

Instruction Manual 72-350Ja

**for the use of Versa-Cal™
DIGITAL THERMOCOUPLE
TEST SET**

Catalog No. 720350 Series

February 1982

**Biddle Instruments
Blue Bell, PA 19422**

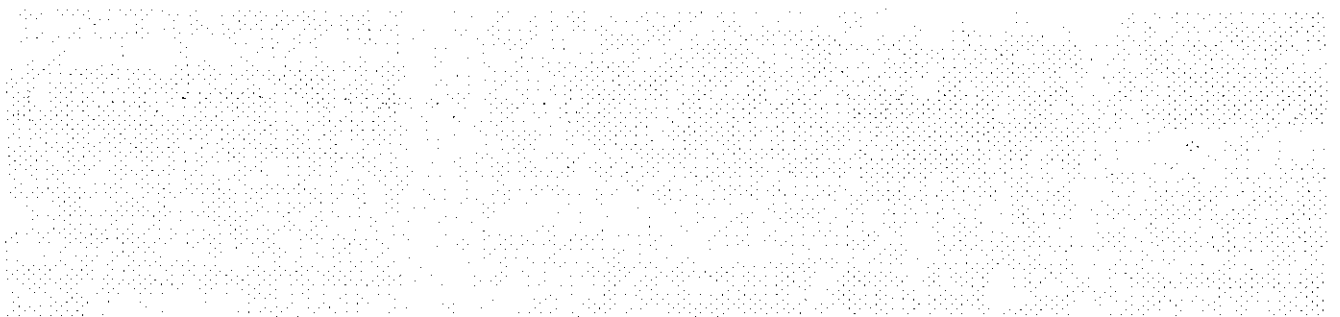


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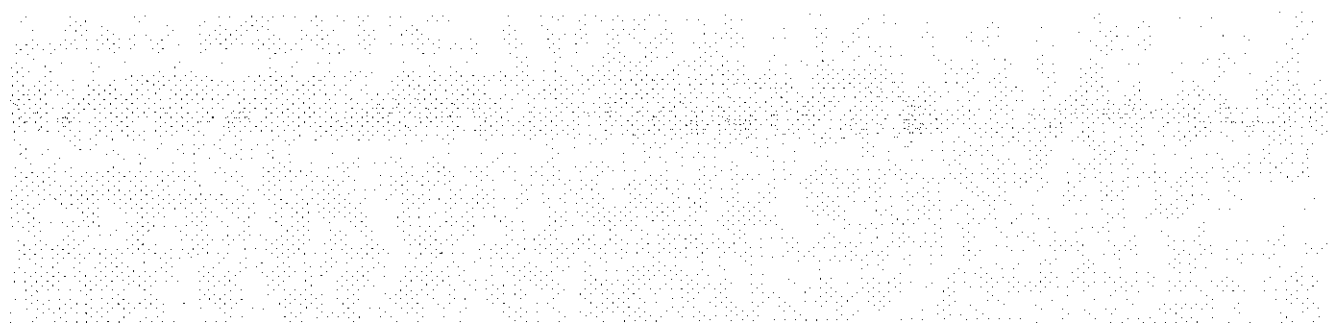
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**Figure 1: The Catalog No. 720350-1 Versa-Cal™
Digital Thermocouple/Millivolt Test Set.**



SECTION A INTRODUCTION

The Catalog No. 720350 Series Biddle Versa-Cal Digital Thermocouple/Millivolt Test Sets are portable, lightweight, rugged, and completely self-contained multi-range instruments with measure and simulate up to seven thermocouples in both °F and °C as well as millivolts. The test sets provide high accuracy, high resolution and digital readout.

The Catalog No. 720350-1 incorporates the three most popular thermocouple ranges: J, K and T, with readout in degrees F or C; plus a millivolt range.

The Catalog No. 720350-2 has all the ranges and features of the Catalog No. 720350-1 plus four additional thermocouple ranges: E, R, S, and C. The test sets feature automatic reference-junction and thermocouple linearity compensation to provide a direct digital display of temperature from thermocouples. The thermocouple output ranges are also reference-junction compensated and linearized so that the digital display, when energizing external equipment, indicates a temperature exactly as if it had originated at a thermocouple. Reference-junction compensation is not used with the Millivolt range.

The test sets utilize the latest in digital electronic technology, a high-reliability CMOS microprocessor developed for military use. This microprocessor actually calculates the linearity correction for each thermocouple reading using equations developed by the National Bureau of Standards. This method enables far better conformity than the line segment approximation which has been the best available prior to the microprocessor availability.

The analog system is also of comparable sophistication and tolerates the high levels of interference often found in industrial applications. Careful electronic and thermal design enable one-microvolt resolution and zero stability, and 0.005% full scale calibration. A simple arrangement of internal calibration adjustments is also provided.

The test sets are simple to operate, easy to read, and maintain their high accuracy over a wide ambient temperature range. The instruments are battery-powered with self contained rechargers. The instruments are equipped with two "infinite resolution" film-type concentric controls, a multi-turn coarse control, and a single-turn fine control to enable quick setting of the output voltage or temperature equivalent.

INTRODUCTION (Cont'd)

Two pairs of binding post terminals, with a selector switch, are provided for use on input or output.

The test sets may be used for the following typical applications:

1. Measuring temperature with thermocouples.
2. Comparison of working and reference thermocouples.
3. Measuring millivolts from thermocouples or other sources.
4. Calibrating thermocouple-type recorders, controllers, indicators, and other instruments of the deflection, null-balance, or digital type.
5. Calibrating millivolt-type recorders, controllers and indicators.
6. Troubleshooting in thermocouple or millivolt dc control loops.

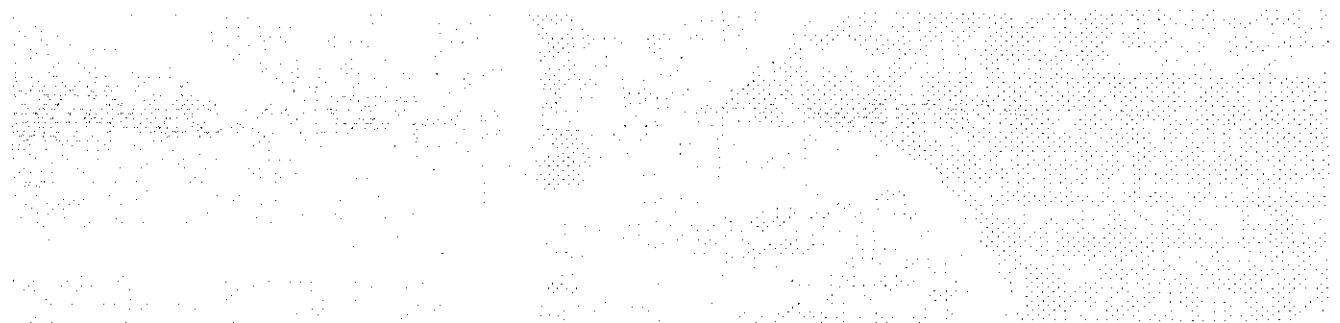
SECTION B SAFETY PRECAUTIONS

— SAFETY IS THE RESPONSIBILITY OF THE USER —

— LA SEGURIDAD ES EL CARGO DEL OPERADOR —

These test sets have been designed and manufactured to meet the requirements of ANSI C39.5-1974 "Safety Requirements for Electrical and Electronic Measuring and Controlling Instrumentation." The test sets themselves do not present any unusual shock hazard during operation; however, all persons making or assisting in tests must use all practical safety precautions to prevent contact with energized parts of other test equipment and associated circuits.

Corrective maintenance must be performed only by a person who is familiar with the construction and operation of the test sets and the shock hazard involved. The high voltage output of the DC/DC Converter which powers the gas discharge display is nominally 175V dc and can deliver up to 35mA. This can be hazardous and particularly could cause injury due to involuntary reaction. Use caution when handling the test set when it is removed from its case. The test set should be battery operated when performing maintenance to avoid the shock hazard from the ac supply line.



SECTION C RECEIVING INSTRUCTIONS

Your Versa-Cal Digital Thermocouple/Millivolt Test Set has been thoroughly tested and inspected to rigid specifications before being shipped. Check the equipment received against the packing list. Notify Biddle Instruments, Blue Bell, PA 19422 of any shortage of materials. The instrument should be examined for damage received in transit. If any damage is found, file a claim with the carrier at once and notify Biddle Instruments or its nearest representative giving a detailed description of the damages observed.

**BEFORE INITIAL USE OF TEST SET, CHARGE
BATTERIES FOR AT LEAST 14 HOURS.**

Refer to Section H4 on page 26 for charging
procedure.



SECTION D
SPECIFICATIONS

RANGES, RESOLUTION, AND LIMIT OF ERROR:

TABLE 1

Range Switch Pos.	¹ T/C	Mode	Range	Resolution and Repeatability	³ Limit of Error 25 ±10°C, 1 year
1	² mV, Lo mV, Hi mV, Lo mV, Hi	Meas. Meas. Output Output	0 to ±20mV ±20 to ±101.1mV -12 to +20mV +20 to +80mV	0.001mV 0.01mV 0.002mV 0.01mV	±(0.03% of rdg + 5 lsd) ±(0.03% of rdg + 2 lsd) ±(0.03% of rdg + 5 lsd) ±(0.03% of rdg + 2 lsd)
2	J	Meas. & Output	-346 to +2192°F -210 to +1200°C	0.1°F 0.1°C	±1°F ±0.6°C
3	K	Meas. & Output	-328 to +2501°F -200 to +1372°C	0.1°F 0.1°C	±1°F ±0.6°C
4	T	Meas. & Output	Primary: -337 to +752°F -205 to +400°C Extended: -405 to -337°F -243 to -205°C	0.1°F 0.1°C 0.1°F 0.1°C	±1°F ±0.6°C ±10°F ±6°C
⁴⁵	E	Meas. & Output	Primary: -389 to +1832°F -234 to +1000°C Extended: -422 to -389°F -252 to -234°C	0.1°F 0.1°C 0.1°F 0.1°C	±1°F ±0.6°C ±5°F ±3°C
^{46,7}	R,S	Meas. & Output	-58 to +3214°F -50 to +1768°C	1°F 1°C	±2°F ±1°C
⁴⁸	C	Meas. & Output	Primary: +32 to 2192°F 0 to 1200°C Extended: 2192 to 3812°F 3812 to 4200°F 1200 to 2100°C 2100 to 2315°C	1°F 1°C 1°F 1°F 1°C 1°C	±1°F ±1°C ±2°F ±3°F ±1°C ±2°C

See notes on next page.

SPECIFICATIONS (Cont'd)

NOTES FOR TABLE 1:

1. Thermocouple symbols are as defined by ANSI except for type C which is not an ANSI recognized symbol.

J — Iron — Constantan
K — Chromel — Alumel
T — Copper — Constantan
E — Chromel — Constantan
C — Tungsten/5% Rhenium — Tungsten/26% Rhenium
R — Platinum/13% Rhodium — Platinum
S — Platinum/10% Rhodium — Platinum

2. Automatic measurement range change, with hysteresis, at ± 19.95 mV.
3. Includes linearization conformity, zero error, span error, noise and reference junction compensation error. Applies to operation with charger off, after warmup of 15 minutes at stable ambient conditions. The linearization conformity to NBS table is within 0.2°F for all type thermocouples within primary range.

On the TC ranges an additional error of up to $+0.5^{\circ}\text{F}$ will occur, within primary range, when operating with charger on.

4. Switch positions 5-8 on Catalog No. 720350-2 only.

INPUT RESISTANCE (Measure Mode): $>1000\text{M}\Omega$

SOURCE RESISTANCE EFFECT (Measure Mode): $2\text{k}\Omega$ source resistance causes less than one digit error on all ranges.

OUTPUT MODE RESISTANCE: $<40\Omega$

REFERENCE JUNCTION COMPENSATION:

Thermocouple ranges — automatic; Millivolt range — none

WARM-UP TIME (for specified limit of error):

<1 minute for 1° or 0.01 mV ranges

<15 minutes for 0.1° or 0.001 mV ranges

SPECIFICATIONS (Cont'd)

SETTLING TIME TO RATED ACCURACY: 0.5 second after input change.

OVERVOLTAGE: 120V dc or 120V ac RMS continuous without damage, except in output mode.

NORMAL MODE REJECTION: >50 db @ 50/60 Hz.

COMMON MODE REJECTION RATIO:

Operating on batteries: not applicable.

Operating on AC: >140 db with 300V isolation.

OPERATING MODES: selectable by rotary switch.

Measure: for measurement within range listed in Table 1.

Output: for generating output within range listed in Table 1.

Check: for checking instrument reading against separate internal "reference" value. The displayed reading can be compared with the recorded value marked on the label in the instrument lid.

Off: Power off, but battery may be charged.

RANGE SELECTOR SWITCH:

4-range unit: 4-position rotary switch (J, K, T, mV).

8-range unit: 8-position rotary switch (J, K, T, E, R, S, C, mV).

