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EFFECT OF STRESS-SOLVENT CRAZING ON TENSILE STRENGTH OF POLYMETHYL METHACRYLATE

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SUMMARY

The loss of strength of tensile specimens of polymethyl methacrylate as a result of stress-solvent crazing at 23° C and 50-percent relative humidity was investigated. The materials tested were commercial cast polymethyl-methacrylate sheets of both heat-resistant and ordinary grades from each of two manufacturers. Most of the tests were made on samples 0.15 inch thick and covered with masking paper on one side only. The tensile specimens were artificially crazed by applying benzene to the central portion of the reduced section while under stress and were subsequently broken. Specimens for controls were treated identically except no benzene was applied. Photographs were taken of the crazed specimens before they were tested. Among the factors studied were the sheet-to-sheet variability of crazed and control specimens, the effect of the masking paper on the crazing, and the relative effect of a few large crazing cracks compared with more numerous finer cracks.

Some of the results and tentative conclusions were as follows. The masking paper had no consistent effect on the loss of strength resulting from crazing. The principal crazing treatment employed, which produced about two cracks per square millimeter with a crack length and depth of roughly 1 and 0.15 millimeter, respectively, caused a loss of strength of approximately 30 percent in all materials. The crazed specimens were more variable than the controls, the coefficients of variation for tensile strength being about 15 and 5 percent, respectively, for all samples. In addition, although the crazing treatment was done in a controlled manner, there was a significant daily variation in treatment that contributed an additional 15 percent to the coefficient of variation for the crazed specimens. It was not found possible to predict the tensile strength of a crazed specimen from its appearance. Accordingly, it is suggested that aircraft enclosures with crazing of the type described in this work should be removed if, in service, tensile stress occurs normal to the crazing cracks.

INTRODUCTION

The loss of strength of polymethyl methacrylate as a result of crazing is a property of considerable importance to the aircraft industry. Information on this subject, however, is quite meager (references 1 and 2). As a result of flexural fatigue tests by the Rohm & Haas Company (reference 2) on specimens taken from partially crazed DC-6 airplane windows, some of the conclusions were: Crazing perpendicular to the flexure stress reduces the flexural fatigue strength of the material and may reduce the flexural strength approximately 35 percent, and "crazing oriented other than perpendicular to flexure stress has very little influence on the flexural fatigue strength of the material." It was recommended in reference 2 that "crazed DC-6 windows should not be used under conditions that produce outward pressure deflection of the outer panel."

The experiments that are described in this report were made to gain more information on the subject of loss of strength as a result of crazing. The experiments were made on tensile specimens that were artifically crazed and then tested for strength. The factors examined included samples from different sources, effect of masking paper, sheet-to-sheet variability, and type of crazing. This investigation was conducted at the National Bureau of Standards under the sponsorship and with the financial assistance of the National Advisory Committee for Aeronautics.

The courtesy of E. I. du Pont de Nemours & Company and the Resinous Products Division of the Rohm & Haas Company in furnishing material for use in this investigation is gratefully acknowledged. The assistance of Miss Mary Jo Watson in performing some of the early experiments and of Mr. John Mandel, who made the statistical analysis, is appreciated.

MATERIALS

The materials were commercial cast polymethyl-methacrylate sheets of both heat-resistant and ordinary grades and were approximately 0.12 to 0.15 inch in thickness. These samples consisted of sheets masked on both sides with the usual adhesive-coated masking paper and sheets masked on one side only as is done for sheets used to make laminated acrylic glazing. The latter samples, masked on one side only, consisted of one sheet from each of three production runs and are subsequently referred to as the "representative samples." A description of the samples is given in table I.

TEST PROCEDURE

Exploratory Tests

Samples L1a, L2a, P1, and P2, which included both the regular and heat-resistant grades of Lucite and Plexiglas, were used for these tests.

The crazing and testing procedure was as follows: Standard tensile specimens (Federal Specification L-P-406a, Method 1011, Type I) were machined from sheets of the four samples. A specimen was stress-solvent crazed by stroking the central 1/4- by 2-inch portion of one face of the specimen with a No. 1 camel's hair brush wet with benzene; this was done with a constant tensile load of 2500 or 3000 psi maintained for 5 minutes. Solvent was not applied to the full width of the specimen as enhanced crazing would result at the edges because of penetration from two sides and residual stresses caused by machining. As the degree of crazing depended on the amount of benzene applied, it was attempted to apply the same amount of benezene to all specimens. This was done as follows: The brush was as wet as possible without dripping and the strokes were repeated at 3- to 5-second intervals with the brush wet before each stroke.

Control specimens were subjected to the same loading conditions. All specimens were conditioned 24 hours at 25° C and 50-percent relative humidity and were tested in the conditioning atmosphere. Prior to testing the crazed specimens, measurements of the average crack length and depth and of the crack density were made in order to specify the degree and character of the crazing. In addition, photographs were made of some sets of specimens. The average crack length and depth were obtained in the following manner. A 20-power Brinell microscope was used to measure the crack lengths and the crack depths. On each specimen the lengths of some selected cracks were measured and the average value noted. To measure the crack depth, the specimen was viewed against a uniform white background and at an angle of about 45° to the lengthwise direction. The crazing cracks, which appeared as shaded areas, were assumed to be normal to the surface of the specimen. The crack depth was then calculated from the apparent depth taking account of the foreshortening resulting from the higher refractive index of the polymethyl methacrylate. The cracks in a small selected area were measured and the average depth value noted. The average values obtained on the specimens ranged from about 0.5 millimeter to 1.5 millimeters for the length and from 0.1 to 0.2 millimeter for the depth. The crack density, estimated on each specimen from a count in a selected area, ranged from about 10 to 220 cracks per square centimeter.

