

AIR PERMEABILITY OF PARACHUTE FABRICS

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Air permeability of parachute fabrics has been one of the important properties included in government specifications covering the manufacture of such material. The performance of the parachute is considerably affected by variation of the air permeability of the canopy material. Rate of descent, stability and magnitude of opening shock are all affected or dependent upon the air permeability of the fabric.

Uniform performance of all parachutes of a particular design is to be desired. Experience often indicates wide variation of parachute performance when comparing parachutes made from the same lot of cloth. On closer examination, the variation in performance is found to compare to the variation of air permeability of the cloth. Therefore, the production of uniformly woven cloth, free from flaws and having uniform air permeability, is to be desired. Furthermore, it is desirable to be able to furnish the weaver with directions as to the yarn denier, twist per inch, numbers of warp and filling threads per inch, weave pattern and finish specification necessary to provide a fabric having a specified or predictable permeability.

Research personnel of the Georgia Institute of Technology were enlisted to help in the solution of the problem involving air permeability of parachute fabrics. The first phase consisted in the design and construction of a low-pressure permeometer having a range of pressure differential across the fabric sample equivalent to 0 - 50 inches of water (2 1/2 pounds per square inch maximum pressure). Also, many yards of nylon, orlon and dacron fabrics were specially woven to include variations of weave pattern and warp and filling ends per inch. These fabrics, plus numerous samples of standard and special parachute fabrics, furnished by the Air Force, were tested on the Low-Pressure Permeometer.

The Low-Pressure Permeometer is shown in Figure 83. The compression of the air is achieved by a 7 1/2 Horsepower fan. Variation of pressure is accomplished by means of the conical shaped plug valve located inside a box containing air filters. The air leaving the fan passes through an orifice section which was designed and calibrated in accordance with specifications of the American Society of Mechanical Engineers. The orifice meter measures the quantity of air flowing through the cloth. The fabric sample is clamped to the end of the air duct in a special sample holder. This sample holder, which

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accommodates a six inch diameter sample, is shown in Figure 84. The pressure differential across the orifice is measured by means of an alcohol micromanometer. The pressure differential across the fabric is indicated on a large water manometer.

Low-pressure (0-55 inches of water) air permeability studies of the nylon, orlon and dacron fabrics generally indicated that the air permeability was a function of the size and number of warp and filling ends per inch, and that the variation of weave pattern did not indicate any significant difference. Figure 85 demonstrates the effect on air permeability resulting from variation of the size and number of threads per inch. Figure 86 shows the effect resulting from variation of weave patterns.

The cloth investigated was subjected to light scouring, stretching and light calendering. Comparison of air permeability of finished versus unfinished cloth, Figure 87, indicated a maximum variation of air permeability. Of the twenty-three possible variables contributing to variation of air permeability that were suspected, only these few described here were found to be critical in the low-pressure phase.

We know that the advent of high-speed high-altitude airplanes have caused pressure differentials across parachute fabrics far in excess of that equivalent to 50 inches of water. In fact, it was decided that the air permeability studies should be extended to include pressure differentials up to that equivalent to fifteen hundred inches of water or 54 pounds per square inch gage. This necessitated a second research phase requiring design and construction of a high-pressure permeometer which will be described later.

Certain that the elastic properties of the fabric play an important part in the air permeability of parachute fabrics at high-pressures, it was decided to make a study of these elastic properties without air flow. Therefore, a special testing machine was designed and constructed that applies simultaneous tension loads in both the warp and filling direction. Figure 88 is a general view of the Biaxial Fabric Tension Testing Machine. A close-up of the fabric in the clamps and with the Bidimensional Extensometer in place is shown in Figure 89.

Electric resistance strain gages, mounted on the load arms of the clamp carriages and on the two flexures of the extensometer, transmit variation of electric current through a Carrier Wave type amplifier and operates sensitive microammeters located in a photo observer. The microammeter readings are recorded on a 16 millimeter moving picture film. From this data, curves of load versus elongation for both warp and filling direction are drawn.

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It was anticipated that the weave pattern would have a significant effect on the elastic properties of the fabrics. Figure 90 is a comparative plot of the biaxial tension test results for a nylon fabric having the same denier, warp and filling ends per inch varying only in weave pattern. Here, the plain, twill and satin weaves are compared.

A special insulated hood was provided for the machine. High temperatures (+130°F.) were obtained by use of heating elements. Low temperatures (-55°F.) were obtained by packing dry ice in the space around the clamp carriages. The effects of temperature variation on the elastic properties of a plain weave nylon cloth are indicated in Figure 91. Here the biaxial load versus elongation curves, taken at room temperature, are compared with the low and the high temperature curves for the same material.

