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Describes the brittle lacquer method for analyzing strain/stress in materiel.

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US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-102
*Test Operations Procedure 3-2-809 29 July 1981
AD No.

BRITTLE LACQUER TECHNIQUE OF STRESS ANALYSIS

			Page
Paragraph	1.	SCOPE	1
	2.	FACILITIES AND INSTRUMENTATION	1
	3.	REQUIRED TEST CONDITIONS	2
	4.	TEST PROCEDURES	3
	5.	DATA PRESENTATION	6
Appendix A.		REFERENCES	A-1

1. SCOPE. This TOP describes the brittle lacquer method for qualitatively analyzing strain/stress in materiel. Brittle lacquer is most often used to locate critically stressed areas, determine principal strain/stress directions, and indicate approximate strain gradients. This makes it possible to properly select, locate, and orient strain gages in order to accurately measure peak strains. When a quantitative analysis and/or more detailed qualitative (full-field) analysis are required, the birefringent coating technique of photoelastic stress analysis (TOP 1-2-605[1]**) should be used. NOTE: Brittle lacquer can be used for only one load application.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

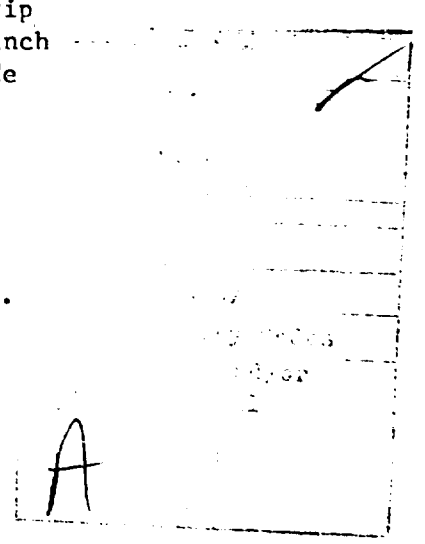
ITEM	REQUIREMENT
Standard calibration strips and clamping device	Rectangular metal strip 12 inches long, 1/4 inch thick, and 1 inch wide
Strain scale for calculating strain sensitivity	

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*This TOP supersedes TOP/MTP 3-2-809 dated 7 September 1966.

**Footnote numbers correspond to reference numbers in Appendix A.

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ITEM (cont'd)	REQUIREMENT (cont'd)
Testing chamber	
Spray gun	
Aluminum-pigmented lacquer and brittle lacquer	
Camera and film	color and b/w

2.2 Instrumentation.

ITEM	MAXIMUM PERMISSIBLE ERROR OF MEASUREMENT
Psychrometer	none

3. REQUIRED TEST CONDITIONS.

3.1 Selection of Coating. Determine and record the proper coating to be used by means of the manufacturer's literature. Whether a particular brittle lacquer coating will fracture under a certain strain depends on the strain sensitivity of the coating. Strain sensitivity, i.e., the least value of strain that will fracture the coating, depends on the grade of lacquer, temperature, and humidity. A fairly accurate prediction of the temperature and relative humidity at the time of testing will help in determining the proper coating. For most test conditions, it is desirable to form a coating that will begin to crack when a nominal strain level of about 500 microcentimeters per centimeter is reached. However, increased temperature or relative humidity will also increase the strain threshold for cracking the coating, thereby causing a loss of sensitivity. Conversely, decreased temperature or relative humidity will decrease the strain threshold for cracking, thereby resulting in increased sensitivity. For best results, the coating sensitivity should remain within the threshold limits of 300 to 700 μcm/cm. At thresholds greater than 700 μcm/cm, the resultant cracks may not always remain open after the load is removed, while at thresholds below 300 μcm/cm, the coating enters a high state of internal tension, and random cracking occurs.

Since the strain sensitivity of a coating is the least value of strain that will fracture the coating, the strain level at the boundary of an area of strain patterns can be assumed to be the same as the strain sensitivity of the coating.
NOTE: Brittle lacquer can be used on all metals, firm plastics, and wood.

