8520A/PRT

Precision Temperature System

Addendum

P/N 653840
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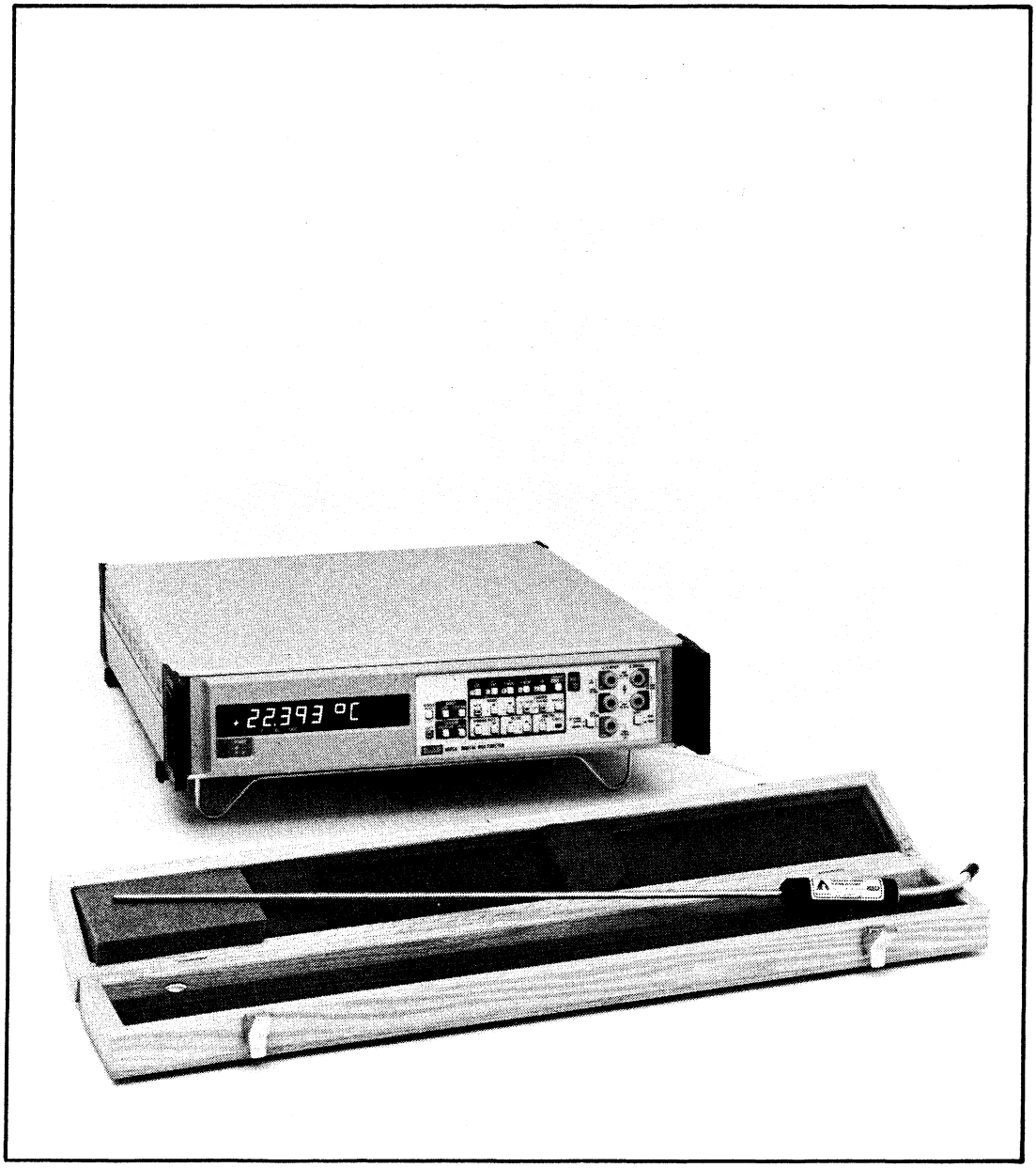

Frontispiece 8520A/PRT Precision Temperature System

INTRODUCTION AND SPECIFICATIONS

Introduction

This addendum provides specifications, handling instructions for the 8520A/PRT (Platinum Resistance Thermometer), operating instructions, and theory of operation. Programming local and remote IEEE-488 functions of the 8520A/PRT Precision Temperature System is covered.

The 8520A/PRT includes an 8520A Digital Multimeter, a Rosemount 162 Series Platinum Resistance Thermometer, and a Reference Resistor Assembly. The multimeter provides high measurement accuracy and substantial math capabilities. The PRT is calibration-matched to the multimeter.

Math Program #15 computes and displays the temperature equivalent of the PRT resistance. The display is normally in degrees Celsius, but the user may also select a display of degrees Fahrenheit or Kelvin. The 8520A DMM automatically loads permanent Alpha, Delta, A4, and C4 parameters for the PRT included with the Precision Temperature System. Temporary parameters can be stored for use with other PRTs, but are replaced with the permanent parameters whenever input power is cycled. The Math Program section of the 8520A Instruction Manual presents a full explanation of general math program use.

Specifications

As shown in Figure 1, the 24 hour accuracy of the 8520A/PRT @ 23°C ± 1°C is ± 10 mK (milli Kelvin) (or ± .01°C) from -100°C to + 100°C. The 90 day accuracy in a 23°C ± 5°C environment varies from ± 15 mK to ± 25 mK (or .015°C to ± .025°C) over the full measurement range of -200°C to + 350°C.

