INSTRUCTION MANUAL

110PV Surface Temperature Probe

Revision: 8/17

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This equipment is warranted by CAMPBELL SCIENTIFIC (CANADA) CORP. (“CSC”) to be free from defects in materials and workmanship under normal use and service for **twelve (12) months** from date of shipment unless specified otherwise. ***** **Batteries are not warranted.** ***** CSC's obligation under this warranty is limited to repairing or replacing (at CSC's option) defective products. The customer shall assume all costs of removing, reinstalling, and shipping defective products to CSC. CSC will return such products by surface carrier prepaid. This warranty shall not apply to any CSC products which have been subjected to modification, misuse, neglect, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied, including warranties of merchantability or fitness for a particular purpose. CSC is not liable for special, indirect, incidental, or consequential damages.

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RMA#_____
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Canada

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Precautions

DANGER — MANY HAZARDS ARE ASSOCIATED WITH INSTALLING, USING, MAINTAINING, AND WORKING ON OR AROUND **TRIPODS, TOWERS, AND ANY ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC**. FAILURE TO PROPERLY AND COMPLETELY ASSEMBLE, INSTALL, OPERATE, USE, AND MAINTAIN TRIPODS, TOWERS, AND ATTACHMENTS, AND FAILURE TO HEED WARNINGS, INCREASES THE RISK OF DEATH, ACCIDENT, SERIOUS INJURY, PROPERTY DAMAGE, AND PRODUCT FAILURE. TAKE ALL REASONABLE PRECAUTIONS TO AVOID THESE HAZARDS. CHECK WITH YOUR ORGANIZATION'S SAFETY COORDINATOR (OR POLICY) FOR PROCEDURES AND REQUIRED PROTECTIVE EQUIPMENT PRIOR TO PERFORMING ANY WORK.

Use tripods, towers, and attachments to tripods and towers only for purposes for which they are designed. Do not exceed design limits. Be familiar and comply with all instructions provided in product manuals. Manuals are available at www.campbellsci.ca or by telephoning (780) 454-2505 (Canada). You are responsible for conformance with governing codes and regulations, including safety regulations, and the integrity and location of structures or land to which towers, tripods, and any attachments are attached. Installation sites should be evaluated and approved by a qualified personnel (e.g. engineer). If questions or concerns arise regarding installation, use, or maintenance of tripods, towers, attachments, or electrical connections, consult with a licensed and qualified engineer or electrician.

General

- Prior to performing site or installation work, obtain required approvals and permits.
- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a **hardhat** and **eye protection**, and take **other appropriate safety precautions** while working on or around tripods and towers.
- **Do not climb** tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

Utility and Electrical

- **You can be killed** or sustain serious bodily injury if the tripod, tower, or attachments you are installing, constructing, using, or maintaining, or a tool, stake, or anchor, come in **contact with overhead or underground utility lines**.
- Maintain a distance of at least one-and-one-half times structure height, 6 meters (20 feet), or the distance required by applicable law, **whichever is greater**, between overhead utility lines and the structure (tripod, tower, attachments, or tools).
- Prior to performing site or installation work, inform all utility companies and have all underground utilities marked.
- Comply with all electrical codes. Electrical equipment and related grounding devices should be installed by a licensed and qualified electrician.

Elevated Work and Weather

- Exercise extreme caution when performing elevated work.
- Use appropriate equipment and safety practices.
- During installation and maintenance, keep tower and tripod sites clear of un-trained or non-essential personnel. Take precautions to prevent elevated tools and objects from dropping.
- Do not perform any work in inclement weather, including wind, rain, snow, lightning, etc.

Maintenance

- Periodically (at least yearly) check for wear and damage, including corrosion, stress cracks, frayed cables, loose cable clamps, cable tightness, etc. and take necessary corrective actions.
- Periodically (at least yearly) check electrical ground connections.

WHILE EVERY ATTEMPT IS MADE TO EMBODY THE HIGHEST DEGREE OF SAFETY IN ALL CAMPBELL SCIENTIFIC PRODUCTS, THE CLIENT ASSUMES ALL RISK FROM ANY INJURY RESULTING FROM IMPROPER INSTALLATION, USE, OR MAINTENANCE OF TRIPODS, TOWERS, OR ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC.

PLEASE READ FIRST

About this manual

Please note that this manual was originally produced by Campbell Scientific Inc. (CSI) primarily for the US market. Some spellings, weights and measures may reflect this origin.

Some useful conversion factors:

Area:	1 in^2 (square inch) = 645 mm^2
Length:	1 in. (inch) = 25.4 mm
	1 ft (foot) = 304.8 mm
	1 yard = 0.914 m
	1 mile = 1.609 km
Mass:	1 oz. (ounce) = 28.35 g
	1 lb (pound weight) = 0.454 kg
Pressure:	1 psi (lb/in2) = 68.95 mb
Volume:	1 US gallon = 3.785 litres

In addition, part ordering numbers may vary. For example, the CABLE5CBL is a CSI part number and known as a FIN5COND at Campbell Scientific Canada (CSC). CSC Technical Support will be pleased to assist with any questions.

About sensor wiring

Please note that certain sensor configurations may require a user supplied jumper wire. It is recommended to review the sensor configuration requirements for your application and supply the jumper wire is necessary.

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110PV Surface Temperature Probe

1. Introduction

The 110PV-L temperature probe uses a thermistor to measure temperature from –40 to 135 °C. It is designed for measuring the back of photovoltaic (PV) module temperature but also can be used to measure other surface temperatures. The 110PV-L is compatible with all Campbell Scientific dataloggers.

NOTE This manual provides information only for CRBasic dataloggers. It is also compatible with our retired Edlog dataloggers. For Edlog datalogger support, see an older manual at *www.campbellsci.com/old-manuals*.

2. Precautions

- READ AND UNDERSTAND the *Safety* section at the front of this manual.
- Do not use epoxy to secure the 110PV to a PV module.
- Prying the 110PV off without heating it will likely damage both the probe and PV module.
- The 110PV's cable must be properly strain relieved after mounting the probe to the measurement surface (Section 7.3, *Cable Strain Relief* *(p. 7)*).
- Placement of the 110PV's cable inside a rugged conduit is advisable for long cable runs, especially in locations subject to digging, mowing, traffic, use of power tools, animals, or lightning strikes.
- Santoprene® rubber, which composes the black outer jacket of the 110PV cable, will support combustion in air. It is used because of its resistance to temperature extremes, moisture, and UV degradation. It is rated as slow burning when tested according to U.L. 94 H.B. and passes FMVSS302. However, local fire codes may preclude its use inside buildings.

