. Use the following instructions to obtain channel addressing of strobe pulses:

5 BIT COMPUTER OUTPUT (WITH COMPLEMENT)

2^4		2^3		2^2		2^1		2^0		
Q	$\overline{Q}$	Q	$\overline{Q}$	Q	$\overline{Q}$	Q	$\overline{Q}$	Q	$\overline{Q}$	Channel
0	1	0	1	0	1	0	1	1	0	1
0	1	0	1	0	1	1	0	0	1	2
0	1	0	1	0	1	1	0	1	0	3
0	1	0	1	1	0	0	1	0	1	4
0	1	0	1	1	0	0	1	1	0	5
0	1	0	1	1	0	1	0	0	1	6
0	1	0	1	1	0	1	0	1	0	7
0	1	1	0	0	1	0	1	0	1	8
0	1	1	0	0	1	0	1	1	0	9
0	1	1	0	0	1	1	0	0	1	10
0	1	1	0	0	1	1	0	1	0	11
0	1	1	0	1	0	0	1	0	1	12
0	1	1	0	1	0	0	1	1	0	13
0	1	1	0	1	0	1	0	0	1	14
0	1	1	0	1	0	1	0	1	0	15
1	0	0	1	0	1	0	1	0	1	16
1	0	0	1	0	1	0	1	1	0	17
1	0	0	1	0	1	1	0	0	1	18
1	0	0	1	0	1	1	0	1	0	19
1	0	0	1	1	0	0	1	0	1	20
1	0	0	1	1	0	0	1	1	0	21
1	0	0	1	1	0	1	0	0	1	22
1	0	0	1	1	0	1	0	1	0	23
1	0	1	0	0	1	0	1	0	1	24
1	0	1	0	0	1	0	1	1	0	25
1	0	1	0	0	1	1	0	0	1	26
1	0	1	0	0	1	1	0	1	0	27
1	0	1	0	1	0	0	1	0	1	28
1	0	1	0	1	0	0	1	1	0	29
1	0	1	0	1	0	1	0	0	1	30
1	0	1	0	1	0	1	0	1	0	31

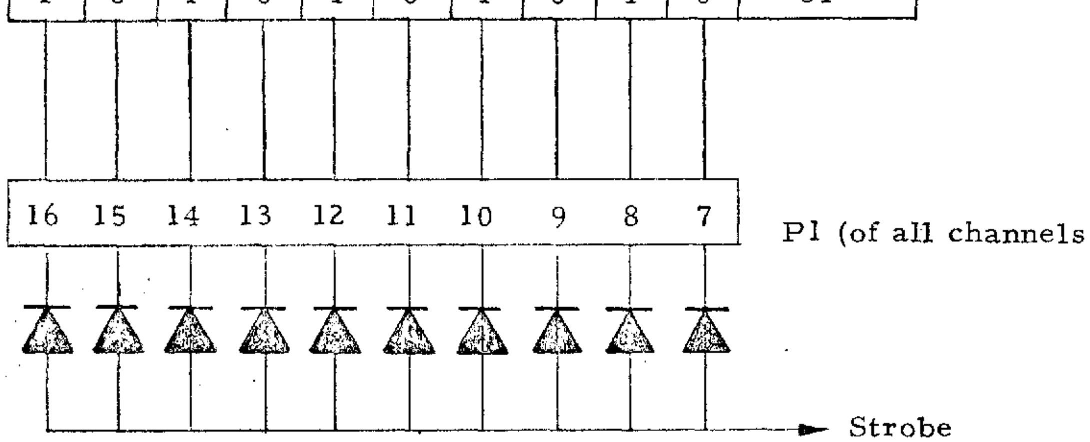


Figure 2-6 Channel Strobe Address Code

1) Using Figure 2-6 and starting with Channel 1, observe the Q and $\overline{Q}$ outputs from the computer for that channel.

2) Follow vertically down each column to find out which terminal of P1 it is connected to.

3) In Power Controller 1, clip out all diodes which are connected to terminals which are under logic zeroes.

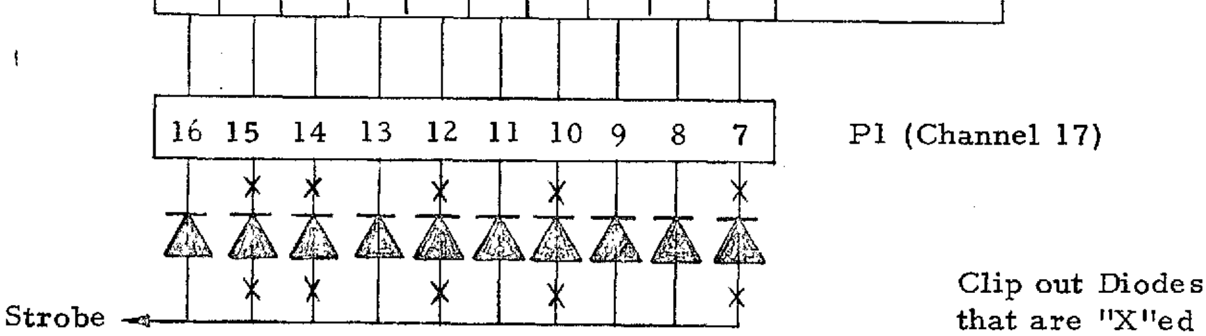
4) Repeat Steps 1 through 3 for all channels, substituting other channel numbers and power controllers.

EXAMPLE

To Strobe Channel 17

$$17_{(10)} = 1\ 0\ 0\ 0\ 1_{(2)}$$

2^4		2^3		2^2		2^1		2^0		
Q	$\overline{Q}$	Q	$\overline{Q}$	Q	$\overline{Q}$	Q	$\overline{Q}$	Q	$\overline{Q}$	Channel
1	0	0	1	0	1	0	1	1	0	17



3-1 General

There are no switches, controls, or indicators for operating the unit on the basic NUMERAC NIPC series power controller. Input power is applied by an external circuit breaker or contactor and binary input words are supplied by a computer. The recommended sequence for applying operating voltages to the NIPC is to apply input power to the unit and then apply the binary input command from the computer. In programming the computer to control the NIPC output power, binary word 000001 produces 1 output cycle for each 63-cycle time frame, 111111 will result in full output power.

The significance of the various options on the operating procedure is covered in the Options Section. Specific procedures for operating the unit with each option is covered in the section for that particular option.

4-1 Introduction

This section contains a description of the standard logic circuits used in the firing circuit control logic and a general and detailed description of firing circuit operation.

Circuitry described on the following pages is shown schematically on Diagrams

D38290	Firing Control Logic
D38377	Master Board Firing Circuit.

4-1-1 Logic Levels

The firing circuit control logic uses positive logic in all circuitry.

Logic levels are:

High or "1"	+ 3.0 to + 5.0 Volts DC
Low or "0"	0 to + 0.6 Volts DC

4-1-2 Standard Logic Circuits

The following paragraphs describe the basic logic circuitry used in the firing circuit control logic.

4-1-2-1 NAND Gate

In the NAND Gate, shown in Figure 4-1, if all inputs are "High", the output is low. If any input is "Low", the output is high.

Truth Table

A	B	F
0	0	1
1	0	1
0	1	1
1	1	0

Figure 4-1. NAND Gate

4-1-2-2 RS Flip-Flop

The RS flip-flop, shown in Figure 4-2, is a bistable multivibrator which retains the output level of the last input signal until reset. In this application, the inputs are inverting, so that with both R and S inputs "High", a "Low" at S will set the flip-flop. It will remain in this state till a "Low" at R resets it.

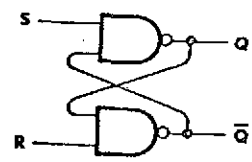


Figure 4-2. RS Flip-Flop

4-1-2-3 JK Flip-Flop

The JK flip-flop configuration in the NIPC uses three inputs: C, J, and K. J and K are used as enables. When both J and K are true, the state of the flip-flop changes with each clock pulse input. This configuration is used in the control logic and the UP/DOWN counter option.

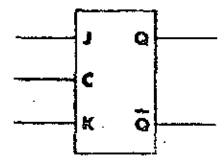


Figure 4-3. JK Flip-Flop

4-1-2-4 One Shot

A one shot, shown in Figure 4-4, is a monostable multivibrator formed by four NAND Gates.

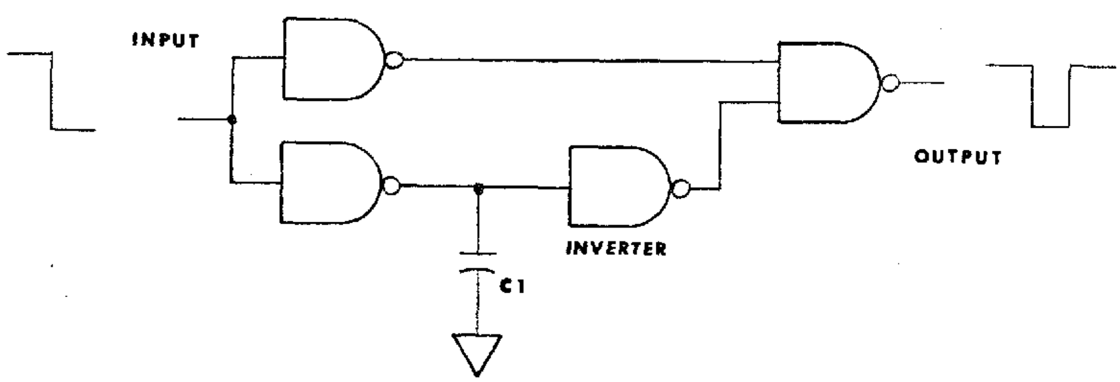


Figure 4-4. One Shot

A low to the input gates gives a low, of fixed duration, out of the output gate until C1 charges to a level high enough to enable the inverter to disable the output gate and return the output to a high level.

4-2 General Theory

The power controller applies full cycles of power to the load evenly distributed over a 63-cycle time frame as controlled by the binary input word.

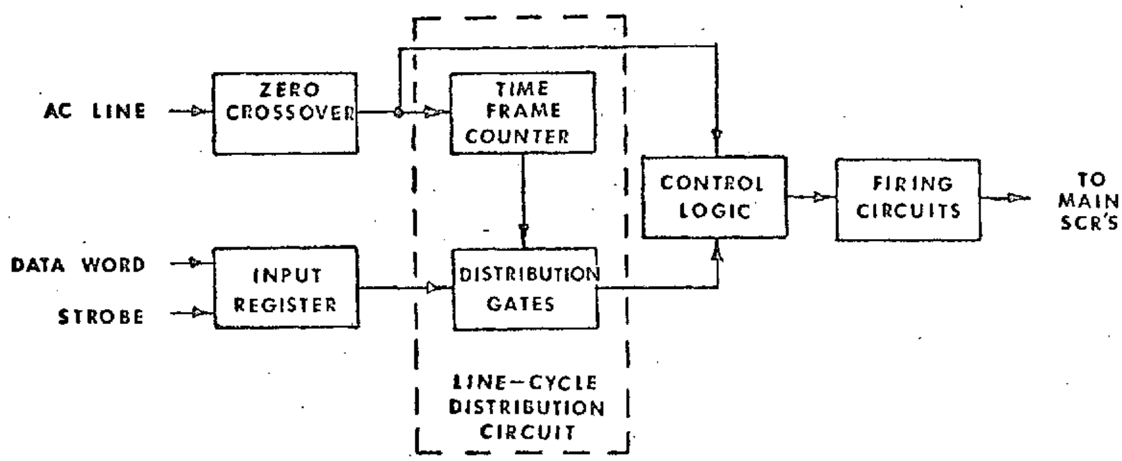


Figure 4-5. Functional Block Diagram

The functional diagram in Figure 4-5 shows the relationship of the major sections of the NIPC circuitry. The data word, specifying the number of cycles applied to the load within each 63-cycle time frame, is stored in the input register if it is accompanied by a strobe pulse. The time frame counter, which is recycled after 62 cycles of line frequency, generates 6 pulse trains each of which is half the frequency of the preceding one. These pulse trains are gated through the distribution gates by "true" data bits in the input register. The combined pulse train, called distribution pulses, represents the best distribution of applied power cycles to the load. They enable line-synchronized pulses from the zero crossover circuit to generate firing pulses in the control logic. Two firing pulses are generated for each distribution pulse: one at the 0° point and one at the 180° point of the cycle. The firing circuit uses these firing pulses from the control logic to fire the driver SCR's.

In the following text, references to points such as "A1-8", "A2-11", etc., refer to specific gates within individual integrated circuits. Refer to Schematic D38290.

4-2-1 Input Register

The input register stores the binary input word until the next binary word entry is made. Each data bit determines the state of one of the three dual J-K flip-flops which make up the input register (D5, D5, D7, D7, D9, D9).

4-2-2 Line Cycle Distribution

The line cycle distribution circuit consists of the time frame counter and the distribution gates.

The time frame counter is a binary ripple counter formed by three dual J-K flip-flops (A5, A5, Au, A7, A9, A9). It generates six distinct pulse trains, one for each data bit, which are combined at the distribution gates to form the distribution pulse train. The distribution gates are B6, B7, B8 and B9. The positive going pulse train at B6-8 is inverted at B5-3 to negative going pulses.

4-2-3 Zero Crossover

Line cycle inputs to Gates D1-12 and D1-9 come from opposite sides of a transformer whose center tap is tied to circuit common and are 180° out of phase. At A1-6, a positive going 5 VDC pulse occurs at the 0° point of every line cycle. At A1-8, a similar pulse occurs at the 180° point of every line cycle (8.33 milliseconds after the 0° pulse). The pulse at A1-8 is also applied to a one-shot (see Section 4-1-2-4) where the negative going leading edge at Gates A2-1 and A2-13 produce a negative going pulse at A2-8. This pulse, which occurs just after the 180° crossover pulse, is used to reset the B5 and B4 flip-flops (see Section 4-1-2-2) in the control logic. The pulse at A2-8 is also applied to another one shot. The positive going output pulse at A4-6 is used to clock the J-K flip-flops in the time frame counter.

4-2-4 Firing Circuit Control Logic

This circuit utilizes the distribution pulses and zero crossover pulses to transmit two firing pulses to the firing circuit to control the main SCR's.

The negative going distribution pulse at B5-4 sets the B5 flip-flop, resulting in a high at B5-10. The 0° crossover pulse at B5-9 results in a negative going pulse at B5-8 which sets the B4 flip-flop. The high at B4-4, results in a negative going pulse at B4-6, which is the 0° firing pulse.

Simultaneously, when B4 flip-flop was set, B4-10 became high. When the 180° crossover pulse is applied to B4-9, a negative going pulse results at B4-8. This is the 180° firing pulse.

Following the 180° firing pulse, the negative going reset pulse at A2-8 resets both the B4 and B5 flip-flops. The circuit is now ready for the next distribution pulse.

4-2-5 Firing Circuit

The firing pulse from the control logic is amplified in the firing circuit, shown on Schematic D38377, to fire the main SCR's and apply power to the load. At zero line-voltage of the applied cycle, a negative firing pulse at J4 Pin 15 is amplified by Q8, and Q9. When Q9, which is normally cut off, conducts, a pulse from T2 enables the SCR to fire.

The firing pulse, for the first half-cycle of load voltage from T2 is applied to the gate of Driver SCR2. Diodes CR3 and CR4 with capacitor C4 comprise a voltage doubler/clamping circuit whose peak positive voltage is the peak-to-peak voltage on the secondary winding of T3. This voltage is the anode voltage for Driver SCR2. The cathode of Driver SCR2 is connected to the main SCR gate terminal G2. At 0° line-cycle, the anode voltage of Driver SCR2 is at one-half the peak voltage, and when it is fired, the anode of Driver SCR2 has sufficient voltage to fire the main SCR2. From the moment the main SCR is first fired, until the end of the first half-cycle, gate current is supplied. The circuitry for firing SCR1 with the negative pulse at J4 Pin 14 to apply the second half-cycle of load voltage operates identically to that for the first half-cycle.

SCR1, which is in series with the 25 VDC power supply for Q8 and Q10, has a one-second delay in the gate circuit to allow the circuitry to stabilize when power is applied. Without this power supply delay, random pulses could cause firing of the main SCR's upon application of power.

4-2-6 5 VDC Power Supply

The power supply, located on the top left portion of Schematic D38377A, provides regulated +5 VDC for the firing circuit control logic circuitry. Transformer T1, located on the firing circuit printed circuit board, supplies 9 VAC, which is bridge-rectified by BR1 and input-filtered by capacitor C1. The resultant voltage is series-regulated to +5 VDC by the compound connected transistors Q2 and Q1. Transistor Q3 is a pre-regulator which supplies constant current to the base of the regulator (Q1) and the collector of the DC amplifier (Q4). Transistors Q6 and Q7 form a differential amplifier with reference and sampling elements. Variations in power supply voltage cause a differential error signal at the collectors of Q6 and Q7. This error signal is fed to the base of the DC amplifier Q4 which changes the base drive to the series regulator Q1 and Q2.

5-1 General

The information in this section is presented as an aid to maintenance personnel for locating faulty components. The NIPC series power controller is designed to provide reliable operation with a minimum of maintenance. However, due to normal component aging and failure, corrective maintenance may be required. Corrective maintenance, which includes normal troubleshooting and repair techniques, should only be performed by qualified maintenance personnel when component failure renders the equipment inoperative, unreliable or potentially hazardous.

5-2 Required Test Equipment

To troubleshoot the equipment adequately, it is recommended that maintenance personnel have access to the following items of test equipment:

1) Oscilloscope

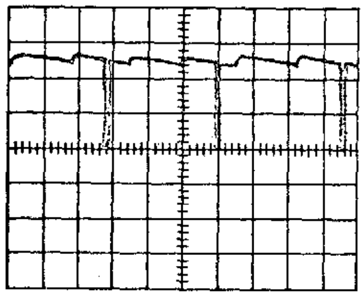
2) Oscilloscope probes (it is recommended that x10 attenuation probes be used)

3) Multimeter

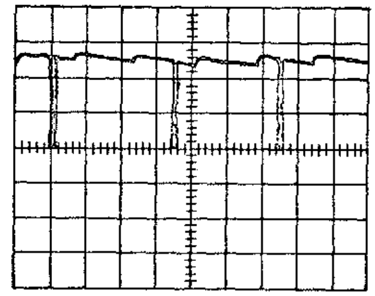
5-3 Representative Wave-forms

The wave-forms shown on the succeeding pages were taken from a standard NIPC power controller under normal operating conditions. Test point locations, oscilloscope settings, and other pertinent information is given for each wave-form. Use these wave-forms as a comparison when troubleshooting the equipment.

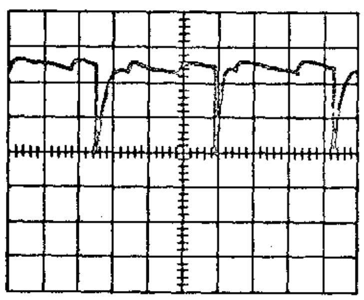
(Horizontal Sensitivity - 5 ms/cm)
Reference Schematic D38377



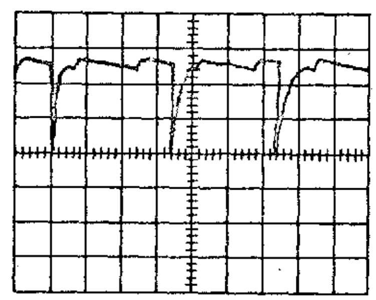
0° Firing Pulse 2 v/cm



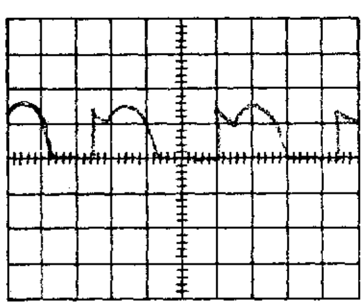
180° Firing Pulse 2 v/cm



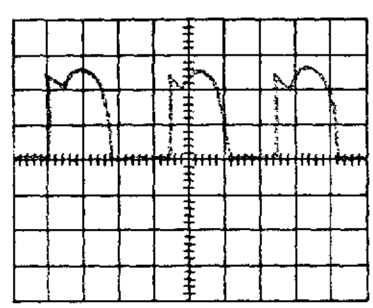
"A" Output 10 v/cm



"B" Output 10 v/cm



G2 to K2 2v/cm



G1 to K1 2 v/cm

5-4 Test Voltages

Table 5-1 lists operating voltages at various points in the NIPC circuitry.

Use these voltages for comparison when troubleshooting the equipment. The readings were taken with a 20,000 ohms/volt V.O.M. Reference Schematic D38377.

TABLE 5-1 OPERATING VOLTAGES

(+ PROBE) FROM	(- PROBE) TO	READING
T1, Yellow Lead	T1, Orange Lead	9 VAC
T1, Red Lead	T1, Brown Lead	23 VAC
+ C7	Circuit Common	+ 27 VDC
+ C3	Circuit Common	+5.2 VDC
T3, Blue Lead	T3, Green Lead	12 VAC
T3, Black Lead	T3, Yellow Lead	12 VAC
Terminal 3, Jack 4	Terminal 4, Jack 4	3.2 VAC

Section VI OPTIONS

The options described in this section are available for the NUMERAC NIPC series power controller. Refer only to those options which are incorporated in the equipment.

A6-1 General

The Manual Entry Option consists of a mounting panel and associated circuitry containing switches and lights to manually enter binary data into the NIPC input register. This option, shown schematically on Drawing B38293 in the Basic Manual, is easily connected to a jack on the master board assembly. Figure 6-1 shows the Manual Entry Option.

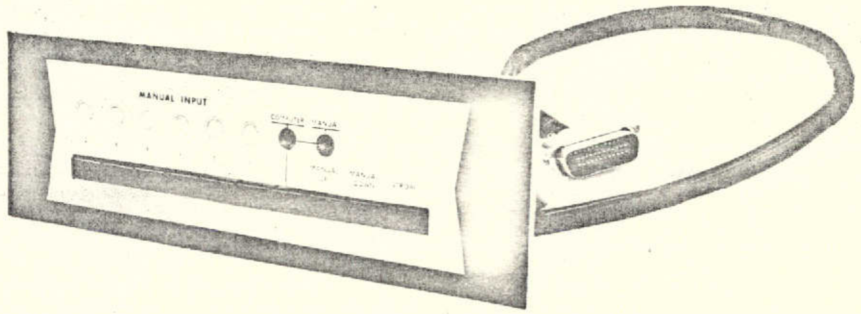


Figure 6-1. Manual Entry Option

A6-2 Installation

Installation consists of mounting the manual entry option panel and connecting the option wiring harness. Refer to the following instructions for installation procedures.

A6-2-1 Mounting

Mount the manual entry option panel on a vertical, flat panel with 4 screws. The panel must be cut out and mounting holes drilled in accordance with the specifications shown in Figure 6-2.

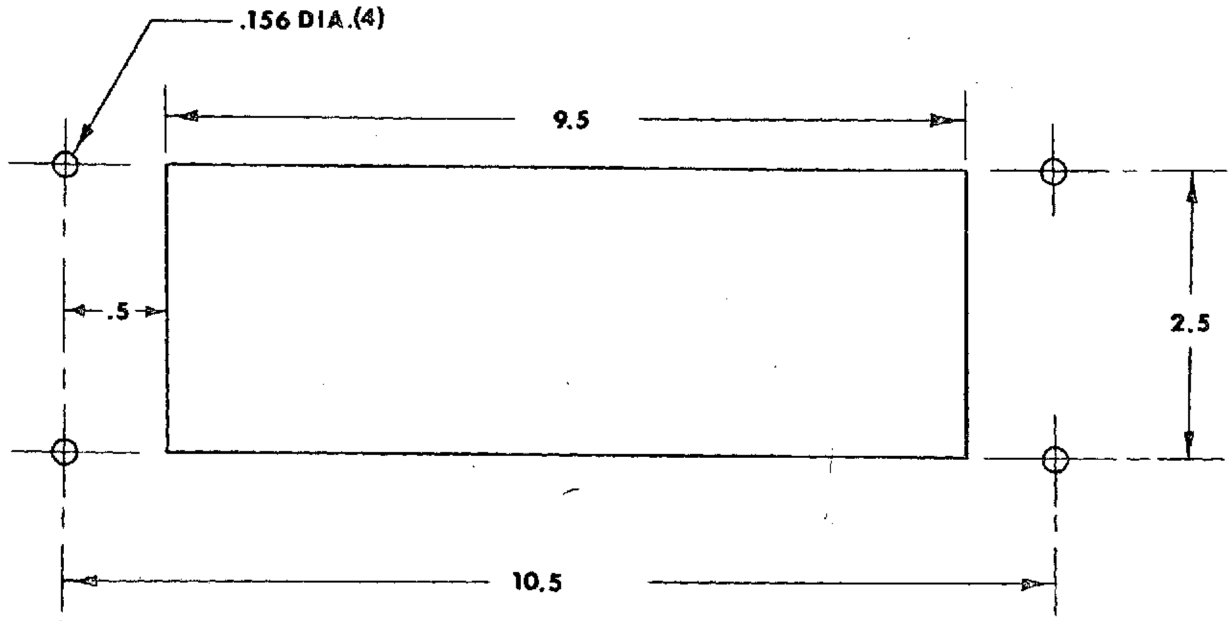


Figure 6-2. Manual Entry Option Mounting Panel Specifications

A6-2-2 Interconnection Wiring

Connect the option wiring harness to J3 Jack shown on Schematic D38377. J3 Jack is located on the masterboard assembly as shown in Figure 2-3 of the Basic Manual.

A6-3 Operation

Items under this heading include a functional description of the lights and pushbuttons on the manual entry option panel and the recommended procedure for operating the manual entry input option.

A6-3-1 Operator Controls and Indicators

Table 6-1 contains a functional description of manual entry option controls and indicators.

TABLE 6-1. OPERATOR CONTROLS AND INDICATORS

NAME	TYPE	FUNCTION
DATA KEYS (6)	2-position pushbutton switches	DEPRESSED - enters associated data bit into the input register when the strobe pushbutton is depressed.
DATA LIGHTS (6)	White Indicating Light	LIGHTED - the data bit in the corresponding input register flip-flop is a "1". EXTINGUISHED - the data bit in the corresponding input register is "0". Depressing the data keys will not change the data lights until the strobe pushbutton is depressed.
COMPUTER	Yellow Indicating Light	ILLUMINATED - data inputs to the NIPC input register may be supplied only by the computer. Lighted when the MANUAL/COMPUTER is depressed.
MANUAL	Yellow Indicating Light	ILLUMINATED - data inputs to the NIPC input register are supplied by the manual entry data keys only. Lighted when the MANUAL/COMPUTER switch is released.
MANUAL/ COMPUTER	2-position pushbutton	DEPRESSED - only the computer can control the NIPC output power. RELEASED - only the manual entry option can control the NIPC power output. Computer inputs are disabled.

TABLE 6-1 (continued) OPERATOR CONTROLS AND INDICATORS

NAME	TYPE	FUNCTION
MANUAL UP	Momentary Pushbutton Switch	DEPRESSED - enables input register to count up in binary steps.
MANUAL DOWN	Momentary Pushbutton Switches	DEPRESSED - enables input register to count down in binary steps.
MANUAL STROBE	Momentary Pushbutton Switch	DEPRESSED - binary word selected by the data keys is entered into the input register.

A6-3-2 Operating Procedure

The following steps list the recommended procedure for manually controlling the NIPC power controller output power at the manual entry option.

1) Release the MANUAL/COMPUTER Pushbutton. The MANUAL indicating light should light to indicate that the unit is in the MANUAL mode of operation.

2) Depress the data keys to set up the desired binary word input. When the data key is depressed, it indicates a "binary 1"; released, it indicates a "binary 0". When all the keys are depressed, it will set up a maximum power output command.

3) Depress the STROBE Pushbutton to enter data into the NIPC register. Data lights corresponding to depressed keys will light and lights corresponding to released keys will extinguish, indicating the contents of the input register. The NUMERAC NIPC series power controller will supply the desired output power.

A6-4 Circuit Description

The lamp driver circuit, shown on Schematic B38293, lights its associated data light when the corresponding input register flip-flop is set. A "High" from the input register, denoting that the flip-flop is set, is applied to the base of the driver transistor. The driver transistor, which is normally cutoff, conducts, to place circuit common on one side of the lamp, thus causing it to light.

Depressing the data key does not directly affect the lamp. When the data key is in the RELEASED position, the data/switch is normally closed, putting a "Low" into the input register flip-flop. Depressing the data key opens the switch to put +5 volts DC into the register inputs. When the strobe pushbutton is depressed, the input register flip-flop corresponding to the data key pushbutton is depressed, is set, and the resulting action lights the associated light.

The MANUAL/COMPUTER Pushbutton determines the mode of operation. When the pushbutton is depressed, one section of the switch lights the COMPUTER lamp. The other section disables the MANUAL input gates and enables the COMPUTER input gates.

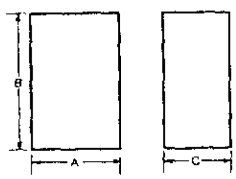
When the pushbutton is RELEASED, one section of the switch lights the MANUAL lamp. The other section disables the COMPUTER input gates and enables the MANUAL input gates.

B6-1 General

The Enclosure Option is a metal enclosure for housing the NUMERAC NIPC series power controller. It has a front hinged door for access to NIPC circuitry and knockouts for line and load interconnection wires. Meter and manual entry options may be mounted on the hinged door.

B6-2 Physical Specifications

Figure 6-3 lists the overall physical dimensions for all sizes of the enclosure option.



ENCLOSURE

INCHES			CENTIMETERS		
A	B	C	A	B	C
20½	20½	10½	52	52.0	26.7

Figure 6-3. Enclosure Option Overall Dimensions

B6-3 Mounting

If the Enclosure option is not factory-installed, install the NIPC Enclosure option by the following recommended procedure:

1) Open the enclosure option front door and insert the NUMERAC NIPC series power controller.

2) Mount the NIPC series power controller to the 1/4 x 20 N.C. weldnuts on the back of the enclosure option.

3) Mount the enclosure option on a vertical flat surface at the four slotted mounting holes on the rear of the option.

B6-3 Mounting (Continued)

4) Run line and load wires to the NUMERAC NIPC series power controller through enclosure knockouts. Wiring is done as described in Section II of the basic NIPC Instruction Manual.

C6-1 General

This option consists of an ammeter and a voltmeter, each connected to its own printed circuit averaging circuits. They indicate the average RMS load voltage and current. They also provide output voltages for external data acquisition instruments.

These meters and printed circuit boards are normally mounted on the option enclosure front door. They are wired as shown on Schematics C39138 in the Basic Manual and Option Schematic B37771 at the rear of this description.

C6-2 Circuit Description

The circuitry on these options averages the full cycle signal from the load to provide average current or voltage levels to the meters. Capacitive averaging circuitry within the option ensures stable meter readings even if only 1 cycle of power is applied to the load for each time frame. Except for input sources and output information, the circuitry is identical. The voltmeter input is tied directly across the load; while the ammeter input comes from a current transformer on the input line.

The AC input signal is averaged by a rectifier/filter network. The AC input to the circuitry is rectified by the input bridge to produce a DC level proportional to the RMS value of the AC input. This rectified voltage is averaged by a filter network formed by R1, R2, R3, C1 and C2. The average voltage level is held for the 63-cycle time frame by the charge/discharge time of the two capacitors.

R5 and R7 are calibration adjustments. They are calibrated at the factory and normally should not require further adjustment. At full output power, R5 is adjusted for a maximum meter reading. At full NIPC output power, R7 is adjusted for a 50-millivolt output signal.

D - WATTMETER OPTION

D6-1 General

The wattmeter option consists of a meter and printed circuit board which indicates the average output wattage. It also provides an additional 0 - 50 millivolt output signal for external data acquisition instruments.

D6-2 Installation

While the wattmeter option may be mounted on any vertical, flat surface near the NIPC power controller, it is recommended that the wattmeter option be mounted on the enclosure option front door. Use the following procedure to install the wattmeter option, if it is not factory-mounted.

1) Mount the printed circuit board and meter.

2) Remove the input line from the input terminal marked LINE 1.

3) Mount the current transformer in front of the terminal marked LINE 1.

4) Run the input line through the current transformer and connect it to LINE 1.

5) Connect the current input terminals on the board to the current transformer.

6) Connect the voltage input terminals on the printed circuit board across the secondary of the load voltage transformer.

D6-3 Circuit Description

The Wattmeter option multiplies load current by load voltage and provides an average level to the meter. This average reading ensures a stable meter reading even if only one cycle is applied for each 63-cycle time frame. The Halltiplier M7K multiples load voltage by load current automatically. Its output is an AC signal which is referenced to a DC level. This signal is filtered and averaged by the resistor-capacitor filter network. The resulting average current, representing wattage, deflects the meter.

R7 and R6 are calibration adjustments. They are normally calibrated at the factory and should not require further adjustment. At full NIPC output power, R6 is adjusted for 50 millivolts out of the data acquisition terminals. R7, also adjusted at maximum NIPC output power, is adjusted for a maximum meter reading. Refer to Schematic A38071.

E - ANALOG INPUT OPTION
(Combined with Manual Entry Option)

E6-1 General

The ANALOG INPUT OPTION, combined with the MANUAL ENTRY OPTION, allows the NIPC power controller to be controlled by an externally generated 0-5 VDC analog signal.

The ANALOG INPUT OPTION compares the 0-5 VDC analog voltage with a negative feedback voltage which is proportional to the contents of the input register on the Main Logic Board. When the analog input is greater than the feedback voltage, indicating an increased power requirement, a positive voltage is supplied to the inverting input of one integrated circuit, and the non-inverting input of another integrated circuit. The outputs of the two amplifiers are always opposite in polarity so that one output disables the DOWN function and the other output enables the UP function. When the feedback voltage exceeds the analog input command, a negative input to the amplifiers results in outputs which disable the UP function and enable the DOWN function.

When the feedback voltage equals the analog command (i.e., power applied is at the desired level), the input to the two amplifiers is zero. The analog input portion of this option will only command the UP/DOWN counter if a difference exists between the analog input and the feedback voltage.

An extra pushbutton on the Manual Entry Assembly selects the analog input. Depressing the ANALOG pushbutton, lights the ANALOG indicator light and enables the analog input function.

Section VII RECOMMENDED SPARE PARTS LIST

7-0 General

The following Recommended Spare Parts Lists include type of item, description, vendor part number and R-I inventory number where applicable and RESEARCH, INCORPORATED recommendation for quantity of units for customer to stock as spare parts.

RECOMMENDED SPARE PARTS LIST

NIPC MASTER BOARD	D40873	
TITLE	NUMBER	REV

ITEM	DESCRIPTION	PART NO.	INVENTORY	QUANTITY 1	2	3	4	☆
1	Driver SCR1, 2	2N4185	16A228		X			
2	Diode CR1, 2, 3, 4, 5, 6	EM502	16B107		X			
3	Transistor Q2, 4, 5, 6, 7	2N3642		X				
4	Transistor Q9, Q11	2N3053	16A158	X				
5	Transistor Q1	2N3055		X				

ORDERING INFORMATION

1) For ordering information and latest prices, contact your local representative or the RESEARCH, Incorporated factory in Minneapolis, Minnesota.

2) When ordering spare parts, please include references both to this parts list number and revision level, plus, the Model Number and Serial Number of the instrument for which these parts are being ordered.

TWX	PHONE MINNEAPOLIS	TELEX
910-576-2837	612-941-3300	029-5328

R·I CONTROLS
A DIVISION OF RESEARCH, INCORPORATED
BOX 24064 MINNEAPOLIS, MINNESOTA USA 55424

RECOMMENDED SPARE PARTS LIST

TITLE	NUMBER	REV
POWER CONTROLLER - SINGLE ZONE POWER CONTROLLER - THREE ZONE	D40642 D40643	

ITEM	DESCRIPTION	PART NO.	INVENTORY	QUANTITY 1	2	3	4	▽
1	Fuse, F1, 3, 6 Carbone - Ferraz							10
	Protistor - 500V, 1000 Amp.	A050SA1000F						
2	Fuse, F2, 4, 5 Carbone - Ferraz							
	Protistor - 1000V, 630A (Parallel 2)	A100FE630F						20
3	Fuse, F7,8 Bussman	KTK1						5
4	Fuse F9, 10, 11, 12, 13, 14 Bussman	KTK2						10
5	SCR Power Semiconductor, Inc.	H1600						6

ORDERING INFORMATION

1) For ordering information and latest prices, contact your local representative or the RESEARCH, Incorporated factory in Minneapolis, Minnesota.

2) When ordering spare parts, please include references both to this parts list number and revision level, plus, the Model Number and Serial Number of the instrument for which these parts are being ordered.

TWX	PHONE MINNEAPOLIS	TELEX
910-576-2837	612-941-3300	029-5328

R·I CONTROLS
A DIVISION OF RESEARCH, INCORPORATED
BOX 24064 MINNEAPOLIS, MINNESOTA USA 55424

Section VIII SCHEMATIC DIAGRAMS

The following drawings are schematic and logical diagrams of the basic NUMERAC NIPC series power controller:

C39138	NIPC - Basic Schematic
D38377	NIPC - Master Board
D38290	NIPC - Logic Board

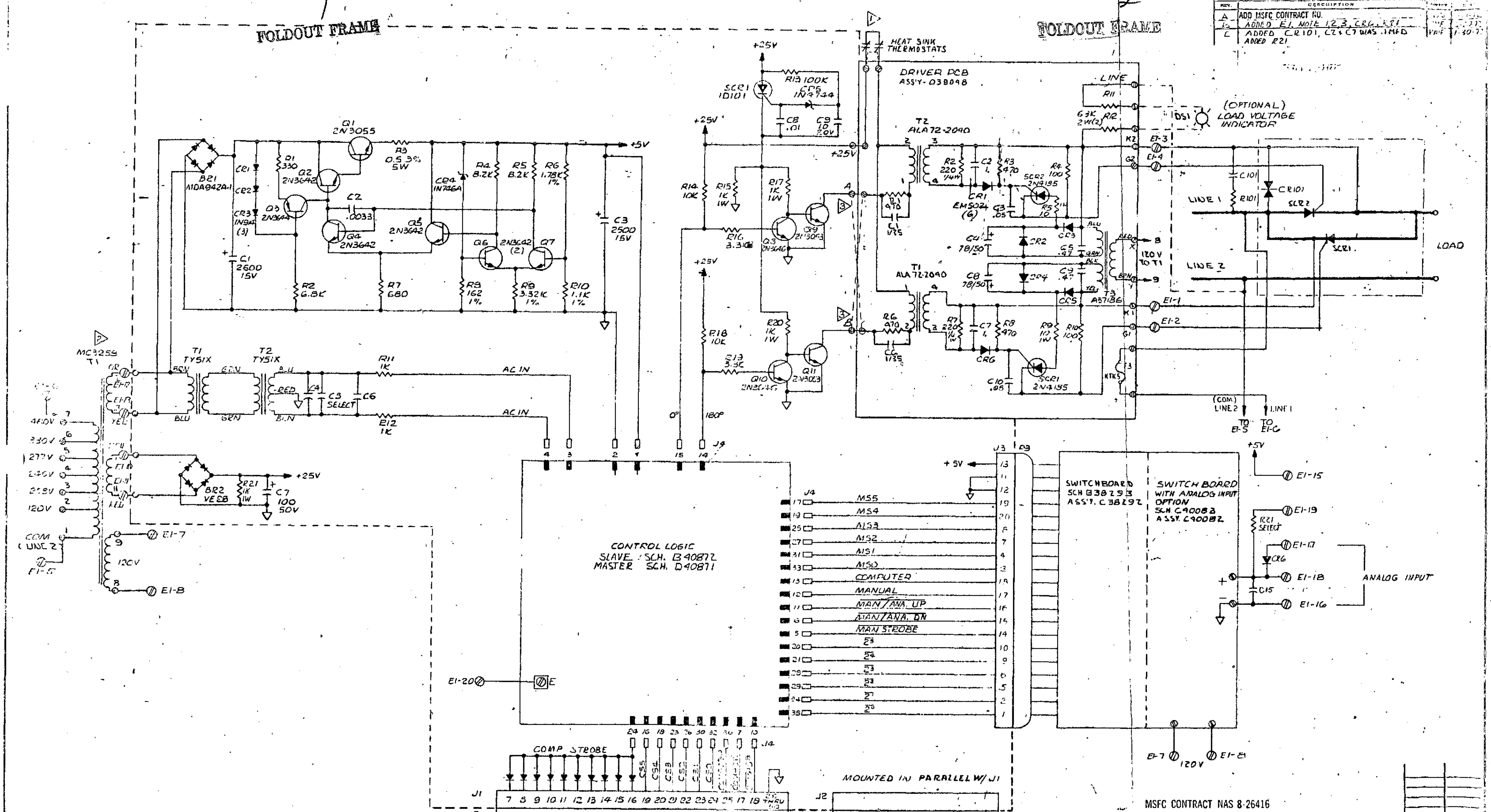
OPTIONS

B38293	Manual Entry Option
B37771	Ammeter and Voltmeter Option
A38071	Wattmeter Option
C40083	Analog Input with Manual Entry

FOLDOUT FRAME

FOLDOUT FRAME

REV.	DESCRIPTION		
A	ADD MSFC CONTRACT NO.		
B	ADDED E1, NOTE 1,2,3, CR6, R21		
C	ADDED CR101, C2+C7 WAS .1MFD ADDED R21		1-30-72



1. ON SINGLE ZONE POWER CONTROLLER (REF. SCH. D40692) FRAME A + C - THE WHITE / YELLOW AND WHITE / BLUE WIRES ARE REVERSED FOR CORRECT PHASING
2. ON SINGLE ZONE POWER CONTROLLER (REF. SCH. D40692) FRAME A + C - GRN AND YEL WIRES ARE REVERSED FOR CORRECT PHASING
3. REMOVE IF HEAT SINK THERMOSTATS ARE NOT USED

MSFC CONTRACT NAS 8-26416

GOR APPROVAL ________ DATE 2/8/72

UNLESS OTHERWISE INDICATED
- RESISTANCE IN OHMS ± 10% ½ WATT
- CAPACITANCE IN MFD ± 20%
- INDUCTANCE IN HENRIES
- USE 60/40 ROSIN CORE SOLDER
- USE NO CORROSIVE FLUX

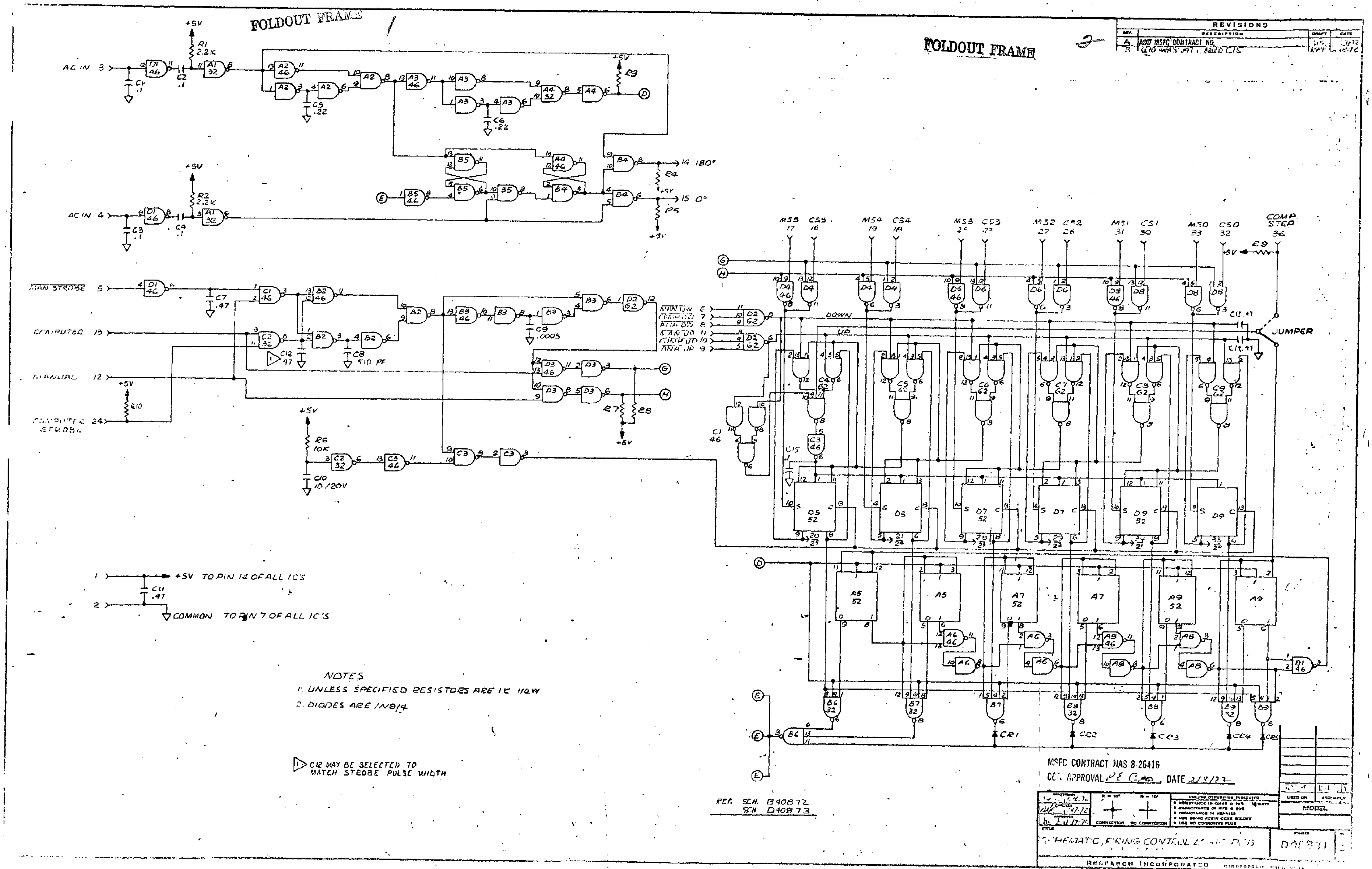
CONNECTION — NO CONNECTION

MODEL

TITLE: SCHEMATIC, MASTER BOARD NIPC, FIRING CIRCUIT PANEL

D40873 C

RESEARCH INCORPORATED MINNEAPOLIS, MINNESOTA


FOLDOUT FRAME
REVISIONS
A ADD MSFC CONTRACT NO.
AC IN 3
AC IN 4
MAN STROBE 5
COMPUTED 13
MANUAL 12
COMPUTER STROBE 24
14 180°
15 0°
MAN DN 6
COMP DN 7
MAN DN 8
MAN UP 11
COMP UP 10
MAN UP 9
DOWN
UP
JUMPER
COMP. STEP 36
1 +5V TO PIN 14 OF ALL IC'S
2 COMMON TO PIN 7 OF ALL IC'S
NOTES
1. UNLESS SPECIFIED RESISTORS ARE 1K 1/4W
2. DIODES ARE IN914
C12 MAY BE SELECTED TO MATCH STROBE PULSE WIDTH
REF. SCH. B40872
SCH D40873
MSFC CONTRACT NAS 8-26416
SCHEMATIC, FIRING CONTROL LOGIC PCB
RESEARCH INCORPORATED

