Direct Measurements, Inc.

DMI SR-1 Operating Manual

March 26, 2006

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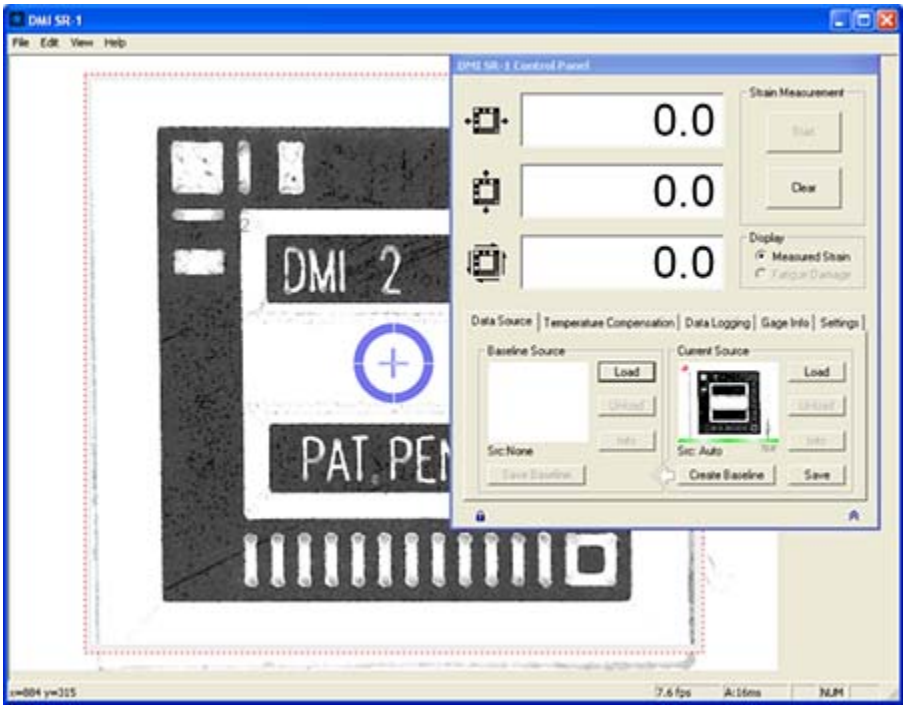
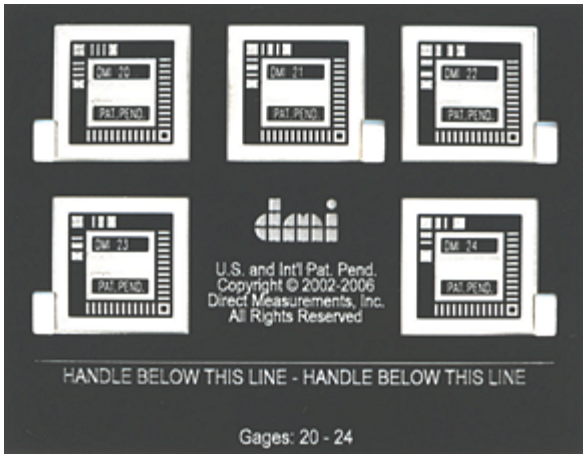
1. INTRODUCTION

Thank you for choosing DMI-powered strain-measurement technology! The DMI SR-1 strain-measurement system consists of a handheld reader tethered to a rugged tablet computer running specialized strain-measurement user-interface software (referred to in this documentation as the “SR-1 interface”). This document is intended to assist in the use of the SR-1 equipment and interface.





2. IMPORTANT SAFEGUARDS

When using electrical devices, basic safety precautions should always be followed. **READ CAREFULLY AND UNDERSTAND ALL INSTRUCTIONS, SAFEGUARDS, AND PRECAUTIONS BEFORE USE.** Keep this manual for future use by any current or subsequent user. The DMI SR-1 strain measurement equipment (referred to below as the "device") must only be used for its intended purpose in accordance with this operating manual.

• Keep this device out of reach of children.

• The device must only be connected to a 120 volt A.C. 15 or 20 amp power supply using the provided 3-wire grounding-type plug. Do not defeat or attempt to defeat the safety purpose of the grounding-type plug.

• The device is not designed for prolonged outdoor use or where exposure to damaging elements may occur.

• Do not handle the plug or cord or device if water is present on floor, near the device's power connections or with wet hands. Do not place or store device where it can fall or be pulled into standing water or other liquid. Do not place or drop device into water or other liquid.

• Do not plug the device in if the device, outlet/receptacle, plug, or power cord has been damaged.

• Never unplug this device by pulling the power cord. To disconnect the power cord from the outlet, grasp the plug and pull it from the outlet.

• Always unplug the device from the electrical outlet when not in use, and never leave the device unattended when plugged in.

• Never carry the device by its power cord. Do not expose the power cord to sharp edges or abrasive surfaces or other conditions that may crush, kink, or otherwise damage the power cord. Keep the power cord away from heated surfaces.

• Never operate the device if it is not working properly, if it has been dropped or damaged, or dropped into water.

• Never operate the device in the presence of explosive fumes. Never clean the device with flammable or explosive fluids. Never operate the device where aerosol (spray) products are being used or where oxygen is being administered.

• Never drop or insert any object into any opening on the device.

• Do not attempt to modify the device in any way.

• Do not attempt to service or repair this equipment yourself. Opening or removing covers may expose you to dangerous voltage or other hazards.

• DAMAGE REQUIRING SERVICE: Unplug the device from the outlet and return the device for service under the following conditions:

- When the power supply cord or plug is damaged.
- If the device has been exposed to rain, water, or other liquids.
- If liquid has been spilled, or objects have fallen into the device
- If the device does not operate normally by following the operating instructions.
- If the device has been dropped or if cabinet/covers have been damaged.
- When the device exhibits a distinct change in performance, indicating a need for service.
- If any external component, cable, or other hardware item is loose or damaged.

3. END USER (“CUSTOMER”) LICENSE AGREEMENT

Direct Measurements, Inc., PO Box 190093, Atlanta, Georgia 31119

IMPORTANT NOTICE: THIS IS A CONTRACT. BY INDICATING YOUR ACCEPTANCE, YOU ACCEPT ALL THE TERMS AND CONDITIONS OF THIS AGREEMENT.

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3.1 LICENSED "AS IS": The DMI Strain Technology Solution (DMI proprietary software, proprietary code symbol(s) and hardware) is licensed "as is". You, the consumer and/or any ultimate user, bear the entire risk relating to the use, quality, and performance of the DMI Strain Technology Solution. In no event shall DMI nor anyone else who has been involved in the creation, production, shipment or delivery incur any liability for any direct, indirect, special, consequential or exemplary damages, or lost profit arising out of, resulting from or any way connected to the use or misuse of the DMI Strain Technology Solution, whether or not based upon warranty, contract, tort or otherwise; whether or not injury was sustained by persons or property or otherwise; and whether or not loss or damage was sustained from, or arose out of, or are the results of the DMI Strain Technology Solution or any services that may be provided by DMI. Additionally, DMI shall not be responsible for direct, indirect, incidental or consequential damages resulting from any defect, error or failure to perform. In the event any liability is imposed on DMI, DMI's liability to you or any third party shall not exceed the purchase price paid for this product. Warranty specifically excludes damage to the product including, but not limited to, the following damage: caused during shipment; caused by liquid intrusion into the inside of the product as a result of case fracture or entry through an external port or door; caused by impact with other objects, or drops and falls, including but not limited to broken display glass, hard drive sector damage or read/write head damage, physical breakaway of internal components; caused by the use of the product for Purposes other than those for which it was designed; caused by any other abuse, misuse, neglect, accident, negligence, mishandling or misapplication; caused by products not supplied by Direct Measurements, Inc. or failures which result from alterations, modifications or foreign objects; from improper maintenance; or damage attributable to acts of God.

3.2 THIRTY (30) - DAY LIMITED WARRANTY AND WHAT IS COVERED: DMI warrants that its products will be free from defects in material and/or workmanship which occur during normal use and perform substantially in accordance with DMI specifications and/or Operating Manual for the specified thirty (30) - day warranty period. DMI will repair the equipment during the warranty period with new or rebuilt parts, free of charge in the United States. A purchase receipt or other proof of date of original purchase may be required before warranty performance is rendered. Products and/or Services DMI acquires from or through a manufacturer, distributor or other third-party provider and resells and/or provides to Customer will carry the original manufacturer's pass-through warranty, if any. The warranty period is not extended as a result of upgrading the product.

3.3 HOW TO OBTAIN WARRANTY SERVICE: Email vendor who sold you the product with contact information Monday through Friday for warranty assistance. Should equipment require service, Direct Measurements, Inc. will issue a Repair Authorization (RA) and shipping instructions through your vendor to you.

3.4 WIRELESS COMMUNICATIONS DISCLAIMER: DUE TO THE NATURE OF WIRELESS COMMUNICATIONS, THE WIRELESS DMI SR-1 READER TABLET SHOULD NOT BE USED IN A WIRELESS MODE TO SEND RESULTS FROM THE TABLET TO A DATA STORAGE UNIT OR REMOTE DISPLAY IN SITUATIONS WHERE LIVES OR PROPERTY WOULD BE ENDANGERED BY AN INABILITY TO FUNCTION OR ESTABLISH COMMUNICATIONS. THEREFORE IN NO EVENT SHALL DMI BE LIABLE TO CUSTOMER OR ANY THIRD PARTY, WHETHER IN CONTRACT, NEGLIGENCE, TORT, OR ON ANY OTHER BASIS, FOR COVER OR FOR ANY SPECIAL, INDIRECT, INCIDENTAL, CONSEQUENTIAL OR PUNITIVE DAMAGE FOR ANY BREACH OF THESE TERMS AND CONDITIONS INCLUDING, BUT NOT LIMITED TO, LOSS OF PROFITS, LOSS OF BUSINESS OR GOODWILL, OR LOSS OF USE, EVEN IF DMI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH LOSS OR DAMAGE OR ANY CLAIM BY ANY THIRD PARTY. FOR ANY BREACH OF THESE TERMS AND CONDITIONS, DMI'S SOLE AND EXCLUSIVE MAXIMUM LIABILITY SHALL NOT IN ANY EVENT EXCEED THE TOTAL PRICE OF THE PRODUCTS ORDERED BY CUSTOMER THAT GIVE RISE TO THE CLAIM.

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4. GETTING STARTED

THE SR-1 TABLET COMPUTER

Providing Power
Connect the power cord's plug to a 120V A.C. grounded outlet. This will power-up the handheld device's camera and light, and will provide power to the computer.

Turning the Computer On and Off
To turn on the computer, press the POWER button, located to the left of the computer's display.

Note: If the computer does not power on, restart it by holding the power button for 4 - 10 seconds.

To turn off the computer, from the *Start* menu, select *Turn Off Computer*; then select the option *Turn Off*. Note: Perform this step before disconnecting the power supply cord. Disconnecting the power supply before performing this step will cause the computer to shut down abnormally.

Resuming Operation
If the computer enters a Screen Saver mode, tap the screen with the computer's stylus pen to resume. If the computer enters a Suspend mode (and does not respond to screen tap), press the POWER button to resume.

Calibrating and Adjusting the Display
To optimize pen and display performance and usability, calibrate the display for your current display mode. To switch between digitizer and touch screen mode, press the *UP* + *Line Down* simultaneously. You will hear one beep for touch screen mode and two beeps for digitizer mode.

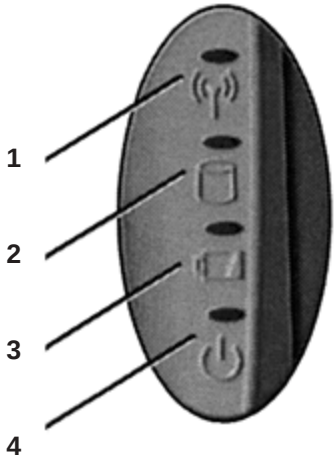
To calibrate the display, ensure you are in the mode you want to calibrate (see above).
From the *Start* menu, select *All Programs, Mobile Computer Tools, Tablet Calibration*. Follow the on screen instructions.

