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THE EFFECT OF SOLAR RADIATION ON THE BREAKING STRENGTH OF OUTDOOR EXPOSED WEBBINGS

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AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
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FOREWORD

This report was prepared by the Textiles Branch, WADC, and was initiated under Project No. 7320, "Air Force Textile Materials", Task No. 73201, "Textile Materials for Parachutes". This program was administered under the direction of the Materials Laboratory, Directorate of Laboratories, Wright Air Development Center, with Mr. Robert A. Wilkinson acting as project engineer.

Acknowledgment is sincerely given to Captain Richard A. Sublette, 1st Lt Peter Y. Stanton and Airman First Class Marshall C. Bird for their part in conducting the numerous evaluations connected with this project.

This report covers work conducted from July 1955 to June 1957.

ABSTRACT

This program was to obtain data as to what degree solar radiation affected the breaking strength of webbings exposed to natural weather. Four groups of webbings were evaluated for breaking strength after being exposed to natural weather for specific time intervals encompassing one year. The exposure sites were Wright-Patterson Air Force Base, Ohio; Las Cruces, New Mexico; and College, Alaska.

Data obtained indicate that the service life of the present type of runway barriers can be increased to 180 days in areas of extremely strong sunlight and to 360 days in areas of moderate or small amounts of sunlight by either one of the following two methods:

1. By using 260 denier 17 filament, Type 300, OD color nylon yarn in the manufacture of the webbing.

2. By using Type 330 nylon yarn in the manufacture of the webbing.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

C. A. Willis

C. A. WILLIS
Chief, Textiles Branch
Materials Laboratory

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

I. INTRODUCTION

A. OBJECTIVE:

The purpose of this program is to determine what effect solar radiation has on the breaking strength of nylon webbing (as is used in aircraft runway barriers) after being exposed outdoors for periods of 15, 30, 45, 60, 90, 120, 180 and 360 days. This was accomplished by natural weather exposure of webbings manufactured from duPont Type 300 nylon yarn untreated and treated with catechol formaldehyde. Webbings manufactured from duPont Type 330 nylon yarn were also exposed. With the nylon webbings, an Orlon* webbing, untreated, was tested simultaneously to determine the possibility of its use in aircraft runway barriers. The objective of this program is to provide data for the selection of a new type yarn or a treatment on presently used webbings which will increase the service life of aircraft runway barriers.

B. GENERAL INFORMATION:

Of all the chemical and physical agents of deterioration, sunlight probably accounts for the most widespread degradation of materials and equipment subjected to natural weather. This is particularly true of nylon textile materials. With this being evident there is an increasing need for webbings with a longer service life to be used in aircraft runway barriers. Previously the initial barriers were constructed of cotton; later, nylon was used in the actuator straps and mildew-proofed cotton in the lifter straps. The life expectancy of this type of barrier was only 30 days under normal weather conditions. Barriers currently being used by the Air Force are fabricated from nylon webbing utilizing 210 denier 34 filament yarn either duPont Type 300 yarn or Chemstrand Type HB yarn, both yarn dyed OD color and treated with an abrasion resistant resin. A previous test program showed that a barrier of the current construction has a service expectancy of 60 days under normal weather conditions and 45 days under extremely strong sunlight. The results of that program are incorporated in a Technical Note WCRT 54-249 entitled "Sunlight Exposure of Nylon Webbing".

The present program was initiated by the Textiles Branch of the Materials Laboratory, Directorate of Laboratories, Wright Air Development Center, to determine if a radiant energy inhibitor treatment on presently used Type 300 nylon or the use of duPont Type 330 yarn (contains an additive which increases the yarn's resistance to ultra violet degradation) in the webbings would increase the service life of aircraft runway barriers. Prior to the beginning of the program a survey of the available radiant energy inhibitors was conducted. The results of that survey are reported in a Technical Memorandum WCRT TM 56-24.

To meet the objective of this program, eight conditions of webbing using duPont Type 300 yarn, four conditions of webbing using du Pont

*Orlon - The trade mark for the E. I. duPont de Nemours and Company acrylic fiber.

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Type 330 yarn, and two Orlon webbings were exposed to natural weather for specific periods of 15, 30, 45, 60, 90, 120, 180 and 360 days. Exposures were conducted at three sites; namely, Wright-Patterson Air Force Base, Ohio; Las Cruces, New Mexico; and College, Alaska. After the exposure periods the webbings were tested to determine the degree of breaking strength retained.

The original test data are recorded in Materials Laboratory Project Record Book No. 17323, pages 1 through 44.

II. PROCEDURE

A. DESCRIPTION OF WEBBING:

1. The nylon webbings were constructed and woven in accordance with Specification MIL-W-4088B, Type XIX with the exception that the yarn size used was 260/17 (denier and filament). At the time this program was planned it seemed advisable to use this yarn size as the yarn manufacturer implied that the 260/17 nylon yarn would be available in both the Type 300 and 330 for production purposes.

2. DuPont Type 300 is a continuous filament, high tenacity bright yarn. Their Type 330 is a continuous filament high tenacity bright yarn which exhibits greater heat durability and resistance to ultra-violet degradation than does the Type 300.

3. The Orlon webbing was designed to have a 4500 pound minimum breaking strength.

4. Sample identification and conditions of webbing used are presented in Appendix I, Table I.

B. EXPOSURE SITES AND EXPOSURE DATE:

The exposure sites were selected to provide a wide variety of amounts of solar radiation. It is customary to describe the exposure condition as arctic, temperate, desert, tropical and semitropical. Atmospheric conditions also may be classified as urban or rural. The exposure sites used for this program were as follows:

Site A. Dayton, Ohio. The facilities of the Materials Laboratory, Wright-Patterson Air Force Base were used at this location. The specimens exposed at this site were monitored by Textiles Branch, Wright-Patterson Air Force Base, which may be classified as temperate, urban, and is located 40° north latitude, 84° west longitude.

Site B. Las Cruces, New Mexico. The facilities of the New Mexico State College were utilized at this location and exposure of the specimens were monitored by the Department of Mechanical Engineering. This site may be classified as desert, rural, and is located 32° north latitude, 106° west longitude.

Site C. College, Alaska. The facilities of the University of Alaska were utilized at this location and exposure of the specimens were monitored by the Department of Chemistry. This site may be classified as sub-arctic, rural, and is located 65° north latitude, 148° west longitude.

The exposure date for all three sites was the same--October 1955 to October 1956.

C. EXPOSURE OF SPECIMENS:

Exposure racks were built so that when the webbing specimens were installed they would be at a 45° angle to ground level, facing south, and in such a manner that the center 18 inches was exposed to the sun's rays. Once the specimens were fastened to the racks they were not turned over or disturbed until their specific exposure period had ended and it was time for their removal.

D. MEASUREMENT OF SOLAR RADIATION:

The total daily radiation in Langleys (gram calories/square centimeter) was recorded by the use of a pyrheliometer. The approximate total dosage for each exposure period is shown in Appendix I, Table II. The data shown are the total radiation on an 18" x 1-3/4" specimen having an area of 203.23 square centimeters. Estimated totals were calculated and substituted for the following days and sites when the pyrheliometer was out of operation.

Wright-Patterson Air Force Base, Ohio: 9-30 November 1955, 1-12 and 25-31 December 1955, 1-5 January 1956.

Las Cruces, New Mexico: 30 January 1956.

College, Alaska: 27, 28 and 31 October 1955, 1 November 1955, 10-31 December 1955, 1-3, 5 and 30 January 1956.

E. STANDARD CONDITIONING:

Upon completion of the outdoor weathering periods the specimens were allowed to condition for a minimum of 24 hours at standard conditions, (i.e., atmosphere having a relative humidity of 65% ±2% and a temperature of 70°F ±2°F) before testing.

F. BREAKING STRENGTH:

After the exposure periods and standard conditioning the specimens were tested for breaking strength using a Tinius Olsen Tester with a 20,000 pound capacity scale. This testing machine is calibrated annually and is rated as having an accuracy of within 1/2 of 1%. The jaw separation speed used was four inches per minute under no load. Appendix I, Table III, lists the average breaking strength for 10 specimens per condition per exposure period per site. Computations of percent strength retention versus number of days exposed are also shown in this table.

G. TABLES AND FIGURES:

Table I lists the sample numbers and the identity of the webbing assigned to each sample number. Reference to the sample numbers only will frequently be found throughout this report.

Table II shows the amount of Langleys measured at the various exposure sites for the exposure periods shown. The total number of Langleys per sample are also shown.

Table III presents the specific breaking strength averages and the specific amount of strength retention (by percent) of the webbing samples after exposure.

Figures 1 through 14 are a graphical presentation of the breaking strength versus number of days exposed obtained from the data presented in Table III.

Figures 15 through 20 are a graphical presentation for the comparison of various samples after exposure to equal amounts of solar radiation. Plotting points were obtained from data shown in Tables II and III.

III. DISCUSSION OF WEBBING WEAVE

A. The nylon webbing used in this program was woven in accordance with the weave diagram for Type XIX of Specification MIL-W-4088B. This type of weave exposes all of the warp yarns to both the face and back surfaces of the webbing. All webbings used by the Air Force do not utilize this weave. For example, webbings manufactured under Specification MIL-W-5625 utilize a tubular weave and some webbings such as Type X and Type XIII under Specification MIL-W-4088C utilize a double plain weave with binders. All of the warp yarns in these webbings are not exposed to both sides of the webbing, i.e., warp yarns weaving on the face surface do not weave on the back surface. This means that half the total number of warp yarns are exposed on one surface of the webbing only, the other half are exposed on the opposite surface only. Consequently direct sunlight would affect only the yarns exposed to the webbing surface facing the sunlight.

B. Inasmuch as the warp yarns are the load bearing yarns in a webbing one can readily understand the importance of the webbing weave as affecting the loss in breaking strength due to direct sunlight degradation. With this in mind, the strength retention or strength loss data presented in this report is not applicable to all nylon webbings. Only the Type XIX Specification MIL-W-4088 woven from a new type yarn and/or treated with a sunlight inhibitor has been evaluated.

IV. DISCUSSION OF RESULTS

A. The breaking strength data presented in Table II shows that some of the webbings after exposure have a higher breaking strength than the unexposed webbings which were used as the control samples. This may seem immediately difficult to understand, therefore, it should be noted that 5-10% variation in the breaking strengths of webbing samples such as were used in this study is not uncommon.

B. Table II shows that the largest amount of solar radiation (Langleys) was recorded at Site B (New Mexico). Of all three exposure sites the webbings exposed at Site B showed the least amount of strength retention after exposure. This was evident regardless of the type of yarn, color, condition or treatment of the webbing used. Reference: Figures 1-12.

C. Of all the webbings evaluated the samples made from Type 300 nylon yarn, natural color, Condition U and R showed the most strength loss after exposure. This was evident at all three exposure sites. Reference: Figures 1 and 3. When the samples of this webbing were woven with the Type 330 nylon yarn or treated with catechol formaldehyde a substantial increase in strength retention after exposure was clearly noticeable. This increase in strength retention was characteristic of these samples at all exposure sites. Reference: Figures 2, 4, 9 and 10.

D. There are no natural colored nylon webbings used in aircraft overrun barriers by the Air Force. For barrier use the webbings are olive drab in color, Condition R treated, utilizing the Type 300 nylon yarn. Comparing Figure 7 with Figure 3 and Sample No. 7 with Sample No. 3 shown in Figures 15 through 20 the advantage of using olive drab color webbing instead of natural colored nylon webbings is clearly shown.

E. When the webbing such as Sample No. 7 was treated with catechol formaldehyde or made from the Type 330 nylon yarn (Reference: Table I, Samples 8 and 12) there was a very small increase in strength retention noticed. It appears that the increase in strength retention for these samples is not sufficient enough to warrant the use of catechol formaldehyde or the Type 330 nylon yarn for webbings which will be used in the olive drab color with Condition R treatment. Reference: Figures 7, 8 and 12, and Samples No. 7, 8 and 12, shown in Figures 16, 18 and 20.

F. Figures 13 and 14 show that the two Orlon webbings exhibit good resistance to weathering, but the tenacity of continuous filament Orlon being only 4-5 grams per denier prevents its use for runway barrier webbings.

V. CONCLUSIONS

A. From the data obtained the following generalized conclusions can be made.

1. Natural color nylon webbings made from Type 300 yarn and without treatment of any kind have poor strength retention after exposure to solar radiation.

2. Type 330 nylon yarn is superior in resistance to sunlight degradation than is the Type 300 nylon yarn.

3. Catechol formaldehyde is a satisfactory sunlight inhibitor for nylon webbings made from Type 300 yarn, and shows to be more effective on the natural color nylon webbings than the OD color nylon webbings.

4. Nylon webbings in an olive drab color have considerably less degradation after exposure to solar radiation than nylon webbings in the natural color.