3. Initial Inspection

- Upon receipt of the 110PV, inspect the packaging and contents for damage. File damage claims with the shipping company.
- The model number, cable length, and cable resistance are printed on a label at the connection end of the cable. Check this information against the shipping documents to ensure the expected product and cable length are received.
- Refer to the Ships With list to ensure that all parts are included (see Section 3.1, *Ships With* *(p. 2)*).

3.1 Ships With

The 110PV ships with:

(2) Adhesive-backed, 3 cm, cable tie mount (pn 2376)
(2) Cable tie, 4-inch, UV stabilized (pn 2207)
(1) Resource DVD

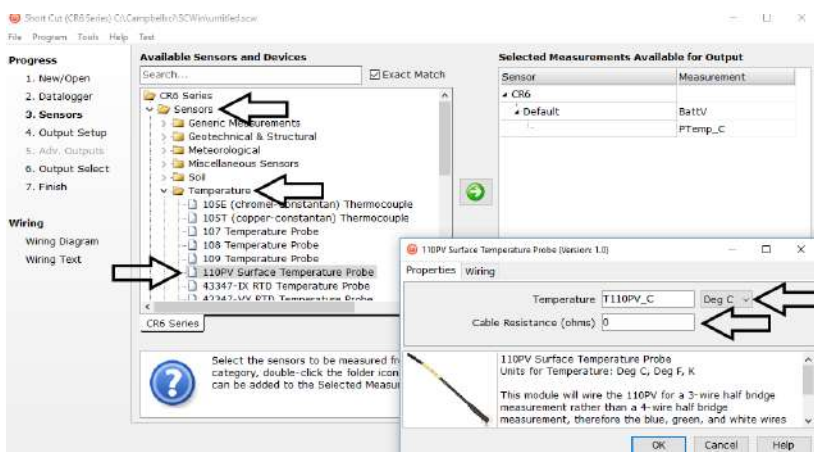
4. QuickStart

Short Cut is an easy way to program your datalogger to measure the 110PV and assign datalogger wiring terminals. *Short Cut* is available as a download on *www.campbellsci.com* and the *ResourceDVD*. The following procedure shows using *Short Cut* to program the 110PV.

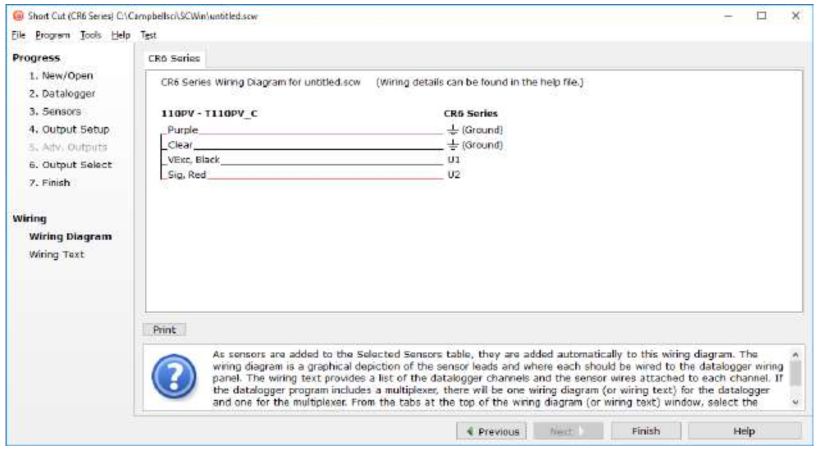
1. Open *Short Cut* and select to create a new program.

2. Double-click the datalogger model.

3. Under the **Available Sensors and Devices** list, select the **Sensors | Temperature | Soil Moisture** and double-click **110PV**. Enter the **Cable Resistance**. This value is unique for each 110PV, and is printed on the heat shrink label attached to the sensor cable. The surface temperature defaults to degree C. This can be changed by clicking the **Temperature** box and selecting one of the other options.



4. After selecting the sensor, click at the left of the screen on **Wiring Diagram** to see how the sensor is to be wired to the datalogger. *Short Cut* uses a 3-wire half bridge measurement, and therefore doesn't use the blue, green, and white wires. The wiring diagram can be printed out now or after more sensors are added.



5. Select any other sensors you have, then finish the remaining *Short Cut* steps to complete the program. The remaining steps are outlined in *Short Cut Help*, which is accessed by clicking on **Help | Contents | Programming Steps**.

6. If *LoggerNet*, *PC400*, *RTDAQ*, or *PC200W* is running on your PC, and the PC to datalogger connection is active, you can click **Finish** in *Short Cut* and you will be prompted to send the program just created to the datalogger.

7. If the sensor is connected to the datalogger, as shown in the wiring diagram in step 4, check the output of the sensor in the datalogger support software data display to make sure it is making reasonable measurements.

5. Overview

The 110PV can provide the photovoltaic (PV) module temperature for solar energy applications. This measurement is useful since the output of a PV module is affected by its temperature. As the temperature of the PV module increases, its output decreases.

The 110PV-L consists of a thermistor encased in an aluminum disk (see FIGURE 5-1). The aluminum disk protects the thermistor and promotes heat transfer from surfaces. An adhesive tab on the probe's aluminum disk fastens the 110PV to the measurement surface. If the temperature may exceed 70 °C, also use Kapton tape (pn 27015) to secure the probe to the measurement surface.

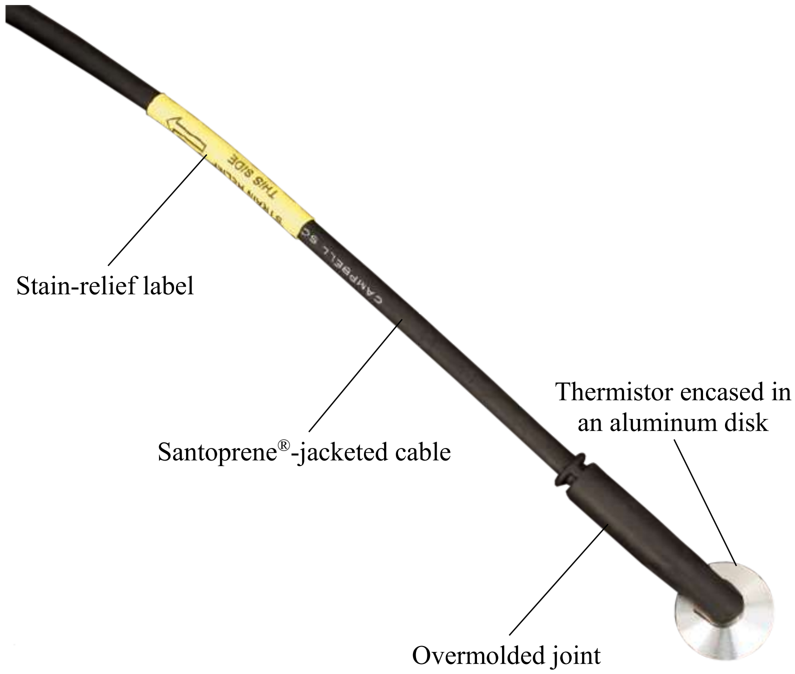


FIGURE 5-1. 110PV Temperature Probe

The –L portion of the probes model number indicates the probe has a user-defined cable length that is specified when the probe is ordered.