The results of the tensile tests are given in table II. The effect of the crazing is to reduce the tensile strength about 30 to 50 percent.

Although it was attempted to craze the specimens in a controlled manner, the crazed specimens for a given sample were much more variable than the controls. The coefficient of variation of tensile strength was 7 to 30 percent for the various sets of crazed specimens compared with 1 to 2 percent for this quantity for the controls. Some of the variability in the crazed specimens was associated with crazing different groups on different days, although in the case of sample P2 the highest and lowest strengths were observed in a group of three specimens from one sheet crazed on the same day.

A correlation between severity of crazing and loss of strength was sought as follows: The tensile strengths of the individual specimens of a set were ranked and density of cracks, average crack length, and average crack depth for each specimen tabulated. By inspection of the data it was found that none of these quantities correlated closely with tensile strength. Next, from photographs of each set of crazed specimens, the tensile strength ranking to be expected on the basis of the degree of crazing was estimated and the estimates compared with the actual results. In most cases the tensile strength ranking could not be judged from the photograph. It was decided to indicate the crazing in subsequent tests of this type by only photographing the specimens.

In an attempt to obtain uniformly crazed specimens, a few experiments were made on tensile specimens that had been exposed without stress to benzene vapor for varying periods. In the first test, after exposure for 16 hours the specimen was heavily crazed and the edges swollen. Subsequently, specimens whose edges were protected with metal foil adhered with silicone grease were exposed for periods of 4 to 7 hours. It was found that the silicone grease did not protect the edges adequately; when these specimens were subjected to loads of about 3000 to 5000 psi no crazing occurred except at the edges. It was decided to abandon this method of producing crazed specimens.

Experiments on Representative Samples

Tapered tensile specimens of the representative samples were stress-solvent crazed with benzene applied with a fine brush. From these specimens it appeared that slight, approximately equivalent crazing would occur at stresses of 2000, 2400, 3000, and 3000 psi for Lucite HC201, Plexiglas Type I-A, Lucite HC202, and Plexiglas II, respectively. These stresses were used in preparing stress-solvent-crazed standard tensile specimens of these samples; the crazing was produced by applying benzene with a No. 1 camel's hair brush to the 1/4- by 2-inch central portion of the previously masked face of the specimen. A controlled amount of benzene, 0.03 to 0.04 gram, was put on the brush from a marked glass dropper. The specimen was then stroked with the brush until the latter was dry. The specimens were broken 1 day after being

crazed; a testing speed of 0.25 inch per minute was used. As was done previously, control specimens were subjected to the same loading conditions. One specimen from each half of each sheet was tested. On the control specimens the load at which stress crazing began was noted. This was done in connection with another phase of the investigation.

The observation of the threshold of stress crazing in the control specimens was found to be difficult in testing at a relative rate of head motion of 0.25 inch per minute. Accordingly, it was decided to use a speed of 0.05 inch per minute for both crazed and control specimens in subsequent tests.

A second series of tests was planned with the representative samples. The variables included in this series in addition to those previously studied were (a) crazing on the masked face against crazing on the unmasked face and (b) coarse against fine crazing.

With regard to variable (b), the purpose of these experiments was to see whether a few large crazing cracks would cause greater loss in strength than a large number of fine cracks. The coarse crazing was produced by applying a larger amount of benzene and a smaller stress than were used to create the fine crazing. As before, a complete set of specimens for crazing in a given manner and on a given face included one specimen from each half of each sheet. Two control sets of specimens were tested, preloaded, respectively, at the two stresses used for crazing.

In studying variable (a), initially it was believed that the crazing treatment was sufficiently uniform so that day-to-day variations would be unimportant and experiments on masked and unmasked sets of specimens were made on different days. As the experiments progressed it was found necessary to make a comparison of the masked and unmasked surfaces of the acrylic sheet on the same day. Accordingly, a test was made in which adjacent specimens from a given sheet of material were solvent-crazed in succession, one on the unmasked, the other on the initially masked face.

All of these tests on the representative samples were made after the specimens had been conditioned at least 3 weeks at 23° C and 50-percent relative humidity. The masking paper was removed at least 7 days prior to the test.

RESULTS AND DISCUSSION

The results of the tensile tests on the crazed and uncrazed specimens of the representative samples are shown in tables III and IV. The appearance of some of the crazed specimens prior to testing is shown

in figures 1 through 5. In these photographs the tensile strength of each specimen is indicated, as well as the half sheet from which the specimen was taken.

The coefficient of variation was not reported for each strength value in tables III and IV because such statistics, based on only six observations, are subject to wide variability. The precision of the data and other statistical points are discussed in detail in the next section of the report.

The statistical analysis showed that for the tests (table IV, groups I and II) in which the relative effects on tensile strength of a few coarse cracks and many finer cracks were compared no significant difference in strength resulted. Figure 1 shows the appearance of specimens of sample L2d crazed on the masked face by the two treatments. In this experiment the two treatments happened to be selected so that they produced essentially the same loss in strength. If the stress or amount of benzene had been different in either treatment, a different result probably would have occurred; for example, if still finer cracks had been produced by treatment II, the loss in strength probably would have been decreased.

