THE UNIVERSITY OF MICHIGAN

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Department of Mechanical Engineering

Tire and Suspension Systems Research Group

Technical Report No. 1

THE ELASTIC CHARACTERISTICS OF TEXTILE CORDS IN COMPRESSION

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I. STATEMENT

Prior to the experiments carried out in connection with this report, no published information was available on the role of textile cords in compression. This role is of particular interest in the general problem of the interaction of cords in rubber since it is possible that in many cord-rubber structures the loads are such as to force some cords into compression. From theoretical considerations one might predict that, if the cord were similar to a thin elastic wire, it might be expected to buckle under very small loads and to carry essentially no compressive force. The physical makeup of a textile cord is, of course, considerably different from that of a thin elastic wire and therefore it was felt that this compressive load-carrying ability could not be understood through theoretical considerations alone, but would have to be determined by experiment.

The shape of the cord-rubber combination modulus in the vicinity of the origin of its stress-strain curve is also of interest. If the tensile modulus of cord-rubber combinations is maintained linearly to within a short distance of the origin, and if similarly the compressive modulus is also maintained linearly to within a short distance of the origin, one can approximate the physical characteristics of cord-rubber combinations by using only two separate moduli, one for tension and one for compression. On the other hand, if the shape of the stress-strain curve is considerably more complicated than this, it is necessary to resort to nonlinear functional descriptions for it.

An obvious complicating factor in a study of the load-carrying ability of textile cords in compression is the role of the adhesive dip on this load-carrying ability. It was felt that to account for this, it would not be possible to test cords alone, even if a way could be found to load them in compression without buckling. It is important to reproduce all the conditions present in the environment in which the cords are used, and hence it was felt desirable to utilize the cords actually imbedded in rubber for any tests to be performed.

II. SUMMARY

Rayon and nylon textile cords imbedded in rubber are found to exhibit a compression modulus different from zero and different from that exhibited when the cords are loaded in tension. The experimental evidence obtained here indicates that this compressive modulus is much smaller than the modulus associated with tensile loads. In addition, experiment indicates that to a first approximation one may consider that the embedded textile cord exhibits a linear stress-strain curve in tension yielding a tensile modulus, and also exhibits a linear stress-strain curve in compression exhibiting a different compression modulus, so long as the cord strains are kept small, say one or two percent.

III. EXPERIMENTAL RESULTS

Figures 1 and 2 show stress-strain curves of rayon and nylon cord-rubber specimens taken under continuous loading conditions starting from the origin. The direction of loading was first into compression followed by a reversal into tension. Both curves illustrate the conclusions stated in the summary, namely, that the tensile and compressive portions of the stress-strain curve, omitting a region very close to the origin, are basically straight lines of different slope. This was the question which these experiments were designed to answer and therefore these curves represent the desired information. The detailed description of the specimen geometry and the methods of testing are given in the succeeding sections of this report.

