

FLUKE®

Calibration

9140

Dry-Well Calibrator

User's Guide

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1 Before You Start

1.1 Symbols Used

Table 1 lists the symbols used on the instrument or in this manual and the meaning of each symbol.

Table 1 International Electrical Symbols

Symbol	Description
	AC (Alternating Current)
	AC-DC
	Battery
	Complies with European Union directives
	DC
	Double Insulated
	Electric Shock
	Fuse
	PE Ground
	Hot Surface (Burn Hazard)
	Read the User's Manual (Important Information)
	Off
	On

Symbol	Description
	Canadian Standards Association
CAT II	OVERVOLTAGE (Installation) CATEGORY II, Pollution Degree 2 per IEC1010-1 refers to the level of Impulse Withstand Voltage protection provided. Equipment of OVERVOLTAGE CATEGORY II is energy-consuming equipment to be supplied from the fixed installation. Examples include household, office, and laboratory appliances.
	C-TIC Australian EMC
	The European Waste Electrical and Electronic Equipment (WEEE) Directive (2002/96/EC) mark.

1.2 Safety Information

Use the instrument only as specified in this manual. Otherwise, the protection provided by the instrument may be impaired. Refer to the safety information below and throughout the manual.

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.

1.2.1 WARNINGS

To avoid personal injury, follow these guidelines.

GENERAL

- **DO NOT** use this instrument in environments other than those listed in the User's Guide.
- Inspect the instrument for damage before each use. **DO NOT** use the instrument if it appears damaged or operates abnormally.
- Follow all safety guidelines listed in the user's manual.
- Calibration Equipment should only be used by Trained Personnel.
- If this equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.
- Before initial use, or after transport, or after storage in humid or semi-humid environments, or anytime the dry-well has not been energized for more than 10 days, the instrument needs to be energized for a "dry-out" period of 2 hours before it can be assumed to meet all of the safety requirements of the IEC 1010-1. If the product is wet or has been in a wet environment, take necessary measures to remove moisture prior to apply-

ing power such as storage in a low humidity temperature chamber operating at 50°C for 4 hours or more.

- **DO NOT** use this instrument for any application other than calibration work. The instrument was designed for temperature calibration. Any other use of the instrument may cause unknown hazards to the user.
- Completely **unattended operation is not recommended**.
- Overhead clearance is required. **DO NOT** place the instrument under a cabinet or other structure. Always leave enough clearance to allow for safe and easy insertion and removal of probes.
- If the instrument is used in a manner not in accordance with the equipment design, the operation of the dry-well may be impaired or safety hazards may arise.
- This instrument is intended for indoor use only.

BURN HAZARDS

- **DO NOT** turn the instrument upside down with the inserts in place; the inserts will fall out.
- **DO NOT** operate near flammable materials.
- Use of this instrument at **HIGH TEMPERATURES** for extended periods of time requires caution.
- **DO NOT** touch the well access surface of the instrument.
- The block vent may be very hot due to the fan blowing across the heater block of the dry-well.
- The temperature of the well access is the same as the actual display temperature, e.g. if the instrument is set to 700°C and the display reads 700°C, the well is at 700°C.
- For top loading dry-wells, the top sheet metal of the dry-well may exhibit extreme temperatures for areas close to the well access.
- The air over the well can reach temperatures greater than 200°C for high temperature (400°C and higher) dry-wells. **Note:** Probes and inserts may be hot and should only be inserted and removed from the instrument when the instrument is set at temperatures less than 50°C. Use extreme care when removing hot inserts.
- **DO NOT** turn off the instrument at temperatures higher than 100°C. This could create a hazardous situation. Select a set-point less than 100°C and allow the instrument to cool before turning it off.
- The high temperatures present in dry-wells designed for operation at 300°C and higher may result in fires and severe burns if safety precautions are not observed.
- For compliance with IEC 1010-1, it is recommended that the cutout mode always be set to the manual mode requiring user intervention to reset the instrument.

ELECTRICAL SHOCK

- These guidelines must be followed to ensure that the safety mechanisms in this instrument will operate properly. This instrument must be plugged into a 115 VAC, 60Hz (230 VAC, 50Hz optional), AC only electric outlet. The power cord of the instrument is equipped with a three-pronged grounding plug for your protection against electrical shock hazards. It must be plugged directly into a properly grounded three-prong receptacle. The receptacle must be installed in accordance with local codes and ordinances. Consult a qualified electrician. **DO NOT** use an extension cord or adapter plug.
- If supplied with user accessible fuses, always replace the fuse with one of the same rating, voltage, and type.
- Always replace the power cord with an approved cord of the correct rating and type.
- **HIGH VOLTAGE** is used in the operation of this equipment. **SEVERE INJURY** or **DEATH** may result if personnel fail to observe safety precautions. Before working inside the equipment, turn power off and disconnect power cord.

1.2.2

CAUTIONS

- Always operate this instrument at room temperature between 41°F and 122°F (5°C to 50°C). Allow sufficient air circulation by leaving at least 6 inches (15 cm) of clearance around the instrument. Overhead clearance is required. **DO NOT** place unit under any structure.
- Component lifetime can be shortened by continuous high temperature operation.
- **DO NOT** leave the sleeve(s) in the instrument for prolonged periods. Due to the high operating temperatures of the instrument, the sleeves should be removed after each use and buffed with a Scotch-Brite® pad or emery cloth. (See Maintenance, Section .)
- **DO NOT** apply any type of voltage to the display hold terminals. Applying a voltage to the terminals may cause damage to the controller.
- **DO NOT** use fluids to clean out the well. Fluids could leak into electronics and damage the instrument.
- **Never introduce any foreign material** into the probe hole of the insert. Fluids, etc. can leak into the instrument causing damage.
- **DO NOT** change the values of the calibration constants from the factory set values. The correct setting of these parameters is important to the safety and proper operation of the calibrator.
- **DO NOT** slam the probe sheath in to the well. This type of action can cause a shock to the sensor and affect the calibration.

- The instrument and any thermometer probes used with it are sensitive instruments that can be easily damaged. Always handle these devices with care. **DO NOT** allow them to be dropped, struck, stressed, or overheated.
- The Factory Reset Sequence (see Section 12.1, Troubleshooting) should be performed only by authorized personnel if no other action is successful in correcting a malfunction. You must have a copy of the most recent Report of Calibration to restore the calibration parameters.
- **DO NOT** operate this instrument in an excessively wet, oily, dusty, or dirty environment. Always keep the well and inserts clean and clear of foreign material.
- The dry-well is a precision instrument. Although it has been designed for optimum durability and trouble free operation, it must be handled with care. Always carry the instrument in an upright position to prevent the probe sleeves from dropping out. The convenient handle allows for hand carrying the instrument.
- If a mains supply power fluctuation occurs, immediately turn off the instrument. Power bumps from brown-outs could damage the instrument. Wait until the power has stabilized before re-energizing the instrument.
- The probe and the block may expand at different rates. Allow for probe expansion inside the well as the block heats. Otherwise, the probe may become stuck in the well.
- Most probes have handle temperature limits. Be sure that the probe handle temperature limit is not exceeded in the air above the instrument. If the probe handle limits are exceeded, the probe may be permanently damaged.

1.3 Authorized Service Centers

Please contact one of the following authorized Service Centers to coordinate service on your Hart product:

Fluke Corporation, Hart Scientific Division

799 E. Utah Valley Drive
American Fork, UT 84003-9775
USA

Phone: +1.801.763.1600
Telefax: +1.801.763.1010
E-mail: support@hartscientific.com

Fluke Nederland B.V.

Customer Support Services

Science Park Eindhoven 5108
5692 EC Son
NETHERLANDS

Phone: +31-402-675300
Telefax: +31-402-675321
E-mail: ServiceDesk@fluke.nl

Fluke Int'l Corporation

Service Center - Instrimpex
Room 2301 Sciteck Tower
22 Jianguomenwai Dajie
Chao Yang District
Beijing 100004, PRC
CHINA

Phone: +86-10-6-512-3436
Telefax: +86-10-6-512-3437
E-mail: xingye.han@fluke.com.cn

Fluke South East Asia Pte Ltd.

Fluke ASEAN Regional Office
Service Center
60 Alexandra Terrace #03-16
The Comtech (Lobby D)
118502
SINGAPORE

Phone: +65 6799-5588
Telefax: +65 6799-5588
E-mail: antng@singa.fluke.com

When contacting these Service Centers for support, please have the following information available:

- Model Number
- Serial Number
- Voltage
- Complete description of the problem

2 Introduction

The Hart Scientific 9140 Mid-Range Field Calibrator may be used as a portable instrument or bench top temperature calibrator for calibrating thermocouple and RTD temperature probes. The 9140 is small enough to use in the field, and accurate enough to use in the lab.

The instrument features:

- Rapid heating and cooling
- Interchangeable multiple hole aluminum probe sleeves
- Convenient hand strap
- RS-232 interface capability

Built in programmable features include:

- Temperature scan rate control
- Temperature switch hold
- Eight Setpoint memory
- Adjustable readout in °C or °F

The temperature is accurately controlled by Hart's hybrid analog/digital controller. The controller uses a precision platinum RTD as a sensor and controls the well temperature with a solid state relay (triac) driven heater.

The LED front panel continuously shows the current well temperature. The temperature may be easily set with the control buttons to any desired temperature within the specified range. The instrument's multiple fault protection devices insure user and instrument safety and protection.

The 9140 dry-well calibrator was designed for portability, low cost, and ease of operation. Through proper use the instrument will provide continued accurate calibration of temperature sensors and devices. The user should be familiar with the safety guidelines and operating procedures of the calibrator as described in the instruction manual.

