1925

A Recording Apparatus for the Measurement of Longitudinal Creep

INTRODUCTION

The classic form of longitudinal creep apparatus consists of a specimen weighted in tension, plus a cathetometer for periodic measurement of elongation.[1] Even though this method has the virtue of simplicity, there are limitations inherent in a nonrecording apparatus. First, it requires almost undivided attention to perform a repetitive operation that a machine could do more efficiently and accurately; second, tests must be carried out within the convenient working schedule of most laboratories. Both these disadvantages are overcome by the apparatus described in this paper.

The desirability of using a variable differential transformer,[2] or a photoelectric device,[3] was investigated. Such devices have excellent linearity and resolution when incorporated into transducers of good design. A transducer design based on a vacuum photoemissive tube was selected as being best suited to our specific needs.

DESCRIPTION OF APPARATUS

Mechanical Components

The basic structural unit is an open rectangular steel frame with a fixed specimen clamp at one end and an offset pulley (ball bearing) at the other. The loading mechanism (Fig. 1) consists of a specimen clamp and shutter fastened to a weighted steel tape which is made to pass over the pulley.[4] With this arrangement the load on the specimen is upward; hence, the unit can be conveniently inserted into the temperature chamber. In addition, the photoelectric transducer can be placed conveniently on top of the environment chamber. The dimensions of the basic structural unit are such that the maximum specimen length is 25 cm.; however, the overall size of the test specimen depends on such parameters as temperature and loading is arrived at experimentally.

* Eastern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

Electronic Components

The photoelectric transducer (Fig. 1) is the sensing part of the apparatus. An RCA 919 phototube* is mounted in an enclosure on a steel channel frame. This frame is provided with adjustable legs for aligning the transducer with the test specimen. A 250 v. d.c. regulated power supply provides the accelerating potential for the phototube. A 2.5 megohm load

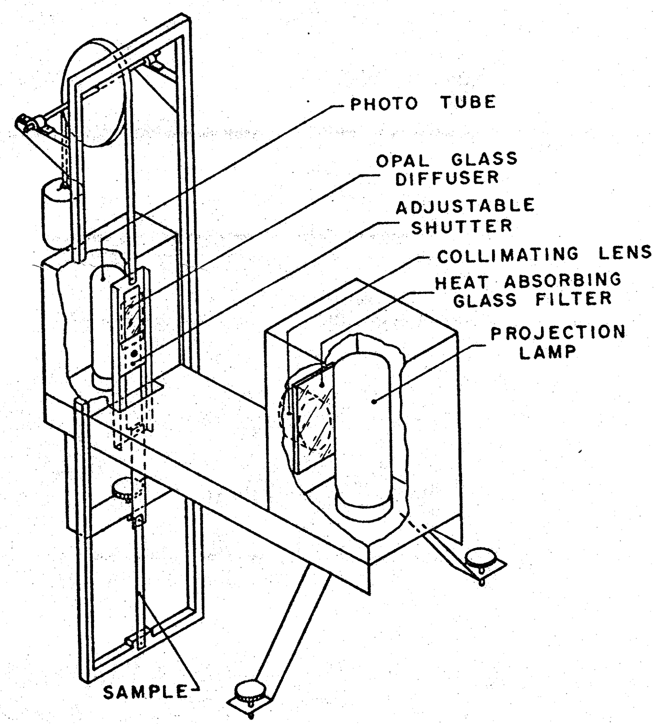

Fig. 1. Assembled components.

resistance is connected from the phototube cathode to the negative terminal of the power supply. The d.c. voltage drop across this resistance is divided so as to provide the desired value (250 mv.) of input signal for the amplifier. The exciting radiation for the phototube is provided by a 100 w. tungsten filament projection lamp located opposite the phototube. The light from the projection lamp is collimated so that a parallel beam strikes an opal glass diffuser placed directly in front of the phototube. This lamp is operated at a reduced voltage (approximately 90 v.) to extend its life. A voltage regulator and autotransformer are used to stabilize and attenuate output of the projection lamp. This lamp was operated on alternating current with no ill effects. The thermal inertia of the lamp filament and the

* Mention of commercial products does not constitute an endorsement by the United States Department of Agriculture over others of a similar nature not mentioned.

excellent 60 cycle rejection of the d.c. amplifier account for this. A heat-absorbing filter in the projection system was needed for stability.