OUTPUT ADJUST CONTROL: Continuously adjustable dual-knob potentiometer. See Table 1 for range and resolution. Coarse (inner) control is a 9-turn potentiometer; Fine (outer) control is a single-turn potentiometer.

°F/°C Selection: Slide switch.

INPUT/OUTPUT TERMINALS: 5-way binding posts. Two pairs, with toggle type selector switch.

DISPLAY: (See Figure 2 on page 10)

- Type: 7-bar gas discharge with 0.33" character height.
- Digits: Five, with decimal point and (-) sign.
- Units: °F or °C for thermocouple ranges;
E for millivolt range.
- Format: See Figure 2.

SPECIFICATIONS (Cont'd)

- Reading update rate: two per second.
- Diagnostic messages:
 - Low Battery: Display blinks off/on.
 - Positive Temperature Overrange: Display indicates "HIGH".
 - Negative Temperature Overrange: Display indicates "LO".
 - Positive Millivolt Overrange: Display indicates "ERROR".
 - Negative Millivolt Overrange: Display indicates "OPEN".
 - Open Thermocouple: Display indicates "OPEN".
 - Malfunction: Display indicates "ERROR".
 - Segment Check: For an interval after power is turned ON or a different range is selected, all segments and two decimal points are lit to indicate proper display function.

BATTERY AND CHARGER

- Five nickel-cadmium cells, "C" size.
- Operating time after full charge: minimum of 8 hours, continuous.
- Battery Charging Time: 14 to 16 hours.
- Battery Life: at least 500 charge/discharge cycles.
- Continuous Charging: Battery can be charged indefinitely without damage.
- Continuous operation: Instrument can be operated continuously while on charge.
- Power supply for charger: 115/230V $\pm 15\%$, 50/60 Hz, 10 watts maximum. The nominal voltage is selected by an internal switch.
- Battery discharge protection: Load automatically switched off approximately 15 minutes after start of low battery indication (flashing display).

SPECIFICATIONS (Cont'd)

OPERATING TEMPERATURE RANGE: -10° to 45°C (14° to 113°F)

STORAGE TEMPERATURE RANGE: -40° to $+50^{\circ}\text{C}$ (-40° to 122°F)
with battery.
 -40° to $+70^{\circ}\text{C}$ (-40° to 158°F)
with battery removed.

SAFETY: Meets ANSI C39.5-1974 specification "Electrical Safety Requirements for Electrical Measuring and Controlling Instrumentation;" insulated case and panel.

ACCESSORIES: AC line cord for battery charger included with instrument, 6 ft. long.

ENCLOSURE: Impact-resistant molded ABS plastic case with handle and hinged removable lid; light gray textured finish. Plastic panel with off-white finish. Storage compartment for manual, test leads, and charger cord.

SPECIFICATIONS (Cont'd)

Display Format

CONDITION	DISPLAY						
T/C — J, K, T, E } + -	2	5	0	1	5	0	[or F
	-	3	8	9	0	0	[or F
T/C — R, S, C } + -		1	7	6	8	0	[or F
	-			4	7	0	[or F
mV, LOW RANGE } + -		1	9	9	5	0	E
	-	1	9	9	5	0	E
mV, HIGH RANGE } + -		1	0	1	1	0	E
	-	1	0	1	1	0	E
TC ABOVE + FS BUT BELOW 101.1mV		H	1	6	H		
TC BELOW - FS BUT ABOVE - 101.1mV			L	0			
INPUT ABOVE 101.1mV OR MALFUNCTION		E	r	r	o	r	
INPUT BELOW - 101.1mV OR OPEN INPUT		0	P	E	n		
SEGMENT CHECK (WHEN CHG RGE)	8	8	8	8	8	8	8
LOW BATTERY	DISPLAY FLASHES ON-OFF						

Figure 2: Display Format.

SECTION E BASIC CIRCUIT DESCRIPTION

1. GENERAL

The Catalog No. 720350 accepts the millivolt output of a thermocouple (or other input) and provides a digital display of the equivalent temperature. To accomplish this, the instrument contains measuring circuitry to convert the input voltage to digital form (a "conversion") and to display the result. Because the voltage generated by the thermocouple is a nonlinear function of temperature, this circuitry includes a "linearizer".

The measuring circuitry of the Catalog No. 720350 is shown in block diagram form in Figure 3, page 58.

The major functional elements of this test set are as follows:

Microprocessor	Digital Section
Power Supply/Battery	Display Section
Analog Section	

2. MICROPROCESSOR CONTROL CYCLE

The microprocessor (DL 10, Figure 3) program automatically performs the following functions:

- (a) determines appropriate preamplifier gain (20, 50, 70 or 200).
- (b) measures reference junction temperature.
- (c) calculates thermocouple temperature, corrected for reference junction temperature.
- (d) formats the display with appropriate resolution (0.1° or 1°).
- (e) formats the display with appropriate messages.

The display is updated two times per second, except as noted later. Each update is the result of two conversions, which are referred to as conversion A and conversion B. The time required for conversion A is 200 milliseconds while conversion B takes 300 milliseconds. Conversion A makes a preliminary measurement of the thermocouple or millivolt signal (always at an amplifier gain of 20). If the signal does not exceed the full scale capability of the preamplifier ($\pm 101.1\text{mV}$), the gain to be used

BASIC CIRCUIT DESCRIPTION (Cont'd)

during conversion B is determined from the result of conversion A. An open thermocouple test is also made during conversion A. The result of conversion B is used in calculating the temperature (or millivolts) to be displayed. Note that, except for certain error messages, the displayed reading is always determined only from the results of conversion B.

During the first of every ten update intervals conversion B measures the reference junction temperature. During the other nine update intervals conversion B measures the thermocouple output voltage. The measured thermocouple voltage is transformed to a temperature reading corrected for the reference junction temperature determined during the first of the ten intervals. Thus the display update rate is 2 per second, except during the conversion when the reference junction temperature is measured. During this time, the display is not updated. When the millivolt range is selected the microprocessor program ignores the reference junction temperature; thus the update rate is always 2 per second.

During conversion A, a 30 nanoamp current (100 M Ω connected to -3V) is fed into the thermocouple junction. If the thermocouple is open, the input voltage will go to -3 volts, causing the display to show "OPEN". During conversion B, the 30 nanoamp current is disconnected; thus it does not affect the accuracy of the displayed temperature.

The functions of conversions A and B are summarized in the following tabulation. The display messages as a function of the selected range and input voltage are also listed.

FIRST UPDATE PERIOD (REFERENCE JUNCTION TEMPERATURE MEASUREMENT)

Conversion A:

- (a) Amplifier gain = 20
- (b) Measures thermocouple input signal (result not used)

Conversion B:

- (a) Amplifier gain = 20
- (b) Measures output of reference junction temperature sensor. This is used in the nine subsequent conversions to correct the temperature calculation for the reference junction temperature.

BASIC CIRCUIT DESCRIPTION (Cont'd)

NEXT NINE UPDATE PERIODS (ACTUAL MEASUREMENTS)

Conversion A:

- (a) Amplifier gain = 20
- (b) Measures thermocouple (or mV) input signal (preliminary):
 - (1) If signal is above +FS but below 101. mV, display "HIGH" (TC range only).
 - (2) If signal is below -FS but above -101.1 mV, display "LO" (TC range only).
 - (3) If signal is above +101.1 mV, display "ERROR".
 - (4) If signal is below -101.1 mV or open input, display "OPEN".
 - (5) If signal is less than ± 101.1 mV, determine preamplifier gain to be used during conversion B.

Conversion B:

- (a) Amplifier gain as determined in conversion A. The gain will be as follows:
 - (1) If signal is 0 to ± 20 mV, gain = 200.
 - (2) If signal is ± 20 to ± 57.1 mV, gain = 70.
 - (3) If signal is ± 57.1 to ± 80.0 mV, gain = 50.
 - (4) If signal is ± 80.0 to ± 101.1 mV, gain = 20.
- (b) Measure thermocouple or mV input signal (final)

3. POWER SUPPLY/BATTERY

The instrument is powered by a battery made up of five series-connected C size nickel-cadmium cells (PS5 in Figure 3) rated at 2.0 ampere hours. The nominal load current of 220 milliamps can be provided for at least eight hours. A built-in transformer (PS2), rectifier (PS3), and current regulator (PS4), are used for charging the battery. An internal switch (PS1) permits operation from either 115 or 230 volts, 50 to 60 Hz. The battery can be charged with the system either on or off. In either case, the battery charging current will be approximately 180 milliamps. When the system is turned on, the charger furnishes an additional 220 milliamps to power the system.

BASIC CIRCUIT DESCRIPTION (Cont'd)

The battery voltage is applied to a DC-DC converter which generates four regulated voltages: 5, 180, +13 and -13 volts. The 5 and 180 volt supplies are referenced to digital ground. The two 13 volt supplies are used for the analog circuitry. Note that the digital circuitry, analog circuitry and metal chassis are all isolated from each other.

The low battery detector (PS8) senses when the battery voltage drops to less than 5.90 volts. A signal is then fed to the microprocessor which in turn causes the display to flash on-off. The power-off detector (PS7) senses when the battery voltage drops to less than 5.85 volts, at which point the system power is turned off to reduce the possibility of the battery being completely discharged.

4. ANALOG SECTION

The analog section contains the following functional circuits:

- (a) dual-slope integrating voltage-to-time interval converter, a part of the analog-digital converter (PC5).
- (b) preamplifier (PC4)
- (c) digital controls for above circuits (PC6)
- (d) reference junction temperature sensor (Q5)
- (e) open thermocouple bias source (PC1)
- (f) output mode voltage adjustor (R49)
- (g) precision reference voltage (PC2)
- (h) check mode voltage source (PC2)

The analog-digital (A/D) converter (PC5) is a dual-slope integrating auto-zeroed type. It can resolve a full scale input of ± 4.0192 volts into ± 40192 counts (100μ volts per count). There are four time intervals which make up each conversion. These intervals are as follows:

- (a) AUTO-ZERO PHASE—The preamplifier input is grounded and any offsets due to the buffer, integrator or comparator are stored in a capacitor. The effects of these offsets will be cancelled out during subsequent integration intervals.

BASIC CIRCUIT DESCRIPTION (Cont'd)

- (b) INPUT INTEGRATION PHASE — The input signal is fed through a preamplifier whose gain is controlled by the microprocessor. The amplified thermocouple, millivolt or reference junction temperature signal is integrated for exactly 100 ms.
- (c) POLARITY SENSING PHASE — This interval is the last 1.91 ms of the input integration phase. During this interval, the polarity of the integrator output is sensed. If the input signal is negative, a pulse (POL) will be generated at the beginning of this interval and sent to the digital circuitry on the POL/EOC line. For positive input signals, the POL pulse is not generated.
- (d) REFERENCE INTEGRATION PHASE — The 4.0192 volts reference is integrated until the comparator output ramps down to ground, at which time an end-of-conversion pulse (EOC) is generated.

The digital controls receive information from the microprocessor (DL10) and control the gain of the preamplifier and the state of the A/D converter. Pulse information is received via two pulse transformers (DL1) which transmit ADVANCE and SET-UP pulses. The ADVANCE pulses determine the state of the A/D converter. The SET-UP pulses determine gain of the preamplifier and the type of conversion: that is, conversion A or B, and millivolts, thermocouple, or reference junction conversion. The auto-zero state is initiated when the microprocessor circuitry simultaneously generates a SET-UP pulse and an ADVANCE pulse. This generates a reset pulse within the reset circuit (PC8). Additional SET-UP pulses, up to a maximum of 13, are used to determine the preamplifier gain, etc. The reference junction temperature is measured with temperature sensor (Q5) which is thermally connected to the four input terminals. This sensor generates a current of one μA per $^{\circ}\text{K}$. For example, at a temperature of 25°C (298.2°K), the output current is $298.2 \mu\text{A}$. This current is transformed into 149.1 mV by passing through R31 and R32 (500 ohms). The preamplifier gain is always 20 when the output of the reference junction temperature sensor is to be digitized. The resolution of the measurement is 0.01°C . The TEMP ZERO trimmer (R31) is used to eliminate any absolute error in the output of the sensor.

The reference junction temperature is used in calculating the displayed temperature reading in the MEASURE and OUTPUT modes.

BASIC CIRCUIT DESCRIPTION (Cont'd)

In these modes, the measured reference junction temperature is converted to the equivalent thermocouple voltage for the selected range. This voltage is subtracted from the measured thermocouple voltage. The result is then converted to temperature. The voltage to temperature conversion is performed by a power series expansion in the microprocessor.

In the Check mode, the output of the reference junction temperature sensor is shorted to ground. The microprocessor is programmed to recognize this zero output as an indication that the CHECK mode has been selected. In this mode, the reference junction temperature is not used in calculating the temperature to be displayed. Likewise, when the mV range is selected, the microprocessor program ignores the reference junction sensor output and the display indicates the absolute voltage present at the input terminals.

The reference voltage for the measuring system is generated across a 6.3 volt precision zener diode within (PC2). The current through this diode is held at 2 milliamps, giving maximum temperature stability of the reference voltage. A precision voltage divider is used to reduce the 6.3 volt reference to 4.0192 volts as required by the A/D converter.

