WADC TECHNICAL REPORT 52-283
PART 3

AIR PERMEABILITY OF PARACHUTE CLOTHS

Part 3. Effect of Loading on Elastic Properties of Parachute Cloths Without Air Flow

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Carpenter Litho & Prtg. Co., Springfield, O.
300 - 21 April 1955

FOREWORD

This report was prepared by the Engineering Experiment Station of the Georgia Institute of Technology, under USAF Contract No. AF 33 (038)-15624. The contract was initiated under Task No. 73201, "Textile Materials for Parachutes", formerly RDO No. 612-12, "Textiles for High Speed Parachutes", and was administered under the direction of the Materials Laboratory, Directorate of Research, Wright Air Development Center, with Mr. Jack H. Ross acting as project engineer.

ABSTRACT

The effects of biaxial tension loads on fabric samples of nylon, Orlon, and Dacron have been studied. The biaxial-fabric-tension-testing machine, used in these tests, was designed and constructed at Georgia Tech.

It was the purpose of these studies to determine the elastic characteristics of selected nylon, Orlon, and Dacron parachute-type cloth under conditions of no air flow. Also, the effect of high temperatures (+140°F) and low temperatures (-14°F) on elastic properties was determined, using plain-weave samples of nylon, Orlon, and Dacron cloth. The data obtained from these tests were used in conjunction with the low- and high-pressure air-permeability studies reported in AF Technical Reports 52-283, Parts 1, 2, and 4.

Variations in temperature and humidity, in the ranges studied, had a marked effect on the elastic properties of the fabrics. However, as humidity was lowered, the elasticity and the tenacity of the fabrics decreased.

Dacron was found to be somewhat more elastic than Orlon, particularly at the lower temperatures.

The number of picks per inch and the weave pattern (plain, twill, and satin) do not markedly affect the elastic properties.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER

M. R. Whitmore

M. R. WHITMORE
Technical Director
Materials Laboratory
Directorate of Research

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I. INTRODUCTION

A. Statement of the Problem

The work presented here is a continuation of the studies reported in USAF Technical Reports No. WADC 52-283, Parts 1 and 2. The studies reported here in Part 3 are for the purpose of determining the elastic properties of nylon, Orlon, and Dacron parachute fabrics under the conditions of simultaneously applied biaxial tension load and without air flow through the cloth.

Since the air permeability is a function of the size of the interstice opening and the fabric is a nonhomogeneous elastic membrane, it was thought that a study of the elastic properties of the cloth under conditions of biaxial tension would show the relation of cloth stretch or elasticity and interstice or void magnitude. The size of the interstice opening is difficult to measure accurately.

It was also important to determine the effects of temperature on the fabric elastic properties.

II. LITERATURE SURVEY

The idea of simultaneous biaxial tension loading of fabrics is not new. The German Scientist, Rudolf Haas (1), constructed an apparatus for biaxial tension testing of balloon cloth in 1912.

Haas's apparatus involved load pans, cables, and levers so arranged as to produce simultaneous tension loads in both warp and filling directions on a cruciform shaped fabric sample. This machine was not motor driven, and variation of load was achieved by manual addition of weights to the load pans. Measurement of the elongation was attained by manual measurement during tests of the dimensions of a grid marked on the cloth sample before tension loads were applied.

Specifications (2) of the American Society for Testing Materials (ASTM) require the grab and strip break testing of five fabric samples of each cloth to be used in determining the average tension values for the type of cloth being investigated. If a break occurs close to the jaws (a jaw break), then that test is discarded, and additional samples are tested until five tests without jaw breaks are obtained.

The cloth is considered a nonhomogeneous elastic membrane. Timoshenko (3) has developed theories for homogeneous membranes of circular shape. It is obvious that these theories cannot be generally applied to biaxial tension studies of fabrics.

Parachute designers have long used a membrane formula to compute the fabric tension of an inflated parachute. The formula is discussed by Stevens and Johns in a British paper (4).

$$P = \frac{T_1}{R_1} + \frac{T_2}{R_2}$$

P = Pressure differential across the fabric, lb/sq ft,

where T_1 = Tension load in hoop direction (lbs),

T_2 = Tension load in generator direction (lbs),

R_1 = Radius of curvature in hoop direction (ft), and

R_2 = Radius of curvature in generator direction (ft).

This indicates that an infinite tension load is involved if the radius of the curvature is infinite.

English experiments were conducted to determine the effect of tension on the porosity of parachute fabrics. This work was reported in 1949 by W. D. Brown (5). The capacity of the permeometer used was low, and the pressure differential across fabric samples was also low. It was noted, as a result of these tests, that as the fabric tension loads were increased in the case of cotton fabrics, the porosity increased. For nylon fabrics investigated, no change in porosity with change in tension was exhibited, and in the case of viscose fabrics, increase of fabric tension resulted in a decrease of porosity. This was the only reference discovered that attempts to correlate the fabric tension and porosity.

III. APPARATUS

The primary apparatus used is the biaxial-fabric-tension-testing machine, which was designed and constructed specially for this program. In general, the purpose of the machine is to apply simultaneous loads to a fabric sample in both warp and filling directions and also to measure the elongations or deformations of this fabric sample while the biaxial tension loads are being applied.

A. Other Similar Machines

In 1916, Dr. Rudolf Haas of Germany built an apparatus to apply simultaneous fabric tension loads to a cruciform-shaped fabric sample. The applied loads were static, and the load increments were applied by hand. Elongations were measured by ruler after each load increment was applied.

An Instron testing machine at the Textile Research Institute of Princeton, N. J. has been equipped with an accessory device. When this device is placed between the testing machine jaws by means of wedge and lever mechanisms, it applies simultaneous biaxial tension loads to the fabric sample. The load-versus-elongation diagram for one axis is recorded on a Brown recorder. The test must be repeated to record the load-versus-elongation diagram for other axis.

The Fabric Research Laboratories, Inc. of Boston, Massachusetts, conducting research sponsored by the Navy, also designed and constructed a biaxial-fabric-tension-testing machine. This machine is devised to permit application of equal loadings along both axis of the test sample. Load-versus-elongation diagrams are plotted by two Brown recorders. This machine is quite similar in design to the Georgia Tech machine.

B. Description of the Biaxial-Fabric-Tension-Testing Machine

The biaxial-fabric-tension-testing machine was designed and constructed by Georgia Tech specially for the Air Force. The machine is shown in a general view in Figure 1. Two intergeared jack screws, located below the machine platform, drive the four-clamp cars in a horizontal direction. Figure 2 shows the four Scott testing machine A-4 type jaws with a 5"x5" fabric sample in place ready for testing. The drive mechanism consists of a 1/4-horsepower motor hooked to a Boston Gear Company transmission, which in turn is geared to one of the jack screws. Appropriate push-button, reversing, and limit switches are provided to control the movement of the test jaws. The jaws recede from each other, at present, at the speed of 2.30 inches per minute.

C. Instrumentation

Cantilever arms, attaching the Scott tester jaws to the cars, are provided with electric resistance strain gages. The arms and strain gages constitute the tension-load-sensing apparatus. Elongation is indicated by the biaxial extensometer device located on the cloth sample. The extensometer device is shown in Figure 2. Three needle points, located in the feet of the extensometer, pierce the cloth sample and secure the device in position. Stretching of the cloth during the test will increase the distance

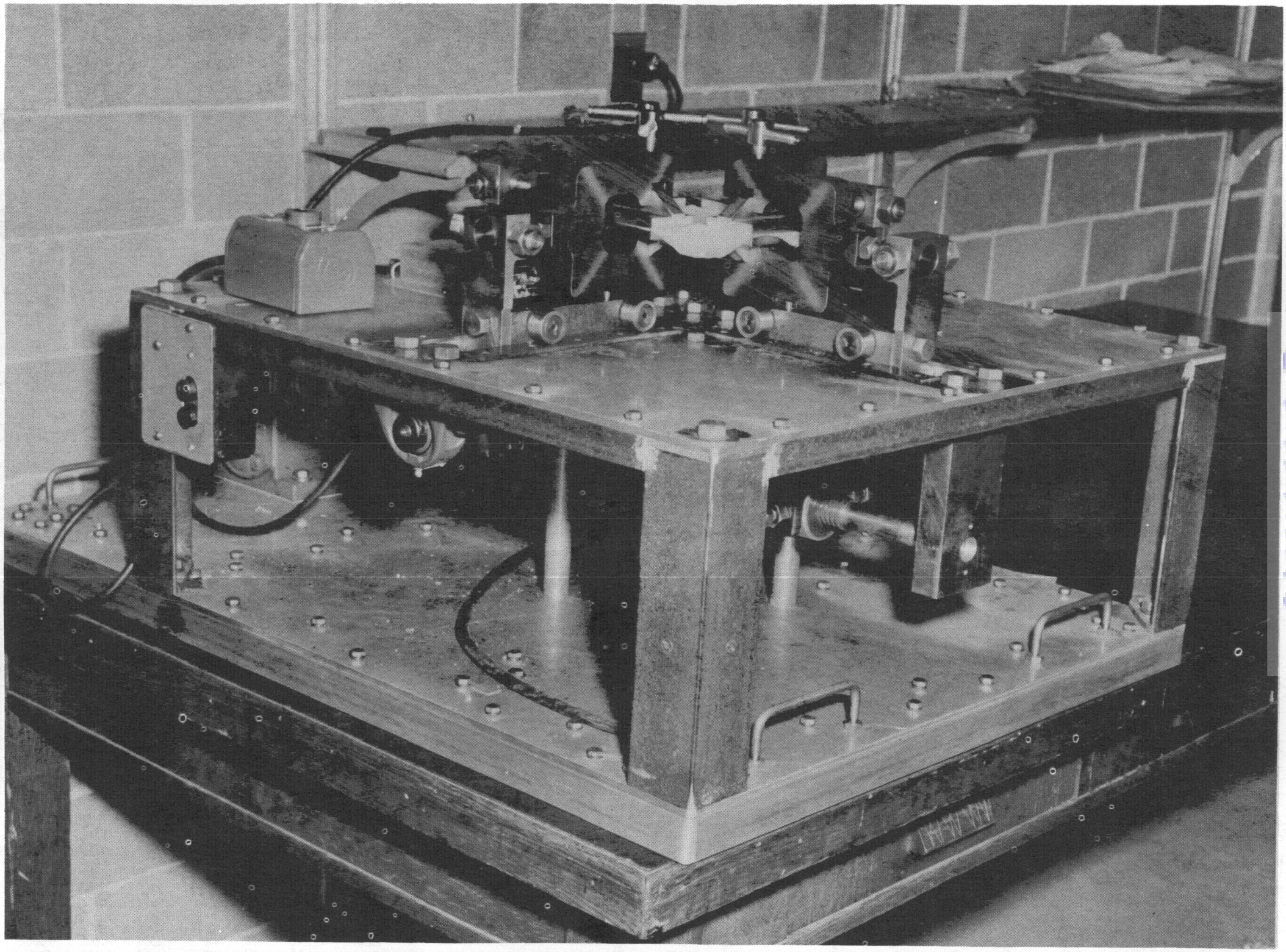

Figure 1. General View of the Biaxial-Fabric-Tension-Testing Machine

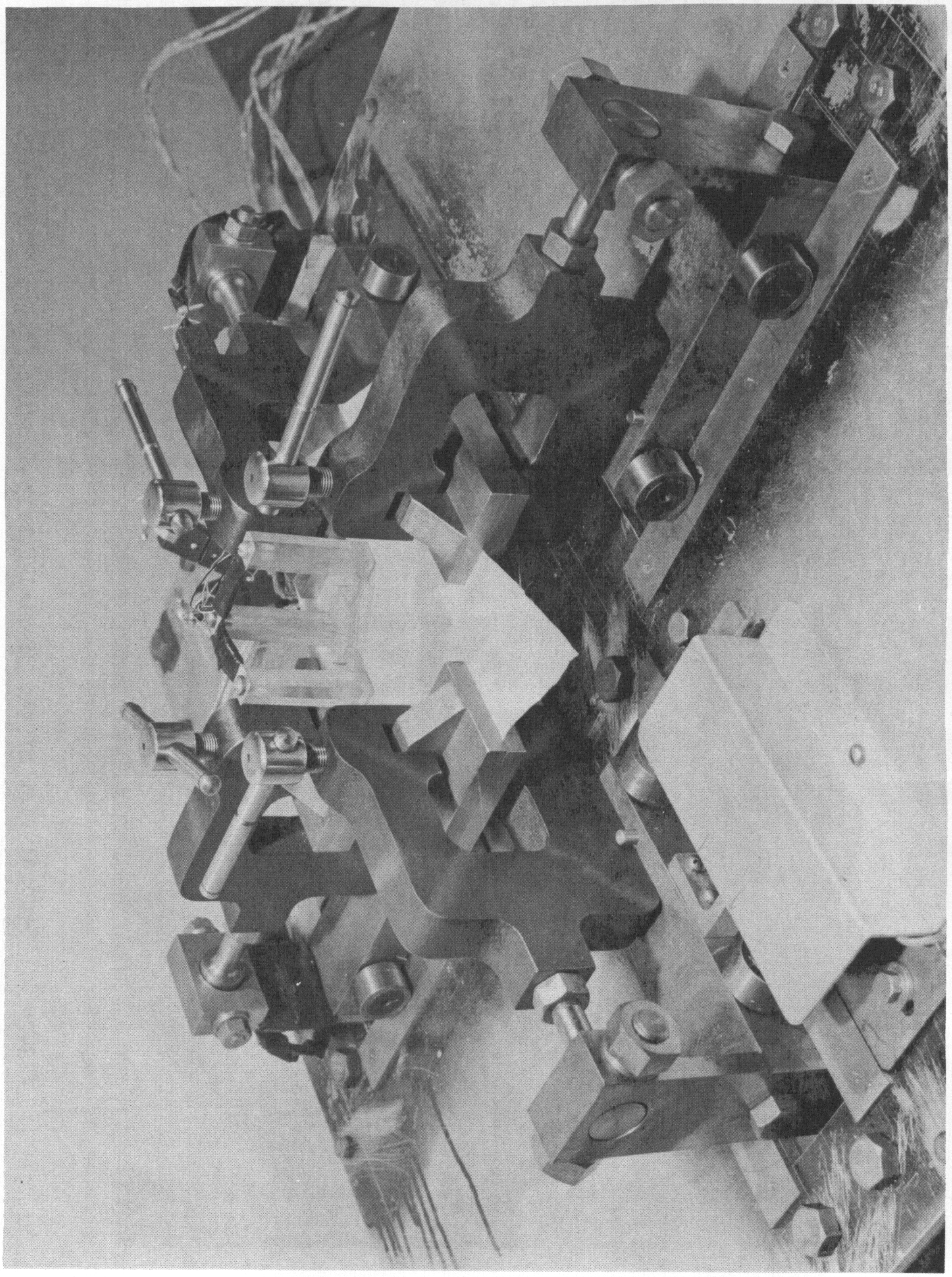

Figure 2. General View of the Biaxial Extensometer in place on the Test Fabric.

between the needle points. Spreading of the extensometer feet causes the metal bands at the top to flex. This flexing of the bands will cause electrical variations in the electrical-resistance-type strain gages mounted on the bands. By means of this variation of electrical resistance and by appropriate calibration of the extensometer device, the electrical variations are converted into microammeter indications as to the magnitude of the elongations being measured.

The electric strain gage devices are hooked up to a CECO Instruments Corp. Type 1-118 Carrier Wave Amplifier (see Figure 3) having four channels. The output of the four amplifiers is connected to four microammeters. The microammeters are located in a photo-observer shown in Figure 4, and as the tests are run, the readings of the four ammeters are recorded by a 16mm Bell and Howell moving-picture camera. From this film, the load-versus-elongation data are obtained, and the results are plotted.

D. Temperature Control Equipment

An insulated hood was made in accordance with ASTM specifications. This hood encloses the jaw and sample area. Heating elements, located inside the hood, are used to produce controlled high temperatures up to +160°F maximum. To obtain low temperatures of -20°F maximum, dry ice is placed under the hood and around the jaws and sample. A small blower attached to the hood causes the air under the hood to circulate. The hood is shown in Figure 5.

Difficulty in stabilizing maximum low and high temperatures resulted in conducting all tests at either -14°F or at +140°F. At both of these values, it was possible to maintain constant temperatures.

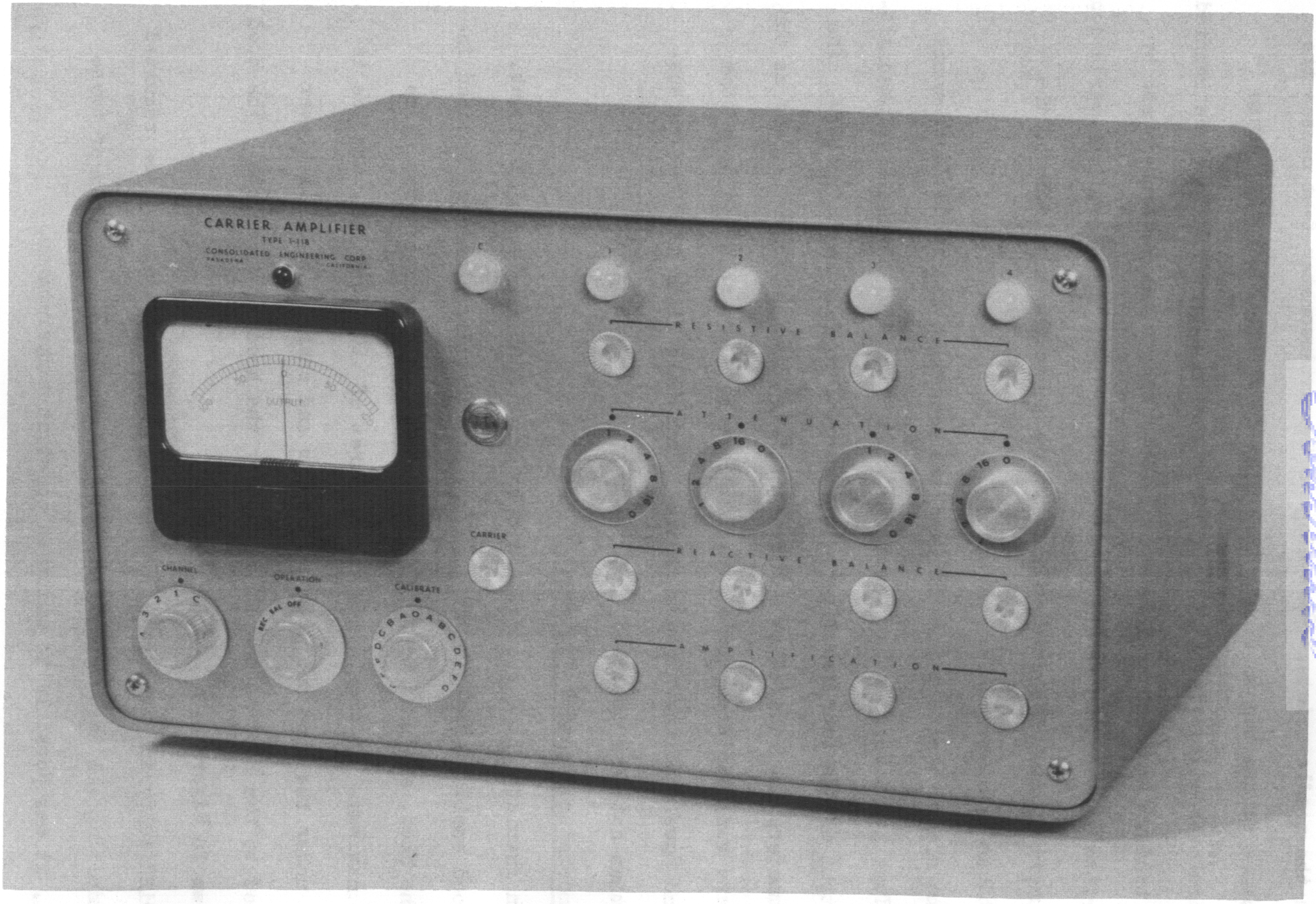

Figure 3. Four Channel Carrier Wave Amplifier.

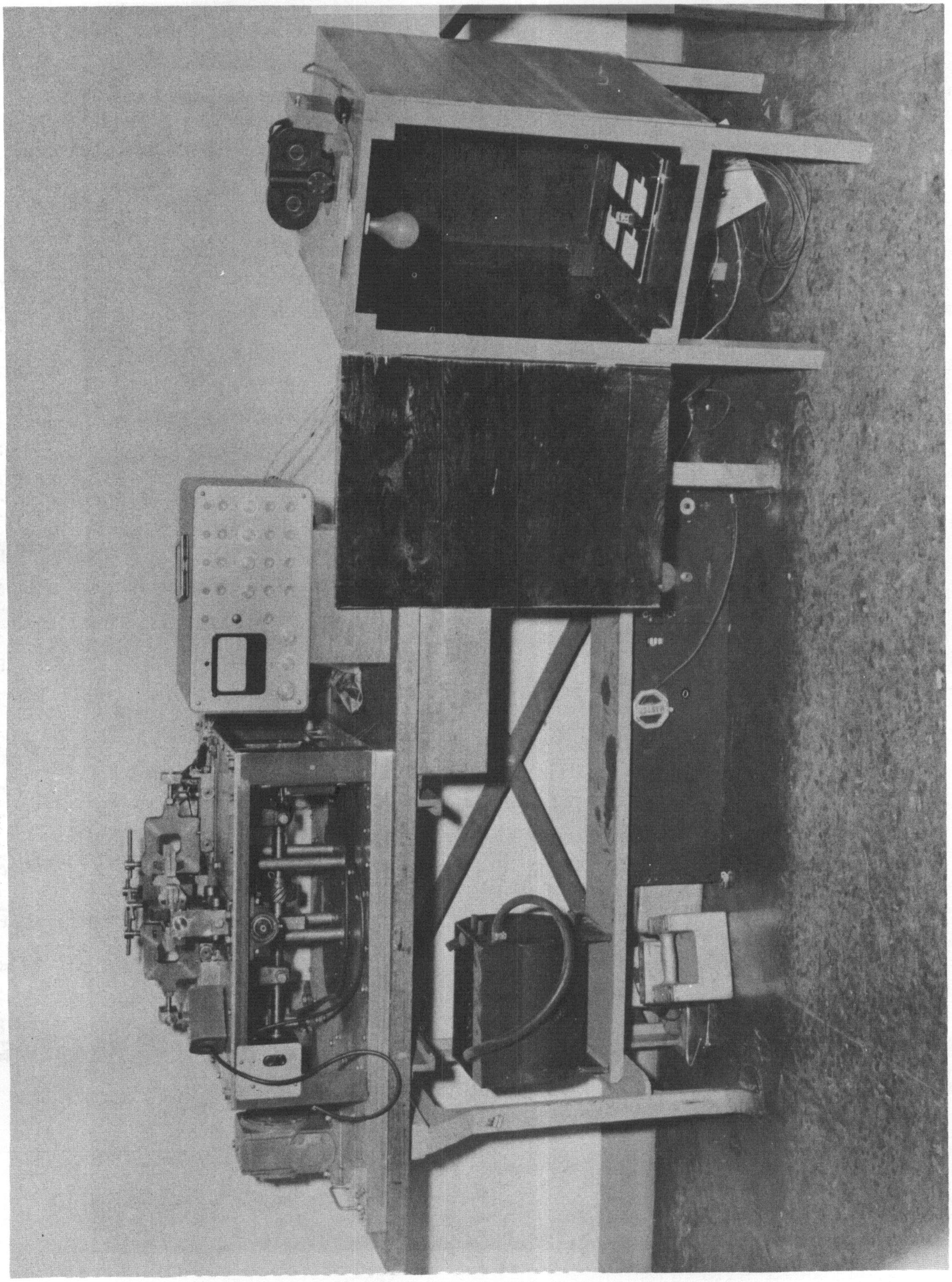

Figure 4. General View of the Biaxial-Fabric-Tension-Testing Machine.

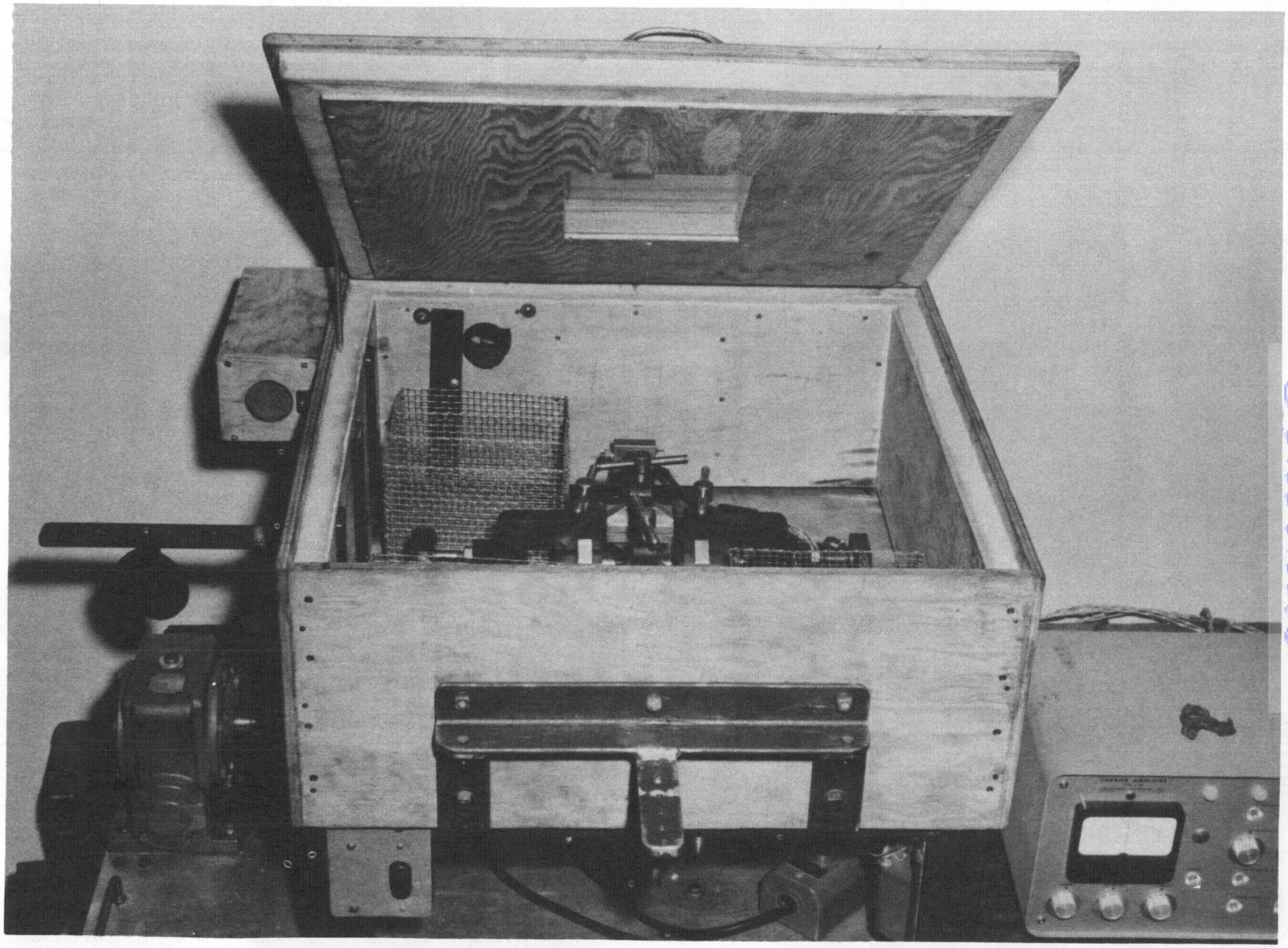

Figure 5. The Biaxial-Fabric-Tension-Testing Machine with Insulated Hood.

E. Method of Calibration

The tension-load arms are calibrated by applying load increments, using load pans, cables, and pulleys. Variation of these loads causes variation in the readings of the microammeters. In this manner, a diagram of microammeter reading versus tension load is constructed. These calibrations are repeated whenever the test temperature conditions are changed.

The extensometer devices are calibrated by inserting blocks, having known dimensions, between the extensometer feet. By this means, a diagram showing microammeter reading versus elongation is constructed. These calibrations must be repeated if the test temperature conditions are changed because of temperature effects on the strain gages.

IV. TEST PROCEDURE AND METHOD OF HANDLING DATA

A. Selection of Cloth Samples

The American Society for Testing Materials specifies that for grab and strip break testing of woven fabrics (ASTM Designation D39-49) no less than five random samples shall be selected and tested to determine an average tensile value. In air-permeability tests, it was the practice to locate samples at least one-third of the cloth width inward from the selvage edge. The samples were taken at random throughout the piece. This procedure, in selecting cloth samples, was followed in conducting the tests reported here.

Early experimenters used cruciform shaped samples in conducting biaxial-fabric-tension tests. Most failures occurred in the cloth arm adjacent to the test jaws or clamps. This resulted in an excessive number of jaw breaks. It should have been expected that the cruciform-shaped cloth would break in the region adjacent to the jaw which is the weakest portion of the sample.

A square sample was used in the tests reported here, and supplementary investigations indicated this sample shape to be most satisfactory.

B. Sample Mounting Procedure

The test jaws are run forward until the front edges of the four jaws form a closed rectangle. The sample is inserted between the four loose jaws of the testing machine. The operator aligns the warp and filling threads by eye with the respective pulling axis of the machine. Then one jaw in each direction is tightened. The operator pulls slightly on the fabric enough to eliminate slack first in the warp direction, and then in the filling direction; then the clamps of the remaining two test jaws are tightened.

The biaxial extensometer is carefully installed on the upper surface of the fabric sample. Care is taken to align the extensometer so that extensions in the warp direction and extensions in the filling direction are separately indicated.

C. Operation of the Testing Machine

After the sample is mounted, the lights in the photo-observer are turned on. The 16-mm Bell and Howell moving-picture camera is then started. The operator, using the push-button control, starts the test. The run is continued until the cloth fails.

D. Computation and Reduction of Data

The test data are recorded on 16-mm moving-picture film. A time history of the variation of each of the microammeter dials can be obtained from a study of each film frame. Since the film speed used was eight frames per second, only the instrument readings on every fourth frame are recorded on an appropriate data sheet. This gives a series of test readings at approximately half-second intervals from the start of the tests until the rupture occurs.

By varying circuit resistances, it was found possible to adjust the four circuits to permit reading the load and elongation measurements, either directly or by merely dividing or multiplying by a factor of two or four.

After the film data have been put down in table form, warp and filling load-versus-elongation curves are drawn for each cloth sample. From five such curves, average data representing load-versus-elongation data representative of that type of cloth are prepared. The curves, shown in the appendix of this report, are all average curves.

The photo-observer and the necessity to read film and prepare data tables will be eliminated by installation of two "X-Y" type recorders at a later date. These instruments will construct load-versus-elongation curves as the actual test runs are being conducted.

V. SPECIAL EFFECTS

A. Tests at Room Temperature

The laboratory room was not air conditioned. However, tests conducted at room temperature were all at approximately 80°F and 50% relative humidity. Previous studies reported in WADC Technical Report 52-283, Part II, indicate that humidity variations in the vicinity of 50% relative humidity did not significantly affect the air-permeability properties of synthetic fabrics. It is not expected that small humidity changes will appreciably affect the elastic properties of synthetic fabrics reported here. This opinion is substantiated by the elastic studies of yarns incorporating various twists as reported by J. L. Taylor, et al. (6).

Under laboratory or room temperature conditions, selected test fabrics described in Appendix II, Table I, were tested on the biaxial-fabric-tension-testing machine to demonstrate the effect of varying picks and weave patterns on elastic properties of these test fabrics. Other tests were conducted to show, comparatively, the elastic properties of similar Orlon and Dacron parachute-weight fabrics. Comparisons at +140°F and -14°F are also included to show the effect of varying picks and weave patterns.

B. Effect of High and Low Temperatures

Fabrics of nylon, Orlon, and Dacron, selected from those described in Table I, were tested on the biaxial-fabric-tension-testing machine at low test temperatures of -14°F and at high temperatures of +140°F. These test data, in combination with the room or laboratory condition test results (approximately 80°F), should demonstrate the effect of temperature on fabric elastic properties.

VI. DISCUSSION OF TEST RESULTS

A. Effect of Varying Picks

Figures 6 through 17 are presented here to show the effect of varying the number of picks in special nylon, Orlon, and Dacron parachute-weight fabrics. Since the test temperature conditions were -14°F, +80°F, or +140°F, the groupings are such that the comparisons indicate only the effect of varying the pick count.

All of the experimental fabrics testedwere constructed of test yarns incorporating many turns per inch in warp yarns and little or no more than producers twist in the filling yarn. The curves of Figures 6 through 17 indicate that by variation of twist it is possible to reverse trends such that for yarns of high twist, the larger number of picks will yield greater elongation for a given load than that of a fabric having thirty less picks per inch. In the case of the elastic properties of filling yarns having essentially producers twist, the fabric having the largest number of picks will yield less elongation than that of a fabric having thirty less picks per inch. This seems to indicate the importance of twist on elastic properties. In general, the curves of Figures 6 through 17 demonstrate little effect on elastic properties resulting from variation of the numbers of picks per inch.