3 Specifications and Environmental Conditions

3.1 Specifications

The following table lists the specifications for this instrument. Accuracy specifications are applicable for a one-year calibration interval. In line with normal prudent metrology practices, Hart Scientific recommends a short-cycle interval of six months for new units during the first year.

Power	115 VAC ($\pm 10\%$), 4.4 A or 230 VAC ($\pm 10\%$), 2.2 A, switchable 500 W
Ambient Temperature	5–50°C (41–122°F)
Operating Range	35–350°C (95–662°F)
Resolution	0.1°C or °F resolution
Readout	Switchable°C or °F
Accuracy	$\pm 0.5^\circ\text{C}$ ($\pm 0.9^\circ\text{F}$), in holes greater than 1/4" (6.35 mm) accuracy is $\pm 1^\circ\text{C}$ ($\pm 1.8^\circ\text{F}$)
Stability	$\pm 0.03^\circ\text{C}$ at 50°C, $\pm 0.05^\circ\text{C}$ at 350°C
Uniformity	$\pm 0.4^\circ\text{C}$ typical, $\pm 0.1^\circ\text{C}$ with similarly sized wells
Controller	Digital controller with data retention
Heater	500W
Heating Time	12 minutes from ambient to 350°C
Cooling Time	15 minutes from 350°C to 100°C
Cooling	2 speed internal fan
Stabilization Time	7 minutes
Immersion Depth	124 mm (4.88 inches)
Fault Protection	Sensor burnout and short protection, over temperature thermal cut-out, electrical fuses
Test Wells	31.8 mm dia. x 123.7 mm deep (1.25" x 4.87"). Multi-hole inserts are available.
Exterior Dimension	152.4 mm H x 85.7 mm W x 196.9 mm D (6" x 3.375" x 7.75")
Weight	2.7 kg (6 lbs.)
Fuse Rating	115 V: 6 A (fast acting), 250 V 230 V: 3.15 A (fast acting), 250 V
Safety	OVERVOLTAGE (Installation) CATEGORY II, Pollution Degree 2 per IEC1010-1

3.2 Environmental Conditions

Although the instrument has been designed for optimum durability and trouble-free operation, it must be handled with care. The instrument should not be

operated in an excessively dusty or dirty environment. Maintenance and cleaning recommendations can be found in the Maintenance Section of this manual.

The instrument operates safely under the following conditions:

- temperature range: 5–50°C (41–122°F)
- ambient relative humidity: 15–50%
- pressure: 75kPa–106kPa
- mains voltage within $\pm 10\%$ of nominal
- vibrations in the calibration environment should be minimized
- altitude does not effect the performance or safety of the unit

3.3 Warranty

LIMITED WARRANTY AND LIMITATION OF LIABILITY

Each Fluke product is warranted to be free from defects in material and workmanship under normal use and service. The warranty period is one year and begins on the date of shipment. Parts, product repairs, and services are warranted for 90 days. This warranty extends only to the original buyer or end-user customer of a Fluke authorized reseller, and does not apply to fuses, disposable batteries, or to any product which, in Fluke's opinion, has been misused, altered, neglected, contaminated, or damaged by accident or abnormal conditions of operation or handling. Fluke warrants that software will operate substantially in accordance with its functional specifications for 90 days and that it has been properly recorded on non-defective media. Fluke does not warrant that software will be error free or operate without interruption.

Fluke authorized resellers shall extend this warranty on new and unused products to end-user customers only but have no authority to extend a greater or different warranty on behalf of Fluke. Warranty support is available only if product is purchased through a Fluke authorized sales outlet or Buyer has paid the applicable international price. Fluke reserves the right to invoice Buyer for importation costs of repair/replacement parts when product purchased in one country is submitted for repair in another country.

Fluke's warranty obligation is limited, at Fluke's option, to refund of the purchase price, free of charge repair, or replacement of a defective product which is returned to a Fluke authorized service center within the warranty period.

To obtain warranty service, contact your nearest Fluke authorized service center to obtain return authorization information, then send the product to that service center, with a description of the difficulty, postage and insurance prepaid (FOB Destination). Fluke assumes no risk for damage in transit. Following warranty repair, the product will be returned to Buyer, transportation prepaid (FOB Destination). If Fluke determines that failure was caused by neglect, misuse, contamination, alteration, accident, or abnormal condition of operation or handling, including overvoltage failures caused by use outside the product's specified rating, or normal wear and tear of mechanical components, Fluke will provide an estimate of repair costs and obtain authorization before commencing the work. Following repair, the product will be returned to the Buyer transportation prepaid and the Buyer will be billed for the repair and return transportation charges (FOB Shipping Point).

THIS WARRANTY IS BUYER'S SOLE AND EXCLUSIVE REMEDY AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. FLUKE SHALL NOT BE LIABLE FOR ANY SPECIAL, INDIRECT, INCIDENTAL, OR CONSEQUENTIAL DAMAGES OR LOSSES, INCLUDING LOSS OF DATA, ARISING FROM ANY CAUSE OR THEORY.

Since some countries or states do not allow limitation of the term of an implied warranty, or exclusion or limitation of incidental or consequential damages, the limitations and exclusions of this warranty may not apply to every buyer. If any provision of this Warranty is held invalid or unenforceable by a court or other decision-maker of competent jurisdiction, such holding will not affect the validity or enforceability of any other provision.

Fluke Corporation
P.O. Box 9090
Everett, WA 98206-9090
U.S.A.

Fluke Europe B.V.
P.O. Box 1186
5602 BD Eindhoven
The Netherlands

4 Quick Start

4.1 Unpacking

Unpack the dry-well carefully and inspect it for any damage that may have occurred during shipment. If there is shipping damage, notify the carrier immediately.

Verify that the following components are present:

- 9140 Dry-well
- Insert
- Insert Removal Tool
- Power Cord
- Serial Cable
- User's Guide
- 9930 Software Package

4.2 Set-Up

Place the calibrator on a flat surface with at least 6 inches of free space around the instrument. Plug the power cord into a grounded mains outlet. Observe that the nominal voltage corresponds to that indicated on the back of the calibrator.

Carefully insert the probe sleeve into the well. Probe sleeves should be of the smallest hole diameter possible still allowing the probe to slide in and out easily. Sleeves of various sizes are available from Hart Scientific. The well must be clear of any foreign objects, dirt and grit before the sleeve is inserted. The sleeve is inserted with the two small tong holes positioned upward.

Turn on the power to the calibrator by toggling the switch on the power entry module. The fan should begin quietly blowing air through the instrument and the controller display should illuminate after 3 seconds. After a brief self test the controller should begin normal operation. If the unit fails to operate please check the power connection.

The display will begin to show the well temperature and the well heater will start operating to bring the temperature of the well to the set-point temperature. After using the calibrator, allow the well to cool by setting the temperature to 25°C and waiting for the instrument to reach temperature before turning the instrument off.

4.3 Power

Plug the dry-well power cord into a mains outlet of the proper voltage, frequency, and current capability. Refer to Section 3.1, Specifications, for power details. Turn the dry-well on using the rear panel "POWER" switch. The

dry-well will turn on and begin to heat to the previously programmed temperature set-point. The front panel LED display will indicate the actual dry-well temperature.

4.4 Setting the Temperature

Section 7.2 explains in detail how to set the temperature set-point on the calibrator using the front panel keys. The procedure is summarized here.

- (1) Press “SET” twice to access the set-point value.
- (2) Press “UP” or “DOWN” to change the set-point value.
- (3) Press “SET” to program in the new set-point.
- (4) Press “EXIT” to return to the temperature display.

When the set-point temperature is changed the controller will switch the well heater on or off to raise or lower the temperature. The displayed well temperature will gradually change until it reaches the set-point temperature. The well may require 5 to 10 minutes to reach the set-point depending on the span. Another 5 to 10 minutes is required to stabilize within $\pm 0.1^{\circ}\text{C}$ of the set-point. Ultimate stability may take 15 to 20 minutes more of stabilization time.

5 Parts and Controls

The user should become familiar with the dry-well calibrator and its parts:

5.1 Rear Panel

Figure 1 on page 13.

Power Cord - At the rear of the calibrator is the removable power cord inlet that plugs into an IEC grounded socket.

Power Switch - The power switch is located on the power entry module (PEM). The PEM also houses the fuses and the dual voltage selector. The PEM and Heater Voltage Switch (see below) allow the unit to be field switchable for 115 VAC ($\pm 10\%$) or 230 VAC ($\pm 10\%$) operation.

Heater Voltage Switch - To be used only when changing the input voltage. (See [Section 6.3](#) for instructions on changing the input voltage.)

Note: The input voltage and heater voltage switch settings should always be the same value.

Serial Port - A DB-9 male connector is present for interfacing the calibrator to a computer or terminal with serial RS-232 communications.

