Electro Optical Industries, Inc.

INSTRUCTION MANUAL

BLACKBODY RADIATION SOURCE
Model ___CS1250-100___

and

TEMPERATURE CONTROLLER
Model ____2500E___

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SECTION 1

INTRODUCTION

1.1 DESCRIPTION

The EOI source you are now using is one of a complete family of sources manufactured by Electro Optical Industries.

The EOI Model 2500 series Temperature Controller is included with the source. The temperature setting is changed via the front panel keypad, or by a remote message sent over the optional serial interface. The source temperature and set point are displayed on the front panel.

The microprocessor-based controller uses carefully selected components to provide extremely stable and repeatable control of the source. The controller is designed for minimum susceptibility to line and environmental changes.

1.2 LIST OF ITEMS FURNISHED

(1) Blackbody Radiation Source Assembly

(2) Model 2500 series Temperature Controller

(3) Cables (2)

(4) Instruction Manual

1.3 MODEL NUMBER SPECIFICATION

2500 _____ **/** _____

Output Power (E)   RS232

Add /RS232 to model number for optional RS232 serial interface.

Electro Optical Industries, Inc.

SECTION 2

SPECIFICATIONS

EOI Blackbody Radiation Source Model CS1250-100

EOI Temperature Controller Model 2500E

Temperature range	50 °C to 1250°C
Stability	± 0.25V
Sensing element	Platinum thermocouple (Type S)
Type of control	Zero crossing solid state relay, PWM control, AC Power.
Cavity diameter	1.00 inch, 15 degree recessed cone
Cavity emissivity	0.99 (± 0.01)
Warm up time to 1250°C	50 minutes or less
Maximum input power to source (warm up)	500 watts
Power for control at 1250°C (source)	300 watts
Housing temperature	Less than 50°C at 1250°C
Power requirement	100/120/200/240 VAC, 50/60 Hz, 1 phase (voltage selection by internal jumpers)

SECTION 3

INSTALLATION

3.1 INITIAL INSPECTION

This instrument was carefully inspected before shipment.

Shipping cartons should be inspected for damage before and after unpacking. Inspect instruments for physical damage incurred in transit or while in storage. If damages have occurred during shipping, notify the carrier and Electro Optical Industries, Inc. at once. Inspect package for items and accessories as listed in Section 1.2.

3.2 INSTALLATION

(1)   Install source and temperature controller in suitable location.

(2)   Connect cable from source assembly to the circular connector on rear of temperature controller.

(3)   Connect thermocouple cable to the connector on the rear of the source assembly and to the connector on the rear of the temperature controller.

(4)   Connect temperature controller power cord to correct source of AC power.

CAUTION

Connect only to AC line power as shown on tag at the rear of instrument. Other voltages require wiring changes as shown on interconnect drawing.

3.3 REPACKING FOR SHIPMENT OR STORAGE

Using the original cartons to ship or store these instruments is not recommended. Use new cartons and follow the procedure below.

(1) Wrap instruments in heavy plastic or other waterproof material before placing in inner container.

(2) Fill space around instruments with packing material. Protect front panel to prevent damage to controls.

(3) Place in outer container with packing between the containers. Seal with heavy tape or metal bands.

(4) Mark containers "DELICATE INSTRUMENTS, FRAGILE".

(5) DO NOT ship via parcel post.

3.4   STORAGE

If instruments are to be stored, follow packaging instructions in Section 3.3. Locate them in an approved area for storing electronic instruments.

Storage temperature range: -40°C to +50°C.

SECTION 4

OPERATION

4.1   MODEL 2500 series CONTROLS

4.1.1   Front Panel Controls and Indicators

POWER switch
Turns line power ON [1] or OFF [0]. Front panel displays illuminate when power is on.

EC Display

4 character red display indicates the current source temperature or error codes.

SET Display

4 character green display above keypad indicates the current temperature setting controlled by the ⌃ and ⌄ keys.

4.1.2   Keypad

⟳ ⌃ ⌄ ≡

Keypad

⟳ MENU ACCESS KEY
Used to enter the menu system, index to the next menu and enter the security
level menu.

⌃ RAISE KEY
Used to increase selected parameter value and set point temperature. When held, value increases rapidly after a short delay.

⌄ LOWER KEY
Used to decrease selected parameter value and set point temperature. When held, value increases rapidly after a short delay.

≡ PARAMETER/MODE KEY
Used to enter parameter selections, access operating modes and
index through menu items.

CAUTION

Changing parameters in these menus
will most likely result in malfunction of
the controller and possible damage to
the source and/or controller.

4.1.3 Error Message Display

Problems in the Model 2500 are displayed as error messages on
the   C display. Reported errors as A/D converter problems, and
problem SENSOR conditions.

The problem messages and needed actions are as follows:

DISPLAY	PROBLEM	ACTION
Err.H	Open sensor	Check sensor & wiring
Err.L	Shorted sensor	Check sensor & wiring
— — — —	Sensor over- or under-range	Check sensor & wiring
Err.O	A/D error	Return to EOI
Err.J	A/D error	Return to EOI

4.2   BASIC OPERATING PROCEDURE IN LOCAL CONTROL

4.2.1 Power ON

Turn power ON. All LED segments and indicators are illuminated to verify
proper operation. The display then identifies the temperature display units
and the software revision number.

After the controller has been energized for 3 seconds, the °C display will
indicate the temperature of the source and the SET display will indicate
the current temperature set- point (the set-point will be the same as when
the controller was last turned off).