3.2 Painting Safety Precautions.

a. Make sure the chamber in which the operator will apply lacquer to the test items is well ventilated.
b. Make sure the operator wears a gas mask.
c. Make sure the chamber is free of any potential fire hazards.

4. TEST PROCEDURES. Brittle lacquer coatings, being temperature-sensitive and affected by humidity, are best suited to laboratory investigations. Satisfactory results can be obtained outdoors, however, with painstaking attention to detail.

4.1 Pre-Test Data. Record the following:

a. Nomenclature and serial number of the test item
b. Material coated with lacquer (steel, wood, etc.)
c. Surface area to be tested
d. Run number
e. Coating used (manufacturer, type, cure temperature, test temperature, manufacturer's sensitivity rating, etc.)
f. Time of testing (hour, day, month, year)
g. Place of testing
h. Ambient temperature in °C
i. Relative humidity at test site

4.2 Preparation of Test Item.

4.2.1 Method.

a. Remove all loose scale, grease, and oil from surface.
b. Remove all surface coating that may be affected by various thinners in the brittle lacquer. NOTE: Most hard, dry films may ordinarily be left intact.
c. Wipe the surface with a clean, lint-free cloth that has been saturated with a cleaner fluid that will not leave a residue.
d. Smooth all surfaces of small critical areas such as fillets.
e. Coat the surfaces with an aluminum-pigmented lacquer to serve as a crack-visibility aid and undercoating for the brittle lacquer.

NOTE: The surface of the basic material to be tested cannot be one whose surface is dissolved or etched by the brittle lacquer thinner. If the surface is micro-etched, it may create starting points for cracks in the surface of the specimen itself. When the coating is applied over a painted surface, there is some danger that the lacquer thinner might soften the paint which, in turn, might contaminate the lacquer.

f. Coat the proper area of the test item and one side of three calibration strips to a thickness of about 0.006 inch by spraying. The coating is brought to this thickness in increments by making about 10 passes with the spray gun.
g. Age the coating from 18 to 24 hours in an ambient temperature higher than that for which the coating was selected. NOTE: For outdoor testing, observe the following:

Summer. Coat the test items in the morning; dry all afternoon while protecting the coating from direct sun rays; and test late in the afternoon when the temperature is falling.

Winter. Apply the coating to the test items in the afternoon; age in a heated enclosure during the night; test on the following day.

h. Place the unpainted surface of the calibration strip in contact with the unpainted surface of the test item to achieve temperature equilibrium if possible.
i. Before field tests, cover all coated areas with absorbent cotton and wrapping paper to prevent damage to coatings and to guard against sudden temperature changes.

4.2.2 Data Required. Record the following:

a. Aging temperature in °C
b. Aging time in hours

4.3 Calibration of Strip.

a. Hold the standard calibration strip in the clamping device.
b. Deflect its free end to a fixed distance, thereby producing a graduated tensile strain on its upper surface and a compressive strain on its undersurface. The greatest strain is at the fulcrum.
c. Record the distance deflected.
d. Determine the strain sensitivity of the coating by placing the tested calibration strip in a strain scale (Figure 1). Note the least strain required to fracture the coating. The strain scale shown is graduated to show the strain on the calibration strip when it was tested in a standard calibrating device which is part of a commercially available stress coat kit.

NOTE: If the strain sensitivity value of the calibration strip is higher than desired, warm up the test item. If the strain sensitivity value of the calibration strip is too low, cool the test item. Record the adjusted temperature, if applicable.

4.4 Load Application.

a. Load the test item and record applied load.
b. Determine test item sensitivity by visually inspecting the cracks (strain patterns) of the coating against the tested calibration strip.