5. Webbings made from continuous filament Orlon yarn have very good resistance to sunlight degradation.

B. Based upon the results obtained from the webbings tested in this program it is concluded that the service life of the present type of runway barriers (OD color Condition R) can be increased to 180 days in areas of extremely strong sunlight and to 360 days in areas of moderate or small amounts of sunlight by either one of the following two methods:

1. By the use of 260 denier 17 filament, Type 300 nylon yarn in the manufacture of the webbing.

2. By the use of Type 330 nylon yarn in the manufacture of the webbing.

C. The Orlon webbing showed good resistance to sunlight degradation through the 360 day exposure period, but the E. I. duPont de Nemours and Company has served notice that they have discontinued the production of the continuous filament yarn as was used in this program. Due to the poor abrasion resistance of the Orlon webbing and the fact that up to date there is no known abrasion resistant treatment that can be applied to Orlon webbing, this fiber does not appear to be suitable for use in aircraft runway barriers.

APPENDIX I

TABLE I

SAMPLE IDENTIFICATION

Sample Number	Type, Color, and Condition	Site & Sample
	Webbings Woven From Type 300 Yarn	
1	XIX, Natural, Condition-U*	A1, B1, C1
2	XIX, NAtural, Condition-U* treated with catechol formaldehyde	A2, B2, C2
3	XIX, Natural, Condition-R**	A3, B3, C3
4	XIX, Natural, Condition-R,**treated with catechol formaldehyde	A4, B4, C4
5	XIX, Olive Drab, Condition-U*	A5, B5, C5
6	XIX, Olive Drab, Condition-U,* treated with catechol formaldehyde	A6, B6, C6
7	XIX, Olive Drab, Condition-R**	A7, B7, C7
8	XIX, Olive Drab, Condition-R,**treated with catechol formaldehyde	A8, B8, C8
	Webbings Woven from Type 330 Yarn	
9	XIX, Natural, Condition-U*	A9, B9, C9
10	XIX, Natural, Condition-R**	A10, B10, C10
11	XIX, Olive Drab, Condition-U*	A11, B11, C11
12	XIX, Olive Drab, Condition-R**	A12, B12, C12
	Webbings Woven from Orlon Yarn	
13	4500 pound, Natural, Condition-U*	A13, B13, C13
14	4500 pound, Dope Dyed Black, Condition-U*	A14, B14, C14

* Not treated for abrasion
** Treated for abrasion resistance

APPENDIX I

TABLE II

EXPOSURE IN LANGLEYS

Exposure Period	Gm Cal/cm^2*			Total Langleys Per Specimen		
	Site A	Site B	Site C	Site A	Site B	Site C
15 days	5,148	9,728	1,546	105×10^4	198×10^4	31×10^4
30 days	9,975	19,452	3,093	203×10^4	395×10^4	63×10^4
45 days	14,486	28,930	5,042	294×10^4	588×10^4	102×10^4
60 days	18,435	35,712	5,900	375×10^4	726×10^4	120×10^4
90 days	25,475	52,620	6,271	518×10^4	1069×10^4	127×10^4
120 days	30,833	65,720	7,897	627×10^4	1335×10^4	160×10^4
180 days	37,859	81,930	11,730	769×10^4	1665×10^4	238×10^4
360 days	127,430	211,778	112,979	2589×10^4	4304×10^4	2296×10^4

* Langleys

APPENDIX I

Table III

AVERAGE BREAKING STRENGTHS* AND PERCENT
OF RETENTION AFTER EXPOSURE

Sample and Site	Property	Control Breaking Strength	Number of Days Exposed							
			15	30	45	60	90	120	180	360
A_1	Breaking Strength (lbs)	10170	10099	9355	8756	8413 1/	8154	6916	5540	1385
	% Retention		99.3	91.9	86.1	82.7	81.2	68.0	54.5	13.6
B_1	B.S.**	10170	9272	8835	8045	7239	6198	5559	3579	1205
	% Retention		91.2	86.9	79.1	71.2	60.9	54.7	35.2	11.8
C_1	B.S.**	10170	9762	10079	9941	9849	9874 2/	9849 3/	9197 5/	2192
	% Retention		95.9	99.1	97.7	96.9	97.2	96.9	90.4	21.5
A_2	B.S.**	10332	10258	9946	10010	9657 1/	9876	9547	9058	6337
	% Retention		99.3	96.3	96.9	93.5	95.6	92.4	87.6	61.3
B_2	B.S.**	10332	10342	10294	10353	9646	9763	9272	8456	5353
	% Retention		100.1	99.6	100.2	93.4	94.5	89.7	81.8	59.8
C_2	B.S.**	10332	10040	10049	10066	10096	10261 2/	10134 3/	9702 5/	8101
	% Retention		97.2	97.3	97.4	97.7	99.3	98.1	93.9	78.4
A_3	B.S.**	10209	10064	9580	9445	9693 1/	9318	8875	7700	2654
	% Retention		98.6	93.8	92.5	94.9	91.3	86.9	75.4	26.0
B_3	B.S.**	10209	9848	8986	8582	8551	8381	7781	5698	1815
	% Retention		96.5	88.0	84.1	83.8	82.1	76.2	58.1	17.7
C_3	B.S.**	10209	10050	10164	10095	10051	10044 2/	10162 3/	9672 5/	4976
	% Retention		98.4	99.6	98.9	98.5	98.4	99.5	94.7	49.0
A_4	B.S.**	10688	10314	9870	9852	9779 1/	9906	9469	8966 4/	5900
	% Retention		96.5	92.3	92.2	91.5	92.7	88.6	83.9	55.2
B_4	B.S.**	10688	10283	9797	9911	9725	9283	8841	8192	4715
	% Retention		96.2	91.7	92.7	90.9	86.9	82.7	76.6	44.1
C_4	B.S.**	10688	10152	10363	10348	10342	10348 2/	10235 3/	9698 5/	7789
	% Retention		94.9	96.9	96.8	96.8	96.8	95.8	90.7	72.8
A_5	B.S.**	10207	10142	10137	10195	10241 1/	10216	9979	9375	5788
	% Retention		99.4	99.3	99.9	100.3	100.1	97.2	91.8	56.7
B_5	B.S.**	10207	10142	10126	10159	10087	9816	9622	8354	4422
	% Retention		99.4	99.2	99.5	98.8	96.2	94.3	81.8	43.3
C_5	B.S.**	10207	9924	10010	9979	9953	10100 2/	9929	9372 5/	8350
	% Retention		97.2	98.1	97.8	97.5	98.9	97.3	91.8	81.8
A_6	B.S.**	10149	10088	10014	9725	9635 1/	10087	9399	9176	6853
	% Retention		99.4	98.7	95.8	94.9	99.4	92.6	90.4	67.5
B_6	B.S.**	10149	10701	10368	9964	10139	9762	9427	8651	5595
	% Retention		105.4	102.1	98.2	99.9	96.2	92.8	85.2	55.0
C_6	B.S.**	10149	10377	10119	10338	10237	10329 2/	10139 3/	9468 5/	8443
	% Retention		102.2	99.7	101.9	100.9	101.8	99.9	93.3	83.2
A_7	B.S.**	10175	10395	10078	9986	9864 1/	10087	9713	9219	6412
	% Retention		102.2	99.0	98.1	96.9	99.1	95.5	90.6	63.0
B_7	B.S.**	10175	10122	9921	9906	9951	9677	9602	8461	4798
	% Retention		99.5	97.5	97.4	97.8	95.1	94.4	83.2	47.1
C_7	B.S.**	10175	10270	10122	10032	9945	10131 2/	10098	9791	8395
	% Retention		100.9	99.5	98.6	97.7	99.6	99.2	96.2	82.5
A_8	B.S.**	10518	10378	9918	10020	9723 1/	10015	9783	9612	7154
	% Retention		98.7	94.3	95.3	92.5	95.2	93.0	91.4	68.0
B_8	B.S.**	10518	10229	10003	10004	10000	9702	9496	8024	6038
	% Retention		97.3	95.1	95.1	95.1	92.3	90.3	76.3	57.4
C_8	B.S.**	10518	10187	10118	10204	10274	10284 2/	10020 3/	9879	8821
	% Retention		96.9	96.2	97.0	97.7	97.8	95.3	93.9	83.8
A_9	B.S.**	10199	9837	9833	9940	10001 1/	9874	9609	9079 4/	5160
	% Retention		96.5	96.4	97.5	98.1	96.8	94.2	89.0	50.6
B_9	B.S.**	10199	9927	9733	9995	9716	9465	9279	8689	5830
	% Retention		97.3	95.4	97.9	95.3	92.8	90.9	85.2	57.2
C_9	B.S.**	10199	9969	9756	9879	9746	9927 2/	9857 3/	9484	8517
	% Retention		97.7	95.7	96.9	95.6	97.3	96.6	92.9	83.5
A_{10}	B.S.**	10129	9765	9848	9949	9708 1/	9779	9537	9347	6056
	% Retention		96.4	97.2	98.2	95.8	96.5	94.2	92.3	59.8
B_{10}	B.S.**	10129	9948	9826	9804	9919	9864	9574	9322	6239
	% Retention		98.2	97.0	96.8	97.9	97.4	94.5	92.0	61.6
C_{10}	B.S.**	10129	9948	9945	10098	9891	9937 2/	9745 3/	9544	8949
	% Retention		98.2	98.2	99.7	97.7	98.1	96.2	94.2	88.3
A_{11}	B.S.**	9904	9800	10087	10216	9971 1/	9718	9669	9317 4/	7456
	% Retention		98.9	101.8	103.1	100.7	98.1	97.6	94.0	75.3
B_{11}	B.S.**	9904	10291	10070	10134	10009	9715	9512	8676	5178
	% Retention		103.9	101.6	102.3	101.0	98.1	96.0	87.6	52.3
C_{11}	B.S.**	9904	10029	9887	10092	9896	9878 2/	9743	9480	9186
	% Retention		101.2	99.8	101.8	99.9	99.7	98.4	95.7	92.7
A_{12}	B.S.**	10147	10204	9844	9700	9771 1/	9602	9617	9204	6890
	% Retention		100.6	97.0	95.6	96.3	94.6	94.8	90.7	67.9
B_{12}	B.S.**	10147	9839	9732	9647	9433	9140	9199	8221	4718
	% Retention		96.9	95.9	95.1	92.9	90.1	90.7	81.0	46.5
C_{12}	B.S.**	10147	9881	9915	9732	9798	9663 2/	9874 3/	9452	8719
	% Retention		97.4	97.7	95.9	96.6	95.2	97.3	93.1	85.9
A_{13}	B.S.**	4917	4824	4734	4956	5013 1/	4352	4749	4480	4113
	% Retention		98.1	96.3	100.8	101.9	88.5	96.6	91.1	83.6
B_{13}	B.S.**	4917	4839	4576	4708	4806	4888	4919	4952	4254
	% Retention		98.4	93.1	95.7	97.7	99.4	100.0	100.7	86.5
C_{13}	B.S.**	4917	4882	5005	5059	5018	5034 2/	4885 3/	5055	4930
	% Retention		99.3	101.8	102.9	102.1	102.4	99.3	102.8	100.3
A_{14}	B.S.**	4646	4689	4716	4702	4657 1/	4114***	4575	4453	4350
	% Retention		100.9	101.5	101.2	100.2	88.5	98.5	95.8	93.6
B_{14}	B.S.**	4646	4657	4705	4668	4683	4703	4653	4687	4256
	% Retention		100.2	101.3	100.5	100.8	101.2	100.2	100.9	91.6
C_{14}	B.S.**	4646	4574	4724	4658	4654	4688 2/	4709 3/	4737	4624
	% Retention		98.5	101.7	100.3	100.2	100.9	101.4	101.9	99.5

* Average of ten specimens
** Break Strength, lbs
*** Samples had an abraded strip across the width caused by flapping against exposure racks

1/ 61 days exposed
2/ 89 days exposed
3/ 122 days exposed
4/ 194 days exposed
5/ 165 days exposed

