Valco Instruments Co. Inc.

Instrumentation Temperature Controller Instruction Manual

MAN-ITC
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1. INTRODUCTION AND GENERAL DESCRIPTION

The Instrumentation Temperature Controller (ITC) is an isothermal temperature controller intended for broad spectrum usage in thermal systems common to modern analytical instrumentation. The instrument is designed to be a flexible building block with which the user can configure a thermal system to suit particular requirements. Although the controller is only a single element in such a system, its flexibility and performance ultimately determine the stability, reproducibility, and accuracy of the entire system.

Inasmuch as we do not attempt to present a portfolio of specific applications, this manual is more general than specific. Instead, we are attempting to strike a spark of intuitive understanding and interest for how the ITC functions. The ITC's function and relationship to thermal systems are the most valuable notions transmitted by this manual. Just as there is no application manual for vice-grip pliers, there is not an application manual for the ITC. Both are basic, extremely useful devices, whose real worth is determined by the user.

1.1 Standard Features

1.11 Thermocouple Sensors

The ITC utilizes thermocouple sensors fabricated from ordinary thermocouple wire. A variety of factors lead to this being the best choice of sensors:

- Sensor junctions of very low mass can be easily fabricated. Lower mass means quicker recognition of temperature changes.
- Thermocouples are inherently rugged, requiring little in the way of special handling precautions.
- Thermocouple wire is inexpensive and readily available.

In keeping with this choice of sensors, the instrument is appropriately equipped with:

- **Automatic reference junction compensation.** Circuitry automatically references to 0°C, regardless of ambient temperature.
- **Thermocouple break detection.** Should the thermocouple break, the heater power circuitry will be disabled, and a front panel indicator illuminated.
- **High impedance differential input circuitry.** This circuitry allows the instrument to tolerate floating or grounded thermocouples, with high common-mode noise immunity.

The ease of fabrication for sensors compatible with the ITC is such that users can seriously consider making their own. (In many cases, all that is needed is a small torch, silver solder, and a roll of thermocouple wire.)

1.12 Proportional Heater Power Control

The ITC utilizes proportional power application to minimize temperature overshoot, and improve temperature stability about the setpoint. Controls are accessible to the user, allowing the proportioning bandwidth (in ^{o}C) to be adjusted to meet specific requirements.

1.13 Power Attenuation

Many temperature controllers are used in conjunction with variacs (variable output transformers) in order to improve temperature stability. By reducing the maximum power available to the heater, the user is adjusting the heater "size" to suit his particular thermal system. This is a practical, flexible solution to the problem, but requires two devices to control the temperature, one of which is heavy, inefficient, and expensive.

The ITC employs a pushbutton switch so the user can attenuate the total power available to the heater circuit. Attenuation is selectable from 0 to 90%, in increments of 10%.

1.14 Zero Crossing Power Application

Power is applied to the load in increments of integral half cycles, only. This technique drastically reduces RFI/EMI normally associated with high current AC switching.

1.15 Digital Temperature Setting

The ITC employs a bank of three digital thumbwheel switches for temperature setpoint selection. The setpoint is selectable in 1^{o} increments. The most obvious advantage to this scheme is 100% setting repeatability.

1.16 Compact Rugged Construction and Functional Layout

The ITC's physical characteristics are strictly utilitarian. In all cases, rugged construction techniques are employed, insuring that the assembled instrument is not delivered by a freight company in kit form. The instrument is housed in an aluminum/cycolac enclosure measuring 2.4" x 8.3" x 5.9". The top of the enclosure can be quickly removed, allowing access to all fuses, electronics, etc.

It is worthy of note that almost all electronic components are mounted on a single printed circuit board. This feature directly translates to simple troubleshooting methods and minimal spare parts inventory.

1.2 Product Numbers and Specifications

Product Numbers: ITC10X
X corresponding to
399 for 0°C to 399°C range
999 for 0°C to 999°C range

Example:
ITC10399: ITC, 1000 watts maximum heater power, 0°C to 399°C range

Sensor Requirement	Thermocouple; Type K
Range	0° to 390°C, or 0° to 999°C, as ordered
Absolute Accuracy	±.5% of full scale
Repeatability	.5°C at constant ambient
Sensititivity to Ambient Changes	.05°C per °C change
Operating Ambient	10° to 50°C
Switched AC Power	1000 watts; zero-crossing error: 5V AC max.
Proportioning Bandwidth	±3**°C**
Proportioning Frequency	2 Hz
Setpoint	1° C increments; push button selection
Max. Power Input Requirement	10.0 amps at 117 VAC
Power Attenuation	0 to 90% in 10% increments
Physical Dimensions	2.4" x 8.3" x 5.9"; weight 1 lb. 14.4 oz.

Visual Indicators

- Power On (PWR) - illuminated whenever the instrument is plugged into a source of 120V AC, and the PWR switch is in the ON position
- Heater On (HTR) - illuminated whenever the controller applies power to the heater
- Thermocouple Fault (TCPL) - illuminates whenever thermocouple sensor opens. (If a sensor failure is detected, heater power is automatically interrupted, and the HTR indicator will remain OFF.)

1.3 Technical Description

A general knowledge of the ITC's organization and operation is helpful to its successful implementation. To facilitate understanding, three questions are posed:

1. What position does the ITC occupy in a thermal system?

2. How is the ITC organized to accomplish its task?

3. What is the most important aspect of the ITC's organization?

These questions are answered by Sections 1.31, 1.32, and 1.33, respectively.

1.31 Thermal System Overview

Figure 1 depicts a generalized closed-loop control system. The system is termed closed-loop since the controller bases its corrective actions on the actual status of the controlled function. In an open-loop system, corrective actions are based on anticipated status. Closed-loop systems are definitely preferable.

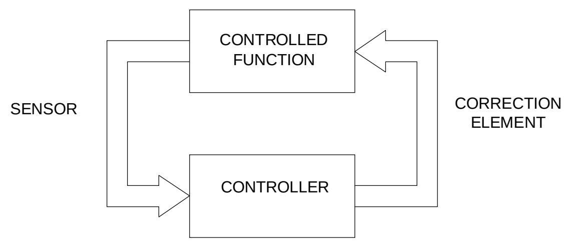


Figure 1

The system is comprised of:
- **Controlled Function.** Water level, air pressure, etc.
- **Sensor.** Appropriate to the function; level sensor, pressure transducer, etc.
- **Controller.** Determines when corrective action is necessary, based on information supplied by the sensor.
- **Correction Element.** Means of adding water, increasing pressure, etc.

With slight modification, the diagram becomes appropriate to a thermal system utilizing an ITC, as shown in **Figure 2**.

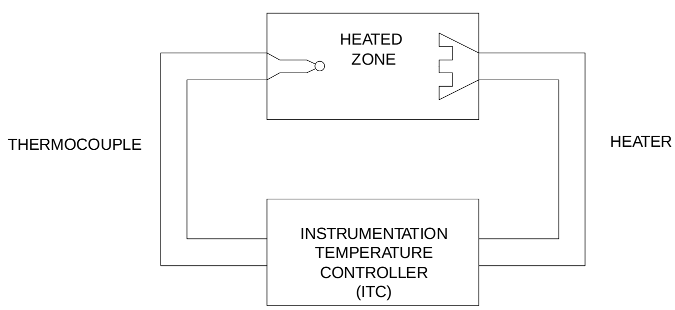


Figure 2

It is readily seen that the ITC is responsible for maintaining the temperature within the heated zone. However, proper selection and application of the thermocouple and heater are essential if the ITC is to perform its function. (Refer to Section 2.2.)

1.32 ITC Block Diagram by Function

Almost any electronic device can be described by a block diagram of its circuit elements, each element performing something essential to the function of the device. Indeed, such a diagram is typically the first state in its design. Further, devices of similar function will have similar block diagrams.