(1) Direct the light from a small focused point (e.g., a flashlight) onto the coating; any cracks will light up or shine.
(2) In some cases, cracks in the coating that close very tightly will be detected by soaking the surface with a fluid containing a dye that selectively etches the cracks and leaves a residue within them.

c. Photograph (and retain photos) the strain patterns that received the dye treatment with color film to indicate the following:

(1) Distribution of sensitivity strain
(2) Location of sensitivity strain
(3) Sequence of sensitivity strain
(4) Magnitude of strain, if possible

d. Repeat 4.2.1.f, g, h, i, and 4.4 at least 3 times to "bracket" the strain value in the area being tested, using lacquer one degree less sensitive than the preceding coat. NOTE: To obtain quantitative data, several tests are often necessary. Initially, a high-sensitivity coating is used, and the strain patterns are noted. Other tests are then conducted in which lower sensitivity coatings are used. It is then possible to "bracket" the strain value in an area by noting the coating that caused the last vestige of strain patterns to appear.

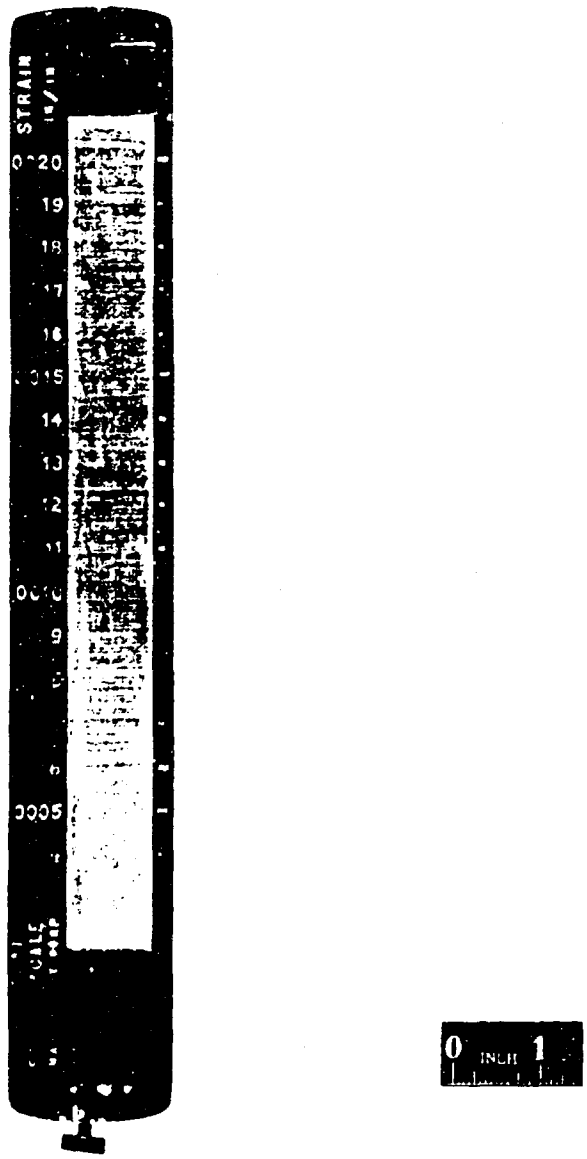


Figure 1. A brittle lacquer-coated calibration strip in a strain scale. The strain sensitivity of the coating was 600 micro-centimeters per centimeter.

4.5 Data Required. Record the following:

a. Calibration strip:

(1) Distance deflected of the strip in centimeters
(2) Strain obtained in cm/cm

b. Adjusted temperature of test item, if applicable, in °C
c. Load applied to test item in kPa
d. Strain sensitivity of test item in μcm/cm

5. DATA PRESENTATION. From a qualitative point of view, the overall strain picture is graphically presented, as shown in Figure 2. Closeup views are shown in Figures 3 and 4. Based on the premise that the greater the density of the strain pattern, the greater the strain, it is often possible to determine which section or areas are strained more than others. In Figure 4, area number 2 was strained more than area number 1.

Since strain patterns in brittle lacquer coatings form at right angles to the principal strain, the location and axial orientation for electrical resistance strain gages can be selected so that the maximum strain can be accurately measured.

Brittle lacquer coatings will flake off during yielding if the compressive strain exceeds 1 percent or the tensile strain exceeds 2 percent. Whether the flaking was caused by tensile or compressive strains cannot be definitely ascertained from an examination of the coating. Strain patterns emanating from the flaked off area usually signify, however, that the flaking was due to tensile strain.