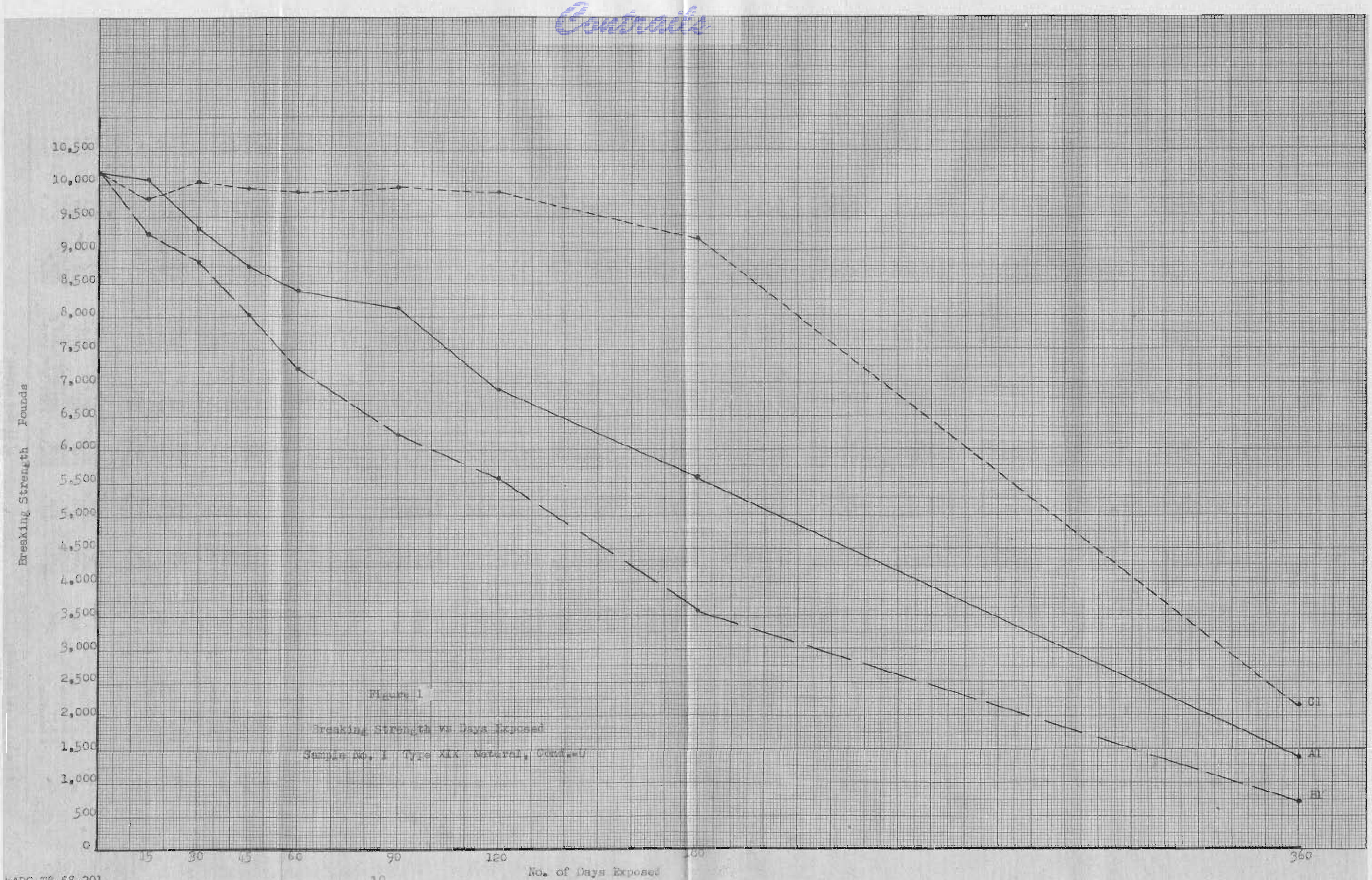

Figure 1

Breaking Strength vs Days Exposed

Sample No. 1 Type XIX Natural, Cond.-U

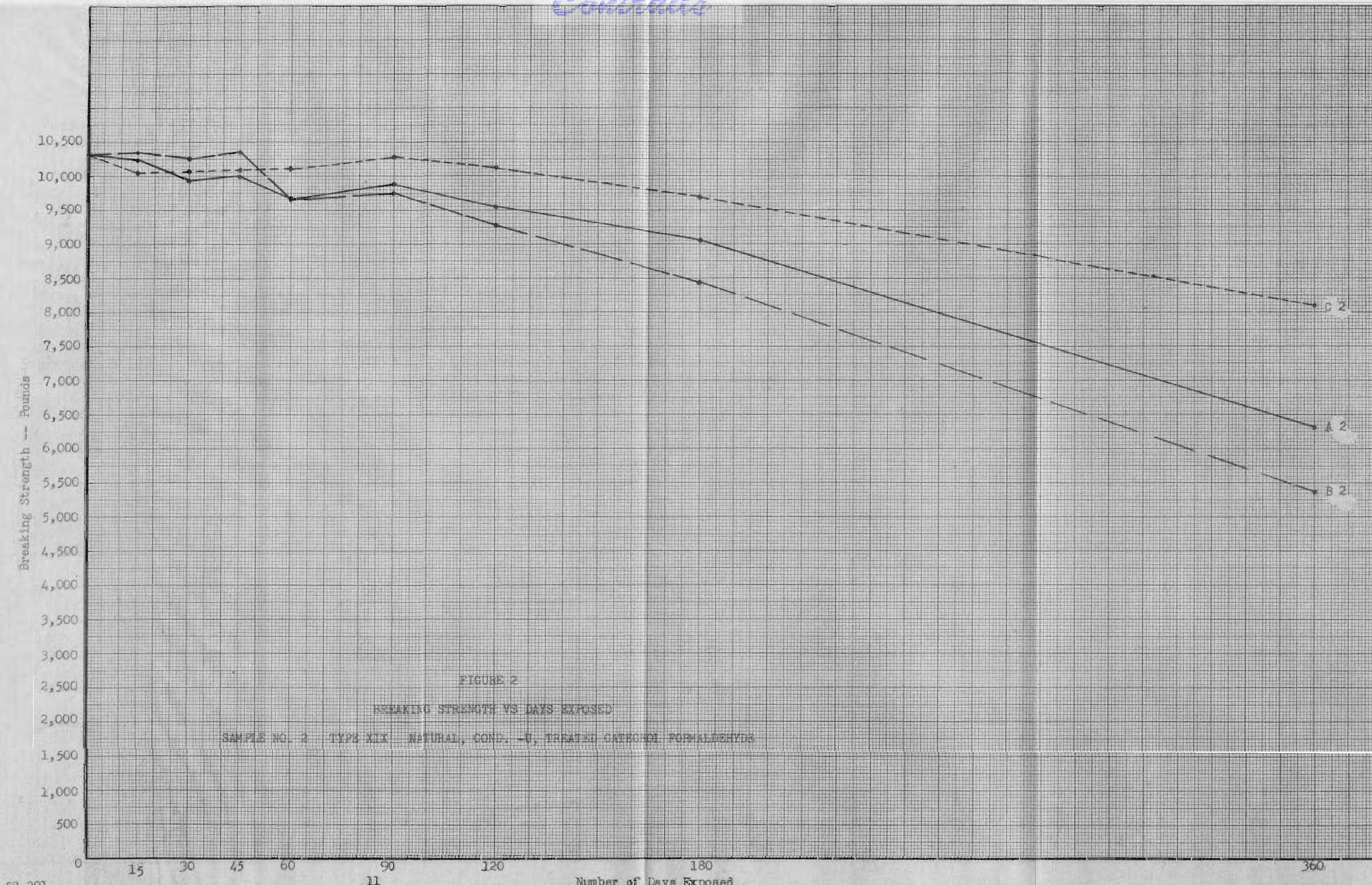

FIGURE 2

BREAKING STRENGTH VS DAYS EXPOSED

SAMPLE NO. 2 TYPE XIX NATURAL, COND. -U, TREATED CATECHOL FORMALDEHYDE

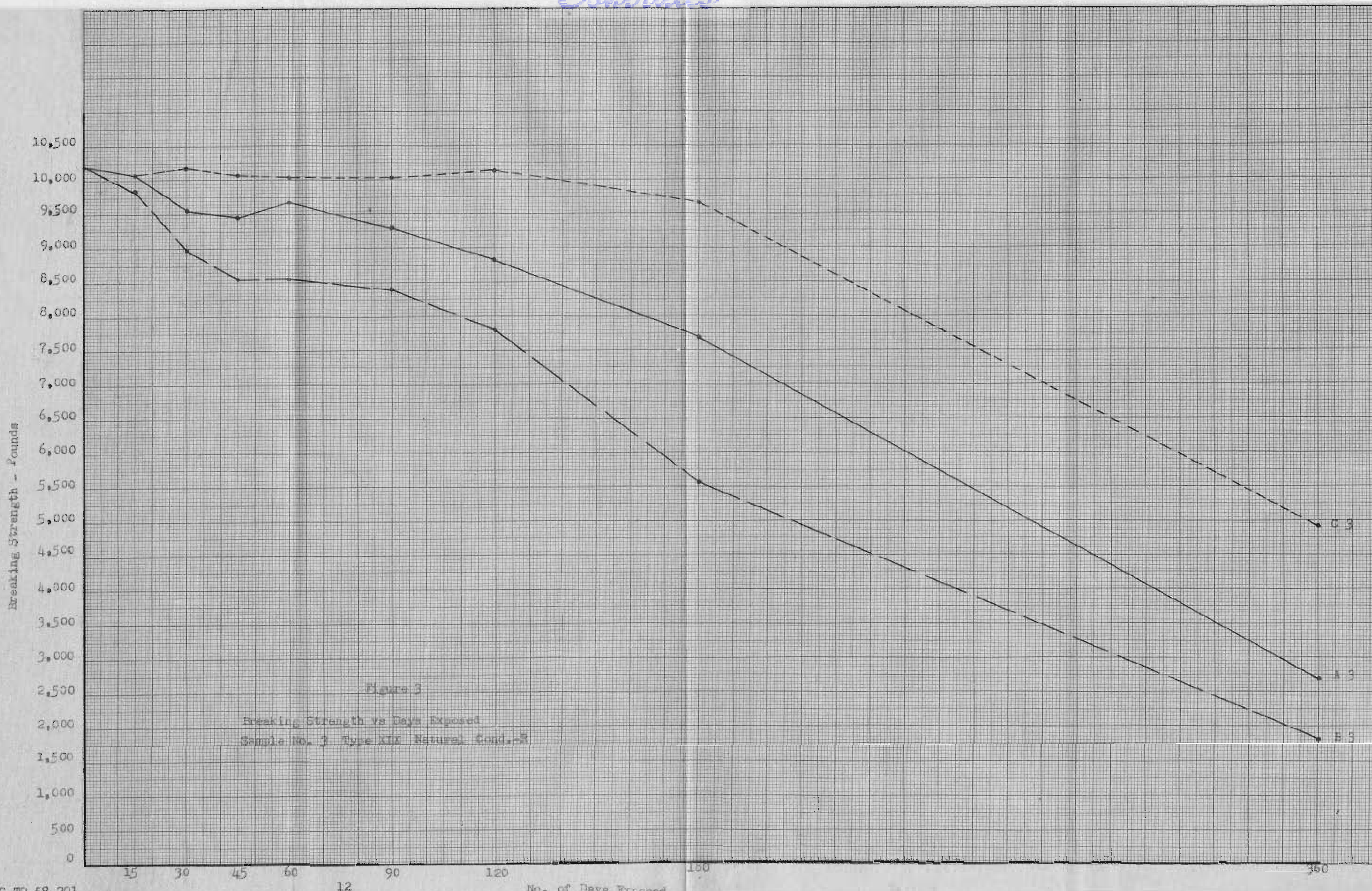

Figure 3

Breaking Strength vs Days Exposed

Sample No. 3 Type XIX Natural Cond.-R

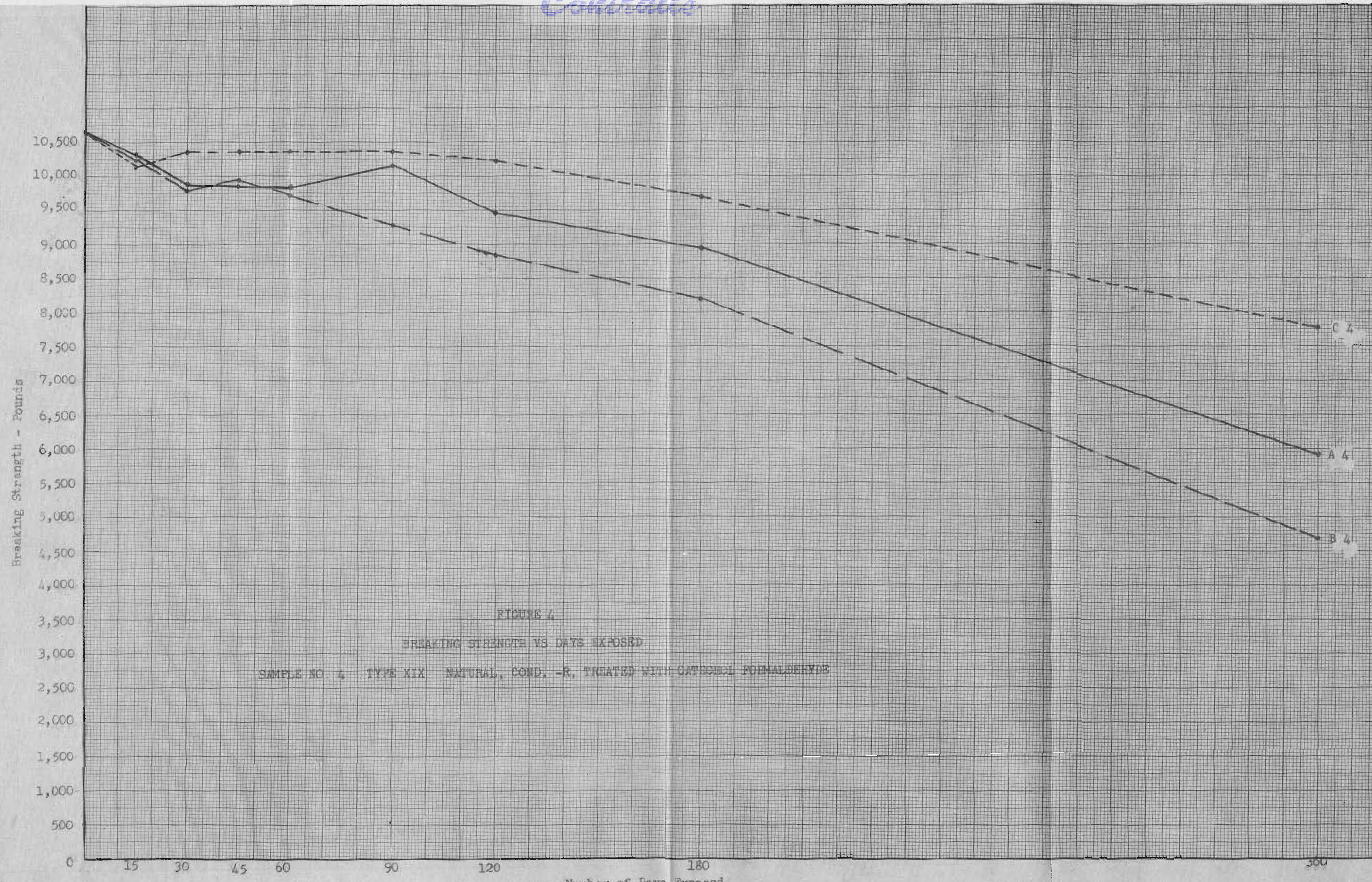

FIGURE 4

BREAKING STRENGTH VS DAYS EXPOSED

