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INSTRUCTION BOOK

YSI MODEL 72 PROPORTIONAL CONTROLLER

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220 VOLT INFORMATION

If this instrument has been purchased as a 220 Volt Model, the following notes should apply to statements made in the instructions.

1. 220 Volt Operable from 190-250 VAC.
2. Wattage as stated in instructions.
3. Current requirement of instrument and capacity of relays, etc., is ½ that stated.
4. Use Bussman Limitron KTK5A fuse only, not KAA10 stated in Specifications.
5. The Schematic contains notes indicating changes which have been made to the circuit.

MODEL 72 PROPORTIONAL CONTROLLER

GENERAL DESCRIPTION

The Model 72 Proportional Temperature Controller is a precision solid state electronic controller capable of maintaining temperatures with a constancy far exceeding that of on-off type controllers. The instrument is provided with a direct dialing system which enables the user to select the desired control point directly in degrees Centigrade. The use of solid state circuitry throughout results in very high reliability of the instrument.

The temperature is sensed by means of a thermistor probe which forms one leg of a modified alternating current Wheatstone bridge. The output of the bridge is an a.c. error signal whose amplitude is proportional to the temperature deviation of the probe from the selected temperature, and whose phase determines the direction of this deviation. This signal is amplified by means of a stabilized amplifier to an amplitude corresponding to a voltage gain of about 1000. The amplified signal is demodulated, by means of a phase sensitive detector, so that a d.c. output appears whenever the phase of the error signal indicates that the temperature of the probe has exceeded the selected control point. The d.c. signal is fed to a firing circuit which controls the conduction angle of two silicon-controlled rectifiers so that a continuously variable power is fed to the heater. Because of the linear nature of the intervening circuits, the power to the heater can be varied smoothly, and is an inverse function of the temperature rise above the set point. In a control situation the controlled temperature differs from the selected temperature only by a small error signal which is a function of the thermal losses of the controlled medium. Once control has been established, any disturbance of the controlled medium will be sensed by the probe and the controller will immediately furnish corrective action by supplying or withholding heat to the medium at the rate required to maintain the controlled temperature constant.

The bridge of the instrument is supplied from a variable alternating current source which is manually adjustable from the front panel of the instrument. By means of this control the sensitivity or bandwidth may be varied to render the instrument compatible with a wide variety of control applications. The bandwidth is presented in degrees Centigrade and represents the temperature band within which the instrument is performing its intended function. If, for example, the bandwidth control is set at 0.1°C, the controller output will vary from 0 to 100% power for a 0.1°C drop of the sensed temperature.

SPECIFICATIONS

Direct Dialing: Any control temperature between 0°C and 120°C may be directly selected to an accuracy of ±0.5°C.

Setability: Within ±0.005°C by using last selector dial as vernier.

Controlled Medium Stability: The controlled temperature point may be maintained to within less than ±0.01°C in well designed control systems. (See Operation)

Long Term Instrument Stability: (bandwidth set at 0.1°C) — The instrument control point will be maintained to within ±0.06°C for an ambient temperature change of ±10°C and/or a line voltage variation of ±10%.

Bandwidth: The proportioning band, hereafter referred to as the "bandwidth" is nominally variable from less than 0.1°C to more than 3°C. (See Operation)

Power Output: 117V AC resistive heater loads of up to 1KW may be controlled by the instrument. (See Operation)

Power Requirements:

1. 117 Volts 50 to 60 Hz. Up to approximately 1KW power may be required depending upon heater requirements. The instrument is operable under a line voltage variation of 100 to 135 Volts.

2. Fuse: The instrument is protected by a fast acting fuse type KAA10 manufactured by Bussmann Manufacturing Division, McGraw-Edison Company, St. Louis 7, Missouri. One replacement is included with each instrument. Only exact replacement fuses must be used, otherwise the silicon-controlled rectifiers may be permanently damaged in the event of accidental short in the heater circuit.

Ambient Temperatures: The instrument is operable within an ambient temperature range of 0° - 50°C.