In the Output mode an internally generated regulated voltage is fed to the concentric potentiometer (R49), whose amplitude can be adjusted between -12 and +80 mV. This voltage is applied to the selected pair of input binding posts and is displayed as either a millivoltage or an equivalent temperature.

In the Check mode, a stable voltage of approximately 5 millivolts is developed within (PC2). This voltage is applied through the front panel mode selector switch to the system input in place of the thermocouple input. Proper operation is indicated when the displayed reading compares with the value recorded in the lid of the instrument. As described previously, the reference junction temperature does not affect the displayed reading in this mode.

5. DIGITAL SECTION

All digital timing is controlled by the 2.41152 MHz oscillator (DL4). This clock is divided by six in divider (DL6) and applied to an 8-bit binary counter (DL7). The output of this counter occurs every 636.9 μ S and is used as the interrupt for the microprocessor. The 8-bit counter

BASIC CIRCUIT DESCRIPTION (Cont'd)

(2⁸) also serves as part of the result counter for the A/D converter. The result counter is completed by a software counter which can count up to 157. The complete result counter, in combination with the system clock, determines the period of the A/D converter first integration and the full scale count capability of the converter, as follows:

$$\text{Period of input integration} = \frac{6 \times 256 \times 157}{2.41152 \times 10^6} = 0.10 \text{ second}$$

$$\text{Full scale converter counts} = 256 \times 157 = 40192.$$

Note that, although the resolution of the converter is one part in 40192 at full scale, the displayed resolution never exceeds one part in 20,000 in the mV mode (at 20.000 millivolt input), or one part in 25016 in the temperature mode (a K thermocouple at 2501.6°F).

The POL/EOC logic (DL5) detects the end-of conversion (EOC) pulse which is generated by the analog circuitry at the end of the reference integration interval. At this time, part of the result exists in the 8-bit counter while the rest of the result exists in the software x 157 counter. The number in the 8-bit counter is stored in an 8-bit latch (DL8). This can then be entered into the microprocessor via the data bus and combined with the number stored in the software counter. The ADVANCE and SET-UP pulses are also generated to control the A/D analog circuitry.

The microprocessor (DL10) has four error flag (EF) inputs which are utilized as follows:

- EF1: This accepts the output of the low battery detector in the power supply.
- EF2: The POL pulse which is generated by the analog circuitry is detected by the POL/EOC logic and enters the microprocessor via EF2.
- EF3: This accepts the output of the °F/°C switch on the display card.
- EF4: Accepts the output of the RANGE switch on the display card.

BASIC CIRCUIT DESCRIPTION (Cont'd)

To generate the required 13-bit memory address, a 5-bit latch (DL11) is used to provide the five most significant bits.

Address decoding (DL14) is also used for addressing the memory.

6. DISPLAY SECTION

The multiplexed display contains seven digits which utilize 0.33" planar gas discharge displays.

Digit and segment data is loaded from the data bus into two 8-bit latches. Latch DS1 is used to select one digit at a time while latch DS2 contains the 7-segment plus decimal point data for the selected digit. Each digit is turned on for one interrupt interval (636.9 microseconds). Nine interrupt intervals (5.73 milliseconds) are used to scan all digits. For two of these intervals, no digit is turned on.

The °F/°C switch connects one of the microprocessor ERROR FLAG inputs to +5 volts for °F or ground for °C.

The range switch is connected to the eight digit-drive outputs of latch DS1. The position of the switch can be sensed by the microprocessor because of the fact that, at any given instant, only one of the digit drive lines will be at a high logic level.

SECTION F

CONTROL and TERMINAL FUNCTIONS

1. GENERAL

Since proper operation of the Biddle Versa-Cal Digital Thermocouple/Millivolt Test Set depends on correct use of switches and controls, the function of these devices is described prior to the operating procedures. The locations of the controls on the panel are shown in Figure 4.

2. CONTROLS and TERMINALS

(a) MODE Selector

This is a four-position rotary switch having the following mode selections:

- (1) OFF: Turns instrument OFF. Remember to turn *off* instrument when not in use to conserve battery power. The battery may be charged with the instrument either ON or OFF (OFF recommended).
- (2) MEASURE: In this position the unit will measure and display temperature (or mV) in accordance with the setting of the Range selector switch, for the connection made to the selected TC binding post pair (A or B).

NOTE: Refer to Section D Specifications or the Figure 2 Display Format for diagnostic messages.

- (3) OUTPUT: In this position the selected binding post pair (A or B) is driven at a voltage determined by the setting of the OUTPUT ADJUST control. The instrument displays the simulated temperature (or mV) in accordance with the setting of the Range selector switch.

NOTE: Refer to Section D, Specifications or the Figure 2 Display Format for diagnostic messages.

Connection of a thermocouple to the selected TC binding posts will short out the output voltage thus defeating the operation of this mode.

CONTROL and TERMINAL FUNCTIONS, (Cont'd)

- (4) **CHECK:** In this position the instrument input is disconnected from the binding posts on the front panel and connected to an internally generated reference voltage (approximately 5mV). The reference-junction circuit is simultaneously disabled. The normal reading for your instrument, on each range, is recorded on a label in the lid of the instrument. Obtaining normal readings assures the operator that the measuring circuitry is functioning properly.
- (b) **RANGE Selector**
Selects the desired thermocouple or millivolt range.
- (c) **°F/°C Selector**
Selects the desired °F or °C temperature display.
- (d) **Output Adjust**
This is a dual-knob control for adjusting the instrument output voltage when operating in the OUTPUT mode. The Coarse (inner) control is a 9-turn potentiometer and the Fine (outer) control is a single-turn potentiometer. The ratio of the range of adjustment of the Coarse control to the Fine control is approximately 150 to 1. Turning the controls clockwise causes the output voltage to become more positive.
- (e) **Binding Posts (TC A or TC B)**
For connection to input or output.
- (f) **Binding Post Selector**
Selects the desired pair of binding posts (A or B).
- (g) **Charge Receptacle**
This receptacle is provided for recharging the batteries. An internal switch permits operation from either 120 or 240V, 50 to 60 Hz. The front panel is marked to indicate the setting at the time of manufacture. A special ac line cord is furnished with the instrument and is stored in the lid compartment.

CONTROL and TERMINAL FUNCTIONS, (Cont'd)

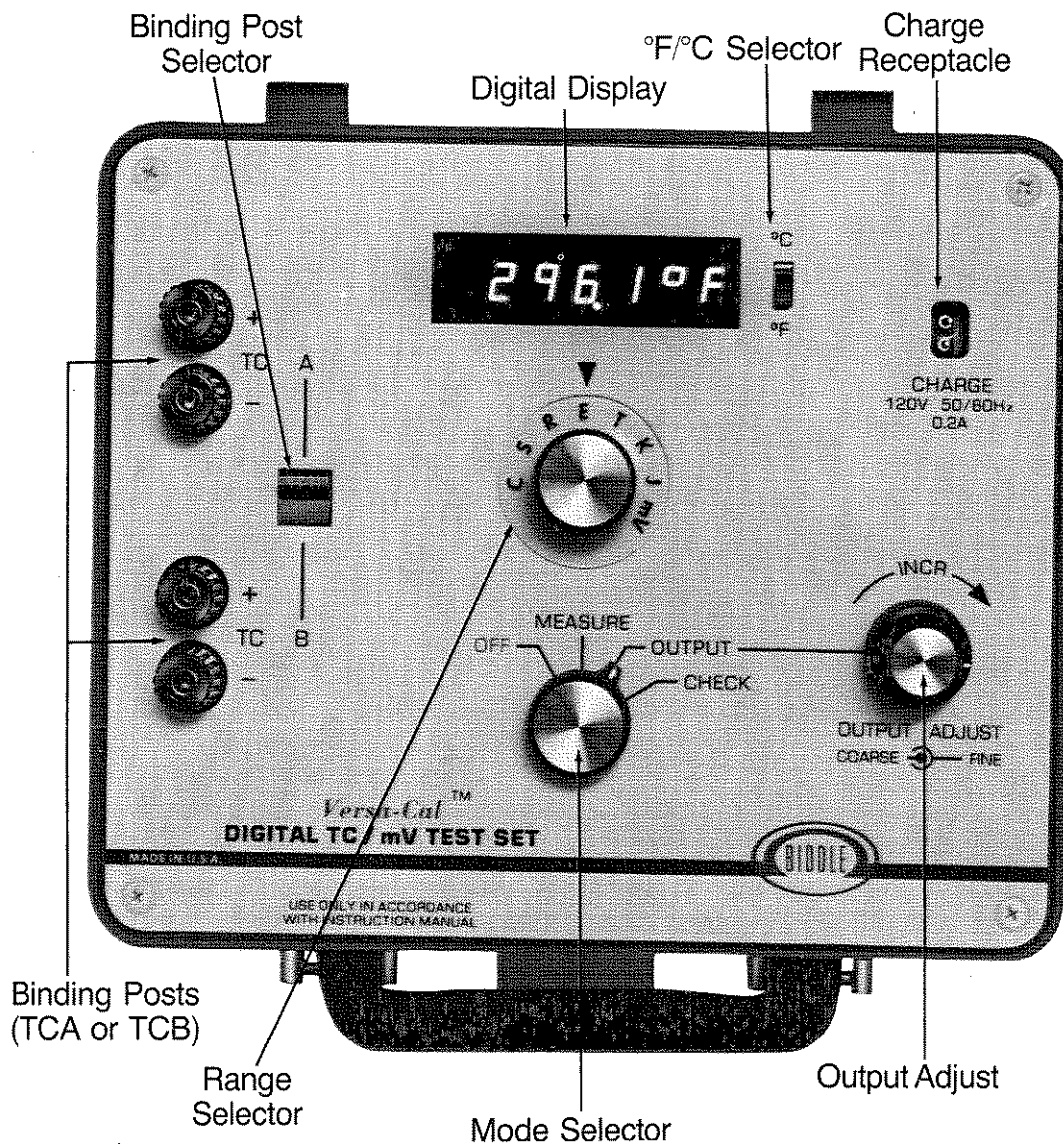


Figure 4: Cat. No. 720350-2 Control Identification. (Note: In the four-range instrument, Range Select knob is marked "mV", "J", "K", and "T".)

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SECTION G CONNECTIONS

1. TEMPERATURE MEASUREMENT WITH A THERMOCOUPLE

Connect the thermocouple to be measured to either pair of input binding posts (A or B) as shown in Figure 5, taking care to connect the negative thermocouple wire (red) to the (-) binding post and the positive wire to the (+) binding post. Thermocouple extension leadwires of the same type as the thermocouple *must* be used if it is desired to make the measurement at a remote location from the thermocouple termination.

If a shielded thermocouple is used, it is recommended that the shield be returned to the (-) input binding post along with the negative thermocouple lead.

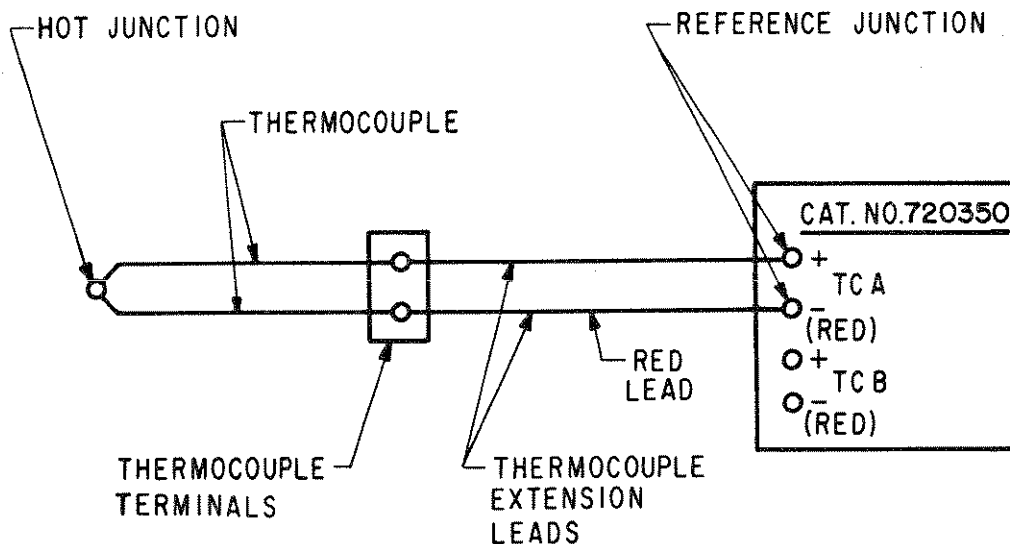


Figure 5: Connection to a Thermocouple.