B. Effect of Variation of Weave Pattern

Figures 18 through 29 show the effect on elastic properties of the selected test fabrics resulting from the variation of weave pattern. The elastic properties of several fabric constructions involving plain-, twill-, and satin-weave patterns were investigated.

Figures 18 through 23 indicate that in general a twill requires a greater load for a given elongation than a similar plain fabric having the same number of ends and picks per inch. The trend indicated is in the order of twill, satin, and then plain. However, the Figures 24 through 29 indicate that a higher load is required for a given elongation, in the case of a plain weave fabric as compared to that of a similar satin weave having the same number of ends and picks per inch. In this group the trend is plain, twill, and satin. The latter group is comprised of 125x80 nylon, 100x70 Orlon, and 110x70 Dacron as compared with 70x50-70 nylon in the first group described above. It would appear that the changes in trend discussed here are a result of increasing the number of warp ends.

For the experimental fabrics studied, the magnitude of variation of elastic properties, as affected by changing the weave patterns, appears to be very small.

C. Effect of Material Variation

At the time of weaving the experimental Georgia Tech parachute-type cloths, it was not possible to obtain more than one size of Orlon and Dacron yarn. A comparison of finished Georgia Tech fabrics indicated that only certain of the Orlon and Dacron test fabrics were closely similar. Also none of the nylon fabrics compared sufficiently close to Orlon and Dacron test fabrics to permit drawing the conclusions that differences of elastic properties were due to material change and not due to fabric construction differences.

The experimental Orlon and Dacron fabrics studied were constructed of yarns of approximately 70 denier, and the Orlon and Dacron warps each had approximately 100 ends per inch. Figures 30 through 35 show, comparatively, the elastic properties of the GT-34 Orlon and GT-46 Dacron at the three temperatures of -14°F, +80°F, and +140°F. In each case, the Dacron appears to be more elastic than the Orlon. The largest differences in elastic properties occurred at the low temperatures where the Dacron was considerably more elastic than the similar Orlon material.

D. Effect of Varying the Temperature

It was hoped that the effect on fabric elastic properties, caused by variation of ambient temperature, could be demonstrated by testing the fabrics in the biaxial-fabric-tension-testing machine at temperatures of -14°F, +80°F, and +140°F. However, it was discovered that when the temperature under the insulated hood was -14°F, the absolute humidity was 0.001

lbs water/lbs air. At room or laboratory temperatures, the absolute humidity was about 0.015 lbs H_2O and at +140°F, the absolute humidity dropped to 0.010 lbs water/lbs air. Therefore, to obtain true tests showing only the effect on elastic properties, caused by varying the temperature, it would be necessary to conduct the tests at all times under either dry or saturated conditions. This would require special air-conditioning equipment which is not available now.

Figures 36 through 63 are presented here to demonstrate the effect of temperature on fabric elastic properties. These curves do not present the load-versus-elongation data for each fabric at all of the three test temperatures (-14°F, +80°F, and +140°F). A failure of a machine at the film processing laboratory resulted in the loss of an important record film containing data at -14° for fabrics GT-35, 30, 22 and at 80° for GT-31. Tests were not run at 140° for fabrics GT-32, 40, 44, 47 because the supply of these materials was exhausted. However, analysis of the data presented here indicated that these curves show the effect of temperature on fabric elastic properties and that no significant and different results would be obtained by repeating the tests to obtain elastic curves for each fabric at all three temperatures.

The elastic properties of several nylon fabrics, under the three temperature conditions, are shown in Figures 36 through 47. The differences demonstrated between the warm and cold elastic properties are indicative of the effect of temperature on the elastic properties of these fabrics. However, the differences shown for the +80°F tests and those conducted at +140°F are indicative of the effect on elastic properties caused by variation of the relative humidity. It is not to be expected that a temperature change of only 60°F (from +80°F to +140°F) would appreciably affect the elastic properties of the nylon yarn. However, a relative humidity change from 50% to 5% can be expected to have some effect. The trend, that dry conditions or low relative humidity will result in less elasticity and lower tenacity, seems to be valid and in line with experience obtained in testing yarns.

Test results for several Orlon fabrics are presented in Figures 48 through 55. Based on knowledge of the physical properties of Orlon yarn, one does not expect humidity changes to greatly affect the elastic properties of the fabric. This is demonstrated by the test results as presented in Figures 48 through 55.

In the case of Dacron fabric and again based on knowledge of the effect of temperature and humidity on Dacron yarn, it is to be expected that the Dacron fabric tested on the biaxial-fabric-tension-testing machine at the three test temperatures will act like nylon. Figures 56 through 63 present the test results for the Dacron parachute fabrics investigated. The test results bear out the foregoing expectation. The magnitude of variations for the Dacron fabric are less than those for the nylon fabrics.

VII. CONCLUSIONS

The following conclusions are based upon the test results and analysis presented here:

1. Comparatively, the magnitude of over-all variations of elastic properties for synthetic parachute fabrics, considered as a group, is not large.

2. Small variations of warm temperatures (140°F and under) will not appreciably affect fabric elastic properties.

3. Variation of relative humidity from 50% to 5% in the +80°F to +140°F temperature range does not have considerable effect on the fabric elastic properties of nylon and Dacron cloth.

4. Variation of the relative humidity does not appreciably affect the elastic properties of Orlon.

VIII. RECOMMENDATIONS

1. An attempt should be made to modify the biaxial-fabric-tension-testing machine to permit testing under saturated atmosphere conditions at several temperatures.

2. Considering the apparent stability of Orlon elastic properties, under conditions of varying humidity and temperature, it is recommended that this material be further considered for use as parachute material.

3. It is recommended that additional twist in the filling yarns would result in more elongation for a given load; hence, improved and increased elastic properties of parachute fabrics.

4. A study of the elastic properties of single yarns is recommended to predict the elastic properties of experimental fabrics.

APPENDIX I

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APPENDIX II

TABLE I

GEORGIA TECH SELECTION OF FABRICS FOR HIGH-PRESSURE AIR PERMEABILITY STUDIES

Fabric Designation	Construction	Denier		Weave	Material	Style or Color	Reference
		W	F				
GEORGIA TECH FABRICS:							
Fabric No. 3	70x70	75	80	Satin	Nylon	White	Tech. Rpt. No. 2, p. 31
Fabric No. 4	70x50	75	80	Satin	Nylon	White	Tech. Rpt. No. 2, p. 31
Fabric No. 5	70x50	74	80	Satin	Nylon	White	Tech. Rpt. No. 2, p. 31
Fabric No. 6	70x40	75	80	Satin	Nylon	White	Tech. Rpt. No. 2, p. 31
Fabric No. 9	70x70	75	80	Plain	Nylon	White	Tech. Rpt. No. 2, p. 31
Fabric No. 10	70x60	75	80	Plain	Nylon	White	Tech. Rpt. No. 2, p. 31
Fabric No. 11	70x50	75	80	Plain	Nylon	White	Tech. Rpt. No. 2, p. 32
Fabric No. 13	70x50	75	80	Twill	Nylon	White	Tech. Rpt. No. 2, p. 32
Fabric No. 14	70x50	75	80	Twill	Nylon	White	Tech. Rpt. No. 2, p. 32
Fabric No. 15	70x70	75	80	Twill	Nylon	White	Tech. Rpt. No. 2, p. 32
Fabric No. 16	70x80	75	80	Twill	Nylon	White	Tech. Rpt. No. 2, p. 32
Fabric No. 22	125x80	40	80	Plain	Nylon	White	Tech. Rpt. No. 2, p. 33
Fabric No. 23	125x80	40	80	Satin	Nylon	White	Tech. Rpt. No. 2, p. 33
Fabric No. 29	125x50	40	80	Twill	Nylon	White	Tech. Rpt. No. 2, p. 34
Fabric No. 30	125x60	40	80	Twill	Nylon	White	Tech. Rpt. No. 2, p. 34
Fabric No. 31	125x70	40	80	Twill	Nylon	White	Tech. Rpt. No. 2, p. 34
Fabric No. 32	125x80	40	80	Twill	Nylon	White	Tech. Rpt. No. 2, p. 34
Fabric No. 33	100x40	80	80	Plain	Orlon	White	Tech. Rpt. No. 2, p. 36
Fabric No. 34	100x50	80	80	Plain	Orlon	White	Tech. Rpt. No. 2, p. 36
Fabric No. 35	100x60	80	80	Plain	Orlon	White	Tech. Rpt. No. 2, p. 36
Fabric No. 36	100x70	80	80	Plain	Orlon	White	Tech. Rpt. No. 2, p. 36
Fabric No. 40	100x70	80	80	Twill	Orlon	White	Tech. Rpt. No. 2, p. 36
Fabric No. 44	100x70	80	80	Satin	Orlon	White	Tech. Rpt. No. 2, p. 36
Fabric No. 45	110x40	80	80	Plain	Dacron	White	Tech. Rpt. No. 2, p. 37
Fabric No. 46	110x50	80	80	Plain	Dacron	White	Tech. Rpt. No. 2, p. 37
Fabric No. 47	110x60	80	80	Plain	Dacron	White	Tech. Rpt. No. 2, p. 37
Fabric No. 48	110x70	80	80	Plain	Dacron	White	Tech. Rpt. No. 2, p. 37
Fabric No. 52	110x70	80	80	Twill	Dacron	White	Tech. Rpt. No. 2, p. 37
Fabric No. 56	110x70	80	80	Satin	Dacron	White	Tech. Rpt. No. 2, p. 37

APPENDIX III

FIGURES

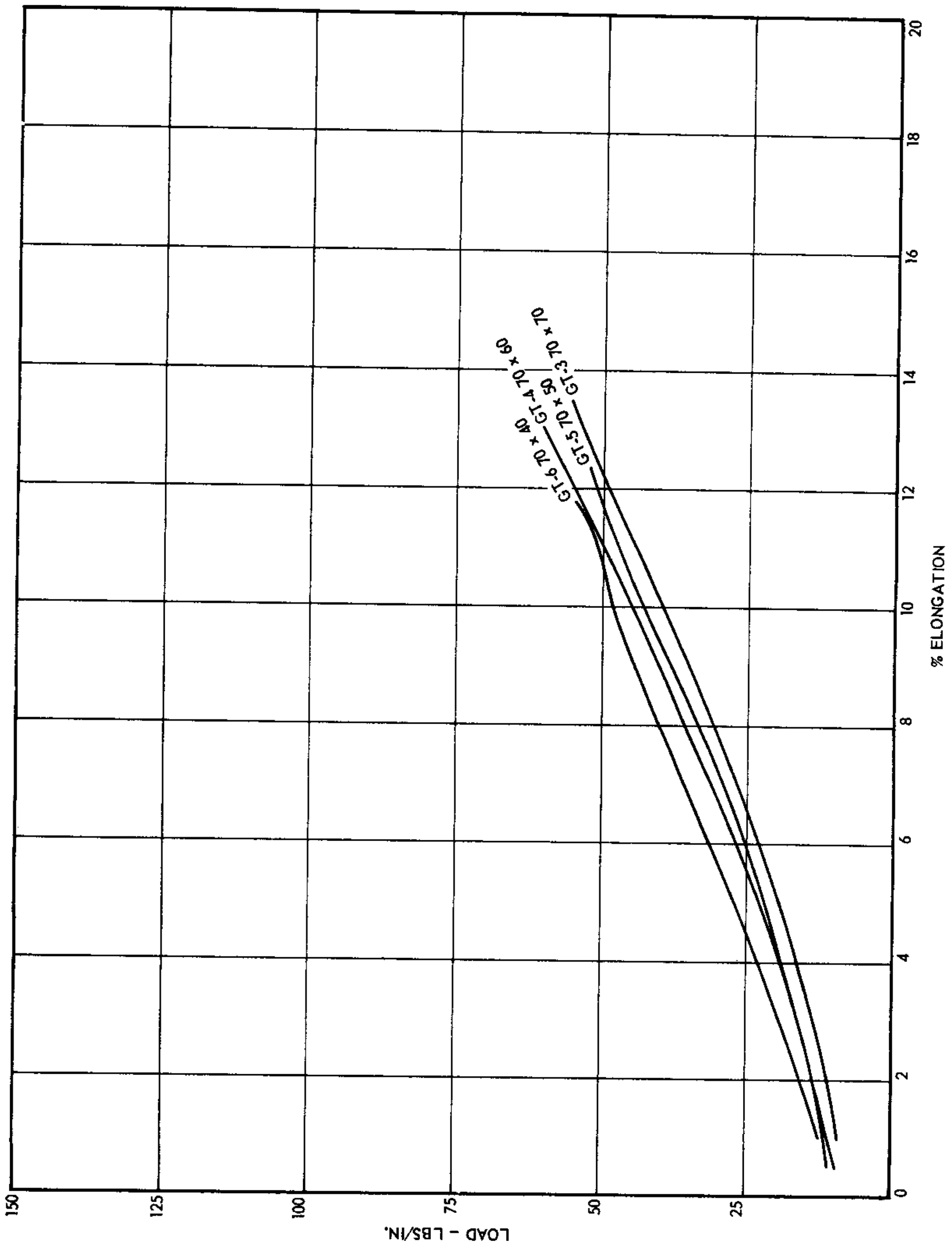

Figure 6. Effect of Pick Variation on Elastic Properties at 140°F. for Satin Weave Nylon Warp.

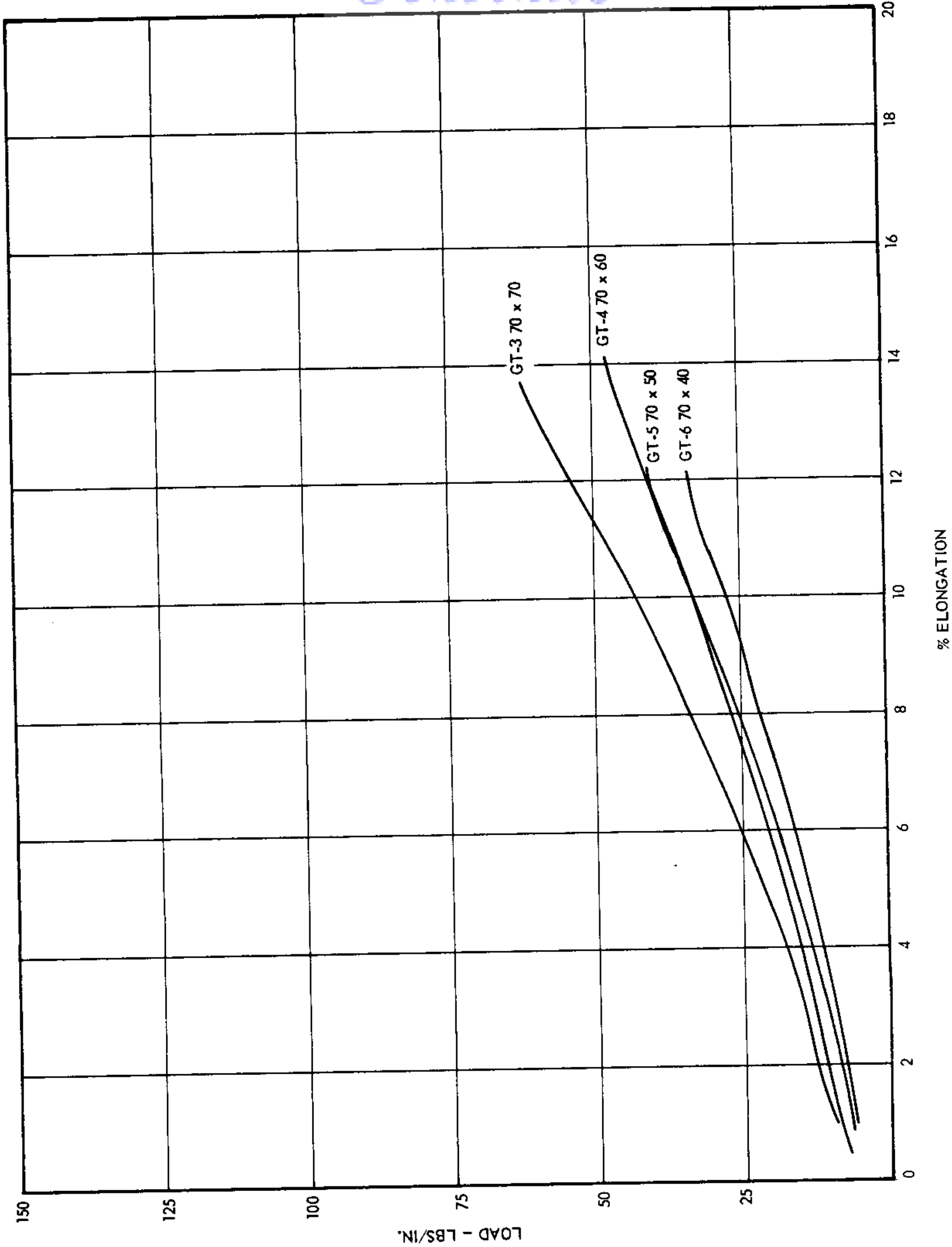

Figure 7. Effect of Pick Variation on Elastic Properties at 140°F. for Satin Weave Nylon Filling.

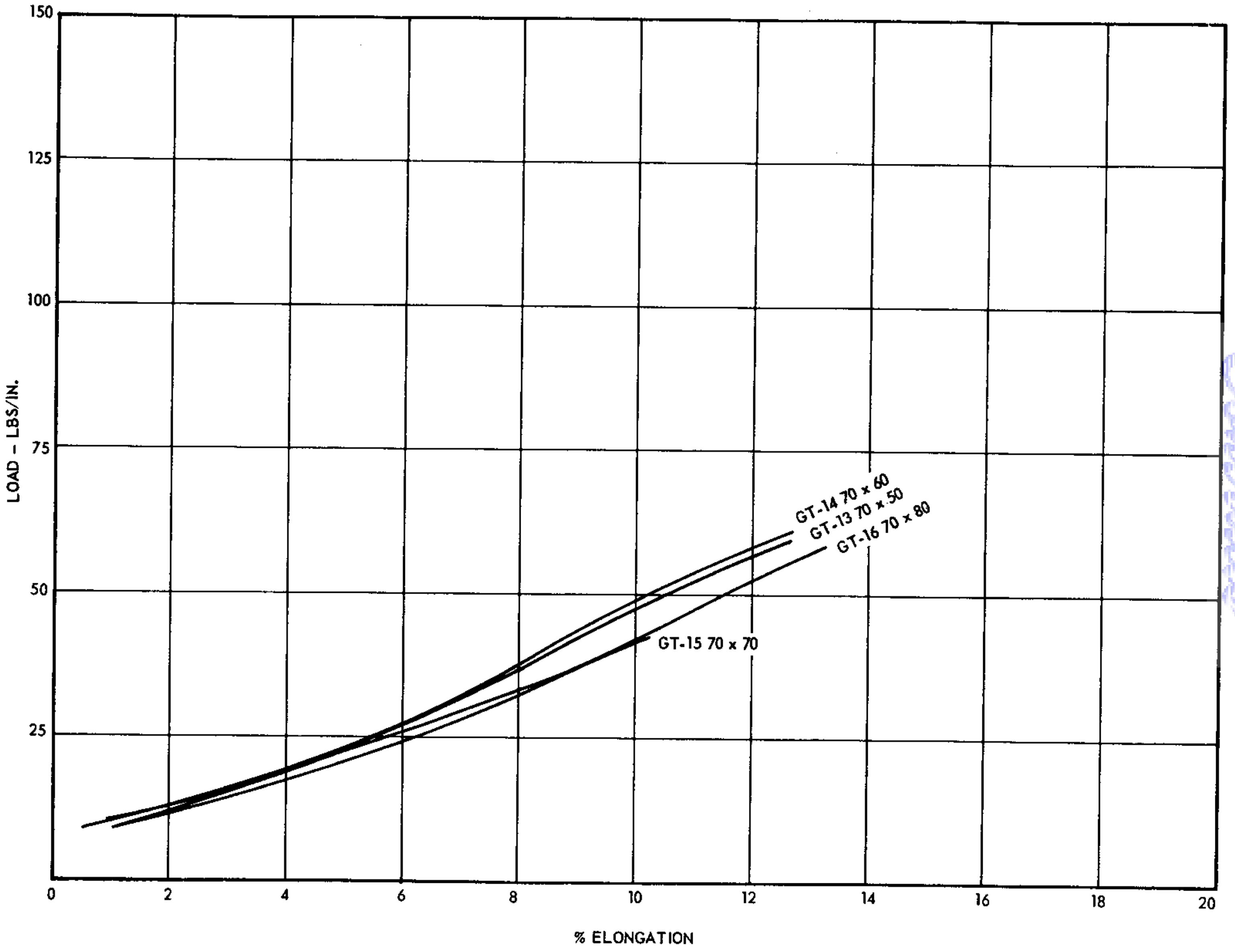

Figure 8. Effect of Pick Variation on Elastic Properties at 140°F. for Twill Weave Nylon Warp.

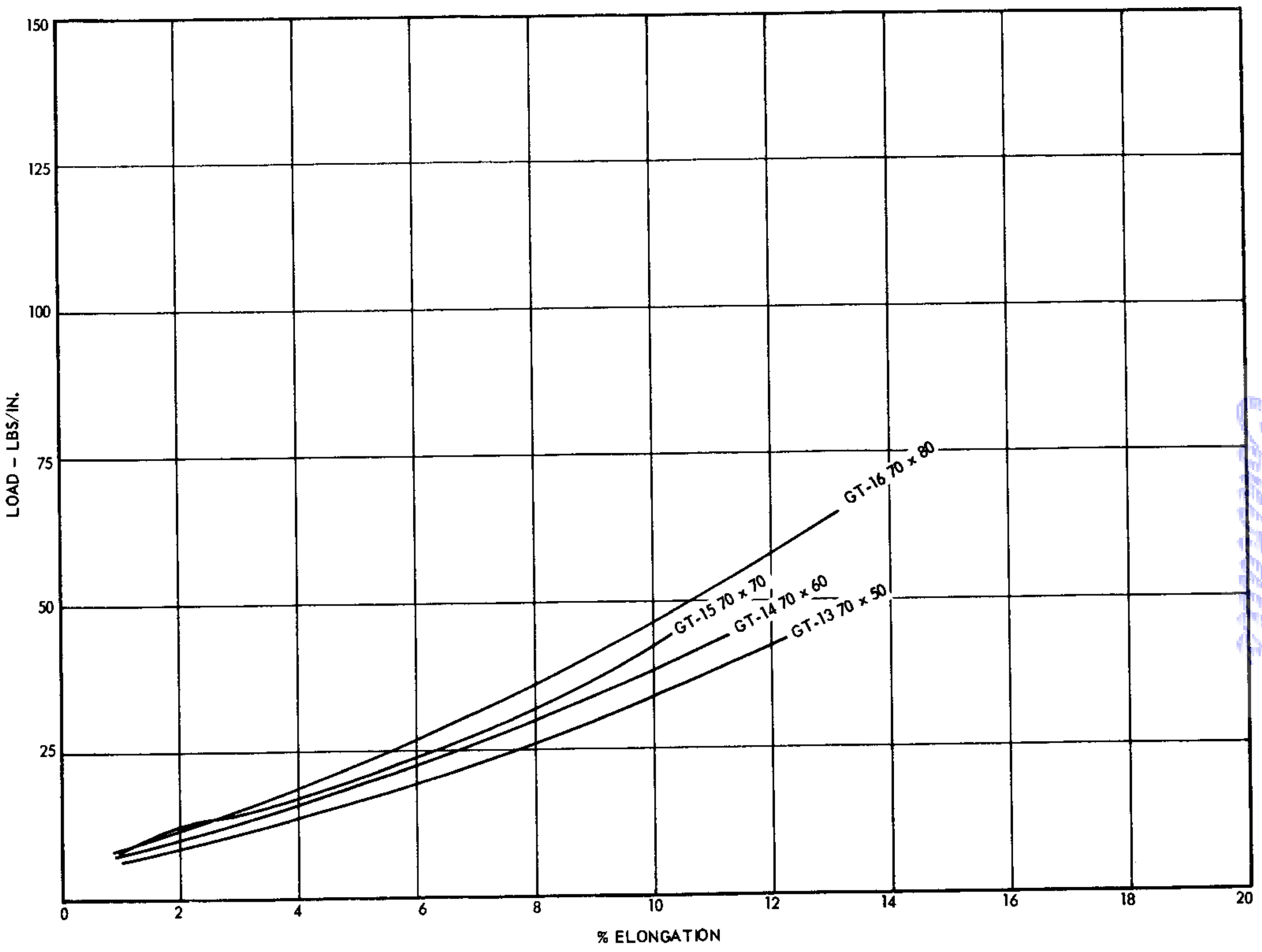

Figure 9. Effect of Pick Variation on Elastic Properties at 140°F. for Twill Weave Nylon Filling.

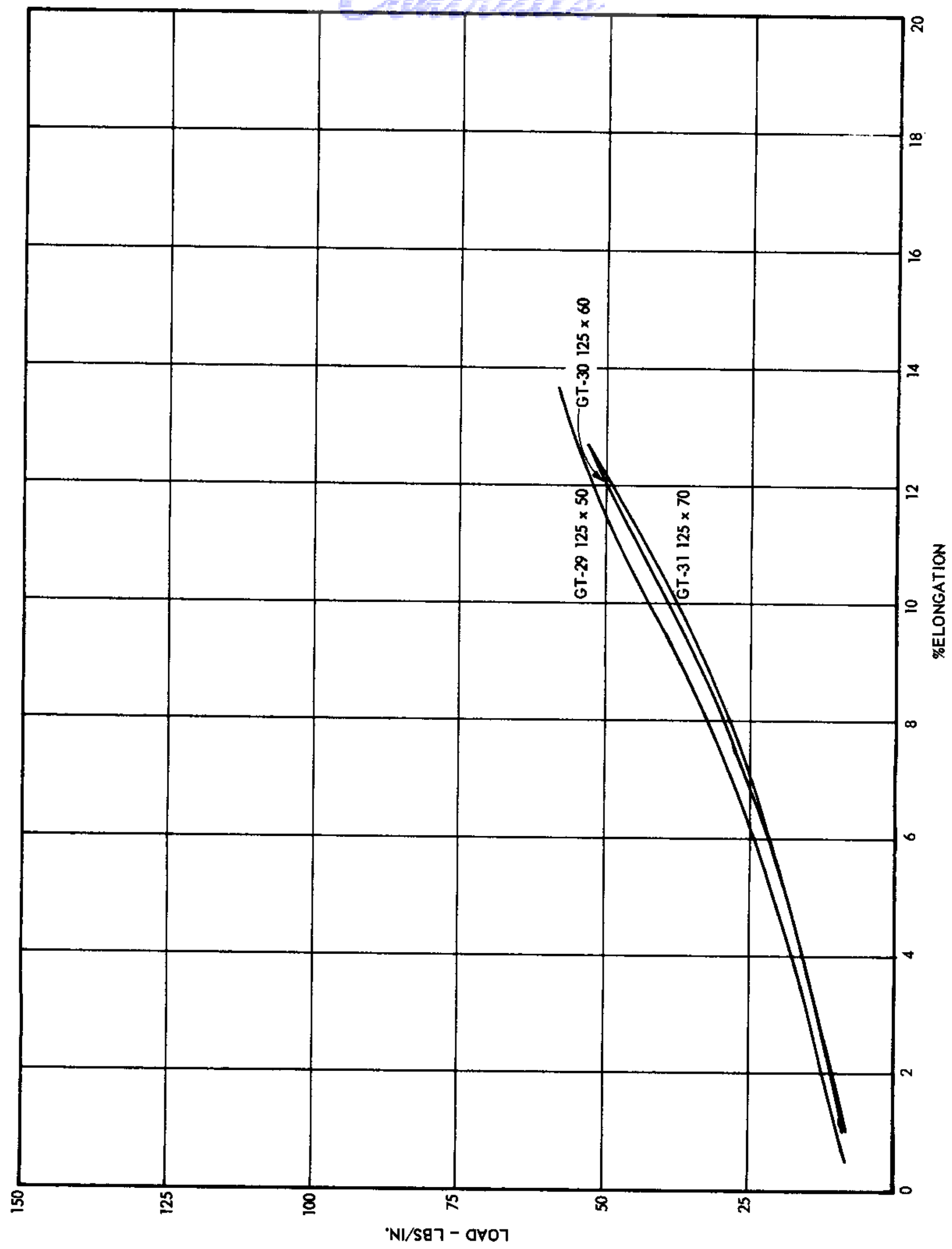

Figure 10. Effect of Pick Variation on Elastic Properties at 140°F. for Twill Weave Nylon Warp.

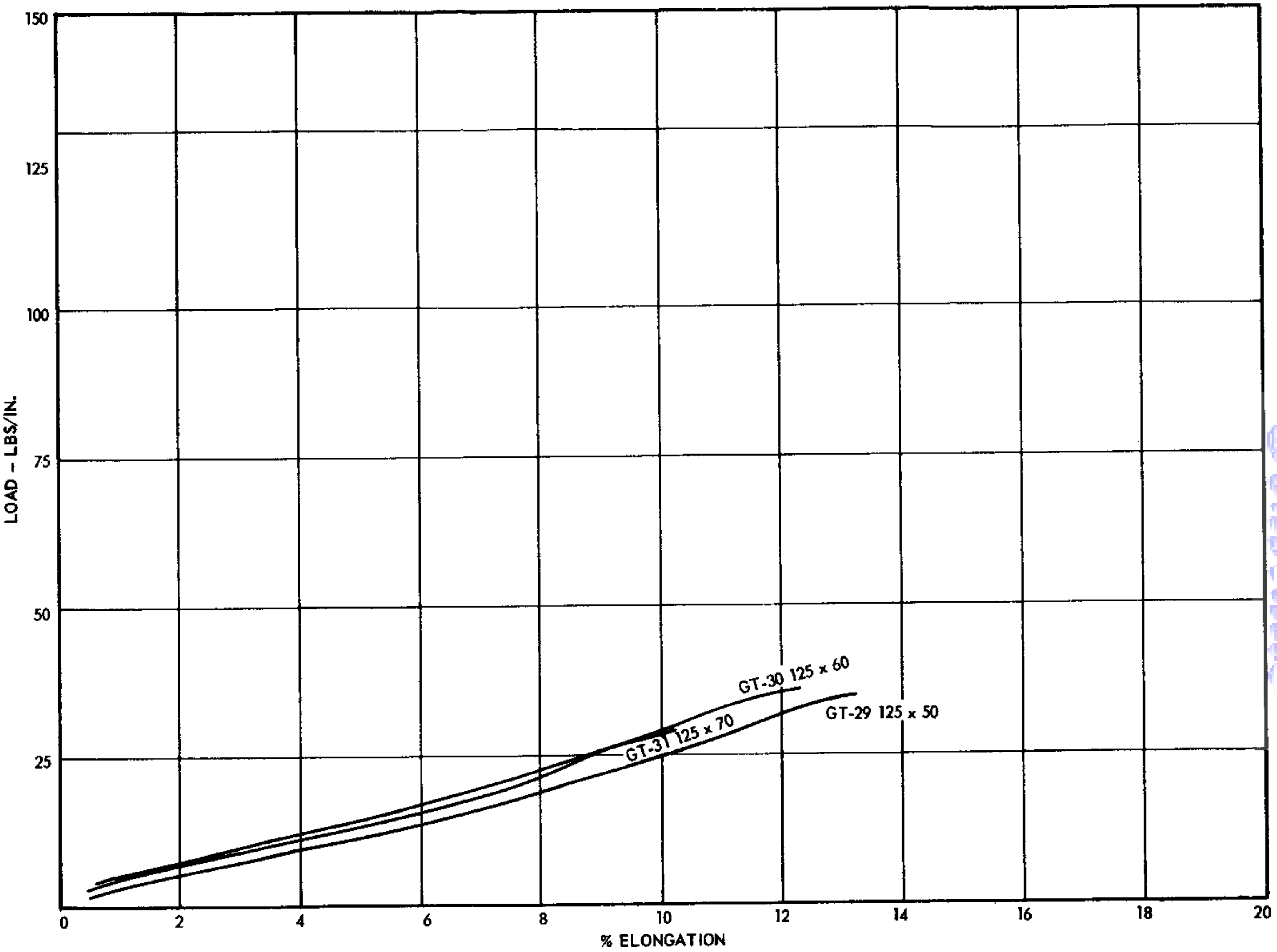

Figure 11. Effect of Pick Variation on Elastic Properties at 140°F. for Twill Weave Nylon Filling.