OPERATING INSTRUCTIONS

1. Installation: The Model 72 may be installed where a convenient 117V 10 amp 50 or 60 Hz alternating current is available. For optimum performance and maximum safety the instrument should be supplied from a three-way socket which effectively grounds the instrument chassis. If a three-way socket is not available, the adapter supplied with the instrument may be used, but it is recommended that the instrument be well grounded through the adapter ground spade lug.

The Model 72 has been specifically designed for operation with YSI 400 series interchangeable thermistor probes which make possible the direct dialing feature of the instrument. The thermistor probe and the heater are connected to the instrument by suitable outlets on the back panel. The probe is simply plugged into the phone jack, and the heater connection may be made through a 3-way or 2-way standard a.c. plug. The perforated back panel of the instrument has been designed to permit adequate cooling of the internal SCR heatsinks by free air convection. It is imperative therefore that the instrument be placed in a location which will allow a free flow of air through the back panel perforations.

OPERATING PARAMETERS

The need for proportional type of temperature control arises in control systems where the temperature cycling of on-off controls can not be tolerated. The inherent property of proportional control is the ability of the controller to supply power to the heater which is continuously proportional to the temperature deviation from the set point. Because of the absence of discontinuities around the set point, very smooth control is achieved and the controlled temperature may be held constant with negligible temperature cycling. In practical applications discontinuities do occur in the form of sudden changes in the thermal load of the system or sudden changes in line voltage. The speed with which these disturbances can be sensed, and corrected for by the controller, largely determines the control stability and the degree of success of the whole system.

Considerations in designing a stable proportional control system involve the careful choice and application of the elements of the entire system so as to facilitate the fastest possible response consistent with control stability. The response of the Model 72 contributes negligible time lag (time constant, approximately 0.1 second) compared to some of the essential parameters (e.g. heater time constant) of a given control system. The adjustable bandwidth and fast response time features render the Model 72 applicable to almost any control situation, provided certain control criteria are observed. The control criteria are discussed below with particular reference to the various elements necessary in putting together a temperature control installation. With the proper design of the entire system, control stabilities of better than $\pm.01\,^\circ C$ are possible.

It should be noted what difficulties can arise when a failure occurs. If there is a power interruption the system turns off since the controller gets power from the same source as the heater. If a component in the controller fails the system can either turn completely on or off, depending on which component fails. Thus some component failures could cause the medium being controlled to grossly overheat. To protect against this an inexpensive bi-metal switch or similar device should be used in series with the heater or the controller for unattended operations. Merely set the switching temperature of the bi-metal a few degrees higher than the control temperature.

