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SOME EFFECTS OF COMPRESSION AND HEAT ON DECELERATOR MATERIALS

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FOREWORD

This report was prepared by Fabric Research Laboratories, Inc. under USAF Contract No. AF 33(616)-6738. The contract was initiated under Project No. 7320 "Fibrous Materials for Decelerators and Structures", Task No. 73203, "Fibrous Structural Materials". The work was administered under the direction of the Nonmetallic Materials Laboratory, Materials Central, Directorate of Advanced Systems Technology, Aeronautical Systems Division, with Miss Joyce McGrath acting as project engineer.

This report covers work conducted from August 1959 to February 1961.

Included among those who cooperated with the author, N. J. Abbott, in the research and preparation of the report were Mr. M. J. Coplan, Assistant Director, Mr. W. D. Higgins, Senior Research Associate, and Mr. R. Desai, Intermediate Research Associate, all of Fabric Research Laboratories, Inc.

The unnamed organic fiber referenced in this report may now be referred to as HT-1. Released by the E. I. duPont de Nemours and Company on 3 May 1961.

ABSTRACT

The degradation of some nylon parachute materials, as well as similar materials made from Dacron, glass, an unnamed organic fiber, and stainless steel, when subjected to varying conditions of temperature, pressure, and time was studied. Temperatures up to 1000°F, pressures up to 250 p.s.i., and times up to 72 hours were used, but because of the degradation properties of the nylon materials most of the exposures were carried out at 350°F.

The amount of degradation for most of the materials was found to be consistent with that reported by other authors who did not study the influence of pressure. Pressure was less important than temperature or time, but it did tend to decrease degradation somewhat because of the reduction in the amount of oxygen contained within the structure. The increased resistance to degradation of Type 700 nylon was apparent in the results, although it had not been known in advance that any of the materials had been made from anything other than Type 300 nylon. The improved resistance to degradation of Dacron as compared to nylon is well known. Glass fabrics retained most of their strength up to 500°F, and the unnamed organic fiber up to 600°F (although at 650°F it was badly degraded). Stainless steel showed little change after being exposed to 1000°F for 72 hours.

All of the materials, with the exception of the unnamed organic fiber and steel, showed marked stiffening at 350°F, due primarily to inter-fiber sticking. This seemed in some respects to be a more serious fault than any tensile degradation which might occur, for it could easily prevent successful deployment of a parachute. This fact was made very obvious by examining a parachute which had been pressure-packed and heated in an oven. The stiffening and setting in the folded configuration which the parachute had assumed in the deployment bag made it very doubtful that successful deployment could have been achieved.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

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I. INTRODUCTION

The traditional need in air-borne components of any sort for maximum performance at minimum weight is well known. Recent advances in high speed vehicles and special weapons systems has introduced new requirements, particularly with respect to reduced volume and resistance to elevated temperature. The necessity for keeping the volume of the packed parachute to a minimum has led to the use of pressure packing, utilizing hydraulic presses to achieve pressures as high as 250 p.s.i. on the folded assembly. Parachutes may often be stored in this condition aboard vehicles where they will be subjected to temperatures considerably above ambient for extended periods of time.

The effect on parachute materials of exposure in air to elevated temperature for prolonged times has been studied by Coplan[1], by Kaswell and Coplan[2], and by Muse[3]. All of these studies showed that the specimens were degraded when hung in an air filled oven. The first was concerned with yarns, the second with sewing thread and fabric; and the third with parachute materials. The results from the three investigations are substantially in agreement. The investigation carried out under the present contract was designed to give information primarily about the influence of another parameter, packing pressure, on the temperature-time-degradation behavior of materials currently in use in parachutes, as well as a few materials not now being used, but of interest because of their potential resistance to the effects of elevated temperature.

The effect of packing pressure on the volume of a parachute pack was investigated by M. Steinthal Co.[4]. By applying pressures up to 200 p.s.i. they were able to reduce the volume of the pack by about 50%, and achieve packing factors (i.e., the ratio of fiber volume of total pack volume) as high as about 0.5. No measurements of the effect of this packing on the mechanical properties of the components was made; nor was any exposure to elevated temperature made.

Phase I of the study described in the present report was concerned solely with typical parachute materials in the form of fabric, ribbon or webbing. No effect of heterogeneous packing was introduced. Pressures up to 250 p.s.i. were employed, temperatures up to 1000°F, and times of exposure up to 72 hours. Phase II of the study was concerned with two types of parachutes, pressure-packed to about 250 p.s.i., and exposed to a temperature of 350°F for 6 hours.

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II. MATERIALS STUDIED

The materials studied included four standard nylon parachute cloths, six nylon ribbons, and three nylon webbings. In addition, three fabrics and one ribbon made of Dacron were obtained, the ribbon and fabric woven to conform to nylon specifications. Two glass fabrics were included, one weighing 9 oz/yd^2, the other 19 oz/yd^2. One metal fabric was also tested, namely a 320 mesh stainless steel made of 3 mil wire. Finally, one fabric was included made of an unnamed organic fiber. Further specifications of these materials are given in Table 1.

All of these materials were said to be in the unfinished, undyed state with the exception of the nylon webbing MIL-W-4088C, Type X, which was dyed, but otherwise unfinished. The glass fabrics, of course, carried a finish typical of all glass fabrics for applications requiring resistance to flexing and abrasion.

It was assumed initially that all the nylon materials were made from Type 300 nylon. Results indicated, however, that the MIL-W-4088C, Type X and MIL-W-4088C, Type XX webbings must have been made from either Type 700 nylon or Chemstrand RHB nylon. Moreover, the assumption that all materials were unfinished appeared not to apply to the ribbons, whose behavior indicated the presence of some finish.

All the nylon materials were obtained from the stocks of the Pioneer Parachute Company, with the exception of the two ribbons MIL-T-5608E, Class E, Types V and VI, which were specially woven by the Narricot Corporation. The glass fabrics were obtained from the J. P. Stevens Co.; the metal fabric was available through another project; the unnamed organic fiber fabric* and the Dacron fabric MIL-C-8021B, Type III, were supplied by ASD; and the remaining Dacron materials were available at FRL.

In addition to these materials, four nylon parachutes were provided by ASD for use in Phase II of the program. These were manufactured by M. Steinthal Co., and consisted of two 12-foot ribbon parachutes, and two 6-foot guide-surface parachutes.

III. EXPOSURE CONDITIONS AND TESTING

Pressures were applied to the materials while they were contained in steel compression boxes, described in Appendix I. Three pressure levels were used: "zero", which was actually about 0.5 p.s.i., and was the lowest pressure possible with the apparatus as designed, 50 p.s.i. and 250 p.s.i., the maximum pressure level called for in the contract. The compression boxes were electrically heated, so that temperatures of up to 1000°F could be obtained while the samples were held in the compressed condition. Times

* The unnamed organic fiber will be designated throughout this report by the letters U.O.F.

up to 72 hours were employed when the resistance of the specimen to degradation warranted such a long exposure.

All specimens were exposed to a common set of conditions, selected because these were sufficient to cause considerable degradation in the nylon materials[1,2,3]. These were a temperature of 350°F for 6 hours, at pressure levels of 0, 50 and 250 p.s.i.; and at the same temperature for 2 hours at 250 p.s.i. Other exposure conditions were included only when the characteristics of any individual material made them of some practical interest. Longer exposure times were used, for example, for those specimens containing heat resistant nylon, the unnamed organic fiber, or Dacron; and higher temperatures for Dacron, glass, U.O.F., and metal. Unless otherwise specified, all tests were made in the warp direction of the material. It was assumed that the behavior in the filling direction would be comparable to that in the warp direction.

Most of the information needed was obtained from tensile tests, which showed the effect of exposure on breaking strength, breaking elongation, and energy to rupture. It is clear that when the strength, for example, drops below some critical value, the material is no longer serviceable. However, failure after deployment due to excessive degradation would be no more serious than failure to deploy due to the effects of sticking. In general, these effects were detectable at temperatures or times of exposure not sufficient to cause excessive strength degradation; for this reason the extent of sticking was examined in some detail.

Two types of sticking were evidenced, either of which might be troublesome. The first of these was the sticking which occurred between layers of specimens as they were piled up in the heated compression box. A quantitative measure of the severity of inter-layer sticking was obtained by measuring the force required to pull the specimens apart. The specific technique is described in Appendix II-3.

The other type of sticking was that which occurred between individual fibers within the structure of any one specimen. This has the effect of stiffening the specimen in a way which has been discussed by Abbott, Coplan and Platt[5]. They have shown that one of the important factors which determines the stiffness of a woven material is the degree of association which exists between fibers within the yarns in the structure. This is expressed quantitatively as a "degree of clustering". In this concept, the fibers within the structure are visualized as acting as if they were adhering to one another in clusters such that no inter-fiber movement is possible within the cluster, but that complete freedom of movement exists between clusters. The average number of fibers contained in a cluster, through any cross-section of the yarn, is called the degree of clustering, n. The authors show that the rigidity of the structure will be related to the rigidity of an individual fiber in proportion to the factor $\frac{n}{P}$, where P is the packing factor of the fibers in the cluster. Since P varies only over a narrow range with the size of the cluster, it can be assumed that the flexural rigidity of the material is roughly proportional to the average number of fibers in a cluster.

The degree of clustering depends upon the specific construction of the yarn and the fabric, and may also increase with increasing relative humidity. But it is clear that a major influence would be the extent to which fibers are caused to stick to one another because of exposure to elevated temperatures. Conversely, it can be seen that a measure of flexural rigidity, or rather of the change in flexural rigidity brought about by the application of heat and pressure for some time, is a good measure of the extent to which inter-fiber sticking has occurred. It should also be pointed out that any effect of heat on the bending modulus of the fiber will also be reflected in the change of flexural rigidity of the structure. It is believed, however, that this is a less consequential factor than the influence of inter-fiber adhesion. Measurements of stiffness before and after exposure were carried out, therefore, using a cantilever test, as described in Appendix II-4.

All of the experimental results were obtained by testing samples of materials which were compressed together in a manner which was highly idealized relative to the configurations which the materials assume in a packed parachute. Although it did not seem possible to duplicate the heterogeneity of a packed parachute in the small compression chambers, three configurations were included which can be said to be typical of a packed parachute. The first, of course, was in the simple flat state. Another of these was a folded specimen, for which the effects of heat, pressure, and time on tensile properties were studied. The third was as seamed specimens. For this last purpose the various specimens were seamed in configurations typical of those which would be used for the material in question in normal parachute fabrication.

Finally, in order to obtain some information on the applicability of the experimental results to the case of a packed parachute, two types of parachute packs were tested. These were packed in deployment bags by packers at Hanscom Field. Two were pressure-packed in steel cylinders built for the purpose at pressures of about 250 p.s.i. Two others were not subjected to compression. They were then heated in an oven at 380°F for 12 hours, cooled to room temperature, unpacked, and examined to determine the extent of the damage.

IV. EXPERIMENTAL RESULTS

1. Compressibility of Cold Materials

The effect of compressing a mass of textile material is essentially a "squeezing out" of the air contained within the structure, so that the minimum volume, or the maximum density, which one could expect to achieve would be that of the fibrous material. Volume compression of the fibers themselves is negligible at pressures up to 250 p.s.i. Thus the most informative way of characterizing the degree of compression is through the "packing factor", which is the ratio of the volume of fiber substance to the over-all volume of the structure. (Estimates of the effect of pressure on packing factor require, therefore, that measurements of volume at known pressures be made.)

The compression boxes were designed to accommodate a pile of ten or more specimens. They consisted of a heavy steel rectangular open-ended trough of length 8 inches and width the same as that of the specimen to be compressed. The trough was closed at the top by a vertically movable but snugly-fitting platen to which load could be applied. After the desired pressure had been reached, the platen could be held stationary by inserting four screws which, when properly tightened, held the material at constant volume for heating.*

The chamber containing a pile of specimens was mounted in a compression cage designed for use with an Instron tester, having a maximum capacity of 10,000 pounds. Since the deflections to be measured were very small, adequate accuracy was obtained by mounting dial gauges on either end of the compression chamber to measure the vertical movement of the platen relative to the trough. During compression these two gauges were read at specific load intervals. Since their readings were never greatly different, they were averaged to obtain a mean compression over the full 8-inch specimen length.

Detailed measurements of compressibility were made only on three materials - one fabric, one ribbon, and one webbing. It was felt that these would give values of packing factor which would adequately represent the behavior of all the materials. The curves obtained are shown in Figure 1. The initial packing factors for the materials were about 0.4 for the fabric, 0.5 for the ribbon, and 0.65 for the webbing. The reason for the difference is related to the construction of these materials. Webbing, and to a lesser extent ribbon, has a predominantly unidirectional construction, in which a large proportion of the total mass is in the warp yarns. Thus these materials approach more closely the ideal optimum packing of an array of parallel cylinders (about 0.9), than the fabric, which has its mass distributed much more evenly between warp and filling. Compression has a bigger effect on the fabric packing factor than on the webbing, as might be anticipated. At 250 p.s.i., the packing factor of the webbing and ribbon was about 0.7, that of the fabric about 0.6.

It was assumed that the curves of Figure 1 would be representative of the behavior of all the nylon materials. Since other materials were included in the program, sample compression curves were obtained for some of them also. These are plotted for Dacron, U.O.F. and glass in Figure 2.

These curves were obtained using a continuously increasing load in the manner of a typical load deflection test. This resulted from moving the Instron crosshead at a speed of 0.02 inches per minute. The influence of rate of compression on the compressibility of 5 layers of webbing is indicated in Figure 3. The three curves plotted here were obtained at strain rates differing by as much as a factor of 10. It can be seen that over this range of strain rates, the effect upon the packing factor achieved at any pressure is very small. Up to a pressure of 250 p.s.i. it can be taken

* These chambers are described in more detail in Appendix I.

as being completely negligible.

Another packing variable which might influence the packing factor achieved at any pressure is the number of layers of material being compressed. The effect of changing the number of layers of webbing MIL-W-4088C, Type XIX, is shown in Figure 4. Compression curves were plotted up to a pressure of 750 p.s.i. for 1, 5 and 10 layers of webbing. No difference in the curves is apparent until pressures in excess of about 400 p.s.i. have been reached, and even at 750 p.s.i. the difference between the packing factors is small. Over the range of pressures to be used in this work it can be assumed that the relationship between packing factor and pressure is not significantly dependent upon the number of layers of material used.

The calculation of packing factor has assumed that the change in volume of the compressed material is dependent only upon the change in thickness of the pile. This would be true only if the cross-sectional area remained unchanged. The width of the assembly is defined by the width of the compression chamber. However, since the chamber is open-ended, there existed the possibility that lengthwise spreading introduced an appreciable error. This was checked by carrying out a few compression tests in a closed chamber, which was 1" x 2" in cross section. These are compared to compression tests of 1" x 2" specimens in an open-ended chamber, and to those of 2" x 6" specimens in an open-ended chamber. Reducing the cross-section from that used in the other tests (by a factor of 6) would be expected to exaggerate any influence of lack of end restraint. The results are plotted in Figure 5. These experiments were carried out using 10 layers of ribbon. The differences between the curves is very small, probably no more than can be accounted for by the experimental error of determination of the packing factors and the reproducibility obtainable. It is interesting to note that when the small specimens were subjected to a pressure of about 3500 p.s.i., the "undeformed" maximum packing factor of 0.9 was reached.

Since textile materials exhibit viscoelastic behavior, it seemed desirable to investigate briefly the effectiveness with which the packing factor might be reduced by mechanical working. For this reason, the influence of cyclic compression was studied, in which the load was cycled between 0 and either 50 or 250 p.s.i. fifty times. The effect of this cycling on the packing factor of the ribbon MIL-T-5608E, Class E, Type IV, is plotted in Figure 6. Also plotted in this figure is the effect of building the load up to a selected value, and then maintaining it at that value for some time. The times selected were those required to carry out the fifty cycles of loading in the previous experiment, so as to permit direct comparison. Curve 1 represents both the change in packing factor through 50 cycles to 250 p.s.i., and its change during 30 minutes holding at 250 p.s.i. Curves 2 and 3 give similar information for loading to 50 p.s.i. It can be seen that the effect of repeated cycling after the first loading, or of time under load, is very small, amounting at most to a change in packing factor of less than 0.03, and that there is no important difference between the effect of cycling and that of maintaining a constant load. Thus these techniques seemed to be of little interest, and were not used in the

remaining work. This finding is in essential agreement with that of Steinthal(4) who found that varying the rate of application of load had little effect on the ultimate volume of a packed parachute.

Because of the shape of all of these curves, it was decided that three pressures would be sufficient to describe the effect of pressure on degradation. The pressures selected were 0, (the weight of the platen resting on the material, which was about 0.5 p.s.i.), 50 p.s.i., and 250 p.s.i.

For routine loading of the chambers, it was not necessary to use the compression cage and the Instron tester. Because of the relative insensitivity of packing factor to pressure changes over small ranges, great accuracy of measurement was not needed. Therefore, for convenience, the pressure levels were established by using a simple, manually operated hydraulic press.

2. Tensile Characteristics

The results of the tensile tests on all the materials are summarized in Table 2 which gives breaking strength, Table 3 which gives breaking elongation, and Table 4 which gives the energy to rupture the specimen. Table 5 shows rather more clearly the effect of the various exposure conditions by exhibiting the decrease in breaking strength expressed as a percentage of the original strength.

