

BULLETIN S-134-1

PHOTOSTRESS[®] INSTRUMENTATION

Full-Field Measurement Systems
for Stress Analysis Testing



030 Series

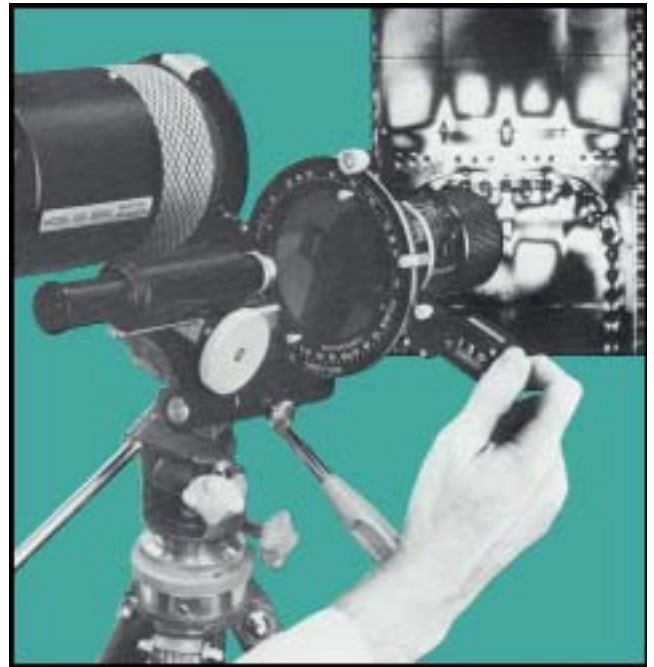
Modular Reflection Polariscopes System

The 030 Series Modular Polariscopes System has been the reflection polariscopes standard in both industrial and educational laboratories for the past 25 years. Its modular design, featuring optional specialty accessories, gives the 030 Series a broad range of strain measurement capabilities.

Basic measurement capabilities of the 030 Series can be enhanced by equipping the polariscopes with a null-balance compensator as well as a digital strain indicator/printer. And measurements made on small parts or in regions of high stress concentration are both easier and more accurate when the optional telemicroscope accessory is attached.

The standard light source used for static measurements is replaceable with an optional stroboscopic light accessory for cyclical dynamic measurements.

Dependable, versatile and expandable, the 030 Series Modular Polariscopes System and Accessories are described on Pages 4 through 7.



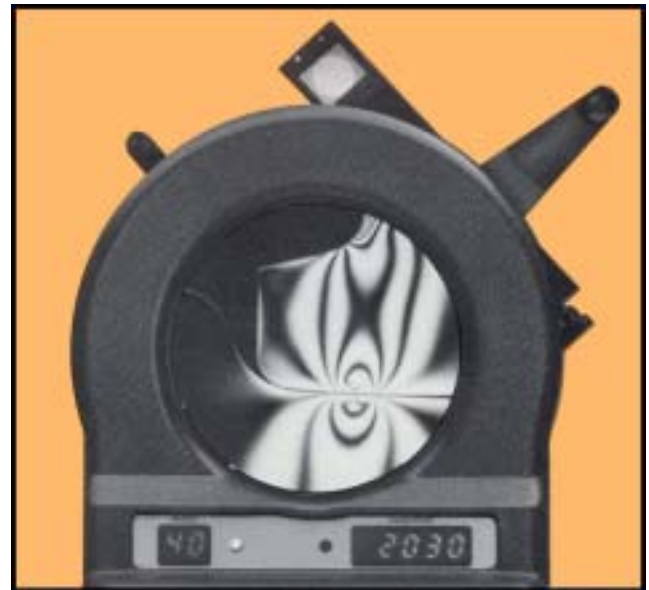
Model 040

Direct Digital Display Reflection Polariscopes System

The Model 040 is a new, innovative reflection polariscopes with numerous built-in features. These include a fan-cooled light source, null-balance compensator and electronics for direct display of measurements of both stress and strain. In fact, the Model 040 comes complete with everything needed to make high-quality static strain measurements by the PhotoStress method.