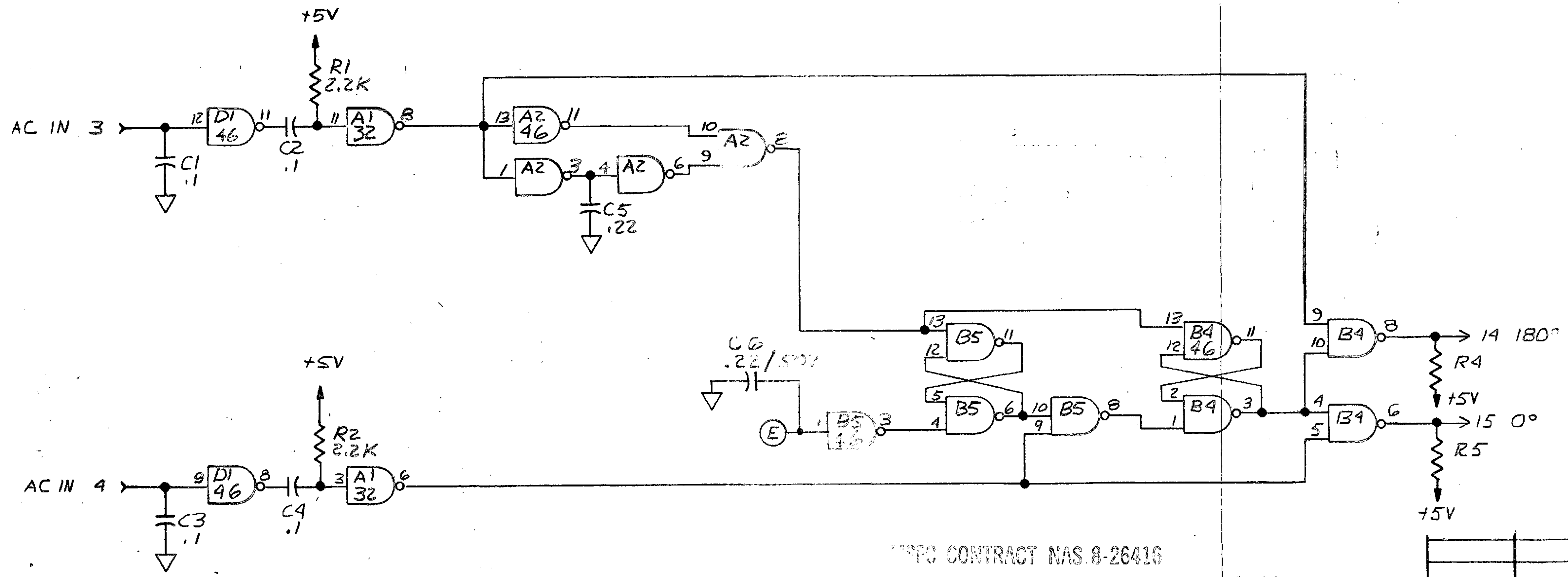
FOLDOUT FRAME 2

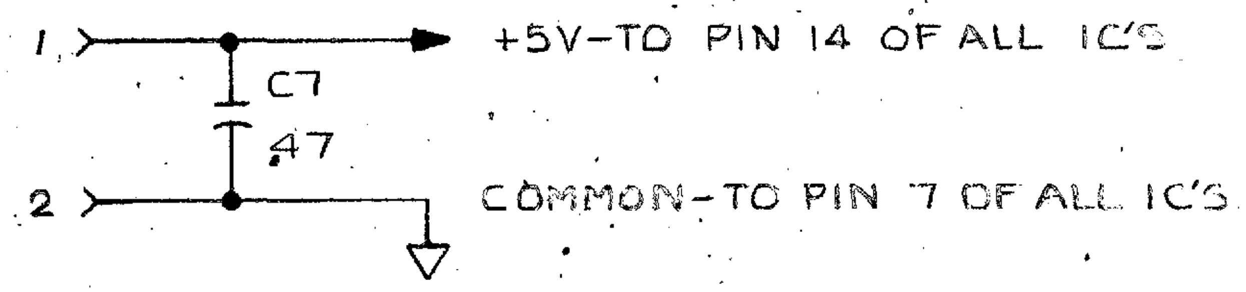
NOTE:
1- UNLESS SPECIFIED RESISTORS ARE 1K 1/4W

FOLDOUT FRAME 1

REVISIONS

SYM.	ZONE	DESCRIPTION	DRAFT	CHECK	DATE
A		ADD MSFC CONTRACT NO.	DS		1-17-72
B		ADDED C6	RMF		[illegible]





MSFC CONTRACT NAS 8-26416
COR APPROVAL R.E. [illegible] DATE 2/2/72

REF. SCH. D40873
SCH. D40871

USED ON	ASSEMBLY
500B	D41311

MODEL

DRAFTSMAN RMF 11-4-71
CHECKED [illegible] 1-17-72
APPROVED [illegible] 1-17-72

K = 10³ M = 10⁶

CONNECTION NO CONNECTION

UNLESS OTHERWISE INDICATED
- RESISTANCE IN OHMS ± 10% 1/4 WATT
- CAPACITANCE IN MFD ± 20%
- INDUCTANCE IN HENRIES
- USE 60/40 ROSIN CORE SOLDER
- USE NO CORROSIVE FLUX

TITLE SCHEMATIC - FIRING CONTROL LOGIC PCB SLAVE

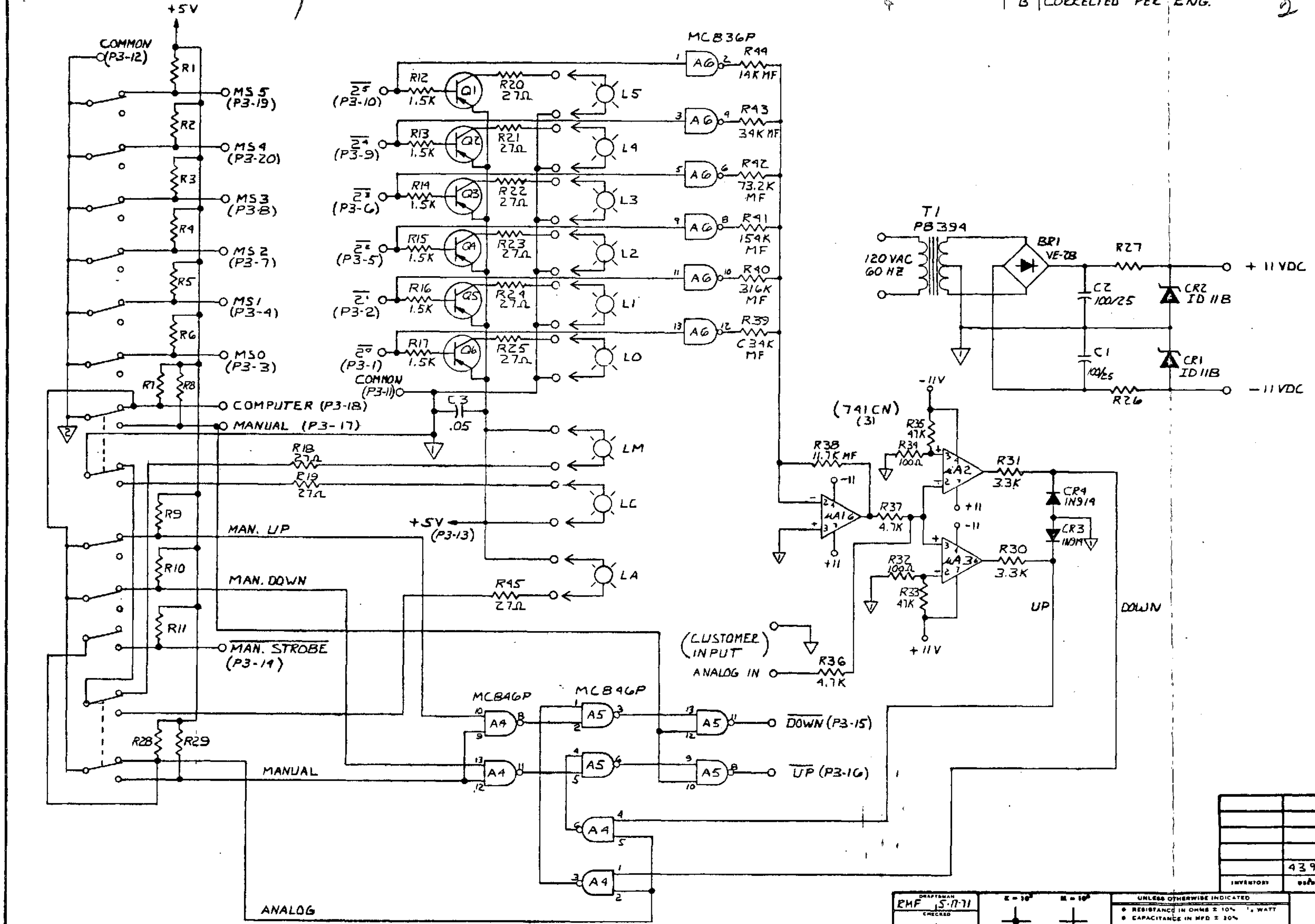
NUMBER B40872 B

SHT 1 OF 1

CONTROLS DIVISION - RESEARCH, INCORPORATED - MINNEAPOLIS 24, MINNESOTA

FOLDOUT FRAME

SYM.	DESCRIPTION	DRAFT.	DATE
A	REVISED PER CHECKOUT	KMF	6-22-71
B	CORRECTED PER ENG.	RMF	12-7-71



FOLDOUT FRAME

	4393	C40082
INVENTORY	USED ON	ASSEMBLY

DRAFTSMAN	RMF 5-17-71
CHECKED	
APPROVED	

CONNECTION — NO CONNECTION

UNLESS OTHERWISE INDICATED
- RESISTANCE IN OHMS ± 10% ¼ WATT
- CAPACITANCE IN MFD ± 20%
- INDUCTANCE IN HENRIES
- USE 60/40 ROSIN CORE SOLDER
- USE NO CORROSIVE FLUX

INVENTORY

TITLE: SCHEMATIC PUSH BUTTON ENTRY WITH ANALOG INPUT OPTION

NUMBER: C40083 — REV: B

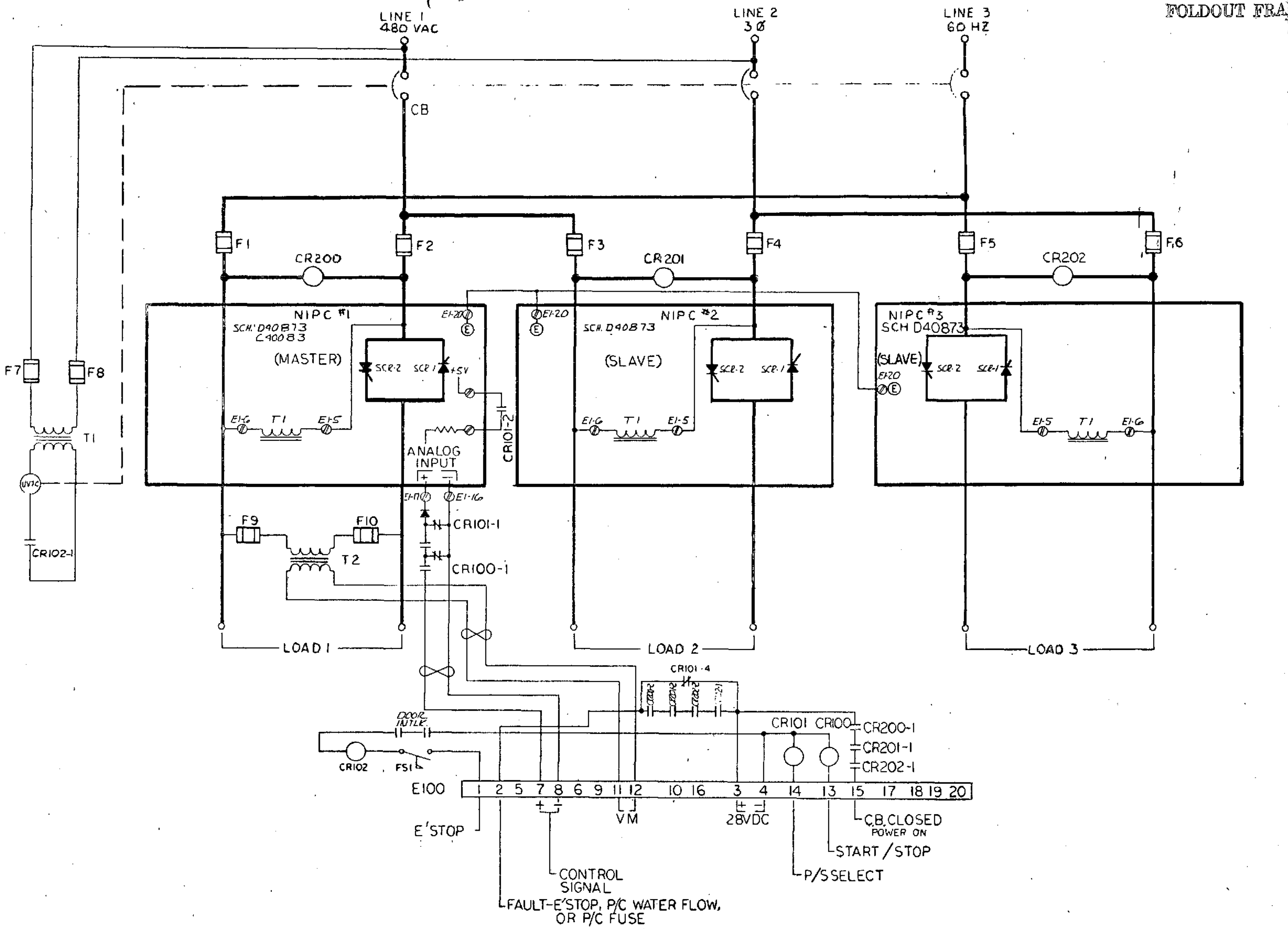
SHEET 1 OF 1

R·I CONTROLS — A DIVISION OF RESEARCH, INCORPORATED, MINNEAPOLIS, MINNESOTA 55424

FOLDOUT FRAME 1

FOLDOUT FRAME 2

A	REVISED PER ENG.		
B	REVISED PER ENG.		
C	REVISED PER ENG.		
D	ADDED NASA CONTRACT NO		1-7-72
E	REVISED NUMBERING OF E100		
F	REVISED PER ENG.		



MSFC CONTRACT NAS 8-26416

COR APPROVAL P.E. Cates DATE 2/8/72

500B D40350

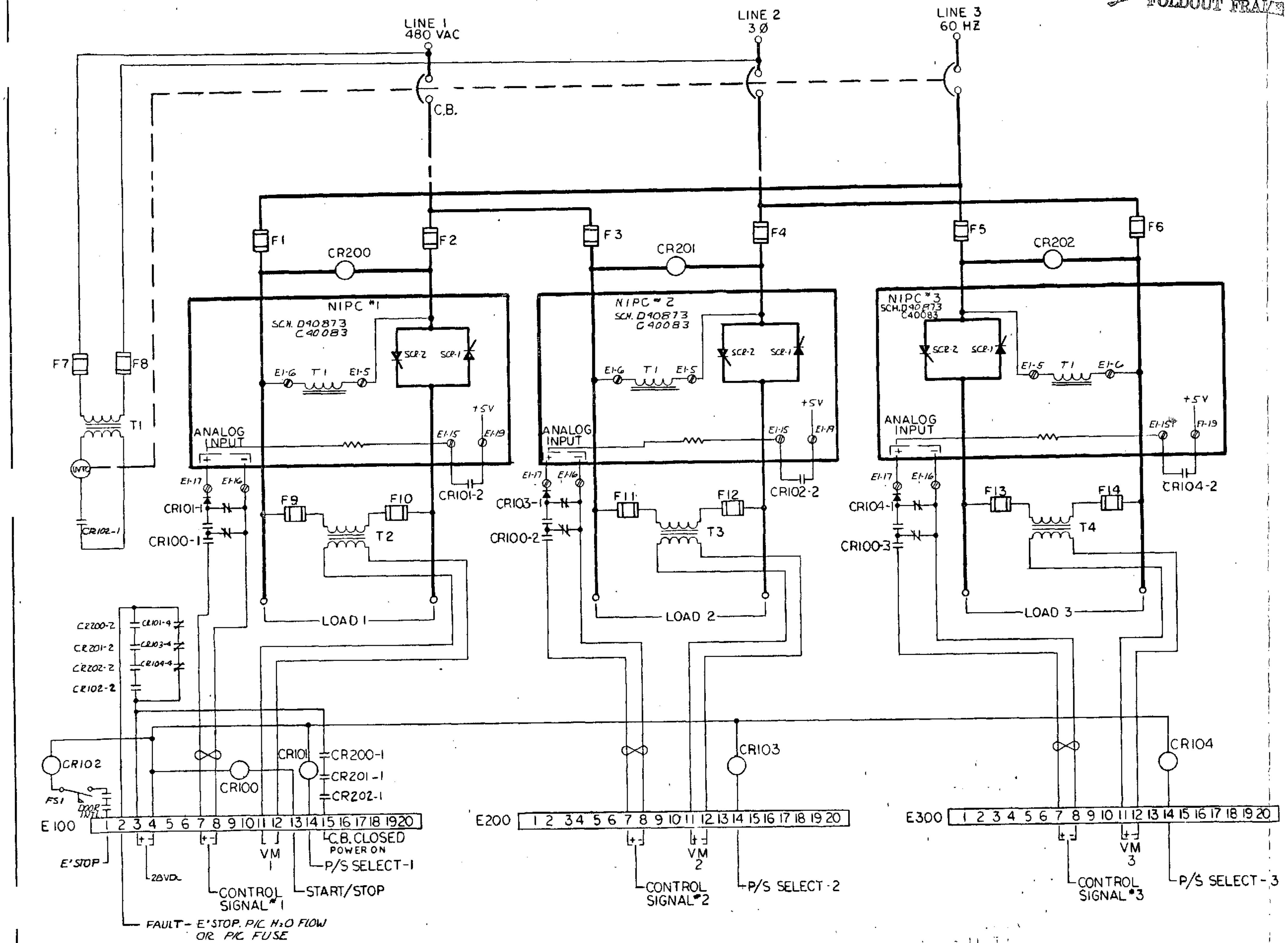
SCHEMATIC-POWER CONTROLLER
(SINGLE ZONE)

D40642 F

FOLDOUT FRAME 1

FOLDOUT FRAME 2

REVISIONS			
SYM.	DESCRIPTION	DRAFT.	DATE
A	REVISED PER ENG	RMF	11-9-71
B	REVISED PER ENG	DJH	11-19-71
C	REVISED PER ENG.	RMF	11-29-71
D	ADDED NASA CONTRACT NO	DS	1-7-72
E	REVISED PER ENG	RMF	6-16-72



MSFC CONTRACT NAS 8-26416

COR APPROVAL *P.E.C.* , DATE *2/8/72*

INVENTORY	USED ON	ASSEMBLY
	500B	D40350

DRAFTSMAN: LPF 12-2-71
CHECKED: RKG 1-17-72
APPROVED: 1-17-72

MATERIAL
FINISH

TOLERANCE UNLESS OTHERWISE NOTED: 2 PLACE DEC. ± ; 3 PLACE DEC. ± ; FRACTIONAL ± ; ANGULAR ±
REMOVE ALL BURRS AND SHARP EDGES

SCALE
SCHEMATIC

TITLE: SCHEMATIC-POWER CONTROLLER (3 ZONE)

INVENTORY

NUMBER: D40643 REV: E

SHEET 1 OF 1

R·I CONTROLS

A DIVISION OF RESEARCH, INCORPORATED
MINNEAPOLIS, MINNESOTA 55424

MAINTENANCE

General

Maintenance will consist mainly of keeping any accumulation of dust off the printed circuit board.

If an electrical circuit component is changed, the Match-Pack may be recalibrated using the following procedure. (Refer to Ass'y Dwg. C38023).

1. Between terminals 8 and 9 put a 1000 ohm potentiometer or precision resistor, and with power applied, adjust trimpot R11 for a voltage reading of 5 VDC between terminals 8 and 9.
2. Set trimpot R15 to mid range.
3. With OV input and terminal 11 jumpered to terminal 12, adjust trimpot R12 for 10 milliamperes at the output terminals.
4. Move jumper from terminal 12 to terminal 13 and adjust trimpot R13 for 4 milliamperes at the output terminals.
5. Move jumper from terminal 13 to terminal 14 and adjust trimpot R14 for 1 milliampere at output terminals.
6. Apply 5VDC to input terminals and adjust trimpot R15 for 5 milliamperes at the output terminals.
7. Repeat steps 3, 4, 5, and 6.
8. With 5VDC to input terminals and jumper from terminal 11 to terminal 13 the output should read 20 milliamperes.
9. Move tap from terminal 13 to terminal 12, the output should now be 50 milliamperes.
10. Steps 3, 4, 5, and 6 may have to be repeated more than twice because of the interaction of some of the adjustments.

R-I CONTROLS DIVISION
RESEARCH INC
BOX 24064 MINNEAPOLIS, MINNESOTA USA 55424

SERVICE AND OPERATING
INSTRUCTIONS

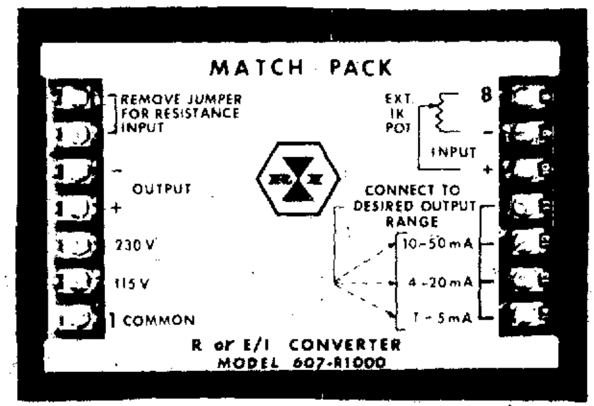
MODEL 607-R1000

MATCH-PACK

INTRODUCTION AND GENERAL DESCRIPTION

Scope

This pamphlet describes the Model 607-R1000 Match-Pack and provides information pertinent to its installation and operation.



General Description

The Model 607-R1000 Match-Pack is a versatile electronic device which can be used as a resistance to current converter or a voltage to current converter.

Its input can either be a 0-5 VDC signal or a 1000 ohm potentiometer. Its output is selectable between 1 to 5 milliamperes, 4 to 20 milliamperes, and 10 to 50 milliamperes.

INSTALLATION

Mounting

Holes are provided in the bottom of the Match-Pack's case to facilitate mounting of the unit to any flat surface.

Wiring

All connections are made to screw terminals on the printed circuit board which are accessable through cut outs on the Match-Pack's case.

Power wiring utilizes terminals 1, 2, and 3. Input voltage of 115 VAC uses terminals 1 and 2. Input voltage of 230 VAC uses terminals 1 and 3.

If a 0-5 VDC signal is being used as the input, terminal 9 is neg. and terminal 10 is pos. There must also be a jumper between terminals 6 and 7.

When the input is to be a 1000 ohm potentiometer, the CW end goes to terminal 8, the wiper goes to terminal 10, and the CCW end goes to terminal 9. The jumper between terminals 6 and 7 must be removed for the resistance input.

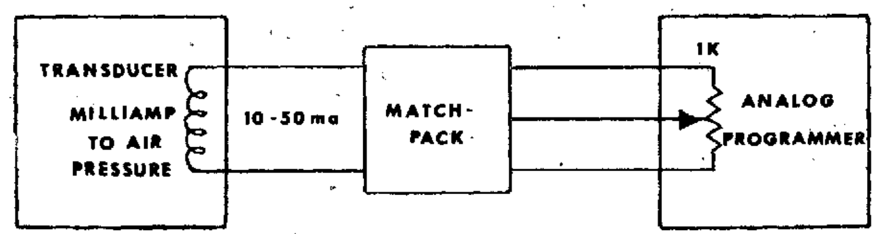
Terminals 4 and 5 are the output terminals with 4 being the positive terminal and 5 being negative.

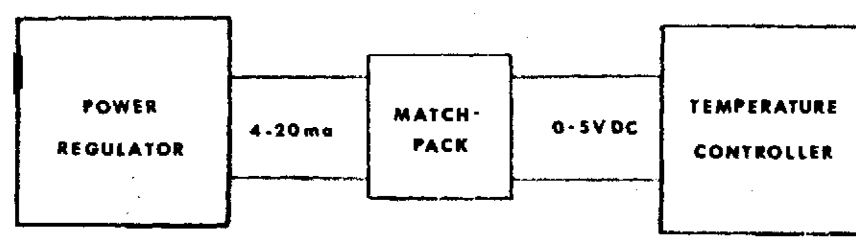
OPERATION

By referring to schematic C 38021 we see that terminals 9 and 10 are the input terminals whether resistance or voltage excitation is used. Terminals 9 and 10 are connected through R3 and R4 to the inputs of an operational amplifier which gives isolation between the input and output terminals. The output of the operational amplifier is connected to the base of the output transistor Q1, which is connected in a constant current configuration.

Terminals 11, 12, 13, and 14 are used in selecting the different output currents. When terminal 11 is jumpered to terminal 12, the output current will be 10 to 50 milliamperes provided the load impedance on the output terminals 4 and 5 does not exceed 500 ohms. When terminal 11 is jumpered to terminal 13, the output current will be 4 to 20 milliamperes provided the load impedance on output terminals 4 and 5 does not exceed 1200 ohms. When terminal 11 is jumpered to terminal 14, the output current will be 1 to 5 milliamperes, provided the load impedance on output terminals 4 and 5 does not exceed 5000 ohms.

The following diagrams show a few ways that the Match-Pack may be used.





REVISIONS			
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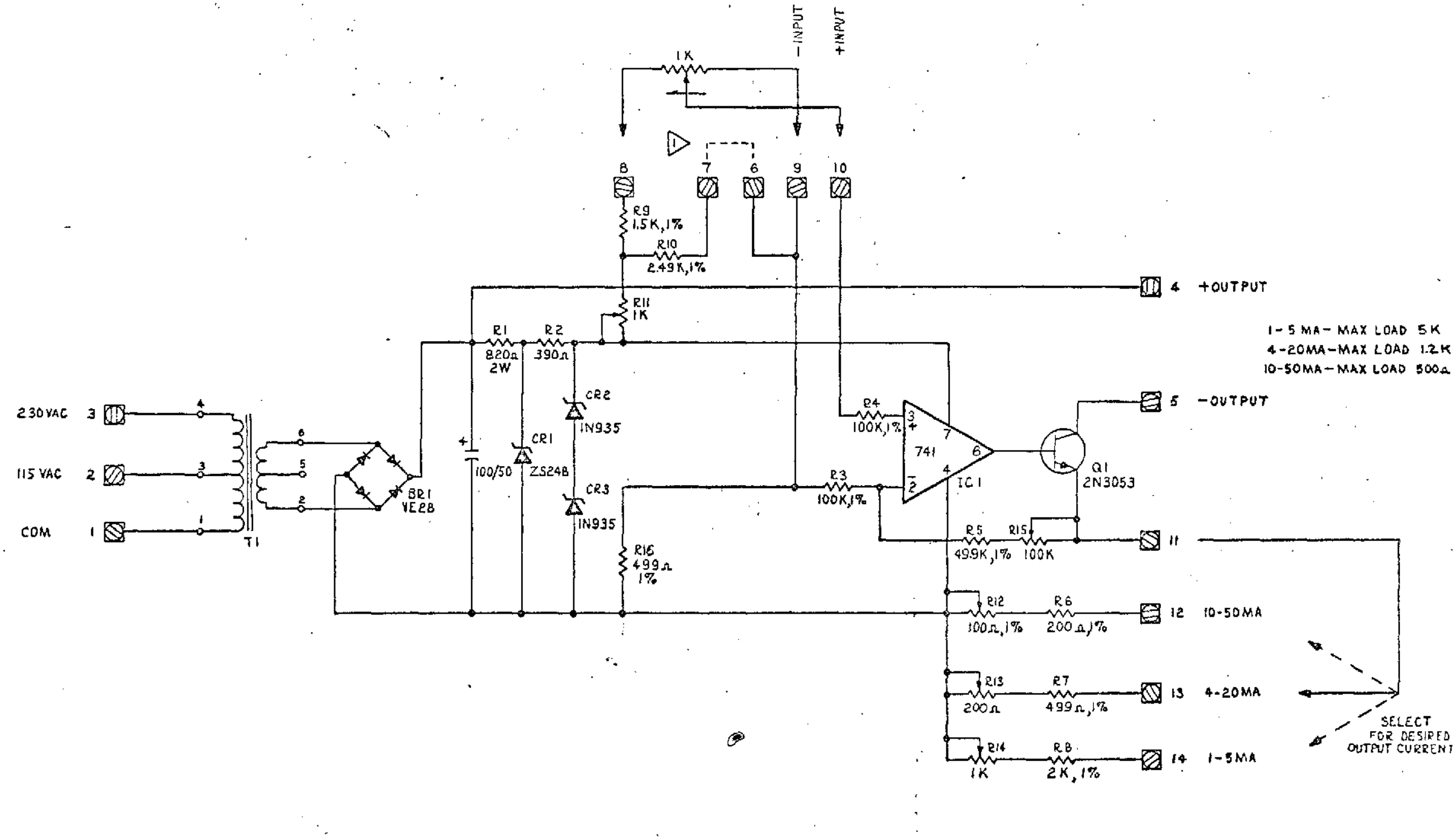
A	CHNG. INV. NO.'S		10-10-72



1 IF 1K REMOTE POT IS NOT USED, JUMPER TERMINAL 6 TO 7

3D1095	607	C38023
INVENTORY	USED ON	ASSEMBLY

DRAFTSMAN: WRH 11/4/69
CHECKED
APPROVED

K = 10³ M = 10⁶
CONNECTION NO CONNECTION

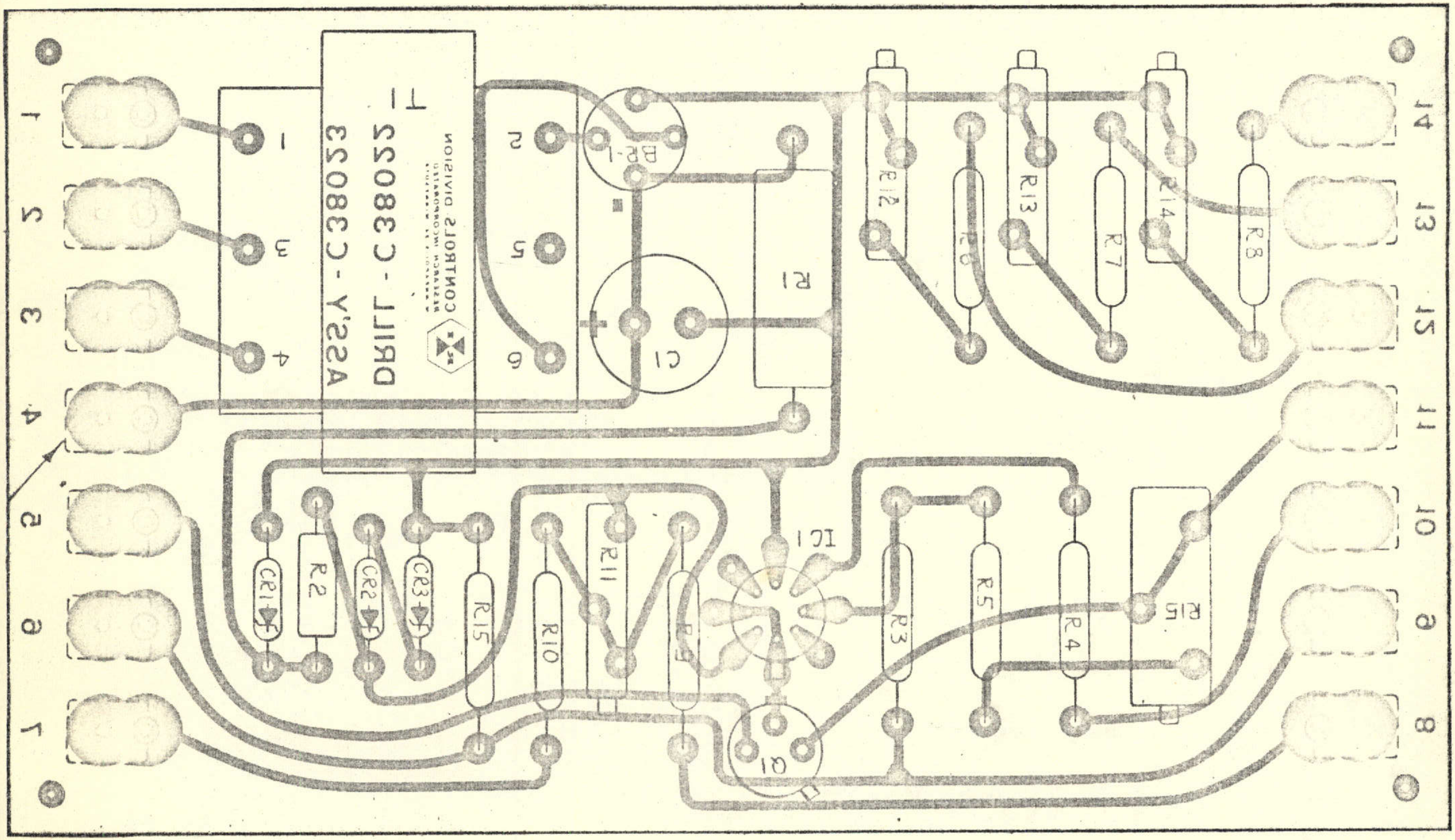
UNLESS OTHERWISE INDICATED
- RESISTANCE IN OHMS ± 10% ½ WATT
- CAPACITANCE IN MFD ± 20%
- INDUCTANCE IN HENRIES
- USE 60/40 ROSIN CORE SOLDER
- USE NO CORROSIVE FLUX

INVENTORY 3B1094

TITLE: SCHEMATIC-MATCH PACK MODEL 607
R OR E/I CONVERTER

NUMBER KC38021 REV A
SHEET 1 OF 1

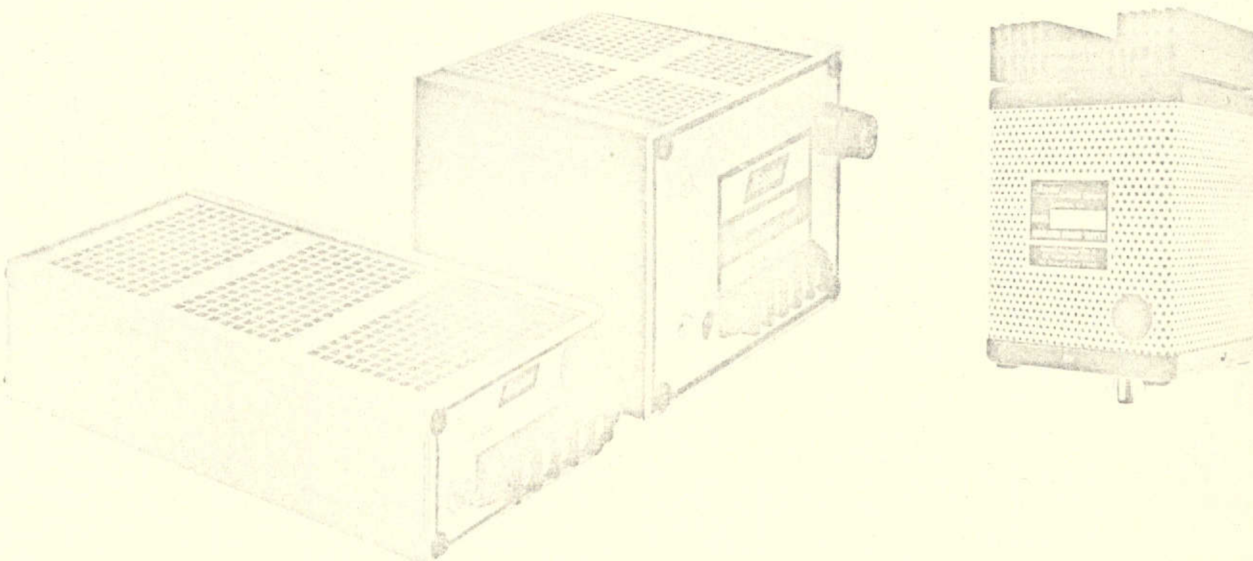
R·I CONTROLS
A DIVISION OF RESEARCH, INCORPORATED
MINNEAPOLIS, MINNESOTA 55424


ASS'Y - C38023
DRILL - C38022
T1
CONTROLS DIVISION
BR-1
C1
R1
R2
R3
R4
R5
R7
R8
R9
R10
R11
R12
R13
R14
R15
CR1
CR2
CR3
IC1
Q1

C38023

OPERATING & INSTRUCTION MANUAL

REGULATED POWER SUPPLIES



This manual is applicable to Series B and plug-in type power supplies.

ACOPIAN CORP., EASTON, PENNSYLVANIA 18042

TELEPHONE: (215) 258-5441

OPERATING & INSTRUCTION MANUAL
REGULATED POWER SUPPLIES

Acopian modular power supplies are ideally suited to all applications where compact, high performance and high reliability power supplies are required. Modular construction and plug-in interconnections (barrier strip or solder terminals are also available) provide mounting and wiring convenience and flexibility. Externally accessible screw-driver-slot adjustments on regulated supplies permit rapid local setting of output voltages, or remotely located potentiometers can be used. All models have floating outputs which may be used floating, with either the positive or negative side grounded, and/or in series with another supply (ies). All regulated models have built-in short circuit protection; provision for remote sensing of output voltage at the load is optional, for application where voltage regulation is critical. Reliability over a wide temperature range is insured by the use of silicon semiconductors.

Acopian can ship any of the more than 82,000 standard single and dual output power supplies listed in the annual catalog within three days after receipt of order. Rack-mounting power supply systems are also available. If you have questions regarding any product listed, or wish to investigate how your specific requirements can best be met, call Acopian at Area Code 215, 258-5441, and ask for an Applications Engineer.

COMPARISON OF "SLOT" AND WIDE-ADJUST POWER SUPPLIES

A "slot" type power supply is defined as one having its DC output voltage variable through a relatively narrow range. Although the wide-adjust type of supply has the obvious advantage of greater versatility, it is generally advisable to specify the "slot" type when such versatility is not required. Advantages usually gained by the use of "slot" supplies include

1. Minimized power dissipation permits cooler operation, which in turn improves stability and reliability (MTBF),
2. Optimum power conversion efficiency, and
3. Minimum volume for a given power output.

If required, Acopian can furnish a "slot" type supply with an output voltage adjustment range greater than that specified in the annual catalog, resulting in a unit that is optimized for a specific application.

THEORY OF OPERATION

GENERAL

Figures 1 and 2 illustrate the functional and circuit configurations of a typical Acopian single output regulated power supply. A specific unit may differ from these illustrations in some particulars — for example, a half-wave rectifier configuration may be used in place of the bridge shown here, or another stage of amplification may be added before the series regulator—but all Acopian solid state regulated supplies are closely related to the circuit shown.

Description of Basic Circuit

AC input power is decoupled from the supply circuitry and converted to the required voltage level by means of input power transformer T_1. The secondary voltage is rectified by diodes K_{1-4}, and filtered by capacitor C_5, providing unregulated DC voltage to the regulator circuit. Transistor Q_1, which is in series with the unregulated voltage and the load, functions as a variable resistance. Automatic variance of the effective resistance of Q_1 maintains the output voltage at a relatively constant value (as specified) and independent of variations in the amplitude of the unregulated DC voltage caused by loading changes and line voltage fluctuations.

The effective resistance of Q_1 is determined by a negative feedback path consisting of Q_2, Q_3, and related components, and connecting the emitter of Q_1 back to its base. Q_3 is referenced to a constant voltage by the connection of its emitter to Z_2. Any change in either the unregulated or regulated output voltages is sensed at the base of Q_3 (through R_{10} or R_8, respectively), changing the operating points of amplifier Q_2, and of Q_1, and tending to compensate the changes in the output voltage that would otherwise occur.

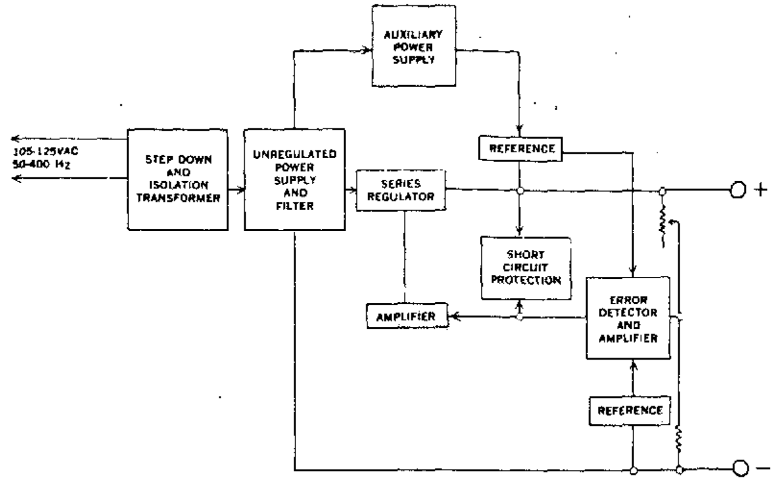


Figure 1. FUNCTIONAL DIAGRAM OF TYPICAL REGULATED POWER SUPPLY

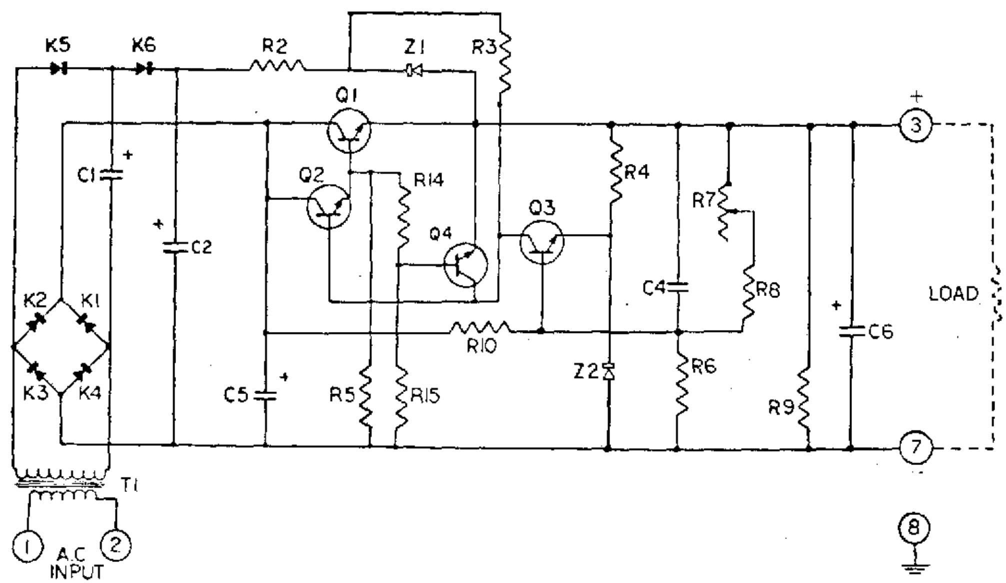


Figure 2. SCHEMATIC DIAGRAM OF REGULATED POWER SUPPLY

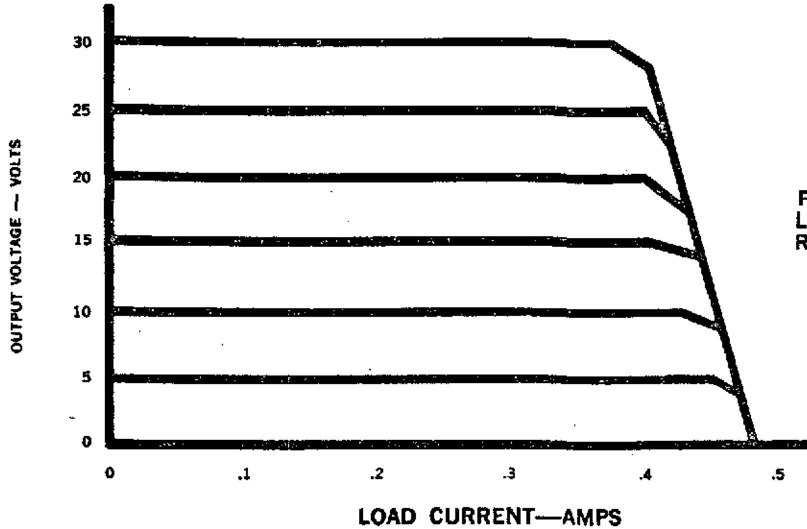


Figure 3. TYPICAL CURRENT LIMITING CHARACTERISTICS OF REGULATED POWER SUPPLIES

Diodes K_5 and K_6, and capacitors C_1 and C_2, are configured as a voltage doubling network. Its output is applied to R_2 and to zener diode Z_1, which is referenced to the regulated output voltage, to provide a stable voltage source of higher amplitude than the regulated output voltage for R_3, the collector load resistor of Q_3. By including this fixed increment in the voltage supplied to R_3, the effect of change in the regulated output voltage upon the current flowing through R_3, and therefore upon the voltage appearing at the base of Q_2, is reduced.

Short Circuit Protection

If the components of a power supply can withstand a short circuit for the period of time required to open a slow-blow fuse in the primary circuit, this form of protection is usually preferable. It is inherently more reliable due to its simplicity. Short duration current overloads, caused by switching a non-linear load such as a DC motor or relay, can be tolerated without difficulty if the average output current remains within the rating of the supply; with electronic current limiting, voltage will drop drastically during any period of overload, which could result in a load malfunction. However, when load dissipation must be closely guarded, and at high currents where supply ratings become more critical, fusing alone may not provide adequate protection, and electronic current limiting becomes necessary.

With current limiting, as output current increases, the voltage across the emitter-base junction of Q_1, also increases, causing Q_4 base current to be proportional to the Q_1 emitter-base voltage drop minus the Q_4 emitter-base voltage drop (which is relatively constant, due to the smaller current). As Q_4 approaches saturation, *it limits the voltage* across the emitter-base junctions of Q_1 and Q_2, which are series connected in parallel with Q_4. Output current is also limited at this point, because a higher current would require higher emitter-base voltage drops across Q_1 and Q_2, but the voltage limiting action of Q_4 prevents it.

Therefore, as loading increases, current remains at the limiting point and, in compliance with Ohm's Law, voltage drops to the amplitude at which the load draws the limiting current. This is shown in graphical form in Figure 3.

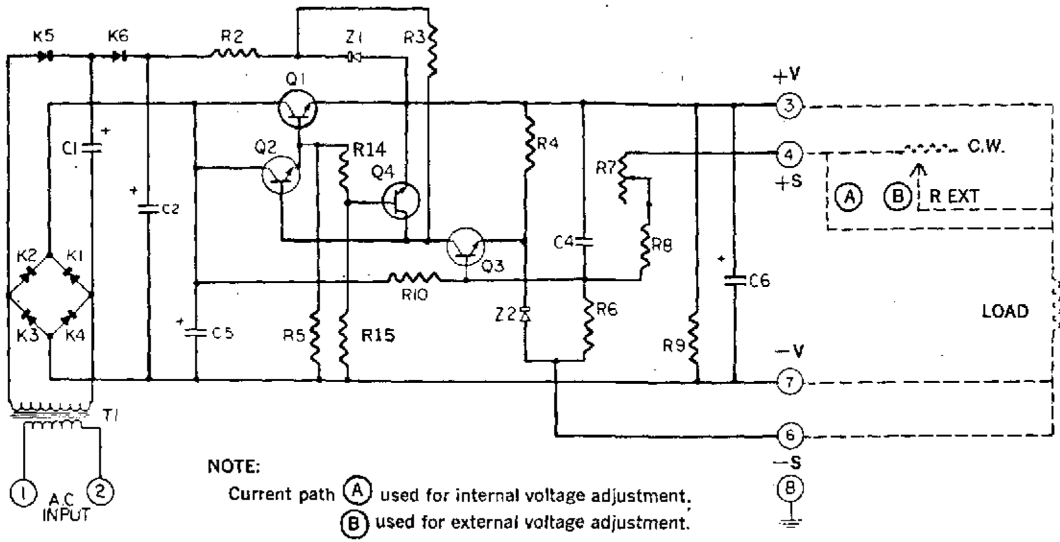


Figure 4. SCHEMATIC DIAGRAM OF TYPICAL REGULATED POWER SUPPLY WITH REMOTE VOLTAGE SENSING AND EXTERNAL VOLTAGE ADJUSTMENT

OUTPUT VOLTAGE COMPENSATION AND CONTROL

The feedback loop of the regulator circuit enables it to keep constant the current that flows through the current path including R_8, and therefore, the voltage present at the base of Q_3. Because R_8 is tied to the output voltage, any change in the output voltage without a corresponding change in the total resistance of the current path including R_8 will change the current through R_8 and the voltage at the base of Q_3. This change is amplified and inverted in polarity by Q_3, so that Q_2 and Q_1 tend to return the output voltage to its *initial amplitude*.

If voltage regulation requirements are not critical, the R_8 current path can be completed on the output connector of the supply, by connecting pins #4 and 5. However, the IR voltage drop in the load lines from the supply to the load can become significant when currents are high or when extremely high regulation is needed, and may require that the output voltage be compensated for these drops.

REMOTE SENSING OF OUTPUT VOLTAGE

All modular regulated supplies can be furnished with provision for remote sensing of output voltage. See Figure 4. Output line voltage drops are compensated by sensing the voltage at the load, by wiring pin #4 to the positive and pin #6 to the negative terminals of the load, through separate leads isolated from the output leads except at the load connections. Because the sensing leads are thus prevented from carrying load current, no significant voltage drop occurs through them, and Q_3 can sense and accurately compensate the voltage actually seen by the load, instead of the less meaningful voltage present at the output terminals of the supply.