The probe's cable can terminate in:

- Pigtails that connect directly to a Campbell Scientific datalogger (option –PT).
- Connector that attaches to a prewired enclosure (option –PW). Refer to *www.campbellsci.com/prewired-enclosures* for more information.
- Connector that attaches to a CWS900 Wireless Sensor Interface (option –CWS). The CWS900 allows the 110PV to be used in a wireless sensor network. Refer to *www.campbellsci.com/cws900* for more information.

6. Specifications

Features:

- Easy to install—adhesive strips on the 110PV's smooth face adhere to the back of a solar panel or other device
- Aluminum disk protects thermistor and promotes heat transfer from surfaces
- Makes accurate measurements in environments with heavy electromagnetic interference
- Compatible with Campbell Scientific CRBasic dataloggers: CR200(X) series, CR300 series, CR6 series, CR800 series, CR1000, CR1000X, CR3000, and CR5000

Temperature Range:	–40 to 135 °C
Survival Range:	–50 to 140 °C
Accuracy[1]	
Worst Case:	±0.2 °C (–40 to 70 °C) ±0.5 °C (71 to 105 °C) ±1 °C (106 to 135 °C)
Maximum Steinhart-Hart Linearization Error:	0.0024 °C at –40 °C
Maximum Cable Length:	304.8 m (1000 ft)
Disk Diameter:	2.54 cm (1.0 in)
Overall Probe Length:	6.35 cm (2.5 in)
Overmolded Joint Dimensions	
Width:	1.12 cm (0.44 in)
Height:	1.47 cm (0.58 in)
Length:	5.72 cm (2.25 in)
Cable Diameter:	0.622 cm (0.245 in)
Material	
Disk:	Anodized Aluminum
Cable Jacket:	Santoprene®
Cable/Probe Connection:	Santoprene®
Weight:	90.7 g (0.2 lb) with 3.2 m (10.5 ft) cable

[1] The overall probe accuracy is a combination of the thermistor's interchangeability specification, the accuracy of the bridge resistor, and error of the Steinhart-Hart equation. The major error component is the interchangeability specification (tolerance) of the thermistor. The bridge resistor has a 0.1% tolerance with a 10 ppm temperature coefficient. Effects of cable resistance is discussed in Section 8.3, *Long Lead Lengths* ***(p. 10)***.

7. Installation

If you are programming your datalogger with *Short Cut*, skip Section 7.4, *Wiring* ***(p. 8)***, and Section 7.5, *Datalogger Programming* ***(p. 8)***. *Short Cut* does this work for you. See Section 4, *QuickStart* ***(p. 2)***, for a *Short Cut* tutorial.

7.1 Placement on a Photovoltaic (PV) Module

The PV module may or may not have distinctive solar cells (FIGURE 7-1). If the PV module does not have distinctive solar cells, center the 110PV on the back of the PV module. If the module has several distinctive photocells, center the 110PV on the back of the photocell that is the middle of the PV module.

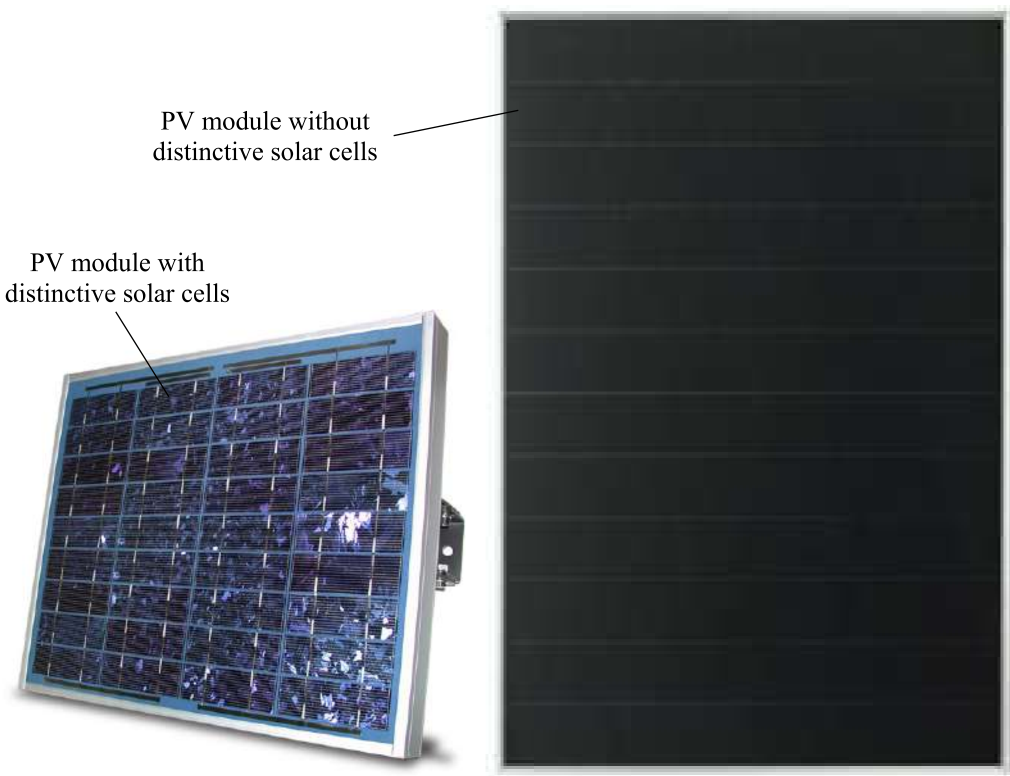


FIGURE 7-1. Types of PV modules

7.2 Mounting to a PV Module or Other Device

The 110PV includes an adhesive mounting strip adhered to the flat surface of the aluminum disk. To mount the 110PV, remove the paper from the mounting strip and adhere it to the back of the PV module or other device. The mounting strip must be adhered to a clean surface for its adhesive to function properly.