Fan - The fan inside the calibrator runs continuously when the unit is being operated to provide cooling for the instrument. It has two speeds, a slow speed for control operation and a faster speed for rapid cooling. Slots at the top and

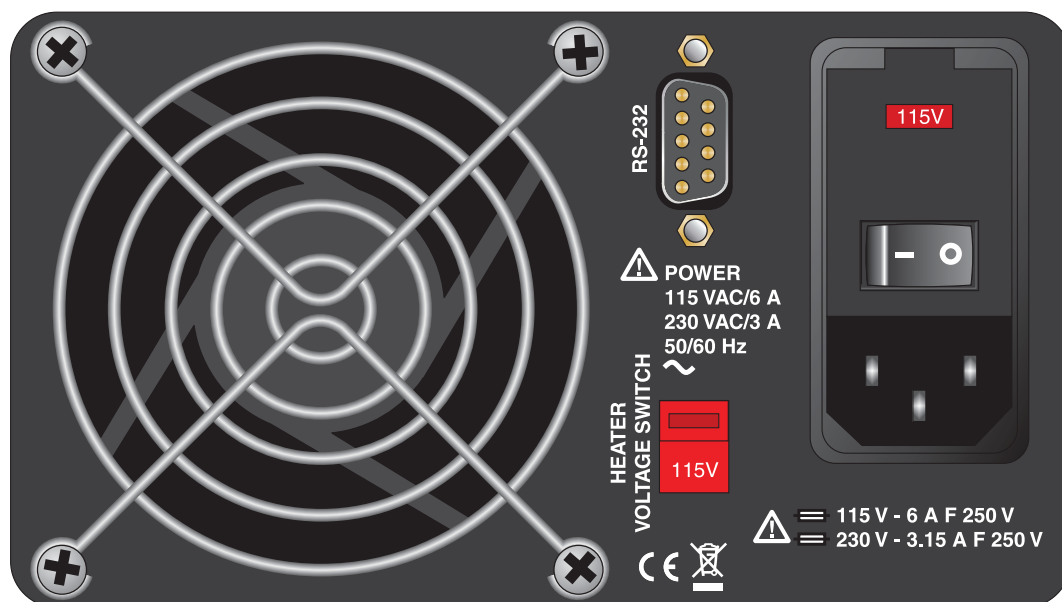


Figure 1 9140 Back Panel

around the two corners of the calibrator are provided for airflow. The area around the calibrator must be kept clear to allow adequate ventilation. The airflow is directed upward and as a result, can be extremely hot.

5.2 Front Panel

Figure 2 on page 14.

Controller Display - The digital display is an important part of the temperature controller because it not only displays set and actual temperatures but also various calibrator functions, settings, and constants. The display shows temperatures in units according to the selected scale °C or °F.

Controller Keypad - The four button keypad allows easy setting of the set-point temperature. The control buttons (SET, DOWN, UP, and EXIT) are used to set the calibrator temperature set-point, access and set other operating parameters, and access and set calibration parameters.

Setting the control temperature is done directly in degrees of the current scale. It can be set to one-tenth of a degree Celsius or Fahrenheit.

The functions of the buttons are as follows:

SET – Used to display the next parameter in the menu and to store parameters to the displayed value.

DOWN – Used to decrement the displayed value of parameters.

UP – Used to increment the displayed value.

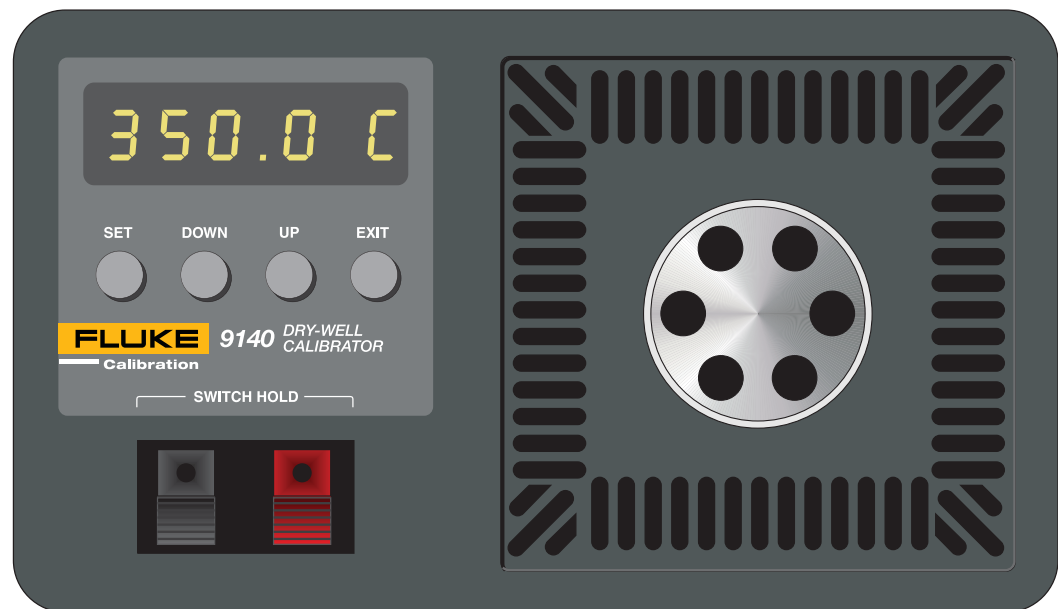


Figure 2 9140 Front Panel

EXIT – Used to exit a function and to skip to the next function. Any changes made to the displayed value are ignored.

5.3 Constant Temperature Block Assembly

Figure 3 on page 15.

5.3.1 Constant Temperature Block

The “Block” is made of aluminum and provides a relatively constant and accurate temperature environment in which the sensor that is to be calibrated is inserted. A 1.25 inch diameter well is provided that may be used for sensors of that size or may be sleeved down with various sized multi-hole probe sleeves. Heaters surround the block assembly and provides even heat to the sensor. A high-temperature platinum RTD is imbedded at the base of the block assembly to sense and control the temperature of the block. The entire assembly is suspended in an air cooled chamber thermally isolated from the chassis and electronics.



CAUTION: The block vent cover may be very hot due to the fan blowing upward. Please use caution.

5.3.2 Probe Sleeves and Tongs

The calibrator is supplied with a multi-hole aluminum probe sleeve for insertion into the calibrator well and tongs for removing sleeves. Probe sleeves of various hole sizes are available to allow the user's probe to fit snugly into the well whatever the diameter of the probe.

One insert, whichever is ordered, is shipped with the unit:

- Insert A (variety block): 1/2", 3/8", 3/16", 1/8", and 1/16" holes
- Insert B (comparison block): 2 3/8", 2 1/4", and 2 3/16" holes
- Insert C (1/4" comparison block): 6 1/4" holes

or

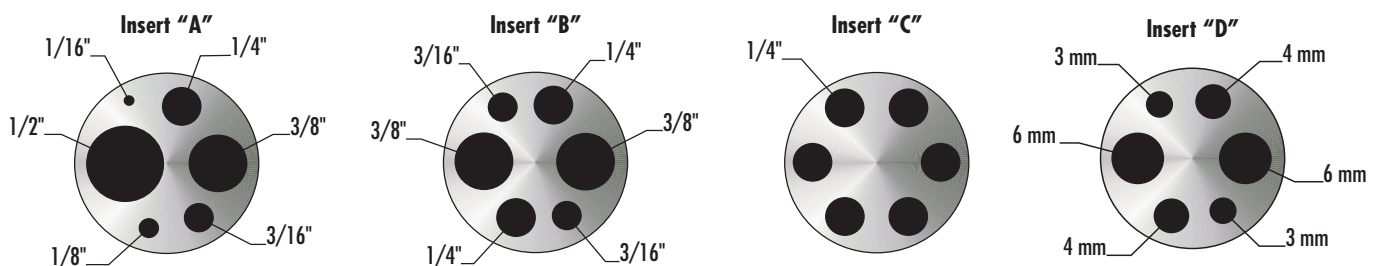


Figure 3 Inserts available for the 9140 block assembly

- Insert D (comparison block): 2 each at 3 mm, 4 mm, and 6 mm

6 General Operation

6.1 Calibrator Set-Up

Place the calibrator on a flat surface with at least 6 inches of free space around the instrument. Overhead clearance is required. **DO NOT** place under a cabinet or other structure. Plug the power cord into a grounded mains outlet. Observe that the nominal voltage corresponds to that indicated on the back of the calibrator.

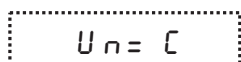
Gently insert the probe sleeve into the well. The probe sleeve should be of the smallest hole size possible while allowing the probe to slide in and out easily. Sleeves of various sizes are available from the manufacturer. The well must be clear of any foreign objects, dirt and grit before the sleeve is inserted. The sleeve is inserted with the two small tong holes positioned upward.

Turn on the power to the calibrator by toggling the switch at the rear of the instrument to the “I” (on) position. The fan will begin circulating air through the instrument. After a brief self test the controller should begin normal operation showing the well temperature. The block will heat or cool until it reaches the programmed set-point.

6.2 Changing Display Units

The 9140 can display temperature in Celsius or Fahrenheit. The temperature units are shipped from the factory set to Celsius. To change to Fahrenheit or back to Celsius there are two ways:

- 1 - Press the “SET” and “UP” simultaneously. This will change display units.
- 2 - Press the “SET” key three times from the temperature display to show



Press the “UP” or “DOWN” key to change units.

6.3 Switching to 230 V Operation

The 9140 is switchable from 115 VAC to 230 VAC 50/60 Hz. Switching the voltage can change the calibration, so it is recommended to recalibrate the unit after changing the input voltage.

To change from 115 VAC to 230 VAC:

- Unplug the unit
- With a small straight slot screwdriver remove the fuse holder located on the rear panel. Replace the two 6 amps fuses with 3 amp 250 V fuses.
- Replace the fuse holder with the “230V” in the display window.

- Using the same straight slot screwdriver, move the heater switch to display “230V”. See the rear panel drawing in [Figure 1](#) on page 13.



NOTE: *If the heater switch and the fuse holder do not both read 230V when complete, the unit will either not heat or only heat at a fraction of its capacity. If not done properly, the unit could become damaged and void the calibration and warranty.*



CAUTION: *DO NOT plug the unit into 230 V if the heater switch and fuse holder read 115. This will cause the fuse to blow and may damage the instrument.*

6.4 Setting the Temperature

Section 7.2 explains in detail how to set the temperature set-point on the calibrator using the front panel keys. The procedure is summarized here.

- (1) Press “SET” twice to access the set-point value.
- (2) Press “UP” or “DOWN” to change the set-point value.
- (3) Press “SET” to program in the new set-point.
- (4) Press “EXIT” to return to the temperature display.

