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POLYESTER-RESIN ANCHOR CREEP STUDY

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On November 6, 1979, the Bureau of Reclamation was renamed the Water and Power Resources Service in the U.S. Department of the Interior. The new name more closely identifies the agency with its principal functions — supplying water and power.

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INTRODUCTION

Anchorage systems have long been a weak link in obtaining reliable rock bolt system performance which utilizes nearly the full strength of the steel bolt. Mechanical anchors have proven unsatisfactory for use in certain types of rock and often slip or pull out long before the ultimate strength of the bolt can be realized. Interest was therefore expressed that high-strength, quick-setting resin anchors should be tested, which could effectively replace mechanical anchors, grouting, or both. Because the amount of creep which could be expected from the resin anchors in a rock bolt system was unknown, this research project was initiated to determine the long and short term creep and ultimate load characteristics of the rock bolt resin anchor system.

CONCLUSION

A steel rock bolt resin anchor system was laboratory tested for creep and ultimate load. The resin anchor performed well in all tests; resin curing time was short; early and sustained load carrying capacities were good. An initial tensile load of 166 MPa (24 000 lb/in^2) was applied to the system, and load reduction due to creep was monitored. The tendency of the rock bolt resin anchor system to creep appeared to decrease with time, with a maximum load reduction of 27 percent occurring over an elapsed time of 21 months. The system remained in a stressed condition for the next 3-1/2 years, although no readings were taken during this period. In a subsequent pullout test, the steel bolt failed at a load of 229 kN (51 500 lbf); the resin anchor held securely.

FIELD TESTS

Since the initiation of this research project, resin anchors have been used on several Service (Water and Power Resources Service) projects with great success. Most noteworthy was the Navajo Indian Irrigation Project where resin-anchored rock bolts were

used directly behind the tunnel-boring machine as a ground support system. Where mechanical expansion anchors had failed, the resin anchors did an excellent job of supporting the sandstone-siltstone-shale tunnel rock. Resin anchors were also used successfully at the Auburn damsite near the diversion tunnel outlet, and at Crystal damsite to alleviate slope stability problems.

Although field tests were initiated at the latter two locations, very little information on resin anchor performance was obtained due to personnel changes and ongoing construction work. Verbal reports indicated satisfactory installation and adequate holding capacity. Crystal damsite personnel reported that older resin cartridges required a longer curing time than anticipated, and that temperature greatly influenced the curing time. The Crystal personnel were installing the anchors at temperatures from -1° to 10 °C (30° to 50 °F), resulting in a slow curing rate, but were able to decrease the curing time to an acceptable level by warming the cartridges. Auburn personnel reported that they had experienced no difficulties during installation and that the anchor systems had good holding capabilities. Neither pullout tests nor load monitoring were attempted at either location.

LABORATORY TESTS

The creep and strength tests conducted in the laboratory were performed under more favorable conditions than were generally available in the field. The laboratory test anchorage was placed in tension and the loads monitored for 21 months. The anchorage remained in a tensioned state for the next 40 months, although the load was not monitored. After a total of 61 months, the anchorage was tested to failure.

The laboratory test equipment consisted of a No. 8 steel reinforcing bar, threaded on one end and anchored on the other end with a polyester-resin cartridge (fig. 1) commonly referred to as a sausage. The cartridge contains polyester resins and measured quantities of catalyst and hardener in an easily ruptured plastic capsule. The cartridge is gently

placed in the anchor hole; the steel bar is inserted into the hole far enough to rupture the capsule; and the bar is spun in the resin to mix the plastic, catalyst, and hardner.

The laboratory test anchorage was in a 0.61-m (2-ft) diameter by 1.22-m (4-ft) long concrete cylinder (fig. 2), in which a 38-mm (1.5-in) diameter hole was drilled approximately 0.51 m (20 in) deep. The hole was thoroughly cleaned with a wet swab, loaded with a polyester-resin cartridge (Celtite type HV0001, size 3212), and the steel bar spun in the resin with an electric drill for about 40 seconds. As specified by Celtite, the set time for the cartridge was 1 minute. The length of bond of the anchor was estimated to be approximately 300 mm (12 in). Immediately after the drill was removed, a load cell was installed and a tensile load of 166 MPa (24 100 lb/in^2) or 84.5 kN (19 000 lbf) was applied to the bolt and anchor system. This load indicated exactly 600 μm/m (μin/in) on the strain indicator connected to the load cell (fig. 3). The load cell had been previously calibrated by placing it in a compression testing machine, applying a known load to the cell, then taking a strain reading from a strain indicator connected to the load cell.