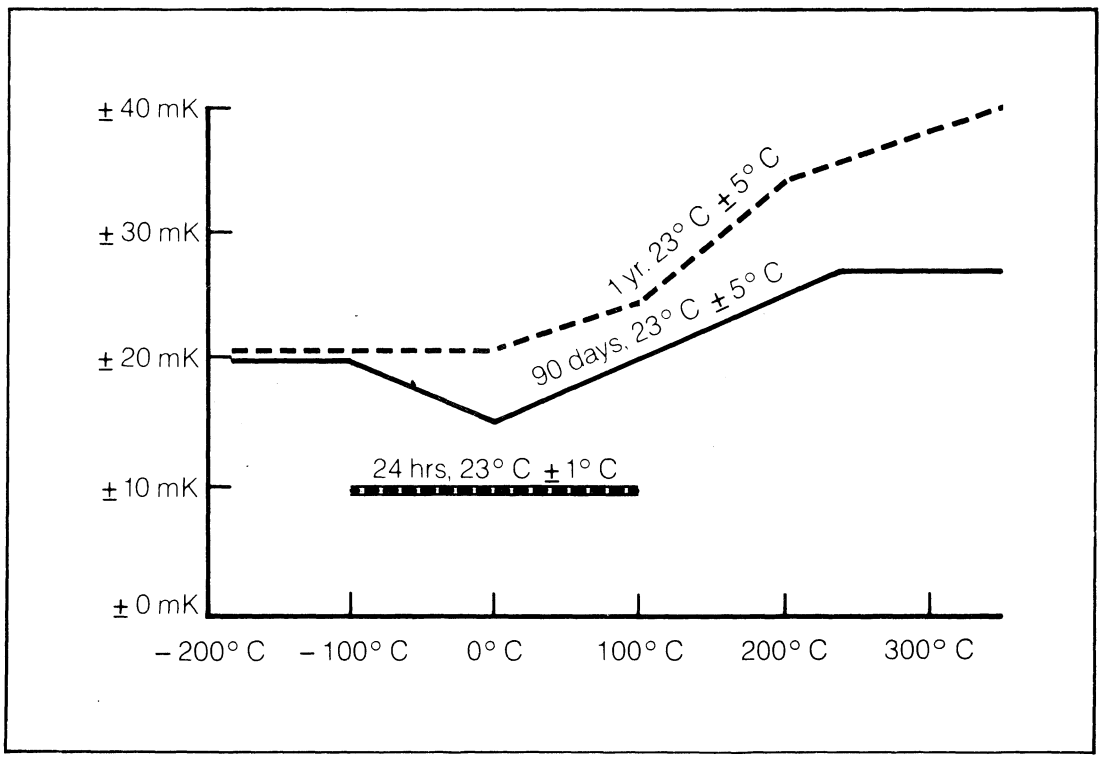

Figure 1. 8520A/PRT Temperature Accuracy

OPERATING INSTRUCTIONS

PRT Handling

The PRT is a delicate precision instrument. Always store the PRT in its box or leave it secured in a temperature bath. Never leave the PRT in any other position. Fluke is not responsible for PRT damages attributable to abuse.

CAUTION

Handle the PRT with care. The platinum lattices are more delicate than glass. Any small amount of force (such as a tap) could change the calibration. Any greater amount of force (such as a drop) could destroy the PRT.

PRT Setup

The calibration seal on the PRT box secures calibration integrity from the laboratory. Do not open the box until setup is required. During the following procedure refer to Figure 2 and Table 1 titled Rear Panel Controls and Connectors, and Figure 3 and Table 2 titled Front Panel Controls, Connectors, and Indicators.

Use the following procedure to setup the PRT:

1. Break the calibration seal on the PRT box.
2. Leaving the PRT in the box, pull out the connector at the end of the PRT cable.
3. Secure this connector to the 8520A REAR ANALOG INPUT (see Table 1).
4. Mount the PRT in the temperature bath when ready.
5. On the 8520A, connect the 100-ohm standard resistor to the front panel inputs.
6. Connect the power cord and energize the 8520A. Allow a two-hour warm-up to ensure full accuracy.