SAMPLE NO. 4 TYPE XIX NATURAL, COND. -R, TREATED WITH CATECHOL FORMALDEHYDE

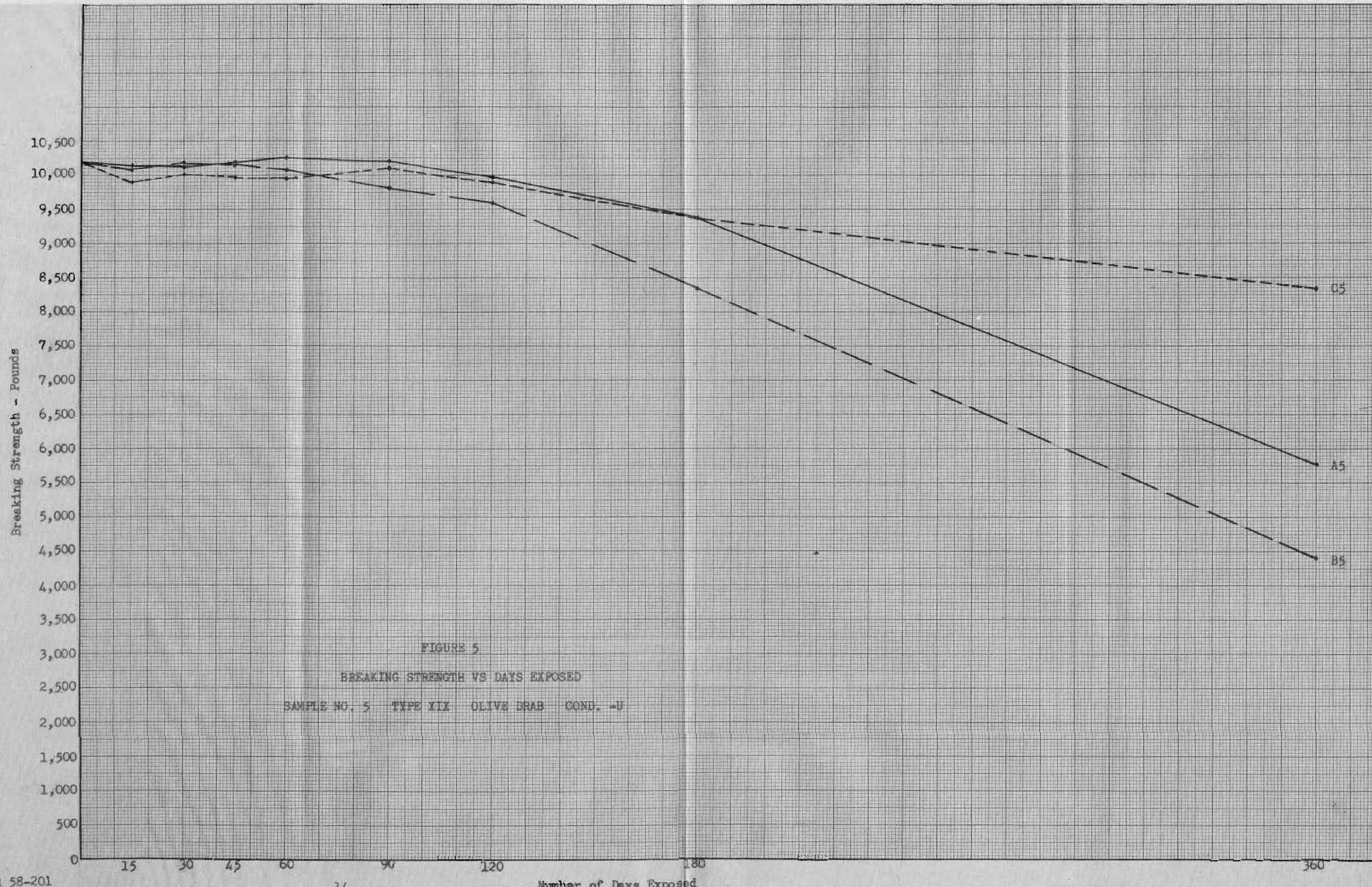

FIGURE 5

BREAKING STRENGTH VS DAYS EXPOSED

SAMPLE NO. 5 TYPE XIX OLIVE DRAB COND. -U

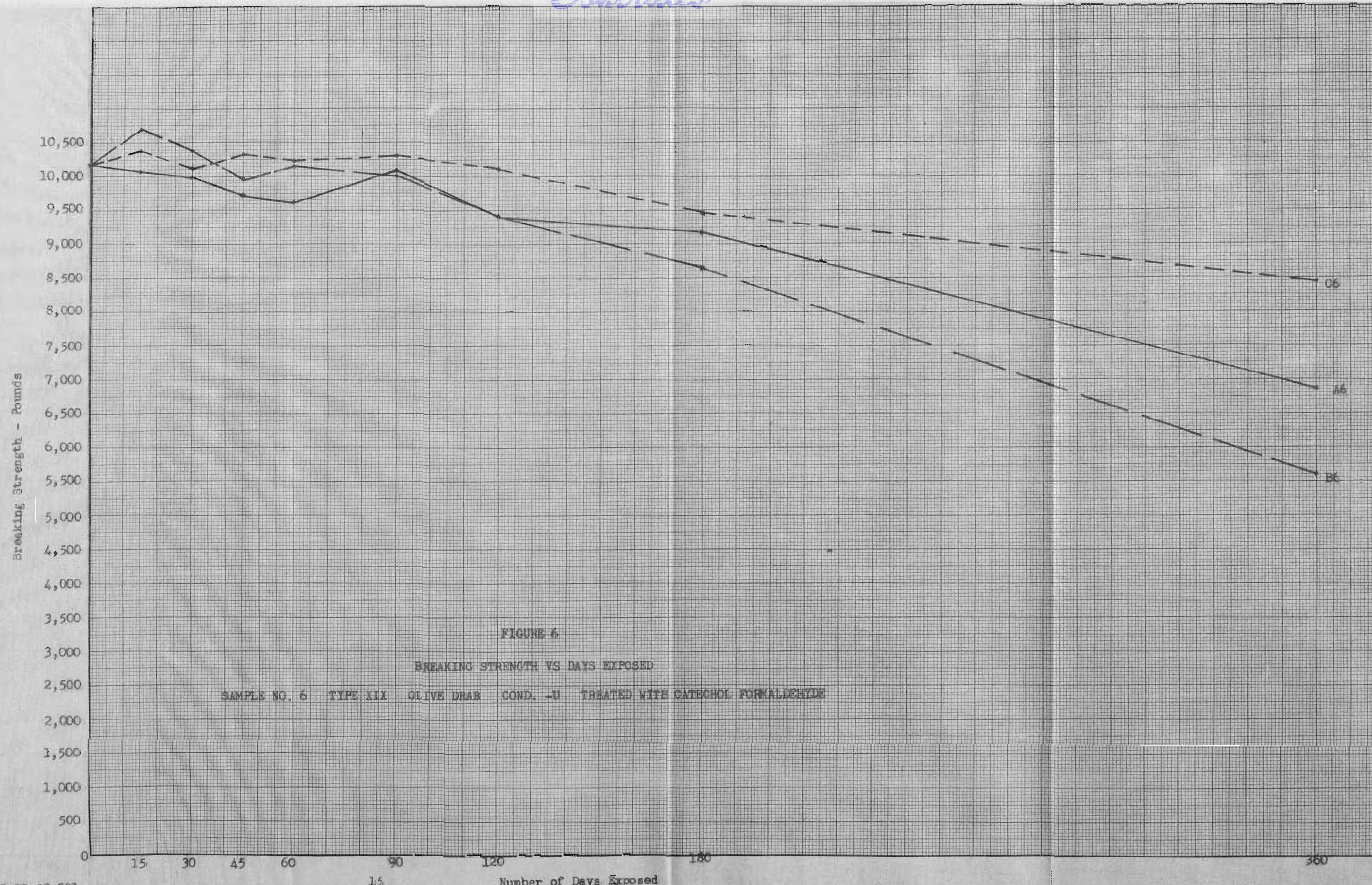

FIGURE 6

BREAKING STRENGTH VS DAYS EXPOSED

SAMPLE NO. 6 TYPE XIX OLIVE DRAB COND. -U TREATED WITH CATECHOL FORMALDEHYDE

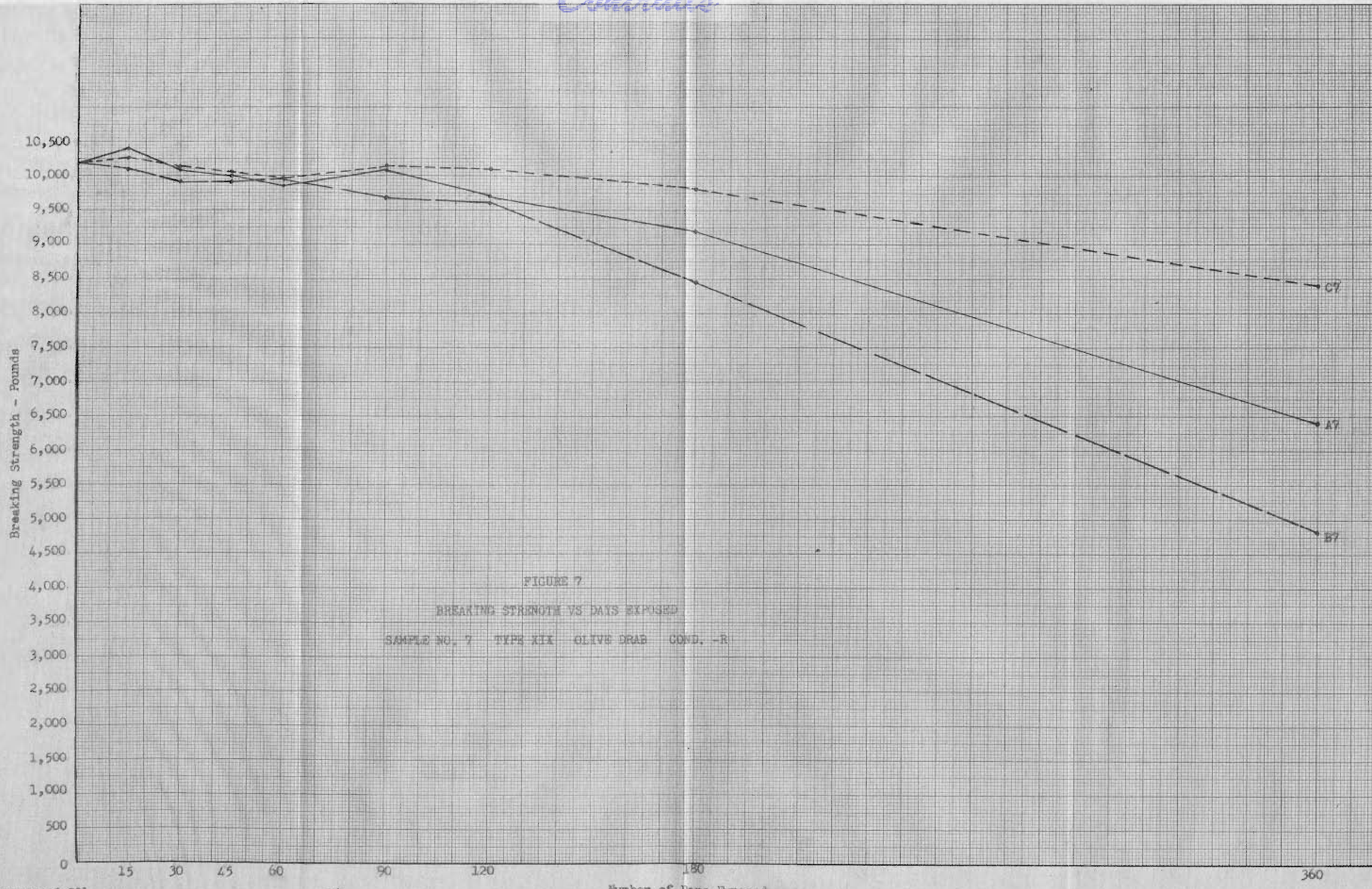

FIGURE 7

BREAKING STRENGTH VS DAYS EXPOSED

SAMPLE NO. 7 TYPE XIX OLIVE DRAB COND. -R

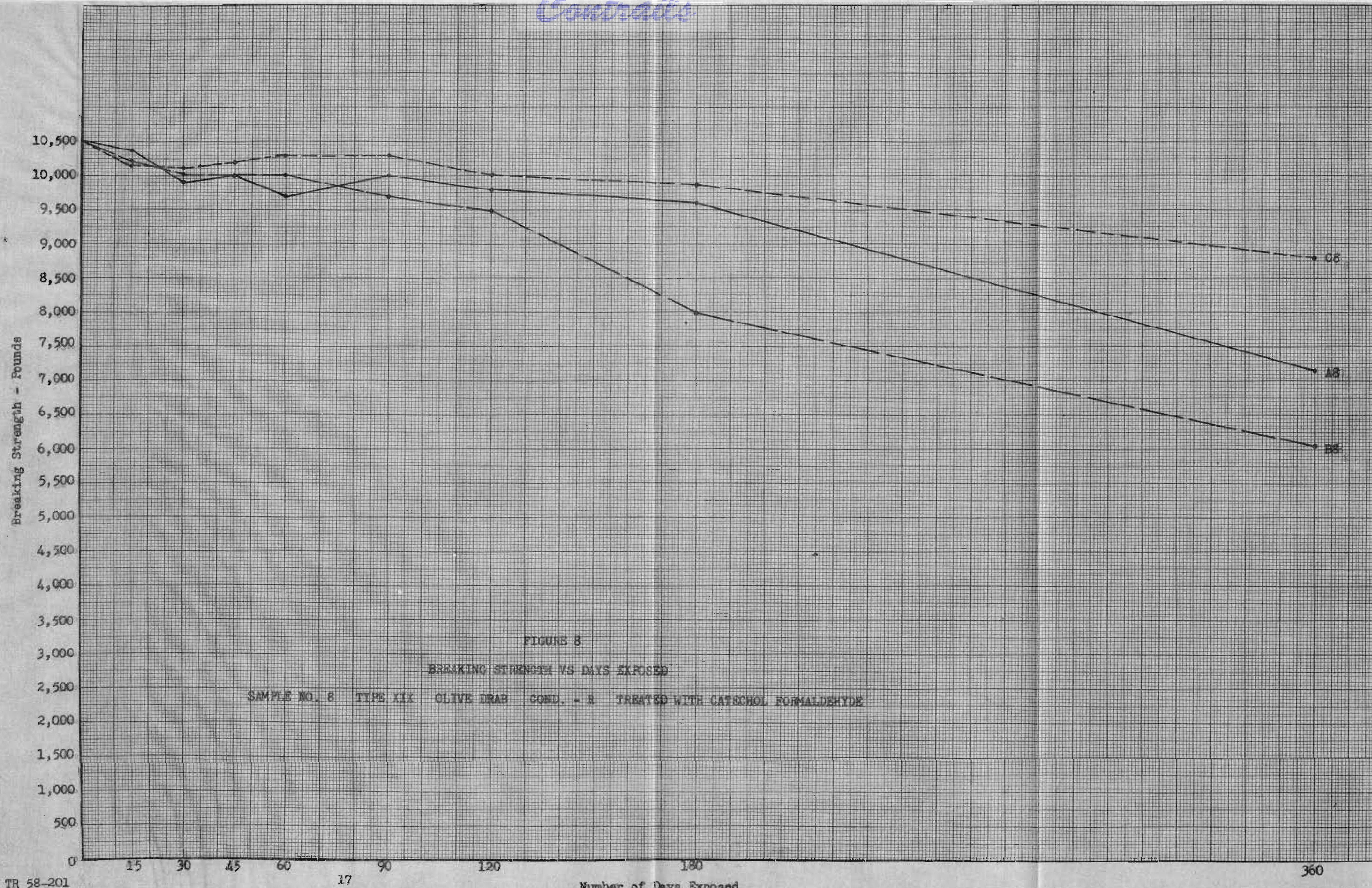

FIGURE 8