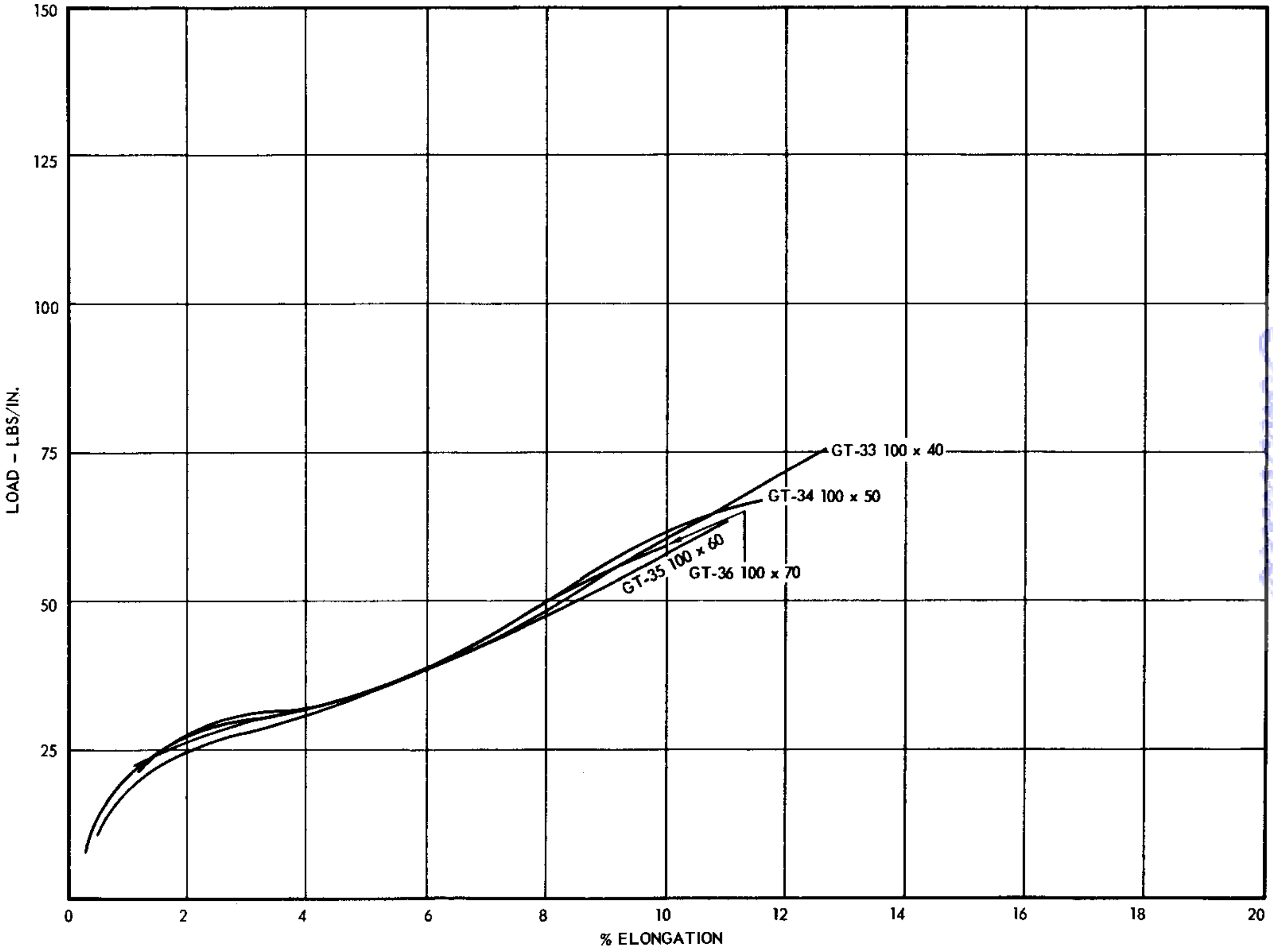

Figure 12. Effect of Pick Variation on Elastic Properties at 80°F. for Plain Weave Orlon Warp.

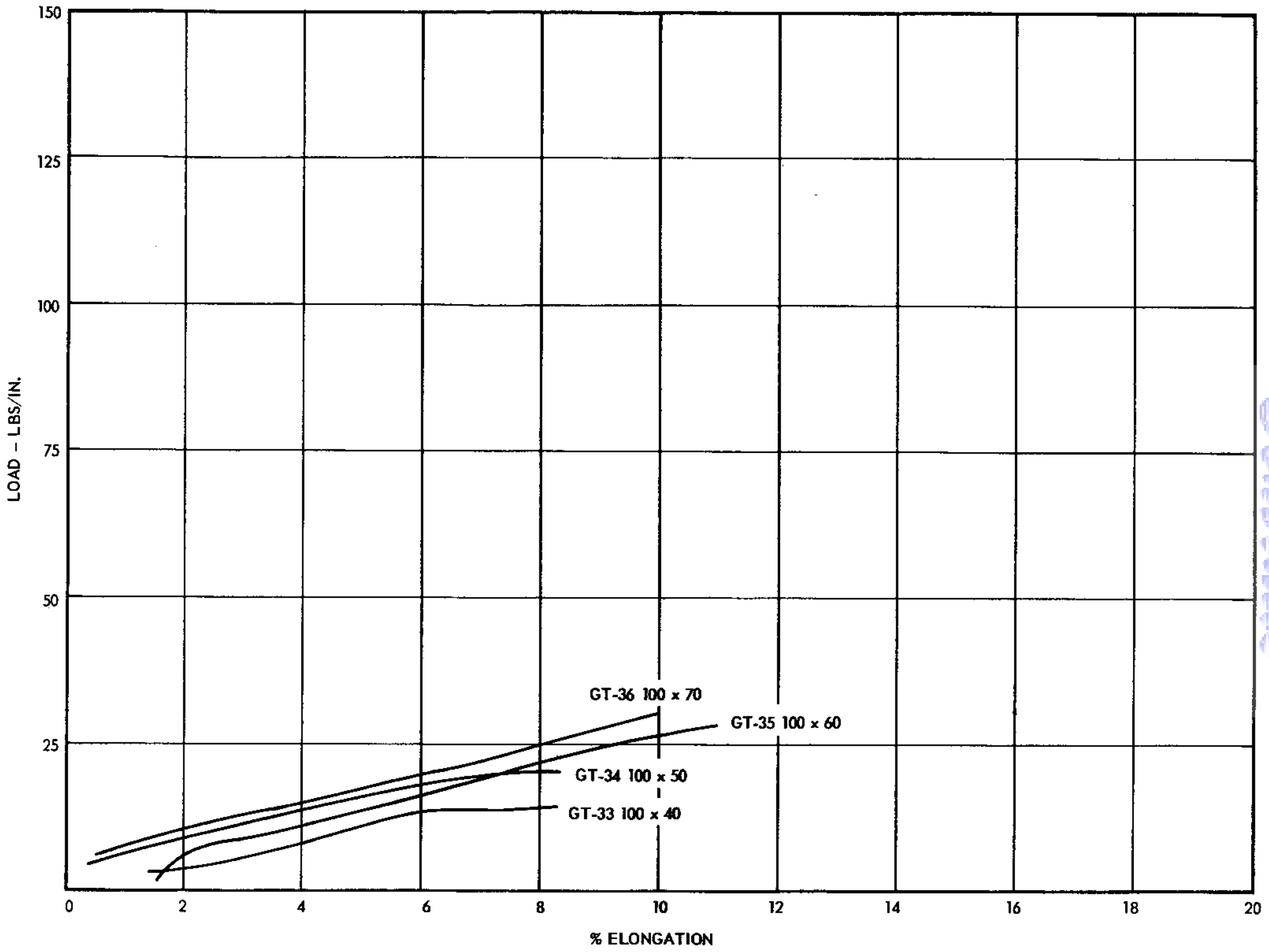

Figure 13. Effect of Pick Variation on Elastic Properties at 80°F. for Plain Weave Orlon Filling.

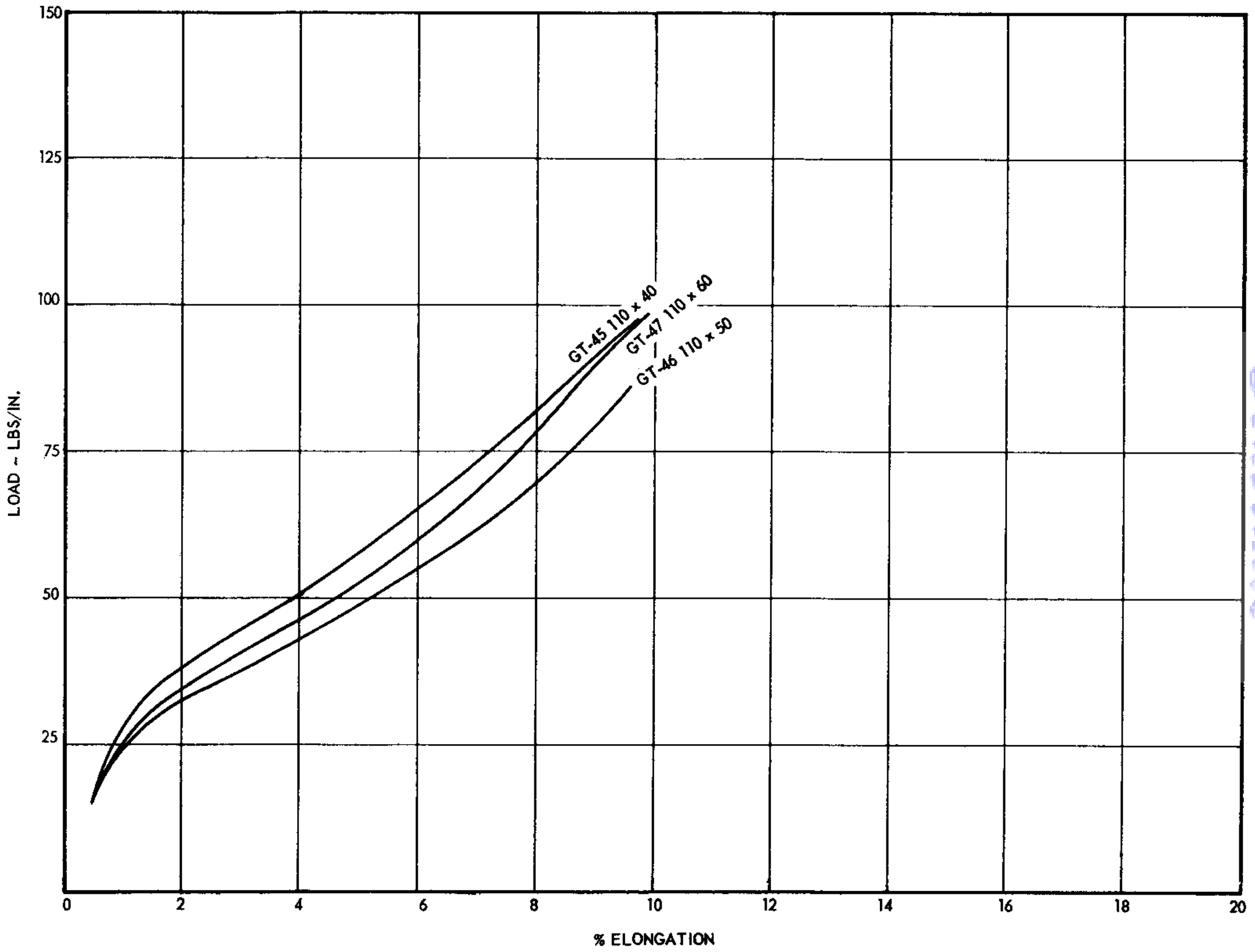

Figure 14. Effect of Pick Variation on Elastic Properties at -14°F. for Plain Weave Dacron Warp.

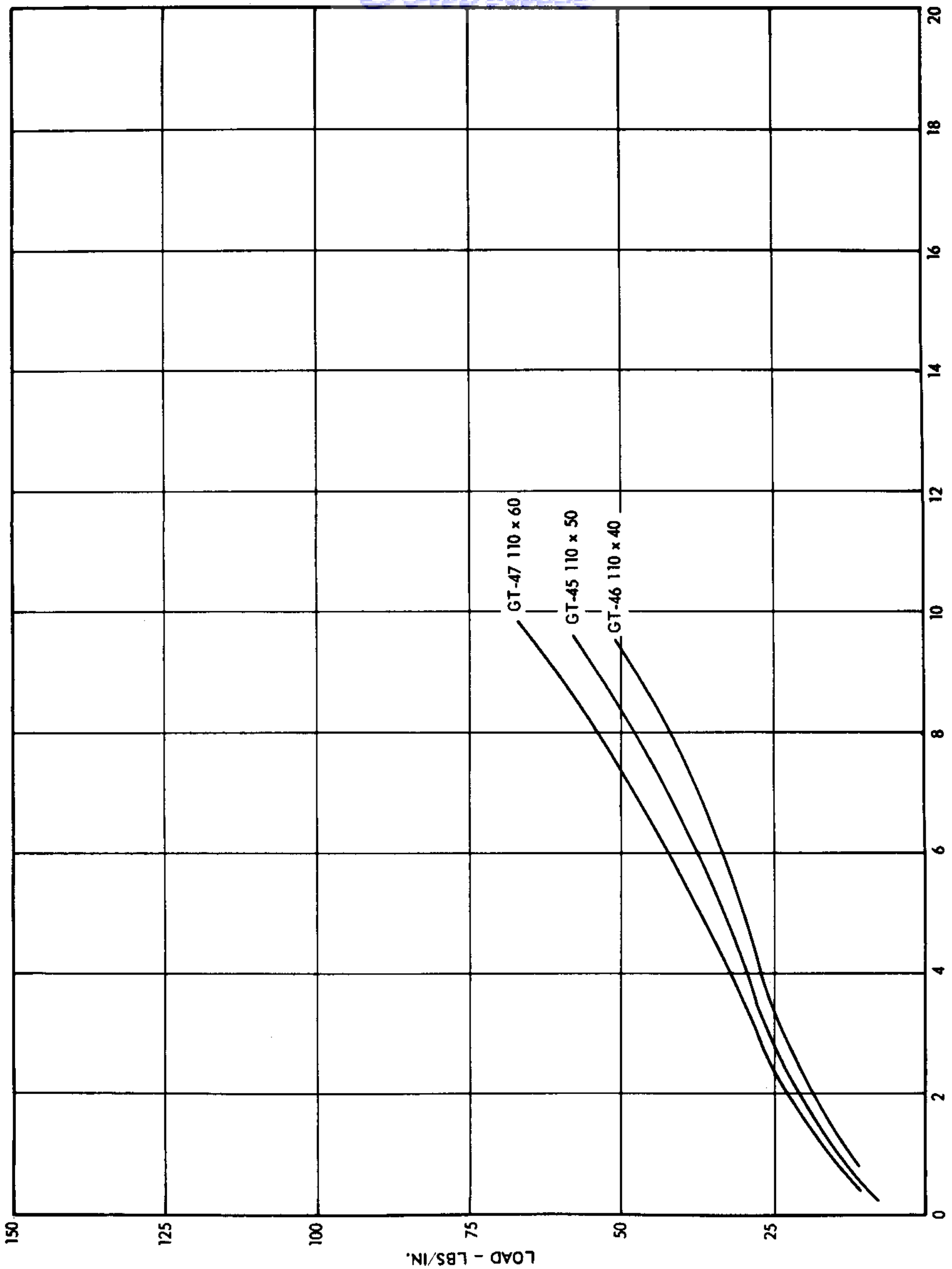

Figure 15 EFFECT OF PICK VARIATION ON ELASTIC PROPERTIES AT -14°F. FOR PLAIN WEAVE DACRON FILLING.

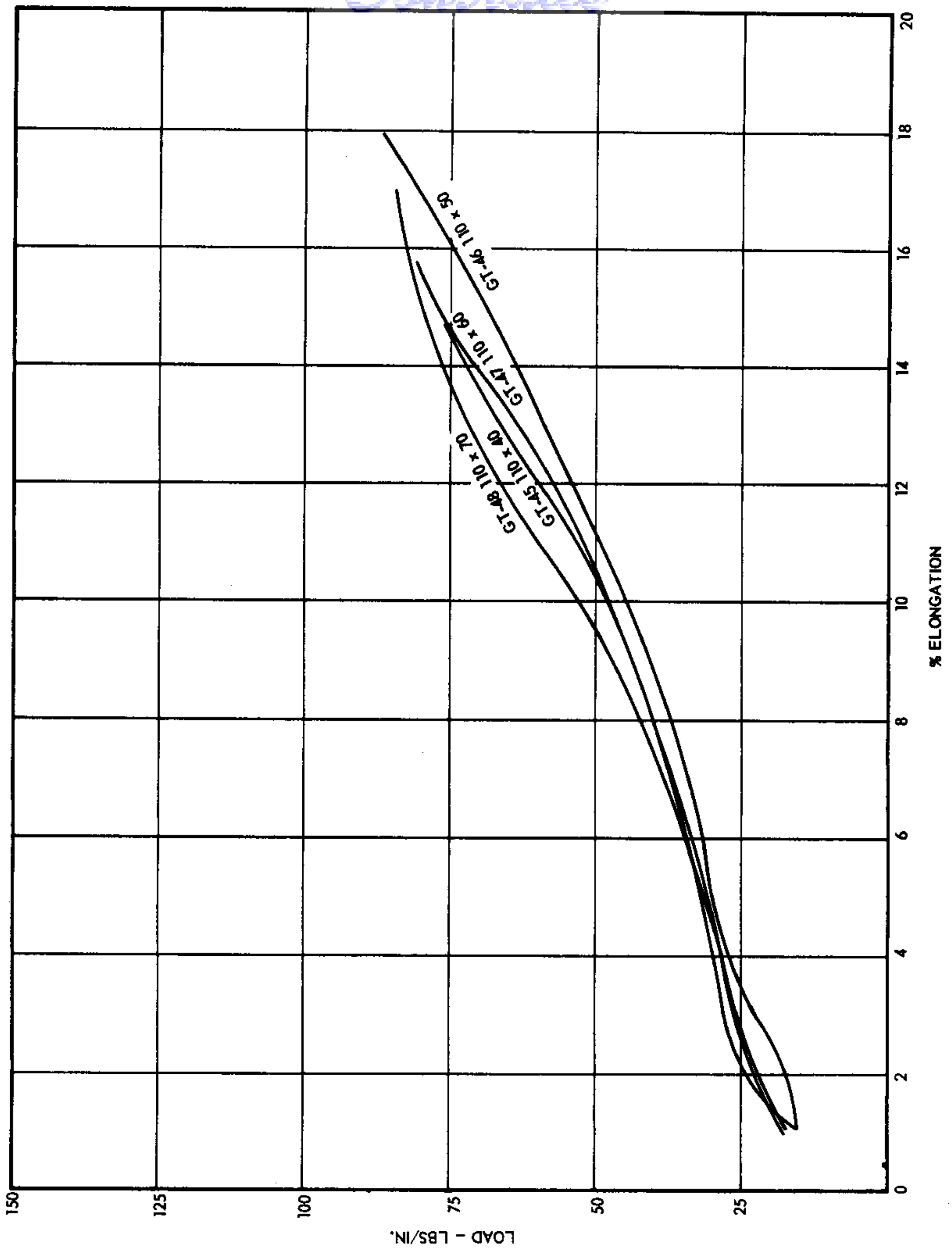

Figure 16. Effect of Pick Variation on Elastic Properties at 80°F. for Plain Weave Dacron Warp.

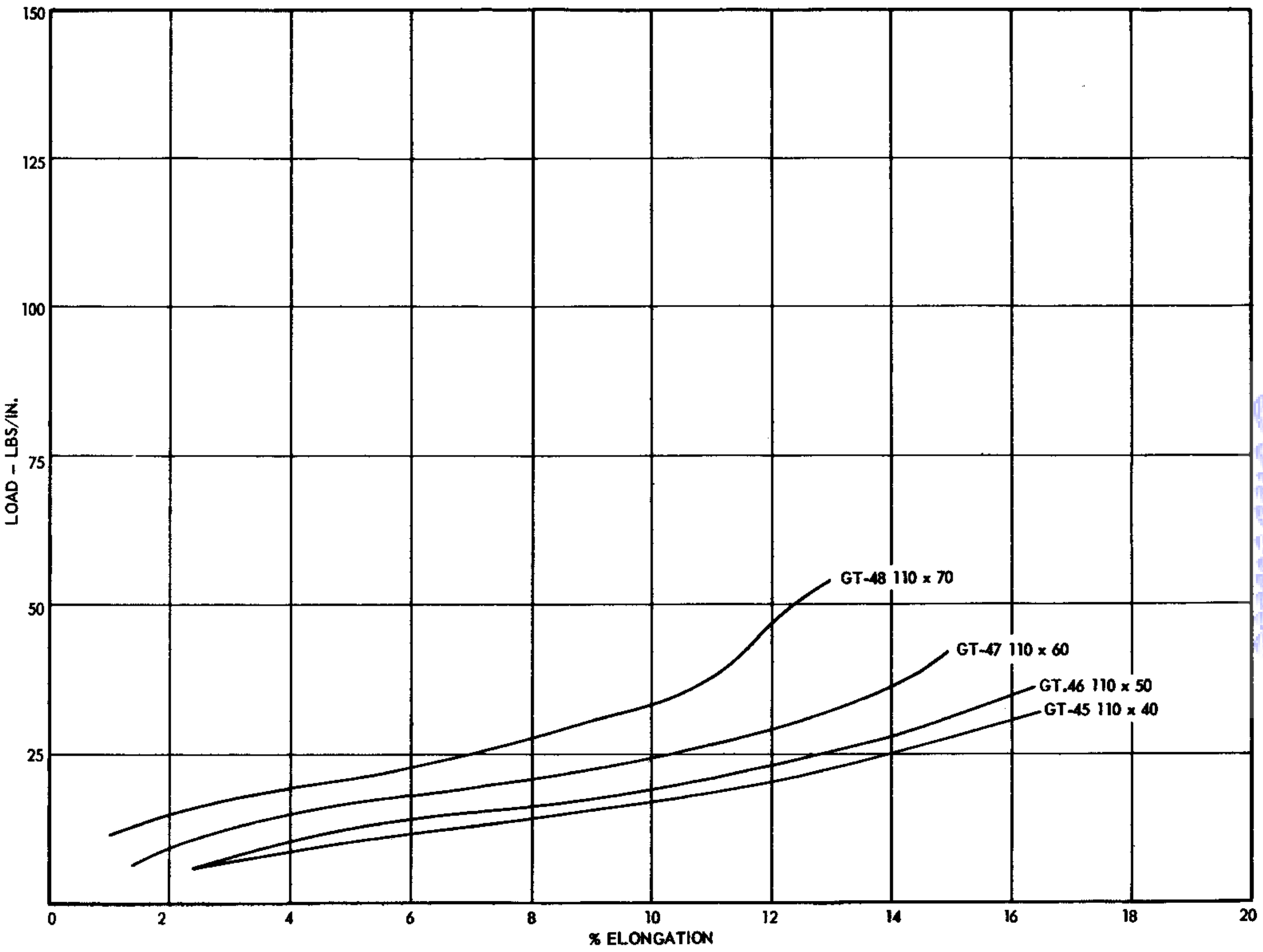

Figure 17. Effect of Pick Variation on Elastic Properties at 80°F. for Plain Weave Dacron Filling.

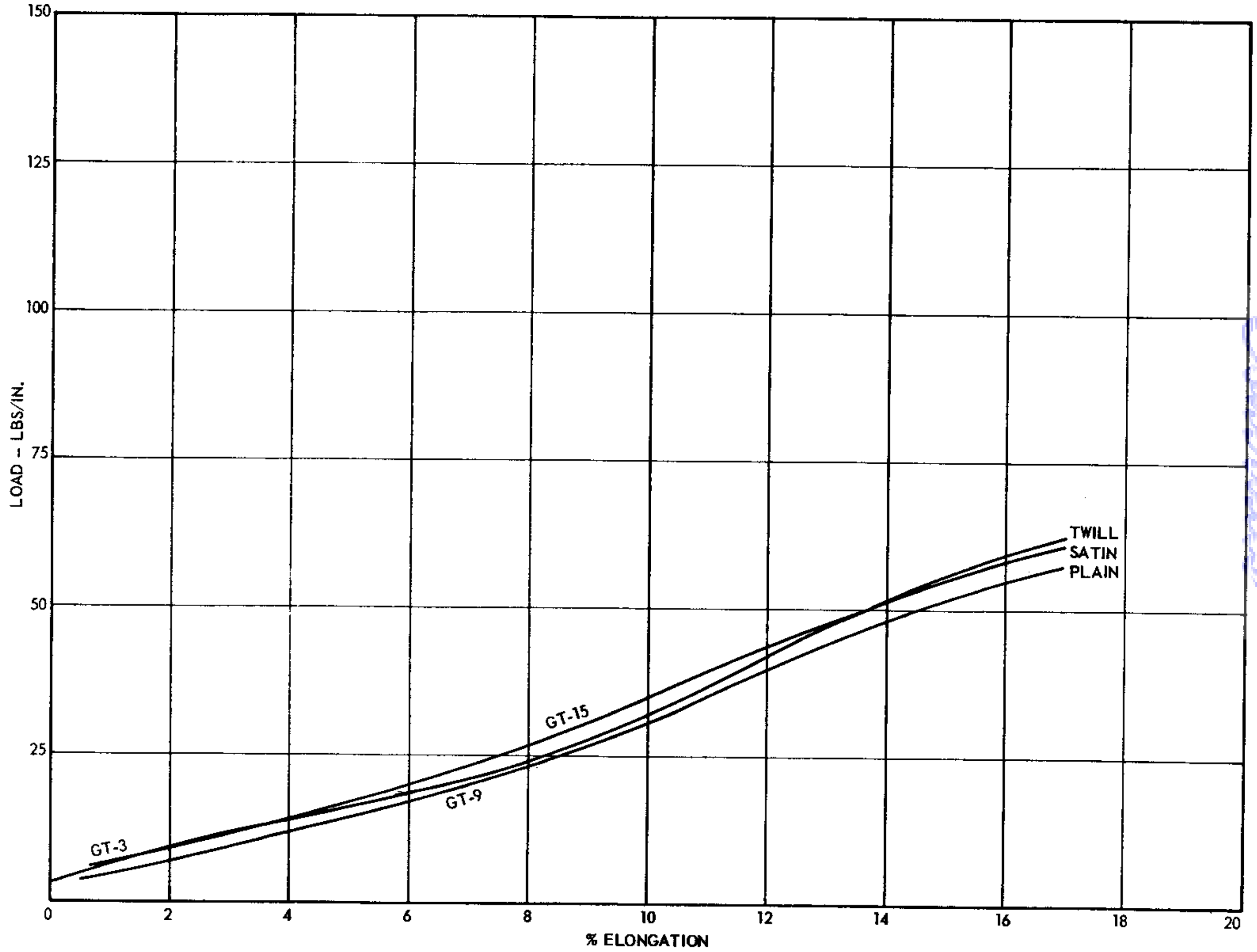

Figure 18. Effect of Weave Variation on Elastic Properties at 80°F. for 70x70 Nylon Warp.

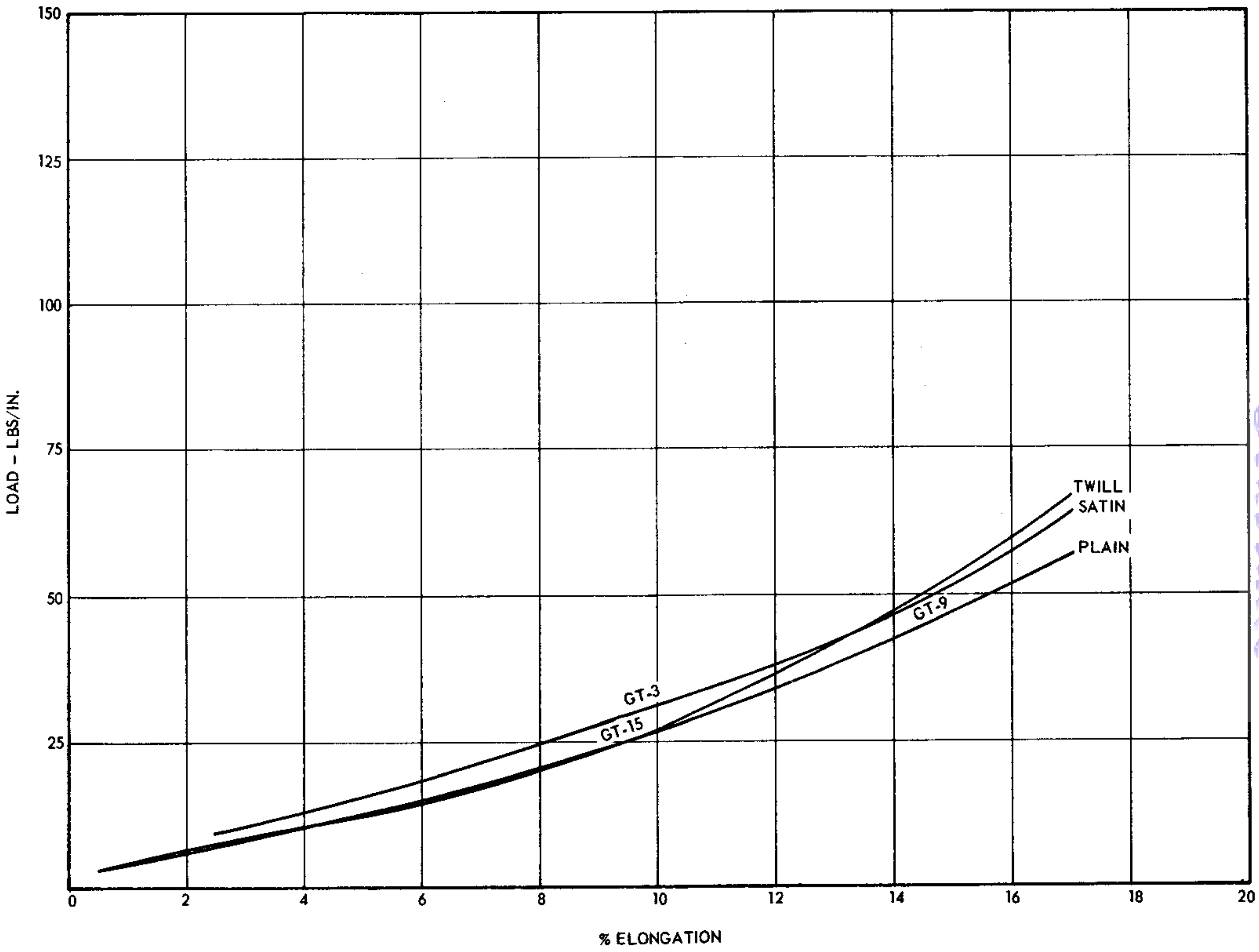

Figure 19. Effect of Weave Variation on Elastic Properties at 80°F. for 70x70 Nylon Filling.

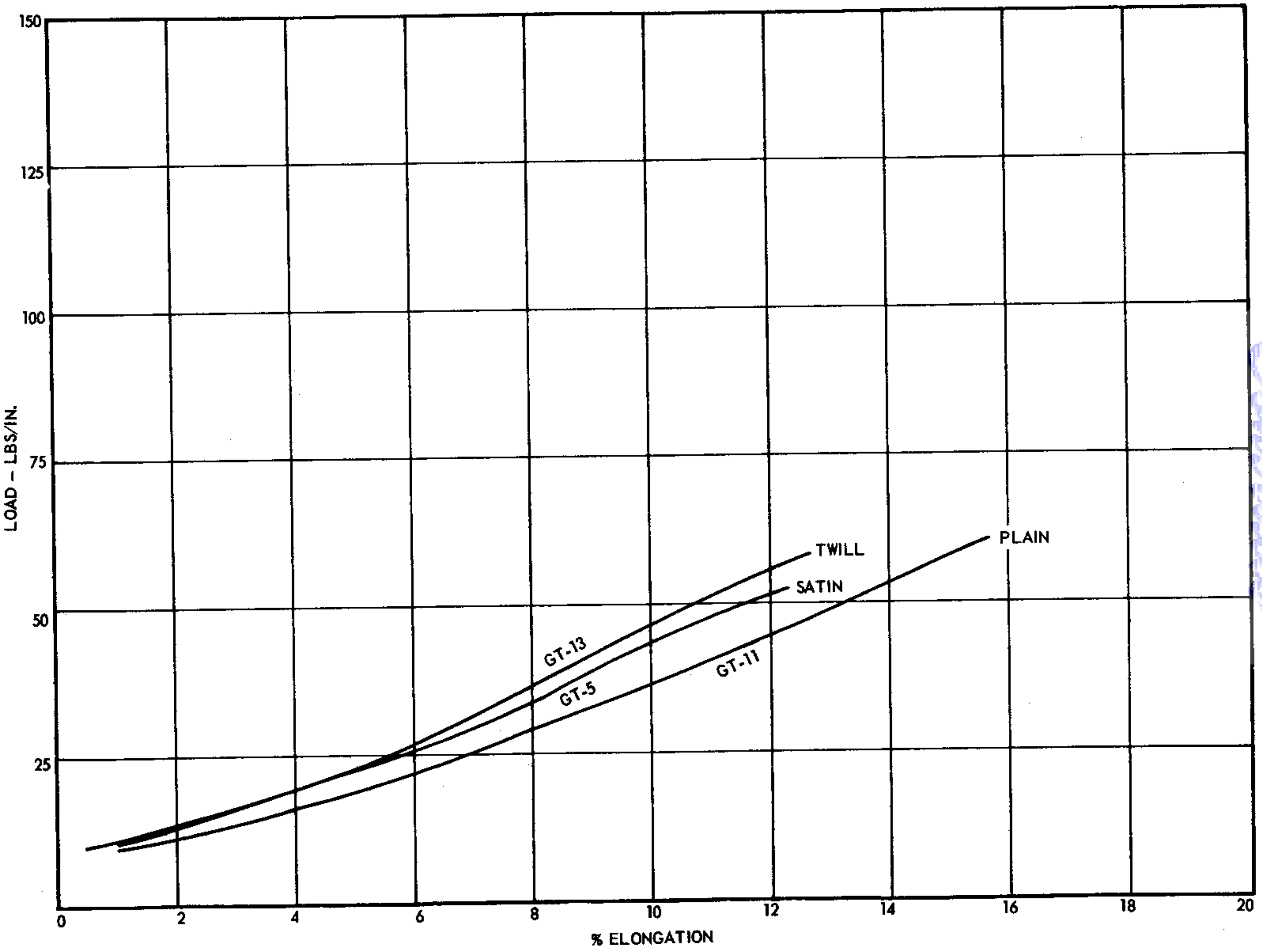

Figure 20. Effect of Weave Variation on Elastic Properties at 140°F. for 70x50 Nylon Warp.