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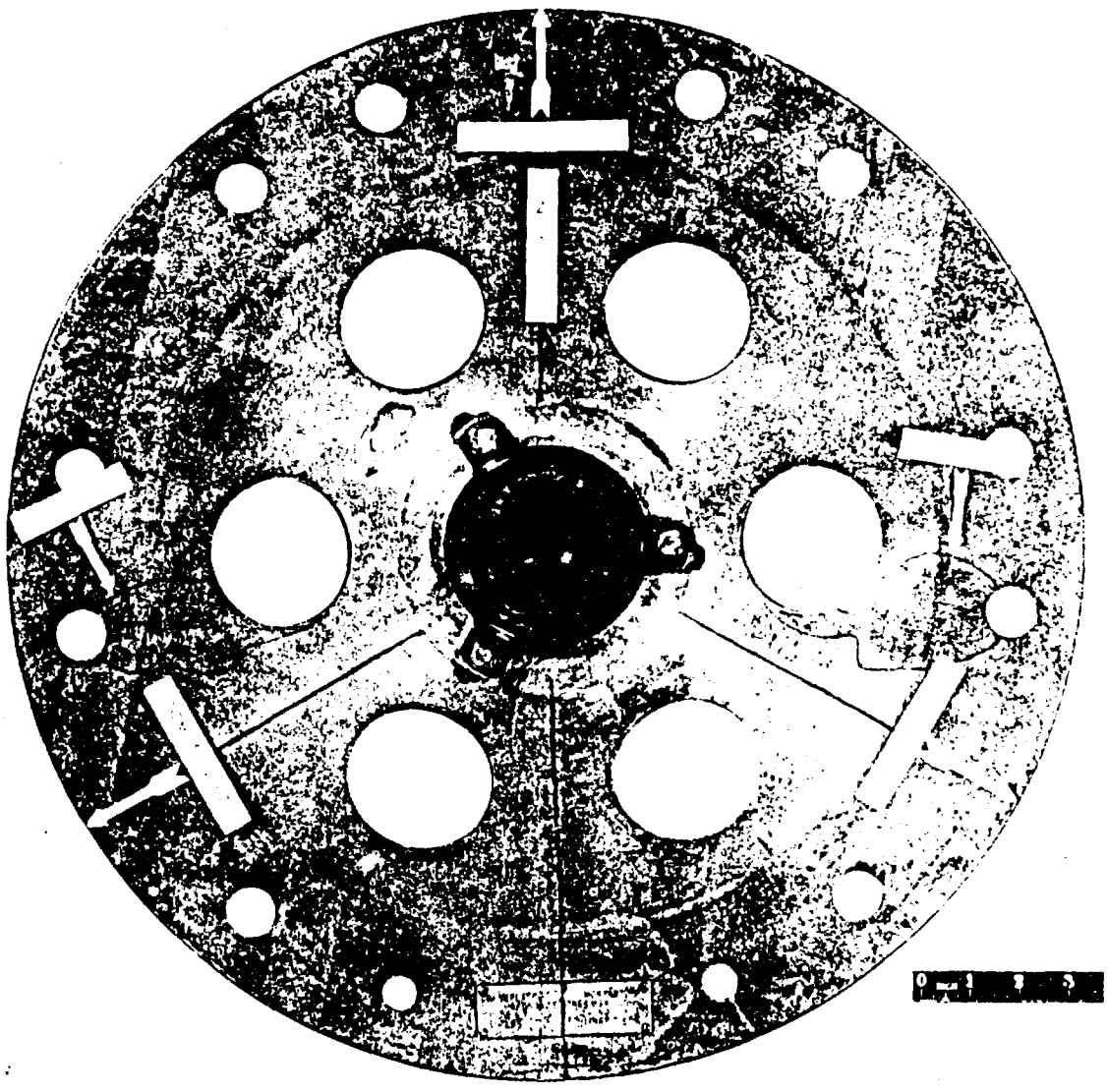


Figure 2. Strain patterns in brittle lacquer show locations of maximum strain on the top surface of a mortar baseplate.