If the temperature might exceed 70 °C, use Kapton tape (pn 27015) to secure the probe to the measurement surface (see FIGURE 7-2). To ensure that the probe is adequately fastened to the measurement surface, use three strips of Kapton tape:

1. Place the first strip of tape across the sensor and rub the tape surface to remove bubbles.

2. Place the other strips of tape on the first strip of tape and rub the tape surface to remove bubbles. The three strips of tape should form an “H” (FIGURE 7-2).

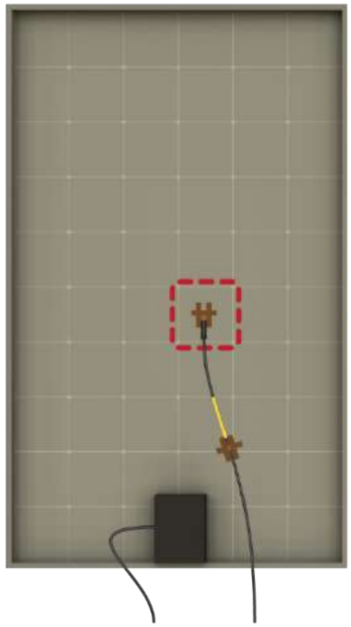


FIGURE 7-2. 110PV mounted to a PV module using Kapton tape

7.3 Cable Strain Relief

The 110PV's cable must be properly strain relieved after mounting the probe to the measurement surface. To accomplish this, the probe comes with cable ties and a cable tie mount. A yellow label on the 110PV's cable indicates where the cable should be tied down (see FIGURE 7-3).

NOTE Placement of the cable inside a rugged conduit is advisable for long cable runs, especially in locations subject to digging, mowing, traffic, use of power tools, animals, or lightning strikes.

FIGURE 7-3. 110PV's strain relief label

CAUTION Do not use epoxy to secure the 110PV to a PV module.

7.4 Wiring

NOTE When *Short Cut* software is used to generate the datalogger program, the sensor should be wired to the channels shown on the wiring diagram created by *Short Cut*.

Connections to Campbell Scientific dataloggers are given in TABLE 7-1. Most CRBasic dataloggers can measure the 110PV using either a 4-wire half bridge or 3-wire half bridge. The CR200(X) dataloggers can only use a 3-wire half bridge. The 4-wire half bridge method is preferred because it reduces cable errors. The 4-wire half bridge method requires two differential input channels and one voltage excitation channel. The 3-wire half bridge method uses one single-ended input channel and one voltage excitation channel.

Multiple probes can be connected to the same excitation channel. The number of probes per excitation channel is physically limited by the number of lead wires that can be inserted into a single voltage excitation terminal, approximately six.

TABLE 7-1. Connections to Campbell Scientific Dataloggers

Color	Description	4-Wire Half Bridge	3-Wire Half Bridge
Black	Voltage Excitation	Voltage Excitation	Voltage Excitation
Red	Signal	Differential Input (H)	Single-Ended Input
Purple	Signal Reference	Differential Input (L)	⏚
Blue	Signal Reference	⏚	Not Used
Clear	Shield	⏚	⏚
Green	Sense +	Differential Input (H)	Not Used
White	Sense –	Differential Input (L)	Not Used

7.5 Datalogger Programming

Short Cut is the best source for up-to-date datalogger programming code. Programming code is needed when:

- Creating a program for a new datalogger installation
- Adding sensors to an existing datalogger program

If your data acquisition requirements are simple, you can probably create and maintain a datalogger program exclusively with *Short Cut*. If your data acquisition needs are more complex, the files that *Short Cut* creates are a great source for programming code to start a new program or add to an existing custom program.

NOTE *Short Cut* cannot edit programs after they are imported and edited in *CRBasic Editor*.

A *Short Cut* tutorial is available in Section 4, *QuickStart* ***(p. 2)***. If you wish to import *Short Cut* code into *CRBasic Editor* to create or add to a customized program, follow the procedure in Appendix A, *Importing Short Cut Code Into CRBasic Editor* ***(p. A-1)***.

Programming basics for CRBasic dataloggers are provided in the following sections. Complete program examples for select CRBasic dataloggers can be found in Appendix B, *Example Programs* ***(p. B-1)***. Programming basics and programming examples for Edlog dataloggers are provided at *www.campbellsci.com\old-manuals.*

If applicable, please read Section 8.2, *Electrical Noisy Environments* ***(p. 10)***, and Section 8.3, *Long Lead Lengths* ***(p. 10)***, prior to programming your datalogger. Measurement details are provided in Section 8.1, *Measurement Details* ***(p. 10)***.

7.5.1 Resistance Measurement

The CR300 series, CR6, CR800, CR850, CR1000, CR1000X, CR3000, CR5000, and CR9000(X) can use either the **BrHalf4W()** instruction or **BrHalf()** instruction to measure the 110PV. The **BrHalf4W()** instruction reduces cable errors, but the **BrHalf()** instruction requires fewer input channels.

A typical **BrHalf4W()** instruction is:

BrHalf4W(*Dest,1,mV2500,mV2500,1,Vx1,1,2500,True ,True ,0,250,1.0,0***)**

A typical **BrHalf()** instruction is:

BrHalf(*Dest,1,mV2500,1,Vx1,1,2500,True ,0,250,1.0,0***)**

The CR200(X)-series dataloggers use the **ExDelSe()** instruction to measure the 110PV. The **ExDelSe()** instruction has the following syntax:

ExDelSE(*Dest, Reps, SEChan, ExChan, ExmV, Delay, Mult, Offset* **)**

A multiplier of 1.0 and offset of 0.0 should be used in the **ExDelSe()**, **BrHalf4W()**, and **BrHalf()** instructions to provide a temperature in degrees Celsius. For Fahrenheit, multiply the calculated Celsius temperature by 1.8 then add 32.

7.5.2 Converting Resistance Measurement to Temperature

The Steinhart-Hart equation is used to convert the resistance measurement to temperature.

Temp_C = (1/(A+B*LOG(T110PV_Res)+C*(LOG(T110PV_Res))^3))-273.15

The coefficients used for the Steinhart-Hart equation are:

$A=1.129241*10^{-3}$
$B=2.341077*10^{-4}$
$C=8.775468*10^{-8}$

8. Operation

8.1 Measurement Details

Understanding the details in this section is not necessary for general operation of the 110PV Probe with our dataloggers.