Notes:

1. The maximum voltage output rating of the supply must exceed the total of the voltage to be maintained across the load plus the voltage drop through the load lines at maximum output current.
2. Never permit the current paths between the positive output terminal of the supply and R_8, and between the negative terminal of the load and pin #6, to open during operation. This would result in severe damage to the power supply. If the lines must be switched or opened during operation, diodes should be wired in parallel with the sense lines, one with its cathode connected to pin #4 and its anode to the positive terminal of the load, and the other with its cathode to pin #7 and anode to pin #6. In normal operation, the diodes will be shorted and will not affect operation, but when a line opens, the diode will conduct and protect the supply. When line drops are large, two or more diodes should be used in series across each sense line, so that in normal operation, the voltage drop across the line is less than the combined forward voltage drops of the diodes. When the protection diode is conducting, output voltage will rise by an amount equal to the difference in the forward voltage drop of the diode and the voltage drop of the load line.
3. To minimize inductive noise pickup, the use of shielded sensing lines, with the shields grounded at the power supply end only, is recommended. In an extremely noisy environment, the use of a bypass capacitor from pin #6 to chassis ground may be necessary. A capacitor of 1 to 4 mfd is usually adequate for this purpose; however, use the minimum value which permits proper performance, since high values tend to increase the recovery time of the supply.
4. When remote sensing is used, switching off the load will result in a transient voltage at the load end of the output leads that is higher than the loaded voltage by an amount equal to the load line drop. The duration of the transient voltage depends on the output capacitance and the bleeder resistance of the supply. The overvoltage can be reduced by a capacitor at the load; however, this forms an RC circuit with the lead resistance, the time constant of which increases the duration of the overvoltage transient and lengthens the response time of the supply.

EXTERNAL VOLTAGE ADJUSTMENT

When the output voltage is sampled by R_8 through internal voltage adjust potentiometer R_7, its amplitude will vary with the adjustment of R_7, as required to keep the current through R_8 constant.
Voltage can alternately be adjusted by means of an externally-located potentiometer connected between the output voltage of the supply and (Figure 4) to R_8 via pin #4; in this case, potentiometer R_7 is set fully CCW at 0 ohms. (Remote sensing can also be incorporated if the connection to the output voltage is made at the load.) A potentiometer used for this purpose must be of good quality and with a high enough wattage rating (½ watt minimum) to insure electrical stability, so that supply performance will not be degraded.

Notes 2, 3, and 4 listed under Remote Sensing of Output Voltage also apply when voltage is adjusted by means of an external control. However, because the maximum voltage across the control is greater than that typically present across the sensing loop, protection against an open sensing loop is best provided by means of a zener diode with its cathode connected to the positive output terminal and its anode connected to pin #4.
The optimum avalanche voltage rating of this diode will vary with the output voltage of the supply, in accordance with

$$V_z = V_{out} \frac{R_{external}}{R_6 + R_8 + R_{external}} + X$$

where

R external = the maximum resistance of the external potentiometer, and

X = the voltage margin between the maximum voltage across the control in normal operation and the diode rating; a one to two volt margin is suggested.

TEST PROCEDURES

General

The performance of a regulated power supply is determined primarily by the internal (source) impedance of the supply, which the intended load sees in series with it and the voltage at which the supply is operating. Since the instantaneous voltage at the load is therefore equal to the operating voltage minus the drop across the source impedance, a power supply must have an extremely small source impedance in order to provide a well regulated output voltage. For example, a 12 volt supply with $\pm.01\%$ load regulation and a current rating of 100ma would exhibit a maximum voltage variance of $12 \times 10^{-4} \times 2 = 2.4 \times 10^{-3}$ volts, or 2.4 millivolts, and would have a static source impedance of

$$\frac{2.4 \times 10^{-3}}{10^{-1}} = 24 \text{ milliohms.}$$

Obviously, to accurately measure voltages and resistances of these orders of magnitude requires the use of a test setup that will not introduce additional unintended impedance between the voltage source and the point at which the voltage is observed. **No** current can be permitted to flow through the measurement leads, and these must be connected as close as possible to the voltage source. For example, when testing a supply that is plugged into an octal socket, the test leads should be soldered directly to the output lugs **on the socket** at the same points as the output leads. If the supply under test has provision for remote sensing, there will of course be an additional lead from the output lug to the sensing lug; however, the output must be taken at, and observed on, the output lug, to avoid adding the impedance of the jumper and extra connection to the source impedance under measurement. Similarly, alligator clips or other contacts **cannot** be used between the output lug and the point at which voltage is observed because of the resistance they introduce. Plug contacts must be clean and tight.

Measurement of Regulation

Accurately measuring a voltage change of less than one percent requires either the use of a high resolution digital voltmeter or the application of differential measuring techniques. The latter is most easily accomplished by placing an adjustable voltage source in series (but opposite in connection polarity) with an analog voltmeter or millivoltmeter (VOM or VTVM), or a high sensitivity DC-coupled oscilloscope, and with the voltage being measured. The adjustable voltage can then be set to "buck-out" or cancel the voltage being tested, at a given operating point of the supply, so that the voltmeter is nulled. The voltmeter will then indicate not the absolute voltage, but the change in voltage resulting from a change in operating conditions.

Test for Line Regulation

The supply under test must be furnished with an accurately metered and adjustable source of line voltage that is capable of handling the full load primary current.

The use of an adjustable autotransformer is recommended. An accurately metered resistive output load capable of being adjusted to draw the full rated load current is also required. Observe change in output voltage as discussed above.

1. Set input voltage to 115VAC, 50 to 400 Hz. Set output load to draw full rated current. Null output voltmeter if differential measurement technique is being used.
2. Vary input voltage from 105 to 125 volts while observing output voltage change and noting maximum deviation from the output obtained with 115VAC input.
3. Line regulation performance is within specifications if the maximum change in output voltage is equal to, or less than,

$$\frac{\text{DC output voltage x line regulation specification in percent}}{100}$$

Test for Load Regulation

The supply under test must be furnished with a stable source of 115VAC, 50 to 400 Hz. An accurately metered resistive output load capable of being adjusted to draw either half or the full rated load current is also required. Observe change in output voltage as discussed above.

1. Adjust output voltage and load so that half the rated current is being drawn from the supply at the nominal output voltage. Null output voltmeter if differential measurement technique is being used, or note reading of digital voltmeter.
2. Remove load and note change in output voltage, then adjust load to draw the full rated current and again note the change from the nominal voltage. The larger change represents the load regulation.

Thus, if

$$\begin{array}{l}\text{larger}\\\text{voltage}\\\text{change}\end{array} < \frac{\pm\%\text{ load regulation specification x Nominal output voltage}}{100}$$

the supply is within its load regulation specification.

Test for AC Ripple and Noise

The 2.8/1 peak-to-peak/RMS voltage ratio is not completely valid in determining the RMS ripple of a power supply by observation of the peak-to-peak amplitude, because the wave-form typically is not sinusoidal. However, for all but the most exacting applications, division of the peak-to-peak amplitude by a factor of three will determine the RMS amplitude with a practical degree of accuracy.

An AC millivoltmeter may be used for reading ripple, but an AC coupled oscilloscope is generally more practical. The supply under test should be loaded to deliver its full current rating while ripple amplitude is being read.

Measurement of Source Impedance

The AC internal impedance of a regulated power supply is a function of frequency and, in general, increases with frequency. The impedance at a given frequency can be most easily determined by driving a known AC current of approximately 10 ma. RMS (the voltage drop across an external resistor can be used to calculate current. $I_{p-p} = E_{p-p}/R$) through the output terminals of the power supply, and measuring the AC voltage drop across them. Source impedance $= E_{p-p}/I_{p-p}$.

Since the supply must be operating to perform this measurement, a capacitor must be used in series with the supply and the signal generator, to prevent application of the DC voltage to the generator. In making this measurement, care must be taken to minimize lead lengths and to prevent ground loops, since these factors can greatly affect the accuracy of test results.

LINE TRANSIENT PROTECTION

If the AC input power contains large voltage spikes ("noise") induced by the switching of high currents, inductive loads, electromechanical components, etc., the input power leads to the supply should include some means of transient suppression. Otherwise, a portion of the noise may be coupled through the supply into the load. Also, the supply could be damaged.

The means of suppression that is easiest to install is a one or two mfd. capacitor across the AC input terminals of the supply. In extremely severe cases, the use of RF chokes in series with each side of the line may also be required.

SERIES AND PARALLEL OPERATION

Two or more Acopian power supplies may be series connected to obtain higher voltages than available from a single supply. If remote voltage adjust or sensing are required, the most positive supply is wired accordingly, but the other (s) is wired for internal sensing and/or control. The total voltage across the series string should not exceed 900 volts. To avoid ripple and ground current problems, connect all chassis ground terminals together. Each set of output terminals should have a normally back-biased high current rectifier diode connected across them, to act as a low impedance shunt path for reverse voltage and prevent the damage which could otherwise occur should the load become short circuited.

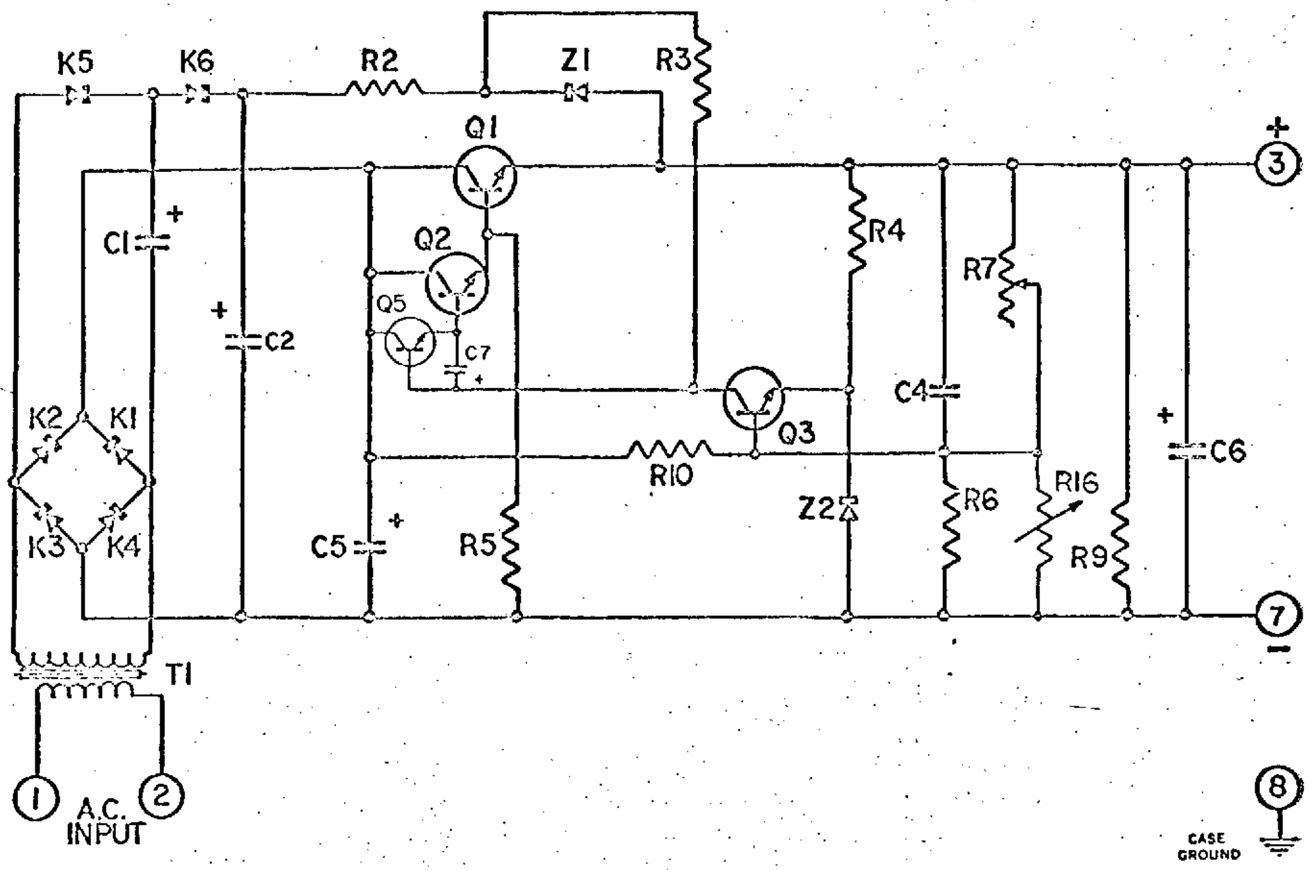
Parallel operation of power supplies requires consideration of factors which vary with model number. Consult the factory for full information on your specific application.

DUAL OUTPUT POWER SUPPLIES

Acopian duals consist of two power supplies sharing a common case and a power transformer with two isolated secondary windings, but which are otherwise completely independent of each other. Unlike designs which derive more than one output voltage from a single basic circuit, a change in the adjustment of one section does not unintentionally interact with the operation of the other. "Tracking" — the requirement that temperature change affect two power supplies in an identical manner — is necessary only if the temperature coefficient is high; since the average temperature coefficient of Acopian supplies is low (0.015% per degree C), provision for tracking becomes unnecessary.

Circuit configuration and operation particulars are the same as given for single output supplies.

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.



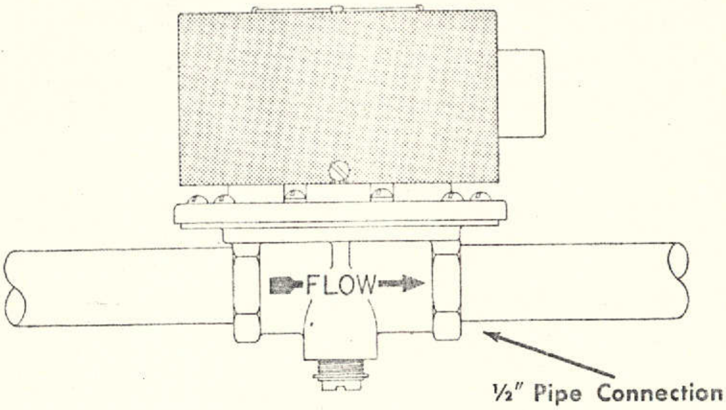
SHORT CIRCUIT PROTECTION

This power supply is designed to take short circuit conditions for a short period of time without permanent damage to the unit. If short circuit condition is gone unnoticed for extended period of time, permanent damage may result, therefore a slow-blow fuse of 3/8 amp. is recommended at the A.C. input of power supply.

Acopian Technical Company		EASTON, PENNA.
PROJECT NUMBER	SCALE	DR. ANP
		CK.
TITLE SCHEMATIC FOR POWER SUPPLY MODEL 5J200		
DATE 3/13/69	DRAWING NUMBER	

INSTALLATION DATA FOR McDONNELL No. FS1 FLOW SWITCH

Maximum pressure, 100 psi.
Maximum temperature, 225° F.



LOCATION

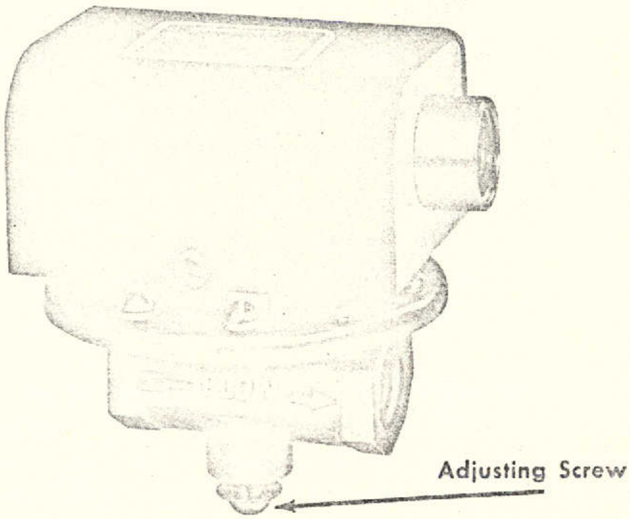
The McDonnell No. FS1 Flow Switch should be located in a horizontal section of pipe, as illustrated.

INSTALLATION

Mount the flow switch in position so that the arrow mark on the side is pointing in direction of flow.

ADJUSTMENT

The flow switch is factory set so it will operate at minimum flow velocities. To obtain higher velocities before the flow switch is actuated, turn the adjusting screw in a clockwise direction.

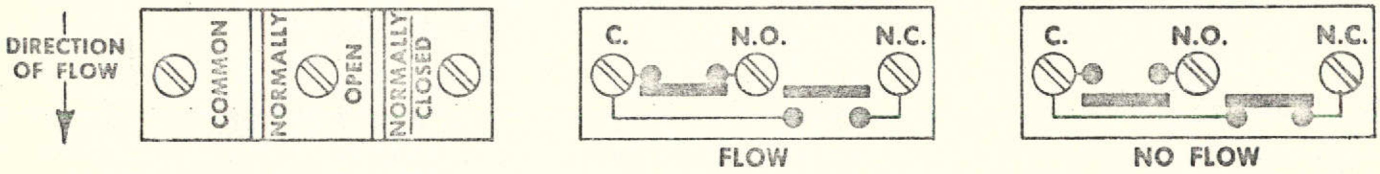


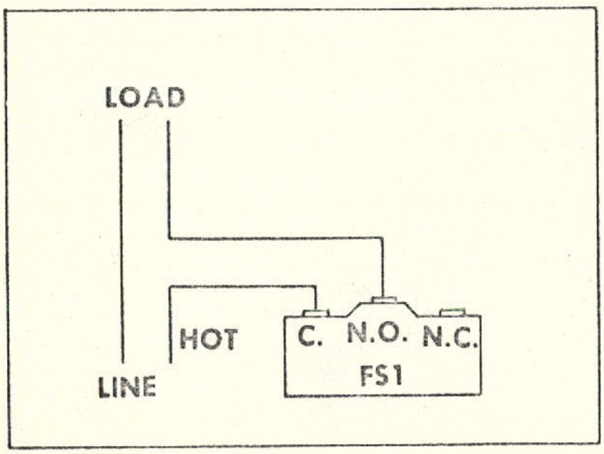
WIRING INSTRUCTIONS

ELECTRICAL RATINGS
(Underwriters Listed)

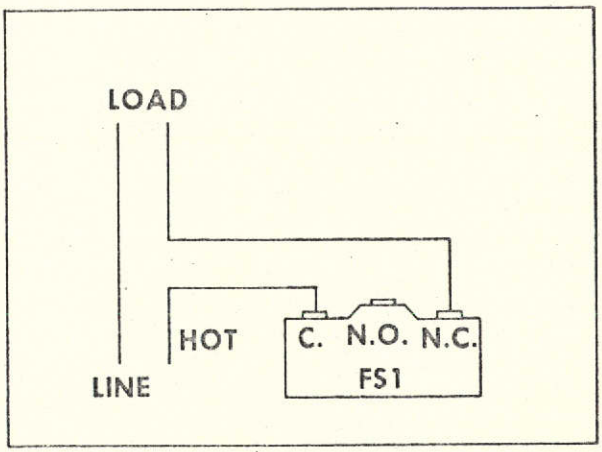
AMPERE RATING

Motor Duty Full Load Locked Rotor	115 V.A.C. 7.4 Amps. 44.4 Amps.	230 V.A.C. 3.7 Amps. 22.2 Amps.
	115 V.D.C. 0.3 Amps.	230 V.D.C. 0.15 Amps.
PILOT DUTY: A.C. 125 V.A., 115-230 V.		





1 Used to actuate signal, alarm or other device when flow occurs.



2 Used to actuate signal, alarm or other device when no flow occurs.

McDONNELL & MILLER, *Inc.*, 3500 N. Spaulding Ave., Chicago, Ill. 60618

Bulletin No. I-FS1A

Doing One Thing Well

Printed in U.S.A.

Gaseous Nitrogen Cooling System

Control Valve

Instruction and Maintenance Manuals

Bottom Region

3" Fisher Type 667 ET Diaphragm Control V lve, 600# flanged carbon steel body, standard hardened stainless steel trim, Composition seats, balanced valve plug, equal percentage flow characteristic Teflon packing, Size 45 Reverse-acting Diaphragm Actuator, 6-30 psi signal to open actuator - valve to fail closed on loss of operating medium. Complete with yoke-mounted Type 3590 Electro-Pneumatic Positioner with yoke-mounted Type 67FR Airset and nipple-mounted Type 1301F First-cut operating medium regulator; 4-20 ma signal to positioner, 6 - 30 psi positioner output.

<u>Service Conditions</u>

Flowing Medium: Nitrogen
Inlet Pressure: 500 psig
Outlet Pressure: 90 - 150 psig
Capacity Required: 360,00 SCFH

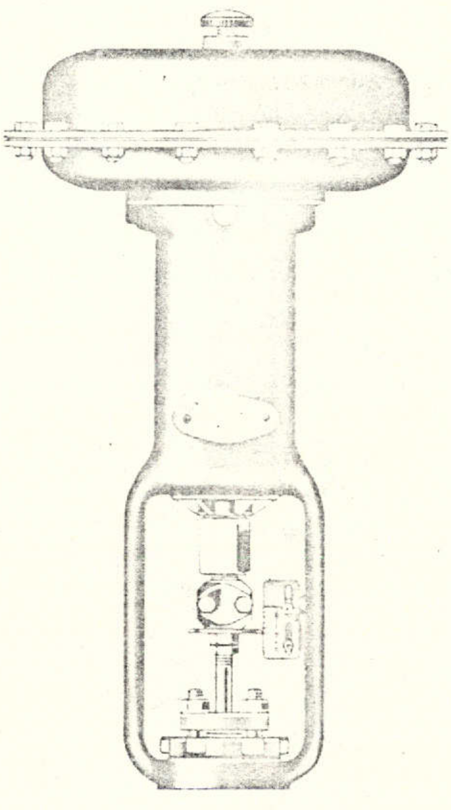
Top and Side Regions

2" Fisher Type 667ET Diaphragm Control Valve, construction specifications identical to above.

<u>Service Conditions</u>

Flowing Medium: Nitrogen
Inlet Pressure: 500 psig
Outlet Pressure: 90-150 psig
Capacity Required: (1) 153,500 SCFH (Side Region)
(1) 123,500 SCFH (Top Region)

Instructions and Parts List



Type 667 Diaphragm Actuator

FISHER Controls

TYPE 667 DIAPHRAGM ACTUATORS

Sizes 30, 34, 40, 45, 50, 60, 70 and 87

FISHER CONTROLS COMPANY

Marshalltown, Iowa | Coraopolis, Pa.
Woodstock, Ont., Can. | Toluca, Mexico

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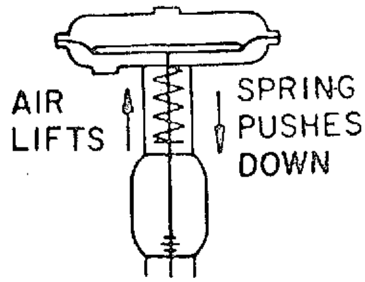
FORM 1203C
(Supersedes Form 1203B)

TYPE DESCRIPTION

The Fisher Type 667 is a reverse acting, spring opposed diaphragm actuator that is used for the operation of automatic control valves. The opening, closing or throttling of the valve plug in the body is accomplished by varying the pneumatic loading pressure on the diaphragm. This loading pressure is transmitted from an automatic controller which may be controlling pressure, liquid level, temperature or flow.

In a reverse acting diaphragm actuator, an increasing loading pressure causes the actuator stem to move upward, compressing the spring. When the diaphragm pressure is decreased, the spring moves the actuator stem downward. In the event of failure of the loading pressure or the operating medium pressure to the automatic controller, the actuator stem moves to the extreme downward position. Thus, by the proper selection of the valve plug action, either "push down to close" or "push down to open", the control valve will either close or open on failure of the diaphragm loading pressure. Type 667 actuators are generally used with valve bodies with a "push down to close" valve plug.

Type 667 Reverse Acting Diaphragm Actuator



Stem moves downward with loss of operating medium.

Figure 1—Illustration showing the action of a Type 667 reverse acting diaphragm actuator.

The following tabulation gives specifications for the various sizes (except Size 80) available within the Type 667 series.

TYPE 667 DIAPHRAGM ACTUATOR SPECIFICATIONS

Actuator Size	30	34	40	45	50	60	70	87
Nominal Effective Area, Sq. In.	50	75	75	113	113	170	220	220
Yoke Boss Size, In.	2-1/8	2-1/8	2-13/16	2-13/16	3-9/16	3-9/16	3-9/16	5
Valve Body Stem Size, In.	3/8	3/8	1/2	1/2	3/4	3/4	3/4	1
Maximum Allowable Stem Force, Lbs.	1500	1500	2500	2500	5000	5000	5000	8000
Maximum Travel, In.	3/4	3/4	1-1/2	2	2	2	3	3
Maximum Diaphragm Case Pressure to Stroke Valve, Psi *	40	40	40	40	40	40	40	40
Maximum Excess Diaphragm Case Pressure, Psi †	70	45	45	30	30	15	15	15

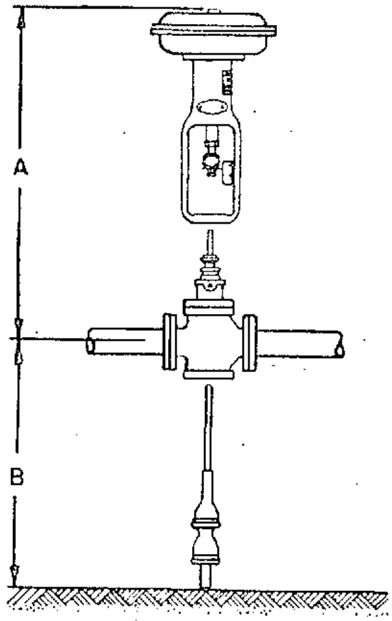
* Maximum diaphragm case pressure to be used to raise the diaphragm to a position where travel stop cap screw contacts the upper case.
† Maximum additional diaphragm case pressure that may be applied after travel stop cap screw contacted the upper case.

INSTALLATION

The diaphragm actuator is normally furnished mounted on a valve body. Follow the valve body instructions when installing the control valve in the pipeline. The connection of the loading pressure piping is made to the ¼" (Sizes 30 through 60) or ½" (Sizes 70 and 87) tapping in the top of the yoke just below the lower diaphragm case. In case of the larger sizes, it may be desired to bush the tapping down to ¼". Either pipe or tubing may be used and it should be run to the output connection on the automatic controller. Keep the length of tubing or pipe as short as possible to avoid transmission lag in the control signal. If long distances are involved, always use a valve positioner on the actuator. If a valve positioner is furnished, the loading pressure connection to the actuator will be made at the factory.

At times the actuator will be shipped alone for field mounting on a control valve body. Mount it on the body and secure it in place with the yoke locknut. The stem connector should then be made up to clamp the actuator stem and valve plug stem together to provide the proper valve travel. This procedure is outlined in the Assembly section of these instructions.

The control valve should be located where it will be accessible for servicing. Room should be left above and below the control valve to permit removal of the actuator and valve plug. The accompanying table in Figure 2 shows the removal clearances that should be provided.



VALVE SIZE INCHES	ACTUATOR SIZE	667—A		667—AR	
		A		B	
		WITH STANDARD BONNET	WITH RADIATION BONNET	WITH STANDARD BONNET	WITH RADIATION BONNET
1/2–3/4	30	29 7/8	32 3/8	15 1/4	17 3/4
1–1 1/4	30	30 5/8	33 1/8	17 1/4	19 3/4
1 1/2	34	35 3/8	37 7/8	20	22 1/2
2	40	40 3/8	45 3/4	24 7/8	30 1/8
2 1/2	40	40 3/4	46 3/8	26	31 1/4
3	40	42	47	28 3/4	34
4	45	49 3/4	55 3/8	32 7/8	38 1/8
5	50	55 5/8	58 5/8	39 7/8	43 1/4
6	50	57	60 7/8	44 1/4	47 5/8
8	60	58	62 1/4	47 1/2	51 3/4
5	70	62	65 7/8	39 7/8	43 1/4
6	70	63 3/8	68	44 1/4	47 5/8
8	70	64 3/8	69 3/8	47 1/2	51 3/4
6	87	66 5/8	71 1/4	43 5/8	47 3/8
8	87	67 5/8	72 5/8	50 1/8	55 1/4
10	87	71 3/4	75 1/8	60 1/4	63 5/8
12	87	72	75 1/2	61	64 3/8

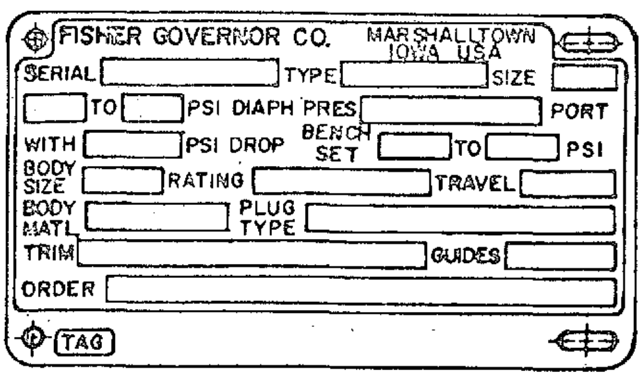
Dwg. BF7626

Figure 2—Removal clearance required for a Type 667-A or 667-AR control valve. Values are for top and bottom guided double port valve bodies. Therefore, clearances are ample for port guided valve plugs and all single port valves.

OPERATION AND ADJUSTMENT

The nameplate attached to the yoke of the actuator contains valuable information as to the specific construction and operating range. The spring and diaphragm have been selected to meet the requirements of the application and, in service, the actuator should create full travel of the valve plug when the diaphragm pressure range indicated on the nameplate is applied. This diaphragm pressure range is generally 3 to 15 psi or 6 to 30 psi but other ranges may be used.

The pressure drop across the valve body port affects the actual operating pressure range. In some instances, the valve may not stroke completely over the indicated range because the pressure conditions in the body are different from those for which the control valve has been set at the factory. A simple spring adjustment, however, is all that is required to obtain correct travel for the diaphragm pressure range utilized. It should be noted that the actuator spring has a fixed pressure span and that adjustment of the spring compression merely shifts this span up or down to make valve travel coincide with the diaphragm pressure range.



Dwg. IK3257

Figure 3—Nameplate used when "bench set" is required.

There are two nameplates in use, one of which will be attached to your actuator yoke. One nameplate specifies a "bench set" pressure range in addition to a standard diaphragm pressure range. The "bench set" range is that pressure range required to stroke the valve fully without any pressure in the body, as would be the case if the valve were set on the work bench. A "bench set" range is generally specified for single port control valves where high valve unbalance can be expected. However, in service with the specified pressure drop impressed across the valve, it should stroke over the standard diaphragm pressure range indicated on the nameplate. The other nameplate in use does not indicate a "bench set" range but only a standard range of 3 to 15 psi or 6 to 30 psi. It is used when the effect of valve unbalance can be ignored as in some double port control valves.

When the control valve is completely installed and connected to the controller, it should be checked for correct travel, freedom from friction, and correct action (air-to-open or air-to-close) to match the controlling instrument. For successful operation, the actuator stem and valve plug stem must move freely in response to the loading pressure change on the diaphragm.

DISASSEMBLY INSTRUCTIONS

Type 667 Actuator

Refer to the exploded drawings in Figure 4 and the assembly drawings in Figures 5, 6 and 7.

1. Bypass the control valve. Reduce the loading pressure to atmospheric and remove the tubing or pipe from the connection in the top of the yoke (Key 15).

2. Turn the spring adjustor (Key 19) counterclockwise to relieve all spring compression.

3. Remove the entire actuator from the valve body by removing the two cap screws (Key 20A) and separating the two halves of the stem connector (Key 20), and loosening the yoke locknut.

4. Unscrew the spring adjustor (Key 19) from the actuator stem (Key 16). The spring seat (Key 18) and the actuator spring (Key 17) can then be taken out.

5. Remove the diaphragm case cap screws and nuts (Keys 2 and 3), and lift off the diaphragm case (Key 1).

6. Take out the diaphragm (Key 5), diaphragm plate (Key 6) and actuator stem (Key 16) as an assembly. Be careful when pulling the threads of the actuator stem through the seal bushing (Key 12) to avoid damaging the "O" rings (Key 14).

7. Separate the parts of this assembly by removing the cap screw (Key 4.1A).

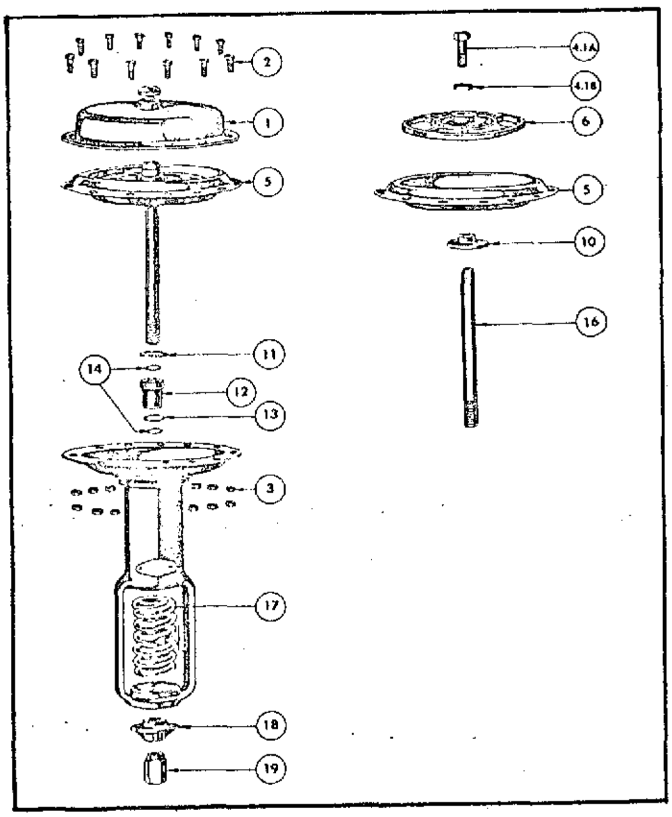


Figure 4—Exploded views of Type 667 actuator and diaphragm plate-actuator stem assembly.

8. To remove seal bushing (Key 12), remove the snap ring (Key 11) and lift out the bushing. Check the "O" rings for excessive wear or damage.

9. Remove cap screws (Key 7) and take off the lower diaphragm case (Key 8) and the gasket (Key 9).

Note: The above procedure describes how the actuator can be completely disassembled. When inspection or repairs are required, disassemble only those parts necessary to accomplish the particular job.

ASSEMBLY INSTRUCTIONS

Type 667 Actuator

1. Mount the lower diaphragm case (Key 8) and tighten the cap screws (Key 7). Use a new gasket (Key 9) between the diaphragm case and yoke.

2. Lubricate the three "O" rings (Key 13 and 14) and place them in the seal bushing (Key 12).

3. Fill the seal bushing with Phillips No. L-1 multi-purpose grease or equivalent and install the bushing in place in the top of the yoke (Key 15). Secure with snap ring (Key 11).

4. Make up the assembly of the actuator stem (Key 16), lower diaphragm plate (Key 10), diaphragm (Key 5), diaphragm plate (Key 6), and the travel stop cap screw and spacer (Keys 4.1A and 4.1B). Place this assembly in the actuator. Take care when pushing the actuator stem through the seal bushing so that the threads do not damage the "O" rings.

5. Install the diaphragm case (Key 1) and secure with cap screws and nuts (Keys 2 and 3). Tighten evenly, using a criss-cross pattern to insure a proper seal.

6. Install the actuator spring (Key 17) and spring seat (Key 18). Apply Lubriplate No. 130AA lubricant or equivalent to the threads of the actuator stem and to the surface of the spring adjustor (Key 19) which contacts the spring seat. These locations are indicated by "A" on the assembly drawings in Figures 5, 6 and 7. Thread spring adjustor on the actuator stem.

7. Thread the stem locknuts (Keys 23 and 24) on the valve plug stem and place the travel indicator (Key 22) on these nuts with the "cupped" portion downward.

8. Mount actuator on the valve body and secure with yoke locknut.

9. Make up the stem connection as follows to insure proper valve travel.

A. **Mounted on Body with "Push Down To Close" Valve Plug**

a) Set the valve plug on its seat.

b) Pull the valve plug stem upward the required travel.

c) Apply full loading pressure to the diaphragm case to move the actuator stem to the extreme upward position. Attach the stem connector at this point, making sure that there is full engagement of the actuator stem threads. Install the two cap screws in the stem connector but tighten them only slightly at this time. Tighten stem locknuts slightly to position the travel indicator properly.

d) The travel indicator should show the valve to be closed (with no pressure in the diaphragm case) or open (with full loading pressure applied). If it doesn't, loosen screws (Key 26) and shift the travel indicator scale (Key 27) until it does.

e) Vary the pressure to the diaphragm case over its full range and observe the valve travel and make sure that the valve plug seats on the seat rings. If the travel is not correct, it can be changed by screwing the valve plug stem into or out of the stem connector. Use a wrench on the stem locknuts to turn it but do not turn it when the valve plug is on the seat. When the travel is set properly, lock the stem locknuts against the stem connector and tighten the cap screws in the stem connector.

f) If travel starts at a pressure lower or higher than the required pressure, adjustment can be made by turning the spring adjustor. Turning it counterclockwise will decrease the spring compression and cause valve travel to start at a lower value of loading pressure. Turning the spring adjustor clockwise will compress the spring and cause travel to start at a higher value of loading pressure. For a 3 to 15 psi diaphragm pressure range, the valve should start traveling at 3 psi pressure.

B. Mounted on Body with "Push Down To Open" Valve Plug

Note: The Type 667 actuator is generally not used with this type of valve plug action but there is no physical or mechanical reason why a control valve of this type cannot be furnished.

a) Pull the valve plug stem up to seat the valve plug.

b) Apply full loading pressure to the diaphragm case to move the actuator stem to the extreme upward position. Attach the stem connector at this point, making sure that there is full engagement of the actuator stem threads. Install the two cap screws in the stem connector but tighten them only slightly at this time.

c) Reduce the loading pressure to move the valve plug away from its seat. Turn the valve plug stem into the stem connector about 1/8". This insures that the valve plug will seat before the travel stop cap screw contacts the diaphragm case. Tighten the stem locknuts slightly to position the travel indicator properly.

d) The travel indicator should show the valve to be closed (with full loading pressure applied) or open (with no pressure in the diaphragm case). If it doesn't, loosen screws (Key 26) and shift the travel indicator scale (Key 27) until it does.

e) Proceed as in Step "e" of Section A above.

f) Proceed as in Step "f" of Section A above.

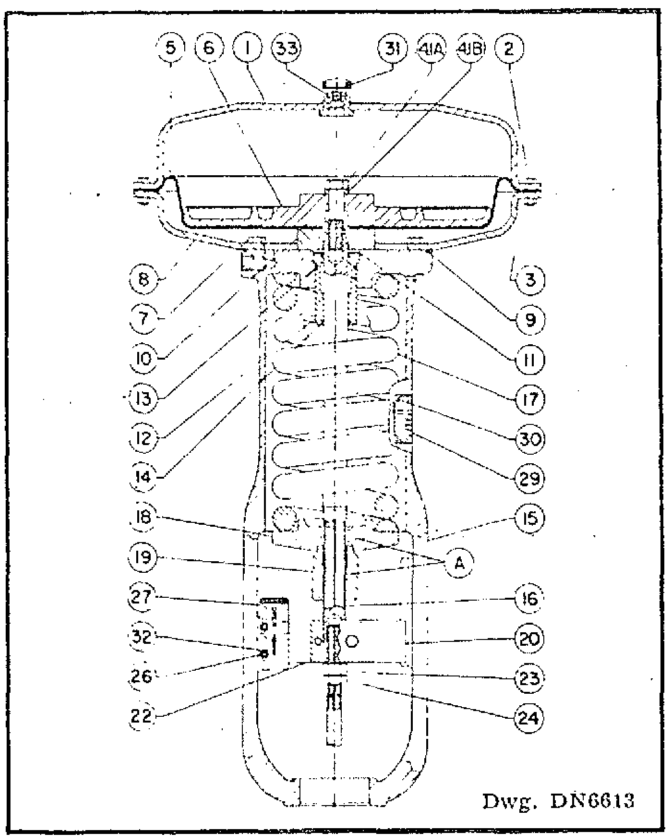


Figure 5—Type 667 actuator, Size 70.

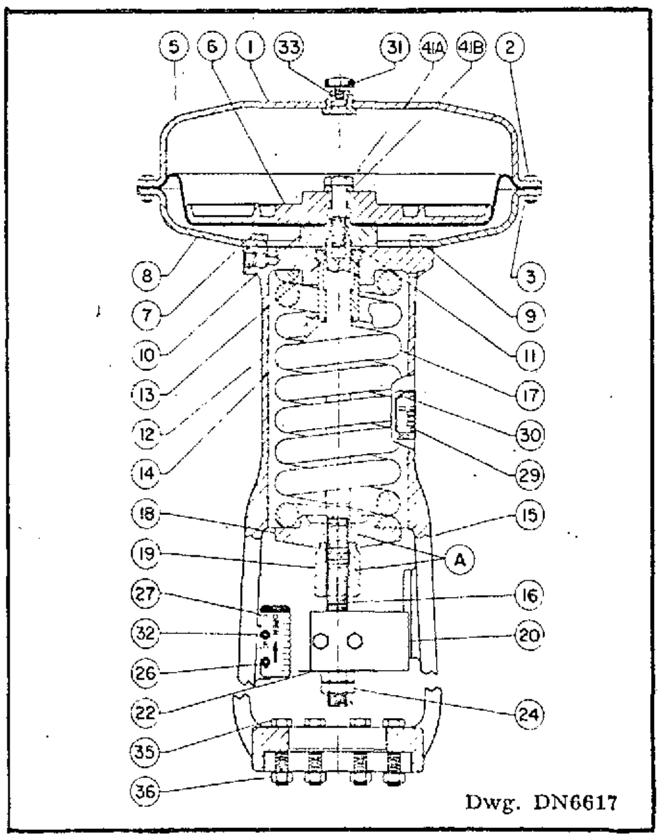


Figure 6—Type 667 actuator, Size 87.

Parts Reference — Type 667 Diaphragm Actuators

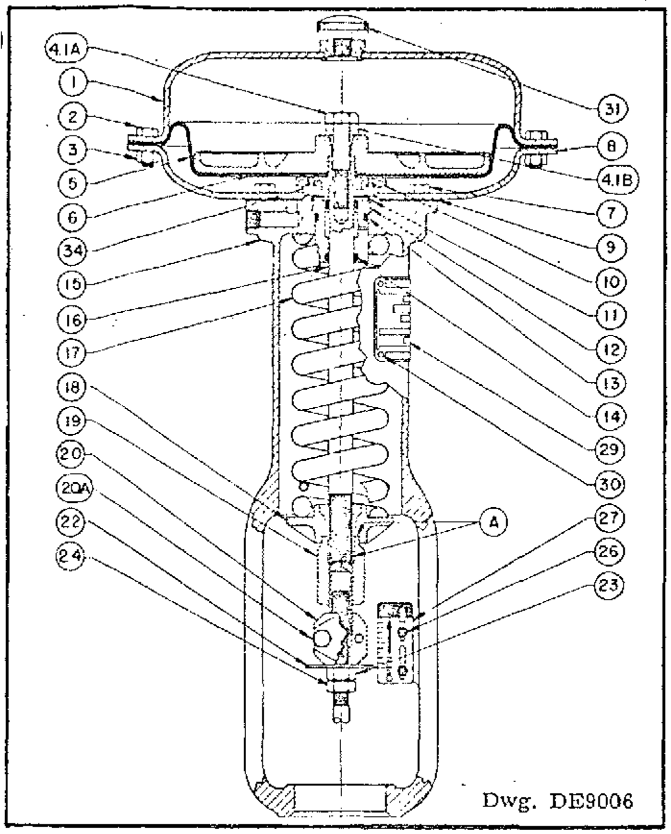


Figure 7—Type 667 actuator for all sizes other than Sizes 70 and 87.