To adjust the display brightness, press *FN* + *Security* to darken the display.

Press *FN* + *Rotate* to lighten the display.

Status LEDs
When the computer is running, a set of LEDs indicates the computer's activity status.

1. Wireless Radio Status LED: Solid blue = Integrated radio(s) are powered on.
2. Hard Disk Drive Status LED: Blinking green = Accessing the drive
3. Battery Status LED: The unit is not equipped with a battery.
4. Power Status LED: Solid blue = unit is turned on, Blinking blue = unit is suspended



Important Operating Considerations
The DMI SR-1's computer is intended to be a dedicated device for running the SR-1 interface only. Installing or running additional programs or applications, web 'surfing,' using email, etc. is NOT recommended.

THE SR-1 INTERFACE

The SR-1 interface can be started by double clicking (or double tapping) the SR-1 program icon (located on the computer desktop).

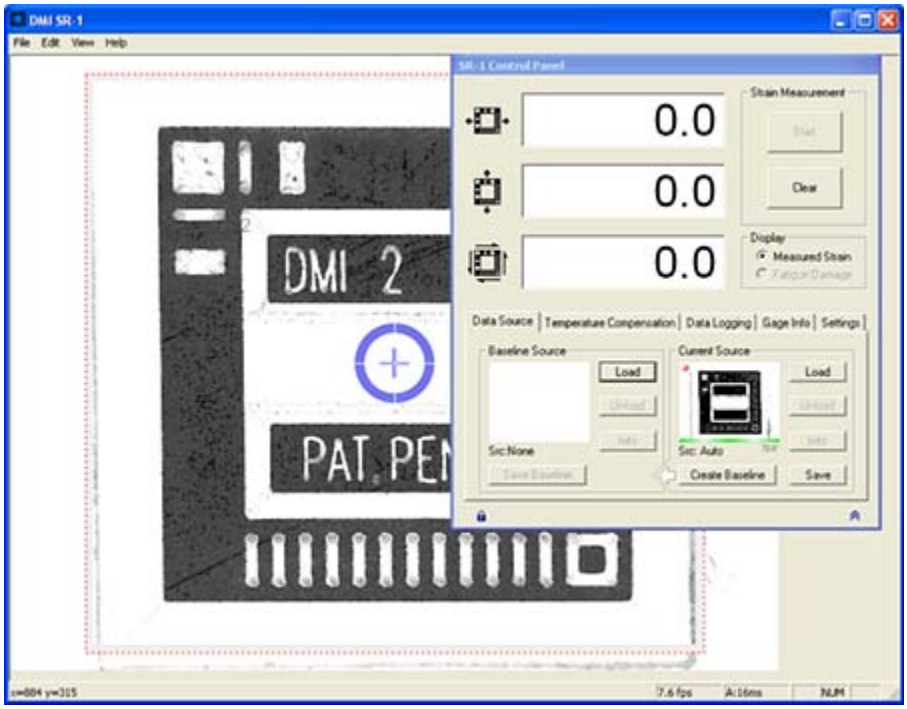
Alternatively, the SR-1 interface will start automatically by double clicking (or double tapping) any previously saved SR-1 “workspace” file (or “.dwk” file) icon.

Large Icon (*.dwk file)

Small Icon (*.dwk file)

Once the SR-1 interface starts, the End-User License Agreement window opens. Users of the DMI SR-1 strain-measurement system must agree to all the terms and conditions set forth in this agreement in order to proceed.

After agreeing to the End-User License Agreement, the SR-1 interface should open to full screen as shown below:



SR-1 Interface

To close the SR-1 interface, choose menu option *File, Exit* or click the red close box in the upper right corner of the main window.

SR-1 SERIES POLYMER GAGES

The DMI SR-1 strain-measurement system is designed to work with SR-1 series polymer (or “stick on”) gages. SR-1 series polymer gages are packaged in ‘coupons’ of five (5) numbered gages.

There are important gage and gage-coupon handling and application considerations:

• Individual gages should only be handled using tweezers or latex gloves to prevent oil contamination on the gage bonding surface.

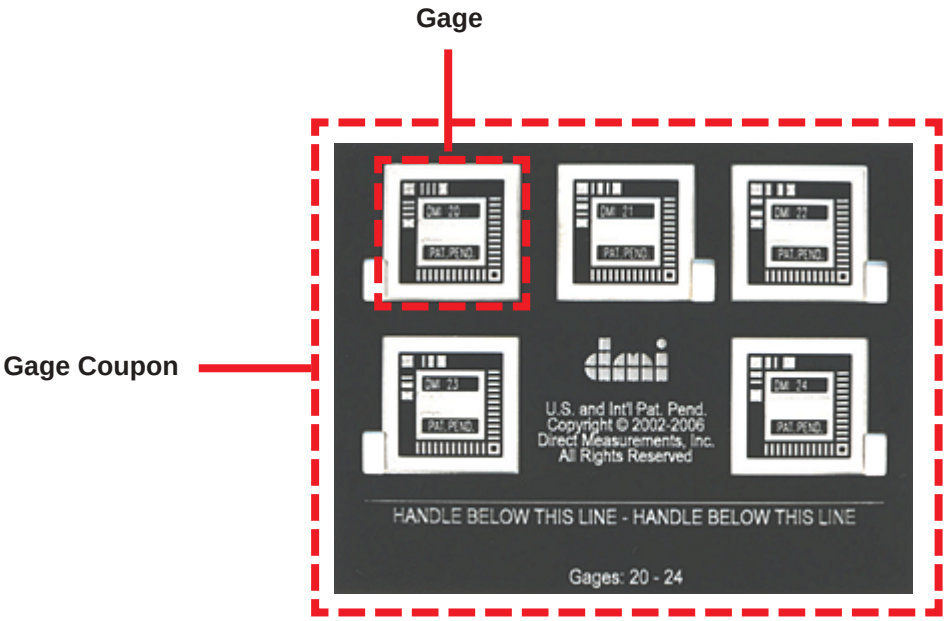
• Gage coupons can be handled ‘by hand’ (in the designated coupon handling region) but care should be taken not to touch the bonding surface of any gage.

• Gages should be kept clean and free of dirt, debris, and other foreign materials or contaminants. Gages can be cleaned with isopropyl alcohol. DO NOT USE ACETONE TO CLEAN GAGES.

• A clearance hole is cut next to each gage to provide access to individual gages using tweezers. Gages are designed to ‘lift out’ from the gage coupon.

• Individual gages and gage coupons should remain inside their protective enclosure when not in use.

• SR-1 series polymer gages are applied to materials using industry-accepted bonding methods and materials used in the application of conventional electrical strain gages (e.g. Vishay AE-10). It is assumed that users of the DMI SR-1 strain-measurement system are familiar with strain gage application, therefore application of SR-1 series polymer gages to various materials is beyond the scope of this manual.

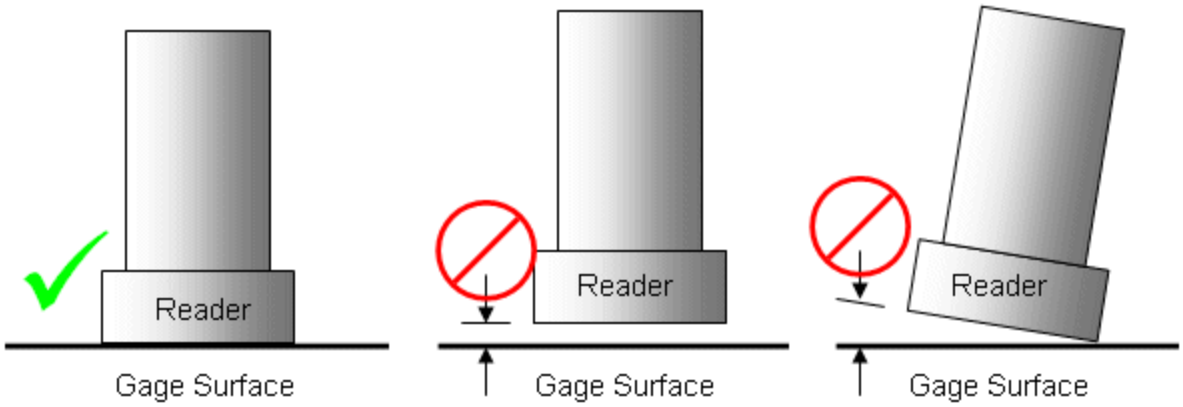


ACQUIRING GAGE DATA

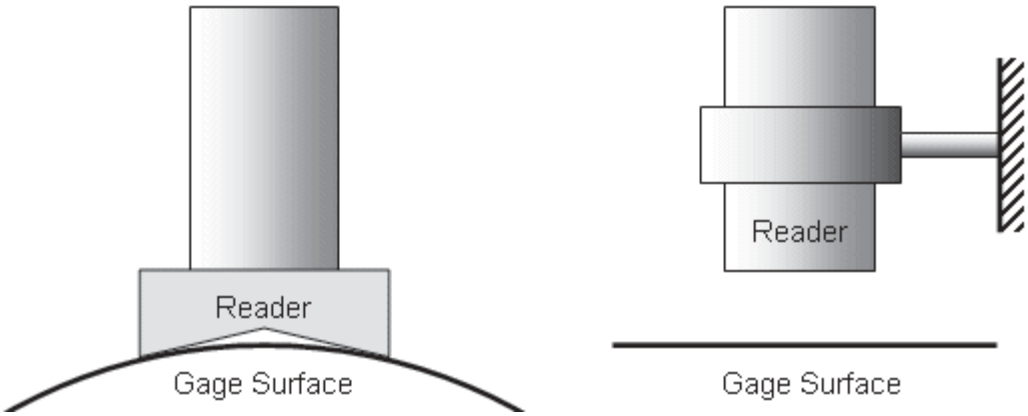
Acquiring gage data with the SR-1 system is very simple, and involves little more than centering the handheld device over a gage. Consistency is key to reliable results, and the following steps will assist in obtaining optimal performance from your DMI-powered equipment.

Handheld Reader Orientation

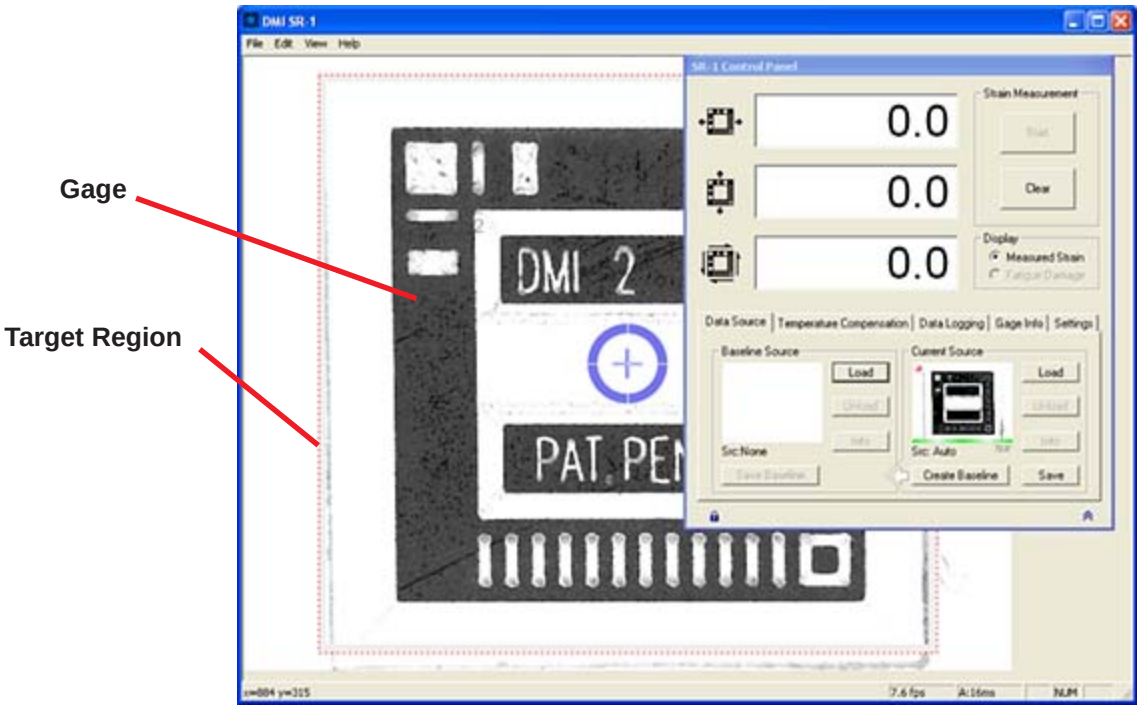
The handheld device must be positioned such that the reader is at a fixed, repeatable distance and orientation with respect to the gage surface. For example, on flat surfaces the handheld device must be resting flat on the gage surface.