Simple half bridge measurement, ignoring cable resistance, has a measured voltage, V, of:

$$V = V_{EX} \frac{4{,}990}{4{,}990 + R_t}$$

Where V_{EX} is the excitation voltage, 4,990 ohms is the resistance of the fixed resistor and R_t is the resistance of the thermistor

The resistance of the thermistor is:

$$R_t = 4{,}990\left(\frac{V_{EX}}{V} - 1\right)$$

The Steinhart-Hart equation is used to calculate temperature from Resistance:

$$T_K = \frac{1}{A + B\ln(R_T) + C(\ln(R_T))^3}$$

Where T_K is the temperature in Kelvin. The Steinhart- Hart coefficients used are:

A = $1.129241\text{x}10^{-3}$
B = $2.341077\text{x}10^{-4}$
C = $8.775468\text{x}10^{-8}$

8.2 Electrical Noisy Environments

AC power lines, pumps, and motors, can be the source of electrical noise. If the 110PV probe or datalogger is located in an electrically noisy environment, the 110PV probe should be measured with the 60 or 50 Hz rejection option as shown in Appendix B.1.1, *Half Bridge CR1000 Program* *(p. B-1)*, and Appendix B.1.2, *4-Wire Half Bridge CR1000 Program* *(p. B-3)*.

8.3 Long Lead Lengths

Cable resistance can cause significant error. For each 110PV, the cable resistance (ohms) is printed on the heat shrink label on the sensor cable. When measuring the 110PV in a 3-wire configuration, the cable resistance can be subtracted from the measured resistance value (see Appendix B.1.1, *Half Bridge CR1000 Program* *(p. B-1)*, and Appendix B.2, *Example CR200X Program* *(p. B-4)*).

Alternatively, the 110PV-L's cable includes leads allowing it to be measured with a 4-wire half bridge configuration, which corrects for cable resistance (see Appendix B.1.2, *4-Wire Half Bridge CR1000 Program* *(p. B-3)*).

Additional settling time may be required for lead lengths longer than 300 feet, where settling time is the delay before the measurement is made. The 60 and 50 Hz integration options include a 3 ms settling time; longer settling times can be entered into the *Settling Time* parameter.

9. Maintenance and Troubleshooting

NOTE For all factory repairs, customers must get an RMA. Customers must also properly fill out a “Declaration of Hazardous Material and Decontamination” form and comply with the requirements specified in it. Refer to the *Assistance* page at the front of this manual for more information.

9.1 Troubleshooting

Symptom: Temperature is NAN, –INF, –9999, –273

Verify the red wire is connected to the correct single-ended analog input channel as specified by the measurement instruction, the black wire is connected to the switched excitation channel as specified by the measurement instruction, and the purple wire is connected to datalogger ground.

Symptom: Incorrect Temperature

Verify the multiplier and offset parameters are correct for the desired units (Section 7.5, *Datalogger Programming* (p. 8)). Check the cable for signs of damage and possible moisture intrusion.

CAUTION If the 110PV needs to be sent to Campbell Scientific for repairs, remember that the probe must be heated to 70 to 80 °C before removing it from the measurement surface. Prying the probe off without heating it will likely damage both the probe and the PV module.

Symptom: Unstable Temperature

Try using the 60 or 50 Hz integration options, and/or increasing the settling time. Make sure the clear shield wire is connected to datalogger ground, and the datalogger is properly grounded.

9.2 Maintenance

The 110PV probe requires minimal maintenance. Periodically check cabling for proper connections, signs of damage, and possible moisture intrusion.

Appendix A. Importing Short Cut Code Into CRBasic Editor

This tutorial shows:

- How to import a *Short Cut* program into a program editor for additional refinement
- How to import a wiring diagram from *Short Cut* into the comments of a custom program

Short Cut creates files, which can be imported into *CRBasic Editor*. Assuming defaults were used when *Short Cut* was installed, these files reside in the C:\campbellsci\SCWin folder:

- .DEF (wiring and memory usage information)
- .CR2 (CR200(X)-series datalogger code)
- .CR300 (CR300-series datalogger code)
- .CR6 (CR6-series datalogger code)
- .CR8 (CR800-series datalogger code)
- .CR1 (CR1000 datalogger code)
- .CR1X (CR1000X datalogger code)
- .CR3 (CR3000 datalogger code)
- .CR5 (CR5000 datalogger code)

Use the following procedure to import *Short Cut* code and wiring diagram into *CRBasic Editor*.

1. Create the *Short Cut* program following the procedure in Section 4, *QuickStart* *(p. 2)*. Finish the program and exit *Short Cut*. Make note of the file name used when saving the *Short Cut* program.
2. Open *CRBasic Editor*.
3. Click **File | Open**. Assuming the default paths were used when *Short Cut* was installed, navigate to C:\CampbellSci\SCWin folder. The file of interest has the .CR2, .CR300, .CR6, .CR8, .CR1, .CR1X, .CR3, or .CR5 extension. Select the file and click **Open**.
4. Immediately save the file in a folder different from C:\Campbellsci\SCWin, or save the file with a different file name.

NOTE Once the file is edited with *CRBasic Editor*, *Short Cut* can no longer be used to edit the datalogger program. Change the name of the program file or move it, or *Short Cut* may overwrite it next time it is used.

5. The program can now be edited, saved, and sent to the datalogger.
6. Import wiring information to the program by opening the associated .DEF file. Copy and paste the section beginning with heading "-Wiring for CRXXX–" into the CRBasic program, usually at the head of the file. After pasting, edit the information such that an apostrophe (') begins each line. This character instructs the datalogger compiler to ignore the line when compiling.

Appendix B. Example Programs

TABLE B-1. Wiring for Example Programs

Color	Description	Datalogger Connection	
		BrHalf	BrHalf4W
Black	Voltage Excitation	VX1 or EX1	VX1 or EX1
Red	Signal	SE1	Diff 1H
Purple	Signal Reference	⏚	Diff 1L
Blue	Signal Reference	Not Used	⏚
Clear	Shield	⏚	⏚
Green	Sense +	Not Used	Diff 2H
White	Sense –	Not Used	Diff 2L

