FLUKE®

Calibration

5698

Working Standard Platinum Resistance Thermometer

Users Guide

2004, Rev. 1, 4/11

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Introduction

General

The Fluke Working Standard Platinum Resistance Thermometer (SPRT) is designed to be the best primary standard interpolating instrument converting resistance to temperature. With full calibration options, ITS-90 coefficients can be used with your 1594A/1595A Super-Thermometer, 1560 Black Stack, or the 1529 Chub-E4 Thermometer readout. With drift rate typically around ±3 mK, this SPRT gets you from –200 °C up to 670 °C.

Each SPRT is carefully annealed at the appropriate temperatures and precisely tested for stability. Convection prevention discs are used to reduce stem errors caused by thermal radiation. The sensing element is fabricated using high purity platinum wire wound in a strain free design on a fused silica cross frame. A fused silica sheath is pressure sealed with a special argon/oxygen mixed gas and fitted with a terminal box handle with a strain relieved connection to the four wire cable. Gold plated spade lugs terminate the wires.

Application

The 5698 SPRT shown in Figure 1 is a working standard. A working standard is defined in terms of transfer of the ITS-90 from a standards laboratory to a customer's laboratory. Working standards are calibrated in a standards lab using known intrinsic values.



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Figure 1. 5698 Working Standard Platinum Resistance Thermometer

Calibration

In order for any instrument to be used as a standard it must be calibrated. The SPRT may be purchased calibrated or non-calibrated. Fluke has the capability of performing fixed-point calibrations traceable to NIST. The 5698 can be economically calibrated using the comparison method or any one of several fixed point calibrations matching ITS-90 subranges.

Calibration Options

In order for the SPRT to make accurate temperature measurements, it must be calibrated. Calibration can be attained through any recognized primary standard laboratory performing temperature calibrations. Fluke can provide either comparison calibration or fixed-point calibrations.

Recalibration

The recalibration of the SPRT should be scheduled according to the user's company Quality Assurance requirements. Generally, an SPRT is used over a specific range. The SPRT should be calibrated over the range applicable to its use. The SPRT should only be calibrated over its full temperature range if it is used over its full range. For information on recalibrating your SPRT, contact Fluke for assistance (see "How to Contact Fluke").

Before You Start

Symbols Used

Table 1 lists the International Electrical Symbols. Some or all of these symbols may be used on the instrument or in this manual.

Table 1. International Electrical Symbols

Symbol	Description	Symbol	Description
	Electric Shock	O	Off
	Hot Surface (Burn Hazard)	I	On
	Read the User's Manual (Important Information)		Fuse
	AC (Alternating Current)		Battery
	AC-DC	 N10140	C-TICK Australian EMC Mark
	DC		Canadian Standards Association
	Double Insulated	CE	CE Complies with European Union Directives
	PE Ground	**CAT II**	CAT II equipment is designed to protect against transients from energy-consuming equipment supplied from the fixed installation, such as TVs, PCs, portable tools, and other household appliances.

Safety Information

Use this instrument only as specified in this manual. Otherwise, the protection provided by the instrument may be impaired.

The following definitions apply to the terms "Warning" and "Caution".

- "Warning" identifies conditions and actions that may pose hazards to the user.
- "Caution" identifies conditions and actions that may damage the instrument being used.

⚠Warning

To avoid personal injury, follow these guidelines:

- **DO NOT use this instrument for any application other than calibration work. Use of the instrument outside the designed use may subject the user to unknown hazards.**
- **DO NOT use this instrument in environments other than those listed in the Users Guide. Use of the instrument in inappropriate environments may subject the user to unknown hazards or damage the instrument.**
- **Follow all safety guidelines listed in the Users Guide.**
- **Calibration equipment should only be used by trained personnel.**
- **DO NOT use this instrument to measure the temperature of any hazardous live component. Electric shock may occur.**
- **Use of this instrument at high temperatures for extended periods of time can cause the handle to become hot.**

⚠Caution

To avoid possible damage to the instrument, follow these guidelines:

- **DO NOT remove the label from the handle. The delicate nature of the instrument is described on the label.**
- **Read "Care and Handling Guidelines" before removing the SPRT from the shipping box or case. Incorrect handling can damage the SPRT and void the warranty.**
- **If the SPRT has been calibrated, follow the procedure outlined in "Verifying SPRT accuracy", (or your quality procedure) for verifying the accuracy of your SPRT before placing the instrument in service.**
- **DO NOT subject the SPRT to mechanical shock.**
- **Use of the SPRT at temperature greater than 500 °C requires a specified minimum cooling rate in order to prevent damage to the SPRT. Refer to "Cooling Rates at High Temperatures".**
- **Keep the shipping container in case it is necessary to ship the SPRT. Incorrect packaging of the SPRT for shipment can cause irreparable damage.**

Verifying SPRT Accuracy

⚠Caution

This section is applicable only if the SPRT has been calibrated.