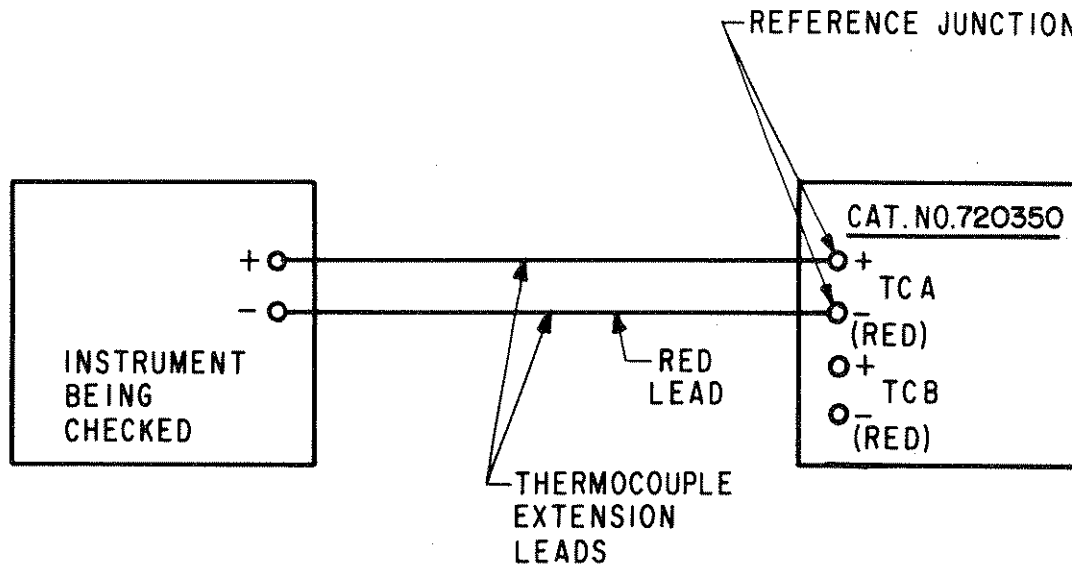
2. CHECKING RECORDERS, INDICATORS OR CONTROLLERS

Connect the instrument to be checked to either pair of the test set binding posts (A or B) as shown in Figure 6. When using the TC range of the test set, thermocouple extension leadwires of the same type as the instrument calibration *must* be used to connect the two instruments. Take care to connect the negative thermocouple wire (red) to

CONNECTIONS, (Cont'd)

the (-) terminals of both instruments and the positive wire to the (+) terminals of both instruments.

Use copper wire to connect the two instruments when using the mV range of the test set.



**Figure 6: Connection for Calibrating Another Instrument
(use Copper Leads if Test Set is on mV Range).**

SECTION H OPERATING PROCEDURE

TO SAVE BATTERIES TURN SET OFF WHEN NOT IN USE.

1. GENERAL

The test set can be operated in any position and is unaffected by normal vibration. The warmup time is less than one minute for the instrument to settle to within 1° or 0.01 mV. The test set has been designed to maintain its high accuracy over a wide ambient temperature range for both battery-powered and ac line operation; however, the following operating precautions should be observed to obtain maximum accuracy:

- Operate test set in an area free from drafts where the temperature is stable. If drafts cannot be avoided, wrap the terminals with a few layers of soft cloth or other convenient insulating material.
- Before starting measurements allow the test set to normalize for about 30 minutes in the test ambient, especially if the set has been subjected to an extreme ambient temperature change.
- Make measurements with the charger not connected to minimize internal temperature rise.
- When making TC measurements with the charger connected, wrap the terminals with a soft cloth to minimize temperature gradients at the terminals caused by the internal temperature rise.

2. TEMPERATURE MEASUREMENTS USING TC RANGES

Proceed as follows:

- (a) Connect the instrument as described in Section G1 and as shown in Figure 5.
- (b) Set the binding post selector switch to the position corresponding to the pair of binding posts used.
- (c) Rotate the Range selector switch to the TC position which corresponds to the thermocouple type being measured.

OPERATING PROCEDURE, (Cont'd)

- (d) Set the °F/°C slide switch to the position corresponding to the desired °F or °C temperature display.
- (e) Rotate the Mode selector switch to the MEASURE position.
- (f) Read the value of the measured temperature on the display.

NOTE: The cold or reference-junction compensation circuitry is functioning in this mode so that the test set reads the correct hot junction temperature.

3. CHECKING RECORDERS, INDICATORS, OR CONTROLLERS, TC TYPE, USING TC RANGE

Proceed as follows:

- (a) Connect the instrument as described in Section G2 and as shown in Figure 6. Use thermocouple extension leadwires.
- (b) Set the binding post selector switch to the position corresponding to the pair of binding posts used.
- (c) Standardize the instrument to be checked, if required.
- (d) Rotate the Range selector switch to the TC position which corresponds to the thermocouple type of the instrument to be checked.
- (e) Set the °F/°C slide switch to the position corresponding to the desired °F or °C temperature display.
- (f) Rotate the Mode selector switch to the OUTPUT position.
- (g) On millivoltmeter Pyrometers it will be necessary to add an external resistance in either one of the connection leads to compensate for the lead resistance of the millivoltmeter. The value of this resistance should be equal to the resistance value which is marked on the scale of the millivoltmeter Pyrometer being checked.
- (h) Adjust the OUTPUT ADJUST of the test set so that the instrument to be checked comes to the selected check point.
- (i) Read the value of the simulated temperature on the display. By repeating the procedure at various check points, a series of correction factors may be obtained.

OPERATING PROCEDURE, (Cont'd)

NOTE: In some cases it may be more convenient to set the test set to the desired simulated temperature and then observe the reading on the instrument to be checked.

The cold or reference-junction compensation circuitry is functioning in this mode so that the test set and the instrument to be checked need not be at the same temperature.

When checking manual balanced instruments which have a low resistance circuit (<200 ohms) set the check instrument to the desired check value, then adjust the output of the test set. This will avoid annoying interaction between the instruments due to off-null loading of the test set output circuit.

4. BATTERY CHARGING

To charge the battery, plug the battery charger line cord into the CHARGE receptacle and the appropriate 120 or 240V, 50/60 Hz power line as indicated by the marking on the front panel. The battery can be charged with the instrument either on or off; likewise, the instrument can be operated while on charge indefinitely. A fully charged battery will provide a minimum of eight hours of continuous operation and can be fully charged in 14 to 16 hours (overnight). The battery should not be charged below 40°F (4°C).

NOTE: The battery cannot be harmed if it is continuously charged for extended periods of time. However, it is a characteristic of all Ni Cad batteries that their capacity will decrease if they are subjected to an extended overcharge. Therefore, a system which has been charged for a period of time much greater than 16 hours will actually provide less than eight hours of operation. This "memory" effect is, however, not permanent. The full capacity of the battery can be recovered by fully discharging and then recharging for the recommended 14 to 16 hours. In a similar fashion, a battery which has been left in a discharged condition for a long period of time might exhibit decreased capacity after it has been charged. However, a complete charge-discharge-charge cycle should restore the battery to full capacity.

OPERATING PROCEDURE (Cont'd)

5. CHECKING OPERATION

Proceed as follows:

- (a) Rotate the Mode selector switch to the CHECK position.
- (b) Set the °F/°C slide switch to the °C position.
- (c) Rotate the Range selector switch to the desired TC (or mV) position.
- (d) The test set should display the temperature (or mV) value, within indicated tolerance, as marked on the Range label in the instrument lid.

NOTE: If the check reading is out-of-tolerance it is recommended that a calibration check be performed on the test set.

6. OTHER OPERATING PROCEDURES

Refer to Section I, Applications, for additional operating procedures.

SECTION I APPLICATIONS

1. TEMPERATURE MEASUREMENTS USING mV RANGE

Proceed as follows:

- (a) Connect the test set as described in Section G1 and as shown in Figure 5.

NOTE: The automatic reference-junction compensator is not in the circuit on mV calibrated range; therefore, copper leads may be used in place of thermocouple extension leadwire between the test set and the thermocouple termination.

- (b) Measure the thermocouple reference-junction temperature with an accurate mercury-in-glass thermometer and record the temperature.

NOTE: The reference-junction is at the point where the thermocouple leads or thermocouple extension leads are connected to the test set; however, if copper leads are used in place of thermocouple extension leads the reference-junction will be located at the point where the copper leads are connected to the thermocouple.

- (c) Convert the reference-junction temperature (thermometer) reading to millivolts by referring to the appropriate table in JGB Thermocouple Temperature-Millivolt Conversion Table in manual 72-35T, or NBS Monograph 125 or ASTM Standard E-230-72.
- (d) Set the binding post selector switch to the position corresponding to the pair of binding posts used.
- (e) Rotate the Range selector switch to the mV position.
- (f) Rotate the Mode selector switch to the MEASURE position.
- (g) Read and record the value of the measured emf.
- (h) Add, algebraically, the measured emf reading and the millivolt equivalent of the reference-junction temperature (step C).
- (i) Convert the corrected millivolts to temperature directly from the

APPLICATIONS (Cont'd)

same conversion table. This value is the hot (measuring) junction temperature reading.

Example: When ambient temperature is above 32°F,
Test set emf reading is 35.98 mV
Reference junction at 75°F Type J is 1.22 mV

Sum 37.20 mV
From conversion table 37.20 mV = 1235°F

Example: When ambient temperature is below 32°F,
Test set emf reading is 15.07 mV
Reference junction at 20°F Type J is -0.34 mV

Sum 14.73 mV
From conversion table 14.73 mV = 520°F

2. CHECKING THERMOCOUPLES

In order to check a thermocouple, some means such as an electric checking furnace must be provided to maintain the hot (measuring) junction of the thermocouple at a known temperature. The checking procedure is basically that of comparing the emf output of a thermocouple at a known temperature. The checking procedure is basically that of comparing the emf output of a thermocouple to be checked against that of a Reference Thermocouple when the hot junctions of the two thermocouples are at the same temperature. The procedure is as follows:

- (a) Insert the hot (measuring) junctions of the Reference and Check thermocouples, to a sufficient depth, into a temperature equalizing block within the checking furnace. This will maintain thermal uniformity between the two thermocouples and also will prevent the hot junction of the couples from being affected by heat flow along the wires. Connect the thermocouples to the test set as shown in Figure 7, observing proper polarity as described in Section G1.

NOTE: When optimum accuracy is not required, the temperature equalizing block can be eliminated; however, if practical, the thermocouples should be inserted into the check furnace in

APPLICATIONS (Cont'd)

intimate contact with each other and necessary precautions should be taken to minimize errors at the hot junction due to non-uniformity of temperature.

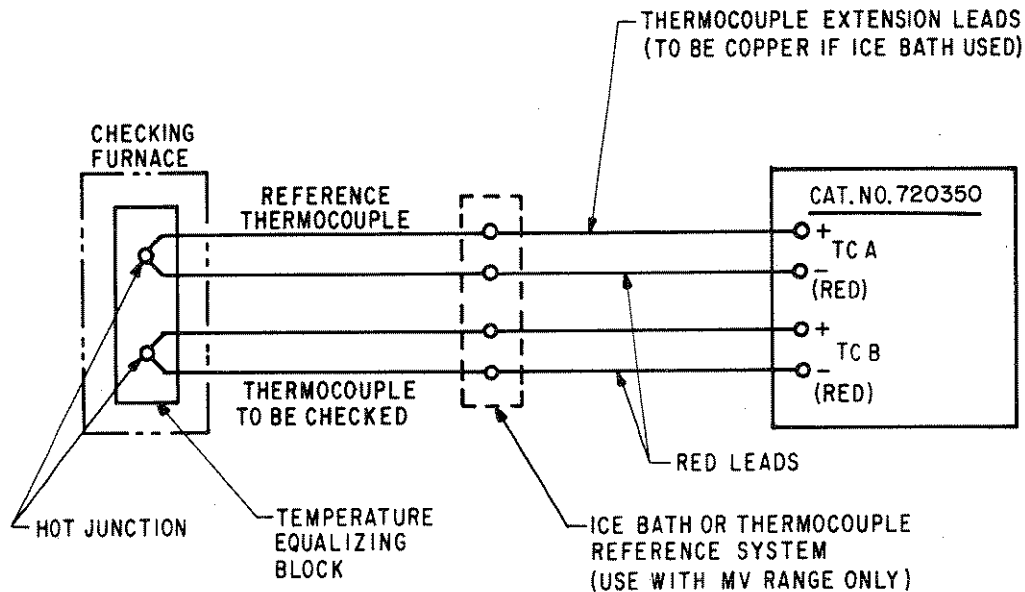


Figure 7: Checking Thermocouples.

- (b) Adjust the furnace control to the temperature at which the thermocouples are to be checked.
- (c) Set the Binding Post selector switch to position A.
- (d) Rotate the Range selector switch to the TC position which corresponds to the thermocouple type being measured.
- (e) Set the °F/°C slide switch to the desired position.
- (f) Rotate the Mode selector switch to the MEASURE position.
- (g) Re-adjust the controls on the checking furnace, if necessary, until the desired temperature is obtained.
- (h) Read the value of the measured temperature (Reference Thermocouple).
- (i) Set the Binding Post Selector switch to position B.
- (j) Read the value of the measured temperature (Check Thermocouple). The thermocouple error is the difference between the

APPLICATIONS (Cont'd)

temperature measured with the Check Thermocouple from that measured with the Reference Thermocouple.