When the set-point temperature is changed the controller will switch the well heater on or off to raise or lower the temperature. The cycle indicator, a two color LED, will also indicate on (red and heating) or off (green and cooling). The displayed well temperature will gradually change until it reaches the set-point temperature. The well may require 5 to 20 minutes to reach the set-point depending on the span. Another 5 to 10 minutes is required for the temperature to stabilize.

6.5 Calibrating Probes

The dry-well block provides a constant temperature environment in which probes may be compared. The probes inserted into the block may be compared to the well temperature displayed on the front panel of the calibrator. The probes should be inserted the full depth of the well since the temperature at the bottom of the well will most closely agree with the displayed temperature.

For greater accuracy the probes may be compared to a reference thermometer inserted into the block. The reference thermometer may be inserted into one hole while the probes to be calibrated are inserted into another. The drawback to this method is that because of temperature variations throughout the block there may be a small temperature difference between one hole and another which can cause errors.

Using the same hole for the reference thermometer and the test probe may have better results. This however requires switching the probes which takes more time. One must allow a few minutes after inserting the probes for the temperature to stabilize before making measurements. Because of temperature variations along the length of the well, best results are obtained when comparing probes of similar construction and inserting them the same depth into the well.

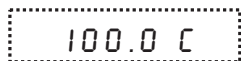
7 **Controller Operation**

This chapter discusses in detail how to operate the dry-well temperature controller using the front control panel. Using the front panel key-switches and LED display the user may monitor the well temperature, set the temperature set-point in degrees C or F, monitor the heater output power, adjust the controller proportional band, and program the calibration parameters, operating parameters, and serial interface configuration. Operation of the functions and parameters are shown in the flowchart in Figure 4 on page 22. This chart may be copied for reference.

In the following discussion a button with the word SET, UP, EXIT or DOWN inside indicates the panel button while the dotted box indicates the display reading. Explanation of the button or display reading are to the right of each button or display value.

7.1 **Well Temperature**

The digital LED display on the front panel allows direct viewing of the actual well temperature. This temperature value is what is normally shown on the display. The units, C or F, of the temperature value are displayed at the right. For example,

 *Well temperature in degrees Celsius*

The temperature display function may be accessed from any other function by pressing the “EXIT” button.

7.2 **Temperature Set-point**

The temperature set-point can be set to any value within the range and with resolution as given in the specifications. Be careful not to exceed the safe upper temperature limit of any device inserted into the well.

Setting the temperature involves two steps: (1) select the set-point memory and (2) adjust the set-point value.

7.2.1 **Programmable Set-points**

The controller stores 8 set-point temperatures in memory. The set-points can be quickly recalled to conveniently set the calibrator to a previously programmed temperature set-point.

To set the temperature one must first select the set-point memory. This function is accessed from the temperature display function by pressing “SET”. The number of the set-point memory currently being used is shown at the left on the display followed by the current set-point value.

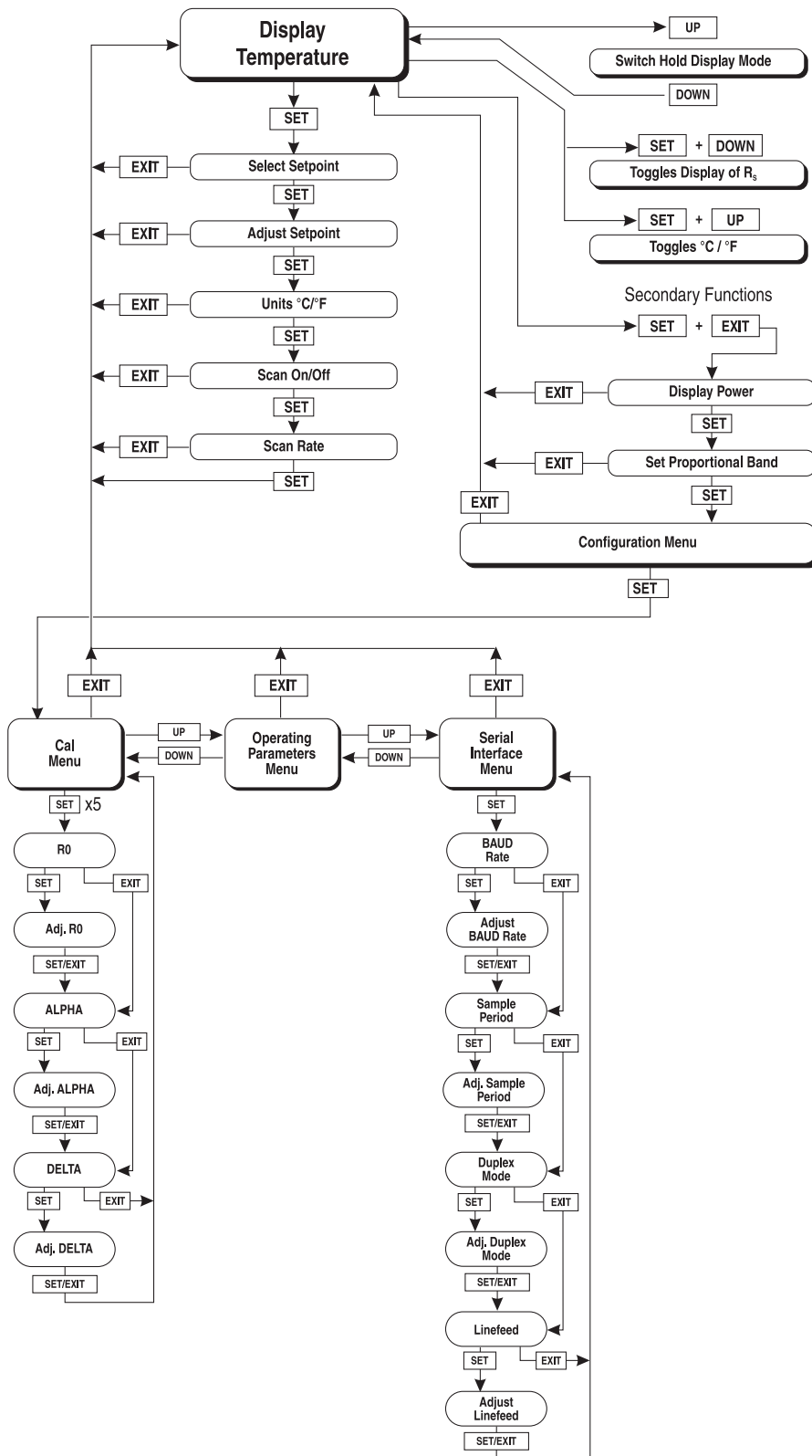


Figure 4 Controller Operation Flowchart

100.0 C

Well temperature in degrees Celsius



Access set-point memory

1. 100.

Set-point memory 1, 100°C currently used

To change to another set-point memory press “UP” or “DOWN”.

4. 300.

New set-point memory 4, 300°C

Press “SET” to accept the new selection and access the set-point value.



Accept selected set-point memory

7.2.2 Set-point Value

The set-point value may be adjusted after selecting the set-point memory and pressing “SET”.

4. 200.

Set-point 4 value in °C

If the set-point value need not be changed then press “EXIT” to resume displaying the well temperature. To change the set-point value, press “SET” and then press “UP” or “DOWN.”

220.0

New set-point value

When the desired set-point value is reached press “SET” to accept the new value and access the temperature scale units selection. If “EXIT” is pressed instead then any changes made to the set-point will be ignored.



Accept new set-point value

7.2.3 Temperature Scale Units

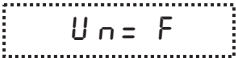
The temperature scale units of the controller maybe set by the user to degrees Celsius (°C) or Fahrenheit (°F). The units are used in displaying the well temperature, set-point, and proportional band.

Press “SET” after adjusting the set-point value to change display units.

U n = C

Scale units currently selected

Press “UP” or “DOWN” to change the units.

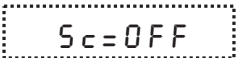
 *New units selected*

7.3 Scan

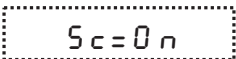
The scan rate can be set and enabled so that when the set-point is changed the dry-well heats or cools at a specified rate (degrees per minute) until it reaches the new set-point. With the scan disabled the dry-well heats or cools at the maximum possible rate.

7.3.1 Scan Control

The scan is controlled with the scan on/off function that appears in the main menu after the temperature scale units.

 *Scan function off*

Press “UP” or “DOWN” to toggle the scan on or off.

 *Scan function on*

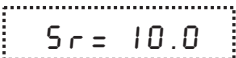
Press “SET” to accept the present setting and continue.

 *Accept scan setting*

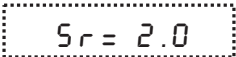
7.3.2 Scan Rate

The next function in the main menu is the scan rate. The scan rate can be set from .1 to 99.9°C/min. The maximum scan rate however is actually limited by the natural heating or cooling rate of the instrument. This is often less than 100°C/min, especially when cooling.

The scan rate function appears in the main menu after the scan control function. The scan rate units are in degrees per minute, degrees C or F depending on the selected units.

 *Scan rate in°C/min*

Press “UP” or “DOWN” to change the scan rate.

 *New scan rate*

Press “SET” to accept the new scan rate and continue.

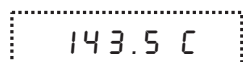
 *Accept scan rate*

7.4 Temperature Display Hold

The 9140 has a display hold function which allows action of an external switch to freeze the displayed temperature and stop the set-point from scanning. This is useful for testing thermal switches and cutouts. This section explains the functions available for operating the temperature hold feature. An example follows showing how to set up and use the hold feature to test a switch.