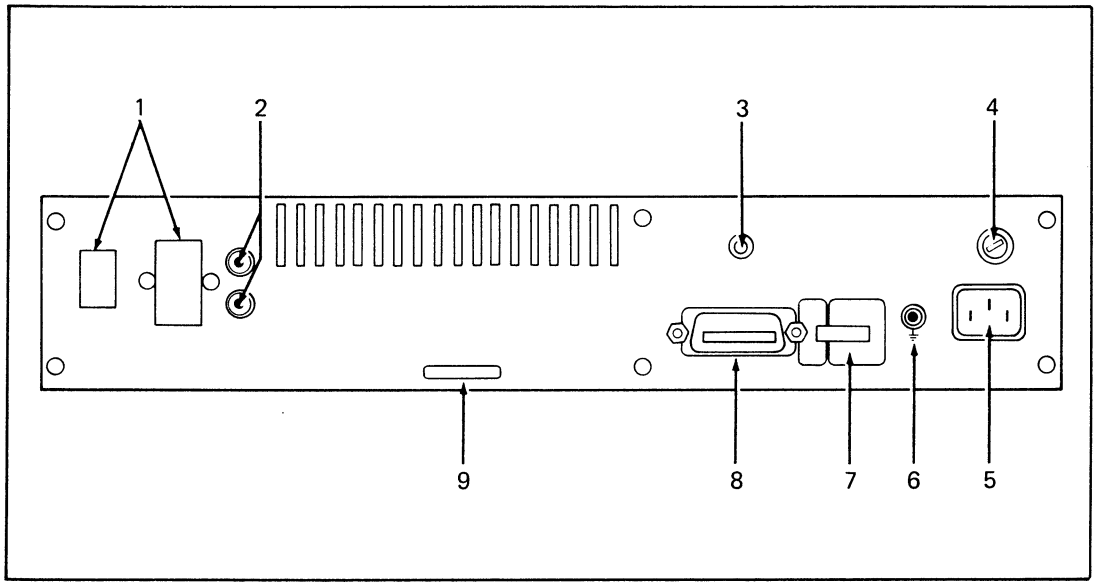

Figure 2. 8520A Rear Panel Controls and Connectors

Table 1. 8520A Rear Panel Controls and Connectors

REF NO.	NAME	FUNCTION
1	REAR ANALOG INPUTS (J6)	20 pin connector and pin assignment chart. Duplicates the function of the front panel V/Ω INPUT, Ω SOURCE, and GUARD terminals.
2	EXTERNAL REFERENCE HI Terminal (J25) LO Terminal (J26)	Binding posts. HI is red. LO is black. External reference signal is applied to these terminals.
3	BNC TRIGGER Terminal (J7)	BNC connector for input of external trigger.
4	FUSE	Line power fuse, F201, and chart listing the appropriate line power fuse for each line power configuration.
5	Line Power Receptacle	Receptacle for line power cable.
6	Terminal (J9)	Binding post connected to chassis ground.
7	IEEE-488 ADDRESS Switches	Eight recessed toggle switches.
	INST ADDRESS	Determine the IEEE-488 address of the 8520A.
	TRIGGER	Select rising or falling edge of BNC TRIGGER input for triggering.
	TALK ONLY	Enable/disable IEEE-488 Talk Only (TON) function.
	SHIELD	Connect/disconnect IEEE-488 Interface cable and 8520A ground.
8	IEEE-488 CONNECTOR	Standard 24 pin IEEE-488 receptacle.
9	Instrument Model Number and Instrument Serial Number	