The phototube detects the creep or recovery of the specimen by having its cathode surface increasingly shadowed by a shutter that is attached directly to the free end of the specimen. The loading mechanism, including the shutter, is placed directly in front of the opal glass diffusor, thereby causing the sharpest possible shadow to fall on the photocathode (Fig. 1). In addition to the above advantage, placing of the loading mechanism next to the phototube enclosure greatly facilitates insertion of the test specimen. The shutter is so arranged that the twofold function (detection of creep and/or recovery) can be accomplished without disturbing the specimen other than making a simple shutter adjustment in conjunction with application or removal of the load.

The phototube signal was amplified by a Hewlett Packard 425A low-drift d.c. amplifier with cathode-follower output which provides a convenient means of making an impedance match between the phototube and the millivolt recorder. An amplifier with an adjustable input range is necessary because the initial creep which takes place during the 0–100 sec. period is large compared with the long time creep.

A 10 mv. strip chart recorder was used. Only one chart speed was used (5 in./hr.) throughout the test. However, a two-speed recorder is preferable because it is advantageous to measure the initial creep at a relatively high chart speed. A millivolt recorder with an offset zero and a zero suppression device were found necessary because spurious voltages appeared when the amplifier sensitivity was changed.

Temperature Chamber

The temperature chamber consists of an insulated liquid bath into which a rectangular copper can projects. The specimen holder is placed within this copper can. The above arrangement effectively prevents the specimen from coming into contact with the liquid bath. The atmosphere plus radiation within the copper container heats the specimen. With this arrangement the moisture content of the atmosphere surrounding the sample can also be controlled. The temperature in the specimen chamber can be maintained constant at ±0.5°C. over a temperature range of −40° to 150°C.

Adjustment and Calibration

Prior to adjustment or testing, all components were brought to equilibrium temperature (approximately 1 hr.).

The following steps are necessary to put the detecting and recording systems into operation. *(1)* With the amplifier range switch set at the 300 mv. range and the full usable area of the photocathode exposed, the light intensity is adjusted to produce a phototube output of 250 mv. *(2)* The amplifier output is then attenuated to match the full-scale input (10 mv.) of the Brown Electronik recorder. *(3)* The zero point of the system is set by

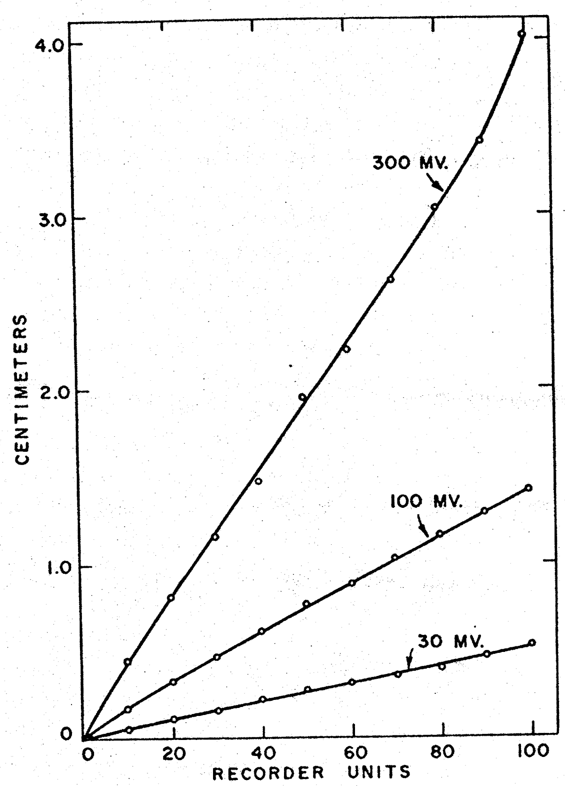

Fig. 2. Calibration graph.

means of the zero suppressor with the phototube masked to occlude all light. (*4*) The system is calibrated simply by moving the shutter lengthwise past the photocathode in discrete increments and noting the corresponding recorder pen displacement. The shutter's displacement was measured with a cathetometer to ±0.001 cm. The system was also calibrated for two additional amplifier ranges, 100 and 30 mv.). The calibration was also made for a reverse motion of the shutter starting as originally with a fully illuminated cathode surface. Plots of recorder pen displacement units versus shutter displacement in centimeters were made with these data (Fig. 2). The curves are substantially linear except near the extreme ends of the less sensitive plot (300 mv. range). A check of the transducer linearity showed that the maximum deviation from a straight line was no more than 1.5% of full-scale reading.

