LF/Z-2

Reflection Polariscope Instruction Manual

Micro-Measurements

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INTRODUCTION

The basic theory of PhotoStress hasn't changed for the past 50 years. Regardless of the instrument used, the same theory applies. Those interested in the fundamental concepts and principles of PhotoStress should refer to the Bibliography listed at the end of this manual. The user is also advised to read the video camera instruction manual and become familiar with the various features of the camera.

The LF/Z-2 Reflection Polariscope incorporates the following new features:

- The handling and manipulation of the polariscope is simple and easy to learn. Use of the new LF/Z-2 does not require previous knowledge of photoelasticity.
- A digital video camera is an integral part of the polariscope, and the photoelastic color pattern is viewed on a computer monitor. The computer card and software supplied will allow live viewing or capturing of either still or video images.
- An innovative laser light permits viewing of directions of principal stresses directly on the structure.
- A new Model 832 Electronic Digital Compensator takes measurements that eventually produce the difference in principal stresses $\sigma_1 - \sigma_2$, and the individual principal stresses, σ_1 and σ_2.
- New software, PSCalc™, solves for principal strains and principal stresses.
- Separation of principal stresses is performed by a new technique called Slitting.

NOTE:

For simplicity, some of the Photoelastic terminology used in this instruction manual differs from the traditional terminology used in our technical notes and other publication on Photoelasticity. Translation is as follows:

TRADITIONAL TERMINOLOGY	NEW TERMINOLOGY
Fringe	Color Band
Fringe Order (*N*)	Compensator Reading (*R*)
Fringe Value (*f*)	Calibration Value (*f*)
Fringe Pattern	Color Band Distribution
Isochromatics	Equal Color Bands
Isoclinics	Directional Dark Bands

LF/Z-2 Reflection Polariscope Instruction Manual

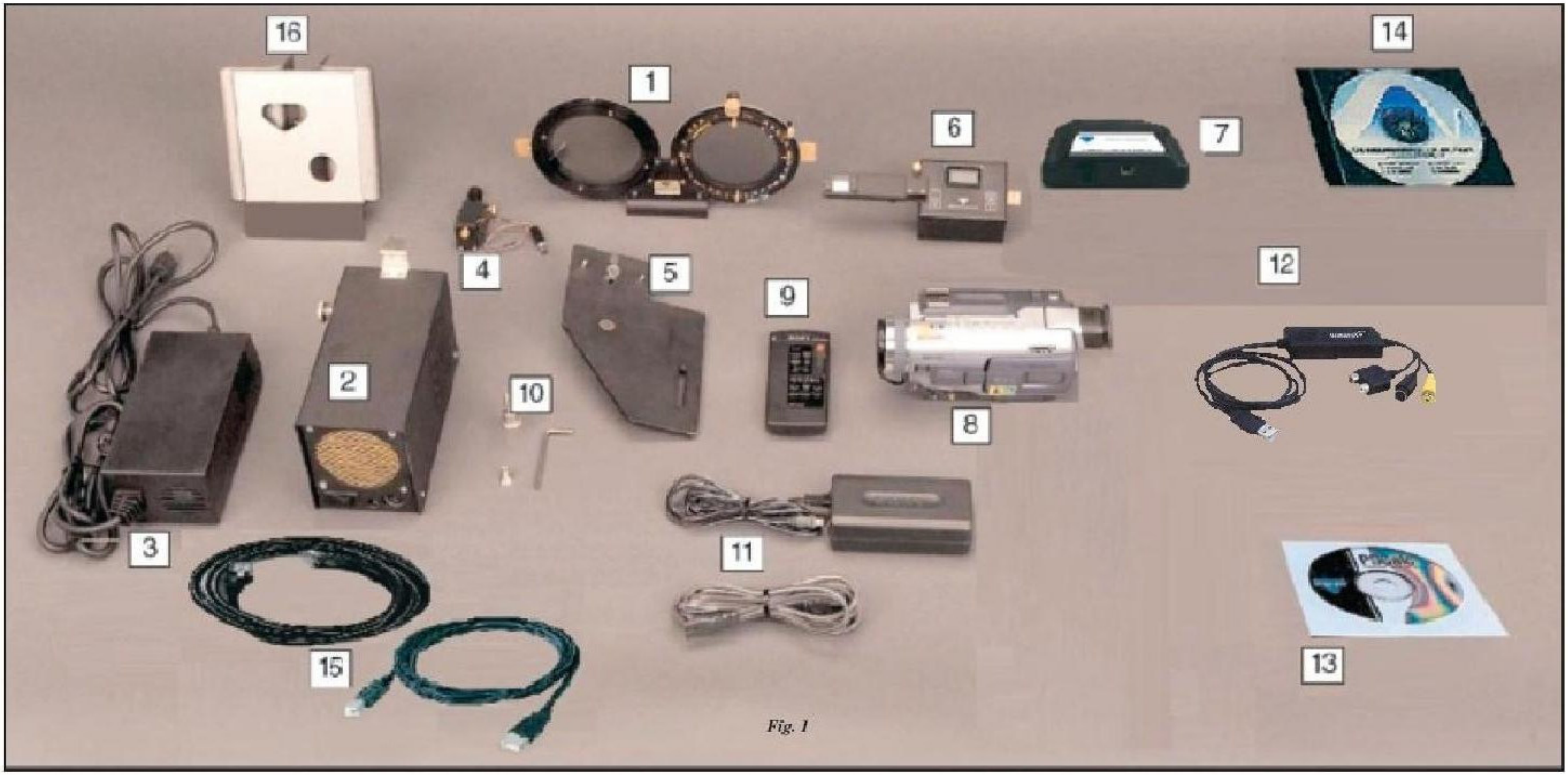


Fig. 1

1. Polariscope Head.
2. Polariscope Light Source.
3. Light Source Power Supply.
4. Laser Light Source.
5. Polariscope and Video Camera Mounting Plate.
6. Model 832 Electronic Compensator.
7. Compensator USB Interface Module.
8. Video Camera.
9. Video Camera Remote Control.
10. Video Camera Mounting Hardware.
11. Video Camera Power Supply.
12. USB Video Interface Card (PCI or PCMCIA based on pc type).
13. PSCalc™Software.
14. Compensator Data Acquisition Software.
15. Compensator USBInterface cables (RJ45 and USB).
16. Test Specimen and Cradle.

Not Shown:

– Heavy Duty Tripod
– Custom Storage Case.
– Instruction/Technical Manual

LF/Z-2 Reflection Polariscope

Assembling the Polariscope

1. Remove the tripod components from their boxes (Fig. 2), and assemble them as in Fig. 3.
2. Attach the polariscope mounting plate to the polariscope head as shown in Fig. 4 using mounting screw and hex key.
3. Remove original tripod head screw by lifting the rubber stopper. Attach the polariscope mounting plate to the tripod head with the “wing nuts” suppplied (Fig. 5).
4. Attach the light source to the polariscope head assembly as shown in Fig. 6. The top and bottom mounting brackets are spring loaded. Place one of them on one mounting pin, and pull the other one until it slips over the other pin. The third mounting bracket is loose. After placing it over the third pin, tighten the locking screw.
5. Carefully remove the Laser Light Source from its wrapping and attach it to the polariscope head assembly as shown in Fig. 7. Tighten locking knob on the back to secure the laser. Insert the laser pin-type power plug into the power socket on the side of the polariscope light source.
6. Remove the video camera from its box and go through the preparation instructions found in the instruction manual. *Do not* install a video tape at this stage.