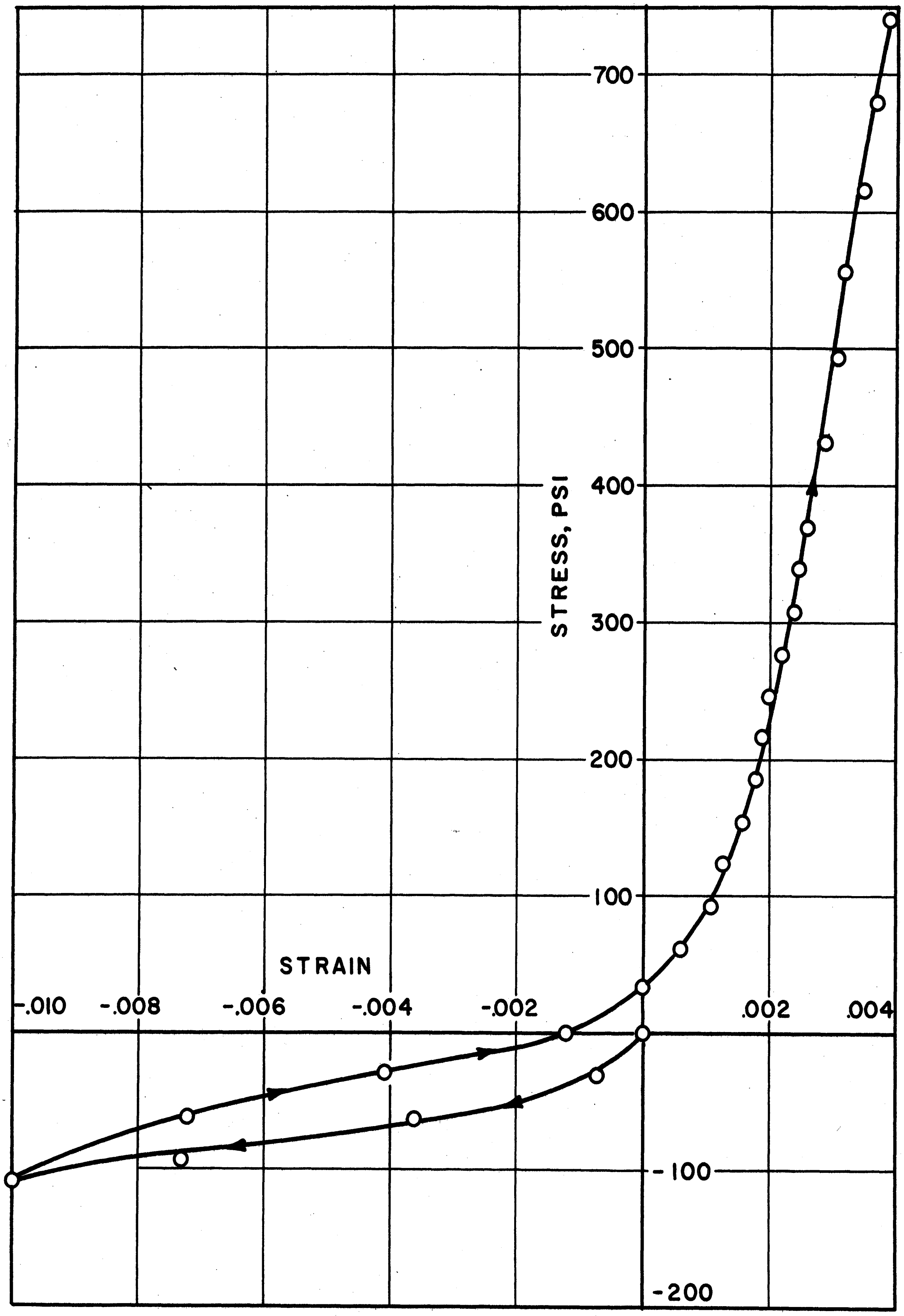

Fig. 1. Stress-strain curve for rayon cord specimen.