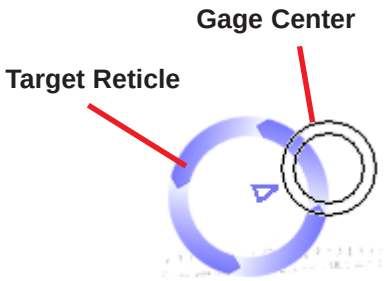
On highly curved surfaces, complex-shaped surfaces, or surfaces where contact is not desired, special fixtures may be required for repeatable positioning. A standard “tripod-mount” hole (1/4”-20) is located on the body of the reader to aid in fixturing.



Finally, the handheld device must be positioned such that the gage appears within the 'target region' of the SR-1 interface. Once the gage appears in the target region, it is also recommended that the gage be 'aligned' (as described in the following section, **Gage Alignment**).



Gage Alignment



When possible, and for optimal results, the gage should be aligned within the target region. Alignment is indicated by the 'target-reticle' and 'gage-center' graphics. Note: These graphics are only visible when a gage is inside SR-1 interface view's target region. As the name implies, the gage-center graphic represents the center of the gage. The target reticle represents an optimal alignment location and orientation.

The target-reticle graphic attempts to provide visual clues regarding how the reader's position should be adjusted to achieve alignment. Rotating arrows on the perimeter of the target reticle indicate the direction the reader should be rotated. A triangular arrow near the center of the target reticle indicates the direction the reader should be moved. Alignment is indicated when no arrows are present in the target reticle graphic. The following are examples of alignment indications:

Reader is neither x-y aligned nor rotationally aligned. Reader must be rotated in a counter-clockwise direction and must be moved up and toward the right.

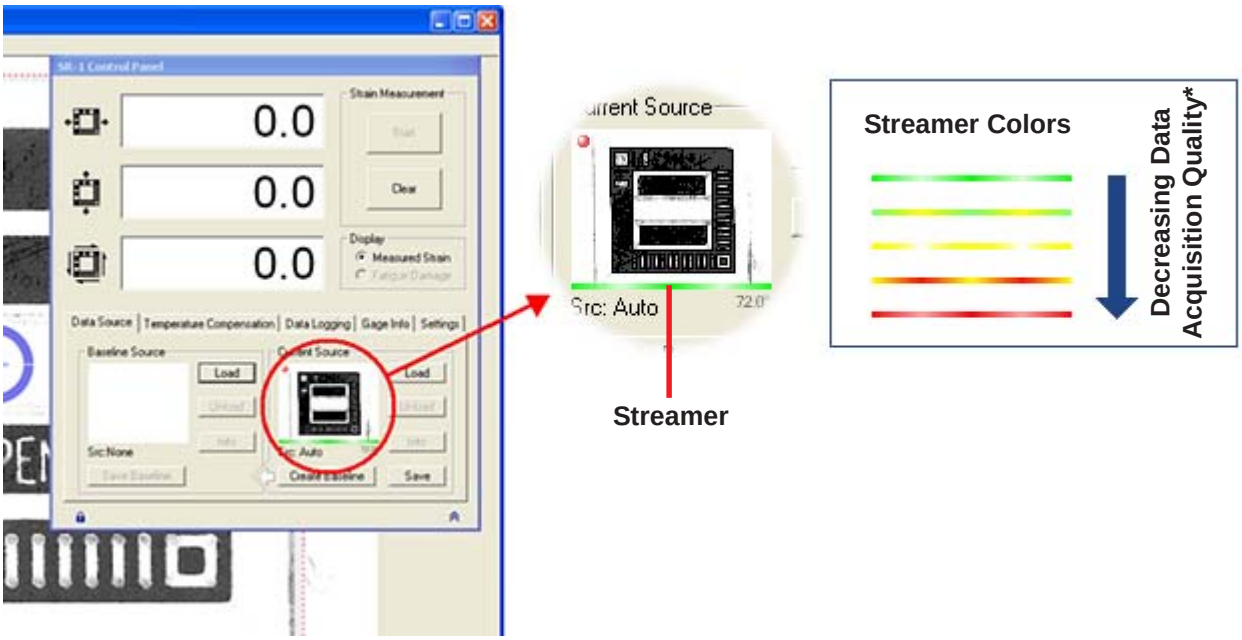
Reader is rotationally aligned, but not x-y aligned. Reader must be moved up and to the left.

Reader is x-y aligned, but not rotationally aligned. Reader must be rotated in a clockwise direction

Reader is both x-y aligned and rotationally aligned.

Data Acquisition Quality*

On the main SR-1 interface in the *SR-1 Control Panel*, the *Data Source* tab displays two thumbnail images. When the SR-1 interface is streaming live images from the reader, the current live image is shown in the *Current Source* thumbnail (as shown below). Just below this thumbnail image is a 'streamer' graphic, which should always be moving when live images are being acquired from the reader. The streamer is designed to give some indication of data-acquisition quality* (NOT STRAIN MEASUREMENT QUALITY, SEE NOTE BELOW) via color shading.



* Note: Data-acquisition quality is NOT an indicator of strain-measurement quality or accuracy. Data-acquisition quality is a cumulative indicator of the SR-1 interface's ability to: characterize the gage in the target region; assess reader's stability; and determine the accuracy of other analysis parameters. While low data-acquisition quality will likely result in poor strain-measurement results, it is possible to have high data-acquisition quality and poor strain-measurement results (as other factors, such as inconsistency in reader orientation, degraded or damaged gages, lighting inconsistencies, etc. can introduce error into strain measurements).

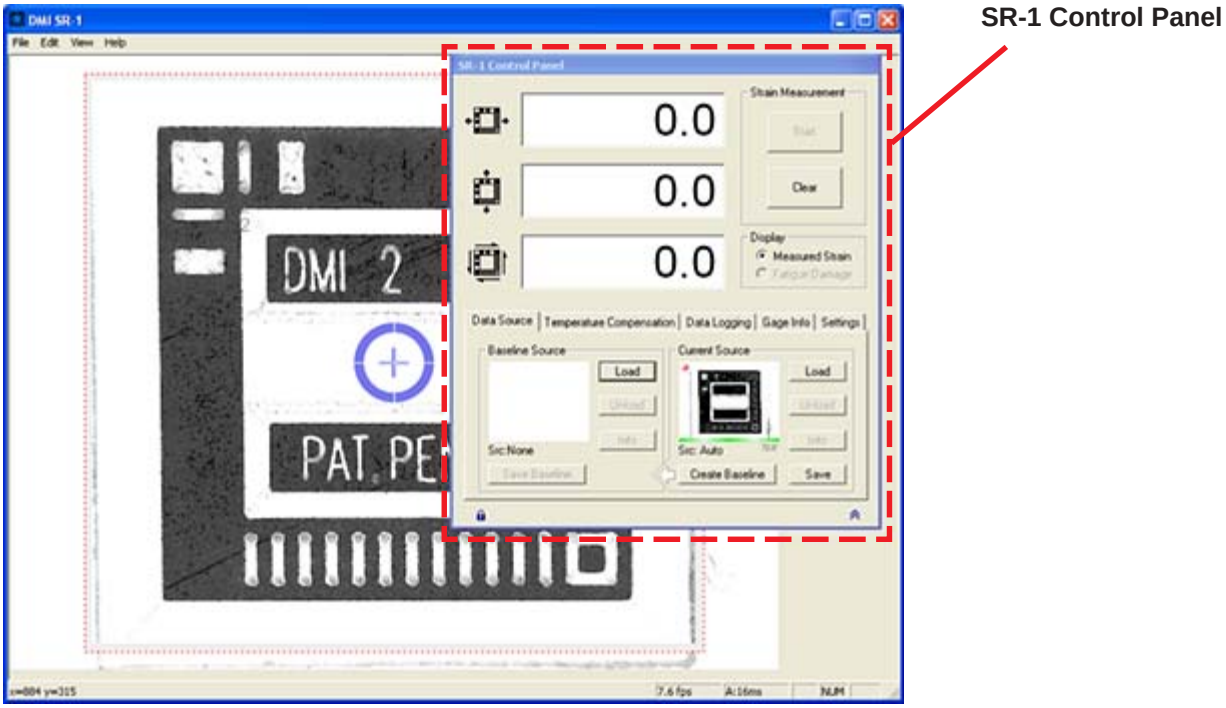
5. SR-1 INTERFACE SOFTWARE OVERVIEW

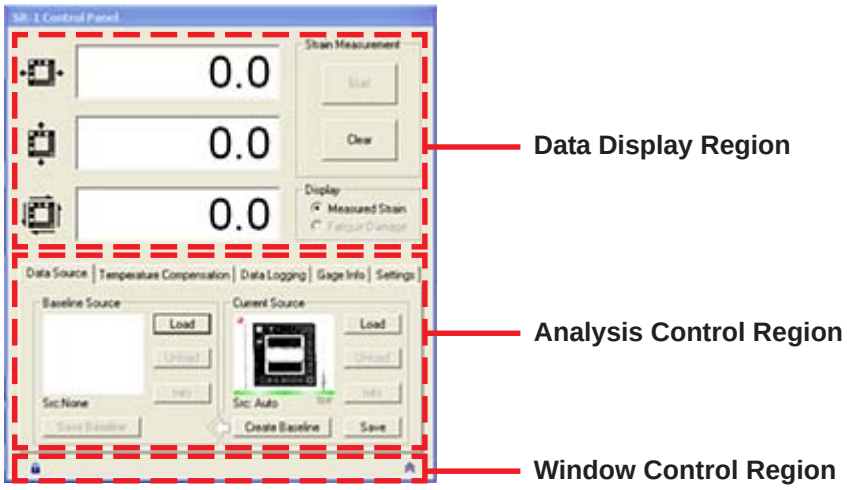
THE SR-1 CONTROL PANEL

The *SR-1 Control Panel* provides data display, as well as control over SR-1 interface settings and parameters.

SR-1 Control Panel Layout

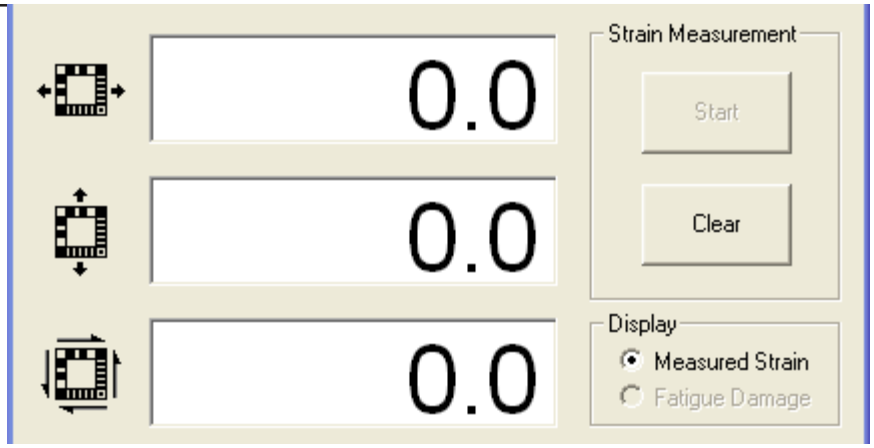
The *SR-1 Control Panel* is made up of a 'Data Display Region,' an 'Analysis Control Region,' and a 'Window Control Region.' Each region contains specific user-interface and/or analysis controls and settings for managing and customizing measurement tasks.