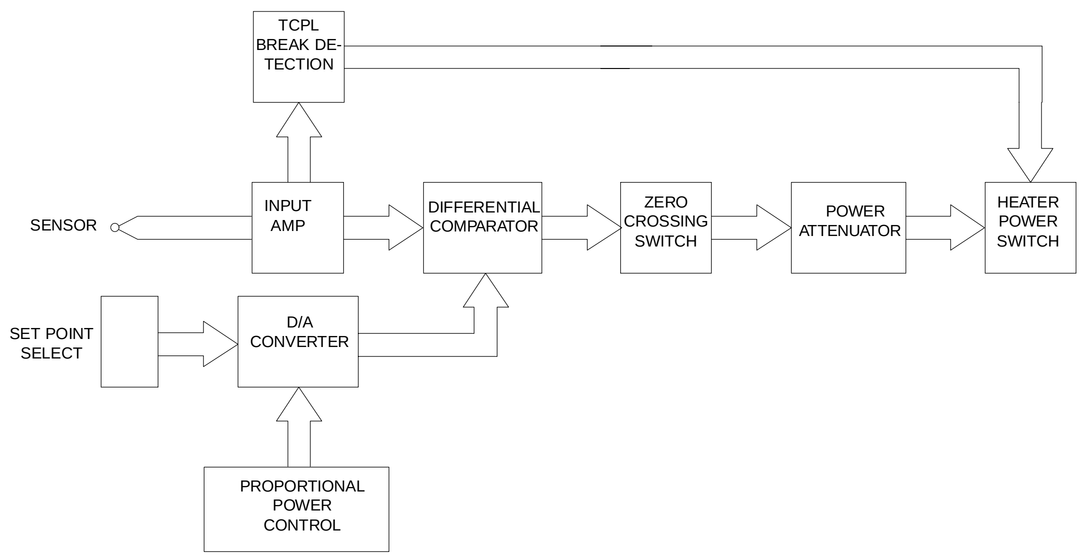


Figure 3

The function of the ITC is to control the temperature in a heated zone. A brief discussion of what is required to perform the function reveals the elements contained in its block diagram, **Figure 3**.

1.321 Input Amplifier

The signal supplied by the thermocouple is too small to be recognized by the other circuit elements (approx. 50 microvolts/^{o}C). Therefore, the signal must be amplified to a useful level.

1.322 Set Point Selectors and D/A Converter

The thumbwheel switches provide a means of representing the desired temperature within the heated zone. (This temperature is hereafter referred to as the **setpoint**.) The switches provide a digital representation of the setpoint, which is then converted to a more useful signal by means of a ten-bit D/A converter. The D/A converter conforms to the same transfer function as the input amplifier; i.e., a representation of 100° C by the input amplifier is identical to the D/A converter's representation of 100^{o} C.

1.323 Differential Comparator

A differential comparator is used to compare the output of the D/A converter with that of the input amplifier. Subsequently, the comparator's output denotes whether the zone temperature is higher or lower than the setpoint.

1.324 Heater Power Switch

In accordance with the comparator's decision, the power circuitry will apply power to the heater when the zone temperature is below the setpoint and interrupt power when it is above the setpoint.

In strictly theoretical terms, the above four elements are all that would be required to implement the controller's function. However, practical application requires three additional elements:

1.325 Thermocouple Break Detection

The most common physical malfunction in thermocouples is a break, or open circuit. If a break occurs, the input amplifier can no longer report the zone temperature, and usually will report the ITC's temperature, instead. From the preceding discussion, one can deduce that this is a potentially disastrous situation. However, a separate circuit is employed specifically to detect a break condition. Its output will cause the Heater Power Switch to be disabled, and a front panel indicator to be illuminated whenever a break occurs.

1.326 Proportional Power Control

To this point, power application to the heater has been described as simply "applied or interrupted". In reality, this would be analogous to trying to maintain a dragster's speed at 30 mph using full throttle applications only. Obviously, power must be delivered according to the need. For this reason, the ITC employs proportional power control, where net power is delivered to the heater according to the difference between the setpoint and zone temperature. The proportioning technique is discussed in Section 1.33.

1.327 Power Attenuation

Effective heater size can be tailored to the application by proper adjustment of the power attenuation control. Excessive heater ratings are often the cause of system instability at near ambient temperatures. Proportional control and power attenuation work hand-in-hand to produce excellent temperature stability. (Refer to Section 2.3.)

1.328 Zero Crossing Switch

This allows the heater to come on only if the AC waveform is at zero to suppress noise on the powerline.

1.33 Proportional Power Control

Although the ITC's input amplifier and D/A circuitry are accurate and predictable in their temperature representations, they do not in themselves constitute a good temperature controller. In a control system, the essential factor is stability. A temperature controller is not doing its job if the zone temperature is allowed to oscillate about the setpoint to a degree which upsets the process. In short, the aim is to reduce a thermal system's natural tendency to oscillate to a level where it is not significant.

If zone heater power is simply applied or interrupted according to the comparator's verdict (correction required/not required) the result is wholly unacceptable. To illustrate:

> Assume that a zone is to be heated from room ambient to 75^{o} C. If 100% power is applied until the temperature reaches 75^{o}, and then interrupted, the temperature will overshoot. As the temperature settles back to 75^{o}, 100% power will again be applied in an effort to prevent the temperature from falling below the setpoint. As a result, the temperature will overshoot again. In this manner, the temperature will continue to oscillate about the setpoint.

As can be seen, on/off, stop/go, etc. are corrective measures that would make the ITC unacceptable for all but the crudest applications.

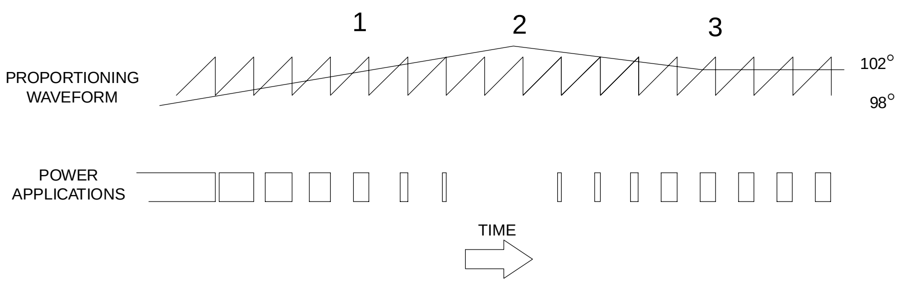
The key to obtaining acceptable stability lies in applying heater power relative to the need. Using the above example, but employing proportional control, more reasonable results are obtained:

> While the temperature rises from ambient toward 75^{o} C, power is applied continuously, just as before. However, at a point just *below* the setpoint, say 70^{o}, the power is reduced to 95%. As the temperature continues to rise, power is linearly reduced such that power will be applied 50% of the time when the temperature reaches the setpoint, and only 5% when it reaches 80^{o}. When the temperature begins to settle, the process is reversed. Heater power is gradually increased as the temperature declines toward the setpoint. As a result, the temperature will tend to stabilize at a point where the power application is sufficient to maintain equilibrium.

In conclusion, the system's tendency to oscillate is greatly reduced if some form of proportional control is employed.

Commonly, two methods can be used to electronically control AC power: phase proportioning, and time proportioning. With phase proportioning, some percentage of each AC cycle is applied to the load. While this method is just fine for power drills, it is not acceptable for instrument use. This is due to the fact that the power is not switched at zero-crossings. Therefore, large amounts of RFI/EMI can be generated. (If such electrical "noise" is generated, it may upset the operation of other instruments in the vicinity.) With time proportioning, the average power is controlled by dividing time into specified periods. During each period, the percentage of power ON versus OFF time is proportional to the difference between the setpoint and the controlled temperature. Power is switched only at AC voltage zero-crossings, avoiding RFI/EMI generation.

Figure 4 is a graphic representation of time proportioning as it is implemented in the ITC. The heart of the process is the proportioning waveform. This sawtooth-shaped waveform defines three important parameters of operation: lower temperature boundary, setpoint, and upper temperature boundary. The setpoint will always be situated in the exact center of the waveform. The **lower temperature boundary** represents the point below which 100% power will be applied. The **upper temperature boundary** represents the point above which no power will be applied. And, as stated earlier, the **setpoint** denotes the point at which power will be applied 50% of the time. Observe, also, that between the two boundary temperatures, the average applied power is linearly proportional to the difference between the setpoint and the actual temperature within the heated zone.



1 CONTROLLED TEMPERATURE RISING FROM AMBIENT;
NOTICE POWER APPLICATION IS PROGRESSIVELY REDUCED AS THE TEMPERATURE RISES
2 OVERSHOOT; NO POWER APPLIED
3 EQUILIBRIUM;CONTROLLED TEMPERATURE HAS SETTLED AT APPROX. 40% POWER

Figure 4

The number of degrees between the upper and lower temperature boundaries is referred to as the **proportioning bandwidth**. Proper adjustment of the bandwidth will further enhance temperature stability within the heated zone. Some guidelines for adjustment are found in Section 2.4.