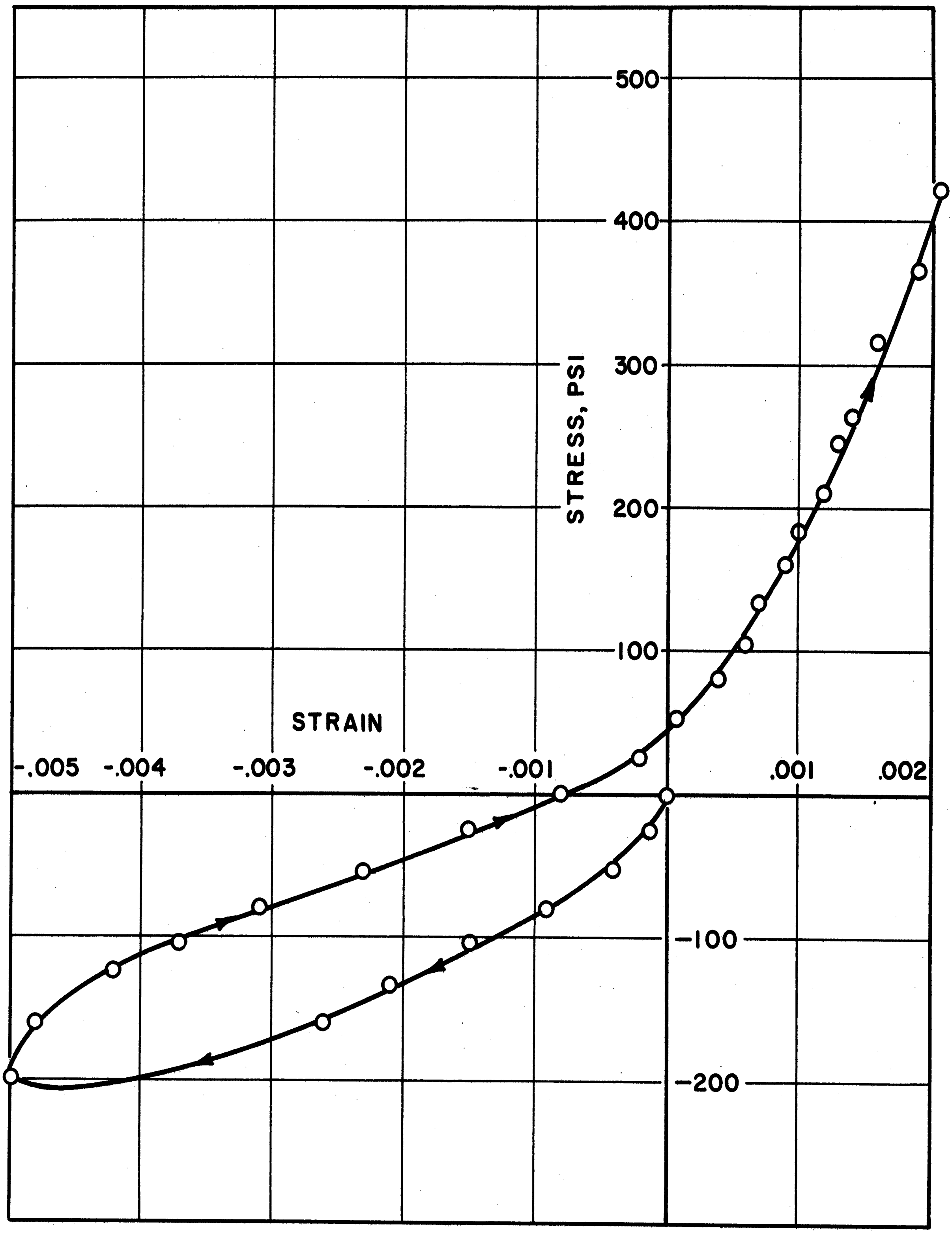

Fig. 2. Stress-strain curve for nylon cord specimen.

IV. DESCRIPTION OF SPECIMENS

These specimens were primarily required to sustain either extension or contraction without failure or buckling, since it was desired to obtain a specimen in which a continuous stress-strain curve could be obtained, starting from the origin and working either first into tension and then backwards into compression, or else the reverse. It was felt that, due to the low modulus of rubber and textile, the primary difficulty here would be buckling of the entire specimen. A design was chosen which could withstand approximately one percent strain before elastic buckling took place in compression. This design is illustrated in Fig. 3. The objective here was to maintain a relatively large moment of inertia of the cross section of the specimen compared to its length. This reduces the tendency toward column buckling. Experience with this specimen has indicated the desirability of maintaining the same approximate dimensions in future specimens, but the quantity of textile cord should be considerably reduced. The minimum length which could be used without incurring the danger of excessive end effects on the specimen would be, it was thought, ten inches. Greater length would, of course, have resulted in lower compressive buckling loads.

The general method of construction for this specimen was to position textile cords parallel to the longitudinal axis of the cylinder. This allows one to load the cords directly into compression or directly into tension. To prevent accidental chafing or destruction of the cords at the outer surfaces, a protective layer of rubber was used to cover both the inner bore of the hollow cylinder and its outer surface.

Since the compression modulus of a textile cord could be obtained only by separating out the effects of the cord from the effects of the rubber, a number of specimens, both of nylon and rayon, as illustrated in Fig. 3, were ordered along with a number of identical rubber specimens made from the same kind of rubber used to imbed the cords. Thus, both cylinders of pure rubber and cylinders of the same geometry containing a large number of textile cords were available.

V. TESTING PROCEDURE

The stress-strain curves shown in Figs. 1 and 2 of this report were obtained from tests made on a standard Baldwin-Southwark model FGT screw-type testing machine. This machine was chosen since it is designed to go through tension into compression and vice-versa without any lag or mechanical clearance in the fittings and grips.

End connections were necessary to attach the specimens to the heads of the machine. These end fittings were machined from steel and a drawing of them is shown in Fig. 4. They were designed to provide a firm, flat base for compressive loads as well as to provide a rigid set of faces to which the ends of the specimen could be glued. After some experimentation, it was decided to use Eastman 910 to glue the ends of the specimens to the faces of the fittings. This glue can develop a tensile stress of about 5000 psi under favorable conditions and this is ample to illustrate the principle involved in these experiments. Figure 5 shows a typical glue bond after it has been broken. It can be seen that the ends of the specimen made contact with the glue on the flat face of the fitting, in that the glue marks associated with each individual cord can be seen as a pattern on that face.

Figure 6 illustrates the mechanical components used in this test. The heavy blocks at the top and bottom of the photograph are the tension-compression heads of the testing machine, while the steel fittings shown in Fig. 4 can be seen immediately adjacent to the specimen itself. The plug part of the fitting serves to align the two ends of the specimen directly above and below one another.

Load measurement was carried out using the usual load weighing system on the testing machine. This is a strain-gage load-cell weighing scheme and is quite accurate and lag-free. Strain measurement on the specimen required considerably more care and a number of preliminary experiments were performed to perfect an acceptable technique. The most convenient scheme would be to use the distance between heads as a measure of the total elongation of the specimen. Unfortunately, the end effects cause an uncertainty to arise concerning the exact effective length of the specimen, so that it was necessary to use a cathetometer to measure the extension of a trial section near the center of the specimen, a region in which end effects are negligible. This extension was compared with the extension averaged over the entire specimen, which could be obtained by measuring the head deflection and dividing by the total length of the specimen. A comparison between strain records taken in these two different ways is given in Fig. 7. For convenience, this experiment was performed on a different kind of machine in which the head travel could be recorded automatically; the technique, however, is applicable to any testing machine. From