It can be seen immediately from Table 5 that even among the nylon specimens there is considerable variability in behavior. In general the materials group themselves into three classes: (a) those which lose 40% or more of their strength in six hours - all the fabrics, ribbons MIL-T-5608E, Class E, Types II, III and IV, and webbing MIL-W-4088C, Type XX; (b) those which lose 15 to 30% in six hours - ribbons MIL-T-5608E, Class C, Type V, MIL-T-5608E, Class E, Types V and VI; (c) those which show no significant loss in strength in six hours - webbings MIL-W-4088C, Types X and XIX. Because of the peculiar grouping of these materials it was apparent that one could not explain these differences in terms of constructional geometry. It is likely that at least two, if not three, types of nylon are present in this group of materials. Unfortunately, because of the way the materials were purchased, it was not possible to trace back and see what kind of yarn had gone into their construction. They were made at a time when duPont nylon Type 300 or Type 700, or Chemstrand nylon, Type RHB, might have been used. Technical Information Bulletin XIII of E. I. duPont de Nemours and Co. gives information about the comparative loss in strength of Types 300 and 700 nylon when exposed for various times at 350°F. For the relatively short exposure times with which we are concerned, there is a very great difference in the degree of degradation. It is stated that 10% strength loss occurs in less than one hour for Type 300 yarn and in ten hours for Type 700 yarn. No similar information for Chemstrand's Type RHB nylon has been seen, but it is understood that it is similar to duPont's Type 700 in behavior. To verify that the differences in degradation observed were due to the type of nylon used, and not to the construction of

the materials, single warp yarns were raveled out of each of the materials and exposed hanging freely in an oven at 350°F for periods of 2 hours and 6 hours. The effect of these exposures on the breaking strength of the yarns is given in Table 6. In this table it is clear that the nylon yarns group themselves in exactly the same way as the fabrics have been grouped. We can be confident, therefore, that there are two, if not three, different kinds of nylon present in the materials being studied.

As would be anticipated, the Dacron, U.O.F., and glass materials show very little degradation at 350°F even for 6 hours. Exposures of some of these materials at 350°F were carried out for longer times, as shown in Tables 2, 3 and 4. Exposures were also made at higher temperatures for these materials and the metal fabric. The results of these tests are given in Table 15. Since only limited quantities of the Dacron materials were available, it was possible to do further testing only on Dacron fabric MIL-C-8021B, Type III. Exposure at 350°F for 24 hours, and at 400°F for 6 hours still showed very little degradation. The glass fabrics were exposed at 500°F for 6 hours, and at this temperature showed an appreciable amount of degradation. At temperatures as low as this, of course, we are not measuring the effect of the temperature on the glass fiber itself, but rather on the finish which is used to minimize inter-fiber abrasion. It is fairly certain that the strength of the fabric would decrease rapidly as the temperature increased over 500°F due to the loss of this finish. The fabric made of the unnamed organic fiber showed no degradation when exposed for 2 hours at 500°F; only very slight degradation at 600°F for 2 hours; and severe loss of strength at 650°F and 700°F for 2 hours. The stainless steel fabric showed an unimportant loss in strength even after 72 hours at 1000°F.

A study of the effect of packing pressure on the degree of degradation shown in Table 5 indicates that this is only a minor factor. In general it can be said that for all of the specimens, with the possible exception of U.O.F. and glass fiber, greater degradation occurred at low pressures than at high pressures. This can be attributed directly to the fact that most of the degradation which occurred was due to oxidation and at the high pressures less oxygen is available within the specimen and therefore less degradation takes place. However, the effect is a relatively small one; for practical considerations the important result is that the application of pressures up to 250 p.s.i. does not have an adverse effect on the amount of degradation which occurred at elevated temperatures.

Some typical load-elongation curves are plotted in Figures 7 to 12 inclusive. It will be seen from these that in no case is the curve seriously altered by degradation, other than in the reduced breaking load. The accompanying decrease in breaking elongation or in energy to rupture, shown in Tables 3 and 4, reflectsprimarily this fact, and therefore provides no additional information about degradation effects.

Since the degradation observed appeared to be primarily due to oxidation, it seemed desirable to study briefly the effect of atmospheres other than air. For this purpose it was not sufficient simply to immerse the specimen in an oxygen-free atmosphere; the specimen had to be filled with

N_2 ATMOS.

this atmosphere, for it was the residual oxygen contained within the specimen which was responsible for the degradation. One simple experiment which was carried out on two nylon materials was to saturate the specimens with water prior to pressure packing; then, when the compressed specimens were heated, the water still remaining in them was turned to steam, which displaced all or part of the air which normally would be contained in the specimen. Results of this treatment are summarized in Table 7. Degradation of the specimen has been considerably reduced by the presence of the water, although there still remains a substantial amount.

N_2 ATMOS

In several materials an attempt was made to replace the air within the specimen by nitrogen prior to pressure packing. This was done by covering the specimens with a bell jar and reducing the pressure to about 100 microns. For about an hour the air was allowed to bleed out of the specimens, after which time the bell jar and specimens were filled with nitrogen. They were then quickly transferred to the compression chambers, compressed, and heated to 350°F for 6 hours in a nitrogen atmosphere. The effect of this is shown in Table 8. The decrease in degradation is similar to that resulting from wetting the specimen. The loss in strength is significantly less than that resulting when the specimens contained air, but degradation has not been eliminated. Better results might have been achieved if the pressure packing could have been carried out in a nitrogen atmosphere.

3. Effect of Folding a Specimen

A study was made to determine whether the presence of a fold in a specimen would have any influence on the amount of degradation which took place. In several cases, specimens were folded in a direction at right angles to their length. They were laid into the compression box in such a way that the fold of any specimen abutted the fold of the previous specimen. Pairs of folded specimens were arranged in the box so that no folds lay directly over any other folds. In this way an attempt was made to minimize the existence of localized high pressure areas at the fold, though it must be realized that to some extent these did exist.

Results are summarized in Table 9, which shows that in general the presence of a fold had no influence on the amount of degradation which took place. Even in those cases where the folded specimen shows greater degradation than the flat specimen, it was observed that the specimen did not break at the fold. The reason for these instances of excessive degradation has not been explained. Even the glass fabrics have not been damaged by folding. It can be stated, however, that there is no evidence which indicates that when a folded specimen is compressed excessive degradation will occur in the region of the fold.

4. Tear Strength

The effect of compression and heating on the tear strength of the fabrics (with the exception of the glass fabrics) was also studied. Results are summarized in Table 10 which gives the actual values of tear strength, and in Table 11, which gives the percent loss in tear strength. The important consideration here, of course, is whether the tear strength has been lowered

at a different rate from the breaking strength. In Figure 13 the percent loss in tear strength for the various specimens is plotted against the percent loss in breaking strength for specimens which have been subjected to the same exposure conditions. It would appear that conditions producing a relatively small loss in breaking strength have a tendency to produce a somewhat larger loss in tear strength. However, when the degradation becomes really appreciable there appears to be a one-to-one relationship between the two. In general, it seems safe to assume that any loss in tear strength which is experienced is primarily due to the loss in breaking strength of the individual yarns making up the fabric, although in early stages of degradation reduction of the tensile rupture elongation of yarns will cause a somewhat greater tear strength reduction than tensile strength losses.

5. Seam Strength

Seams were sewn in all of the materials with the exception of the fabrics made from glass fiber and from the unnamed organic fiber. The latter materials were not sewn because a suitable sewing thread was not available. The seams that were used were typical of those that would be encountered in normal parachute construction. The sewing thread used, the number of stitches per inch, the number of rows of stitching and the type of overlap were selected to be suitable for the particular material being sewn. In the fabrics the seam was sewn parallel to the warp direction, and was the type known as an LS_C seam. For the webbings an overlap distance of 8 inches was used and a 3-point seam sewn parallel to the long axis. The ribbons were overlapped 2" and short lengths of the same ribbon were sewn at right angles to the axis of the ribbon over and under the overlapped portion. Eight rows of stitching were sewn through the 4-layer sandwich. In the case of the Dacron materials, a Dacron sewing thread was used.

The specimens were loaded into the compression box in such a way that no two seams lay directly on top of one another. The total load used in compressing the specimens was calculated to give the desired pressure based on the total area of seam in the box.

Standard tensile tests could be used for the ribbon and webbing seamed specimens, but for the fabric seams a modification had to be introduced. The test used for the seamed fabrics was essentially that described by Coplan[6]. The specimens were cut 4" wide by 10" long with the seam running across the center. To insert the specimen into a 2" wide compression box, each edge of the specimen was folded into the center, resulting in a folded specimen 2" wide. After compression and heating, slits were cut from each side of the specimen parallel to and adjacent to both sides of the seam, leaving a 2" width of fabric intact abutting the seam. The fabric was gripped by 3" jaws with their facing edges aligned with the slits and 1/4" away from them. Thus a 2" length of seam was at right angles to the direction of applied tension.

An examination of the results in Table 12 will show that in every case the strength of the seam was determined by the load at which the sewing thread

broke, and that this sewing thread became degraded at about the same rate as the fabric had become degraded in an unseamed specimen. There is no evidence from these results that the presence of a seam alters in any way the way in which the assembly degrades.

6. Inter-Layer Sticking

The method used to measure inter-layer sticking is described in Appendix II-3. No appreciable amount of inter-layer sticking was found for any of the conditions of temperature or pressure used for the fabric or the webbings. The ribbons, however, all showed some evidence of sticking. The results for the ribbons are summarized in Table 13.

Since there is presumably no difference between the nylon used in the ribbons and that in the fabrics, it must be assumed that the presence of sticking in the ribbons is a result of some finish which remains on the material. Specific identification of this finish has not been made. It will be seen, however, that in some cases it can result in very serious inter-layer sticking. It can be seen, also, that specimens which have become more degraded as a result of longer exposure at low pressure show less sticking than those which have evidenced less degradation because of a shorter time of exposure, or of higher packing pressure. This fact was further verified by taking some of the material which showed considerable sticking and subjecting it to some oxidative degradation in an oven before inserting the specimens in the compression chamber and carrying out a standard exposure and sticking test. This preliminary degradation completely eliminated the inter-layer sticking. This lack of sticking may not be associated simply with the degradation of the nylon, but rather with the removal or modification of the finish during the pre-heating treatment. An attempt was made to check the effect of the finish by removing it with a solvent scour. This, however, produced inconclusive results. In some instances the sticking force was reduced; in others it was actually increased. However, it appears that the inter-layer sticking which is evidenced in the ribbons is associated with the finish which they carry.

7. Stiffening: Inter-Fiber Sticking

Specimen stiffening due to exposure to heat and pressure was determined, using the technique described in Appendix II-4. The relationship between stiffening of the materials and the extent of inter-fiber sticking has been discussed in a previous section of this report. The results of the measurements are expressed in terms of flexural rigidity and are summarized in Table 14. In the case of the nylon materials, flexural rigidity has been raised by heating by factors ranging from about 2 to more than 100. Generally it can be seen that even the relatively short two-hour exposure at 350°F under a pressure of 250 p.s.i. is sufficient to cause a marked increase in specimen stiffness. This increase appears to be greatest for the ribbons and webbings, and also for fabric MIL-C-8021B, Type III. Increasing the duration of the exposure to 6 hours at 350°F under 250 p.s.i. does not appear to have a uniform effect on all of the

specimens. In many cases the rigidity is increased still further, but in some cases it is reduced somewhat. Increasing the temperature to 450°F, still at a pressure of 250 p.s.i., generally effects a very marked increase in rigidity, even for a very short exposure time. The effect of pressure can be seen, either for the 6 hour exposures at 350°F, or for the zero time exposures at 450°F. With few exceptions, decreasing the pressure decreases considerably the degree of stiffening which takes place. This is exactly as might be anticipated, for it is reasonable that when the intimacy of contact between the fibers is increased by increasing the pressure, the extent to which inter-fiber sticking takes place is also increased.

The effect of temperature, time, and pressure on the stiffening of Dacron fabrics is approximately the same as that experienced in nylon fabrics. The amount of stiffening which is experienced in the glass fabrics under any given exposure conditions is also about the same, almost certainly due to reaction of the surface finish. The only material tested which showed no appreciable stiffening at 350°F, and only a relatively small increase in stiffness at 450°F, is the unnamed organic fiber. This only became significantly stiffer at temperatures over 500°F.

The specific relationship between stiffness and ease of deployment of the parachute is not known. It seems likely, however, that deployability of a parachute will be affected by the stiffness of its components, and that there must be some maximum of stiffness beyond which the parachute would not deploy in a satisfactory manner. It would appear, therefore, that the observed influence of temperature and pressure on the stiffness of *these* parachute materials must be viewed seriously. In fact, because of the fairly marked increase in stiffness which occurs at relatively low temperatures and short times of exposure, it would seem that under some circumstances this factor may be even more important than the amount of degradation which may have taken place. It is important to note that even Dacron and glass, which showed relatively minor degradation at 350°F, might prove to be unacceptable as parachute materials for pressure-packed parachutes because of the inter-fiber sticking which might occur. It would appear that the unnamed organic fiber material has a marked superiority over any other material tested, with the exception of the metal, because of its very good resistance to degradation and the comparative lack of inter-fiber sticking which occurs.

The effect of wetting out the material prior to compression and heating was investigated on fabric MIL-C-8021B, Type II. This was treated at 350°F for 6 hours under 250 p.s.i. pressure. The presence of water did not have a large effect on the stiffening of the material. It did seem to reduce the stiffening approximately to the value which was obtained at zero p.s.i., namely 20 gm-cm^2. This would not, however, seem to be a means of eliminating inter-fiber sticking.

The effect of filling the specimens with nitrogen was also investigated. In three out of the five cases the stiffness of the specimen was increased, which is consistent with the previous observation that degradation tends to decrease inter-fiber adhesion; or conversely, that less degradation as a result of the nitrogen atmosphere increases inter-fiber adhesion. In the

remaining two cases the stiffness was apparently somewhat reduced. It can be concluded that insofar as heat-stiffening is concerned a nitrogen atmosphere is likely to have an adverse effect, because at least some of the components of the parachute may be stiffened even more than in a normal atmosphere.

V. PRESSURE PACKED PARACHUTES

The two types of parachutes studied in this program were a 6-foot guide surface parachute and a 12-foot ribbon parachute. These were packed, using normal parachute packing methods, in deployment bags of a suitable size. These were not the deployment bags which were originally provided by ASD with the parachutes, but they were bags into which the parachutes fitted snugly. One parachute of each type was packed by professional packers at L. C. Hanscom Field, Bedford, Mass.

Steel cylinders were made up to contain the packed parachute for pressure packing. These are pictured in Figure 14. The cylinder for the large parachute was 18" in diameter and 18" high; that for the small parachute was 9" in diameter and about 12" high. The walls of the cylinder were 1/8" steel plate; the ends were 1/2" Dural held together with tie rods. A 1" thick Dural plate rested on top of the parachute pack inside the cylinder, and could be pushed down by inserting the ram of a hydraulic press through a hole in the center of the top plate. When the desired amount of compression had been achieved the piston was held in position by tightening down bolts which were threaded through the top plate.

Figures given in the Steinthal reports(4) indicate that they were able to achieve packing factors in the range of 0.4 to 0.5 in a pressure packed parachute. It was decided, therefore, to compress these two parachutes to packing factors in that range. The degree of compression achieved is indicated by comparing the depth of the piston on which the rule is sitting, as shown in Figures 14 and 15. For both parachutes the compressed volume was approximately two-thirds the initial volume. This resulted in a packing factor of 0.46 for the small parachute and 0.52 for the large parachute. The pressures required to achieve this degree of compression were not specifically recorded, but they were of the order of 200 to 250 p.s.i.

The parachutes were packed in the afternoon and allowed to sit overnight. The following morning the steel cylinders containing the packed parachutes were placed in a recirculating hot air oven which was operating at 380°F. They remained in the oven for 12 hours and then the heat was turned off and the doors opened. About 80 hours later the cylinders were opened up and the parachutes removed. At this time there was no residual pressure on the packed parachute other than the weight of the top Dural plate although its volume, of course, had not changed from that corresponding to a packing factor of about 0.5. When the parachutes were removed from the cylinders their appearance was as illustrated in Figure 16. There was no evidence of any dimensional recovery.

During the exposure the temperature at various locations within the packed parachute was measured by means of thermocouples. Three thermocouples were inserted by drilling holes into each of the cylinders. The large parachute pack contained one thermocouple extending 3" in from the outside edge near the top of the pack, one extending 7-1/2" in at the middle of the pack and one extending 5" in near the bottom of the pack. These can be seen in Figure 15. In the small parachute the thermocouple near the top of the pack extended 3" in from the outside edge; the one in the middle 2-1/2" in; and the one near the bottom 1" in. The curves representing the temperature at each of these locations over a 48-hour period are plotted in Figure 17. It took the small parachute 12 hours to reach a uniform temperature equal to that of the oven. The large parachute did not reach this uniform temperature even after the 12-hour heating period. The outermost thermocouple indicated that probably only the outer 2 or 3 inches reached the oven temperature. Cooling took place even more slowly. The small parachute was back down to room temperature after a cooling period of something over 30 hours. The outer 3" of the large parachute also reached room temperature in about the same length of time. However, even after 36 hours of cooling the innermost thermocouple in the large parachute, which was 1-1/2" away from the center of the pack, was still reading about 10° above room temperature.

These curves illustrate very clearly that the results obtained in the idealized exposure in the compression chambers cannot be interpreted directly into the effect of similar exposures on a packed parachute. Obviously the influence of time is going to be quite different and will depend to a marked degree on the size and shape of the parachute pack. Moreover, if the packed parachute is exposed to cyclic heating, as is likely to be the case if it is carried in an airplane which must land periodically for re-fueling and overhaul, it is clear that unless the lengths of time on the ground are very long, repeated exposures to high temperature for a period of a few hours can result in a gradual increase in temperature from heating cycle to heating cycle. By making measurements of the sort described in this report on a particular type of parachute pack, it should be possible to predict the temperatures which will result at various points within the pack for any type of heating and cooling history. It is clear that this behavior will be dependent upon the relationship between the mass of material being heated and the surface area of the containing cylinder. The rate of heating may in some cases depend upon the rate of heat transfer through the packed material, but is more likely to be dependent upon the rate at which heat can be transferred from the surrounding atmosphere through the walls of the cylinder.

The condition of the parachutes when unpacked was such that deployment would have been difficult to achieve, if indeed it could have been accomplished at all. As would have been predicted from the results of the idealized experiments, this was not because of the degradation which had taken place. Rather it was because of the extreme stiffening of all the components which had taken place, and because these stiffened materials had been set by the heat into the compact, folded configuration which they had been forced to assume within the pack. A bight of harness which had been inserted into a loop in the deployment bag took a pull of perhaps 100 pounds to release it.