4.2.2 Setting Temperature

The source temperature can be changed by pressing the RAISE ⌅ or
LOWER ⌄ keys and watching the temperature value on the SET display.
When either key is held down, the value changes rapidly after a short
delay.

4.2.3 Cool Down Procedure

Set the blackbody temperature to 50°C. After it reaches 50°C, turn the power off.

CAUTION

If you turn the system off without first letting it cool down, high heat may damage the system. First let it cool to a lower temperature, then shut it off.

4.3 Remote Control (Option /R RS232 Interface)

The optional RS232 interface allows bi-directional data transfer via a three conductor cable consisting of signal ground, receive input and transmit output. It is recommended that the cable length be less than fifty feet between computer terminal and the controller. Note that multiple instruments cannot be connected to the same port.

The communication parameters are fixed at 9600 Baud, no parity, 8 data bits and 1 stop bit. No NULL MODEM needed.

<u>RS232 connector pin-out</u> (DB9S, female)

pin 2 ------- Tx (transmit line <u>out</u> of controller)
pin 3 ------- Rx (receive <u>in</u> to controller)
pin 5 ------- COM (signal common)

CAUTION

COM is a signal ground only. DO NOT connect to earth ground or damage to the controller may result.

4.3.1 Temperature Control

To set the temperature of the source via RS232 interface, send the temperature setpoint command in the proper format as described below.The setpoint command format:

[START CHAR] [ID] [TYPE] [PARAM] [DATA] [CHKSUM] [END CHAR]

| | $ | 0101 | W | 09 | xx.xxx | yy |
| <CR> | | | | | | |

There are two fields you need to fill in.
[DATA] is a six-character ASCII representation of a numeric value. All ASCII representations of numeric values must be done using the characters '0'-'9' and '.'.

Note:

1. Valid number should between 0 - 1250. This range varies for each Source.

2. No space character allowed in this field.

3. Must be six characters critically(including '.'). If the number you want to set is less than 6 characters, add zeros before or after to make it 6-character long. 020.00 is valid.

   [CHKSUM] is a two-character Message Code Numbering System, representing the sum of the ASCII values of all the characters(excluding the START CHAR, the END CHAR, and the CHKSUM themselves) in the command. The sum is computed using the following formula:

   CHKSUM = SUM(All Characters) % 256
   % is the modulus operator.

   In Message Code Numbering System, the most significant digit is represented with the numbers 0-9 and the letters A-Z and the least significant digit is represented with the numbers 0-9. The numbers 0-9 have the same values as their decimal counterparts and the letters A-Z have the values of 100 - 350 inclusively in increments of 10.

CHKSUM value	=	Decimal value
"00"		0 + 0 = 0
"99"		90 + 9 = 99
"A0"		100 + 0 = 10
"B8"		110 + 8 = 118
"P5"		250 + 5 = 255

   After sending a setpoint command, you will receive a response message from the controller. You must read the response message after sending a command.

   The response message has the format:

   [START CHAR] [ID] [TYPE] [PARAM] [ERROR] [CHKSUM] [END CHAR]

%	0101	W	09	x	yy	<CR>

   [ERROR] field shows if the communication was successfully. The data in this field would be:

0 means No error. Then, the number in [DATA] field will display on the Front Panel.

3 means Transmission failed: Parity error.

5 means Transmission failed: Bad message. Message cannot be understood.

6 means Transmission failed: Bad checksum. The checksum received did not match the checksum of the message.

A means Transmission failed: Bad data. Bad representation in the [DATA] field or data is out of range.

[CHKSUM] is the same as above. You can use it as the way to check if you have successfully received the message.

EXAMPLES:

Command	Temp. Setting	Response Message	Notes
$0101W0910.123G7	10.123°C	%0101W090H8	No error
$0101W09020.00G2	20°C	%0101W090H8	No error
$0101W09002000G5	2000°C	%0101W09AJ5	Out of range
$0101W0901000B5	1000°C	%0101W09	Message.
[DATA]		field is less than 6 characters	

4.3.2 Temperature Readout

The current temperature as shown on the front panel display can be read via RS232 interface. A read command must first be sent to the controller. The command format:

[START CHAR] [ID] [TYPE] [PARAM] [CHKSUM] [END CHAR]

$ 0101   R   05   C1   <CR>

[CHKSUM] field is the same with above. It is fixed as "C1" for this command. So, the message sent to the controller to read the temperature is:

$0101R05C1<CR>

The Read response message has the format:

[START CHAR] [ID] [TYPE] [PARAM] [DATA] [CHKSUM] [END CHAR]

%   0101   R   05   xxx.xxx   yy   <CR>

where xxx.xxx is the current temperature and, as before, yy is the checksum.

EXAMPLES:

Response Message	Current Temp.
%0101R05016.304L3<CR>	16.304°C
%0101R05020.030K4<CR>	20.030°C

4.3.3 Example Code

a) CHECKSUM calculation in C Language

```
// CHKSUM.C

// This short program is to show how to calculate the CHECKSUM in the setpoint
// command and how to append the CHECKSUM and Carriage Return character
to  // the original message.

#include "stdio.h"
#include "stdlib.h"
#include "string.h"
unsigned char LUT[26];
void main()
{
char RequestStr[15]="$0101W0910.123"; // For instance, Set Point = 10.123
char SendOut[17];  // SendOut contains original message, CHECKSUM and <CR>
        int i;
unsigned int sum=0, rem;

for( i=0; i<=9; i++)      // Prepare the Look Up Table {
LUT[i] = 0x30 + i;       // for 0 – 9  }
for( i=10; i<26; i++ )                {
LUT[i] = 0x41 + i - 10; // for A – P  }

// Calculate the sum of characters excluding the START CHAR
for(i=1; i<strlen(RequestStr); i++)
sum += RequestStr[i];                // which is $ and the CHKSUM themselves.

rem = sum % 256;             // get modulus when sum is divided by 256
```

```
// append the two characters CHKSUM and <CR>( 0x0d ) to the original
message
sprintf(SendOut,"%s%c%c%c",RequestStr,LUT[rem/10],LUT[rem-
rem/10*10],'\x0d');

printf("%s",SendOut);  }
```

b) <u>Communications Software in LabVIEW</u>

See Remote.exe and Remote.llb(LabVIEW source code) on accompanying CD.