B.1 CR1000 Programs

B.1.1 Half Bridge CR1000 Program

CRBasic Example B-1. Half Bridge CR1000 Program

```
'CR1000 Series Datalogger
'This example program measures a single 110PV-L probe utilizing
'the BrHalf instruction once a second and stores the average
'temperature in degrees C every 10 minutes.

'110PV-L Wiring Configuration
'Lead Color      CR1000 Channel      Description
'Black           VX1                 Voltage Excitation
'Red             SE1                 Signal
'Purple          AG                  Signal Reference
'Blue            Not Used            N/A
'Green           Not Used            N/A
'White           Not Used            N/A
'Clear           AG                  Shield

'Declare variables for temperature measurement using Half Bridge configuration
Public T110PV_mV
Public T110PV_Res
Public T110PV_Temp_C
Public T110PV_Temp_F

'Declare Constants to be used in Steinhart-Hart equation
Const A=1.129241*10^-3
Const B=2.341077*10^-4
Const C=8.775468*10^-8
Const R_cable=0  'see sensor cable for cable resistance

'Declare variable units
Units T110PV_mV= millivolts
Units T110PV_Res=Ohms
Units T110PV_Temp_C=Deg C
```

```
Units T110PV_Temp_F=Deg F

'Define a data table for 10 minute averages
DataTable (AvgTemp,1,1000)
  DataInterval (0,10,Min,10)
  Average (1,T110PV_Temp_C,FP2,False)
EndTable

BeginProg
  Scan (1,Sec,3,0)
    'Measure 110PV-L probe
    BrHalf (T110PV_mV,1,mV2500,1,Vx1,1,2500,True ,0,_60Hz,1.0,0)
    'Convert mV to ohms
    T110PV_Res=4990*(1-T110PV_mV)/T110PV_mV
    'Subtract off cable resistance (see 110PV-L cable for R_cable)
    T110PV_Res= T110PV_Res-R_cable
    'Using the Steinhart-Hart equation to convert resistance to temperature
    T110PV_Temp_C = (1/(A+B*LOG(T110PV_Res)+C*(LOG(T110PV_Res))^3))-273.15
    'Convert Celsius to Fahrenheit
    T110PV_Temp_F = T110PV_Temp_C * 1.8 + 32
    'Call AvgTemp data table
    CallTable AvgTemp
  NextScan
EndProg
```

B.1.2 4-Wire Half Bridge CR1000 Program

CRBasic Example B-2. 4-Wire Half Bridge CR1000 Program

```
'CR1000 Series Datalogger
'This example program measures a single 110PV-L probe utilizing the
'BRHalf4Winstruction once a second and stores the
'average temperature in degrees C every 10 minutes.

'110PV-L Wiring Configuration
'Lead Color      CR1000 Channel      Description
'Black           VX1/EX1             Voltage Excitation
'Red             DIFF1H              Signal
'Purple          DIFF1L              Signal Reference
'Blue            AG                  Signal Reference
'Green           DIFF2H              Sense +
'White           DIFF2L              Sense -
'Clear           AG                  Shield

'Declare variables for temperature measurement using Half Bridge configuration
Public T110PV_mV
Public T110PV_Res
Public T110PV_Temp_C
Public T110PV_Temp_F

'Declare constants to be used in Steinhart-Hart equation
Const A=1.129241*10^-3
Const B=2.341077*10^-4
Const C=8.775468*10^-8

'Declare variable units
Units T110PV_mV= millivolts
Units T110PV_Res=Ohms
Units T110PV_Temp_C=Deg C
Units T110PV_Temp_F=Deg F

'Define a data table for 10 minute averages
DataTable (AvgTemp,1,1000)
  DataInterval (0,10,Min,10)
  Average (1,T110PV_Temp_C,FP2,False)
EndTable

BeginProg
  Scan (1,Sec,3,0)
    'Measure 110PV-L probe
    BrHalf4W (T110PV_mV,1,mV2500,mV2500,1,Vx1,1,2500,True,True,0,_60Hz,1.0,0)
    'Convert mV to ohms
    T110PV_Res=4990 *T110PV_mV
    'Use the Steinhart-Hart equation to convert resistance to temperature
    T110PV_Temp_C = (1/(A+B*LOG(T110PV_Res)+C*(LOG(T110PV_Res))^3))-273.15
    'Convert Celsius to Fahrenheit
    T110PV_Temp_F = T110PV_Temp_C * 1.8 + 32
    CallTable AvgTemp
  NextScan
EndProg
```

B.2 Example CR200X Program

CRBasic Example B-3. Example CR200X Program

```
'CR200 Series Datalogger
'This example program measures a single 110PV-L probe
'once a second using the ExDelSE instruction and stores
'the average temperature in degrees C every 10 minutes.

'110PV-L Wiring configuration for program example
'Lead Color      CR200(X) Channel     Description
'Black           VX1                  Voltage Excitation
'Red             SE1                  Signal
'Purple          AG                   Signal Reference
'Blue            Not Used             N/A
'Green           Not Used             N/A
'White           Not Used             N/A
'Clear           AG                   Shield

'Declare variables for temperature measurement
Public T110PV_mV
Public T110PV_Res
Public T110PV_Temp_C
Public T110PV_Temp_F

'Declare constants to be used in Steinhart-Hart equation
Const A=1.129241*10^-3
Const B=2.341077*10^-4
Const C=8.775468*10^-8
Const R_cable=0  'see sensor cable for cable resistance

'Declare variable units
Units T110PV_mV= millivolts
Units T110PV_Res=Ohms
Units T110PV_Temp_C=Deg C

'Define a data table for 10 minute averages
DataTable (AvgTemp,1,1000)
  DataInterval (0,10,min)
  Average (1,T110PV_Temp_C,False)
EndTable

'Main Program
BeginProg
  Scan (1,Sec)
    'Measure 110PV-L probe with SE1
    ExDelSE (T110PV_mV,1,1,Ex1,mV2500,500,1.0,0)

    'Convert mV to ohms
    T110PV_Res = 4990*(2500/T110PV_mV)-4990

    'Subtract off cable resistance (see 110PV-L cable for R_cable)
    T110PV_Res = T110PV_Res-R_cable

    'Using the Steinhart-Hart equation to convert resistance to temperature
    T110PV_Temp_C = (1/(A+B*LOG(T110PV_Res)+C*(LOG(T110PV_Res))^3))-273.15

    'Convert Celsius to Fahrenheit
    T110PV_Temp_F = T110PV_Temp_C * 1.8 + 32

    'Call AvgTemp data table
    CallTable AvgTemp
  NextScan
EndProg
```

Appendix C. Probe Material Properties

The probe consists of 6061 aluminum (clear anodized), thermistor, 3M9485PC adhesive, and Santoprene® jacketed cable.

C.1 3M 9485PC Adhesive

Humidity Resistance: High humidity has a minimal effect on adhesive performance. Bond strengths are generally higher after exposure for 7 days at 90 °F (32 °C) and 90% relative humidity.

U.V. Resistance: When properly applied, nameplates and decorative trim parts are not adversely affected by outdoor exposure.

