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AUTOGRAPHIC LOAD-ELONGATION APPARATUS FOR FIBERS

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ABSTRACT

An autographic load-elongation apparatus for testing single fibers is described. The apparatus is adapted to making a continuous load-elongation record at constant rate of elongation and to making a point by point record at constant rate of loading. It is also useful for obtaining relaxation curves for single fibers. It combines the principles of a hand-operated machine developed in this laboratory and an automatic electronic balance developed by Muller and Garman [5].[2] Sensitive automatic operation is attained by means of photoelectric controls, and autographic recording in rectangular coordinates is provided. Examples are given of the performance of the apparatus.

CONTENTS

I. INTRODUCTION

In studies of the mechanical properties of textile materials, it has been found useful to investigate the properties of the individual fibers, since complications introduced by yarn structure and weave are thereby eliminated. There have been numerous types of apparatus designed to study the load-elongation properties of single fibers, the descriptions of which are given elsewhere [1, 2, 3]. Some of these machines are very sensitive, and have found wide application in studies of fiber properties. None of them, however, combines autographic operation with sufficient sensitivity for the investigation of weak fibers and sufficient magnification for the investigation of relatively inextensible fibers.

In previous work at the Bureau, a modified chemical balance has been used to obtain load-elongation curves of single fibers [4]. The procedure used with this apparatus was to attach the fiber (mounted on glass hooks) to the left balance beam and to a platform which could be raised or lowered by a rack and pinion. Increments of load were added to the right balance pan, the platform was lowered by

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[2] Figures in brackets indicate the literature references at the end of this paper.

means of hand-operated gearing to return the balance pointer to zero, and the elongation was obtained by measuring the displacement of the platform. The test procedure is described in detail elsewhere [4]. This apparatus provides sufficient sensitivity for investigation of weak fibers, but its operation is tedious and slow, and does not allow continuous stretching of the fiber. The basic suitability of the balance principle has been demonstrated, however, and it therefore seemed desirable to adapt a balance apparatus to automatic and autographic operation. The sensitive and stable automatic electronic balance of Muller and Garman [5] provides the means for accomplishing this.

The basis of the present apparatus is a magnetically damped analytical balance equipped with a Chainomatic column. The method of obtaining a load-elongation curve is similar to that described above, but in contrast with the earlier apparatus, the present machine automatically either elongates or loads a fiber at a constant rate. This arrangement combines the high sensitivity of the analytical balance with autographic recording. Constant rate of elongation is obtained by lowering at a constant speed the platform to which the fiber is attached; constant rate of loading is obtained by lowering at a constant rate the end of the chain which is attached to the Chainomatic column. The balance pointer is continuously and automatically maintained at the zero point within close limits by photoelectric controls. For constant rate of elongation the load is recorded continuously as a function of the elongation, but for constant rate of loading the elongation is recorded only at intervals. The recording system could, however, be modified to produce a continuous load-elongation curve for constant rate of loading.

II. CONSTRUCTION

1. GENERAL AND MECHANICAL DESCRIPTION

A general view of the apparatus is given in figure 1. The recording drum (kymograph drum), which is normally mounted on the vertical shaft in front of the balance, has been omitted from this photograph in order to give an unobstructed view of the balance. The kymograph protrudes through a hole in the table top in front of the balance. The box on top of the balance houses the light source for the photoelectric control. The control chassis is at the left of the balance. The motors and gear reducers are mounted on a shelf about 6 in. below the table top, and the power-supply chassis on a shelf at the lower left side of the table, out of the way of the operator. A schematic diagram of the arrangement of the mechanical and optical parts is given in figure 2, from which the recording system has been omitted.

The fiber is elongated by lowering the platform, *H*, the extent of the elongation being indicated by the dial gage, *J*, (range 2 in.), which is rigidly attached to the platform by the arm, *K*. The platform can be controlled manually by means of the rack, *L*, and pinion, *M*. The shaft to which the rack is attached is hollowed and split for about 2 in. at its lower end to receive the upper end of the threaded shaft, *O*. The two shafts can be easily attached by means of the friction clamp, *N*, and the platform can then be controlled by means of a mechanical drive. Power is transmitted from a constant-speed motor (not shown