SECTION 5

THEORY OF OPERATION

5.1   GENERAL

Referring to Interconnect drawing for Model 2500 series, temperature measurement and control functions are provided by A2. It also provides the user input for set point and display functions. K1 is a zero-crossing solid state relay (SSR) that controls the power to the source driven by a pulse-width modulated (PWM) signal from A2.

5.2   TEMPERATURE MEASUREMENT AND CONTROL (A2)

This module reads the source thermocouple connected at terminals 9 and 10 and converts the reading to temperature for display on the front panel. The temperature set point is changed with the front panel keys.

The module provides a PWM drive signal at terminals 1 and 2 to SSR K1 to control the power to the source. The line voltage is stepped down by transformer T1 (Model 2500D only) to provide low voltage drive to the source.

SECTION 6

MAINTENANCE

<u>WARNING</u>

These servicing instructions are for qualified service personnel only. To avoid electrical shock, do not perform any servicing other than that contained in the operating instructions unless you are qualified to do so.

6.1   PREVENTIVE MAINTENANCE

Under normal conditions, no preventive maintenance procedures are necessary for operation of the temperature controller.

6.2   TROUBLESHOOTING

In a complex microprocessor-based instrument such as this, a specific troubleshooting guide cannot be generated. Repair of the instrument will require a thorough understanding of the circuitry and careful application of good troubleshooting techniques. A review of the THEORY OF OPERATION in Section 5, would be helpful before attempting repair.

Frequently, the symptoms point to failure of one specific card, and the most expedient repair would be replacement of the entire card.

If repair is necessary, it is strongly recommended that the instrument be returned to Electro Optical Industries, Inc. where appropriate test equipment, trained service personnel and a complete stock of replacement parts can assure a satisfactory repair.

SECTION 7

CALIBRATION

7.1   INTRODUCTION

Calibration of the blackbody source and temperature controller is performed at Electro Optical Industries, Inc. If for some reason the accuracy of the source has changed, it is recommended that the source and controller be returned to Electro Optical Industries for checkout and re-calibration.

The recommended calibration cycle for EOI sources is as follows:

> (1) 50°C to 600°C Range, 5000 hours.
> (2) 80°C to 1000°C Range, 2000 hours.
> (3) 500 K to 1500 K Range, 1000 hours.

This cycle coincides with the expected shift in the control sensor in the source.   A calibration procedure is provided in the following section.

7.2   RECOMMENDED EQUIPMENT FOR CALIBRATION

(1) Calibrated and certified Pt/Pt + 10% Rh thermocouple whose calibration is known at three or more data points (similar to EOI Model 153S).

(2) A laboratory stand to hold the thermocouple during calibration.

(3) EOI Model 506 Potentiometric Microvoltmeter or equivalent.

(4) An ice bath dewar flask such as Thermos bottle (for thermocouple cold reference probe).

7.3   USE OF CALIBRATION DATA SHEETS (Refer to Figure 7.1)

Definition of terms used on calibration sheets.

(1) <u>Measured mV</u>: output of a thermocouple in millivolts.

(2) <u>Measured Temperature</u> in °C: "Measured mV" converted to temperature by using a conversion chart for type S thermocouples. (See Table 7.1)

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(3) <u>Error Temperature</u> in °C: deviation from the conversion chart (for type S thermocouple, see Table 7.1 at the end of this section) for a specific thermocouple. When using a calibrated thermocouple, plot the error (error vs. temp) on graph paper by using the error points marked on the thermocouple tag.
You can then find the error to any temperature by interpolation.

(4) <u>True Temperature</u> in °C: actual source temperature found by combining the thermocouple "error temp." in °C with the temperature found on the conversion chart for type S thermocouple.

BLACKBODY/TEMPERATURE CONTROLLER DATA SHEET

Blackbody Model	Potentiometer #
Controller #	**Certified Thermocouple Model**
Contract #	**Customer**
Serial #	**Identification**
Blackbody Res.	**NIST**

	EXTERNAL THERMOCOUPLE					EXTERNAL THERMOCOUPLE				
SET TEMP	MEAS. mV	MEAS. TEMP °C	ERROR TEMP °C	TRUE TEMP °C	MEAS. mV	MEAS. TEMP °C	ERROR TEMP °C	TRUE TEMP °C	V	I

Date _____

Signed _____

Figure 7.1 Calibration Data Sheet

7.4   CALIBRATION SET-UP PROCEDURE (Manually from front panel) (Figure 7.2)

1) Set up a laboratory ring stand with a thermometer clamp.

2) Mount the calibrated thermocouple header in the thermometer clamp.

3) Adjust the height of clamped thermocouple until it is on center with blackbody cavity.

CAUTION

DO NOT insert or remove the thermocouple while cavity is hot. Maximum safe temperature is 100°C.