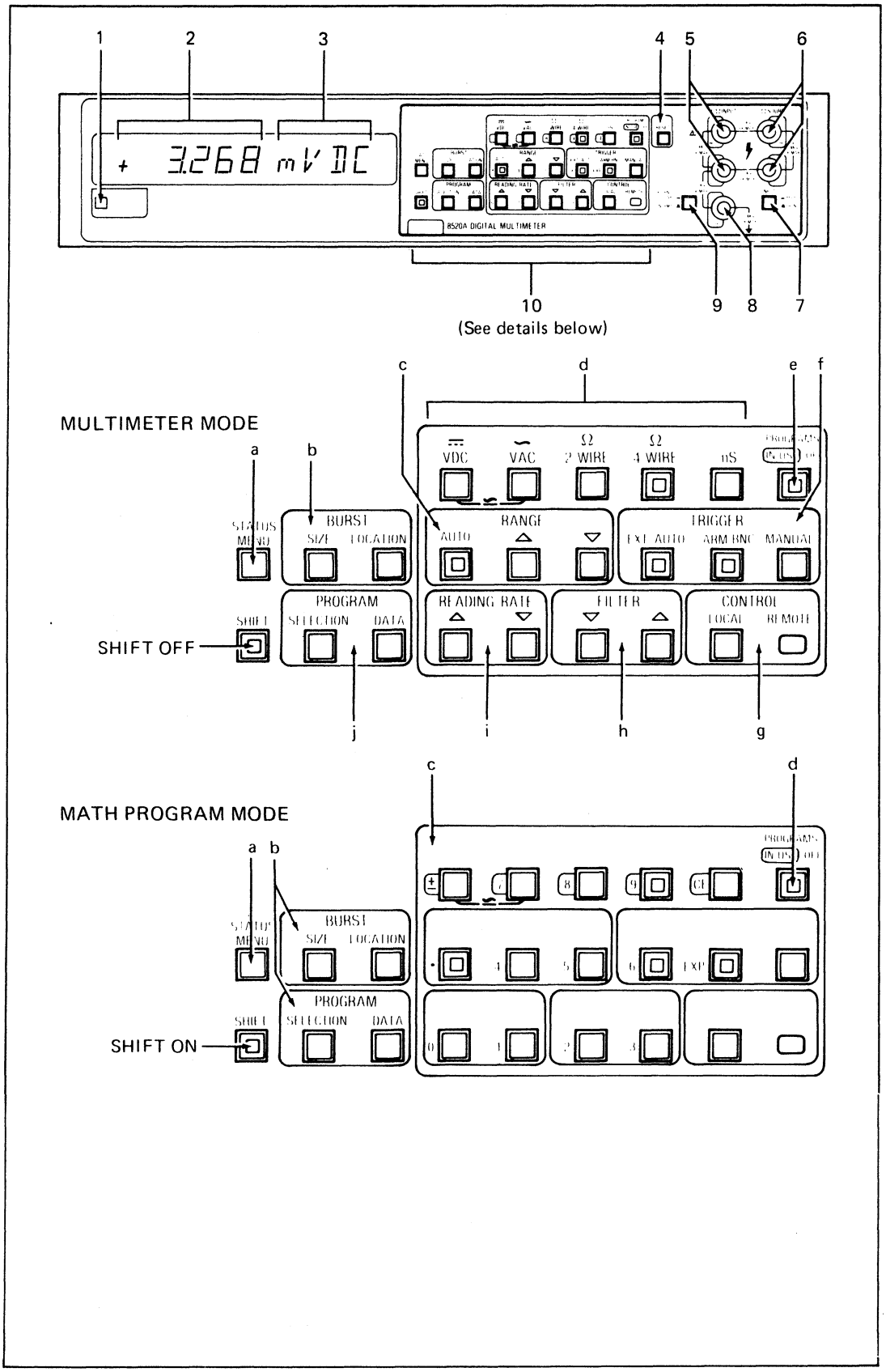

Figure 3. 8520A Front Panel Controls, Connectors, and Indicators

Table 2. 8520A Front Panel Controls, Connectors, and Indicators

REF NO.	NAME	FUNCTION
1	POWER ON/OFF Switch	Push ON (in)/push OFF (out) for line power and POWER ON default set-up (See Defaults in the Operation section of this manual).
2	Left Display	5 1/2, 7-segment LED digits with polarity indication and six decimal point positions.
3	Right Display	Four, 14-segment alphanumeric LED digits.
4	RESET Switch	Momentary contact pushbutton used to reset the instrument to two different default set-ups. (See Defaults in the Operation section of this manual.
5	V/Ω INPUT HI Terminal LO Terminal	Recessed terminals (for increased operator safety). HI is red. LO is black. Voltages and resistances to be measured are applied to these terminals.
6	Ω SOURCE HI Terminal LO Terminal	Recessed terminals (for increased operator safety). HI is red. LO is black. The ohms source output is present at these terminals when the Ω 4 WIRE measurement function is selected (the 8520A opens these terminals when any other function is selected).
7	INPUT REAR/FRONT Switch	Push to REAR (in) to connect the instrument to the Rear Analog Input terminals. Push to FRONT (out) to connect the instrument to the front panel terminals.
8	GUARD Terminal	Blue recessed terminal used for External Guard Operation.
9	EXTERNAL GUARD/NORMAL Switch	Push to NORMAL (in) to disconnect/push to EXTERNAL GUARD (out) to connect the GUARD terminal and the internal guard circuit.
10	Keyboard Switches	23 momentary pushbuttons and one indicator (REMOTE). The pushbuttons are dual function controls. Each control has one function when the instrument is in the Multimeter Mode and another function when the instrument is in the Math Program Mode. Six of the pushbuttons have an integral LED to indicate the status of the control.
	SHIFT	Push to shift between the Multimeter Mode (LED off) and the Math Program Mode (LED on).
	MULTIMETER MODE OF OPERATION (SHIFT LED off)	
a	STATUS	Push to display present function, Range, Reading Rate, and Filter.
b	BURST SIZE	Push to display current burst size.
c	RANGE	Three range controls that can enable autoranging (AUTO LED on), select the next higher (▲) or lower (▼) range.
d	Function	Five software interlocked controls that determine the measurement function.

Table 2. 8502A Front Panel Controls, Connectors, and Indicators (cont)

REF NO.	NAME	FUNCTION
e	PROGRAMS IN USE/OFF	Push to enable or disable the math program(s) selected. The math programs are in use when the LED is on.
f	TRIGGER	Three controls that determine instrument triggering.
g	CONTROL	Push LOCAL to select local (front panel) control of the instrument. REMOTE on indicates that an external device has assumed control of the instrument via the IEEE-488 interface.
h	FILTER	Push to decrease (▼) or increase (▲) settling time and rejection of filter.
i	READING RATE	Push to select next faster (▲) or next slower (▼) Reading Rate.
j	PROGRAM SELECTION	Push to display the number(s) of the math program(s) selected.
	MATH PROGRAM MODE OF OPERATION (SHIFT LED on)	
a	MENU	Push and release to step or push and hold to scroll through the menu of math programs.
b	Numeric Terminator Buttons	Four controls used after Numeric Keyboard entries.
	BURST SIZE	Used following Numeric Keyboard entries to program burst size.
	LOCATION	Used following Numeric Keyboard entries to display the contents of any location in burst memory.
	PROGRAM SELECTION	Used following Numeric Keyboard entries to select math programs and to enter data.
	DATA	Used following either a Numeric Keyboard entry or use of the MANUAL TRIGGER control to store and enter data.
c	Numeric Keyboard	Controls used to enter numeric values, to select math programs, or retrieve constants or data.
d	PROGRAMS IN USE/OFF	Used to enable or disable the math program(s) selected. The LED on indicates that the selected math programs(s) are in use.

Maintaining a PRT Record Sheet

A daily record must be maintained. This record keeping and proper calibration are necessary to keep the thermometer within specifications. Table 3 shows a sample record sheet. Offset and gain must first be determined. Either the Ice Bath Method or the Standard Resistor Method is used.

Table 3. Record Sheet and Programming Instruction

Date	Offset, mV r15.8	Std. Temp. °C (a)	Indicated Temp. °C (b)	Gain °C (a)-(b)=r15.9
3-1-81	-0.008	0.000°C	-0.0054°C	+0.0054°C

ICE BATH METHOD

This method is used with the PRT immersed at least four inches into a calibrated ice bath that is guaranteed to within 2 mK (0.002°C). A Rosemount 911A is suitable for this purpose. Follow any necessary steps in the PRT setup procedure first.

Compute and Enter Offset

The following procedure computes and programs the offset figure into the 8520A program register r15.8:

1. Select dc volts function (VDC) and autoranging (AUTO). Observe the display and verify that the 8520A DMM downranges to the 100-mV range.

2. Increase the filter time-out to 1,000 ms as indicated in the 8520A display.

3. Average several readings to compensate for any digital rattle. Use this average (assume -0.008 mV) as the offset figure for the PRT Daily Record.

4. Select the four-wire ohms function (4 WIRE). Verify that the 8520A DMM autoranges down to the 100-ohm range as indicated on the 8520A display.

5. Increase the filter time-out to 1,000 ms as indicated on the 8520A display.

6. Select program #15 (SHIFT 1 5 SELECTION). The 8520A display responds with:

   15=PRT

   Then:

   r15.8=mVOF

7. Enter the offset figure from step 3:

   [-] [.] [0] [0] [8] [DATA]

   The 8520A display responds with:

   r15.9 GAIN

Compute and Enter Gain

The following procedure computes and enters the gain into the 8520A register r15.9.

1. Set the gain register (r15.9) to zero and press:

   [SHIFT] [1] [5] [.] [9] [SELECTION] [0] [DATA]

2. Set the 8520A DMM for temperature measurement and press:

   [PROGRAM IN USE]

   The LED titled PROGRAM IN USE comes on.

3. Average several readings to compensate for any digital rattle. Use this average (assume -0.0054°C) as the indicated temperature figure for the PRT Daily Record.

4. Compute the gain by subtracting the indicated temperature from the standard temperature (0.000°C for the ice bath). Enter this gain figure in the PRT Daily Record and press:

   [SHIFT] [1] [5] [.] [9] [SELECTION]

5. Now enter the gain figure computed in step 4 (+0.0054°C) and press:

   [.] [0] [0] [5] [4] [DATA]

6. Set the 8520A DMM for normal temperature measurements by pressing:

   [PROGRAM IN USE]

STANDARD RESISTOR METHOD

This method using a 100-ohm standard resistor is substituted for the ice bath method under certain conditions. Basically, the Standard Resistor Method is used if PRT calibration has not deteriorated since the last ice bath calibration. The following procedure is used:

1. An initial ice bath calibration must be conducted. All steps of the Ice Bath Method must be followed.

2. Ice bath measurements should then yield an 8520A display average of 0.0000°C (with some digital rattle in the least significant digits).