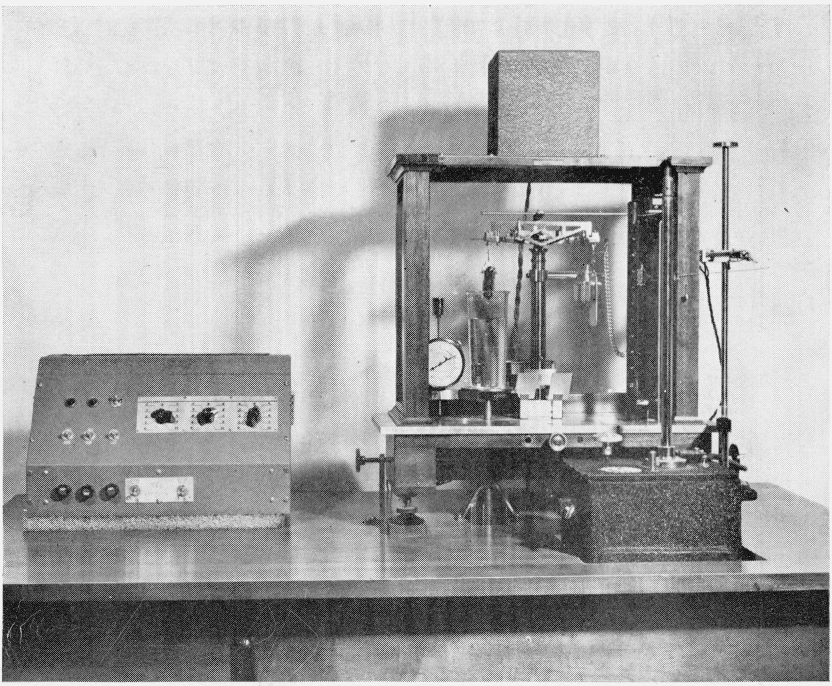

FIGURE 1.—*General view of the autographic load-elongation apparatus.*
The recording drum has been omitted.

in fig. 2) by means of a gear-box and chain-and-sprocket combination to the sprocket, *R*, the worm, *P*, and the tapped worm-gear, *Q*, which raises or lowers the threaded shaft, *O*, which is provided with a key to prevent rotation.

The load is applied by means of the chain or chains, *E*. Power is transmitted through a gear-box and chain-and-sprocket drive to the