1.34 Power Attenuation

In the preceding section, proportional power control was described as the process by which the ITC applies a percentage of power proportional to the difference between the setpoint and the controlled temperature. It is not unusual that this technique, alone, will not yield acceptable temperature stability. Commonly, this situation occurs when near ambient temperatures are desired of a thermal system originally designed for higher temperatures. Consequently, the heater size (rated output) is much too large for system demand.

In compensating for such difficulties, laboratory personnel often employ variacs (variable output, step-down transformers) to attenuate the power delivered to the heater.

Power delivered to the heater can be attenuated in increments of 10% by setting the ITC's front panel mounted ATTN pushbutton switch. This control performs exactly the same function as the variac mentioned above. However, the method by which the ITC performs this function differs considerably from variac operation. Here's how:

> A variac provides a means of adjusting the voltage (and consequently, the power) applied to the heater. The ITC varies the number of half-cycles *available* to be delivered by its power circuitry. For example, 100% is available when the ATTN control is set to 0. If the attenuation is changed to 4 (40%), only six of every ten half-cycles are available for delivery to the heater. As a result, the heater output will be 60% of its full rating.

In summary, the proportioning circuitry determines the percentage of time during which power will be applied, while the attenuation circuitry determines what percentage of power is to be available for delivery during this time.

2. OPERATION

In this section practical considerations for the ITC's usage are discussed.

2.1 Physical layout of the ITC

Following are illustrations of the various models of the Instrumentation Temperature Controller. **Figure 5** shows the front panel, and **Figure 6** shows the top view of the ITC. **Figures 7** and **8** show the back panels of the 110V AC and 220V AC models. The numbers on the illustrations relate to the numbered parts below.

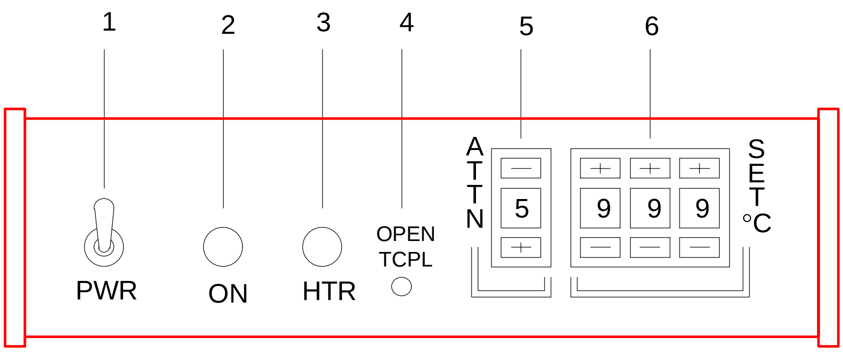


Figure 5: Front panel, model ITC10

1 **Power Switch PWR**
Front mounted toggle switch controlling power to heater and power supply circuits.

2 **Power On Indicator**
Front mounted neon indicator; illuminated whenever the power switch is in the ON position and power supply fuse is intact.

3 **Heater Power On**
Front mounted neon indicator; illuminated whenever instrument applies power to heater; will not illuminate if heater is not connected, or if broken thermocouple is detected.

4 **Thermocouple Fault Indicator**
Front mounted LED indicator; lights whenever thermocouple circuit is broken.

5 **Heater Power Attenuation Switch**
Front panel mounted bidirectional ATTN switch; denotes heater power attenuation in increments of 10 percent.

6 **Setpoint Switches**
Front panel mounted switches; denote controlled temperature setpoint in ^{o}C.

7 **Calibration Adjustments**
Printed circuit board mounted pots; DO NOT attempt adjustment.

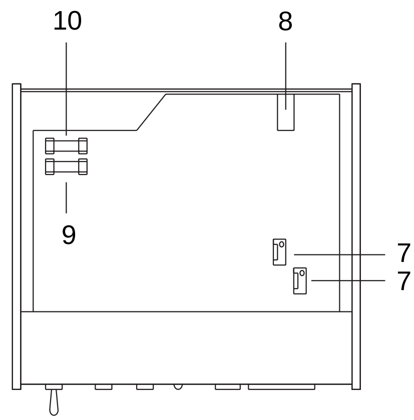


Figure 6: Top view, model ITC10

8 **Thermocouple Connector**
Printed circuit board mounted connector; connect red lead of thermocouple to Terminal R.

9 **.5 Amp Fuse**
Printed circuit board mounted; fuses power supply primary circuitry.

10 **10 Amp Fuse**
Printed circuit board mounted; fuses heater power circuitry.

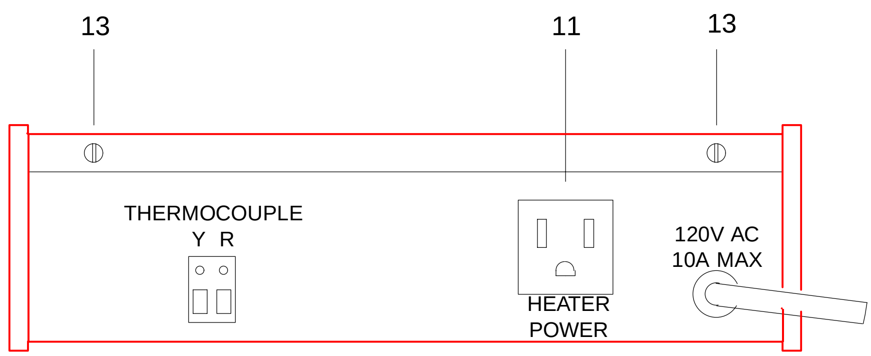


Figure 7: Back panel, model ITC10 110V AC

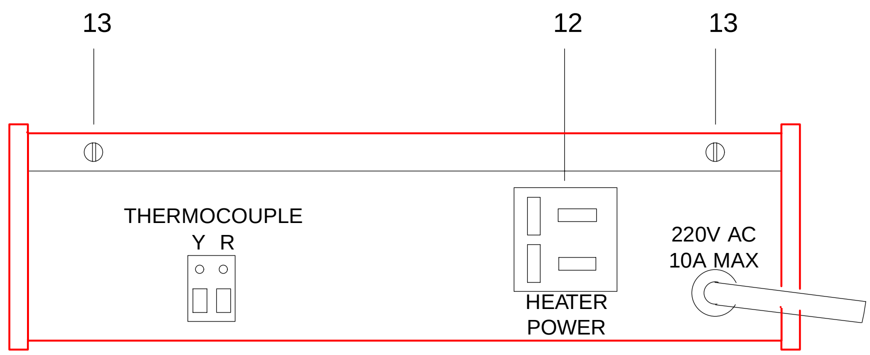


Figure 8: Back panel, model ITC10 220V AC

11 **Heater Receptacle, 120V AC only**
Rear panel mounted AC receptacle; two-wire plus ground; connects heater via standard 16 or 18 gauge three-wire power cord (not supplied).

12 **Heater Receptacle, 220V AC only**
Rear panel mounted AC receptacle; two-wire plus ground; connects heater via power cord (black and white to heater, green to ground). Power cord is not supplied.

13 **Top Cover Retaining Screws**
Remove these screws to gain access to interior of ITC.

2.2 Thermocouples

Thermocouples, when used properly, are a very expedient and reliable means of sensing temperature. In this section, we will attempt to help the user avoid certain general and specific pitfalls in thermocouple usage with the ITC.

Thermocouple measuring junctions are fabricated by joining two dissimilar metals. A type K thermocouple is formed from chromel and alumel. In theory, the thermocouple is functional so long as the two metals remain in contact. (This does imply that a measuring junction can be formed by twisting two wires together. We would point out that the junction will not be suitable for any real application, however.)

Maintaining the integrity of the measuring junction is of prime importance. This means that for a given application, thought must be given the junction's maximum attainable temperature, corrosion resistance to its environment, and mechanical strength.

Commercially available thermocouples are usually joined by welding. This produces a junction in which the maximum temperature and corrosion resistance properties are those of the metals themselves. For applications below 400^{o}C, a quite serviceable junction can be formed by twisting the bare ends of the wire together, and then securing with silver solder. For applications above 400^{o}C, the junction should be welded. In the case of silver soldered junctions, we would again point out that the environment and maximum temperature must not be harmful to the solder.

It is important to note that considerations pertaining to junction integrity are also applicable to the *insulation* around each wire. As stated earlier, a new junction is formed each time the two thermocouple wires come into contact. Obviously, unplanned junctions are to be avoided.