   Referring to the video camera manual, connect the supplied composite video cable to the USB Video interface shown in Fig. 8. Install the drivers for the USB Video interface, then connect the other end of the cable to the USB port of your Desktop or Laptop PC.

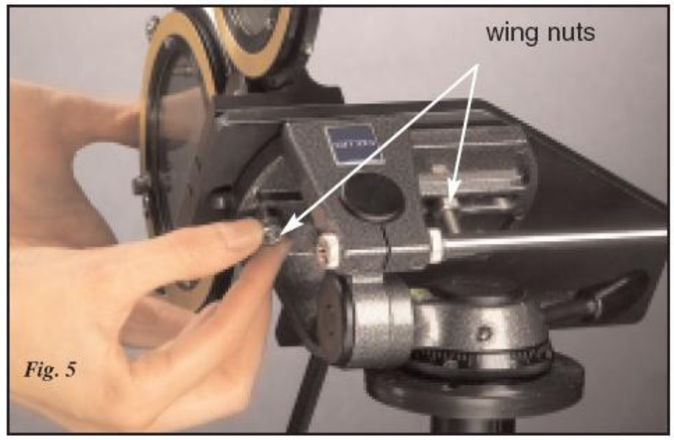


Fig. 5

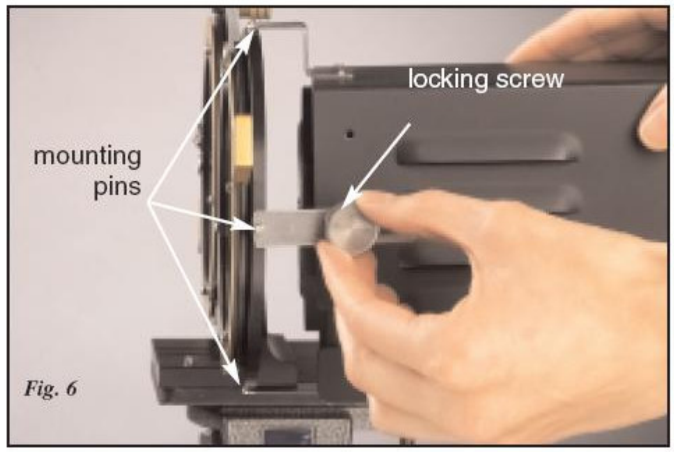


Fig. 6

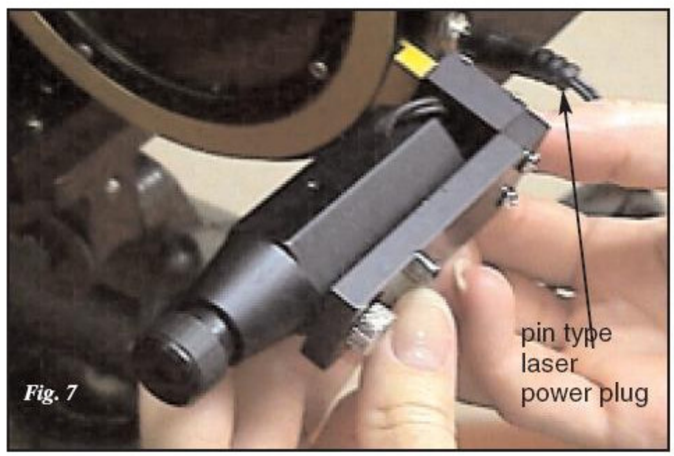


Fig. 7


Fig. 2


Fig. 3


Fig. 4

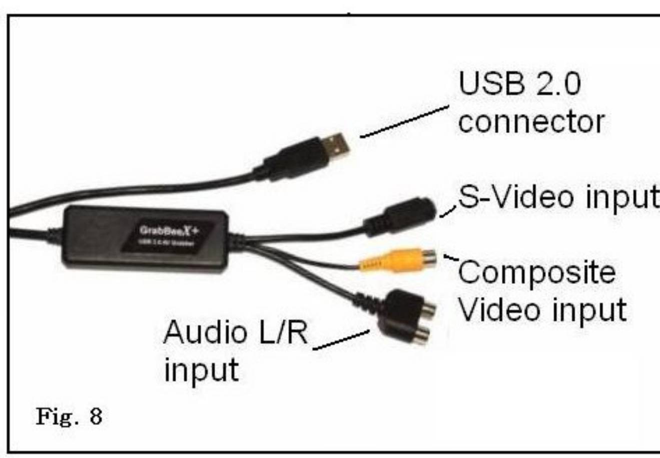


Fig. 8


Fig. 9

7. Attach the camera to the mounting plate as shown in Fig. 9. Align the camera lens to be in the center of the polariscope glass plate, and about half an inch away. Basic instructions for using the camera with the LF/Z-2 Polariscope are given later.

> **WARNING**
>
> The camera should be mounted using the special screw supplied for this purpose. Using other screws or bolts may damage the camera.

8. Attach the power supply to the polariscope light source by plugging the special 8-pin plug into the special socket on the back of the light source. Insure that the ON/OFF switch at the back of the light source is in the OFF or “0” position, and connect the power cord from the power supply to a main power socket.

   NOTE: The power supply is a multi-voltage device. No adjustment is required when used at 110-240 volts.

9. The Model 832 Electronic Digital Compensator (from here on, referred to as Compensator) mounts on the right side of the polariscope head as shown in Fig. 10. There is no need to mount the device at this time. Further instructions about the Compensator will be given at a later stage.

Preparation of the Computer

Install the video imaging software using the supplied CD, following the manufacturer’s instructions.

Connect the USB Interface Module to the Compensator and USB port respectively.

Install the USB Interface Module data acquisition software and follow the manufacturer’s instructions.

Install the PSCalc™ software using the supplied CD. Follow the instructions that appear on the screen after loading the CD in your CD ROM drive.

Setting Up and Operating the Polariscope

Place the polariscope next to a bench or table and adjust the height to about two feet (600 mm) above the bench. Place the supplied test specimen on the bench about 7 feet (2 meters) away from the polariscope. Rest the test specimen on it’s supplied support (see Fig. 1 Item 17) facing the polariscope. Insure that the winged nut loading screw on the test specimen is loose.