The remaining two parachutes were packed in deployment bags in the normal way, and, without pressure packing, were exposed to a temperature of 380°F for 12 hours in an oven as had been done for the pressure-packed parachutes. This was done to determine whether the use of pressure packing was a significant factor in the effect of elevated temperature exposure on the packed parachute. The results obtained from this exposure were unexpected, and not completely understood. The large parachute was not greatly affected, although undoubtedly somewhat degraded. It had not been stiffened nearly as much as the pressure packed parachute, as would have been expected from the previous observations on the effect of pressure on stiffening of small specimens. The small parachute, however, was very badly degraded, even though it was in the same oven for the same length of time. Parts of it were thoroughly blackened and very brittle. It is known that the degradation reaction is an exothermic one, and sets in at about 375°F. What probably happened is that the small parachute reached the critical temperature, and had sufficient oxygen available for this reaction to start, and to generate still more heat, which caused it to spread.

It must be concluded, then, that pressure packing can have a beneficial effect by minimizing degradation by reducing available oxygen in contact with the fibrous substance. But it also has a marked deleterious effect due to the stiffening and heat-setting of the materials, which could cause difficulty in deployment.

VI. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Compressive forces up to 250 p.s.i. on any of the materials or configurations studied had no deleterious effect on their strength at any of the conditions of temperature or time. On the contrary, under certain conditions the reduction of void volume resulting from compression had a certain salutory effect on the heat-oxidation degradation of the nylon materials.

At any given temperature-time conditions the amount of degradation in the materials studied could be attributed simply to the availability of oxygen within the structure of the material. This was reduced by the application of pressure, but since the change in packing factor which was possible by compression was only of the order of about 30%, the effect of pressure on degradation was not large. Degradation could be reduced appreciably by replacing the oxygen within the material with an inert atmosphere such as nitrogen or even steam.

All the nylon specimens, with the exception of two webbings (believed to have been made from Type 700 duPont nylon or Chemstrand RHB) showed considerable degradation when exposed at 350°F for 6 hours. The Dacron materials retained their strength to temperatures somewhat over 400°F. The glass materials were appreciably weakened at 500°F probably due to degradation of the finish. The fabric made from an unnamed organic fiber showed little strength loss at 600°F for 2 hours, but was badly damaged at 650°F. The stainless steel fabric was degraded only slightly when exposed to 1000°F for 72 hours.

Most of the exposures were carried out with the specimens in a flat configuration. It was found that folding or seaming the specimen had no appreciable effect on the way any of the materials degraded.

Sticking between layers of most of the materials was not a phenomenon of serious proportions at any temperature or time. The exceptions to this were several of the nylon ribbons whose behavior was markedly different from all of the other materials, suggesting that the effects observed could probably be attributed to thermal reactions of finish on their surfaces.

A factor which was considered to be as important as the loss in strength or elongation which took place was the stiffening of the material which is here attributed to inter-fiber sticking. This was very appreciable, in all materials except those made from the unnamed organic fiber and stainless steel even under exposure conditions which produced little strength loss.

The effect on a pressure packed parachute of heating at 380°F for 12 hours was essentially as would have been predicted from the results obtained in the controlled tests on small specimens. Some oxidative degradation as evidenced by yellow discoloration was apparent, but the most important result seemed to be the extreme stiffening of the various components, and heat-setting in the tightly-packed, folded configuration. It seemed likely that this would make the parachute difficult, if not impossible, to deploy. An additional oven exposure of a parachute which had not been pressure-packed showed less stiffening and more degradation, just as is indicated by the results of all the experiments on component materials. There was no evidence of inter-layer sticking among the components of the heated parachutes either pressure-packed or not.

It is recommended that any further study be concerned more with fabric stiffening than with the effects of pressure on tensile properties, about which much is now known. Means of reducing the stiffening brought about by heat, and of minimizing the effects of setting in a folded configuration, should be sought. The properties of the unnamed organic fiber included in this investigation are very interesting in this regard. It seems to combine a resistance to degradation and to stiffening up to temperatures high enough to be of considerable practical interest. Further study of its reaction to heat when in the heterogeneously packed condition found in a parachute pack would seem to be indicated.

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VIII. APPENDIX I

DESCRIPTION OF THE COMPRESSION BOX

The box in which the materials were compressed and heated is pictured in Figure 18, consisting of an open ended rectangular trough and a snugly fitting platen for compressing the specimens. The walls and bottom of the trough were made of 1" thick steel and each contained a 300 watt tubular electric heating element. The platen also contained a similar heating element so that the compressed specimens were surrounded by four heated walls. The length of the box was 8", and its width was variable (by inserting a bottom and a platen of suitable width) so as always to be the same width as the specimens being treated. The series of materials used included widths of 1", 1-3/4" and 2".

Compression was accomplished in a hydraulic press as described elsewhere in the report. When the desired degree of compression was achieved the platen was held in that position by four bolts, thus maintaining a constant compressed volume even though the actual value of the pressure decayed with time.

Uniformity of temperature over the walls of the compression box was measured with a surface pyrometer. It was found that the temperature variation could be reduced to less than 4°F provided the heaters in the side walls were connected in series. This is the way the box was operated, therefore, and it can be assumed that very satisfactory uniformity of temperature was achieved at all operating temperatures.

Temperature was controlled by a West Model J Controller using as a sensing element a specially designed iron-constantan thermocouple. Twisted and bared thermocouple wires were silver soldered into a groove running the full length of a 1/8" thick brass plate having the same dimensions as the bottom of the compression box. This plate was laid in the bottom of the box and the specimens piled on top of it.

Measurements of the rate at which the specimens within the box heated up were made by inserting three thermocouple plates in a pile of 10 specimens. One plate was at the bottom of the pile, in contact with the bottom of the box; one was in the middle of the pile; and one was at the top in contact with the platen. Curves which show the rate of rise of temperature at these three locations are shown in Figure 19. In this case the box was set to control at 400°F, and it will be seen from the temperature of the bottom thermocouple plate that this controlling temperature was reached in about 35 minutes from the time the heat was turned on. The temperature of the middle and top plates lagged behind the temperature of the bottom plate somewhat, but about 15 minutes after the temperature of the box began to be controlled, the temperature was uniform throughout the pile of material. Most of the exposures were carried out at a box temperature of 350°F. It can be assumed therefore, that the box reached this temperature in a period of somewhat less than one-half hour and that about 10 minutes later the

temperature was uniform throughout the whole of the pile of specimens. For this reason, ten minutes after the box temperature started to be controlled was taken as zero time for all of the exposures. Six compression boxes of this type were constructed, each capable of being converted to any of the three widths. All six boxes could be used concurrently. During the heating period they were contained within a marinite-insulated enclosure pictured in Figure 18. The controller was connected to the boxes through a cycling circuit which permitted the controller to sense each of the six boxes in succession and determine whether the heater in that box needed to be turned on or off. Thus, during any one exposure all the tests had to be carried out at the same temperature, but different values of pressure and time could be used. Since each of the boxes could be loaded with more than one type of specimen, this made it possible to carry out several exposures at one time.

Specimens which were to be used for tensile testing had to be cut as long as 40 inches; thus there was a considerable length of specimen extending outside the compressed heated area of the box. These long ends, however, were contained within the insulated chamber and were, therefore, subjected to an elevated but uncontrolled temperature. Because of the more or less unlimited supply of oxygen within the insulated chamber, it was sometimes found that the length of specimen outside the compression box became more degraded than the specimen inside the box, and during tensile testing broke in a region outside that being studied. It was possible to eliminate this difficulty simply by filling the insulated chamber with nitrogen, and bleeding nitrogen into the chamber throughout the duration of the heating time at a low rate. This almost completely eliminated degradation of the part of the specimen outside of the compression box, and breaks could be obtained in the desired area of the specimen. It should be noted, however, that even though the heating was done in an atmosphere of nitrogen, this did not mean that the specimen was immersed in a nitrogen atmosphere, for the air originally contained within that part of the specimen which was being compressed was not displaced by this procedure.

IX. APPENDIX II

TEST METHODS

1. Tensile Tests

Most of the materials used in this investigation were too strong to be tested by conventional methods such as are described, for example, in CCC-T-191b, Method 5104. Modifications both of the methods of gripping the specimens and of the speed of testing had to be made in order to accommodate the much higher strengths. Two methods of gripping the specimen were used, one of which was suitable for the fabrics and the other for the ribbons and webbings.

All fabric specimens were cut initially 2" wide by 14" long, the longer dimension being parallel to the warp yarns of the fabric. They were compressed and heated and then, prior to tensile testing, raveled to 1" wide so that all the strength figures quoted are for a 1" raveled strip test. The clamps of the testing machine carried serrated flat faces 2" wide by 1-1/2" long. These were lined with leather to prevent cutting of the specimens. Each end of the test specimen was coated with powdered rosin to minimize slippage. It was then passed through the jaws, around a 1/4" rod, and back through the jaws. This method of gripping a specimen prevented excessive slippage and minimized jaw breaks. It did not, however, eliminate so-called "jaw penetration" and the elongation of the specimen was not accurately recorded on the chart of the tester. Elongation and energy to rupture had to be determined by a specialized technique which is described below.

The ribbons and webbings were held in capstan-type jaws. This required a specimen 40" long and, of course, did not permit the direct determination of specimen elongation. The technique for determination of elongation and energy to rupture was the same as that used for fabrics. All ribbons and webbings were tested full width.

The elongation of the specimen was recorded photographically. Narrow tabs of black electrical tape were stuck to the face of the specimen at an initial spacing of 5 inches. This distance was recorded by photographing the mounted specimen initially and at specified load increments during the progress of the test. The specific loads at which photographs were taken were indicated by pips on the recorder chart. Values of elongation were determined at several points by inserting the developed film in a microfilm reader, and measuring the distance between the black tabs with a ruler. An accurate load-elongation curve could then be plotted, which was extrapolated up to the rupture load. The energy was determined by measuring the area under this curve with a planimeter.

All tests were carried out at 65% R.H., 70°F. Because of the time-consuming nature of this type of testing, and because of the large numbers of specimens which required testing, only three specimens were tested for each sample of material at each exposure condition (except for the initial

values, for which 5 tests were carried out). It should be realized, therefore, that the precision of the results is such that differences between results of less than about 5% are of doubtful significance.

Only the glass fabrics had to be treated differently from the methods described above. Glass fabrics are known to be very susceptible to jaw cutting. In addition to this, the fabrics which were used had a marked tendency to fray, and were so easily distortable that it was difficult to be sure that the same yarns were gripped in the upper and lower jaws. A method of breaking glass fabrics is described in ASTM Standards, Method D579-49. This describes a technique for coating the ends of the specimen with butyl methacrylate in order to prevent jaw cutting. This method was tried, but considerable variability in test results was obtained because of the difficulty in maintaining uniform yarn tension during the application of the coating material, and because the yarns at the edge of the specimen tended to pop out of the structure, thereby failing to carry their share of the applied load.

A simple technique was developed which overcame all of these difficulties and produced uniform and reasonable results. A test specimen was cut 2 x 14 inches as in the case of the other fabrics, and after compression and exposure to the required temperature conditions it was carefully laid out on a horizontal surface. A 1" wide strip of masking tape was applied down the center of the test specimen, care being taken to keep the edge of the masking tape parallel to the lengthwise yarns of the specimen. Those yarns outside the masking tape were then frayed out and the specimen inserted in the jaws exactly as described above for the other fabrics, keeping the side which carried the masking tape adjacent to the leather jaw faces. It was not necessary to apply any correction for the tensile characteristics of the masking tape because the load required to stretch the masking tape to the breaking extension of the glass fabrics was only about 3 pounds. This was a negligible error in a fabric which had a strength of almost 400 pounds.

2. Tear Tests

The tear strength of the fabrics was measured by the tongue tear test as described in CCC-T-191b, Method 5134, except that in order to fit the compression chamber, the specimen was cut 2 inches wide instead of the 3 inches specified in the test.

3. Inter-Layer Sticking

In order to obtain a quantitative estimate of the extent of interlayer sticking which occurred during heating, a simple test was devised for measuring the force required to separate the specimens. Specimens were cut 10" long by 2" wide (or the full width of the material, if less than 2"), 3 being required for each test. A sandwich was made of these three specimens in such a way that the center specimen extended 2" beyond the outer 2 specimens at one end. Thus the length of overlap was 8", and this central 8" was compressed and heated in the compression chamber. After the heating

period the specimens were removed from the box and were checked to see whether any appreciable degree of sticking had resulted. If so, the three-layer assembly was conditioned at 65% R.H. and then inserted in the jaws of an Instron tester in such a way that the outer 2 specimens were gripped at one end in one jaw and the inner specimen gripped at the other end in the other jaw. The force which was necessary to slide the inner specimen out from between the outer two was then measured.

4. Stiffness Tests

The stiffness of the specimens which was used as a measure of inter-fiber sticking was measured by the cantilever test. For the original specimens and for those which were not stiffened too much by heating, the technique used was essentially that described in ASTM Method D-1388-55T. However, the heavier glass fabrics, the heavier ribbons, and the webbings became too stiff after heat treatment to be measured with this technique. Peirce[7] gives the expression for deflection of a weighted cantilever beam. A simple device was set up, therefore, in which the stiffened specimen could be loaded by hanging weights at its free end, and measurements of the angle of deflection could be made. It was found, when making these measurements, that the specific value of rigidity obtained was dependent upon the degree of curvature, as illustrated for a few materials in the curves of Figure 19. It is possible that some points of adhesion were broken as the specimen bent, resulting in a rigidity which decreased as the degree of bending increased. In order to minimize variability, it was decided to deflect all the specimens to an angle of about 40°, which was chosen because in this range of bending the measured value of rigidity was not greatly affected by the angle of deflection. Moreover, this is approximately the angle which was used in the standard unloaded cantilever test. It should be realized, therefore, that the values of rigidity quoted are for a specimen which has received a small amount of "working", and that its initial stiffness may be somewhat higher than the figure quoted.

All values are given in terms of the flexural rigidity of the specimen, which is the weight per unit length multiplied by the cube of its bending length. Metric units have been used and the flexural rigidities are in the units, gms.cm^2.

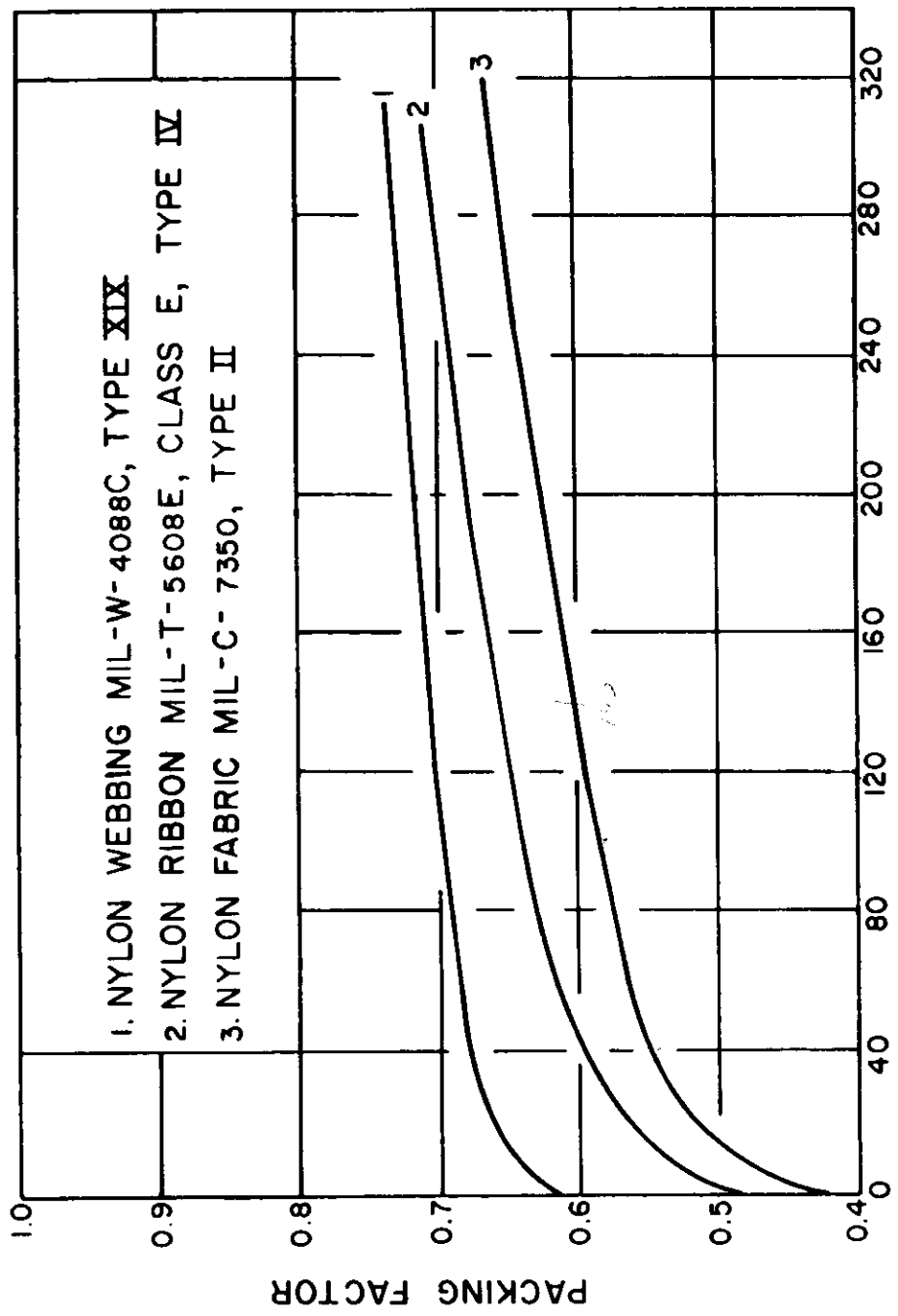


FIGURE 1 - COMPRESSIBILITY OF NYLON MATERIALS.