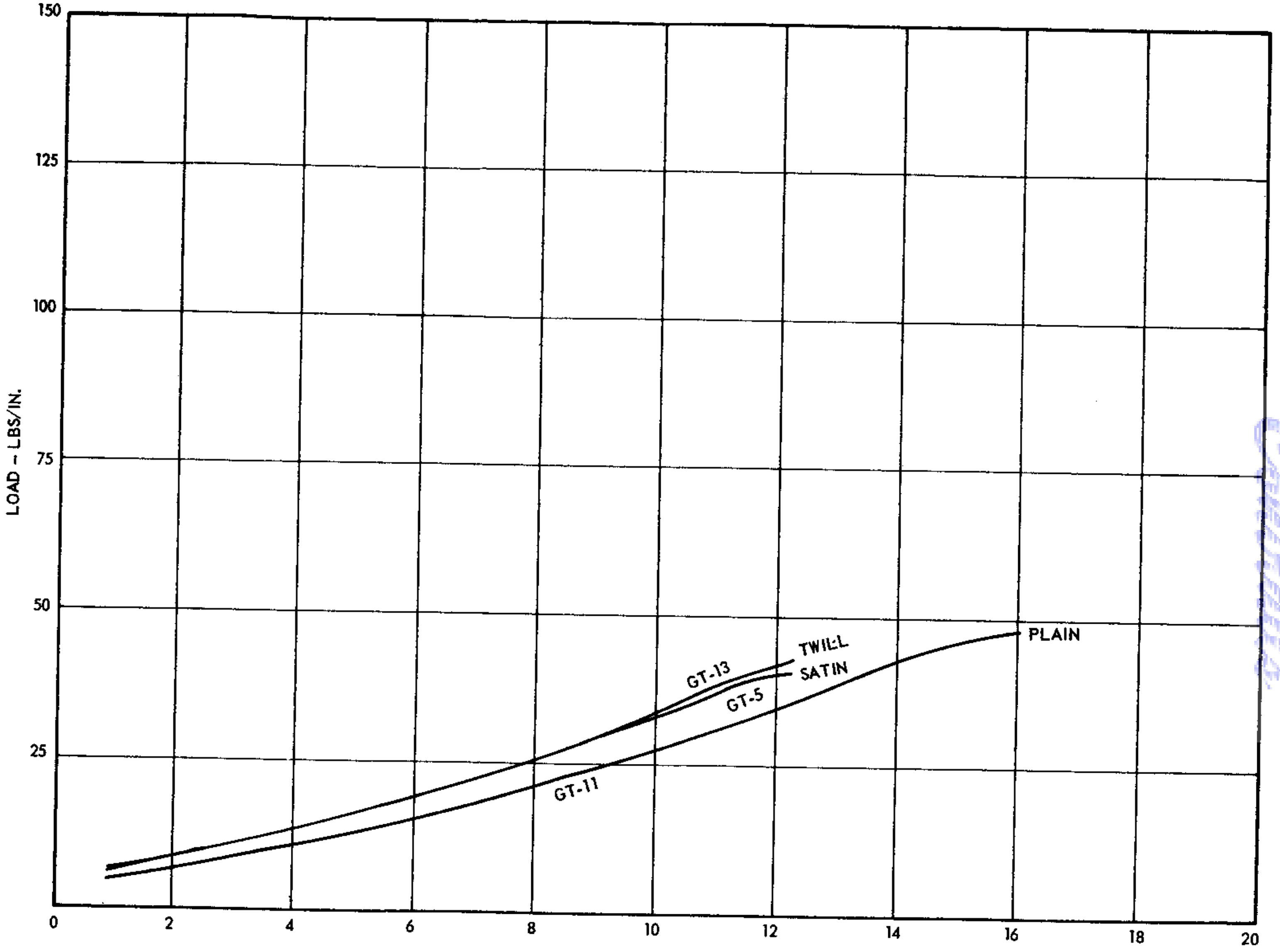

Figure 21. Effect of Weave Variation on Elastic Properties at 140°F. for 70x50 Nylon Filling.

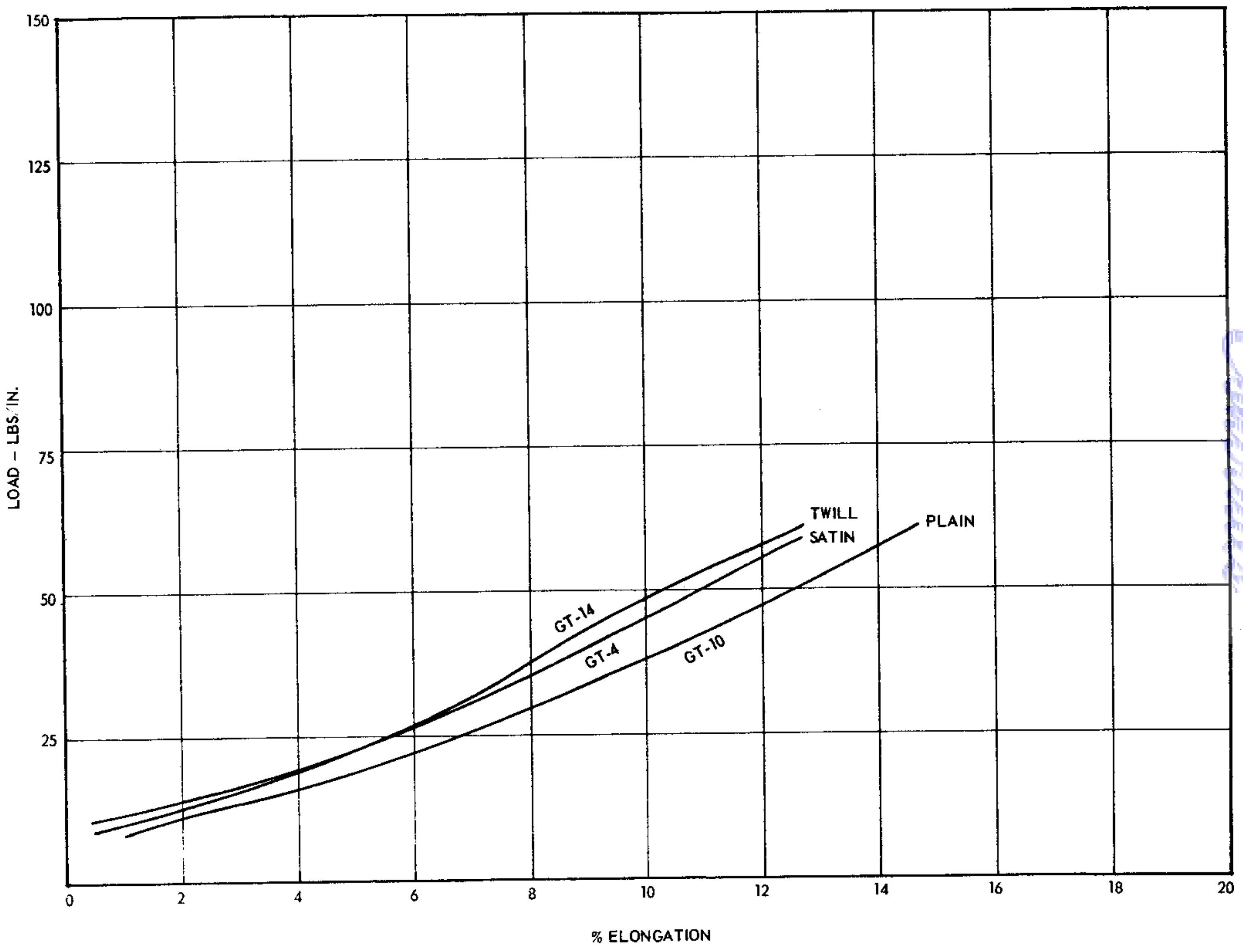

Figure 22. Effect of Weave Variation on Elastic Properties at 140°F. for 70x60 Nylon Warp.

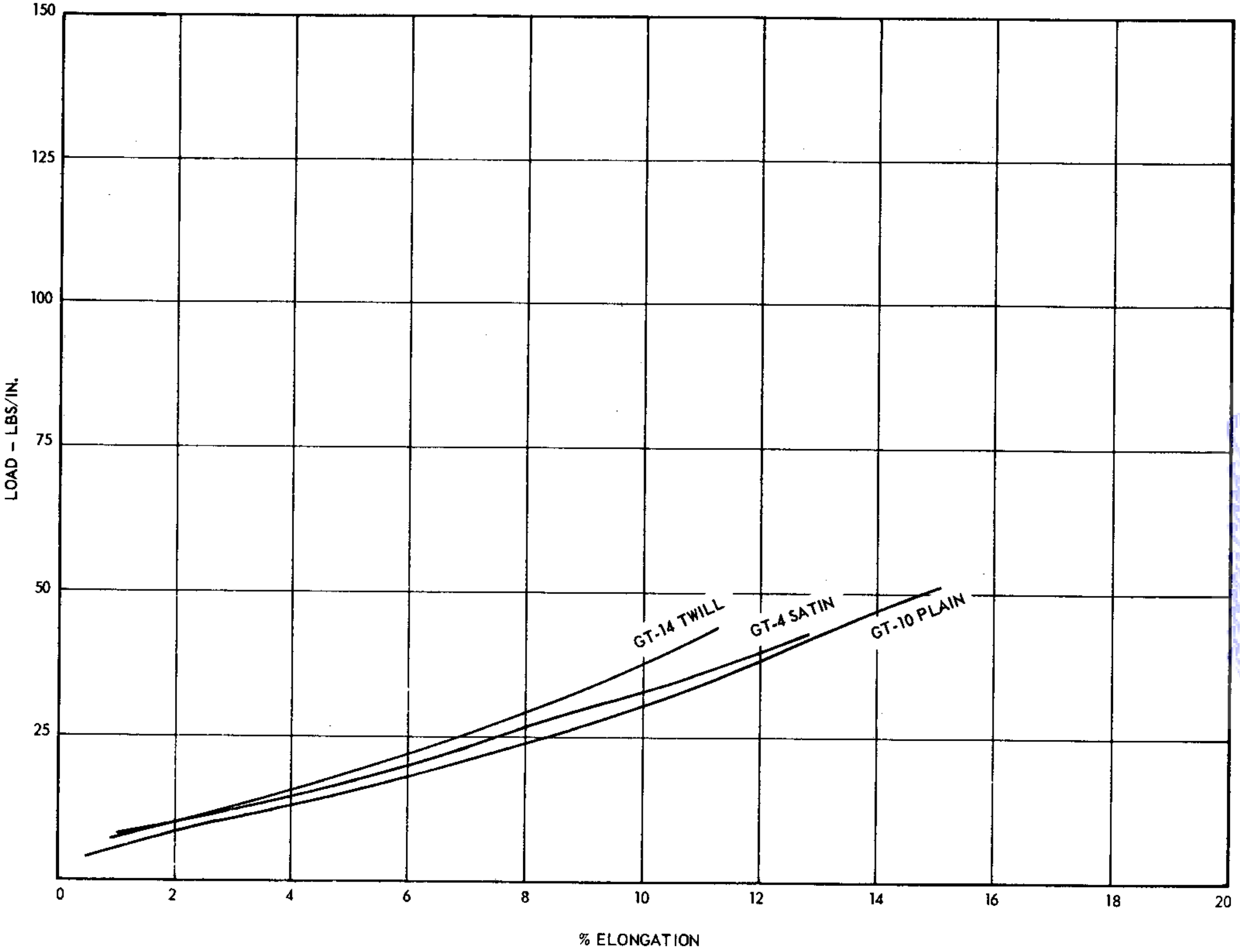

Figure 23. Effect of Weave Variation on Elastic Properties at 140°F. for 70x60 Nylon Filling.

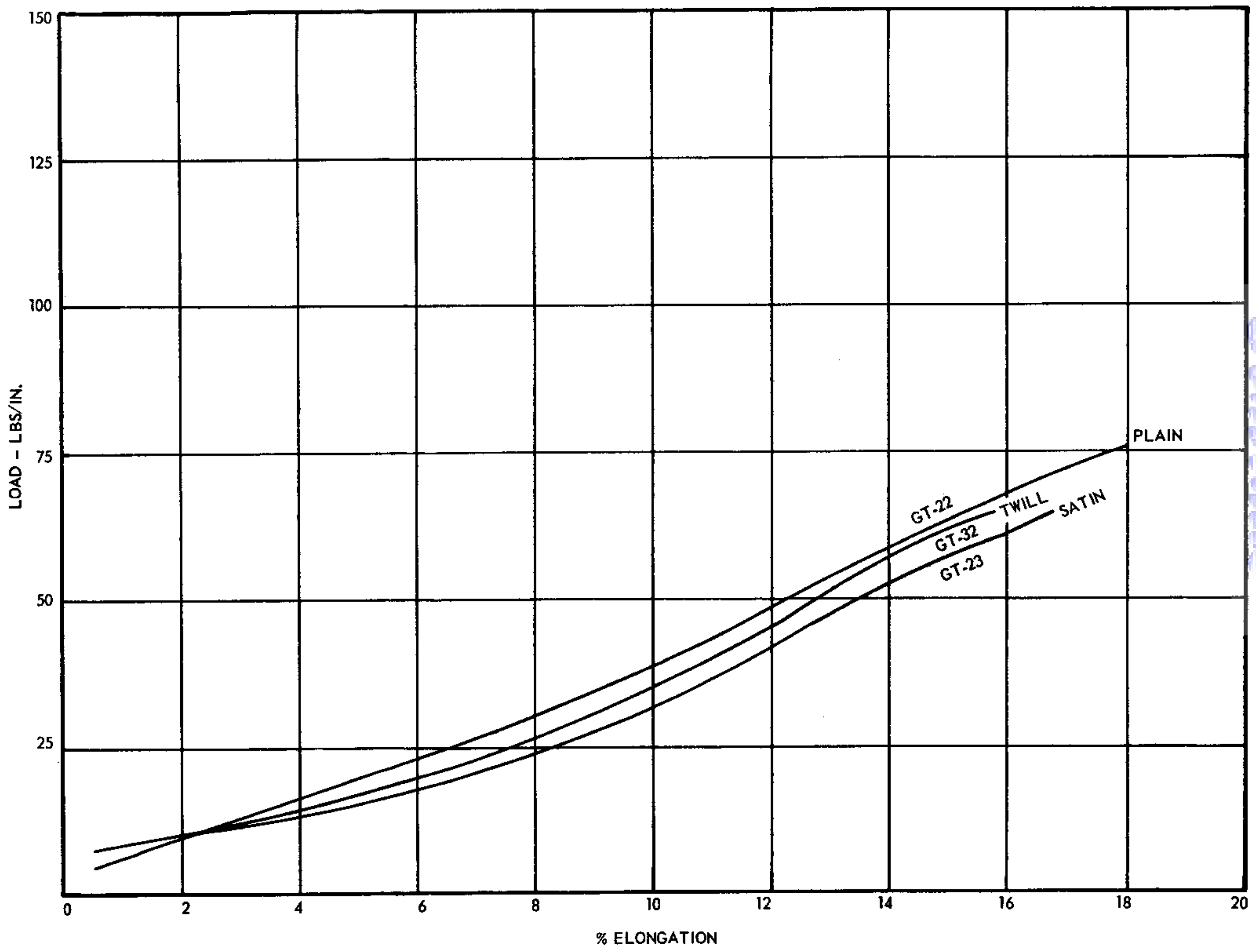

Figure 24. Effect of Weave Variation on Elastic Properties at 80°F. for 125x80 Nylon Warp.

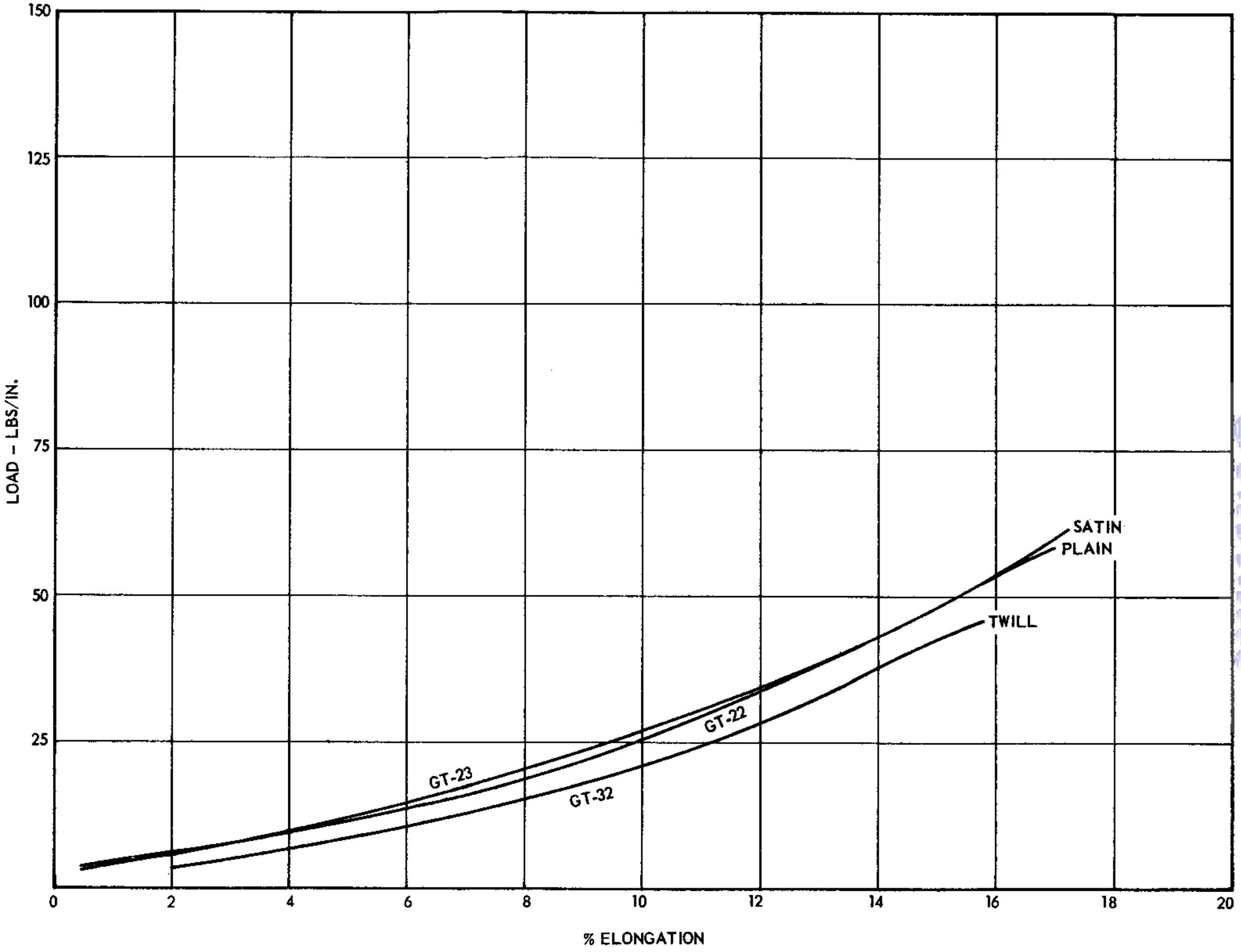

Figure 25. Effect of Weave Variation on Elastic Properties at 80°F. for 125x80 Nylon Filling.

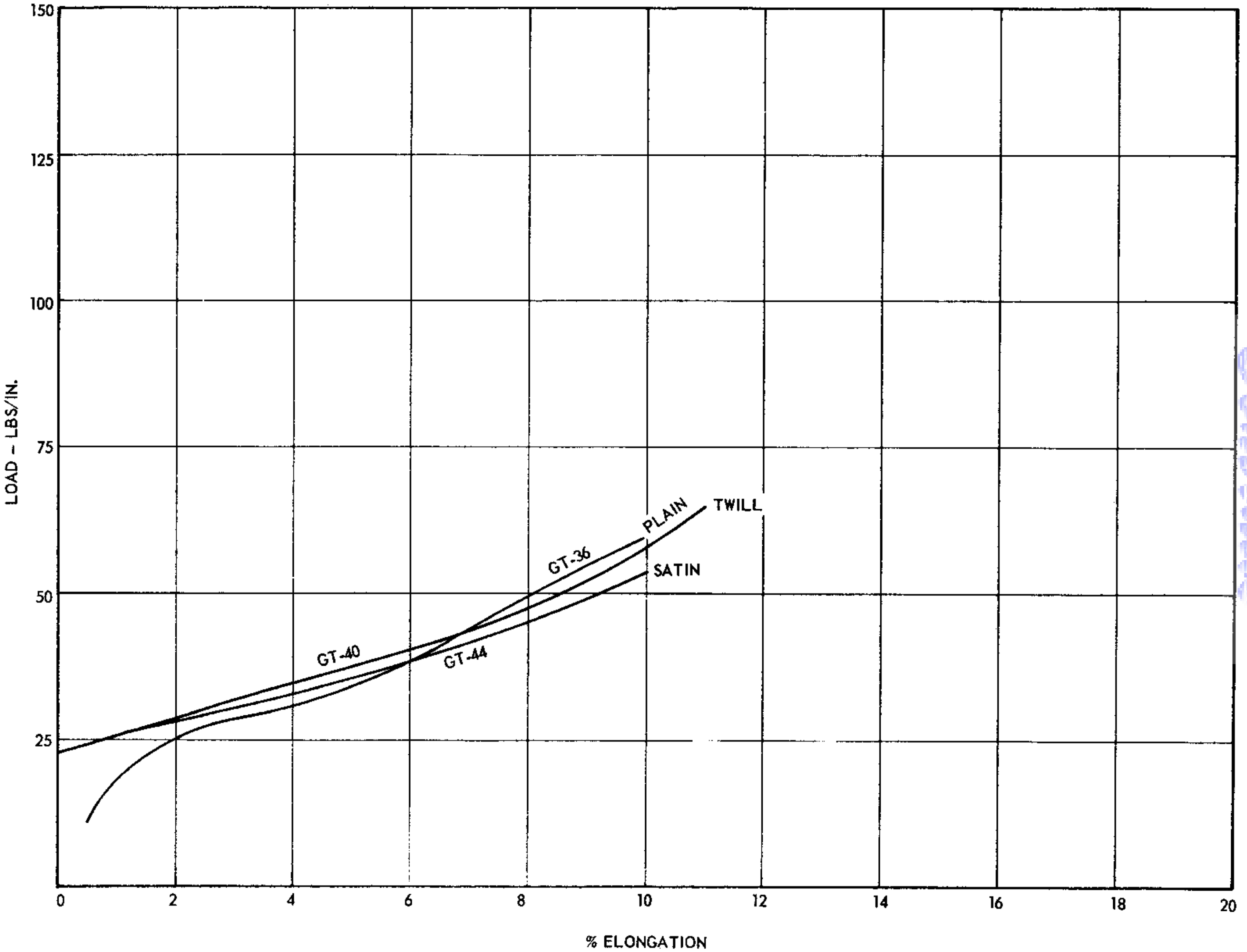

Figure 26. Effect of Weave Variation on Elastic Properties at $80^{\circ}F$. for 100x70 Orlon Warp.

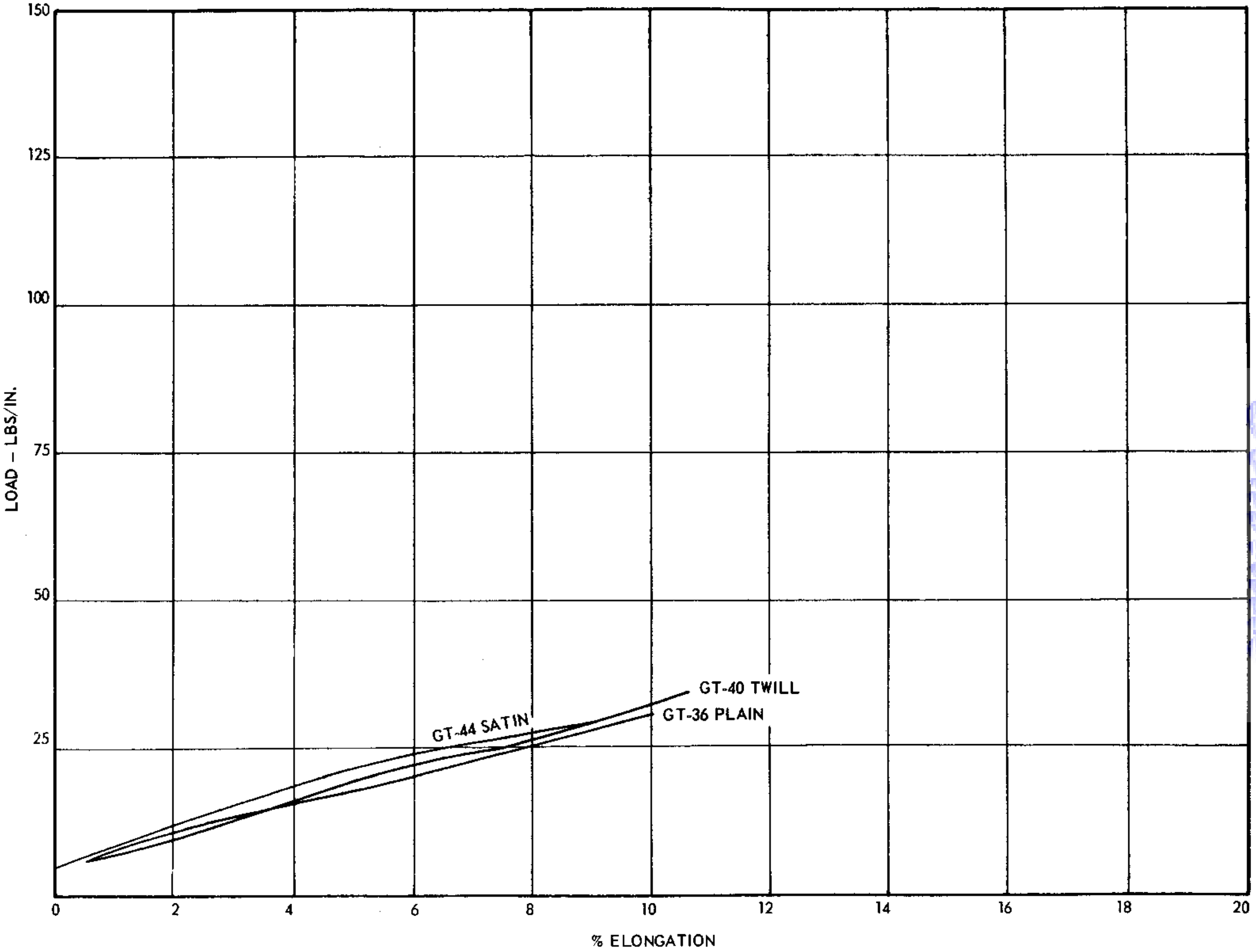

Figure 27. Effect of Weave Variation on Elastic Properties at 80°F. for 100x70 Orlon Filling.

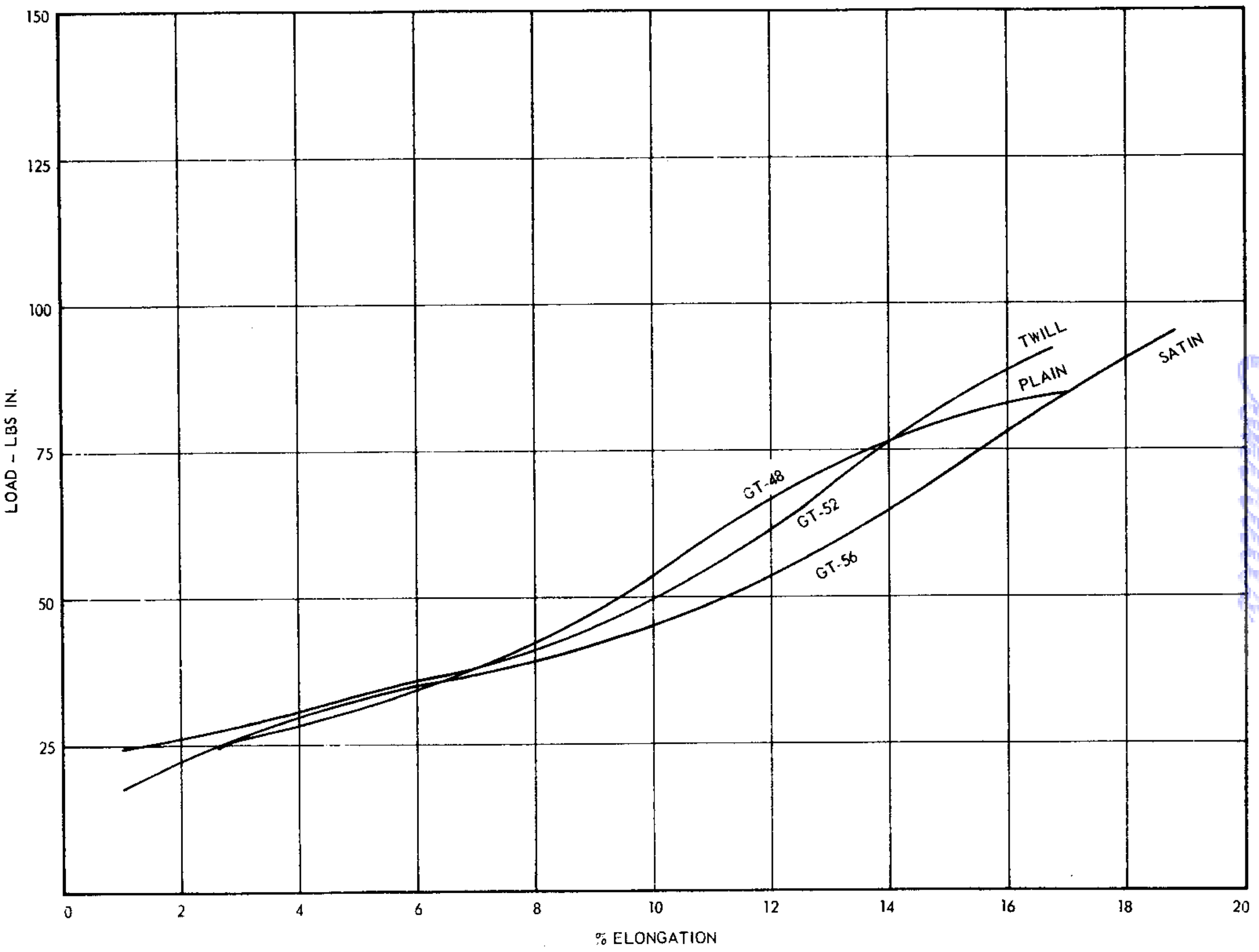

Figure 28. Effect of Weave Variation on Elastic Properties at 80°F. for 110x70 Dacron Warp.