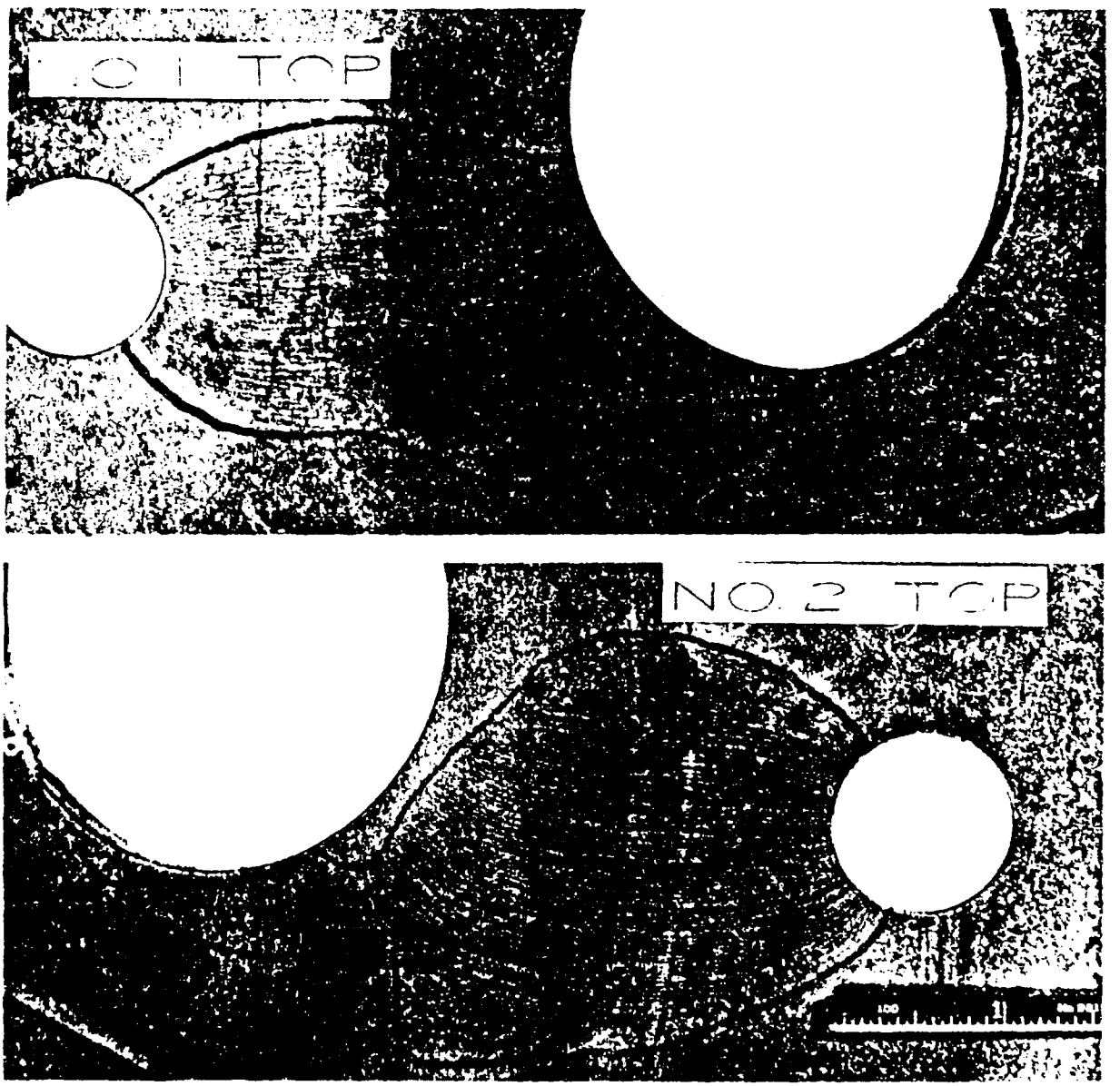


Figure 3. Strain patterns in brittle lacquer on top surface of mortar baseplate; note direction of strain pattern.