In matters concerning the thermocouple, measuring junction mass, thermal conductivity of the controlled medium and placement can greatly affect controlled temperature stability. In Section 1.326, an example was given illustrating temperature instability. It was pointed out that stability is obtained by supplying heater power proportional to the need. At this point, it is important to recall that the thermocouple is responsible for telling the controller what the need is. Most importantly, any change in temperature must be reported without appreciable delay. This causes instability, regardless of how craftily the correction is carried out. This notion of minimizing delay is carried to fact by observing two rules:

1. The measuring junction should be of the lowest mass practicable for the application. Simply put, the higher the mass, the more time required for the junction to reach the temperature of its surroundings.

2. The measuring junction should be placed as close as possible (thermally) to the heater. Whenever there is doubt about proper location of a thermocouple, follow these suggestions:

a. Place the junction directly between the heater and the object to be heated, as close to the heater as possible.

b. In a stirred air or liquid bath, place the junction immediately downstream from the heater.

In addition to the more common considerations, there are a few important specific notions regarding thermocouples to be used with the ITC.

- **Electrical contact.** If the measuring junction is in electrical contact with an object, that object must be connected to AC ground. For example, this would require a heater block to be grounded unless the thermocouple is electrically insulated from it. (The junction must float or be grounded.)
- **Thermocouple resistance.** The following data describes the thermocouples normally shipped with the ITC:

  ITC-K: 10 ft., 28 gauge, 40 ohm , ANSI Type K

2.3 Setpoint (Set °C)

Loosely defined, the setpoint denotes the desired temperature within the heated zone. However, the user should be aware that the denoted setpoint is not necessarily the temperature at which the zone will stabilize.

To be more precise, the setpoint denotes the temperature at which power will be applied 50% of the time. It is entirely possible that the zone will require more or less than 50% power to maintain stability. As a consequence, the zone temperature will settle above the setpoint if less than 50% power is required, and below the setpoint if more than 50% power is needed.

Essentially, this characteristic offset is brought about by the proportional power control method used in the ITC, coupled with the thermal characteristics of the user configured heated zone. Without prior knowledge of the zone's heat input vs. heat loss properties, the only certainty is that the zone temperature will stabilize *somewhere* within the proportioning bandwidth. Exactly *where* the temperature settles, can be optimized by adjustment of the proportioning bandwidth. (Refer to Section 2.4.)

2.4 Proportioning Bandwidth

> **Note:** Current models of the ITC may have fixed valued resistors in the trim pot location for the bandwidth calibration. If the ITC needs further calibration they may be replaced with 10K trim pot and the following text will explain the band width adjustments.

Given that the controlled temperature is reasonably accurate, stability becomes a most important measure of system performance. Perfect stability is obtained by applying the exact amount of power required to offset a system's demand. In addition, the power must be applied instantaneously whenever a demand occurs. Think about this. Theoretical notions like "exact" and "instantaneous" soon reveal the meaning of the term, "optimum".

In attempting to achieve optimum stability, we assume that the user will experiment with the proportioning bandwidth adjustment pot. (Refer to Section 2.1, item 7.) In keeping with this assumption, we offer the following explanation of bandwidth adjustment.

2.41 Bandwidth Defined

Rigorously defined, bandwidth is the peak to peak value of the proportioning waveform, expressed in degrees centigrade. The bandwidth pot controls the height of the waveform. More importantly, the height determines the slope of the diagonal. In **Figure 9**, two waveforms are shown: one with 3° bandwidth, and the other with 6° bandwidth. In each case, the controlled temperature is depicted 1 below the peak height of the waveform. Notice that the resulting power applications are different. In fact, power is applied twice as long in the 3° example as in the 6° example. This is due to the slope of the diagonal, and, as we shall see, is a very useful thing to remember.

The important thing to notice in **Figure 9** is that as the controlled temperature changes within the bandwidth, the resulting change in heater power is dependent on the slope of the diagonal. More specifically, the *rate of change* in applied power is controlled by the slope of the diagonal.

If, in each case, the temperature falls 1° (1° excursion), the resulting changes in applied power are dramatically different. In the 3° example, application changes from 33- 1/3% to 66- 2/3%. The same 1 excursion in a 6° bandwidth causes application to change from 16- 2/3% to 33- 1/3% per degree and 16- 2/3% per degree, respectively. By observation, increasing the bandwidth decreases the amount of change in average applied power for a given change in temperature.

How does all this relate to stability improvement? Well, assuming that a stability problem exists, it may be attributable to excessive heater power. By this, we mean that the heater is simply too powerful for the application. The situation usually results from designing the system to heat quickly and operate over a broad temperature range. The problem is characterized by the controlled temperature's tendency to spend most of the time above the bandwidth, occasionally falling into its upper reaches. The temperature will not stay within the bandwidth because

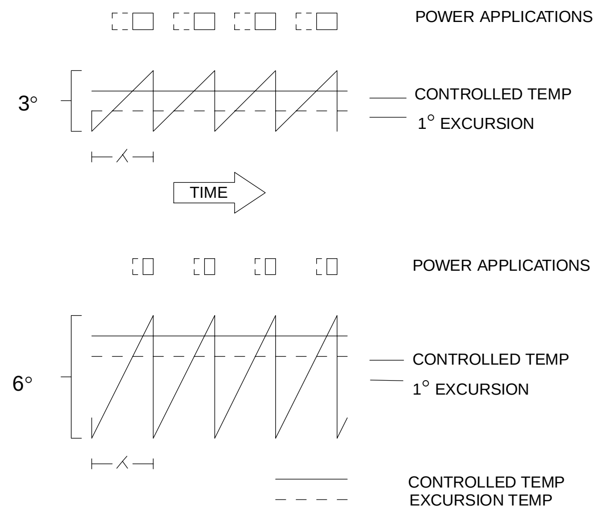


Figure 9

power is increased too abruptly, quickly driving the temperature up, out of reach. If the heater size cannot be reduced, the bandwidth must be increased. Doing so will decrease the rate of change in applied power, hopefully increasing stability. Always allow ten to fifteen minutes after making each adjustment before making another. This will allow the system enough time to reveal whether or not further adjustment is required.

As a consequence of increasing the bandwidth, the user should be aware that the controlled temperature is usually shifted upward, as well. This notion is most easily understood by noting the position of the 1% power point before and after adjustment. Remember that the system will still require the same average power to maintain a given temperature. Therefore, as the bandwidth is increased, the given power point shifts upward, carrying with it, the controlled temperature.

Note that the controlled temperature shifts upward only if it was originally trying to stabilize above the setpoint (50% power point). There usually is no stability problem when the temperature is settling below the setpoint. However, we will point out that in this situation, the temperature will shift downward when bandwidth is increased.

The value of the bandwidth (in °C) can be determined by the following method:

1. Reduce the setpoint temperature until the HTR indicator is OFF continuously. Make note of this temperature.
2. Increase the setpoint until the HTR indicator is ON continuously. Make note of this temperature.
3. Determine the difference between the two temperatures. This value is the bandwidth.

2.5 Installation

The following discussion is intended to assist you in the initial installation of an ITC. It is assumed that you have read the foregoing portions of this manual.

Check the instrument for shipping damages. Open the instrument and check for loose components. There shouldn't be any. In the event that damage is noted, notify the carrier immediately. Valco assumes no responsibility for damage incurred in shipment.

Assuming no damage is seen, perform the following checkout. You will need an ordinary incandescent light or other resistive load that provides indication of when power is applied.

1. Connect the load to the ITC. In 110V models, a receptacle (labeled P1) is provided which accepts ordinary three-wire appliance plugs. The 220V uses a cinch socket.

2. Connect the instrument to a suitable source of 120V AC.

3. Set the setpoint and attenuation switches to 0. Switch the instrument on. The TCPL indicator should illuminate momentarily. (The instrument is determining whether or not its thermocouple is OK.) The HTR indicator should be OFF.

4. After allowing the instrument to warm up for a few minutes, increase the setpoint until the HTR indicator flashed with a 50/50 duty cycle. The setpoint should approximate the ambient temperature.

5. Hold the thermocouple's measuring junction firmly in one hand. Since your skin temperature is usually 10° above ambient (and subsequently, the setpoint), the HTR indicator should cease flashing.