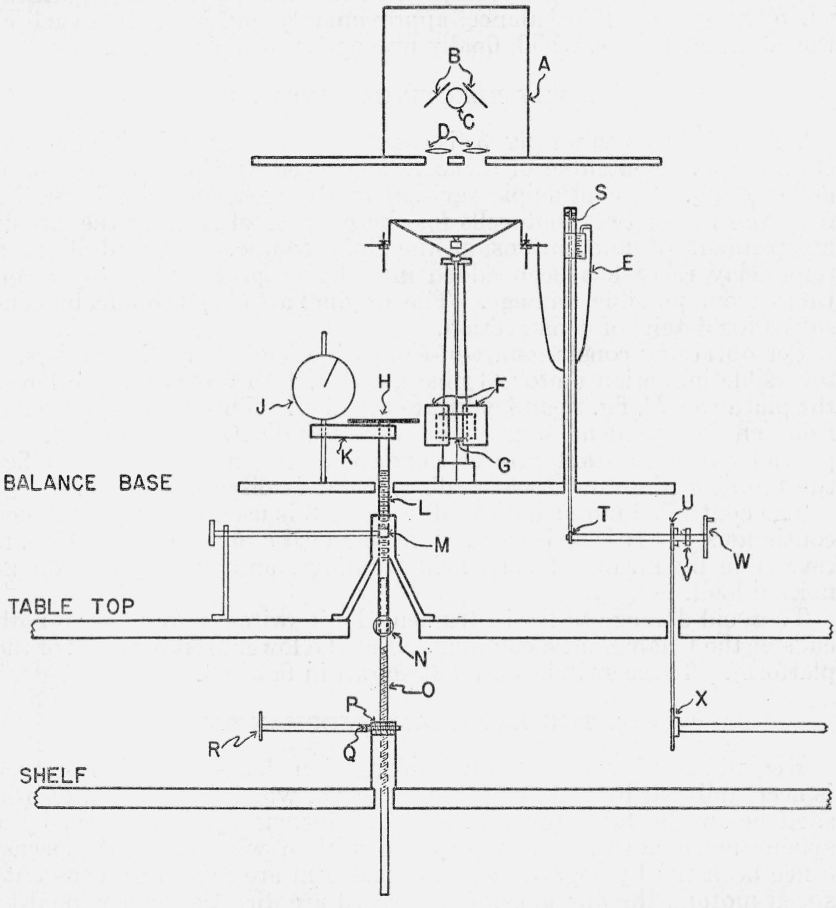

FIGURE 2.—*Schematic diagram of the apparatus.*

A, housing for light source; *B* and *F*, mirrors; *C*, light source; *D*, condensing lenses; *E*, chain; *G*, target; *H*, platform; *J*, dial gage; *K*, connecting arm; *L*, rack; *M*, pinion; *N*, friction clamp; *O*, threaded shaft; *P*, worm; *Q*, worm gear; *R*, *S*, *T*, *U*, and X, sprockets; *V*, clutch; and *W*, wheel for hand operation of chain.

sprockets, *X* and *U*. The vernier of the Chainomatic column, to which the chain is fixed, is driven by a sprocket chain and the sprockets, *S* and *T*. A simple clutch, *V*, is provided adjacent to the sprocket, *U*, so that the chain may be controlled manually by means of the wheel, *W*, or by the motor drive.

2. THE OPTICAL SYSTEM

The arrangement of the optical parts is shown in figure 2. The two light beams originate in the 6 to 8 v, 21 candlepower lamp, *C*, housed in the box, *A*, which is provided with baffles. The beams are reflected downward by the metal mirrors, *B*, through the condensing lenses, *D*. The mirrors, *F*, placed symmetrically in front of the target, *G*, send the beams past the target and to the photocells. (The photocells have been omitted from fig. 2 in the interests of clarity, but they can be seen behind the balance in fig. 1.) Automatic control of the position of the balance pointer is obtained with the help of the target, which, when the system is in balance, approximately half-interrupts each of the two light beams, which finally impinge on the photocells.

3. THE ELECTRICAL SYSTEM

The electrical system (fig. 3) is essentially that given by Muller and Garman [5]. A number of revisions suggested by Garman have been included [6]. The principle revision in the electrical circuit results from the use of two photocells for the purpose of making the circuit independent of fluctuations in the light source. In addition, a time-delay relay has been added in order to protect the thyratron tubes from possible damage. The original article [5] should be consulted for details of construction.

For obtaining constant-rate-of-elongation load-elongation curves, a reversible induction motor (3 phase, 220 v, 1/15 hp) is used to lower the platform (*H*, fig. 2) and elongate the fiber. This motor is powered from an independent source and is not indicated in figure 3. It provides very constant rate of elongation, and in addition simplifies the problem of automatic recording, which is discussed below.

The controlled motor indicated in figure 3 is used to restore balance continuously. It is series wound, for a-c or d-c operation on 115 v, is reversible by means of split field windings, and draws 0.8 amp at normal load.

To avoid damage to the instrument, limit switches are used on both ends of the Chainomatic column, and at the lower limit of travel of the platform. These switches are not shown in figure 3.

4. THE RECORDING MECHANISM

Recording of constant-rate-of-elongation load-elongation curves is accomplished by means of a kymograph, which is mounted on the shelf below the table top (fig. 1). The instrument is powered by a synchronous motor, and is provided with a wide range of speeds. Since both the kymograph and the platform are driven by constant-speed motors, the abscissas of the record are directly proportional to the elongation. It has been found convenient to mark the axis of abscissas at regular intervals of elongation (0. 003 in. or 0.03 in.) by means of signal magnets, or time markers. These are motivated by switches controlled by cams set on a rotating shaft of the platform drive. Rates of elongation from 0.05 to 0.2 in. per minute have been used, but a wider range of rates is easily available.

The load at any elongation is recorded by means of a swivel-mounted writing pen (this is the lower pen in fig. 1) attached to the vernier of the Chainomatic column. The apparatus thus provides a directly recorded load-elongation curve. The ordinates are directly proportional to load, the factor of proportionality depending upon the chains used. Chains (or combinations of chains) for which 1 in. of record corresponds to 2, 4, and 6 g have been used.