KEY NO.	PART NUMBER	PART NAME AND MATERIAL
1		Diaphragm Casé Assembly, Steel
	2E8007 2899	Size 30
	2E6814 2899	Sizes 34 and 40
	3E8446 2899	Sizes 45 and 50
	3E8467 2899	Size 60
	2N1278 2899	Sizes 70 and 87
2		Cap Screw, Steel
	1E7603 2405	Size 30, 12 Req'd
	1E7603 2405	Sizes 34 and 40, 16 Req'd
	1E7603 2405	Sizes 45 and 50, 20 Req'd
	1A6751 2405	Size 60, 24 Req'd
	1A5828 2405	Sizes 70 and 87, 28 Req'd
3	1A3465 2412	Nut, Steel, All Sizes, Same number Req'd as in Key 2
4.1A		Travel Stop Cap Screw - See Table I
4.1B		Travel Stop Spacer - See Table I
5*		Diaphragm, Buna N
	2E8000 0220	Size 30
	2E6699 0220	Sizes 34 and 40
	2E8596 0220	Sizes 45 and 50
	2E8598 0220	Size 60
	2N1309 0220	Sizes 70 and 87
6		Diaphragm Plate, Cast Iron (Standard Construction)
	2E8804 1904	Size 30
	3E8805 1904	Sizes 34 and 40
	2E8315 1904	Sizes 45 and 50
	2E8475 1904	Size 60
	2N1270 1904	Sizes 70 and 87
6		Diaphragm Plate, Steel (Special Construction)
	2H5109 2201	Size 30
	3H5111 2201	Sizes 34 and 40
	2H5113 2201	Sizes 45 and 50
	2H5115 2201	Size 60
	2N7575 2201	Sizes 70 and 87
7		Cap Screw, Steel
	1D5298 2405	Size 30, 6 Req'd
	1A3684 2405	Sizes 34 and 40, 6 Req'd
	1A3684 2405	Sizes 45, 50 and 60, 8 Req'd
	1N1293 2899	Sizes 70 and 87, 12 Req'd
8		Lower Diaphragm Case, Steel
	2E8011 2506	Size 30
	2E6826 2506	Sizes 34 and 40
	3E8453 2506	Sizes 45 and 50
	3E8477 2506	Size 60
	2N1310 2506	Sizes 70 and 87
9*		Gasket, Asbestos
	1E8012 0402	Sizes 30, 34 and 40
	1E8454 0402	Sizes 45, 50 and 60
9*	1D2691 0699	"O" Ring, Synthetic Rubber, Sizes 70 and 87 Only
10		Lower Diaphragm Plate (Standard Construction)
	1E7913 4402	Size 30, Zinc
	1E6827 4402	Sizes 34 and 40, Zinc
	1E8455 4402	Sizes 45, 50 and 60, Zinc
	1N1315 2409	Size 70 and 87, Steel
10		Lower Diaphragm Plate, Steel (Special Construction)
	1F8858 2409	Sizes 34 and 40
	1F8909 2409	Sizes 45, 50 and 60
11		Snap Ring, Stainless Steel
	1E8013 3702	Sizes 30, 34 and 40
	1E8456 3899	Sizes 45, 50, 60, 70 and 87
12		Seal Bushing, Brass
	1E7912 1401	Size 30
	1E6828 1401	Sizes 34 and 40
	1E8457 1401	Sizes 45, 50 and 60
	1N1316 1401	Sizes 70 and 87
13*		"O" Ring, Synthetic Rubber
	1C4157 0699	Sizes 30, 34 and 40
	1E8458 0699	Sizes 45, 50, 60, 70 and 87
14*		"O" Ring, Synthetic Rubber, 2 Req'd
	1E5914 0699	Size 30
	1D2375 0699	Sizes 34 and 40
	1C5622 0699	Sizes 45, 50 and 60
	1E7369 0699	Sizes 70 and 87
15		Yoke, Cast Iron (Standard Construction)
	3E8014 1904	Size 30
	2E8846 1904	Size 34
	3E8208 1904	Size 40
	3E9006 1904	Size 45
	3E8459 1904	Sizes 50 and 60
	3N1303 1904	Size 70
	3N6642 1904	Size 87
15		Yoke, Steel (Special Construction)
	3K8156 2201	Size 30
	2H7671 2201	Size 34
	3H7673 2201	Size 40
	3H7875 2201	Size 45
	3K8303 2201	Sizes 50 and 60
	3N1306 2201	Size 70
	3N7587 2201	Size 87
16		Actuator Stem, Chrome Plated Steel
	1E8016 2422	Size 30
	1E8847 2422	Size 34
	1E8209 2422	Size 40
	1J3328 2422	Size 45
	1E8461 2422	Sizes 50 and 60
	2N1317 2422	Size 70
	2N6647 2422	Size 87
17		Actuator Spring - See Table II
18		Spring Seat
	1E7928 4402	Size 30, Zinc
	1R1799 2312	Sizes 34 and 40, Steel
	1R1800 2312	Sizes 45, 50 and 60, Steel
	1N1296 1905	Sizes 70 and 87, Cast Iron (Standard)
	1N7577 2201	Sizes 70 and 87, Steel (Special)
19		Spring Adjustor, Steel
	1E8017 2410	Size 30
	1E8210 2410	Sizes 34 and 40
	1E8462 2410	Sizes 45, 50 and 60
	1N1318 2450	Sizes 70 and 87
20		Stem Connector Assembly, Stainless Steel
	1E7977 000A	Sizes 30 and 34
	1E8033 000A	Size 40
	1J3330 000A	Size 45
	1E8337 000A	Sizes 50 and 60
	1N1319 000A	Size 70
	1N6644 000A	Size 87
20A		Cap Screw, Steel, 2 Req'd
	1C3791 2405	Sizes 30, 34 and 40
	1A7820 2405	Sizes 45, 50 and 60
	1A3445 2405	Size 70
	1A5147 2405	Size 87
22		Travel Indicator, Stainless Steel
	1E7931 3899	Sizes 30 and 34
	1E8075 3899	Sizes 40 and 45
	1E8328 3899	Sizes 50 and 60
	1B9718 3899	Size 70
	1H8718 3899	Size 87
23		Nut, Steel
	1P1312 2412	Sizes 30 and 34, 2 Req'd
	1A4132 2412	Size 40
	1A3754 2412	Sizes 50, 60 and 70
24		Jam Nut, Steel
	1A3537 2412	Size 40
	1A3537 2412	Size 45, 2 Req'd
	1A3511 2412	Sizes 50, 60 and 70
	1C6352 2412	Size 87, 2 Req'd

* Indicates Recommended Spare Parts For Stock

Parts Reference — Type 667 Diaphragm Actuators

KEY NO.	PART NUMBER	PART NAME AND MATERIAL
26		Screw, Stainless Steel, 2 Req'd
	1E7932 3899	Sizes 30, 34, 40 and 45
	1E8313 3899	Sizes 50, 60, 70 and 87
27		Travel Indicator Scale - See Table III
28		Twin Speed Nut for Travel Indicator Scale, Stainless Steel (not shown)
	1E7939 3899	Sizes 30 and 34
	1E8084 3899	Sizes 40 and 45
	1E8335 3899	Sizes 50, 60, 70 and 87
29	1K3257 3899	Nameplate, Stainless Steel
30	1A3682 2899	Nameplate Drive Screw, Steel, 4 Req'd
31	1E8955 000A	Vent Assembly, Zinc
32	1E8730 2899	Washer, Sizes 70 and 87, Steel, 2 Req'd
33	1C3790 2899	Pipe Bushing, Sizes 70 and 87, Steel
34		Down Travel Stop, Steel, 2 Req'd, Used with "Push Down To Open" Valve Plugs
	1H4935 2409	Sizes 30, 34 and 40
	1H4943 2409	Sizes 45, 50 and 60
35	1A9362 2405	Cap Screw, Size 87, Steel, 8 Req'd
36	1A3433 2412	Nut, Size 87, Steel, 8 Req'd

TABLE I — KEYS 4.1A AND 4.1B — TRAVEL STOP CAP SCREW AND SPACER, STEEL

ACTUATOR SIZE	PART NAME	PART NUMBER FOR TRAVEL STOP CAP SCREW AND SPACER						
		7/16" TRAVEL	5/8" TRAVEL	3/4" TRAVEL	1-1/8" TRAVEL	1-1/2" TRAVEL	2" TRAVEL	3" TRAVEL
30	Cap Screw	1A6857 2405	1A6857 2405	1B2275 2405				
	Spacer	1R4087 2409	1R4086 2409	1R4085 2409				
34	Cap Screw	1R4088 2405	1R4089 2405	1R4089 2405				
	Spacer	1R4093 2409	1R4094 2409	1R4095 2409				
40	Cap Screw	1R4088 2405	1R4089 2405	1R4089 2405	1R4091 2405	1R4092 2405		
	Spacer	1R4093 2409	1R4094 2409	1R4095 2409	1R4096 2409	1R4097 2409		
45	Cap Screw		1R4098 2405	1R4098 2405	1R4099 2405	1R4101 2405	1R4102 2405	
	Spacer		1R4104 2409	1R4105 2409	1R4108 2409	1R4106 2409	1R4107 2409	
50	Cap Screw		1R4098 2405	1R4098 2405	1R4099 2405	1R4101 2405	1R4102 2405	
	Spacer		1R4104 2409	1R4105 2409	1R4108 2409	1R4106 2409	1R4107 2409	
60	Cap Screw		1R4098 2405	1R4098 2405	1R4099 2405	1R4101 2405	1R4102 2405	
	Spacer		1R4104 2409	1R4105 2409	1R4108 2409	1R4106 2409	1R4107 2409	
70	Cap Screw			1R4110 2405	1R4111 2405	1R4098 2405	1R4099 2405	1R4102 2405
	Spacer			1R4116 2409	1R4115 2409	1R4114 2409	1R4113 2409	1R4107 2409
87	Cap Screw			1R4110 2405	1R4111 2405	1R4098 2405	1R4099 2405	1R4102 2405
	Spacer			1R4116 -2409	1R4115 2409	1R4114 2409	1R4113 2409	1R4107 2409

TABLE II — KEY 17 — ACTUATOR SPRING, STEEL

ACTUATOR SIZE	DIAPHRAGM PRESSURE RANGE, PSI.	ACTUATOR SPRING PART NUMBER						
		7/16" TRAVEL	5/8" TRAVEL	3/4" TRAVEL	1-1/8" TRAVEL	1-1/2" TRAVEL	2" TRAVEL	3" TRAVEL
30	3-15	1E7953 2708	1E7955 2709	1E7923 2709				
	6-30	1E7956 2708	1E7954 2708	1E7924 2708				
34	3-15	1E8051 2708	1E8049 2708	1E8058 2708				
	6-30	1E8050 2708	1E8048 2708	1E8052 2708				
40	3-15	1E8051 2708	1E8049 2708	1E8058 2708	1E8053 2709	1E8056 2709		
	6-30	1E8050 2708	1E8048 2708	1E8052 2708	1E8055 2708	1E8058 2708		
45	3-15		1E8267 2708	1E8262 2708	1E8261 2708	1E8266 2708	1E8269 2708	
	6-30		1E8256 2708	1E8255 2708	1E8264 2708	1E8262 2708	1E8265 2708	
50	3-15		1E8267 2708	1E8262 2708	1E8261 2708	1E8266 2708	1E8269 2708	
	6-30		1E8256 2708	1E8255 2708	1E8264 2708	1E8262 2708	1E8265 2708	
60	3-15		1E8258 2708	1E8257 2708	1E8262 2708	1E8265 2708	1E8270 2708	
	6-30			1E8260 2708	1E8255 2708	1E8257 2708	1E8263 2708	
70	3-15			1N1279 2708	1N7193 2708	1N1287 2708	1N1284 2708	1N1286 2708
	6-30				1N1281 2708	1N1279 2708	1N1285 2708	1N1287 2708
87	3-15			1N1279 2708	1N7193 2708	1N1287 2708	1N1284 2708	1N1286 2708
	6-30				1N1281 2708	1N1279 2708	1N1285 2708	1N1287 2708

TABLE III — KEY 27 — TRAVEL INDICATOR SCALE, STAINLESS STEEL

ACTUATOR SIZE	TRAVEL INDICATOR SCALE PART NUMBER						
	7/16" TRAVEL	5/8" TRAVEL	3/4" TRAVEL	1-1/8" TRAVEL	1-1/2" TRAVEL	2" TRAVEL	3" TRAVEL
30	1E7934 3899	1E7935 3899	1E7936 3899				
34	1E7934 3899	1E7935 3899	1E7936 3899				
40	1E8076 3899	1E8077 3899	1E8081 3899	1E8082 3899	1E8083 3899		
45	1E8076 3899	1E8077 3899	1E8081 3899	1E8082 3899	1E8083 3899	1R4445 3899	
50		1E8330 3899	1E8331 3899	1E8332 3899	1E8333 3899	1E8334 3899	
60	1F5352 3899	1E8330 3899	1E8331 3899	1E8332 3899	1E8333 3899	1E8334 3899	
70			1H7457 3899	1H7458 3899	1H7459 3899	1H7460 3899	1H7461 3899
87			1H7457 3899	1H7458 3899	1H7459 3899	1H7460 3899	1H7461 3899

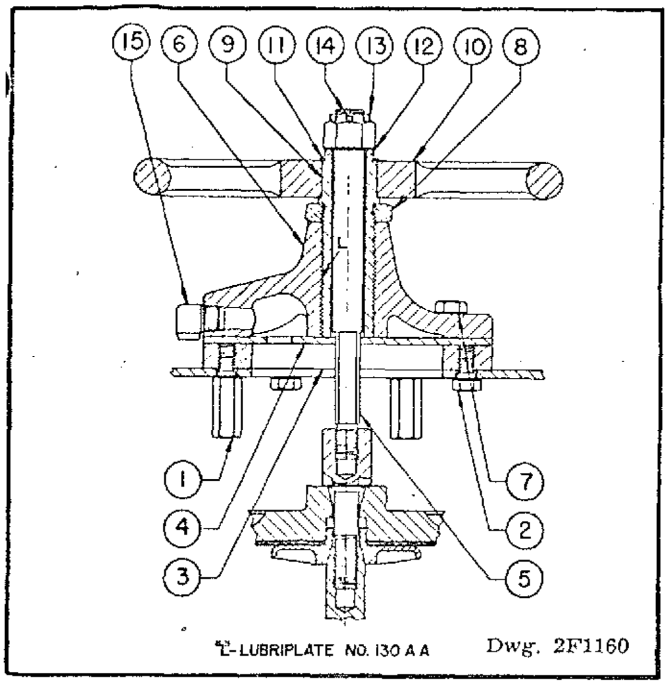


Figure 8—Top mounted handwheel for Type 667 actuators, Sizes 30 through 60. Top mounted handwheel for Sizes 70 and 87 is similar.

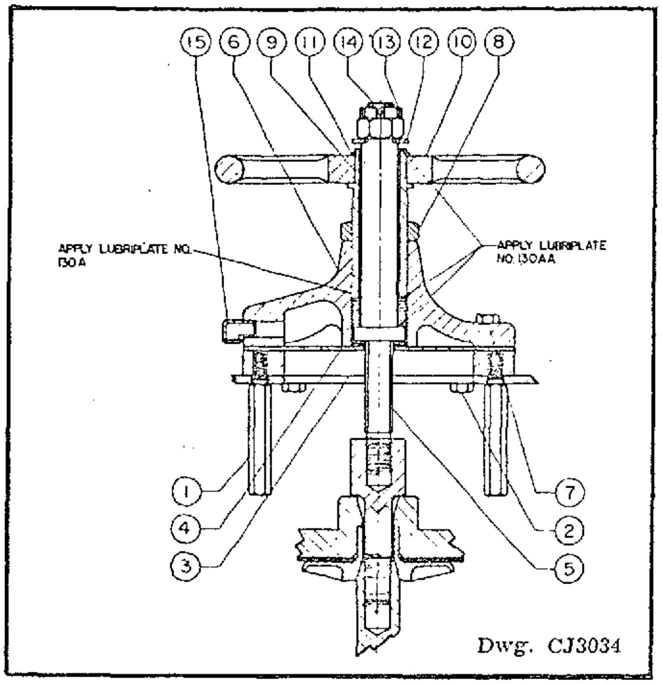


Figure 9—Type P-2 top mounted handwheel assembly for Sizes 45, 50 and 60 actuators.

TOP MOUNTED HANDWHEELS

Figures 8 and 9 show top mounted handwheel assemblies for the Type 667 diaphragm actuators. Turning the handwheel counterclockwise out of the handwheel body will compress the spring and move the actuator stem upward. Turning it clockwise will allow the actuator spring to move the actuator stem downward. Top mounted handwheels, however, are used more often as an adjustable travel stop than as manual operators. In the type shown in Figure 8, full closing of a valve can be restricted if the valve body has a "push down to close" valve plug. If the valve plug is a "push down to open" type, full opening of the valve can be restricted by use of the handwheel.

The Type P-2 handwheel shown in Figure 9 is a similar design but it can be used to limit travel in either the up or down direction. It is used on the Sizes 45, 50 and 60 actuators only.

Parts Reference — Top Mounted Handwheels

KEY NO.	PART NUMBER	PART NAME AND MATERIAL
1		Travel Stop, Steel, Size 30, 3 Req'd
	1F3932 2409	7/16" Travel
	1E7979 2409	5/8" Travel
	1E7925 2409	3/4" Travel
1		Travel Stop, Steel, Sizes 34 and 40, 3 Req'd
	1E8064 2409	7/16" Travel
	1E8065 2409	5/8" Travel
	1E8066 2409	3/4" Travel
	1E8067 2409	1-1/8" Travel
	1E8068 2409	1-1/2" Travel
1		Travel Stop, Steel, Sizes 45, 50 and 60, 4 Req'd
	1E8273 2409	5/8" Travel
	1E8318 2409	3/4" Travel
	1E8319 2409	1-1/8" Travel
	1E8064 2409	1-1/2" Travel
	1E8321 2409	2" Travel
1		Travel Stop, Steel, Sizes 70 and 87, 3 Req'd
	1N1288 2409	3/4" Travel
	1N1289 2409	1-1/8" Travel
	1N1290 2409	1-1/2" Travel
	1N1291 2409	2" Travel
	1N1292 2409	3" Travel
2		Cap Screw, Steel
	1D5298 2405	Sizes 30, 34 and 40, 3 Req'd
	1A3684 2405	Sizes 45, 50 and 60, 4 Req'd
	1N1293 2899	Sizes 70 and 87, 9 Req'd

KEY NO.	PART NUMBER	PART NAME AND MATERIAL
3		Handwheel Mounting Plate, Cast Iron (Standard Construction)
	1F1165 1904	Sizes 30, 34 and 40
	1F1193 1904	Sizes 45, 50 and 60
3		Handwheel Mounting Plate, Steel (Special Construction)
	1H5526 2201	Sizes 30, 34 and 40
	1H5509 2201	Sizes 45, 50 and 60
4		Guide Plate, Steel
	1F1164 2899	Sizes 30, 34 and 40
	1F1195 2899	Sizes 45, 50 and 60
5		Extension Rod
	1F1192 3523	Size 30, Stainless Steel
	1F1157 3523	Sizes 34 and 40, Stainless Steel
	1F1199 3513	Sizes 45, 50 and 60, Stainless Steel
	1J3032 2410	Sizes 45, 50 and 60, Steel, Type P-2
	2N8376 3116	Sizes 70 and 87, Steel
6		Handwheel Body, Cast Iron (Standard Construction)
	1F1162 1904	Sizes 30, 34 and 40
	2F1173 1904	Sizes 45, 50 and 60
	2N8377 1902	Sizes 70 and 87
6		Handwheel Body, Steel (Special Construction)
	1H5524 2201	Sizes 30, 34 and 40
	2H5511 2201	Sizes 45, 50 and 60

KEY NO.	PART NUMBER	PART NAME AND MATERIAL
7		Cap Screw, Steel
	1A3449 2405	Sizes 30, 34 and 40, 6 Req'd
	1A3418 2405	Sizes 45, 50 and 60, 8 Req'd
8		Locknut
	1F1189 1404	Sizes 30, 34 and 40, Brass
	1F1201 1404	Sizes 45, 50 and 60, Brass
	1N8378 2410	Sizes 70 and 87, Steel
9		Handwheel Screw, Brass
	1F1190 1404	Size 30
	1F1159 1404	Sizes 34 and 40
	1F1196 1404	Sizes 45, 50 and 60
	1J3033 1404	Sizes 45, 50 and 60, Type P-2
	1N8374 1404	Sizes 70 and 87
10		Handwheel, Cast Iron (Standard Construction)
	1F1191 1904	Size 30
	1F1158 1904	Sizes 34 and 40
	1F1198 1904	Sizes 45, 50 and 60
	2N8379 1904	Sizes 70 and 87
10		Handwheel, Steel (Special Construction)
	1H5519 2201	Sizes 34 and 40
	1H5521 2201	Sizes 45 50 and 60
11		External Retaining Ring, Steel
	1A3116 2899	Sizes 30, 34 and 40
	1F1200 2899	Sizes 45, 50 and 60
	1N8373 2898	Sizes 70 and 87
12		Washer, Stainless Steel
	1B6037 3513	Sizes 30, 34 and 40
	1F1640 3899	Sizes 45, 50 and 60
13		Handwheel Nut, Steel
	1B6038 2899	Sizes 30, 34 and 40
	1F1202 2412	Sizes 45, 50, 60, 70 and 87
14		Groove Pin, Steel
	1B5996 3507	Sizes 30, 34 and 40
	1F1197 2899	Sizes 45, 50, 60, 70 and 87
15		Vent Assembly, Zinc
	1C8937 000A	Sizes 30, 34, 40, 45, 50 and 60
	AF5502 000A	Sizes 70 and 87

KEY NO.	PART NUMBER	PART NAME AND MATERIAL

NOTE: The following parts are for the Sizes 70 and 87 only. They are not shown in Figure 8.

16	1B8774 2899	Screw, Steel, 4 Req'd, Sizes 70 and 87
17	1A3291 3299	Lockwasher, Steel, 4 Req'd, Sizes 70 and 87
18	1N8380 9901	Thrust Bearing, Steel, Sizes 70 and 87
19	1N8381 9901	Thrust Race, Steel, 2 Req'd, Sizes 70 and 87
20	1N8382 2410	Bearing Retainer, Steel, Sizes 70 and 87
21	1N8375 2898	Extension Rod Guide, Steel, Sizes 70 and 87
22	1N8383 3101	Extension Rod Connector, Steel, Sizes 70 and 87
25	1A9538 2601	Pipe Nipple, Steel, Sizes 70 and 87

NOTE: When a top mounted handwheel is used, the diaphragm case (Key 1) and the travel stop cap screw and spacer (Keys 4.1A and 4.1B) shown in the Parts Reference on Page 7 are replaced with the following parts:

KEY NO.	PART NUMBER	PART NAME AND MATERIAL
1		Diaphragm Case, Steel
	2E7922 2506	Size 30
	2E8063 2506	Sizes 34 and 40
	3E8316 2506	Sizes 45 and 50
	2E8474 2506	Size 60
	2N1271 2506	Sizes 70 and 87
4		Extension Rod Connector, Steel
	1F1188 2409	Size 30
	1F1359 2409	Sizes 34 and 40
	1F1194 2409	Sizes 45, 50 and 60

SIDE MOUNTED "MO" HANDWHEELS

Type 667 actuators can be furnished with "MO" side mounted handwheel assemblies as shown in Figures 10, 11 and 12. These are continuously connected types with an indicator to show the neutral position of the handwheel. At this setting automatic operation is possible over full valve travel. When the handwheel is positioned at any other point, full travel will be restricted. The "MO" handwheel can be positioned to limit travel in either direction but not both at the same time. An arrow on the handwheel indicates the rotation required to open the valve.

In the Type MO handwheel for Sizes 34 through 60 (Figures 10 and 11), there are two screw assemblies available, one with a right hand thread and the other with a left hand thread. The right hand thread screw is used with valve bodies that have a "push down to open" valve plug; the left hand thread screw is used with a "push down to close" valve plug. Thus, with the proper screw installed, counterclockwise rotation of the handwheel opens the valve.

In the "MO" assembly for the Sizes 70 and 87 (Figure 12), the location of the handwheel with respect to the worm gear determines what rotation is required to open the valve. Counterclockwise rotation should always open the valve. To accomplish this, if the valve plug is a "push down to close" type, the handwheel will be assembled as shown in Figure 12. When the valve plug action is "push down to open", the handwheel will be assembled 180 degrees from that shown in Figure 12. The handwheel mounting position can be changed in the field.

All side mounted "MO" handwheel assemblies are provided with a Zerk grease fitting. Lubricate these assemblies periodically with a good grade multi-purpose grease such as Phillips No. L-1.

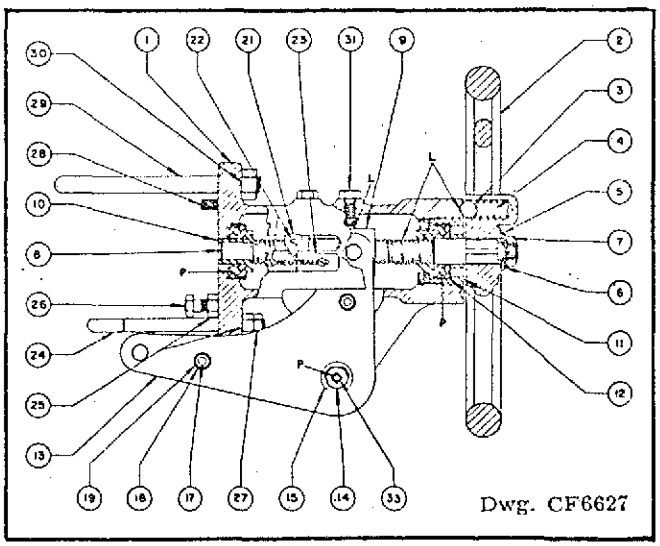


Figure 10—Type MO side mounted handwheel for Sizes 34 and 40 Type 667 actuators.

DISASSEMBLY INSTRUCTIONS

Type MO Side Mounted Handwheel for Sizes 34 through 60

Refer to Figures 10 and 11 and proceed as follows:

1. If desired, the "MO" handwheel assembly can be removed from the actuator yoke. To do this, remove the nuts (Keys 25, 27 and 30) from the U-bolts (Keys 24 and 29) that hold the assembly to the yoke.
2. Remove retaining ring (Key 15) and drive out lever pivot pin (Key 14).
3. There are two machine screws (Key 17) on the Sizes 34 and 40 and two cap screws (Key 17) on the Sizes 45, 50 and 60 that hold the right and left hand levers (Key 13) together. Remove the nut from the top screw (or cap screw) and pull out the screw. The levers will drop down out of the assembly. Disassemble further, if necessary, by removing the nut from the other screw (or cap screw).
4. Remove screw (Key 22) and pointer mounting bolt located behind pointer (Key 21).
5. Remove nut (Key 7) and take off the handwheel (Key 2). Be careful not to lose the small ball (Key 3) and spring (Key 4).
6. Using a suitable tool, unscrew the bearing retainer (Key 11) after loosening the locking set screw (Key 32). The bearing (Key 12) will come out with the retainer.
7. Pull the screw assembly (Key 8) out of the handwheel body. The operating nut (Key 9) will come out with the screw but the bearing (Key 12) may not. On the Sizes 34 and 40, the bushing (Key 10) should come out with the screw also.
8. If required, remove the bearings (Key 12), one from the bearing retainer (Key 11) and the other from the handwheel body.

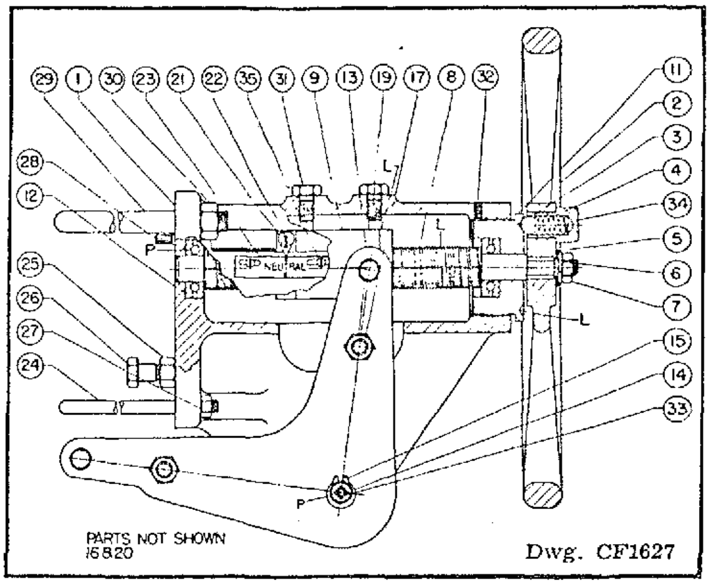


Figure 11—Type MO side mounted handwheel for Sizes 45, 50 and 60 Type 667 actuators.

ASSEMBLY INSTRUCTIONS

Type MO Side Mounted Handwheel for Sizes 34 through 60

When assembling the "MO" handwheel, refer to the drawings in Figures 10 and 11. There are no special precautions to be observed but certain parts should be lubricated as follows:

a) Use Lubriplate No. 130AA or equivalent on the threads of the screw assembly, on the ball and on the tips of the guide bolts (Key 31). These locations are indicated by an "L" on the drawings.

b) Use Phillips L-1 multi-purpose grease or equivalent in the bearings and on the lever pivot pin. These locations are indicated by a "P" on the drawings.

Parts Reference — Type MO Side Mounted Handwheel for Sizes 34 through 60

(See Figures 10 and 11)

KEY NO.	PART NUMBER	PART NAME AND MATERIAL
1		Handwheel Body Assembly, Cast Iron
	3F6572 000A	Sizes 34 and 40
	3F1446 000A	Sizes 45, 50 and 60
1A		Handwheel Body Bearing, Bronze, 2 Req'd (not shown)
	1H3056 1803	Sizes 34 and 40
	1H3055 1803	Sizes 45, 50 and 60
2		Handwheel, Cast Iron
	2D3585 1905	Sizes 34 and 40
	2D4050 1904	Sizes 45, 50 and 60
3	1A3427 3299	Ball, Steel
4	0D0059 1601	Spring, Bronze
5	1A5189 2507	Washer, Steel
6	1A3538 2899	Lockwasher, Steel
7	1A3524 2412	Jam Nut, Steel
8		Screw Assembly for Body with "Push Down To Close" Valve Plug (Left Hand Thread), Bronze
	1F6584 000A	Sizes 34 and 40
	1F5486 1405	Sizes 45, 50 and 60
8		Screw Assembly for Body with "Push Down To Open" Valve Plug (Right Hand Thread), Bronze
	1F6583 000A	Sizes 34 and 40
	1F5487 1405	Sizes 45, 50 and 60
9		Operating Nut for Left Hand Thread Screw Assembly, Steel
	1F6590 2409	Sizes 34 and 40
	2F5485 2409	Sizes 45, 50 and 60
9		Operating Nut for Right Hand Thread Screw Assembly, Steel
	1F6589 2409	Sizes 34 and 40
	2F5484 2409	Sizes 45, 50 and 60

KEY NO.	PART NUMBER	PART NAME AND MATERIAL
10	1F6579 2409	Bushing, Steel, Sizes 34 and 40 only
11		Bearing Retainer
	1F6580 1401	Sizes 34 and 40, Brass
	1D3852 2409	Sizes 45, 50 and 60, Steel
12	1D3613 9901	Bearing, Steel, 2 Req'd
13		Handwheel Lever and Pin Assembly (Right Hand), Steel
	1F6614 000A	Sizes 34 and 40
	1F1541 000A	Sizes 45, 50 and 60
13		Handwheel Lever and Pin Assembly (Left Hand), Steel
	1F6613 000A	Sizes 34 and 40
	1F1539 000A	Sizes 45, 50 and 60
14		Lever Pivot Pin, Stainless Steel
	1F6581 3523	Sizes 34 and 40
	1F1562 3523	Sizes 45, 50 and 60
15		Retaining Ring, Steel, 2 Req'd
	1F5994 2899	Sizes 34 and 40
	1A9030 2899	Sizes 45, 50 and 60
16		Lever Spacer, Steel, 2 Req'd (not shown)
	1F6582 2409	Sizes 34 and 40
	1F1625 2409	Sizes 45, 50 and 60
17		Screw, Steel, 2 Req'd
	1D9806 2899	Sizes 34 and 40
	1F1576 2405	Sizes 45, 50 and 60
18	1C2256 2899	Lockwasher, Steel, 2 Req'd, Sizes 34 and 40 only
19		Nut, Steel, 2 Req'd
	1A3457 2412	Sizes 34 and 40
	1A3412 2412	Sizes 45, 50 and 60

KEY NO.	PART NUMBER	PART NAME AND MATERIAL
20		Pointer Mounting Bolt, Stainless Steel (not shown)
	1F6578 3513	Sizes 34 and 40
	1F1565 3513	Sizes 45, 50 and 60
21	1F1575 3601	Pointer, Stainless Steel
22		Screw, Steel
	1A3319 2899	Sizes 34 and 40, 3 Req'd
	1E1758 2899	Sizes 45, 50 and 60
23		Indicator Plate, Aluminum
	1F9364 1199	Sizes 34 and 40
	1D3574 1199	Sizes 45, 50 and 60
24		Mounting U-Bolt, Steel, 2 Req'd
	1F6576 2409	Sizes 34 and 40
	1F5488 2409	Size 45
	1F1556 2409	Sizes 50 and 60
25		Nut, Steel
	1A3753 2412	Sizes 34 and 40, 4 Req'd
	1A3412 2412	Sizes 45, 50 and 60, 2 Req'd
26		Cap Screw, Steel, 2 Req'd
	1C4038 2405	Sizes 34 and 40
	1A3444 2405	Sizes 45, 50 and 60

KEY NO.	PART NUMBER	PART NAME AND MATERIAL
27		Nut, Steel
	1A3522 2412	Sizes 34 and 40, 2 Req'd
	1A3753 2412	Sizes 45, 50 and 60, 4 Req'd
28	1D4198 2899	Dowel Pin, Steel, 2 Req'd
29		Mounting U-Bolt, Steel
	1F6577 2409	Sizes 34 and 40
	1F1555 2409	Sizes 45, 50 and 60
30		Nut, Steel, 2 Req'd
	1A3412 2412	Sizes 34 and 40
	1A3433 2412	Sizes 45, 50 and 60
31		Guide Bolt, SST, 2 Req'd
	1F6575 3513	Sizes 34 and 40
	1F1552 3513	Sizes 45, 50 and 60
32		Set Screw, Steel
	1A3447 2418	Sizes 34 and 40
	1A3415 2899	Sizes 45, 50 and 60
33	1H3061 9901	Zerk Grease Fitting, Steel
34	1D3851 2409	Spring Cap, Steel, Sizes 45, 50 and 60 only
35	1A3319 2899	Screw, Steel, 2 Req'd, Sizes 45, 50 and 60 only

When a side mounted Type MO handwheel assembly is used, the following parts are used instead of the corresponding parts listed in the Parts Reference on Pages 6 and 7.

KEY NO.	PART NUMBER	PART NAME AND MATERIAL
16		Actuator Stem, Chrome Plated Steel
	1E8209 2422	Size 34
	1F3259 2422	Size 40
20		Stem Connector Assembly, Stainless Steel
	1F6592 2514	Size 34
	1F1369 2514	Size 40
	2F1678 000A	Size 45
	2F1672 000A	Sizes 50 and 60
20A		Cap Screw, Steel
	1F1448 3299	Sizes 34 and 40, 2 Req'd
	1F1639 3299	Sizes 45, 50 and 60, 4 Req'd

KEY NO.	PART NUMBER	PART NAME AND MATERIAL
22		Travel Indicator, Size 45, consisting of:
	1B2856 2899	Screw, Steel, 2 Req'd
	1B5090 1402	Spacer, Steel
	1L2045 3601	Pointer
26	1B9925 2899	Screw, Stainless Steel, 2 Req'd
28		Travel Indicator Nut for Size 45, consisting of:
	1A3319 2899	Screw, Steel, 2 Req'd
	1F5482 1401	Travel Indicator Adaptor, Brass, 2 Req'd

DISASSEMBLY INSTRUCTIONS

Type 667MO, Sizes 70 and 87 (See Figure 12)

1. Bypass the control valve. Reduce the loading pressure to atmospheric. Disconnect the loading pressure tubing or pipe at the yoke.

2. Remove cover band (Key 60) and relieve the spring compression by turning the spring adjustor (Key 19) counterclockwise.

3. Remove the cap screws and nuts (Keys 2 and 3) and lift off the diaphragm case (Key 1).

4. Remove the travel stop cap screw (Key 4.1A) and take off the diaphragm plate (Key 6), the diaphragm (Key 5), and the lower diaphragm plate (Key 10).

5. If required, remove cap screws (Key 7) and take off lower diaphragm case (Key 8). Remove "O" ring (Key 9).

6. Remove cap screws (Key 62) and take off the spring case adaptor (Key 61). Remove seal bushing (Key 12) from the adaptor after removing the snap ring (Key 11).

7. Take out the actuator spring (Key 17).

8. Remove the stem connector (Key 20) after loosening the cap screws (Key 20A).

9. Pull the actuator stem (Key 16) up and out of the yoke. The spring seat (Key 18), spring adjustor (Key 19), thrust bearing (Key 37), and the pinned adjusting screw (Key 63) will come out with the actuator stem.

10. Turn the handwheel in a direction to lower the lower sleeve (Key 46). This is the part with the Acme thread. Continue turning the handwheel until the sleeve is free of the worm gear (Key 44).

11. Loosen two set screws (Key 40) and unscrew the bearing retainer flange (Key 39), using a suitable tool in the open neck of this part. Take out the worm gear and two thrust bearings (Key 42), one on each side of the gear.

12. The worm shaft (Key 45) and associated parts can be disassembled, if desired, by first removing handwheel nut (Key 54) and the handwheel (Key 51). Don't lose the small ball (Key 55) and spring (Key 56).

13. Loosen one set screw (Key 41) at each end and unscrew the worm shaft retainers (Keys 48 and 49). The ball bearings (Key 50) will come out with the retainers.

ASSEMBLY INSTRUCTIONS

Type 667MO, Sizes 70 and 87

Careful observation during any disassembly and use of the sectional drawing in Figure 12 will greatly aid in the assembly of the Type 667MO actuators. Please observe the following precautions and lubrication procedures.

1. The threaded parts retained with set screws have a slot in them so that the set screw does not damage the threads. These parts are the bearing retainer flange (Key 39), worm shaft front retainer (Key 48), and the worm shaft back retainer (Key 49). Make sure that the slot is in the proper position before tightening the set screws.

2. Clean all parts thoroughly before assembly.

3. When installing the actuator stem through the seal bushing, do so carefully to avoid damaging the "O" rings with the threads on the actuator stem.

4. Lubricate the following parts as indicated:

a) Apply Molykote No. 77 or equivalent to the threads of the bearing retainer flange (Key 39) and to the threads of the adjusting screw (Key 63).

b) Coat the Acme thread of the lower sleeve (Key 46) and the teeth of the worm gear (Key 44) and worm shaft (Key 45) with Lubriplate No. 130A or equivalent.

c) Pack all bearings (Keys 37, 42 and 50) and seal bushing (Key 12) with Phillips No. L-1 multi-purpose grease or equivalent.

Parts Reference — Type 667MO Sizes 70 and 87

(See Figure 12)

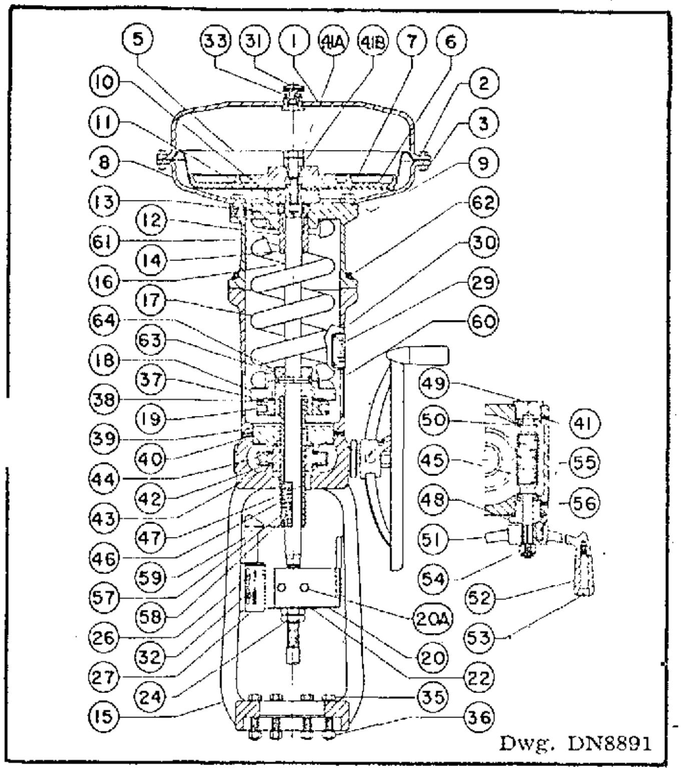


Figure 12—Type 667MO Size 87 actuator with side mounted handwheel. Size 70 is similar except for the smaller yoke boss.

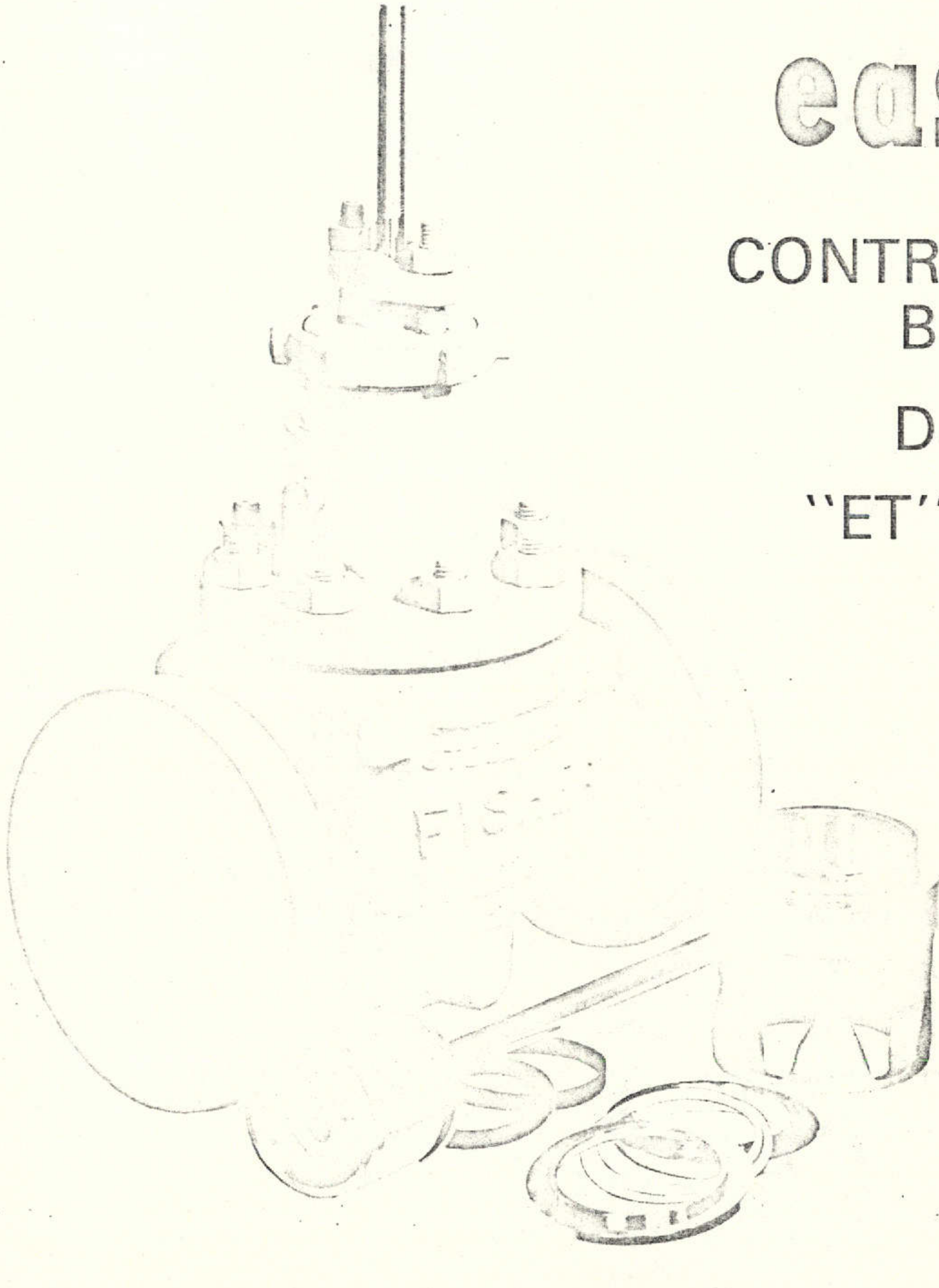
NOTE: Key Nos. 1, 2, 3, 4.1A, 4.1B, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 17, 20A, 22, 23, 24, 27, 29, 30, 31, 33, 35 and 36 are the same as listed in the basic parts reference for Type 667 actuators on Pages 6 and 7. The following parts are for the Type 667MO, Sizes 70 and 87 only.

KEY NO.	PART NUMBER	PART NAME AND MATERIAL
15		Yoke, Cast Iron
	4N8901 1904	Size 70
	4N8866 1904	Size 87
16		Actuator Stem, Chrome Plated Steel
	2N8906 2422	Size 70
	2N8896 2422	Size 87
18	1N8871 1904	Spring Seat, Cast Iron
19	1N8869 2439	Spring Adjustor, Steel
20		Stem Connector Assembly, Stainless Steel
	1N8903 000A	Size 70
	1N6644 000A	Size 87 (same as basic actuator)
26	1A3431 2899	Screw, Stainless Steel, 2 Req'd
32	1F5656 1899	Washer, Brass, 2 Req'd
37	1N8885 9901	Thrust Bearing, Steel
38	1N8886 9901	Thrust Bearing Race, Steel, 2 Req'd
39	1N8892 1904	Bearing Retainer Flange, Cast Iron
40	1F7310 2899	Set Screw, Steel, 2 Req'd
41	1A7103 2899	Set Screw, Steel, 2 Req'd
42	1N8887 9901	Thrust Bearing, Steel, 2 Req'd
43	1N8888 9901	Thrust Bearing Race, Steel, 4 Req'd
44	2N8862 1205	Worm Gear, Bronze
45	2N8863 3109	Worm Shaft, Steel
46	2N8882 2409	Lower Sleeve, Steel
47	1N8880 2509	Key, Steel
48	1N8884 2409	Worm Shaft Front Retainer, Steel
49	1N8883 2449	Worm Shaft Back Retainer, Steel
50	1A3392 2899	Ball Bearing, Steel, 2 Req'd
51	3H7343 1905	Handwheel, Cast Iron
52	0U0756 2409	Handgrip, Steel
53	0U0774 2409	Handgrip Bolt, Steel
54	1A7805 2899	Nut, Steel
55	1A3427 3299	Ball, Steel
56	0D0059 1601	Spring, Bronze
57	1H7365 2899	Screw, Steel, 2 Req'd
58	1N8872 3601	Travel Stop Indicator, Stainless Steel
59	1J4608 3899	Handwheel Indicator, Stainless Steel
60	1N8879 000A	Cover Band Assembly
61	2N8894 1904	Spring Case Adaptor, Cast Iron
62	1N8724 2899	Cap Screw, Steel, 12 Req'd
63	1N8897 3513	Spring Adjusting Screw, Steel
64	1N8898 2701	Roll Pin, Steel
65	1A9267 2899	Zerk Fitting, Steel (not shown)

Give the serial number from the nameplate in correspondence and when ordering spare parts. Give also the ten-character part number of each part required.

Design ET

INSTRUCTIONS AND PARTS LIST



easy-e®

CONTROL VALVE BODY

Designs "ET" & "EAT"

Printed in U.S.A.
15M—9-70
JSS

FISHER CONTROLS COMPANY

Marshalltown, Iowa | Coraopolis, Pa.
Woodstock, Ont., Can. | Toluca, Mexico

FORM 2370

INTRODUCTION

The "ET" and "EAT" bodies are generally shipped as part of a control valve assembly, and have a diaphragm, piston or manual actuator mounted on them. Detailed instructions for Fisher actuators are provided in separate manuals. This manual pertains only to the Design "ET" and "EAT" valve bodies.

INSTALLATION

1. Before installing an easy-e body, inspect it for any shipment damage and for any foreign material that may have collected during crating and shipment.
2. Blow out all pipelines to remove pipe scale, chips, welding slag, and other foreign materials.
3. Install the valve so that flow through the body will be in the direction indicated by the flow direction arrow. In the balanced Design "ET" body, the direction is through the cage openings and down through the seat ring. *If Whisper Trim™ is used, the flow should be up through the seat ring.*
4. Install the valve using good piping practices. For flanged bodies, use a suitable gasket between the body and pipeline flanges.
5. Control valves with an easy-e body can be installed in any position, but the normal method is with the actuator vertical above the body.
6. If continuous operation is required during maintenance and inspection, install a conventional three-valve bypass around the body.
7. Iron easy-e valve bodies are rated at 125 and 250 lb. ANSI; steel and alloy steel bodies are rated at 150, 300, and 600 lb. ANSI. Do not install the valve in a system where the working pressures exceed those specified in the standards.

MAINTENANCE

CAUTION: Before attempting any repairs, isolate the control valve from the system and make sure that all pressure is released from the easy-e body.

A. Disassembly Instructions

1. After the actuator is disconnected and taken off the body, remove the nuts or cap screws from the bonnet flange.
2. Lift off the bonnet along with the valve plug and stem.
3. Loosen the packing flange nuts, and separate the valve plug and stem from the bonnet. If the stem needs replacing, drive the groove pin out the top of the plug and unscrew the stem. If the valve plug needs replacing, always replace the entire valve plug and stem assembly. *(Do not reuse the old stem on a new valve plug.)*
4. The internal parts of the bonnet can be disassembled, if desired. For packing replacement, instructions are given in the section "To Replace TFE V-Ring Packing". For bellows seal replacement, follow section entitled "Bellows Seal Replacement". (Page 4)
5. Lift out the cage and gaskets. For restricted trim (Figure 12) also remove cage adaptor and seat ring adaptor. If the cage is stuck, use a screwdriver to pry it loose. A groove is provided near the top of the cage for this purpose.
6. Lift out the seat ring and its gasket. For soft seat, also remove the disc retainer and elastomer seat.

B. Assembly Instructions

1. Clean all gasketed surfaces. (Use all new gaskets for assembly)
2. For restricted trim, (Figure 12) replace the adaptor gasket and the adaptor.
3. Install the seat ring gasket, and replace the seat ring. If a soft seat (Figure 13) is being used, assemble it by inserting the disc into the disc retainer, and slip this combination over the disc seat.
4. Install the cage on top of the seat ring. Be sure that the cage slips onto the seat ring properly. Any rotational orientation of the cage with respect to the body is acceptable.
5. For full size trim, place cage gasket, spiral wound gasket, and bonnet gasket on the shoulder of the cage.
6. For restricted trim, replace the (1) cage gasket, spiral wound gasket, (2) cage gasket, cage adaptor & bonnet gasket.
7. If a new stem is to be assembled in the valve plug, screw the stem into the valve plug until it wedges tight at the end of the valve stem thread. Locate the pilot hole in the valve plug and continue drilling the hole through the valve plug and stem assembly at the same angle. (Determine drill size from table on Page 3). Drive in the groove pin to lock the assembly.
8. To replace the back-up ring and seal ring, apply Moly No. 80 lubricant to both rings. Slide the back-up ring into place. Then position the seal ring over the back-up ring.
9. When installing the valve plug assembly in the cage, be careful not to damage the seal ring because of the interference fit between the seal ring and the cage wall.
10. Mount the bonnet on the body with the lubricator (or pipe plug) facing downstream.
11. Tighten the bonnet-to-body bolts to the recommended bolt torques given in the following table (follow good bolting practices and lubricate bolts).

Body Size	Recommended Bolt Torque, Ft-Lbs
1"	104
1-1/2"	75
2"	75
2-1/2"	104
3"	130
4"	191
6"	404

Proper tightening of the bonnet bolts accomplishes two purposes:

1) The spiral wound gasket compresses enough to both load and seal the seat ring gasket.

2) The outer portion of the top asbestos gasket compresses so that the bonnet-to-body joint forms a seal.