6. Increase the setpoint until the HTR indicator is ON continuously. (Try 50°.) Change the power attenuation switch to 9. The HTR indicator should flicker faintly. Progressively decrease the ATTN setting, noting that the HTR indicator "brightness" increases at each position. When the ATTN switch is at zero, the HTR indicator should be ON continuously, with no visible flickering.

Regarding the zone heater specifications, care should be taken to avoid exceeding the ITC's specifications for switched power. The ITC10 will switch loads up to 1000 watts. If you attempt to exceed this rating, the instrument will probably sacrifice its fuses and/or power triac.

The present ITC power circuitry is intended to switch resistive loads only. This means that inductive loads, such as electric motors, solenoids, and especially variacs cannot be switched successfully.

Damage may result if inductive loads are used.

Always use three-wire power connections for the instrument, as well as heater connection. (Ref. Section 2.2.) It is important that the heater block, etc. be connected to AC ground. Failure to do so may cause a shock hazard, or controller malfunction, or both.

Locate the ITC where it will not be subjected to abrupt changes in ambient temperature. This will improve the controlled temperature stability.

When installing the thermocouple, be sure to observe electrical restrictions noted in Section 2.2.

Actual installation consists of, first, thinking about what must be done, then connecting the heater, and finally inserting the thermocouple. After this is done, turn it ON and play with the system. Notice whether or not corrections need to be made in such areas as thermocouple location, bandwidth adjustment, etc. Enjoy! (If you're not enjoying yourself, call us. We'll try to help in any way we can.)

2.6 Troubleshooting and Schematic Diagram

Troubleshooting the ITC is straightforward, in most cases. The device can be thought of as being divided into two sections; instrumentation and power circuitry. Problems with the power circuitry are the most easily identified, and can be handled with a minimum of electronics experience. Isolation and repair of malfunctions in the instrumentation circuitry require sophisticated test equipment and extensive electronics expertise. For this reason, it is recommended that the factory be consulted when the following procedures are of no help.

2.61 Situation: PWR ON indicator fails to illuminate; instrument does nothing.

A 1/2 amp fuse is employed to fuse the instrument's DC power supply. If this fuse is blown, the PWR ON indicator will not illuminate, and the instrument will not perform any functions. The fuse is located at the left rear corner of the enclosure. (Refer to **Figure 6**, Item 10.) If the ITC persists in blowing this fuse, consult the factory.

2.62 Situation: TCPL indicator ON continuously; no power applied to heater

When the TCPL indicator is ON continuously, the instrument thinks an open circuit has developed in the thermocouple. As a consequence, the ITC will refuse to apply power to the heater. The thermocouple is connected to the instrument by a barrier strip, designated B1. (Refer to **Figure 6**, Item 9.) Be certain these connections are snug. As a second consideration, be certain that proper connection to AC ground is made in any case where the thermocouple measuring junction contacts metal. If this is not done, the TCPL circuit can sometimes be fooled into believing there is a malfunction. As a final consideration, disconnect the thermocouple, and check it for electrical continuity. If the problem is not located, consult the factory.

2.63 Situation: No power being applied to heater; TCPL indicator OFF.

In this situation, the HTR indicator remains OFF. The power triac is protected against continuous current overload with a 10 amp fuse. (Refer to **Figure 6**, Item 11.) If this fuse is blown, no power is available to the heater circuitry. In addition to replacing a blown fuse, consider what may have caused the overload. The heater and/or power triac may have developed a short circuit. This sort of occurrence is usually accompanied by burned wiring. Be certain that the heater doesn't exceed the power rating for the ITC (1000 watts).

It is the case that the situation described above can occur without blowing the fuse. If this occurs, consider whether or not the load is inductive. Remember that such loads cannot be switched with the ITC's present circuitry.

The appropriate schematic diagram is supplied in this section. Should you require any explanation of the circuitry, please contact the factory.

3. WARRANTY

This Limited Warranty gives the Buyer specific legal rights, and a Buyer may also have other rights that vary form state to state.

For a period of 365 calendar days from the date of shipment, Valco Instruments Company, Inc. (hereinafter Seller) warrants the goods to be free from defect in material and workmanship to the original purchaser. During the warranty period, Seller agrees to repair of replace defective and/or nonconforming goods or parts without charge for material or labor OR at seller's option demand return of the goods and tender repayment of the price. Buyer's exclusive remedy is repair or replacement of defective and nonconforming goods OR at Seller's option repayment of the price.

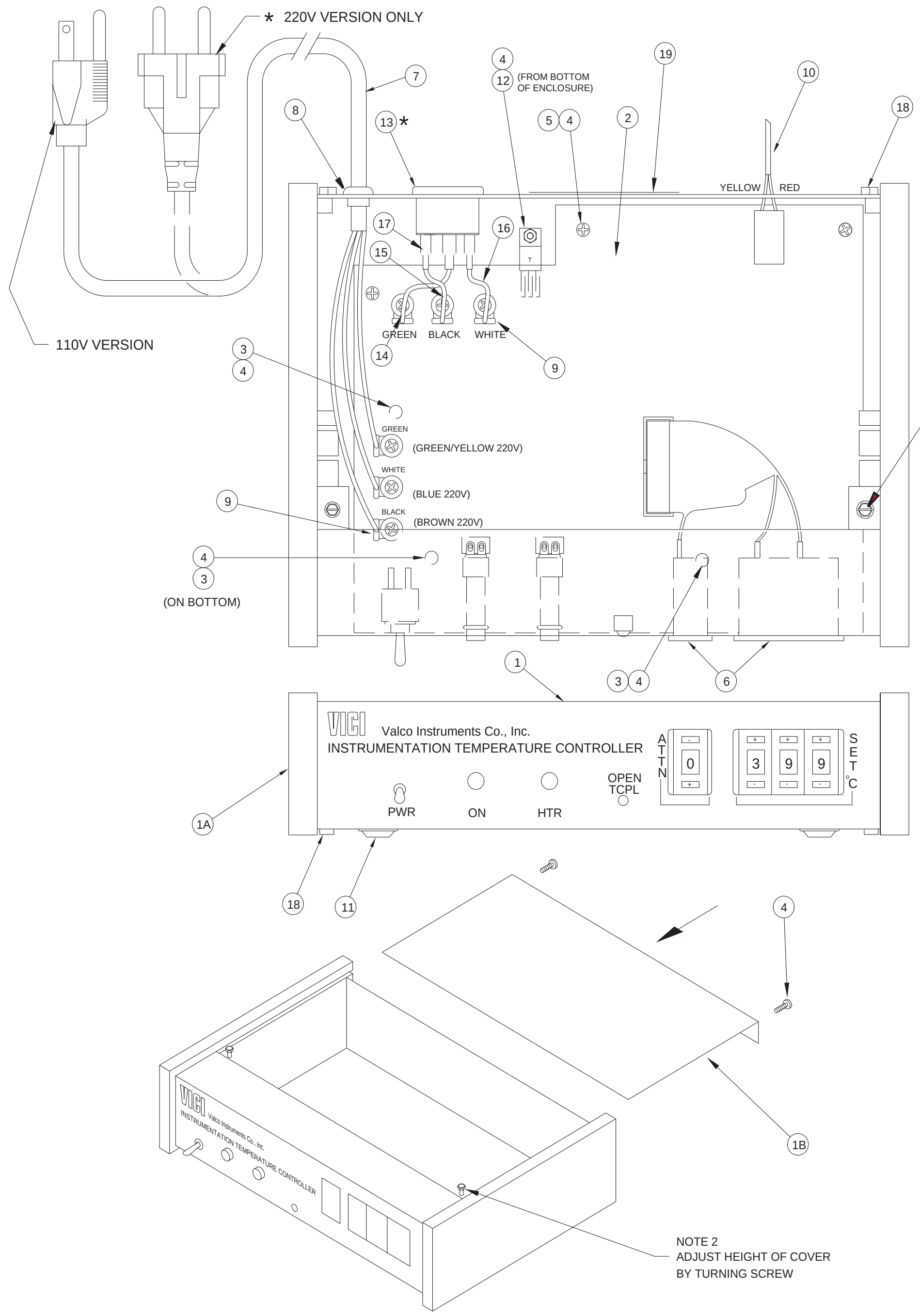
SELLER EXCLUDES AND DISCLAIMS ANY LIABILITY FOR LOST PROFITS, PERSONAL INJURY, INTERRUPTION OF SERVICE, OR FOR CONSEQUENTIAL INCIDENTAL OR SPECIAL DAMAGES ARISING OUT OF, RESULTING FROM, OR RELATING IN ANY MANNER TO THESE GOODS.