3. Ensure that a 100-ohm standard resistor is connected to the 8520A front terminals (standard resistor).

4. Switch the 8520A DMM input from the rear (PRT) to the front. Record the reading obtained using the front inputs as the Standard Temperature on the PRT Daily Record.

5. In the future, the offset and gain is determined and entered using the 100-ohm standard resistor at the 8520A front inputs. All steps used with the Ice Bath Method are also used with the Standard Resistor Method.

Local Programming Instructions

The following procedures document the local programming use and implementation of Math Program #15.

SELECTING MATH PROGRAM #15

The following procedure is used to select PRT Math Program (#15). This procedure must be initially completed before the program is changed or implemented. For information on stacking multiple programs see Section 7 of the 8520A Operator Manual titled STACKING (Selecting Several) PROGRAMS.

1. Connect the PRT to the 8520A in a four-wire resistance measurement configuration.

2. On the 8520A, press the 4 WIRE push button.

3. In sequence, press the following push buttons and verify the 8520A response:

[SHIFT]	"?" NMBR
[1] [5]	15 NMBR
[SELECTION]	15=PRT
	r15.8=mVOF
	xxxxx mVOF

4. If no part of register 15 is changed, proceed to Implementing Math Program #15.

CHANGING OFFSET AND GAIN VALUES

If the offset (r15.8) or gain (r15.9) registers must be reprogrammed, use the following procedure:

1. Select Math Program #15.

2. To enter a new offset value, first verify an 8520A display of:

   xxxxx mVOF

   Then, program the offset digits.

3. press:

   [DATA]

   The 8520A display responds with:

   r15.9=GAIN

   Then:

   xxxxxx GAIN

4. Digits for a new gain value can now be programmed.

CHANGING CALIBRATION CONSTANTS

Permanent calibration constants (corresponding to the PRT shipped with the Precision Temperature System) are stored in the 8520A ROM. The serial number for this PRT is stored in register 16. Another temporary set of calibration constants can be stored in the RAM. Multiple PRTs can be used with a single 8520A DMM. The RAM is reinitialized to permanent calibration constants at power-up. Any of the temporary calibration constants can be changed with the following procedure:

1. Select Math Program #15 by pressing:

   [SHIFT]

2. Select the desired register by pressing:

   [1] [5] [.] [X]

   "X" represents the register number (3, 4, 5, 6, or 7).

3. Activate access to the desired register by pressing:

   [SELECTION]

4. The display now shows first the register number and name, then the register value.

5. With the old register value displayed, enter the new value.

6. Complete entry of the new value by pressing:

   [DATA]

   This action also accesses the next higher register (number and name, then value). With the old value displayed, the new value is entered.

7. Each higher register can now be accessed by successively pressing DATA. All higher registers must be stepped through in this manner before the PRT Math Program can be exited.

IMPLEMENTING MATH PROGRAM #15

Once Program #15 has been selected and all changes have been entered in the desired registers, the following procedure can be used for implementation.

1. Verify that the 4 WIRE push button has been pressed for four-terminal ohms measurements.

2. With the 8520A display showing the contents of register 15.9 (gain); press:

   [DATA]

   A normal ohms display should now commence.

3. press:

   [PROGRAM IN USE]

   The display now shows degrees Celsius. Degrees Fahrenheit or Kelvin can also be displayed. The applicable procedure is described in the following paragraphs.

Remote Programming Instructions

Programming commands P15 (PRT Program) and P16 (PRT Serial Number), are available in addition to the regular 8520A DMM Instruction Set. Table 4 list the 14 instruction classifications. Remote commands offer simplified operation over local control. The following examples cover all programming requirements.

1. "P15" selects program #15. Programs can be stacked as long as numerical order is observed on entry. For example, programs #8 and #15 can be selected by programming:

   [P] [8] [1] [5]

   Remember the following restrictions:

   a. A maximum of three programs can be stacked in this fashion.

   b. P11, 12, 13, 14, and 15 should not be stacked in any fashion.

2. "M1" implements the program selected, corresponding to the local PROGRAMS IN USE push button.

3. "KRr/v" enters the value "v" into the register "r" at any time. This command is, therefore, used to enter offset, gain, or new calibration constants.

4. "GRr" returns the contents of register "r".

Temperature Display

READINGS WITH .1 MK RESOLUTION -19.9999 TO +19.9999

The display presents four decimal places for readings from -19.9999 to +19.9999. This degree of resolution is useful when determining an average reading (especially for gain error).

READINGS WITH 1 MK RESOLUTION -199.999 TO -20.000 AND +20.000 TO 600.00

All other readings present three decimal places. For readings beyond ±200°C or ±1100°F, the last two alphanumeric LEDs are used as adders to the most significant digit (which cannot exceed 1). The type of display (degrees Celsius, Fahrenheit, or Kelvin) determines the exact usage.

NOTE

Whenever making measurements beyond 350° C (662° F or 623K), refer the the appropriate instructions and caution mentioned in the following.

For the 8520A Celsius display, adders of "1", "2", "3", "4", and "5" extend the display to over 600°C. For example, "+2" in the alphanumerics and "100.000°C" in the display equal 300°C.

For the 8520A Fahrenheit display, adders of "1" through "9", "A", and "B" extend the display to 1200°F. "A" equals 10, and "B" equals 11. For example, "A" in the alphanumerics and "152.512" in the display equal 1152.512°F.

For the 8520A Kelvin display, adders of "1" through "8" extend the display to 900K. For example, "+4" in the alphanumerics and "126.187" in the display equal 526.187K.

Table 4. Instruction Set

FUNCTION

V	VDC
VA	VAC
VC	DC+AC V
Z2	2 Term OHMS
Z3	Nano Siemens
Z4	4 Term OHMS

"R3R7D8F5M0N5," is performed also.

