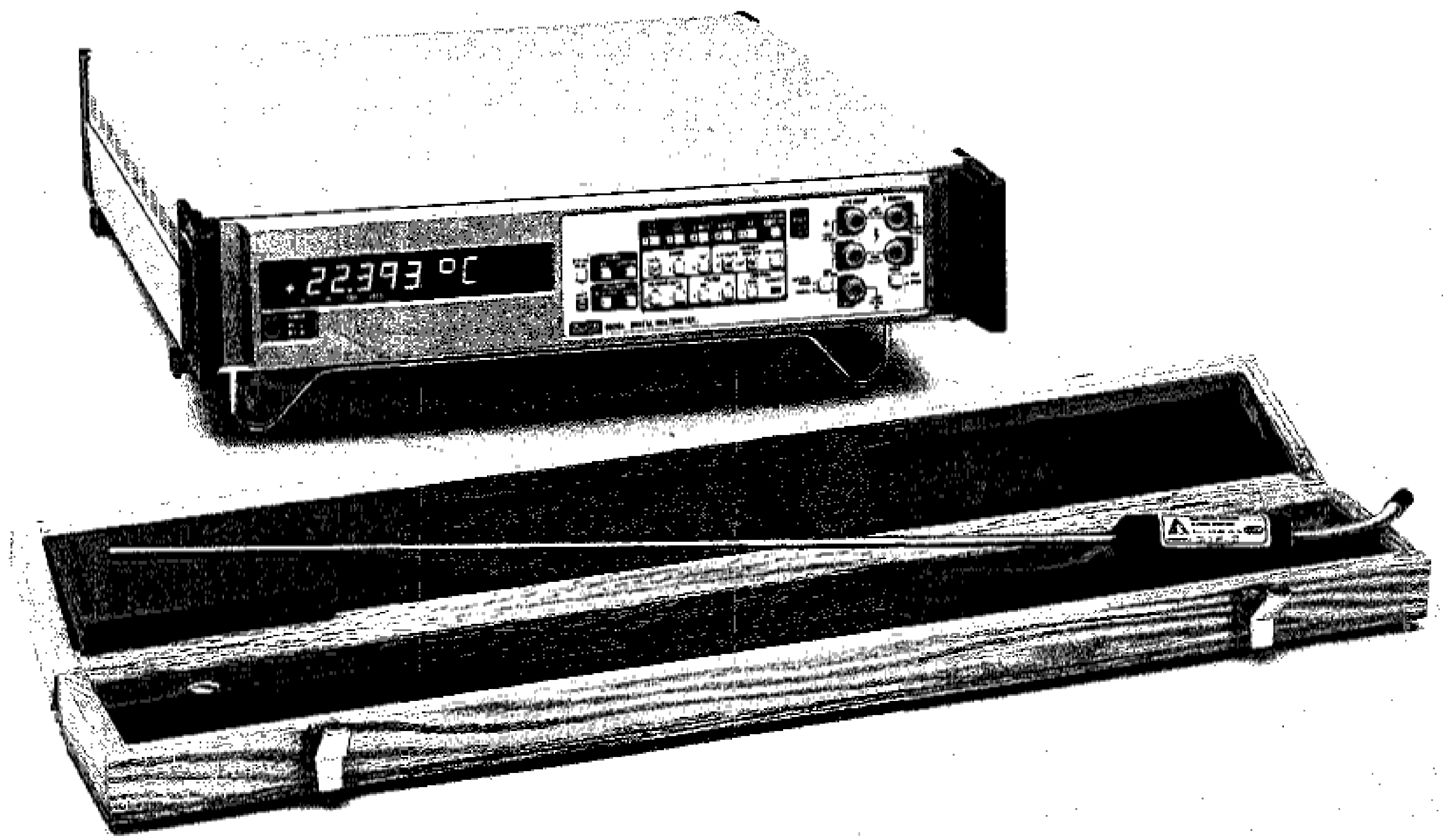
FLUKE®

8520A/PRT

Precision Temperature System

- IEEE-488
- .001°C resolution
- .010°C to .040°C system accuracy
- -200°C to +350°C (IPTS68) range



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Thank you for your cooperation, and for your interest in Fluke.