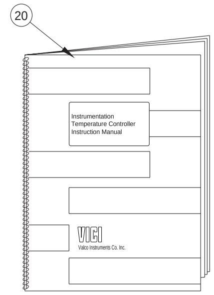
The Limited Warranty dose not cover defects, damage or nonconformity resulting from abuse, misuse, neglect, lack of reasonable care, modification or the attachment of improper devices to the goods. This Limited Warranty does not cover expendable items. This warranty is VOID when repairs are performed by a non-authorized service center or representative. If you have any problem locating an authorized service center or representative, please call or write Customer Repairs, (713) 688-9345, Valco Instruments Company, Inc., P.O. Box 55603, Houston, Texas 77255. At Seller's option, repairs or replacements will be made on site or at the factory. If repairs or replacements are to be made at the factory, Buyer shall return the goods prepaid and bear all the risks of loss until delivered to the factory. If Seller returns the goods, they will be delivered prepaid and Seller will bear all risks of loss until delivery to Buyer. Buyer and Seller agree that this Limited Warranty shall be governed by and construed in accordance with the laws of the State of Texas.

THE WARRANTIES CONTAINED IN THIS AGREEMENT ARE IN LIEU OF ALL OTHER WARRANTIES EXPRESSED OR IMPLIED, INCLUDING THE WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

This Limited Warranty supercedes all prior proposals or representations oral or written and constitutes the entire understanding regarding the warranties made by the Seller to Buyer. This Limited Warranty may not be expanded or modified except in writing signed by the parties hereto.

4. TECHNICAL DRAWINGS





REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	ITC BD. ASSY. REV. M,N	20FEB89	
B	ENCLOSURE C-21527 REV. G	22FEB89	
C	ECN #2050 CLARIFY DWG	8AUG94	J DURR
D	ECN #4668 CLARIFY 220V VERSION	22MAR99	J DURR

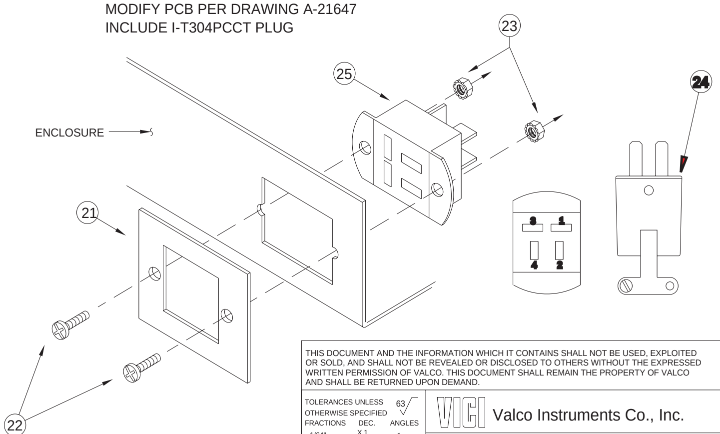
	PARTS LIST				
	ITEM	DESCRIPTION	VALCO #	QTY	
	1	ENCLOSURE: ITC, 10 AMP.	I-21527	1	
	2	PCB ASSY: ITC 10 AMP	I-22218	1	
	3	STANDOFF: 4-40*1/4, THREADED, NYLON	HWSO-4050	3	
	4	SCREW,PLMS: 4-40*1/4 lg,PANHD,PH,SS	HWSC-PL4-4	9	
	5	STANDOFF: 4-40*1/4 SWAGE THREADED	HWSO-1650-2	3	
	6	SWITCH ASSY: ITC TEMP.CTRL. (399 DEG.C)	I-21280-02	1	
*	7	POWER-CORD: GREY 6' 18/3 SVT	I-W-CS-21	1	
	8	STRAIN-RELIEF: SRR-10, HEYCO#: 5P-4 1147	HWSRR-10	1	
	9	LUG: FEMALE SLIP-ON, 16-14 AWG	HWLUG-4218B	6	
	10	THERMOCOUPLE-ASSY: 10'2 (ITC) K TYP	I-21014-01	1	
	11	FEET: RUBBER STICK-ON	HW-1658	4	
	12	NUT, HEX: #4-40 UNC, STAINLESS	HWNUT-HEX#4	1	
	13	RECEPTACLE: POWER OUTLET BLACK	HW-OUTLET	1	
	14	WIRE: 14 AWG TEFLON BLACK CSA SPEC	I-W-14-BLACK	.333	4"
	15	WIRE: 14 AWG TEFLON GREEN CSA SPEC	I-W-14-GREEN	.333	4"
	16	WIRE: 14 AWG TEFLON WHITE CSA SPEC	I-W-14-WHITE	.333	4"
	17	TUBING: HEAT SHRINK 1/4" ID.	I-STUBE.250	.125	
	18	SCREW,SMS : #4*3/8 LG, PL, SS	HWSC-SM4-6	6	
	19	TAG: SERIAL, ALL ELEC. DEVICES	I-21988	1	
	20	MANUAL: OPERATION, ITC	MANUAL:ITC	1	
	21	PLATE, ADAPTER 220V ITC PLUG	I-21820	1	
	22	SCREW,PLMS: 6-32 X 3/8 LG	HWSC-PL6-6	2	
	23	NUT, KEP: #6-32	HWNUT-KEP#6	2	
	24	PLUG: 4 PIN CABLE	I-T304PCCT	1	
	25	SOCKET-MOUNT: 4 PIN PANEL	I-T304SAB	1	
*	REF	POWER CORD: "SCHUKO" PLUG	I-W-17800	1	

* NOTE: FOR 220V MODEL.
REMOVE ITEM 13 AND DRILL MOUNTING HOLES USING DRILL TEMPLATE A-21819.
INSTALL CINCH SOCKET #S304-AB WITH COVER PLATE ITEM 20 (A-21820).

WIRE SCHEDULE	
WIRE (PCB)	TERMINAL (SOCKET)
BLACK (HOT)	1
WHITE (NEUT.)	2
GREEN (GND)	3

POWER CORD 220V	
I-W-17800	
HOT	BRN
NEUT	BLU
GND	YEL/GRN

MODIFY PCB PER DRAWING A-21647
INCLUDE I-T304PCCT PLUG

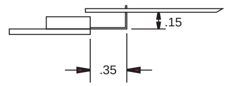


TOLERANCES UNLESS OTHERWISE SPECIFIED 63√ FRACTIONS 1/64" DEC. .X.1 .XX.01 .XXX.005 ANGLES 1	Valco Instruments Co., Inc.
APPROVED / DATE	ITC ASSY. 10 AMP
DRAWN R.B.D. / M.C. 2/20/94 2/20/89	REV. M,N,P — ITC10399-220 ITC10399
DESIGNED	SCALE --- / SIZE C / DRAWING NO. 21556
CHECKED	
FINAL ASSY / FILE NAME 21556 / SUB-DIR \ITC\	USA PROJECTION / SHEET OF