The effect of the masking paper on the loss of strength of stress-solvent-crazed specimens was demonstrated best by the tests (group III, table IV) in which adjacent specimens were crazed in succession, one on the unmasked, the other on the initially masked face. The statistical analysis indicated no consistent effect of the masking paper on the strength of the crazed specimens. The specimens for this experiment are shown in figures 2 through 5. For sample L1d (fig. 2), it appears that the crazing treatment caused fewer cracks on the masked than on the unmasked side; however, for each half sheet, the strength of the specimen crazed on the masked side was on the average the same as that for the unmasked specimen. Similarly, it appears that on one or two sheets of other samples (figs. 3 and 4) the crazing treatment caused fewer cracks on the masked than on the unmasked faces.

An examination of the tensile strength values on the photographs indicates that the tensile strength is not easily predicted from the appearance of the crazed specimen. This is in agreement with the observation made regarding the exploratory tests. This unpredictability and the greater variability in strength of the crazed specimens are perhaps related and may be explained as follows: The strength of a specimen of a material is a flaw-dependent property. Hence, the creation of a large number of relatively large flaws in the specimen by crazing might be expected to result in a loss in strength of a widely varying amount.

The loss in strength (table IV) produced by the treatments I and II was roughly 30 percent for all materials. It should be noted that to produce this loss in strength, a higher stress was used in crazing the heat-resistant-grade as compared with the ordinary-grade material. This is in agreement with the well-known fact that the threshold stress for solvent crazing is higher for the heat-resistant than for the ordinary-grade cast material.

Since it was not found possible to predict the tensile strength of a crazed specimen from its appearance, it seems that an acrylic aircraft enclosure that has crazing similar to that produced in the experiments described herein should be replaced if, in service, tensile stresses normal to the crazing cracks exist.

STATISTICAL ANALYSIS OF RESULTS

Control Specimens

As a preliminary to analyzing the data on the solvent-crazed specimens, the data on the control specimens in tables III and IV were examined for the effect of factors such as testing speed, stress used for crazing, sheet-to-sheet variability, and so forth. A comparison of the data for control specimens in group I of table IV with similar data in table III showed the following: (a) For all materials the tensile strength obtained at 0.25 inch per minute is significantly higher than that obtained at 0.05 inch per minute. (b) For all materials there is a significant variation in tensile strength between sheets.

The effect on tensile strength of using different stresses for crazing in treatments I and II (table IV) was examined for the control specimens and found not significant. The analysis of these data also indicated a significant sheet-to-sheet variability in tensile strength.

The coefficient of variation C_v of the tensile strength of specimens from the three sheets of each material was calculated from the data for 0.05-inch-per-minute testing speed. As there was not enough evidence for these values for the four materials being different from each other, the results were combined. A value of about 5 percent for C_v was obtained. If the effect of variability between sheets is removed, an average value for C_v of 1.2 percent results.

The coefficient of variation in percent was obtained from

$$C_v = \frac{s}{\bar{x}} 100$$

In this equation, standard deviation s is

$$s = \sqrt{\frac{\sum_i (x_i - \bar{x})^2}{N - 1}}$$

where

N number of measurements

x_i i^{th} measurement

$\bar{x}$ arithmetic mean of x_i's

Crazed Specimens

The data (group III, table IV) for adjacent specimens solvent-crazed alternately on the unmasked and the initially masked faces were analyzed with the following results: (a) There seems to be no consistent effect on the tensile strength from masking, either between materials or even between sheets of the same material. (b) For all materials the standard deviation of a single measurement of tensile strength is significantly higher than for the controls. (c) Sheet-to-sheet variability is not apparent, probably because of the increased within-sheet variability.

In view of the previous result that there was no consistent difference between specimens crazed on the unmasked and initially masked faces, the data in groups I and II of table IV were analyzed to determine the day-to-day variability of the two treatments. The results of the analysis are as follows: (a) There is no evidence that the treatments I and II, the former designed to produce a few large crazing cracks, and the latter designed to result in numerous finer cracks, differ with respect to their effect on strength. (b) The variability between results on the same material given the same treatment on different days is (1) affected by a large daily effect (the same for all materials) and (2) affected by additional daily variability, which is not the same for all materials and which is not entirely accounted for by within-day variability.

The coefficient of variation values for the data in groups I and II of table IV were calculated and examined. It was found that the coefficient of variation C_v of the tensile strength does not vary significantly between materials or between the two treatments and is equal on the average to 15 percent; the day-to-day variability contributes roughly another 15 percent variability. The coefficient of variation of the

crazed specimens, 15 percent, is significantly greater than the corresponding value, 5 percent, for the control specimens. These data for the coefficient of variation are in good agreement with similar data obtained in the exploratory work described previously.

CONCLUSIONS

On the basis of the experiments described in this report the following tentative conclusions may be drawn:

1. When tensile specimens of heat-resistant and ordinary-grade polymethyl-methacrylate sheet are stress-solvent crazed with benzene in a controlled manner to produce crazing cracks roughly 1 millimeter in length and 0.1 to 0.2 millimeter in depth and with a density of about 2 cracks per square millimeter, the strength is reduced approximately 30 percent.

2. The coefficient of variation of the tensile strength of the crazed specimens is approximately 15 percent compared with about 5 percent for the controls. In addition, although the crazing was done in a controlled manner, there is a daily variation in the treatment that contributes an additional variability of roughly 15 percent to the coefficient of variation for the crazed specimens.

3. The tensile strength of a specimen of polymethyl methacrylate, crazed to the extent indicated above, cannot be predicted from the appearance of the crazing.

4. The use of acrylic aircraft enclosures that contain crazing as severe or more so than that described above is not recommended if, in service, tensile stresses normal to the crazing cracks exist.