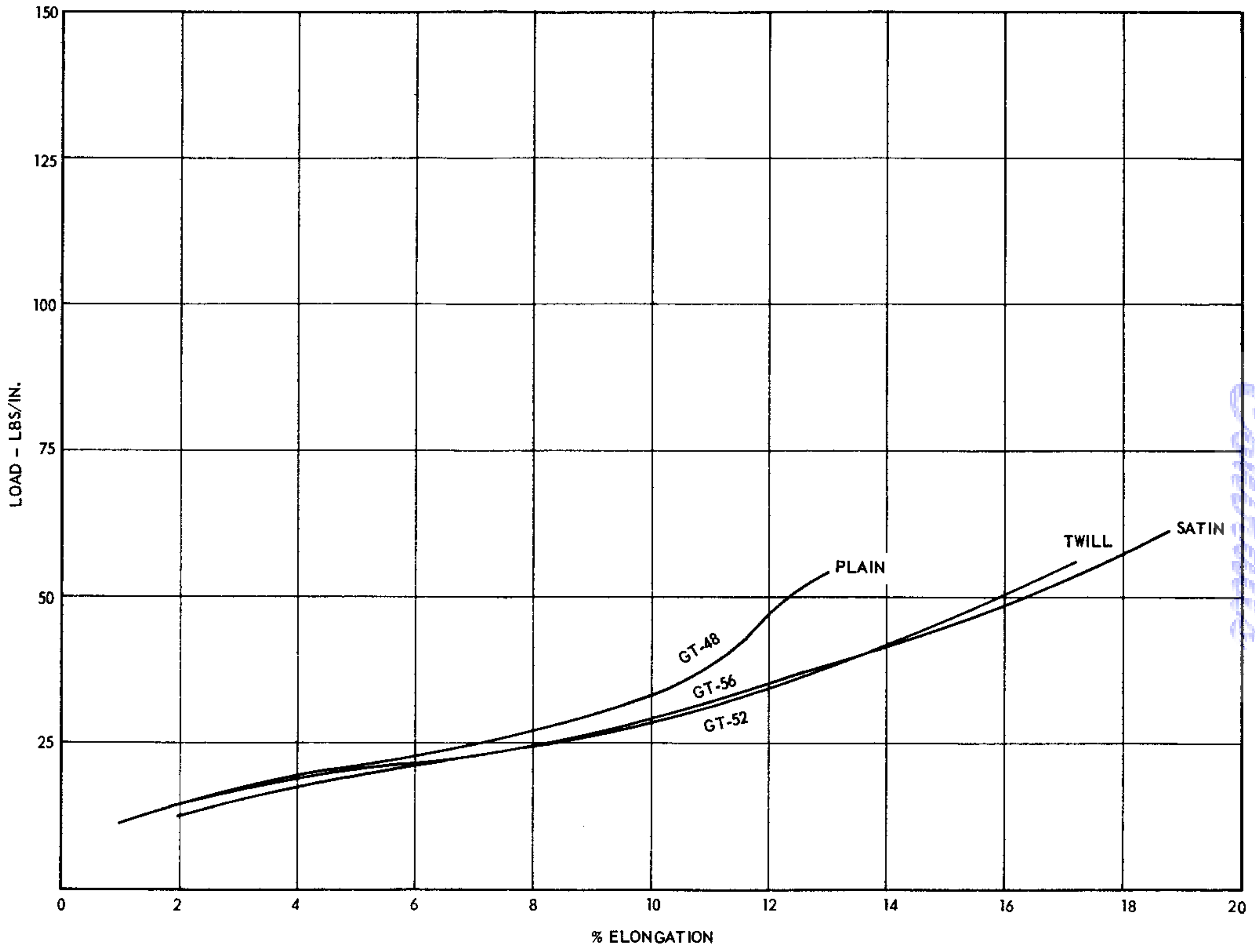

Figure 29. Effect of Weave Variation on Elastic Properties at 80°F. for 110x70 Dacron Filling.

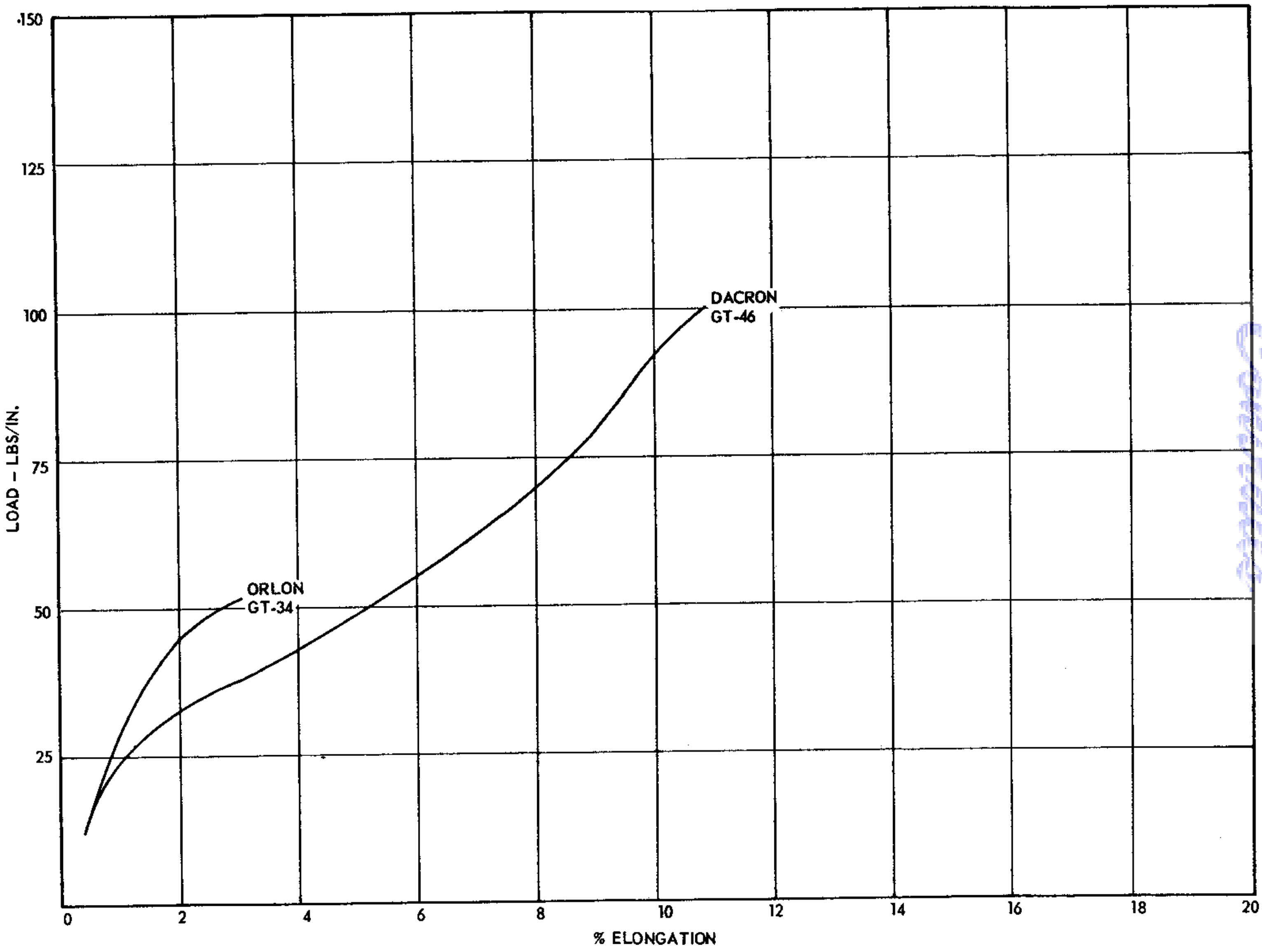

Figure 30. Effect of Material Variation on Elastic Properties at -14°F. for 100x50 Construction Warp.

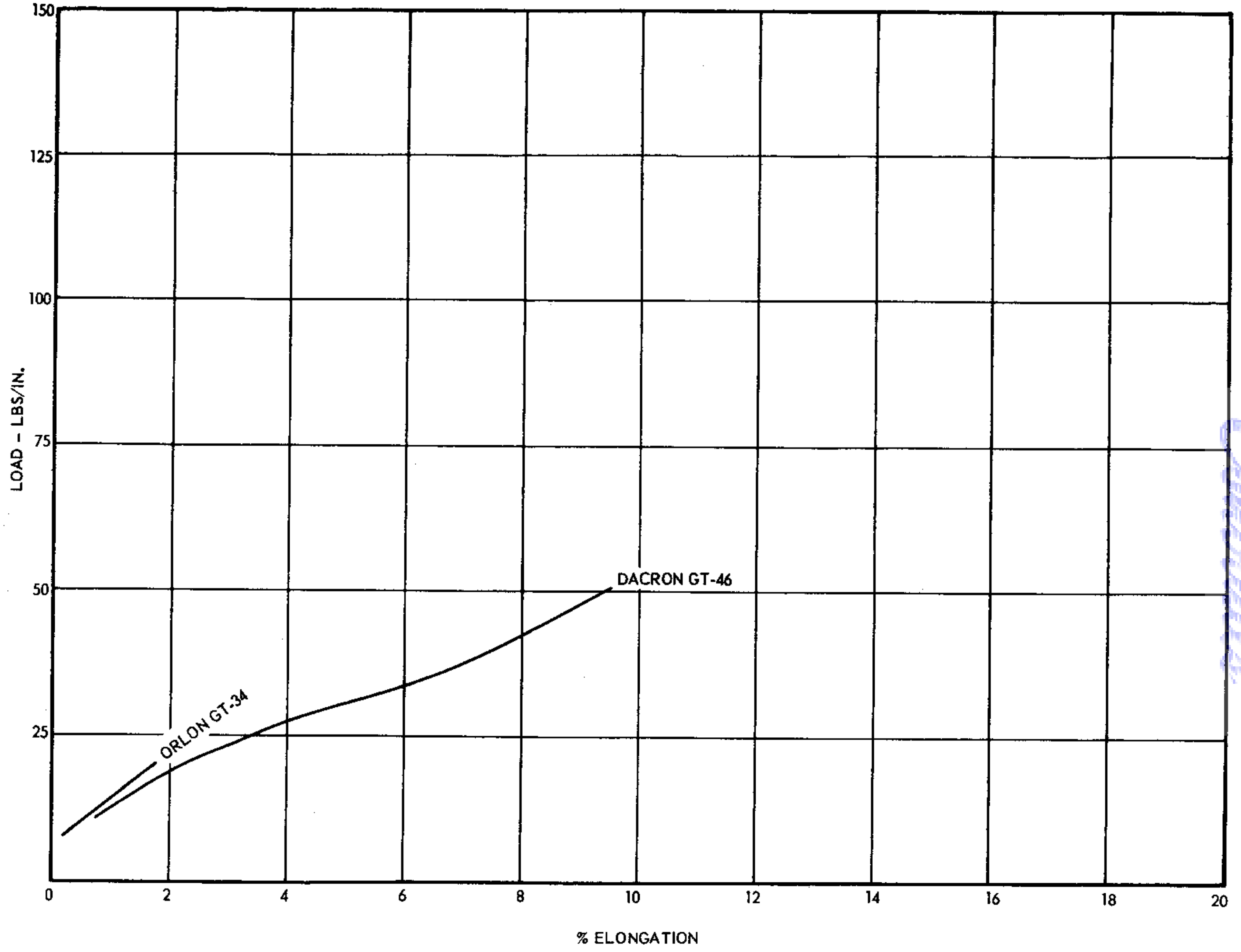

Figure 31. Effect of Material Variation on Elastic Properties at -14°F. for 100x50 Construction Filling.

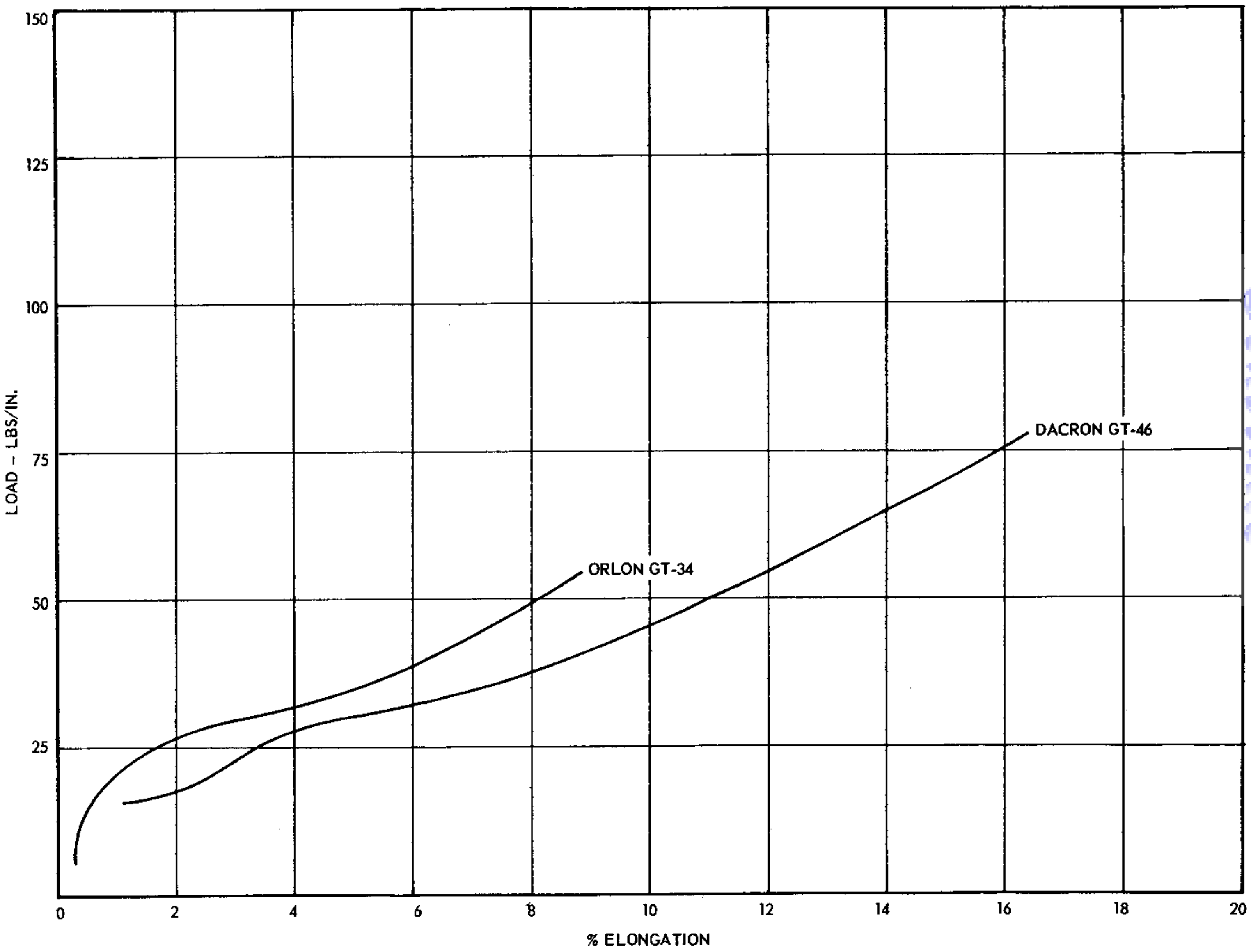

Figure 32. Effect of Material Variation on Elastic Properties at 80°F. for 100x50 Construction Warp.

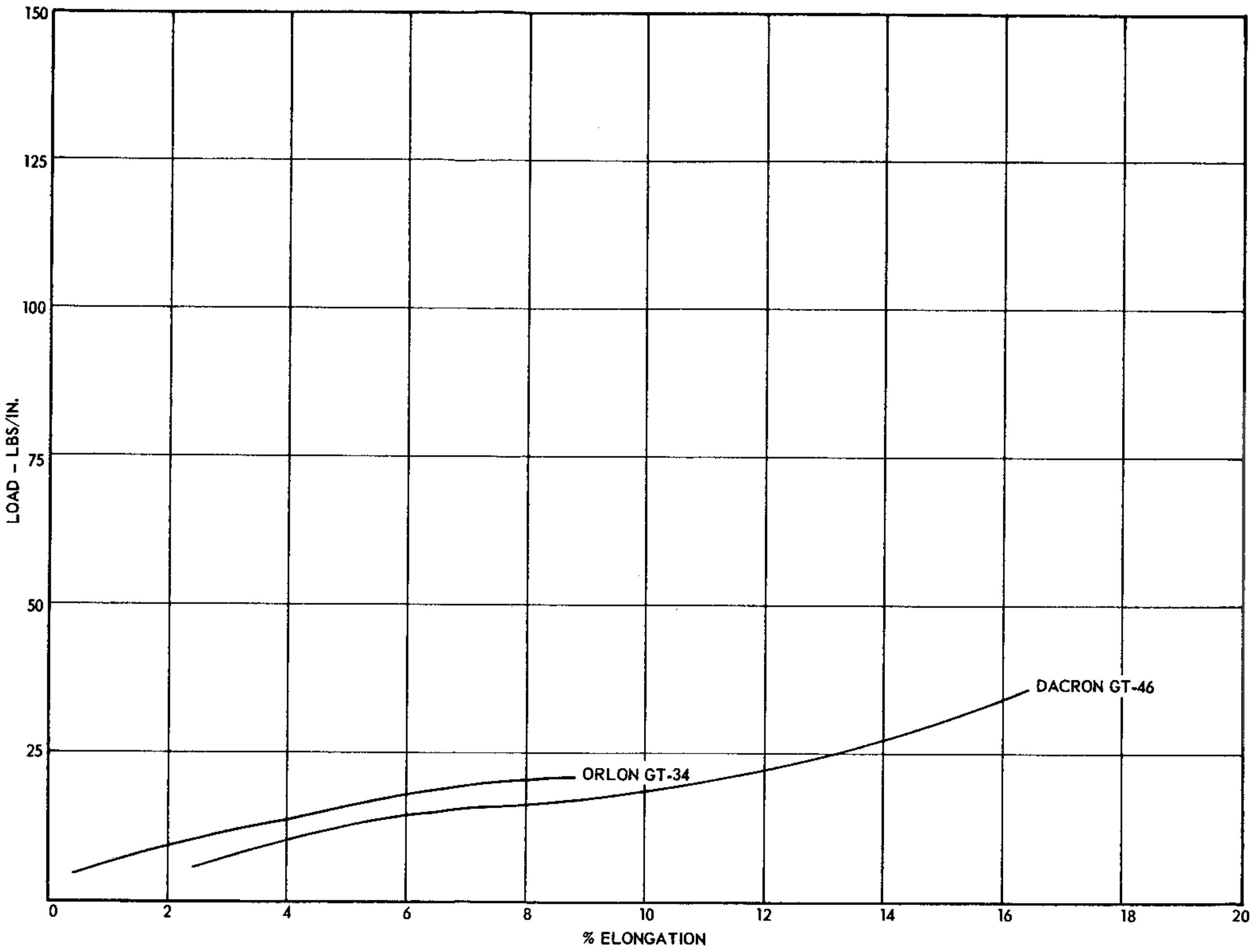

Figure 33. Effect of Material Variation on Elastic Properties at 80°F. for 100x50 Construction Filling.

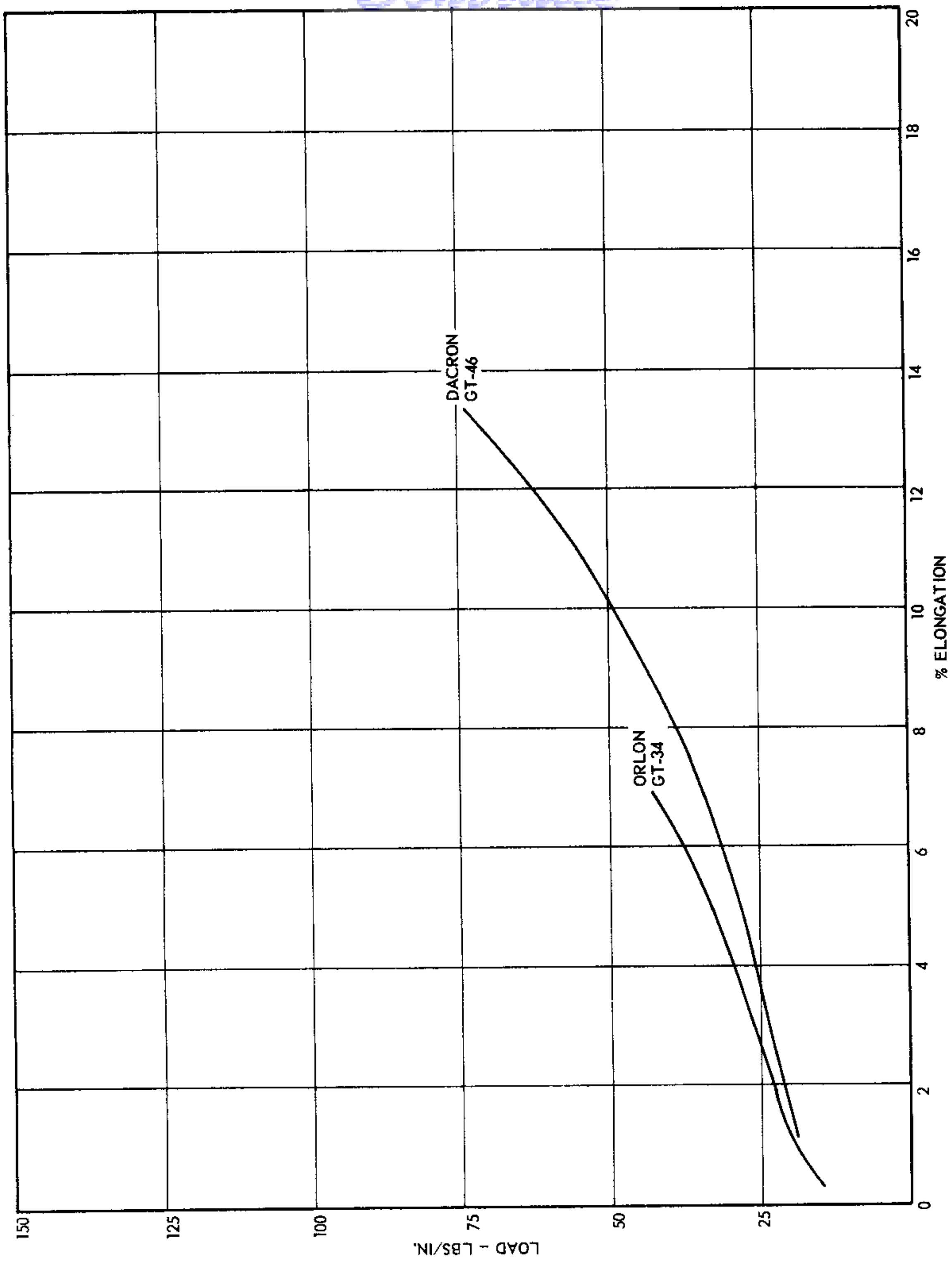

Figure 34. Effect of Material Variation on Elastic Properties at 140°F. for 100x50 Construction Warp.

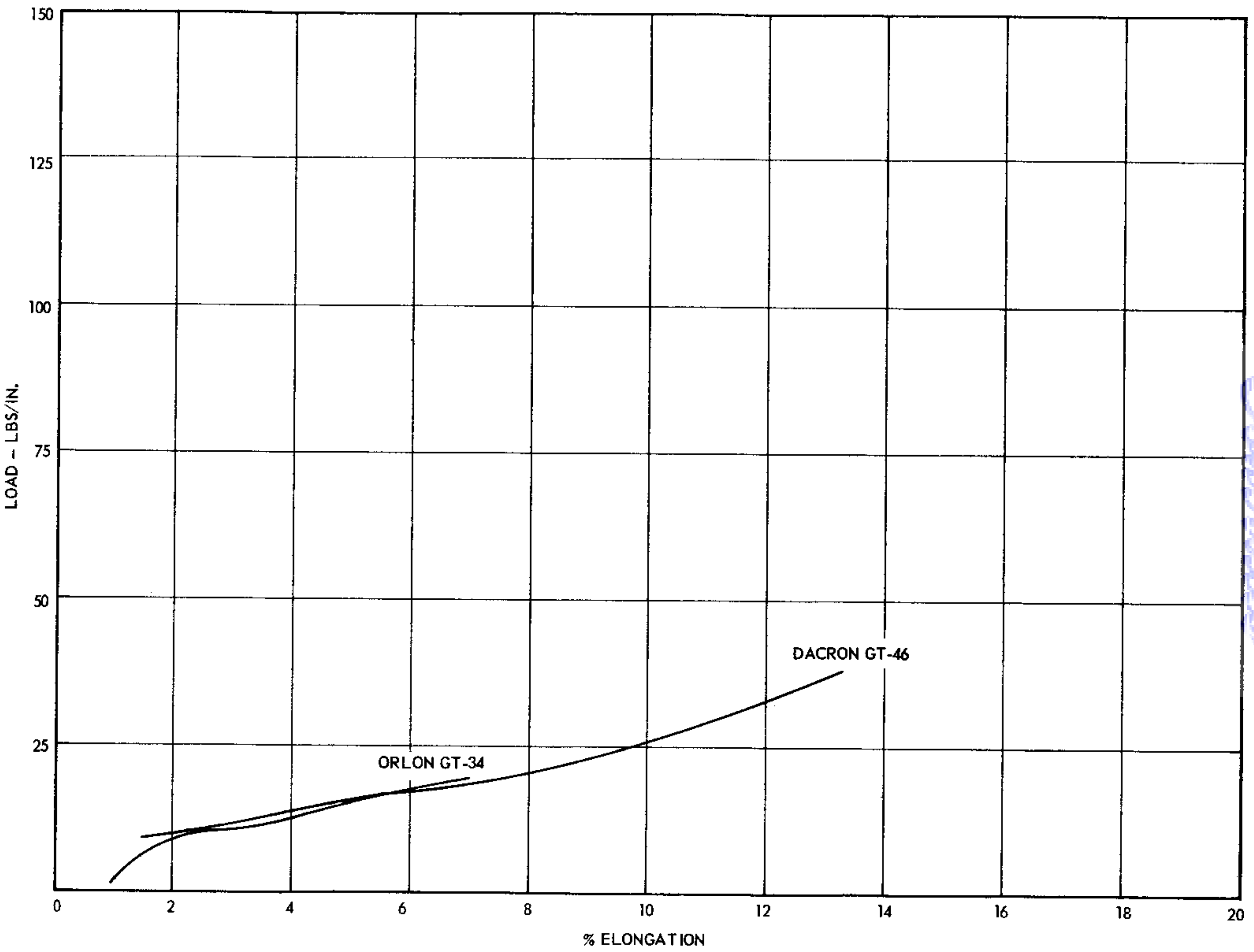

Figure 35. Effect of Material Variation on Elastic Properties at 140°F. for 100x50 Construction Filling.

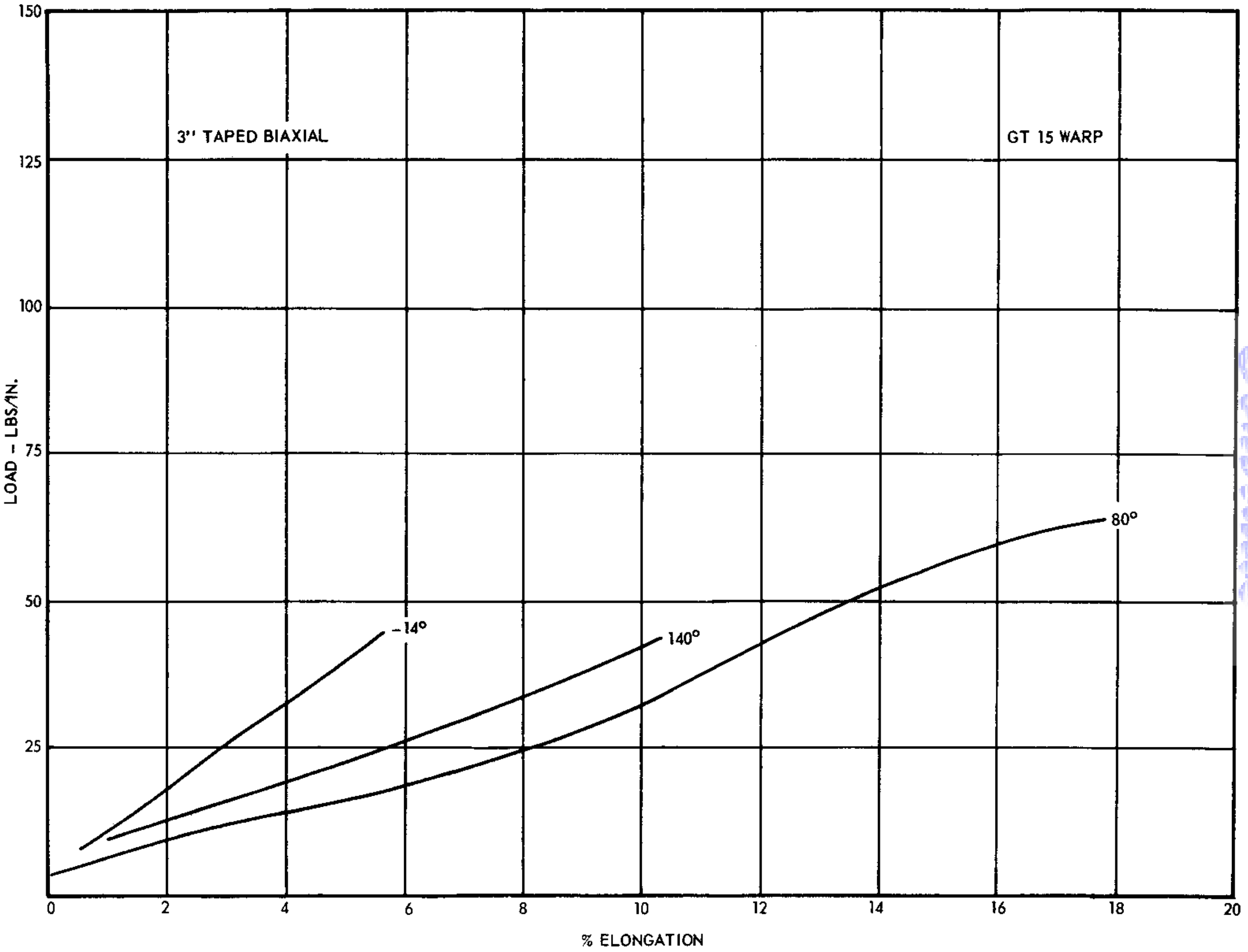

Figure 36. Effect of Temperature Variation on Elastic Properties of Nylon for GT-15 70x70 Twill Warp.

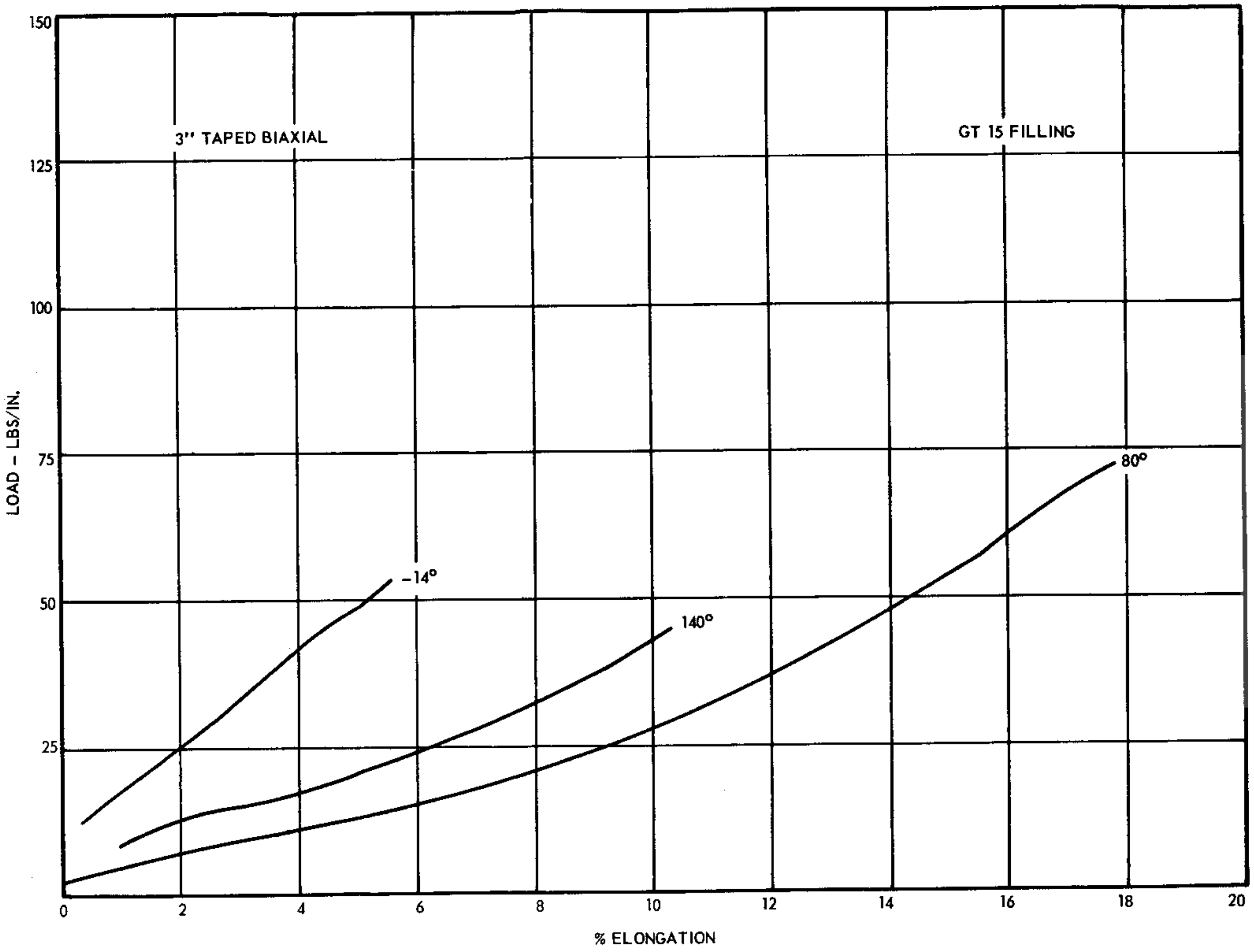

Figure 37. Effect of Temperature Variation on Elastic Properties of Nylon for GT-15 70x70 Twill Filling.