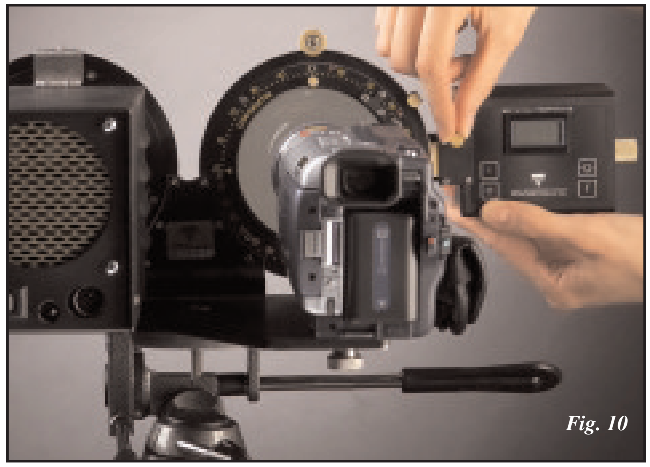


Fig. 10

Turn ON the polariscope light source by flipping the ON/OFF switch to the ON or “1” position.

Align the light source to illuminate on the test specimen by loosening the locking screw of the center mounting bracket (see Fig. 6). Lock the screw after alignment is done.

Boot the computer and turn on the video camera by moving the power switch to the CAMERA position.

Double click the PS Calc software icon either on the desktop or by going to START, PROGRAMS, PS Calc and click the PS Calc icon. The video imaging tab should be visible, and if the camera is on, a live view of the test specimen should appear on the screen as shown in Figure 11.

Turn the wing nut on the back of the test specimen a few turns and place it back on its support. The computer screen should show a pattern of color bands. Use the video camera zoom control to fill the computer screen with the PhotoStress color pattern.

CAUTION: If the video camera is not switched ON, a warning appears saying that an illegal operation has been performed. Close the window, switch the camera to the CAMERA position and repeat the preceding operation. Also, there may be static on the imaging screen at startup. This will disappear when the proper source is chosen.

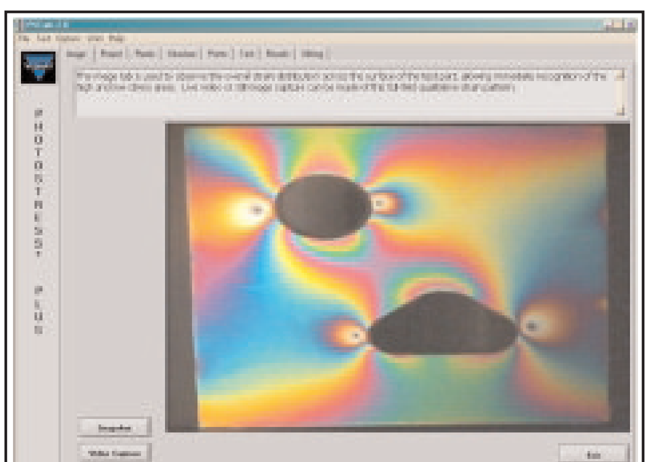


Fig. 11 — Image tab

Full-Field Analysis

To realize the full-field power of PhotoStress analysis it's necessary to understand the relationship between the PhotoStress color pattern, stress, and strain.

A fundamental relationship is:
Strain (ϵ) = Calibration Value (f) x Compensator Reading (R)
(*f*) has a given catalogue value of $\mu\epsilon$ (μm/m) for a certain PhotoStress plastic, or it can be obtained by physical calibration. (*R*) is a number measured by the Compensator. A detailed description and operation of the Compensator begins in the section on **Measurement of Principal Strains and Stresses** using the Model 832 Compensator. For a given value of (*f*), when (*R*) increases, strain, as well as stress, increases.

Referring to the cantilever beam (Fig. 12) and Table 1, we can conclude that as colors progress from yellow to red to blue or to green, we are moving in the direction of increasing strain or stress.

TABLE 1
Approximate Relationship Between Color Bands, Compensator Reading (*R*), and Stress

Color	Compensator Reading and Equivalent Stress ($\sigma_1 - \sigma_2$) when using PhotoStress Coating Type PS-1A on Aluminum
BLACK	0
YELLOW	0.6
RED	0.9
RED/BLUE TRANSITION	1.0 (4,736 PSI)
BLUE-GREEN	1.2
YELLOW	1.5
RED	1.75
RED/GREEN TRANSITION	2.00 (9,472 PSI)
GREEN	2.2
YELLOW	2.5
RED	2.8
RED/GREEN TRANSITION	3.0
GREEN	3.2 (14,208 PSI)

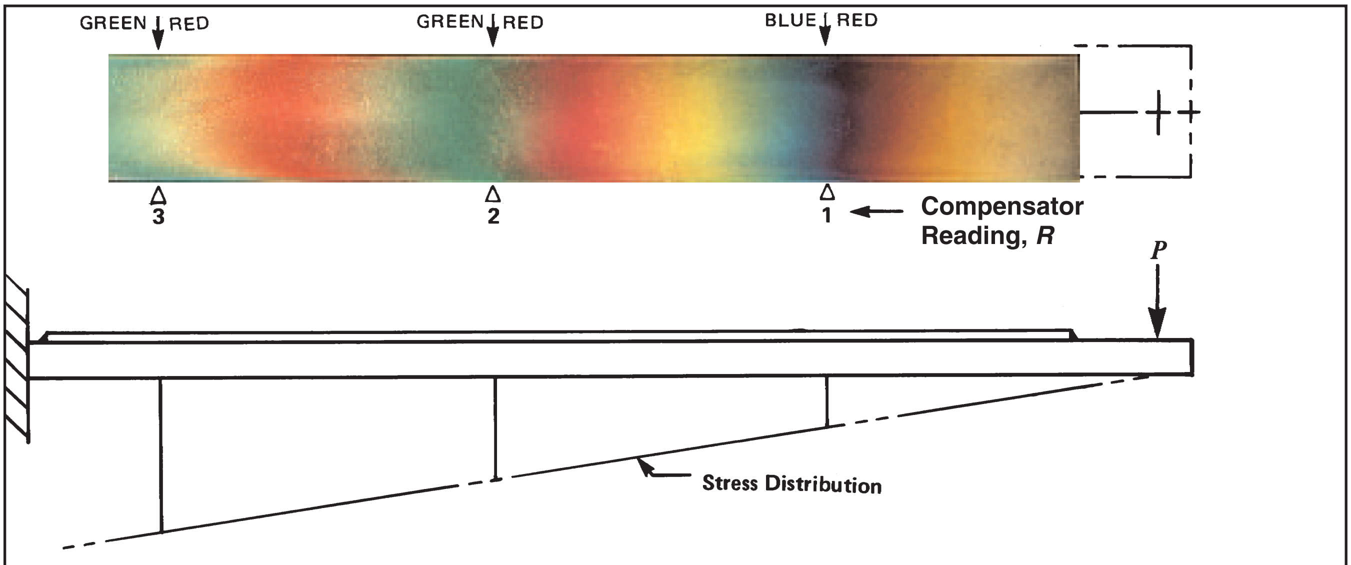
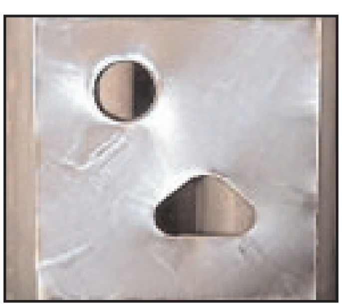


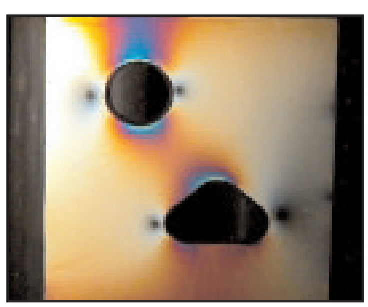
Fig. 12—Color band sequence on a coated aluminum cantilever beam.