7.4.1 Hold Temperature Display

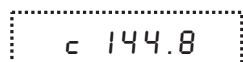
The hold feature is enabled by simply pressing the “UP” button. The hold temperature display shows the hold temperature on the right and the switch status on the left. For the status “c” means the switch is closed and “o” means the switch is open. The status flashes when the switch is in its active position (opposite the normal position). The hold temperature shows what the temperature of the well was when the switch changed from its normal position to its active position. While the switch is in the normal position the hold temperature will follow the well temperature. Operation of the hold temperature display is outlined below.



Well temperature display



Access hold display



Switch status and hold temperature

To return to the normal well temperature display press “DOWN”.

7.4.2 Mode Setting

The Hold Function is always in the automatic mode. In this mode the normal position is set to whatever the switch position is when the set-point is changed. For example, if the switch is currently open when the set-point is changed, the closed position then becomes the new active position. The normal position is set automatically under any of the following conditions, (1) a new set-point number is selected, (2) the set-point value is changed, (3) a new set-point is set through the communications channels.

The operating mode of the temperature hold is set in the primary menu after the scan rate setting.

7.4.3 Switch Wiring

The thermal switch or cutout is wired to the calibrator at the two terminals in the front of the dry-well calibrator labeled “SWITCH HOLD”. The switch wires may be connected to the terminals either way. Internally the black terminal connects to ground. The red terminal connects to +5V through a 100 kΩ re-

sistor. The calibrator measures the voltage at the red terminal and interprets +5V as open and 0V as closed.

7.4.4 Switch Test Example

This section describes a possible application for the temperature hold feature and how the instrument is set up and operated.

Suppose you have a thermal switch which is supposed to open at about 75°C and close at about 50°C and you want to test the switch to see how accurate and repeatable it is. You can use the temperature hold feature and the scan function to test the switch. Measurements can be made by observing the display or, preferably, by collecting data using a computer connected to the RS-232 port. To set up the test do the following steps.

1. Connect the switch wires to the terminals on the front of the dry-well and place the switch in the well.
2. Enable set-point scanning by setting the scan to “ON” in the primary menu (see section 7.3.1).
3. Set the scan rate to a low value, say 1.0°C/min. (see section 7.3.2). If the scan rate is too high you may lose accuracy because of transient temperature gradients. If the scan rate is too low the duration of the test may be longer than is necessary. You may need to experiment to find the best scan rate.
4. Set the first program set-point to a value below the expected lower switch temperature, say 40°C, in the program menu.
5. Set the second program set-point to a value above the expected upper switch temperature, say 90°C.
6. Set the program soak time to allow enough time to collect a number of data points, say 2 minutes.
7. Collect data on a computer connected to the RS-232 port. Refer to [Section 8](#) for instructions on configuring the RS-232 communications interface.

7.5 Secondary Menu

Functions which are used less often are accessed within the secondary menu. The secondary menu is accessed by pressing “SET” and “EXIT” simultaneously and then releasing. The first function in the secondary menu is the heater power display. (See [Figure 4](#).)

7.5.1 Heater Power

The temperature controller controls the temperature of the well by pulsing the heater on and off. The total power being applied to the heater is determined by the duty cycle or the ratio of heater on time to the pulse cycle time. By knowing the amount of heating the user can tell if the calibrator is heating up to the set-point, cooling down, or controlling at a constant temperature. Monitoring the percent heater power will let the user know how stable the well temperature

is. With good control stability the percent heating power should not fluctuate more than $\pm 1\%$ within one minute.

The heater power display is accessed in the secondary menu. Press “SET” and “EXIT” simultaneously and release. The heater power will be displayed as a percentage of full power.

100.0 C Well temperature

SET + EXIT Access heater power in secondary menu

5 E C Flashes SEC for secondary menu and then displays the heater power

12.0 P Heater power in percent

To exit out of the secondary menu press “EXIT”. To continue on to the proportional band setting function press “SET”.

7.5.2 Proportional Band

In a proportional controller such as this the heater output power is proportional to the well temperature over a limited range of temperatures around the set-point. This range of temperature is called the proportional band. At the bottom of the proportional band the heater output is 100%. At the top of the proportional band the heater output is 0. Thus as the temperature rises the heater power is reduced, which consequently tends to lower the temperature back down. In this way the temperature is maintained at a fairly constant level.

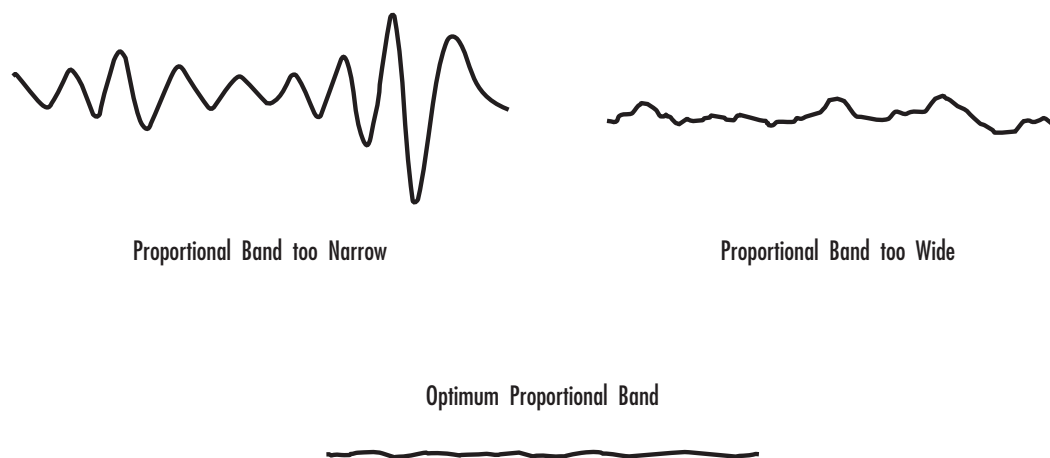


Figure 5 Well temperature fluctuation at various proportional band settings

The temperature stability of the well and response time depend on the width of the proportional band. If the band is too wide the well temperature will deviate excessively from the set-point due to varying external conditions. This is because the power output changes very little with temperature and the controller cannot respond very well to changing conditions or noise in the system. If the proportional band is too narrow the temperature may swing back and forth because the controller overreacts to temperature variations. For best control stability the proportional band must be set for the optimum width.

The proportional band width is set at the factory to about 15.0°C. The proportional band width may be altered by the user if he desires to optimize the control characteristics for a particular application.

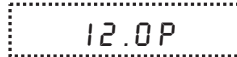
The proportional band width is easily adjusted from the front panel. The width may be set to discrete values in degrees C or F depending on the selected units. The proportional band adjustment is accessed within the secondary menu. Press “SET” and “EXIT” to enter the secondary menu and show the heater power. Then press “SET” to access the proportional band.



Access heater power in secondary menu



Flashes SEC for secondary menu and then displays the heater power



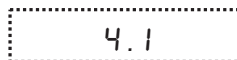
Heater power in percent



Access proportional band

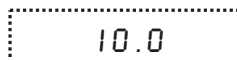


Flashes Prop then displays the setting



Proportional band setting

To change the proportional band press “UP” or “DOWN”.



New proportional band setting

To accept the new setting press “SET”. Press “EXIT” to continue without storing the new value.



Accept the new proportional band setting

7.6 Controller Configuration

The controller has a number of configuration and operating options and calibration parameters which are programmable via the front panel. These are accessed from the secondary menu after the proportional band function by pressing “SET”. Pressing “SET” again enters the first of three sets of configuration parameters — calibration parameters, operating parameters and serial interface parameters. The menus are selected using the “UP” and “DOWN” keys and then pressing “SET”.

7.6.1 Calibration Parameters

The operator of the instrument controller has access to a number of the calibration constants namely R_0 , ALPHA, and DELTA. These values are set at the factory and must not be altered. The correct values are important to the accuracy and proper and safe operation of the instrument. Access to these parameters is available to the user so that in the event that the controller memory fails the user may restore these values to the factory settings. The user should have a list of these constants and their settings with the instrument manual.



CAUTION: *DO NOT change the values of the instrument calibration constants from the factory set values. The correct setting of these parameters is important to the safety and proper operation of the instrument.*

The calibration parameters menu is indicated by,



Calibration parameters menu

Press “SET” five times to enter the menu. The calibration parameters menu contains the parameters, R_0 , ALPHA, and DELTA, which characterize the resistance-temperature relationship of the platinum control sensor. These parameters may be adjusted to improve the accuracy of the calibrator. This procedure is explained in detail in Section 10, Calibration Procedure.

The calibration parameters are accessed by pressing “SET” after the name of the parameter is displayed. The value of the parameter may be changed using the “UP” and “DOWN” buttons. After the desired value is reached press “SET” to set the parameter to the new value. Pressing “EXIT” causes the parameter to be skipped ignoring any changes that may have been made.

7.6.1.1 R_0

This probe parameter refers to the resistance of the control probe at 0°C. The value of this parameter is set at the factory for best instrument accuracy.

7.6.1.2 ALPHA

This probe parameter refers to the average sensitivity of the probe between 0 and 100°C. The value of this parameter is set at the factory for best instrument accuracy.

7.6.1.3 DELTA

This probe parameter characterizes the curvature of the resistance-temperature relationship of the sensor. The value of this parameter is set at the factory for best instrument accuracy.

7.7 Operating Parameters

The operating parameters menu is indicated by,

P A R *Operating parameters menu*

The operating parameters menu contains **NOTHING AT PRESENT.**

7.8 Serial Interface Parameters

The serial RS-232 interface parameters menu is indicated by,

S E R I A L *Serial RS-232 interface parameters menu*

Press “UP” to enter the menu. The serial interface parameters menu contains parameters which determine the operation of the serial interface. These controls only apply to instruments fitted with the serial interface. The parameters in the menu are — baud rate, sample period, duplex mode, and linefeed.