TEST PROCEDURE

The test procedure and conditioning for creep samples have been previously described.[5] Once the instrument is calibrated the shutter is moved to cover the amount of the phototube necessary to give the range desired. This is determined by the amount of change in length expected.

The elongation is kept below 10% of the initial specimen length for all tests. This is done by varying the load and temperature of testing. At any time during the creep test the shutter can be reversed, the load removed, and the recovery recorded.

PERFORMANCE

To test the performance of the apparatus, the following material was prepared: polyvinyl chloride plasticized with 35 wt.-% of butyl-2-(diethylphosphono)stearate. The test was run over a temperature range of 41–80°C., inclusive. The creep was followed both by the recording unit and the cathetometer.

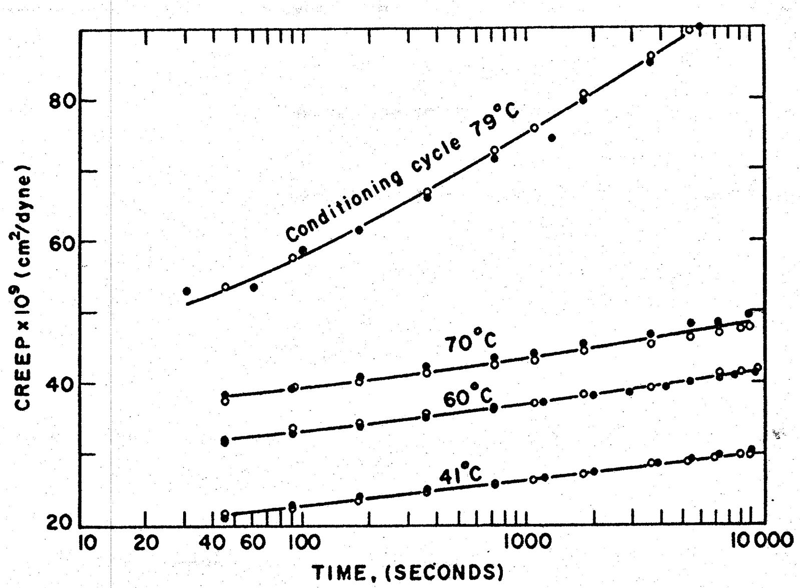

Fig. 3. Creep curves at various temperatures, comparing data obtained with the recorder and the cathetometer: (O) recorder; (●) cathetometer.

The creep data were calculated per unit stress[6] and then plotted against the logarithm of time in seconds. The creep curves in Figure 3 show that very good agreement was obtained between the cathetometer and the recording unit. Figure 4 further illustrates the agreement of these data. It shows the data reduced to one temperature,[7] 41°C., and plotted as log (*at*) versus creep.

CONCLUSIONS

The apparatus described is superior to a cathetometer in measuring creep and recovery of viscoelastic polymeric films for the following reasons: it is possible to get an accurate creep measurement for the 0–100 sec. period of testing, it gives greater resolution for the full testing period, it provides a