Both new and experienced stress analysts will appreciate the simplicity of operation afforded by the Model 040. Compact and portable, this new instrument can be operated either from an ac powerline or 12 Vdc automobile battery.

Complete specifications for the Model 040 are given on Pages 8 and 9.



Comparison of the 030 Series and Model 040 Reflection Polariscope Systems

In selecting a PhotoStress instrument system to fit particular testing requirements, the chart below provides a guide for comparing the capabilities of each. Depending on the diversity of testing anticipated for PhotoStress analysis, there will be many instances when both polariscope systems should be incorporated to maximize use of the technique in the most cost-effective manner.

Measurement Capability or Feature		030	040
Principal Strain Directions		Yes	Yes
Tardy Compensation		Yes	No
“Null-Balance” Compensation		Yes*	Yes
Indicates Sign of Compensation		No	Yes
Electronic Digital Display		Yes*	Yes
Analog Output for Computer Interfacing		Yes*	Yes
Dynamic Analysis		Yes*	No
Printout of Digital Display		Yes*	No
Principal Strain Separation	Oblique Incidence	Yes*	No
	PhotoStress Separator Gauge	Yes*	Yes*
Magnification		Variable* to 15X	Fixed 6X
Camera Adapter		Yes	Yes
Camera/Magnification Interface		Yes*	No
Battery Operation (12 Vdc)	Light Source	Yes	Yes
	Electronic Readout	No	Yes

*** Optional Accessory Required**

Measurements Group, Inc., warrants all instruments it manufactures to be free from defect in materials and factory workmanship and agrees to repair or replace any instrument that fails to perform as specified within one year after date of shipment. A copy of the complete Measurements Group warranty statement is available upon request.

O30 Series

Model 031 Basic Reflection Polariscope

The Model 031 Reflection Polariscope is the foundation unit of the O30 Series Modular System. With this precision optical instrument, the user can measure: **principal strain angles** at any point on the coated test object - **the difference in principal strains** or stresses (maximum shear strain or stress) at any point - **principal stress magnitudes** at all edges, free boundaries and other areas of uniaxial stress (applicable only to homogeneous materials which are isotropic and linearly elastic in their mechanical properties). An important feature of the instrument is its capacity for full-field (overall) stress analysis. Highly stressed areas (potential failure points) are immediately apparent to the operator, as are unstressed regions, where material savings can be achieved.

The basic polariscope consists of two primary components: the optical head assembly and a high-intensity light source. Included in the optical head and integrated by a common frame, are two ball-bearing-mounted polarizer/quarter-wave plate assemblies. The light source attaches to one of these; and the other, equipped with color-coded, engraved instrument dials, is used by the operator for viewing and measuring strain directions and magnitudes.

Actuation of a single lever on the head assembly optically removes the quarter-wave plates from the light path and prepares the polariscope for measurement of strain angles. Setting the lever in its alternate position restores the quarter-wave plates to the light path for strain magnitude measurements. The analyzing filter is designed for independent rotation to permit rapid strain measurement by the Tardy compensation method.

SPECIFICATIONS

- **Sensitivity:**
 - Principal strain angles, $\pm 1^\circ$.
 - Strain magnitudes, ± 0.01 fringe [approximately 50 psi (350 kPa) on aluminum, 150 psi (1,050 kPa) on steel, when used with types PS-1A coating].
- **Light Source:** 100W lamp, fan-cooled.
- **Power:** 115/230 Vac; 50/60 Hz.
- **Polarizing and Quarter-Wave Filters:** Glass-laminated and ball-bearing mounted, with assemblies mechanically coupled for synchronous rotation.
- **Basic Reflection Polariscope Includes:**
 - Optical head assembly.
 - High-intensity light source.
 - Fitted carrying case.
 - Heavy-duty elevating tripod, with three-way adjustable head and carrying case.
 - Detachable handgrip for portable operation.
 - Spare lamp for light source.
 - Comprehensive instruction manual.
 - Camera bracket.
- **Weight:** Basic Unit 4.4 lb (2 kg).



Model 632 Digital Strain Indicator/Printer

The Model 632 Digital Strain Indicator/Printer provides direct readings of measurement point, strain direction and strain magnitude when used in conjunction with the Model 031 Basic Polariscope.