A special high-pressure permeometer was designed and constructed to conduct the high-pressure phase of the research. A supersonic wind tunnel was modified to become the Georgia Tech High-Pressure Permeometer. This permeometer equipment will make possible both steady state and impact load air permeability tests in the pressure range equivalent to 55 - 1500 inches of water. Actually, this apparatus is expected to permit tests up to pressure differentials equivalent to 2100 inches of water or approximately 75 pounds per square inch gage. This permeometer, consisting of a large air compressor, adsorption dryer, 1000 cubic foot reservoir, pressure regulator, and cut-off valves, orifice meter section and sample holders, is housed in two buildings. A schematic view of the permeometer is shown in Figure 92.

Air pressure and temperature changes are picked up by electric strain gage type transducers and bi-metal thermocouples. The signals are then fed into a 9-Channel photo-recording oscillograph. The inertia free pick-ups and the versatile oscillograph permits the study of air permeability of the fabrics under a wide range of loading conditions varying from impact loadings comparable to the opening shock to the steady state condition of the descent.

Variation of air temperature is achieved in a variety of ways. By shutting down the flow of water through the air compressor after-cooler, high temperatures of the order of +168°F. are obtained. Introduction of liquid air into the air stream results in the low air temperatures of the order of -50°F. Varying the amount of drying will permit some variation of humidity. Humidity is indicated by the dew point of the stored air prior to tests.

Biaxial tension loads in the fabric sample are measured during high-pressure permeability tests. A special Biaxial Tension Measuring Sample Holder, Figure 93, has been designed and constructed.

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Electric resistance strain gages, mounted on the cantilever load arms, transmit the variation of fabric tension load through the Carrier Wave Type Amplifier to appropriate channels of the Nine-Channel Oscillograph.

Figure 94 shows, comparatively, the high-pressure permeability of several nylon cloths. These data were taken at normal machine operating conditions. Figure 95 shows the effect of temperature on the high-pressure permeability of a plain weave nylon cloth. Figure 96 shows the fabric tension load variation with air permeability under the effect of high-pressure differentials across the cloth.

So far, we have studied many aspects of the air permeability of parachute type cloths. Of the 23 possible variables, many have been ruled out as having insignificant effect. The importance of elastic properties on the air permeability of parachute type cloths requires further study. However, it appears certain that we will soon have a knowledge of the important factors to be considered in providing parachute type cloth having predictable permeability characteristics and uniform air permeability.