NOTE: Spiral wound gasket boltup characteristics are such that tightening of one bolt may loosen an adjacent bolt. This will occur on subsequent tightening of all the bolts until the bonnet-to-body seal is made. This requires several trials on each bolt until the nut does not turn at the given torque.

12. Mount the actuator on the bonnet and make up the stem connection according to procedure on Page 4.

C. To Replace TFE V-Ring Packing (Figures 2 & 16)

1. After the actuator and bonnet have been taken off the body according to Steps 1-3 of the disassembly instructions, remove the packing nuts (Key 23), packing flange (Key 21), a felt wiper ring (Key 30), and packing follower (Key 31) from the bonnet. Pull out the old packing with a packing hook, being careful to avoid scratching the packing box wall. The packing may also be pushed out using a rod inserted through the hole in the bottom of the bonnet.
2. Clean the packing box and all metal parts: spring (Key 26), washer (Key

28), and packing box ring (Key 29).
3. Replace the valve plug and install the bonnet on the body using new gaskets.

4. Install new packing and associated parts in the sequence shown in Fig. 2 Be careful not to damage the packing during installation. Replace the packing flange and packing flange nuts. Tighten the nuts as far as they will go.
5. Mount the actuator and set the stem connector to obtain required travel as outlined on Page 4.

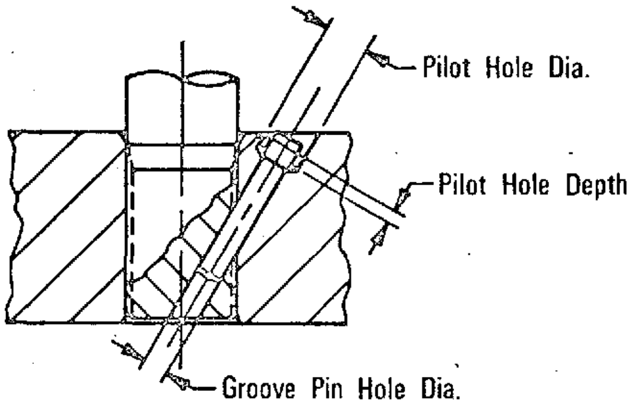
NOTE: A similar procedure can be followed for TFE impregnated asbestos packing and graphited asbestos packing. Since these packings come in split rings, it is possible to replace them without removing the actuator from the body. The arrangement of packing parts is shown in Figure 2. Packing flange nuts should be tightened only enough to stop leakage.

D. Grinding Metal Seats

A certain amount of leakage should be expected with metal-to-metal seating in any valve body. If the leakage becomes excessive, however, the condition of the seating surfaces of the valve plug and seat ring can be improved by grinding. (Large nicks and cuts should be machined out rather than ground out.) Many grinding compounds are available commercially. Use a good quality one, or make your own with a mixture of 600 grit carborundum compound and solidified vegetable oil. White lead should be applied to the seat to prevent excessive cutting or tearing during grinding. The bonnet must be bolted to the body during the grinding procedure to position the cage and seat ring properly and also to help align the valve plug with the seat ring. A simple grinding tool can be made from a piece of strap iron, locked to the valve plug stem with nuts. After grinding, remove bonnet, clean seating surfaces, and test for shutoff. Repeat grinding procedure if leakage is still excessive.

E. Bellows Seal Replacement (Figure 3)

1. After the actuator is disconnected and taken off the body, remove nuts (Key 16) and lift off the bonnet. If the bellows seal adaptor, bellows seal and valve plug assembly comes out with the bonnet, simply separate it from the bonnet by pulling it free.



VSC * (In.)	Drill Size (In.)	Groove Pin
3/8	3/32	1V3226 3507
1/2	1/8	1V3227 3507
3/4	3/16	1V3260 3507
1 & 1-1/4	1/4	1V3340 3507

* Valve Stem Connection

Figure 1. Groove Pin Data

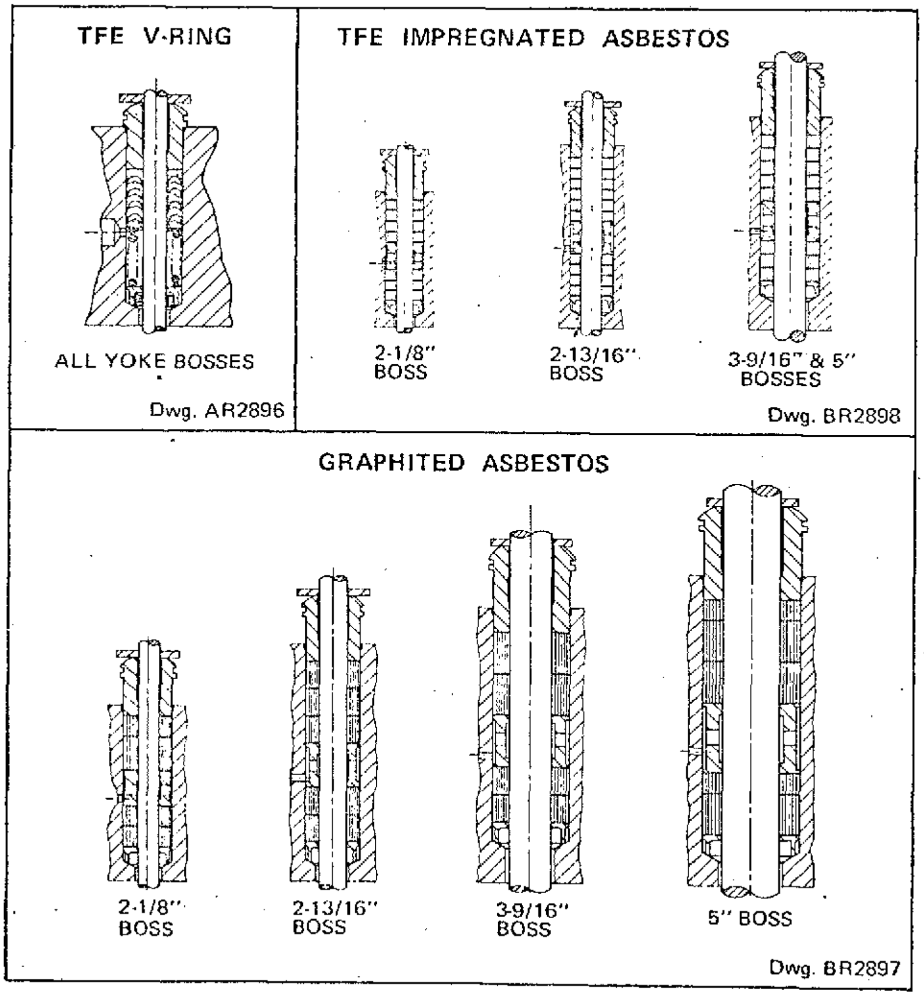


Figure 2. Packing Box Arrangement for Various Packing

2. Unscrew the valve plug stem extension (Key 7) from the bellows seal assembly (Key 38).
3. Remove cap screws (Key 41) from the bellows seal adaptor.
4. Unscrew the bellows seal assembly from the connection stud (Key 35). Use a wrench on the flats of the shaft extending out the top of the bellows seal assembly, and on the flats of the connection stud near the valve plug end of it.
5. Install the new bellows assembly by screwing it onto the connection stud. Make sure that the new gaskets (Key 39), anti-rotator (Key 36) and the travel stop (Key 37) are in place.
6. Bolt the bellows seal assembly to the bellows seal adaptor (Key 34) with cap screws.
7. Screw the valve plug stem extension into the shaft of the bellows seal assembly.
8. Using all new gaskets between the bellows seal adaptor and the body, and between the bellows seal adaptor and the bonnet, mount the bonnet on the body. Install and tighten nuts (Key 16). Mount the actuator on the body.

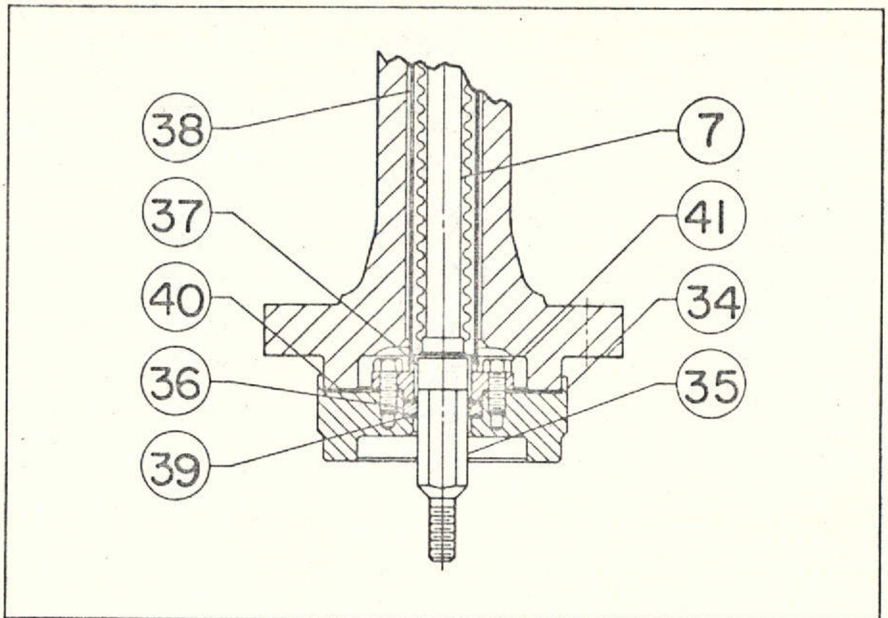


Figure 3. Partial Sectional of Bellows Seal

F. Making Up Stem Connector (Figure 4)

a). For Direct Acting Actuator

1. Move the valve plug to the closed position.
2. Screw the locknuts (Key 4) onto the stem, and set the travel indicator disc on these nuts with the "cupped" portion downward.
3. Pull the valve plug stem up the required travel and attach the stem connector (Key 1), making sure that there is full engagement of the actuator stem threads. Install the two cap screws (Key 2) in the stem connector, but tighten them only slightly at this time. Tighten the stem locknuts slightly to position the travel indicator disc against the bottom of the stem connector.
4. The travel indicator should show the valve to be wide open with no pressure on the diaphragm. If it doesn't, loosen the screws that hold the travel indicator scale, and shift the scale to the required position.
5. Apply and vary the pressure to the diaphragm case and observe the valve travel. Make sure the valve plug seats on the seat ring. If the travel is not correct, it can be changed by screwing the valve plug stem in or out of the stem connector. Turn the stem by using a wrench on the locknuts; never use a pipe wrench or pliers on the stem itself, and never turn the plug while its on the seat. When the travel is set properly, tighten the cap screws in the stem connector and lock the stem locknuts against the stem connector.

b.) Reverse Acting Actuator

1. Move the valve plug to the closed position.
2. Screw the locknuts (Key 4) onto the stem, and set the travel indicator disc on these nuts with the "cupped" portion downward.
3. Apply full loading pressure to the diaphragm case to move the actuator stem to the extreme upward position. Pull the valve plug stem up the required travel and attach the stem connector (Key 1), making sure that there is full engagement of the actuator stem threads. Install the two cap screws in the stem connector, but tighten them only slightly at this time. Tighten the stem locknuts slightly to position the travel indicator disc against the bottom of the stem connector.
4. The travel indicator should show the valve to be wide open with full loading pressure applied to the diaphragm. If it doesn't, loosen the screws that hold the travel indicator scale, and shift the scale to the required position.
5. Same as Step 5 for a direct acting actuator.

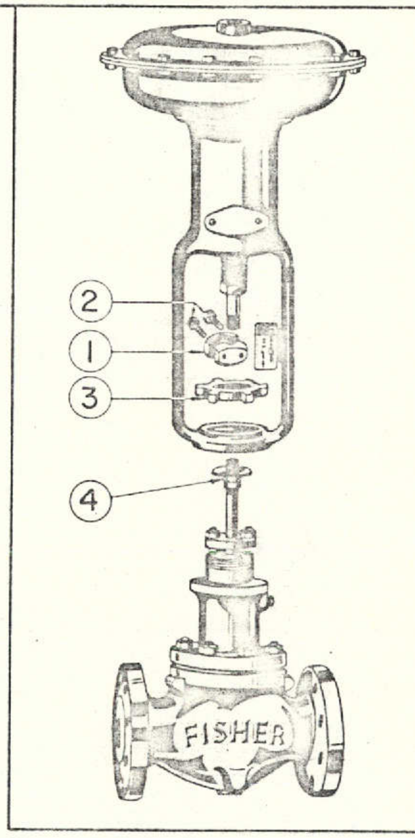


Figure 4. Exploded view showing how diaphragm actuator mounts on easy-e body. (Type 657 illustrated) Numbered parts are stem connector (1), cap screws (2), yoke locknut (3), and stem locknuts (4).

SERIAL NUMBER

A serial number is assigned to each easy-e body and it should always be referred to in correspondence and parts orders to the factory. When ordering parts, also give the ten character part number shown in the Parts Reference.

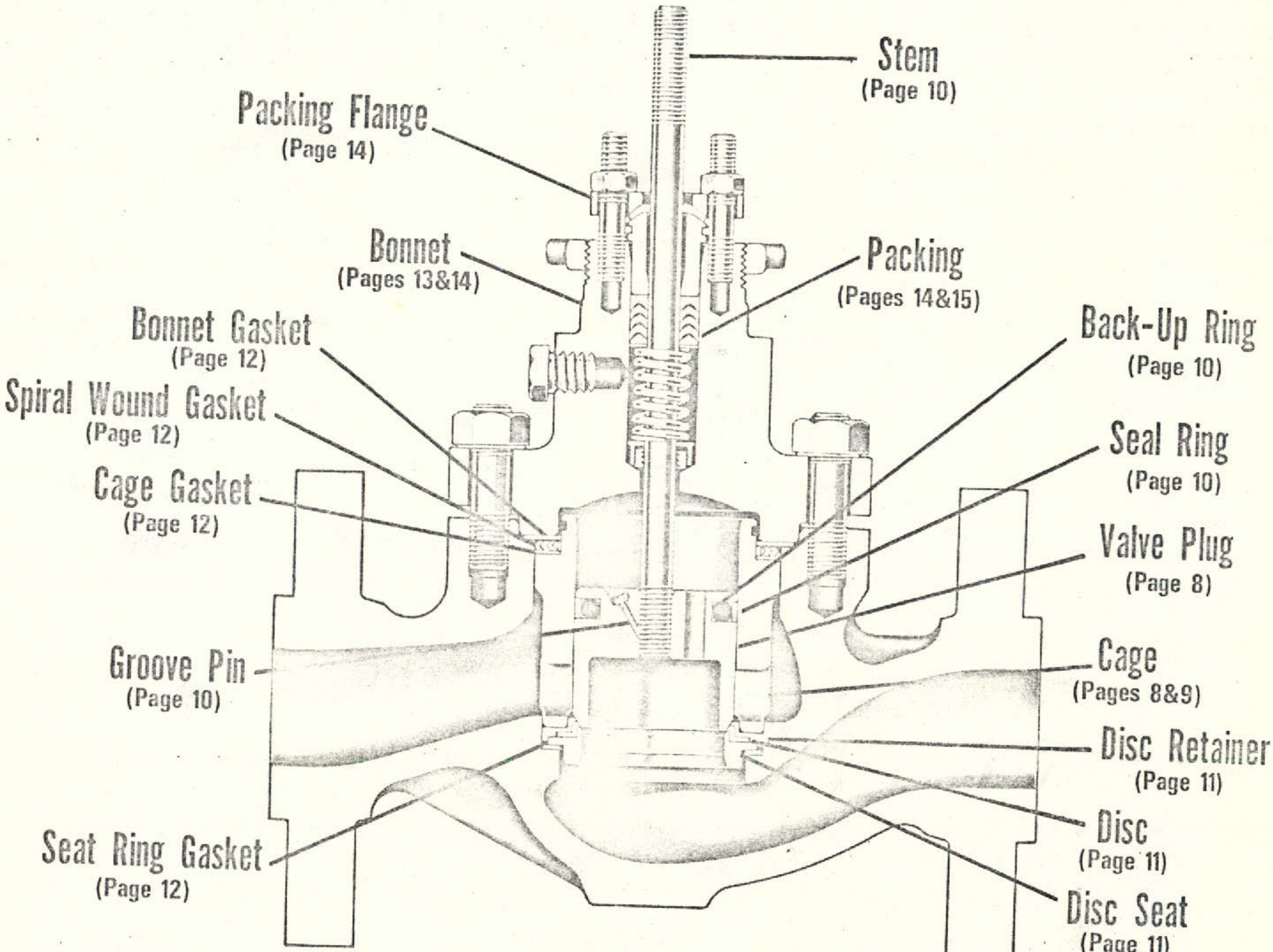


Figure 5. Sectional of Design "ET" shown with Parts Reference Index

Parts Reference

"ET" and "EAT"

KEY 1 Design "ET" Valve Body (Without Drain Plug Tapping)

(Iron)

End Connection		Body Size, Inches								
		1/2	3/4	1	1-1/2	2	2-1/2	3	4	6
Screwed		2U5374 1901	2U5376 1901	2R2748 1901	2R2976 1901	2R3190 1902	...	...	...	...
FF Flg.	125 lb.	...	...	2R2746 1901	2R2974 1901	2R3188 1901	2R3763 1901	2R3409 1902	2R3567 1902	2U5030 1902
RF Flg.	250 lb.	...	...	2R2747 1901	2R2975 1901	2R3189 1902	2R3764 1902	2R3410 1902	2R3568 1902	2U5031 1902

(Steel)

End Connections		Body Size, Inches								
		1/2	3/4	1	1-1/2	2	2-1/2	3	4	6
Screwed		2U5358 2201	2U5360 2201	2R2712 2201	2R2940 2201	2R3154 2201	...	...	...	...
RF Flg.	150 lb.	...	...	2R2703 2201	2R2931 2201	2R3145 2201	2R3729 2201	2R3375 2201	2R3527 2201	2U5012 2201
	300 lb.	...	...	2R2705 2201	2R2933 2201	2R3147 2201	2R3731 2201	2R3377 2201	2R3529 2201	2U5013 2201
	600 lb.	...	...	2R2707 2201	2R2935 2201	2R3149 2201	2R3733 2201	2R3379 2201	2R3533 2201	2U5015 2201
RTJ Flg.	150 lb.	...	...	2R2704 2201	2R2932 2201	2R3146 2201	2R3730 2201	2R3376 2201	2R3528 2201	2U5016 2201
	300 lb.	...	...	2R2708 2201	2R2934 2201	2R3148 2201	2R3732 2201	2R3378 2201	2R3530 2201	2U5017 2201
	600 lb.	...	...	2R2708 2201	2R2936 2201	2R3150 2201	2R3734 2201	2R3380 2201	2R3534 2201	2U5019 2201
Weld End	Socket	2U5370 2201	2U5372 2201	2R2711 2201	2R2939 2201	2R3153 2201	...	...	...	...
	Sch 40	2U5362 2201	2U5364 2201	2R2709 2201	2R2937 2201	2R3151 2201	2R3735 2201	2R3381 2201	2R3535 2201	2U5010 2201
	Sch 80	2U5366 2201	2U5368 2201	2R2710 2201	2R2938 2201	2R3152 2201	2R3736 2201	2R3382 2201	2R3536 2201	2U5011 2201

(316 SST)

End Connections		Body Size, Inches								
		1/2	3/4	1	1-1/2	2	2-1/2	3	4	6
Screwed		2U5358 3309	2U5360 3309	2R2712 3309	2R2940 3309	2R3154 3309	...	...	...	...
RF Flg.	150 lb.	...	...	2R2703 3309	2R2931 3309	2R3145 3309	2R3729 3309	2R3375 3309	2R3527 3309	2U5012 3309
	300 lb.	...	...	2R2705 3309	2R2933 3309	2R3147 3309	2R3731 3309	2R3377 3309	2R3529 3309	2U5013 3309
	600 lb.	...	...	2R2707 3309	2R2935 3309	2R3149 3309	2R3733 3309	2R3379 3309	2R3533 3309	2U5015 3309
RTJ Flg.	150 lb.	...	...	2R2704 3309	2R2932 3309	2R3146 3309	2R3730 3309	2R3376 3309	2R3528 3309	2U5016 3309
	300 lb.	...	...	2R2708 3309	2R2934 3309	2R3148 3309	2R3732 3309	2R3378 3309	2R3530 3309	2U5017 3309
	600 lb.	...	...	2R2708 3309	2R2936 3309	2R3150 3309	2R3734 3309	2R3380 3309	2R3534 3309	2U5019 3309
Weld End	Socket	2U5370 3309	2U5372 3309	2R2711 3309	2R2939 3309	2R3153 3309	...	...	...	...
	Sch 40	2U5362 3309	2U5364 3309	2R2709 3309	2R2937 3309	2R3151 3309	2R3735 3309	2R3381 3309	2R3535 3309	2U5010 3309
	Sch 80	2U5366 3309	2U5368 3309	2R2710 3309	2R2938 3309	2R3152 3309	2R3736 3309	2R3382 3309	2R3536 3309	2U5011 3309

(C-5 Chrome Moly)

End Connection		Body Size, Inches								
		1/2	3/4	1	1-1/2	2	2-1/2	3	4	6
Screwed		2U5358 2902	2U5360 2902	2R2712 2902	2R2940 2902	2R3154 2902	...	...	...	...
RF Flg.	150 lb.	...	...	2R2703 2902	2R2931 2902	2R3145 2902	2R3729 2902	2R3375 2902	2R3527 2902	2U5012 2902
	300 lb.	...	...	2R2705 2902	2R2933 2902	2R3147 2902	2R3731 2902	2R3377 2902	2R3529 2902	2U5013 2902
	600 lb.	...	...	2R2707 2902	2R2935 2902	2R3149 2902	2R3733 2902	2R3379 2902	2R3533 2902	2U5015 2902
RTJ Flg.	150 lb.	...	...	2R2704 2902	2R2932 2902	2R3146 2902	2R3730 2902	2R3376 2902	2R3528 2902	2U5016 2902
	300 lb.	...	...	2R2708 2902	2R2934 2902	2R3148 2902	2R3732 2902	2R3378 2902	2R3530 2902	2U5017 2902
	600 lb.	...	...	2R2708 2902	2R2936 2902	2R3150 2902	2R3734 2902	2R3380 2902	2R3534 2902	2U5019 2902
Weld End	Socket	2U5370 2902	2U5372 2902	2R2711 2902	2R2939 2902	2R3153 2902	...	...	...	...
	Sch 40	2U5362 2902	2U5364 2902	2R2709 2902	2R2937 2902	2R3151 7902	2R3735 2902	2R3381 2902	2R3535 2902	2U5010 2902
	Sch 80	2U5366 2902	2U5368 2902	2R2710 7902	2R2938 2902	2R3152 2902	2R3736 2902	2R3382 2902	2R3536 2902	2U5011 2902

KEY 1 Design "ET" Valve Body (With Drain Plug Tapping)

(Iron)

End Connections		Body Size, Inches								
		1/2	3/4	1	1-1/2	2	2-1/2	3	4	6
Screwed		2U5373 1901	2U5375 1901	2R2874 1901	2R2979 1901	2R3193 1902	. . .	. . .	. . .	. . .
FF Flg.	125 lb.	. . .	. . .	2R2749 1901	2R2977 1901	2R3191 1901	2R3765 1901	2R3411 1902	2R3569 1902	2U5032 1902
RF Flg.	250 lb.	. . .	. . .	2R2750 1901	2R2978 1901	2R3192 1902	2R3766 1902	2R3412 1902	2R3570 1902	2U5033 1902

(Steel)

End Connections		Body Size, Inches								
		1/2	3/4	1	1-1/2	2	2-1/2	3	4	6
Screwed		2U5357 2201	2U5359 2201	2R2722 2201	2R2950 2201	2R3164 2201	. . .	. . .	. . .	. . .
RF Flg.	150 lb.	. . .	. . .	2R2713 2201	2R2941 2201	2R3155 2201	2R3737 2201	2R3383 2201	2R3537 2201	2U5022 2201
	300 lb.	. . .	. . .	2R2715 2201	2R2943 2201	2R3157 2201	2R3739 2201	2R3385 2201	2R3588 2201	2U5023 2201
	600 lb.	. . .	. . .	2R2717 2201	2R2945 2201	2R3159 2201	2R3741 2201	2R3387 2201	2R3592 2201	2U5025 2201
RTJ Flg.	150 lb.	. . .	. . .	2R2714 2201	2R2942 2201	2R3156 2201	2R3738 2201	2R3384 2201	2R3538 2201	2U5026 2201
	300 lb.	. . .	. . .	2R2718 2201	2R2944 2201	2R3158 2201	2R3740 2201	2R3386 2201	2R3539 2201	2U5027 2201
	600 lb.	. . .	. . .	2R2718 2201	2R2946 2201	2R2160 2201	2R3742 2201	2R3388 2201	2R3542 2201	2U5029 2201
Weld End	Socket	2U5369 2201	2U5371 2201	2R2721 2201	2R2949 2201	2R3163 2201	. . .	. . .	. . .	. . .
	Sch 40	2U5361 2201	2U5363 2201	2R2719 2201	2R2947 2201	2R3161 2201	2R3743 2201	2R3389 2201	2R3543 2201	2U5020 2201
	Sch 80	2U5365 2201	2U5367 2201	2R2720 2201	2R2948 2201	2R3162 2201	2R3744 2201	2R3390 2201	2R3544 2201	2U5021 2201

(316 SST)

End Connections		Body Size, Inches								
		1/2	3/4	1	1-1/2	2	2-1/2	3	4	6
Screwed		2U5357 3309	2U5359 3309	2R2722 3309	2R2950 3309	2R3164 3309	. . .	. . .	. . .	. . .
RF Flg.	150 lb.	. . .	. . .	2R2713 3309	2R2941 3309	2R3155 3309	2R3737 3309	2R3383 3309	2R3537 3309	2U5022 3309
	300 lb.	. . .	. . .	2R2715 3309	2R2943 3309	2R3157 3309	2R3739 3309	2R3385 3309	2R3588 3309	2U5023 3309
	600 lb.	. . .	. . .	2R2717 3390	2R2945 3309	2R3159 3309	2R3741 3309	2R3387 3309	2R3592 3309	2U5025 3309
RTJ Flg.	150 lb.	. . .	. . .	2R2714 3309	2R2942 3309	2R3156 3309	2R3738 3309	2R3384 3309	2R3538 3309	2U5026 3309
	300 lb.	. . .	. . .	2R2718 3309	2R2944 3309	2R3158 3309	2R3740 3309	2R3386 3309	2R3539 3309	2U5027 3309
	600 lb.	. . .	. . .	2R2718 3309	2R2946 3309	2R3160 3309	2R3742 3309	2R3388 3309	2R3542 3309	2U5029 3309
Weld End	Socket	2U5369 3309	2U5371 3309	2R2721 3309	2R2949 3309	2R3163 3309	. . .	. . .	. . .	. . .
	Sch 40	2U5361 3309	2U5363 3309	2R2719 3309	2R2947 3309	2R3161 3309	2R3743 3309	2R3389 3309	2R3543 3309	2U5020 3309
	Sch 80	2U5365 3309	2U5367 3309	2R2720 3309	2R2948 3309	2R3162 3309	2R3744 3309	2R3390 3309	2R3544 3309	2U5021 3309

(C-5 Chrome Moly)

End Connections		Body Size, Inches								
		1/2	3/4	1	1-1/2	2	2-1/2	3	4	6
Screwed		2U5357 2902	2U5359 2902	2R2722 2902	2R2950 2902	2R3164 2902	. . .	. . .	. . .	. . .
RF Flg.	150 lb.	. . .	. . .	2R2713 2902	2R2941 2902	2R3155 2902	2R3737 2902	2R3383 2902	2R3537 2902	2U5022 2902
	300 lb.	. . .	. . .	2R2715 2902	2R2943 2902	2R3157 2902	2R3739 2902	2R3385 2902	2R3588 2902	2U5023 2902
	600 lb.	. . .	. . .	2R2717 2902	2R2945 2902	2R3159 2902	2R3741 2902	2R3387 2902	2R3592 2902	2U5025 2902
RTJ Flg.	150 lb.	. . .	. . .	2R2714 2902	2R2942 2902	2R3156 2902	2R3738 2902	2R3384 2902	2R3538 2902	2U5026 2902
	300 lb.	. . .	. . .	2R2718 2902	2R2944 2902	2R3158 2902	2R3740 2902	2R3386 2902	2R3539 2902	2U5027 2902
	600 lb.	. . .	. . .	2R2718 2902	2R2946 2902	2R3160 2902	2R3742 2902	2R3388 2902	2R3542 2902	2U5029 2902
Weld End	Socket	2U5369 2902	2U5371 2902	2R2721 2902	2R2949 2902	2R3163 2902	. . .	. . .	. . .	. . .
	Sch 40	2U5361 2902	2U5363 2902	2R2719 2902	2R2947 2902	2R3161 2902	2R3743 2902	2R3389 2902	2R3543 2902	2U5020 2902
	Sch 80	2U5365 2902	2U5367 2902	2R2720 2902	2R2948 2902	2R3162 2902	2R3744 2902	2R3390 2902	2R3544 2902	2U5021 2902

KEY 1 Design "EAT" Valve Body, Steel

End Connection		Body Size (Inches) 1	2	3	4	6
RF Flg.	150 lb.	2U3793 2201	2U3802 2201	2U3811 2201	2U3820 2201	2U3831 2201
	300 lb.	2U3794 2201	2U3803 2201	2U3812 2201	2U3821 2201	2U3832 2201
	600 lb.	2U3795 2201	2U3804 2201	2U3813 2201	2U3823 2201	2U3834 2201
RTJ Flg.	150 lb.	2U3796 2201	2U3805 2201	2U3814 2201	2U3824 2201	2U3835 2201
	300 lb.	2U3798 2201	2U3806 2201	2U3815 2201	2U3825 2201	2U3836 2201
	600 lb.	2U3798 2201	2U3807 2201	2U3816 2201	2U3827 2201	2U3838 2201
Welded	Socket	2U6421 2201	2U6422 2201	. . .	. . .	. . .
	Sch 40	2U3799 2201	2U3808 2201	2U3817 2201	2U3828 2201	2U3839 2201
	Sch 80	2U3800 2201	2U3809 2201	2U3818 2201	2U2829 2201	2U3840 2201

KEY 2.2* Valve Plug

"ET" Body Size (Inches)	VSC (Inches)	416 SST	316 SST	"EAT" Body Size (Inches)
1/2, 3/4 1	3/8 1/2	1V6571 4617 1V6572 4617	1V6571 3507 1V6572 3507	1
1-1/2	3/8 1/2	1V6573 4617 1V6574 4617	1V6573 3507 1V6574 3507	2
1-1/2 x 1	3/8	1V6571 4617	1V6571 3507	2 x 1
2, 3 x 2	1/2 3/4	1V6575 4617 1V6576 4617	1V6575 3507 1V6576 3507	4 x 2
2 x 1	3/8	1V6571 4617	1V6571 3507	. . .
2-1/2, 4 x 2-1/2	1/2 3/4	1V6577 4617 1V6578 4617	1V6577 3507 1V6578 3507	3 & 6x2-1/2
[illegible]2 x 1-1/2	3/8	1V6573 4617	1V6573 3507	3 x 1-1/2
3	1/2 3/4	1V6579 4617 1V6580 4617	1V6579 3507 1V6580 3507	4
4	1/2 3/4 1	1V6581 4617 1V6582 4617 1V6583 4617	1V6581 3507 1V6582 3507 1V6583 3507	6
6	3/4 1 1-1/4	1V6584 4617 1V6585 4617 1V6586 4617	1V6584 3507 1V6585 3507 1V6586 3507	. . .
6 x 4	3/4	1V6582 4617	1V6582 3507	. . .

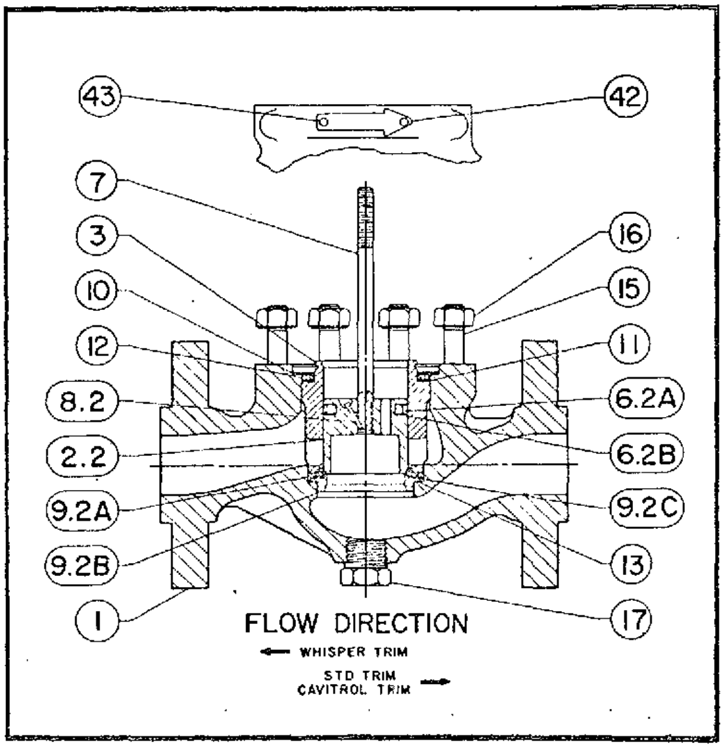


Figure 6. Design "ET" with full size trim

KEY 3 Cage (Equal Percentage & Quick Opening)

"ET" Body Size (Inches)	Equal Percentage: 17-4PH SST, Hardened	Equal Percentage: 316 SST Nickel Coated	Equal Percentage: 316 SST Chrome Plated	Quick Opening: 17-4PH SST Hardened	Quick Opening: 316 SST Nickel Coated	Quick Opening: 316 SST Chrome Plated	Quick Opening: Cast Iron Nickel Coated	"EAT" Body Size (Inches)
1/2, 3/4, 1 1-1/2 x 1, 2 x 1	2U2153 3327	2U7408 4893	2U6913 4610	2U2150 3327	2U7403 4893	2U6911 4610	2U7403 4924	1, 2 x 1
1-1/2, 2-1/2 x 1-1/2	2U2195 3327	2U7409 4893	2U6919 4610	2U2192 3327	2U7254 4893	2U6918 4610	2U7254 4924	2, 3 x 1-1/2
2, 3 x 2	2U2237 3327	2U7410 4893	2U6922 4610	2U2234 3327	2U7404 4893	2U6921 4610	2U7404 4924	4 x 2
2-1/2, 4 x 2-1/2	2U2279 3327	2U7411 4893	2U6925 4610	2U2276 3327	2U7405 4893	2U6924 4610	2U7405 4924	3, 6 x 2-1/2
3	2U2321 3327	2U7412 4893	2U6928 4610	2U2318 3327	2U7406 4893	2U6927 4610	2U7406 4924	4
4	2U2363 3327	2U7413 4893	2U6931 4610	2U2360 3327	2U7407 4893	2U6930 4610	2U7407 4924	6
6	2U5059 3327	2U8067 4893	2U6937 4610	2U5063 3327	2U8069 4893	2U6935 4610	2U8069 4924	. . .
6 x 4	2V3723 3327	2V3713 4893	2V3716 4610	2V3722 3327	2V3714 4893	2V3717 4610	. . .	. . .

*Recommended Spare Part

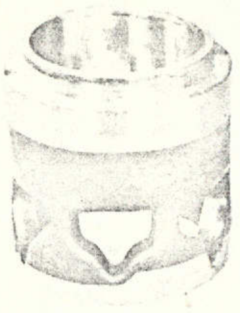


Fig. 7. Equal Percentage Cage

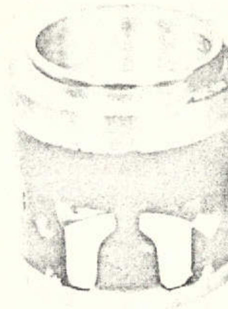


Fig. 8. Linear Cage

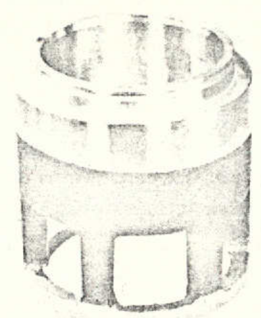


Fig. 9. Quick Opening Cage

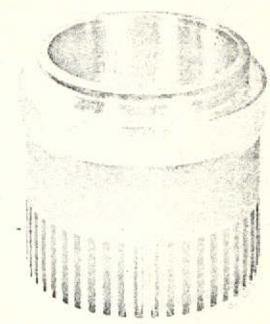


Fig. 10. Whisper Trim™ Cage

KEY 3 Cage (Linear & Whisper Trim)

"ET" Body Size (Inches)	Linear			Whisper			"EAT" Body Size (Inches)
	17-4PH SST, Hardened	316 SST		17-4PH SST, Hardened	316 SST		
		Nickel Coated	Chrome Plated		Nickel Coated	Chrome Plated	
1/2, 3/4, 1, 1-1/2 x 1, 2 x 1	2U2156 3327	2U7414 4893	2U6917 4610	2V5023 3327	2V5030 4893	2V5037 4610	1, 2 x 1
1-1/2, 2-1/2x1-1/2	2U2198 3327	2U7415 4893	2U6920 4610	2V5024 3327	2V5031 4893	2V5038 4610	2, 3x1-1/2
2, 3 x 2	2U2240 3327	2U7416 4893	2U6923 4610	2V5025 3327	2V5032 4893	2V5039 4610	4 x 2
2-1/2, 4 x 2-1/2	2U2282 3327	2U7417 4893	2U6926 4610	2V5026 3327	2V5033 4893	2V5040 4610	3, 6x2-1/2
3	2U2324 3327	2U7418 4893	2U6929 4610	2V5027 3327	2V5034 4893	2V5041 4610	4
4	2U2366 3327	2U7419 4893	2U6933 4610	2V5028 3327	2V5035 4893	2V5042 4610	6
6	2U5061 3327	2U8068 4893	2U6938 4610	2V5029 3327	2V5036 4893	2V5043 4610	...
6 x 4	2V3718 3327	2V3712 4893	2V3715 4610	...	...	...	...

Figure 11. Cavitrol® Cage

KEY 3 Cage (Cavitrol)

"ET" Body Size (Inches)	Cavitrol			"EAT" Body Size (Inches)
	17-4PH SST, Hardened	316 SST		
		Nickel Coated	Chrome Plated	
1/2, 3/4, 1, 1-1/2 x 1, 2 x 1	3V8933 3327	3V8933 3309	3V8935 5002	1, 2 x 1
1-1/2,2-1/2x1-1/2	3V8937 3327	3V8937 3309	3V8939 5002	2, 3 x1-1/2
2, 3 x 2	3V8941 3327	3V8941 3309	3V8943 5002	4 x 2
2-1/2, 4 x 2-1/2	3V8945 3327	3V8945 3309	3V8947 5002	3,6 x2-1/2
3	3V8949 3333	3V8949 3309	3V8951 5002	4
4	3V8953 3333	3V8953 3309	3V8955 5002	6
6	3V8957 3327	3V8957 3309	3V8959 5002	...

KEY 4 Cage Adaptor

"ET" Body Size (Inches)	Body Material			"EAT" Body Size (Inches)
	Iron & Steel	316 SST	C-5 Chrome Moly	
1-1/2 x 1	1U2218 2449	1U2218 3507	1U2218 3507	2 x 1
2 x 1	1U1207 2449	1U1207 3507	1U1207 3507	...
2-1/2 x 1-1/2	1U2302 2449	1U2302 3507	1U2302 3507	3 x 1-1/2
3 x 2	1U1246 2201	1U1246 3309	1U1246 2902	4 x 2
4 x 2-1/2	1U1251 2201	1U1251 3309	1U1251 2902	6 x 2-1/2
6 x 4	Not Req'd.	Not Req'd.	Not Req'd.	...

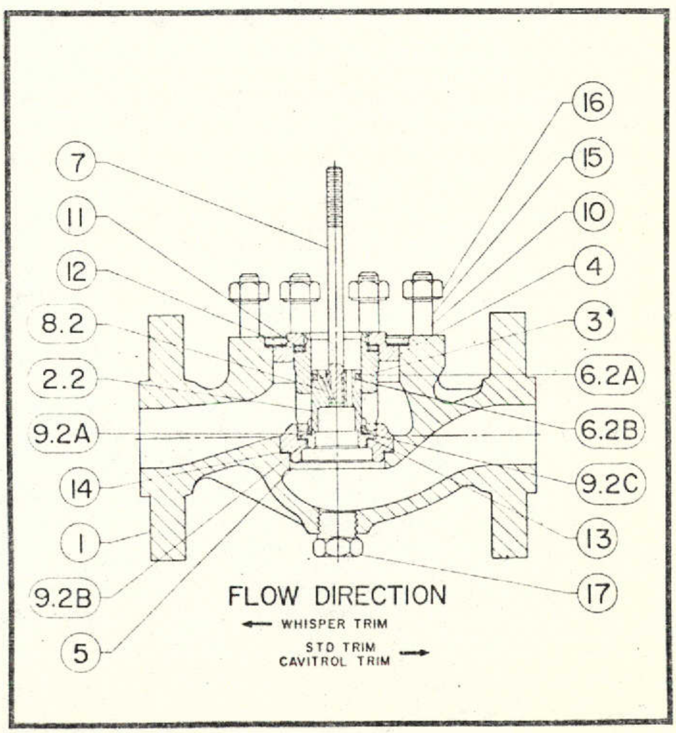


Figure 12. Design "ET" with restricted trim

KEY 5 Seat Ring Adaptor

"ET" Body Size (Inches)	Body Material			"EAT" Body Size (Inches)
	Iron & Steel	316 SST	C-5 Chrome Moly	
1-[illegible] 1	Not Req'd	Not Req'd	Not Req'd	2 x 1
2 x 1	1U2262 2449	1U2262 3507	1U2262 3507	. . .
2-1/2x1-1/2	1U2304 2449	1U2304 3507	1U2304 3507	3 x 1-1/2
3 x 2	1U2346 2201	1U2346 3309	1U2346 2902	4 x 2
4 x 2-1/2	1U2396 2201	1U2396 3309	1U2396 2902	6 x 2-1/2
6 x 4	Not Req'd	Not Req'd	Not Req'd	. . .

KEY 8. 2* Groove Pin, 316 SST

3/8" VSC 1V3226 3507
1/2" 1V3227 3507
3/4" 1V3260 3507
1" & 1-1/4" 1V3340 3507

KEY 6* Piston Ring

"ET" Body Size (Inches)	6.2A	6.2B		"EAT" Body Size (Inches)
	Seal Ring TFE Carbon Filled	Back-up Ring		
		0° to 400° F	-40° & 200° F	
		Viton (std)	Syn. Rubber	
1/2,3/4,1 1-1/2 x 1 2 x 1	1V6591 0509	1V6590 0529	1V6590 0305	1, 2 x 1
1-1/2, 2-1/2x 1-1/2	1V6593 0509	1V6592 0529	1V6592 0305	2, 3 x 1-1/2
2, 3 x 2	1V5508 0509	1V5507 0529	1V5507 0305	4 x 2
2-1/2, 4 x 2-1/2	1V6595 0509	1V6594 0529	1V6594 0305	3, 6 x 2-1/2
3	1V6597 0509	1V6596 0529	1V6596 0305	4
4, 6 x 4	1V6599 0509	1V6598 0529	1V6598 0305	6
6	1V6601 0509	1V6600 0529	1V6600 0305	. . .