Data Display Region

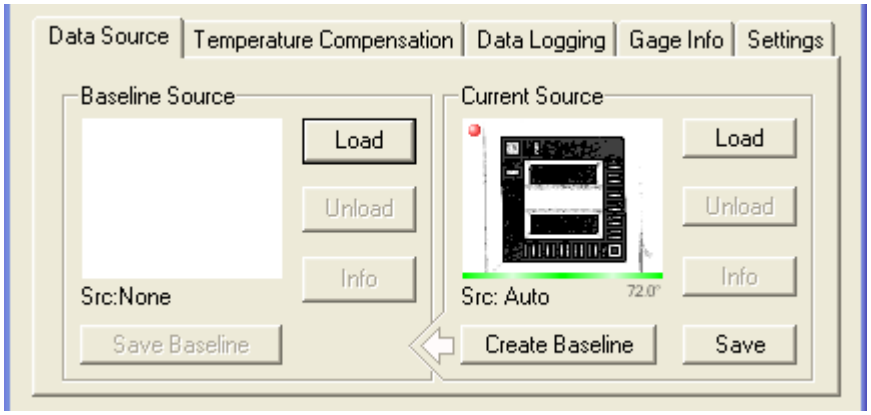
The Data Display region has three panel displays for the three strain components. It also has buttons to start, stop, and clear strain readings. Detailed instructions for using the Data Display region controls are found in the **Data Display** section of this operating manual.



SR-1 Control Panel, Data Display Region

Analysis Control Region

The Analysis Control region provides most of the user controls for managing and customizing measurement tasks. As shown, the *SR-1 Control Panel* has 'tabs' for: selecting input data (or data source); handling temperature compensation; performing data logging; viewing gage information; and controlling certain program settings. Each of these tabs are discussed in detail in the following operating manual sections: **Data Source Tab, Temperature Compensation Tab, Data Logging Tab, Gage Info Tab, and Settings Tab**.



SR-1 Control Panel, Analysis Control Region

Window Control Region

Lock
(lock/unlock position)

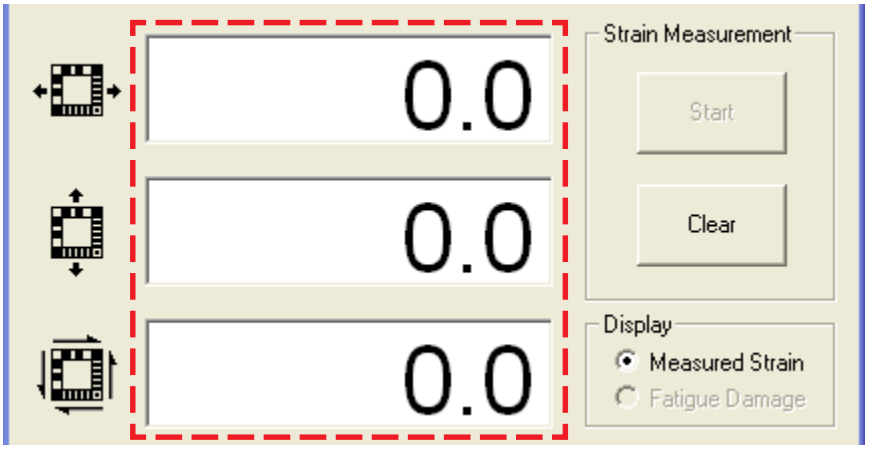
Double Arrow
(expand/collapse view)

SR-1 Control Panel, Window Control Region

The Window Control region is used to affect the *SR-1 Control Panel* state and position. By default, the *SR-1 Control Panel* is expanded and locked in the upper right corner of the SR-1 interface main window. The *SR-1 Control Panel* can be either 'expanded' or 'collapsed' by clicking on the 'double-arrow' icon in the lower right corner. When locked, the *SR-1 Control Panel* can not be moved from its default location. Clicking the 'lock' icon (found in the lower left corner) toggles the *SR-1 Control Panel's* lock state . When unlocked, the *SR-1 Control Panel* can be dragged anywhere on screen. When locked, the *SR-1 Control Panel* returns to its default position, i.e. in the upper right corner of the SR-1 interface main window.

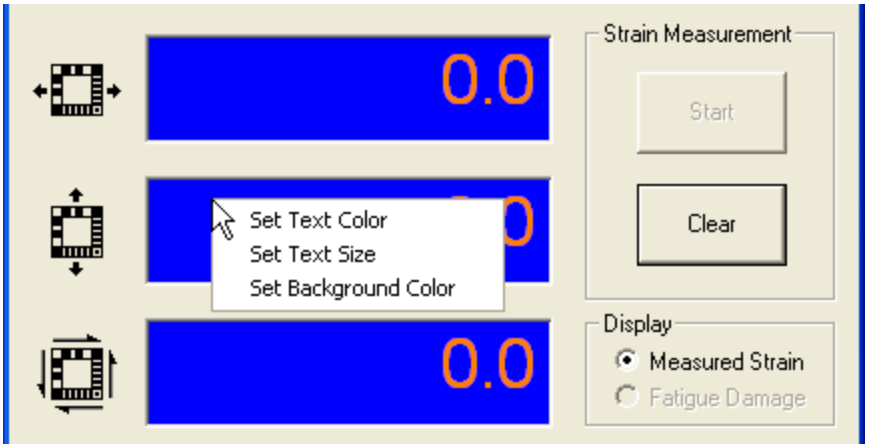
DATA DISPLAY

Strain Component Readouts



The SR-1 interface can extract normal and shear strain components from a single gage. These results are displayed in three readout panels, and each panel represents an individual strain component. The first two panels display normal strains, and the third panel displays the shear strain. The graphic next to each panel show the direction (with respect to gage orientation) of each strain component. Note: The units for the displayed values are 'micro-strain' (or 10^{-6} linear units/linear units).

Customizing the Readout Panels

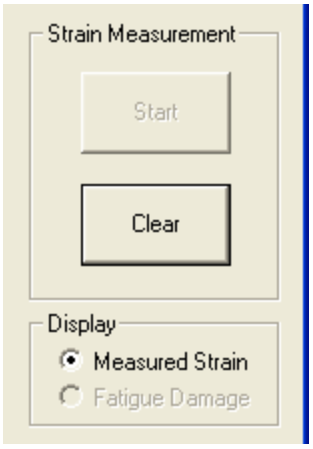


The strain readout panel text color, text size, and background color are all user adjustable. Right-click in any panel to display a context menu that gives access to these customization features. Note: Any appearance setting change for a particular panel is automatically applied to all three panels.

Start, Stop, Clear Strain Readouts

A *Start* button is provided for starting and stopping strain measurement. Pressing the *Start* button will cause the strain readout panels to begin updating with current strain readings. If strain measurement has been started, the *Start* button will change to a *Stop* button, which can be used to pause or stop strain measurement.

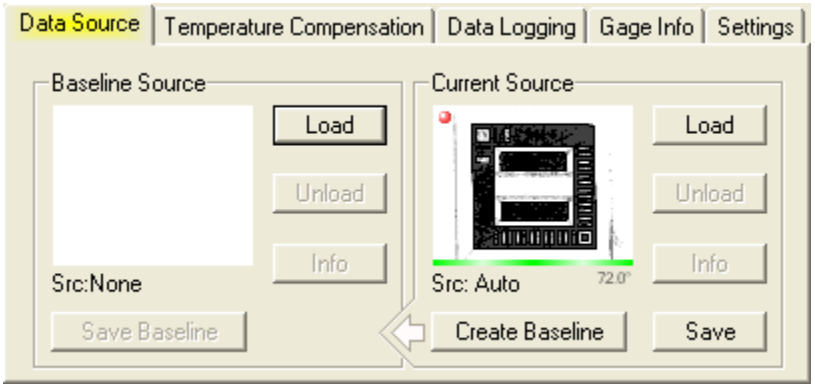
If the *Start* button is disabled, i.e. the text is gray, this means there is insufficient data to perform a strain measurement. The operating manual sections **Data Source Tab** and **Measuring Strain** provide details on using data sources to measure strain.



The *Clear* button is available anytime strain measurement is off, and it's function is to simply reset the values displayed in the strain readout panels to zero. Note: Clearing the panel values is NOT the same as 'zeroing' strain. Zeroing is discussed in the **Creating a Baseline Source** and **Strain Measurement** sections of this operating manual.

In addition, two *Display* options are shown below the *Start* and *Clear* buttons; they are *Measured Strain* and *Fatigue Damage*. In this version of the SR-1 interface, only the *Measured Strain* display is available.

DATA SOURCE TAB



The first 'tab' in the Analysis Control region of the *SR-1 Control Panel* is the 'Data Source' tab. The Data Source tab is used to specify the *Baseline Source* and *Current Source* used in strain measurement. In the SR-1 interface, strain is ALWAYS a relative measurement made between two strain states. The two small thumbnail images on this tab provide a visual representation these two states.

This concept is critical to proper use of the SR-1 interface: <u>You must have a *Baseline Source* and a *Current Source* to perform strain measurement.</u>

Data Sources

In the SR-1 interface, strain is defined as the change in linear dimensions of some *Current* state with respect to some *Baseline* state. A qualitative illustration of this is, if the gage represented in the *Current Source* is 'larger' than the gage represented in the *Baseline Source*, the normal strains are positive. In other words, the *Baseline Source* ALWAYS represents the 'reference' state for strain measurement. The *Current Source* represents some 'subsequent' state which is gaged against the 'reference' state (or *Baseline Source)* to measure strain.

The *Baseline Source* can only hold 'static' data, i.e. data loaded from disk, or created from reader data as described below in **Creating a Baseline Source**. The *Current Source* can hold either static data (loaded from disk) or dynamic (continuous) data from the reader.

By default, reader data is continuously loaded and displayed in the *Current Source* location. To measure strain using reader data, a *Baseline Source* must be specified, either by loading a *Baseline Source* from disk, or creating a *Baseline Source* from reader data. Strain measurement can also be made without the use of reader data by loading from disk static data into both the *Baseline Source* and the *Current Source* locations. Loading, unloading, and creating data sources are described in later sections of this operating manual.

Data Source Thumbnail Images

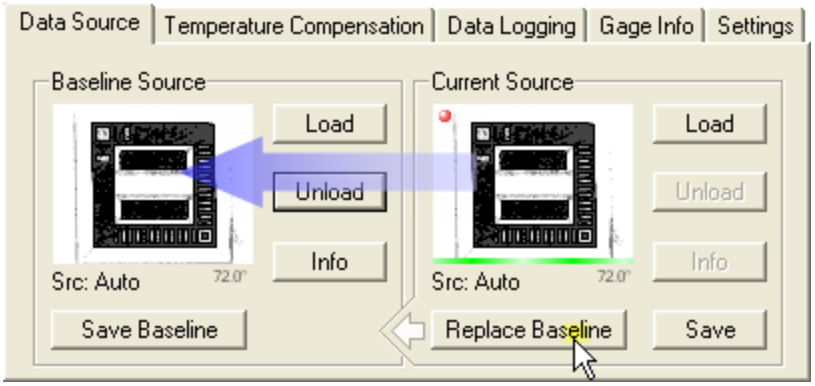
The Data Source tab shows two thumbnail images, which provide a visual representation of the *Baseline* and *Current* data sources presently in use. Beneath each thumbnail image is a 'Src:' and temperature text display. The 'Src:' text indicates from where the data source was obtained, and can be any one of the following values:

Text	**Meaning**
Src: None	No source data is loaded
Src: Auto	Source data is loaded from the reader
Src: Disk	Source data is loaded from disk

The temperature display represents the temperature associated with a particular data source, and this value is used in temperature compensation. Temperature compensation is discussed in the **Temperature Compensation Tab** section of this operating manual.

Creating a Baseline Source

When acquiring reader data, a *Baseline Source* can be created from the *Current Source* by pressing the *Create Baseline* button. When the *Create Baseline* button is pressed, a static representation of the *Current Source* is copied into the *Baseline Source* location. Now, with a static *Baseline Source* defined, it is possible to measure strain, since any dimensional changes to the gage in the *Current Source* are measurable with respect to the static *Baseline Source*.