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The Fluke 8520A/PRT (Platinum Resistance Thermometer) combines high-resistance measurement accuracy with powerful on-board math capability to dramatically reduce the cost of making precision laboratory temperature measurements.

With this system, we've eliminated the painstaking time and skill formerly required when using balance bridges for high-precision temperature measurements. The 8520A performs all the analysis and provides outputs with a direct digital display. All of this makes laboratory precision much more affordable and, for the first time, makes high-precision temperature measurement practical for any R&D or process and production application.

The 8520A/PRT includes the 8520A precision digital multimeter with the Rosemount 162-Series Platinum Resistance Thermometer in one easy-to-order calibrated unit. Or add the Fluke 1720A Instrument Controller and 2204A-06 Low Thermal Scanner for a complete temperature data acquisition system that can be tailored to any application. Contact your local Fluke representative for more information on integrating the 8520A/PRT into your specific application.

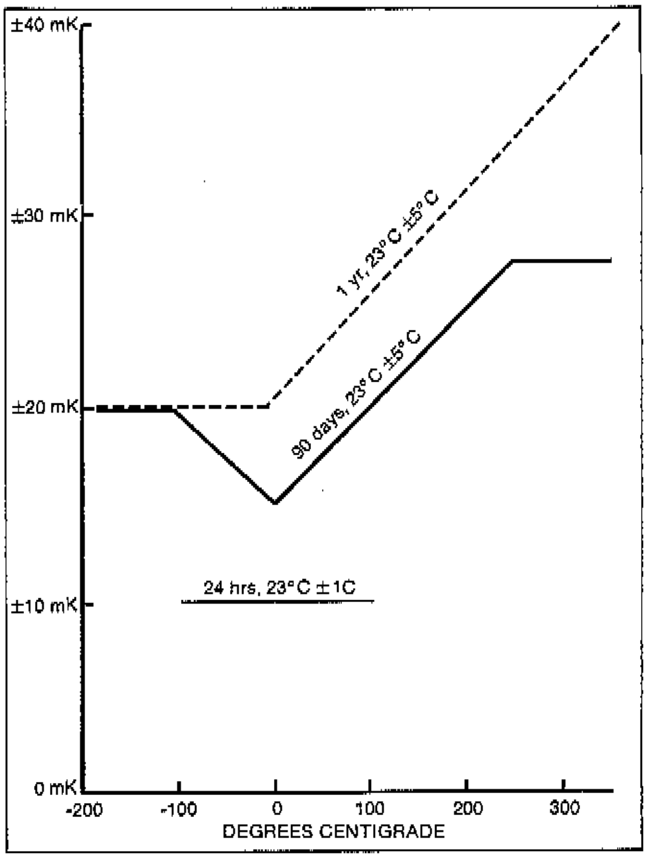


Table 1. 8520A/PRT specifications

I. Operation Instruction

1.0 Hardware

The calibration seal on the PRT wooden box secures the calibration integrity from the laboratory to the user. The PRT is a delicate precision instrument and PRT should be left in its box or securely fastened in a temperature bath; not laying on a work bench.

Note: Fluke is not responsible for damages to the PRT due to physical abuse. Any tapping or knocking will produce adverse effects. A blow or drop onto a hard surface constitutes abuse. For details see Section II, 2.10.

Break the calibration seal and take out the green rear input connector at the end of the PRT cable, leaving the PRT in its box. Connect this to the 8520A rear analog input. Mount the PRT into the temperature bath when ready.

Plug in the standard 100-ohm resistor to the 8520A front input. Connect power cord to 8520A and power on. A warm-up period of 2 hours is needed for full accuracy.