4) Push thermocouple into blackbody cavity until the thermocouple probe tip is in direct contact with the apex of the cavity.

5) Thermocouples with cold junction probe, insert into a crushed ice bath. Without cold junction probe, attach extension leads to an electronic 0°C reference junction.

6) Connect thermocouple leads to a potentiometric microvoltmeter.

7.5   CALIBRATION PROCEDURE

1) Turn temperature controller power ON and use the keypad to select the low end temperature of 50°C.

2) Allow sufficient time for stabilization at this temperature setting.

3) Record the measured millivolts (mV) of the calibrated thermocouple.

4) Convert into temperature using the NIST thermocouple reference table (see Table 7.1 at the end of this section).

5) To determine the true temperature of the source, plot an error curve from the calibration points given with the calibrated thermocouple.

   a) If the error is negative, add to the source temperature.

b) If the error is positive, subtract from the source temperature.

6) Next, Set the source temperature to 100° C and allow sufficient time for the blackbody to stabilize.

7) Record the measured millivolt output of the calibrated thermocouple. Continue this process as in steps 6 & 7 for every 100° until you have completed the blackbody temperature calibration.

8) After completion of calibration, set the temperature of the source to 50° C and allow the blackbody to cool. Pull the thermocouple out approximately 1½ inch so it's not touching the apex of the cavity.

CAUTION

Do not remove the calibrated thermocouple until the blackbody has cooled down to a Temperature of 100°C or below.

9) Convert into temperature using the NIST thermocouple reference table (see Table 7.1 at the end of this section).

10) To determine the true temperature of the source, plot an error curve from the calibration points given with the calibrated thermocouple.

a) If the error is negative, add to the source temperature.

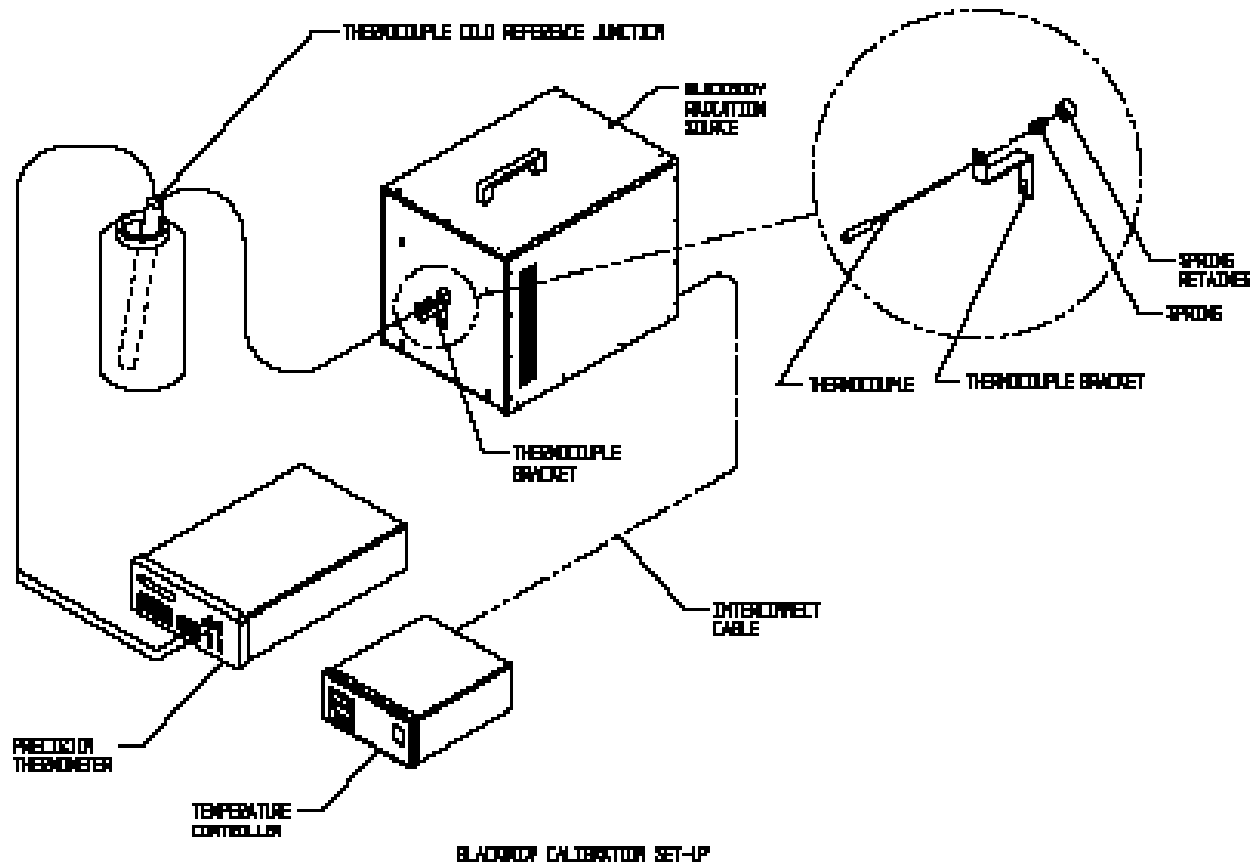b) If the error is positive, subtract from the source temperature.

Figure 7.2 Calibration Equipment Set up

See Appendix for Type S Thermocouple Table

SECTION 8

REPLACEABLE PARTS

8.1   ORDERING INFORMATION

To obtain replacement parts, order from the address on the front of the manual. Identify parts by EOI STOCK CODE, if this can be determined.