ITEM	DESCRIPTION	VALCO #	QTY
PCB	PCB ASSY: ITC 10 AMP	I-PCB22217	1 EA
T1	TRANSFORMER 115/230V DSC4-24	I-X-DSC4-24	1 EA
F1	FUSE: 10AMP 3AG	HWFUSE-10A	1 EA
F2	FUSE: 3AG SLO BLO 1/2 AMP (TYPE 313.5)	HWFUSE-.5A	1 EA
TP1-10	TERMINAL: HOLLOW USECO	HW-2010B	10 EA
CO1	CONN: 20 PIN HEADER, ANSLEY	I-T6092027	1 EA
CO2	CONN: 2 POSITION BLOCK	I-T4888-6	1 EA
C03,4	CONN: 2 PIN MOLEX	I-T09641021	2 EA
CO5,6	CONN: DIALIGHT	I-TCM21-3	2 EA
Z1	IC: K TYPE THERMOCOUPLE CONDITIONER	I-ICAD595AQ	1 EA
Z2-4	IC: COMPARATOR (DUAL)	I-ICLM358	3 EA
Z5	IC: DUAL TYPE D FLIP-FLOP	I-IC4013	1 EA
Z6	IC: DECIMAL CTR/DIVIDER. RCA OR MOT	I-IC4017	1 EA
Z7	IC: OPTO-TRIAC MOC3011	I-IC3011	1 EA
S1,5	SOCKET: DIP, 14 PIN LOW PROFILE	I-TDS-14-LP	2 EA
S2-4	SOCKET: DIP, 8 PIN, LOW PROFILE	I-TDS-8-LP	3 EA
S6	SOCKET: DIP, 16 PIN, LOW PROFILE	I-TDS-16-LP	1 EA
S7	SOCKET: DIP, 6 PIN, LOW PROFILE	I-TDS-6-LP	1 EA
TR1	TRIAC: T0220, 400V 15AMP	I-Q4015L5	1 EA
C1,2	CAP: ELECT, 220uF 35V, AXIAL LEAD	I-CE227-35AL	2 EA
C3,4,14	CAP: TANTAL, 4.7MF 35V	I-CT475-35	3 EA
C5,6,8-10, 15,16	CAP: CERAMIC, .022uF 50V, .250 LEADS	I-CC223-50	7 EA
C7	CAP: CERAMIC, 27 PF 50V	I-CC270-50	1 EA
C11	CAP: MONO CERAMIC, .22 uF 50V, .2"LEADS	I-CC224-50	1 EA
C12,13	CAP: TANTAL, 1MF 35V	I-CT105-35	2 EA
RN1	RES NET: 10 K, 16 PIN DIP, DISCRETE	I-RN761-3-10K	1 EA
RN2,3	RES NET: 100 K, 16 PIN DIP, DISCRETE	I-RN761-3-100K	2 EA
Q1	TRANSISTOR: NPN, T093, DARLINGTON	I-QMPSA13	1 EA
Q2,3	TRANSISTOR: PNP, TO93, DARLINGTON	I-QMPSA65	2 EA
SW1	SWITCH: TOGGLE DPDT-RPC-N-P-S	I-SW-MTM206	1 EA
L1,2	LAMP: NEON, RED (9001-52-C-03-2RN)	I-LAMP-R	2 EA
L3	LED: RED, WITH MOUNT (9001-52-C-03-2RN)	I-LED550-01	1 EA
BR1	RECTIFIER BRIDGE	I-D-VE28	1 EA
VR1	IC: VOLTAGE REGULATOR, -12V TO220	I-IC7912	1 EA
VR2	IC: VOLTAGE REGULATOR, 12V, TO220	I-IC7812	1 EA
D1	DIODE: SILICON SIGNAL	I-D1N914	1 EA
R1	RES: 100, 5%, 1/2W	I-R521000	1 EA
R2	RES: 1.27 K, 1%, 1/4W	I-R111271	1 EA
R3	RES: 2.2 MEG, 5%, 1/4W	I-R512204	1 EA
R4	RES: 10, 1%, 1/4W	I-R1110R0	1 EA
R5,7	RES: 10 K, 5%, 1/4W	I-R511002	2 EA
R6	RES: 953, 1%, 1/4W	I-R119530	1 EA
* R8A	RES: 10.0 K, 1%, 1/4W	I-R111002	1 EA
* R8B	RES: 715, 1%, 1/4W	I-R117150	1 EA
* R9,R10	POT: 10 K, TRIM, SHORT CT9W	I-RTP103	2 EA
R11	RES: 100 K, 5%, 1/4W	I-R511003	1 EA
R12	RES: 1 K, 5%, 1/4W	I-R511001	1 EA
MT1-6	MALE TABS	HW-607	6 EA
SC1-6	SCREW,PLMS: 6-32 X 1/4 LG, SS	HWSC-PL6-4	6 EA
KN1-6	NUT, KEP: #6-32 UNC	HWNUT-KEP#6	6 EA
FC1-4	FUSE CLIP: PCB MOUNT (102080)	HWFUSECLIP-1	4 EA
R13-14	FOR 110V MODELS-WIRE:BUSS, UNINSULATED,.025 DIA,22 AWG	I-W-BUSS-1	.75" EA
	FOR 220V MODLES - RES, 237 K, 1%, 1/4W	I-R112373	2 EA

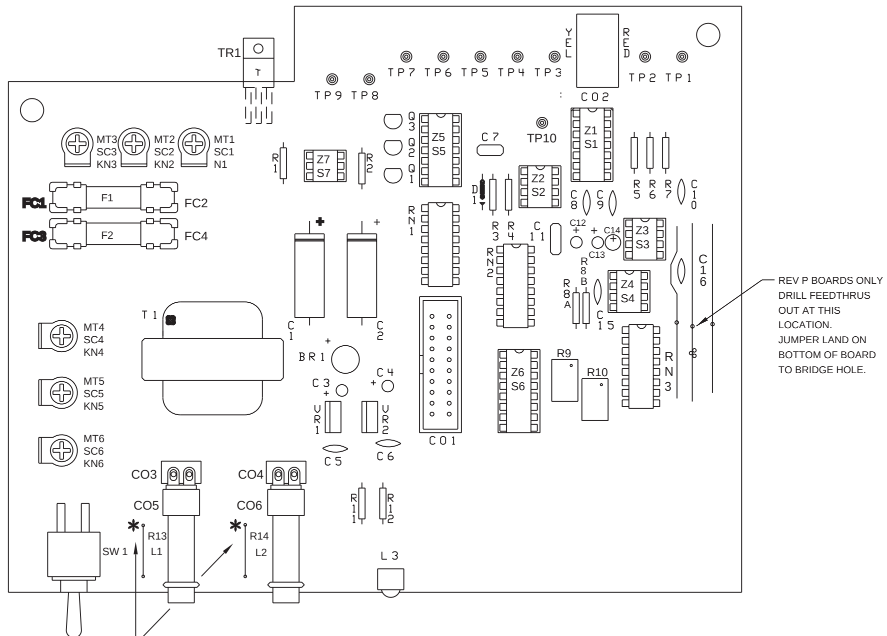
* R6,R8A,R8B MAY BE SUBSTITUTED BY TRIM POTS.

NOTE: INSTALL TR1 AS SHOWN

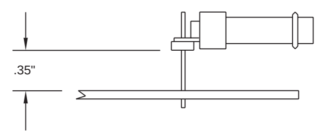


REVISIONS

LTR	DESCRIPTION	DATE	INITIATED
A	REPLACE R9A,R9B FOR TRIM POT 10K (R9)	2/28/89	
B	ECN #1805 UPDATE PER REV. P BOARDS	4/5/94	J DURR
C	ECN #2145 CHG R2 TO 1.27K WAS 2.2K	22SEP94	J DURR



* INSTALL JUMPERS FOR R13 & R14 (110V MODELS)
INSTALL R13 & R14 ON 220V MODELS
REFER TO DWG 21647



TOLERANCES UNLESS OTHERWISE SPECIFIED 63
FRACTIONS 1/64" | DEC. .X.1 .XX.01 .XXX.005 | ANGLES 1

VICI Valco Instruments Co., Inc.