National Bureau of Standards
Washington, D. C., September 21, 1950

REFERENCES

1. Bonza, L. F.: Tests of Model 49 Cabin Windows. Rep. No. 6174, Lockheed Aircraft Corp., May 26, 1947.

2. Gouza, J. J.: Fatigue Strength and Physical Properties of Crazed Douglas DC-6 Windows. Phys. Lab. Rep. No. 336, Rohm & Haas Co., April 5, 1949.

TABLE I.- DESCRIPTION OF POLYMETHYL-METHACRYLATE SAMPLES

Material	NBS sample	Date received	Nominal thickness (in.)	Batches in sample	Sheets in sample	Sheet size (in.)	Masking paper	Remarks
Lucite HC201	L1a	3/49	0.125	1	1	36 by 48	Both faces	----------
Lucite HC202	L2a	3/49	.125	1	1	36 by 48	-----do------	----------
Lucite HC201	L1d	9/49	.150	3	3	[a]36 by 48	One face only	Sample treated the same as material for acrylic-polyvinyl butyral laminate.
Lucite HC202	L2d	9/49	.150	3	3	[a]36 by 48	-----do------	----------do----------
Plexiglas I-A	P1	Early 1949	.150	---	10	12 by 12	Both faces	----------
Plexiglas II	P2	----do----	.150	---	10	12 by 12	-----do------	----------
Plexiglas I-A	P1a	10/49	.150	3	3	[a]36 by 48	One face only	Sample treated the same as material for acrylic-polyvinyl butyral laminate.
Plexiglas II	P2a	10/49	.150	3	3	[a]36 by 48	-----do------	----------do----------

[a]For convenience, sheets were cut in two at factory.

TABLE II.- LOSS OF TENSILE STRENGTH OF STRESS-SOLVENT-CRAZED SAMPLES OF POLYMETHYL METHACRYLATE[1]

Material	NBS sample	Dates tested (2)	Crazed specimens[3]					Uncrazed specimens[4]		
			Conditions for crazing[5]		Specimens tested	Tensile strength		Specimens tested	Tensile strength	
			Brush strokes	Stress (psi) (6)		Average (psi)	Range (psi)		Average (psi)	Range (psi)
Lucite HC201	L1a	6/23	10	2500	6	4600	4000-6200	6	6900	6800-7100
Lucite HC202	L2a	6/8,7/13	10	2500	8	4800	4100-5600	9	9300	9200-9500
Plexiglas I-A	P1	6/4,6/7, 6/22	5	2500	11	5100	3800-6200	11	7500	7300-7600
Plexiglas II	P2	6/17,6/22, 6/23	10	3000	8	6000	4400-8300	9	9200	8800-9400

[1]Tests were made on standard tensile specimens, Federal Specification L-P-406a, Method 1011, Type I. Relative rate of head motion was 0.05 in./min. Specimens of Lucite and Plexiglas were 0.12 and 0.15 in. thick, respectively.

[2]All specimens tested in 1949. On each date, group of crazed specimens and group of controls from same sheet were tested.

[3]After stress-solvent crazing, specimens were conditioned 24 hr at 25° C and 50-percent relative humidity and then tested in conditioning atmosphere.

[4]Specimens subjected to same loading cycle and conditioning treatment as crazed specimens.

[5]A No. 1 camel's hair brush was dipped in benzene. Central 1/4- by 2-in. portion of one face of specimen was stroked with brush which was as wet as possible without dripping. Strokes were repeated at 3- to 5-sec intervals and brush was wet before each stroke.

[6]Load applied for 5 min.

TABLE III.- TENSILE STRENGTH OF STRESS-SOLVENT-CRAZED SPECIMENS OF REPRESENTATIVE SAMPLES OF POLYMETHYL METHACRYLATE TESTED AT 0.25 INCH PER MINUTE[a]

Material	NBS sample	Crazed specimens[b]			Uncrazed control specimens[c]
		Stress used for crazing (psi) (d)	Tensile strength		Average tensile strength (psi)
			Average (psi)	Percent of control average	
Lucite HC201	L1d	2000	7,900	92	8,600
Lucite HC202	L2d	3000	8,300	77	[e]10,800
Plexiglas I-A	P1a	2400	6,800	76	8,900
Plexiglas II	P2a	3000	10,200	94	10,900

[a]Six specimens were tested, one from each half of three sheets representing three production runs. Tests were made on standard tensile specimens, Federal Specification L-P-406a, Method 1011, Type I. Specimens were conditioned at least 3 weeks at 23° C and 50-percent relative humidity. Masking paper was removed at least 7 days prior to test. Specimens were tested 1 day after they were solvent-crazed.

[b]Benzene in amount of 0.03 to 0.04 gram was put on No. 1 camel's hair brush (about 0.1-in. diam., 0.5-in. length). Then central 1/4- by 2-in. portion of specimen was stroked repeatedly with brush. Benzene was applied to surface that had been masked.

[c]Subjected to loading conditions used to cause stress-solvent crazing.

[d]Maintained 5 min.

[e]Five specimens.