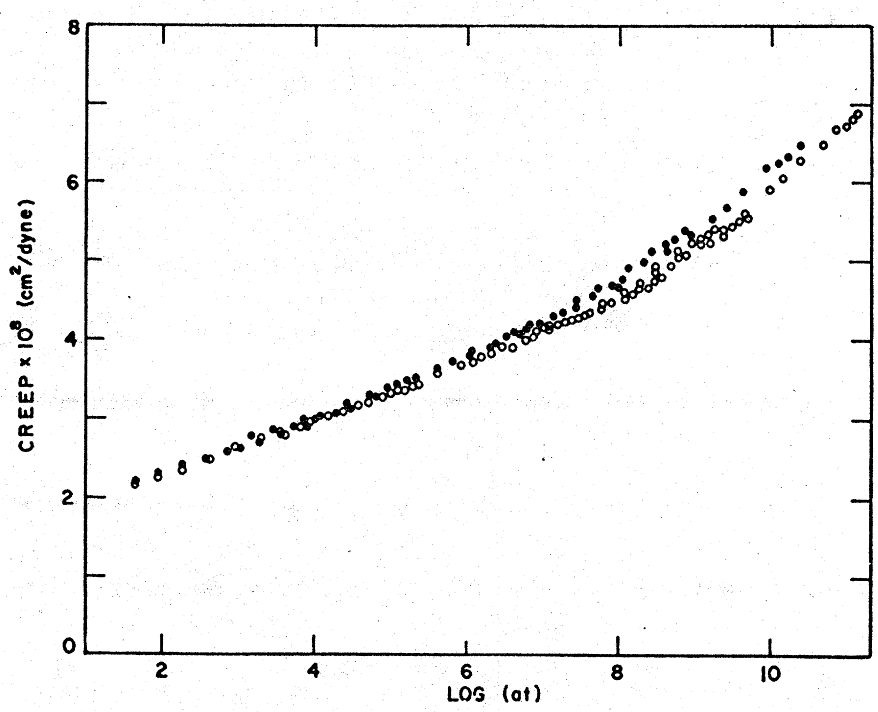

Fig. 4. Creep data reduced to 41°C.: (O) recorder; (●) cathetometer.

permanent visual record suitable for later analysis, and the need for constant operator attention is eliminated. The latter feature makes it possible to carry on a continuous creep test for periods of 24 hrs. or more.

References

1. Leaderman, H., *Technical Report to the Office of Naval Research,* Mechanics and Materials Branch Project ONR(QMC)NR-033-314 from National Bureau of Standards, May 11, 1949.
2. Gossick, B. R., *Rev. Sci. Instr.,* **25,** 907 (1954).
3. Leaderman, H., R. G. Smith, and R. W. Jones, *J. Polymer Sci.,* **14,** 47 (1954).
4. Catsiff, E., T. Alfrey, Jr., and M. T. O'Shaughnessy, *Textile Research J.,* **23,** 808 (1953).
5. Leaderman, H., *Elastic and Creep Properties of Filamentous Materials and Other High Polymers,* The Textile Foundation, Washington, D. C., 1943, p. 5.
6. Aiken, W., T. Alfrey, Jr., A. Janssen, and H. Mark, *J. Polymer Sci.,* **2,** 178 (1947).
7. Bueche, F., *J. Appl. Phys.,* **26,** 738 (1955).

Synopsis

A recording apparatus for measuring longitudinal creep was developed to study viscoelastic properties of polymeric films. The heart of the apparatus is a photoelectric transducer that converts specimen extension and contraction into a voltage which is then applied to a millivolt recorder through a d.c. low-drift amplifier. As used in this apparatus, the phototube detects the variable by having its photocathode surface shadowed by a movable mask. Supplementing the recording part of the apparatus is a mechanism for controlling specimen temperature. A polymer of plasticized polyvinyl

chloride was studied, to demonstrate the applicability of the apparatus. The results obtained compared favorably with the method of visually observing the displacement with a cathetometer.

Résumé

On a développé un appareil enrégistreur pour mesurer le fluage longitudinal, et ce en vue d'étudier les propriétés viscoélastiques des films de polymère. Le coeur de l'appareil est un transformateur photoélectrique qui convertit l'extension et la contraction du spécimen en un voltage qui est alors appliqué à un enrégistreur de millivolts à travers un amplificateur à courant continu. Dans cet appareil le photo-tube détecte la variable en ayant la surface de sa photo-cathode cachée par un masque mobile. En plus de la partie enrégistreuse, l'appareil possède un mécanisme pour contrôler la température de l'échantillon. On a étudié un chlorure de polyvinyle plastifié pour démontrer que le système est applicable. On peut favorablement comparer les résultats avec ceux obtenus en observant visuellement le déplacement au moyen d'un cathétomètre.

Zusammenfassung

Ein registrierender Apparat zur Messung des longitudinalen Kriechens wurde zur Untersuchung der viskoelastischen Eigenschaften von Polymerfilmen entwickelt. Das Herz des Apparates bildet ein photoelektrischer Transducer, der die Probendehnung und -kontraktion in eine elektrische Spannung umwandelt, die dann mit einem Gleichstrom-Low-drift-Verstärker einem Millivoltrecorder zugeführt wird. Die in dem Apparat verwendete Photoröhre arbeitet mit einer beweglichen Maske über der Photokathode. Zum Rekorderteil des Apparats kommt noch ein Kontrollmechanismus für die Probentemperatur. Die Verwendbarkeit des Apparats wurde an einer Probe aus weichgemachtem Polyvinylchlroid gezeigt. Die erhaltenen Ergebnisse liessen sich sehr gut mit den durch visuelle Beobachtung der Verschiebung mit einem Kathetometer erhaltenen vergleichen.