Before using your SPRT, verify that its behavior has not changed significantly from the most recent calibration (as can sometimes occur from mechanical shock during shipping, for example). To verify your SPRT, check the SPRT at the triple point of water (0.01 °C) or in a well-constructed ice bath, by following these steps:

1. Connect the SPRT to a calibrated readout.
2. Properly prepare a triple point of water cell (TPW) or ice bath. Ensure that the SPRT is pre-chilled prior to measurement. Contact Fluke if assistance is required (see "How to Contact Fluke"). A triple of water cell is preferred. Ice baths should use distilled water and crushed ice made with distilled water in a Dewar flask or thermos bottle. The ratio of ice-to-water should be such that the mixture is firm after preparation.
3. Set your readout to read in ohms rather than temperature. Place your pre-chilled SPRT in the TPW or ice bath and allow it to stabilize. (Remember a TPW is at 0.01 °C and an ice bath is at 0 °C.)
4. If using a TPW cell, compare the resistance value on your readout with the resistance value at TPW given on the probe's certificate. If using an ice bath, compare the resistance value on your readout with the resistance indicated on the certificate for 0 °C. (You may have to use the SPRT's temperature versus resistance table to get the SPRT's calibrated resistance value at 0 °C.)
5. Considering the SPRT's uncertainty specification and the uncertainty of the thermometer readout, determine whether or not it is within tolerance, as specified in your quality requirements, of the data on its most recent Report of Calibration. If it is, it may be placed in service.

Fluke recommends that an SPRT be periodically checked against a standard such as a triple point of water cell (or well-constructed ice bath if an ITS-90 fixed-point standard is not available). The verification interval depends on how the SPRT is handled, how much it is used, and your documented experience with it. Your probe should also be checked any time you suspect it may have received mechanical shock or whenever its accuracy appears suspect.

How to Contact Fluke

To contact Fluke, call one of the following telephone numbers:

- Technical Support USA: 1-800-44-FLUKE (1-800-443-5853)
- Calibration/Repair USA: 1-888-99-FLUKE (1-888-993-5853)
- Canada: 1-800-36-FLUKE (1-800-363-5853)
- Europe: +31 402-675-200
- Japan: +81-3-3434-0181
- Singapore: +65-738-5655
- Anywhere in the world: +1-425-446-5500

Or, visit Fluke's website at www.fluke.com.

To register your product, visit http://register.fluke.com.

To see, print, or download the latest manual supplement, visit

http://us.fluke.com/usen/support/manuals.

Return Procedure

Note

Call Fluke for a return authorization prior to shipping the SPRT.

We recommend that a good TPW measurement be made before returning the SPRT to ensure stability. Extreme care must be taken when shipping an SPRT. Place the SPRT in the factory provided protective storage case. Be sure the case is latched securely. Place the protective case in the original manufacturer's wooden shipping crate or wooden crate with similar dimensions (44.5 in x 11.75 in x 11.75 in). Place soft insulation on all sides of the crate to cushion the SPRT against mechanical shock. The cover of the crate should be attached with screws. We recommend that you label the crate as extremely fragile. Whether the SPRT is returned for repair or warranty, please include a letter containing the following information:

- Description of the faulty operation and circumstances of failure.
- Complete shipping instructions for the return of the thermometer to the customer.

Specifications

See Table 1 for a list of the specifications.

Table 2. Specifications

Parameter	Range
Temperature Range	–200 °C to 670 °C
Nominal R_{tpw}	25.5 Ω (±0.5 Ω)
Current	1.0 mA
Resistance Ratios	W (234.315 K) ≤0.844235 W (302.9146 K) ≥1.11807
Sensitivity	0.1 Ω/°C
Drift Rate	<0.006 °C/100 Hours at Max Temperature (Typically <0.003 °C)
Diameter of Pt Sensor Wire	0.07 mm (0.003 in)
Protective Sheath	Fused Silica Glass Diameter: 7 mm (0.28 in) Length: 485 mm (10.1 in)
Lead Wires	Four Lead Wires

Construction

Construction of the 5698 is shown in Figure 2. The 5698 covers the range from –200 °C to 670 °C. The 25.5 Ω sensor element is crafted using high purity platinum wire wound in a strain free design on a fused silica cross frame. The 5698 has a sensitivity of 0.1 Ω/°C.