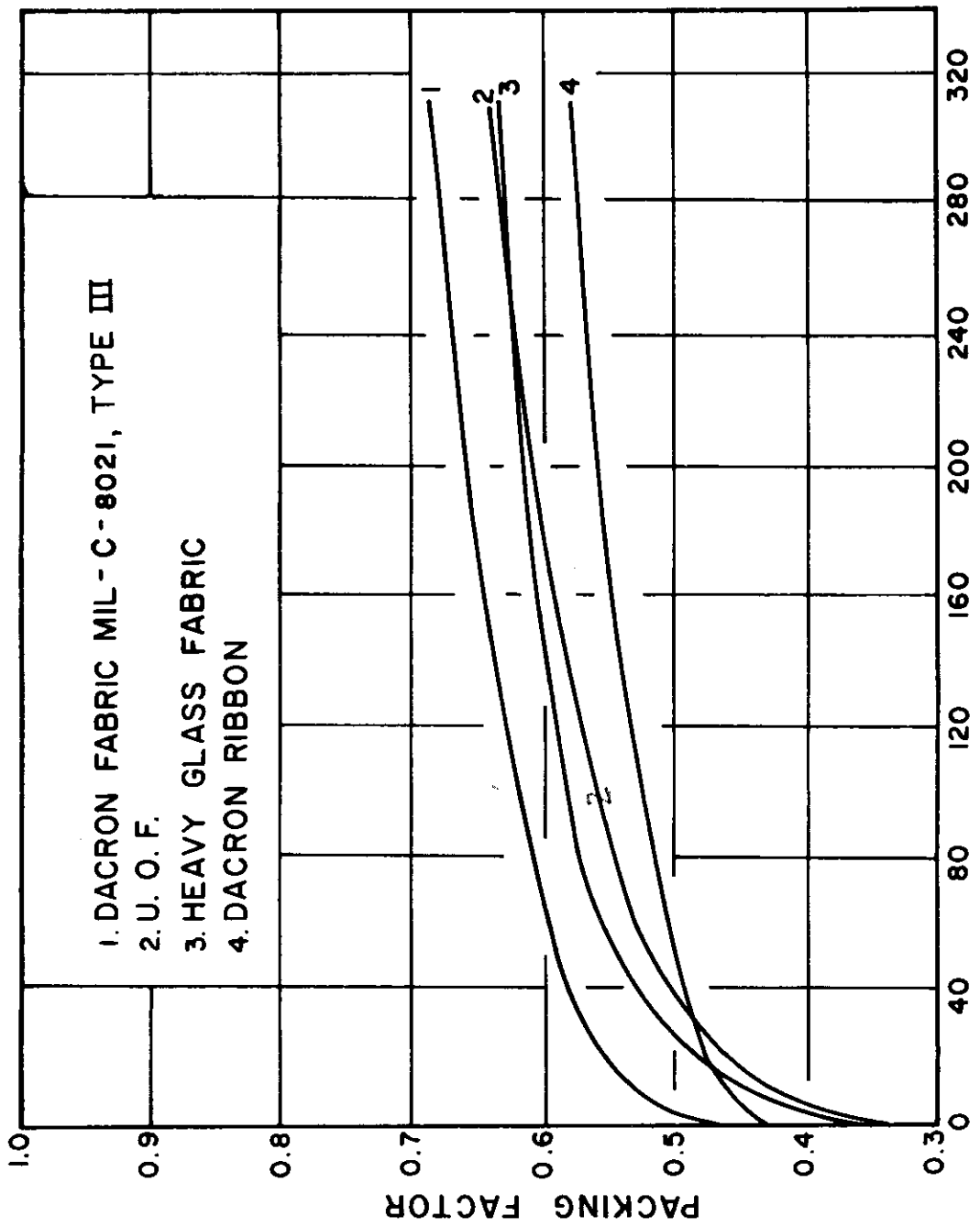


FIGURE 2 - COMPRESSIBILITY OF OTHER MATERIALS.

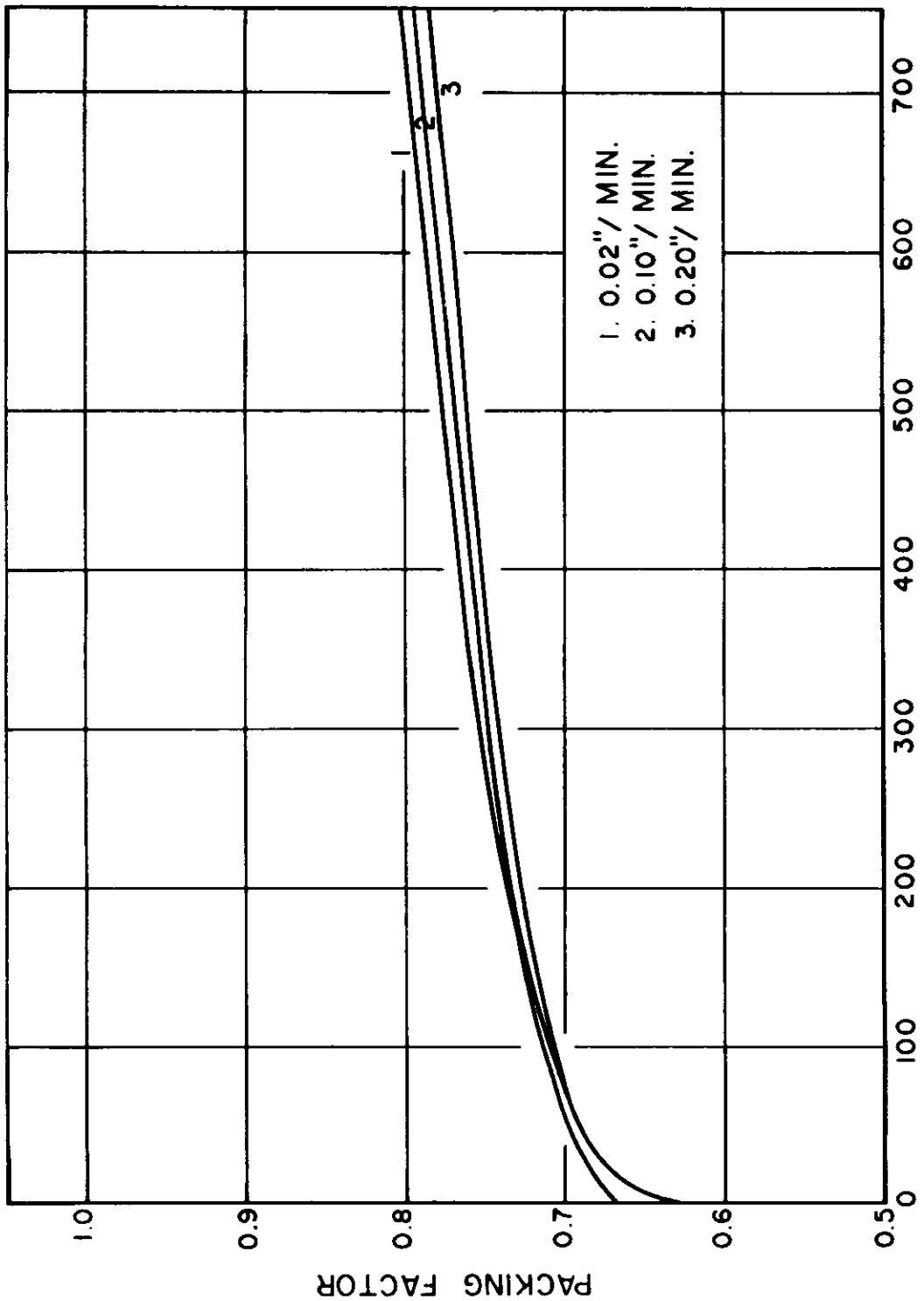


FIGURE 3 - EFFECT OF STRAIN RATE ON THE COMPRESSION OF 5 LAYERS NYLON WEBBING MIL-W-4088C, TYPE XIX.

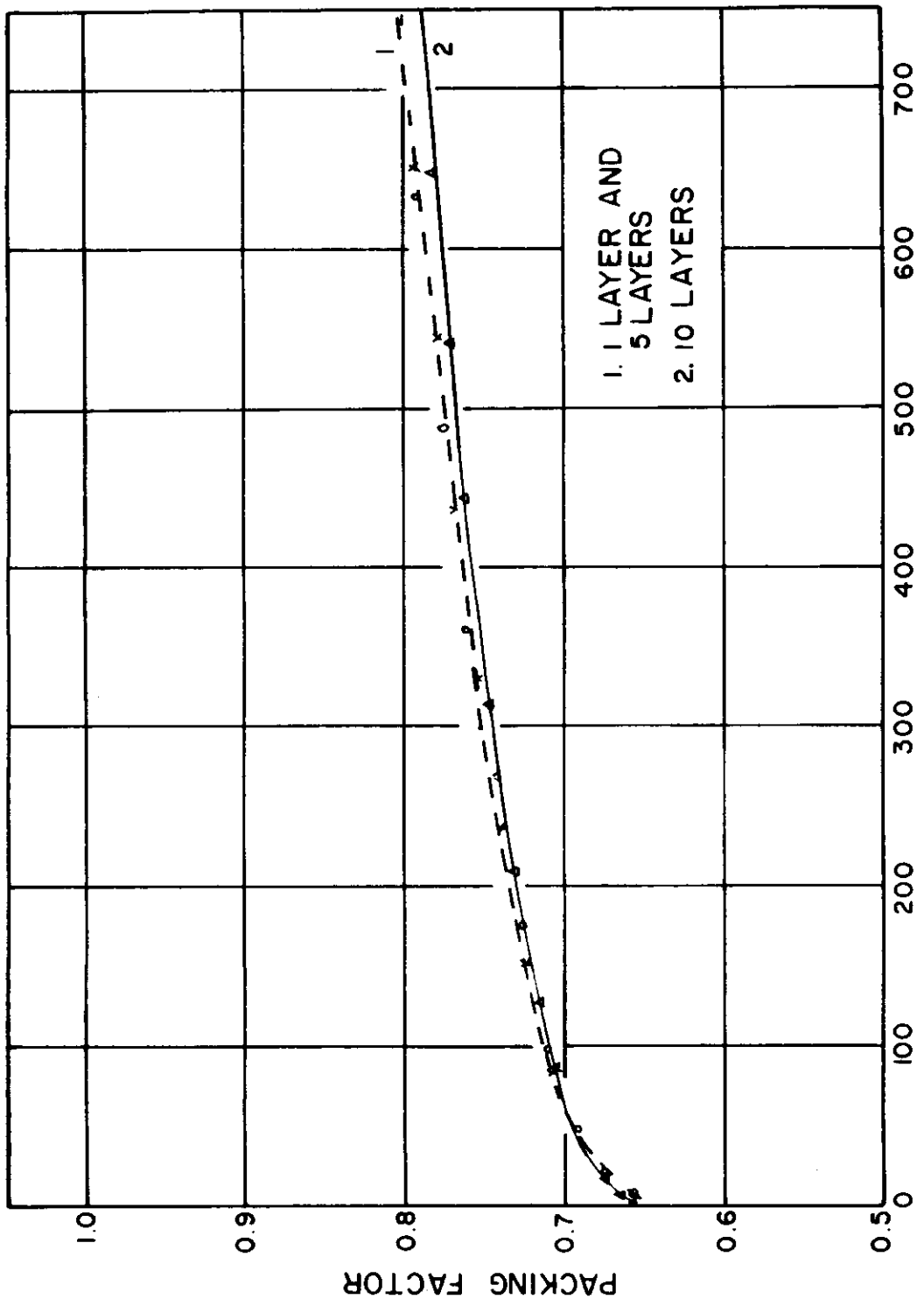


FIGURE 4 - EFFECT OF NUMBER OF LAYERS OF MATERIAL ON THE COMPRESSION OF NYLON WEBBING MIL-W-4088C, TYPE XIX.

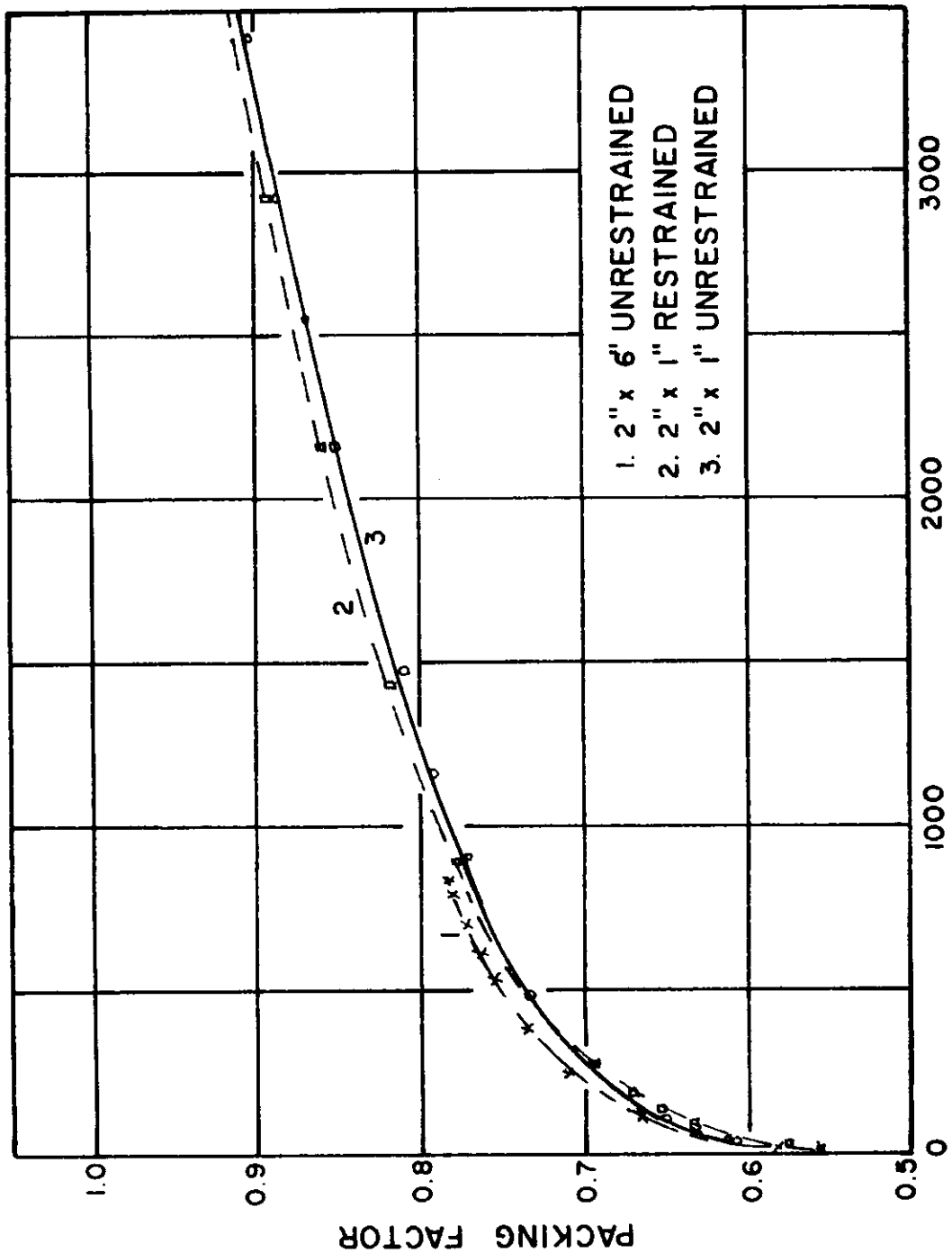
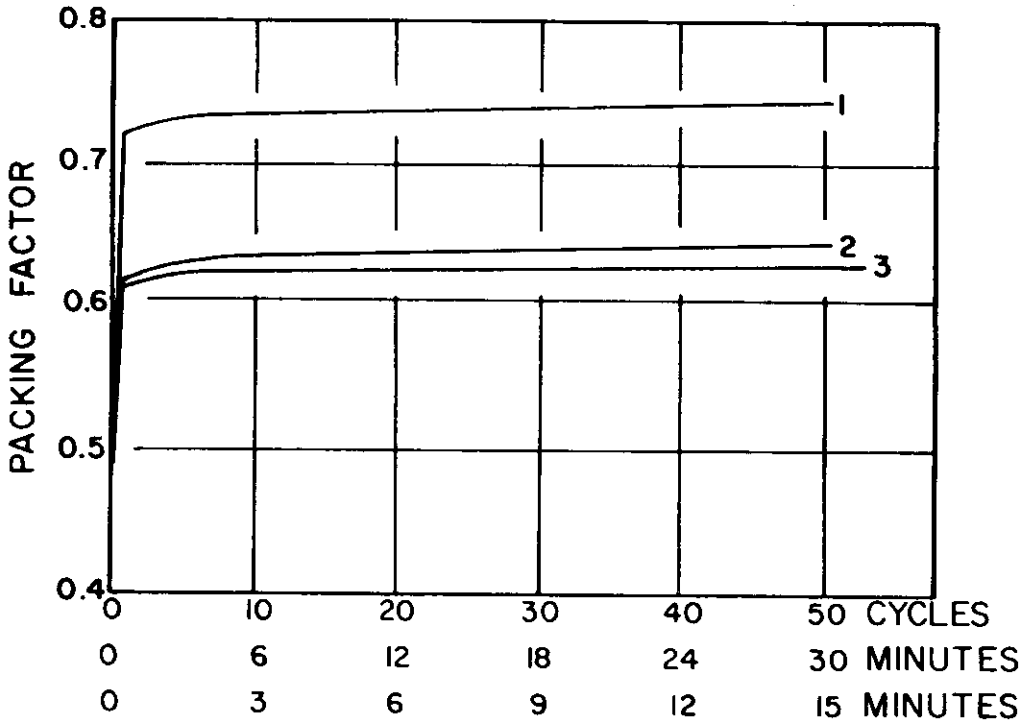


FIGURE 5 - EFFECT OF SAMPLE SIZE AND END RESTRAINT ON THE COMPRESSION OF 10 LAYERS OF NYLON RIBBON MIL-T-5608E, CLASS E, TYPE IV.



1. 250 PSI, 50 CYCLES AND 250 PSI, 30 MINUTES
2. 50 PSI, 50 CYCLES
3. 50 PSI, 15 MINUTES

FIGURE 6 - EFFECT OF CYCLING AND TIME UNDER PRESSURE ON THE COMPRESSION OF 10 LAYERS OF NYLON RIBBON MIL-T-5608E, CLASS E, TYPE IV.