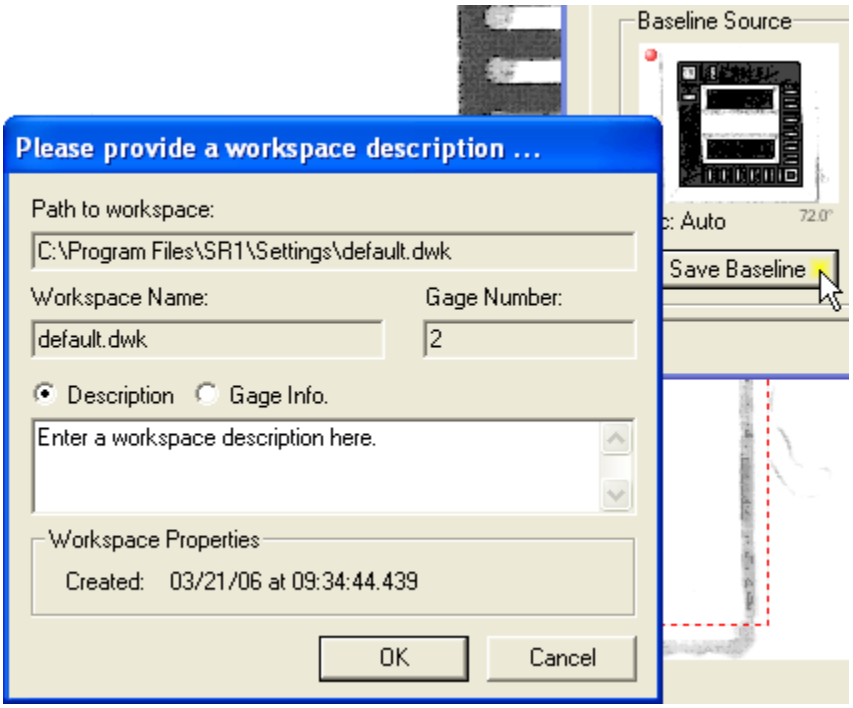
Note: After creating a baseline, the *Create Baseline* button's text changes. If strain measurement is off, the *Create Baseline* button's text changes to *Replace Baseline* and if strain measurement is on the button text changes to *Replace & Zero*. In either case, pressing the button again will replace the *Baseline Source* with the data presently in the *Current Source*.

When strain measurement is on, replacing the *Baseline Source* with the data from the *Current Source* will cause an instantaneous 'zeroing' of the strain readings (since both states are instantaneously identical).

Saving a Baseline Source

Once a *Baseline Source* is created (as described above), it can be saved to disk by clicking the *Save Baseline* button (located underneath the *Baseline Source* thumbnail image). Saving a *Baseline Source* will create an SR-1 'workspace' file. Note: SR-1 workspace files end with a '.dwk' file extension.

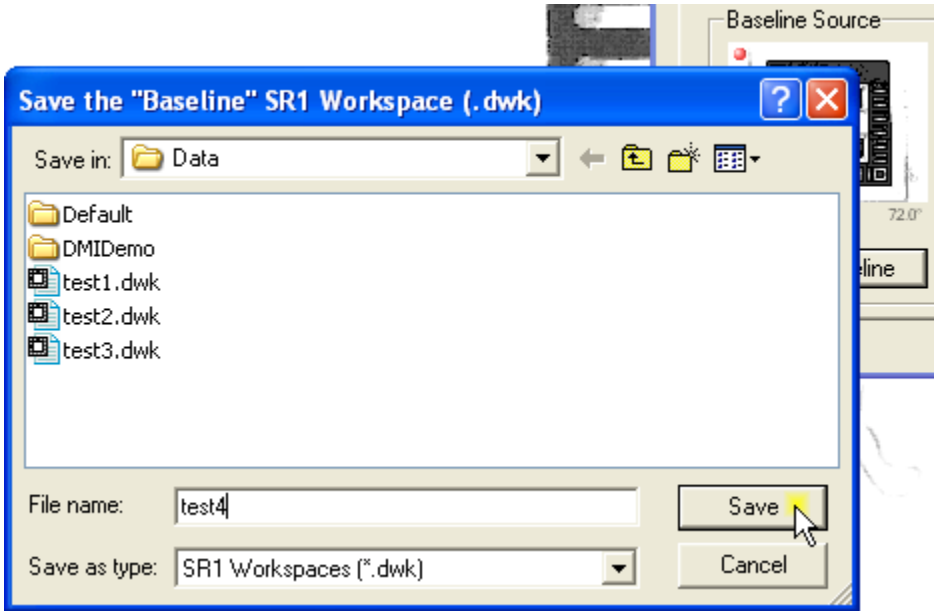
After clicking the *Save Baseline* button, a dialog window will open requesting a description of the saved workspace. Any desired description can be entered, and can include information about the gage location, installation date, usage, etc., but should as a minimum include enough descriptive information to properly identify that particular workspace file.



In this dialog window, the *Path to workspace* and *Workspace Name* fields show that this source was created from the default (reader) data. These can be ignored in this step, since both fields will be changed in the following steps.

After changing the description (if desired), press the OK button to proceed with the next step in saving the workspace file.

After pressing the OK button above, a standard 'Save File' dialog window opens. Here the save path can be specified using the *Save in:* dropdown. In this example, the workspace will be saved in the 'Data' folder. The workspace file can be given any name the *File name:* field, and in this example it'll be called 'test4.dwk.' Note: the .dwk extension does not have to be typed, as it will be appended automatically to the file name entered.



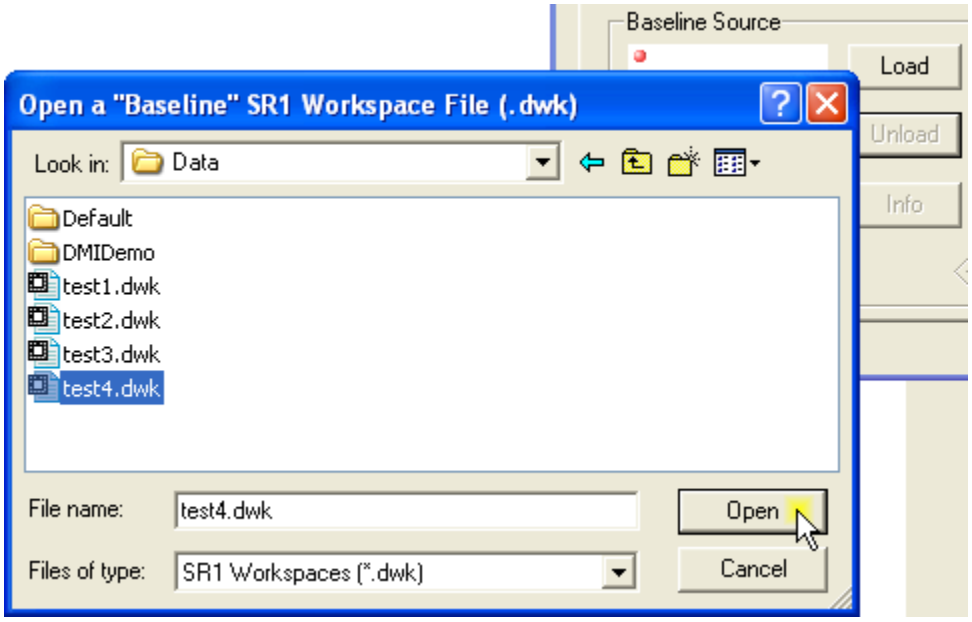
Previously saved workspace files can be overwritten if desired. Also, the save can be canceled at this point by pressing the *Cancel* button. Otherwise, once the *Save*' button is pressed, a dialog window should open confirming a successful save.

Saving a Current Source

To save a *Current Source*, select the *Save* button near the *Current Source* thumbnail image. This option is also available under the menu option *File, Save Current*. Note: *Baseline Source* and *Current Source* workspace files have the same file format, and either can be saved and later loaded as a reference for strain measurement.

Loading a Data Source

A saved SR-1 workspace file (with a .dwk file extension) can be loaded as a *Baseline Source*, a *Current Source*, or both. To load a *Baseline Source*, click the *Load* button next to the *Baseline Source* thumbnail image. To load a *Current Source*, click the *Load* button next to the *Current Source* thumbnail image. These options are also available under the menu option *File, Save Current*, and *File, Save Baseline*.



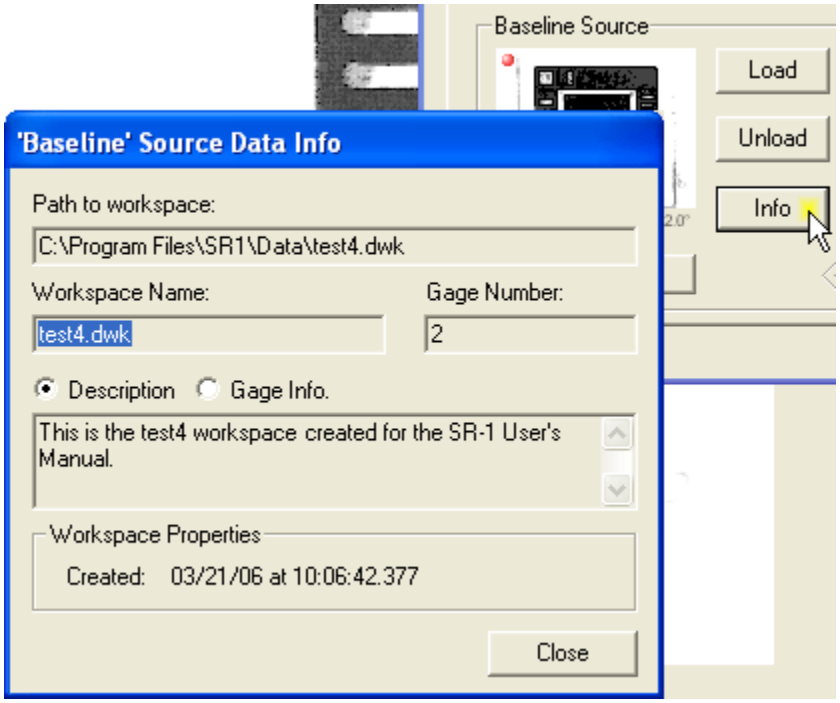
In the example above, the *Baseline Source's Load* button is clicked, which opens a standard 'Open File' dialog window. Navigate to, and click the .dwk file you wish to load, and then click the *Open* button. This will load the selected workspace. In this example, we're loading the workspace file 'test4.dwk' we created above. Note: Static workspace files can not be loaded when strain measurement is on. If strain measurement is on, the *Load* buttons will be disabled. You must stop strain measurement to load static data sources.

Unloading a Data Source

To unload a *Baseline Source*, click the *Unload* button next to the *Baseline Source* thumbnail image. To unload a *Current Source*, click the *Unload* button next to the *Current Source* thumbnail image. This will unload the selected workspace.

Note: If strain measurement is on, the *Unload* buttons are disabled. Also, only static data sources (i.e. loaded from disk, or created using the *Create Baseline* button) can be unloaded.

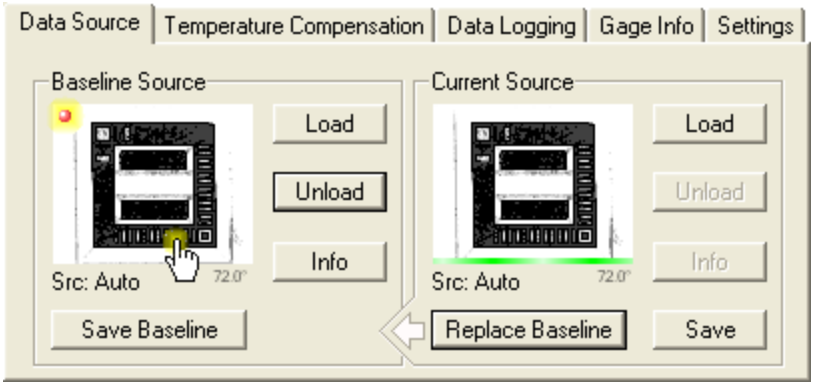
Viewing Data Source Information



An *Info* button is provided for the *Baseline Source* and the *Current Source*. The *Info* button provides summary information about a particular static workspace (i.e. loaded from disk, or created using the *Create Baseline* button). In the example to the right, the workspace file 'test4.dwk' was previously loaded into the *Baseline Source*. The *Baseline Source's Info* button is pressed. As shown, the data source path, name, description, gage info, gage number (or encoded value), and creation date/time are provided in the Info window. The Info window is closed by clicking it's OK button. As described above in **Saving a Baseline Source**, the path, name, and description are user-provided values.