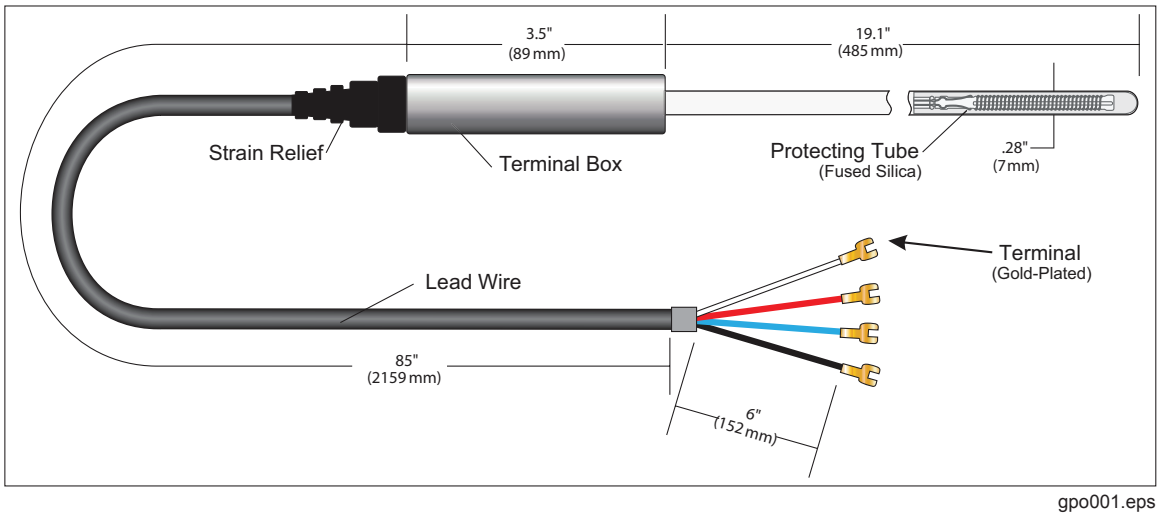


Figure 2. Standard Dimensions

Electrical Circuit

The SPRT is provided with a terminal box handle. The eight-foot cable has four Teflon coated wires enclosed in a silicon rubber jacket with a stainless steel spring strain relief. Gold plated spade lugs terminate the wires.

Installation

Environmental Issues

Primary standard equipment should be used in a calibration laboratory or other facility specifically designed for this purpose. Environmental requirements include:

- Stable temperature and humidity.
- Clean, draft-free area.
- Low noise level: low radio frequency, magnetic or electrical interference.
- Low vibration levels.

Mounting

Most often temperature standards, primary and secondary, are used to calibrate other temperature-sensitive equipment. Three representative applications are shown in the following figures:

- Figure 3. Liquid Bath Installation
- Figure 4. Water Triple Point Cell in an Ice Bath Dewar
- Figure 5. Fluke 9114 Metrology Furnace with SPRT in Fixed Point Cell

The SPRT must be mounted carefully to avoid any damage to the sheath or sensor. If the fluid bath used does not have a lid designed for SPRT insertion, clamps should be used to ensure the handle and cable are not immersed. If metal comparison blocks are used in the bath, maintain a close fit between the SPRT sheath and the well in the comparison block. However, allow for the thermal expansion and contraction of the SPRT sheath and block when determining block well tolerances.

For applications where the fluid in the bath is not compatible with the SPRT (example: salt), the SPRT can be slid into a thin walled metal sheath for protection. Ensure that the sheath is clean inside. The gap between the protective sheath and the SPRT should not be any larger than 0.08 mm (0.003 in).

At high temperatures, the SPRT is subject to metal ion contamination. If a metal equilibration block is used in a furnace above 700 °C, protective shielding such as thin wall platinum tubing or high purity ceramic is advised.

Lead Wire Identification

The SPRT is equipped with a four-wire cable (see Figure 6). Four lead wires are used to prevent measurement errors due to lead wire resistance. For proper measurement, the readout device should be equipped to handle four-terminal resistors.