Water Resistance: Immersion in water has no appreciable effect on the bond strength. After 100 hours in room temperature water the bond actually shows an increase in strength.

Temperature Cycling Resistance: Bond strength generally increases after cycling four times through:

- 4 hours at 158 °F (70 °C)
- 4 hours at –20 °F (–29 °C)
- 16 hours at room temperature

Chemical Resistance: When properly applied, adhesive will hold securely after exposure to numerous chemicals including gasoline, oil, Freon™ TF, sodium chloride solution, mild acids, and alkalis.

Heat Resistance: Adhesive 350 is usable for short periods (minutes, hours) at temperatures up to 350 °F (177 °C) and for intermittent longer periods (days, weeks) up to 250 °F (121 °C).

Low Temperature Service: –40 °F (–40 °C). Parts should be tested for low temperature shock service.

C.2 Santoprene®

The following information is from Advanced Elastomer Systems; Santoprene Rubber Fluid Resistance Guide; pp 2, 3, 9; copyright 2000.

Fluid Resistance of Santoprene Rubber General Purpose Grades

INTRODUCTION

This bulletin summarizes the physical properties of general purpose Santoprene® thermoplastic rubber after exposure to a variety of fluids and solvents. Immersion times were approximately one week (166 hours, per ASTM method D-471) at temperatures ranging from 5°C to 150°C (41°F to 302°F), depending upon the fluid. The data for a given hardness level are applicable to the 100 series (black) as well as the 200 series (colorable) general purpose grades of Santoprene rubber and are representative of performances expected for many of the grades.

Results of these tests demonstrate that Santoprene rubber is inherently resistant to a wide variety of oils, solvents and chemicals. Santoprene rubber is not readily soluble in any common solvent, but will swell in aromatic solvents, halogenated organic solvents and hot petroleum oils.

Highly polar fluids, such as alcohols, ketones, glycols, esters and aqueous solutions of acids, salts and bases have little effect upon Santoprene rubber. Weight changes in these fluids are typically less than 10%, and physical property changes are minimal.

Test Methods

Injection molded test plaques (82.4 mm x 117 mm x 2.97 mm) were prepared. Test specimens were die cut from these plaques to measure the effect of fluid immersion upon tensile properties, hardness and weight change, using ASTM procedures.

Property	ASTM Test Procedure
Ultimate Elongation	D 412, die C*
Tensile Strength	D 412, die C*
Stress at 100% Elongation	D 412, die C*
Hardness	D 2240, 5 sec. delay
Weight Change	D 471

*Note: 50D is D638

Discussion

Santoprene thermoplastic rubber is designed to offer fluid and oil resistance equivalent to that of conventional thermoset rubbers such as neoprene.

The resistance of the Santoprene rubber grades to oil and heat can be classified by using the SAE J200/ASTM D2000 Standard Classification System for rubber.

Santoprene Rubber Grade	Type and Class
111-35	AA, BA, BC, CA
111-45, 211-45	AA, BA, BC, CA
101-55, 201-55	AA, BA, BC, CA
101-64, 201-64	AA, BA, BC, BE, CA
101-73, 201-73	AA, BA, BC, BE, CA, CE
101-80, 201-80	AA, BA, BC, BE, BF, CA, CE
101-87, 201-87	AA, BA, BC, CA
103-40, 203-40	AA, BA, BC, BG

In this classification system, the first of the two letters designates the heat resistance of the rubber. The second letter designates the oil resistance (volume swell in IRM 903 oil). As the letters progress through the alphabet, the heat and oil resistance become progressively higher.

Rubber compounds with a hardness of 50 Shore D are not included in the ASTM D2000 classification. Therefore, Santoprene rubber grades 103-50 and 203-50 are not included.

Table I provides a qualitative rating of the effect of immersion in each fluid on Santoprene rubber grades with hardnesses 55A, 64A, 73A, 80A, 87A, 40D and 50D. In this rating, percent weight change is the variable shown according to the scale:

Rating	Percent Weight Change
A	< 20
B	20-39
C	40-59
D	60-79
E	80-100
F	> 100

Tables II-VIII provide detailed information on the effect of immersion upon tensile properties, hardness and weight change of general purpose Santoprene rubber grades with hardness of 35 Shore A to 50 Shore D, following ASTM test procedure D-471.

Fluid Resistance of Santoprene Rubber General Purpose Grades

TABLE I:

Fluid Resistance of Santoprene Thermoplastic Rubber, Qualitative Ratings[1,2]

	Fluids	Immersion Temperature °C	Santoprene Rubber Shore Hardness 55A	64A	73A	80A	87A	40D	50D
Acids and Alkalis	98% Sulfuric Acid	23	A	A	A	A	A	A	A
	10% Hydrochloric Acid	23	A	A	A	A	A	A	A
	50% Sodium Hydroxide	23	A	A	A	A	A	A	A
	10% Potassium Hydroxide	23	A	A	A	A	A	A	A
Aqueous Solutions	Water	100	A	A	A	A	A	A	A
	10% Zinc Chloride	23	A	A	A	A	A	A	A
	Sea Water	23	A	A	A	A	A	A	A
	15% Sodium Chloride	23	A	A	A	A	A	A	A
	18% Calcium Chloride/ 14% Calcium Bromide	150	A	A	A	A	A	A	A
	2.5% Detergent (Tide)	23	A	A	A	A	A	A	A
Organic Solvents	Acetic Acid	23	A	A	A	A	A	A	A
	Acrylonitrile	23	A	A	A	A	A	A	A
	Aniline	23	A	A	A	A	A	A	A
	Bromobenzene	23	F	E	D	C	B	B	B
	n-Butyl Acetate	23	A	A	A	A	A	A	A
	Cyclohexane	23	E	C	D	B	B	A	A
	Diethyl Ether	23	A	A	A	A	A	A	A
	Dimethylformamide	23	A	A	A	A	A	A	A
	Dioctyl Phthalate	23	A	A	A	A	A	A	A
	1,4-Dioxane	23	B	A	A	A	A	A	A
	95% Ethanol	23	A	A	A	A	A	A	A
	Glycerol	23	A	A	A	A	A	A	A
	n-Hexane	23	B	A	A	A	A	A	A
	Methylethylketone	23	B	B	A	A	A	A	A
	Nitrobenzene	23	A	A	A	A	A	A	A
	Piperidine	23	C	B	A	A	A	A	A
	1-Propanol	23	A	A	A	A	A	A	A
	Pyridine	23	A	A	A	A	A	A	A
	Trichloroethylene	23	F	F	F	F	E	D	C
	Turpentine	23	E	D	C	C	B	B	A
	Xylene	23	D	C	C	B	B	B	A
Petroleum Oils and Fuels	ASTM #1 Oil	100	B	B	B	A	A	A	A
		125	B	B	B	B	B	A	A
	IRM 902 Oil	100	D	C	C	B	B	A	A
		125	D	D	C	C	B	B	B
	IRM 903 Oil	100	E	E	D	C	B	B	B
		125	F	E	D	D	C	C	C
	Reference Fuel A (Isooctane)	23	B	B	B	B	A	A	A
	Reference Fuel B (Isooctane/Toluene, 70/30)	23	D	C	C	C	B	B	A
	Reference Fuel C (Isooctane/Toluene, 50/50)	23	D	C	C	C	B	B	A
Automotive Fluids	Automatic Transmission Fluid	125	D	C	C	C	C	B	B
	Hydraulic Brake Fluid	23	A	A	A	A	A	A	A
		100	B	A	A	A	A	A	A
	Lithium Grease	23	A	A	A	A	A	A	A
		100	C	C	B	B	A	A	A
	Power Steering Fluid	125	E	D	D	C	C	B	B
	Antifreeze, 50/50 Ethylene Glycol (Prestone®)/water	125	A	A	A	A	A	A	A
Industrial Fluids	Pydraul® 312 (Monsanto, phosphate ester)	125	A	A	B	A	A	A	A
	Skydrol® 500 B4 (Solutia, phosphate ester)	125	B	A	A	A	A	A	A
	Sunvis® 706 Fluid (Sun Oil, petroleum base)	125	C	C	C	C	B	B	B
	Ucon® CC732 (Union Carbide, polyalkylene glycol)	125	A	A	A	A	A	A	A
	Ucon® 50HB5100 (Union Carbide, polyalkylene glycol)	125	A	B	B	B	A	A	A
	Freon® 11 (DuPont, halocarbon)	5	F	C	C	C	B	B	B