Data Source View Selection

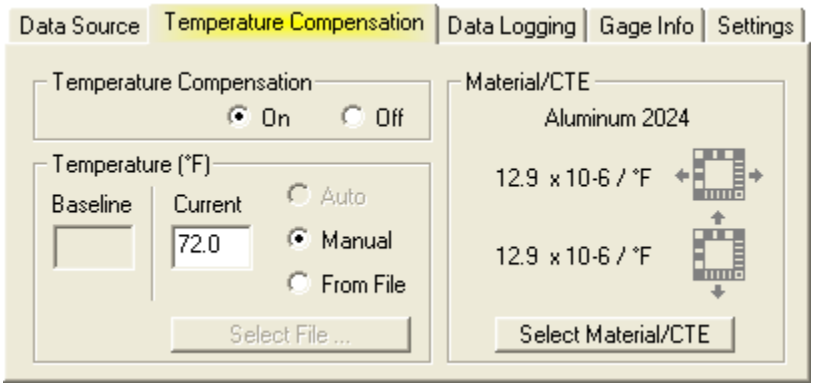
The large view window in the SR-1 interface can display either the *Baseline Source* or the *Current Source* image data. A small red dot icon in the upper-left corner of the data source thumbnail image indicates which source image is presently displayed.



Clicking on the *Baseline Source* thumbnail displays the current *Baseline Source* image, and clicking on the *Current Source* thumbnail displays the *Current Source* image. In this example, the *Baseline Source* thumbnail is clicked, which causes the *Baseline Source's* image to be displayed in the SR-1 interface main view window.

View selection can also be made by selecting the menu option *View, Baseline Source* or *View, Current Source*. Additionally, these same menu options are available by right clicking anywhere in the SR-1 interface main view window.

TEMPERATURE COMPENSATION TAB



The second 'tab' in the Analysis Control region of the *SR-1 Control Panel* is the 'Temperature Compensation' tab. The SR-1 interface measures true strain, i.e. changes in linear dimensions with respect to linear dimensions. Therefore, thermal expansion can affect strain measurement results. It is left to the end-user to decide whether or not temperature compensation is needed.

The Temperature Compensation tab controls if, and how, temperature compensation is to be applied to strain measurements. On this tab, temperature compensation can be switched on and off; a method by which temperature values are supplied to the analysis can be specified; and a bidirectional coefficient of thermal expansion can be selected or entered.

Enable/Disable Temperature Compensation

Temperature compensation can be turned on or off using the *On* or *Off* radio buttons on this tab window. When switched on, temperature compensation is applied to strain readings as follows:

(1) $\varepsilon_{xx} = \varepsilon_{xx} - (T_c - T_b) \times CTE_{xx}$
(2) $\varepsilon_{yy} = \varepsilon_{yy} - (T_c - T_b) \times CTE_{yy}$
(3) $\varepsilon_{xy} = f(\varepsilon_{xx},\varepsilon_{yy})$

where: CTE_{xx} = coefficient of thermal expansion in the direction indicated by 

CTE_{yy} = coefficient of thermal expansion in the direction indicated by 
T_c = temperature associated with the *Current Source*
T_b = temperature associated with the *Baseline Source*

When temperature compensation is switched off, the above simply becomes:

(4) $\varepsilon_{xx} = \varepsilon_{xx}$
(5) $\varepsilon_{yy} = \varepsilon_{yy}$
(6) $\varepsilon_{xy} = f(\varepsilon_{xx},\varepsilon_{yy})$

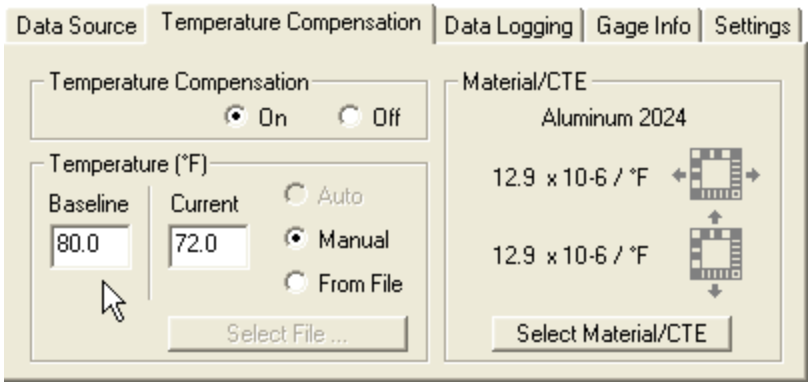
Default Settings

By default, temperature compensation is switched *On* and is set to *Manual* mode. As shown above, the SR-1 interface automatically applies a default temperature to the *Current Source* of 72 ºF. If this value is not changed manually, any *Baseline Source* created using reader data (by pressing the *Create Baseline* button on the Data Source tab) will also have a 72 ºF temperature value associated with it. Therefore, even though temperature compensation is on, the temperature difference term in equations (1) and (2) goes to zero, which has the same effect as having temperature compensation switched off. In other words, if the default settings shown above are left unchanged, the result is, there will be no compensation applied to strain readings because of equivalent temperatures. For temperature compensation to be applied, an 'actual' temperature measurement should be used, and methods for providing temperature data are described in the following sections.

Manual Temperature Entry

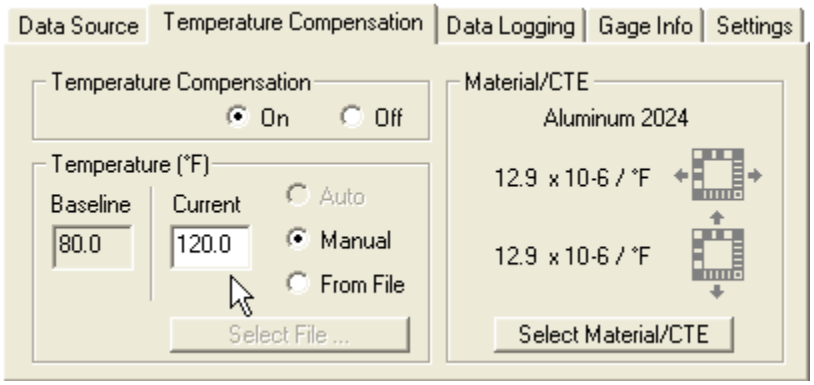
Manual temperature compensation is useful when temperatures are measured using some external device, e.g. thermocouple, RTD, pyrometer, etc. For example, at the beginning of a test, say a surface temperature is measured near the gage of 80 ºF. A strain-measurement baseline is created using the *Create Baseline* button (which creates a copy of the *Current Source* in the *Baseline Source*). To associate a temperature 80 ºF to the new *Baseline Source*, click the Temperature Compensation tab, and edit the *Baseline's* temperature using the edit box under the caption 'Baseline.' Note: The *Baseline Source's* associated temperature value can be edited only prior to saving the workspace file. Once a workspace file is saved, its associated temperature can not be changed, and its edit box on the Temperature Compensation tab will be disabled, or 'grayed-out.'

In the example to the right, a user creates a new *Baseline Source* and wants to associate a temperature of 80 ºF to this reference data source. After creating the *Baseline Source* using the *Create Baseline* button on the Data Source tab (BUT BEFORE SAVING IT) the user clicks the Temperature Compensation tab and changes the *Baseline* temperature from 72 ºF to 80 ºF. Note: After editing the temperature value, you must 'click away' from the edit box to force the change (i.e. click somewhere in the gray area of the tab window). After setting the *Baseline Source* temperature, the user may return to the Data Source tab and save this workspace file for future use (if so desired). On the Data Source tab, the temperature text beneath the *Baseline Source* thumbnail image should reflect the new temperature value entered on the Temperature Compensation tab.



Continuing with the previous example, the temperature associated with any subsequent strain readings must be input in the *Current* edit box on the Temperature Compensation tab. For example, if the surface temperature near the gage has changed to 120 ºF, this value is manually entered as shown prior to recording the strain reading.

Note: Since the *Baseline Source* was previously saved, it's associated temperature can no longer be edited.



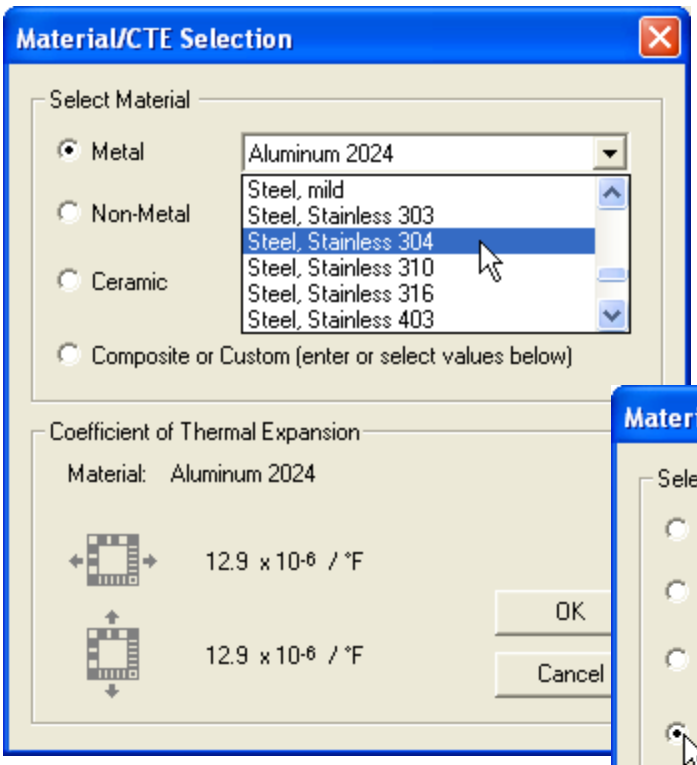
In summary, temperature compensation via manual temperature entry requires that; (1) a *Baseline Source* is in use with some associated reference temperature; and (2) 'Current' temperature values are manually updated to reflect the most recent test conditions prior to recording a strain reading.

From-File Temperature Entry

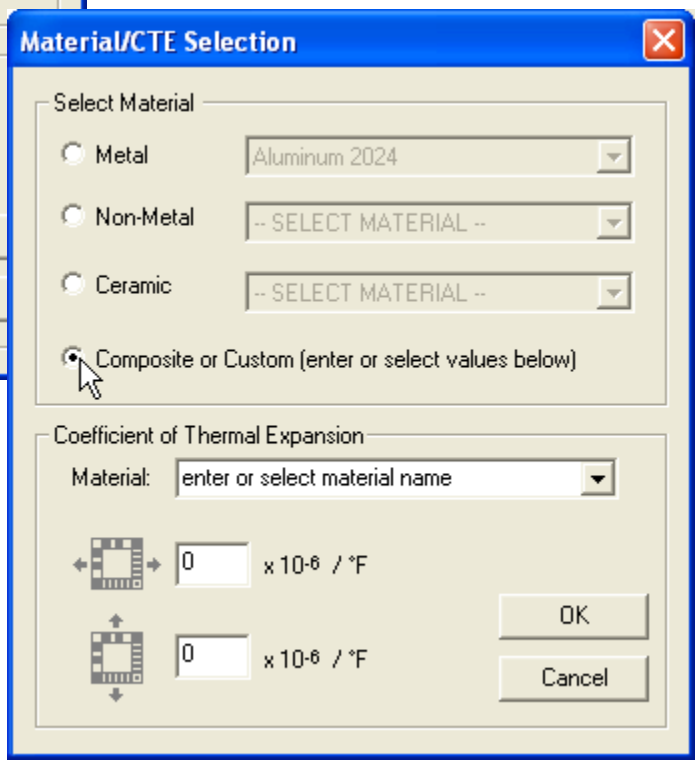
The *From File* option is a quasi-automatic method of inputting temperature values for temperature compensation. When the *From File* radio button is clicked, a file is selected using the *Select File* button from which temperature values are read. When this option is enabled, the SR-1 interface reads the very first line of the selected text file, and expects exactly one double-precision temperature value on that line. This value is reread on each image cycle (or roughly 8 times per second). This option is used to provide connectivity to external data loggers.