The Model 632 incorporates an optical transducer, or null-balance compensator, which converts the optical image to an electrical output displayed and printed by the indicator. The Model 632's built-in printer can be activated remotely through the compensator.



SPECIFICATIONS

- **Magnitude Range:**
0 to 19,990 $\mu\epsilon$ (X1 range);
0 to 50,000 $\mu\epsilon$ (X10 range).
- **Angular Measurement Range:**
0 to ± 90.0 deg.
- **Magnitude Accuracy:**
 $\pm 10\mu\epsilon$ or 1% of reading, whichever is greater.
- **Angle Accuracy:**
 ± 1 deg.
- **Fringe Constant Selection Range:**
0 to 9,999 $\mu\epsilon$ /fringe.
- **Compensator Linearity:**
 ± 0.005 fringe.
- **Print Format:**
 - Measurement Point: 00 to 99.
 - Polarity: + for positive; - for negative.
 - Magnitude: 0 to 19,990 $\mu\epsilon$ (X1 range);
0 to 50,000 $\mu\epsilon$ (X10 range).
 - Angel: 0 to ± 90.0 deg. in 1-deg. increments.
 - Overrange: Prints asterisk (*) in overrange columns.
 - Columns: 10 active.
- **Tape:**
2-1/4 in W x 150 yd L (57 mm x 137.2 m) roll, black-on-white thermal print paper.
- **Power:**
115/230 Vac $\pm 10\%$, 50/60 Hz, 20W typical.
- **Measurement Point Display:**
00 to 99 LED with automatic and manual advance and reset to zero.
- **Analog Outputs for Computer Usage:**
 - 100 $\mu\text{V}/\mu\epsilon$ to 1.1 mV/ $\mu\epsilon$ at fringe constant of 1.000 (nominal).
 - 10 mV/deg. to 110 mV/deg. (nominal, limited to ± 2.50 Vdc).

Manual Null-Balance Compensator

Model 232 Uniform-Field Compensator

As an alternate to the Model 632, a compact, manual compensator can be used for measuring the photoelastic fringe value. The measured fringe value can then be converted to strain by applying the *fringe-constant* of the PhotoStress coating.

The optical specifications of the Model 232 Manual Compensator are identical to those of the Model 632's Compensator, with resolution of 0.01 fringe and nominal range of 4-1/2 fringes.

Model 232-RE Compensator Range Extender

(Not Illustrated)

For measurements at high levels requiring more than 4-1/2 fringes of compensation, the range of the Model 632 or 232 Compensator can be extended to 9 fringes (nominal) by installing the clip-on Model 232-RE Range Extender.



Model 137 Telemicroscope

The telemicroscope greatly expands the capabilities of the 030 Series PhotoStress System, providing a magnified view of the measurement area for detailed analysis in regions of high strain gradient (stress concentration) and for measurements at extended working distances. It also provides for close-up examination, with magnification up to 15X, when measuring stress concentration in regions of high strain gradient.

The Model 137 Telemicroscope consists of the basic microscope barrel with a 6X objective lens and 10X eyepiece; f/3.5, 35 - 105 mm zoom lens; and cast swivel-

mounting base. The swivel base allows for swing-away removal of the telemicroscope from the field of view when it is not needed.

A special adapter is included to permit photographic recording of the image seen through the telemicroscope. The Telemicroscope/Camera Adapter is a self-contained unit that attaches directly to the microscope tube and to the camera body in place of the camera lens. Viewing is done through the camera.



Model 033 Oblique-Incidence Adapter

Separating the principal strains in areas other than on free boundaries requires an additional measurement which can be obtained with the Model 033 Oblique-Incidence Adapter. With oblique incidence, the light from the polariscope traverses the plastic coating at an angle to the surface normal. The resultant fringe-order measurement corresponds to the secondary principal strain difference in the plane perpendicular to the oblique light path. The combined measurements under normal and oblique incidence are used to determine the individual principal strains and stresses.

In use, the lightweight oblique-incidence adapter is attached to the polariscope base, and positioned close to the test part. The light from the polariscope is accurately directed through the coating at the proper angle and reflected back to the analyzer of the instrument by the fixed-angle front-surface mirrors in the head of the adapter. Measurements are made with the polariscope and strain indicator in the conventional manner.