The above conclusion is fundamental to PhotoStress analysis, and makes this technique a powerful stress analysis tool. It allows us to look at a PhotoStress pattern on a loaded structure, and immediately identify areas of high-stress gradients, as well as areas of very low stresses. To illustrate the usefulness of this effect, pictured below are three photos of the supplied test specimen under three different loading conditions.

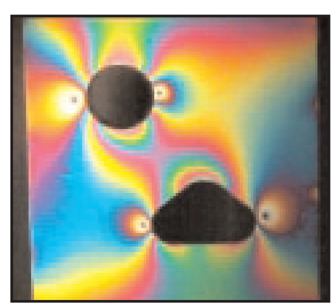
Observing at the High-Load condition, we can immediately recognize that the highest stress points are at the boundary of the cutout. This may also be evident from the Medium Load condition.The user is encouraged to duplicate these conditions using the test specimen provided with the system.



No Load

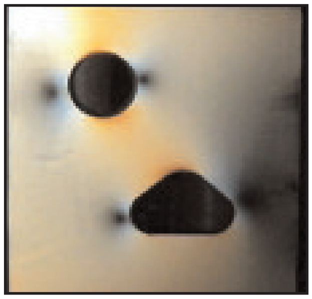


Medium Load

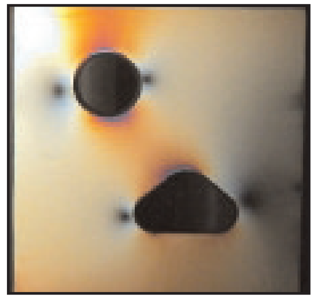


High Load

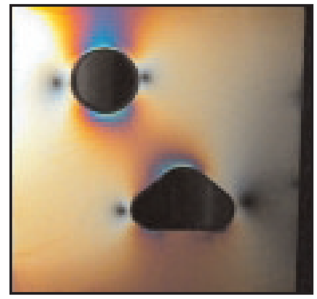
No Load



Load 1



Load 2 > Load 1



Load 3 > Load 2

As we can see from the previous discussion, PhotoStress provides a quick and effective way for identifying points where the maximum stresses occur. The development of color, and its propagation, is linear as the load (or stress) increases. And, during the early stages of loading, the points of maximum stress are immediately revealed by the first appearance of color.

To illustrate this, the four images above are of the supplied test specimen with progressive small loads applied from left to right. It becomes apparent that the high stress locations can be identified at very low loading conditions as compared to the higher load images shown on the test specimen on page 3. Thus, PhotoStress is a valuable tool for locating points of maximum stress when testing an expensive prototype that should not be destroyed during the test. Notice that even at Load 1 we can already identify the maximum stress points. As the load is increased these points become much more obvious.

Relevant Note: During the past 50 years of using PhotoStress analysis, it has been shown that structures fail wherever a high-concentration of color bands occurs.

Recognizing high stress areas is not the only information provided by PhotoStress testing. Very low stresses, or zero stress areas have great importance when trying to reduce the weight of the structure. As mentioned earlier, when viewing PhotoStress color patterns on a loaded structure, any area showing black is considered to be at zero stress or close to it. The three images shown below describe a practical case history that highlights the value of this feature. This object is a reduced scale model of a chain linkage. It is part of a large conveyor system and it initially weighed too much. The first image shows the original design, the second shows the first modification, and the last shows the final design with the minimum weight and the lowest stress distribution. The model is identically loaded in all three cases.

Notice the black (zero) areas on top and bottom of the original design, and then look at the first modification., Removal of material from these zero stress areas relocated the high stresses from the bottom hole to the top hole. However, at the same time the center of the link became black (zero stress), and a candidate for removal of material. As shown in the second modification, introducing a hole at the center, redistributed the stresses in a very favorable way. This final modification provided the manufacturer with a lighter structure and a better stress distribution of lower magnitude.

In the above section, it was demonstrated how PhotoStress can be used as a qualitative tool in stress analysis testing. When more qualitative results of the specific strain/stress values are required, the next section provides the procedure for making these measurements.

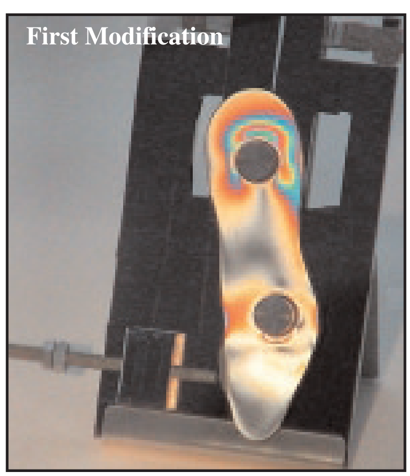
Principal Stress (or Strain) Directions

In this example, the set-up for measuring the directions of the principal strains/stresses are given. This is a necessary first step prior to measurement of the principal strain/stress values at a point.

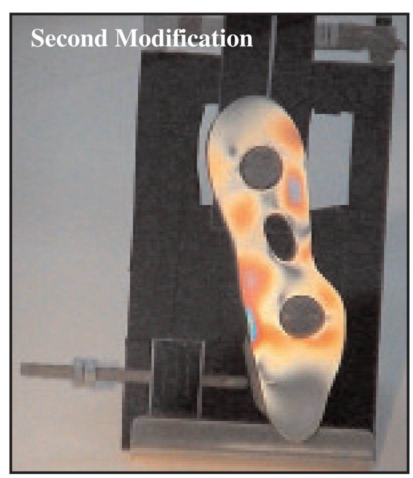
If the computer, video camera, and polariscope light source were turned off, repeat ***Setting-Up and Operating the Polariscope***. Insure that the test specimen is under load.

Using a water-soluble marker, mark a point on the supplied test specimen somewhere between the blue-green band and the next green, for example. If a second green band is not visible, continue turning the loading nut until a second green appears.

Original



First Modification



Second Modification

Move knob "B" from the **M** (magnitude) position to the **D** (direction) position (see Fig. 13). The computer screen should now show a dark pattern superimposed on top of the color pattern. Unlock control knob "H" and slowly start rotating it in either the clockwise or counterclockwise direction. As you rotate you will observe that the dark pattern is moving. Keep rotating knob "H" until the marked point is covered by the dark pattern, and lock knob "H". Move knob "B" back to the **M** position. The polariscope is now set in the direction of the principal stresses *at the marked point*, with respect to a vertical reference between the polariscope and test part. In the following section, the relationship between the principal strain directions and measurement of strain magnitude is explained further.