BREAKING STRENGTH VS DAYS EXPOSED

SAMPLE NO. 8 TYPE XIX OLIVE DRAB COND. - R TREATED WITH CATECHOL FORMALDEHYDE

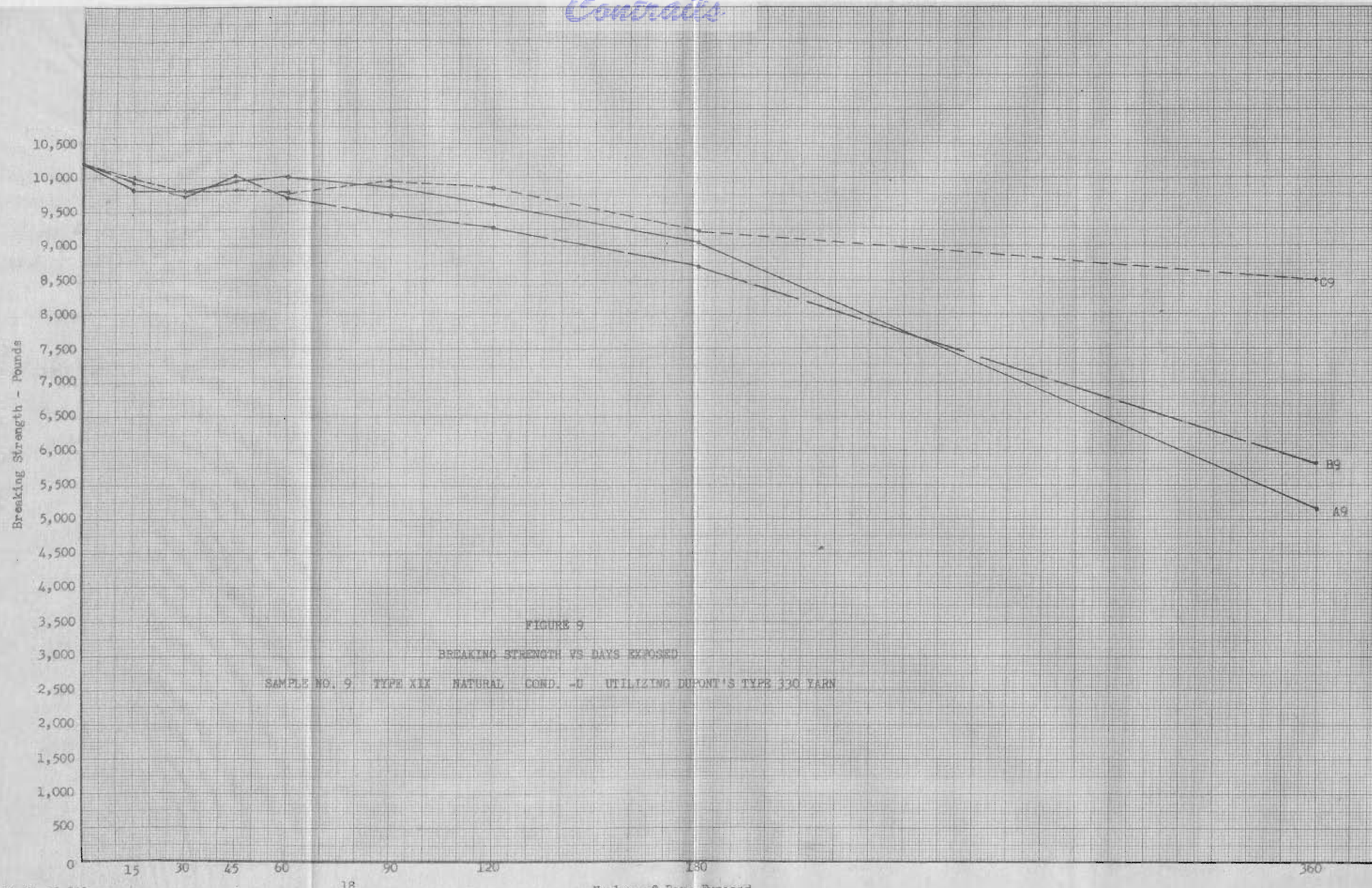

FIGURE 9

BREAKING STRENGTH VS DAYS EXPOSED

SAMPLE NO. 9 TYPE XIX NATURAL COND. -D UTILIZING DUPONT'S TYPE 330 YARN

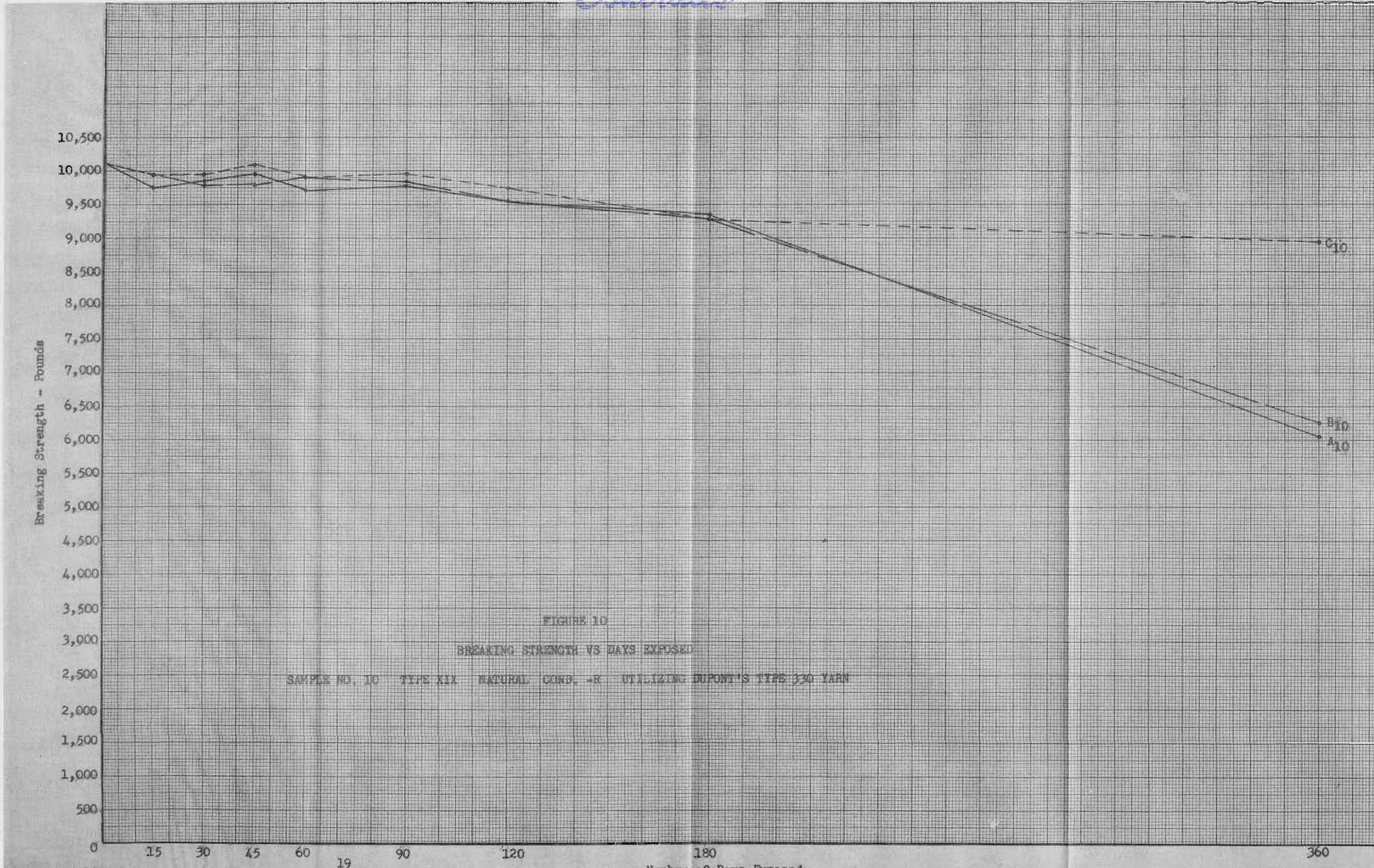

FIGURE 10

BREAKING STRENGTH VS DAYS EXPOSED

SAMPLE NO. 10 TYPE XIX NATURAL COND. -R UTILIZING DUPONT'S TYPE 330 YARN

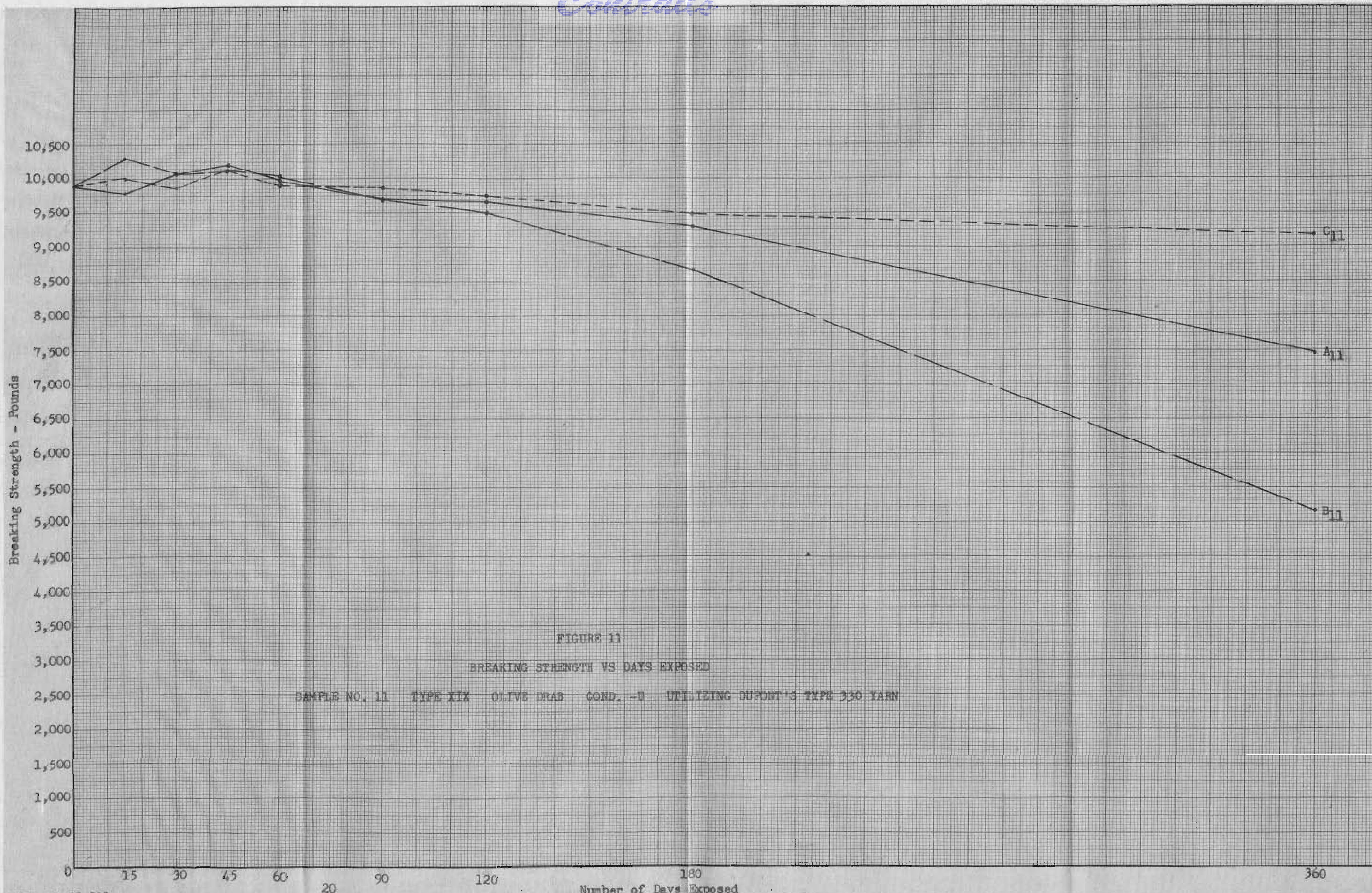

FIGURE 11

BREAKING STRENGTH VS DAYS EXPOSED