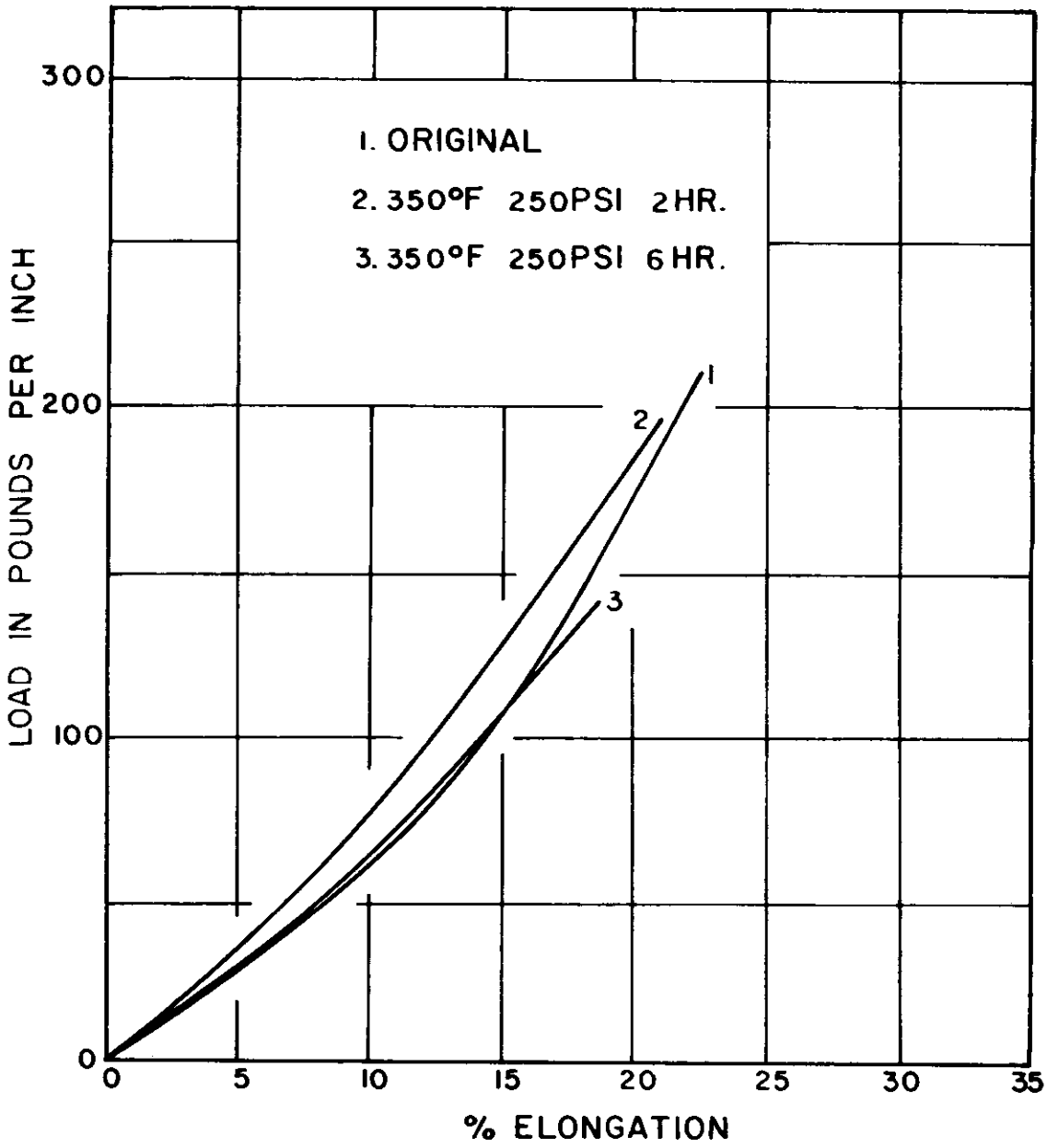


FIGURE 7 - LOAD-ELONGATION CURVES FOR NYLON FABRIC MIL-C-8021B, TYPE I.

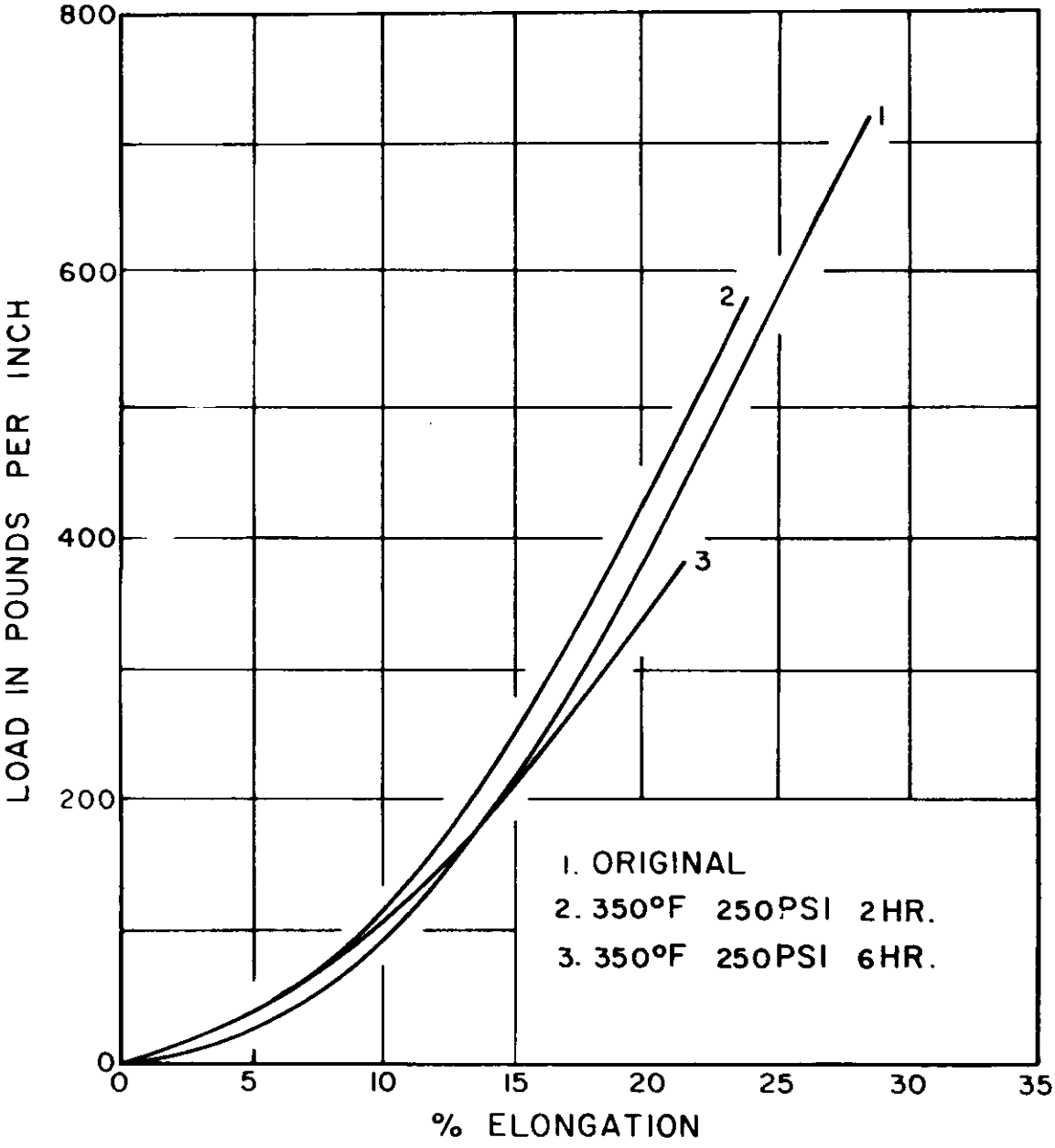


FIGURE 8 - LOAD-ELONGATION CURVES FOR NYLON FABRIC MIL-C-8021B, TYPE III.

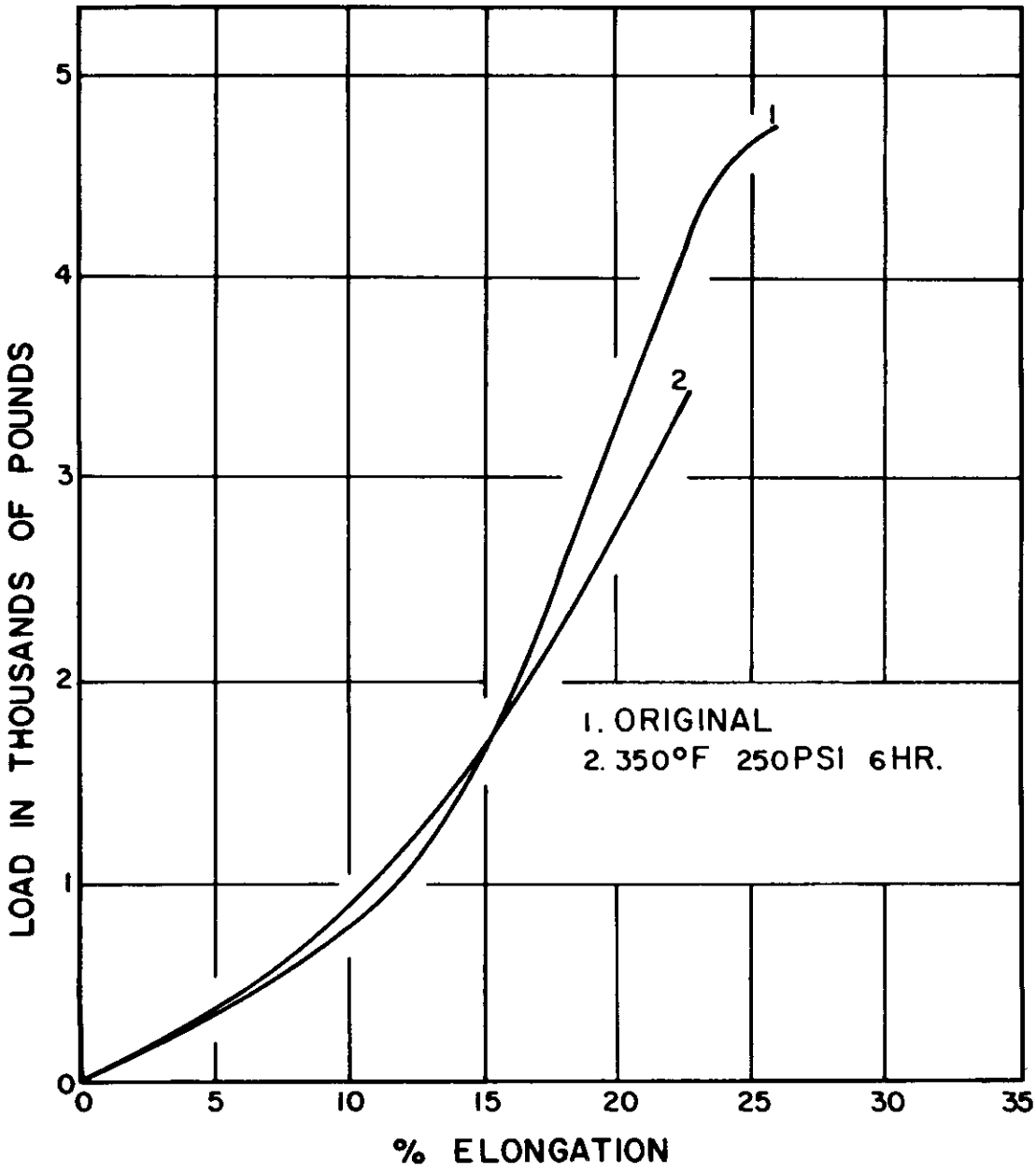


FIGURE 9 - LOAD-ELONGATION CURVES FOR NYLON RIBBON MIL-T-5608E, CLASS E, TYPE VI.

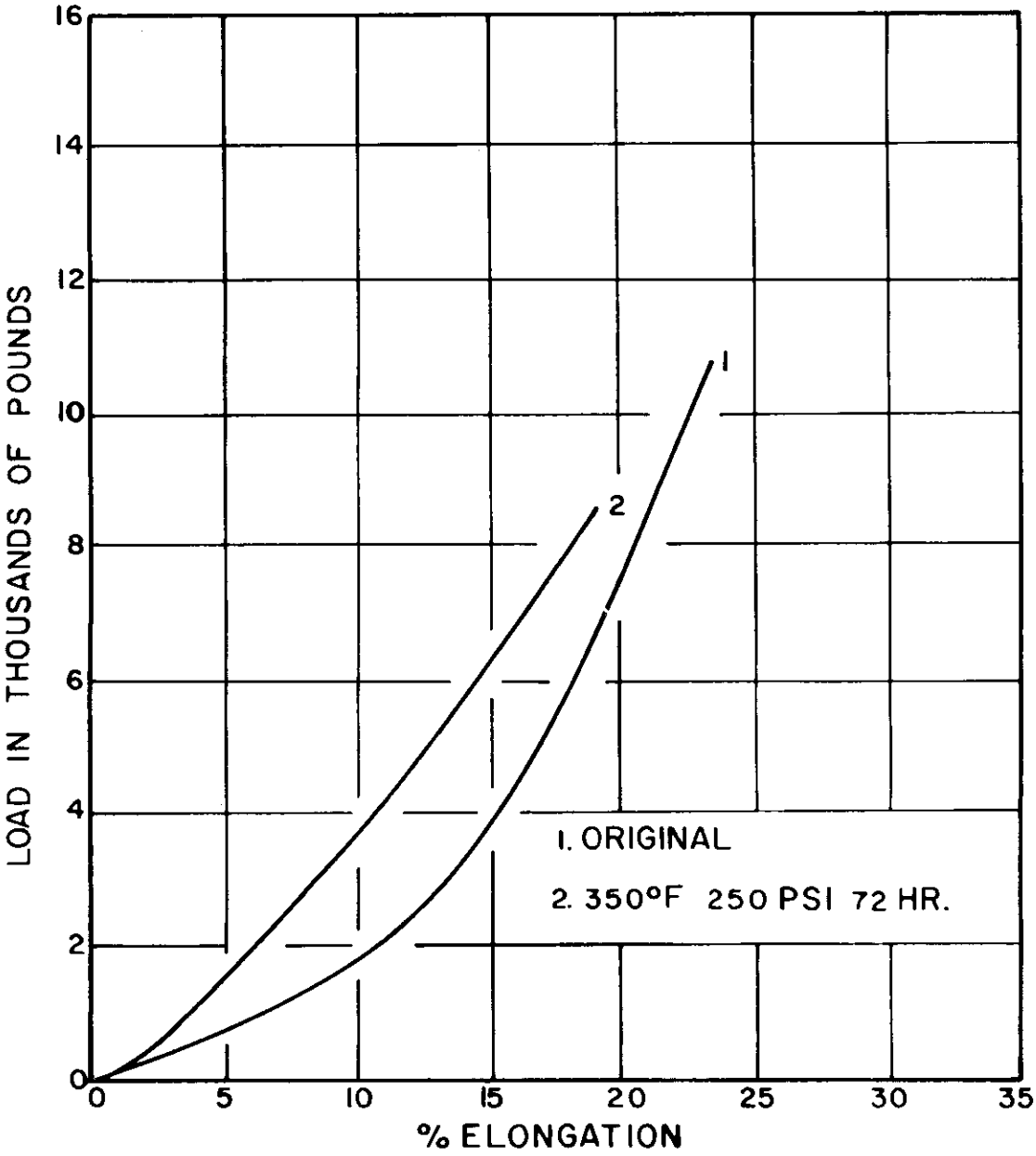


FIGURE 10-LOAD-ELONGATION CURVES FOR NYLON WEBBING MIL-W-4088C, TYPE XIX.

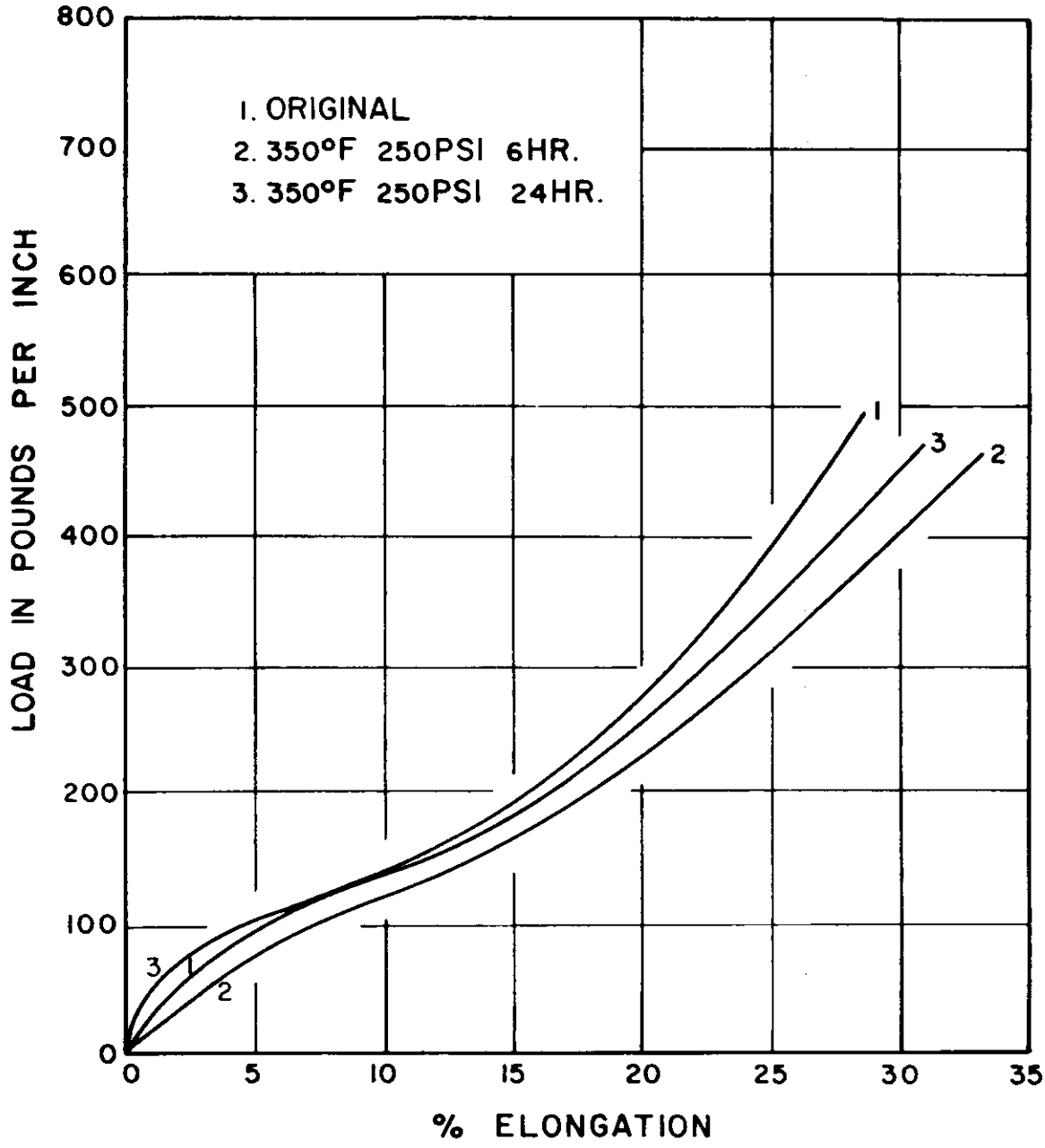


FIGURE II - LOAD-ELONGATION CURVES FOR DACRON FABRIC MIL-C-8021B, TYPE III.