A Bureau of Mines type hydraulic pressure cell, which was also included in the system (fig. 3), indicated approximately 12.4-MPa (1800-lb/in^2) pressure. The method of calibrating this pressure cell was the same as for the load cell, except pressure readings were taken directly from the dial indicator gage attached to the pressure cell, and therefore did not indicate the stress applied to the bolt and anchor but rather the pressure of the fluid within the body of the cell. This cell proved to be rather unreliable due to the large effect of temperature on the hydraulic fluid. The load cell to which the strain indicator was connected also exhibited temperature dependence, but to a lesser extent than the Mines pressure cell.

TEST RESULTS

The rate of load loss was closely monitored, particularly during the first week of the test. During the first 22 hours of the test, the load on the bolt decreased from 166 MPa

(24 100 lb/in^2) to 145 MPa (21 000 lb/in^2), a 13-percent reduction. The bolt was retensioned to 170 MPa (24 700 lb/in^2) by tightening the loading nut. During the next 24 hours, load relaxation was approximately 4 percent. The bolt was again retensioned to 166 MPa (24 100 lb/in^2) and the creep monitored for 48 hours, at the end of which load reduction was again 4 percent. The bolt was retensioned to 170 MPa (24 700 lb/in^2) and 71 hours later the bolt had lost 5 percent of its load. The bolt was retensioned a final time to 166 MPa (24 100 lb/in^2) on March 4, 1974, 7 days after initial loading (fig. 4). The room temperature remained relatively constant at 21$\pm$1 °C (70 $\pm$2 °F) during this 7-day period.

From March 4, 1974, to November 30, 1975, load cell, pressure cell, and temperature readings were recorded daily (figs. 5 and 6). During these 21 months, the load fell off 27 percent to 121 MPa (17 600 lb/in^2). Most of the load reduction (21 percent) occurred during the first 7 months following final tensioning, declining to 131 MPa (19 000 lb/in^2) by the end of September 1974. The remaining 14 months showed continuing relaxation, but at a slower rate. The relaxation rate (fig. 6) appears to have increased slightly during the 5 months from June through November 1975.

The bolt was retensioned to 166 MPa (24 100 lb/in^2) in November 1975 (21 months after initial loading), and was not again retightened. The load did not fall off appreciably from that time until April 11, 1979 (40 months later). The sustained creep test loading equipment was removed after a total of about 61 months of loading. The Bureau of Mines pressure cell, which indicated 12.8 MPa (1850 lb/in^2) at the time of last retensioning, was reading approximately 11.7 MPa (1700 lb/in^2) at the end of the creep test, which indicates the ability of the anchor to carry a sustained load.

Shortly after the creep-test apparatus was removed, a hydraulic loading jack was installed, and a load applied to the bolt-anchor system to determine the ultimate strength of the system. The steel bar failed in the threaded section at a load of 229 kN (51 500 lbf), thus the load carrying capacity of the resin bond exceeded that of the steel. According to

a comprehensive study of resin anchors [1]*, this result is predictable based upon bolt and hole diameter considerations.

DISCUSSION OF RESULTS

The gradual decrease of load with time indicates the nature of creep of the system (figs. 4, 5, and 6). As the plotted points indicate, both the Mines pressure cell and the load cell gave readings which were temperature dependent. In an effort to eliminate temperature effects on figures 5 and 6, data points corresponding to a reading temperature of 21 °C (70 °F) were chosen and circled on the plots. It was then possible to fit a line through these points which gave an indication of the temperature independent creep nature of the system. Distribution of data points around the expected behavior curve was thereby improved considerably and the general trend was revealed. As expected, the rate of creep decreased as time advanced and load decreased, except during the final 5 months of recorded data.

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* Number in brackets refers to literature cited in the bibliography.