- NOTE:
- (1) By repeating the above procedure at various known temperatures, a thermocouple can be checked for accuracy over its intended measurement range.
 - (2) It is not critical that the checking furnace be adjusted to the exact check temperature since the thermocouples are compared by a temperature difference method.
 - (3) To check a thermocouple using a millivolt calibrated range, follow the procedure as outlined in Section I-1. Maximum accuracy, in this case, can be achieved by maintaining the reference junction precisely at 32°F (0°C) by using a melting ice bath or an equivalent ice-point thermocouple reference system. A Gallium Melting-Point Standard, which maintains the reference junction precisely at 29.772°C, may also be used; however, this method is not as convenient to use due to the unavailability of thermocouple temperature-millivolt conversion tables based on this reference temperature.

3. CHECKING RECORDERS, INDICATORS, OR CONTROLLERS, TC TYPE, USING mV RANGE

Proceed as follows:

- (a) Connect the instrument to be checked to the desired binding posts (A or B) of the test set using copper wire and observing proper polarity. See Figure 6.

- NOTE:
- (1) The automatic reference junction compensator is not in the circuit on the mV calibrated range.
 - (2) On millivoltmeter Pyrometers it will be necessary to add an external resistance in either one of the connection leads to compensate for the lead resistance of the millivoltmeter. The value of the resistance must be equal to the resistance value which is marked on the scale of the Pyrometer.

APPLICATIONS (Cont'd)

- (b) Measure the reference junction temperature with an accurate mercury-in-glass thermometer and record the temperature.

NOTE: The reference junction is located at the thermocouple terminals of the instrument to be checked.

- (c) Convert the reference-junction temperature reading to millivolts by referring to the appropriate table in Biddle Thermocouple Temperature-Millivolt Conversion Table in manual 72-35T, or ASTM Standard E 230-72 or NBS Monograph 125.
- (d) Standardize the instrument to be checked, if required.
- (e) Disconnect the leadwire at the instrument to be checked.
- (f) Connect a short circuit jumper across the input terminals if the instrument is a null balance type; leave open-circuited for deflection-type instruments.
- (g) The instrument to be checked should indicate the same reference-junction temperature as measured above. If necessary, adjust the reference-junction compensation for the correct temperature indication.
- (h) Remove the short circuit jumper and reconnect the leadwire.
- (i) Set the Binding Post selector switch to the position corresponding to the pair of binding posts used.
- (j) Rotate the Range selector switch to the mV position.
- (k) Rotate the Mode selector switch to the OUTPUT position.
- (l) Convert the temperature point to be checked to the equivalent millivolt value using the proper temperature-millivolt conversion table. Subtract, algebraically, the millivolt equivalent of the reference-junction temperature (Step c). This value is the corrected hot junction equivalent millivolts for the simulated temperature.
- (m) Adjust the OUTPUT ADJUST of the test set to the corrected hot junction equivalent millivolt value.
- (n) The temperature indicated on the check instrument should agree with the selected check point temperature value.

APPLICATIONS (Cont'd)

4. CHECKING POTENTIOMETER INDICATORS, RECORDERS, or mV TYPE CONTROLLERS

Proceed as follows:

- (a) Connect the instrument to be checked to the desired binding posts (A or B) of the test set using copper wire and observing proper polarity. See Figure 6.
- (b) Standardize the instrument to be checked, if required.
- (c) Set the Binding Post Selector switch to the position corresponding to the pair of binding posts used.
- (d) Rotate the Range selector switch to the mV position.
- (e) Rotate the Mode selector switch to the OUTPUT position.
- (f) Adjust the OUTPUT ADJUST of the test set so that the instrument to be checked balances at the selected check point.
- (g) The mV value indicated on the check instrument should agree with the mV reading on the test set.

NOTE: The automatic reference junction compensation is not in the circuit on mV calibrated ranges.

5. MEASURING FROM SEVERAL THERMOCOUPLES

Up to six (or more) thermocouples can be quickly measured by using the Biddle Catalog No. 72-990 Thermocouple Selector Switch accessory unit.

Connect the POT binding posts of the Thermocouple Selector Switch to the desired (TC A or TC B) binding posts of the test set. Observe polarity of all connections. One to six thermocouples may be connected to the pairs of thermocouple binding posts located on the accessory unit which may then be selected by the rotary switch for connection to the measuring instrument. Measurements are made by following the procedure in Section H2. Up to six more TC's can be handled by using a second Selector Switch connected to the second pair of TC binding posts.

For best cold junction compensation, connect the Selector Switch to the test set using the pair of gold-plated copper links provided. In any

APPLICATIONS (Cont'd)

event, the Selector Switch should be located as close to the test set as possible to keep them both at the same temperature.

6. TESTING and TROUBLESHOOTING pH and ORP SYSTEMS

Complete testing of these cells and related instruments can be accomplished using the test set and the Biddle Cat. No. 72-545 Versabuffer accessory module. The Versabuffer is fully described in a separate instruction manual. It provides convenient features for both voltage calibration and resistance tests.

In the measuring mode, shown below in Figure 8, the Versabuffer functions as a high-impedance, unity-gain voltage follower whose output is attenuated by a factor of ten to provide a millivolt output from a voltage input. Pushbuttons inject test currents for making cell resistance tests. In the output mode the Versabuffer functions as an isolation amplifier with a gain of ten, capable of directly driving all pH instruments. The following tests can be made:

- Measurement of the output of pH and ORP cells and other high resistance sources.
- Calibrating pH and ORP indicators, recorders and controllers.
- Measurement of pH or ORP cell electrode resistance.
- Measurement of instrument preamplifier input resistance.

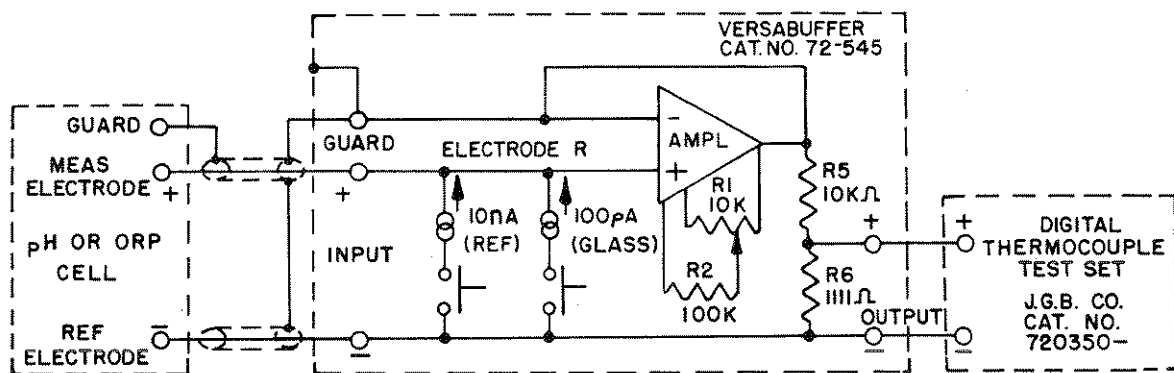


Figure 8: Measuring emf of pH and ORP Cells, (Versabuffer in Measure Mode).

APPLICATIONS (Cont'd)

7. MEASUREMENTS to 1000 VOLTS USING the VOLT BOX ACCESSORY

The Biddle Cat. No. 72-910 Volt Box extends the measurement range of the test set to 1000 volts. Combined limit of error is 0.08% of reading, equivalent to a four-digit DVM. The connections are shown in Figure 9. Further details are given in the Instruction Sheet supplied with the Volt Box.

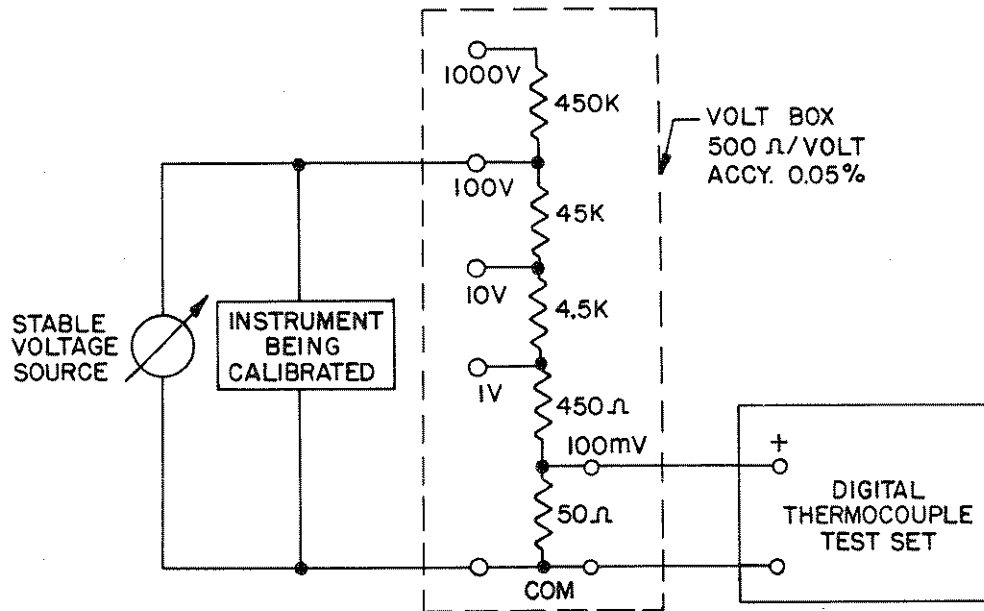


Figure 9: Schematic of Cat. No. 72-910 Volt Box Connected for Calibrating a DVM or other Instrument in the 0-100 Volt Range.

8. DC CURRENT CALIBRATION USING the SHUNT BOX ACCESSORY

The Biddle Cat. No. 72-920 Shunt Box adapts the test set to measurement of DC current up to 1 ampere, and a sensitivity of 0.1 microampere. Ranges of 10, 100, and 1000 mA provide 100 mV output. Overall accuracy is $\pm 0.08\%$ of reading on all ranges.

Connections are shown in Figure 10. Further details are given on the Instruction Sheet supplied with the Shunt Box.

APPLICATIONS (Cont'd)

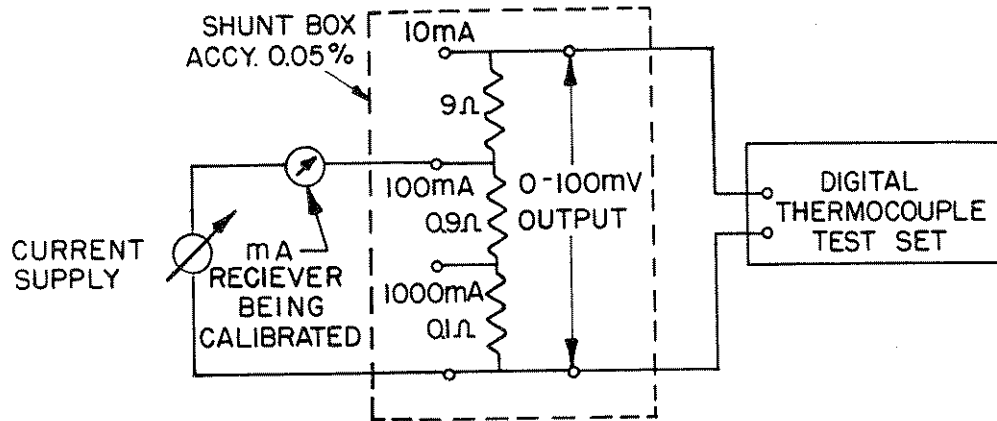


Figure 10: Schematic of Cat. No. 72-920 Shunt Box Connected for Calibrating a 4-20 mA Process Control Unit.

9. RESISTANCE and RESISTANCE THERMOMETER MEASUREMENTS

The test set is an ideal instrument for precision low resistance measurements. Lead resistances of hundreds of ohms cause no error. In this method, the unknown is compared to a known reference resistor by passing a current through both resistors in series and measuring the voltage across each, taking advantage of the convenient dual input terminals of the test set. As shown in Figure 11, a stable, preferably adjustable current supply is required.

Best accuracy of $\pm 0.02\%$ is obtained if both resistors are of the same order of magnitude, say within 2 to 1, and if both voltage drops fall in the upper part of the test set range.

Range of Measurements:

Upper limit = $10,000\Omega$, because of input resistance limitations.
Lower limit = $1\mu\Omega$, when a test current of 1A is used.

A convenient procedure is the following:

- (a) Determine the approximate current to be used based on the resistor ratings, the current available, and the test set range. Compute the expected voltage across the reference resistor. Connect as in Figure 11.
- (b) Set the Selector Switch to binding posts A. (reference resistor).