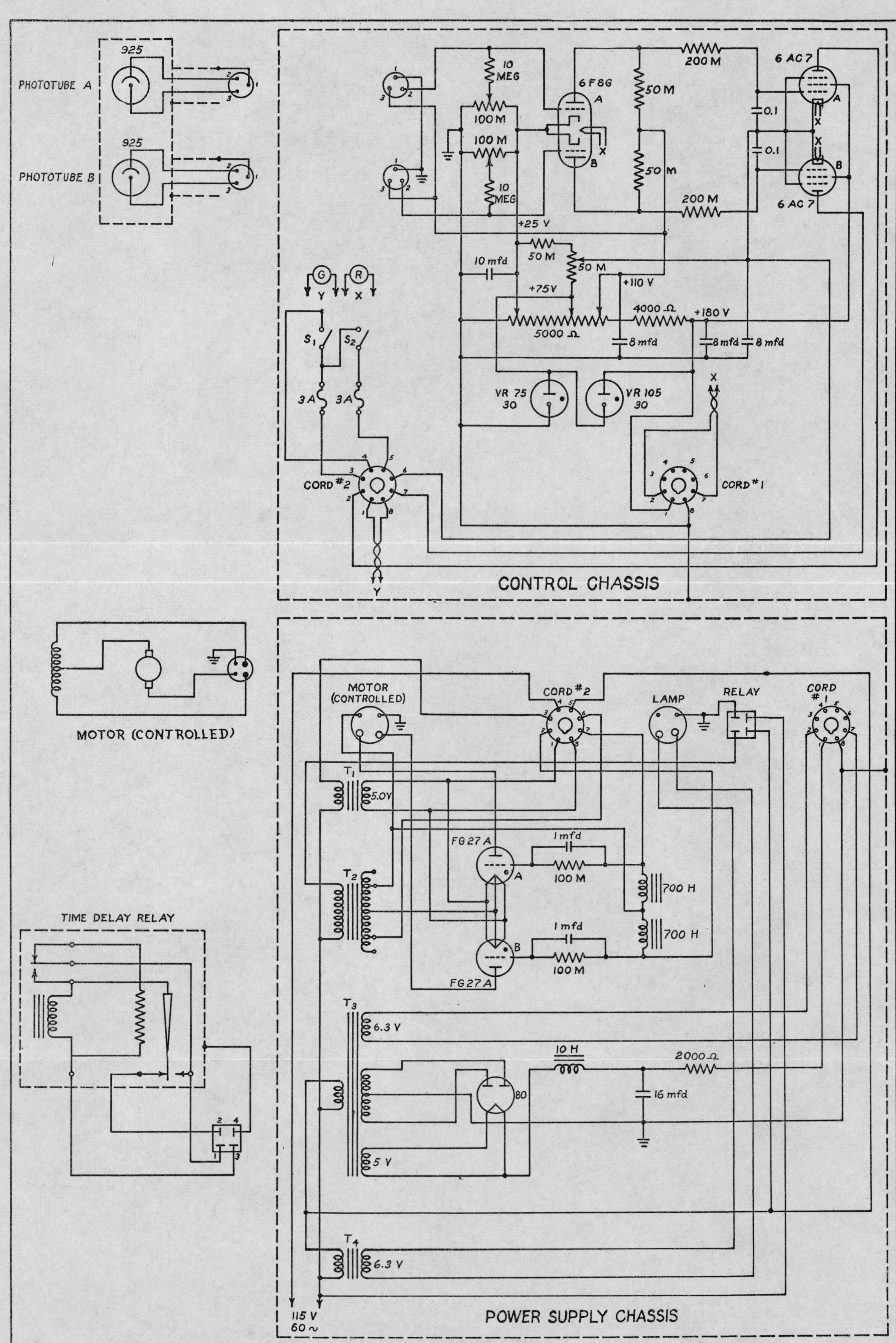

FIGURE 3.—*Diagram of the electrical circuit.*

The symbol *M* denotes: 1,000 ohms.
T_1=Filament transformer, 5 v center tap, 13-amp secondary.
T_2=Power transformer rewound so that secondary gives 175 or 180 v a-c, 250 ma on either side of tap.
T_3=Power transformer, 385-0-385 v, 70 ma, 5 v, 2 amp, and 6.3 v, 2.5 amp center tap secondaries.
T_4=Filament transformer, 6.3 v center tap, 6-amp secondary.
Time delay relay: Delay 1 minute, immediate recycling, coil 110 v a-c, 60 cycles, contacts 110 v a-c amp.
Ckokes: 700 h, 0.5 ma, 6,150 ohms.