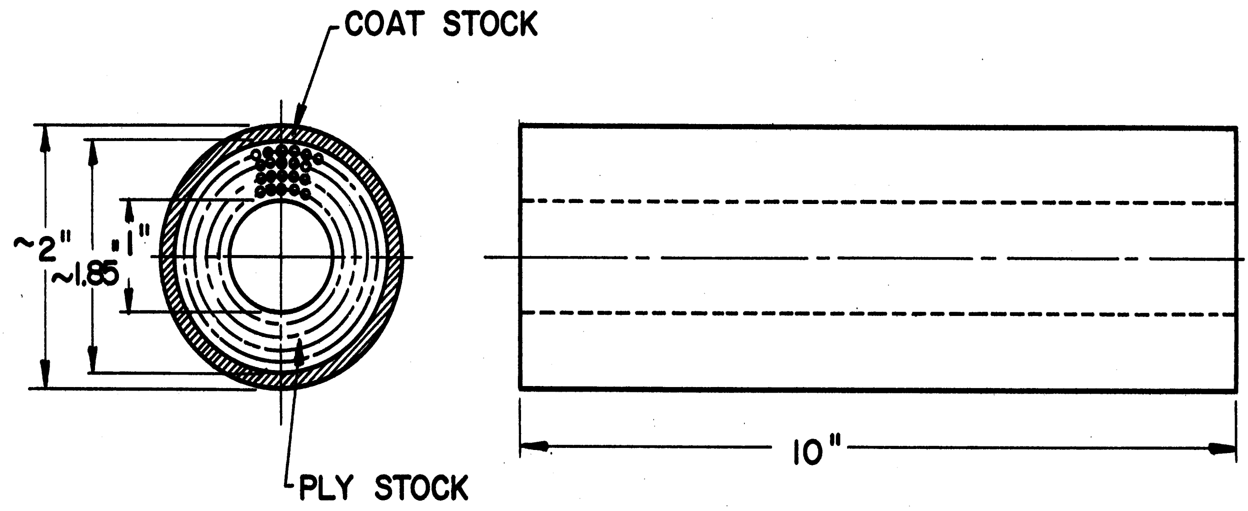

Fig. 3. Typical specimen geometry, with cord specimen shown. Rubber specimens are of identical outside dimensions.

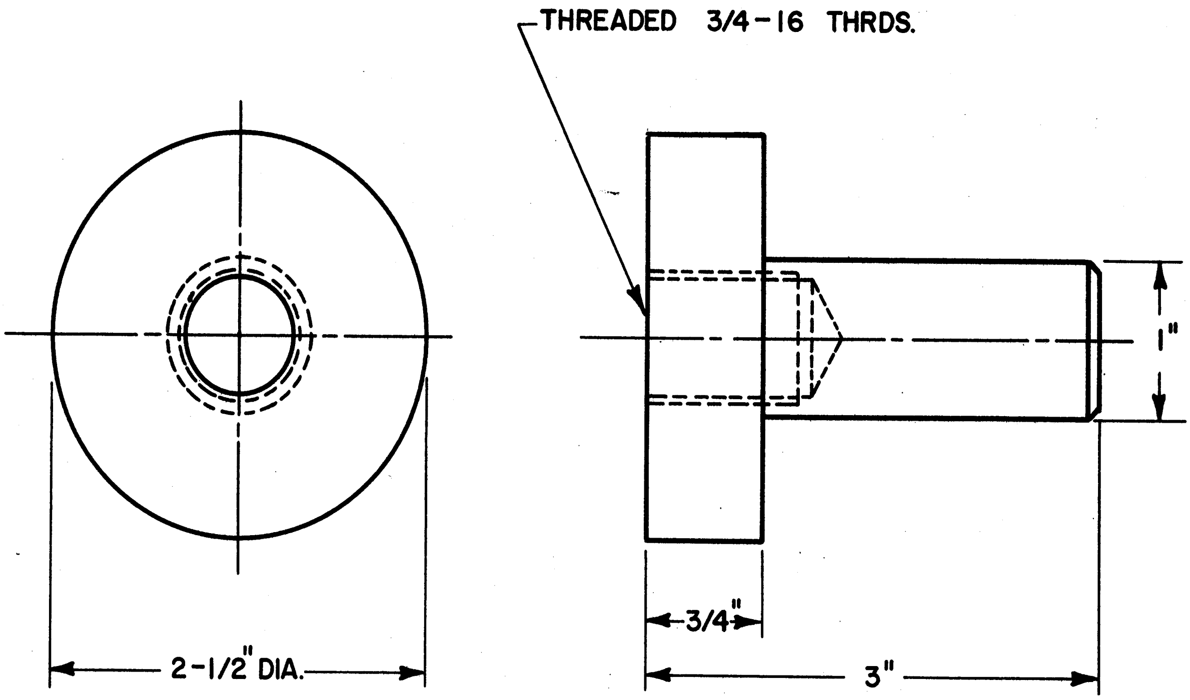

Fig. 4. Steel end fittings for specimens.