APPLICATIONS (Cont'd)

- (c) Set the Mode switch to MEASURE.
- (d) Set the Range switch to mV.
- (e) Adjust the current adjusting rheostat or adjustable current supply to obtain the desired millivolt value. Record the reading as V_R .
- (f) Select binding post B, the unknown resistor.
- (g) Record the new reading as V_X .
- (h) Check the V_R reading again to make sure that the current has remained stable. This is especially important when reading a resistance thermometer to measure temperature, as any changes in its resistance due to change in temperature may change the current.
- (i) Find the value of the unknown resistor from the following equation:

$$R_X = \frac{V_X}{V_R} R_R$$

If the value of the unknown, R_X , is close to the value of the reference R_R , the ratio accuracy is within 0.02%.

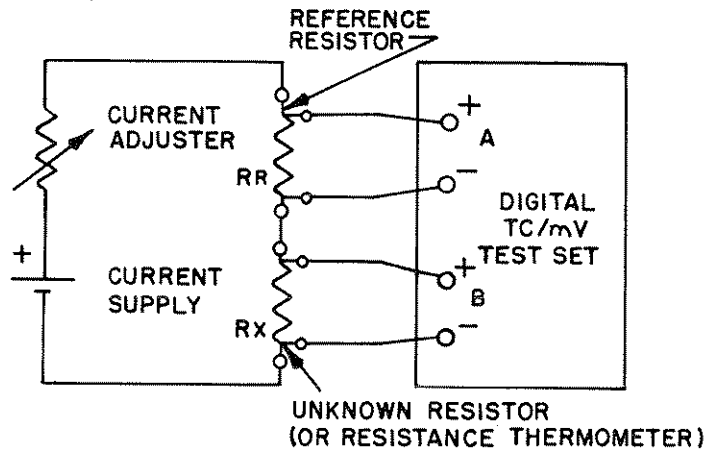


Figure 11: Measuring an Unknown Resistance by Comparison to a known Reference Resistor. The Cat. No. 72-920 Shunt Box is an Excellent Reference Resistor; a Large Dry Cell Supplies Currents up to 1A.

APPLICATIONS (Cont'd)

10. VOLTAGE DIVIDER RATIO MEASUREMENT

This is an excellent way to check the linearity or conformity of the test set to 0.03%, or to check the ratio of fixed dividers. Full accuracy is obtained for values of $R_1 + R_2$ up to 10,000 ohms.

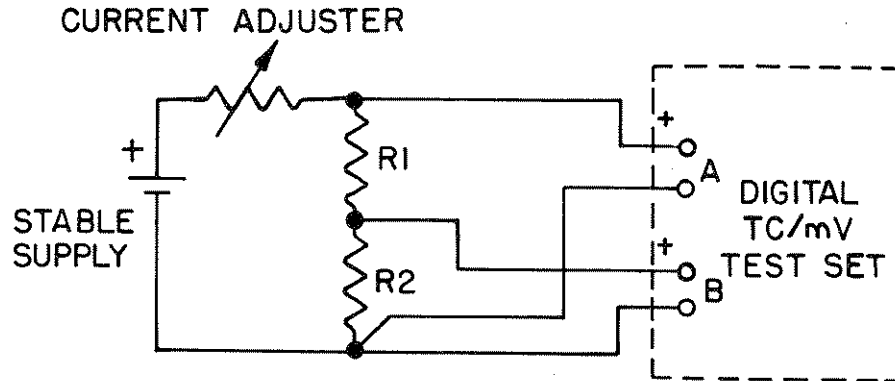


Figure 12: Measuring the Divider Ratio $\frac{R_2}{R_1 + R_2}$

With the connections as shown in Figure 12, proceed as follows:

- Adjust the current for a voltage near full range across $R_1 + R_2$ (V_A).
- Measure V_A and V_B .
- The voltage divider ratio is:
$$\frac{R_2}{R_1 + R_2} = \frac{V_B}{V_A}$$

11. AC, OSCILLOSCOPE, other ELECTRONIC CIRCUIT Applications

In sensitive electronic circuits, the test set has special advantages:

- It is completely floating and has low impedance so it can be used anywhere in the circuit without introducing noise.
- It is more accurate and sensitive than the usual electronic test gear, and provides a calibrated output. Useful applications are:
 - Improving oscilloscope accuracy by 10 or more for dc or pulses.

APPLICATIONS (Cont'd)

- AC current measurement using Shunt Box and Oscilloscope.
- DC or pulse amplifier gain measurement.

SECTION J CALIBRATION

1. GENERAL

The purpose of this calibration is to check or correct changes caused by component aging or by replacement of critical parts. Before attempting to recalibrate the test set, check for proper operation. A complete overall accuracy check, including verification of the test set CHECK READINGS (Section H, Para. 5), should be performed before attempting to readjust any of the calibration trimmers. A calibration check should be made at least once a year and should be performed in a laboratory free from drafts and where the temperature is stable and maintained at $25^{\circ}\text{C} \pm 2^{\circ}\text{C}$. The test set should be battery-operated for the entire calibration and should be *off* charge for at least 2 hours before starting calibration.

Two calibration methods are described for checking the thermocouple ranges, one using a Melting Ice Bath (or equivalent Ice-Point Thermocouple Reference System) in conjunction with a portable millivolt Potentiometer; the other using a portable millivolt Potentiometer having a built-in reference junction compensator. The Melting-Ice Bath method is recommended; however, the other is generally more convenient.

All calibration trimmers are located on the analog card except for the BTRY LOW trimmer which is located on the side of the digital card near the ac line connector. Figure 15 shows the location of the trimmers and test points on the analog card.

2. EQUIPMENT RECOMMENDED

(a) Precision millivolt potentiometer or adjustable voltage standard. Output range 100mV, accuracy $\pm 0.01\%$ of reading, resolution and stability $1\mu\text{V}$. (For calibration to full accuracy.)

or Precision millivolt potentiometer with manual reference-junction compensator. Output range 100mV, accuracy $\pm 0.03\%$ of reading, Resolution and stability $1\mu\text{V}$. (For calibration to 0.03% accuracy.) Biddle Cat. No. 72-3110

CALIBRATION (Cont'd)

- (b) Melting-ice bath or equivalent ice-point thermocouple reference system capable of maintaining a temperature of 32°F (0°C) $\pm 0.2^{\circ}\text{F}$.

or

Large aluminum heat sink block for room temperature reference point. (See Figure 14).

- (c) Thermocouple extension leads, "J" Type.
- (d) Mercury thermometer capable of reading 32°F (0°C) or ambient temperature; accuracy $\pm 0.2^{\circ}\text{F}$.
- (e) Variable power supply
0 to 10 volts dc output, 1A
(to set low battery blink point).
- (f) Digital voltmeter, accuracy $\pm 0.2\%$.

3. CALIBRATION OF MILLIVOLT RANGE

Proceed as follows:

- (a) Connect the test set directly to the check instrument using copper wire and observing proper polarity.
- (b) Set the binding post selector switch of both instruments to the proper position.
- (c) Rotate the function selector switch of the check instrument to the EMF OUTPUT position.
- (d) Rotate the Range selector switch of the test set to the mV position.
- (e) Rotate the Mode selector switch of the test set to the MEASURE position.
- (f) Set the mV output of the check instrument to the values shown in TABLE 2. Follow the sequence indicated.

CALIBRATION (Cont'd)

- (g) Read the corresponding mV values on the test set. The displayed readings should agree with the TABLE 2 values within the tolerance indicated. Mark a check (✓) in the last column of TABLE 2 if the reading is within tolerance.

TABLE 2

Check Inst. Set at (mV)	Cat. No. 720350 Reading (mV)	Allowable Tolerance (mV)	Calibration Trimmer Symbol	Cat. No. 720350 Reading Within Tolerance
0.000	0.000	±0.003	mV Zero	
15.000	15.000	±0.006	K4	
40.000	40.00	±0.01	K3	
70.000	70.00	±0.01	K2	
90.000	90.00	±0.02	K1	
-15.000	-15.000	±0.006	K4	
-40.000	-40.00	±0.01	K3	
-70.000	-70.00	±0.01	K2	
-90.000	-90.00	±0.02	K1	

- (h) If the deviation exceeds the allowable tolerance, remove the test set from the case (four panel screws) to gain access to the calibration trimmers.
- (i) Following steps (f) and (g) procedure, readjust the calibration trimmer as indicated in TABLE 2 to obtain the indicated test set display reading. If necessary adjust the indicated trimmer to balance the error between positive and negative inputs.
- (j) If unable to obtain readings within tolerance the Preamp Offset (R21) trimmer probably requires adjustment. This should seldom be necessary. To adjust this trimmer proceed as follows using an oscilloscope:
- (1) Use test set mV Range and MEASURE mode.
 - (2) Short the input binding posts of test set with copper wire.
 - (3) Connect scope External Trigger probe between the "TP7" and "GND" (ground) test points on the analog card.

CALIBRATION (Cont'd)

- (4) Set scope sweep at 20 ms per division and trigger on leading (+ going) edge of trace.
- (5) Connect scope input probe to the preamp output (TP2) test point on the analog card. Ground the probe shield.
- (6) The waveform will alternate between two different voltage levels. Adjust the Preamp Offset trimmer R21 so that both voltage levels are less than ± 0.1 volt. Note that once every five seconds the waveform will go to a large positive value. This is the output of the reference-junction temperature sensor and should be ignored.

WARNING

Body contact with any electrically-conductive part in the high voltage (175V dc) circuit is a potential shock hazard! Refer to Section B, Safety Precautions.

- (k) If Preamp Offset (R21) trimmer has been readjusted, repeat the entire calibration procedure steps (a) through (i).
- (l) Place the test set in its case and proceed with the remaining calibration checks.

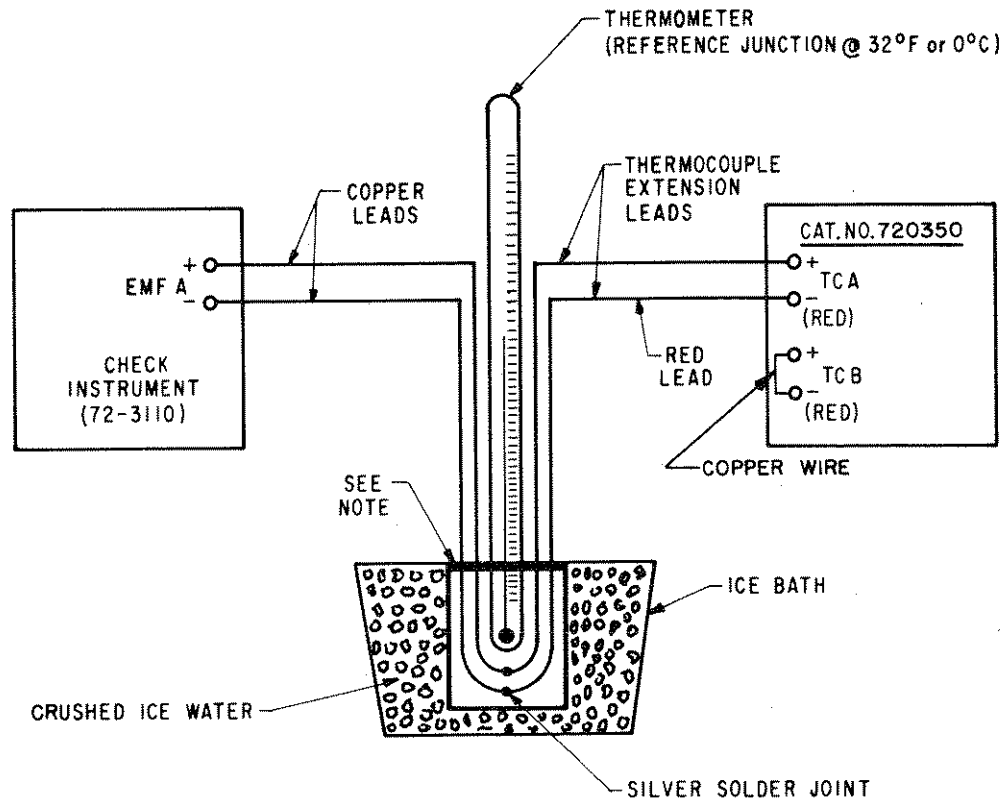
NOTE: If the test set error exceeds the TABLE 2 tolerance values, after readjusting all previously noted calibration trimmers, it is recommended that the test set be returned to the factory. However, a careful check of the setup should be made as this is a very accurate instrument.

4. CALIBRATION of THERMOCOUPLE RANGES USING MELING ICE BATH

Proceed as follows:

- (a) Connect the test set to the check instrument (Biddle Cat. No. 72-3110) as shown in Figure 13. Use "J" type thermocouple extension leadwires to connect the ice bath to the test set. Short-circuit the (B) binding posts of the test set with a short piece of solid copper wire.

CALIBRATION (Cont'd)



NOTE: THERMOCOUPLE & THERMOMETER IN METAL TUBE, SEALED AT TOP TO PREVENT AIR FROM CIRCULATING IN & OUT OF TUBE. BOTTOM OF TUBE TO BE PACKED WITH HEAT SINK COMPOUND TO COVER THERMOCOUPLE JUNCTION & THERMOMETER BULB.

Figure 13: Calibration of Thermocouple Ranges by Ice-Bath Method.

NOTE: The following procedure utilizes a "J" type thermocouple for the calibration check; the same result can be obtained by using a different appropriate thermocouple.