Z3 performs "R4D8F5M0N5,"

RANGE

R0	100 mVDC, 10 OHMS
R1	1 VOLT, 100 OHMS
R2	10 VOLT, 1000 OHMS
R3	100 VOLT, 10K OHMS R4, R5, R6=Hi Ohms
R4	1000 VOLT, 100K OHMS 100 nSiemens
R5	AUTO VOLT,1M OHMS
R6	AUTO VOLT, 10M OHMS
R7	AUTO RANGE
R8	FIX RANGE

When in ohms and the reading rate is faster than D6, R4 thru R6 will be converted to R3.

TRIGGER

T0	Internal trigger (continuous)
T1	External trigger

PROGRAMS IN USE/OFF

M0	Programs off
M1	Programs "IN USE"

READING RATE

DC volts and Low Ohms

	Readings/second			deflt filter
D0	ASYNChronous			F0
	400Hz	60Hz	50Hz	
D1	228	240	200	F0
D2	114	120	100	F0
D3	57	60	50	F1
D4	38	40	40	F1
D5	19	20	20	F2
All functions and ranges				
D6	9.5	10	10	F3
D7	4.8	5	5	F4
D8	1.9	2	2	F5
D9	1	1	1	F6
	Readings/minute			
D10		30		F6
D11		12		F6
D12		6		F6
D13		2		F6
D14		1		F6
	Readings/hour			
D15		30		F6
D16		12		F6
D17		6		F6
D18		2		F6
D19		1		F6

400 Hz is .03% fast for reading rates slower than 2/sec.

Note that the "D" command changes the filter.

When in ohms and R4 thru R6, D0 thru D5 are converted to D6.

FILTER

	DC volts : Lo Ohms :	AC volts DC+AC	: Hi Ohms : nSiemens
F0	5mSEC	100mSEC	FAST
F1	25mSEC	100mSEC	FAST
F2	50mSEC	100mSEC	FAST
F3	100mSEC	100mSEC	FAST
F4	200mSEC	200mSEC	FAST
F5	500mSEC	500mSEC	FAST
F6	1000mSEC	1000mSEC	SLOW

FAST = 300mSEC max

SLOW = 4000mSEC max

Table 4. Instruction Set (cont)

BURST MEMORY CONTROL

Bn Burstsize = n; max n = +/–999
GMn Transmit memory location
max n = +/–999
Wn/m Transmit memory from n to m
max n,m = +/–999
Yn/m Scan memory from n to m
(W and Y perform selected math if 'M1' is active)

PROGRAMS

P0	"NONE" program	*
P1	TEST	*
P2	ZERO	
P3	EXTERNAL REFERENCE	
P4	OFFSET, SCALE, RATIO	
P5	PERCENT DEVIATION	
P6	PEAK VALUES	
P7	LIMITS	
P8	STATISTICS	
P9	LF RMS	
P10	DB RATIO	
P11	RTD TEMP CONVERSION	
P12	80T-150 C PROBE	
P13	80T-150 F PROBE	
P14	THERMISTOR CONVERSION	

Pabc = up to 3 programs allowed
* may not be grouped
P11, 12, 13, 14,should not be grouped with each other.

MATH PROGRAM REGISTERS

GRr	Transmit register r
KRr/v	Keep data v in register r

STATUS

GF	Transmit full status
GS	Transmit short status
KEs	Keep 's' as error response
KVs	Keep 's' as overrange response

IMMEDIATE CHARACTERS

*	Reset to default state
%	Force 8520 to look at command buffer and clear 8520 output buffer
&	Clear serial poll "rsv"

*,% both output one byte to 488 bus

TERMINATOR COMMANDS

,	Execute command string
?	Execute, trigger, and transmit
!	Execute, arm BNC trigger, and transmit

MISC CONTROL

x=N or I (i.e. N1 or I1)

x1	Front panel on/off
x2	Filter timeout on/off
x3	Linefeed yes/no
x4	ASCII/binary
x5	Normal/High speed
x6	EOI on/off
x7	Lock/Unlock reading transfer

SERIAL POLL

Si jkm Enable serial poll option
0001 Output ready, Overrange, Error
0002 Overrange
0004 Error
0010 End of burst
0020 New high peak
0040 New low peak
0100 Reading HIGH
0200 Reading PASS
0400 Reading LOW
1000 LFAC reading ready
2000 undefined
4000 undefined
Acceptable forms
Sm, Skm, Sjkm, Sijkm
S1=S01=S001=S0001
Add options for multiple SRQ
S11=Output ready, end of burst

CHANGING THE DISPLAY FAHRENHEIT OR KELVIN

The temperature is displayed in degrees Celsius after any setup or default procedure. With the 8520A DMM displaying degrees Celsius, a change to a Fahrenheit or Kelvin display can be specified. The following procedure is used for this change:

1. Initiate the display change by pressing:

   [SHIFT] [.] [1] [SELECTION]

2. For degrees Fahrenheit; press:

   [1] [5] [.] [1] [DATA]

3. For Kelvin; press:

   [1] [5] [.] [2] [DATA]

   A Celsius display can be resumed by pressing:

   [SHIFT] [.] [1] [SELECTION] [1] [5] [.] [0] [DATA]

OPERATION BEYOND 3500C (662°F)

CAUTION

The PRT may be damaged at high temperatures. Before using the PRT beyond 350°C, refer to Deterioration of PRT Calibration (Ro Increase) in the Theory of Operation section of this addendum.

The 8520A DMM encounters a range point at 250 ohms. This point, which approximates 350°C (662°F or 623K), causes an "Err03" message in the 8520A display. Further operation requires computation of a new gain figure. No offset change is required. Proceed as follows:

1. Place the PRT in a calibrated ice bath. The 100-ohm standard resistor is used if PRT calibration has not deteriorated since the last ice bath calibration.