[1] See note A, Disclaimer of Warranty and Liability, on inside front cover.
[2] All solution concentrations by weight. These alphabetical ratings are based on a specific range in the percentage of weight change as described on page 2.

Fluid Resistance of Santoprene Rubber General Purpose Grades

TABLE VII: 80 Shore A

Effect of 166 Hour Immersion (ASTM D-471) on Properties of 80 Shore A General Purpose Santoprene Thermoplastic Rubber[1,2]

	Fluids	Temp., °C	Ultimate Elongation, % Change	Tensile Strength, % Change	Stress at 100% Elongation, % Change	Hardness Change, Shore A Units	Weight, % Change
Acids and Alkalis	98% Sulfuric Acid	23	-25	-19	8	0	3.0
	10% Hydrochloric Acid	23	7	11	1	1	0.6
	50% Sodium Hydroxide	23	-4	1	6	0	-0.1
	10% Potassium Hydroxide	23	0	-2	7	0	0.9
Aqueous Solutions	Water	100	-26	-13	2	-2	3.1
	10% Zinc Chloride	23	0	2	2	1	0.4
	Sea Water	23	-7	-8	2	0	0.5
	15% Sodium Chloride	23	-10	-14	2	0	0.4
	18% Calcium Chloride/ 14% Calcium Bromide	150	-27	-19	8	-4	0.7
	2.5% Detergent (Tide)	23	-1	-3	7	1	-0.1
Organic Solvents	Acetic Acid	23	-2	-3	3	-2	4.6
	Acrylonitrile	23	1	2	9	0	0.7
	Aniline	23	-2	-5	0	-1	1.3
	Bromobenzene	23	-19	-19	-10	-10	50.0
	n-Butyl Acetate	23	2	6	-3	0	-6.6
	Cyclohexane	23	-19	-21	-18	-14	54.8
	Diethyl Ether	23	-5	-6	-11	-5	0.3
	Dimethylformamide	23	2	4	-1	1	1.0
	Dioctyl Phthalate	23	0	-3	3	0	-1.0
	1,4-Dioxane	23	0	-4	-2	-1	1.6
	95% Ethanol	23	6	0	-2	0	-1.9
	Glycerol	23	-4	-6	4	0	0.4
	n-Hexane	23	-10	-11	-14	-12	11.3
	Methylethylketone	23	7	10	-3	2	-11.1
	Nitrobenzene	23	2	1	2	1	-4.6
	Piperidine	23	-6	-7	-7	-14	16.8
	1-Propanol	23	10	12	-6	1	-7.2
	Pyridine	23	2	8	3	2	-7.1
	Trichloroethylene	23	-29	-24	-13	-16	120.0
	Turpentine	23	-26	-27	-17	-15	48.9
	Xylene	23	-24	-24	-15	-14	37.8
Petroleum Oils and Fuels	ASTM #1 Oil	100	-17	-4	-2	-7	17.1
		125	-38	-23	-7	-10	25.2
	IRM 902 Oil	100	-27	-18	-3	-12	36.7
		125	-44	-26	-4	-16	45.9
	IRM 903 Oil	100	-40	-28	-10	-17	55.4
		125	-54	-38	-16	-24	71.3
	Reference Fuel A (Isooctane)	23	-10	-7	-4	-7	20.2
	Reference Fuel B (Isooctane/Toluene, 70/30)	23	-14	-16	-10	-9	40.7
	Reference Fuel C (Isooctane/Toluene, 50/50)	23	-17	-16	-10	-11	42.5
Automotive Fluids	Automatic Transmission Fluid	125	-43	-27	-18	-10	46.7
	Hydraulic Brake Fluid	23	7	16	-3	1	-1.7
		100	10	22	-1	3	-14.5
	Lithium Grease	23	-10	-5	-3	-1	5.5
		100	-24	-7	-4	-9	23.2
	Power Steering Fluid	125	-40	-30	-19	-21	56.0
	Antifreeze, 50/50 Ethylene Glycol (Prestone®)/water	125	-17	-21	-3	-2	4.2
Industrial Fluids	Pydraul® 312	125	-21	-11	-7	-8	18.3
	Skydrol® 500 B4	125	-12	-4	-6	0	-7.1
	Sunvis® 706 Fluid	125	-43	-24	-16	-17	44.2
	Ucon® CC732	125	-31	-4	-1	-3	4.6
	Ucon® 50HB5100	125	0	21	12	6	-21.8
	Freon® 11	5	-13	-12	-12	-12	41.8

[1] See note A, Disclaimer of Warranty and Liability, on inside front cover.
[2] All solution concentrations by weight.

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