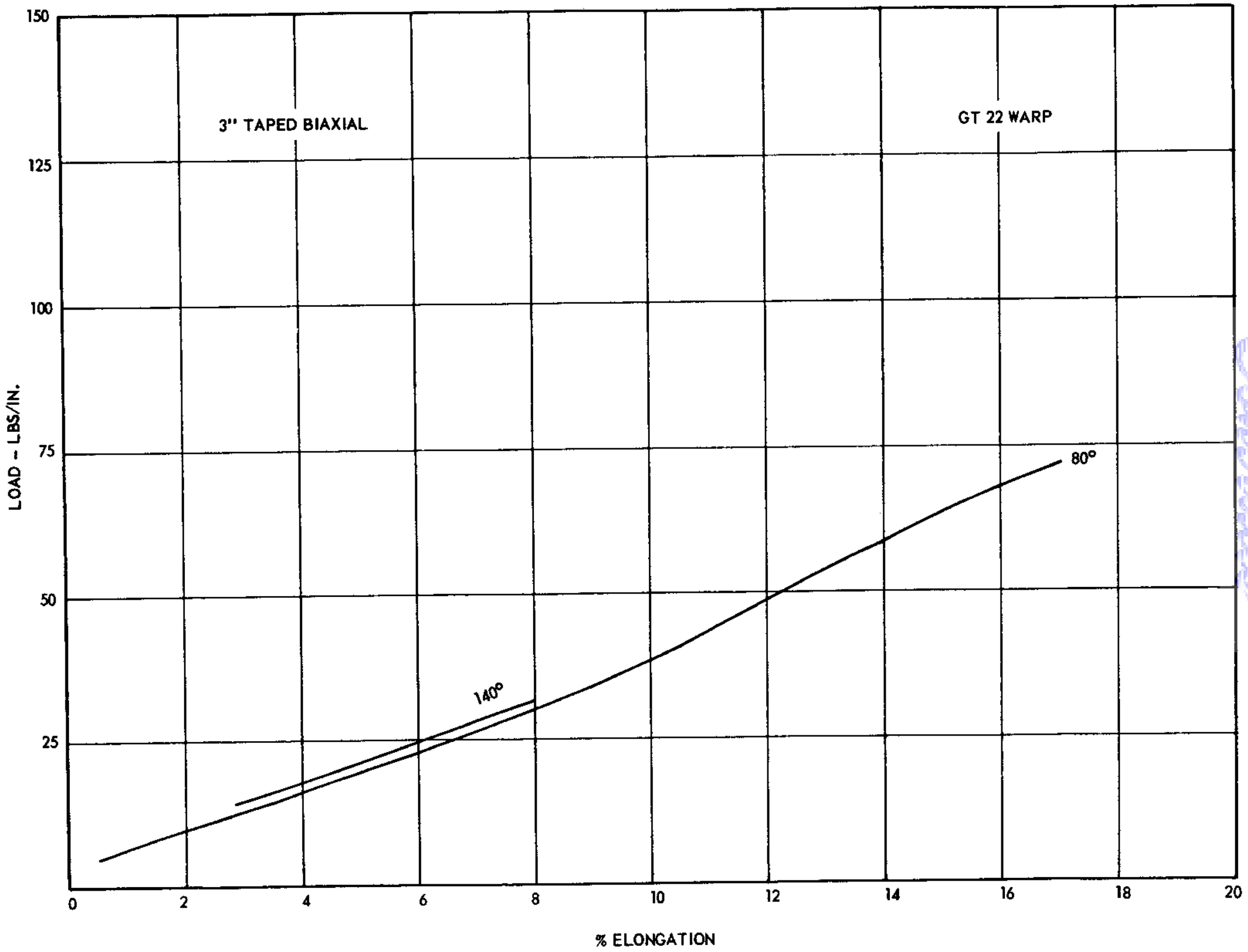

Figure 38. Effect of Temperature Variation on Elastic Properties of Nylon for GT-22 125x80 Plain Warp.

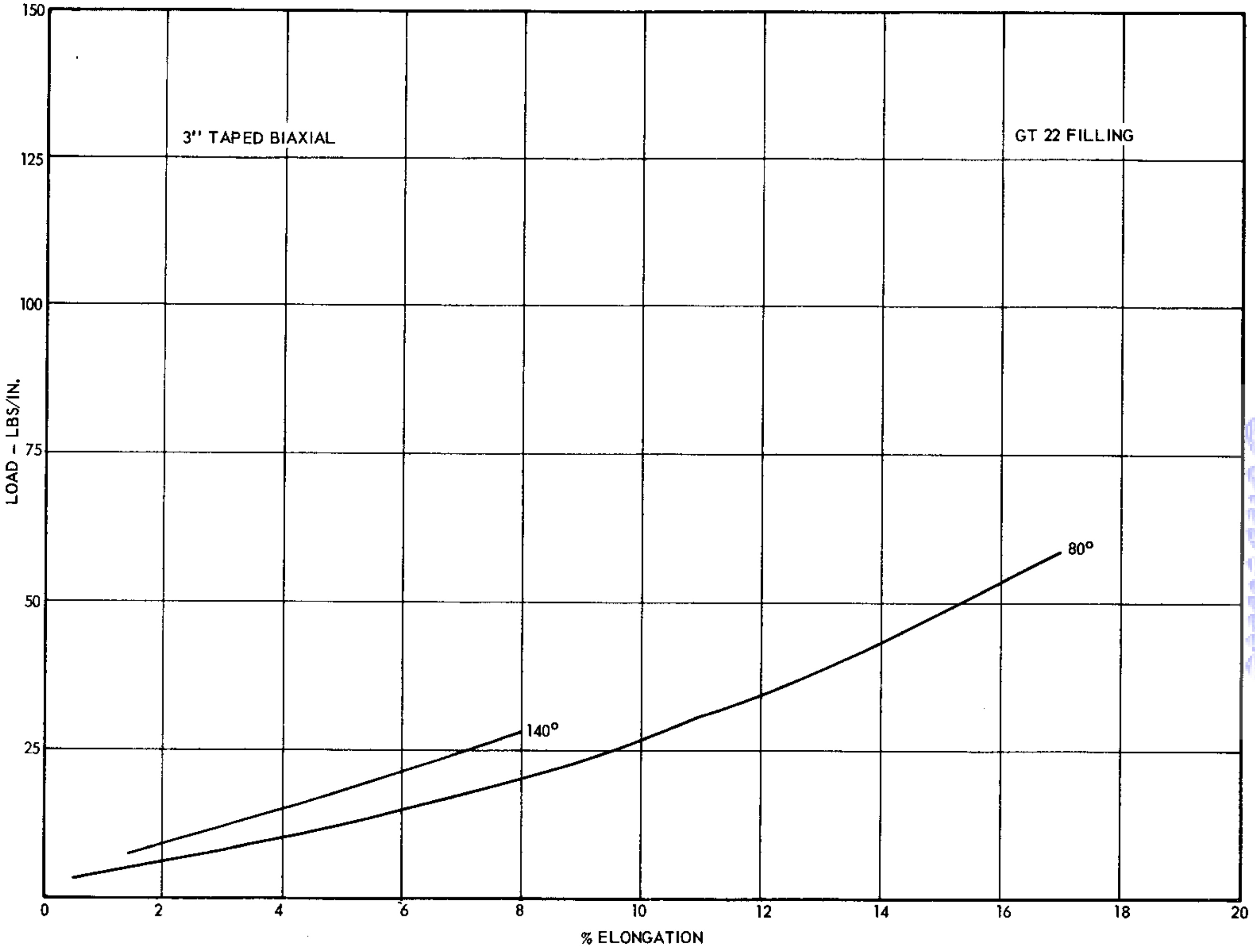

Figure 39. Effect of Temperature Variation on Elastic Properties of Nylon for GT-22 125x80 Plain Filling.

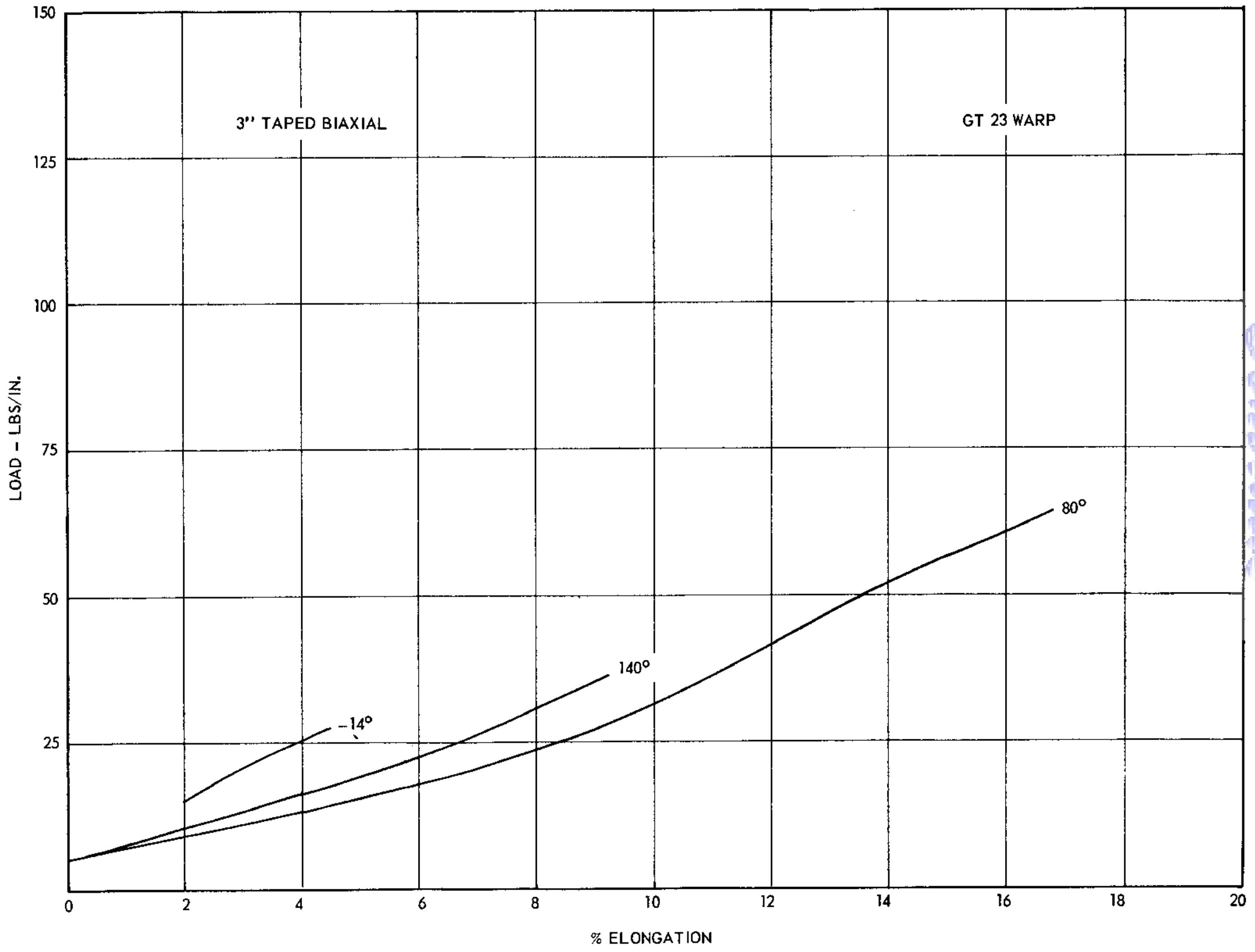

Figure 40. Effect of Temperature Variation on Elastic Properties of Nylon for GT-23 125x80 Satin Warp.

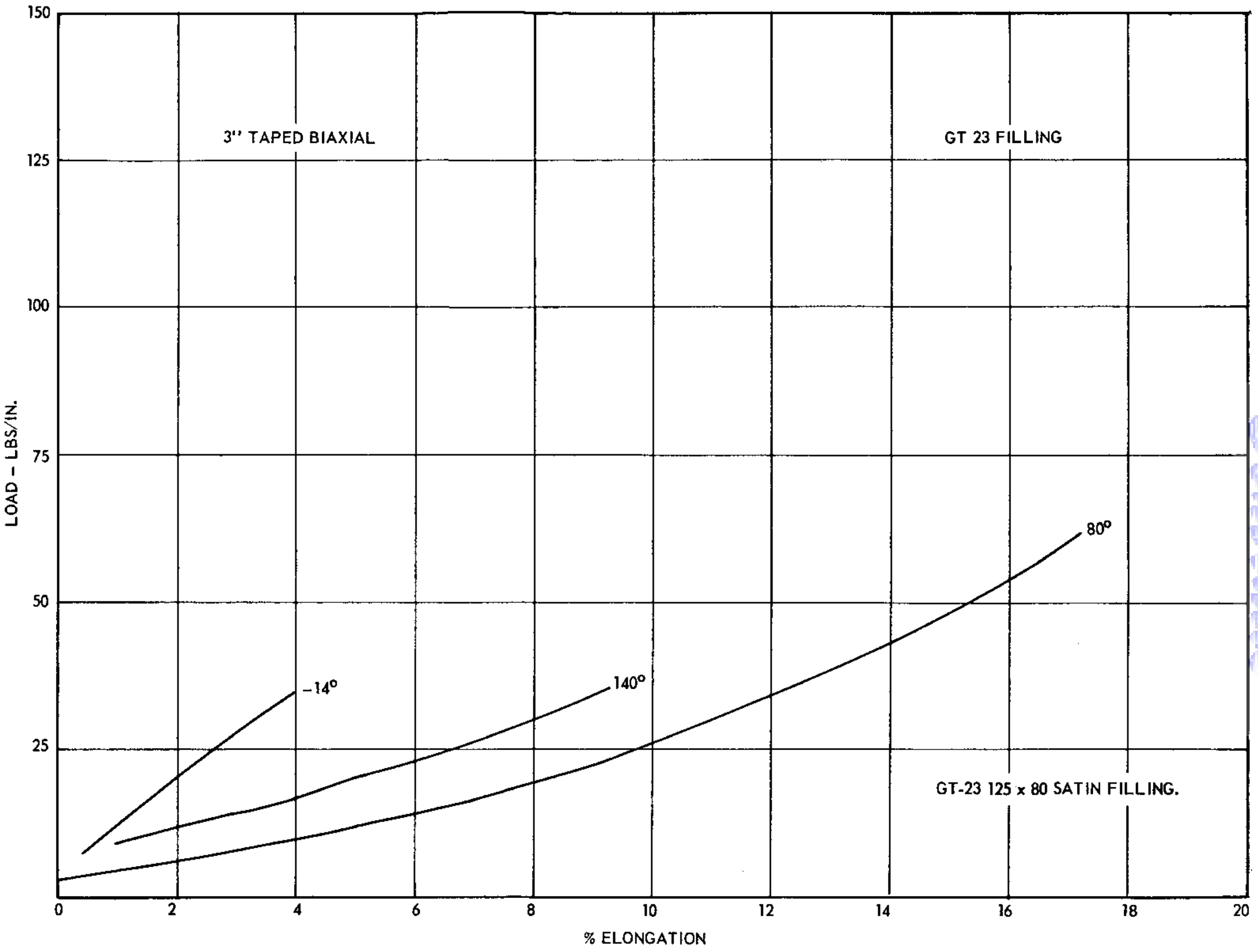

Figure 41. Effect of Temperature Variation on Elastic Properties of Nylon for GT-23 125x80 Satin Filling.

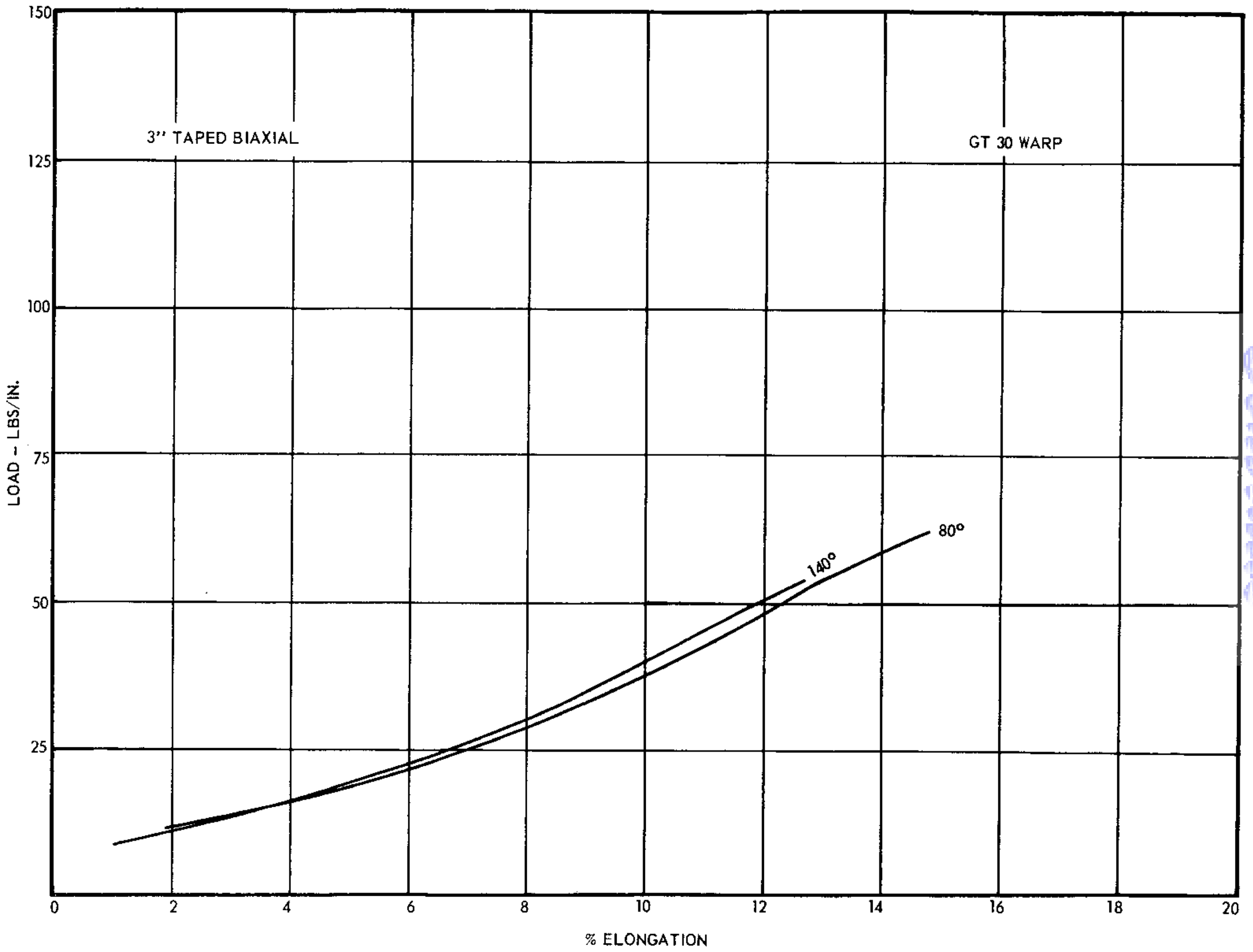

Figure 42. Effect of Temperature Variation on Elastic Properties of Nylon for GT-30 125x60 Twill Warp.

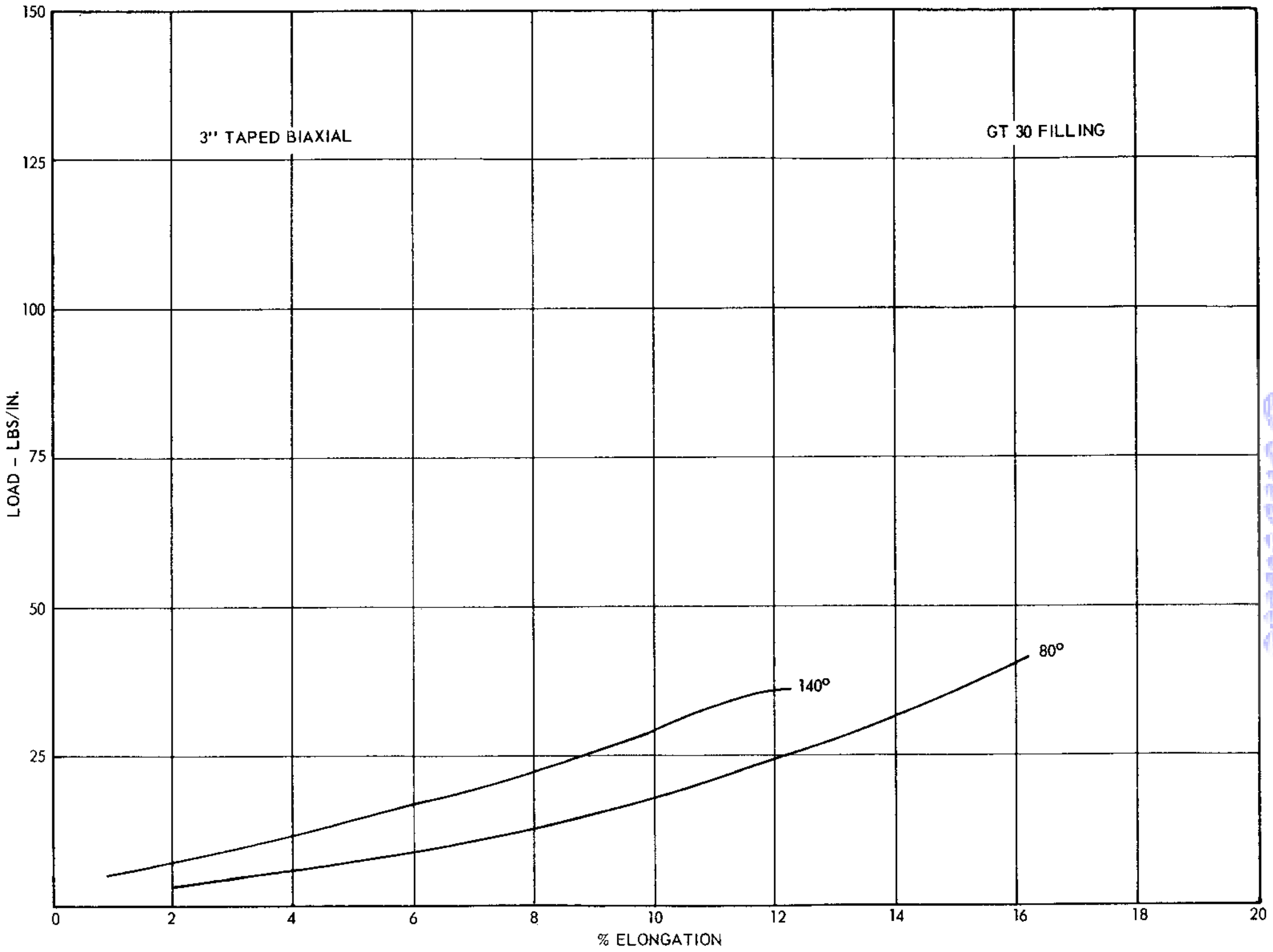

Figure 43. Effect of Temperature Variation on Elastic Properties of Nylon for GT-30 125x60 Twill Filling.

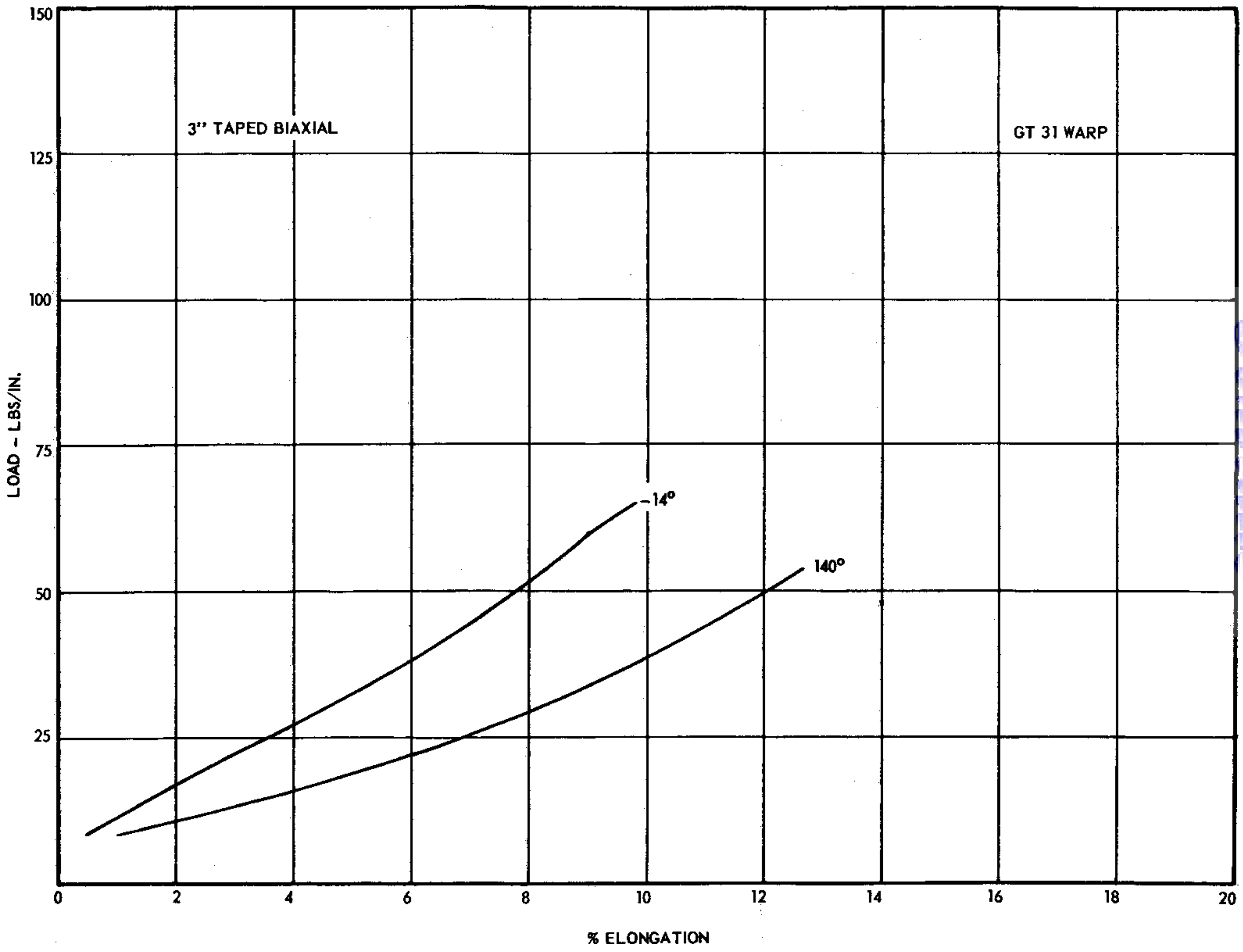

Figure 44. Effect of Temperature Variation on Elastic Properties of Nylon for GT-31 125x70 Twill Warp.

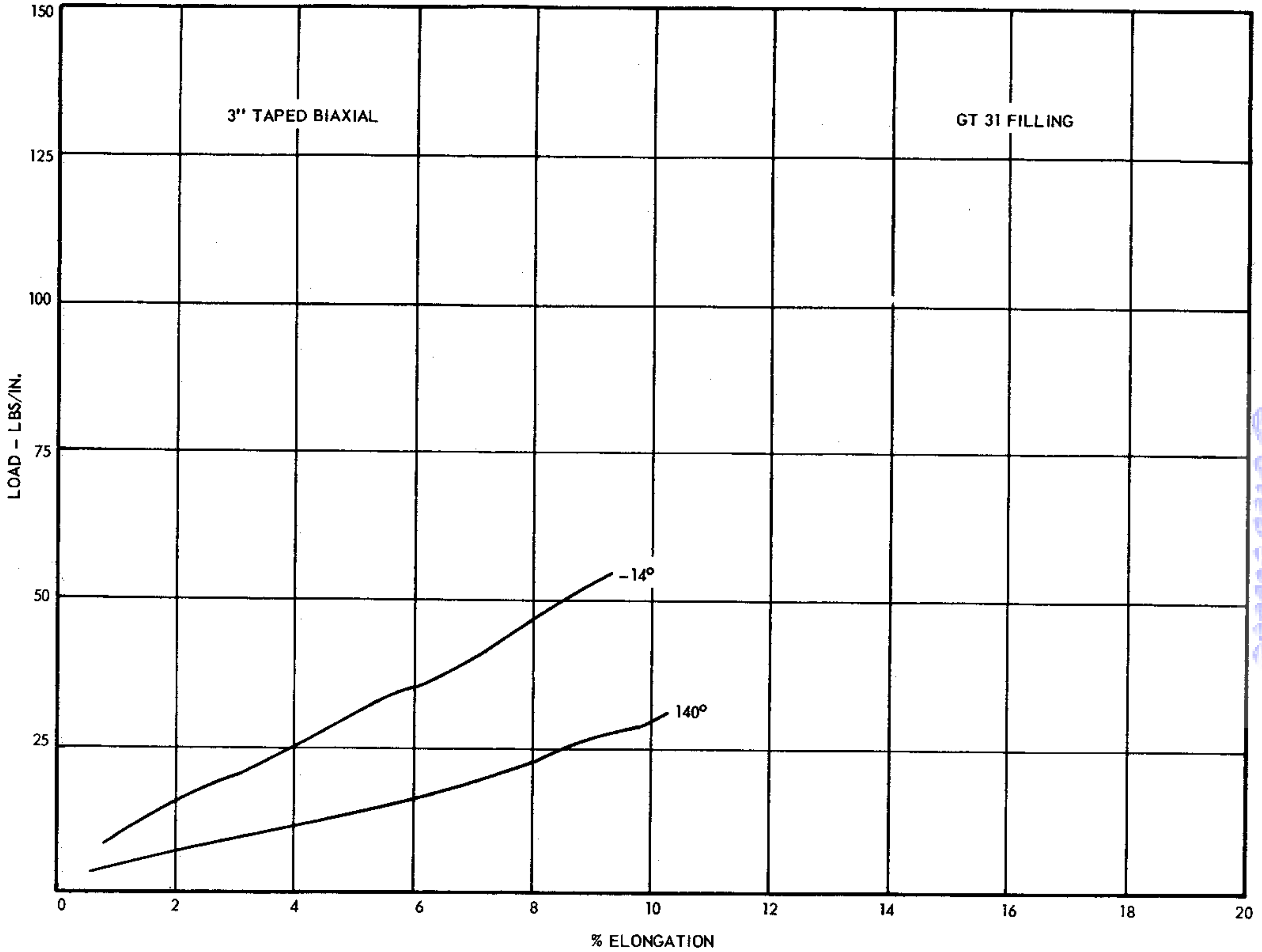

Figure 45. Effect of Temperature Variation on Elastic Properties of Nylon for GT-31 125x70 Twill Filling.

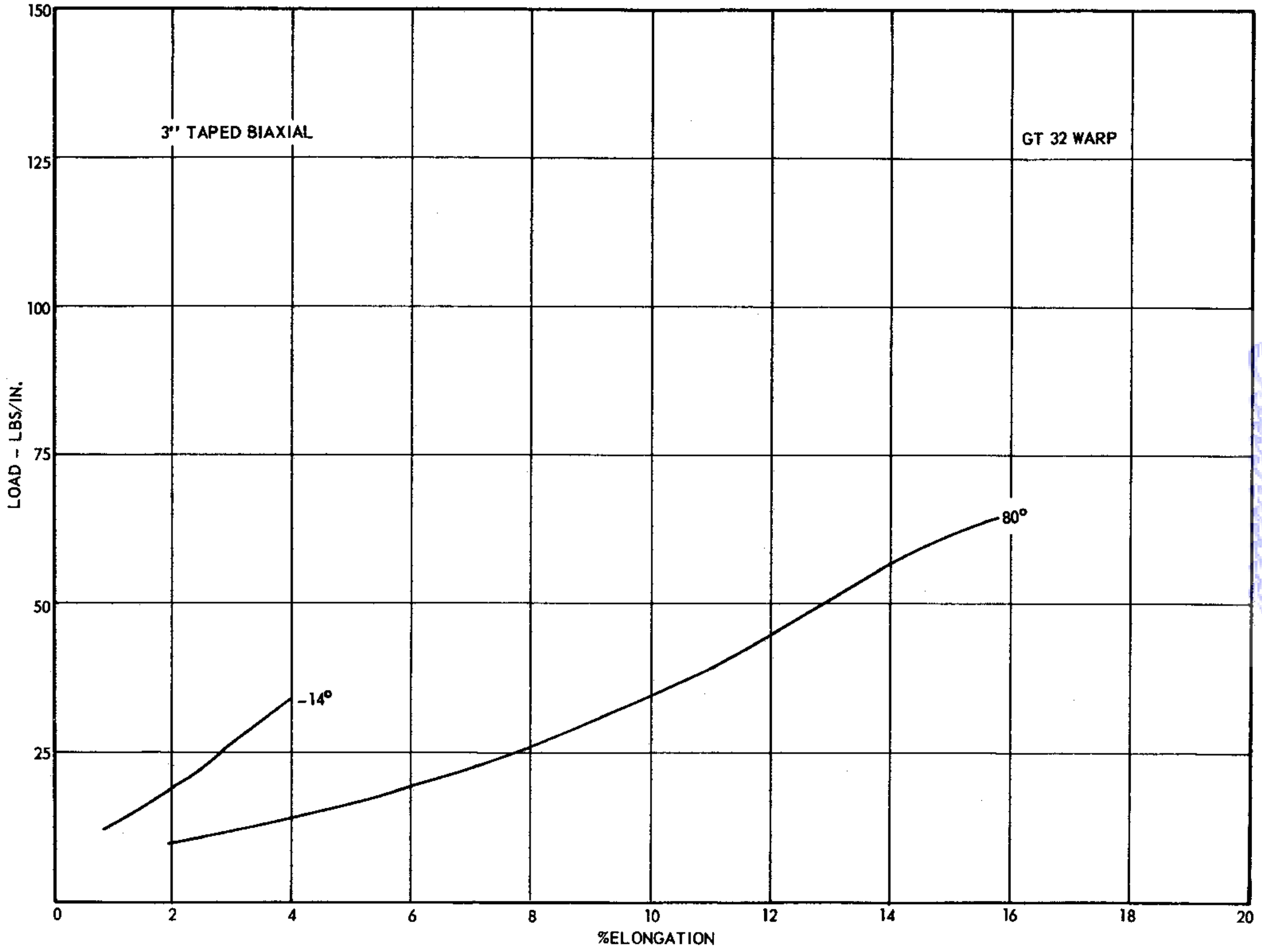

Figure 46. Effect of Temperature Variation on Elastic Properties of Nylon for GT-32 125x80 Twill Warp.