7.8.0.1 Baud Rate

The baud rate is the first parameter in the menu. The baud rate setting determines the serial communications transmission rate.

The baud rate parameter is indicated by,

B A U D *Serial baud rate parameter*

Press “SET” to choose to set the baud rate. The current baud rate value will then be displayed.

2400 b *Current baud rate*

The baud rate of the serial communications may be programmed to 300, 600, 1200, 2400, 4800, or 9600 baud. The default factory setting is 2400 baud. Use “UP” or “DOWN” to change the BAUD rate value.

4800 b *New baud rate*

Press “SET” to set the baud rate to the new value or “EXIT” to abort the operation and skip to the next parameter in the menu.

7.8.1 Sample Period

The sample period is the next parameter in the serial interface parameter menu. The sample period is the time period in seconds between temperature measurements transmitted from the serial interface. If the sample rate is set to 5, the instrument transmits the current measurement over the serial interface approximately every five seconds. The automatic sampling is disabled with a sample period of 0. The sample period is indicated by,

S P E r *Serial sample period parameter*

Press “SET” to choose to set the sample period. The current sample period value will be displayed.

S P = 1 *Current sample period (seconds)*

Adjust the value with “UP” or “DOWN” and then use “SET” to set the sample rate to the displayed value. Press “EXIT” to continue without changes.

S P = 60 *New sample period*

7.8.1.1 Duplex Mode

The next parameter is the duplex mode. The duplex mode may be set to full duplex or half duplex. With full duplex any commands received by the calibrator via the serial interface are immediately echoed or transmitted back to the device of origin. With half duplex the commands are executed but not echoed. The duplex mode parameter is indicated by,

d U P L *Serial duplex mode parameter*

Press “SET” to access the mode setting.

d = F U L L *Current duplex mode setting*

The mode may be changed using “UP” or “DOWN” and pressing “SET”.

d = H A L F *New duplex mode setting*

7.8.1.2 Linefeed

The final parameter in the serial interface menu is the linefeed mode. This parameter enables (on) or disables (off) transmission of a linefeed character (LF, ASCII 10) after transmission of any carriage-return. The linefeed parameter is indicated by,

L F *Serial linefeed parameter*

Press “SET” to access the linefeed parameter.

L F = 0 n *Current linefeed setting*

The mode may be changed using “UP” or “DOWN” and pressing “SET”.

L F = 0 F F *New linefeed setting*

8 Digital Communication Interface

The dry-well calibrator is capable of communicating with and being controlled by other equipment through the digital serial interface.

With a digital interface the instrument may be connected to a computer or other equipment. This allows the user to set the set-point temperature, monitor the temperature, and access any of the other controller functions, all using remote communications equipment. Communications commands are summarized in [Table 2](#) on page 36.

8.1 Serial Communications

The calibrator is installed with an RS-232 serial interface that allows serial digital communications over fairly long distances. With the serial interface the user may access any of the functions, parameters and settings discussed in [Section 7](#) with the exception of the BAUD rate setting.

8.1.1 Wiring

The serial communications cable attaches to the calibrator through the D-9 connector at the back of the instrument. Figure 6 shows the pin-out of this connector and suggested cable wiring. The serial cable should be shielded. If the unit is used in a heavy industrial setting the shielded cable must be limited to **ONE** meter.

8.1.2 Setup

Before operation the serial interface must first be set up by programming the BAUD rate and other configuration parameters. These parameters are programmed within the serial interface menu. The serial interface parameters menu is outlined in [Figure 4](#) on page 22.

To enter the serial parameter programming mode first press “EXIT” while pressing “SET” and release to enter the secondary menu. Press “SET” repeatedly until the display reads “ ϵRL ”. Press “UP” until the serial interface menu is indicated with “5 ϵRL ”. Finally press “SET” to enter the serial parameter menu. In the se-

RS-232 Cable Wiring for
IBM PC and Compatibles

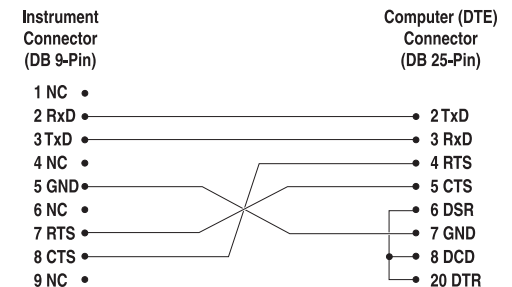
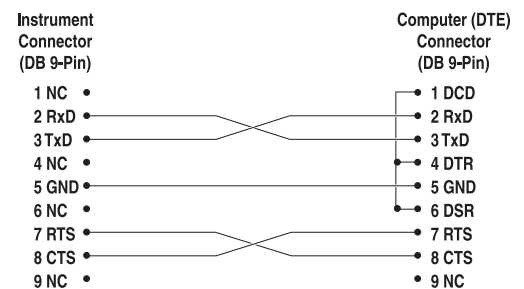


Figure 6 Serial Cable Wiring

rial interface parameters menu are the BAUD rate, the sample rate, the duplex mode, and the linefeed parameter.

8.1.2.1 Baud Rate

The baud rate is the first parameter in the menu. The display will prompt with the baud rate parameter by showing “*BAUD*”. Press “SET” to choose to set the baud rate. The current baud rate value will then be displayed. The baud rate of the 9140 serial communications may be programmed to 300, 600, 1200, 2400, 4800, or 9600 baud. The baud rate is pre-programmed to 1200 baud. Use “UP” or “DOWN” to change the baud rate value. Press “SET” to set the baud rate to the new value or “EXIT” to abort the operation and skip to the next parameter in the menu.

8.1.2.2 Sample Period

The sample period is the next parameter in the menu and prompted with “*SPEr*”. The sample period is the time period in seconds between temperature measurements transmitted from the serial interface. If the sample rate is set to 5 for instance then the instrument will transmit the current measurement over the serial interface approximately every five seconds. The automatic sampling is disabled with a sample period of 0. Press “SET” to choose to set the sample period. Adjust the period with “UP” or “DOWN” and then use “SET” to set the sample rate to the displayed value.

8.1.2.3 Duplex Mode

The next parameter is the duplex mode indicated with “*DUP L*”. The duplex mode may be set to half duplex (“HALF”) or full duplex (“FULL”). With full duplex any commands received by the thermometer via the serial interface are immediately echoed or transmitted back to the device of origin. With half duplex the commands are executed but not echoed. The default setting is full duplex. The mode may be changed using “UP” or “DOWN” and pressing “SET”.

8.1.2.4 Linefeed

The final parameter in the serial interface menu is the linefeed mode. This parameter enables (“On”) or disables (“OFF”) transmission of a linefeed character (LF, ASCII 10) after transmission of any carriage-return. The default setting is with linefeed on. The mode may be changed using “UP” or “DOWN” and pressing “SET”.

8.1.3 Serial Operation

Once the cable has been attached and the interface set up properly the controller immediately begins transmitting temperature readings at the programmed rate. The serial communications uses 8 data bits, one stop bit, and no parity. The set-point and other commands may be sent via the serial interface to set the temperature set-point and view or program the various parameters. The inter-

face commands are discussed in [Section](#). All commands are ASCII character strings terminated with a carriage-return character (CR, ASCII 13).

8.2 Interface Commands

The various commands for accessing the calibrator functions via the digital interfaces are listed in this section (see [Table 2](#)). These commands are used with the RS-232 serial interface. The commands are terminated with a carriage-return character. The interface makes no distinction between upper and lower case letters, hence either may be used. Commands may be abbreviated to the minimum number of letters which determines a unique command. A command may be used to either set a parameter or display a parameter depending on whether or not a value is sent with the command following a “=” character. For example “s”<CR> returns the current set-point and “s=150.0”<CR> sets the set-point to 150.0 degrees.

In the following list of commands, characters or data within brackets, “[” and “]”, are optional for the command. A slash, “/”, denotes alternate characters or data. Numeric data, denoted by “n”, may be entered in decimal or exponential notation. Characters are shown in lower case although upper case may be used. Spaces may be added within command strings and will simply be ignored. Backspace (BS, ASCII 8) may be used to erase the previous character. A terminating CR is implied with all commands.