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[1] Dunham, R. K., "Some Aspects of Resin Anchored Rock Bolting," *Tunnels and Tunnelling*, Dorset, England, vol. 5, pp. 376-385, July 1973

[2] Caverson, B., and J. Parker, "Roof Bolts Hold Best With Resin," *Mining Engineering*, vol. 23, pp. 54-57, May 1971

[3] McLean, D. C., "Use of Resins in Mine Roof Support," *Mining Engineering*, vol. 16, January 1964

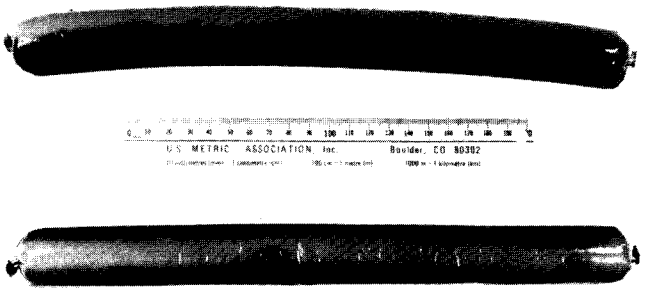

Figure 1.—Celtite resin anchor cartridges, size 3212, as used in test. P-801-D-79409

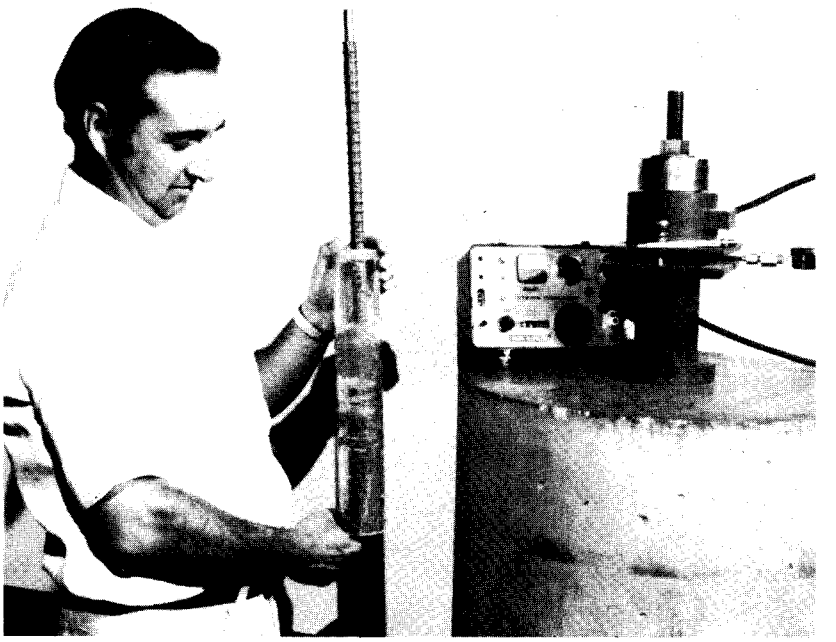

Figure 2.—Concrete test cylinder and apparatus (right). No. 6 rebar is resin-anchored in transparent plastic tube for display purposes (left). P-801-D-79410