Probe Selection

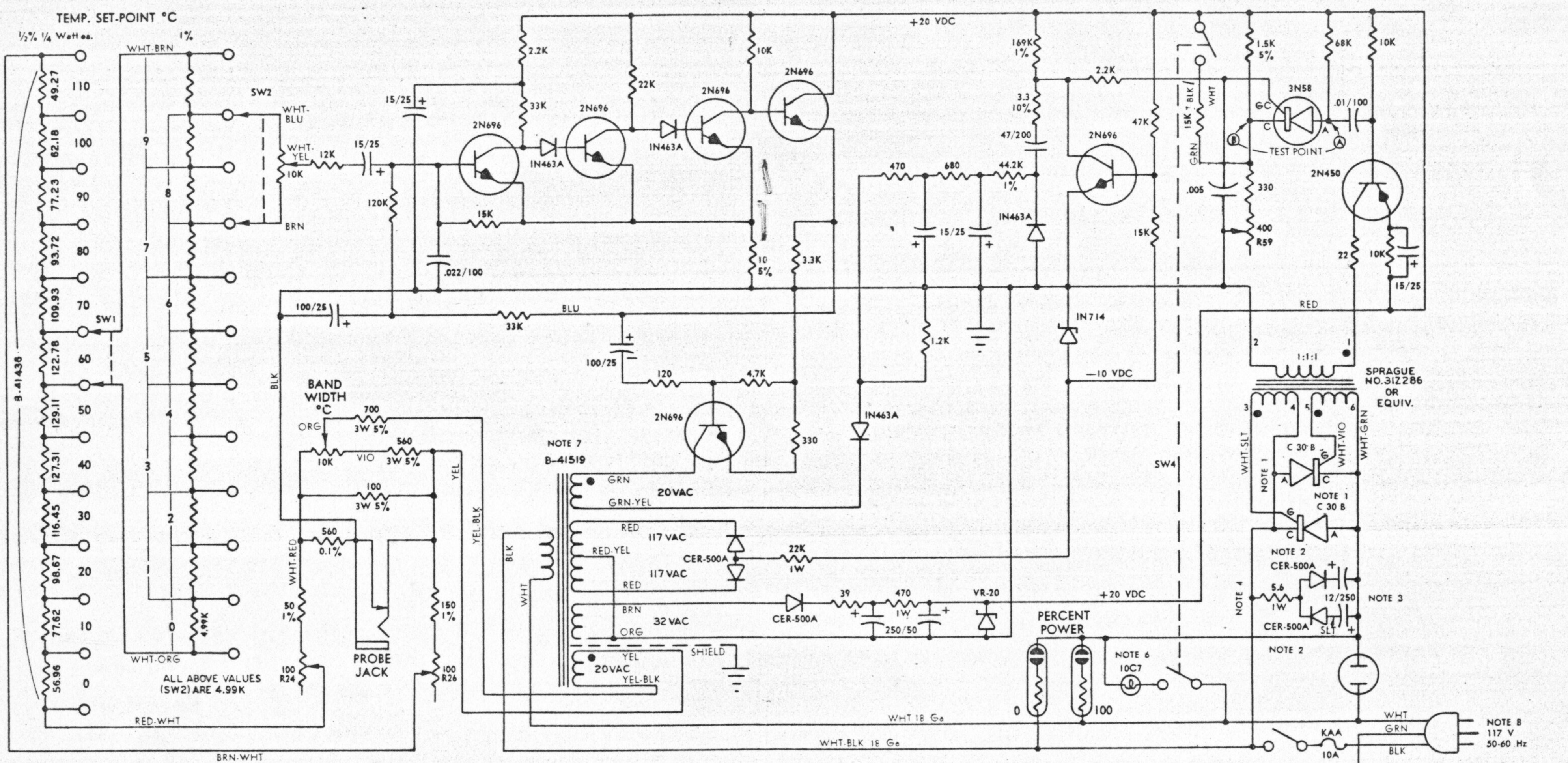
The YSI Model 72 Proportional Temperature Controller has been designed specifically for use with the YSI 400 Series interchangeable probes. The medium to be controlled will largely dictate the physical characteristics of the probe, although a wide range of configurations for each medium is possible with the 400 Series probes. The following guide should prove useful:

Media	Applicable 400 Series Probes
Liquids	402, 403, 404, 406, 408, 409 410, 415, 417, 418, 419, 421 423, 425, 426, 427
Solids (Surface Temperatures)	408, 409, 421, 425, 426, 427
Semi-solids (Internal Temperatures)	403, 404, 406, 410, 416, 418 419
Gases	405, 408, 409, 421, 426, 427
Special Applications: Internal Temperatures, Medical or Biological	401, 402, 423

It is recommended that when selecting a probe, reference be made to the YSI Short Form Catalog which gives detailed specifications on all 400 Series probes. The time constant of the probe is an important consideration, particularly where close control is required. Fast probes tend to speed up overall system response and enable the operator to achieve good stability with narrow bandwidths. The proper selection of a suitable probe for critical applications is also in part dependent upon the setting of the bandwidth control. (See Bandwidth Adjustments)

Probe Location

In locating the probe with respect to the rest of the system, it must be kept in mind that the purpose of the probe is to sense the temperature changes imparted to the system by the heater. Consequently the probe should be located in the path of the heat propagation from the heater to the rest of the system. Agitation, stirring, circulating or other methods of mixing must be employed to attain this end for two principal reasons: (a) to minimize temperature gradients in the medium and (b) to facilitate



NOTE:
On 220 V. Model the following changes are effective:

1. C 30 D
2. 1N3642
3. 12 uf 450 V
4. 11 ohm 2 W 5%
5. KTK 5 A
6. Two each 10 C 7 (series)
7. B 41522
8. 220 V

MODEL 72

PROPORTIONAL TEMPERATURE CONTROLLER

SCHEMATIC

All Resistors are 1/2W 10% Unless Otherwise Specified

All Capacitors are in Mfd.