TABLE IV.- TENSILE STRENGTH OF STRESS-SOLVENT-CRAZED SPECIMENS OF REPRESENTATIVE SAMPLES OF POLYMETHYL METHACRYLATE TESTED AT 0.05 INCH PER MINUTE[a]

Material	NBS sample	Stress used for crazing (psi) (b)	Tensile strength of crazed specimens				Average tensile strength of uncrazed control specimens (psi) (b)(c)
			Masked surface crazed		Unmasked surface crazed		
			Average (psi)	Percent of control average	Average (psi)	Percent of control average	
Group I - Treatment I: Stress as indicated; crazed by method B[d]							
			Crazed 1/30/50; tested 2/1/50		Crazed 2/8/50; tested 2/10/50		Loaded 2/15/50; tested 2/17/50
Lucite HC201	L1d	2000	5500	69	4400	55	8,000
Lucite HC202	L2d	3000	7100	73	5000	52	9,700
Plexiglas I-A	P1a	2400	5000	62	4600	57	8,100
Plexiglas II	P2a	3000	8400	84	[e]6300	63	10,000
Group II - Treatment II: Stress as indicated; crazed by method A[f]							
			Crazed 1/18/50; tested 1/20/50		Crazed 2/7/50; tested 2/9/50		Loaded 1/23/50; tested 1/25/50
Lucite HC201	L1d	3000	[g]7800	99	4400	56	7,900
Lucite HC202	L2d	4000	7600	78	5300	55	9,700
Plexiglas I-A	P1a	3200	6200	76	4700	58	8,100
Plexiglas II	P2a	4000	9300	90	8000	78	10,300
Group III - Treatment II: Stress as indicated; crazed by method A[f]							
			Crazed 4/12/50; tested 4/14/50				
Lucite HC201	L1d	3000	6300	80	6500	82	
Lucite HC202	L2d	4000	7500	77	7000	72	
			Crazed 4/18/50; tested 4/20/50				
Plexiglas I-A	P1a	3200	5500	68	5100	63	
Plexiglas II	P2a	4000	7300	71	6600	64	

[a]Six specimens were tested, one from each half of three sheets representing three production runs. Tests were made on standard tensile specimens, Federal Specification L-P-406a, Method 1011, Type I. Specimens were conditioned at least 3 weeks at 23° C and 50-percent relative humidity. Masking paper was removed at least 7 days prior to test. Specimens were tested 2 days after they were solvent-crazed.

[b]Stress was maintained for 5 min after benzene was applied. Control specimens were also subjected to this stress for 5 min.

[c]Control specimens were tested 2 days after they were loaded.

[d]Method B: No. 1 camel's hair brush was dipped in benzene and wiped against side of container so as not to drip. Then central 1/4- by 2-in. portion of specimen was stroked twice with brush. This process was repeated nine times.

[e]Four specimens.

[f]Method A: Benzene in amount of 0.03 to 0.04 gram was put on No. 1 camel's hair brush (about 0.1-in. diam., 0.5-in. length). Then central 1/4- by 2-in. portion of specimen was stroked repeatedly with brush.

[g]Five specimens.