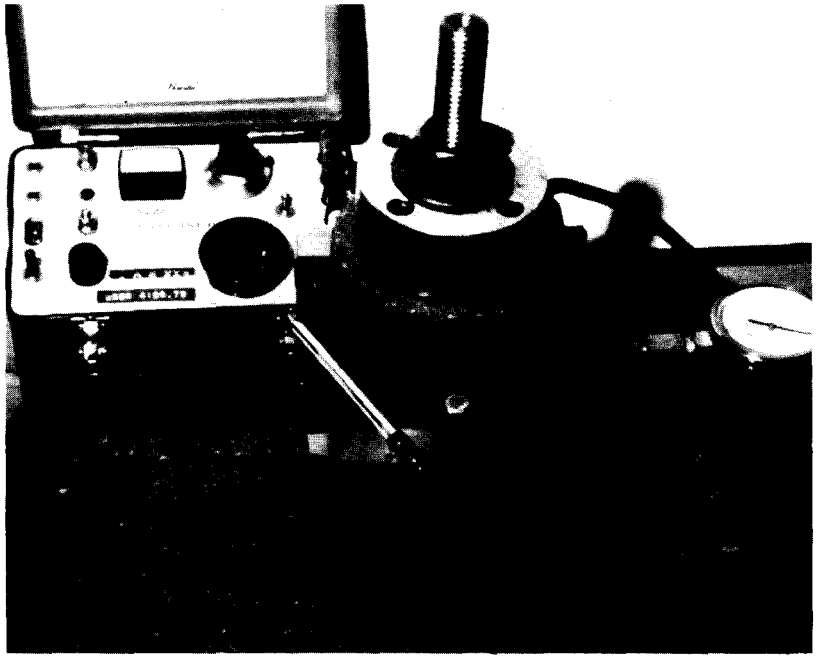

Figure 3.—Load cell connected to the strain indicator, and Bureau of Mines pressure cell. P-801-D-79411

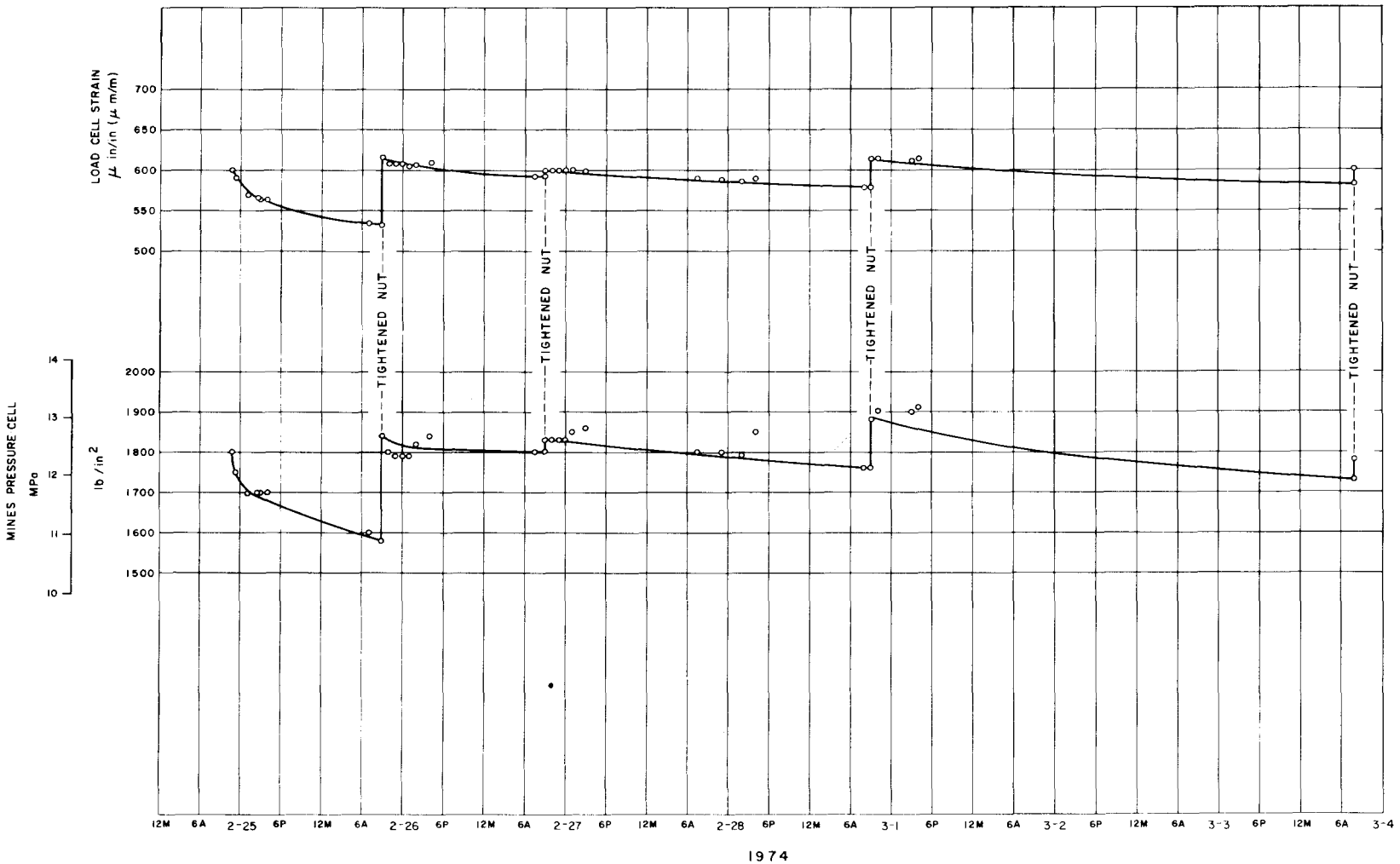

Figure 4.—Graph of loading sequence and creep, first week.