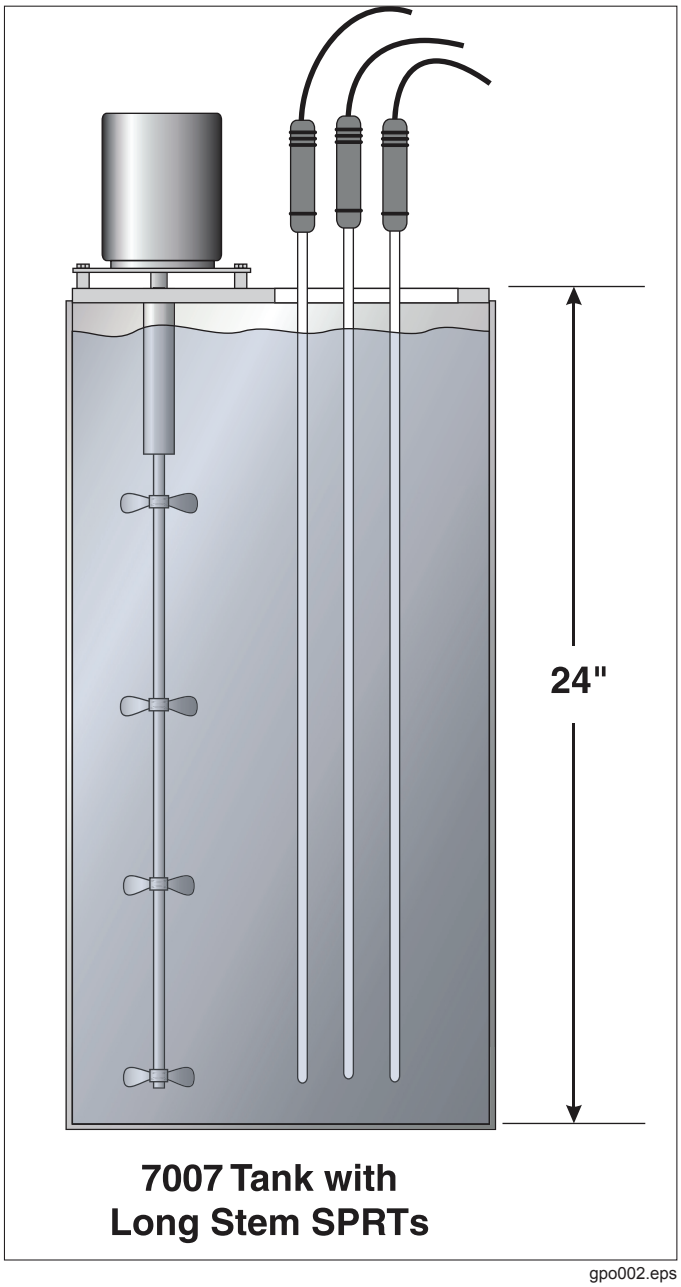


Figure 3. Liquid Bath Installation

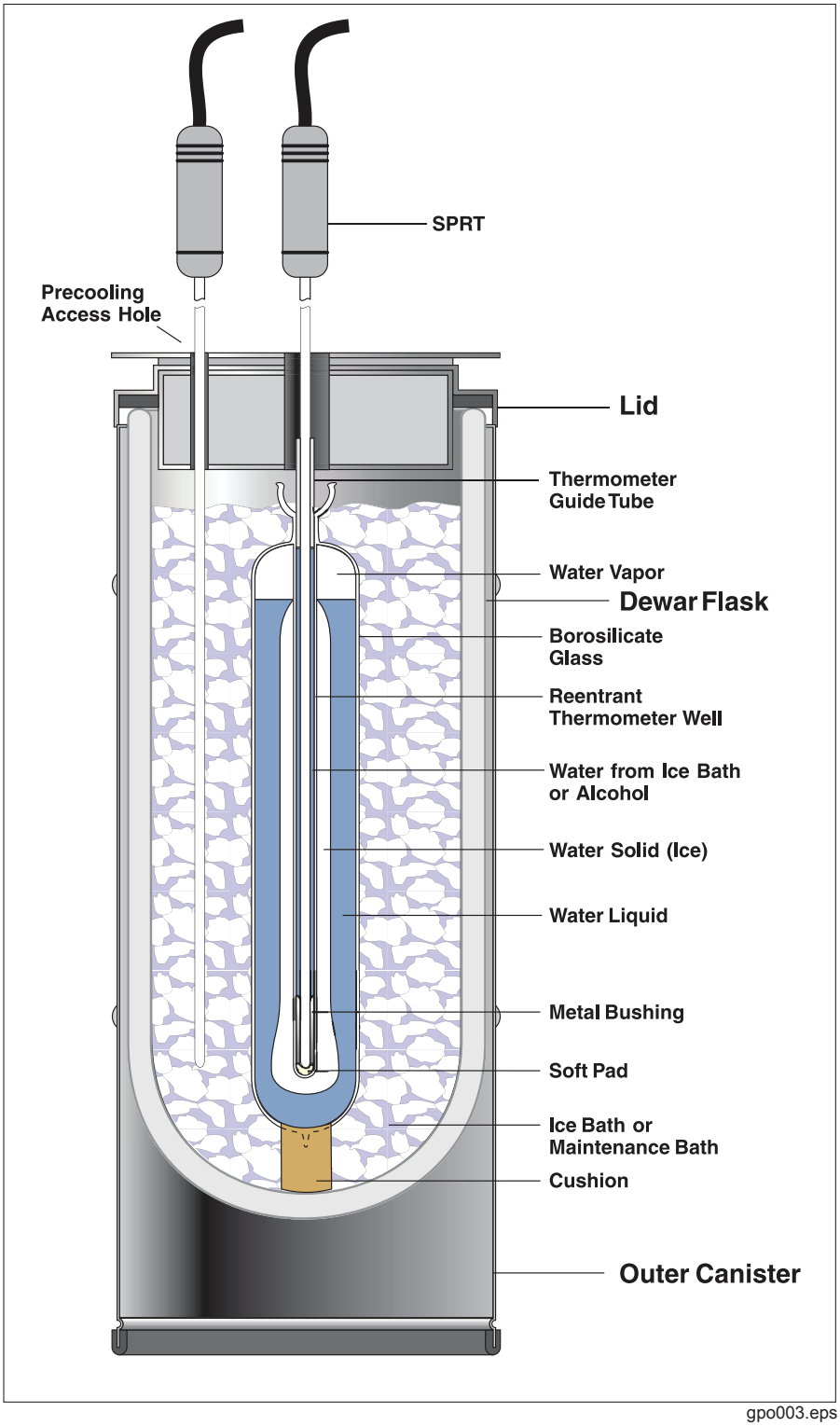


Figure 4. Water Triple Point Cell in an Ice Bath Dewar

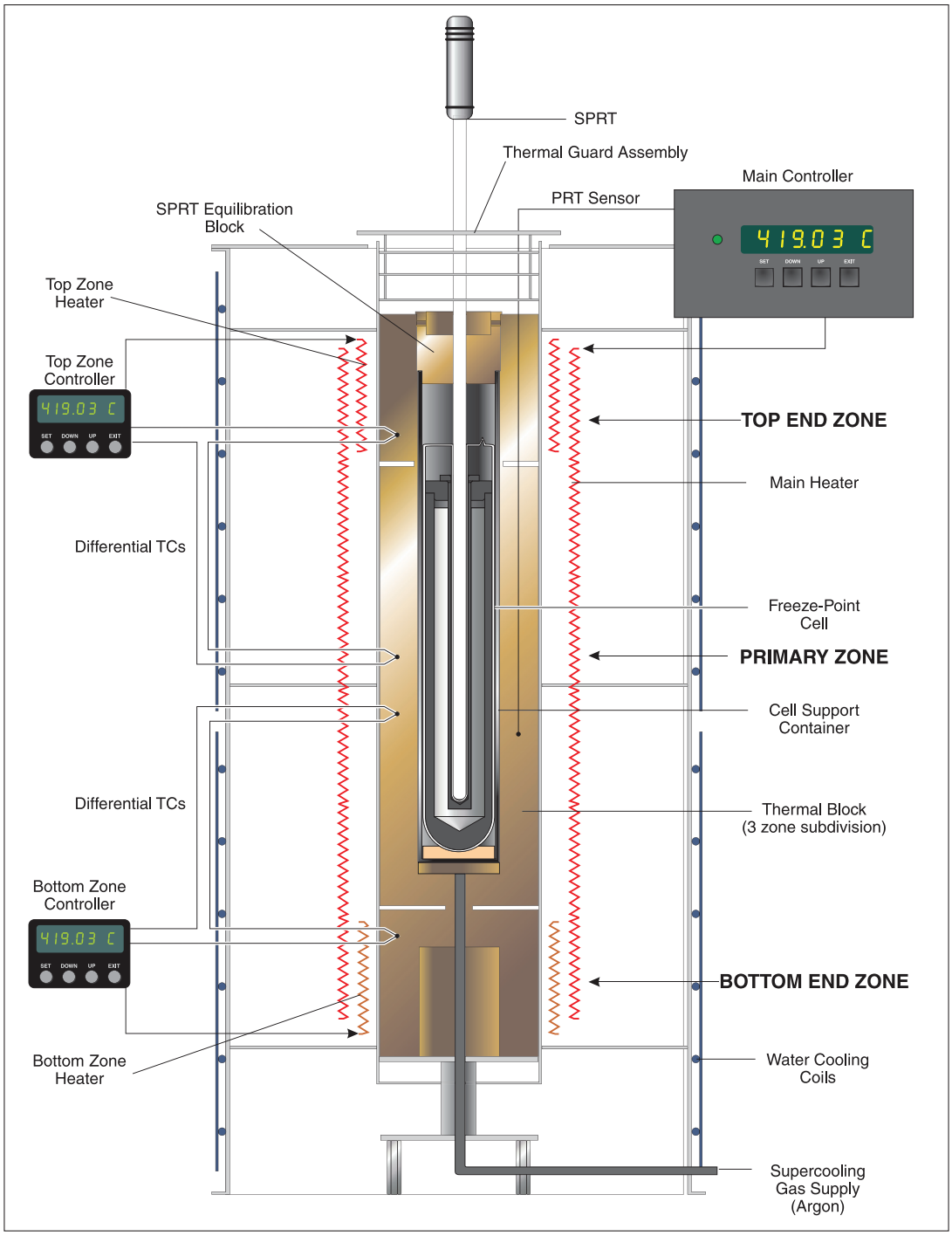


Figure 5. Fluke 9114 Metrology Furnace with SPRT in Fixed Point Cell

The lead wire colors are red, black, white, and blue. Lead wire pairs attached to each end of the sensor are identified by heat shrink tubing. Red and black wires have red heat shrink tubing. Blue and white wires have black heat shrink tubing (see Figure 6). The circuit is connected in true four terminal configuration. Therefore, there is no distinction between voltage (sense) and current (source) leads.

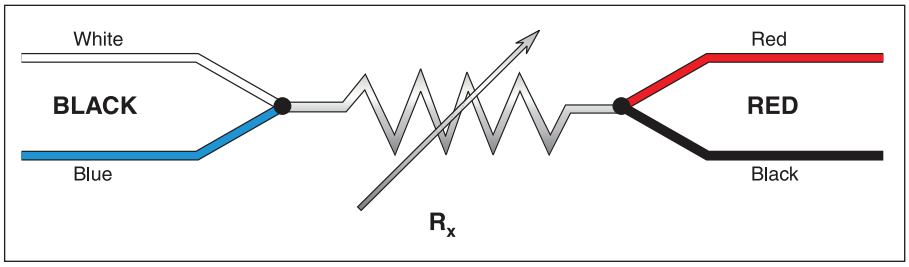


Figure 6. SPRT Circuit Schematic

Care and Handling Guidelines

⚠Caution

Read before removing the SPRT from the case.

SPRT Care

The 5698 Working Standard Platinum Resistance Thermometer (SPRT) is an extremely delicate instrument. Great care must be taken in handling the SPRT to maintain calibration accuracy. Vibration or shock may cause the resistance to increase. A slight tap to the SPRT tip as it is removed from an instrument can cause a change in R_{tpw} as high as 1 mK. At high temperatures, the SPRT may become