C 41520 M

fast transfer of heat from the heater to the rest of the system. The particular method of heat dispersion is dependent upon the choice of the medium to be controlled. Liquids are generally convenient since they offer relatively good heat conductivity and may be easily stirred or agitated.

Generally, very close control will be obtained with minimum overshoot and undershoot when the control point is changed, if the probe is placed close to and downstream from the heater. Placing the probe some distance from the heater results in better average stability despite large changes in the thermal load of the system. It is emphasized here that experimental determination of the probe location is by far the best method. The experimental method has the advantage of automatically including consideration of all the parameters of the particular system under question

Load Considerations

The size of heater load to the Model 72 must be determined in the light of the operating conditions of the system. Normal 117 Volt 50 or 60 Hz heating loads may be connected to the three-way outlet located on the back perforated panel of the instrument. The Model 72 has been designed to deliver up to 1 KW of power to RESISTIVE loads. The load switch at the top of the back cover should be set at the appropriate position for best results. If the selected load is 100 watts the setting of this switch is not critical, the controller will work satisfactorily in either position.

Certain applications require the use of low voltage heaters. In this case the low voltage heater may be coupled to the controller through a Variac with appropriate ratings. CAUTION: When a Variac is connected to the instrument, a resistive load of 300 watts should be connected in parallel with the input to the Variac. The Variac rating must be 7.5 amps or less.

The relative power delivered to the load may be roughly estimated by comparing the relatively brightness of the 0% and the 100% indicators on the front panel. If the 100% indicator is at maximum intensity and the 0% indicator is off, 100% power is being delivered to the load. When the two indicators glow at equal brightness the power to the load is 50%. Other percentages may be estimated by similar comparisons. The two indicators are extremely useful in evaluating system performance. Where the thermal losses of the medium to be controlled are unknown a reasonable estimate of the thermal demand may be made by the use of the two indicators. In general, a satisfactory control condition exists if, upon attainment of equilibrium, the power to the load is indicated within 10% and 60% of full power. Best results will be obtained when the power indicated is approximately 50%; at which point the transfer function of the controller (change of temperature vs. change in load power) is linear. As was the case with determining probe location, the experimental method of determining the right heater capacity will by far yield the best and quickest results. The percent power indicators should prove very useful in this case.

Bandwidth Adjustments

A change in the bandwidth control setting changes the bridge a.c. supply thereby altering the magnitude of error signal required to effect a certain change in output power. With narrow bandwidths, the temperature change in the controlled medium required to offset thermal losses is very small. In this case the temperature of the medium is held to a very close tolerance, typically with ±.02°C. A very narrow bandwidth setting demands a good overall system design to achieve control stability. The control elements should be carefully selected to assure fast response of the overall system (fast probe and heater), and good mixing of the medium should be provided.

In general the best bandwidth setting may be determined by experiment. For any particular situation the bandwidth control should be manipulated so that a stable control condition is reached. For maximum accuracy the narrowest possible bandwidth consistent with acceptable stability should be used. When using liquid media, such as water, alcohol or oil, provided adequate heat dispersion is obtained, the Model 72 will accurately control temperatures to ±0.01°C, with the bandwith set at 0.1°C.

Due to the fact that at narrow bandwidths the voltage supplied to the instrument bridge is high, certain YSI probes may "self-heat" and introduce a small error with variations in line voltage. The following guide gives the narrowest bandwidth permissible for each class of 400 Series probes, so that the "self-heat" error will be negligible with variations in line voltage.

Narrowest Bandwidth Setting	Media	400 Series Probe Type	Best Possible Control Stability (Short Term)
0.1°C	Liquids, solids, surface	408, 409, 421	±.005°C
0.2°C	Liquids, solids, surface	402, 403, 404, 406, 410, 415, 416, 417, 418, 419, 425, 426 427	±.01°C
0.3°C	(Special Applications — Medical, Biological)	401, 402, 423	±.05°C
0.4°C	Gases, low heat — conductivity media	405, 408, 409, 421, 425, 426 427	±0.1°C

It should be noted that the calibration of the bandwidth control is only nominal, and that variations in absolute bandwidth will be experienced from instrument to instrument and through the temperature range of a particular instrument. Generally the tolerance will be ±50% for the range of 20°C - 90°C, and ±100% for the rest of the range.