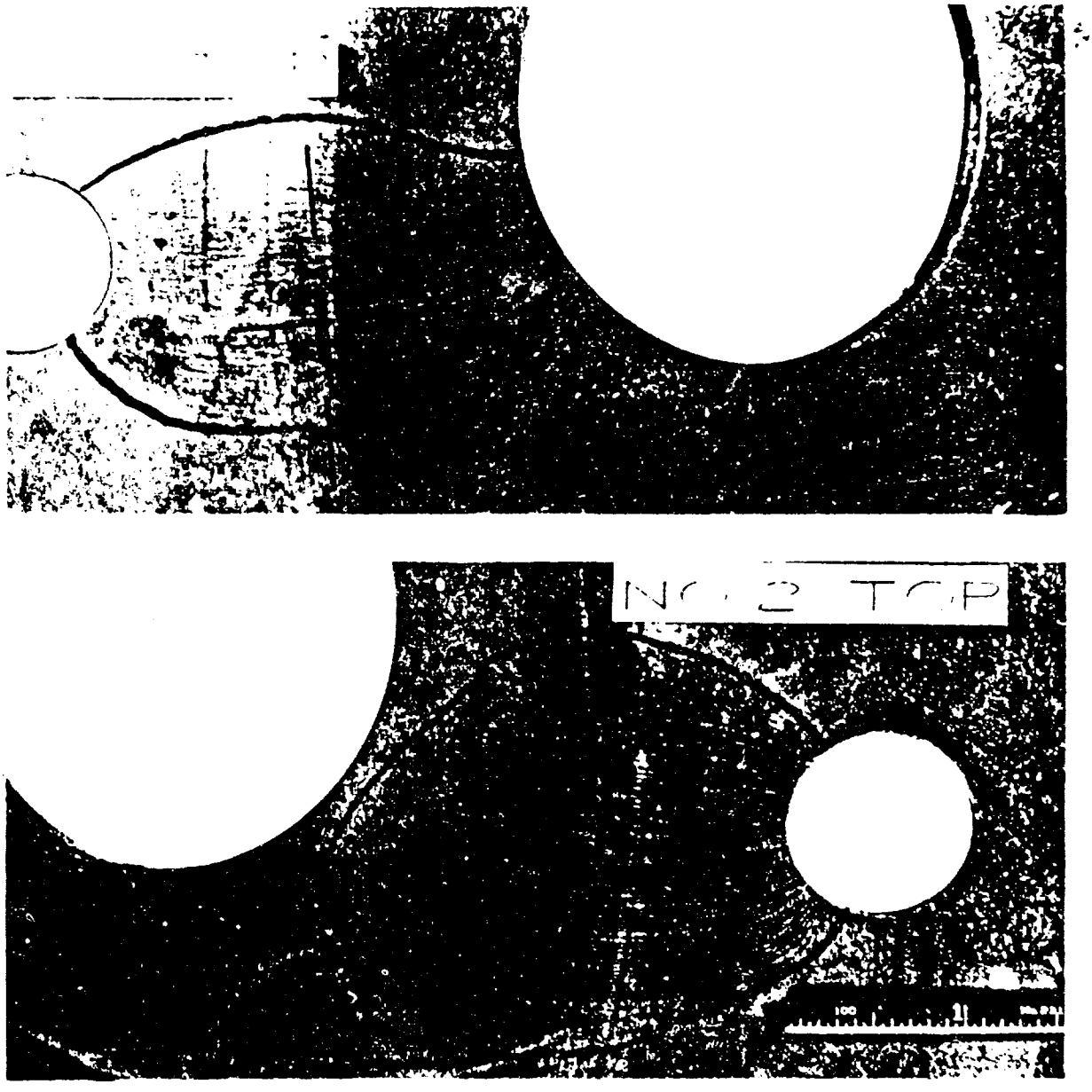


Figure 4. Location of electrical strain gages perpendicular to strain pattern.

APPENDIX A
REFERENCES

1. Test Operations Procedure (TOP) 1-2-605, Birefringent Coating Technique of Photoelastic Stress Analysis, 28 August 1980.