2.0 Record Sheet and Programming Instruction

Example:

Date	Offset, mV r15.8	Std. Temp. °C (a)	Indicated Temp. °C (b)	Gain °C (a)-(b)=r15.9
3-1-81	-0.008 (See Sec. I, Para. 3.1)	0.000°C	-0.0054°C	+0.0054°C (See Sec. I, Para. 3.2)

It is essential to keep a simple daily record of the thermometer. The record will help keep the thermometer within specification. A suggested format is included above. Given the proper information on the record sheet (see Section I, Para. 3 and 4), the thermometer can be easily set up within specification by the following instruction sequence:

1. [4-wire]
   Select 4-wire ohms function.
2. [auto range]
   Down range to 100-ohm range, as indicated on display.
3. [Δ Filter]
   Increase filter time to maximum 1000 ms, as indicated on display.
4. [Shift]
   Change front panel button definition for programming.
5. [1] , [5] , [Selection]
   Select program 15. Display will prompt "15=PRT" and then "r15.8=mVOF".
6. [-] , [.] , [0] , [0] , [8] , [Data]
   Input offset of -0.008 mV to register r15.8 (see sample record above, column 2). Next, display will prompt "r15.9GAIN".
7. [.] , [0] , [0] , [5] , [4] , [Data]
   Input gain of 0.0054° C to register r15.9. (See sample record above, column 5)
8. [Program in use]
   LED comes on, thermometer is ready.

3.0 Using Ice Bath to Determine Offset and Gain

Use a calibrated ice bath, e.g. Rosemount 911A, guaranteed to within 2 mK (0.002° C). Immerse PRT into bath at least four inches (Section II, 2.2). Use rear input on 8520A. This procedure is needed initially and periodically thereafter (See Section II, 2.0).

3.1 Determine Offset

1. [VDC]
   Select dc volts function.
2. [auto range]
   Down range to 100 mV range, as indicated on display.
3. [Δ Filter]
   Increase filter time out to 1000 ms, as indicated on display.

Take the average of the digital rattle as offset and write down on record sheet, column 2.

3.2 Determine Gain

Follow sequence in Section I, 2.0, from Step 1 through Step 6. Use the value of offset previously determined in Section I, 3.1. Next step:

1. [0] , [Data]
   Register r15.9 at zero.
2. [Program in Use]
   LED comes on.

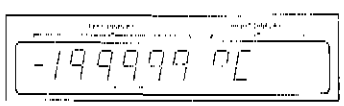
Observe the temperature display and estimate the average of the digital rattle. Write down the average indicated temperature on record sheet, column 4. The gain (column 5) is determined by subtracting the indicated temperature from the standard temperature (column 3), which is 0.000° C for ice bath.

4.0 Using Standard Resistor to Determine Offset and Gain

Under some conditions[1], a standard 100-ohm resistor can be substituted for ice bath calibration (see Section II, 2.0). Immediately following an ice bath calibration, input the determined offset and gain to r15.8 and r15.9 (see Section I, 2.0). The average display should indicate 0.0000° C with same digital rattle in the least significant digits. Switch the input from rear to front where the standard resistor is. Write down the temperature on column 3 as the standard temperature for future use. In the future, determine offset and gain by following Section I, 3.1 and 3.2.

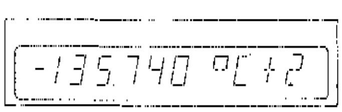
5.0 Temperature Display

5.1 From -19.9999 to +19.9999, four decimal places are displayed. The extra digit may help in determining gain error (Section I, 3.2) within 1/2 mK (0.0005° C) by "eyeball" averaging or arithmetical averaging using 8520A-010's statistic program P8 or instrument controller, like Fluke 1720A. For example, -19.9999° C appears as



5.2 All other temperatures carry three decimal places. When temperature is over 200° C, the most significant digit is displayed with the help of the last two alphanumeric LED's. For example, 200.001° C appears as

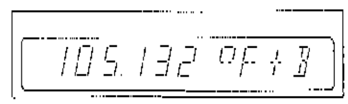
The last alphanumeric LED represents 1x100 degrees. For example, -350.740° C appears as



(1) The assumption is that the PRT calibration has not deteriorated since the last ice bath calibration.