For non-listed parts, include the instrument Model and Serial numbers, the location of the part (Interconnect number or Component designator) and a description of the part (e.g., 10 µF 35 V Tantalum Capacitor).

Because of the complexity of our instruments, or the microelectronics in them, some parts are not available and repairs should, or must, be done in our facility.

For very old equipment, it is helpful to know the original purchaser name, the purchase order number and the purchase date. We keep records of everything we sell. We can investigate these records to satisfy your requests. The more information we have, the easier it is to find what you need. Some parts for old equipment are no longer available. In these cases, we can try to find compatible parts to get your system back in service.

Here is a list of information that will help us find your parts:

- Model number;
- Serial number;
- Interconnect Number and revision letter;
- Component name and description;
- Any know specifications of component;
- Original purchaser name;
- Original purchase date;
- Purchase order number;
- Information on what the problem is, how often and under what circumstances it occurs.

LIMITED WARRANTY

Electro Optical Industries, Inc. (EOI) warrants this new Product against defects in materials or workmanship as follows:

For a period of Two (2) years from the date of shipment, EOI will repair or replace the Product, at EOI's option, without charge for parts or labor. After the period of Two (2) years their purchaser must pay all parts and labor charges.

The limited warranty is extended only to the original purchaser. It does not cover damages or failure caused by or attributed to Acts of God, abuse, misuse, improper or abnormal usage, faulty installation, improper maintenance, war, lightning, or other incidences of excessive voltage, or any repairs or tempering by other than an EOI authorized repair facility. It does not cover replacement of consumable parts, transportation costs, or damage in transit. *For the purposes of this warranty heater elements, emitting surface coatings and re-calibration are considered consumables.* This warranty will become void if any factory seals are removed or broken, or the serial number or model number identification has been wholly or partially removed or erased. Repair or replacement under the terms of this warranty does not extend the terms of this warranty. The specific components which are repaired or replaced are warranted for a period of six months. This warranty can not be modified by any agent of EOI, except in writing and signed by an officer of EOI.

Should this product prove defective in workmanship or material, the purchaser's sole remedies shall be such repair or replacement as provided by the terms of this warranty. Under not circumstances shall EOI be liable for any loss or damage, direct, consequential, or incidental, arising out of the use of or inability to use this Product.

To obtain warranty services, call or write EOI for a Return Material Authorization (RMA) number. Packaging must be suitable for the form of shipment used. Mark the RMS number clearly on the outside of the package. Include a copy of a description of the symptoms, contact name, organization, address, phone number and any special return shipping instructions. Then deliver or ship the product, postage or shipping costs prepaid, to EOI.

If Product is returned to EOI during the limited warranty period, but problem with the Product is determined to not be covered under the terms and conditions of this limited warranty the purchaser will be notified and given an estimate of the charges the

purchaser must pay to have the Product repaired, with all shipping charges billed to the purchaser. If the estimate is refused, the Product will be returned COD for the standard evaluation charge, if any, freight collect. If the Product is returned to EOI after the expiration of the warranty period, EOI's normal service policies shall apply and the purchaser will be invoiced for all shipping charges.

Purchaser may also have other rights, which may vary from state to state.

ANY IMPLIED WARRANTY OF MERCHANTABILITY, OR FITNESS FOR A PARTICULAR PURPOSE OR USE, SHALL BE LIMITED TO THE DURATION OF THE FOREGOING WRITTEN WARRANTY, OTHERWISE, THE FOREGOING WARRANTY IS THE PURCHASER'S SOLE AND WXCLUSIVE REMEDY AND IN LIEU OF ALL OTHER WARRANIES, EXPRESS OR IMPLIED. EOI SHALL NOT BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES OR LOSS OF ANTICIPATED BENEFITS OR PROFITS, RESULTING FROM THE PURCHASE OR USE OF THE PRODUCT ARISING FROM THE BREACH OF THE WARRANTY EVEN IF EOI KNEW OF THE LIKELIHOOD OF SUCH DAMAGES.

* * *

APPENDIX

TABLE 7

Type S Thermocouples - Thermoelectric voltage as a function of temperature (ºC)
Reference Tables N.I.S.T. Monograph 175 Revised to ITS-90.

