INTRODUCTION

Often in the characterization of the mechanical properties of materials at low temperatures, difficulties are encountered in the mating of the Dewar/cryostat to the mechanical test facility. Considerable frustration arises from the fact that common hydraulic or electrohydraulic, servo-controlled testing machines will not accommodate the bulk of a cryostat. Similarly, the actuator position of most testing devices does not lend itself easily to the task of load-frame design and materials testing. There are two design alternatives when setting up a test system for the characterization of low-temperature material response: modification of the testing machine to accommodate an existing research Dewar or fabrication of a special Dewar to mate with an existing mechanical testing system. Either of these processes can be extremely expensive and often results in a final system with limited capability.

Another possibility is the use of lightweight, compact, inexpensive pneumatic actuators with a pneumatic logic circuit for load variation and control. A materials testing system can be designed that is flexible enough to accommodate nearly any of the wide variety of open-mouth research Dewars presently available and is much less expensive than modifying an existing material test system to fulfill the same function.

SPECIFICATIONS

In the determination of the mechanical response of a material at low temperatures, small specimens are often used to conserve cryogen. Thus, the total load range needed to characterize the response will generally be near or below 20 kN. This relatively low-load range is ideal for a wide variety of pneumatic actuators and is well suited for most industrial air supplies.

Although the total deformation of most materials decreases with temperature and small specimens usually exhibit little elongation or contraction to failure, there are some materials, such as polymeric films, that may experience 200 or 300% strains. This may necessitate a testing facility with a stroke capability on the order of 10 cm. Again, pneumatic actuators have this capacity.
Currently, many programs are concerned with the investigation of fatigue, creep, or the fracture characteristics of materials at low temperatures. To produce these more complex load histories, the testing machine must be programmable to some degree. Typically, this control has been accomplished mechanically, hydraulically, or electronically; however, pneumatic logic circuits can be designed to fulfill an extreme variety of desired responses with differing degrees of complexity.

A material test system can be described as being composed of three basic components: (1) the loading device or actuator, (2) the load or reaction frame, and (3) the control mechanism. The physical size of the actuator and the load capacity are defined by the material to be tested, the specimen size, and the physical constraints of the test environment. The reaction frame design is dependent on the Dewar size, test temperature, actuator mounting, specimen characteristics, and the type of test to be performed. The controlling mechanism depends almost totally on the type of test to be performed.

The particular system under consideration in this paper was designed specifically to be used with several magnet Dewars capable of sustaining 4.2 K for extended periods. The test facility had to be flexible enough to perform the following tasks:

1. Apply monotonic tensile or compressive loads at varying rates up to 10 kN.
2. Apply and sustain a constant load for a period of days either in tension or compression.
3. Apply cyclic loads in a tension–tension, compression–compression, or fully reversed mode.
4. Apply cyclic loads about some mean tensile or compressive load.
5. Offer a variety of cyclic mean-load and cyclic-load ranges that could be changed easily without disruption of the testing sequence.
6. Offer an extensive stroke range to allow testing of high deformation materials.
7. Be compact and lightweight.
8. Cost less than a modified Dewar and reaction frame, which could have been used in existing large electrohydraulic, servo-controlled materials test systems.

The system that was built and is illustrated in Fig. 1 satisfies these preliminary criteria. The total load capacity of the actuator is 11,500 N tension or compression with an air supply at 770 kPa. With suitable pressure regulation, this load can be sustained for extended periods of time. The rate of loading can be varied from approximately 20 N/s to 6.7 kN/s. The rate of unloading can be varied independently of the rate of loading through the same range. Virtually any combination of tension–tension, tension–compression, compression–compression, and fully reversed cyclic loading sequences can be obtained with a maximum load range of 23 kN. The mean- or cyclic-load ranges may be preprogrammed for immediate application or manually adjusted or varied during a test sequence. The particular double-acting air cylinder used has a total stroke range of 5 cm.

The frequency response of this particular system is load dependent but can be varied from about 1.0 Hz at 9 kN to 5 Hz at 2 kN. These frequencies have proven to be adequate for the test programs run to date.

SYSTEM DESIGN

The actuator chosen for the material test system was obtained from Bellofram Corporation, Burlington, Massachusetts. This unit has an effective surface area of