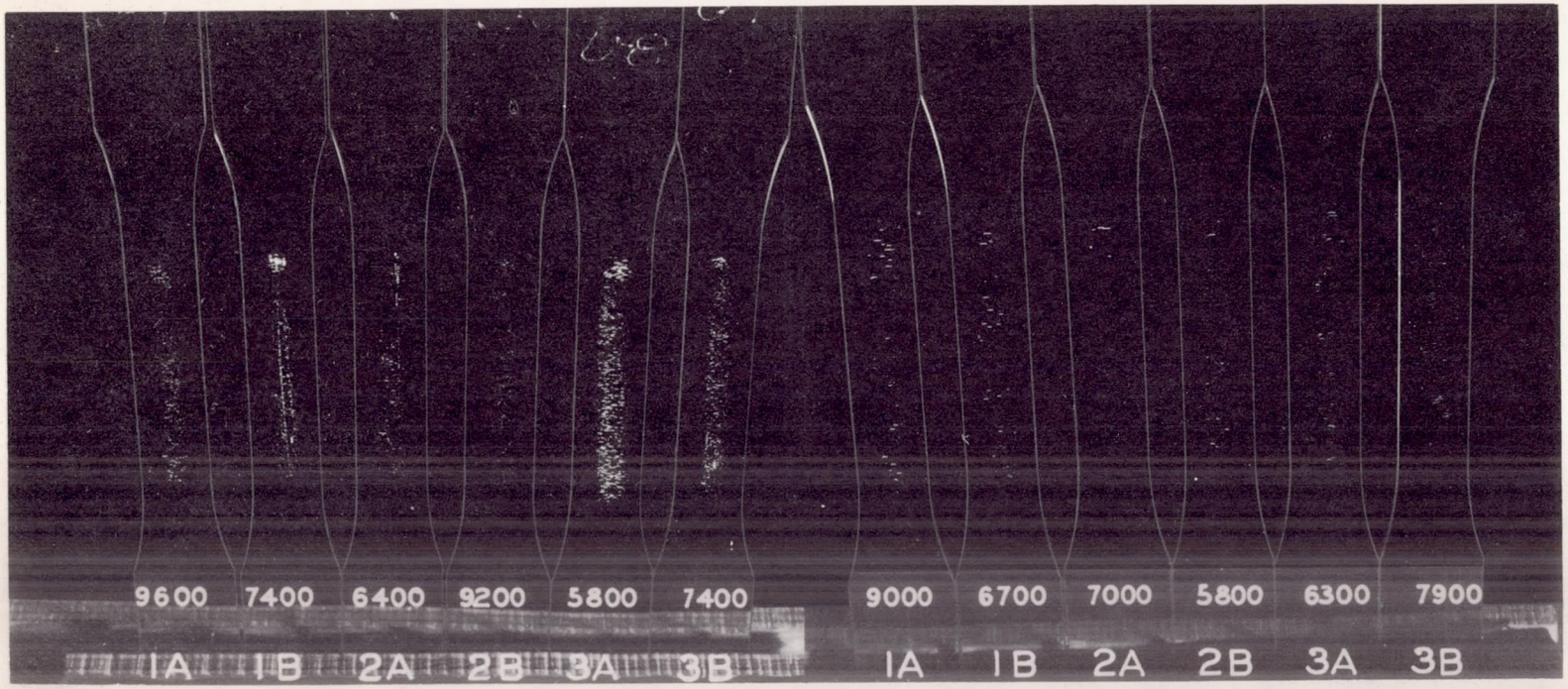

Figure 1.- Tensile specimens of Lucite HC202, sample L2d, crazed on masked face. Series of specimens on left crazed by treatment II (table IV) and series of specimens on right crazed by treatment I (table IV). Tensile strength in psi is shown at lower end of each specimen. Designations 1A, 1B, and so forth, indicate half-sheet from which specimen was taken.

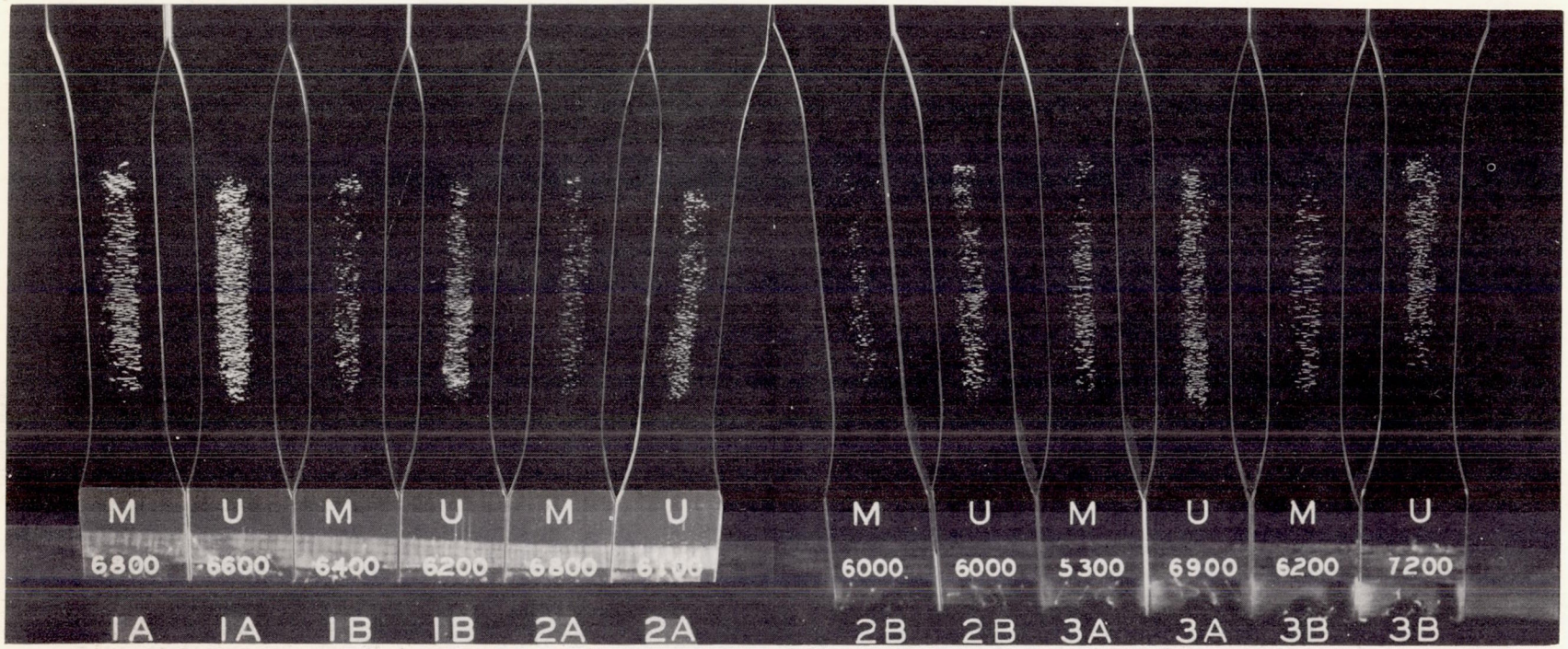

Figure 2.- Tensile specimens of Lucite HC201, sample Lld, crazed by treatment II (table IV). Face on which benzene was applied is indicated as M for masked and U for unmasked. Designations 1A, 1B, and so forth, indicate half-sheet from which specimen was taken. Tensile strength in psi is shown at lower end of each specimen.