contaminated if inserted into metal blocks. This contamination can effect the condition of the sensor if the contamination invades the sensor degrading the purity of the platinum wire. The fused silica sheath is very fragile and also susceptible to contamination. Once a SPRT is contaminated, it can contaminate other standards equipment. (Copper contamination shows as red smudged on the sheath.) Any contamination can cause devitrification of the sheath at high temperatures. The fused silica sheath should not be handled with bare hands. Cotton gloves or other suitable methods should be used in handling the SPRT. The sheath should always be cleaned with 200 proof Ethyl Alcohol or other suitable solvent before exposure to high temperatures. Correct handling of the SPRT will prolong the life expectancy. When not in use, the SPRT should be stored in its protective case.

SPRT Handling Guidelines

1. Keep the SPRT as clean as possible. Always remove any fluid from the sheath as soon as possible after taking the SPRT from a bath. Ensure that the fluid and SPRT have cooled sufficiently to prevent a safety hazard. To remove any possible contaminants, always wipe the sheath with ethyl alcohol or other solvent before submitting the SPRT to high temperatures.
2. Immerse the SPRT in the appropriate liquid for the temperature range. If a dry block is used, the well diameter should allow the SPRT to comfortably slip in and out without excess movement. For best results, immerse the SPRT as deep as possible to avoid "stem effect" (the temperature error caused by the conduction of heat away from the sensor). Do not submerge the handles.
3. Allow sufficient time for the SPRT to stabilize before making measurements. This allows for the best accuracy.
4. Use the correct drive current with the SPRT to prevent error in temperature or resistance.
5. Anneal the SPRT at a temperature slightly higher than the maximum temperature at which the thermometer will be used when it has been subjected to mechanical or temperature shock. The SPRT should also be annealed before calibration. The SPRT should be annealed at 675 °C.
6. Use the protective case provided or other protection when the thermometer is not in use.
7. **DO NOT** subject the thermometer to any physical shock or vibration.
8. **DO NOT** subject the thermometer to temperatures above the highest specified operating temperature.
9. **DO NOT** expose the thermometer's handle or cables to extreme temperatures.
10. **DO NOT** submerge the handle or cable in liquids.