Model 236

Stroboscopic System for Dynamic Testing

For stress analysis under cyclical dynamic conditions, the standard light source may be removed from the polariscope and replaced with a strobe lamp. The Model 236 Strobe Lamp attaches easily to the Model 031 Reflection Polariscope without affecting its portability. The primary feature of the Model 236 is its exceptional light intensity which is required for observing small areas at distances up to 15 ft. (4.7 m) and for working in brightly lighted test areas. The flash is automatically controlled to give highest

intensity possible for any given input range. Energy per flash is adjusted in steps (see Specifications). A Slip-Sync is built-in for complete dynamic motion analysis studies - viewing and stopping the motion through 360 degrees without repositioning the external pickup device. The complete unit consists of the stroboscopic lamp, power supply and oscillator, with connecting cables.



SPECIFICATIONS

- **Maximum Flash Rate:** 300 Hz min. At higher rates, circuit automatically divides the incoming rate down by successive integers to provide synchronized flashes.
- **Triggers:** Internal oscillator, photocell, magnetic pickup, contact closure, fiber-optic input.
- **Beam:** 3.5 degrees beam spread. 3.7 in (94 mm) initial beam dia.
- **Frequency Indication:**
 - Display: 6 digit LED - Hz or RPM.
 - Resolution: 1 RPM or 0.01 Hz.
 - Range: 5 Hz to 5 KHz (300 to 300,000 RPM).
 - Overall Accuracy: ± 1 count.
- **Power:** 90 to 130 or 180 to 260 Vac selectable, 50/60 Hz, 200 watts max.

Light Output and Flash Duration				
Flash Rate (Hz)	0-62	62-94	94-131	131-300
Energy/Flash (watt-sec)	1.25	0.75	0.50	0.25
Light/Output (lum-sec flash)	25	15	10	5
Flash Duration (microseconds)	15	12	10	8

Model 040

Reflection Polariscope

With the Model 040 Reflection Polariscope, measurements are made quickly and accurately. All measurement set-up functions are identified by LED's. The on-board electronics allow direct digital display of the principal strain directions, fringe number and magnitudes of the principal strain or stress differences at a measurement point. At all free boundaries (where the maximum stress usually occurs), the principal stress tangent to the boundary, **as well as its sign**, is measured directly with the built-in null-balance compensator (applicable only to homogeneous materials which are isotropic and linearly elastic in their mechanical properties).

A special feature incorporated in the Model 040 Polariscope is the unique design of the compensator. It is permanently attached to the analyzer portion of the instrument and is swivel mounted so that it can be swung either into or out of the field of view at will. But the compensator's main feature is the capability for introducing either positive or negative birefringence into the light path. Thus, when making null-balance measurement, the instrument automatically displays the correct sign for the measurement being made.

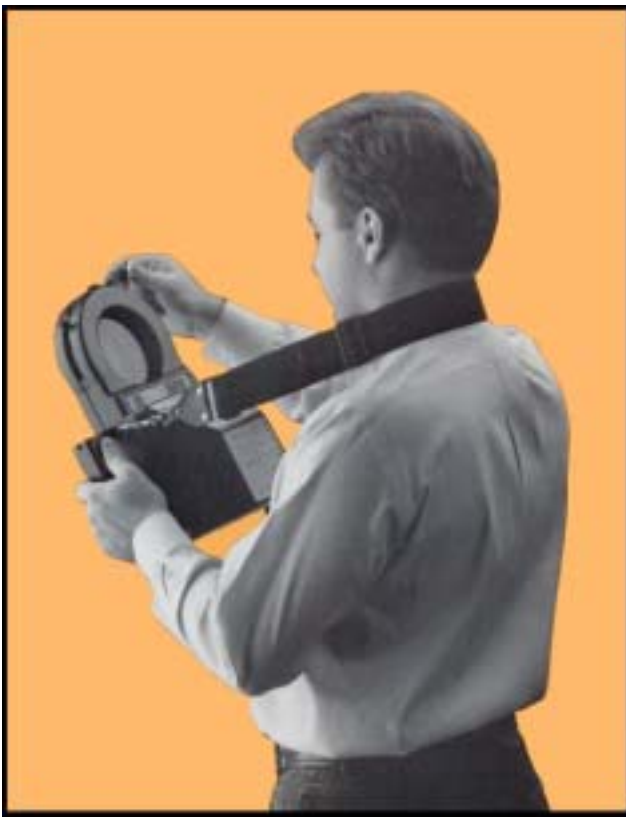
Other principal features of the Model 040 Polariscope are its portability for hand-held use; integral high-intensity, fan-cooled, 100W, 12V light source; and analog output for computer interfacing. The instrument is powered through a compact transformer with selectable nominal voltages from 100 to 130 and 200 to 260 Vac, 50-60 Hz. For maximum portability, the polariscope can be powered from a 12 Vdc battery source.