Selecting a Coefficient of Thermal Expansion (CTE)

The coefficient of thermal expansion (or CTE) is specified by clicking the *Select Material/CTE* button. This opens a dialog window where various CTE values can be selected from dropdown categories (metals, non-metals, ceramics, or composite/custom). Note: It is the user's responsibility to verify the accuracy and/or applicability of any CTE value selected, as these values vary from source to source, and are affected by many factors including (but not limited to) actual material properties, ambient conditions, test conditions, etc.



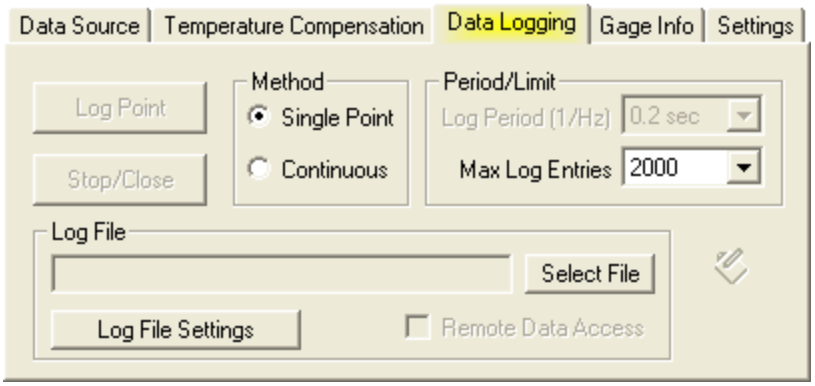
To enter a 'custom' CTE value, select the *Composite or Custom* radio button to create a custom CTE entry (as shown below). Any previously-defined custom CTE entry should be available in the *Material:* dropdown for subsequent use.



As shown in equations (1) and (2) at the beginning of the section **Enable/Disable Temperature Compensation**, CTE values are applied in a bidirectional fashion. When defining custom CTE values, different values for the axial and transverse CTE may be entered if need be.

DATA LOGGING TAB

The third 'tab' in the Analysis Control region of the *SR-1 Control Panel* is the 'Data Logging' tab. The SR-1 interface will log data to text files either continuously at a selected sampling rate, or using a single-point method. The following sections describe SR-1's data logging capabilities and controls.

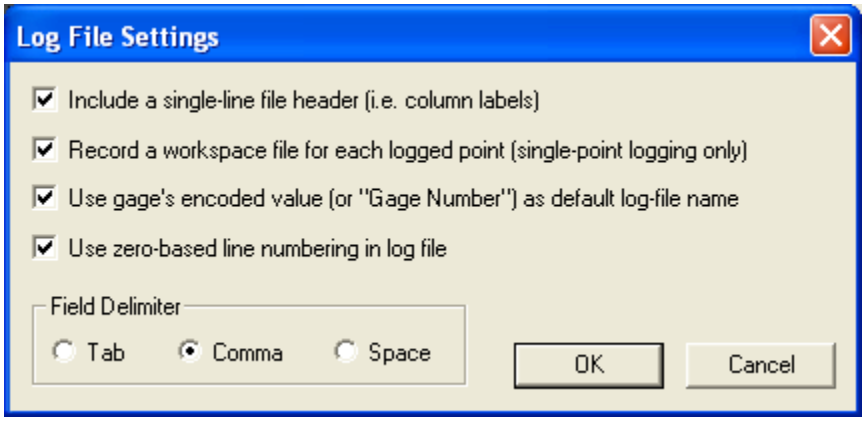


Data Log File

The first step in logging SR-1 strain measurement data is to select a log file. Do this by clicking the *Select File* button. This opens a standard 'Save File' dialog, which is used to specify the desired location and file name for the data log file. Note: The *Log Point* (or *Start Log* if in continuous mode) button is disabled until a data log file has been selected.

Log File Settings

The *Log File Settings* button provides several options for customizing data logs. Pressing this button opens a 'Log File Settings' window as shown below. The first checkbox controls whether or not the log file has a single-line header showing the column labels. The second checkbox is used if a workspace file is to automatically be generated from the *Current Source* for each logged data point. This option is available only for single-point data logging. The third checkbox controls whether or not the gage's encoded value (or gage number) is to be used as a default log file name. For example, if this option is selected, and the gage number is 27097, the default data log file name would be 27097.txt. Finally, every line in the log file is numbered, and the fourth checkbox determines whether line numbering starts with zero (0) or one (1).



The 'Field Delimiter' selection determines what type of delimiter is placed between each data field in the log file.

Start/Stop Data Logging

When a log file has been selected, and the logging method is set to *Single Point*, the *Log Point* button is enabled. In single-point logging, each time the *Log Point* button is pressed, a data point is logged. If the logging method is set to *Continuous* the *Log Point* button's text changes to *Start Log*. Pressing this button will begin continuous data logging at, or about, the period specified in the *Period/Limit* selection area. Logging will automatically end when the number of logged points equals the *Max Log Entries* setting. Whether in continuous mode or single-point mode, pressing the *Stop/Close* button will stop data logging and close the log file.

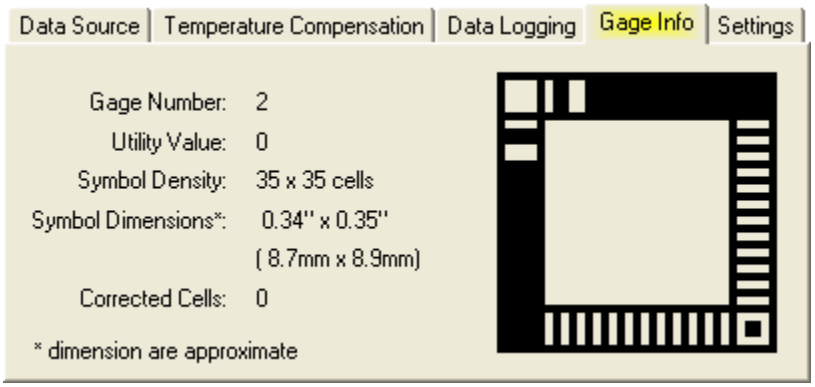
Log File Format

The log file is written in text format. The first line is the file is a header giving the column labels. Note: The header appears only if the header option is selected in the **Log File Settings** as described above. In the current version of the SR-1 interface, each data line in the log file consists of ten data fields, which are described in the table below:

Field	Description	Units
Count	An integer value indicating the data-point number	N/A
Date	Date log was recorded (Format MM/DD/YY)	N/A
Time	Time log was recorded (Format HH:MM:SS.SSS)	N/A
Temperature	Temperature associated with the Current Source	ºF
Temp Source	Method of temperature input (0=Auto, 1=Manual, 2=From File)	N/A
Encoded Value	"Gage Number", an integer value 'stored' in the gage's barcode	N/A
Exx	Axial strain component	unitless
Eyy	Transverse strain component	unitless
Exy	Shear strain component	unitless
MOI	Measure of instability (lower numbers are better)	%

Each field is separated by a user-selected delimiter, as described in the **Log File Settings** section.

GAGE INFO TAB



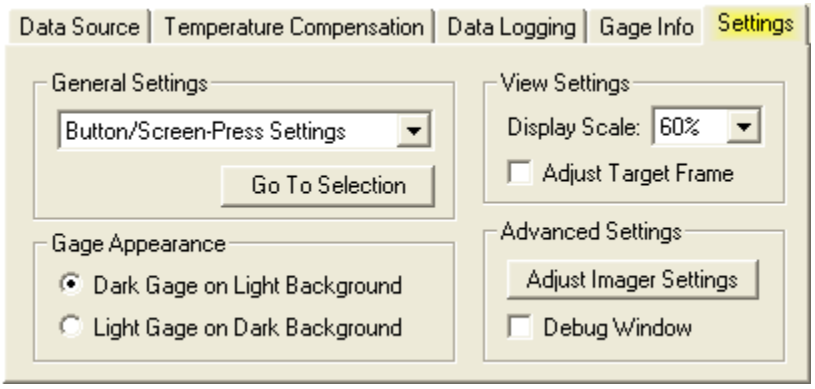
The fourth 'tab' in the Analysis Control region of the *SR-1 Control Panel* is the 'Gage Info' tab. The information available in this tab window comes from the *Current Source* when the reader is streaming data. If a readable gage is positioned inside the target area of the SR-1 interface main view, the Gage Info tab attempts to provide information about the gage.

The *Gage Number* is the integer 'stored' or encoded in the gage's barcode area. The *Utility Value* is not used in this version of SR-1. *Symbol Density* should always be '35 x 35 cells' in this version of SR-1. The *Symbol Dimensions* provided in this tab window are approximate values calculated using a field-of-view value associated with the originally-installed handheld optics. Data stored in the gage's barcode is encoded using an error-correcting code (ECC) technique, which aids in data recovery should the gage become scratched or damaged. Note: The encoding scheme does not ensure data recovery in the event of gage damage, but it does provide an additional measure of recoverability. Should the SR-1 interface correct any cells while decoding the gage number, the number of corrected cells is displayed in the *Corrected Cells* value on this tab window.

The graphic to the right is NOT a thumbnail view of the actual *Current Source* gage, rather it is fabricated using the *Gage Number.* In addition, should any cells be corrected during the decoding step, corrected cells would be outlined in red on the gage graphic in this tab window.

SETTINGS TAB

The fifth, and final 'tab' in the Analysis Control region of the *SR-1 Control Panel* is the 'Settings' tab. This tab window provides access to many SR-1 options, settings, and features.



General Settings

In the *General Settings* area, to access a desired settings category, a selection is made from the dropdown, and then the *Go To Selection* button is pressed.

General settings listed in the dropdown are: Button/Screen-Press Settings, Material/CTE Settings, Log File Settings, and Default Folder Locations. Material/CTE Settings and Log File Settings are described in detail in previous sections of this operating manual.

Button/Screen-Press Settings is used to customize the SR-1 double click (or double tap) feature. This feature is used to perform some user-selected task when the SR-1 interface main view window is double clicked (or double tapped).

The Default Folder Locations settings option provides some control over the folders SR-1 uses to load files, save files, and store log files. In addition, you may instantly navigate to any of these folders by pressing the small folder icon [📂] to the left of each path.

View Settings

The *Display Scale:* dropdown controls the SR-1 interface main view window scale. This is strictly a “display” property, and the selected scale-factor value has no affect on strain-measurement calculations. The *Adjust Target Frame* checkbox is used when the target frame must be moved or resized. It is recommended the target frame remain at its default size and location, as it is centered in the handheld’s field of view. However, when this box is checked, the target frame’s resize and drag capabilities are enabled. Unchecking this box will again disable the target frame resize and drag.

Gage Appearance

The two radio buttons are used to select the gage’s contrast type; *Dark Gage on Light Background*

or

Light Gage on Dark Background

Advanced Settings

The *Adjust Imager Settings* button will open a dialog that allows adjustment of imager-control settings. These include Shutter, Gamma, Gain, and Saturation. These values should NOT be changed. The ability to change these settings in SR-1 is provided as a versatility/extensibility feature for future gage types/appearance.

The *Debug Window* checkbox opens a window that displays SR-1 status messages. This feature is provided for support purposes only.

6. MEASURING STRAIN

The SR-1 interface is used to measure strain from SR-1 series polymer gages. The first step in strain measurement is to permanently bond a polymer gage to a part or test specimen, preferably in a 'flat' region which will allow for stable, repeatable contact between the part and the SR-1 handheld reader.

In the SR-1 interface, strain is defined as the change in linear dimensions of some 'current' state with respect to some 'reference' state. As described in the Data Source Tab section of this operating manual, the two states which are used to measure strain are depicted graphically in the *Baseline Source* and *Current Source* thumbnail images on the Data Source tab.