SAMPLE NO. 11 TYPE XIX OLIVE DRAB COND. -U UTILIZING DUPONT'S TYPE 330 YARN

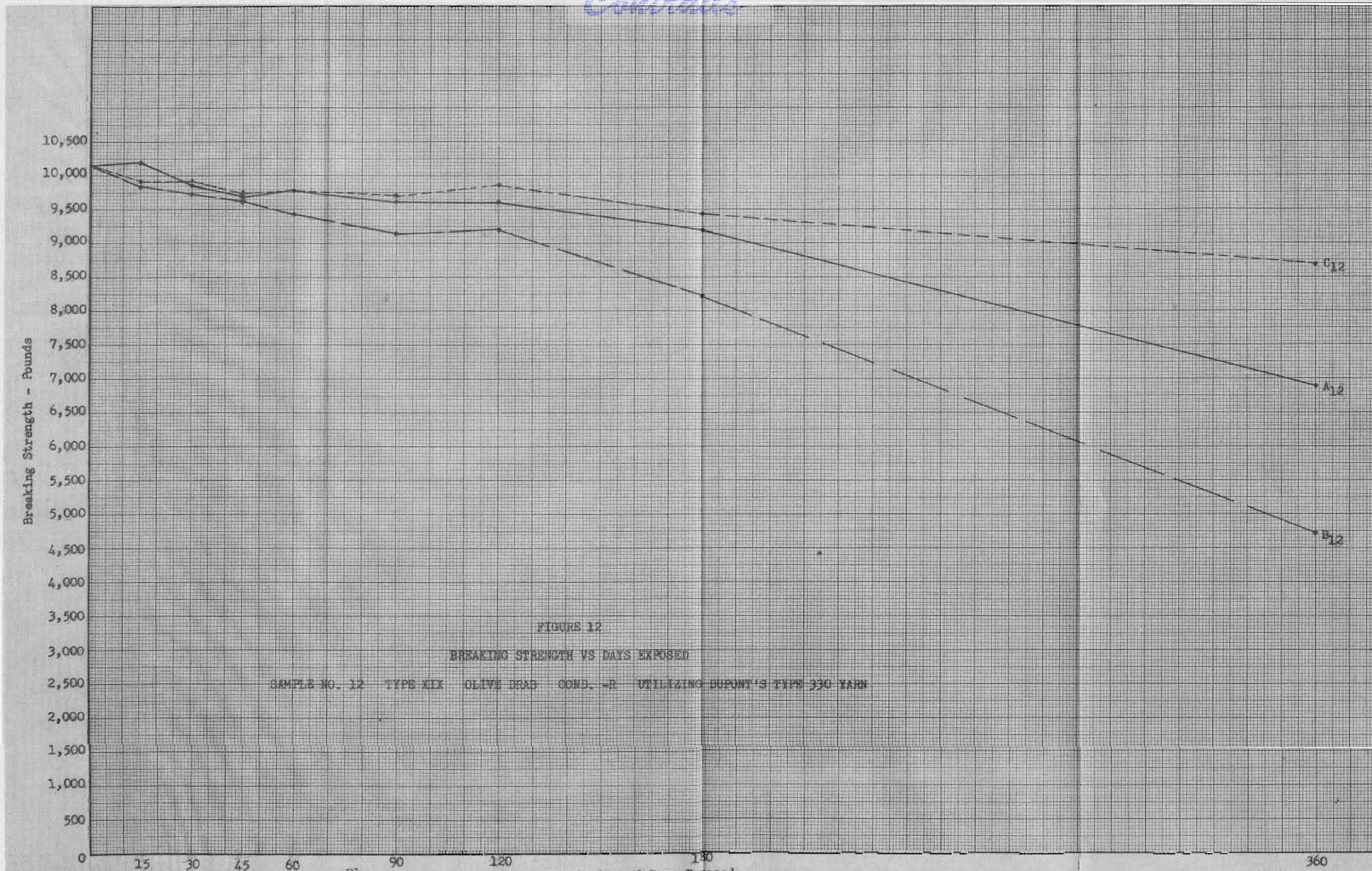

FIGURE 12

BREAKING STRENGTH VS DAYS EXPOSED

SAMPLE NO. 12 TYPE XIX OLIVE DRAB COND. -R UTILIZING DUPONT'S TYPE 330 YARN

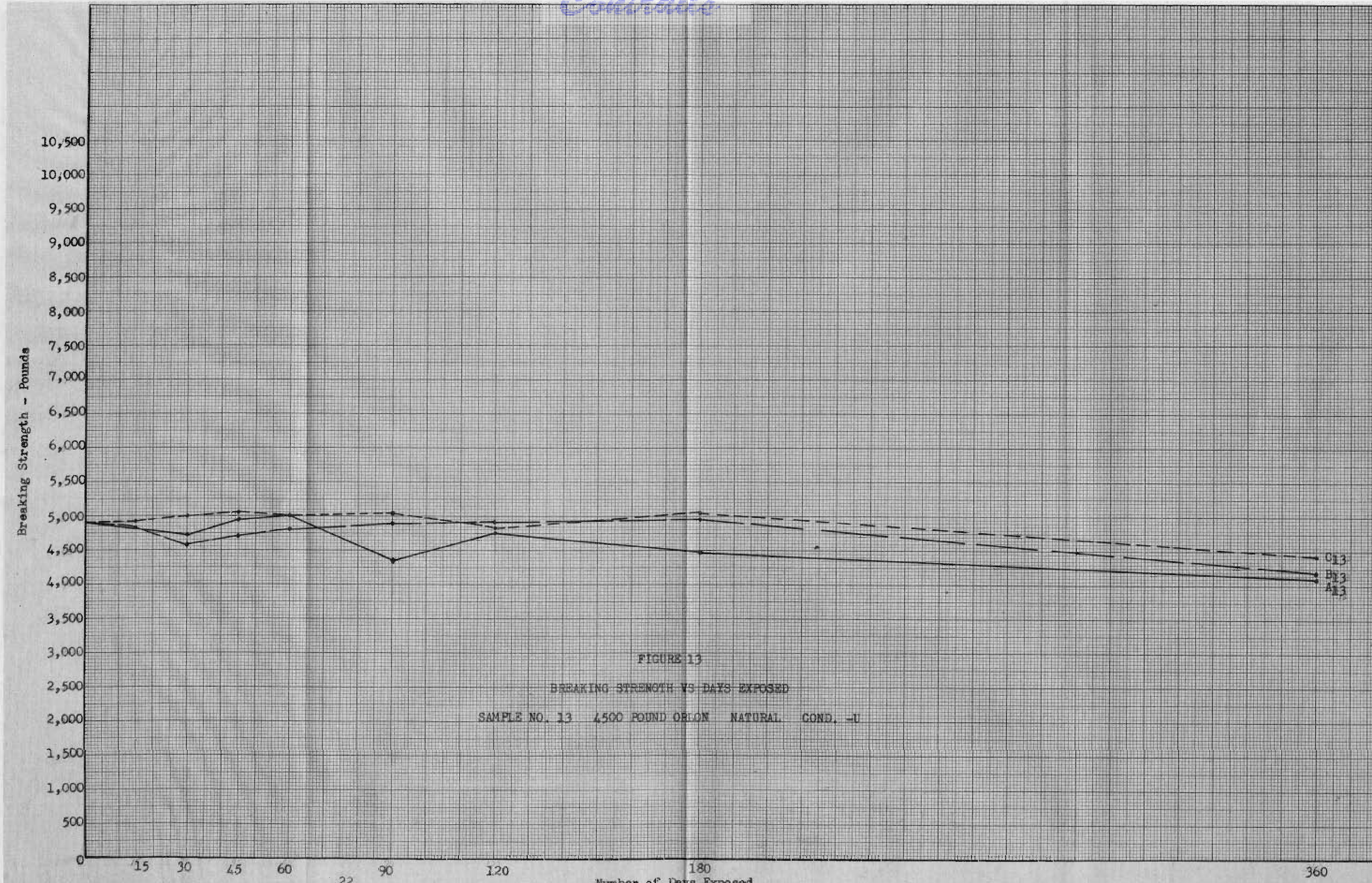

FIGURE 13

BREAKING STRENGTH VS DAYS EXPOSED

SAMPLE NO. 13 4500 POUND ORLON NATURAL COND. -U

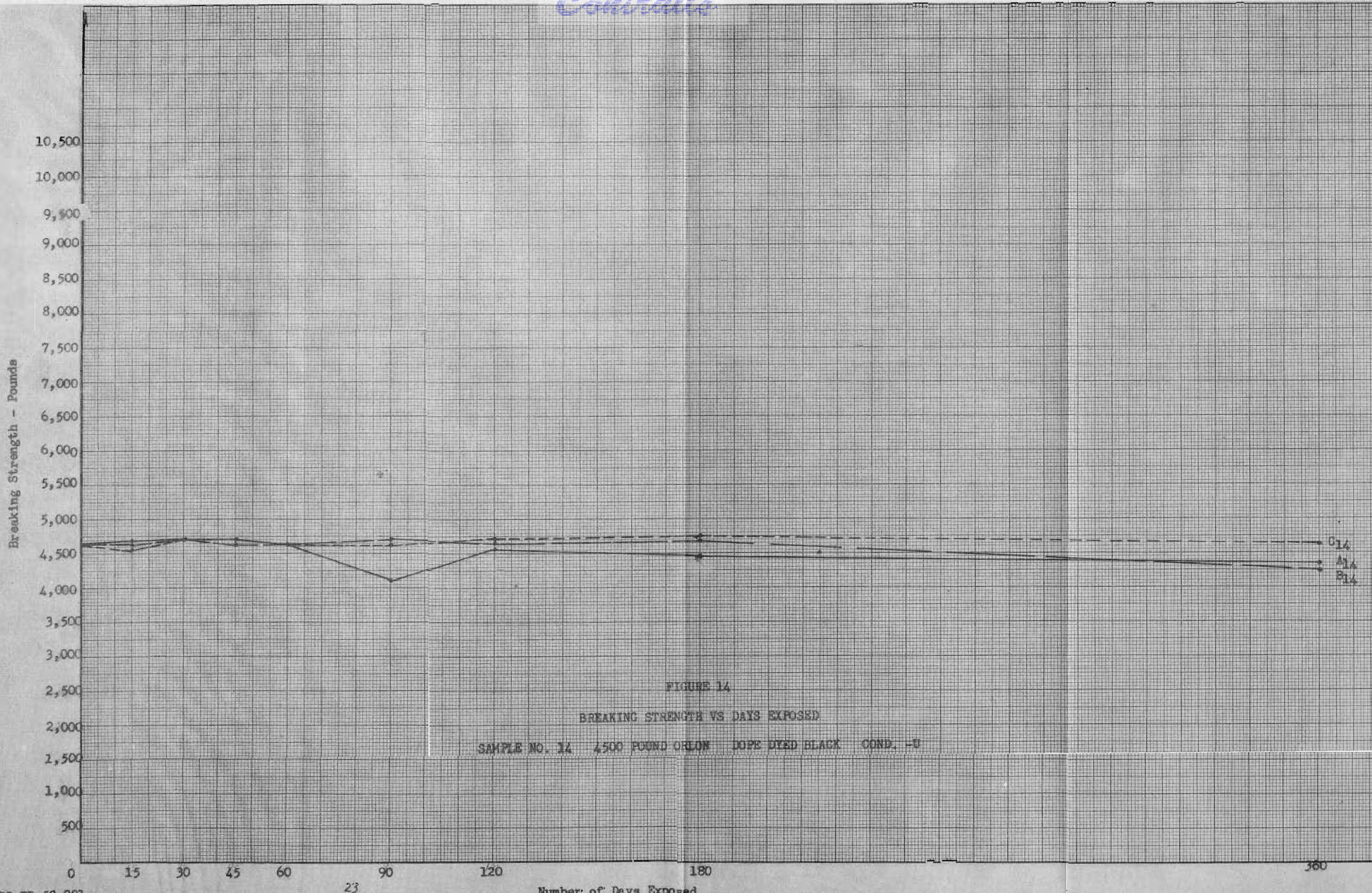

FIGURE 14

BREAKING STRENGTH VS DAYS EXPOSED

SAMPLE NO. 14 4500 POUND ORLON DOPE DYED BLACK COND. -U

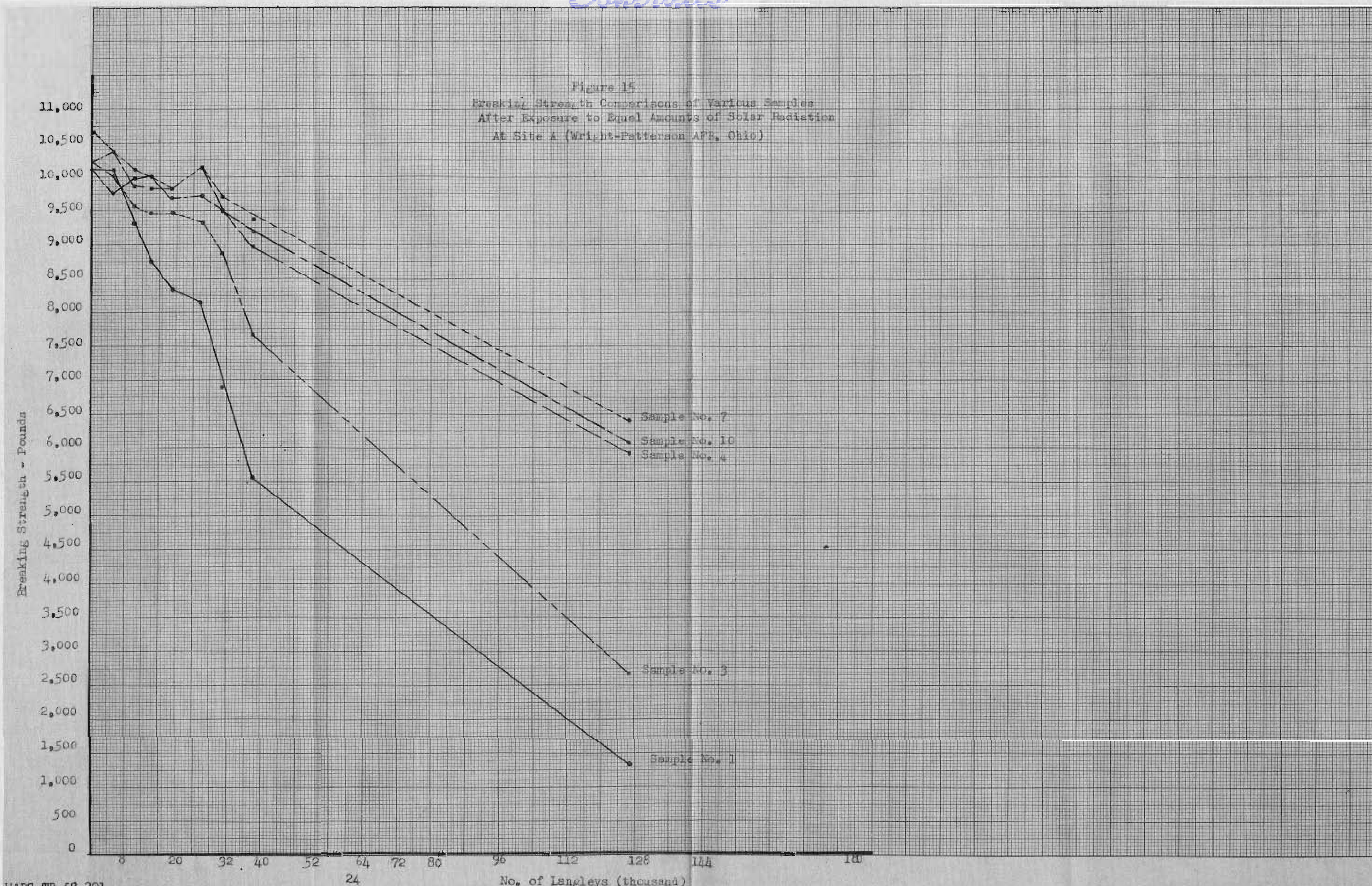