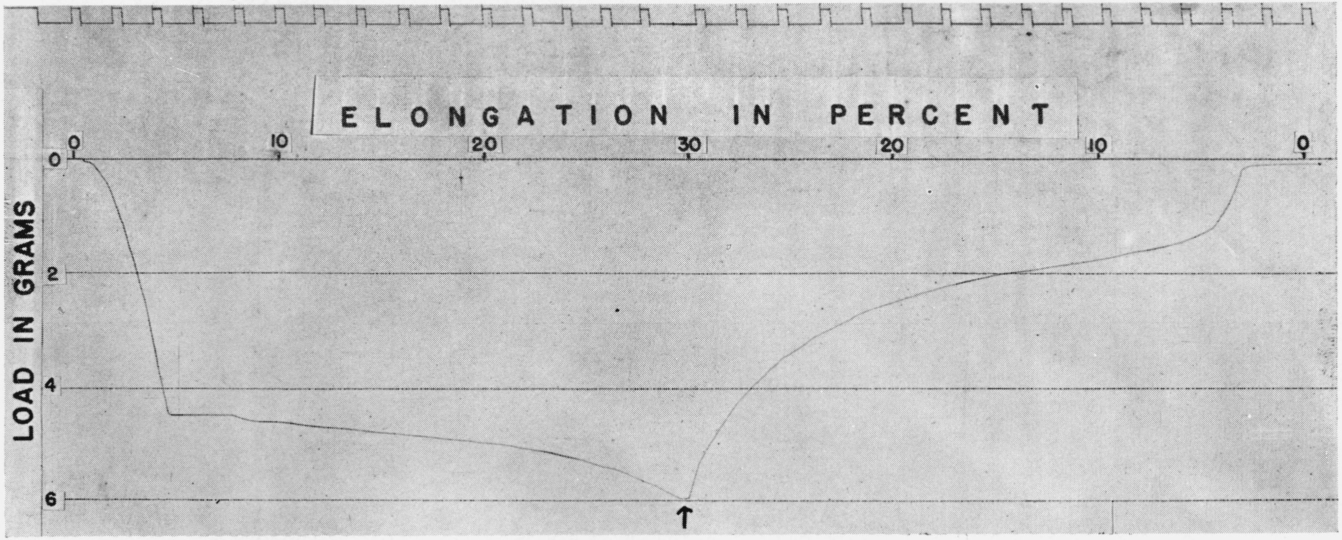

FIGURE 4.—*Loading and recovery cycle for a wool fiber, stretched 30 percent in water.*