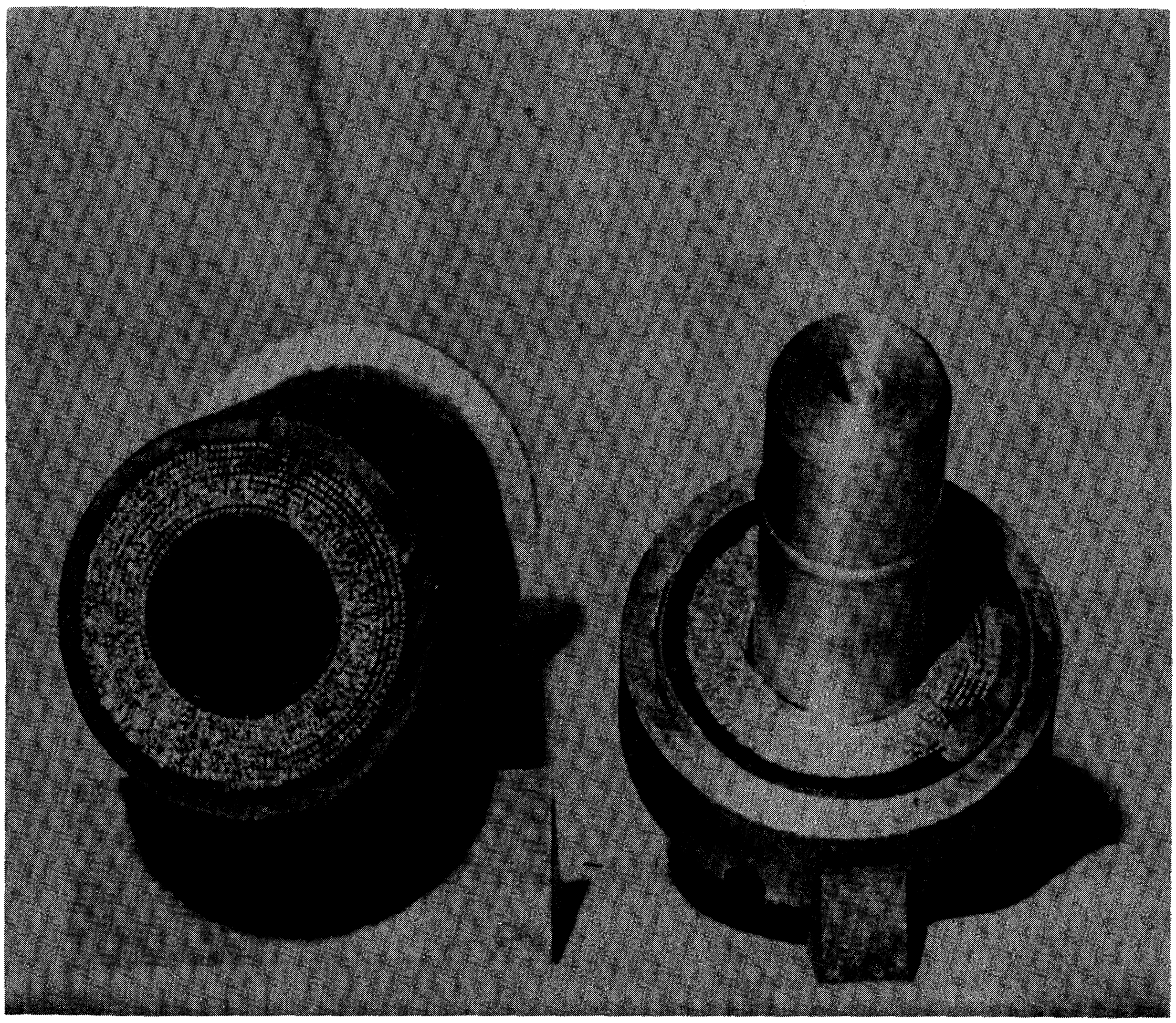

Fig. 5. Broken glue joint. Note cord pattern on the steel face.