Figure 15
Breaking Strength Comparisons of Various Samples
After Exposure to Equal Amounts of Solar Radiation
At Site A (Wright-Patterson AFB, Ohio)

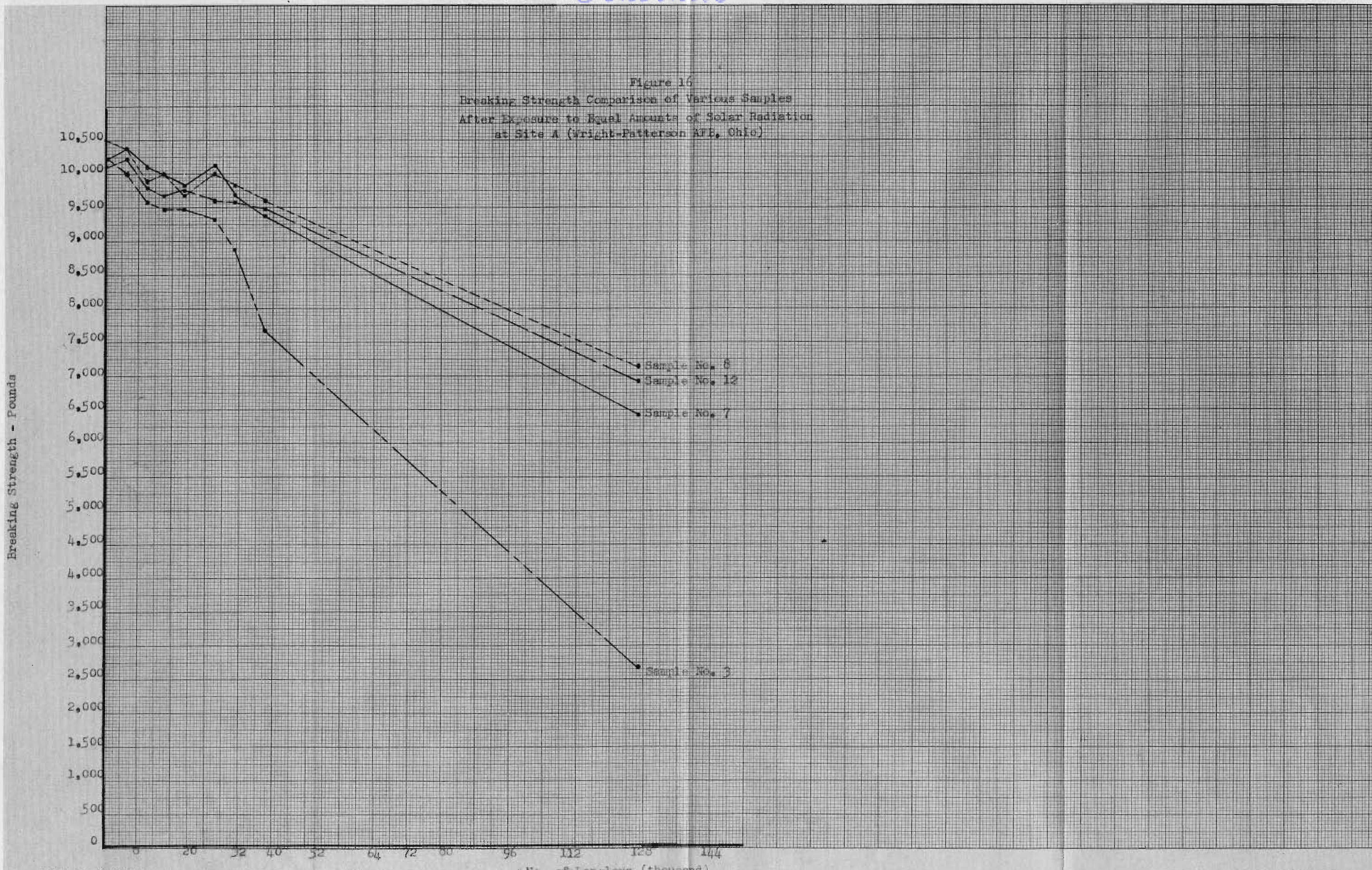

Figure 16
Breaking Strength Comparison of Various Samples
After Exposure to Equal Amounts of Solar Radiation
at Site A (Wright-Patterson AFB, Ohio)

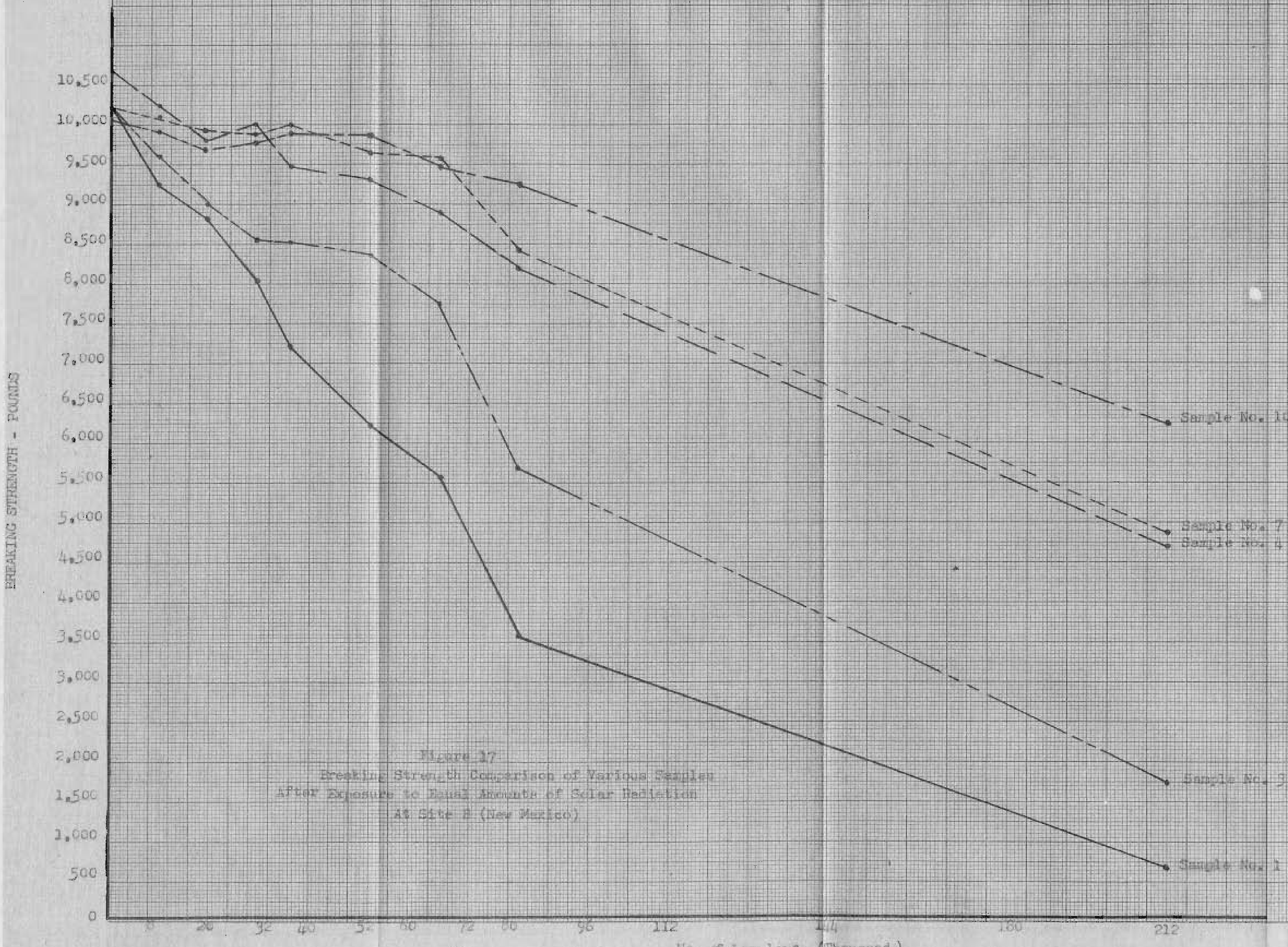

Figure 17
Breaking Strength Comparison of Various Samples
After Exposure to Equal Amounts of Solar Radiation
At Site 2 (New Mexico)