Metal Ion Contamination of SPRTs

Since the acceptance of ITS-90, information has been accumulating about contamination of SPRTs. ITS-90 extended the range of the SPRT as an interpolation device and new problems manifested themselves. Metal ion contamination is one of the new problems and can start at approximately 700 °C.

At high temperatures the lattice structure of most metals becomes open. This allows energetic metal ions to come off the surface, analogous to steam rising from hot water. Since the molecular activity increases with temperature, so does the amount of ion loss and the risk of contamination. Ion transfer occurs at different temperatures for different metals. Copper, nickel, iron, and manganese are metals that have been attributed to causing contamination. In addition, the fused silica lattice structure also becomes open at these high temperatures. This allows the fused silica to become transparent to these metal ions permitting the transfer of these ions from adjacent metal surfaces to the pure platinum wire of the SPRT sensor. The contaminated platinum behaves unpredictably, resulting in a loss of stability and calibration.

Contamination can be spread by an "infected" SPRT to other primary standards analogous to a virus. Therefore, it is very important to avoid contamination as much as possible to ensure the longevity of the SPRT itself and to decrease the spread to other standards.

Isolation of sensitive materials can prevent contamination. Pure platinum foil is being used by some experts to intercept the ions before they reach the SPRT. Silicon carbide is also used by some experts to shield the SPRT because it is less expensive than platinum foil. Information on contamination effects and prevention is still being gathered by experts in the field.

Devitrification of Fused Silica Glass

Devitrification is a natural process with quartz materials. The fused silica is utilized in a glass (non-crystalline) state. The most stable state for fused silica is crystalline. Therefore, devitrification is the tendency of the fused silica to return to its most stable state. If the fused silica is kept extremely clean and free of contamination, devitrification occurs only at high temperatures. The process occurs more rapidly and at lower temperatures when the glass is contaminated by alkaline metals (Na, K, Mg, and Ca). The alkalis found in normal tap water can trigger the process.

Removal of the devitrification is not practical as it requires drastic measures and is potentially dangerous to the instrument and/or the user.

Devitrification starts with a dulling or opacity of the fused silica sheath. It develops into a rough and crumbling surface. Devitrification ultimately weakens the fused silica until it breaks or is otherwise no longer useful.

The best cure for contamination and devitrification is prevention. Being aware of the causes and signs of contamination can help the user take the steps necessary to control contamination of the SPRT. Keep your SPRT clean and avoid contact with metals at temperatures above 700 °C.

Operation

For best results, be familiar with the operation of the calibration bath or furnace and the readout instrument. Be sure to follow the manufacturer's instructions for the readout instrument and the calibration bath or furnace.

Comparison Calibration of Other Instruments

The uniformity and stability of the bath and the degree of accuracy required determine the number of temperature measurements necessary. However, to follow "good" practice procedures, always measure the triple point of water (R_{tpw}) after each temperature measurement. This provides the most accurate measurement of the ratio:

$$W_t = \frac{R_t}{R_{tp}}$$

Measuring Current

The 5698 SPRT has a specified drive current. The recommended current is listed in Table 3.

Table 3. Suggested Drive Current

Model	Resistance	Drive Current
5698	25 Ω	1 mA

Errors caused by self-heating of the element need to be minimized. Allowing sufficient time for the SPRT to stabilize and the heat to be dispersed into the surrounding medium will provide the most accurate results. The Report of Calibration provided with the SPRT represent data that has been extrapolated. For example, on a 5698 measurements are made at 1 mA and 1.4 mA. These measurements are then extrapolated to zero current. This can be done graphically by plotting i^2 vs. R and extrapolating to zero power or by using the following equation:

$$R_0 = R_1 - \frac{i_1^2 (R_2 - R_1)}{i_2^2 - i_1^2}$$

where:

R_0 = Zero current resistance

R_1 = Resistance measured at current i_1

R_2 = Resistance measured at current i_2

Immersion Requirements

Stem effect can cause measurement errors for SPRTs not immersed in the fluid at least six inches. This error is due to heat lost or gained by the sensing element through the thermometer stem. In addition, heat losses occur due to radiation losses from the sensing element to the housing. The sand-blasted finish on the fused silica sheath is designed to minimize losses due to radiation piping. Convection prevention discs also provide multiple radiation shields along the lead wires. Convection discs and the quartz insulation on lead wires cause some shunt resistance at very high temperatures. However, the effect of the shunt resistance is insignificant. Full immersion is recommended in a furnace or freeze point cell.

The immersion depth for primary standards is dependent on several factors including accuracy requirements and type of liquid. Therefore, we recommend an 0.8 in minimum immersion depth.