Temperature Adjustment

Any control point within the range of 0°C to 120°C may be selected directly in °C from the front panel of the Model 72. The bridge is calibrated for a bandwidth setting of 0.1°C, and a dialing accuracy of ±0.5°C may be expected with this bandwidth. Since the bandwidth control alters the output of the bridge, the initial calibration of the instrument will be altered to a degree dependent upon the bandwidth setting. Increasing the bandwidth raises the control temperature by approximately half the temperature indicated by the bandwidth pointer, assuming a steady state controller output of around 50% power.

To select a desired control temperature, simply rotate the "Temperature Set Point" dials to the desired temperature and note the percent power indicators. If the temperature of the medium to be controlled is below the selected temperature, 100% power will be indicated by the % indicators, showing that the heater is full on and that the temperature of the medium is rising. As the control point is approached the indicated power will drop to a level required for maintaining the temperature of the medium constant. Important information of the system stability will be observed by observing the indicators when the control point is approached. An initial overshoot after reaching the control point is normal. The behavior of the system should be observed long enough to establish whether the system is oscillatory or stable. If the power output of the controller does not stabilize, but shows evidence of large cyclic variation, the probable cause is that the system is too sensitive. In this case the bandwidth should be increased to obtain smooth and stable operation.

If the power output, on the other hand, indicates large random variations one possible cause may be poor heat transmission from the heater — to the medium — to the probe, and an improvement of the medium mixing or probe location is indicated. Another possible cause is large random variations in the ambient temperature surrounding the controlled medium.

An excellent "feel" for optimizing a certain control situation will in most cases result if the operator familiarizes himself by experimentation.

CALIBRATION

The bridge of the instrument is initially calibrated at the factory and should not require recalibration during the lifetime of the instrument unless bridge parts are replaced or potentiometer settings in the instrument are accidentally disturbed.

Whenever bridge calibration is necessary it is recommended that the instrument be sent to the factory for calibration. If this is not possible, the following procedure should be adopted. To ready the instrument for calibration, remove dust cover by removing six slotted screws, two on each side and two on top of the instrument. Obtain a precision resistance decade box such as the General Radio Type 1432-M or equivalent. Connect two leads from the resistance decade to a standard phone plug. The outside terminal of the phone plug should be connected to the grounded terminal of the resistance decade box. Remove probe and substitute the phone plug of the resistance decade box, and turn instrument on.

The calibration of the instrument is carried out in two steps. The first step sets the level of the error signal for correct operation, while the second step is the temperature calibration of the "Temperature Set Point" dials.

Step 1 — Set up

(a) Connect a 100W - 117V lamp to output.

(b) Set resistance of decade box to 4482.6 ohms.

(c) Turn dials to 40.00°C, set load switch to 100 - 1000 watts.

(d) Adjust R59 to fully counter clockwise position.

(e) Adjust R59 clockwise until 0% light just goes out.

(f) Check: 100 watt lamp should be full brightness.
100% indicator should be full brightness.
0% indicator should be off.

Step 2 — Temperature Calibration

(a) Set bandwidth control to 0.1°C.

(b) Set dials to 8.00°C.

(c) Set decade resistance to 4937.1 ohms.

(d) Adjust R_{24} (outside control) so that 0% and 100% indicators are both lit.

(e) Set dials to 102.00°C.

(f) Set decade resistance to 144.6 ohms.

(g) Adjust R_{26} (inside control) so that 0% and 100% indicators are both lit.

(h) Return to Step (d) and repeat (d), (e), (f), and (g) if necessary.

GUARANTEE

The Model 72 Controller carries a one-year unconditional guarantee on all workmanship and components. Damage through accident, misuse, or tampering will be repaired at a nominal charge when the instrument is returned to our plant. Probes are similarly guaranteed for a period of six months.

NOTES