The Model 040 Polariscope is also supplied with an Image Magnifier which provides an enlarged view of the photoelastic pattern for more detailed analysis in regions of high stress gradient. A bracket is also included for mounting a 35mm camera behind the analyzer for making photographs of the stress patterns observed.



THE MODEL 040 POLARISCOPE INCLUDES:

- **A heavy-duty elevating tripod for laboratory test setups.**
- **Handles and neck-strap for portable operation.**
- **Image Magnifier (fixed 6X).**
- **Swiveling bracket for mounting Image Magnifier or camera.**
- **Cabling for battery operation.**
- **Spare lamps (2).**
- **Operating / technical manual.**
- **Custom carrying / storage case.**



SPECIFICATIONS

Criteria	Display Range	Resolution
FRINGE NUMBER	±4.00	0.01
FRINGE CONSTANT SETTING	500 to 10,000µε/Fringe	10µε
STRAIN READING	0 to 20,000µε (X1 Range)	10µε
	0 to 40,000µε (X10 Range)	100µε
STRESS READING	For High-Modulus ±199.9 x 10 ³ psi (X1 Range)	100 psi
	Material Settings: ±1,999 x 10 ³ psi (X10 Range)	1,000 psi
	For Low-Modulus ±1.999 x 10 ³ psi (X1 Range)	1 psi
	Material Settings: ±19.99 x 10 ³ psi (X10 Range)	10 psi
ANGLE	0 to 90 Degrees	1 Degree

ELECTRONIC ACCURACY ±1% of reading, ±1 active count (typical).

LED DIGITAL DISPLAY
Angle: Two digits.
Magnitude: 3-1/2 digits active with polarity and fixed-zero digit.

ANALOG OUTPUT:
Angle: 10 mV/count (+900 mV full scale).
Magnitude: 1 mV/count (±1.999V full scale).

LIGHT SOURCE 100W lamp, fan-cooled.

POWER REQUIREMENTS 115/230 Vac, 50/60 Hz; 12 Vdc optional.

SIZE & WEIGHT (BASIC UNIT) 13.1 H x 6.6 W x 6 D in (333 x 168 x 153 mm); 5 lb (2.3 kg).

Recording Stress Patterns

Permanent recording of PhotoStress patterns for later study or presentation in test reports is a common and recommended practice.

For photographic recording, the use of a high-quality 35mm camera is recommended. The Model 335, described below, is offered as a service to customers unable to purchase a camera directly.

PhotoStress tests can also be documented very effectively with a "camcorder", or video camera / recorder. By placing the video camera, mounted on a separate tripod, directly

behind the Model 031 or 040 Polariscope, the PhotoStress pattern, visible through the analyzer, can also be viewed through the video camera eyepiece. Due to the range of variables involved, video equipment should be obtained locally.

Model 335 Camera

This high-quality single-lens reflex camera offers through-the-lens viewing for easy, rapid positioning and accurate focusing. The self-compensating light meter system, which provides fully automatic through-the-lens exposure control, is a particularly important feature because it makes the proper exposure correction for the filtering effect of the polarizing elements in the polariscope.

