STRENGTH of HIGH-TEMPERATURE MATERIALS

Special information on the properties of refractory materials is needed for the design of hypersonic vehicles because of the relatively severe temperatures that will be encountered. Most data on refractory metals, such as columbium, tantalum, tungsten, and molybdenum, are being gathered in the interest of long-term applications in nuclear reactors or space vehicles. However, there has also been a very definite need for the study of such materials under short-term conditions in probable hypersonic missile trajectories.

At the Applied Physics Laboratory, a machine was designed to measure creep of refractory metals and to determine the creep strength of special alloys at high strain rates. In addition to the machine itself, its designers, M. L. Hill and J. M. Akridge,* developed a novel extensometer and special techniques for temperature measurements.

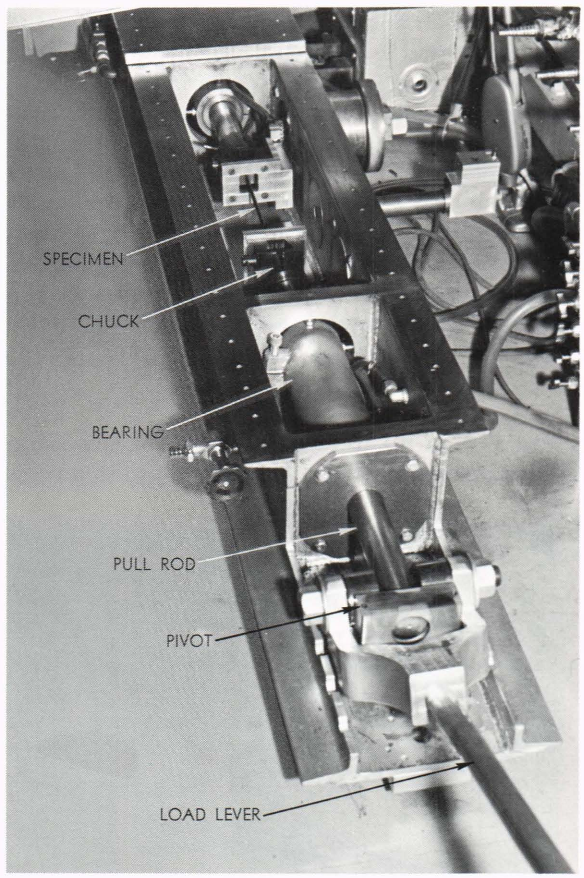

Fig. 1—Horizontal creep frame.

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* M. L. Hill is Supervisor of the High-Temperature Materials Project in the Bumblebee Flight Research Group and J. M. Akridge, formerly a staff member of that Project, is now at the Georgia Institute of Technology doing graduate study in mechanical engineering.

These innovations have produced higher quality data than are often obtained in this type of measurement; yet, the equipment is substantially less complex than devices that have commonly been used for this purpose.

The present apparatus, which makes possible the determination of creep properties of metals at temperatures to about 3300°F, is shown in Fig. 1. It consists of two horizontal channels separated by four bulkheads with a single pivot support for a loading lever. The loading lever exerts a constant force on the 10-inch length specimen through a pull rod that is supported by two axial bearings. A commercial load cell is connected to the end of the fixed pull rod to measure the load on the specimen.

The desired high temperature is produced by passing electrical current through the sample from a low-voltage, high-current transformer. The sample temperature is controlled by using the direct-current output from a photovoltaic pyrometer to operate a thyratron power controller that provides power to the transformer.

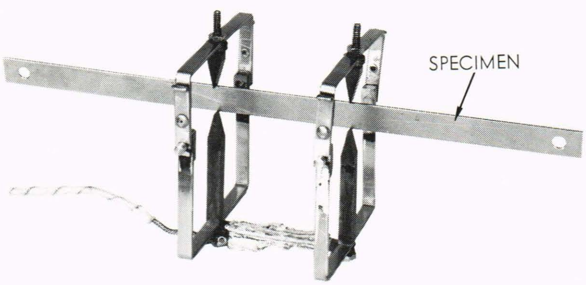

Fig. 2—APL "bent beam" extensometer.

The high temperatures that are of interest preclude the use of conventional extensometers for this work. Other investigators have used photographic techniques, crosshair motion, specially shaped specimens, counterbalanced or float-stabilized lever extensometers, and many other equally complicated devices in attempts to measure strain at high temperatures.

The slow response and inaccuracy of these devices prompted the development of the "bent beam" extensometer shown in Fig. 2. This extensometer consists of a plastic beam having dual strain gages attached to it plus two posts whose knife-edge tips are made of tungsten carbide. The strain gages at the top and bottom of the beam are connected in a bridge circuit that provides a DC output proportional to the bending of the beam during extension of the specimen. Because of its light weight, this extensometer need not be counterbalanced, and, more important, its low inertia permits its use at very rapid loading rates. A special "clip on" feature permits the use of a simple strip specimen that significantly reduces the cost of specimens and improves the reproducibility of loading.

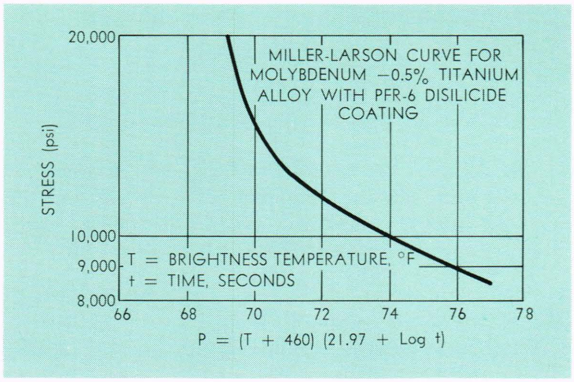

Fig. 3—Parametric plot of short-term, high-temperature creep data as a function of time and temperature.

Some short-term, high-temperature creep data that were taken using this apparatus are shown in Fig. 3. The data are presented on a parametric plot of stress as a function of time and temperature through the aid of the Miller-Larson parameter, *P*. This parameter permits the determination of stress that will result in 1% creep strain for any combination of temperature and time. The molybdenum-0.5% titanium alloy that was used was coated with Pfaudler PFR-6 oxidation resistant coating and is typical of the refractory alloys that have significant strength at temperatures above 2000°F. Similar data have been repeated for other amounts of strain.