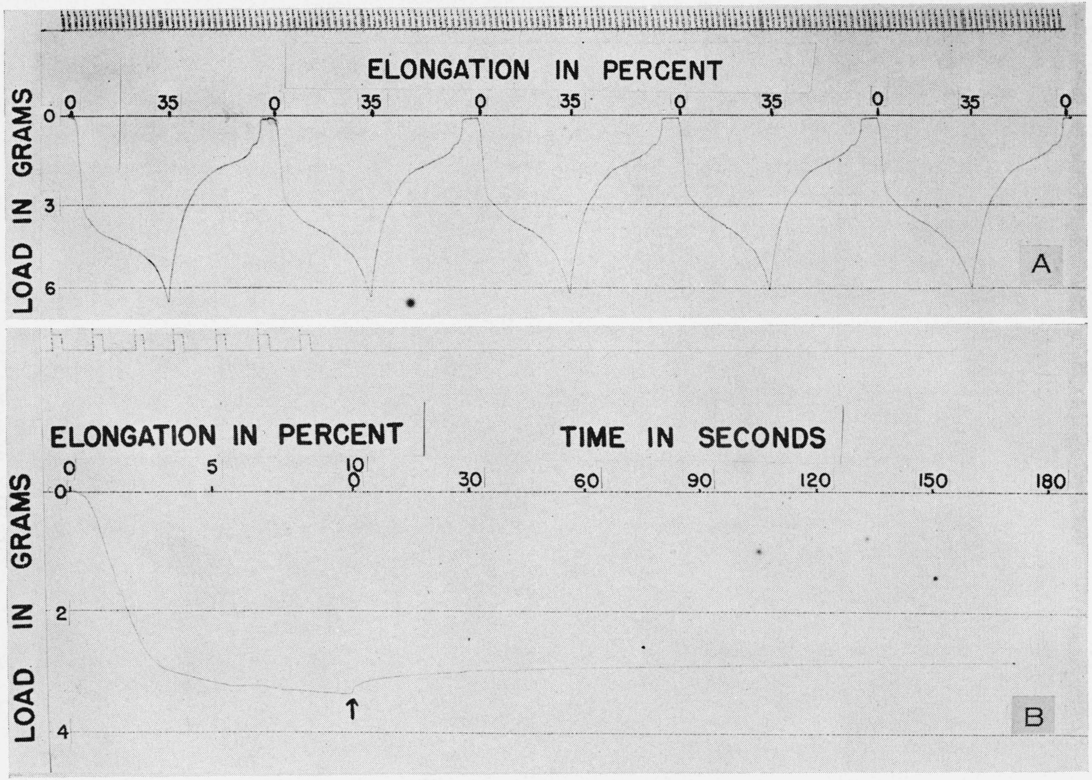

FIGURE 6.—*Load-elongation and relaxation curves for single wool fibers.*

A, Successive loading and recovery cycles for a wool fiber, stretched 35 percent in water five times; *B*, relaxation curve for a single wool fiber. The fiber was stretched to 10-percent elongation in the wet state, and then allowed to relax.

III. OPERATION AND EXAMPLES

At the start of a load-elongation experiment, a mounted fiber, calibrated with respect to length and average cross section, is hung from the left balance beam, and the balance pointer is brought to the zero point by manual adjustment of the chain or a rider on the balance beam. A flask with a glass hook sealed to the bottom is then set on the platform (*H*, fig. 2) if the fiber is to be elongated wet; a weight with a hook attached is used if the experiment is to be conducted in a conditioned atmosphere. The friction clamp, *N*, is then loosened, and the platform is adjusted manually with the rack and pinion so that the glass hook on the lower end of the fiber engages the hook of the flask or weight. The platform is lowered until the balance pointer is just displaced. The dial-gage reading at this point is the initial value (zero elongation). The friction clamp, *N*, is tightened with the balance pointer at zero, the controls are turned on, and the motor which lowers the platform is started. The machine thereafter records the load-elongation curve for the fiber automatically. Hysteresis curves can be obtained by reversing the motor which lowers the platform at any given elongation. The dial gage serves to indicate when a required elongation has been reached during an experiment. At the end of the experiment, lines corresponding to any given values of load or stress may be marked on the drum by lowering the chain with its writing pen, and rotating the kymograph drum by hand. The abscissa values may be easily obtained from the signal-magnet tracings.

Successful automatic operation depends on the proper adjustment of the speed of the platform, the motion of the chain, the size of the chain used, and the sensitivity of the controls. In particular, the chain must be capable of moving rapidly enough to take care of the most rapid changes of load (usually in the Hooke's law portion of the curve). The chain should be light enough, however, so that the scale of the ordinates is not unduly compressed. The scale of the abscissas may be easily adjusted by changing the speed of the kymograph drum.

Automatically recorded constant-rate-of-loading load-elongation curves can be obtained by running the chain side at a constant speed, and using a controlled motor on the platform side. Since the kymograph drum is driven at a constant rate by a synchronous motor, and since the platform is driven by the controlled motor, which does not run at a uniform rate, the elongation is not proportional to the abscissas lengths under these conditions. The recording system could be modified to give the conventional type of record for both constant-rate-of-loading and constant-rate-of-elongation experiments. This could be accomplished by using the motor which lowers the platform to rotate the kymograph drum as well. This change would, however, involve difficulties arising from backlash in the long gear train, which gives the kymograph its desirable range of speeds. In addition, the apparatus would not then be suitable for relaxation studies.

The factor which limits the accuracy of the results appears to be the uniformity of the chains used to load the fiber. For small loads, chains designed for use with Chainomatic balances are suitable. For higher loads, inexpensive jewelry chains were used. They were found to be accurate to ± 0.5 percent of their maximum load at any point. It is believed that this error could be reduced by the use of specially made chains. It has been found convenient to use several heavy chains in parallel for testing strong fibers.