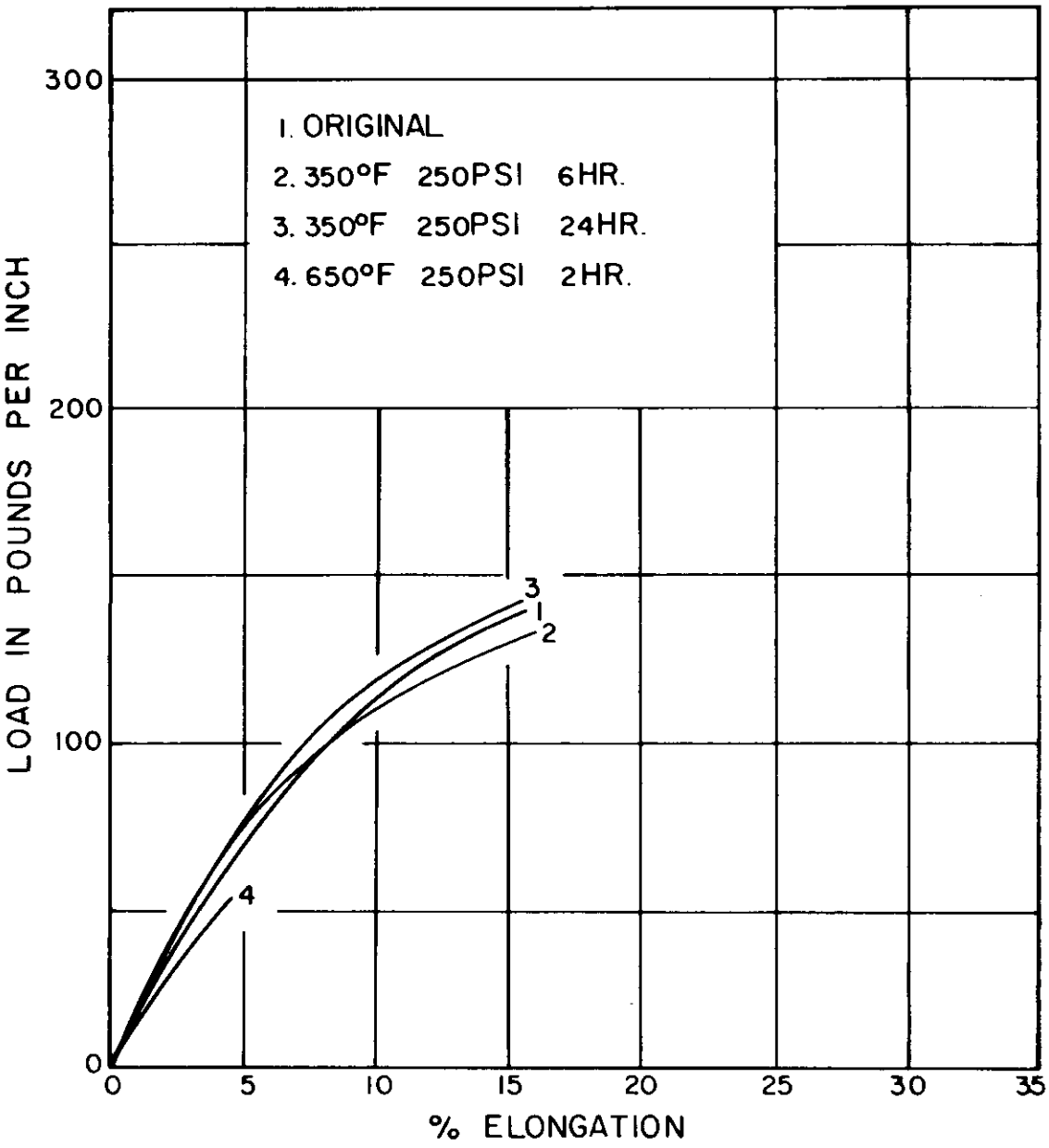


FIGURE 12 - LOAD-ELONGATION CURVES FOR FABRIC OF UNNAMED ORGANIC FIBER.

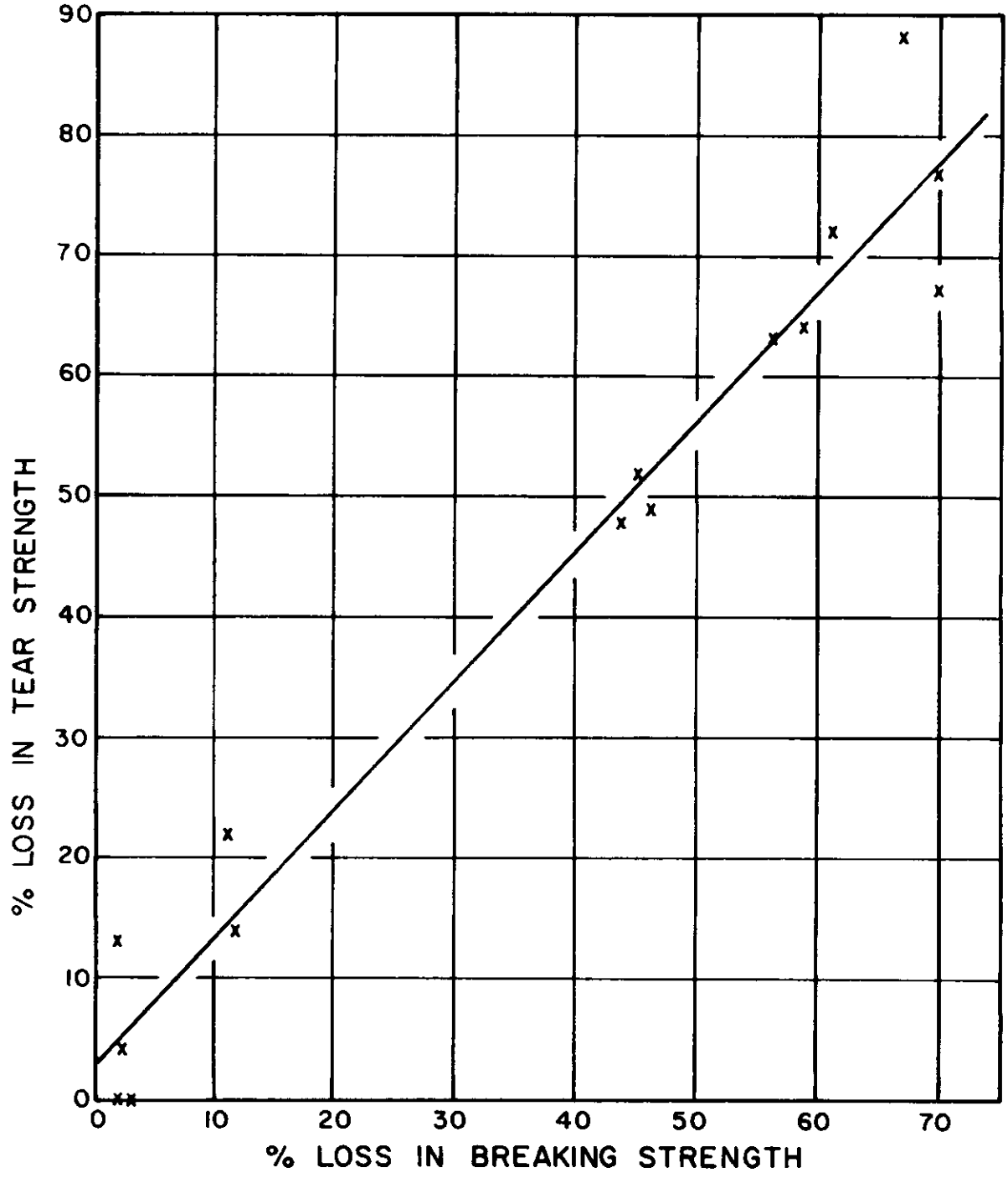


FIGURE 13- RELATION BETWEEN LOSS IN TEAR STRENGTH AND LOSS IN BREAKING STRENGTH.

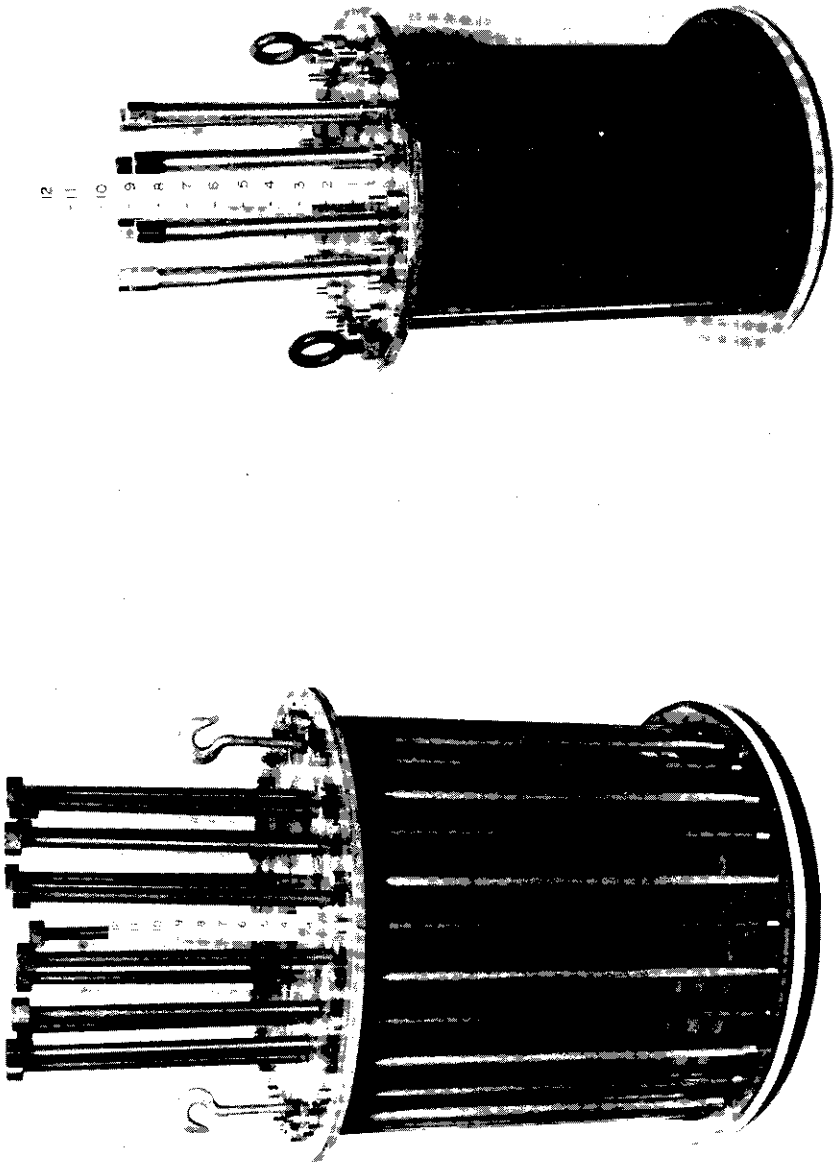


FIGURE 14 - CYLINDERS BEFORE PRESSURE PACKING.

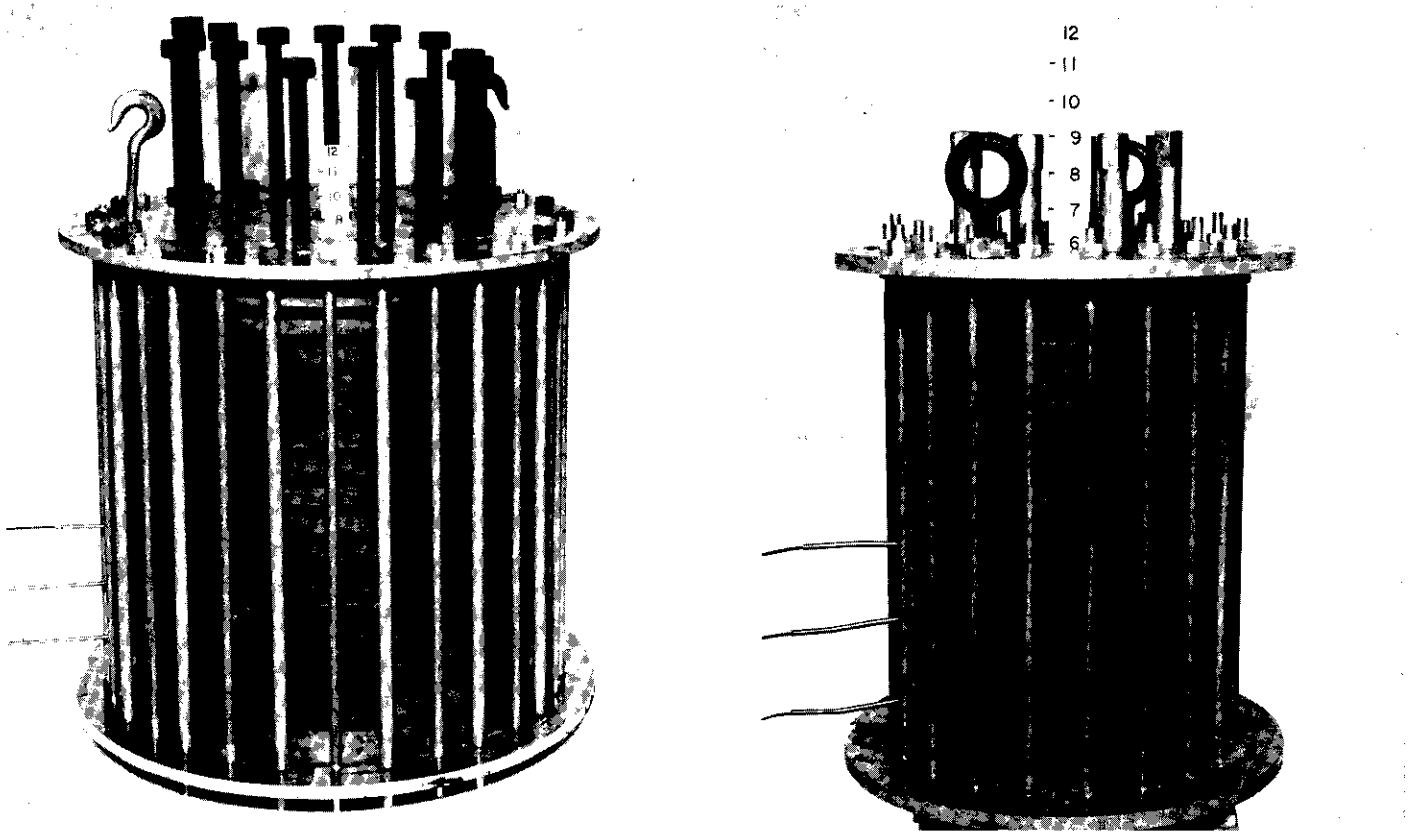


FIGURE 15 - CYLINDERS AFTER PRESSURE PACKING WITH THERMOCOUPLES INSERTED.

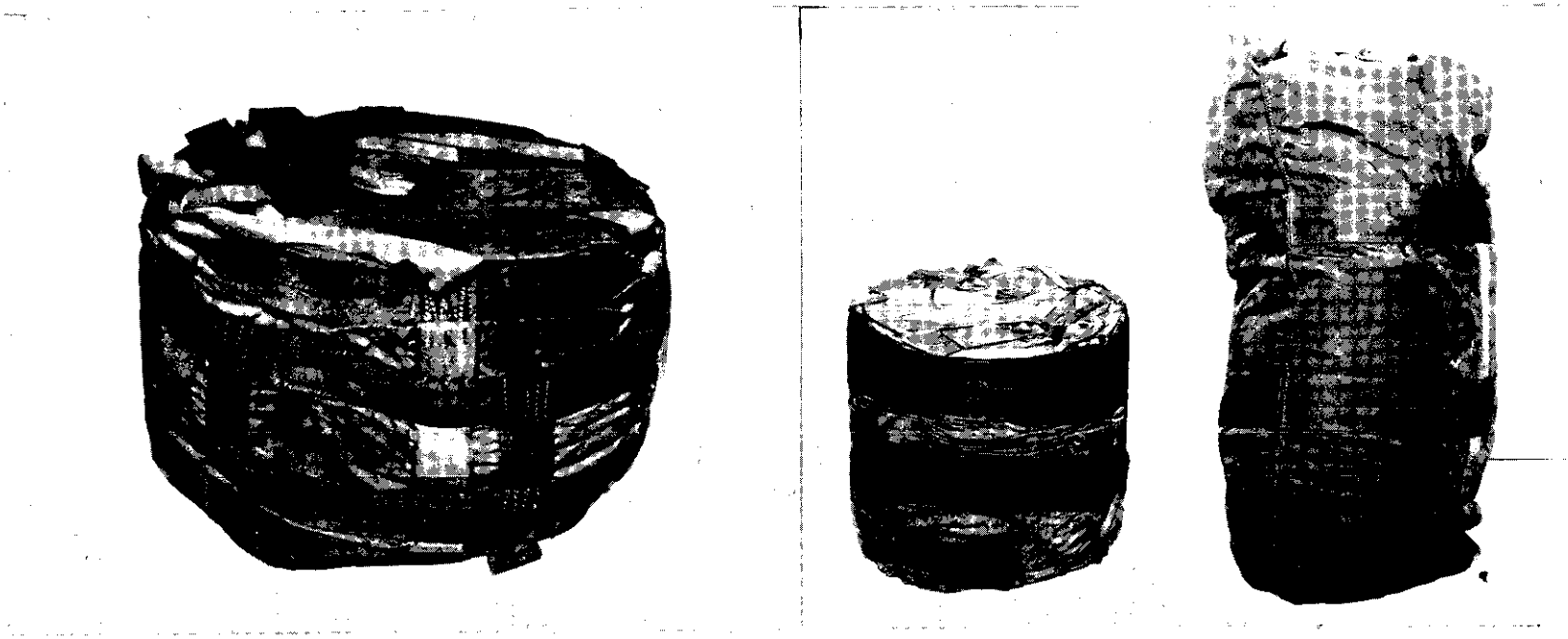


FIGURE 16 - PARACHUTES AFTER PRESSURE PACKING AND HEATING.