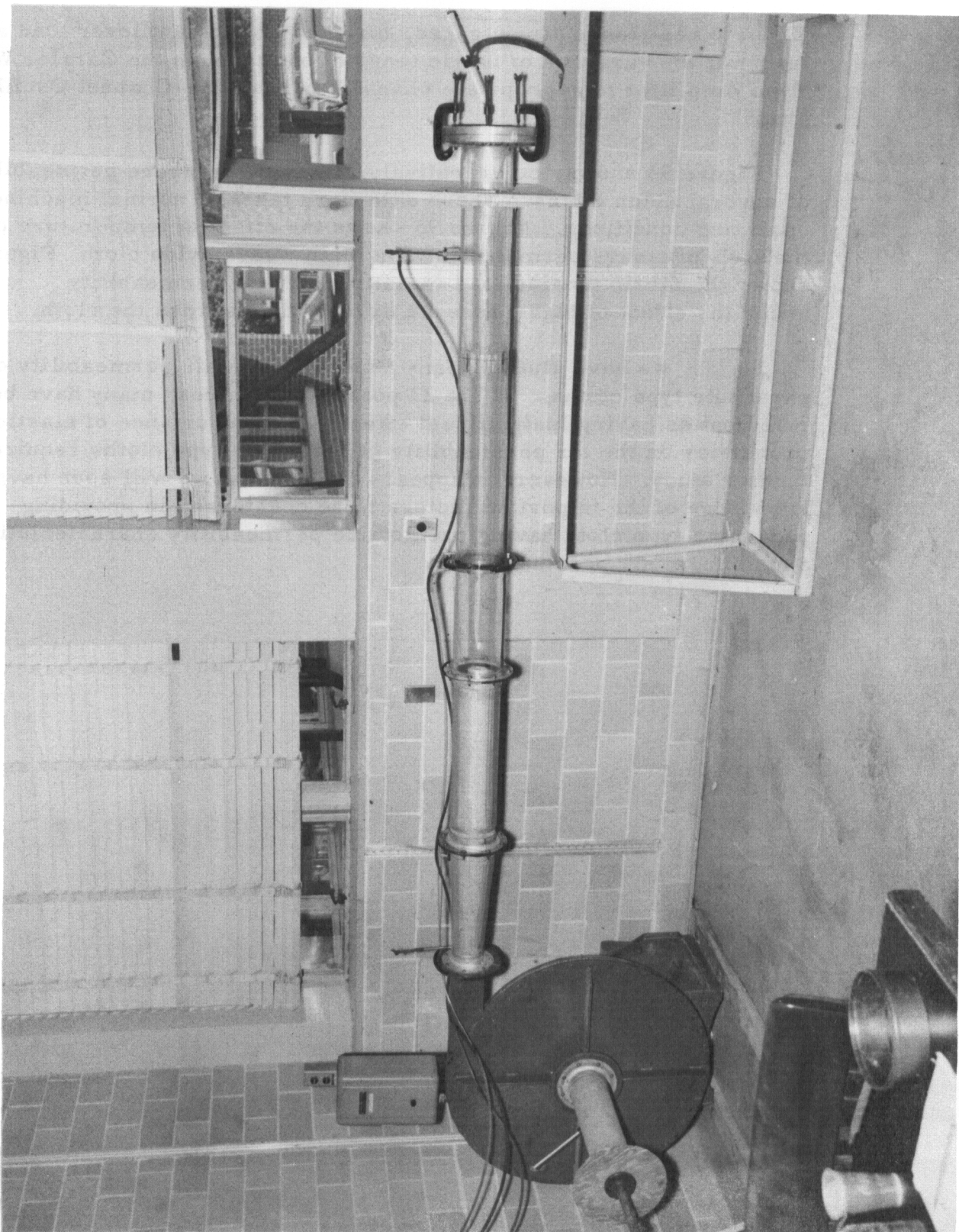


Figure 83 The Low-Pressure Dynamometer

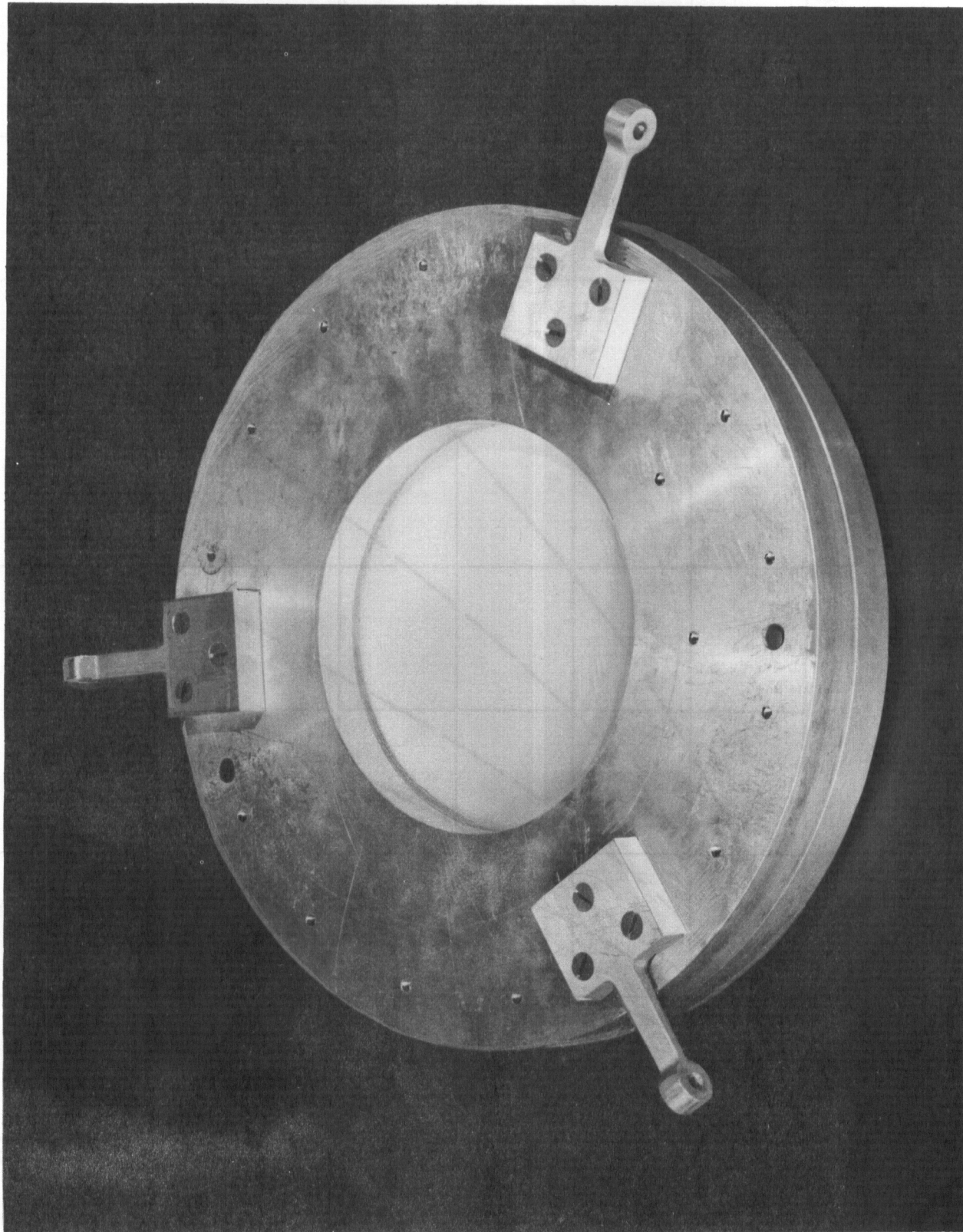


Figure 84. Sample Holder.