Figure 4 shows a load-elongation curve obtained from the apparatus for a wool fiber elongated at a constant rate in water. The fiber was

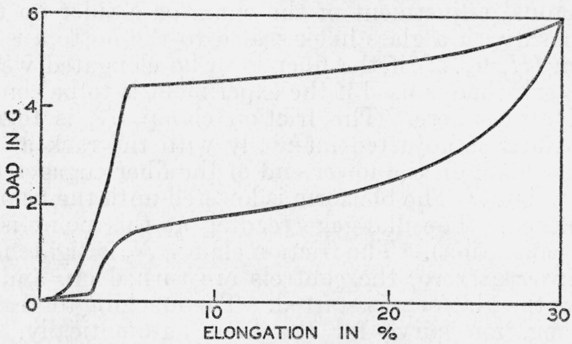

FIGURE 5.—*Hysteresis loop obtained by tracing the curve of figure 4.*

elongated to 30 percent, and then returned to zero elongation. The point of reversal of the platform motor is marked by the arrow. It should be noted from this figure that the load increases in a downward direction, and also that the kymograph drum does not reverse

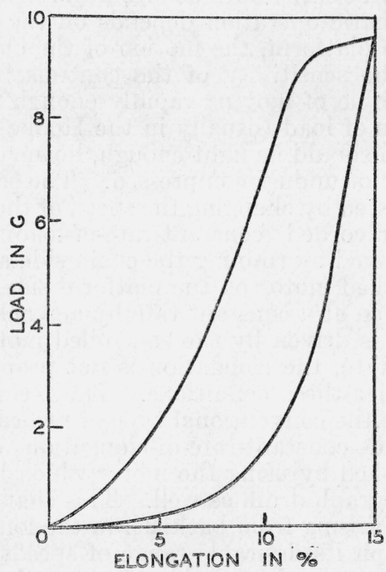

FIGURE 7.—*Loading and recovery cycle for a single filament of drawn nylon (2.3 denier), which was stretched in the wet state to 15-percent elongation and then returned to its initial length.*

when the fiber is returned to zero elongation. The conventional type of hysteresis loop, with load plotted against elongation, can be obtained from the curve of figure 4 by folding the record paper along a vertical axis passing through the arrow, and then inverting the paper. A tracing made in this way is shown in figure 5.

A series of load-elongation and recovery cycles on a single wool fiber extended in the wet condition is shown in figure 6 (*A*). In this experiment, the fiber was elongated 35 percent, after which the platform was reversed. When the fiber had returned to zero elongation, the cycle was repeated, etc. The figure shows the progressive decrease in the load developed by stretching the fiber to 35 percent in successive cycles. For this type of experiment, continuous unidirectional rotation of the kymograph motor is advantageous, since the record would be very confusing after a number of cycles if the curve returned to the origin.

Figure 6 (*B*) shows a relaxation curve for a single wool fiber. The fiber was stretched to 10 percent in the wet state, at which point (marked by the arrow) the platform was stopped. The machine then automatically recorded the decay of tension in the fiber as a function of time. Figure 7 shows a loading and recovery cycle for a single

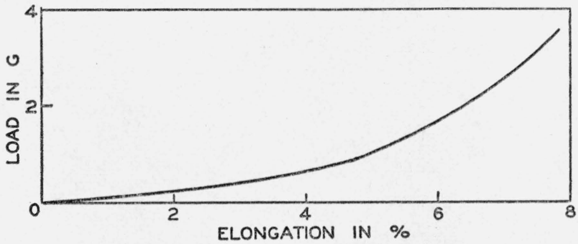

FIGURE 8.—*Load-elongation curve to failure for a single fiber of Sea Island cotton stretched in the wet state.*

filament of drawn nylon (2.3 denier), which was stretched in the wet state to 15-percent elongation, and then returned. The curve was traced from the record made by the machine, in the manner described above. A load-elongation curve to the break on a single fiber of Sea Island cotton elongated in the wet state is shown in figure 8.

For all the examples described above, the platform was lowered at a constant speed of 0.169 in. per minute, and the gear reduction between the controlled motor (which lowers the chain) and the sprockets of the Chainomatic column was 500:1.

IV. REFERENCES

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[6] Private communication from Dr. Garman.

WASHINGTON, February 15, 1943.