2. Select the 1,000Ω (manual) range.

3. Complete the Compute and Enter Gain procedure previously defined.

Reading PRT Serial Number

Because the PRT and the 8520A DMM are shipped as a set, the serial number for this PRT is stored in the 8520A DMM memory and is checked by pressing:

[SHIFT] [1] [6] [SELECTION]

THEORY OF OPERATION

Temperature Calculation

The PRT resistance varies with temperature. The 8520A microprocessor uses this relationship in computing the temperature from a measurement of the PRT resistance. For positive temperatures, the equation in Figure 4 titled Temperature Calculation is used.

The following IPTS68 equation is used for positive temperatures from 0°C to 630°C:

$$\frac{R_t}{R_o} = W(t) = 1 + \alpha \left[t' - \delta \left(\frac{t'}{100}\right) \left(\frac{t'}{100} - 1\right) \right]$$

1. $t' = t_{90} + 0.045 \frac{t'}{100} \left(\frac{t'}{100} - 1\right) \left(\frac{t'}{419.58} - 1\right) \left(\frac{t'}{630.74} - 1\right)$

2. R_t is the PRT resistance at temperature to C.

3. R_o is the PRT resistance at ice point 0°C.

4. Alpha (α) and Delta (δ) are calibration parameters.

5. For negative temperatures (0°C to -200°C) an approximation to IPTS68 is used.

6. Calculation error is less than 1Ω mK.

NOTE: IPTS68 means International Practical Temperature Scale of 1968. For more information refer to Monograph 126 from the National Bureau of Standards (U.S.).

Figure 4. Temperature Calculation

Registers

Program #15 stores all register information for the PRT. Once program #15 is selected (1 5 SELECTION), the 8520A display responds with:

15=PRT

Then begins prompting with register r15.8. Any other register (x) can then be selected with the sequence:

SHIFT	1	5	.	X	SELECTION

The registers are identified in Table 5, Program Registers.

1. The raw measured value of resistance (R't) is adjusted for offset:

   $Rt = R't - r15.8.$

2. The gain error is adjusted by recalculating:

   $$Ro = r15.3 - \frac{r15.9}{2.5}$$

   r15.9 is converted to resistance:

   OC, 1 mQ = 2.5 mK

Thus:

$$W(t) = \frac{R(t)}{Ro} = \frac{R'(t) - r15.8}{r15.3 - \frac{r15.9}{2.5}}$$

Table 5. Program Registers

REGISTER NUMBER	RIGHT DISPLAY	DESCRIPTION	FORMULA	DEFAULT VALUE
r15.0	°C	PRT Degrees Celsius	T	0
r15.1	°F	PRT Degrees Fahrenheit	1.8T + 32	0
r15.2	°K	PRT Degrees Kelvin	T + 273.15	0
r15.3	RO	PRT resistance	RO	100
r15.4	ALPH	Alpha	$\frac{R100 - RO}{100(RO)}$	
r15.5	DELT	Delta	$\frac{At^1-[(Rh/Ro)-1]}{A[(t^1/100)-1][t^1/100]}$	
r15.6	A4			
r15.7	C4			
r15.8	mVOF	Offset		
r15.9	GAIN	Gain		

1. The raw measured value of resistance (R^1t) is adjusted for offset: $Rt = R^1t$ - r15.8.

2. The gain error is adjusted by recalculating:

$$Ro = r15.3 - \frac{r15.9}{2.5}$$

(r15.9 is converted to resistance: at 0°C, 1 mΩ = 2.5 mK)

Thus:

$$W(t) = \frac{R(t)}{Ro} = \frac{R^1(t) - r15.8}{r15.3 - \frac{r15.9}{2.5}}$$

Error Analysis

An understanding of error analysis is essential in achieving accurate temperature measurements. The following paragraphs outline possible error sources and cures.

ZERO OFFSET ERRORS

All three of the following zero offset errors must be considered. Subsequent adjustments for linear and nonlinear errors become invalid if zero offset errors have not first been compensated for. For example, if zero offset is not corrected, adjusting gain at ice-point creates large errors at other temperatures.

Offset Error (8520A)

The user of any digital multimeter may encounter a significant offset error. For example, an offset of only a few microvolts on the 100-mV range could signify a noticeable error. With the 8520A, the offset is measured and entered in software (register r15.8). This procedure is described in the Theory of Operation section of this addendum. The offset entry is then subtracted from subsequent PRT measurements.

Some additional (but temporary) offset error occurs when the 8520A function is changed between dc volts and ohms. This action energizes a reed relay, generating thermal emfs at the relay contacts. Offsets caused in this manner disappear within 10 minutes.

Thermal EMF (PRT)

A thermal emf of several microvolts may appear at the 8520A input if a temperature gradient of several degrees is present from the probe tip to 4 inches. This error can be detected by a comparison. With the probe and bath temperature equalized, compare the offset of the standard resistor (applied to the front inputs) with that of the PRT (connected to the rear inputs).

EMI Pickup

The PRT cable is shielded and properly guarded to minimize EMI pickup. However, strong microwave radiation can cause induced emfs to appear as a fluctuating offset error. This problem must be cured by changing the proximity of the PRT to the radiation source.

8520A DMM ERRORS

Component instability with changes in time and temperature cause the majority of 8520A DMM errors. Time instability is unavoidable. Temperature instability is caused by the difference between ambient temperatures at calibration and operation. This difference can be minimized.

Scaling Error

A scaling error is defined as a linear time and temperature instability. Compensation for scaling error can be made using software register r15.9. Therefore, scaling error does not affect the thermometer accuracy specifications.

Non-Linear Error

Software compensation is not made for non-linear time and temperature instability. Therefore, about half of the accuracy specification (stated in terms of time and temperature change since calibration) result from non-linear error.

PRT ERRORS

Normal PRT Error (Repeatability)

Repeatability defines the ability of the PRT to return to the same bath resistance value when repeatedly placed in and out of a constant temperature bath. The thermometer accuracy specification incorporates this repeatability to the equivalent of 3 mK (0.003°C). The probe thermal history in between returns to the bath affects the actual repeatability specification.

Normal PRT Error (Hysteresis)

All PRTs exhibit hysteresis during temperature changes. The cycle of change for the PRT must be within the range of operations (–200°C to +400°C). The Rosemount 162N exhibits hysteresis of less than 0.001% of the temperature span. The worst case hysteresis error (at mid-span) is incorporated in the thermometer accuracy specification.