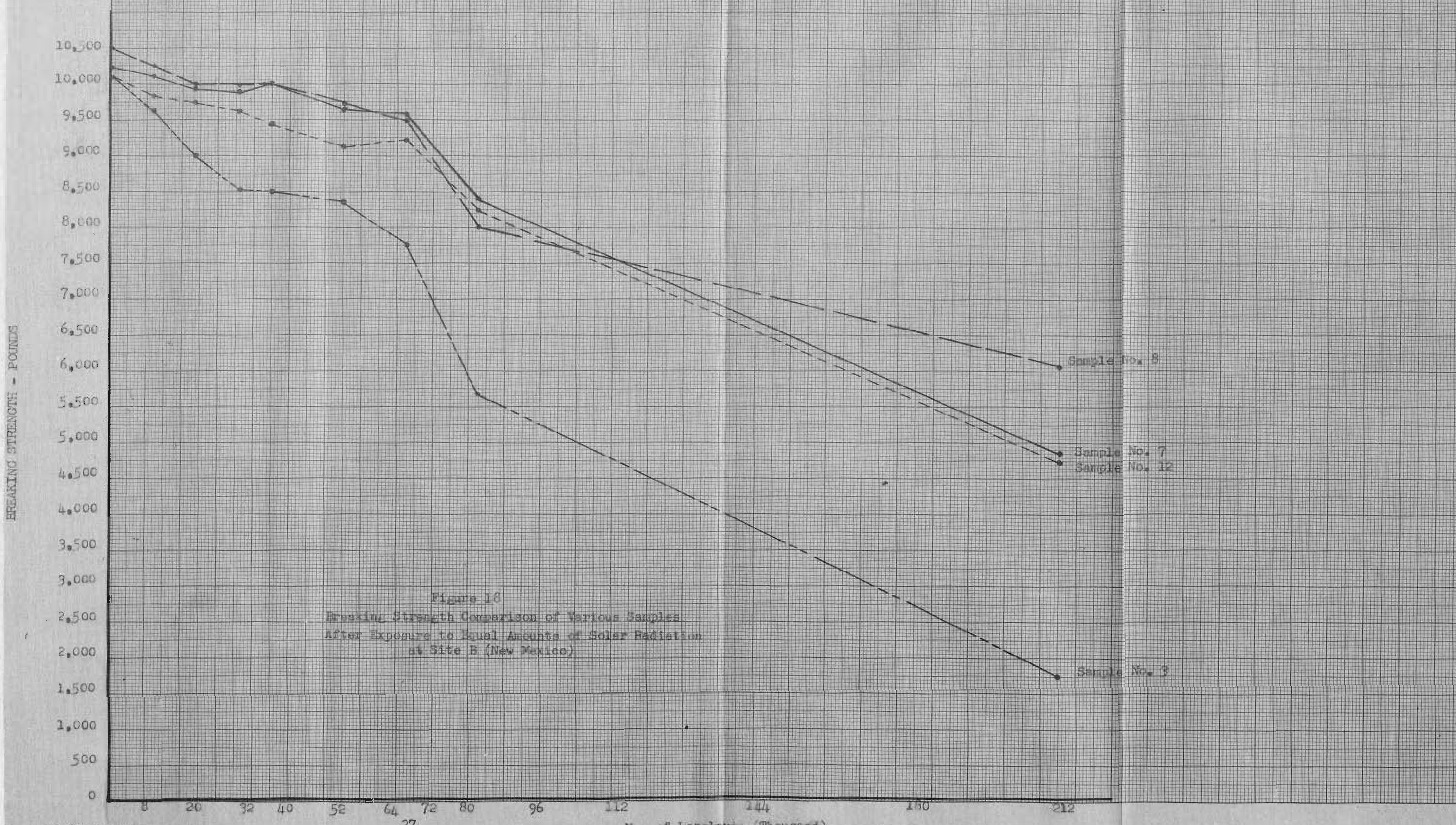

Figure 18
Breaking Strength Comparison of Various Samples
After Exposure to Equal Amounts of Solar Radiation
at Site B (New Mexico)

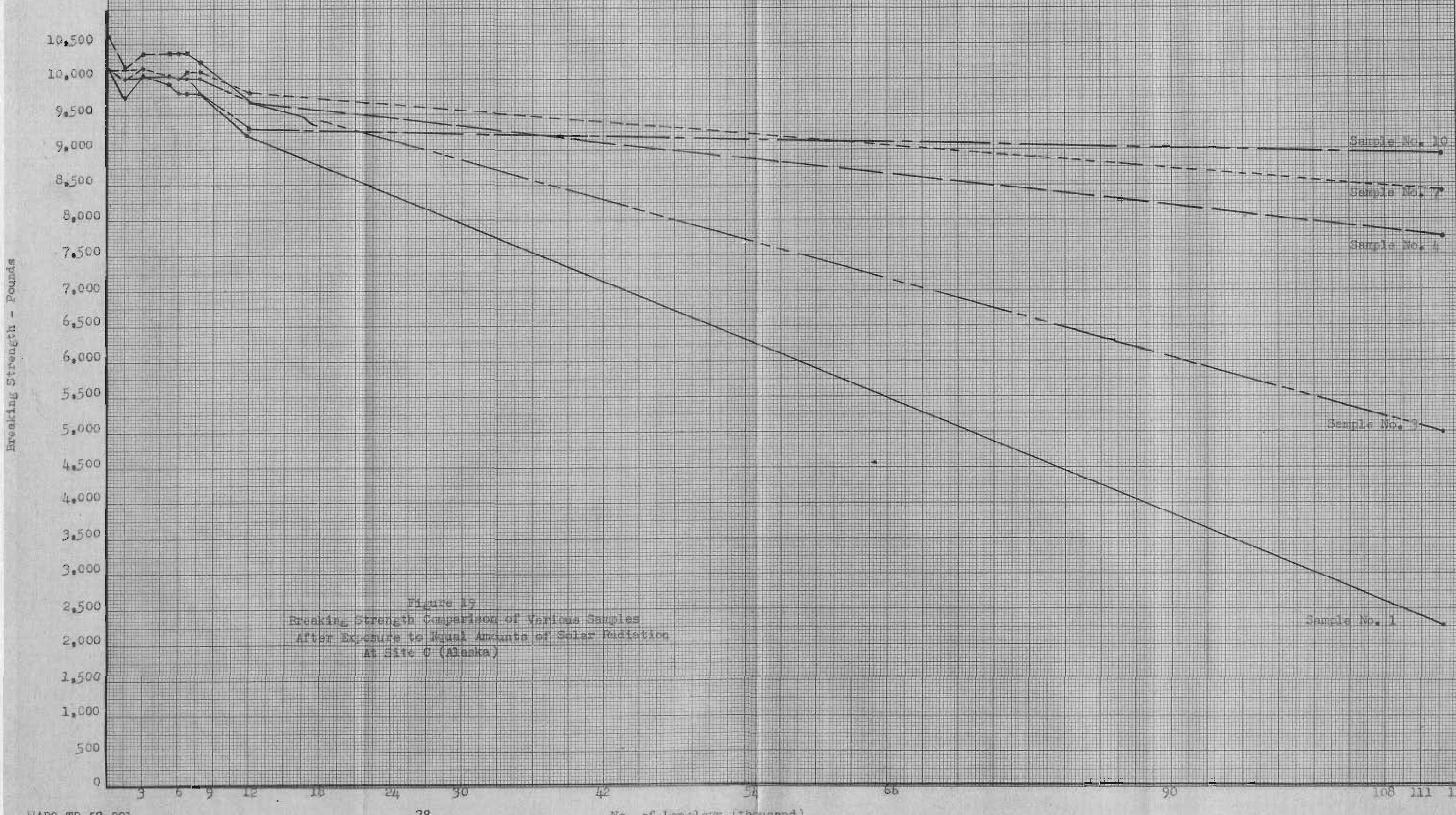

Figure 19
Breaking Strength Comparison of Various Samples
After Exposure to Equal Amounts of Solar Radiation
At Site C (Alaska)

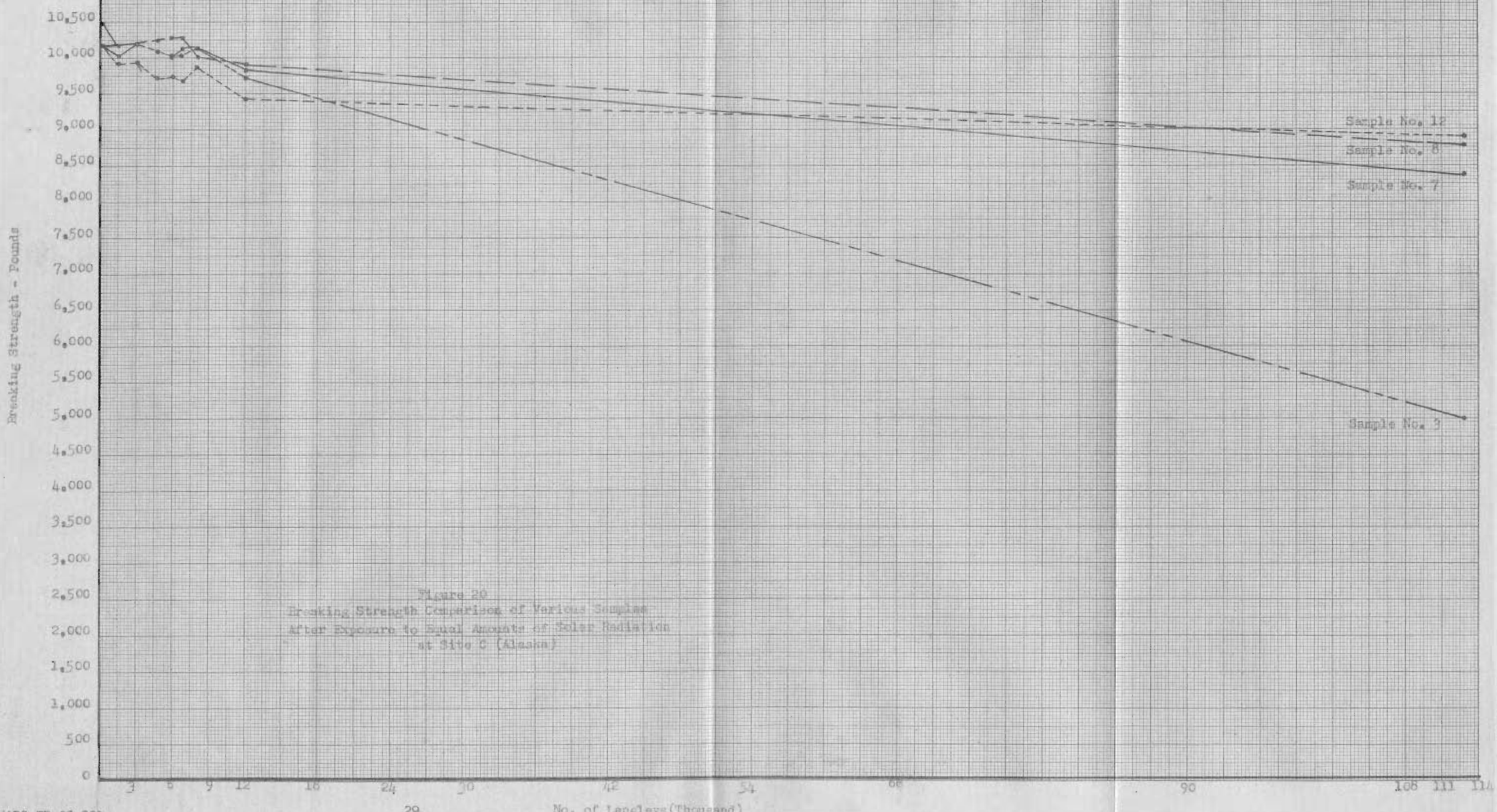

Figure 20
Breaking Strength Comparison of Various Samples
After Exposure to Equal Amounts of Solar Radiation
at Site C (Alaska)