Thermoelectric Voltage in millivolts for Type S Thermocouples											
deg C	0	1	2	3	4	5	6	7	8	9	10	deg C
0	0.000	0.005	0.011	0.016	0.022	0.027	0.033	0.038	0.044	0.050	0.055	0
10	0.055	0.061	0.067	0.072	0.078	0.084	0.090	0.095	0.101	0.107	0.113	10
20	0.113	0.119	0.125	0.131	0.137	0.143	0.149	0.155	0.161	0.167	0.173	20
30	0.173	0.179	0.185	0.191	0.197	0.204	0.210	0.216	0.222	0.229	0.235	30
40	0.235	0.241	0.248	0.254	0.260	0.267	0.273	0.280	0.286	0.292	0.299	40
50	0.299	0.305	0.312	0.319	0.325	0.332	0.338	0.345	0.352	0.358	0.365	50
60	0.365	0.372	0.378	0.385	0.392	0.399	0.405	0.412	0.419	0.426	0.433	60
70	0.433	0.440	0.446	0.453	0.460	0.467	0.474	0.481	0.488	0.495	0.502	70
80	0.502	0.509	0.516	0.523	0.530	0.538	0.545	0.552	0.559	0.566	0.573	80
90	0.573	0.580	0.588	0.595	0.602	0.609	0.617	0.624	0.631	0.639	0.646	90
100	0.646	0.653	0.661	0.668	0.675	0.683	0.690	0.698	0.705	0.713	0.720	100
110	0.720	0.727	0.735	0.743	0.750	0.758	0.765	0.773	0.780	0.788	0.795	110
120	0.795	0.803	0.811	0.818	0.826	0.834	0.841	0.849	0.857	0.865	0.872	120
130	0.872	0.880	0.888	0.896	0.903	0.911	0.919	0.927	0.935	0.942	0.950	130
140	0.950	0.958	0.966	0.974	0.982	0.990	0.998	1.006	1.013	1.021	1.029	140
150	1.029	1.037	1.045	1.053	1.061	1.069	1.077	1.085	1.094	1.102	1.110	150
160	1.110	1.118	1.126	1.134	1.142	1.150	1.158	1.167	1.175	1.183	1.191	160
170	1.191	1.199	1.207	1.216	1.224	1.232	1.240	1.249	1.257	1.265	1.273	170
180	1.273	1.282	1.290	1.298	1.307	1.315	1.323	1.332	1.340	1.348	1.357	180
190	1.357	1.365	1.373	1.382	1.390	1.399	1.407	1.415	1.424	1.432	1.441	190
200	1.441	1.449	1.458	1.466	1.475	1.483	1.492	1.500	1.509	1.517	1.526	200
210	1.526	1.534	1.543	1.551	1.560	1.569	1.577	1.586	1.594	1.603	1.612	210
220	1.612	1.620	1.629	1.638	1.646	1.655	1.663	1.672	1.681	1.690	1.698	220
230	1.698	1.707	1.716	1.724	1.733	1.742	1.751	1.759	1.768	1.777	1.786	230
240	1.786	1.794	1.803	1.812	1.821	1.829	1.838	1.847	1.856	1.865	1.874	240
250	1.874	1.882	1.891	1.900	1.909	1.918	1.927	1.936	1.944	1.953	1.962	250

Thermoelectric Voltage in millivolts for Type S Thermocouples

deg C	0	1	2	3	4	5	6	7	8	9	10	deg C
260	1.962	1.971	1.980	1.989	1.998	2.007	2.016	2.025	2.034	2.043	2.052	260
270	2.052	2.061	2.070	2.078	2.087	2.096	2.105	2.114	2.123	2.132	2.141	270
280	2.141	2.151	2.160	2.169	2.178	2.187	2.196	2.205	2.214	2.223	2.232	280
290	2.232	2.241	2.250	2.259	2.268	2.277	2.287	2.296	2.305	2.314	2.323	290
300	2.323	2.332	2.341	2.350	2.360	2.369	2.378	2.387	2.396	2.405	2.415	300
310	2.415	2.424	2.433	2.442	2.451	2.461	2.470	2.479	2.488	2.497	2.507	310
320	2.507	2.516	2.525	2.534	2.544	2.553	2.562	2.571	2.581	2.590	2.599	320
330	2.599	2.609	2.618	2.627	2.636	2.646	2.655	2.664	2.674	2.683	2.692	330
340	2.692	2.702	2.711	2.720	2.730	2.739	2.748	2.758	2.767	2.776	2.786	340
350	2.786	2.795	2.805	2.814	2.823	2.833	2.842	2.851	2.861	2.870	2.880	350
360	2.880	2.889	2.899	2.908	2.917	2.927	2.936	2.946	2.955	2.965	2.974	360
370	2.974	2.983	2.993	3.002	3.012	3.021	3.031	3.040	3.050	3.059	3.069	370
380	3.069	3.078	3.088	3.097	3.107	3.116	3.126	3.135	3.145	3.154	3.164	380
390	3.164	3.173	3.183	3.192	3.202	3.212	3.221	3.231	3.240	3.250	3.259	390
400	3.259	3.269	3.279	3.288	3.298	3.307	3.317	3.326	3.336	3.346	3.355	400
410	3.355	3.365	3.374	3.384	3.394	3.403	3.413	3.423	3.432	3.442	3.451	410
420	3.451	3.461	3.471	3.480	3.490	3.500	3.509	3.519	3.529	3.538	3.548	420
430	3.548	3.558	3.567	3.577	3.587	3.596	3.606	3.616	3.626	3.635	3.645	430
440	3.645	3.655	3.664	3.674	3.684	3.694	3.703	3.713	3.723	3.732	3.742	440
450	3.742	3.752	3.762	3.771	3.781	3.791	3.801	3.810	3.820	3.830	3.840	450
460	3.840	3.850	3.859	3.869	3.879	3.889	3.898	3.908	3.918	3.928	3.938	460
470	3.938	3.947	3.957	3.967	3.977	3.987	3.997	4.006	4.016	4.026	4.036	470
480	4.036	4.046	4.056	4.065	4.075	4.085	4.095	4.105	4.115	4.125	4.134	480
490	4.134	4.144	4.154	4.164	4.174	4.184	4.194	4.204	4.213	4.223	4.233	490
500	4.233	4.243	4.253	4.263	4.273	4.283	4.293	4.303	4.313	4.323	4.332	500
510	4.332	4.342	4.352	4.362	4.372	4.382	4.392	4.402	4.412	4.422	4.432	510
520	4.432	4.442	4.452	4.462	4.472	4.482	4.492	4.502	4.512	4.522	4.532	520
530	4.532	4.542	4.552	4.562	4.572	4.582	4.592	4.602	4.612	4.622	4.632	530
540	4.632	4.642	4.652	4.662	4.672	4.682	4.692	4.702	4.712	4.722	4.732	540
550	4.732	4.742	4.752	4.762	4.772	4.782	4.793	4.803	4.813	4.823	4.833	550
560	4.833	4.843	4.853	4.863	4.873	4.883	4.893	4.904	4.914	4.924	4.934	560