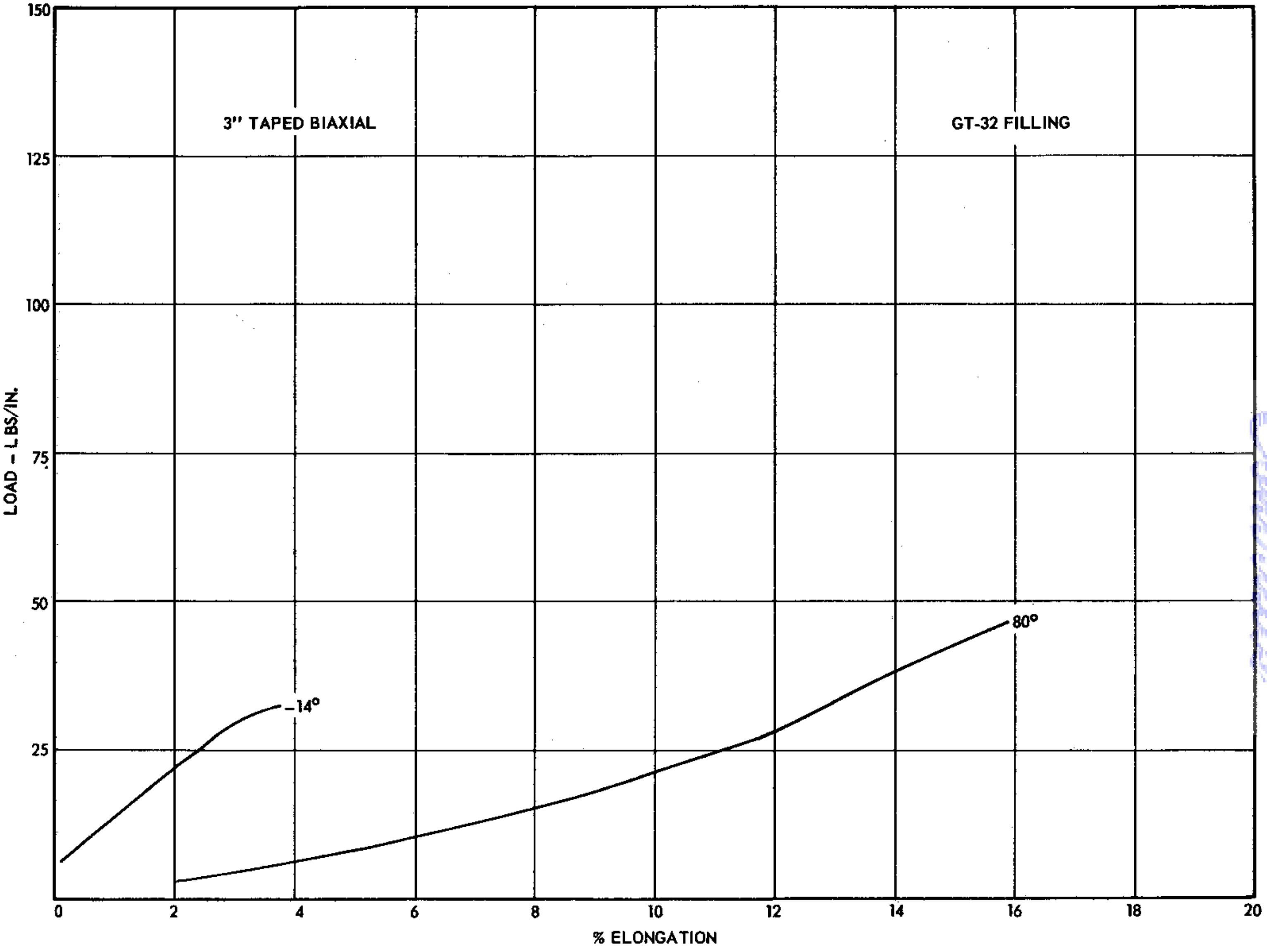

Figure 47. Effect of Temperature Variation on Elastic Properties of Nylon for GT-32 125x80 Twill Filling.

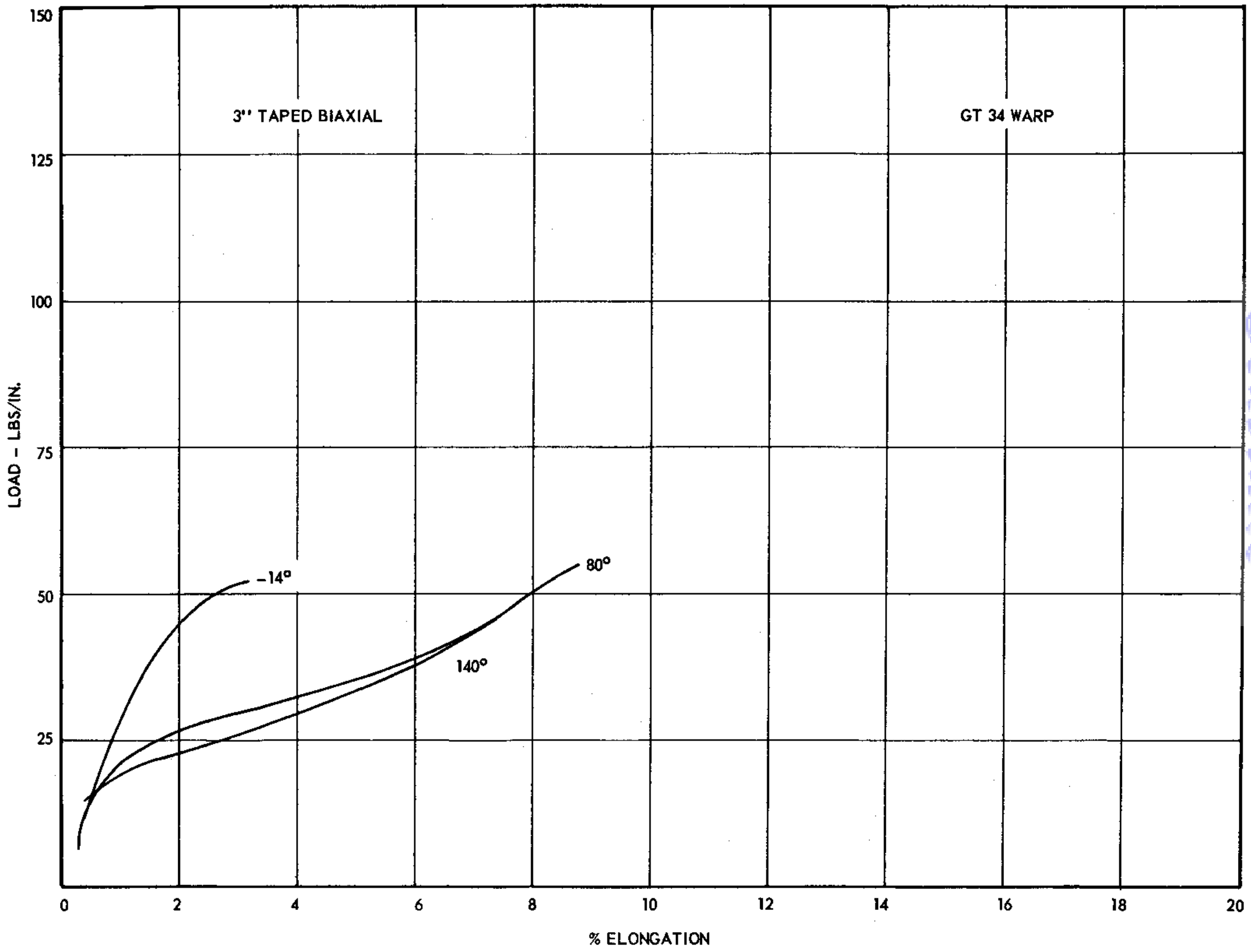

Figure 48. Effect of Temperature Variation on Elastic Properties of Orlon for GT-34 100x50 Plain Warp.

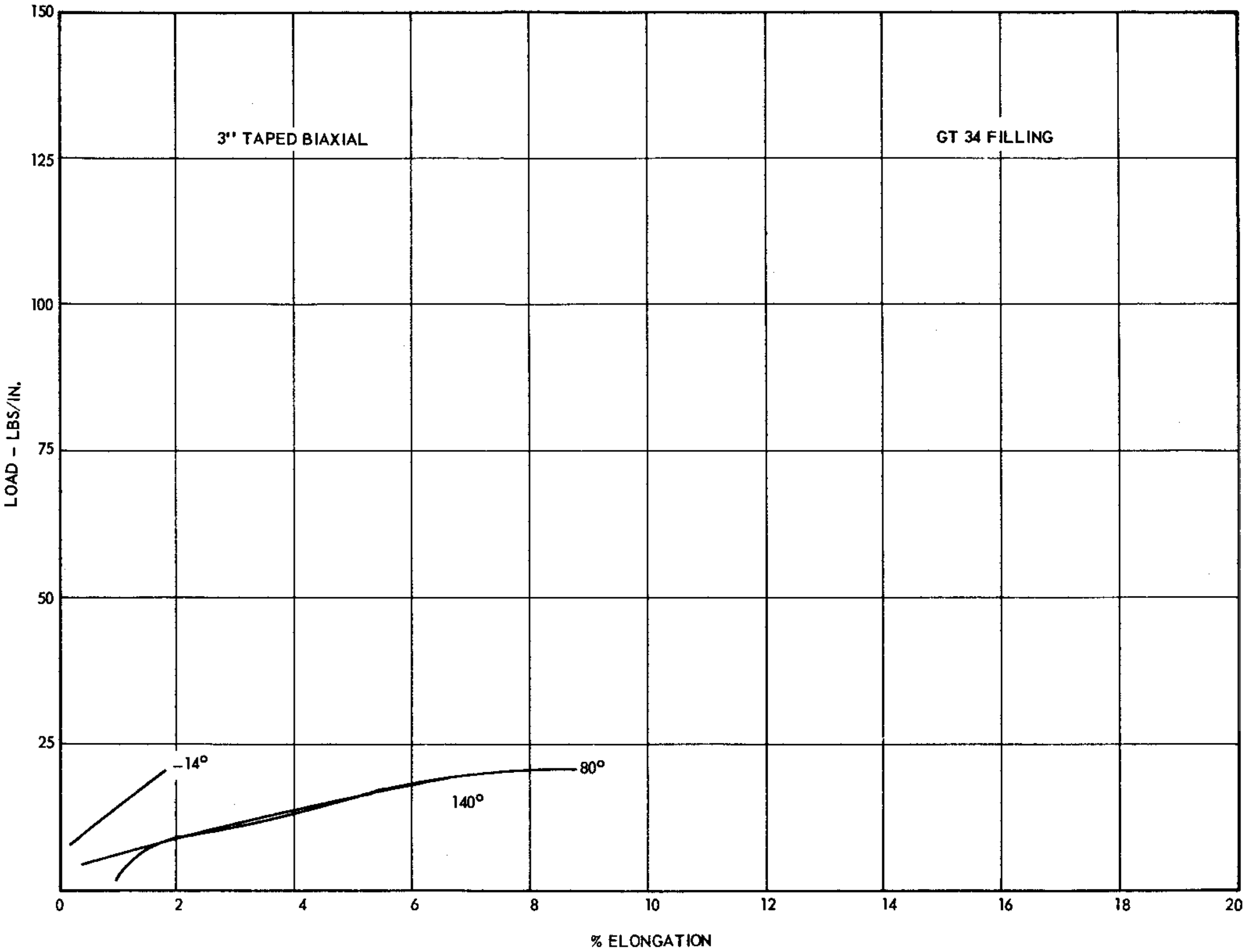

Figure 49. Effect of Temperature Variation on Elastic Properties of Orlon for GT-34 100x50 Plain Filling.

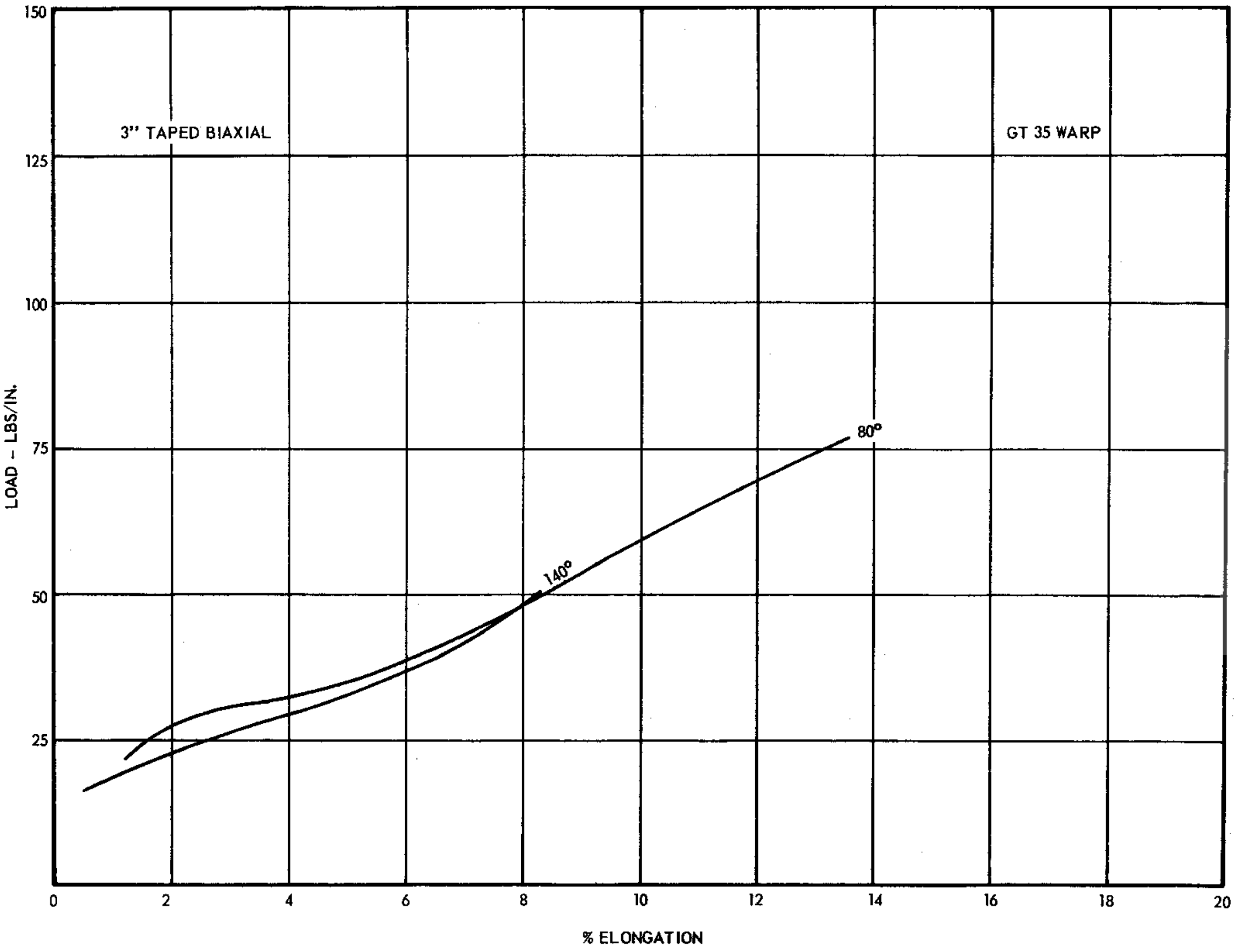

Figure 50. Effect of Temperature Variation on Elastic Properties of Orlon for GT-35 100x60 Plain Warp.

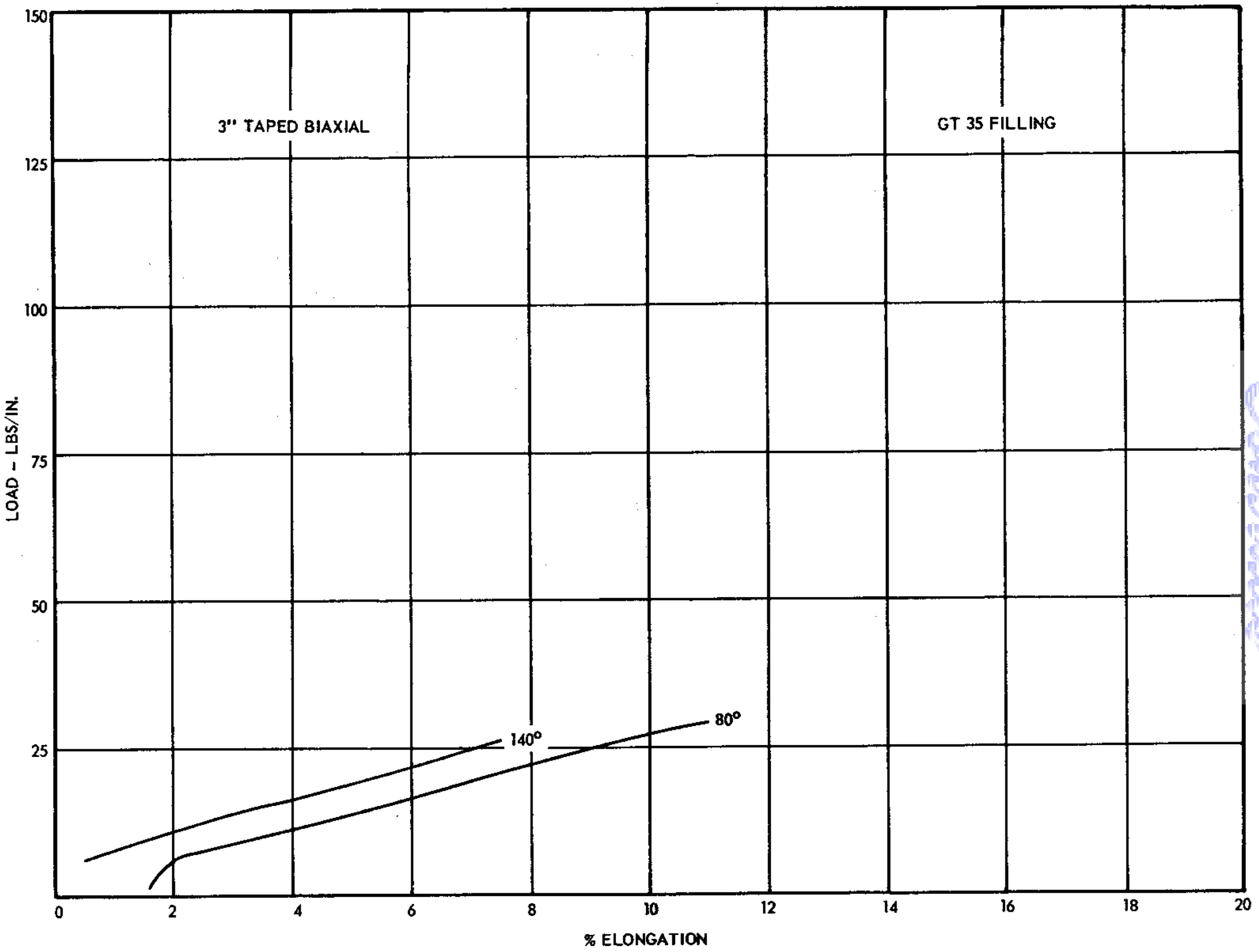

Figure 51. Effect of Temperature Variation on Elastic Properties of Orlon for GT-35 100x60 Plain Filling.

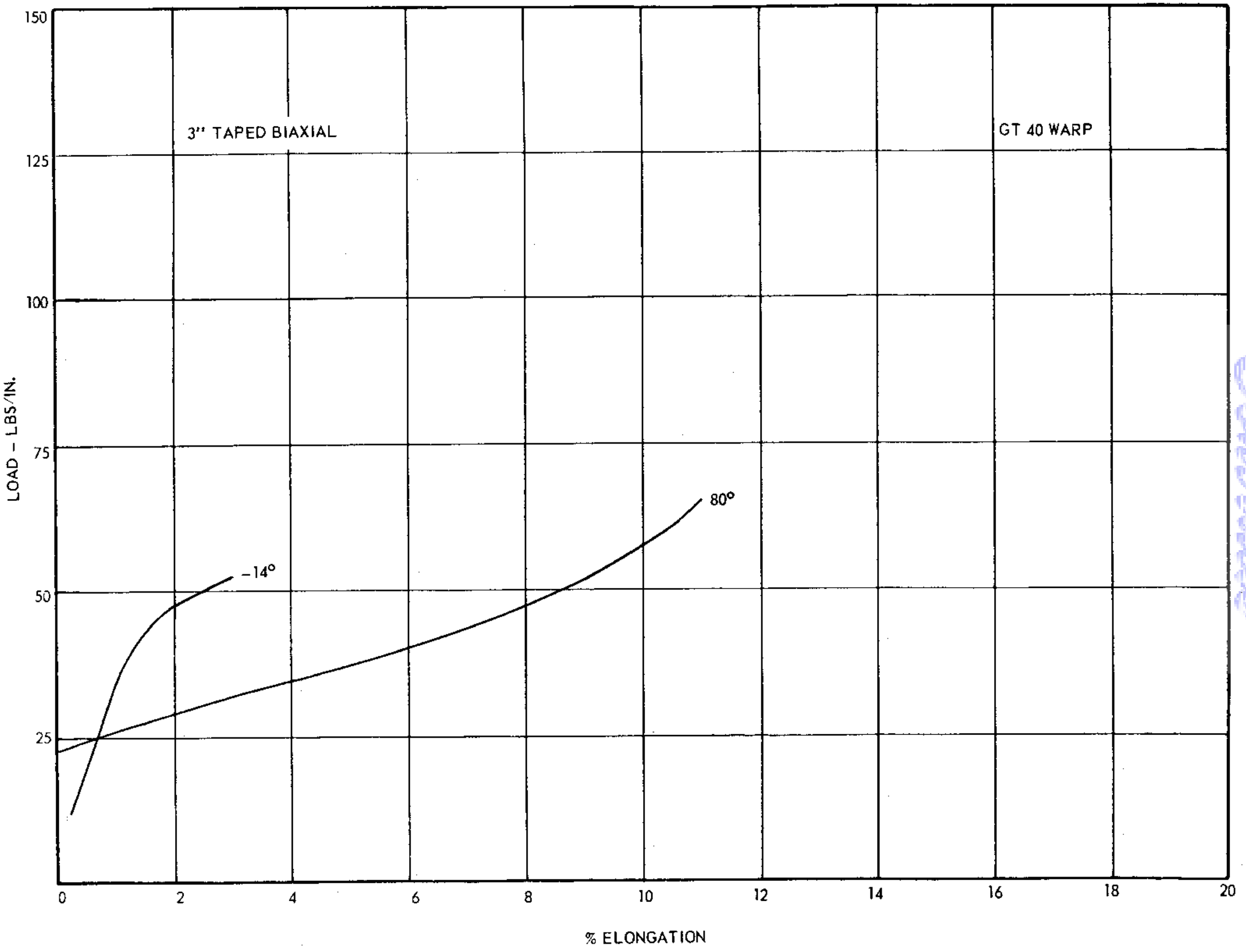

Figure 52. Effect of Temperature Variation on Elastic Properties of Orlon for GT-40 100x70 Twill Warp.

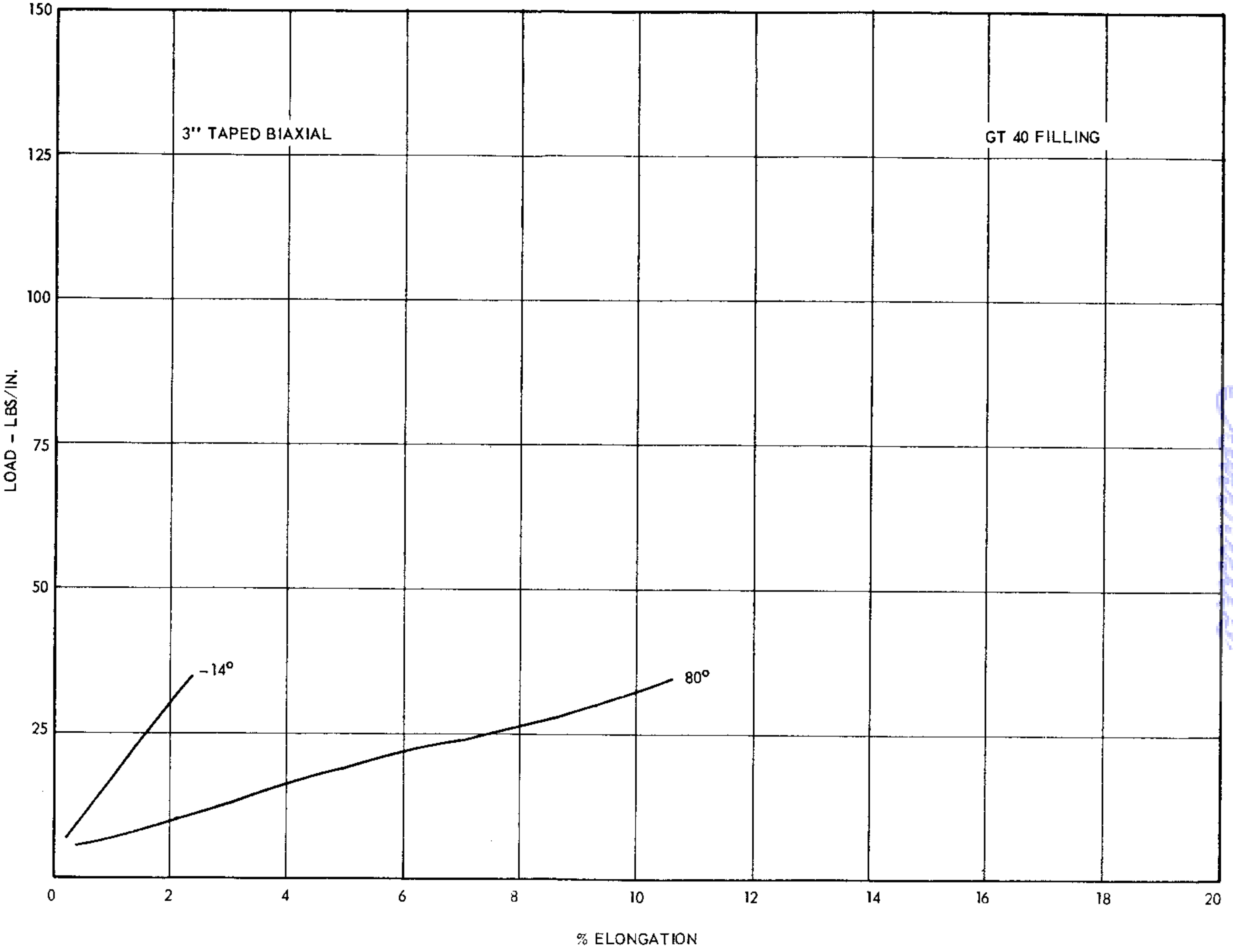

Figure 53. Effect of Temperature Variation on Elastic Properties of Orlon for GT-40 100x70 Twill Filling.

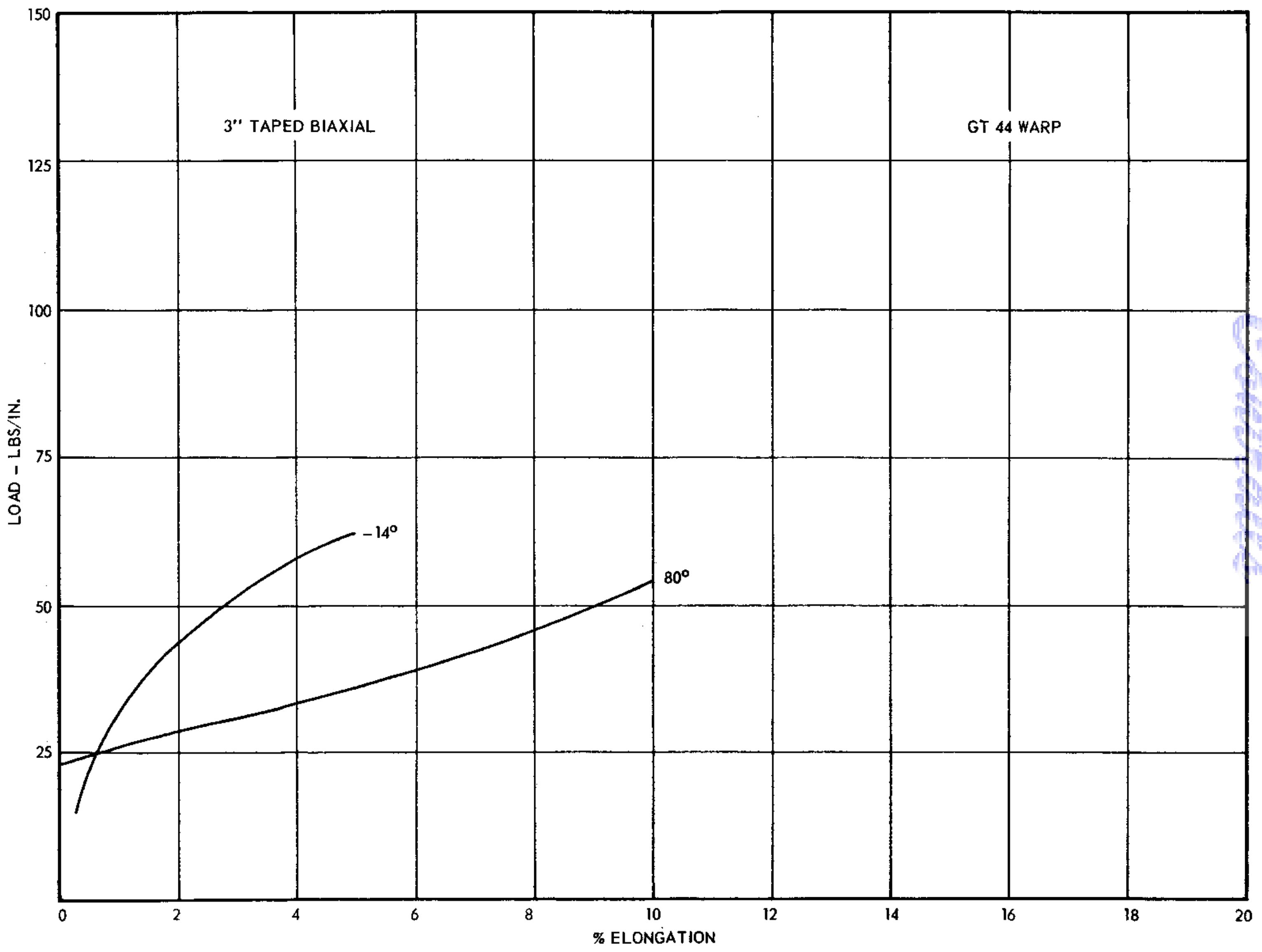

Figure 54. Effect of Temperature Variation on Elastic Properties of Orlon for GT-44 100x70 Satin Warp.