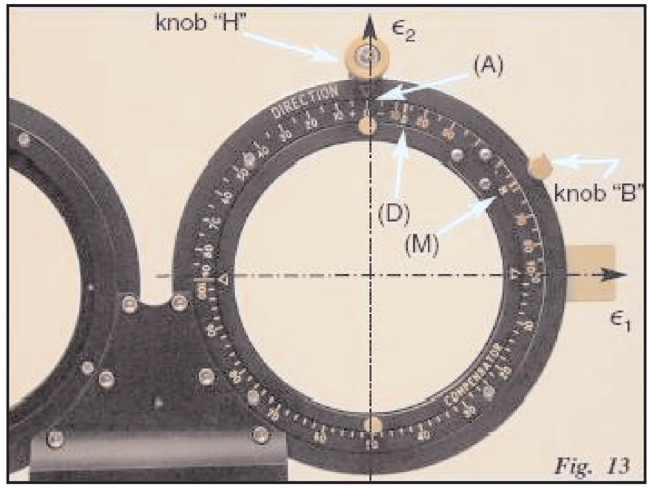


Fig. 13

Measurement of Principal Strains and Stresses Using Model 832 Compensator

The following equations form the basis of PhotoStress analysis:

$$\sigma_1 - \sigma_2 = \frac{E_S}{1+\nu_S}(\epsilon_1 - \epsilon_2) \quad (1)$$

$$(\epsilon_1 - \epsilon_2) = (R_1 - R_0) \bullet f_c \quad (2)$$

Combining Eqs. (1) and (2):

$$\sigma_1 - \sigma_2 = \frac{E_S}{1+\nu_S} \bullet (R_1 - R_0) \bullet f_c \quad (3)$$

where: σ_1, σ_2 = principal stresses
ϵ_1, ϵ_2 = principal strains
ν_s = Poisson's constant of structure material
E_s = Young's modulus of structure material
R_0 = Zero Reading of digital compensator
R_I = Final Reading of digital compensator
f_c = calibration value of coating material

The calibration value f_c may be obtained by physical calibration or calculated using the following equation and nominal values given by Micro-Measurements.

$$f_c = \frac{11.35}{K \bullet t_c} \quad \text{For US customary units} \quad (3a)$$

$$f_c = \frac{287.5}{K \bullet t_c} \quad \text{For SI (metric) units} \quad (3b)$$

Where K is an optical constant (a number) of the PhotoStress plastic given by Micro-Measurements and t_c is the plastic thickness given in inches for US customary units and in mm for SI units.

All the values on the right side of Eq. (3), except R_0, and R_1, are PhotoStress and structure material constants. To solve for $\sigma_1 - \sigma_2$ all we have to do is measure R_0 and R_1 using the Compensator. The model 832 Compensator operates on the principal of null-balance measurement. When viewing through the Compensator after attaching to the polariscope, it (the Compensator), can be adjusted to optically superimpose an equal but opposite sign color over that which exists at the measurement point on the loaded test part. As a result, the measurement point will appear black (color extinguished), produced by the null-balance compensation. The Compensator is a precision calibrated device, and when coupled with PSCalc software, the measurement process (described below) is straightforward, simple, and fast.

For the following exercise, set-up the polariscope in conjunction with the loaded test specimen as described under the section of Principal **Stress (or Strain) Directions**.

Note: * Any initial color pattern in a PhotoStress Coating prior to applying test loads, must be accounted for before making measurements at the applied test loads. The measurement procedure for R_o is identical to that described here for R_1. If the coating exhibits and unusual amount of initial color, because of severe mishandling prior to or after application to the test object, it is preferable to strip off the coating and apply a new one.

Attach the compensator to the mounting lug on the right side of the polariscope and tighten the locking screw (See Fig. 14). Press the ON button of the Compensator. The LCD should display three digits. If the display is other than 000 rotate the control knob until 000 is obtained.

Watch the computer screen and start rotating the control knob counterclockwise. After 3-4 turns, a black band should appear moving towards the marked point on the test specimen. If a black band does appear, the Compensator lengthwise axis is aligned with the algebraically greater principal strain direction ϵ_1, which it must be to achieve compensation.

If compensation cannot be achieved (no black band appears) at the point of measurement on the test specimen, the

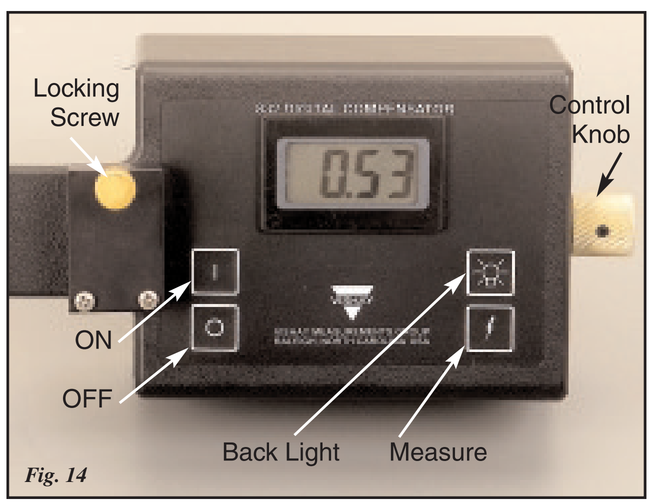


Fig. 14

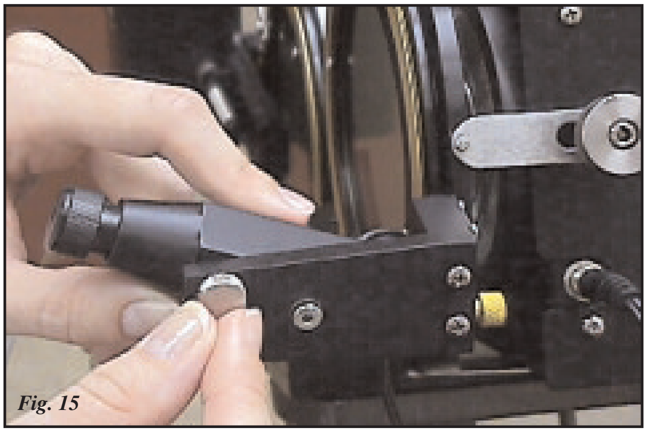


Fig. 15

Compensator's lengthwise axis must be realigned in the direction of ϵ_1, which will be at a right angle,or 90° to its current position. This is accomplished as follows:

Observe the upper scale on the polariscope in front of the video camera (see Fig. 13). It is a ±90° scale calibrated in ±5° increments. Noting the position of the scale relative to the triangular directional indicator (A), unlock and use knob "H" to rotate the optical assembly until the complimentary angle is reached from its current position. For example, if indicator (A) is initially at -35°, rotate the optical assembly using knob "H" until the direction indicator is set at +55°. The compensator's lengthwise axis will now be aligned with σ_1 (ϵ_1), and compensation at the point of measurement can begin.

To better visualize and identify the principal strain directions, turn on the laser light switch which is located on the back of the polariscope light source. A red line should be visible at the point of measurement on the test specimen. If the red line is not visible, or is located off to the side of the measurement point, unlock the brass screw on the side of the laser housing (see Fig. 15), and rotate the housing until the laser line touches the marked point. Turning off the polariscope light source allows enhanced viewing of the laser line.