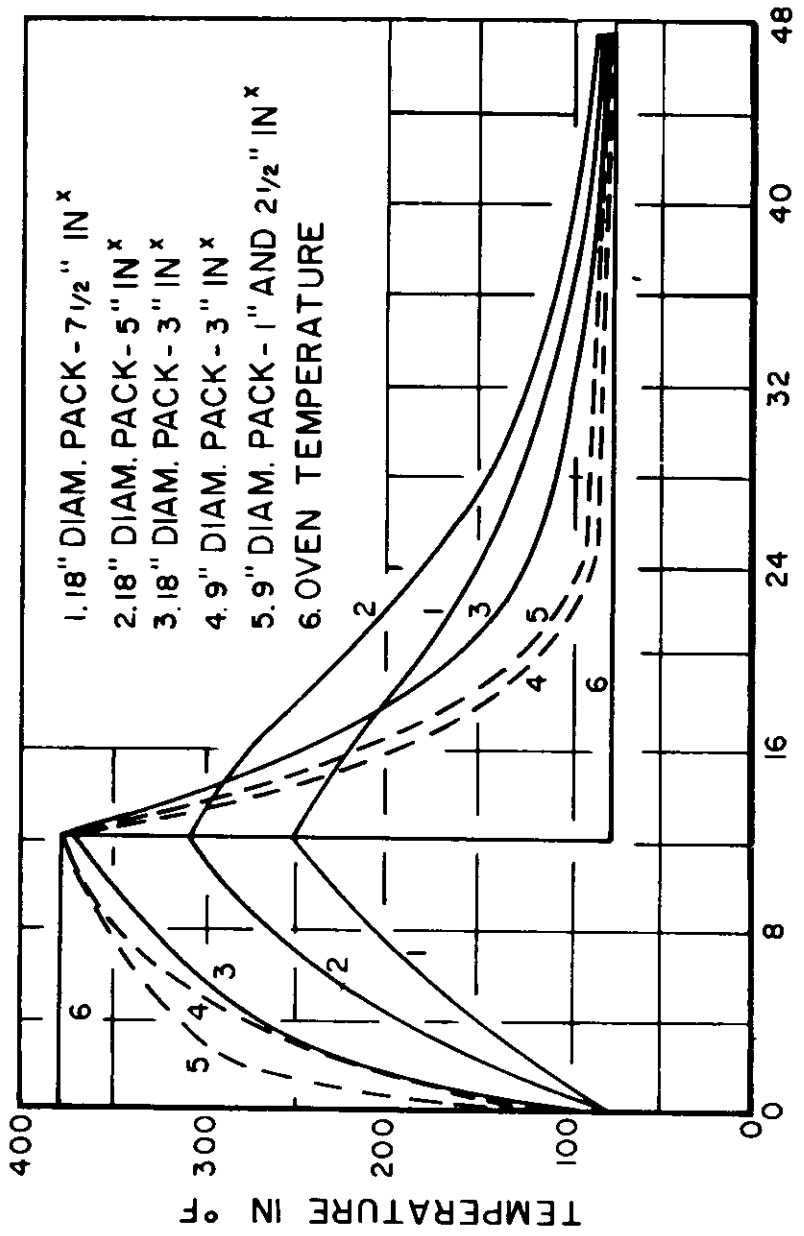
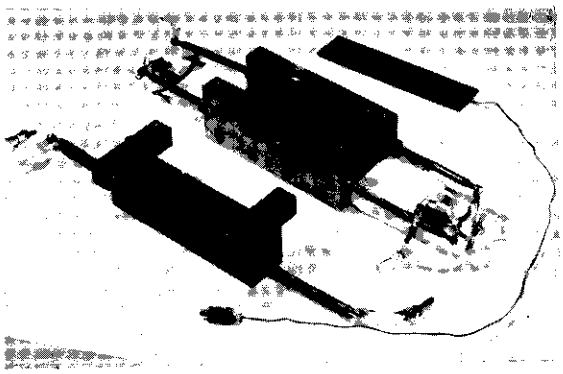
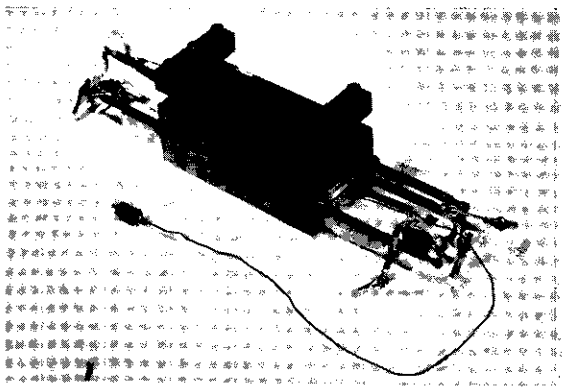


FIGURE 17 - HEATING AND COOLING RATES OF COMPRESSED PARACHUTE PACKS.

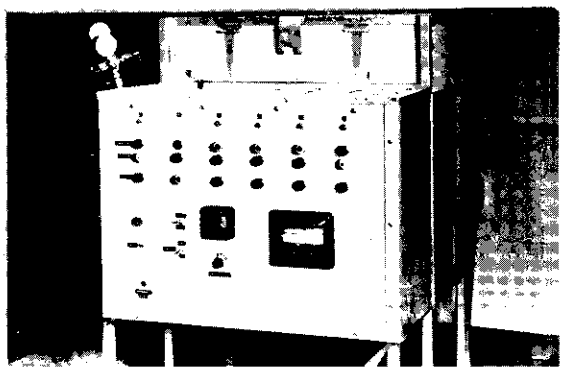
x DEPTH OF INSERTION OF THERMOCOUPLE.



COMPRESSION BOX AND THERMOCOUPLE PLATE DISASSEMBLED.



COMPRESSION BOX ASSEMBLED WITH FABRIC SPECIMENS.



INSULATED ENCLOSURE FOR CONTROLLING TEMPERATURES.

FIGURE 18 - HEATED COMPRESSION BOX AND INSULATED ENCLOSURE FOR CONTROLLING TEMPERATURES.

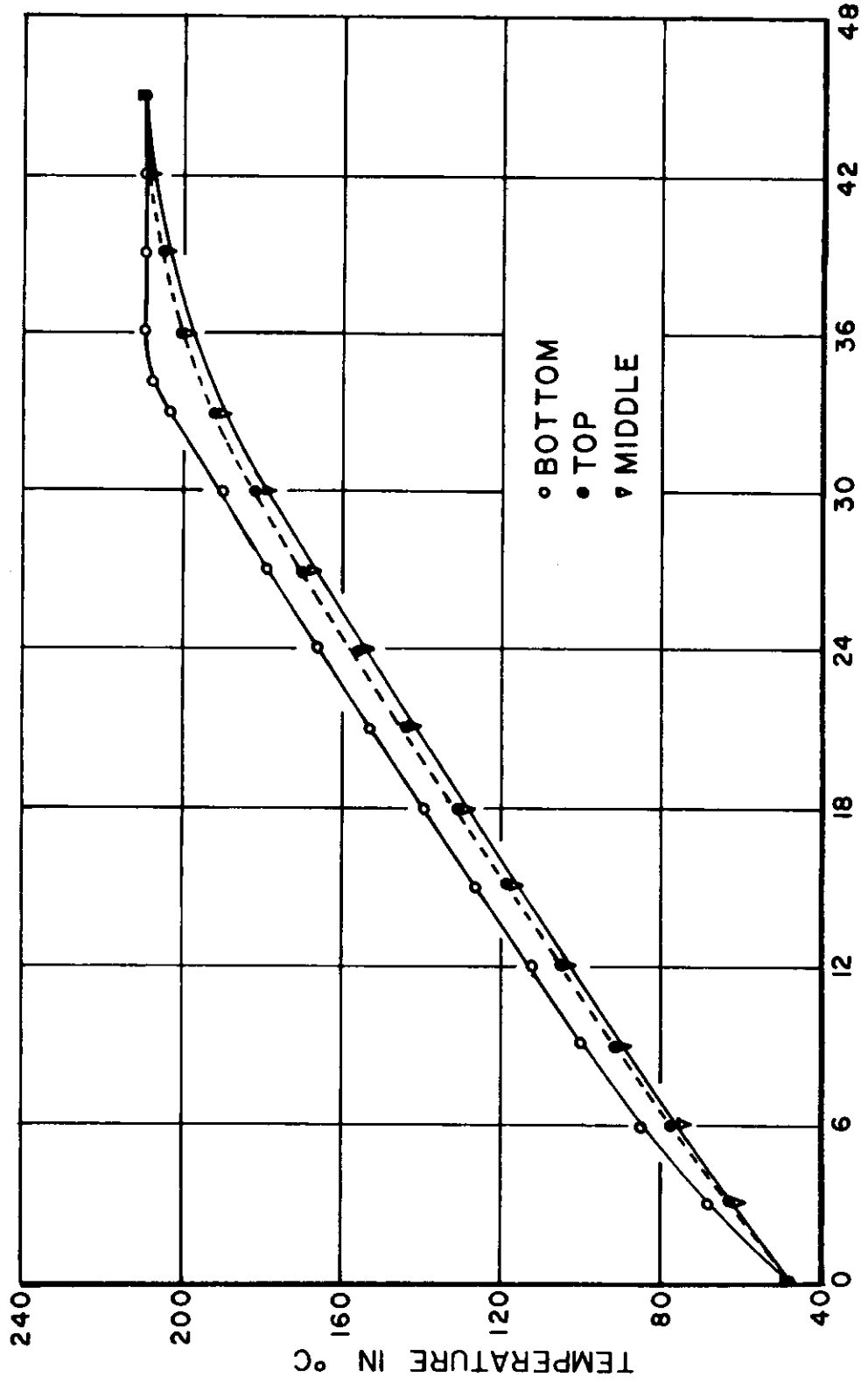


FIGURE 19 - RATE OF HEATING OF COMPRESSION CHAMBER CONTAINING 10 LAYERS OF NYLON RIBBON MIL-T-5608E, CLASS E, TYPE IV.

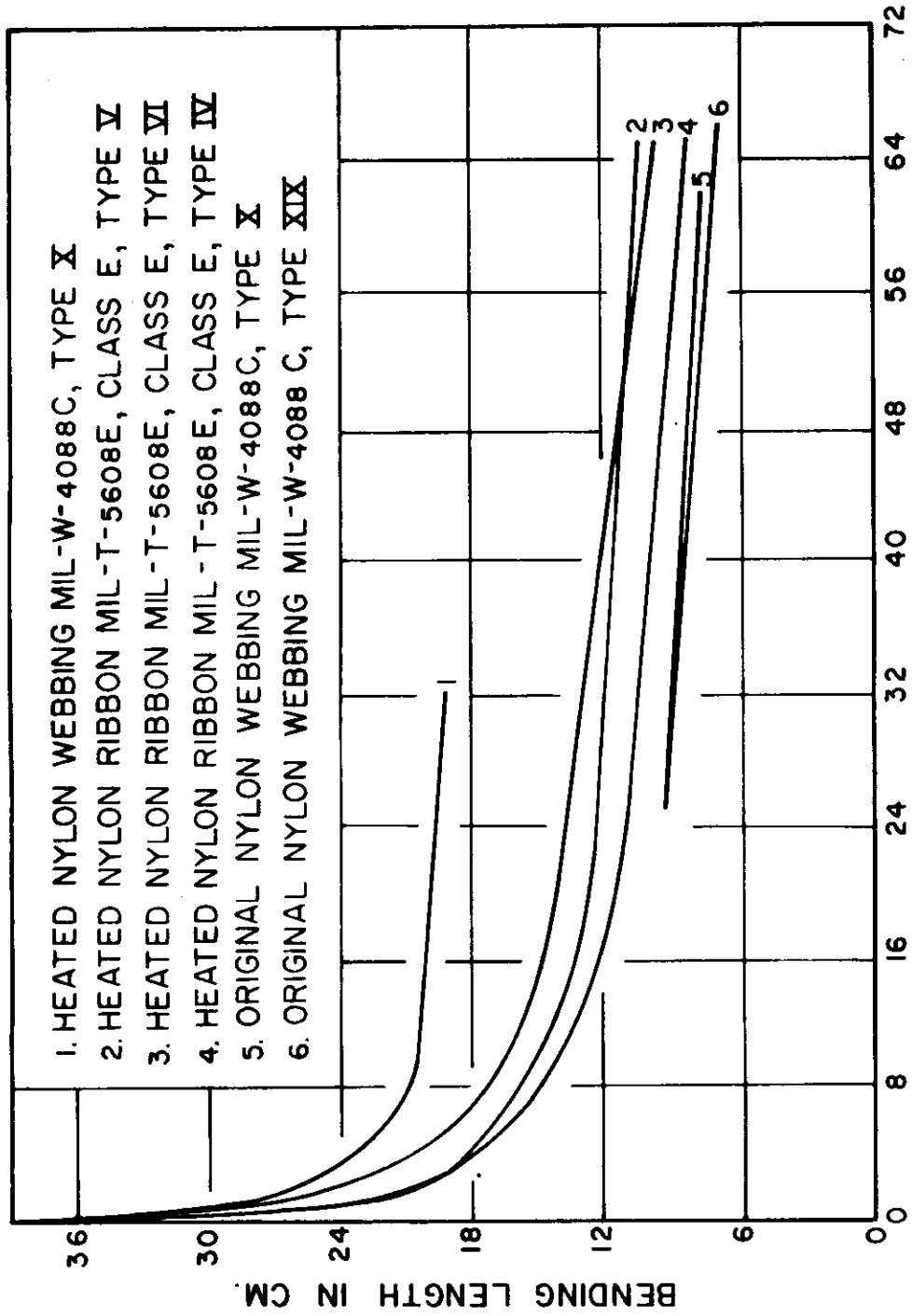


FIGURE 20-EFFECT OF SPECIMEN CURVATURE ON BENDING LENGTH.

TABLE 1

SPECIFICATIONS OF MATERIALS

Type of Material	Fiber	Specification No.	Nominal Weight	Nominal Warp Breaking Strength
Fabric	Nylon	MIL-C-7350C, Type II	3.5 oz/yd^2	135 lb/in
	Nylon	MIL-C-8021B, Type I	4.75 oz/yd^2	200 lb/in
	Nylon	MIL-C-8021B, Type II	7.0 oz/yd^2	300 lb/in
	Nylon	MIL-C-8021B, Type III	14.0 oz/yd^2	600 lb/in
	Dacron) limited	MIL-C-7350C, Type II	-	-
	Dacron) quantity	MIL-C-8021B, Type I	-	-
	Glass light	-	9.0 oz/yd^2	-
	Glass heavy	-	19.0 oz/yd^2	-
	Stainless Steel	-	(320 mesh, 3 mil)	-
	U.O.F.	-	3.7 oz/yd^2	-
Ribbon	Nylon	MIL-T-5608E, Class C, Type V	100 yd/lb	300 lb
	Nylon	MIL-T-5608E, Class E, Type II	30 yd/lb	1000 lb
	Nylon	MIL-T-5608E, Class E, Type III	22 yd/lb	1500 lb
	Nylon	MIL-T-5608E, Class E, Type IV	17 yd/lb	2000 lb
	Nylon	MIL-T-5608E, Class E, Type V	13 yd/lb	3000 lb
	Nylon	MIL-T-5608E, Class E, Type VI	11 yd/lb	4000 lb
	Dacron	Unknown	-	-
Webbing	Nylon	MIL-W-4088C, Type X	3.7 oz/yd	8700 lb
	Nylon	MIL-W-4088C, Type XIX	4.1 oz/yd	10,000 lb
	Nylon	MIL-W-4088C, Type XX	3.25 oz/yd	9000 lb

TABLE 2

BREAKING STRENGTH

Material	Original	Time & Pressures; Exposed at 350°F: 2 hr 250 psi	6 hr 0 psi	6 hr 50 psi	6 hr 250 psi	24 hr 250 psi	72 hr 250 psi
Fabric, Breaking Strength (lbs/in)							
Nylon MIL-C-7350C, Type II	158	141	89	80	87	-	-
Nylon MIL-C-8021B, Type I	210	197	69	62	92	-	-
Nylon MIL-C-8021B, Type II	335	294	101	131	137	-	-
Nylon MIL-C-8021B, Type III	720	550	384	395	377	-	-
Dacron MIL-C-7350C, Type II	146	-	143	141	141	-	-
Dacron MIL-C-8021B, Type I	190	-	192	194	195	-	-
Dacron MIL-C-8021B, Type III	493	498	463	458	469	469	-
U.O.F.	138	135	135	134	133	139	-
Glass light	387	-	430	390	430	-	-
heavy	664	-	628	680	634	-	-
Ribbon, Breaking Strength (lbs) full width							
Nylon MIL-T-5608E, Class C, Type V	288	246	196	202	218	-	-
Nylon MIL-T-5608E, Class E, Type II	1210	679	374	443	574	-	-
Nylon MIL-T-5608E. Class E, Type III	1760	1180	850	1090	1000	-	-
Nylon MIL-T-5608E, Class E, Type IV	2320	1830	660	740	840	-	-
Nylon MIL-T-5608E, Class E, Type V	3600	3130	2850	3020	3030	-	-
Nylon MIL-T-5608E, Class E, Type VI	4750	4070	3430	3520	3570	-	-
Dacron	1070	1060	970	1040	1030	-	-

TABLE 2

BREAKING STRENGTH (Cont'd)

Material	Original	Time & Pressures; Exposed at 350°F: 2 hr 250 psi	6 hr 0 psi	6 hr 50 psi	6 hr 250 psi	24 hr 250 psi	72 hr 250 psi
Webbing, Breaking Strength (lbs) full width							
Nylon MIL-W-4088C, Type X	9300	-	-	-	-	9150	8700
Nylon MIL-W-4088C, Type XIX	10,800	-	-	-	-	10,350	8570
Nylon MIL-W-4088C, Type XX	9960	8570	5130	5630	7980	2730	1670