When the temperature is over 1100° F, the last alphanumeric LED shows 10 as A and 11 as B (hexadecimal). For example, -1152.512° F appears as

and +1205.132° F appears as



5.3 Optional Display in ° F or K

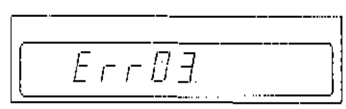
After the 8520A is totally set up (see Section I, 2.0) and displaying temperature in ° C, the scale can be changed to ° F or K by following the sequence:

[Shift] , [0] , [.] , [1] , [Selection]

either [1], [5], [.], [1] for ° F
or [1], [5], [.], [2] for K } , [Data]

6.0 Operation Beyond 350° C (662° F)

The 8520A has a range point at 250 ohms which is approximately equivalent to a temperature of 350° C. Beyond 350° C, an error message will appear as



To continue, one must re-setup the 8520A using the 1000-ohm range instead of 100-ohm range in Section I, 2.0, Step 2, and 3.2. The offset remains the same but the gain has changed. The user is cautioned against the possibility of damaging the PRT at these high temperatures (see Section II, 2.9 and 2.10).

II. Theory of Operation

1.0

1.1 The temperature of the PRT is calculated from resistance measurement by the Z-80 microprocessor in the 8520A. For positive temperatures from 0° C to 630° C, the following IPTS682 equation is used.

$$\frac{R_t}{R_o} = W(t) = 1 + \alpha\left[t' - \delta\left(\frac{t'}{10}\right)\left(\frac{t'}{100} - 1\right)\right]$$

where $t' = t - 0.045\frac{t'}{100}\left(\frac{t'}{100} - 1\right)\left(\frac{t'}{419.58} - 1\right)\left(\frac{t'}{630.74} - 1\right)$

and R_t is the PRT resistance at temperature t° C.

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

α (Alpha) and δ (Delta) are calibration parameters. For negative temperatures from 0° C to -200° C, an approximation to IPTS68 is used. The calculation error is less than 1 mK.

1.2 Registers

r15.0	Display in °C	
r15.1	Display in °F, r15.1 = 32° + 9/5 r15.0	
r15.2	Display in K, r15.2 = 273.15° + r15.0	
r15.3	R_o ohm	Calibration constants, default value correspond to a specific PRT
r15.4	α Alpha	
r15.5	δ Delta	
r15.6	A_4	
r15.7	C_4	
r15.8	Offset mV	
r15.9	Gain °C	

The raw measured value of resistance R'(t) is adjusted for offset, R(t) = R'(t) - r15.8. The gain error is adjusted by recalculating $R_o = r15.3 - \frac{r15.9}{2.5}$

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

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

(Note) IPTS68 means International Practical Temperature Scale of 1968. For reference see Monograph 126 from National Bureau of Standards (U.S.).

This value is converted to t using IPTS68 equations, in Section II, 1.0.

When program 15 is selected, prompting begins with registers r15.8. Any other register can be selected by the sequence:

[Shift], [1], [5], [.], [x], [Selection]

2.0 Error Analysis

To achieve accurate temperature measurements to within a few hundredth of a degree requires strict adherence to proper procedures and an understanding of error analysis. The following is a brief outline of this thermometer's possible error sources and their remedies. The 8520A/PRT should not be operated without first reading the following.