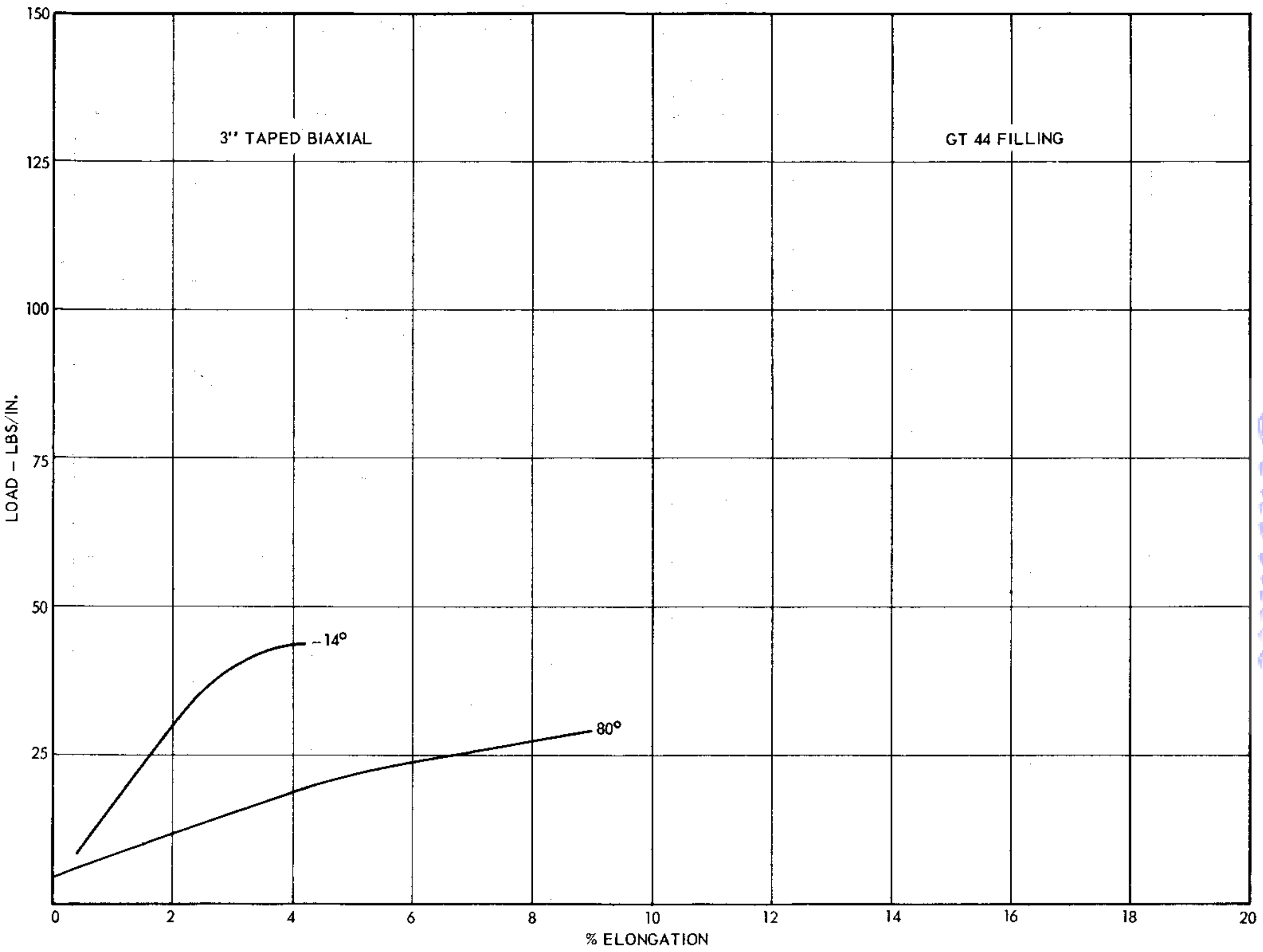

Figure 55. Effect of Temperature Variation on Elastic Properties of Orlon for GT-44 100x70 Satin Filling.

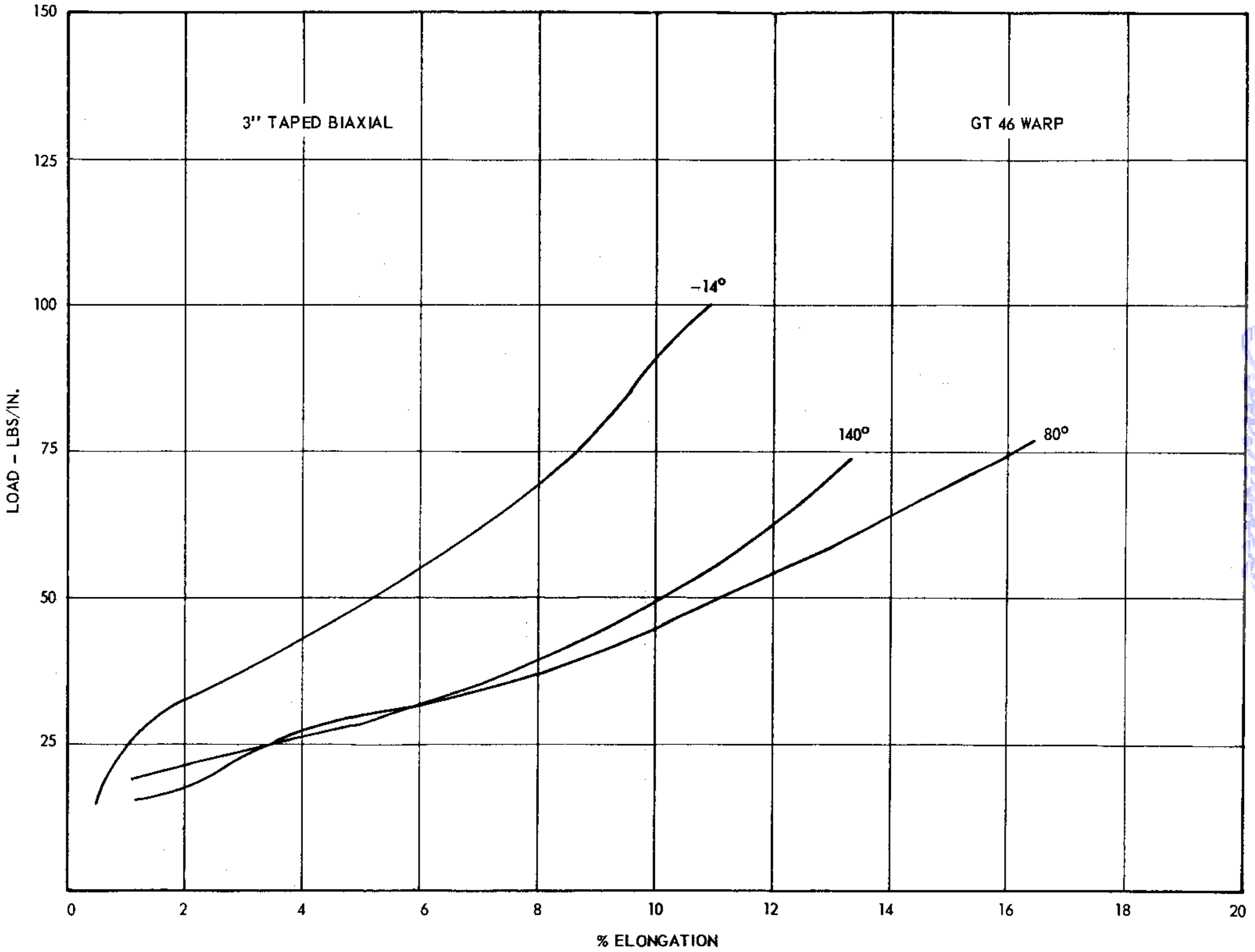

Figure 56. Effect of Temperature Variation on Elastic Properties of Dacron for GT-46 110x50 Plain Warp.

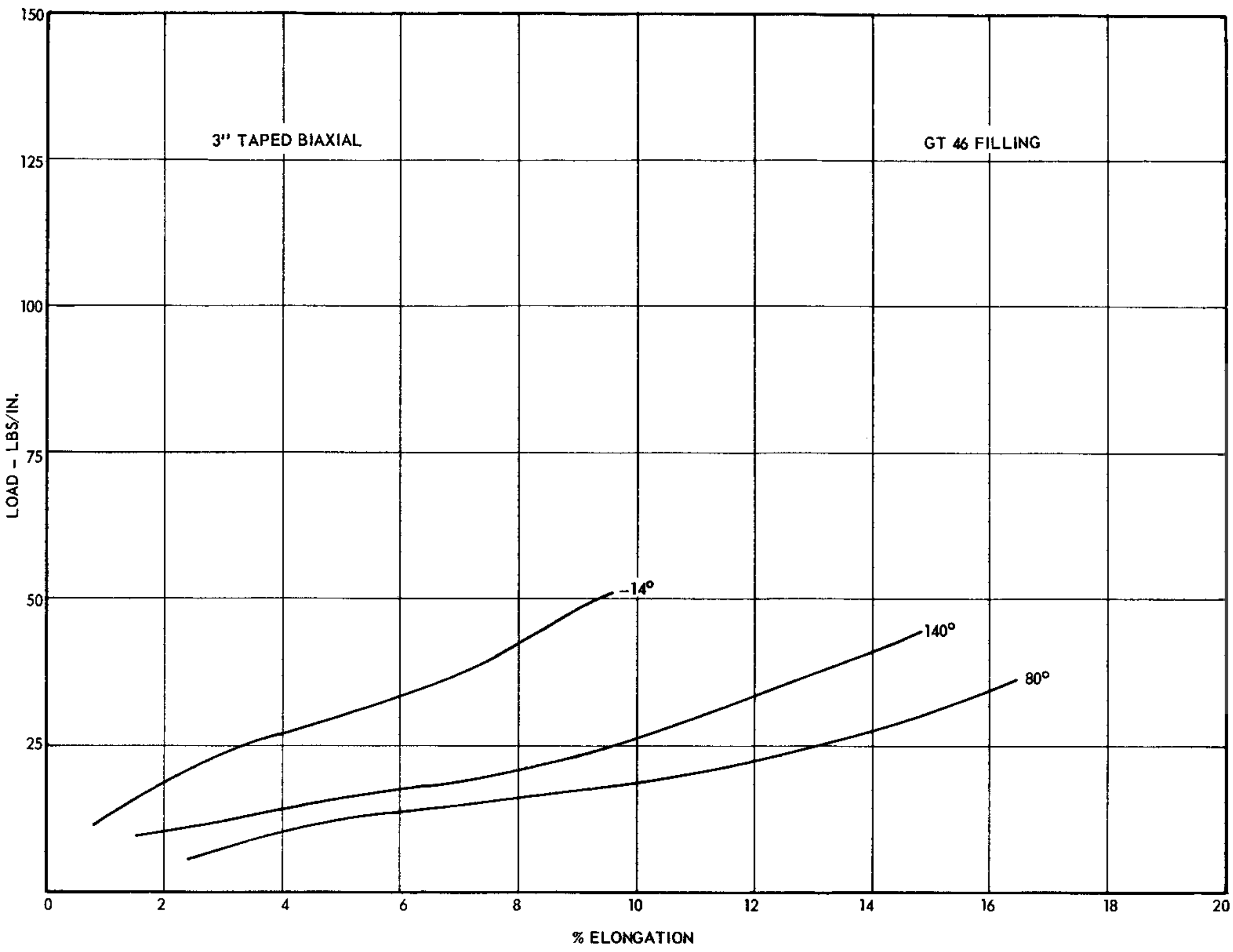

Figure 57. Effect of Temperature Variation on Elastic Properties of Dacron for GT-46 110x50 Plain Filling.

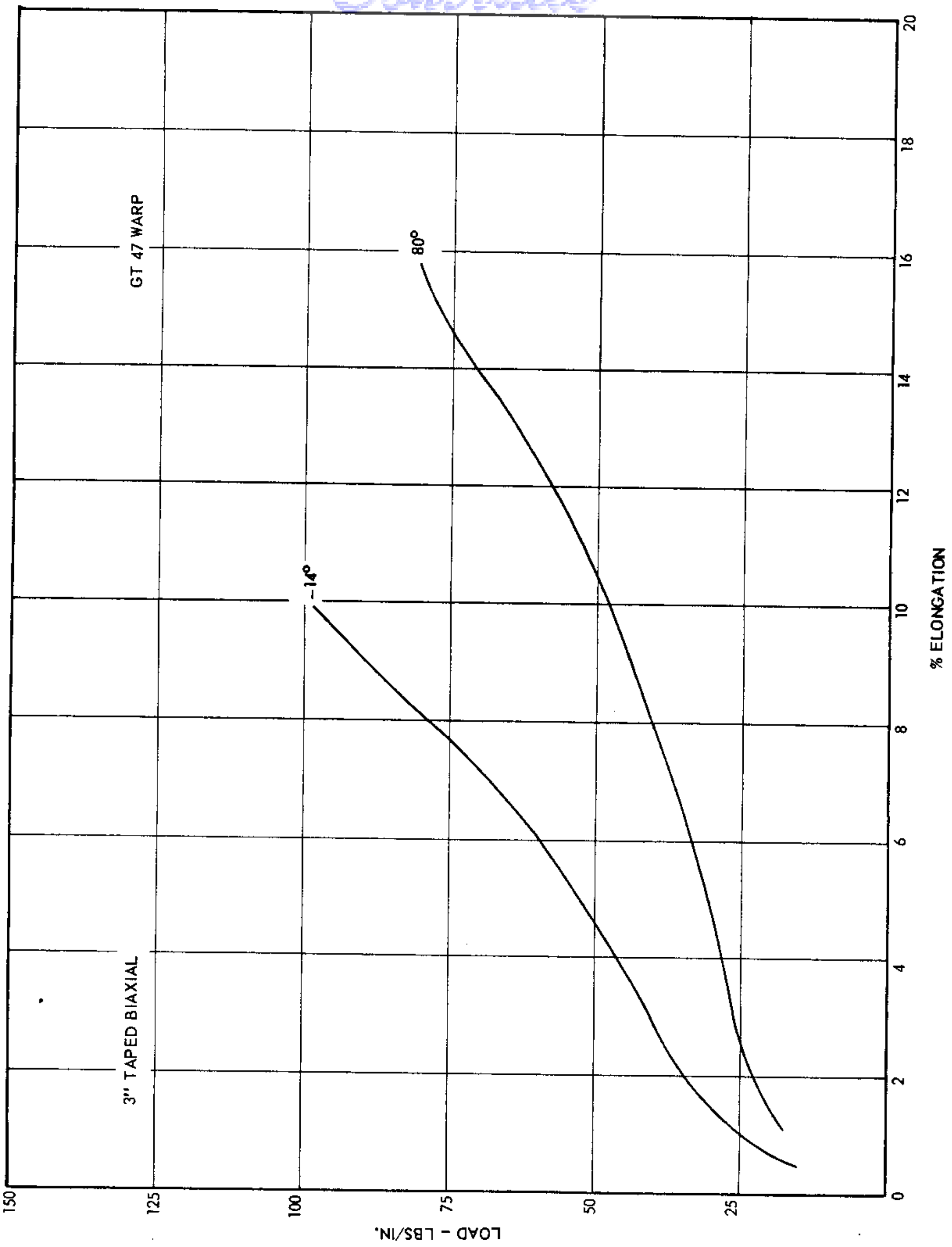

Figure 58. Effect of Temperature Variation on Elastic Properties of Dacron for GT-47 110x60 Plain Warp.

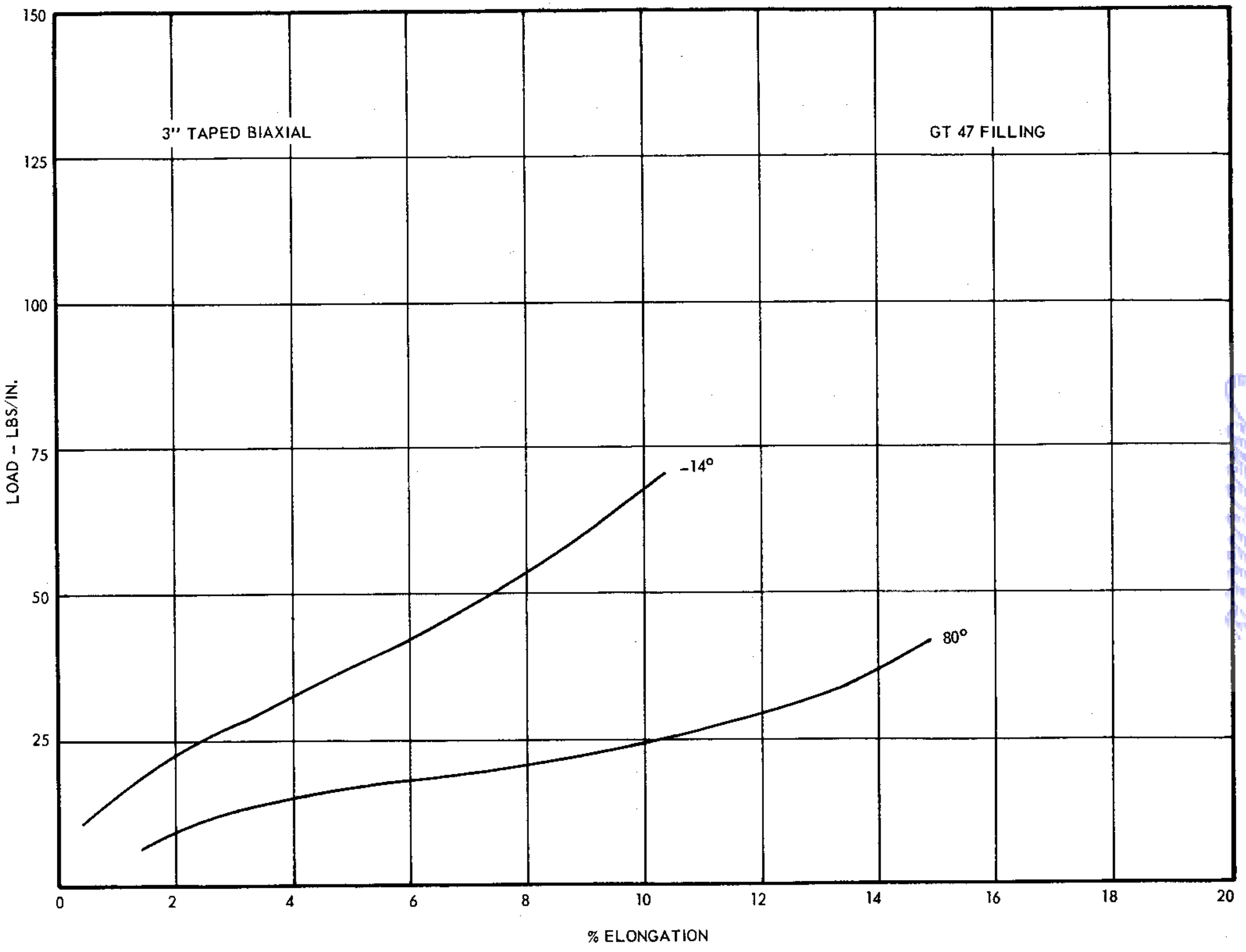

Figure 59. Effect of Temperature Variation on Elastic Properties of Dacron for GT-47 110x60 Plain Filling.

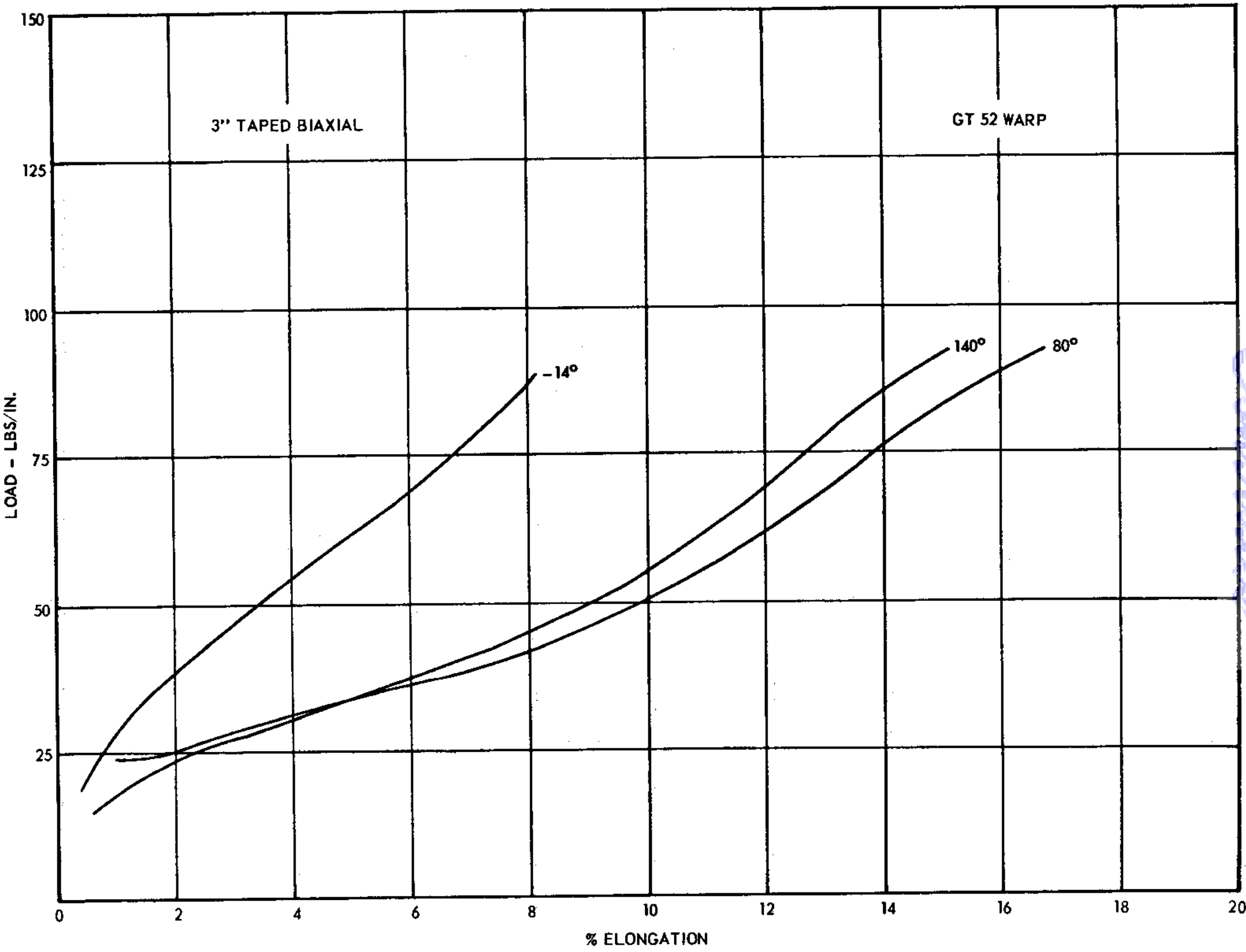

Figure 60. Effect of Temperature Variation on Elastic Properties of Dacron for GT-52 110x70 Twill Warp.

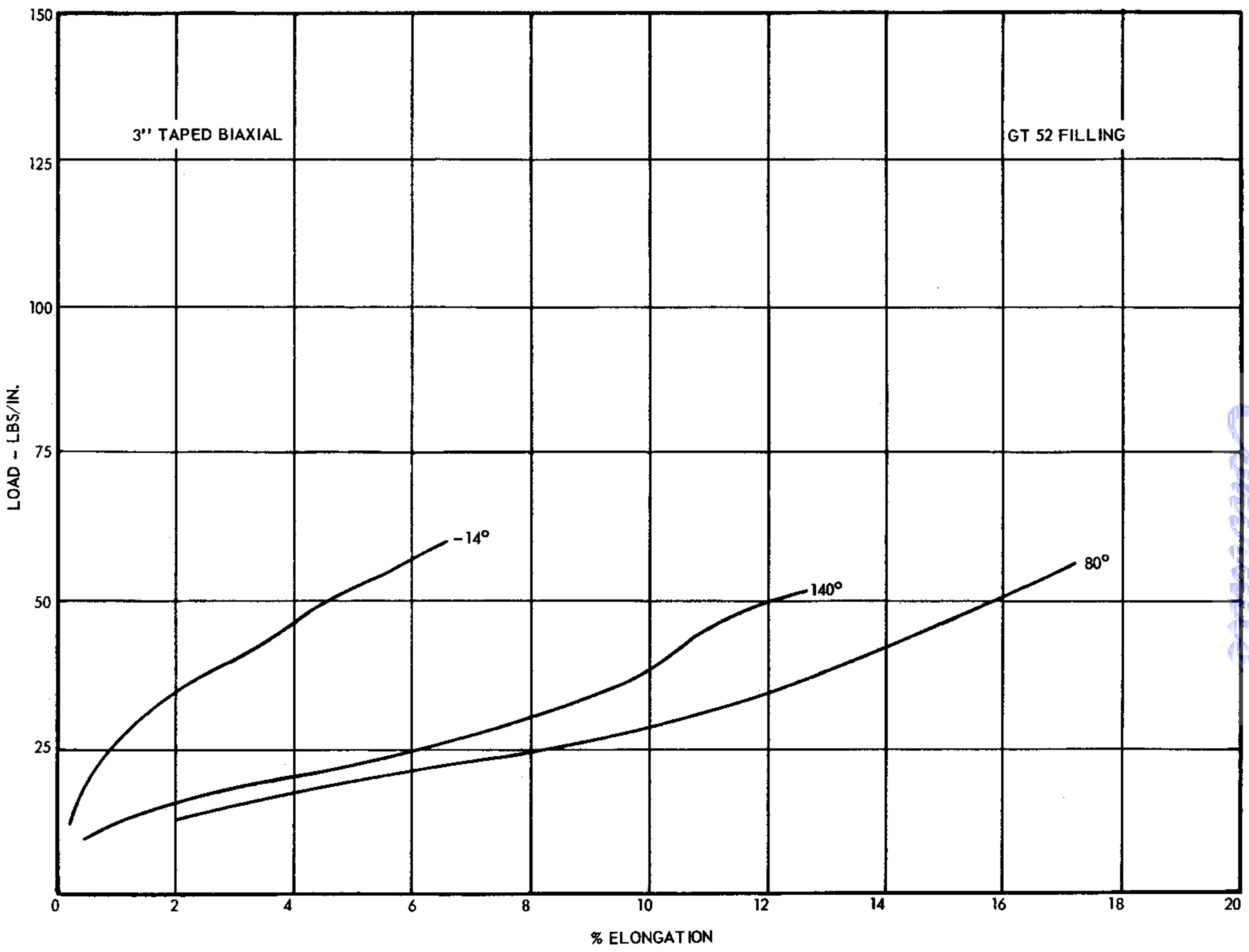

Figure 61. Effect of Temperature Variation on Elastic Properties of Dacron for GT-52 110x70 Twill Filling.

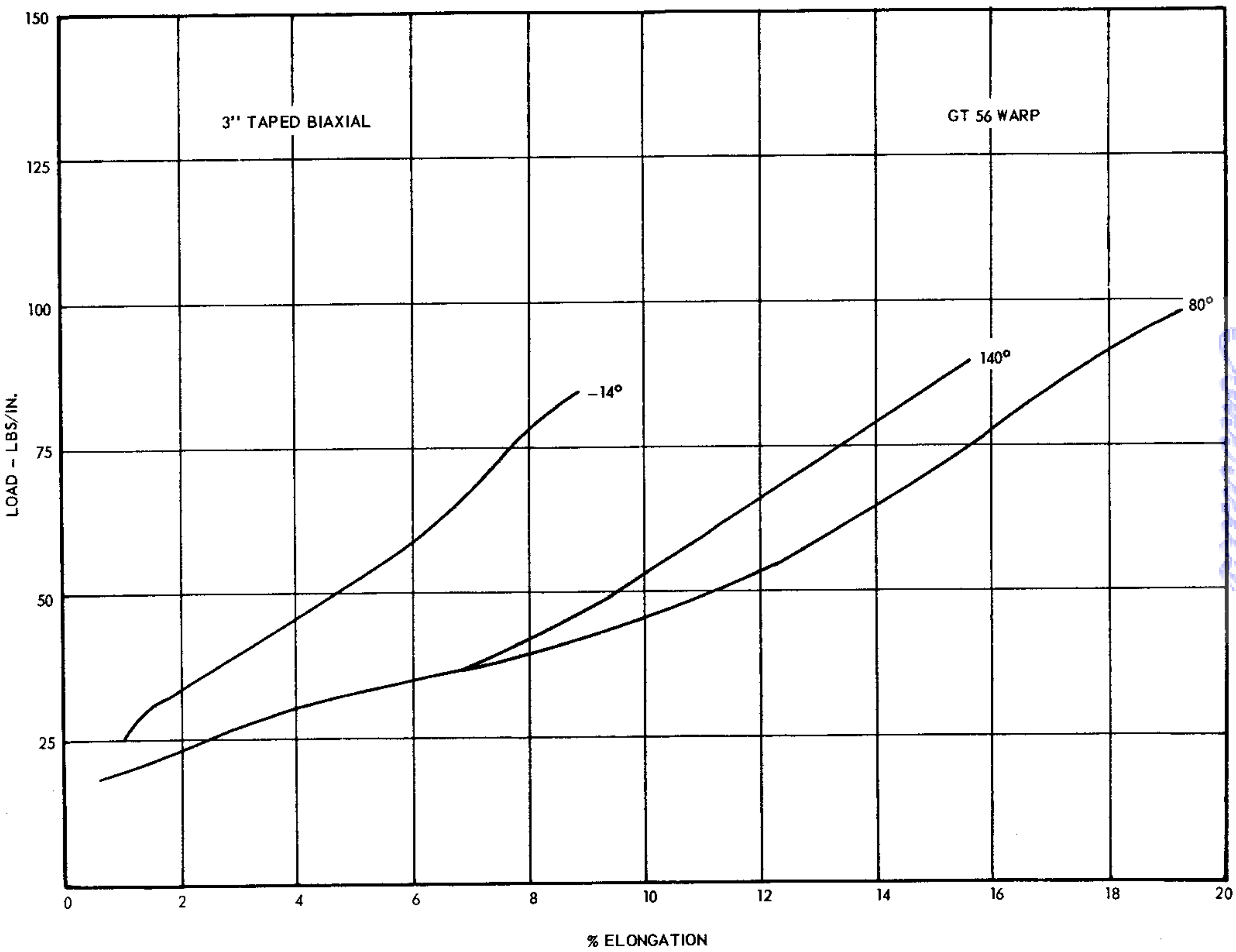

Figure 62. Effect of Temperature Variation on Elastic Properties of Dacron for GT-56 110x70 Satin Warp.

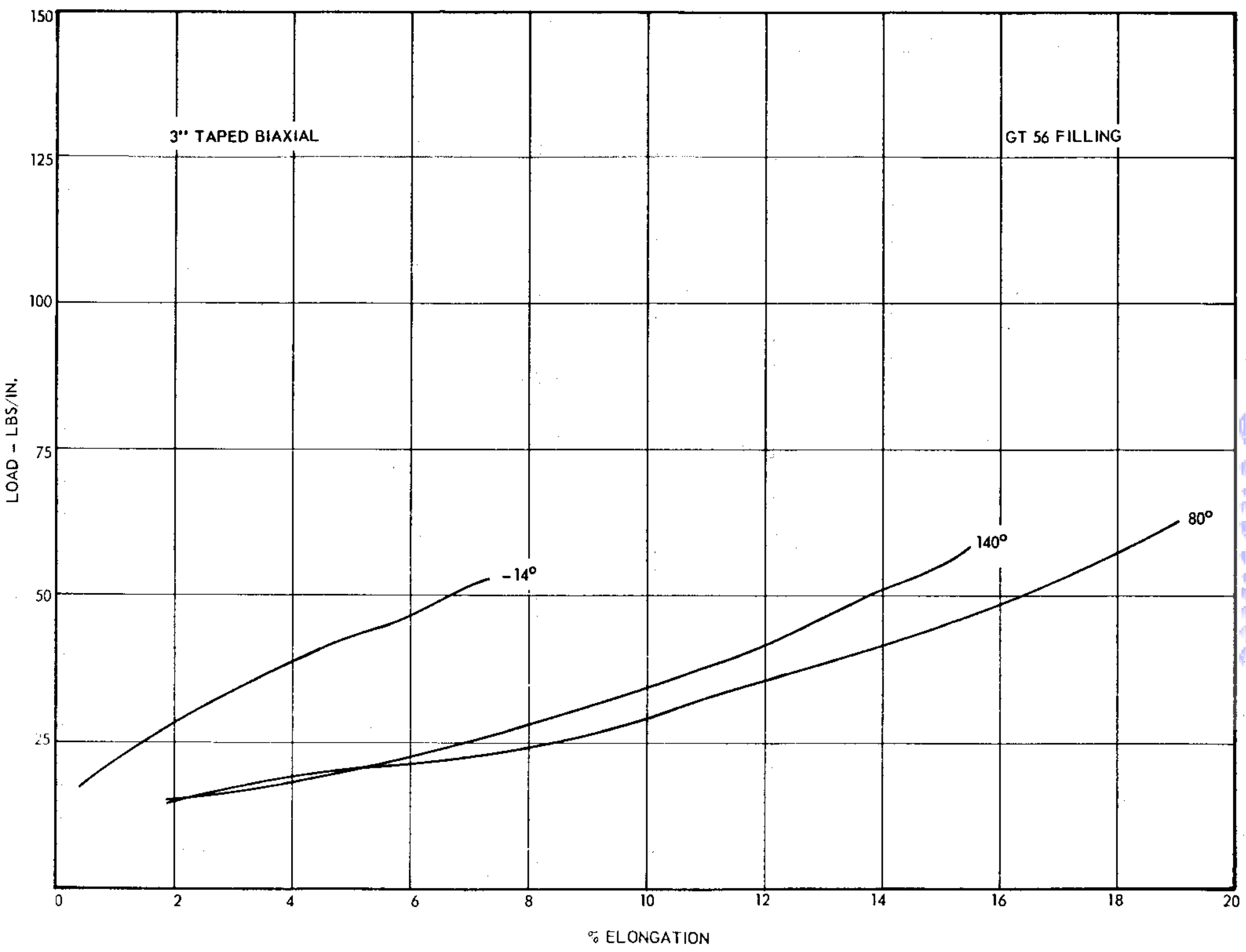

Figure 63. Effect of Temperature Variation on Elastic Properties of Dacron for GT-56 110x70 Satin Filling.