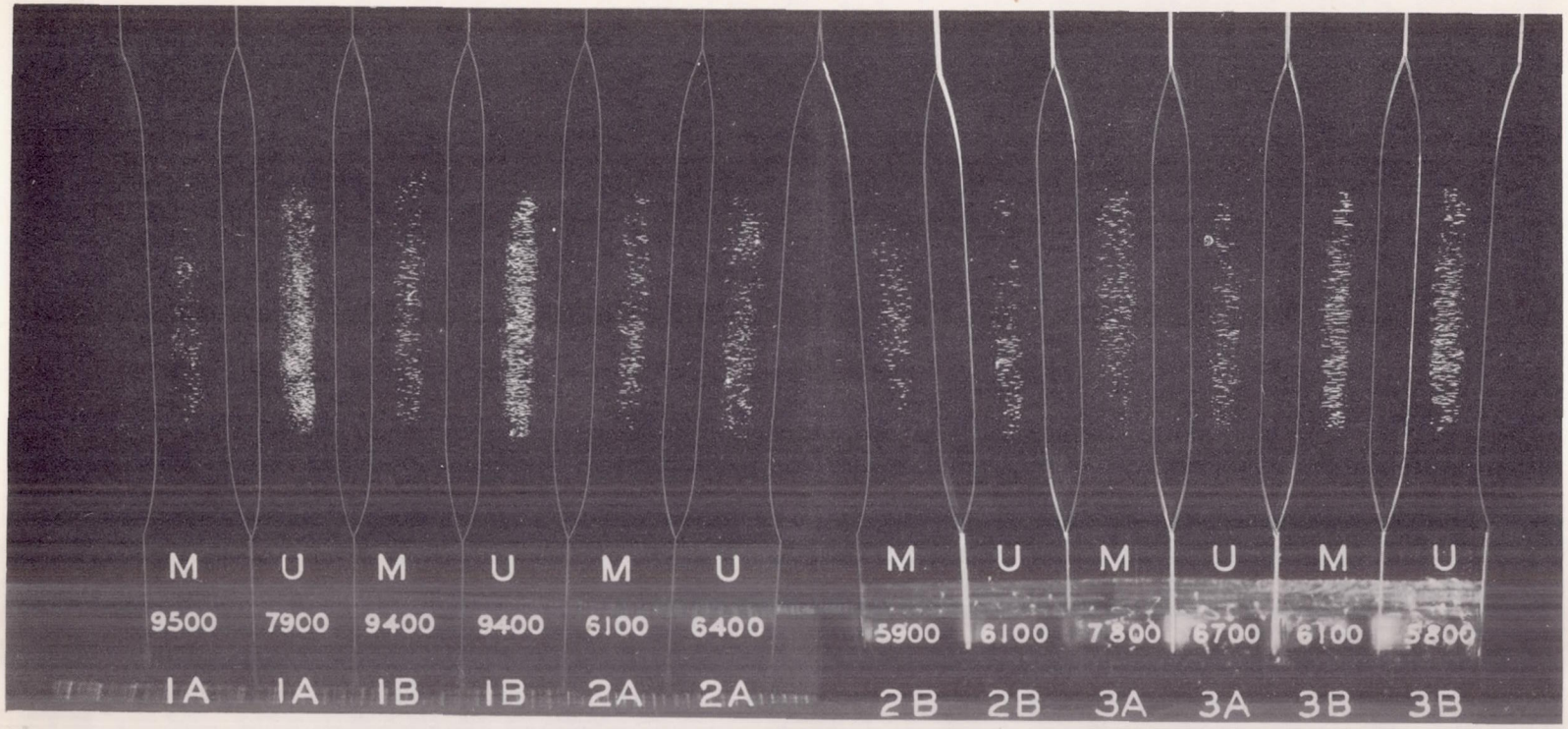

Figure 3.- Tensile specimens of Lucite HC202, sample L2d, crazed by treatment II (table IV). Face on which benzene was applied is indicated as M for masked and U for unmasked. Designations 1A, 1B, and so forth, indicate half-sheet from which specimen was taken. Tensile strength in psi is shown at lower end of each specimen.