2.1 Offset Error of 8520A

The input signal from a current of 1 mA running through a resistor of around 100Ω is only 100 mV. All digital multimeters will have possible significant offset error of a few microvolts (10^{-6}V). The offset is determined by shorting the 8520A input. In the 100 mV dc mode, the input impedance is over 10^{10} ohm. A 100-ohm resistor will essentially serve as an input short. This offset error should be less than ±10 uV and changes very slowly from week-to-week. A recalibration of the 8520A will diminish this error. Since we can compensate for it in software (r15.8), this will not impact the thermometer's accuracy (see Section I, 2.0, column 2 of record sheet).

A function change in the 8520A from dc to ohms (or vice versa) requires energizing a reed relay, causing temporary thermal e.m.f. at the contacts. These microvolts of offset will disappear within 10 minutes as the reed relay cools off.

2.2 Thermal e.m.f. from PRT

If the tip 4 inches of the probe has a temperature gradient of a few degrees, a thermal e.m.f. of a few microvolts may be present at the 8520A input. This error can be detected by comparing the offset at the front input with the standard resistor, versus the rear input with the PRT. One must wait until the probe and the bath both come to an even temperature before valid measurements can be made.

2.3 EMI Pickup
Even though the PRT cable is shielded and properly guarded, strong microwave radiation can cause induced e.m.f.'s, appearing as fluctuating offset error. Such source of radiation must be removed.

2.4 This completes all zero order errors in the thermometer. Failure to make valid adjustment for any of these error sources will invalidate all following adjustments for linear and nonlinear errors. It is important to realize that the different orders of error cannot compensate for each other. For example, if one ignores offset, adjusting for gain at ice point will create large errors at other temperatures. (This is a common mistake among industrial grade thermometers.) Procedure in Section I, 2.0 and 3.0 is valid only if offset is adjusted before gain.

2.5 Scaling Error of 8520A
Typically, the bulk of DMM errors are scaling errors due to component instability over time and temperature (i.e. the temperature difference between the room temperature at calibration and the ambient temperature at operation). Time instability is unavoidable. The ambient temperature change may be minimized. Since this scaling error can be compensated by software (r15.9), there is no impact on the thermometer's accuracy (see Section I, 2.0, column 5 of record sheet).

2.6 Non-linear Error of 8520A
Component instability over time and temperature also creates non-linear error that software cannot compensate for. About half of our accuracy specification results from these errors. For this reason, our specifications are stated in terms of time and temperature changes from calibration (i.e. 24 hrs ±1°C, 90 days, ±5°C and 1 yr., ±5°C).

2.7 Normal PRT Error, Repeatability
If the probe is taken in and out of a constant temperature bath repeatedly, the PRT resistance while inside the bath will be guaranteed to return to the same value within a narrow range of the equivalent of 3 mK (0.003°C). This is a statement of the high quality of the 162N Probe. The actual repeatability depends on the thermal history in between the returns to the bath. However, the maximum 3 mK repeatability error is incorporated into the accuracy specification of the thermometer.

2.8 Normal PRT Error, Hysteresis
All PRT's exhibit hysteresis during temperature cycles (e.g. from -200°C to +400°C and back to -200°C). The worst error occurs at the middle of the temperature span (at 100°C in the previous example). The 162N will have hysteresis less than 0.001% of span (less than 6 mK in the example). This is also a statement of quality, unachievable in any industrial PRT. The temperature cycle must be within the range of operations, -200°C to +400°C. The worst case of hysteresis error is incorporated in the thermometer's accuracy statement.

2.9 Calibration Error of PRT
All 162N Probes are calibrated against primary standard PRT (SPRT). The resultant uncertainties, due to resistance bridge measurements and bath media instability, etc., are incorporated into the thermometer accuracy specification.

2.10 Deterioration of PRT Calibration, R_0 Increase
Constant exposure to high temperature will produce irreversible changes to the PRT, most noticeably in the resistance at ice point, R_0. Constant immersion at 400°C can produce R_0 increase, equivalent to 25 mK/100-hr. (e.g. after 300 hrs. at 400°C, the R_0 may indicate 0.075°C at ice point). These changes are cumulative even though a leveling off after an initial 500 hours is commonly observed. Any exposure to temperature greater than 400°C will cause similar, but more severe, error.