- (b) Check thermometer to make sure temperature of melting ice bath is 32°F (0°C) $\pm 0.2^{\circ}\text{F}$.
- (c) Rotate the Function selector switch of the check instrument to the EMF OUTPUT position.
- (d) Set the binding post selector switch of both instruments to position (A).

CALIBRATION (Cont'd)

- (e) Rotate the Range selector switch of the test set to the "J" thermocouple position.
- (f) Rotate the Mode selector switch of the test set to the MEASURE position.
- (g) Set the °F/°C slide switch to the °F position.
- (h) Set the output of the check instrument to 0.000 mV.
- (i) Read the temperature value on the test set. The displayed reading should agree with the TABLE 3 value within the tolerance indicated. Also check the reading on the °C range. Mark a check (✓) beyond the last column of TABLE 3 if the reading is within tolerance.
- (j) If the deviation exceeds the given tolerance, remove the test set from the case to gain access to the calibration trimmers.
- (k) Adjust the TEMP ZERO trimmer to obtain a 32.0°F display.

NOTE: This calibrates the measurement of the reference junction temperature. However, this temperature is actually measured at five-second intervals. Therefore, the change in the displayed reading will be delayed for up to five seconds after the TEMP ZERO control has been adjusted.

- (l) Place the test set in its case.
- (m) Set the binding post selector switch of the test set to position (B).
- (n) Read the temperature value on the test set for each of the thermocouple ranges. The display should indicate the room ambient temperature value (nominally 77°F). The agreement between the temperature values should be within the tolerances indicated on TABLE 3. Record a check (✓) if within tolerance.
- (o) Repeat the above step on the °C test set range (nominal 25°C ambient temperature).
- (p) Return °F/°C slide switch to the °F position, and binding post selector switch to position (A).
- (q) Set the output of the check instrument to the remaining two TABLE 3 values.

CALIBRATION (Cont'd)

- (r) Read the corresponding temperature values on the test set, both in °F and °C. The displayed readings should agree with the TABLE 3 values within the tolerance indicated. Record a check (✓) if within tolerance.

NOTE: A three-point check on only one TC range is sufficient for verifying the accuracy of all the thermocouple ranges. The test set's microprocessor automatically measures the thermocouple input voltage and the reference-junction temperature then calculates all TC linearity corrections based on equations developed by NBS, after correcting for reference junction temperature.

If the test set error exceeds the TABLE 3 tolerance value, after readjusting all previously noted calibration trimmers, it is recommended that the test set be returned to the factory.

TABLE 3

Cat. No. 720350 Instrument Being Calibrated

Check Inst. Set at mV	Range Switch Set at	Binding Post Switch Set at	Reading (°F)	Allowable Tolerance* (°F)	Reading (°C)	Allowable Tolerance (°C)	Trimmer Adjustment
0.000	J	A	32.0	0.4	0.0	0.2	Temp Zero
—	J	B	Nominal 77°F Ambient Temp.	0.4	Nominal 25°C Ambient Temp.	0.2	—
—	K	B		0.4		0.2	—
—	T	B		0.4		0.2	—
—	E	B		0.4		0.2	—
—	R	B		1		1	—
—	S	B		1		1	—
—	C	B		1		1	—
67.240	J	A	2120.0	0.7	1160.0	0.4	—
-6.159	J	A	-220.0	0.6	-140.0	0.3	—

Note: Table based on using a "J" type thermocouple for calibration.

*Tolerance values when Binding post switch is at B apply to each reading relative to all other readings higher in the table.

CALIBRATION (Cont'd)

5. CALIBRATION of THERMOCOUPLE RANGES, REFERENCE-JUNCTION COMPENSATION METHOD

Proceed as follows:

- (a) Connect the test set to the check instrument (Cat. No. 72-3110 as shown in Figure 14). Use "J" type thermocouple extension leadwires to connect the heat sink block to the test set. Short-circuit the (B) binding posts of the test set with a short piece of solid copper wire.

NOTE: The following procedure utilizes a "J" type thermocouple for the calibration check, however, the same result can be obtained by using a different appropriate thermocouple.

- (b) Measure the reference-junction temperature in the Heat Sink Block with the mercury-in-glass thermometer.
- (c) Set the reference-junction emf (equivalent to the reference-junction temperature for the type "J" or other appropriate thermocouple) on the REF JCT Compensator dial of the Cat. No. 72-3110 check instrument. The procedure is explained in the Cat. No. 72-3110 instruction manual.
- (d) Rotate the Function Selector switch of the Cat. No. 72-3110 check instrument to the TC OUTPUT position.

NOTE: The reference-junction compensator of the Cat. No. 72-3110 is functioning in this output position.

- (e) Following the exact procedure as stated in Paragraph 4, steps (d) through (r), proceed with the calibration check for the thermocouple ranges.

6. CHECK MODE VERIFICATION

Following the procedure as described in Section H, Paragraph 5, verify the test set CHECK READINGS.

NOTE: Long-term component aging or recalibration of the test set may dictate re-marking the Check Readings on the instrument Range label. The change, however, should be very minimal.

CALIBRATION (Cont'd)

7. CALIBRATION of LOW BATTERY BLINK POINT

Proceed as follows:

- (a) Disconnect the battery cable from connector (J4) on the digital card.
- (b) Connect the variable dc Power Supply (Para. 2, item f) to the same connector observing proper polarity. The orange wire is positive (+) polarity.
- (c) Rotate the Mode selector switch of the test set to the CHECK position.
- (d) Set the BTRY LOW trimmer, located on digital card, so the threshold of blinking is between 5.87 to 5.93 volts input voltage.
- (e) Reconnect the battery cable, and replace the test set in its case.

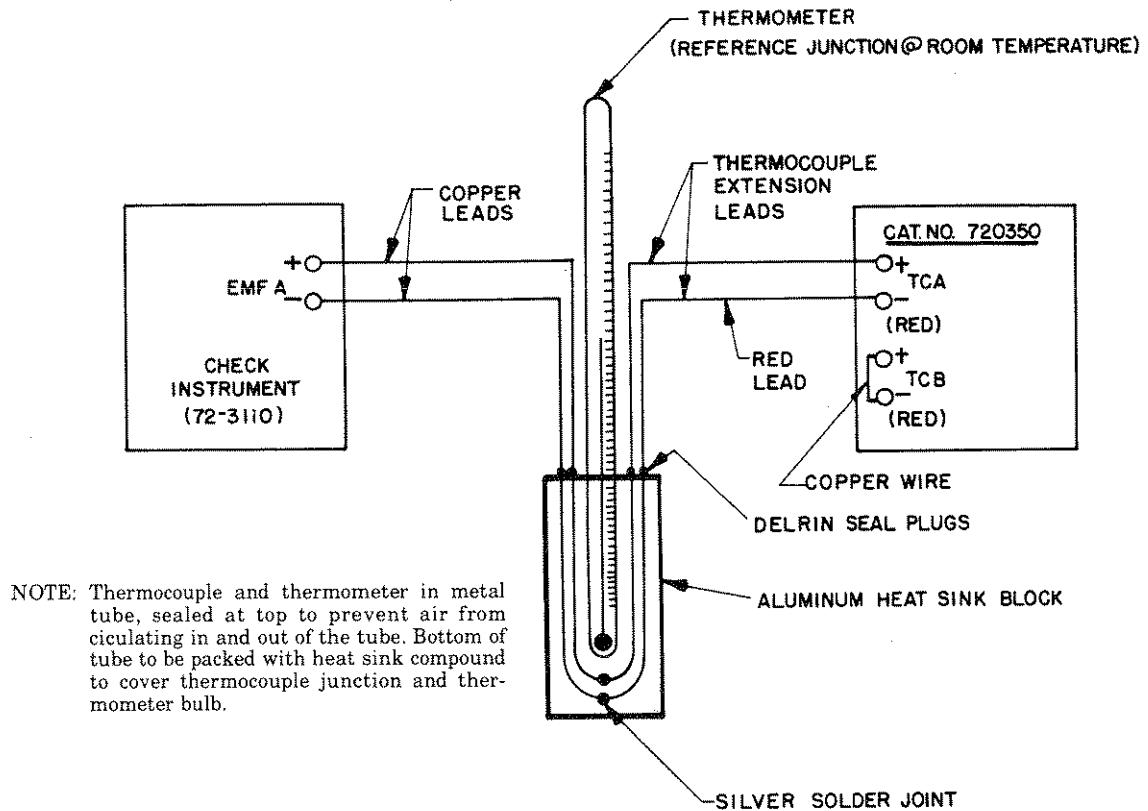


Figure 14: Calibration of Thermocouple Ranges by Reference Junction Compensation Method.

CALIBRATION (Cont'd)

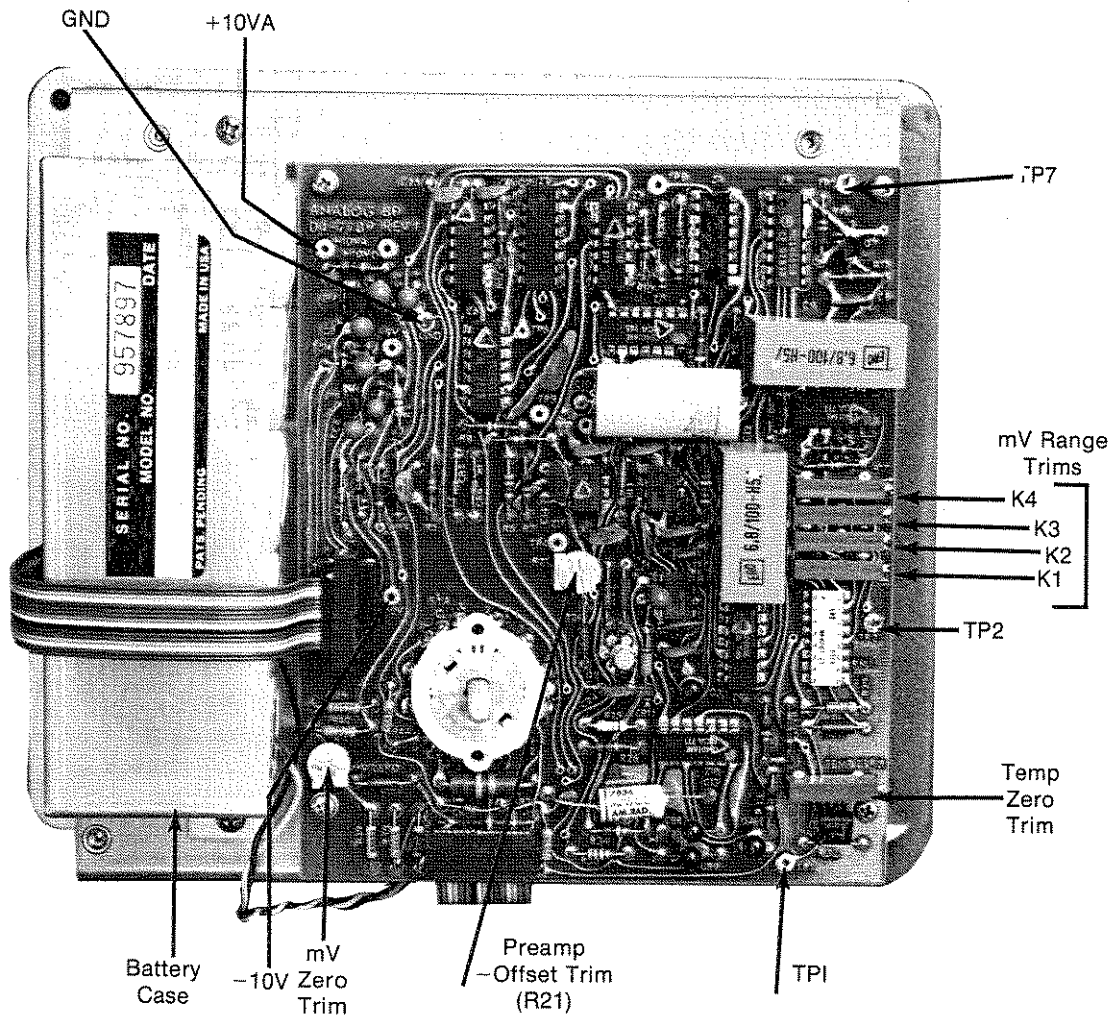


Figure 15: Rear View Showing Analog Board with location of Calibration Trimmers and Test Points.

SECTION K MAINTENANCE

1. GENERAL

For maintenance not described below, or the replacement of parts not listed in Section M, it is recommended that the test set be returned to the factory. Additional service support documentation 72-350S is available from Biddle, and contains the following:

- (a) Test set assembly drawing.
- (b) PC board assembly drawings.
- (c) Circuit schematics.
- (d) Parts lists.

2. REMOVAL OF TEST SET FROM CASE

Unscrew the four front panel mounting screws and lift the unit out of its case. With the unit out of its case it may be inspected for broken wires or unplugged or loose connectors or subassemblies.