Figure 85. Effect of Varying Number and Size of Threads on Air Permeability.

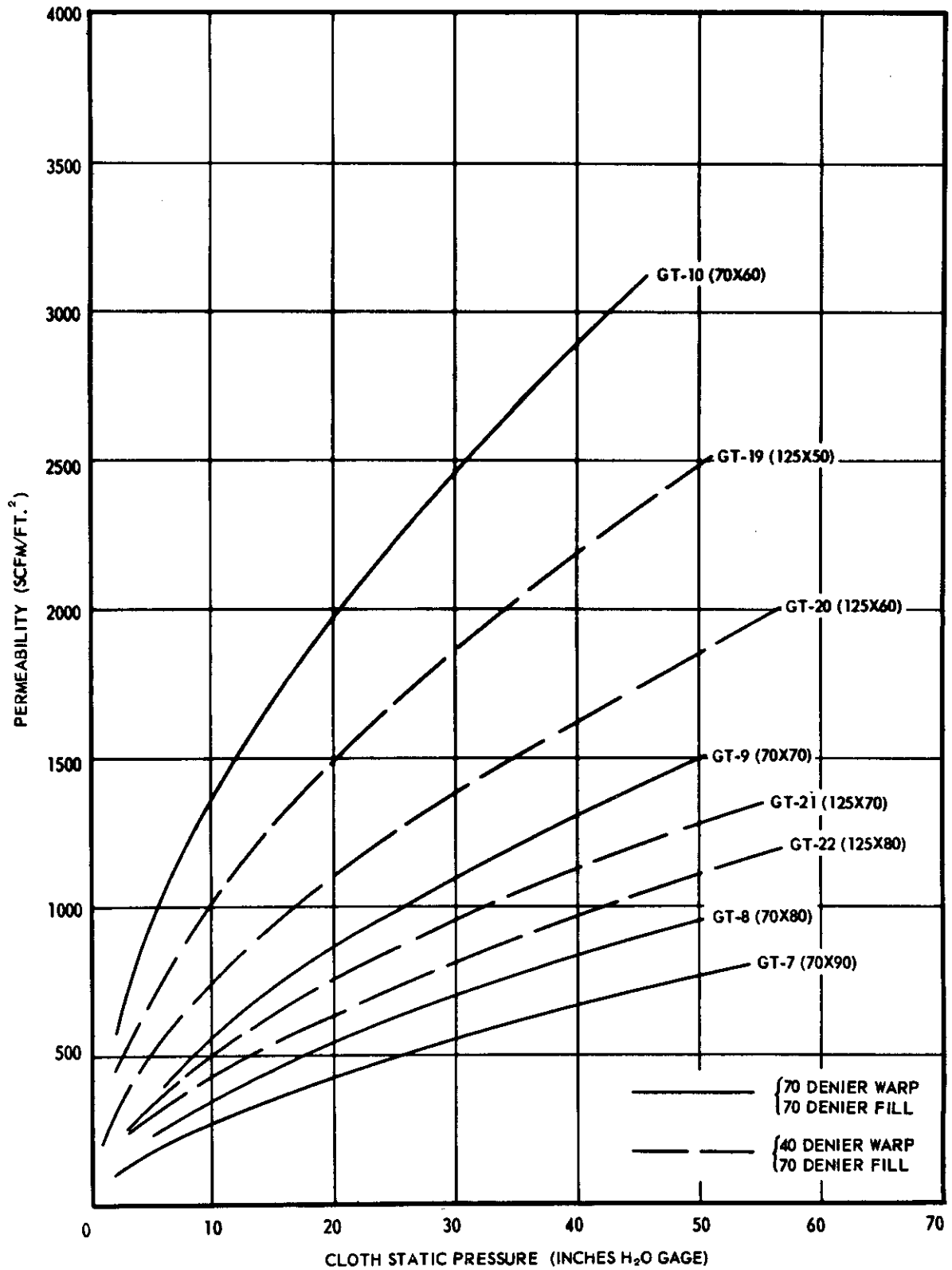


Figure 85. Effect of Varying Number and Size of Threads on Air Permeability.