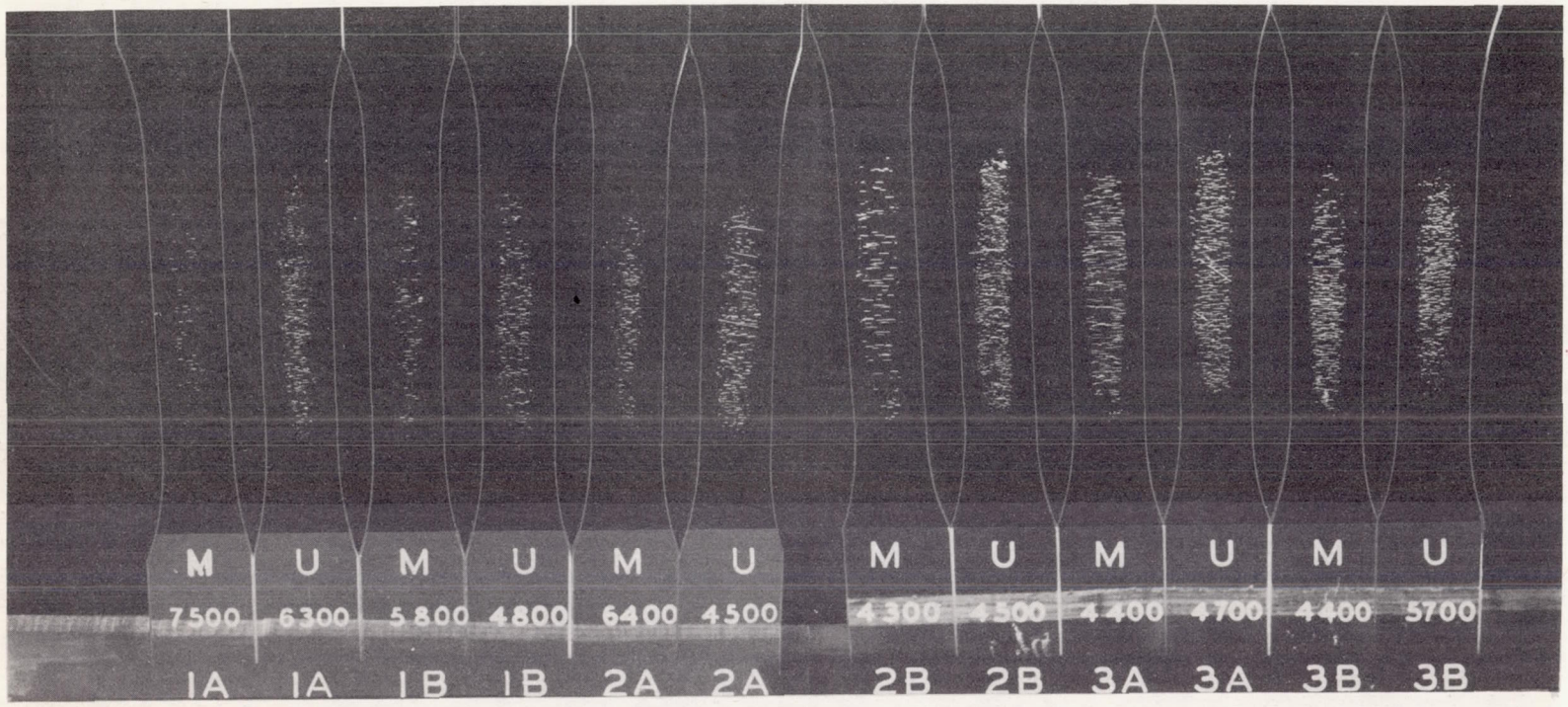

Figure 4.- Tensile specimens of Plexiglas I-A, sample Pla, crazed by treatment II (table IV). Face on which benzene was applied is indicated as M for masked and U for unmasked. Designations 1A, 1B, and so forth, indicate half-sheet from which specimen was taken. Tensile strength in psi is shown at lower end of each specimen.

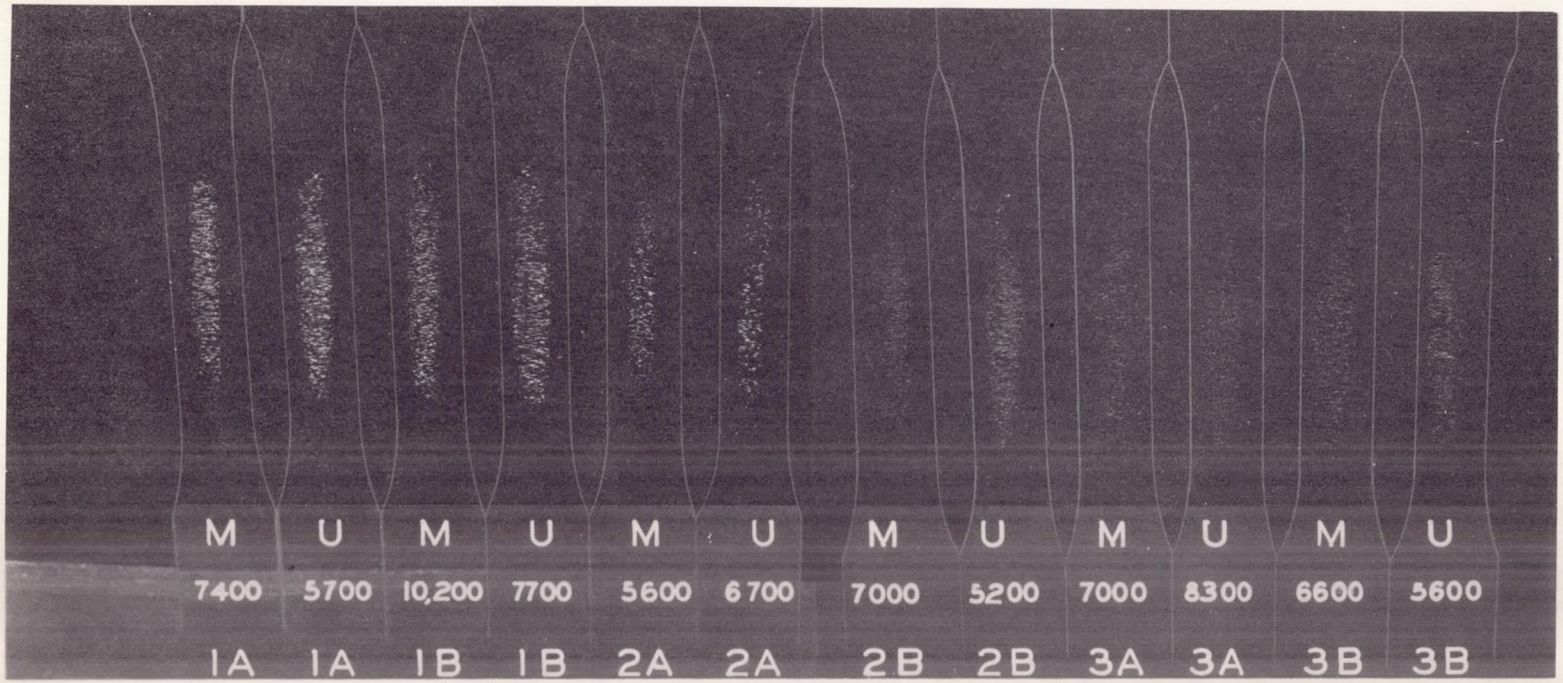

Figure 5.- Tensile specimens of Plexiglas II, sample P2a, crazed by treatment II (table IV). Face on which benzene was applied is indicated as M for masked and U for unmasked. Designations 1A, 1B, and so forth, indicate half-sheet from which specimen was taken. Tensile strength in psi is shown at lower end of each specimen.

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