TABLE 3

BREAKING ELONGATION

Material	Original (%)	Time & Pressures; Exposed at 350°F: 2 hr 250 psi (%)	6 hr 0 psi (%)	6 hr 50 psi (%)	6 hr 250 psi (%)	24 hr 250 psi (%)	72 hr 250 psi (%)
Fabric							
Nylon MIL-C-7350C, Type II	19	16	19	17	15	-	-
Nylon MIL-C-8021B, Type I	22	21	11	11	13	-	-
Nylon MIL-C-8021B, Type II	26	23	17	16	15	-	-
Nylon MIL-C-8021B, Type III	28	24	22	23	21	-	-
Dacron MIL-C-7350C, Type II	34	-	33	35	34	-	-
Dacron MIL-C-8021B, Type I	33	-	34	32	33	-	-
Dacron MIL-C-8021B, Type III	29	-	35	37	34	31	-
U.O.F.	16	14	17	16	16	15	-
Glass light	4	-	3	-	3	-	-
Glass heavy	3	-	-	3	3	-	-
Ribbon							
Nylon MIL-T-5608E, Class C, Type V	17	12	18	14	14	-	-
Nylon MIL-T-5608E, Class E, Type II	19	13	15	12	13	-	-
Nylon MIL-T-5608E, Class E, Type III	21	20	19	17	16	-	-
Nylon MIL-T-5608E, Class E, Type IV	23	21	19	16	14	-	-
Nylon MIL-T-5608E, Class E, Type V	25	24	28	25	-	-	-
Nylon MIL-T-5608E, Class E, Type VI	28	-	27	-	22	-	-
Dacron	-	36	37	40	41	-	-
Webbing							
Nylon MIL-W-4088C, Type X	31	-	-	-	-	-	30
Nylon MIL-W-4088C, Type XIX	23	-	-	-	-	-	19
Nylon MIL-W-4088C, Type XX	22	-	22	-	21	8	-

TABLE 4

ENERGY TO RUPTURE

Material	Original	Exposed at 350°F. and Pressures of 250 psi for 2 hr	6 hr	24 hr	72 hr
	Inch-pounds per inch of specimen width				
Fabric					
Nylon MIL-C-7350C, Type II	11	8	6	-	-
Nylon MIL-C-8021B, Type I	18	18	5	-	-
Nylon MIL-C-8021B, Type II	29	27	8	-	-
Nylon MIL-C-8021B, Type III	73	48	30	-	-
Dacron MIL-C-7350C, Type II	21	-	24	-	-
Dacron MIL-C-8021B, Type I	25	-	29	-	-
Dacron MIL-C-8021B, Type III	62	-	-	-	-
U.O.F.	13	11	14	14	-
Glass light	4	-	3	-	-
Glass heavy	11	-	9	-	-
Ribbon					
Nylon MIL-T-5608E, Class C, Type V	20	13	14	-	-
Nylon MIL-T-5608E, Class E, Type II	91	36	28	-	-
Nylon MIL-T-5608E, Class E, Type III	140	120	68	-	-
Nylon MIL-T-5608E, Class E, Type IV	200	170	49	-	-
Nylon MIL-T-5608E, Class E, Type V	365	270	-	-	-
Nylon MIL-T-5608E, Class E, Type VI	440	-	280	-	-
Dacron	-	170	200	-	-
Webbing					
Nylon MIL-W-4088C, Type X	890	-	-	-	1070
Nylon MIL-W-4088C, Type XIX	930	-	-	-	720
Nylon MIL-W-4088C, Type XX	975	820	620	82	-

TABLE 5

PERCENT LOSS IN BREAKING STRENGTH

Material	Time & Pressures: exposed at 350°F					
	2 hr	6 hr			24 hr	72 hr
	250 psi (%)	0 psi (%)	50 psi (%)	250 psi (%)	250 psi (%)	250 psi (%)
Fabric						
Nylon MIL-C-7350C, Type II	11	44	49	45	-	-
Nylon MIL-C-8021B, Type I	6	67	70	56	-	-
Nylon MIL-C-8021B, Type II	12	70	61	59	-	-
Nylon MIL-C-8021B, Type III	19	47	45	48	-	-
Dacron MIL-C-7350C, Type II	-	2	3	3	-	-
Dacron MIL-C-8021B, Type I	-	0	0	0	-	-
Dacron MIL-C-8021B, Type III	0	6	7	5	5	-
U.O.F.	2	2	2	3	-	-
Glass light	-	-11*	0	-11*	-	-
Glass heavy	-	5	0	5	-	-
Ribbon						
Nylon MIL-T-5608E, Class C, Type V	15	32	30	24	-	-
Nylon MIL-T-5608E, Class E, Type II	44	69	63	53	-	-
Nylon MIL-T-5608E, Class E, Type III	33	52	38	43	-	-
Nylon MIL-T-5608E, Class E, Type IV	49	72	68	64	-	-
Nylon MIL-T-5608E, Class E, Type V	13	21	16	16	-	-
Nylon MIL-T-5608E, Class E, Type VI	14	28	26	25	-	-
Dacron	1	9	3	4	-	-
Webbing						
Nylon MIL-W-4088C, Type X	-	-	-	-	1	6
Nylon MIL-W-4088C, Type XIX	-	-	-	-	2	19
Nylon MIL-W-4088C, Type XX	14	49	44	20	73	83

* A minus sign indicates an increase in strength.

TABLE 6

SINGLE WARP YARN BREAKING STRENGTH

Material	Control (lb)	350°F (hung in oven) 2 hr (lb)	6 hr (lb)	% Loss 2 hr (%)	6 hr (%)
Fabric					
Nylon MIL-C-7350C, Type II	3.3	1.3	1.1	61	67
Nylon MIL-C-8021B, Type I	3.2	1.0	1.1	69	66
Nylon MIL-C-8021B, Type II	6.1	2.0	2.1	67	66
Nylon MIL-C-8021B, Type III	16.3	8.1	6.1	51	63
Dacron MIL-C-7350C, Type II	2.9	2.9	2.8	0	3
Dacron MIL-C-8021B, Type I	2.7	2.5	2.4	7	11
Dacron MIL-C-8021B, Type III	14.1	15.5	15.3	-10*	-9*
U.O.F.	2.5	2.4	2.5	4	0
Glass light	6.3	7.2	8.2	6	-14
Glass heavy	14.5	13.6	16.6	-14	-30
Ribbon					
Nylon MIL-T-5608E, Class C, Type V	0.39	0.34	0.28	13	28
Nylon MIL-T-5608E, Class E, Type II	2.6	1.2	0.88	54	66
Nylon MIL-T-5608E, Class E, Type III	5.4	2.4	1.8	56	67
Nylon MIL-T-5608E, Class E, Type IV	5.8	2.5	1.8	57	69
Nylon MIL-T-5608E, Class E, Type V	13.7	12.8	12.1	7	12
Nylon MIL-T-5608E, Class E, Type VI	13.0	12.4	11.5	5	12
Dacron	3.0	3.0	3.0	0	0
Webbing					
Nylon MIL-W-4088C, Type X	37.9	42.1	39.4	-11	-4
Nylon MIL-W-4088C, Type XIX	43.3	42.3	40.2	2	7
Nylon MIL-W-4088C, Type XX	63.8	26.4	21.4	59	66

*A minus sign indicates an increase in strength.

TABLE 7

EFFECT OF A STEAM ATMOSPHERE ON BREAKING STRENGTH

Material	Original (lb)	350°F, 250 psi Pressure, Normal Atmosphere, 2 hr (lb)	350°F, 250 psi Pressure, Normal Atmosphere, 6 hr (lb)	350°F, 250 psi Pressure, Immersed in Steam, 2 hr (lb)	350°F, 250 psi Pressure, Immersed in Steam, 6 hr (lb)
Nylon Fabric MIL-C-8021B, Type II	335	294	137	327	215
Nylon Ribbon MIL-T-5608E, Class E, Type IV	2317	2200	840	2123	1381

TABLE 8

EFFECT OF A NITROGEN ATMOSPHERE ON BREAKING STRENGTH AND BREAKING ELONGATION

Material	Breaking Strength, Original (lb/in)	Breaking Strength, 350°F, 6 hr., 250 psi Pressure, Normal Atmosphere (lb/in)	Breaking Strength, 350°F, 6 hr., 250 psi Pressure, Nitrogen Atmosphere (lb/in)	Breaking Elongation, Original (%)	Breaking Elongation, 350°F, 6 hr., 250 psi Pressure, Normal Atmosphere (%)	Breaking Elongation, 350°F, 6 hr., 250 psi Pressure, Nitrogen Atmosphere (%)
Nylon Fabric MIL-C-7350C, Type II	158	87 55%	103 65%	19	15	15
Nylon Fabric MIL-C-8021B, Type II	335	137 41%	262 78%	26	15	21
Nylon Ribbon, MIL-T-5608E,* Class E, Type II	1210	574 47.5%	750 62%	19	13	15
Nylon Ribbon, MIL-T-5608E,* Class E, Type V	3600	3030 84%	3270 91%	25	22	23
Nylon Webbing, MIL-W-4088C,* Type XX	9960	7980 80%	9150 92%	22	21	25

* lbs - Full Width

TABLE 9

EFFECT OF FOLDING THE SPECIMEN ON BREAKING STRENGTH

Exposed at 350°F

Material	Original	Flat Specimen 2 hr 250 psi	Flat Specimen 6 hr 50 psi	Flat Specimen 6 hr 250 psi	Folded Specimen 2 hr 250 psi	Folded Specimen 6 hr 50 psi	Folded Specimen 6 hr 250 psi
Fabric; Breaking Strength (lbs/in)							
Nylon MIL-C-7350C, Type II	158	141	-	-	140	-	-
Nylon MIL-C-8021B, Type I	210	197	62	92	197	71	125
Nylon MIL-C-8021B, Type II	335	294	131	137	288	115	89
Nylon MIL-C-8021B, Type III	493	498	-	-	502	-	-
U.O.F.	138	135	-	-	139	-	-
Glass light	387	-	-	295)*	-	-	290)*
Glass heavy	664	-	-	454)*	-		380)*
Ribbon, Breaking Strength (lbs) full width							
MIL-T-5608E, Class C, Type V	304	246	202	218	258	129	127
MIL-T-5608E, Class E, Type IV	2320	-	743	840	-	655	835

* 500°F

TABLE 10

TEAR STRENGTH

Fabric	Original (lb)	Time and Pressure: exposed at 350°F 2 hr 250 psi (lb)	6 hr 0 psi (lb)	6 hr 50 psi (lb)	6 hr 250 psi (lb)	24 hr 250 psi (lb)
Nylon MIL-C-7350C, Type II	27	21	14	15	13	-
Nylon MIL-C-8021B, Type I	27	25	6	9	10	-
Nylon MIL-C-8021B, Type II	36	31	7	10	13	-
Nylon MIL-C-8021B, Type III	-	-	-	-	-	-
Dacron MIL-C-7350C, Type II	24	-	24	23	23	-
Dacron MIL-C-8021B, Type I	27	-	27	27	27	-
Dacron MIL-C-8021B, Type III	-	-	-	-	-	-
U.O.F.	23	22	20	23	25	21

TABLE 11

PERCENT LOSS IN TEAR STRENGTH

Fabric	Time and Pressure; exposed at 350°F 2 hr 250 psi (%)	6 hr 0 psi (%)	6 hr 50 psi (%)	6 hr 250 psi (%)
Nylon MIL-C-7350C, Type II	22	48	46	52
Nylon MIL-C-8021B, Type I	-	88	67	63
Nylon MIL-C-8021B, Type II	14	77	72	64
Nylon MIL-C-8021B, Type III	-	-	-	-
Dacron MIL-C-7350C, Type II	-	0	4	4
Dacron MIL-C-8021B, Type I	-	0	0	0
Dacron MIL-C-8021B, Type III	-	-	-	-
U.O.F.	4	13	0	0

TABLE 12

SEAM STRENGTH

Material	Original (lbs)	350°F 6 hr, 250 psi (lbs)	
Fabric			
Nylon MIL-C-7350C, Type II	236	114	48.3%
Nylon MIL-C-8021B, Type I	266	140	52.6
Nylon MIL-C-8021B, Type II	334	149	44.6
Nylon MIL-C-8021B, Type III	878	732	83.4
Dacron MIL-C-8021B, Type III	738	576	78.1
Ribbon			
Nylon MIL-T-5608E, Class C, Type V	248	110	44.4%
Nylon MIL-T-5608E, Class E, Type II	1020	341	33.4
Nylon MIL-T-5608E, Class E, Type III	1056	455	43.1
Nylon MIL-T-5608E, Class E, Type IV	1073	414	38.5
Nylon MIL-T-5608E, Class E, Type V	1150	644	56 0
Nylon MIL-T-5608E, Class E, Type VI	1140	652	57.2
Dacron	620	570	92.0
Webbing			
Nylon MIL-W-4088C, Type X	6600	6750	
Nylon MIL-W-4088C, Type XIX	8040	5570	
Nylon MIL-W-4088C, Type XX	6530	5270	

TABLE 13

INTER-LAYER STICKING

Material	Withdrawal Force			
	Time and Pressure: exposed at 350°F			
	2 hr	6 hr		
	250 psi (lbs)	0 psi (lbs)	50 psi (lbs)	250 psi (lbs)
Nylon MIL-T-5608E, Class C, Type V	-	5	30	58
Nylon MIL-T-5608E, Class E, Type II	63	5	33	50
Nylon MIL-T-5608E, Class E, Type III	19	0	16	20
Nylon MIL-T-5608E, Class E, Type IV	35	0	9	26
Nylon MIL-T-5608E, Class E, Type V	6	0	3	4
Nylon MIL-T-5608E, Class E, Type VI	4	0	0	0

TABLE 14

FLEXURAL RIGIDITY

Material	Original (gm cm²)	Time and Pressures; exposed at 350°F: 2 hr 250 psi	6 hr 0 psi	6 hr 50 psi (gm cm²)	6 hr 250 psi (gm cm²)	24 hr 250 psi	72 hr 250 psi	450°F 0 hr 0 psi	450°F 0 hr 50 psi (gm cm²)	450°F 0 hr 250 psi	Nitrogen 350°F 6 hr 250 psi (gm cm²)
Fabric											
Nylon MIL-C-7350C, Type II	0.16	0.90	0.27	0.49	0.58	-	-	-	0.72	-	1.2
Nylon MIL-C-8021B, Type I	0.19	0.45	0.50	0.67	0.79	-	-	3.0	1.1	2.4	-
Nylon MIL-C-8021B, Type II	1.1	2.0	2.0	3.2	2.9	-	-	1.2	9.5	15.7	2.7
Nylon MIL-C-8021B, Type III	1.8	29.	30.	42.	48.	-	-	54.	44.	37.	-
Dacron MIL-C-7350C, Type II	0.20	-	0.28	0.38	0.29	-	-	-	-	-	-
Dacron MIL-C-8021B, Type I	0.27	-	0.68	-	1.2	-	-	-	-	-	-
Dacron MIL-C-8021B, Type III	0.96	4.5	4.1	6.2	3.9	8.4	-	57.	57.	68.	-
U.O.F.	0.34	0.42	0.34	0.30	0.34	0.79	-	0.51	0.32	0.68	-
Glass light	0.41	0.68	1.4	0.87	1.2	-	-	-	-	-	-
Glass heavy	1.2	1.3	2.8	1.3	2.8	-	-	-	-	-	-
Ribbon											
Nylon MIL-T-5608E, Class C, Type V	1.6	2.5	1.0	1.7	3.0	-	-	3.2	5.9	8.1	-
Nylon MIL-T-5608E, Class E, Type II	5.3	36.	9.2	6.3	12.	-	-	17.	13.	93.	42.
Nylon MIL-T-5608E, Class E, Type III	6.2	25.	16.	26.	29.	-	-	35.	55.	98.	-

TABLE 14

FLEXURAL RIGIDITY (Cont'd)

Material	Original (gm cm²)	Time and Pressures: exposed at 350°F — 2 hr 250 psi	6 hr 0 psi	6 hr 50 psi (gm cm²)	6 hr 250 psi	24 hr 250 psi	72 hr 250 psi	450°F 0 hr 0 psi	450°F 0 hr 50 psi (gm cm²)	450°F 0 hr 250 psi	Nitrogen 350°F 6 hr 250 psi (gm cm²)
Ribbon (cont'd)											
Nylon MIL-T-5608E, Class E, Type IV	12.	62.	58.	85.	91.	-	-	-	48.	-	-
Nylon MIL-T-5608E, Class E, Type V	12.	53.	24.	58.	45.	-	-	69.	460.	1900.	31.
Nylon MIL-T-5608E, Class E, Type VI	18.	91.	27.	52.	96.	-	-	145.	330.	400.	-
Dacron	1.0	1.1	1.7	4.0	11.	-	-	13.	-	13.	-
Webbing											
Nylon MIL-W-4088C, Type X	200.	-	1370.	1030.	-	380.	390.	1960.	2850.	240.	-
Nylon MIL-W-4088C, Type XIX	190.	1200.	560.	940.	1060.	230.	210.	-	-	-	-
Nylon MIL-W-4088C, Type XX	260.	4480.	3350.	4480.	7630.	-	1930.	4550.	-	9220.	8120.

TABLE 15

MISCELLANEOUS EXPOSURES

Material	Exposure Condition °F	Hr	psi Pressure	Breaking Strength Lbs/in	% Loss	Breaking Elongation (%)	Energy To Rupture In-lb per In. Width	Flexural Rigidity (gm cm^2)
Dacron, MIL-C-8021B, Type III	400	6	250	460	7	30	68	8.6
U.O.F.	500	2	250	142	0	13	-	2.4
	600	2	250	118	16	10	-	9.
	650	2	250	52	63	4	-	14.
	700	2	250	43	69	4	-	17.
Glass light	500	6	250	295	24	3	3	2.5
Glass heavy	500	6	250	454	32	3	5	9.
Stainless Steel (original strength 57 lb.)	1000	6	250	56	0	-	-	-
	1000	72	250	50	11	-	-	-