Thermoelectric Voltage in millivolts for Type S Thermocouples

deg C	0	1	2	3	4	5	6	7	8	9	10	deg C
570	4.934	4.944	4.954	4.964	4.974	4.984	4.995	5.005	5.015	5.025	5.035	570
580	5.035	5.045	5.055	5.066	5.076	5.086	5.096	5.106	5.116	5.127	5.137	580
590	5.137	5.147	5.157	5.167	5.178	5.188	5.198	5.208	5.218	5.228	5.239	590
600	5.239	5.249	5.259	5.269	5.280	5.290	5.300	5.310	5.320	5.331	5.341	600
610	5.341	5.351	5.361	5.372	5.382	5.392	5.402	5.413	5.423	5.433	5.443	610
620	5.443	5.454	5.464	5.474	5.485	5.495	5.505	5.515	5.526	5.536	5.546	620
630	5.546	5.557	5.567	5.577	5.588	5.598	5.608	5.618	5.629	5.639	5.649	630
640	5.649	5.660	5.670	5.680	5.691	5.701	5.712	5.722	5.732	5.743	5.753	640
650	5.753	5.763	5.774	5.784	5.794	5.805	5.815	5.826	5.836	5.846	5.857	650
660	5.857	5.867	5.878	5.888	5.898	5.909	5.919	5.930	5.940	5.950	5.961	660
670	5.961	5.971	5.982	5.992	6.003	6.013	6.024	6.034	6.044	6.055	6.065	670
680	6.065	6.076	6.086	6.097	6.107	6.118	6.128	6.139	6.149	6.160	6.170	680
690	6.170	6.181	6.191	6.202	6.212	6.223	6.233	6.244	6.254	6.265	6.275	690
700	6.275	6.286	6.296	6.307	6.317	6.328	6.338	6.349	6.360	6.370	6.381	700
710	6.381	6.391	6.402	6.412	6.423	6.434	6.444	6.455	6.465	6.476	6.486	710
720	6.486	6.497	6.508	6.518	6.529	6.539	6.550	6.561	6.571	6.582	6.593	720
730	6.593	6.603	6.614	6.624	6.635	6.646	6.656	6.667	6.678	6.688	6.699	730
740	6.699	6.710	6.720	6.731	6.742	6.752	6.763	6.774	6.784	6.795	6.806	740
750	6.806	6.817	6.827	6.838	6.849	6.859	6.870	6.881	6.892	6.902	6.913	750
760	6.913	6.924	6.934	6.945	6.956	6.967	6.977	6.988	6.999	7.010	7.020	760
770	7.020	7.031	7.042	7.053	7.064	7.074	7.085	7.096	7.107	7.117	7.128	770
780	7.128	7.139	7.150	7.161	7.172	7.182	7.193	7.204	7.215	7.226	7.236	780
790	7.236	7.247	7.258	7.269	7.280	7.291	7.302	7.312	7.323	7.334	7.345	790
800	7.345	7.356	7.367	7.378	7.388	7.399	7.410	7.421	7.432	7.443	7.454	800
810	7.454	7.465	7.476	7.487	7.497	7.508	7.519	7.530	7.541	7.552	7.563	810
820	7.563	7.574	7.585	7.596	7.607	7.618	7.629	7.640	7.651	7.662	7.673	820
830	7.673	7.684	7.695	7.706	7.717	7.728	7.739	7.750	7.761	7.772	7.783	830
840	7.783	7.794	7.805	7.816	7.827	7.838	7.849	7.860	7.871	7.882	7.893	840
850	7.893	7.904	7.915	7.926	7.937	7.948	7.959	7.970	7.981	7.992	8.003	850
860	8.003	8.014	8.026	8.037	8.048	8.059	8.070	8.081	8.092	8.103	8.114	860
870	8.114	8.125	8.137	8.148	8.159	8.170	8.181	8.192	8.203	8.214	8.226	870
880	8.226	8.237	8.248	8.259	8.270	8.281	8.293	8.304	8.315	8.326	8.337	880

Thermoelectric Voltage in millivolts for Type S Thermocouples

deg C	0	1	2	3	4	5	6	7	8	9	10	deg C
890	8.337	8.348	8.360	8.371	8.382	8.393	8.404	8.416	8.427	8.438	8.449	890
900	8.449	8.460	8.472	8.483	8.494	8.505	8.517	8.528	8.539	8.550	8.562	900
910	8.562	8.573	8.584	8.595	8.607	8.618	8.629	8.640	8.652	8.663	8.674	910
920	8.674	8.685	8.697	8.708	8.719	8.731	8.742	8.753	8.765	8.776	8.787	920
930	8.787	8.798	8.810	8.821	8.832	8.844	8.855	8.866	8.878	8.889	8.900	930
940	8.900	8.912	8.923	8.935	8.946	8.957	8.969	8.980	8.991	9.003	9.014	940
950	9.014	9.025	9.037	9.048	9.060	9.071	9.082	9.094	9.105	9.117	9.128	950
960	9.128	9.139	9.151	9.162	9.174	9.185	9.197	9.208	9.219	9.231	9.242	960
970	9.242	9.254	9.265	9.277	9.288	9.300	9.311	9.323	9.334	9.345	9.357	970
980	9.357	9.368	9.380	9.391	9.403	9.414	9.426	9.437	9.449	9.460	9.472	980
990	9.472	9.483	9.495	9.506	9.518	9.529	9.541	9.552	9.564	9.576	9.587	990