PRT Calibration Error

The Rosemount 162N probe is calibrated against a primary standard PRT (SPRT). The thermometer accuracy specification incorporates any uncertainties resulting from this calibration.

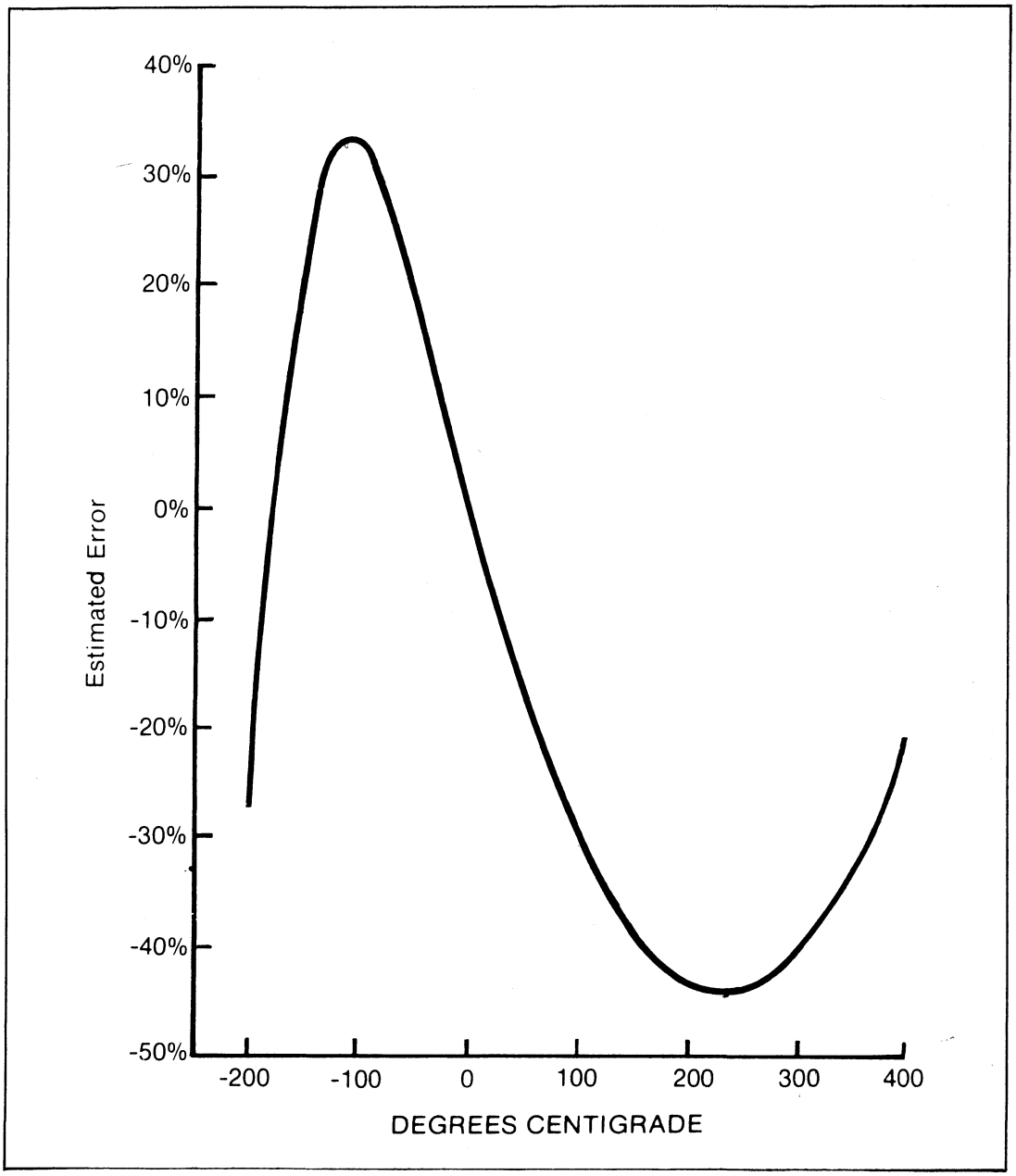

Figure 5. Estimated Errors as Percentage of R_0 Increase

Deterioration of PRT Calibration (Ro Increase)

Constant exposure to high temperature causes irreversible change to the PRT. Resistance at ice point (Ro) is most noticeably affected. Constant immersion at 400°C can produce an Ro increase equivalent to 25 mK/100 hr. For example, after 300 hours, Ro may indicate 0.075°C at ice point. Although this Ro increase is cumulative, a leveling off after the initial 500 hours is commonly observed. Exposure to temperatures greater than 400°C causes more severe Ro increases.

Severe mechanical shock to the platinum molecular lattice also increases Ro. The amount of change depends on the magnitude of the shock. The metallic sheath on the PRT makes the PRT appear more rugged than it actually is. Extreme caution in handling the PRT cannot be over emphasized. The platinum molecular lattice in the PRT is actually more delicate than glass.

Software compensation (r15.9) can be made for an increase in Ro. However, most incidences of Ro increase are accompanied by changes in Delta, Alpha, A4, and C4. These changes can only be eliminated by PRT recalibration.

Deterioration of PRT Calibration (Delta, Alpha, A4, C4 Changes)

The magnitude of the Ro increase is used to predict maximum errors due to accompanying changes in Alpha, Delta, A4, and C4. However, this relationship varies greatly from probe to probe and cannot be considered predictable. Figure 5 graphs the estimated error envelope as a positive or negative percentage of the Ro increase. For example, a 100-mK increase in Ro may produce a -45 mK error at 240°C. The worst error percentage occurs around -110°C and +240°C.

Self-Heating Effect

The Rosemount 162N Probe is calibrated in a liquid bath. There is no significant error due to self-heating if a similar (liquid) medium is used. If a gaseous medium is used, a +12 mK error must be added.