Table 2 9140 controller communications commands

Command Description	Command Format	Command Example	Returned	Returned Example	Acceptable Values
Display Temperature					
Read current set-point	s[etpoint]	s	set: 9999.99 {C or F}	set: 150.00 C	
Set current set-point to <i>n</i>	s[etpoint]= <i>n</i>	s=350			Instrument Range
Read temperature	t[emperature]	t	t: 9999.9 {C or F}	t: 55.6 C	
Read temperature units	u[nits]	u	u: x	u: C	
Set temperature units:	u[nits]=c/f				C or F
Set temperature units to Celsius	u[nits]=c	u=c			
Set temperature units to Fahrenheit	u[nits]=f	u=f			
Read scan mode	sc[an]	sc	sc: {ON or OFF}	sc: ON	
Set scan mode	sc[an]=on/off	sc=on			ON or OFF
Read scan rate	sr[ate]	sr	srat: 99.9 C/min	srat:12.4 C/min	
Set scan rate	sr[ate]= <i>n</i>	sr=1.1			.1 to 99.9
Read hold	ho[ld]	ho	ho: open/closed, 99.9 {C or F}	ho: open, 30.5 C	
Secondary Menu					
Read proportional band setting	pr[op-band]	pr	pb: 999.9	pb: 15.9	
Set proportional band to <i>n</i>	pr[op-band]= <i>n</i>	pr=8.83			Depends on Configuration
Read heater power (duty cycle)	po[wer]	po	po: 999.9	po: 6.5	
Configuration Menu					
Calibration Menu					
Read R0 calibration parameter	r[0]	r	r0: 999.999	r0: 100.7	
Set R0 calibration parameter to <i>n</i>	r[0]= <i>n</i>	r=100.7			97.0 to 105
Read ALPHA calibration parameter	a[lpha]	al	al: 9.999999	al: 0.003865	
Set ALPHA calibration parameter to <i>n</i>	a[lpha]= <i>n</i>	al=0.003865			.002 to .006
Read DELTA calibration parameter	d[elta]	de		de: 1.50	
Read DELTA calibration parameter	d[elta]= <i>n</i>	de=1.37	de: 9.9999		0–3.0000
Operating Parameters Menu					
Serial Interface Menu					
Read serial sample setting	sa[mple]	sa	sa: 9	sa: 1	
Set serial sampling setting to <i>n</i> seconds	sa[mple]= <i>n</i>	sa=0			0 to 999
Set serial duplex mode:	du[plex]=f[ull]/h[alf]				FULL or HALF
Set serial duplex mode to full	du[plex]=f[ull]	du=f			
Set serial duplex mode to half	du[plex]=h[alf]	du=h			

Table 3 9140 controller communications commands continued

Command Description	Command Format	Command Example	Returned	Returned Example	Acceptable Values
Set serial linefeed mode:	lf[eed]=on/of[f]				ON or OFF
Set serial linefeed mode to on	lf[eed]=on	lf=on			
Set serial linefeed mode to off	lf[eed]=of[f]	lf=of			
Miscellaneous Other Commands					
Read firmware version number	*ver[sion]	*ver	ver.9999,9.99	ver.9140,1.21	
Read structure of all commands	h[elp]	h	list of commands		
Read ALL operating parameters	all	all	list of parameters		
Legend:	[] Optional Command data {} Returns either information n Numeric data supplied by user 9 Numeric data returned to user x Character data returned to user				
Note:	When DUPLEX is set to FULL and a command is sent to READ, the command is returned followed by a carriage return and linefeed. Then the value is returned as indicated in the RETURNED column.				

9 Test Probe Calibration

For optimum accuracy and stability, allow the calibrator to warm up for 10 minutes after power-up and then allow adequate stabilization time after reaching the set-point temperature. After completing operation of the calibrator, allow the well to cool by setting the temperature to 100°C for one-half hour before switching the power off.

9.1 Comparison Methods

For information on automating your testing, contact Hart Scientific.

9.1.1 Calibrating a Single Probe

Insert the probe to be calibrated into the well of the dry-well calibrator. The probe should fit snugly into the calibrator probe sleeve yet should not be so tight that it cannot be easily removed. Avoid any dirt or grit that may cause the probe to jam into the sleeve. Best results are obtained with the probe inserted to the full depth of the well. Once the probe is inserted into the well, allow adequate stabilization time to allow the test probe temperature to settle as described above. Once the probe has settled to the temperature of the well, it may be compared to the calibrator display temperature. The display temperature should be stable to within 0.1°C degree for best results.



CAUTION: *Never introduce any foreign material into the probe hole of the insert. Fluids etc. can leak into the calibrator causing damage to the calibrator or binding and damage to your probe.*

9.1.2 Comparison Calibration

Comparison calibration involves testing a probe against a similar reference probe. The advantage to this method is that better accuracy can be achieved since errors due to dry-well inaccuracy, stem effect, and drift can be reduced.

After inserting the probes to be calibrated, allow sufficient time for the probes to settle and the temperature of the dry-well to stabilize.

Both the reference probe and the probe under test should be the same size and construction. Using probes with different lengths, diameters and materials will have different stem effects causing an unknown temperature difference. All dry-wells have horizontal and vertical gradients that change with temperature. This is an unknown variable which can be factored out if probes are the same type, length, diameter, and material. Probes should be inserted to the same depth in the well.

The following procedure can be used to calibrate a probe against a reference while eliminating error due to temperature gradients between wells.

1. Place the reference probe in one well.

2. Place the probe to be calibrated, the unit under test (UUT), in another well.
3. With the reference inserted into one well and the probe under test inserted into a second well, make measurements of each.
4. Swap the locations of the reference probe and probe under test. Allow plenty of time for thermal settling.
5. Make another set of measurements of the reference probe and the probe under test.
6. Average the two measurements of the reference probe. Average the two measurements of the probe under test. Averaging the two measurements in this way eliminates error due to temperature gradients between the two wells.
7. You may now compare the averaged measurement of the probe under test with the averaged measurement of the reference probe.

For best results repeat the test several times at the same temperature and at different temperatures.

This method can be used with different types of probes but the user must determine the uncertainty of the measurement.

9.1.3 Calibration of Multiple Probes

Fully loading the calibrator with probes increases the time required for the temperature to stabilize after inserting the probes. Be sure that the temperature has stabilized before starting the calibration.

Multiple probes may be calibrated simultaneously using either the direct or comparison calibration method. Stem effect will cause less error in the comparison calibration method than with the direct calibration method.

9.2 Dry-well Characteristics

9.2.1 Vertical Gradient

There is a temperature gradient vertically in the test well. The heater has been applied to the block in such a way as to compensate for nominal heat losses out of the top of the dry-well and minimize vertical temperature gradients. However, actual heat losses will vary depending on the number and types of probes inserted into the calibrator and the block temperature. For best results, insert probes the full depth of well.

9.2.2 Heating and Cooling Rates

[Figures 7](#) and [8](#) show typical heating cooling rates of the 9140 dry-well calibrator.



WARNING: *DO NOT* remove inserts when heating or when the unit is hot.

9.2.3 Stabilization and Accuracy

The stabilization time of the dry-well calibrator will depend on the conditions and temperatures involved. Typically the test well will be stable to 0.1°C within 5 minutes of reaching the set-point temperature as indicated by the display. UI-

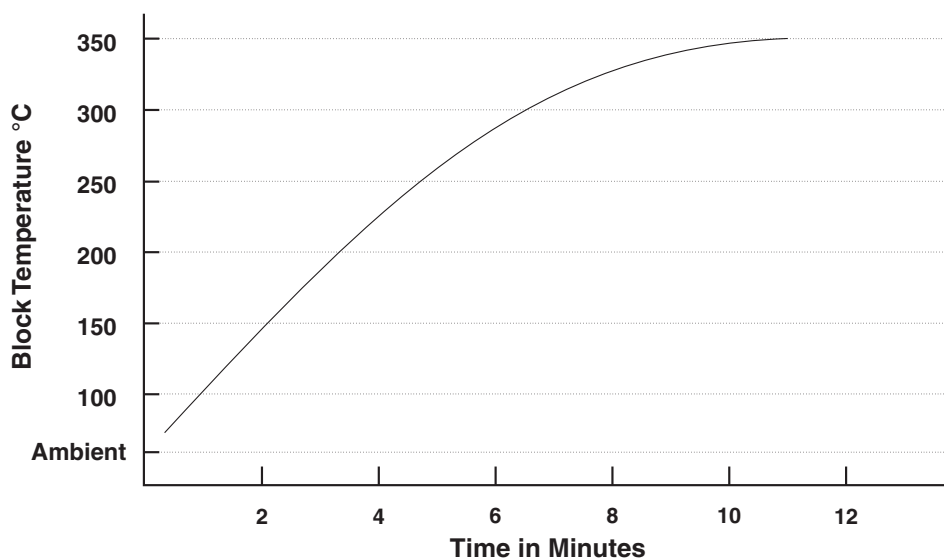


Figure 7 Typical Heating Rate

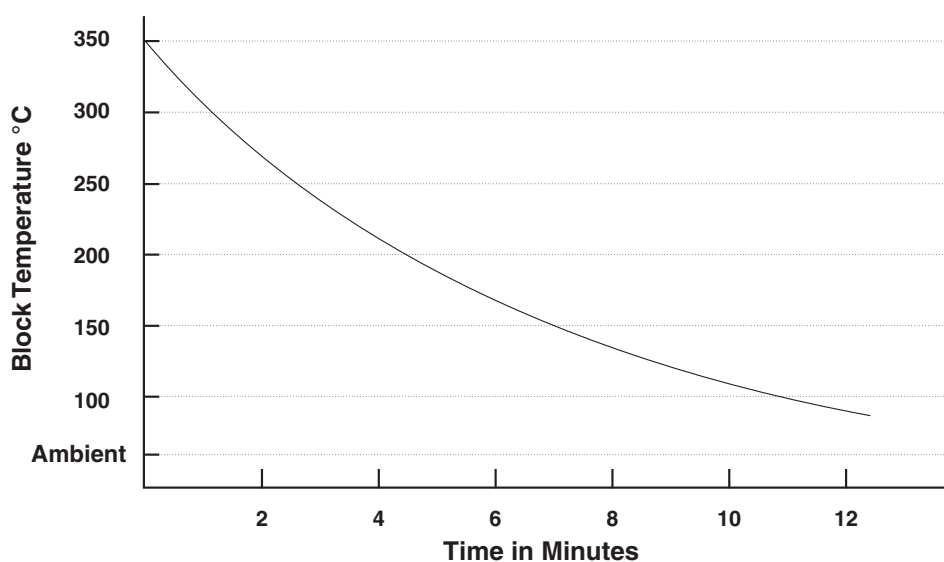


Figure 8 Typical Cooling Rate

imate stability will be achieved 10 to 20 minutes after reaching the set temperature.

Inserting a cold probe into a well will require another period of stabilizing depending on the magnitude of the disturbance and the required accuracy. For example, inserting a .25 inch diameter room temperature probe into a sleeve at 300°C will take 5 minutes to be within 0.1°C of its settled point and will take 10 minutes to achieve maximum stability.