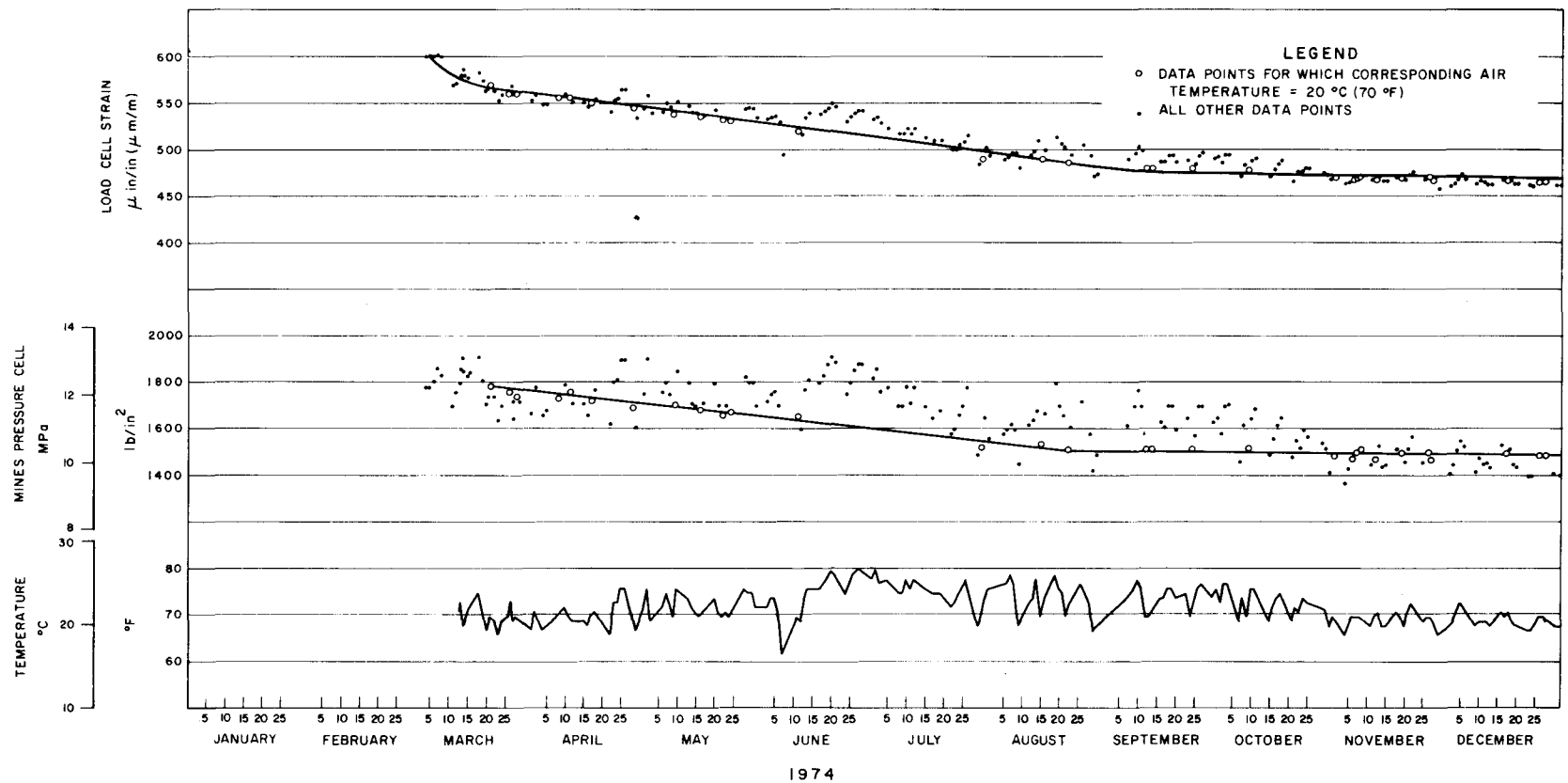

Figure 5.—Graph of creep history 1974.