Severe mechanical shock to the platinum molecular lattice will also produce R_0 increases. The amount of change is dependent on the magnitude of shock. While the 162N is somewhat more rugged than the 162CE SPRT allowing it to be moved around more freely, the delicacy of these platinum lattices cannot be overemphasized. The rugged metallic sheath can be misleading. The PRT is actually more delicate than glass. (Rugged PRT's are inherently inaccurate.)

The error due to an R_0 increase can be compensated for software (r15.9) as gain error (see Section I, 2.0, column 5 of record sheet). However, most incidences of R_0 increases are accompanied by changes in Delta, Alpha, A_4 and C_4, which can only be eliminated by PRT recalibration. The R_0 increase is the same as the decrease in standard temperature, represented by the 100-ohm resistor (column 3 of record sheet) between ice bath calibration.

The deterioration of calibration is entirely the responsibility of the user.

2.11. Deterioration of PRT Calibration, Delta, Alpha, A_4 and C_4 Changes

Depending on the magnitude of the R_o increase, one may predict with some certainty the maximum errors due to the accompanied changes in Alpha, Delta, A_4 and C_4. However, the actual change varies greatly from probe-to-probe, not predictable at the factory. The worst error occurs around -110° C and +240° C. The estimated error envelope is graphed in Table 2, in percentage of R_o increase, e.g. a 100 mK increase in R_o may produce a -45 mK error at 240° C. The 90-day specification for 90 days at 240° C of ±25 mK will be degraded to +25 mK and -70 mK.

2.12 Self-Heating Effect

The 162N Probe is calibrated in liquid baths. There would be no significant error due to self-heating unless the media is not liquid. A +12 mK error should be added if a gaseous media is used.

Ordering Information

8520A/PRT *$5,995*

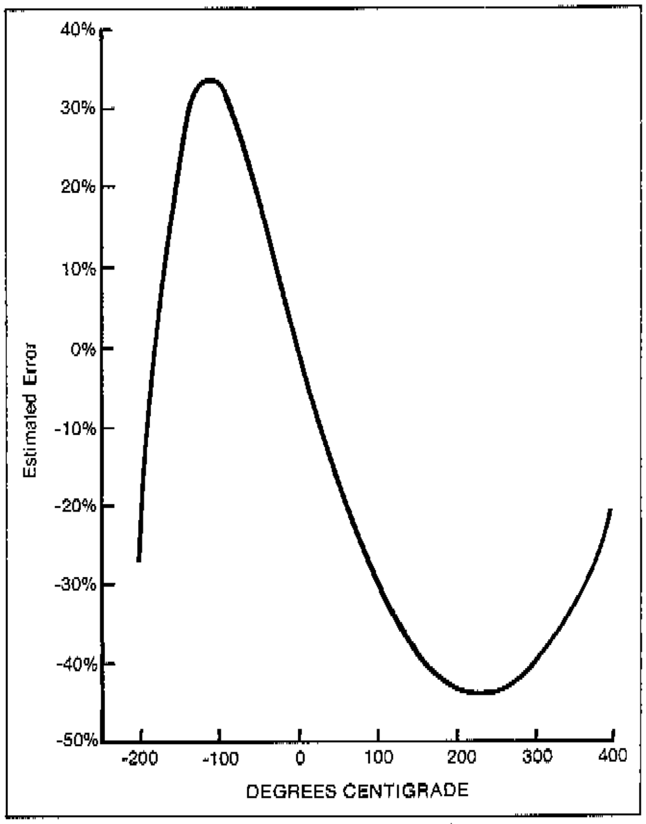


Table 2. Estimated error as percentage of R_o Increase