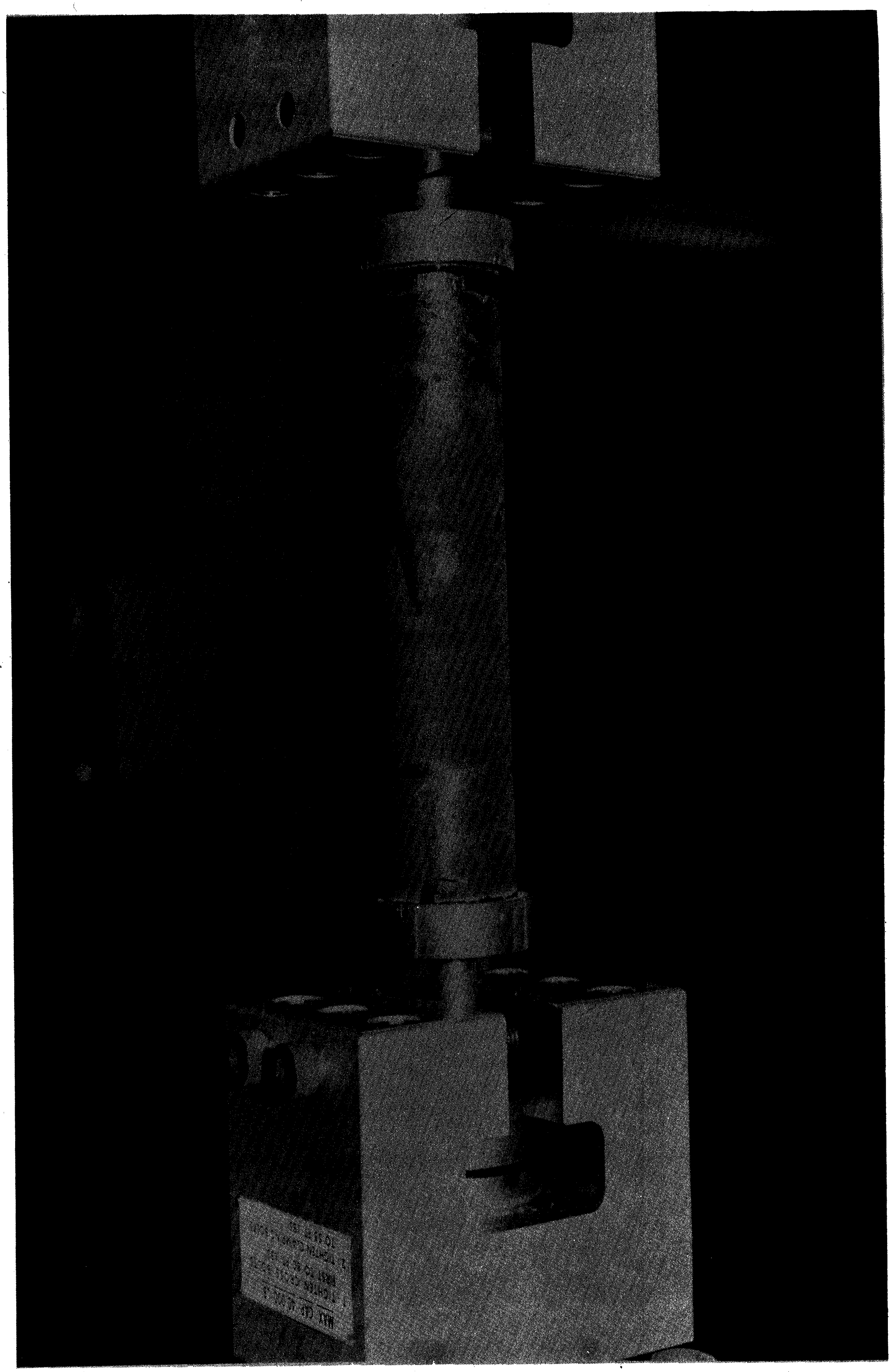

Fig. 6. Specimen in place in testing machine, after failure of the glue bond.