The laser line identifies the algebraically greater principal strain direction ϵ_1, and the compensator will be aligned in that direction.

Once again, set the Compensator to read 000. Observing the computer screen, rotate the Compensator control knob until the black pattern covers the marked point.

NOTE: The black pattern, observed when operating the compensator, is not always completely black. Its darkness depends on the stress gradient, and on the quality of the PhotoStress coating material. The importance of this last procedure is to insure that the dark pattern covers the measured point on the structure.

The number read on the Compensator LCD is R_1 or R_0 for a structure under a load and no load situation respectively. We now have three options:

Option 1 — To enter *R* values into Eq. (3) and manually solve for $\sigma_1 - \sigma_2$.

Option 2 — To activate PSCalc™ program, manually enter *R*, and let the program calculate $\epsilon_1 - \epsilon_2$ and $\sigma_1 - \sigma_2$.

Option 3 — To activate PSCalc™ and enter *R* by pressing the

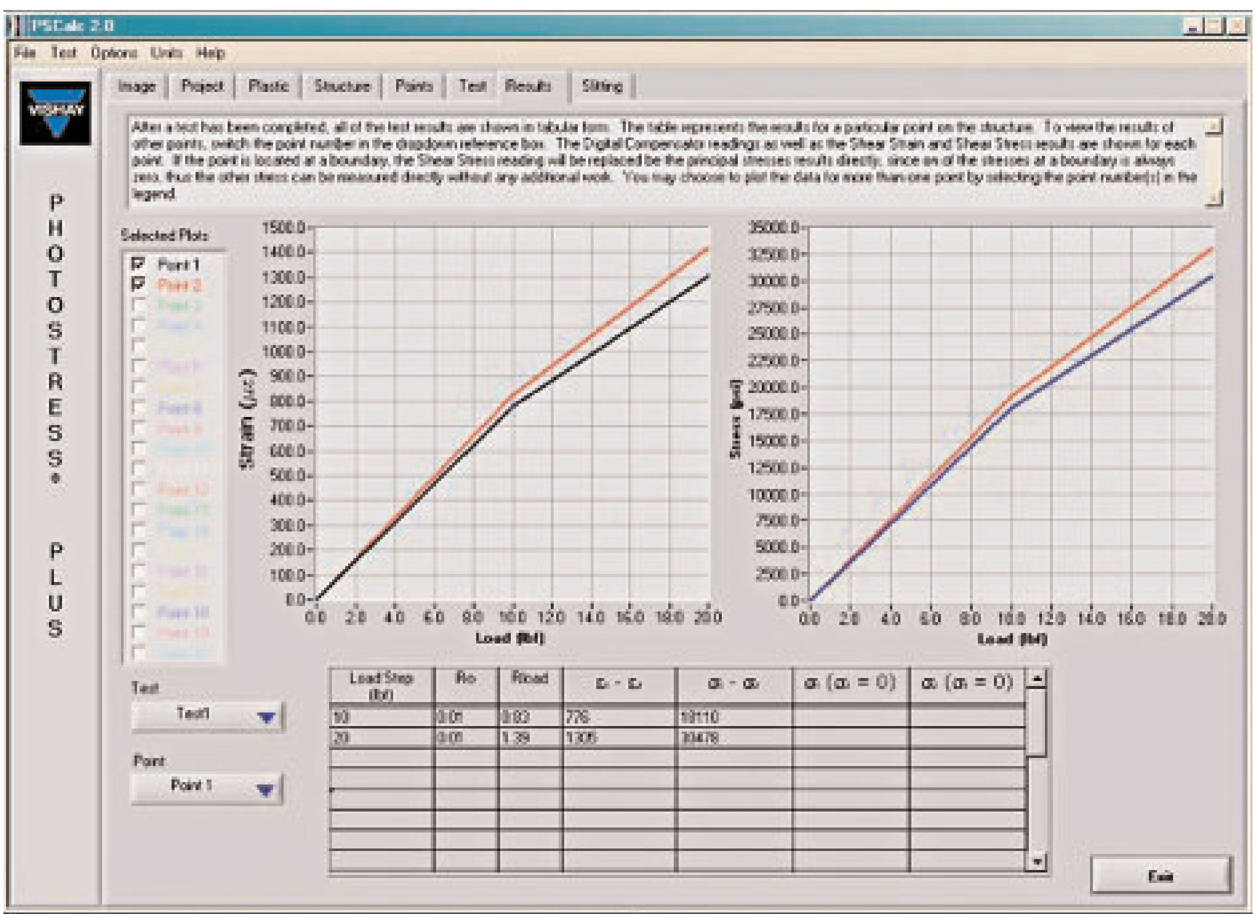


Fig. 16

PSCalc™ — The Stress and Strain Solver Program

Please refer to the software online help when needed, otherwise, select the UNITS menu item to specify the proper units.

Next, create a new Project and any related Tests on the Project tab. After defining the Project and expected Test(s), click on the Plastic tab and select the appropriate photoelastic coating material from the list shown. The nominal value of K_c is also displayed. However, if another value is obtained by a physical calibration, it may be used in place of the nominal value. Next, select the Structure tab and choose an appropriate specimen material type or add a new material if necessary.

On the Points tab, specify point thicknesses. As t_c and f_c are interrelated (see Eqs. 3a and 3b), changing t_c will also change f_c. If an actual physical calibration of the plastic was done, then f_c should be used accepting the automatically selected t_c.

Calculation of $\sigma_1 - \sigma_2$:

On the Test tab, click on the "Measurement Method" and select $\sigma_1 - \sigma_2$.

At this stage it is assumed that the polariscope light source is still ON, that the test specimen is still loaded, and that the Compensator is still in the direction of σ_1.

Turn OFF the Compensator, remove it from its mounting lug, and carefully place it on a nearby surface. Insure that the video camera is turned to CAMERA. The color pattern should be shown on the computer screen.

Mark a point on the test specimen at the lower corner of the triangular hole. The point should be touching the edge of the hole.

Move knob "B" to the **D** position and observe the computer. Unlock knob "H" and rotate it until the black pattern covers the marked point. Lock knob "H" and move knob "B" back to the **M** position.

Re-attach the Compensator on the polariscope and and turn it ON. Since the measurement is made at the boundary of the triangular hole, we know that the principal stress perpendicular to the boundary is zero. When the Compensator is positioned tangent to the boundary and compensation can be made, we solve for σ_1 and the sign is positive ($\sigma_2 = 0$). On the other hand, if compensation can only be achieved when the long axis of the Compensator is perpendicular to the boundary, we solve σ_2 for tangent to the boundary and the sign is negative ($\sigma_1 = 0$).

Unload the test specimen by releasing the loading screw. Observing the computer screen rotate the Compensator control knob until the darkest pattern is observed at the marked point.

Use Option 2 or Option 3, as described on page 6, to enter the Compensator reading under R_0 (no load reading).

Load the test specimen by rotating the loading screw 4-5 times. Insure that the specimen remains in the same position.

Observing the computer screen rotate the Compensator control knob counterclockwise until a black line (or band) covers the marked point.