The exact immersion depth required can be determined by performing a gradient test taking measurements approximately every 1.27 cm (0.5 in) until there is a significant difference in readings. Allow the thermometer to stabilize at each new depth. Plot the results to see the stem effect.

Thermal EMF

Two factors contribute to thermal EMF, chemical consistency and physical consistency. Variations in chemical structure due to impurities and discrepancies in crystal structure can contribute to thermal EMF. These factors are minimized by annealing the full length of wire before construction of the SPRT. Likewise, connection to extension lead wires and readout instruments can be a source of thermal EMF. The thermal EMF is caused by a difference in temperature between two connections. If the two connections are the same temperature, there will be little or no thermal EMF effects. However, if there is a substantial temperature difference between connections, the thermal EMF effects will be significant. Therefore, cover or insulate any exposed bridge or galvanometer terminals to lessen the source of error. The effects of thermal EMF can be reduced by using an ac bridge or a dc bridge with reversible current.

Cooling Rates at High Temperatures

The equilibrium concentration of point defects in the pure platinum wire increase exponentially at higher temperatures. If a high cooling rate (example: removing a SPRT from a high temperature and cooling it to room temperature in less than a minute) occurs above 500 °C, some of the point defects in the platinum wire become trapped in the crystalline structure causing a slight increase in resistance. This slight increase in resistance can be reversed by annealing the SPRT. To avoid this problem, slowly cool the SPRT at a rate of roughly 150 °C/hour above 500 °C before removing to room temperature. The SPRT can be safely removed from an instrument at 500 °C or less and cooled to room temperature without concern for the cooling rate.

Accessories

Case

The SPRTS are shipped in a protective case. The SPRT should be stored in this case when not in use. The SPRT should be shipped in this case when returning (see “Return Procedure”).

SPRT Termination

The 5698 SPRT is terminated with gold plated lugs.

Troubleshooting

In the event that the SPRT appears to function abnormally, the information in Table 4 may help to find and solve the problem. Several possible problem conditions are described along with likely causes and solutions. If a problem arises, read this section carefully and attempt to understand and solve the problem. If the SPRT seems faulty or the problem cannot otherwise be solved, contact Fluke for assistance (see "How to Contact Fluke").

Table 4. 5698 Troubleshooting

Problem	Solution
Data Changes	**Slight mechanical shock can cause temperature errors as much as 2 mK**. If this is observed, first measure and record the R_{tpw}. Next anneal the SPRT at 675 °C overnight (12 hours). Measure the R_{tpw} again. The annealing should decrease the R_{tpw}. Repeat the annealing, R_{tpw} measurement cycle several times. If the R_{tpw} returns to the proper value, the SPRT may be returned to service. If the SPRT does not returen to the proper R_{tpw} value but is stable, return for recalibration. When the R_{tpw} is stable, recalibrate the SPRT. If the R_{tpw} does not stabilize, contact Fluke for assistance (see "How to Contact Fluke"). **Severe mechanical shock can permanently damage the SPRT**. If annealing the SPRT does not resolve the data change, contact Fluke for assistance (see "How to Contact Fluke"). **Oxidation of the platinum sensor may occur after prolonged use between 200 °C and 450 °C**. R_{tpw} will show an increase. To reduce the effects of oxidation, anneal the SPRT at the appropriate temperature as described above. Measure the R_{tpw} again. Repeat the annealing, R_{tpw} measurement cycle several times. This annealing process should return R_{tpw} to within calibration tolerances. If the R_{tpw} is within calibration tolerance, the SPRT is usable. If the R_{tpw} is not within calibration tolerance, but it is stable, recalibrate the SPRT.
Data Unstable	**Connection may not be made.** If the data is unstable at the Triple Point of Water (TPW), check the connection first. If this action does not fix the problem contact Fluke for assistance (see "How to Contact Fluke"). The SPRT may be damaged and need repair. **Electrical noise in the system.** If the data is unstable at high temperatures, it may be due to electrical noise in the system. Reduce the temperature and observe the data. If it is stable, electrical noise is interfering with the measurements at high temperatures. Check the grounding of the readout device and the heat source. A faulty ground on either device could interfere with high temperature measurements.
Temperature Readout is Different than Expected. Example: The Heat Source is set at 300 °C and the SPRT Measures 275 °C.	**Measure the SPRT resistance at TPW**. If the resistance of the SPRT is less than the rated resistance, there may be a short in the sensor. If the resistance of the SPRT is only a few ohms, there may be a short in the four lead-wires. If the SPRT is open, the resistance will be "Out of Limits" or in the kilo-ohm or mega-ohm range. Contact a Fluke for assistance (see "How to Contact Fluke").