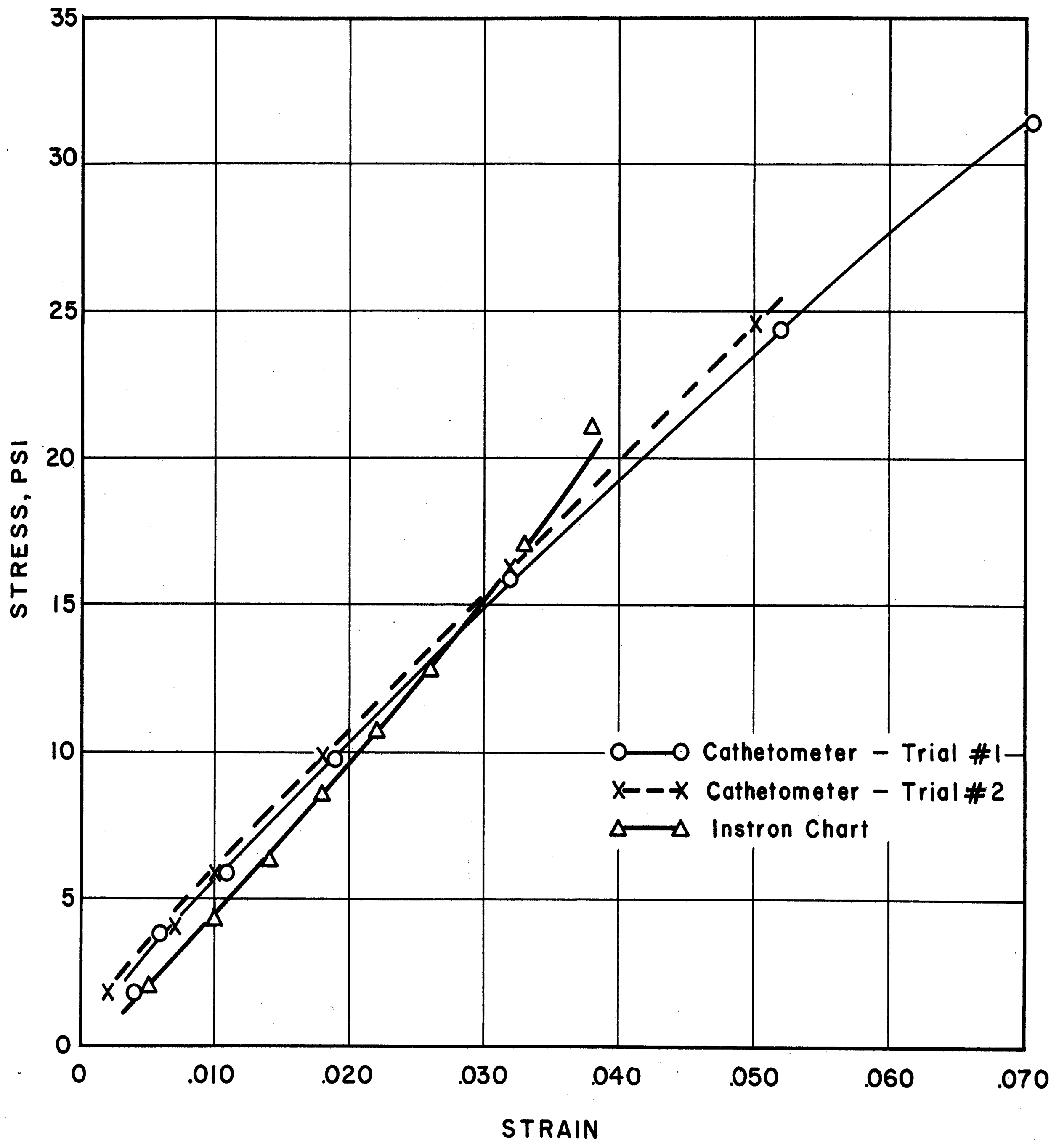

Fig. 7. Strain-measurement comparison showing both head travel and optical strain measurement.

Fig. 7 it may be seen that any error caused by use of the total head travel as a measure of average strain is negligible in this case. The reason for using head travel rather than an optical strain measuring device such as a cathetometer is that the use of the cathetometer is extremely tedious and requires at least one more operator to perform a test. In addition, the cathetometer requires that the test be run at a low enough rate of speed so that optical readings may be taken "on the fly," and in many cases it is necessary to stop the loading process to allow a reading to be taken. This is quite undesirable in materials exhibiting hysteresis since rate of strain is not maintained constant.

During the preliminary testing of these cylinders, one cord-rubber specimen was cycled several times while load and strain were simultaneously recorded. It was found that the second and subsequent load-strain curves were identical. This was used as evidence that, after intial cycling, the various specimens could be tested at approximately the same total number of cycles in their life without introducing an error due to history of loading. This procedure was followed in performing the experiments described in this report.

Difficulty was encountered with the glue bonds, as might be expected. Although great care was taken to make the ends of the specimen perfectly flat by machining them, we did not find it possible at any time to realize the maximum tensile strength from the Eastman 910 glue. Late in this series of experiments some chemical cleaners and surface washes were obtained to attempt to control the pH of the mating glue surfaces and thus to increase the glue bond strength. Generally speaking, these were not very successful and at no time did we exceed 1000 psi in the glue bond without failure.

In practically all tests, the procedure was to begin loading in compression and to continue this compression load until incipient buckling became evident. At that time the direction of head travel was reversed and the compressive load removed. Keeping a constant velocity of head travel, the load now turned to tension, and tension load was continued until failure of one or both of the glue bonds took place. This failure was very obvious in two ways. First, the load of the dial of the testing machine dropped off quite suddenly, and secondly, a loud pop or crack could be heard as the glue joint parted. The glue bonds were examined after the test and in many of the experiments it was necessary to reject the data since, by appearance of the bond, not all the textile cords had been glued to one or both of the faces of the fittings. Only in the tests reported in Figs. 1 and 2 were complete bonds found.

It would perhaps be appropriate at this time to discuss the role of an incomplete glue bond in these tests. It may be seen that the consequences of failure to glue each and every textile cord to both faces of the fittings is that the modulus of the material in tension will be less than would have occurred if the particular textile cord had been glued. Thus it may be seen that as long as the modulus in tension, such as exhibited in Figs. 1 and 2, is greater than the modulus in compression, the only effect of a better bond would have been to make a still greater modulus in tension. One can thus argue that the adequacy of the glue bond is not of real importance so long as the tensile modulus exceeds the compressive modulus. This is the case in both Figs. 1 and 2. The adequacy of the glue bond is not important to the compressive modulus, since all textile fibers will participate in the compressive load carrying process anyway.

The aim in this set of experiments was not to obtain quantitative data on the various compressive and tensile moduli, but to illustrate the principle that different moduli do exist in tension and in compression, and that the compression modulus is different from the modulus of pure rubber.