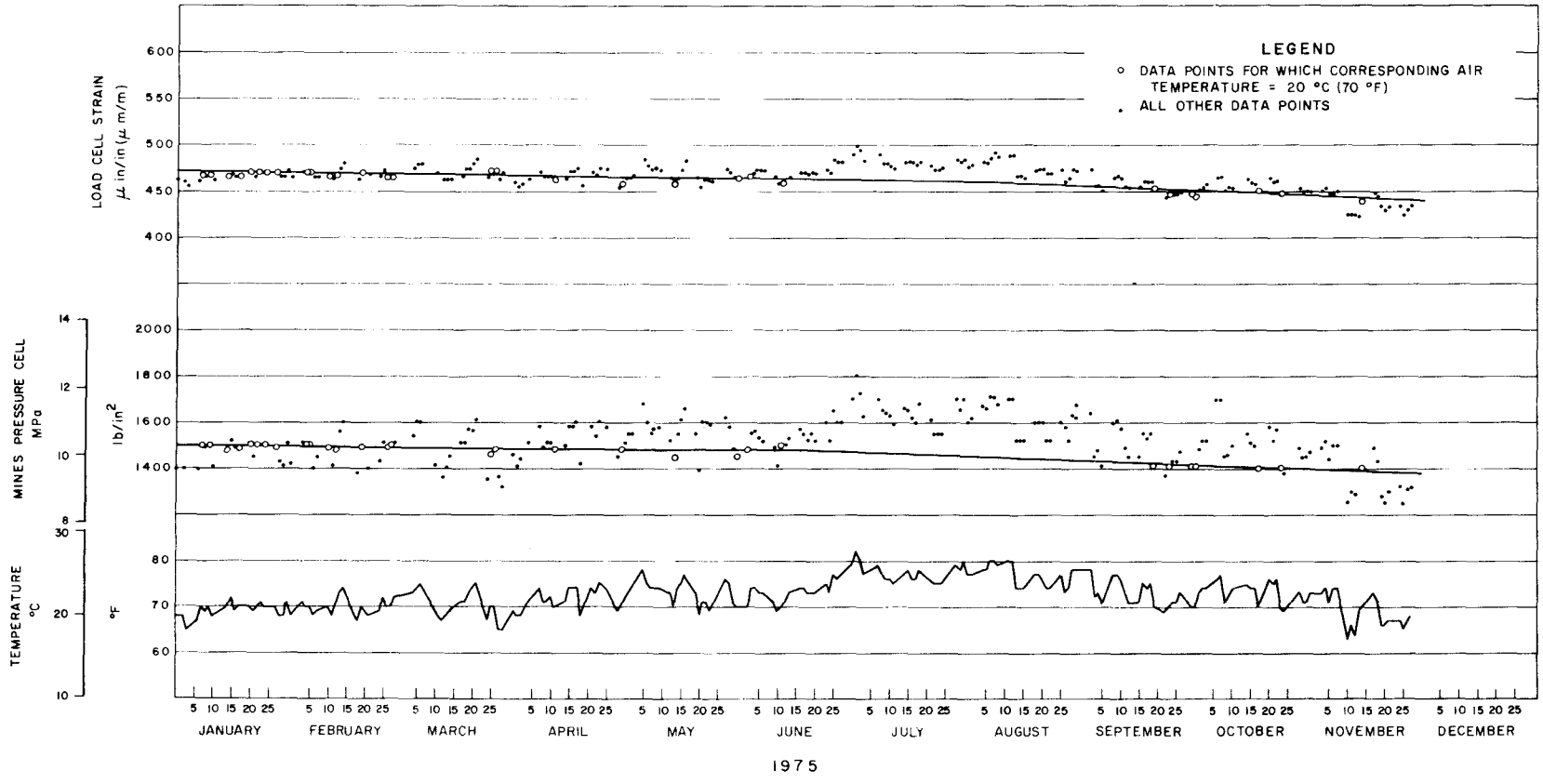

Figure 6.—Graph of creep history 1975.

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