KEY 7* Valve Plug Stem, 316 SST

Design "ET"

Body Size, (Inches)	Stem Size, (Inches)	VSC (Inches)	Plain		Extension Style 1		Extension Style 2		Bellows Seal	
			Stem Length, Inches	Part Number	Stem Length, Inches	Part Number	Stem Length, Inches	Part Number	Stem Length, Inches	Part Number
1/2, 3/4, 1	3/8	3/8	8-7/8	1U3888 3516	12-1/4	1U2177 3516	15-15/16	1U2178 3516	8-3/4	1R2885 3516
	1/2	1/2	11-13/16	1U3890 3516	15-13/16	1U2179 3516	18-5/8	1U2180 3516	11-1/4	1R2888 3516
1-1/2	3/8	3/8	8-7/8	1U3888 3516	12-1/4	1U2177 3516	15-15/16	1U2178 3516	8-3/4	1R2885 3516
	1/2	1/2	11-3/16	1U3890 3516	15-13/16	1U2179 3516	18-5/8	1U2180 3516	11-1/4	1R2888 3516
2	1/2	1/2	12-1/4	1K5869 3516	16-1/4	1U2263 3516	24-3/16	1U2264 3516	12-3/8	1U3892 3516
	3/4	3/4	14-5/8	1U2265 3516	19	1L4001 3516	. . .	. . .	. . .	. . .
2-1/2	1/2	1/2	12-5/8	1U2305 3516	16-9/16	1U2306 3516	24-9/16	1U2307 3516	12-3/8	1U3892 3516
	3/4	3/4	15	1U2308 3516	19-3/8	1K5880 3516	. . .	. . .	. . .	. . .
[illegible]	1/2	1/2	12-5/8	1U2305 3516	16-9/16	1U2306 3516	24-9/16	1U2307 3516	12-3/8	1U3892 3516
	3/4	3/4	15	1U2308 3516	19-3/8	1K5880 3516	. . .	. . .	. . .	. . .
4	1/2	1/2	12-5/8	1U2305 3516	16-9/16	1U2306 3516	24-9/16	1U2307 3516	12-7/8	2R3693 3516
	3/4	3/4	15-1/2	1K5877 3516	19-7/8	1K5881 3516	27-5/16	1U2400 3516	15-1/4	1K5876 3516
	1 (b.)	1	19-1/4	1U2175 3516	. . .	. . .	. . .	. . .	. . .	. . .
	1 (a.)	1	18-1/4	1K7590 3516	. . .	. . .	. . .	. . .	. . .	. . .
6	3/4	3/4	15-7/8	1L9964 3516	20-1/8	1U5071 3516	27-1/2	1U5244 3516	15-1/4	1K5876 3516
	1	1	19-5/8	1N7047 3516	24-13/16	1K7851 3516	. . .	. . .	. . .	. . .
	1-1/4	1-1/4	20	1K4154 3516	25-3/16	1R5624 3516	. . .	. . .	. . .	. . .
BODIES WITH RESTRICTED TRIM										
1-1/2 x 1	3/8	3/8	9-3/8	1U2236 3516	12-3/4	1U2270 3516	16-7/16	1U2272 3516	8-3/4	1R2885 3516
	1/2		12-1/16	1U7400 3516	16-1/16	1U7401 3516	18-15/16	1U7402 3516	11-1/4	1R2888 3516
2 x 1	1/2	3/8	11-5/8	1U5309 3516	15-5/8	1U5310 3516	23-5/8	1U5311 3516	12	1U3891 3516
2-1/2x1-1/2	1/2	3/8	11-5/8	1U5309 3516	15-5/8	1U5310 3516	23-5/8	1U5311 3516	11-5/8	1U3889 3516
3 x 2	1/2	1/2	12-1/4	1K5869 3516	16-1/4	1U2263 3516	24-3/16	1U2264 3516	12	1U3891 3516
	3/4	3/4	14-5/8	1U2265 3516	19	1L4001 3516	. . .	. . .	. . .	. . .
4 x 2-1/2	1/2	1/2	12-5/8	1U2305 3516	16-9/16	1U2306 3516	24-9/16	1U2307 3516	12-7/8	2R3693 3516
	3/4	3/4	15	1U2308 3516	19-3/8	1K5880 3516	26-13/16	1U2323 3516	14-3/4	1U3894 3516
6 x 4	3/4	3/4	15-7/8	1L9964 3516	20-1/8	1U5071 3516	27-1/2	1U5244 3516	15-1/4	1K5876 3516

Design "EAT"

Body Size, (Inches)	Stem Size, (Inches)	VSC (Inches)	Plain Stem Length, Inches	Plain Part Number	Style 1 Stem Length, Inches	Style 1 Part Number	Style 2 Stem Length, Inches	Style 2 Part Number	Bellows Seal Stem Length, Inches	Bellows Seal Part Number
1 & 2	3/8	3/8	8-7/8	1U3888 3516	12-1/4	1U2177 3516	15-15/16	1U2178 3516	8-3/4	1R2885 3516
	1/2	1/2	11-13/16	1U3890 3516	15-13/16	1U2179 3516	18-5/8	1U2180 3516	11-1/4	1R2888 3516
3 & 4	1/2	1/2	12-5/8	1U2305 3516	16-9/16	1U2306 3516	24-9/16	1U2307 3516	12-3/8	1U3892 3516
	3/4	3/4	15	1U2308 3516	19-3/8	1K5880 3516	. . .	. . .	. . .	. . .
6	1/2	1/2	12-5/8	1U2305 3516	16-9/16	1U2306 3516	24-9/16	1U2307 3516	12-7/8	2R3693 3516
	3/4	3/4	15-1/2	1K5877 3516	19-7/8	1K5881 3516	27-5/16	1U2400 3516	15-1/4	1K5876 3516
	1	1	19-1/4	1U2175 3516	. . .	. . .	. . .	. . .	. . .	. . .
			18-1/4	1K7590 3516	. . .	. . .	. . .	. . .	. . .	. . .
	1-1/4	1-1/4	19-1/2	1K7351 3516	. . .	. . .	. . .	. . .	. . .	. . .
BODIES WITH RESTRICTED TRIM										
[illegible]	3/8	3/8	9-3/8	1U2236 3516	12-3/4	1U2270 3516	16-7/16	1U2272 3516	8-3/4	1R2885 3516
	1/2	3/8	12-1/16	1U7400 3516	16-1/16	1U7401 3516	18-15/16	1U7402 3516	11-1/4	1R2888 3516
3 x 1-1/2	1/2	3/8	11-5/8	1U5309 3516	15-5/8	1U5310 3516	23-5/8	1U5311 3516	11-5/8	1U3889 3516
4 x 2	1/2	1/2	12-1/4	1K5869 3516	16-1/4	1U2263 3516	24-3/16	1U2264 3516	12	1U3891 3516
	3/4	3/4	14-5/8	1U2265 3516	19	1L4001 3516	. . .	. . .	. . .	. . .
6 x 2-1/2	1/2	1/2	12-5/8	1U2305 3516	16-9/16	1U2306 3516	24-9/16	1U2307 3516	12-7/8	2R3693 3516
	3/4	3/4	15	1U2308 3516	19-3/8	1K5880 3516	26-13/16	1U2323 3516	14-3/4	1U3894 3516

a. Type 667
b. Type 657 & Series 470

* Recommended Spare Part

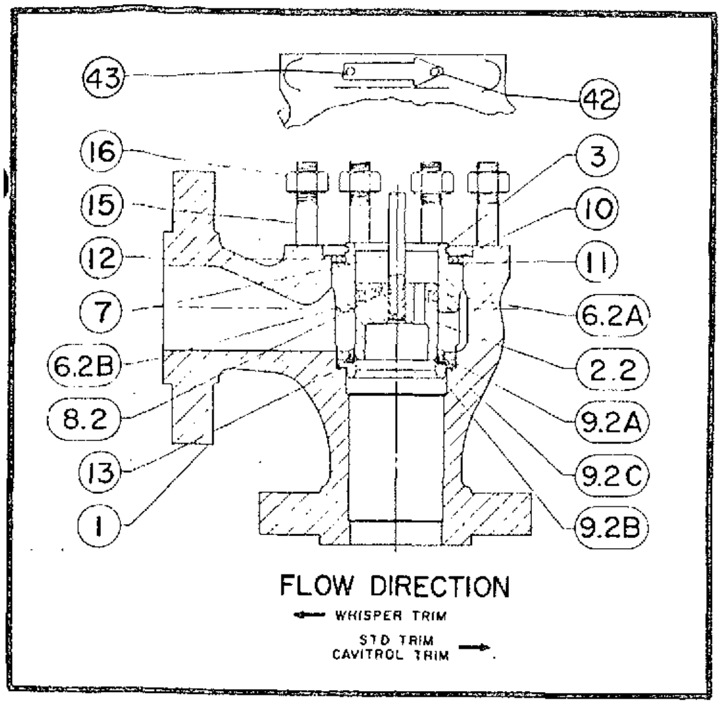


Figure 13. Design "EAT" with full size trim

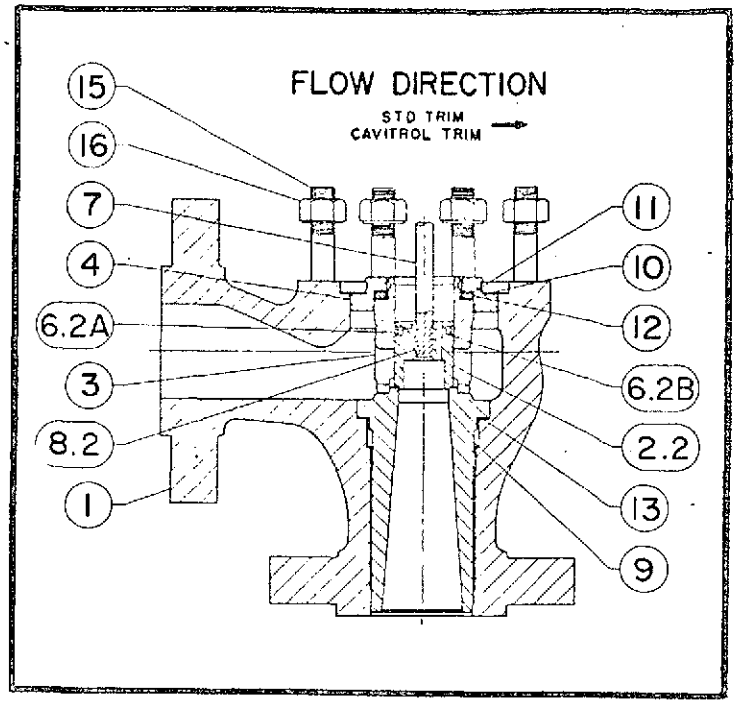


Figure 14. Design "EAT" with restricted trim and liner

KEY 9* Seat Ring

"ET" Body Size (Inches)	9.1	9.2A	9.2B	9.2C	"EAT" Body Size (Inches)
	Metal Seat (416 SST)	Composition Seat			
		Disc Retainer (316 SST)	Disc Seat (316 SST)	Disc (TFE) -70° to 350°F	
1/2, 3/4, 1, 2x1	1U2225 4617	1V7100 3507	1V7102 3507	1V7101 0624	1
1-1/2, 2-1/2 x 1-1/2	1U2219 4617	1V7103 3507	1V7105 3507	1V7104 0624	2, 3x1-1/2
1-1/2 x 1	1U2220 4617	1V7121 3507	1V7122 3507	1V7101 0624	2 x 1
2	1U2226 4617	1V7108 3507	1V7106 3507	1V7107 0624	4 x 2
2-1/2, 4 x 2-1/2	1U2227 4617	1V7109 3507	1V7111 3507	1V7110 0624	3, 6x2-1/2
3	1U2228 4617	1V7112 3507	1V7114 3507	1V7113 0624	4
4	1U2229 4617	1V7115 3309	1V7117 3309	1V7116 0624	6
6	1U5081 4617	1V7118 3309	1V7120 3309	1V7119 0624	...
6 x 4	2V3719 4619	1V7123 3309	2V7124 3309	1V7116 0624	...

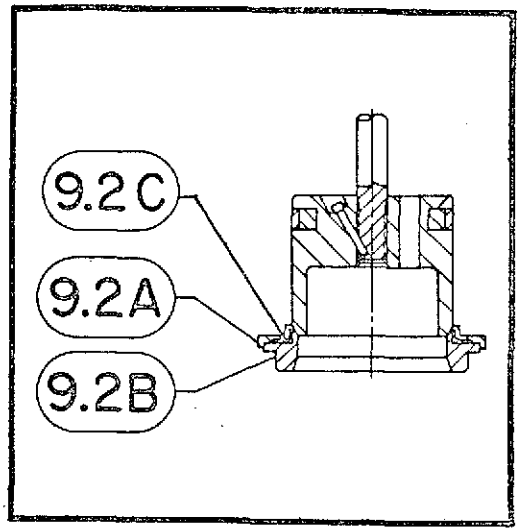


Figure 15. Sectional of Soft Seat

KEY 9* Design "EAT" Seat and Liner, 416 SST

End Connection		EAT Body Size (Inches)								
		1	2 x 1	2	3	3 x 1-1/2	4	4 x 2	6	6 x 2-1/2
RF Flg.	150 lb.	1V5601 4617	1V5606 4617	1V5603 4617	2V5613 4617	2V5609 4617	2V5622 4617	2V5618 4617	2V5631 4617	2V5626 4617
	300 lb.	1U3842 4617	1U3851 4617	1U3843 4617	2U3845 4617	2U3853 4617	2U3847 4617	2U3855 4617	2U3849 4617	2U3857 4617
	600 lb.	1V5602 4617	1V3876 4617	1V5605 4617	2V5616 4617	2V5459 4617	2V5619 4617	2V5612 4617	2V5628 4617	2V5623 4617
RTJ Flg.	150 lb.	1U3842 4617	1U3851 4617	1U3843 4617	2V5614 4617	2V5610 4617	2U3847 4617	2U3855 4617	2V5632 4617	2V5627 4617
	300 lb.	1V5602 4617	1V5607 4617	1V5604 4617	2V5615 4617	2V5611 4617	2V5621 4617	2V5617 4617	2V5630 4617	2V5625 4617
	600 lb.	1V5602 4617	1V3876 4617	1V5605 4617	2V5616 4617	2V5459 4617	2V5619 4617	2V5612 4617	2V5628 4617	2V5623 4617
Weld End	Socket	1V5601 4617	1V5606 4617	1V5603 4617	...	...	...	...	...	...
	Sch 40	1V5601 4617	1V5606 4617	1V5603 4617	2V5613 4617	2V5609 4617	2V5622 4617	2V5618 4617	2U3849 4617	2U3857 4617
	Sch 80	1V5601 4617	1V5606 4617	1V5603 4617	2V5613 4617	2V5609 4617	2V5622 4617	2V5618 4617	2U3849 4617	2U3857 4617

*Recommended Spare Part

KEYS 10*, 11*, 12*, 13* and 14* Gaskets

(Use With Metal Seats)

"ET" Body Size, (Inches)	Key 10 Bonnet Asbestos	Key 11 Cage, Asbestos	Key 12 Spiral Wound, 316L SST-Asbestos	Key 13 Seat Ring, Asbestos	Key 14 Seat Ring Adaptor, Asbestos	"EAT" Body Size (Inches)
1/2, 3/4, 1	1R2859 0402	1R2861 0402	1R2860 9928	1R2862 0402	Not Req'd	1
1-1/2	1R3101 0402	1R3100 0402	1R3099 9928	1R3098 0402	Not Req'd	2
1-1/2 x 1 (b.)	1R3101 0402	1R2861 0402 (a.)	1R2860 9928	1R3098 0402	Not Req'd	2 x 1
2	1R3299 0402	1R3298 0402	1R3297 9928	1R3296 0402	Not Req'd	. . .
2 x 1	1R3299 0402	1R2861 0402 (a.)	1R2860 9928	1R2862 0402	1R3296 0402	. . .
2-1/2	1R3847 0402	1R3846 0402	1R3845 9928	1R3844 0402	Not Req'd	3
2-1/2 x 1-1/2	1R3847 0402	1R3100 0402 (a.)	1R3099 9928	1R3098 0402	1R3844 0402	3 x 1-1/2
3	1R3484 0402	1R3483 0402	1R3482 9928	1R3481 0402	Not Req'd	4
3 x 2	1R3484 0402	1R3298 0402 (a.)	1R3297 9928	1R3296 0402	1R3481 0402	4 x 2
4	1R3724 0402	1R3723 0402	1R3722 9928	1J5047 0402	Not Req'd	6
4 x 2-1/2	1R3724 0402	1R3846 0402 (a.)	1R3845 9928	1R3844 0402	1J5047 0402	6 x 2-1/2
6 & 6 x 4	1U5081 0402	1U5083 0402	1U5085 9928	1U5086 0402	Not Req'd	. . .

(Use With Soft Seats)

"ET" Body Size (Inches)	Key 10 Bonnet Asbestos	Key 11 Cage, Asbestos	Key 12 Spiral Wound, 316L SST-Asbestos	Key 13 Seat Ring, Asbestos	Key 14 Seat Ring Adaptor, Asbestos	"EAT" Body Size, (Inches)
1/2, 3/4, 1	1R2859 0430	1R2861 0430	1R2860 9928	1R2862 0430	Not Req'd	1
1-1/2	1R3101 0430	1R3100 0430	1R3099 9928	1R3098 0430	Not Req'd	2
1-1/2 x 1 (b.)	1R3101 0430	1R2861 0430 (a.)	1R2860 9928	1R3098 0430	Not Req'd	2 x 1
2	1R3299 0430	1R3298 0430	1R3297 9928	1R3296 0430	Not Req'd	. . .
2 x 1	1R3299 0430	1R2861 0430 (a.)	1R2860 9928	1R2862 0430	1R3296 0430	. . .
2-1/2	1R3847 0430	1R3846 0430	1R3845 9928	1R3844 0430	Not Req'd	3
2-1/2 x 1-1/2	1R3847 0430	1R3100 0430 (a.)	1R3099 9928	1R3098 0430	1R3844 0430	3 x 1-1/2
3	1R3484 0430	1R3483 0430	1R3482 9928	1R3481 0430	Not Req'd	4
3 x 2	1R3484 0430	1R3298 0430 (a.)	1R3297 9928	1R3296 0430	1R3481 0430	4 x 2
4	1R3724 0430	1R3723 0430	1R3722 9928	1J5047 0430	Not Req'd	6
4 x 2-1/2	1R3724 0430	1R3846 0430 (a.)	1R3845 9928	1R3844 0430	1J5047 0430	6 x 2-1/2
6, 6 x 4	1U5081 0430	1U5083 0430	1U5085 9928	1U5086 0430	Not Req'd	. . .

Footnote: (a.) 2 cage gaskets required with restricted trim.
(b.) Requires another gasket, 1U2152 0430 (Key 44), between cage adaptor and body.

Gasket Sets

"ET" Body Size (Inches)	Keys Included	Metal Seat	Composition Seat	"EAT" Body Size (Inches)
1/2, 3/4, 1	10, 11, 12, 13	1R2860 X001	1R2860 X003	1
1-1/2	10, 11, 12, 13	1R3099 X001	1R3099 X003	. . .
1-1/2 x 1 †	10, 11, 12, 13, 44	1R2860 X004	1R2860 X006	2 x 1
2	10, 11, 12, 13	1R3297 X001	1R3297 X003	. . .
2 x 1 †	10, 11, 12, 13, 14	1R2860 X007	1R2860 X009	2
2-1/2	10, 11, 12, 13	1R3845 X001	1R3845 X003	3
2-1/2 x 1-1/2 †	10, 11, 12, 13, 14	1R3099 X004	1R3099 X006	3 x 1-1/2
3	10, 11, 12, 13	1R3482 X001	1R3482 X003	4
3 x 2 †	10, 11, 12, 13, 14	1R3297 X004	1R3297 X006	4 x 2
4	10, 11, 12, 13	1R3722 X001	1R3722 X003	6
4 x 2-1/2 †	10, 11, 12, 13, 14	1R3845 X004	1R3845 X006	6 x 2-1/2
6, 6 x 4	10, 11, 12, 13	1U5085 X001	1U5085 X003	. . .

† The set includes two of the same gasket where req'd.

KEY 17 Body Drain Plug, 3/4 NPT

17 Body Drain Plug, 3/4" NPT
Steel, for iron, steel and chrome moly bodies 1A7715 2466
316 SST for 316 SST body 1A7715 3507

KEY 20 Pipe Plug

20 Pipe Plug, for Extension and Bellows Seal Bonnets Only, 1/2" NPT
Steel, for steel and chrome moly bodies 1A3692 2466
316 SST for 316 SST body 1A3692 3507

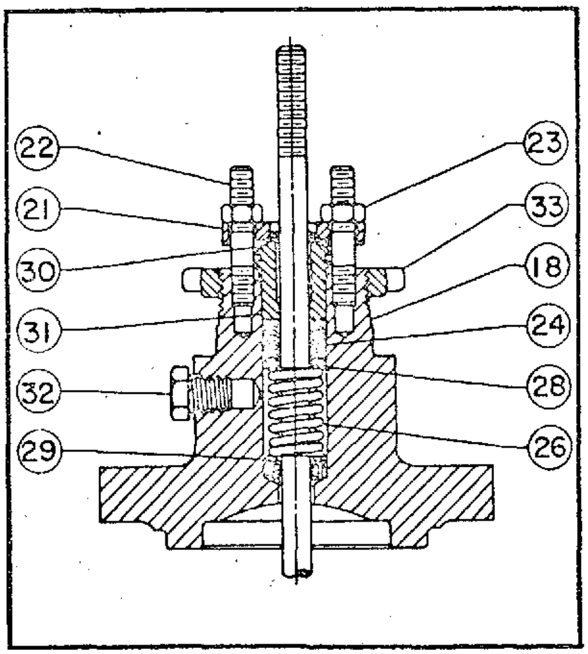


Figure 16. Standard Bonnet

* Recommended Spare Part

KEYS 15 and 16 Body Stud Bolts and Nuts (Cap Screws in Iron Bodies)

"ET" Body Size, (Inches)	Stud Bolt and Cap Screw Size, (Inches)	Number Req'd	Iron Bodies	Steel Bodies			"EAT" Body Size, (Inches)
			Key 15	Key 15	Key 15	Key 16	
			Cap Screws For Plain Bonnet	Studs For Plain and Extension Bonnets	Studs For Bellows Seal Bonnet	Nuts	
1/2, 3/4, 1	9/16-12	4	1R2811 2405	1R2848 3101	1R3873 3101	1C3306 2407	1
1-1/2	1/2-13	8	1A4533 2405	1K2429 3101	1R3089 3101	1A3772 2407	2
1-1/2 x 1	1/2-13	8	1A3616 2405	1U2352 3101	1U2351 3101	1A3772 2407	2 x 1
2, 2 x 1	1/2-13	8	1A4533 2405	1K2429 3101	1R3361 3101	1A3772 2407	. . . .
2-1/2, 2-1/2 x 1-1/2	9/16-12	8	1R2811 2405	1R2848 3101	1R3873 3101	1C3306 2407	3, 3 x 1-1/2
3, 3 x 2	5/8 11	8	1A4541 2405	1R3506 3101	1R3508 3101	1A3760 2407	4, 4 x 2
4, 4 x 2-1/2	3/4-10	8	1A4402 2405	1R3690 3101	1P5902 3101	1A3520 2407	6, 6 x 2-1/2
6 & 6 x 4	1-8	12	1U5131 2405	1A3656 3101	1U5088 3101	1A4409 2407	. . . .

KEY 18 Bonnet (Same Material as Body)

(Steel)

"ET" Body Size, (Inches)	Boss Size, (Inches)	Plain	Extension				Bellows Seal	"EAT" Body Size, (Inches)
			Style 1		Style 2			
			Tapped Boss	Untapped Boss	Tapped Boss	Untapped Boss	Tapped Boss	
1/2, 3/4, 1	2-1/8	2R2814 2302	2R2826 2201	2R2736 2201	3R2865 2201	3R2884 2201	3R2893 2201	1
	2-13/16	2R2813 2201	2R2827 2201	2R2852 2201	3R2866 2201	3R2922 2201	3R2894 2201	
1-1/2	2-1/8	2R3107 2302	2R3318 2201	2R3124 2201	3R3122 2201	3R3059 2201	3R3126 2201	2
	2-13/16	2R3106 2201	2R3119 2201	2R3127 2201	3R3123 2201	3R3060 2201	3R3128 2201	
2	2-13/16	2R3305 2302	2R3315 2201	2R3321 2201	3R3317 2201	3R3322 2201	3R3319 2201	. . .
	3-9/16	2R3304 2201	. . .	. . .	. . .	. . .	. . .	
2-1/2	2-13/16	2R3853 2302	2R3860 2201	2R3861 2201	3R3864 2201	3R3865 2201	3R3867 2201	3
	3-9/16	2R3852 2302	2R3862 2201	2R3863 2201	. . .	. . .	. . .	
3	2-13/16	2R3490 2302	2R3497 2201	2R3498 2201	3R3502 2201	3R3503 2201	3R3504 2201	4
	3-9/16	2R3489 2201	2R3499 2201	2R3500 2201	. . .	. . .	. . .	
4	2-13/16	2R3669 2302	2R3200 2201	2R3678 2201	3R3685 2201	3R3684 2201	3R3688 2201	6
	3- 9/16	2R3667 2201	2R3202 2201	2R3680 2201	3R3687 2201	3R3686 2201	3R3689 2201	
	5	2R3668 2201	. . .	. . .	. . .	. . .	. . .	
6	3- 9/16	3U5094 2302	3U5105 2201	3U5104 2201	2U5112 2201	2U5113 2201	2U5114 2201	. . .
	5 (a.)	2U5098 2201	3U5107 2201	3U5108 2201	. . .	. . .	. . .	
	5 (b.)	2U5099 2201	3U5109 2201	3U5110 2201	. . .	. . .	. . .	

(316 SST)

"ET" Body Size, (Inches)	Boss Size, (Inches)	Plain	Extension				Bellows Seat	"EAT" Body Size, (Inches)
			Style 1		Style 2			
			Tapped Boss	Untapped Boss	Tapped Boss	Untapped Boss	Tapped Boss	
1/2, 3/4, 1	2-1/8	2R2812 3309	2R2826 3309	2R2736 3309	3R2865 3309	3R2884 3309	3R2893 3309	1
	2-13/16	2R2813 3309	2R2827 3309	2R2852 3309	3R2866 3309	3R2922 3309	3R2894 3309	
1-1/2	2-1/8	2R3105 3309	2R3318 3309	2R3124 3309	3R3122 3309	3R3059 3309	3R3126 3309	2
	2-13/16	2R3106 3309	2R3119 3309	2R3127 3309	3R3123 3309	3R3060 3309	3R3128 3309	
2	2-13/16	2R3303 3309	2R3315 3309	2R3321 3309	3R3317 3309	3R3322 3309	3R3319 3309	. . .
	3-9/16	2R3304 3309	. . .	. . .	. . .	. . .	. . .	
2-1/2	2-13/16	2R3851 3309	2R3860 3309	2R3861 3309	3R3864 3309	3R3865 3309	3R3867 3309	3
	3-9/16	2R3852 3309	2R3862 3309	2R3863 3309	. . .	. . .	. . .	
3	2-13/16	2R3488 3309	2R3497 3309	2R3498 3309	3R3502 3309	3R3503 3309	3R3504 3309	4
	3-9/16	2R3489 3309	2R3499 3309	2R3500 3309	. . .	. . .	. . .	
4	2-13/16	2R3666 3309	2R3200 3309	2R3678 3309	3R3685 3309	3R3684 3309	3R3688 3309	6
	3-9/16	2R3667 3309	2R3202 3309	2R3680 3309	3R3687 3309	3R3686 3309	3R3689 3309	
	5	2R3668 3309	. . .	. . .	. . .	. . .	. . .	
6	3-9/16	3U5092 3309	3U5105 3309	3U5104 3309	2U5112 3309	2U5113 3309	2U5114 3309	. . .
	5 (a.)	2U5098 3309	3U5107 3309	3U5108 3309	. . .	. . .	. . .	
	5 (b.)	2U5099 3309	3U5109 3309	3U5110 3309	. . .	. . .	. . .	

(a.) 1" Stem
(b.) 1-1/4" Stem

Continued

KEY 18 Bonnet (Same Material as Body)

(C-5 Chrome Moly)

"ET" Body Size, (Inches)	Boss Size, (Inches)	Plain	Extension Style 1 Tapped Boss	Extension Style 1 Untapped Boss	Extension Style 2 Tapped Boss	Extension Style 2 Untapped Boss	Bellows Seal Tapped Boss	"EAT" Body Size, (Inches)
1/2, 3/4, 1	2-1/8	2R2812 2902	2R2826 2902	2R2736 2902	3R2865 2902	3R2884 2902	3R2893 2902	1
	2-13/16	2R2813 2902	2R2827 2902	2R2852 2902	3R2866 2902	3R2922 2902	3R2894 2902	
1-1/2	2-1/8	2R3105 2902	2R3318 2902	2R3124 2902	3R3122 2902	3R3059 2902	3R3126 2902	2
	2-13/16	2R3106 2902	2R3119 2902	2R3127 2902	3R3123 2902	3R3060 2902	3R3128 2902	
2	2-13/16	2R3303 2902	2R3315 2902	2R3321 2902	3R3317 2902	3R3322 2902	3R3319 2902	...
	3-9/16	2R3304 2902	...	...	...	...	...	
2-1/2	2-13/16	2R3851 2902	2R3860 2902	2R3861 2902	3R3864 2902	3R3865 2902	3R3867 2902	3
	3-9/16	2R3852 2902	2R3862 2902	2R3863 2902	...	...	...	
3	2-13/16	2R3488 2902	2R3497 2902	2R3498 2902	3R3502 2902	3R3503 2902	3R3504 2902	4
	3-9/16	2R3489 2902	2R3499 2902	2R3500 2902	...	...	...	
4	2-13/16	2R3666 2902	2R3200 2902	2R3678 2902	3R3685 2902	3R3684 2902	3R3688 2902	6
	3-9/16	2R3667 2902	2R3202 2902	2R3680 2902	3R3687 2902	3R3686 2902	3R3689 2902	
	5	2R3668 2902	...	...	...	...	...	
6	3-9/16	3U5092 2902	3U5105 2902	3U5104 2902	2U5112 2902	2U5113 2902	2U5114 2902	...
	5 (a.)	2U5098 2902	3U5107 2902	3U5108 2902	...	...	...	
	5 (b.)	2U5099 2902	3U5109 2902	3U5110 2902	...	...	...	

(a.) 1" Stem
(b.) 1-1/4" Stem

KEY 18 Plain Bonnet (Cast Iron)

"ET" Body Size, (Inches)	Boss Size, (Inches)	Iron	"EAT" Body Size (Inches)
1/2, 3/4, 1	2-1/8	2R2820 1902	1
	2-13/16	2R2821 1902	
1-1/2	2-1/8	2R3112 1902	2
	2-13/16	2R3113 1902	
2	2-13/16	2R3310 1902	...
	3-9/16	2R3311 1902	
2-1/2	2-13/16	2R3856 1902	3
	3-9/16	2R3857 1902	
3	2-13/16	2R3493 1902	4
	3-9/16	2R3494 1902	
4	2-13/16	2R3673 1902	6
	3-9/16	2R3674 1902	
	5	2R3675 1902	
6	3-9/16	3U5096 1902	...
	5(a.)	2U5101 1902	
	5(b.)	2U5102 1902	

(a.) 1" Stem
(b.) 1-1/4" Stem

KEY 19 Bushing for Extension Bonnets Only, 416 SST

"ET" Body Size (Inches)	Stem Size, (Inches)	Style 1 Ext.	Style 2 Ext.	"EAT" Body Size (Inches)
1/2, 3/4, 1	3/8	1K8864 3513	1K8864 3513	1
	1/2	1L1409 3513	1L1409 3513	
1-1/2	3/8	1K8864 3513	1K8864 3513	2
	1/2	1L1409 3513	1L1409 3513	
	3/4	1C3519 3513	...	
2	1/2	1L1409 3513	1R3360 3513	...
	3/4	1R3518 3513	1R3518 3513	
2-1/2	1/2	1K4348 3513	1R3360 3513	3
	3/4	1R3518 3513	...	
	1	1V3157 3513	...	
3	1/2	1K4348 3513	1R3360 3513	4
	3/4	1R3518 3513	1R3518 3513	
4	1/2	1K4348 3513	1R3586 3513	6
	3/4	1R3518 3513	1R3713 3513	
	1	1U5676 3513	...	
	1-1/4	1U8023 3513	1L2693 3513	
6	3/4	1R3518 3513	1U7632 3513	...
	1	1U5676 3513	...	
	1-1/4	1U5678 3513	...	

KEYS 21 to 31 - Packing Box Parts - TFE V-Ring Packing

Key	Name of Part and Material	Stem Size (Inches) 3/8	1/2	3/4	1	1-1/4
21	Packing Flange, Steel	1E9437 2410	1E9442 2307	1E9448 2307	0V0024 2505	0W0856 2505
22	Packing Flange Stud, Steel — 2 Req'd	1E9441 3103	1E9444 3103	1E9449 3103	0V0025 3103	0W0869 3103
23	Packing Flange Nut, Steel — 2 Req'd	1E9440 2411	1E9445 2411	1E9446 2411	1L6921 2411	1A3681 2411
24*	TFE V-Ring Packing Set — Fig. 17	1R2900 0101	1R2902 0101	1R2904 0101	1R2906 0101	1R2908 0101
26	Packing Spring, 316 SST	1F1254 3701	1F1255 3701	1F1256 3701	1D5829 3701	1D3874 3701
28	Special Washer, 316 SST	1F1252 3604	1F1251 3604	1F1250 3604	1H9822 3604	1H9959 3604
29	Packing Box Ring, 17-4PH SST	1J8731 3501	1J8732 3501	1J8733 3501	1J8734 3501	1J8735 3501
30	Upper Wiper, Felt	1J8726 0633	1J8727 0633	1J8728 0633	1J8729 0633	1J8730 0633
31	Packing Follower, 316 SST	1E9439 3507	1E9443 3507	1E9447 3507	1H9823 3507	1H9984 3507

*Recommended Spare Part

KEY 24* Packing

(TFE V-Ring Packing)					
Name of Part	Stem Size, Inches				
	3/8	1/2	3/4	1	1-1/4
Female Adaptor	1F1244 0101	1F1243 0101	1F1242 0101	1H9824 0101	1H9957 0101
Packing 3 Req'd	1C7526 0101	1C7527 0101	1C7528 0101	1C 7529 0101	1D3876 0101
Male Adaptor	1F1248 0101	1F1247 0101	1F1246 0101	1H9825 0101	1H9958 0101
Lower Wiper Ring	1J8721 0699	1J8722 0699	1J8723 0699	1J8724 0699	1J8725 0699

(Graphited Asbestos Packing)†					
Name of Part	Stem Size, Inches				
	3/8	1/2	3/4	1	1-1/4
Lantern Ring 316 SST (a.)	1F3641 3507	1J9623 3507	0N0284 3507	0U0997 3507	0W0871 3507
Packing (No Req'd)	1D7474 0105 (3)	1D7487 0105 (5)	1D7490 0105 (2)	1D7518 0105 (2)	1D7520 0105 (2)
Packing (No Req'd)	1D7475 0105 (1)	...	1D7491 0105 (2)	1D7496 0105 (3)	1D7519 0105 (3)

(TFE Impregnated Asbestos Packing)†					
Name of Part	Stem Size, Inches				
	3/8	1/2	3/4	1	1-1/4
Lantern Ring 316 SST (a.)	1F3641 3507	1J9623 3507	0N0284 3507	0U0997 3507	0W0871 3507
Packing (No Req'd)	1E3189 0104 (7)	1E3190 0104 (10)	1E3191 0104 (8)	1E7234 0104 (8)	1E7235 0104 (8)

Footnote: (a.) Lantern ring replaces packing spring.
† KEYS 21, 22, 23, 29, 30 & 31 are same as for TFE V-Ring packing.

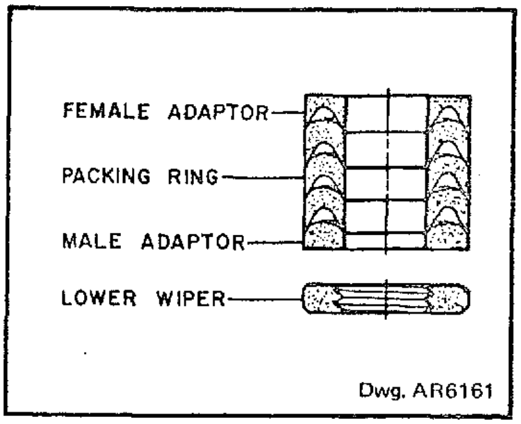


Figure 17. Parts Included in TFE V-Ring Packing Set

KEY 32 Pipe Plug

32 Pipe Plug, Steel, 1/4" NPT..... 1A7675 2466

KEY 33 Yoke Locknut, Steel

33 Yoke Locknut, Steel
For 2-1/8" Yoke Boss 1E7930 2306
For 2-13/16" Yoke Boss ... 1E8074 2306
For 3-9/16" Yoke Boss 1E8327 2306

NOTE: Bodies with 5" yoke boss (1" stem) use cap screws and nuts (8 each) to mount the actuator on the body. Part numbers are as follows:

Cap Screws – 1A9362 2405
Nuts – 1A3433 2412

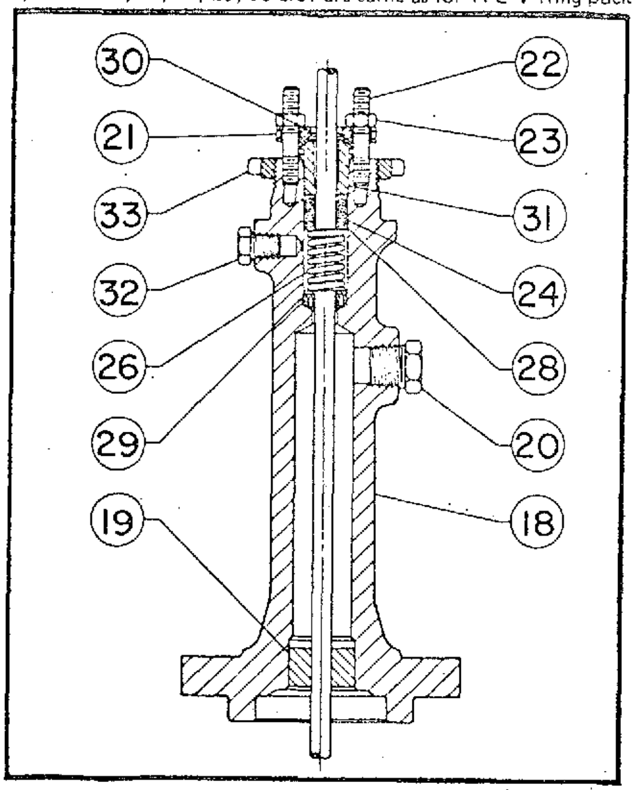


Figure 18. Extension Bonnet

KEY 34 Bellows Seal Adaptor

"ET" Body Size (Inches)	Boss Size (Inches)	Bellows Seal Adaptor			"EAT" Body Size (Inches)
		Steel	316 SST	C-5 Chrome Moly	
1/2 3/4, 1	2-1/8 2-13/16	1R2882 2449	1R2882 3507	1R2882 3507	1
1-1/2	2-1/8 2-13/16	1R3130 2449	1R3130 3507	1R3130 3507	2
2	2-13/16	1R3356 2449	1R3356 3507	1R3356 3507	...
2-1/2	2-13/16	1R3872 2449	1R3872 3507	1R3872 3507	3
3	2-13/16	1R3509 2449	1R3509 3507	1R3509 3507	4
4	2-13/16 3-9/16	2R3698 2449	2R3698 3507	2R3698 3507	6
6	3-9/16	2U5115 2449	2U5115 3507	2U5115 3507	...

* Recommended Spare Part

KEY 35 Connection Stud for Bellows Seal Bonnet, 316 SST

"ET" Body Size, (Inches)	Boss Size, Inches	Stem Size, Inches	VSC. Inches	Part Number	"EAT" Body Size (Inches)
1/2, 3/4, 1	2-1/8	3/8	3/8	1U2181 3507	1
	2-13/16	1/2	3/8	1U2181 3507	
	2-13/16	1/2	1/2	1U2182 3507	
1-1/2	2-1/8	3/8	3/8	1U2181 3507	2
	2-13/16	1/2	1/2	1U2182 3507	
	2-13/16	1/2	3/8	1U2181 3507	
1-1/2 x 1	2-1/8	3/8	3/8	1U7399 3507	2 x 1
	2-13/16	1/2	3/8	1U7399 3507	
2	2-13/16	1/2	1/2	1U2268 3507	...
2 x 1	2-13/16	1/2	3/8	1U5301 3507	...
2-1/2	2-13/16	1/2	1/2	1U2311 3507	3
2-1/2x1-1/2	2-13/16	1/2	3/8	1U5302 3507	3 x 1-1/2
3	2-13/16	1/2	1/2	1U2311 3507	4
4	2-13/16	1/2	3/4	1U2217 3507	6
	3-9/16	3/4	3/4	1U2217 3507	
6	3-9/16	3/4	3/4	1U2217 3507	...

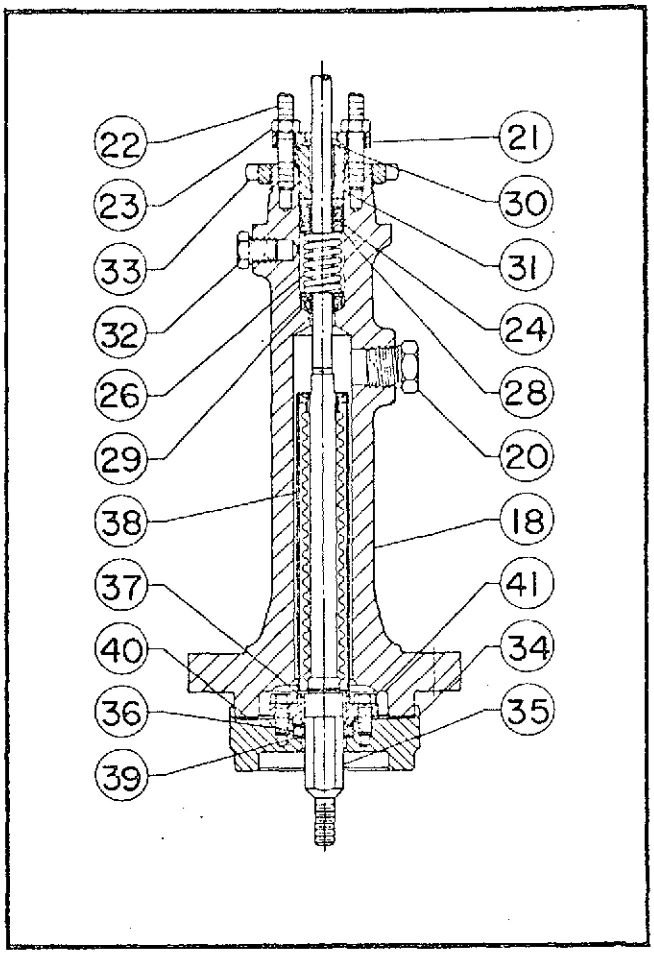


Figure 19. Bellows Seal Bonnet

KEYS 36 to 41 - Parts for Bellows Seal Bonnet

"ET" Body Size, (Inches)	Boss Size, (Inches)	Key 36 Anti-Rotator, 17-4PH SST	Key 37 Travel Stop, 316 SST	Key 38 Bellows Seal Ass'y, 316 SST	Key 39 Anti-Rotator Gasket, Asbestos (2 Req'd)	Key 40* Bonnet Gasket, Asbestos	Key 41 Cap Screw 416 SST (4 Req'd)	"EAT" Body Size (Inches)
1/2, 3/4, 1	2-1/8, 2-13/16	1R2875 3501	1R2872 3507	1R2881 000A	1R2877 0402	1R2891 0402	1A4078 3513	1
1-1/2	2-1/8, 2-13/16	1R2875 3501	1R2872 3507	1R2881 000A	1R2877 0402	1R3101 0402	1A4078 3513	2
2	2-13/16	1R3362 3501	1R3359 3507	2R3368 000A	1R3363 0402	1R3299 0402	1A3816 3513	...
2-1/2	2-13/16	1R3362 3501	1R3359 3507	2R3368 000A	1R3363 0402	1R3847 0402	1A3816 3513	3
3	2-13/16	1R3362 3501	1R3359 3507	2R3368 000A	1R3363 0402	1R3484 0402	1A3816 3513	4
4	2-13/16,3-9/16	1R3702 3501	1R3701 3507	2R3705 000A	1R3703 0402	1R3724 0402	1A3449 3513	6
6	3-9/16	1R3702 3501	1R3701 3507	2R3705 000A	1R3703 0402	1U5081 0402	1A3449 3513	...

KEY 42 Flow Direction Arrow, SST

1/2", 3/4", 1" Bodies 1V1059 3898
1-1/2" to 6" 1V1060 3898
1-1/2" to 6" (Whisper Trim) 1V4170 3898

KEY 43 Drive Screw

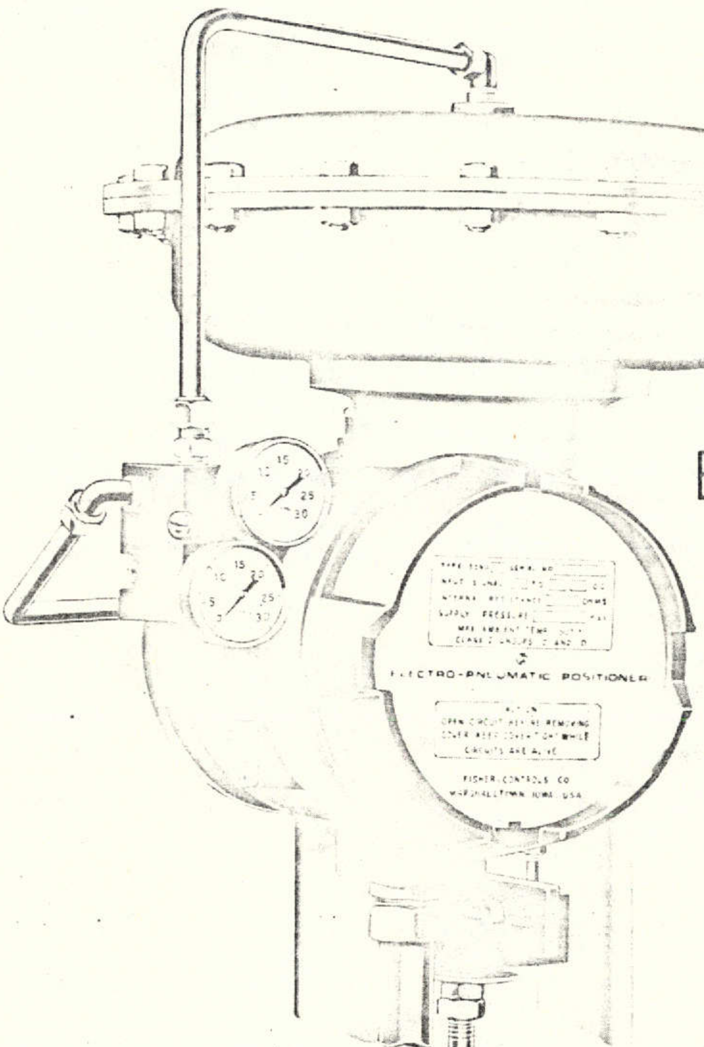
KEY 43, Drive Screw, Steel CD. PL. (2 req'd) . . 1A3682 2898

KEY 44 Body Adaptor Gasket

KEY 44, Body Adaptor Gasket, Asb. 1U2152 0402

*Recommended Spare Part

INSTRUCTION MANUAL AND PARTS LIST



TYPE 3590 ELECTRO-PNEUMATIC VALVE POSITIONER

FISHER CONTROLS COMPANY

Marshalltown, Iowa | Coraopolis, Pa.
Woodstock, Ont., Can. | Toluca, Mexico

15M–12-70–JSS
Printed in U.S.A.

Form 2403

INTRODUCTION

The Fisher Type 3590 electro-pneumatic valve positioner is used in electrical control loops in which the final control element is pneumatically operated. It receives a direct current milliampere input signal, converting it to the required pneumatic output pressure to produce a valve stem position which has a linear relationship to the input signal.

PRINCIPLE OF OPERATION

(Direct Acting Positioner) See Figure 1

Increasing the DC milliampere input signal to the coils rotates the armature of the torque motor about the fixed torsion rod and covers the nozzle. The resulting nozzle restriction produces an increased pressure in the relay. Through relay action, the increased pressure on the relay diaphragm increases the output pressure to the actuator diaphragm and moves the actuator stem downward. Stem movement is fed back to the armature by the mechanical feedback linkage and feedback spring which cause the armature to rotate away from the nozzle. A further increase in nozzle pressure is stopped and additional actuator stem movement is prevented. The positioner is once again at a steady state condition but at a higher input signal and a new actuator stem position.

When the DC milliampere input signal decreases, the armature rotates about the fixed torsion rod and uncovers the nozzle, decreasing the pressure in the relay. Through relay action, the decreased pressure on the relay diaphragm decreases the output pressure to the actuator diaphragm, permitting the stem to move upward. Stem movement is fed back to the armature by the mechanical feedback linkage and feedback spring which cause the armature to rotate toward the nozzle. A further decrease in nozzle pressure is stopped and additional actuator stem movement is prevented. The positioner is once again in a steady state condition.

Reverse acting positioners operate in a similar manner, except that when the DC milliampere input signal increases, the output pressure from the relay decreases. Conversely, a decreasing input signal increases the output pressure.

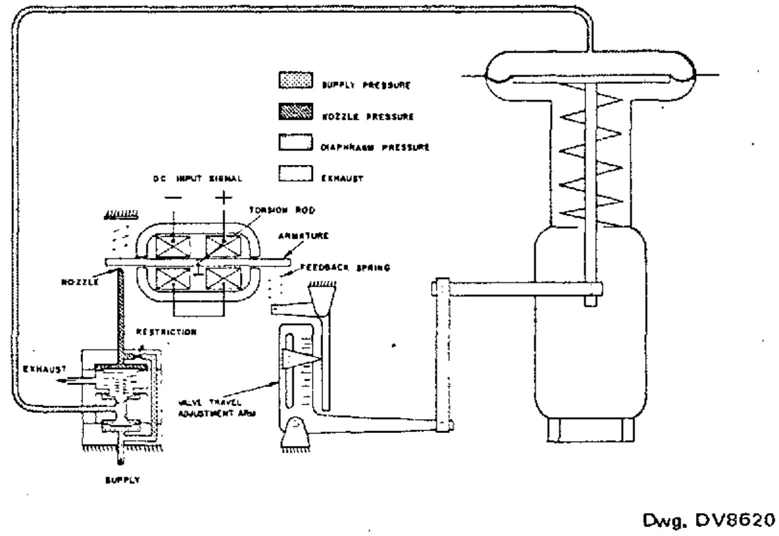


Figure 1. Schematic illustration of Type 3590.

INSTALLATION

When a Type 3590 electro-pneumatic valve positioner is furnished with an actuator, the factory will mount and align the positioner. If the positioner is ordered separately or has had maintenance performed on it in the field, perform Steps 1 through 8.

Figure 2 illustrates the manner in which the Type 3590 valve positioner should be mounted on direct acting Type 657 or reverse acting Type 667 diaphragm actuators.

1. Make sure the proper mounting parts are provided. When mounting a Type 3590 valve positioner on other than Fisher actuators, it may be necessary to provide spacers by cutting sections from 1/2" or 3/8" pipe so that the "X" dimension somewhere between the minimum and maximum values shown in Figure 3 is achieved.

2. Attach connector arm (Key 1, Figure 13) to the stem connector as shown in Figure 4, and align the connector arm perpendicular to positioner mounting pad. Do not allow the actuator stem to rotate.

3. Bolt the positioner to the mounting plate (Key 18, Figure 13).

4. Refer to Figure 5. Holes are indicated for mounting the positioner to the mounting plate and the mounting plate to the actuator. See tables on Page 9 for proper set of holes to be used in mounting the plate on a given type and size of actuator. Bolt the mounting plate to the lower mounting pad of the actuator.

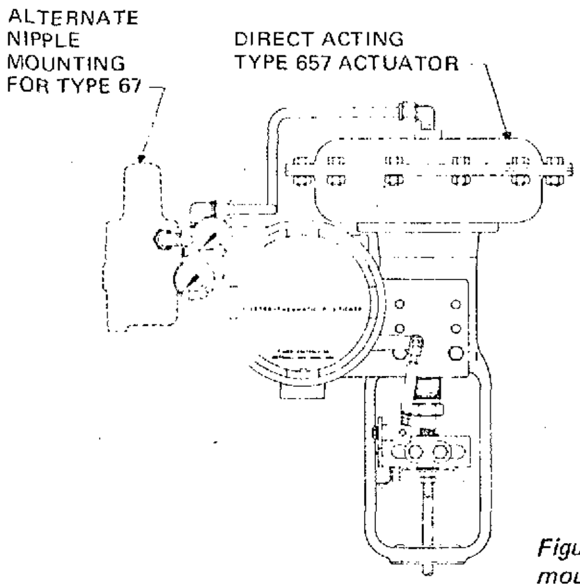
5. Attach connector arm block (Key 2, Figure 13) to connector arm. Do not tighten the cap screw (Key 3, Figure 13). Refer to tables on Page 9 to determine if the connector arm block should be mounted in standard or reverse position for a given type and size of actuator. Standard and reverse mounting of the connector arm block are shown in Figure 13.