IMPORTANT NOTE: In order to accurately measure the maximum stress at the hole edge, it is necessary to bring half of the black line (or band) into the hole, leaving only half the line at the boundary visible.

Again use Option 2 or 3, as mentioned on page 6, to enter Compensator reading R_1.

Click on the Results tab and observe the Calculated Results as well as a recap of the Input Data (see Fig. 16 on page 6).

Since the measured point is on the boundary of the structure, $\sigma_2 = 0$. Therefore, $\sigma_1 - \sigma_2 = \sigma_1$ and $\sigma_1 = \sigma_{max}$.

If the structure is made of thin material and is loaded in bending, it is advisable to correct for reinforcement of the structure by the PhotoStress plastic coating. Using PSCalc™ this correction is done easily.

For REINFORCEMENT CORRECTIONS, return the Project Test definition section on the Project tab and select Reinforcement Correction type.

The structure thickness t_s must now be specified on the Points tab. Enter a value for the structure thickness, t_s, for each point.

As changes are made, results are constantly saved and updated, so there is no need to save the existing Project periodically.

NOTE: In most cases, the structure is stiff and much thicker than the PhotoStress plastic coating and the reinforcement becomes negligible and unnecessary.

Measurement and Calculation of Individual Principal Stresses σ_1 and σ_2

In order to obtain principal stress values at locations removed from free boundaries, an additional measurement is necessary. This is usually obtained by using PhotoStress Separator Gages or experimentally by creating an artificial boundary called a slit. Below are the equations for obtaining the individual stress/strain values using the slitting method if desirable.

Basic stress/strain relationship

$$\sigma_1 - \sigma_2 = \frac{E_S}{1+\nu_S}\left(\epsilon_1 - \epsilon_2\right) \qquad (1)$$

Basic PhotoStress equation

$$(\epsilon_1 - \epsilon_2) = (R_1 - R_0) \bullet f_c \qquad (2)$$

A slit made in the PhotoStress coating in the direction of ϵ_1 or ϵ_2 creates a uniaxial stress state at the slit boundary. To measure the strains at a slit boundary, refer to the equations below where:

ϵ_1, ϵ_2 = Principal strains
σ_1, σ_2 = Principal stresses
E_s = Elastic modulus of structure
ν_s = Poisson's constant of structure
ν_c = Poisson's constant of PhotoStress coating material
f_c = Calibration value for PhotoStress coating material
R_0 = Zero readinn of digital compensator
R_1 = Final reading of digital compensator

PSCalc™ Equations for Slitting

Slitting in direction of ϵ_1:

Measurement before slitting

$$\epsilon_1 - \epsilon_2 = f_c \bullet (R_1 - R_0) \tag{3}$$

Measurement after slitting with Compensator parallel to slit

$$\epsilon_1 = \frac{f_c}{1 + \nu_c} \bullet (R_1 - R_0) \tag{4}$$

Measurement after slitting with Compensator perpendicular to slit

$$\epsilon_1 = -\left[\frac{f_c}{1 + \nu_c} \bullet (R_1 - R_0) \right] \tag{4a}$$

Calculated from (3) and (4)

$$\epsilon_2 = \epsilon_1 - \left[f_c \bullet (R_1 - R_0) \right] \tag{5}$$

Note that the only difference between Eqs. (4) and (4a) is that (4a) has a negative sign.

Slitting in the direction of ϵ_2:

$$\epsilon_1 - \epsilon_2 = f_c \bullet (R_1 - R_0)$$ The same as (3) above

Measurement after slitting with Compensator parallel to slit

$$\epsilon_2 = \frac{f_c}{1+\nu_c} \bullet (R_1 - R_0) \tag{6}$$

Measurement after slitting with Compensator perpendicular to slit

$$\epsilon_2 = -\left[\frac{f_c}{1 + \nu_c} \bullet (R_1 - R_0) \right] \tag{6a}$$

Calculated from (3) and (6)

$$\epsilon_1 = \epsilon_2 + \left[f_c \bullet (R_1 - R_0) \right] \tag{7}$$

Note that the only difference between Eqs. (6) and (6a) is that (6a) has a negative sign.

Measurement Process

PSCalc™ will be used again for this procedure. Click on the Measurement Method dropdown menu and select σ_1 and σ_2, separately.

Apply a load to the structure up to about 50% of maximum load. Observe the color pattern and mark the point to be measured.

With the Compensator removed from its mounting lug move knob "B" to the **D** position and observe the computer screen. Unlock knob "H" and rotate it until a black pattern covers the marked point. Lock knob "H" and move knob "B" to the **M** position.

Re-mount the Compensator and turn it ON. Insure that the LCD screen of the Compensator reads 000. Rotate the Compensator control knob counterclockwise until a dark line (or band) covers the marked point. If no dark line appears, rotate the Compensator 90° and repeat rotation of the Compensator control knob. (The Compensator works only when it is aligned in the direction of ϵ_1.)

Use the switch on the back of the polariscope light source to turn ON the laser light. A red bright line should be visible on the structure. If the line is off the structure, release the brass screw shown in Fig.15 and rotate the laser housing until the red line touches the marked point. Lock the brass screw.

With a felt-tip pen draw a line in the direction of the laser line at the marked point. The red laser line indicates the direction of ϵ_1. Draw another line perpendicular to the ϵ_1. This is the direction of ϵ_2. Turn OFF the laser light and unload the structure.

With the test structure unloaded, observe the computer screen and rotate the Compensator control knob until the darkest pattern is placed over the marked point.

Use Option 2 or 3 as described on page 6 to enter the Compensator reading, R_0.

Insure that the Compensator is still in the direction of ϵ_1 and apply 100% load to the structure. Observing the computer screen, rotate the Compensator control knob counterclockwise until a black line (or band) covers the marked point.

Again use Option 2 or 3, as mentioned earlier, to enter the Compensator reading, R_1.

Unload the structure. Introduce a slit along direction ϵ_1 or ϵ_2 (whichever is more convenient) using the Slitting tool as described below.

The Slitting Tool

As shown in Fig. 17, the slitting tool kit consists of a variable-speed motor connected to a flexible shaft with a cutting disc. Also provided is a spray can that dispenses a freezing spray to keep the surface of the PhotoStress coating from being overheated during the slitting process.

Fig. 17

The Slitting Process

1. Attach a cutting disc to the slitting tool as shown in Fig.18. Ensure that the small, red washer that comes with the slitting tool collet is placed between the cutting disc and screw head.
2. Plug the slitting tool into an electrical outlet and check that the cutting disc rotates without wobbling.
3. Insert the spraying tube into the nozzle of the freezing spray can (Fig. 19), and adjust the nozzle to the medium setting.
4. The following operation requires two people. One person should hold the housing of the flexible shaft with the cutting disc about half an inch above the coating surface. The center of the disc should be above the point to be slit, and the plane of the disc should be parallel to the strain direction line along which the slit will be made, (Fig. 20). Holding the freezing spray can, the second person should bring the end of the spraying tube to within two inches from the point of slitting and spray for 4 to 5 seconds directly below the cutting disc (Fig. 21). As soon as the spraying ends, the first person should turn on the motor of the cutting tool and bring the cutting disc in contact with the plastic coating (Fig. 22). Spraying should be resumed as the slit is being made.