Speeding up the calibration process can be accomplished by knowing how soon to make the measurement. It is recommended that typical measurements be made at the desired temperatures with the desired test probes to establish these times.

10 Calibration Procedure

Sometimes the user may want to calibrate the dry-well to improve the temperature set-point accuracy. Calibration is done by adjusting the controller probe calibration constants R_0 , ALPHA , and DELTA so that the temperature of the dry-well as measured with a standard thermometer agrees more closely with the set-point. The thermometer used must be able to measure the well temperature with higher accuracy than the desired accuracy of the dry-well. By using a good thermometer and following this procedure the dry-well can be calibrated to an accuracy of better than 0.5°C over its full range.

10.1 Calibration Points

In calibrating the dry-well, R_0 , ALPHA , and DELTA are adjusted to minimize the set-point error at each of three different dry-well temperatures. Any three reasonably separated temperatures may be used for the calibration. Improved results can be obtained for shorter ranges when using temperatures that are just within the most useful operating range of the dry-well. The farther apart the calibration temperatures, the larger will be the calibrated temperature range but the calibration error will also be greater over the range. If for instance 150°C to 350°C is chosen as the calibration range then the calibrator may achieve an accuracy of say $\pm 0.3^\circ\text{C}$ over the range 150 to 350°C . Choosing a range of 200°C to 300°C may allow the calibrator to have a better accuracy of maybe $\pm 0.2^\circ\text{C}$ over the range 175 to 325°C but outside that range the accuracy may be only $\pm 0.5^\circ\text{C}$.

10.2 Calibration Procedure

1. Choose three set points to use in the calibration of the R_0 , ALPHA , and DELTA parameters. These set points are generally 50.0°C , 200°C , and 350.0°C but other set points may be used if desired or necessary.
2. Set the dry-well to the low set-point. When the dry-well reaches the set-point and the display is stable, wait 15 minutes or so and then take a reading from the thermometer. Sample the set-point resistance by holding down the SET key and pressing the DOWN key. Write these values down as T_1 and R_1 respectively.
3. Repeat step 2 for the other two set points recording them as T_2 and R_2 and T_3 and R_3 respectively.
4. Using the recorded data, calculate new values for the R_0 , ALPHA , and DELTA parameters using the equations given below:

10.2.1 Compute DELTA:

$$A = T_3 - T_2$$

$$B = T_2 - T_1$$

$$C = \left[\frac{T_3}{100} \right] \left[1 - \frac{T_3}{100} \right] - \left[\frac{T_2}{100} \right] \left[1 - \frac{T_2}{100} \right]$$

$$D = \left[\frac{T_2}{100} \right] \left[1 - \frac{T_2}{100} \right] - \left[\frac{T_1}{100} \right] \left[1 - \frac{T_1}{100} \right]$$

$$E = R_3 - R_2$$

$$F = R_2 - R_1$$

$$\text{delta} = \frac{AF - BE}{DE - CF}$$

T_{1,3} - Measured temperature using thermometer.

R_{1,3} - Value of set-point resistance from display of 9140. (Press SET and DOWN at the same time.)

where

T₁ and **R₁** are the measured temperature and resistance at 50.0 °C

T₂ and **R₂** are the measured temperature and resistance at 200.0 °C

T₃ and **R₃** are the measured temperature and resistance at 350.0 °C

10.2.2 Compute R₀ & ALPHA:

$$a_1 = T_1 + \text{delta} \left[\frac{T_1}{100} \right] \left[1 - \frac{T_1}{100} \right]$$

$$a_3 = T_3 + \text{delta} \left[\frac{T_3}{100} \right] \left[1 - \frac{T_3}{100} \right]$$

$$\text{rzero} = \frac{R_3 a_1 - R_1 a_3}{a_1 - a_3}$$

$$\text{alpha} = \frac{R_1 - R_3}{R_3 a_1 - R_1 a_3}$$

delta is the new value of DELTA computed above

5. Program the new values for DELTA (delta), R₀ (rzero) & ALPHA (alpha) into the dry-well using the following steps.

- a. Press the SET and EXIT keys at the same time and then press SET until **R0** is displayed.

b. Press SET then use the UP or DOWN keys until the correct numerical setting is displayed. Press SET to accept the new value.

c. Repeat step b. for ALPHA and DELTA.

10.2.3 Accuracy & Repeatability

1. Check the accuracy of the dry-well at various points over the calibration range.
2. If dry-well does not pass specification at all set-points, repeat **Calibration Procedure**.

11 Maintenance

- The calibration instrument has been designed with the utmost care. Ease of operation and simplicity of maintenance have been a central theme in the product development. Therefore, with proper care the instrument should require very little maintenance. Avoid operating the instrument in an oily, wet, dirty, or dusty environment.
- If the outside of the instrument becomes soiled, it may be wiped clean with a damp cloth and mild detergent. Do not use harsh chemicals on the surface which may damage the paint.
- It is important to keep the well of the calibrator clean and clear of any foreign matter. Do not use fluid to clean out the well.
- The dry-well calibrator should be handled with care. Avoid knocking or dropping the calibrator.
- For dry-wells with removable probe sleeves, the sleeves can become covered with dust and carbon material. If the buildup becomes too thick, it could cause the sleeves to become jammed in the wells. Avoid this buildup by periodically buffing the sleeves clean.
- If a sleeve should be dropped, examine the sleeve for deformities before inserting it in the well. If there is any chance of jamming the sleeve in the well, file or grind off the protuberance.
- Do not drop the probe stems into the well. This type of action can cause a shock to the sensor.
- If a hazardous material is spilt on or inside the equipment, the user is responsible for taking the appropriate decontamination steps as outlined by the national safety council with respect to the material.
- If the mains supply cord becomes damaged, replace it with a cord with the appropriate gauge wire for the current of the instrument. If there are any questions, call Hart Scientific Customer Service for more information.
- Before using any cleaning or decontamination method except those recommended by Hart, users should check with Hart Scientific Customer Service to be sure that the proposed method will not damage the equipment.
- If the instrument is used in a manner not in accordance with the equipment design, the operation of the dry-well may be impaired or safety hazards may arise.

12 Troubleshooting

If problems arise while operating the 9140, this section provides some suggestions that may help you solve the problem. A wiring diagram is also included.

12.1 Troubleshooting Problems, Possible Causes, and Solutions

In the event that the instrument appears to function abnormally, this section may help to find and solve the problem. Several possible problem conditions are described along with likely causes and solutions. If a problem arises, please read this section carefully and attempt to understand and solve the problem. If the problem cannot otherwise be solved, contact a Hart Scientific Authorized Service Center (see Section 1.3) for assistance. Be sure to have the model number, serial number, voltage, and problem description available.

Problem	Possible Causes and Solutions
Incorrect temperature reading	Incorrect R0, ALPHA, and DELTA parameters. Find the value for R0, ALPHA, and DELTA on the Report of Calibration. Reprogram the parameters into the instrument (see Section , Calibration Parameters). Allow the instrument to stabilize and verify the accuracy of the temperature reading. Controller locked up. The controller may have locked up due to a power surge or other aberration. Initialize the system by performing the Factory Reset Sequence. Factory Reset Sequence. Hold the SET and EXIT buttons down at the same time while powering up the instrument. The instrument displays shows '-init-', the model number, and the firmware version. Each of the controller parameters and calibration constants must be reprogrammed. The values can be found on the Report of Calibration.
The instrument heats or cools too quickly or too slowly	Incorrect scan and scan rate settings. The scan and scan rate settings may be set to unwanted values. Check the Scan and Scan Rate settings. The scan may be off (if the unit seems to be responding too quickly). The scan may be on with the Scan Rate set low (if unit seems to be responding too slowly). Improper line voltage. Verify that the voltage reading in the bottom of the unit matches the source voltage.
Unstable display	Wait. Allow the instrument to stabilize for a few minutes. Proportional band may be incorrect. Refer to the proportional band on the Report of Calibration.

Problem	Possible Causes and Solutions
The display shows an error code	Controller problem. The error messages signify the following problems with the controller. <i>Error 1</i> - a RAM error <i>Error 2</i> - a NVRAM error <i>Error 3</i> - a Structure error <i>Error 4</i> - an ADC setup error <i>Error 5</i> - an ADC ready error <i>Error 6</i> - a defective control sensor <i>Error 7</i> - a heater error Initialize the system by performing the Factory Reset Sequence describe above.
Temperature cannot be set above a certain point	Incorrect High Limit parameter. The High Limit parameter may be set below 125°C. Check this value as described in Section 7.7, Operating Parameters.
Display is reading incorrectly	The instrument was turned off at high temperatures and reenergized too quickly. Turn the instrument off until the display is completely off and then reenergize.
Display flickers when the instrument is turned off	This is normal operation and is more prevalent at high temperatures due to Seebeck Coefficient of the thermoelectric cooling devices. Some time is required to fully discharge the switching power supply and to complete the power off cycle.
The instrument does not reach temperature	The specifications for the instrument include an ambient temperature of 23°C. If the ambient temperature is above 23°C, the instrument may not be able to reach the lowest specified temperature. Check the ambient temperature if the instrument does not reach maximum temperature.

12.2 CE Comments

12.2.1 EMC Directive

Hart Scientific's equipment has been tested to meet the European Electromagnetic Compatibility Directive (EMC Directive, 89/336/EEC). The Declaration of Conformity for your instrument lists the specific standards to which the unit was tested.

12.2.2 Low Voltage Directive (Safety)

In order to comply with the European Low Voltage Directive (73/23/EEC), Hart Scientific equipment has been designed to meet the IEC 1010-1 (EN 61010-1) and IEC 1010-2-010 (EN 61010-2-010) standards.