Therefore, in order to measure strain with the SR-1 interface, there must be data in the *Baseline Source* and *Current Source* locations. By default, dynamic data from the handheld device's imager is continuously streaming into the *Current Source* location. This continuous data stream can only be used to measure strain if there is a *Baseline Source* to reference against. *Baseline Source* data can be created from the *Current Source* data stream by pressing the *Create Baseline* button on the Data Source tab, or it can be loaded from disk (from a previously saved workspace file).

No matter the method of providing a *Baseline Source*, strain is change in linear dimensions of the *Current Source* with respect to the *Baseline Source*. A qualitative illustration of this is, if the gage dimensions in the *Current Source* are 'larger' than the gage dimensions in the *Baseline Source*, normal strains are positive.

The following examples provide some common SR-1 strain-measurement scenarios, and illustrate the techniques used to make strain measurements.

EXAMPLE 1. STRAIN MEASUREMENT USING DYNAMIC (READER) DATA ONLY

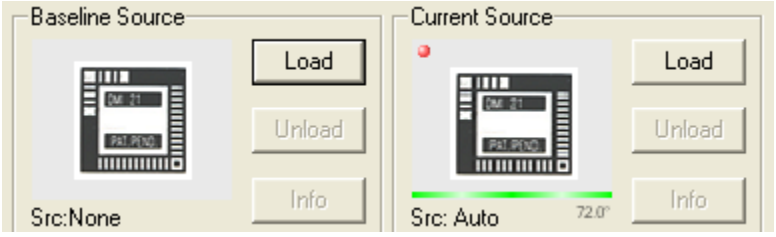
In this example, a polymer gage is affixed to a part. An unloaded state is shown in Figure 1a, and the part will be loaded in the direction of the arrows shown in Figure 1b. Note: Deformation in Figure 1b is exaggerated for illustrative purposes.

Figure 1a.
Unloaded part with polymer gage

Figure 1b.
Loaded part with polymer gage

In this example, we wish to use the state depicted in Figure 1a as our reference state, and we wish to measure the strain state depicted in Figure 1b with respect to the reference state in Figure 1a. In the SR-1 interface, this means the state depicted in Figure 1a must be in the *Baseline Source*, and the state depicted in Figure 1b must be in the *Current Source*.

Ultimately, in this example we want our Data Source tab to contain the two states as shown in the graphic to the right.



Below are the steps to carry-out this example strain-measurement task:

1) Obtain a *Baseline Source*: Since this example involves dynamic (reader) data only, the reference state (or *Baseline Source*) will be obtained from reader data, as described below:
   a) Place the reader over the gage with the part in the unloaded state (Figure 1a). Note: In general, there is no requirement that the reference state be an 'unloaded' state. It is simply a reference state for subsequent strain measurements.
   b) Make sure the *Current Source* thumbnail is chosen as the active display. Do this by clicking the *Current Source* thumbnail image. A red dot should appear in the upper left corner of the *Current Source* thumbnail image, and the reader data should be shown in the SR-1 interface main view window.
   c) Ensure proper gage alignment, as described in the **Gage Alignment** section of this operating manual.
   d) Press the *Create Baseline* button beneath the *Current Source* thumbnail. This will create a static copy of the *Current Source* in the *Baseline Source*.

   A reference state is now defined in the *Baseline Source* location. The *Baseline Source* now will not change until it is replaced or unloaded, therefore we have static reference to measure strain against. If the reader is still in place over the gage and live data continues to stream in the *Current Source* location, the *Start* button on the *SR-1 Control Panel* should now be enabled.

2) Start Strain Measurement: Simply press the *Start* button on the *SR-1 Control Panel*, and the three readout panels should begin to update. Since we haven't loaded the part yet, displayed strains should be near zero since we're essentially comparing two nearly identical states. Note: A gradual increase in both normal strain values at this point may be the result of heating caused by the light inside the handheld reader, and temperature compensation or waiting for thermal steady-state may be required to offset these conditions. Any 'drifting' in 'zero-strain' conditions can be corrected by 'zeroing' the strain readings. To zero the strain readings, simply press the 'Replace & Zero" button.

3) Load the Part: Apply a load to the part as shown in Figure 1b. The *Current Source's* data changes dynamically, while the *Baseline Source* remains a fixed reference. The SR-1 interface automatically and continuously updates the strain readings to reflect the relative strain between the states depicted in the *Current Source* and *Baseline Source*. Note: For the purposes of this example, do not zero strains at this point, since this will replace the *Baseline Source* with the *Current Source*, and the *Baseline Source* (or reference) we created in step 1 will be lost.

4) Save the *Baseline Source* (optional): Before exiting the SR-1 interface software or before starting a new test, it may be desirable to save the *Baseline Source* as a reference for future tests. The SR-1 utilizes 'workspace files' (or '.dwk' files) which can be saved, loaded, and reused for future tests on the same gage. To save the *Baseline Source* created in step 1 to a workspace file, press the *Save Baseline* button beneath the *Baseline Source* thumbnail image. Follow the steps as outlined in the **Saving a Baseline Source** section of this operating manual. For example purposes, we'll call our saved workspace file 'example1.dwk.'

It should be noted that steps 2 and 3 above can be reversed, i.e. it is not necessary to start strain measurement prior to loading the part. In other words, the part can be loaded first, and then the *Start* button can be pressed, which achieves the same desired result for this example.

EXAMPLE 2. STRAIN MEASUREMENT USING A SAVED WORKSPACE AND DYNAMIC (READER) DATA

In this example, rather than creating a reference (or *Baseline Source*) from reader data, we wish to use a previously saved workspace file as a reference. In Example 1 above, a *Baseline Source* was created from reader data, and was saved according to step 4 in Example 1. The following steps outline how a saved workspace file is used in conjunction with dynamic reader data to measure strain:

1) Obtain a *Baseline Source*: In this example, we obtain our reference data (or *Baseline Source*) from a previously saved SR-1 workspace file. In this case, we'll use the workspace file 'example1.dwk' saved in Example 1, step 4 as our reference. There are two ways to load this file as our *Baseline Source*:

   a) The most common method of loading a workspace file into the *Baseline Source* is to 'Load' it. With the SR-1 interface software running, click the *Load* button next to the *Baseline Source* thumbnail. Follow the steps outlined in the **Loading a Data Source** section of this operating manual to load the file 'example1.dwk.'
   b) If the SR-1 interface software is not running, an SR-1 workspace file can be loaded automatically into the *Baseline Source* by double-clicking (or double tapping) the workspace (.dwk) file. In this example, if SR-1 is not running, we would navigate to the file 'example1.dwk' and double-click (or double-tap) it. This would start the SR-1 interface and load 'example1.dwk' into the *Baseline Source* location

   A reference state is now defined in the *Baseline Source* location. The *Baseline Source* will not change until it is replaced or unloaded, therefore we have static reference to measure strain against.

2) Acquire a *Current Source*: In this example we want *Current Source* reader data measured against the loaded *Baseline Source* data. To begin acquiring *Current Source* data:

   a) Unload any previously-loaded static *Current Source* workspace data (don't unload the *Baseline Source* data loaded in step 1). Do this step only if a static workspace was previously loaded in the *Current Source* location (as described later in **Example 3**).
   b) Place the reader over the gage. Note: This should be the SAME GAGE that was used to create the workspace file loaded in the *Baseline Source*.
   c) Make sure the *Current Source* thumbnail is chosen as the active display. Do this by clicking the *Current Source* thumbnail image. A red dot should appear in the upper left corner of the *Current Source* thumbnail image, and the reader data should be shown in the SR-1 interface main view window.
   d) Ensure proper gage alignment, as described in the **Gage Alignment** section of this operating manual.

   At this point, the *Start* button in the Strain Measurement region of the *SR-1 Control Panel* should be enabled. Additionally, the *Create Baseline* option is disabled when a *Baseline Source* is loaded from disk. To create new *Baseline Sources,* any loaded *Baseline Source* workspace file first has to be unloaded.

3) Start Strain Measurement: Simply press the *Start* button on the SR-1 Control Panel, and the three readout panels should begin to update. Note: There is no option to 'zero' strain readings when a workspace is loaded from disk. Recall that zeroing strain involves replacing a *Baseline Source*, and since our *Baseline Source* is a fixed reference loaded from a disk file, its data can not be overwritten by button press.

4) Load the Part: Apply a load to the part as shown in Figure 1b. The *Current Source's* data changes dynamically, while the loaded *Baseline Source* remains a fixed reference. The SR-1 interface automatically and continuously updates the strain readings to reflect the relative strain between the states depicted in the *Current Source* and *Baseline Source*.

5) Save *Current Source* Workspace Files (optional): During testing, it may be desirable to save a *Current Source* workspace file that can be used as a reference for future tests. At any time while reader data is streaming into the *Current Source*, simply press the *Save* button near the *Current Source* thumbnail image, or select the menu option *File, Save Current*. This creates an instantaneous copy of the *Current Source* data, and it can be saved in a user-specified file. For example purposes, we'll call this saved workspace file 'example2.dwk.'

EXAMPLE 3. STRAIN MEASUREMENT USING A SAVED WORKSPACE DATA ONLY

In this example, no 'live' reader data will be used. Rather, we load a static workspace into both the *Baseline Source* and *Current Source* locations. Obviously, this is a simple example which makes a single calculation based on two static states. However, measuring strain between two static states is added functionality that the SR-1 interface provides, which offers utility in post processing and re-baselining previous data. Therefore it is worthy of describing below:

Rather than creating a reference (or *Baseline Source*) from reader data, we wish to use a previously saved workspace file as our reference. In Example 1 above, a *Baseline Source* was created from reader data, and was saved according to step 4 in Example 1. The following steps outline how a saved workspace file is used in conjunction with dynamic reader data to measure strain:

1) Obtain a *Baseline Source*: In this example, we obtain our reference data (or *Baseline Source*) from a previously saved SR-1 workspace file. In this case, we'll use the workspace file 'example1.dwk' saved in Example 1, step 4 as our reference. There are two ways to load this file as our *Baseline Source*:

   a) The most common method of loading a workspace file into the *Baseline Source* is to 'Load' it. With the SR-1 interface software running, click the *Load* button next to the *Baseline Source* thumbnail. Follow the steps outlined in the **Loading a Data Source** section of this operating manual to load the file 'example1.dwk.'
   b) If the SR-1 interface software is not running, an SR-1 workspace file can be loaded automatically into the *Baseline Source* by double-clicking (or double tapping) the workspace (.dwk) file. In this example, if SR-1 is not running, we would navigate to the file 'example1.dwk' and double-click (or double-tap) it. This would start the SR-1 interface and load 'example1.dwk' into the *Baseline Source* location

   A reference state is now defined in the *Baseline Source* location. The *Baseline Source* will not change until it is replaced or unloaded, therefore we have static reference to measure strain against.

2) Obtain a *Current Source*: In this example, we also obtain our subsequent data (or *Current Source*) from a previously saved SR-1 workspace file. In this case, we'll use the workspace file 'example2.dwk' saved in Example 2, step 5. To load a static *Current Source* from disk, click the *Load* button next to the *Current Source* thumbnail. Follow the steps outlined in the **Loading a Data Source** section of this operating manual to load the file 'example2.dwk.'

   This static *Current Source* will not change until it is replaced (by reloading) or unloaded.

   At this point, the *Start* button on the *SR-1 Control Panel* should be enabled. As before, the *Create Baseline* option is disabled when a *Baseline Source* is loaded from disk. To create new *Baseline Sources*, any loaded *Baseline Source* workspace file first has to be unloaded.

3) Start Strain Measurement: Simply press the *Start* button on the *SR-1 Control Panel*, and the three readout panels should update once since the strain measured between two static sources is a constant value. Note: There is no option to 'zero' strain readings when a workspace is loaded from disk. Recall that zeroing strain involves replacing a *Baseline Source*, and since our *Baseline Source* is a fixed reference loaded from a disk file, its data can not be overwritten by button press.

7. ADDITIONAL INFORMATION/UPDATES

If or when available, additional information, updates to this operating manual, or frequently-asked questions (FAQs) may be found on the DMI website at:

www.directmeasure.com