WARNING

Be sure the Mode selector switch is in the OFF position before attempting to replace any parts. Body contact with any electrically conductive part in the high voltage (175V dc) circuit is a potential shock hazard. See Section B, Safety Precautions.

3. CALIBRATION ADJUSTMENTS

All calibration adjustments are found on the underside of the unit. The detailed calibration for the test set is described in Section J, while Figure 15 shows the location of the calibration trimmers except BTRY LOW.

4. BATTERY REPLACEMENT

The symptom of a battery pack failure is the inability of the batteries to hold a charge.

MAINTENANCE (Cont'd)

To replace the battery pack proceed as follows:

- (a) Unplug the battery cable from connector J4 on analog board.
- (b) Remove the battery housing's two hold-down screws.
- (c) Unsolder the orange and black connector wires at the battery solder tabs.
- (d) When installing a new battery pack, connect the orange cable wire to the positive (+) battery solder tab, and the black wire to the minus (-) solder tab.

5. ANALOG PC BOARD REPLACEMENT

To replace the analog board proceed as follows:

- (a) Unplug the two ribbon cables from the connectors (P1 and J3) on the analog board. The plugs are secured with a plastic hold-down strap.
- (b) Remove the analog board's four corner mounting screws; then remove the board.
- (c) When replacing the board, align the flat of the switch rotor with the flat on the switch shaft. Also make sure the cable plugs are resecured with the hold-down straps.

6. DIGITAL AND DISPLAY PC BOARD REPLACEMENT

To replace the Digital or Display board proceed as follows:

- (a) Remove the four front panel controls knobs.
- (b) Remove the plastic front panel from the metal sub-panel. It is held in place by double-sided adhesive tape.
- (c) Remove the four screws which hold the chassis legs to the sub-panel.
- (d) Unplug ribbon cables as necessary. The cable plugs are secured with a plastic hold-down strap.
- (e) The digital board and the display board can now be removed by removing four screws from each board.

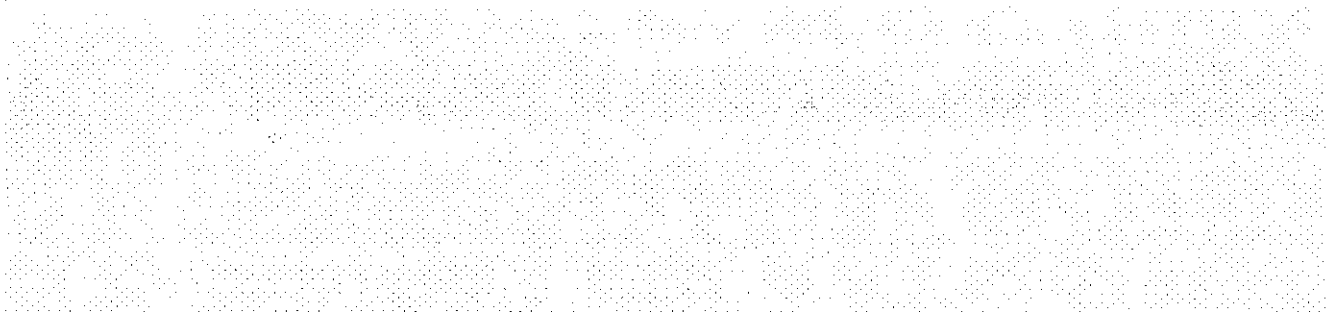
MAINTENANCE (Cont'd)

- (f) When replacing the boards, align the flat of all switch rotors with the flat on the respective switch shaft. Also make sure all cable plugs are resecured with the hold-down straps.

NOTE

The 4K ROM (read-only-memory) DL12 on the digital board is usually implemented with a single 4KX8 masked ROM at Z4. Alternately, two Type 2716 2KX8 EPROM's may be used, located at Z3 and Z4. Jumpers may be installed on the digital board to accommodate the memory chip used.

Memory Chip	Jumpers
Intel or Synertek 2716 (Z3, Z4) EPROM	E4-E5 E7-E8 E10-E12
Intel 2332 (Z4) MASKED ROM	E4-E3 E7-E9 E10-E11



SECTION L TROUBLESHOOTING

1. GENERAL

Before proceeding be sure that the operation of the test set as well as the steps listed below are fully understood. Components shown in parenthesis are a possible cause of the problem.

WARNING!

Body contact with any electrically conductive part in the high voltage (175V dc) circuit is a potential shock hazard. Refer to Section B, Safety Precautions.

2. SYMPTOMS

(a) Display does not light.

- (1) Check that Mode switch is *not* in OFF position.
- (2) Check that battery cable is plugged into J4 connector on digital board.
- (3) Check that ribbon cable from connector P2 on display board to connector J2 on digital board is plugged in properly.
- (4) Check battery fuse (printed wiring fuse F2 on digital board). If blown, replace with AWG 32 or 34 uninsulated copper wire connected between points E1 and E2.
- (5) Replace the ac glass fuse tube if blown; (F1 on digital board).
- (6) Charge battery. Check that line voltage selector switch S2 on digital board is set properly *before* connecting line cord.
- (7) Check that the 5-volt supply voltage is between 4.85 to 5.10 volts; (Z20, Q3, CR4, C11 or T3 on digital board). Check voltage between terminal 11 and ground terminal 10 of J2 connector on digital board.
- (8) Check calibration of BTRY LOW adjustment. Refer to Section J, paragraph 7.
- (9) Check that battery voltage is greater than 6 volts.

(b) Same segment does not light on all display digits.

(Z2; Q15 thru Q22 on display board).

TROUBLESHOOTING (Cont'd)

- (c) **One digit does not light.**
(Z1; Q1, Q2 for left digit; Q3, Q4 for second digit; Q5, Q6 for third digit; Q7, Q8 for fourth digit; Q9, Q10 for fifth digit; Q11, Q12 for sixth digit; Q13, Q14 for seventh digit).
All components are located on display board.
- (d) **Display always indicates "OPEN".**
Check that ribbon cable from front panel is plugged into connector J3 on analog board.
- (e) **Display always indicates "ERROR".**
Check that ribbon cable from connector J1 on analog board to connector J1 on digital board is plugged in properly.
- (f) **One or more of the "mV Range" calibration trimmers, K1 thru K4 cannot be adjusted properly.**
(Z5, Z9 on analog board).
- (g) **Readings are noisy or test set cannot be calibrated;**
See Figure 15 for location of test points.
 - (1) Check that voltage at C3+ to GND test point on analog board is between 12.5 to 13.2 volts dc.
(T3, CR6, C15 on digital board; C3, Z14 on analog board)
 - (2) Check that voltage across C6 (ungrounded measurement) on analog board is between 12.5 to 13.2 volts dc.
(T3, CR5, C16 on digital board; C6, Z15 on analog board).
 - (3) Check that voltage between test points +10VA to GND on analog board is $+10.0 \pm 0.2$ volts.
(Z14 on analog board).
 - (4) Check that voltage between test points
-10V to GND on analog board is -10.0 ± 0.2 volts.
(Z15 on analog board).
 - (5) Check that voltage between test points TP1 to GND on analog board is 4.019 ± 0.010 volts dc.
(Z13, CR11, Q3 on analog board).

SECTION M
FIELD REPLACEABLE PARTS LIST

<u>Designation</u>	<u>Biddle Part No.</u>	<u>Quantity/Instrument</u>	<u>Description</u>
	11166-2	4	Binding Posts (Superior #DF31BC)
	14877-2	1	Knob, Mode Selector (Rogan #RB-67-2-SB-M color black)
	14877-3 (for 3-turn pot)	1	Knob, Dual, Output Adjust (Rogan #RB-67-2A-9+1-M color black)
	14877-4 (for 10-turn pot, option R)	1	Rogan #RB67-2A
	18601-1	1	Knob, skirted, Range Selector, 4-range instrument
	18601-2	1	Knob, skirted, Range Selector 8-range instrument
S3	14870-6	1	Switch (TC A-TC B) (C&K #7201-J60ZQ)
Rn49	18602	1	Potentiometer, Output Adjust, 3-turn
	10231	1	Potentiometer, Output Adjust, 10-turn Option R
	18603	1	Filter, Display
	14910	1	Receptacle, 120V ac
P1	14911	1	Line Cord, 120V/220V ac 6 ft. lg. (Craig #1306-144)
B1	18600	1	Battery Pack (5 cells) (GE #KO5B-111C-SD1)
	16790-4	1	Panel, Marked Overlay
	10998	1	Case, Test Set, Bottom
	10997-16	1	Case, Test Set, Lid (w/lo range label)
	18605-1	1	Range label, 4-range instrument (for lid)
	18605-2	1	Range label, 8-range instrument (for lid)
	18610	1	Reference Junction Sensor (Q1) (Analog Devices AD590JH)
	Manual 72-350J	1	Instruction Manual, Cat. No. 720350 Series
	Manual 72-35T	1	Temperature-Millivolt Conversion Tables
DISPLAY P.C. BOARD ASSEMBLY (BIDDLE P/N 18606)			
DS1	18608-1	1	Display, 3-digit (Beckman SP333)
DS2,3	18608-2	2	Display, 2-digit (Beckman SP332)
Q-	11638-60	15	Transistor, (Q1, Q3, Q6, Q7, Q10, Q12, and Q14 thru Q22), (Motorola MPSA42)
Q-	11638-61	7	Transistor, (Q2, Q4, Q5, Q8, Q9, Q11, and Q13), (Motorola MPSA93)
21,2	19826-13	2	Integrated Circuit (RCA CD4508BE)
S4	18607	1	Switch, °F/°C

FIELD REPLACEABLE PARTS LIST (Cont'd)

<u>Designation</u>	<u>Biddle Part No.</u>	<u>Quantity/Instrument</u>	<u>Description</u>
<u>DIGITAL P.C. BOARD ASSEMBLY (BIDDLE P/N 18609)</u>			
C11	19824-3	1	Capacitor, electrolytic, 1000 μ F, 10 V DC, (Mallory VTL 1000 S10)
C15-17	17132-9	3	Capacitor, tantalum, 3.3 μ F; \pm 20%, 25VDC (Sprague Type 196D)
CR4	11637-39	1	Diode, (1N4933)
CR5,6	11637-6	2	Diode, (1N914)
F1	2567-8	1	Fuse, 3AG, 0.2A, 250V, (Littlefuse 313.200)
Q3,5	11638-62	2	Transistor, (2N3904)
R6	19848-9	1	Trimmer, cermet, 10K Ω \pm 20%, (BTRY Low) (CTS type 375X)
T2	19108-3	1	Transformer, (Signal #DST4-24)
T3	18622	1	Transformer, (Analogic #15-160030)
Z20	19850	1	Integrated Circuit, 16 pin DIP, (Fairchild #78S40)
U4	18617	1	Memory Chip (Z4), Masked ROM Analogic 14NA0017
S2	18620	1	Switch, 115V or 230V, (Switchcraft #46206LFR with PC terminals)
<u>ANALOG P.C. BOARD ASSEMBLY (BIDDLE P/N 18624)</u>			
C1-6	17132-9	6	Capacitor, tantalum, 3.3 μ F, \pm 20%, 35V DC, (Sprague Type 196D)
CR-11	12074-48	1	Diode reference 1N4578 selected 6.2/6.4V
Q3,4	11638-63	2	Transistor, (2N5246)
R20	13183-4	1	Trimmer, cermet, 100 Ω , (K1 adjustment) (Bourns #3006P-1-101)
R18,19	13183-3	2	Trimmer, cermet, 50 Ω , (K2, K3 adjustment) (Bourns #3006P-1-500)
R17	19849-1	1	Trimmer, W.W., 10 Ω , (K4 adjustment) (Bourns #3005P-1-100)
R21,41	19848-8	2	Trimmer, cermet, 5K Ω , (CTS #375Y-5K Ω)
R31	19849-2	1	Trimmer, W.W., 20 Ω , (Bourns #3005P-1-200)

FIELD REPLACEABLE PARTS LIST (Cont'd)

Z5	19826-15	1	Integrated Circuit, CD4555BE
Z7-10	19847-7	4	Integrated Circuit, CD4016AE, selected
Z13	18614	2	Integrated Circuit, LF353N
Z14,15	18615	2	Integrated Circuit, Texas Instr. UA78L10ACLP (Replaces LM340LAZ-10 in early units; 78L09 and two diodes in 1981 units).

SECTION N WARRANTY

All products supplied by Biddle Instruments are warranted against all defects in material and workmanship for a period of one year following shipment. Our liability is specifically limited to replacing or repairing, at our option, defective equipment. Equipment returned to the factory for repair will be shipped Prepaid and Insured. The warranty does not include batteries, lamps or tubes, where the original manufacturer's warranty shall apply. **WE MAKE NO OTHER WARRANTY.**

The warranty is void in the event of abuse or failure by the customer to perform specified maintenance as indicated in the manual.

REPAIRS

Biddle Instruments maintains a complete instrument repair service. Should this instrument ever require repairs, we recommend it be returned to the factory for repair by our instrument specialists. When returning instruments for repairs, either in or out of warranty, they should be shipped Prepaid and Insured, and marked for the attention of the Instrument Service Manager.