6. Refer to Figure 13 and assemble the following parts of the turnbuckle assembly: lower turnbuckle rod (Key 5), lower turnbuckle pivot (Key 6), turnbuckle (Key 7), hex nut (Key 8), and upper clevis (Key 9).

7. Using the clevis pin (Key 10, Figure 13) and E-rings (Key 11, Figure 13), attach the turnbuckle assembly to the arm (Key 21, Figure 11).

8. Looking at side view of actuator, align the turnbuckle in a near vertical position, see Figure 3, and tighten the cap screw (Key 3, Figure 13) to secure the turnbuckle assembly to the connector arm.

CAUTION: After the cap screw (Key 3) has been tightened, the lower turnbuckle rod (Key 5) must move freely without binding on the lower turnbuckle pivot (Key 6). If binding occurs, adjust the orientation of the connector arm block.



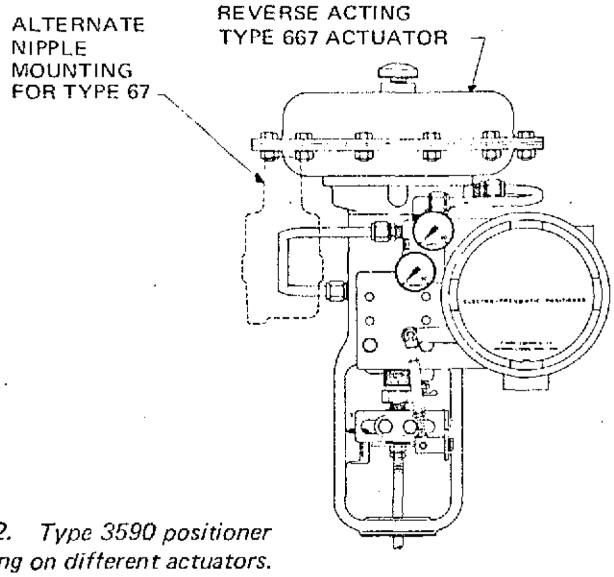
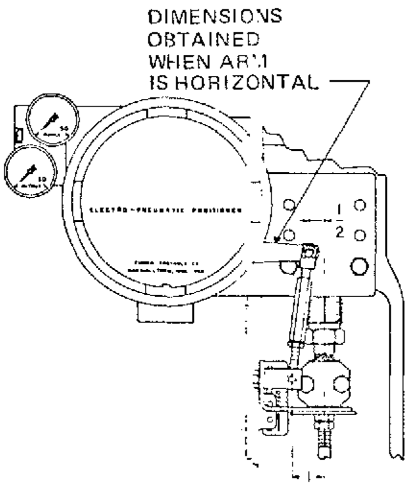
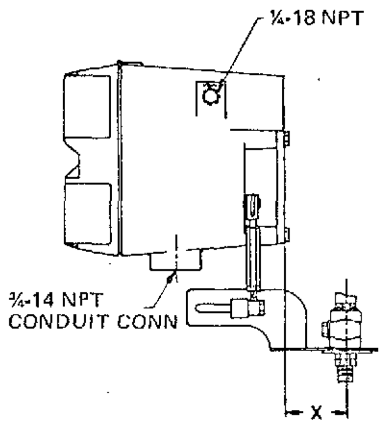


Figure 2. Type 3590 positioner mounting on different actuators.

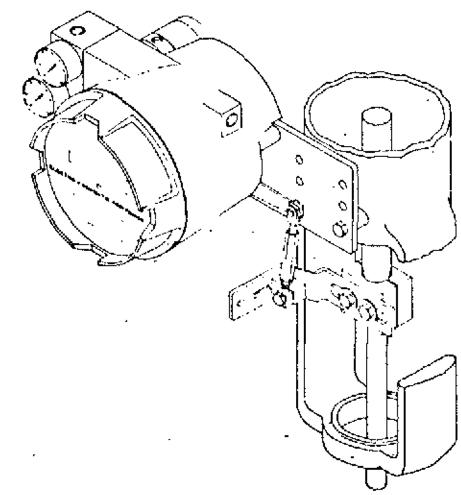




STEM TRAVEL	X					
	3/8 STEM		1/2 STEM		3/4 STEM	
	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.
1 1/8 OR LESS	2	3 3/16	2 1/4	3 7/16	2 3/4	3 15/16
1 1/2	2	3 9/16	2 1/4	3 13/16	2 3/4	4 5/16
2	2	4	2 1/4	4 1/4	2 3/4	4 3/4
2 1/2	4 1/8	4 7/16	4 3/8	4 11/16	4 7/8	5 3/16
3	4 1/8	4 7/8	4 3/8	5 1/8	4 7/8	5 5/8
3 1/2	4 1/8	5 5/16	4 3/8	5 9/16	4 7/8	6 1/16
4	4 1/8	5 3/4	4 3/8	6	4 7/8	6 1/2

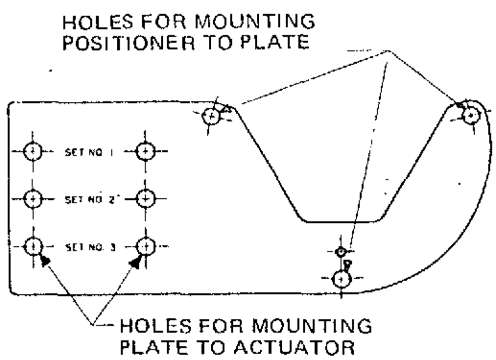
Dwg. DV8657 Modified

Figure 3. Actuator – valve positioner spacing required for other than Fisher actuators.



Dwg. 50A1540

Figure 4. Feedback arrangement and typical stem connection.



Dwg. 20A0925

Figure 5. Mounting plate used with Type 3590 valve positioner.

CONNECTIONS

Electrical

The electrical connections are made in the positioner case. A 3/4" NPT conduit connection is provided in the bottom of the case. Use a suitable conduit seal for hazardous locations. The wires that carry the milliampere signal from the controller are connected to the terminal strip (Key 12, Figure 10).

The terminal strip is marked "+" and "–" to indicate the positive and negative terminals.

For a direct acting unit (i.e., increasing current produces an increasing output pressure), connect the positive wire from the controller to the positive terminal of the positioner and the negative wire to the negative terminal.

For a reverse acting unit (i.e., increasing current produces a decreasing output pressure), connect the positive wire from the controller to the negative terminal and the negative wire to the positive terminal.

Pneumatic

1. **Output Pressure** – Connect 3/8" tubing from the pressure connection in the diaphragm case (Type 657 actuators) or top of the yoke (Type 667 actuators) to the 1/4" tapped hole in the positioner marked "Output". This connection will be made at the factory if the positioner is shipped fitted to a control valve.

2. **Supply Pressure** – Connect 3/8" tubing from the 1/4" "Out" connection on the Type 67FR filter regulator to the 1/4" tapped hole in the positioner marked "Supply". This connection will be made at the factory if the Type 67FR and positioner are factory mounted.

3. **Supply Source** – Connect available supply source to the 1/4" "In" connection of the Type 67FR regulator. Normally this regulator should be set to supply air to the positioner at a pressure 5 psi higher than the upper limit of the output pressure range. Maximum inlet pressure to the 67FR is 250 psi. Maximum supply pressure to the positioner is 50 psi.

CAUTION: The maximum supply pressure should not exceed the pressure rating of the actuator.

NOTE: The screened opening in the side of the case marked "Vent" should be left open to prevent a pressure buildup inside the case and also to provide a way to purge the case. If it is necessary to pipe away the vent, remove the screens in the case and relay vents. Use a line size of at least 3/8" pipe or 1/2" tubing in the case vent. Place a pipe plug in the relay vent.

ALIGNMENT

Make the turnbuckle length adjustment as follows:

CAUTION: To avoid possible damage to the mechanical feedback linkage, this turnbuckle length adjustment operation must be performed before applying supply pressure or an electrical input signal to the positioner.

1. Make certain that both the valve plug travel and the actuator spring adjustment are correct.

2. Loosen the locking screw (Key 29, Figure 11).

3. Using the adjustment gear (Key 26, Figure 11), set the adjustment clamp (Key 25, Figure 11) so its V-notch indicator shows the largest reading (4") on the travel scale.

4. Tighten the locking screw.

5. Using a manual loading regulator or handjacks, position the actuator to its midtravel position.

6. Adjust turnbuckle (Key 7, Figure 13) until the feedback rod (Key 16, Figure 11) is parallel, as shown in Figure 6, to the travel arm assembly (Key 19, Figure 11).

7. Lock turnbuckle with lock nut (Key 8, Figure 13). This adjustment should remain unchanged for any additional calibration operations.

CALIBRATION

Make the zero and span adjustments as indicated below:

To avoid possible damage to the mechanical feedback linkage, make sure the turnbuckle length adjustment operation has been performed before applying supply pressure or an electrical input signal to the positioner.

1. Remove any loading pressure or disengage any handjacks used to position the actuator.

2. Loosen the locking screw (Key 29, Figure 11).

3. Using the adjustment gear (Key 26, Figure 11), set the adjustment clamp (Key 25, Figure 11) so its V-notch indicator shows a reading that corresponds to the valve plug travel. For example, if the plug travel is 1-1/2 inches, set the adjustment clamp so its V-notch indicator reads 1-1/2 inches.

4. Tighten the locking screw.

5. Apply supply pressure to the positioner.

6. Check actuator starting point by applying the low value of DC input signal (4 mA with a 4 to 20 mA input signal) to the positioner. Adjust the zero screw as necessary (see Figure 7) to position the actuator at its starting point.

7. Apply the high value of DC input signal (20 mA for a 4 to 20 mA signal). Observe the actuator travel to determine that the actuator is at the opposite end of the travel achieved in Step 6 and at full travel. If less than full travel results, increase travel by moving the adjustment clamp (Key 25 Figure 11) toward a larger number on the travel scale. If the actuator achieves full travel with less than the high value of the DC input signal, decrease travel by moving the adjustment clamp toward a smaller number on the travel scale.

8. Repeat Steps 6 and 7 until the correct travel is achieved.

SPLIT RANGE OPERATION

The split range operation of the positioner may be used by either of the following methods.

1. Change the feedback spring from full range to split range so the DC milliampere input signal is split equally between two control valves, see table below. For example, in an equal two-way split with a 4-20 mA input signal, one control valve would be set to stroke completely on a 4-12 mA signal, while the other valve would stroke on a 12-20 mA signal.

STANDARD FEEDBACK SPRINGS

Spring	Spring Dwg. No.	Spring Color
Full range	1V4139 4208	Gray
Two-Way Split Range	1V4140 4208	Red

1.1 Change the feedback spring as follows:

1.1.1 Shut off the supply pressure and the DC input signal to the positioner.

1.1.2 Unhook feedback spring (Key 30, Figure 11) from feedback lever (Key 15, Figure 11) and spring anchor (Key 17, Figure 10).

1.1.3 Replace the desired spring.

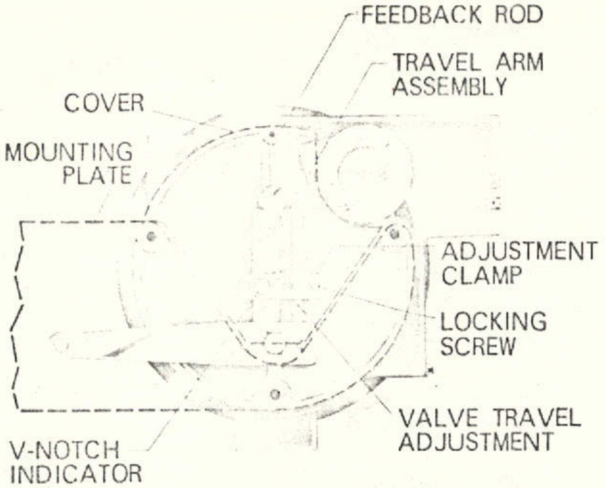


Figure 6. Rear view of Type 3590 valve positioner.

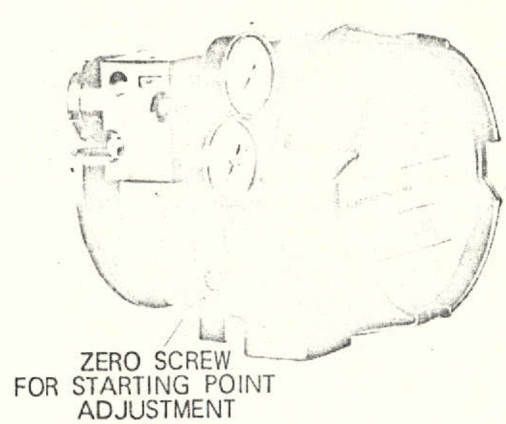


Figure 7. Location of starting point adjustment.

Use care to avoid damage to the spring.

2. The DC input signal can be split equally or in various ranges by using the charts in Figure 8 to obtain the correct travel setting.

2.1 Assume that a positioner having a coil circuit of 4-20 mA DC is to stroke a valve 3 inches with an input signal of 4-16 mA.

Determine "f", the percent of full DC input signal desired to fully stroke the valve.

$$f = \frac{\text{12 mA or the change in 4-16 mA signal}}{\text{16 mA or the change in 4-20 MA signal}} = 75\%$$

2.2 Use the chart for the spring being used, in this case part no. 1V4139 4208. Enter the chart at a valve travel of 3 inches. Move upward to intersect with the line marked "f = 75%. Move horizontally from this intersection and obtain a travel setting of 4. Thus, it is possible to operate a valve having 3 inches of travel with an input signal of 4-16 mA, using the full range feedback spring, if the travel setting is at 4 on the scale.

CAUTION: To avoid damage to the mechanical feedback linkage, never use a travel setting less than the actual valve travel.

3. If either the feedback spring is changed or the charts are used to obtain a correct travel setting, the positioner must be recalibrated.

REVERSING THE ACTION

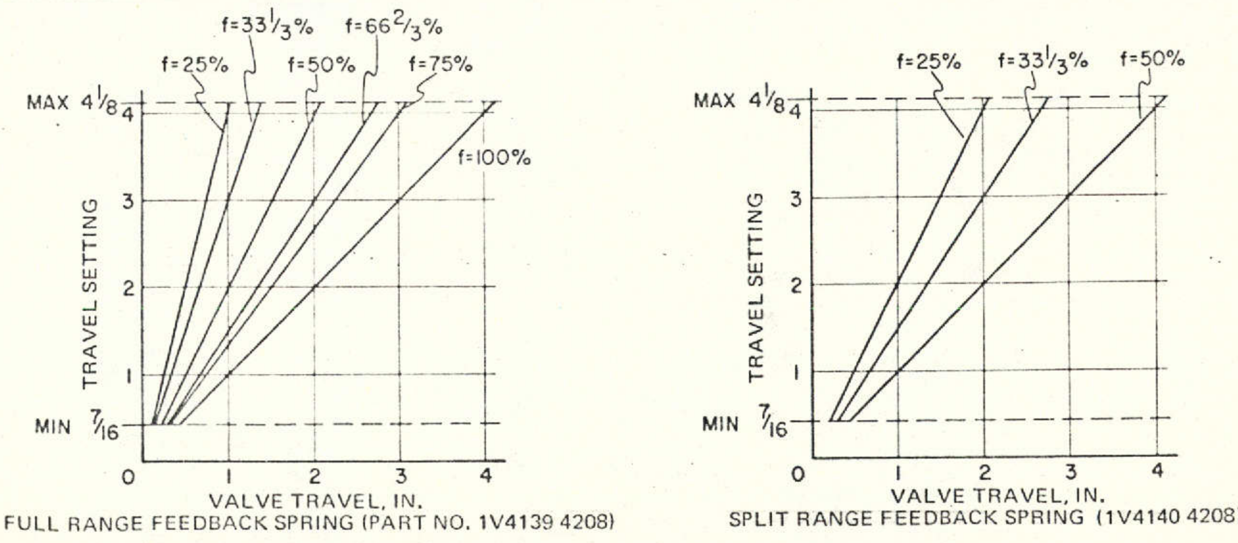
No additional parts are required to convert a Type 3590 positioner from direct acting to reverse acting, or vice versa. To change the action, simply reverse the input leads. After changing the action, it is necessary to adjust the zero setting.

TYPICAL CIRCUITS

The coil circuit will operate on the direct current signal from most electronic controllers.

Typical circuits available are shown below:

Input Signal	Actual Internal Resistance of Positioner
4 to 20 mA DC	300±15 ohms
10 to 50 mA DC	70 ±5 ohms



f = Percent of full DC input signal desired to fully stroke the valve.

Figure 8. Travel setting vs. valve travel for different feedback springs. Dwg. 20A2336

PRECAUTION

The torque motor assembly which consists of permanent magnets, pole pieces, torque motor mounting plate, etc., should never be dissassembled because the level of magnetism in the magnets will decrease, and will not return upon reassembly. Consequently, you will be unable to obtain proper span. If it is known that the torque motor is faulty, replace the entire motor with a new one and return the faulty torque motor to the factory for repairs. Figure 10 shows the torque motor and associated parts. Those key numbers that are shaded indicate the parts that should not be disassembled from the torque motor.

MAINTENANCE

In case of operational difficulties, check the positioner for the following items:

1. Proper Calibration.
2. Controller output reaching the positioner.
3. Leaks in pressure lines and connections.
4. Leaks in pneumatic relay, its diaphragm, and O-rings. Leaks in torque motor O-ring (Key 23, Figure 10) and manifold O-ring (Key 9A, Figure 11).
5. Metal chips in the air gap between the armature and the pole pieces in torque motor assembly. Chips in the air gap will limit armature travel and reduce the flux across the air gap which will shorten the span and cause erratic operation. Blow out any chips with low pressure air.
6. Dirty flame arresters. The entire torque motor assembly, as shown in Figure 10, has to be removed from the case to clean the flame arrester. If flame arresters are dirty, blow them out with air pressure.

CAUTION: Do not attempt any repairs on the torque motor assembly.

7. Open dripwell petcock of the Type 67FR filter-regulator periodically to drain moisture.

Relay Repairing and Cleaning

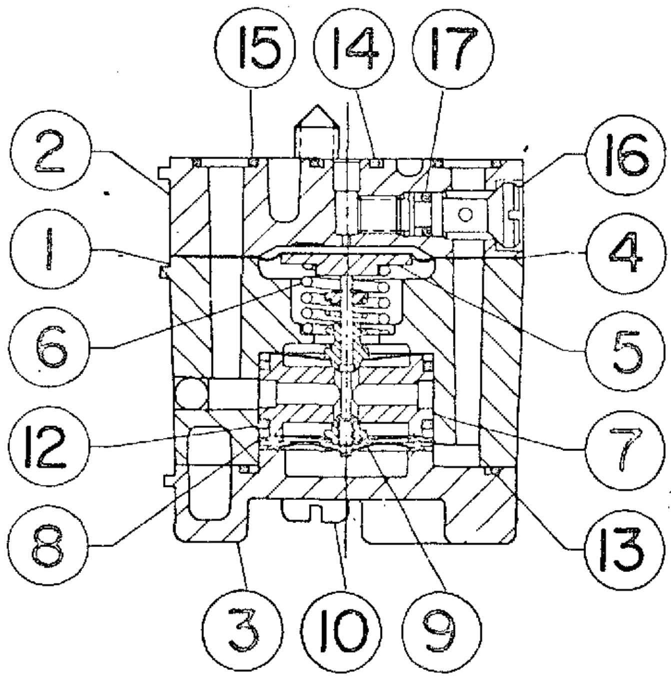
If it is necessary to replace parts other than the diaphragm and O-rings, purchase a complete relay assembly as a spare part. To replace the diaphragm and O-rings or to clean the relay, proceed as follows:

The Type 83H relay can be removed from the positioner case by loosening two mounting screws. If the positioner is mounted on an operating control valve, isolate the control valve from the system and shut off the DC input signal and all pressure lines to the positioner before removing the relay. Refer to Figure 9.

1. Remove two mounting screws (Key 10).
2. Remove four screws that hold the three body sections together.
3. Separate the sections . . . body assembly (Key 1), relay base (Key 2), and cap (Key 3).
4. Use care to avoid losing O-rings.
5. The diaphragm (Key 4), diaphragm head (Key 5), relay spring (Key 6), washer (Key 8) and spring washer (Key 9) can all be separated. Do not attempt to disassemble the seat ring assembly (Key 7) or to remove it from the body (Key 1).
6. Unscrew the nozzle restriction and adaptor assembly (Key 16).
7. With the relay disassembled, check all parts for wear; check for plugging at the fixed restriction (clean with 0.016 diameter or smaller wire). If it is necessary to replace parts other than the diaphragm and O-rings, purchase a complete relay assembly as a spare part.
8. If the relay is to be cleaned, place the body sections in cleaning solvent.
9. Reassemble, using a new diaphragm and O-rings where required. Follow the assembly drawing in Figure 9, paying particular attention to the positioning of the diaphragm so that all holes line up properly. Also, the three body sections should be positioned so that the lug on the outside of each section is in line with the others. Install and tighten four screws to complete the assembly.
10. Install two mounting screws (Key 10) and replace relay on positioner case, making sure the O-rings (Keys 14 and 15) are good and in place.

SERIAL NUMBER

A serial number is assigned to each valve positioner, and it should always be referred to in correspondence and parts orders. This serial number can be found stamped on the nameplate attached to the case. When ordering parts, also give the ten character part numbers for the parts desired.

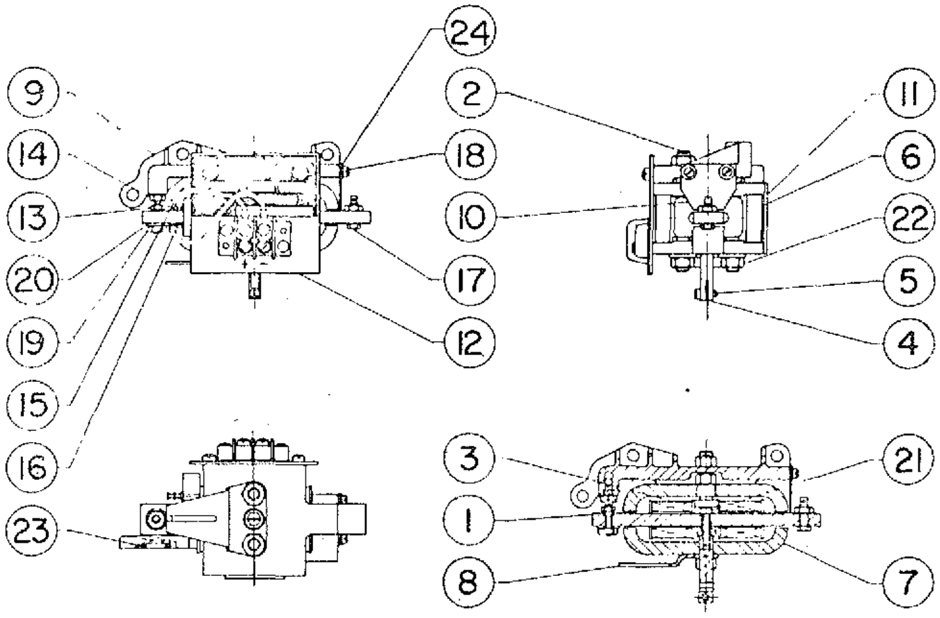


PART NOT SHOWN—11

In this assembly drawing, many items are shaded to indicate that they are not available as individual spare parts. Purchase a complete 83H relay or the non-shaded items as spare parts.

Dwg. CV4084

Figure 9. Type 83H relay.



In this assembly drawing, many items are shaded to indicate that these parts should not be disassembled and that they are not available as individual items. Purchase a complete torque motor assembly or the non-shaded items as spare parts.

Dwg. CV4100

Figure 10. Torque motor.

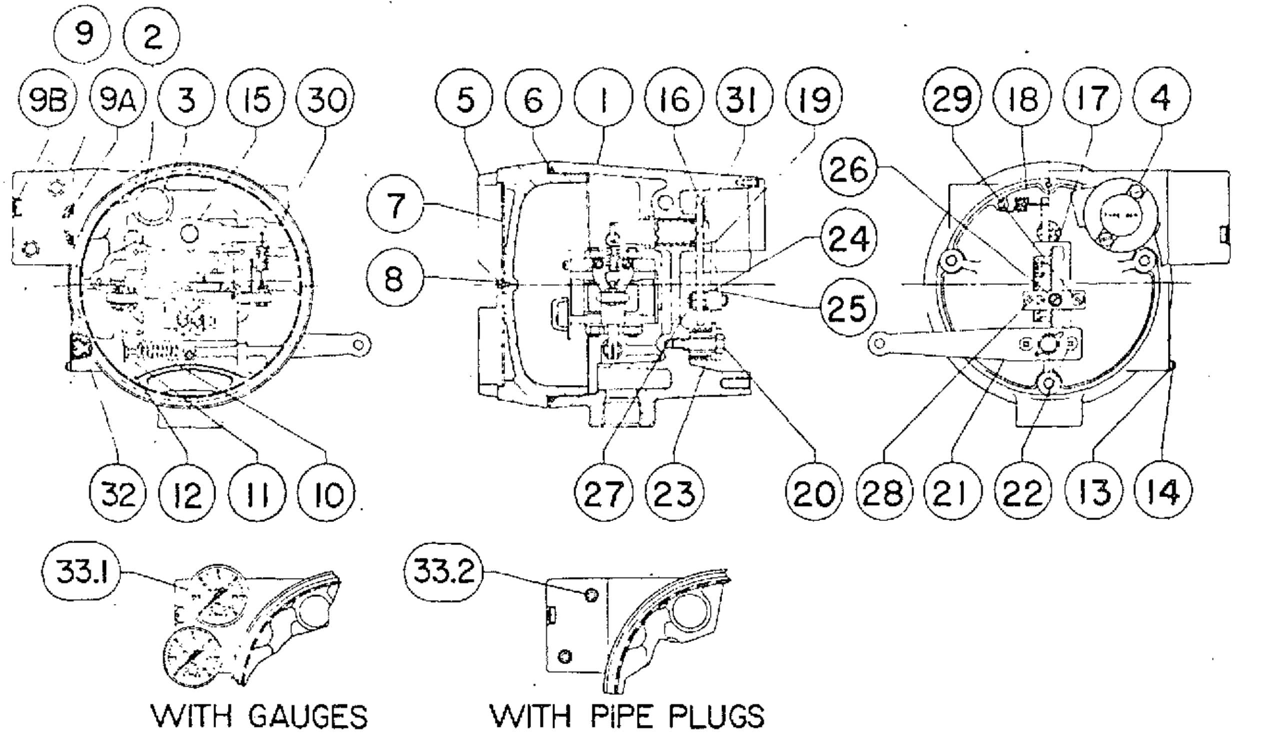
PARTS REFERENCE
TYPE 83H RELAY

Key	Part Name & Material	Part Number
1	Body Assembly	
2	Relay Base	
3	Cap	
4*	Diaphragm, Buna N	1V5578 0203
5	Diaphragm Head	
6	Relay Spring	
7	Seat Ring Assembly	
8	Washer	
9	Spring Washer	
10	Relay Mounting Screw, SST (2 Req'd.)	1U9012 3898
11	Fillister Head Machine Screw Steel, CD PL (4 Req'd.)	1A8177 2898
12*	O-ring, Synthetic Rubber (2 Req'd.)	1E7368 0699
13*	O-ring, Synthetic Rubber	1U8790 0656
14*	O-ring, Synthetic Rubber	1J4888 0699
15*	O-ring, Synthetic Rubber (3 Req'd.)	1D6875 0699
16	Nozzle Restriction & Adaptor Ass'y (orifice & nozzle restriction adaptor)	1V4146 000A
17*	O-ring, Synthetic Rubber	1D1346 0699

PARTS REFERENCE – TORQUE MOTOR ASSEMBLY

Key	Part Name & Material	Part Number
1	Armature	
2	Armature & Coil Support Ass'y	
3	Circuit	
4	Zero Adjustment Rod	
5	Socket Head Cap Screw, SST	1V4159 3899
6	Magnet	
7	Pole Piece	
8	Zero Spring Guide Bracket	
9	Torque Motor Mounting Plate	
10	Armature Travel Stop	
11	Temperature Compensator	
12	Terminal Mounting Bracket Ass'y 4–20 mA 10-50 mA All Other Assy's	 2V4133 X001 2V4134 X001 2V4135 X001
13	Baffle	
14	Nozzle	
15	Hook-up Wire Ass'y, Red	
16	Hook-up Wire Ass'y, Black	
17	Feedback Spring Anchor, SST	1V4132 3503
18	Fillister Head Machine Screw	
19	Hex Nut Machine Screw	
20	Washer	
21	Socket Head Cap Screw	
22	Hex Nut	
23*	O-Ring, Synthetic Rubber	1E5477 0699
24	Washer	

*Recommended Spare Part



Dwg. DV4141

Figure 11. Type 3590 valve positioner.

PARTS REFERENCE – TYPE 3590 ELECTRO-PNEUMATIC VALVE POSITIONER

Key	Part Name & Material	Part Number
1	Positioner Case Ass'y (positioner case, feedback shaft bushing, flame arrestor, breather plug, groove pin, and screen)	3V4106 000A
2	Torque Motor	CV4100 X001
3	Fillister Head Machine Screw, Brass, CD PL (3 Req'd.)	1P4265 1402
4	Type 83H Relay	CV4084 X001
5	Cover, Aluminum	3U8819 0801
6*	O-ring, Synthetic Rubber	1D4448 0699
7	Outside Nameplate, Aluminum	2V4143 1007
8	Self Tapping Screw, Steel, CD PL	1P4269 2898
9	Manifold, Aluminum	3V4110 0801
9A*	O-ring, Synthetic Rubber (2 Req'd.)	1K1499 0699
9B	Fillister Head Machine Screw, Steel, CD PL (2 Req'd.)	1F7728 2898
10	Zero Adjustment Ass'y (zero adjustment screw & zero spring)	1V4112 000A
11	Zero Adjustment Collar, SST	1V4115 3503
12	Retaining Ring, SST	1V4116 3899
13	Zero Adjustment Cover, SST	1V4177 3615
14	Fillister Head Machine Screw, Brass, CD PL	1P4373 1899
15	Feedback Lever Ass'y, SST	1V4117 000A
16	Feedback Rod, SST	1V4120 4633
17	Hex Socket Set Screw, SST	1A5186 3899
18	Tension Spring, SST	1V4121 3702
19	Travel Arm Ass'y (travel arm & travel arm bushing)	1V4122 000A
20	Travel Arm Pivot, SST	1V4125 3503
21	Arm, SST	2V4126 3615
22	Flat Head Machine Screw, SST (2 Req'd.)	1L3435 3899
23	Torsion Spring, SST	1V4127 3702
24	Travel Adjustment Block, Aluminum	2V4087 0801
25	Adjustment Clamp, SST	1V4128 3898
26	Adjustment Gear, Steel, CD PL	1V4129 2430
27	E-ring, SST	1E8659 3899
28	Fillister Head Machine Screw, SST	1V4131 3898
29	Fillister Head Machine Screw, SST	1V4130 3898
30	Feedback Spring	
	Full Range, NI-Span-C (Gray)	1V4139 4208
	Two Way Split Range, NI-Span-C (Red)	1V4140 4208
31*	O-ring, Synthetic Rubber	1J4888 0699
32*	O-ring, Synthetic Rubber	1D1347 0699
33.1	Pressure Gauge	
33.1A	Supply Pressure Gauge	
	0-30 psi	1V1935 9901
	0-60 psi	1V1937 9901
33.1B	Output Pressure Gauge	
	0-30 psi	1V1939 9901
	0-60 psi	1V1941 9901
33.2	Hex Socket Pipe Plug, Steel, CD PL (2 Req'd.)	1E8231 2898

*Recommended Spare Part

Types 513, 513R, 656, 657, 657-8 and 667 Mounting Information

Actuator Type	Actuator Size	Max Travel, In.	Mounting Holes Set No. (a.)	Connector Arm Part No.	Turnbuckle Part No.	Lower Turnbuckle Rod Part No.	Upper Clevis Part No.	Spacer Part No.	Connector Arm Block Position (b)	Pipe Nipple Part No. (For nipple mounted 67 FR regulator only)
513 & 513R	20	3/4	2 (c.)	2V6722 2521	1F3796 1402	1F3785 1513	1F2106 1402	None Req'd.	Std	1C6789 2623
	32	3/4	2 (c.)		1C4529 1402	1F2105 3513				
656	30	2	1	2V1705 2521	1C4529 1402	1F3785 1513	1V6723 1402	None Req'd.	Rev	1C6789 2623
	40	3-1/2	2			1F2105 3513				
	60	4	2			1F3785 1513				
657-8	30	2-1/8	3	2V1889 2521	1F3796 1402	1F2105 3513	1V6723 1402	None Req'd.	Std	1C6789 2623
	34	2-1/8	3	2V1889 2521	1F3796 1402	1F2105 3513				
	40	3-1/8	3	2V6724 2521	1F3796 1402	1F3785 1513				
	40	3-1/2	3	2V6724 2521	1F3796 1402	1F3785 1513				
	46	3-1/8	2	2V6724 2521	1F3796 1402	1F3785 1513				
	46	4-1/8	2	2V6724 2521	1F3796 1402	1F3785 1513				
	47	3-1/8	1	2V6724 2521	1C4529 1402	1F2105 3513				
	47	4-1/8	2	2V6724 2521	1V6721 1402	1F2105 3513				
	60	4-1/8	2	2V6724 2521	1V3796 1402	1F3785 1513				
	70	4-1/8	2	2V6724 2521	1V6721 1402	1F2105 3513				

Actuator Type	Actuator Size	Max Travel, In.	Mounting Holes Set No. (a.) 657	Mounting Holes Set No. (a.) 667	Connector Arm Part No.	Turnbuckle Part No. 657	Turnbuckle Part No. 667	Lower Turnbuckle Rod Part No. 657	Lower Turnbuckle Rod Part No. 667	Upper Clevis Part No.	Spacer Part No.	Connector Arm Block Position (b)	Pipe Nipple Part No.
657 & 667 Without Side Mounted Handwheel	30	3/4	3	3	1U9101 000A	1F3796 1402	1F3796 1402	1F3785 1513	1F3785 1513	1F2106 1402	None Req'd.	Rev	1C6789 2623 (d)
	34	3/4	3	2	1U9101 000A	1F3796 1402	1F3796 1402	1F3785 1513	1F2105 3513	1F2106 1402	None Req'd.	Rev	1C6789 2623 (e)
	40	1-1/2	2	2	2U9099 2521	1F3796 1402	1F3796 1402	1F3785 1513	1F3785 1513	1F2106 1402	None Req'd.	Rev	1C6789 2623 (e)
	45	3/4	2	1	2U9099 2521	1F3796 1402	1C4529 1402	1F3785 1513	1F2105 3513	1F2106 1402	None Req'd.	Rev	1C6789 2623
	45	2	2	1	2U9099 2521	1F3796 1402	1C4529 1402	1F3785 1513	1F2105 3513	1F2106 1402	None Req'd.	Rev	1C6789 2623
	50	2	1	1	2U9099 2521	1F3796 1402	1F3796 1402	1F3785 1513	1F3785 1513	1F2106 1402	None Req'd.	Rev	1C6789 2623
	60	2	1	1	2U9099 2521	1F3796 1402	1F3796 1402	1F3785 1513	1F3785 1513	1F2106 1402	None Req'd.	Rev	1C6789 2623
	70	3	1	2	2U9099 2521	1C4529 1402	1C4529 1402	1F2105 3513	1F2105 3513	1V6723 1402	None Req'd.	Std	1C6789 2623
	80	3	3	1	2U9099 2521	1C4529 1402	1C4529 1402	1F2105 3513	1F2105 3513	1V6723 1402	1V6833 2409 (g)	Std	1C6789 2623
	87	3	1	2	2U9099 2521	1C4529 1402	1C4529 1402	1F2105 3513	1F2105 3513	1V6723 1402	None Req'd.	Std	1C6789 2326

Actuator Type	Actuator Size	Max Travel, In.	Mounting Holes Set No. (a.) 657	Mounting Holes Set No. (a.) 667	Connector Arm Part No.	Turnbuckle Part No. 657	Turnbuckle Part No. 667	Lower Turnbuckle Rod Part No.	Upper Clevis Part No.	Spacer Part No.	Connector Arm Block Position (b) 657 (f)	Connector Arm Block Position (b) 667	Pipe Nipple Part No.
657 & 667 With Side Mounted Handwheel	34	3/4	3	1	2V1889 2521	1F3796 1402	1C4529 1402	1F3785 1513	1F2106 1402	1J8307 2409	Std	Rev	1C6789 2623
	40	1-1/2	2	1	2U9095 2521	1F3796 1402	1F3796 1402	1F3785 1513	1F2106 1402	None Req'd.	Std	Std	
	45	2	2	1	2V1705 2521	1F3796 1402	1H6564 1402	1F2105 3513	1F2106 1402	None Req'd.	Rev	Rev	
	50	2	1	1	2U9095 2521	1F3796 1402	1C4529 1402	1F2105 3513	1F2106 1402	None Req'd.	Std	Std	
	60	2	1	1	2U9095 2521	1F3796 1402	1C4529 1402	1F2105 3513	1F2106 1402	None Req'd.	Std	Std	
	70	3	1	2	2U9099 2521	1C4529 1402	1C4529 1402	1F2105 3513	1V6723 1402	None Req'd.	Std	Rev	
	80	3	1	1	2U9099 2521	1C4529 1402	1C4529 1402	1F2105 3513	1V6723 1402	1V6833 2409 (g)	Std	Rev	
	87	3	3	1	2U9099 2521	1C4529 1402	1V6721 1402	1F2105 3513	1V6723 1402	None Req'd.	Std	Rev	

(a) See Figure 5.
(b) Standard and reversed positions are shown in Figure 13.
(c) Mounting holes set No. 3 must be used with Type 513R actuator.
(d) Type 667 part No. is 1N6240 2623
(e) Type 667 part No. is 1D2397 2623
(f) Mounted between mounting plate and actuator mounting boss. None Req'd. for Type 667.
(g) Mounted between stem connector and connector arm.

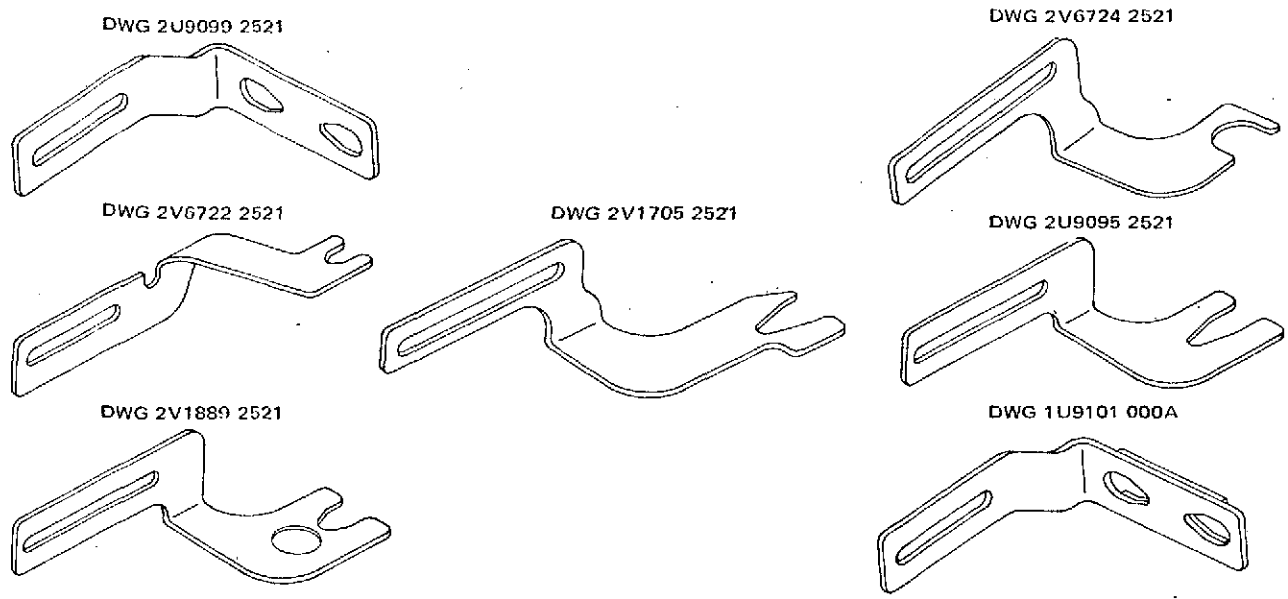


Figure 12. Various connector arms used for mounting Type 3590 valve positioner.

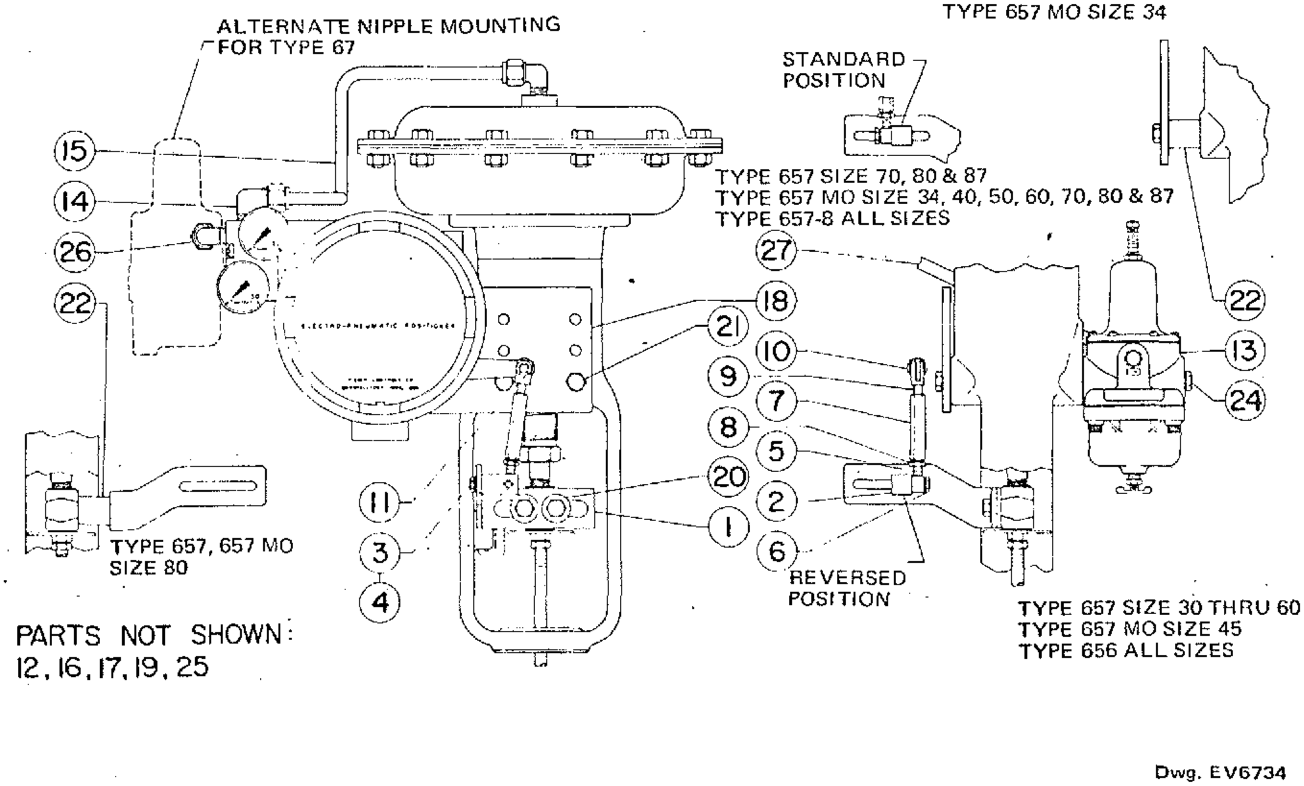


Figure 13. Type 3590 valve positioner mounted on Type 657 actuator.

PARTS REFERENCE – TYPE 3590 MOUNTING PARTS

Parts shown are used to mount Type 3590 valve positioner on all Fisher Actuators unless otherwise indicated.

Key	Part Name & Material	Part Number
1	Connector Arm, Steel, CD PL See tabulations on Page 9.	
2	Connector Arm Block, Brass, CD PL	2V6720 1402
3	Hex Cap Screw, Steel, CD PL	1C4732 2405
4	Washer, Steel, CD PL	1A4988 2898
5	Lower Turnbuckle Rod, Brass, CD PL See tabulations on Page 9.	
6	Lower Turnbuckle Pivot, SST	1F2104 3513
7	Turnbuckle, Brass,CD PL See tabulations on Page 9.	
8	Hex Jam Nut, Steel, CD PL	1A4997 2412
9	Upper Clevis, Brass, CD PL See tabulations on Page 9.	
10	Clevis Pin SST	1V8076 3516
11	E-Ring, Steel, CD PL (2 Req'd.)	1P2575 2899
12	Pipe Nipple, Steel, ZN PL See tabulations on Page 9.	
13	Type 67FR Filter Regulator	FS67FR-221
14	Male Elbow, Brass 2 Req'd. for Types 513 & 513R, 656 & 657 1 Req'd. for Types 657-8 & 667	1B8846 1899
15	Diaphragm Tubing, Copper	1P7487 1701
16	Cover Ass'y, Steel, ZN PL	10A2341 X01
17	Fillister Head Machine Screw, Steel, CD PL (2 Req'd.)	1H2676 2898
18	Mounting Plate, Steel, ZN PL	2V6727 2523
19	Hex Cap Screw, Steel, CD PL (3 Req'd.)	1A3816 2405
20	Washer, Steel, CD PL Type 513 & 513R 1/4" Stem 5/16" Stem 3/8" Stem Type 656 1/2" Stem Size 30 Sizes 40 & 60 Types 657 & 667 Without Handwheel (2 Req'd.) Sizes 30 through 70 Sizes 80 & 87 None required for Types 657 & 667 with side mounted handwheel. Type 657–8 Sizes 30 & 34 Other sizes	 None Req'd. 1B8659 2898 1E7941 2898 1K8995 2507 None Req'd. 1D7162 2898 1K8995 2507 1K8995 2507 None Req'd.
21	Hex Cap Screw, Steel, CD PL (2 Req'd.) Type 657 size 34 with side mounted handwheel All other types & sizes	1A3525 2405 1A3816 2405
22	Spacer Spool, Steel (2 Req'd.) See tabulation on Page 9.	
23	Male Connector, Brass Type 667 only	1B8856 1899
24	Cap Screw, Steel, CD PL (2 Req'd.)	1C3988 2405
25	Male Connector, Brass 2 Req'd. for Types 513R & 667 1 Req'd. for Types 513, 656, 657 & 657-8	1B8856 1899
26	Male Elbow, Brass Types 513, 656, 657 & 657-8 Types 513R & 667	 1B8846 1899 None Req'd.
27	Supply Tubing, Copper	1P7487 1701

PARTS REFERENCE UNIVERSAL MOUNTING

Parts shown are universal mounting parts used in mounting Type 3590 on non-standard actuators with 3/8" through 3/4" stems.