The Model 335 Camera is equipped with an f/1.8, 50mm lens for maximum versatility under varied lighting conditions. The camera is supplied with a cable release and a polarizing filter for use in photographing fringe patterns with the camera separated from the instrument. A special mounting bracket for supporting the camera behind the polariscope analyzer is supplied as a standard component with the basic Model 031 and Model 040 Polariscopes.



Model 036 Monochromator Camera Accessory

The Monochromator is a high-quality interferential optical filter with a narrow bandpass corresponding to the exact wavelength where fringes are observed in white light. There are two principal applications of monochromatic light in PhotoStress testing: (1) black and white photography, and (2) presentation of fringe density and contrast irrespective of the number of fringes occurring in the PhotoStress pattern. (In white light, the colorful fringe pattern becomes paler at high stress levels.)

The Model 036 Monochromator is mounted in a special threaded housing for attachment to the camera lens.



Principal Stress Separation

To separate the principal strains located in areas other than at free boundaries, an additional measurement is required which can be obtained by two different methods. One method employs the Oblique-Incidence Technique, while the other is based on the use of a PhotoStress Separator Gauge. Because of its ease of application and interpretation, the Separator Gauge is usually preferred. However, when working with the medium- and low-modulus class of PhotoStress materials, the Separator Gauge is not applicable and the Model 033 Adapter (page 6) must be used in conjunction with the 030 Series Polariscope System.



PhotoStress Separator Gauge

The PhotoStress Separator Gauge is a unique electrical resistance gauge, designed and produced by Micro-Measurements, that measures the sum of the principal strains. This data, when coupled with the measured difference of principal strains made with the 030 Series or Model 040 Reflection Polariscope, provides the separate principal strain values.

The PhotoStress Separator Gauge has special design features for ease of use and optimum performance in PhotoStress applications. Preattached leadwires are provided to avoid soldering problems after the gauge is bonded to the photoelastic coating, and the gauge is polyimide-encapsulated to eliminate the need for a protective coating in most cases. Gauges are supplied three-to-a-package and are offered in two self-temperature-compensations: types PSG-01-06 and PSG-01-13, for use on steel and aluminum alloys, respectively. The Separator Gauge can be used on photoelastic coating material types PS-1, PS-2, PS-8, PL-1 and PL-8.

RESISTANCE IN OHMS: 200.0 ±0.15%			inches millimetres
GAUGE LENGTH	OVERALL LENGTH	GRID WIDTH	OVERALL WIDTH
0.063	0.255	0.057	0.160
1.60	6.48	1.45	4.06
Matrix size:		0.30 L x 0.20 W	7.6 L X 5.1 W



Model 330 Interface Module

Separator Gauges must be used with a specially designed interface module in conjunction with the Measurements Group P-3500 Strain Indicator. The Model 330 Interface Module is a four-channel switch-and-balance unit with precision resistive circuits for reducing gauge excitation voltage to minimize self-heating effects, supplying bridge-completion for the 200-Ohm Separator Gauge and attenuating the gauge output so that the P-3500 Strain indicator reads out in units of 10 microstrain. Provided with the Model 330 are four specially configured connecting cables for quick and convenient solderless connections between the Separator Gauge leadwires and the Interface Module. The 6-foot (1.8 m) cable incorporates gold-plated push/clamp binding posts to assure negligible contact resistance at leadwire connections.



Materials and Kits

Coating Materials

The selection of PhotoStress coatings and their proper application to the test part are most essential to the success of PhotoStress analysis. A wide range of coating materials is available in both flat-sheet and liquid form for application to metals, concrete, plastics, rubber and most other materials. The coatings are carefully controlled formulations of resins blended to provide known and repeatable photoelastic properties and are supplied with detailed application and handling instructions.

For complete information on PhotoStress coating materials, please refer to Bulletin S-116.



Application Kits

Also available are specially designed application kits, containing everything required for successful installation of the PhotoStress coating on the test part.

Model 011 Coating Application and Calibration Kit contains materials for preparation and calibration of the coating prior to bonding to the surface of the test part.

Model 012 Sheet Casting Kit contains supplies for casting plastic sheets for contour forming to complex-shaped surfaces.

Model 013 Surface Preparation Kit contains hardware for preparing the surface of the test part to accept the photoelastic coating.