PCB ASSY: ITC

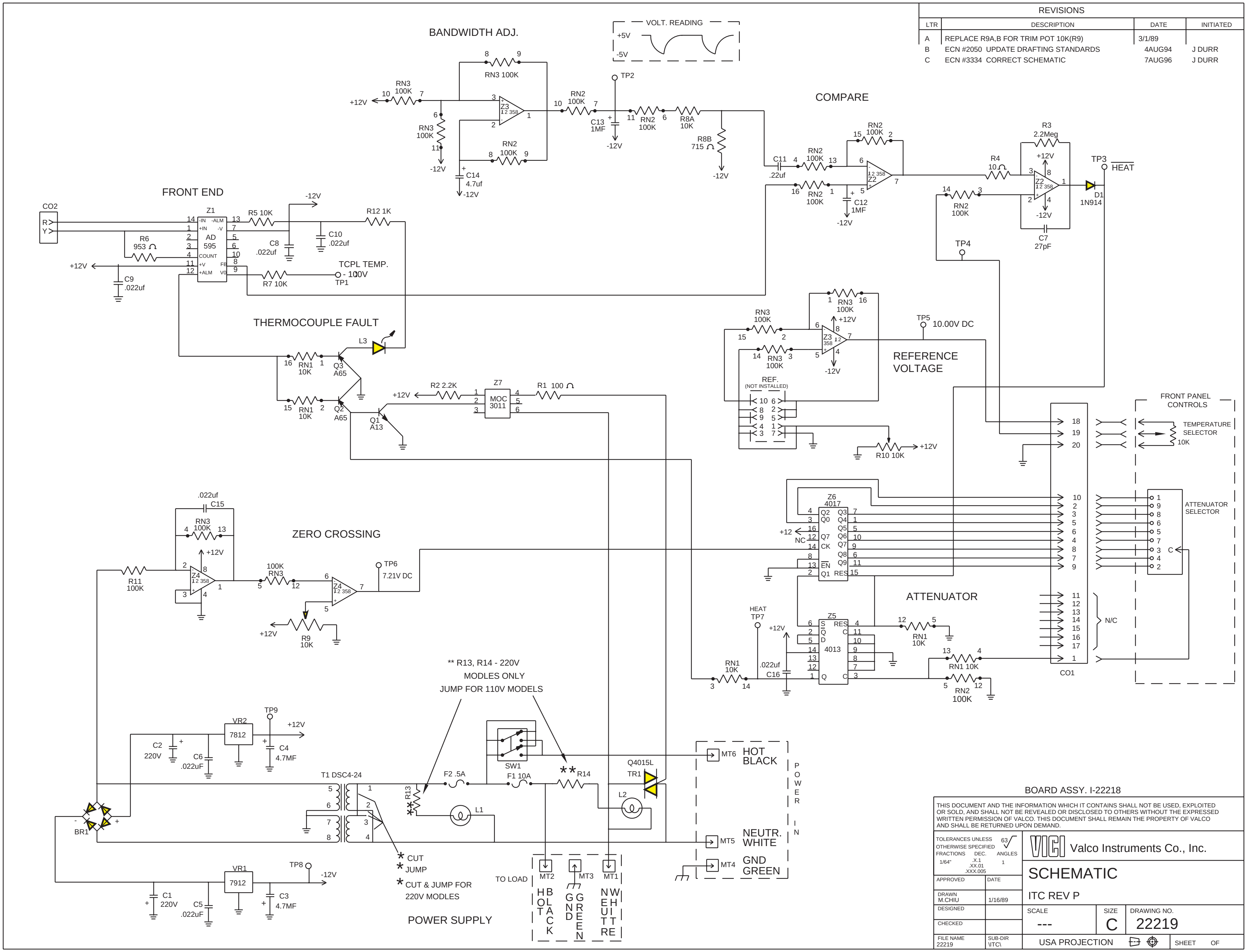
REV M,N,P — I-22218

APPROVED	DATE
DRAWN M.CHIU	1/11/89
DESIGNED	
CHECKED	
FILE NAME 22218	SUB-DIR \ITC\

NEXT ASSY 21556

DO NOT SCALE DRAWING
SCALE ---
SIZE B
DRAWING NO. 22218

USA PROJECTION
SHEET OF



REVISIONS

LTR	DESCRIPTION	DATE	INITIATED
A	REPLACE R9A,B FOR TRIM POT 10K(R9)	3/1/89	
B	ECN #2050 UPDATE DRAFTING STANDARDS	4AUG94	J DURR
C	ECN #3334 CORRECT SCHEMATIC	7AUG96	J DURR

TOLERANCES UNLESS OTHERWISE SPECIFIED: FRACTIONS 1/64"; DEC. .X .1, .XX .01, .XXX .005; ANGLES 1; 63

VICI Valco Instruments Co., Inc.

SCHEMATIC

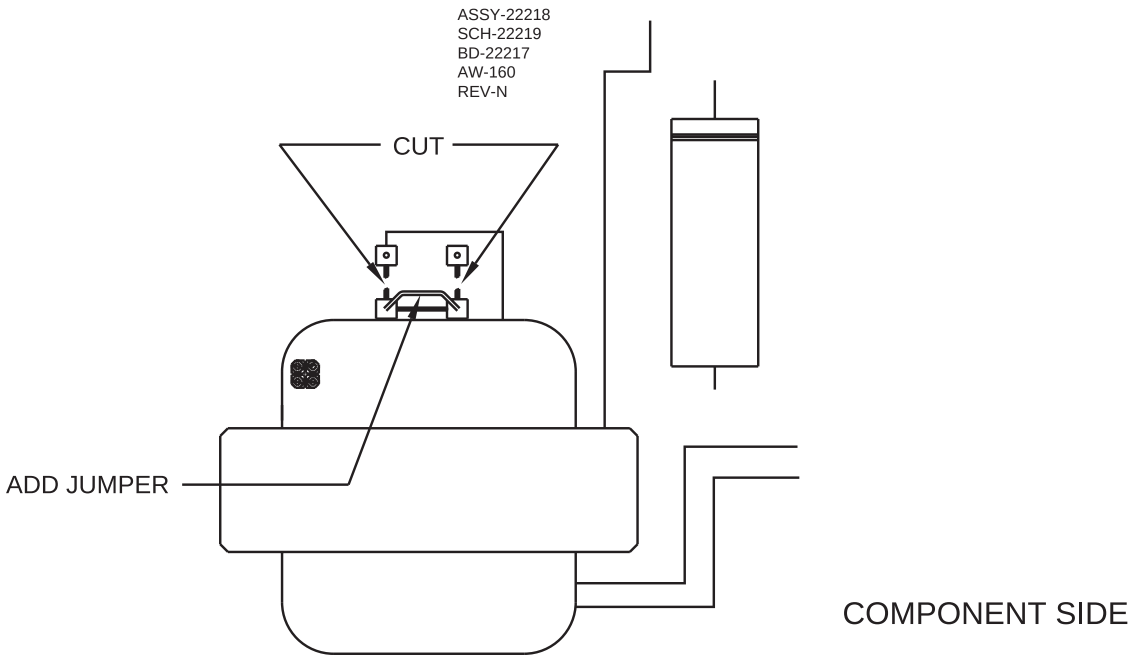
ITC REV P

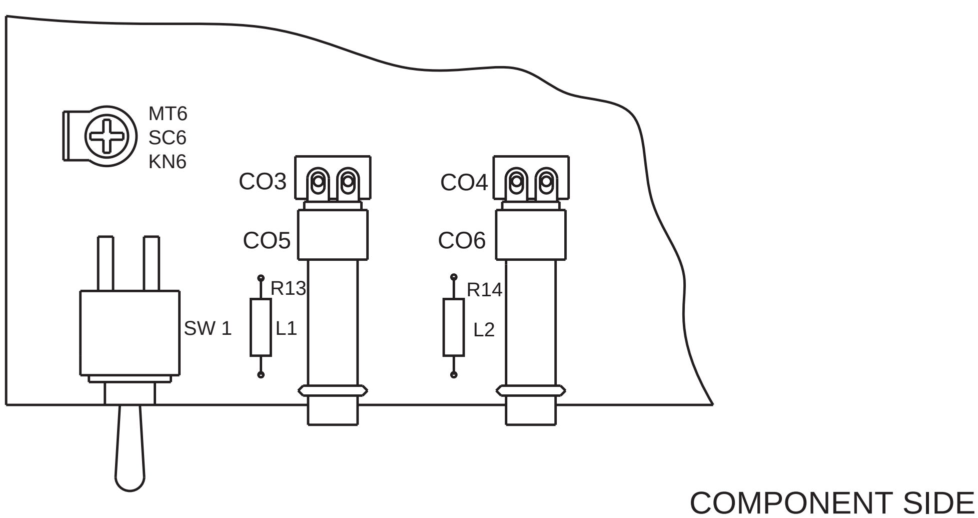
APPROVED	DATE
DRAWN M.CHIU	1/16/89
DESIGNED	
CHECKED	
FILE NAME 22219	SUB-DIR \ITC\

SCALE --- | SIZE C | DRAWING NO. 22219

USA PROJECTION | SHEET | OF

LTR	DESCRIPTION	DATE	APPROVED
A	ITC BD. REV M,N	21FEB89	
B	ECN #1808 NEW DWG	15APR94	J DURR
C	ECN #2050 SHOW NEW VER. W/R13 & R14	8AUG94	J DURR





NOTE: INSTALL R13 AND R14 ON BOARD FOR 220V VERSION.
(237K 1% 1/4W I-R112373)

USA	APPROVED	DATE	TOLERANCES UNLESS OTHERWISE SPECIFIED 63 FRACTIONS +-1/64" DEC. .X.1 .XX.01 .XXX.005 ANGLES +- 1 °	VICI Valco Instruments Co., Inc.
FILE NAME 21647	DRAWN R.B.D.	8/22/90		
SUB-DIR \ITC\	DESIGNED			
SCALE ---	A	DRAWING NO. 21647		PCB CONVERSION, ITC 110V TO 220V
SHEET OF				