The testing of the rubber specimens was considerably simpler than the testing of cord specimens since, in the case of rubber, the glue bonds were strong enough so that rather large strains could be obtained.

The stress-strain curves of several of the solid rubber specimens were obtained. One of these is illustrated in Fig. 8. The modulus obtained from this stress-strain curve is shown, and it may be seen by comparing this modulus with the slopes of Figs. 1 and 2 that the influence of the rubber on the stress-strain curves of Figs. 1 and 2 is generally negligible in both tension and compression. This conclusion is valid even though the cross-sectional area of rubber in the cord-rubber specimens is somewhat greater than the cross-sectional area of cord.

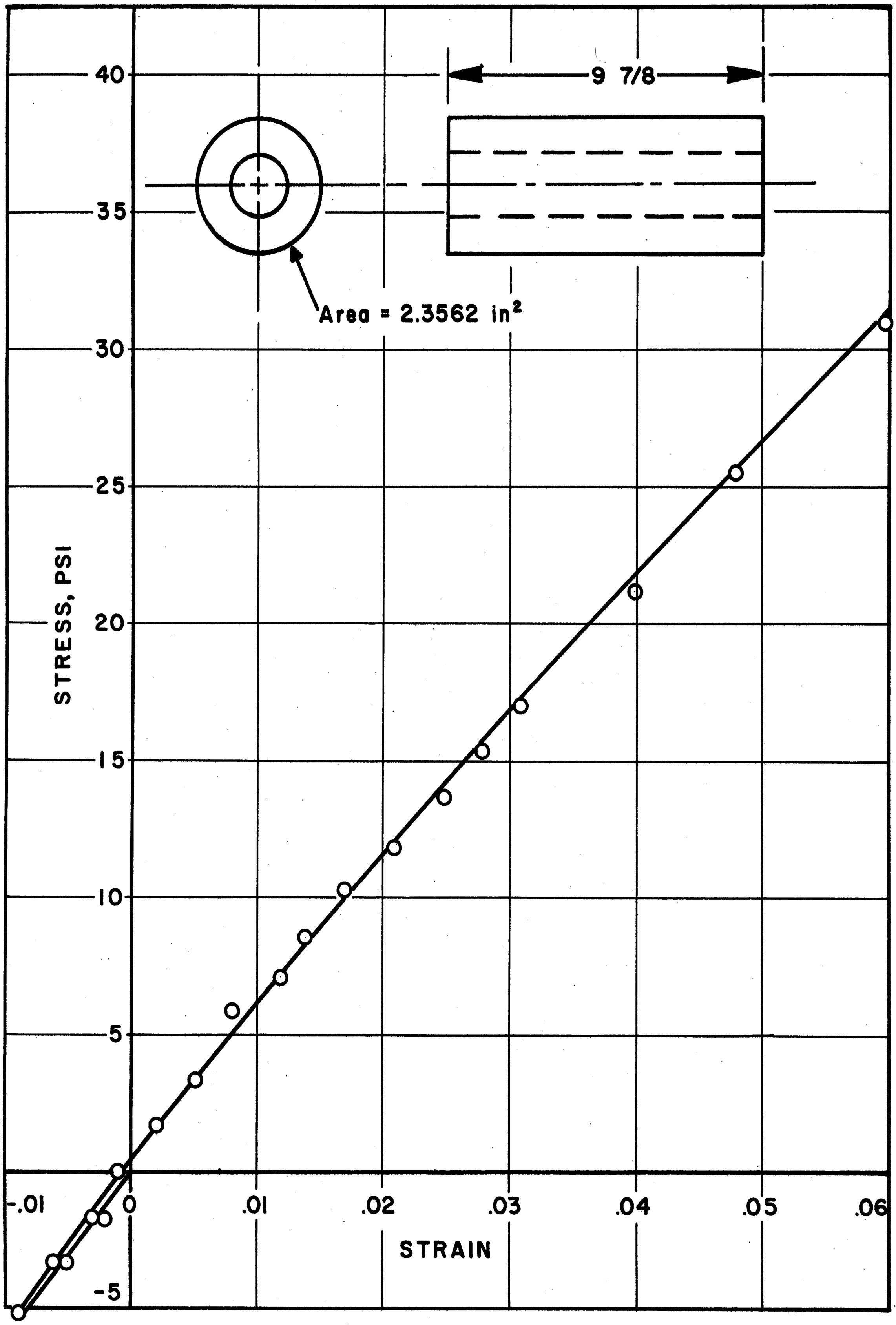

Fig. 8. Stress-strain curve for rubber specimen.

VI. MANUFACTURE OF SPECIMENS

These specimens were constructed using standard cord and coat stocks. Particular care was taken to insure that the cords remained straight and parallel to the longitudinal centerline of the cylinder. Dissection of representative specimens after testing showed that this was indeed true.

VII. ACKNOWLEDGMENT

Mr. Richard N. Dodge aided in performing the experiments described in this report.

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