deg C	0	1	2	3	4	5	6	7	8	9	10	deg C
1000	9.587	9.599	9.610	9.622	9.633	9.645	9.656	9.668	9.680	9.691	9.703	1000
1010	9.703	9.714	9.726	9.737	9.749	9.761	9.772	9.784	9.795	9.807	9.819	1010
1020	9.819	9.830	9.842	9.853	9.865	9.877	9.888	9.900	9.911	9.923	9.935	1020
1030	9.935	9.946	9.958	9.970	9.981	9.993	10.005	10.016	10.028	10.040	10.051	1030
1040	10.051	10.063	10.075	10.086	10.098	10.110	10.121	10.133	10.145	10.156	10.168	1040
1050	10.168	10.180	10.191	10.203	10.215	10.227	10.238	10.250	10.262	10.273	10.285	1050
1060	10.285	10.297	10.309	10.320	10.332	10.344	10.356	10.367	10.379	10.391	10.403	1060
1070	10.403	10.414	10.426	10.438	10.450	10.461	10.473	10.485	10.497	10.509	10.520	1070
1080	10.520	10.532	10.544	10.556	10.567	10.579	10.591	10.603	10.615	10.626	10.638	1080
1090	10.638	10.650	10.662	10.674	10.686	10.697	10.709	10.721	10.733	10.745	10.757	1090
1100	10.757	10.768	10.780	10.792	10.804	10.816	10.828	10.839	10.851	10.863	10.875	1100
1110	10.875	10.887	10.899	10.911	10.922	10.934	10.946	10.958	10.970	10.982	10.994	1110
1120	10.994	11.006	11.017	11.029	11.041	11.053	11.065	11.077	11.089	11.101	11.113	1120
1130	11.113	11.125	11.136	11.148	11.160	11.172	11.184	11.196	11.208	11.220	11.232	1130
1140	11.232	11.244	11.256	11.268	11.280	11.291	11.303	11.315	11.327	11.339	11.351	1140
1150	11.351	11.363	11.375	11.387	11.399	11.411	11.423	11.435	11.447	11.459	11.471	1150
1160	11.471	11.483	11.495	11.507	11.519	11.531	11.542	11.554	11.566	11.578	11.590	1160
1170	11.590	11.602	11.614	11.626	11.638	11.650	11.662	11.674	11.686	11.698	11.710	1170
1180	11.710	11.722	11.734	11.746	11.758	11.770	11.782	11.794	11.806	11.818	11.830	1180
1200	11.951	11.963	11.975	11.987	11.999	12.011	12.023	12.035	12.047	12.059	12.071	1200
1210	12.071	12.083	12.095	12.107	12.119	12.131	12.143	12.155	12.167	12.179	12.191	1210
1220	12.191	12.203	12.216	12.228	12.240	12.252	12.264	12.276	12.288	12.300	12.312	1220
1230	12.312	12.324	12.336	12.348	12.360	12.372	12.384	12.397	12.409	12.421	12.433	1230
1240	12.433	12.445	12.457	12.469	12.481	12.493	12.505	12.517	12.529	12.542	12.554	1240
1250	12.554	12.566	12.578	12.590	12.602	12.614	12.626	12.638	12.650	12.662	12.675	1250
1260	12.675	12.687	12.699	12.711	12.723	12.735	12.747	12.759	12.771	12.783	12.796	1260
1270	12.796	12.808	12.820	12.832	12.844	12.856	12.868	12.880	12.892	12.905	12.917	1270
1280	12.917	12.929	12.941	12.953	12.965	12.977	12.989	13.001	13.014	13.026	13.038	1280
1290	13.038	13.050	13.062	13.074	13.086	13.098	13.111	13.123	13.135	13.147	13.159	1290
1310	13.280	13.292	13.305	13.317	13.329	13.341	13.353	13.365	13.377	13.390	13.402	1310
1320	13.402	13.414	13.426	13.438	13.450	13.462	13.474	13.487	13.499	13.511	13.523	1320

1330	13.523	13.535	13.547	13.559	13.572	13.584	13.596	13.608	13.620	13.632	13.644	1330
1340	13.644	13.657	13.669	13.681	13.693	13.705	13.717	13.729	13.742	13.754	13.766	1340
1350	13.766	13.778	13.790	13.802	13.814	13.826	13.839	13.851	13.863	13.875	13.887	1350
1360	13.887	13.899	13.911	13.924	13.936	13.948	13.960	13.972	13.984	13.996	14.009	1360
1370	14.009	14.021	14.033	14.045	14.057	14.069	14.081	14.094	14.106	14.118	14.130	1370
1380	14.130	14.142	14.154	14.166	14.178	14.191	14.203	14.215	14.227	14.239	14.251	1380
1390	14.251	14.263	14.276	14.288	14.300	14.312	14.324	14.336	14.348	14.360	14.373	1390
1400	14.373	14.385	14.397	14.409	14.421	14.433	14.445	14.457	14.470	14.482	14.494	1400
1410	14.494	14.506	14.518	14.530	14.542	14.554	14.567	14.579	14.591	14.603	14.615	1410
1420	14.615	14.627	14.639	14.651	14.664	14.676	14.688	14.700	14.712	14.724	14.736	1420
1430	14.736	14.748	14.760	14.773	14.785	14.797	14.809	14.821	14.833	14.845	14.857	1430
1440	14.857	14.869	14.881	14.894	14.906	14.918	14.930	14.942	14.954	14.966	14.978	1440