Key	Part Name & Material	Part Number
1	Connector Arm, Steel, CD PL	2U9095 2521
2	Connector Arm Block, Brass, CD PL	2V6720 1402
3	Cap Screw, Steel, CD PL	1C4732 2405
4	Washer, Steel, CD PL	1A4988 2898
5	Lower Turnbuckle Rod, Brass, CD PL	1F2105 1402
6	Lower Turnbuckle Pivot, 416 SST	1F2104 3513
7	Turnbuckle, Brass Short length yokes Average length yokes. Long length yokes	 1F3796 1402 1C4529 1402 1V6721 1402
8	Hex Jam Nut, Steel, CD PL	1A4997 2412
9	Upper Clevis, Brass, CD PL	1V6723 1402
10	Clevis Pin, 316 SST	1V8076 3516
11	E-Ring, Steel, CD PL (2 Req'd.)	1P2575 2899
12	Pipe Nipple, Steel, ZN PL Short length yokes Long length yokes	 1N6240 2623 1C6789 2623
13	Type 67FR Regulator	FS67FR-221
16	Cover Ass'y, Steel, ZN PL	10A2341 X01
17	Fillister Head Machine Screw, Steel, CD PL (2 Req'd.)	1H2676 2898
18	Mounting Plate, Steel, ZN PL	2V6727 2523
19	Hex Cap, Screw, Steel, CD PL, (3 Req'd.)	1A3816 2405
20	Washer 3/8" Stem, Steel, CD PL 7/16" & 1/2" Stem, Steel, CD PL 5/8" & 3/4" Stem, 302 SST	 1E7941 2898 1K8995 2507 1F1640 3899
21	Hex Cap Screw, Steel, CD PL (2 Req'd.)	1A3816 2405

INSTRUCTIONS AND PARTS LIST

TYPES 67F & 67FR

INTRODUCTION

The Types 67F and FR regulators are designed to provide a constant reduced pressure (air or gas), normally to pilot operated controllers and instruments. They can also be used for air spray guns, air jets, and other miscellaneous air and gas applications.

INSTALLATION

All pipe lines should be thoroughly cleaned and blown out before installing the regulator. Be sure that flow is in accordance with the letters denoting "IN" and "OUT" on the body. Inlet and outlet connections are tapped 1/4" NPT. Install with the draincock down.

There is a vent hole drilled in the bonnet, and on outdoor installations, this hole should be in the down position. If this is impractical, protect the regulator so that moisture cannot enter the vent. The vent must not be plugged.

The draincock (Key 17) should be opened periodically to allow moisture which has accumulated to drain. The regularity with which this is done will depend upon how much moisture is in the system.

ADJUSTMENT

The outlet spring range is shown on the paper label attached to the bonnet. Outlet spring ranges are as follows:

Spring Range, PSIG	Spring Color
3 – 20	Green
5 – 35	Cadmium
30 – 60	Blue
35 – 100	Red

The above spring ranges are recommended, although reduced pressure down to 0 psig may be obtained with each spring.

To change the outlet setting of the spring, first loosen locknut (Key 11). Then turn adjusting screw (key 10) clockwise to increase outlet setting or counterclockwise to decrease outlet setting. Be sure to tighten locknut after changing the setting. Maximum inlet pressure is 250 psig.

BASIC CONSTRUCTIONS

The basic styles of the Types 67F & FR are:

67F-101–Pressure regulator with filter dripwell.

67F-109–Pressure regulator with filter, dripwell and handwheel adjustment.

67F-111–Pressure regulator with filter and dripwell for panel mounting.

67FR-105–Pressure regulator with filter, dripwell and relief valve.

67FR-110–Pressure regulator with filter, dripwell, relief valve and handwheel adjustment.

67FR-112–Pressure regulator with filter, dripwell and relief valve for panel mounting.

TO REPLACE VALVE PLUG

Remove the four cap screws (Key 18, Figure 1) to remove filter cap. Filter adaptor (Key 13) may now be removed with a deep socket wrench to gain access to the valve plug.

When the filter element (Key 14) becomes dirty, it should be cleaned or replaced. It can be cleaned by rinsing in a solvent, and blown out with air.

TYPE NUMBER

When corresponding with the factory or representatives in regard to this regulator, always give the type number found stamped on the body. Refer to 10 character part numbers when ordering parts.

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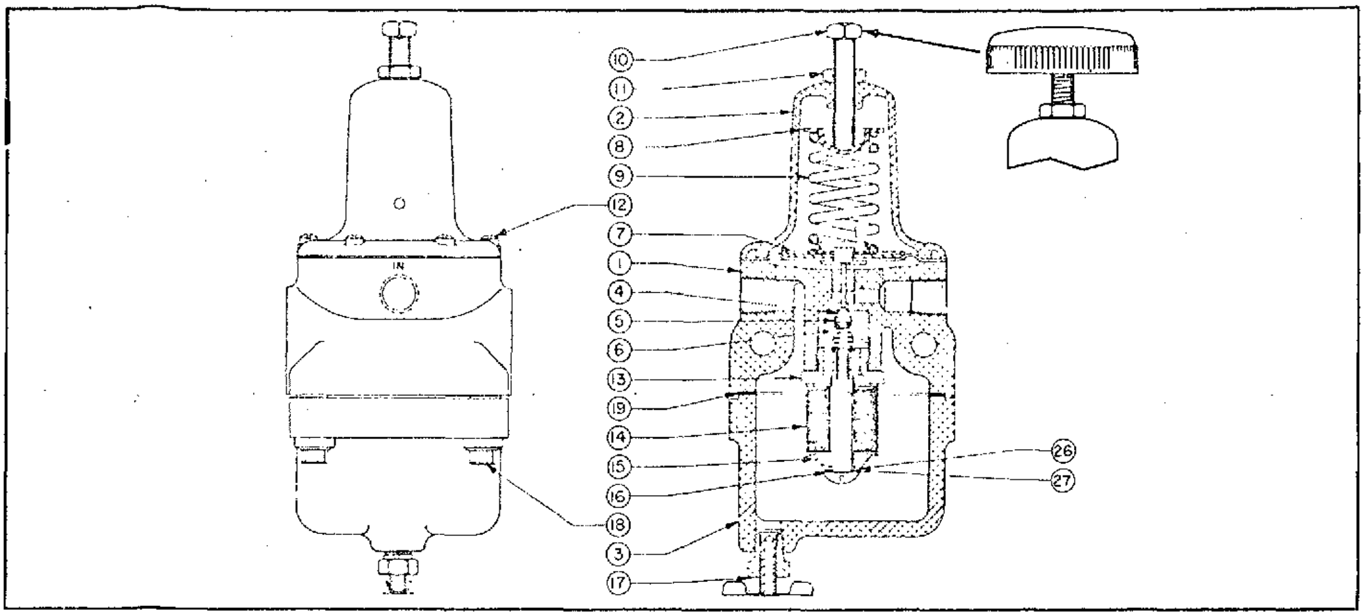
FORM NO. 1692C
(Supersedes Form No. 1692B)

PLI–30M-11-70



PARTS REFERENCE

1 Body Assembly
Alum & Brass (Std) . 1C1270 000A
Alum & SST 1C1270 000B

2 Bonnet,
67F-101, 109,
67FR-105, 110, Alum. 2B7974 0801
For panel mtg. 67F-111,
67FR-112, Brass. . . 3B9855 000A

Filter Cap, Alum. . . . 2C1272 0804

4* Valve Plug With Stem
Brass & Rubber . . . 1D5604 000A
304 SST & Rubber . 1D5604 000B
303 SST 1C7503 3503

5 Lower Spring Seat,
Aluminum 1E5322 1002

6 Valve Spring, 302 SST 1C1273 3702

7* Diaphragm Assembly
67F-101, 109, 111 . . 1B7980 000B
67FR-105, 110, 112 . 1B7989 000B

8 Upper Spring Seat,
Steel, Zinc pl. 1B7985 2506

9 Spring, Steel
3 - 20 psig, Green
Zinc Pl. 1B9860 2721
5 - 35 psig, Cad.,
Cad. pl. 1B7883 2702
30 - 60 psig, Blue,
Cad. pl. 1B7884 2702
35 - 100 psig, Red,
Zinc pl. 1K7485 2720

10 Adjusting Screw, Stl. . 1B7986 2899
Handwheel,
Steel, Zinc pl. 1B7992 000A

11 Adjusting Screw
Locknut, Stl., Cad pl. 1A9463 2412

12 Screw, Steel (6 req'd) . 1B7839 2899

13 Adaptor, Alum. 1C1274 0901

14* Filter Element
Brass 1C1275 9901
Cellulose 1F2577 0699
SST 1J9892 3899

15 Washer, Alum. 1C1276 1199

16 Filter Post, Alum. . . 1C1277 0903

17 Drain Valve
Brass 1K4189 000A
Alum. 1K4189 000B
303 SST AH3946 000B

18 Cap Screw (4 req'd)
67FR-111, 112, Steel 1C1279 2899
67FR-101, 105, 109
110, Stl, Cad: pl. . . 1K7647 2405

19* Gasket, Syn. Rubber . 1C1280 0301

26* Gasket, Asb. 1F8268 0402

27 Spring Washer, Steel . 1H8851 2899

* Recommended Spare Part

WARRANTY

Fisher Controls Company warrants the equipment described hereon to be free from defects in materials and workmanship under normal use and service. Fisher's sole obligation hereunder shall be limited to repairing or replacing the part or parts shown to have been defective at time of shipment. We may require return of the equipment to establish any claim. Deviations from recommended applications, system design, installation, and service practices shall be considered as abuses and render this warranty void.

Fisher's liability hereunder will not exceed the contract price for the equipment claimed to be defective and Fisher will not, in any event, be liable for any special or consequential damages.

This warranty applies for a period of one year after shipment from factory or sixty days after installation of the equipment, whichever is longer.

THE FOREGOING CONSTITUTES FISHER'S SOLE WARRANTY WITH RESPECT TO THE EQUIPMENT COVERED HEREBY AND ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, ARE HEREBY EXCLUDED.

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If it flows through pipe, chances are it's controlled by

FISHER Controls

Instruction Manual and Parts List

Series 1301F, 1301G

TYPE NUMBER EXPLANATION

Type 1301F - Pressure reducing regulator for inlet pressure up to 6000 psi and an outlet pressure range of 10 to 225 psi (3 springs)*. Has 5/64" orifice, and 1/4" inlet and outlet connections.

Type 1301G - A Type 1301F with a heavier spring and larger bonnet for outlet pressure range of 200 - 500 psi (one spring)*.
* All springs will back off to 0 psi.

INSTALLATION

When the regulator is installed, all pipe lines should be clean. Use suitable pipe compound on the male threads, and install the regulator so that flow is in accordance with the letters "IN" and "OUT" stamped on the body. There are two "OUT" connections. The unused one should be plugged, or can be used for a pressure gauge. This regulator should not be installed in systems where the inlet pressure exceeds 6000 psi.

ADJUSTMENT

The reduced pressure setting can be varied within the limits stated on the nameplate. To do this, loosen the locknut (Key 18, Figure 2) and turn the adjusting screw into the spring case to increase the reduced pressure, or out of the spring case to lower the reduced pressure setting. Tighten the locknut when finished.

MAINTENANCE

Before attempting any maintenance, isolate the regulator in the line, and be sure that there is no pressure in the body.

VALVE DISC

The valve disc holder (Key 6) is fitted with a disc at either end, and can be reversed when the disc being used becomes worn. *To do this, follow* the procedure outlined below.

1. Remove the body cap (Key 3) and the bottom cap gasket (Key 14).

2. Engage the hex of the valve disc holder with a suitable wrench, and unscrew it from the yoke (Key 4).

3. Still holding the valve disc holder, use a second wrench, and unscrew the valve disc collar (Key 22) from the disc holder.

4. Now screw the valve collar on to the other end of the valve disc holder, invert the entire assembly so that the unused valve disc contacts the orifice.

5. Before screwing the disc holder assembly back into the yoke, inspect the condition of the orifice (Key 5). If it needs replacing, see section following.

DIAPHRAGM, BODY GASKET, DIAPHRAGM HEAD GASKET, ORIFICE

To replace the body gasket (Key 12), diaphragm head gasket (Key 13) proceed as outlined.

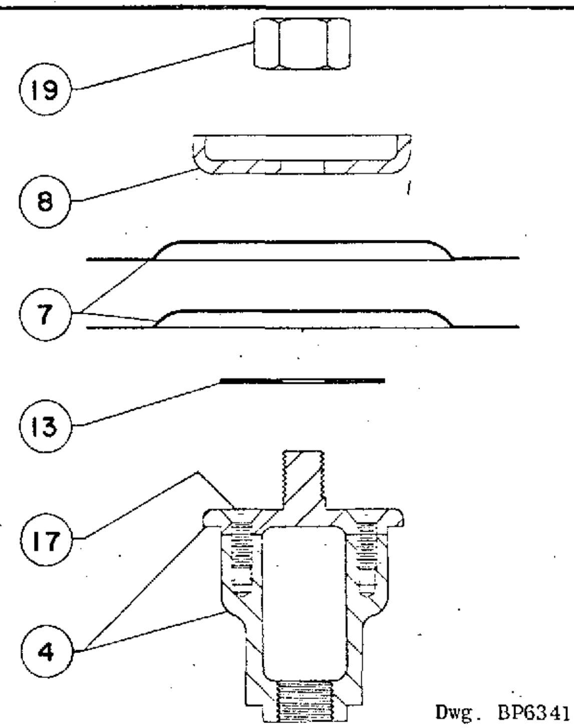

FIGURE 1 - EXPLODED VIEW OF DIAPHRAGM AND YOKE ASSEMBLY

1. Loosen the locknut (Key 18) and back the adjusting screw (Key 15) off until spring (Key 11) compression is relieved.

2. Remove the cap screw (Key 16), and separate the bonnet (Key 2) and the body (Key 1). Be careful not to lose the body gasket (Key 12).

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FORM 1111B
(Supersedes Form 1111A)

3. Unscrew the diaphragm nut (Key 19), and remove the diaphragm head (Key 8), two diaphragms (Key 7), and the diaphragm head gasket (Key 13) in that order.

4. When reassembling the diaphragm and associated parts, see Figure 1 for assistance in getting these components in their proper relationship.

If the orifice needs to be replaced, continue from Step 3 in the preceeding section as follows:

1. Remove the screws (Key 17) which hold the yoke together.

2. Now take off the bottom cap (Key 22), gasket (Key 14), and spring (Key 10). The bottom half of the yoke (Key 4) will also come out.

3. The orifice can now be unscrewed with a 7/16" wrench.

4. After the orifice is replaced, the regulator can be reassembled.

CORRESPONDENCE

When corresponding about this regulator, include the maximum outlet pressure, stamped on the nameplate, and the date of manufacture, stamped on the bottom cap. When ordering spare parts, furnish the complete part number from the parts reference section.

Parts Reference

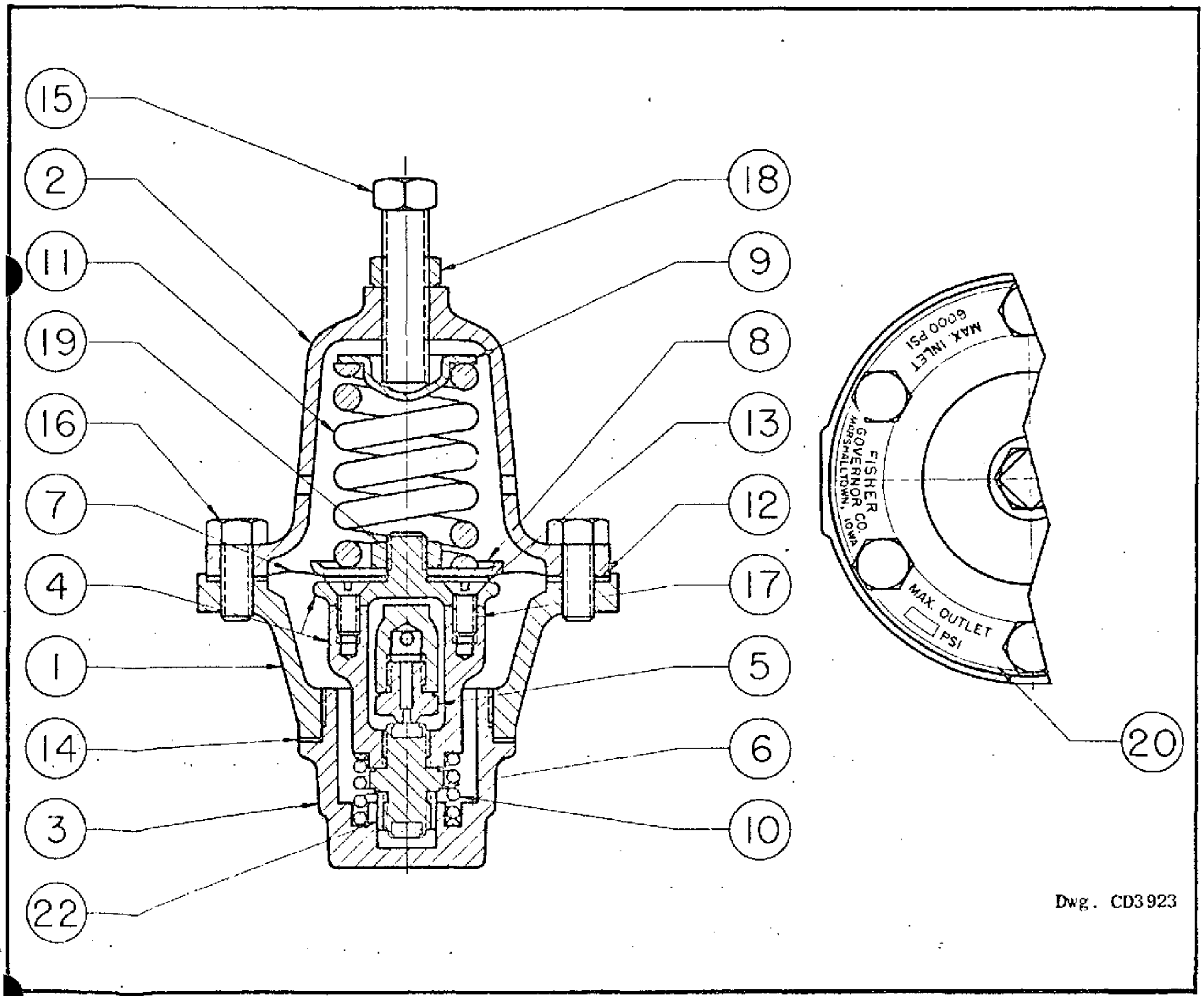

FIGURE 2 - TYPE 1301F

Parts Reference

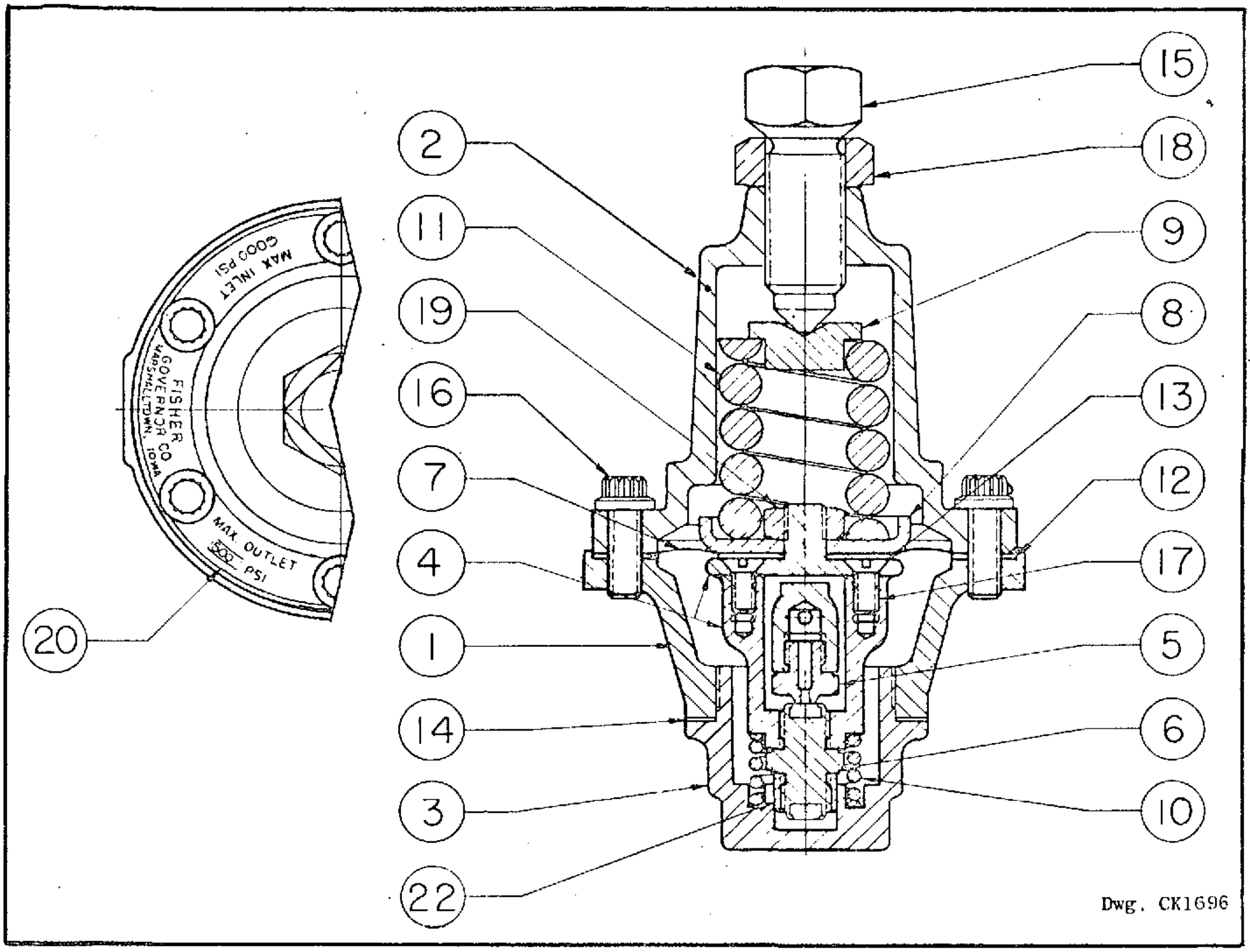

FIGURE 3 - TYPE 1301G

KEY NO.	PART NUMBER	PART NAME	MATERIAL
1	2D3835 1301	Body, 1/4" NPT	BRASS
	2J9200 3309	Body, 1/8" NPT	316 SST
2	1D3831 1301	Bonnet, 1301F.	BRASS
	1J9198 2204	Bonnet, 1301F.	STEEL, CAD. PLATE
	2P1957 1302	Bonnet, 1301G.	BRASS
	2P1957 2204	Bonnet, 1301G.	STEEL
3	1D4685 1301	Bottom Cap	BRASS
	1J9196 3507	Bottom Cap	316 SST
4	1D3833 1301	Yoke	BRASS
	1J9259 3604	Yoke	316 SST
5	1D3865 3503	Orifice.	303 SST
6*	1D4684 000B	Valve Disc Assy, Teflon Disc, Use with SST Trim.	SUB-ASSY.
	1D4684 000A	Valve Disc Assy, Nylon Disc, Use with Brass Trim	SUB-ASSY.
7*	1D3870 3601	Diaphragm, 2 Req.. . . .	302 SST
8	1D3873 2507	Diaphragm Head, 1301F. .	STEEL
	1K1557 2507	Diaphragm Head, 1301G. .	STEEL
9	1B7985 2506	Upper Spring Seat, 1301F	STEEL
	1K1558 2899	Upper Spring Seat, 1301G	STEEL
10	1D3871 3702	Valve Spring	302 SST
11	1D3872 2702	Spring, 0-75 PSI, Blue, 1301F.	SPG. WIRE
	1B7885 2702	Spring, 0-150 PSI, Blue, 1301F.	SPG. WIRE

KEY NO.	PART NUMBER	PART NAME	MATERIAL
11	1D4651 2714	Spring, 0-225 PSI, Red, 1301F.	SPG. WIRE
	1K1560 2714	Spring, 225-500 PSI, 1301G.	STEEL
12*	1D3729 0301	Body Gasket.	NEOPRENE
	1D3729 0412	Body Gasket, SST Const..	VITON
13*	1D3730 0301	Dia. Head Gasket	NEOPRENE
	1D3730 0412	Dia. Head Gasket, SST Const.	VITON
14*	1D3864 0301	Bottom Cap Gasket. . . .	NEOPRENE
	1J9268 0638	Bottom Cap O-Ring, SST Const.	VITON
15	1A3687 2899	Adj. Screw, 1301F. . . .	STEEL
	1K1406 2409	Adj. Screw, 1301G. . . .	STEEL
16	1K7645 2405	Spg. Case Screw, 6 Req..	STEEL
17	1D3869 2899	Yoke Screw, 2 Req. . . .	STEEL
	1J9269 3899	Yoke Screw, 2 Req. SS Const..	STEEL
18	1A5180 1401	Locknut, 1301F Std. Const.	BRASS
	1A3522 2412	Locknut, 1301F SST Const.	STEEL
	1A3540 2412	Locknut, 1301G	STEEL
19	1A3093 2412	Dia. Head Locknut. . . .	STEEL
20	1F1043 1899	Nameplate.	BRASS
22	1D4686 3503	Valve Disc Collar. . . .	303 SST
23	1J9260 3507	Top Connector, SST Const.	316 SST
26	0W0863 4306	Vent Screen, 1301G Std. Const..	MONEL

* Recommended Spare Parts for Stock.

Dynisco
20 Southwest Park
Westwood, Massachusetts 02090
Telephone (617) 326-8210

INSTRUCTIONS FOR DYNISCO PT300 SERIES LOW LEVEL OUTPUT TRANSDUCERS

The Dynisco PT300 series transducers are bonded metal foil strain gauge instruments. The principal of operation is that the pressure to be measured is applied to a metal diaphragm which becomes stressed due to the pressure on one side. This stress is measured by the strain sensing elements and is converted through the strain gauges wired into a wheatstone bridge circuit to produce an electrical output proportional to the sensing pressure.

The electrical output from the transducer is related to the excitation or input voltage. The full scale output is specified in terms of millivolts of output per volt of excitation. To obtain the actual transducer output, multiply the excitation voltage being used by the millivolts/volt output value of the transducer. The full millivolt output is available only when using a readout instrument with a minimum of 100,000 ohms input impedance. A reduced output occurs with lower readout resistances.

The wheatstone bridge circuit of the strain gauges allows the design of a shunt calibration network to electrically simulate various pressures. Dynisco 300 series transducers are shipped with a data sheet that includes the shunt resistance value required to simulate 80% of the full scale output. This "R-cal" value is used to facilitate the electrical calibration of the transducer- readout system.

OPERATION

Obtain a suitable strain gouge transducer power supply and a readout as detailed in the readout section. A combined readout, power supply and signal conditioner may be used for this purpose. Obtain a fixed resistor within 1% of the specified R cal value or use a decade box.

The R cal resistor should be a precision wire wound resistor specified to within 1%. The wiring diagram shows the location of the "R cal" resistor and the location of the calibration switch. The transducer may be zeroed and spaned using the circuits in Figure 1 and Figure 2 respectively if these adjustments are not provided in the readout system. (All Dynisco strain gauge electronic instrumentation contains zero and span networks.) After the transducer is wired into the readout circuit and the power is turned on for 5 minutes minimum, the system is ready for electrical calibration.

. With no pressure applied to the transducer, zero the transducer. After this is accomplished, close the calibration switch and adjust the span control until you read 80% of the transducer's full scale output. Open the calibration switch and recheck zero.

The transducer power supply, signal conditioner, and readout are now electrically calibrated.

Mechanical transducer calibration is done by applying a known pressure to the instrument and comparing the output reading to the pressure input. A dead weight tester should be used as the pressure source for this calibration. Detailed mechanical calibration instructions and sample calculation sheets are attached.

POWER SUPPLY, SIGNAL CONDITIONER AND READOUTS

The accuracy of each transducer is determined by using a precision power supply and high input impedance millivolt readout. To obtain optimum performance from your instrument, high quality strain gauge electronics are required.

The strain gauge power supply must be capable of providing well regulated 10 volts DC or less at 30 milliamps maximum. A very low output noise level is needed and should not exceed 20 microvolts p-p. For calibration work a small capacitor (20pf) may be added to the strain gauge output to eliminate any ripple and noise. This capacitance dampens the transducer response and should be kept to a minimum. In addition, the signal minus (-) lead should be grounded if a floating (ungrounded) power supply is used.

A signal conditioning network to properly zero and span the transducer is required. Figure 1 and 2 show typical networks to provide these adjustments. For calibration work a zero and span network is not required, since the zero unbalance can be subtracted from the readings. All calibration readings are based on a percentage of full scale sensitivity basis and are, therefore, independent of the full scale adjustment.

The readout device must have a full scale equal to the millivolt/volt output sensitivity of the transducer times the excitation voltage available. To obtain the full millivolt output of the transducer, the readout must have an input impedance of 100,000 ohms minimum A digital millivolt meter, servo driven recorder or an amplified analog meter can be used. Direct reading millivolt meters, in general, do not have the correct input impedance. Special meters are available to meet this application requirement. The meters are 20 microamp movements with an input resistance of 400 ohms.

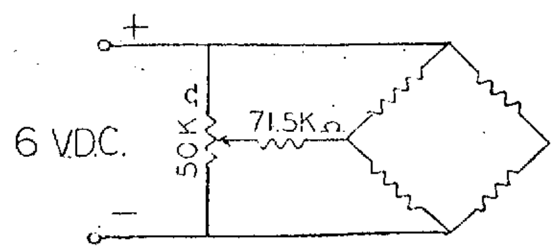

FIG. 1

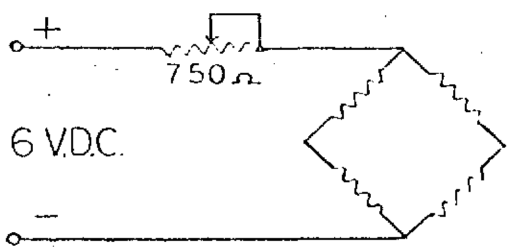

FIG. 2

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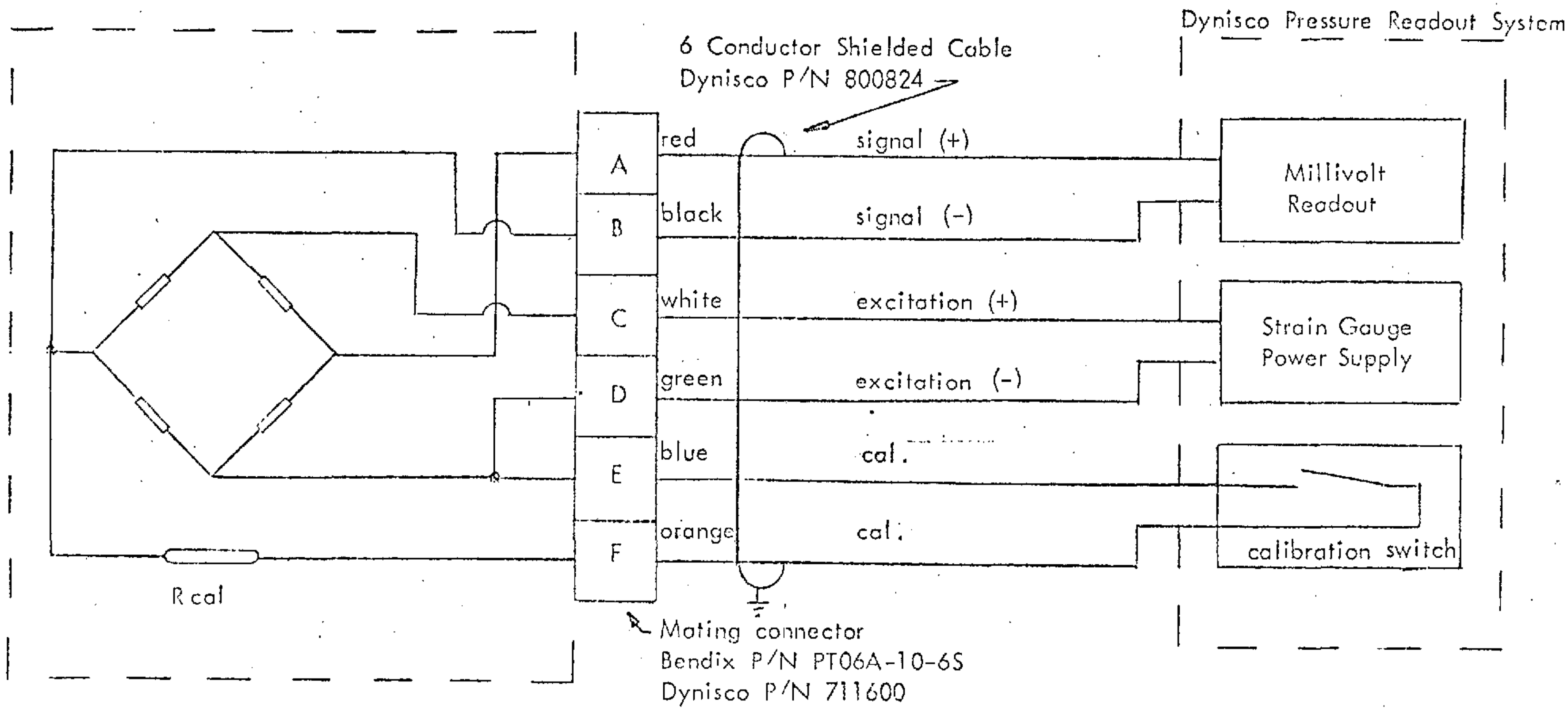
Wiring Diagram for: PT460, PT462, PT464, PT465
PT310S, PT311, and DPT361



NOTE: R cal resistor standard on PT460, PT462, PT464, and PT465. Optional on PT310S, PT311, and DPT361.

REV	DCN	BY	APP	DATE

REVISIONS

UNSPECIFIED TOLERANCES			
FRA	DEC	ANG	DRILLED HOLES LETTER & FRACT / NO.
±	±	± 30'	+.005 -.001 / +.003 -.000

FILLETS & ROUNDS .005 R MAX

SURFACE FINISH 63 ✓ SCALE

MATERIAL

TITLE

MODEL NO. DIC

DWN DATE

CHECKED DATE

APPROVED DATE

DYNISCO

SIZE	DWG NO.	REV

Dynisco 20 Southwest Park
Westwood, Massachusetts 02090
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DATA SHEET

DATE: 3-16-73
DYNISCO ORDER: 26-73
CUSTOMER: RESEARCH, INC.
CUSTOMER ORDER: 93084
MODEL: PT321 SW-5C
RANGE: 0-500 PSIG
SERIAL NUMBER: 57149

INPUT RESISTANCE: N.A
OUTPUT RESISTANCE: N.A
INSULATION RESISTANCE: >500 MΩ
ZERO LOAD OUTPUT: +.002 volts
FULL RANGE SENSITIVITY: 5.002 volts
EXCITATION: 28 V
EXCITATION + WHITE SIGNAL + RED GRND. ___ J - CONSTANTAN
EXCITATION − GREEN SIGNAL − BLACK ___ J + IRON
MAXIMUM MOUNTING TORQUE: ___
THERMOCOUPLE RESISTANCE: N/A
THERMOCOUPLE OUTPUT @ 212 DEG. F.: ___

SHUNT CALIBRATION

S 1413

☐ INTERNAL
☑ EXTERNAL
☐ DOUBLE

Pressure Simulated % F.S.	20	25	40	50	60	75	(80)	100
Pressure Output MV/V								
Shunt Electrical Output MV/V								
Shunt Resistance – Kilohms							71.360 Ω	
Shunt Connections – Pins							BLUE & ORANGE	

TEST TECHNICIAN: 326

FINAL ACCEPTANCE: [stamp] 204

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DATA SHEET

DATE 3-2-73
DYNISCO ORDER 1327-72
CUSTOMER RESEARCH INC.
CUSTOMER ORDER 93024
MODEL PT321 SW-5C
RANGE 0-500 PSIG
SERIAL NUMBER 62026

INPUT RESISTANCE N.A
OUTPUT RESISTANCE N.A
INSULATION RESISTANCE >500 MΩ
ZERO LOAD OUTPUT +.010 volts
FULL RANGE SENSITIVITY 5.005 volts
EXCITATION 28V
EXCITATION + WHITE SIGNAL + RED GRND. ___ J - CONSTANTAN
EXCITATION – GREEN SIGNAL – BLACK J + IRON
MAXIMUM MOUNTING TORQUE
THERMOCOUPLE RESISTANCE N/A
THERMOCOUPLE OUTPUT @ 212 DEG. F.

SHUNT CALIBRATION

S 1413

[ ] INTERNAL
[V] EXTERNAL
[ ] DOUBLE

Pressure Simulated % F.S.	20	25	40	50	60	75	(80)	100
Pressure Output MV/V								
Shunt Electrical Output MV/V								
Shunt Resistance – Kilohms							33,310 Ω	
Shunt Connections – Pins							[illegible]	

TEST TECHNICIAN: [illegible]

FINAL ACCEPTANCE: [illegible]

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20 Southwest Park
Westwood, Massachusetts 02090
Telephone (617) 326-8210

DATA SHEET

DATE 3-2-73
DYNISCO ORDER 26-73
CUSTOMER RESEARCH INC
CUSTOMER ORDER 93084
MODEL PT 321 SW-5C
RANGE 0-500 PSIG
SERIAL NUMBER 57239

INPUT RESISTANCE N.A
OUTPUT RESISTANCE N.A
INSULATION RESISTANCE > 500 MΩ
ZERO LOAD OUTPUT +.027 volts
FULL RANGE SENSITIVITY 5.000 Volts
EXCITATION 28 V
EXCITATION + WHITE SIGNAL + RED GRND. J - CONSTANTAN
EXCITATION − GREEN SIGNAL − BLACK J + IRON
MAXIMUM MOUNTING TORQUE
THERMOCOUPLE RESISTANCE N/A
THERMOCOUPLE OUTPUT @ 212 DEG. F.

SHUNT CALIBRATION

S 1413

[ ] INTERNAL
[v] EXTERNAL
[ ] DOUBLE

Pressure Simulated % F.S.	20	25	40	50	60	75	(80)	100
Pressure Output MV/V								
Shunt Electrical Output MV/V								
Shunt Resistance – Kilohms							64.900 Ω	
Shunt Connections – Pins							BLUE + ORANGE	

326
TEST TECHNICIAN

FINAL ACCEPTANCE

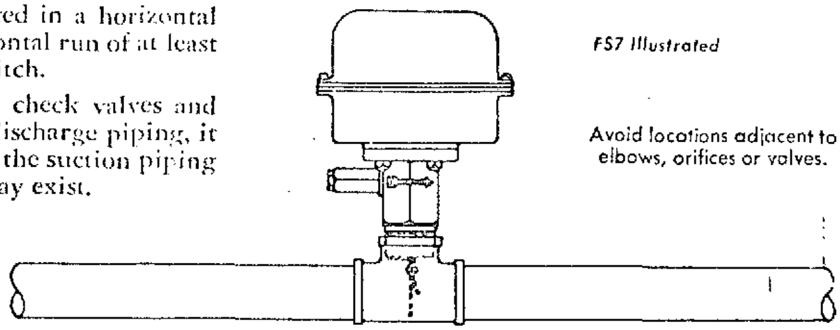
INSTALLATION DATA FOR FS7 SERIES FLOW SWITCH

(Use vapor-proof electrical connections with vapor-proof flow switch models.)

LOCATION: The Flow Switch must be located in a horizontal section of pipe where there is a straight horizontal run of at least 5 pipe diameters on each side of the Flow Switch.

With the increasing usage of spring-load check valves and other close-coupled accessories in the pump discharge piping, it is suggested that Flow Switches be located in the suction piping where less turbulent water flow conditions may exist.

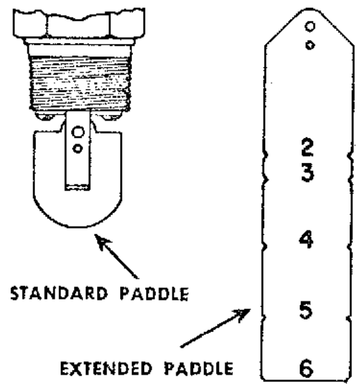
MOUNTING: The Flow Switch should be installed vertical and upright as shown, with paddle at right angle to flow and arrow mark on side of casting in same direction as flow.



INSTALLATION: Adjust the Flow Switch paddle to the size of the pipe in which it is to be used. For maximum sensitivity the paddle should extend as far as possible into the pipe and should be trimmed accordingly (when used with large reducing tees or large standard tees with face or hex bushings).

For average installations chart below can be followed, and paddle trimmed to the markings shown on it.

Pipe Size	Paddle to Use (see illustration)	Tee Size or Welding Fitting
1¼"	Standard	1¼"x1¼"x1¼" Tee
1½"	Standard	1½"x1½"x1¼" Tee
2"	Extended trimmed to 2"	2"x2"x1¼" Tee
2½"	Extended trimmed to 2"	Welding fittings should be **half-couplings** or other welding fittings with minimum length of thread.
3"	Extended trimmed to 3"	
4"	Extended trimmed to 4"	
5"	Extended trimmed to 5"	
6" and larger	Extended full size	



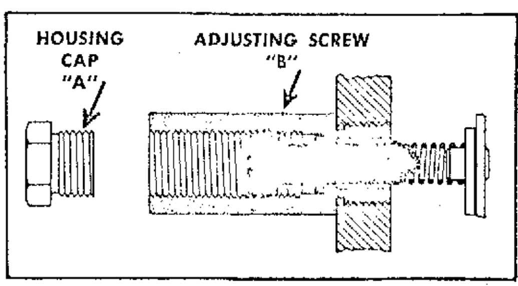
When extended paddle is used, the shorter length standard paddle should be removed so that the longer length paddle will bend with the curvature of the paddle arm.

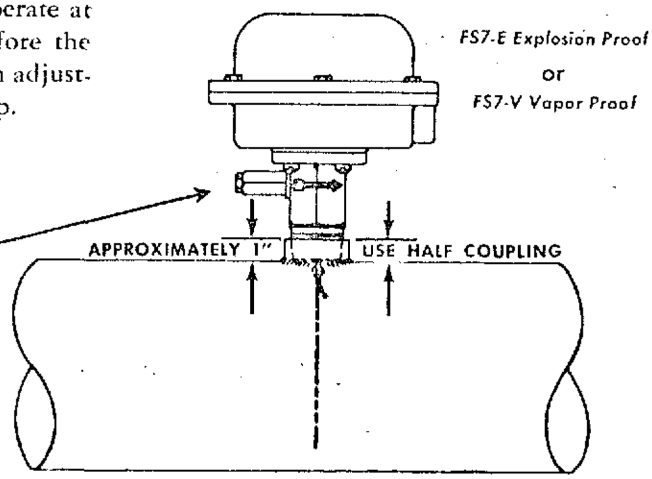
Note: Chart recommendations are based on using tee or reducing tee through 2" pipe size, and **welded half-coupling** on larger pipe sizes.

Important — On higher velocity applications in 6" or larger pipe, trim extended paddle according to table at right.

8 ft. / Sec.	Trim to 5"
10 ft. / Sec.	Trim to 4"
12 ft. / Sec.	Trim to 3"

ADJUSTMENT: The Flow Switch is factory adjusted to operate at minimum flow velocities. To obtain higher velocities before the Flow Switch is actuated, remove housing cap "A", and turn adjusting screw "B" in clockwise direction. Replace housing cap.





McDONNELL & MILLER, *Inc.*, 3500 N. Spaulding Ave., Chicago, Ill. 60618

Doing One Thing Well — REG. U. S. PAT. OFF.

Bulletin No. I-FS7-G

Printed in U.S.A.

Wiring Instructions for McDONNELL FS7 Series Flow Switch

ELECTRICAL RATINGS
(Underwriters Listed)

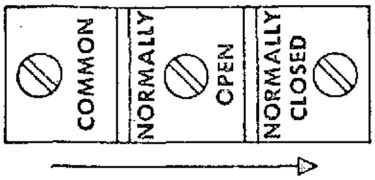
AMPERE RATING

Motor Duty Full Load Locked Rotor	115 V.A.C. 7.4 Amps. 44.4 Amps.	230 V.A.C. 3.7 Amps. 22.2 Amps.
	115 V.D.C. 0.3 Amps.	230 V.D.C. 0.15 Amps.
PILOT DUTY: A.C. 125 V.A., 115-230 V.		

Note: If the temperature of the liquid inside the pipe is over 230°F., use wire suitable for at least 90°C. (194°F.).

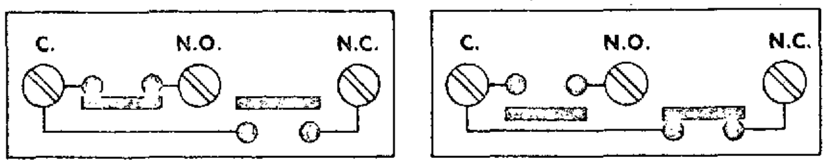
(Use vapor-proof electrical connections with vapor-proof flow switch models.)

Top View of Switch



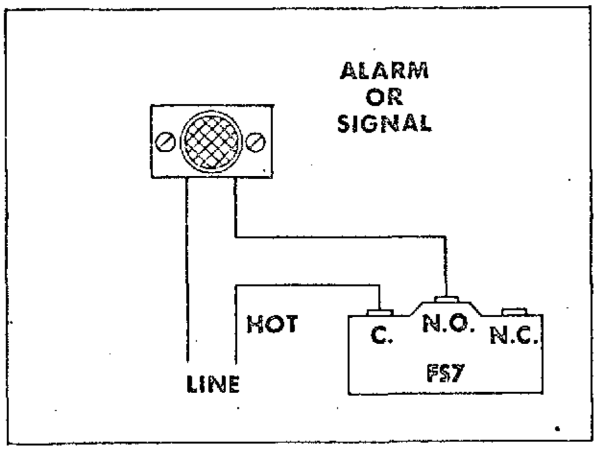
DIRECTION OF FLOW

Schematic of Flow Switch Operation

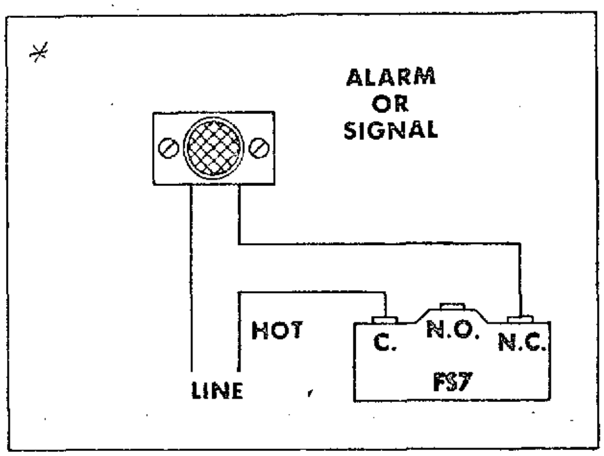


FLOW **NO FLOW**

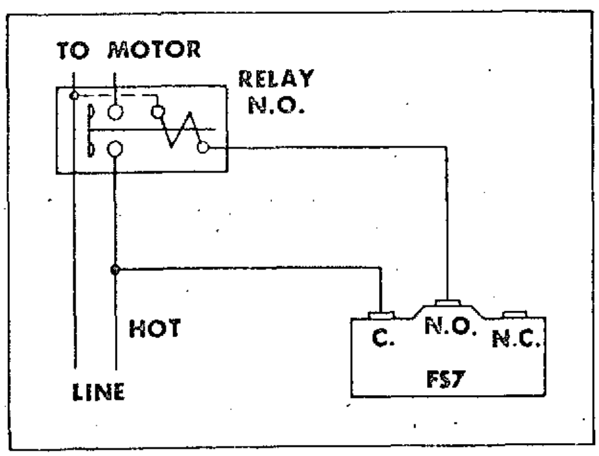
Typical Applications



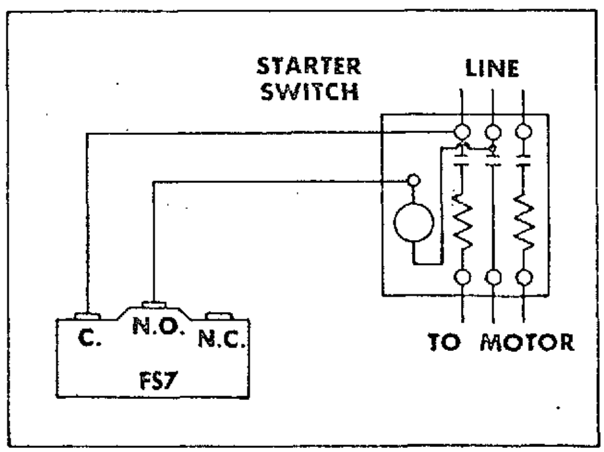
1 Used to sound alarm or light signal when *flow* occurs.



2 Used to sound alarm or light signal when no-*flow* occurs.



3 Used with single phase circuit — *starts* motor when flow occurs, *stops* motor when no-flow occurs.



4 Used with three phase circuit — *starts* motor when flow occurs, *stops* motor when no-flow occurs.

ALL WIRING CONNECTIONS SHALL CONFORM WITH NATIONAL AND LOCAL CODES.