   During cutting, ensure that the freezing spray is directed to the contact point between the cutting disc and the plastic coating. Cutting the slit should take about 2 to 3 seconds.

> **WARNING!**
> Keep the freezing spray away from body.
> Prolonged contact with skin may cause burns.

5. Wait a few seconds after the slit is made, then wipe away the water on the coating until dry.
6. The slitting process may introduce a slight residual color in the plastic coating next to the slit. If the process is done correctly, the discoloration will disappear after about ten minutes at room temperature. If a slight color remains, it will be measured as R_0 during the measurement procedure.

If the slit was made in the direction of ϵ_1:

Turn ON the polariscope light source and direct the light to the slit.

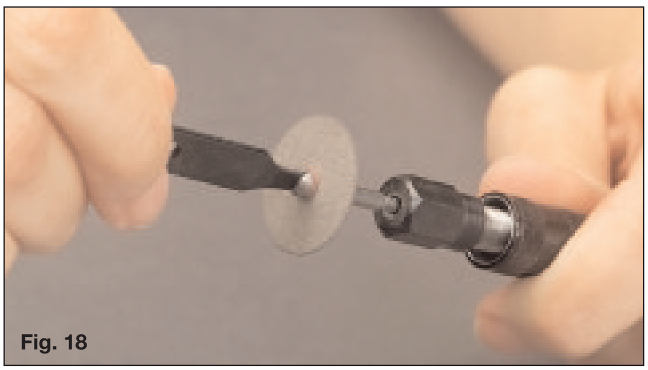


Fig. 18

Fig. 19


Fig. 20


Fig. 21

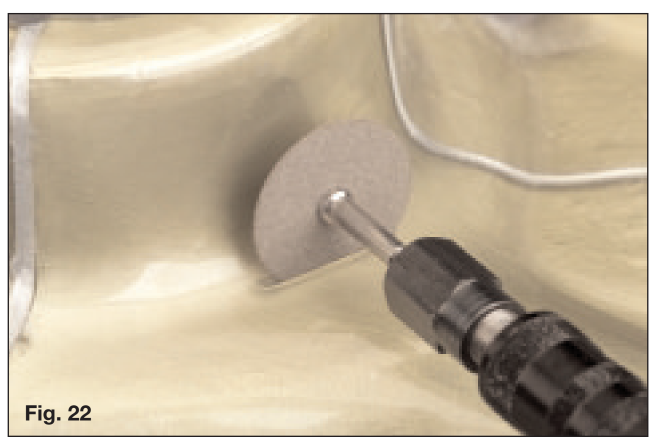


Fig. 22

Set the Compensator to 000, and parallel to the slit. Rotate the Compensator and bring a black band as close as possible to the slit boundary.

In PSCalc™ select Measurement Method σ_1 and σ_2, Slitting in direction of σ_1.

Use Option 2 or 3, as mentioned earlier, to enter the Compensator reading, R_0.

Load the structure to 100% load. With the Compensator set at 000, start rotating the Compensator control counterclockwise. If a black line (or band) approaches the slit, keep rotating until the black line reaches the edge of the slit.

Use Option 2 or 3, as mentioned earlier, to enter the Compensator reading, R_1.

Click CALCULATE and observe the Calculated Results.

If it was not possible to bring a black line to the slit boundary, rotate the Compensator 90° (perpendicular to the slit) and repeat the Compensator reading. Under this condition a black line will reach the slit.

Use Option 2 or 3, as mentioned earlier, to enter the Compensator reading, R_1.

Click CALCULATE and observe the Calculated Results.

If the slit was made in the direction of ϵ_2:

The complete procedure described under slitting in the direction of ϵ_1 is the same for this procedure. The only difference is that we are measuring ϵ_2 instead of ϵ_1. In this case, select Measurement Method, σ_1 and σ_2, Slitting in direction of σ_2. The PSCalc™ software knows how to deal with this.

If the structure is made of thin material and is loaded in bending it is advisable to correct for reinforcement of the structure by the PhotoStress plastic coating. However, using PSCalc™ software this correction is done easily.

Click on REINFORCEMENT CORRECTION to reveal the Types of Correction offered and select Reinforcement in Bending.

Enter the thickness of the structure t_s and click again the CALCULATE button, and observe the change in the Calculated Results.

There are two critical decisions to be made by the operator.

A. To make the slit in the direction of ϵ_1 or in the direction of ϵ_2. This decision will require the operator to select one of the two available Stress Separation Methods. The decision in which direction to make the slit is only a convenience. In either case the final stresses will have the same values.

B. To assign a positive sign to when the Compensator is parallel to the slit, and a negative sign when the Compensator is perpendicular to the slit.

Notes

Related Technical Bulletins from Micro-Measurements

The following instruction and technical bulletins provide additional information about PhotoStress analysis, selection and application of photostress coating materials.

Calibration of PhotoStress Coating	TN-701
Introduction to Stress Analysis by the PhotoStress® Method	TN-702
How to Select Photoelastic Coatings	TN-704
Correction to Photoelastic Coating Fringe-Order Measurements	TN-706
Principal Stress Separation in PhotoStress® Measurements	TN-708
Instructions for Casting and Contouring Photoelastic Sheets	IB-221
Instructions for Bonding Flat and Contoured Photoelastic Sheets to Test-Part Surfaces	IB-223
Instructions for Brushing PhotoStress® Coatings on Test Part Surfaces	IB-239
PhotoStress® Separator Gage Installations with M-Bond 200 Adhesive	IB-237
PhotoStress Coating Materials	S-116c

The above publications are available on request from: Micro-Measurements
P.O. Box 27777
Raleigh, North Carolina 27611, USA

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Replacement Parts for LF/Z-2 Reflection Polariscope System

DESCRIPTION	PHOTOLASTIC PART NO.
Glass-laminated polarizing filter *for light-source side* of polariscope	100-011994
Glass-laminated polarizing filter *for analyzer side* of polariscope	100-010019
Matched pair, glass-laminated quarter-wave-plate filters	910-000001
Fresnel lens for Model LF/Z-2 Light Source	13X300014
Dichroic heat filter for Model LF/Z-2 Light Source	100-011591
Spare Lamp for Model LF/Z-2 Light Source	20X100041
Slitting Tool with Cutters and Freezing Spray	
Extra Cutters, Package of 50	27X100017
Replacement Freezing Spray can, 10 oz (285g)	23X200058
Spare Lamp for Model 236A Stroboscopic Light	20X100015
Fuse for Model 236A — 2.5 ampere, “Slo-Blo” type	16X600035
Tripod screw (3/8-16 UNC), with small locking knob, for mounting telemicroscope and camera-mounting bracket on tripod platform	100-011082
Tripod screw (1/4-20 UNC) for mounting polariscope directly on tripod platform	100-011083

Note: Please consult Photolastic Division for replacement parts pricing and minimum order requirements.

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