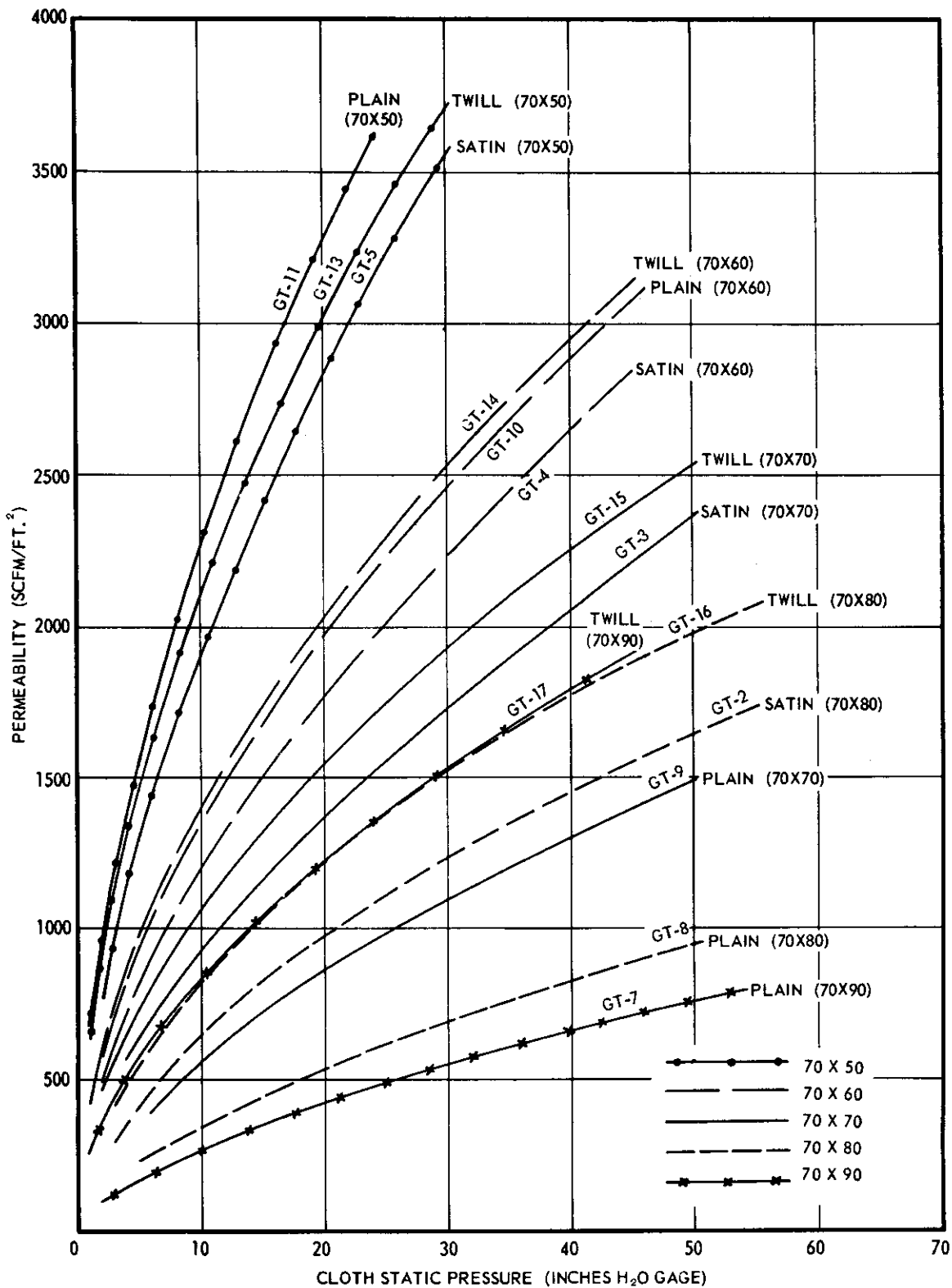


Figure 86. Effect of Variation of Weave Pattern on Air Permeability.

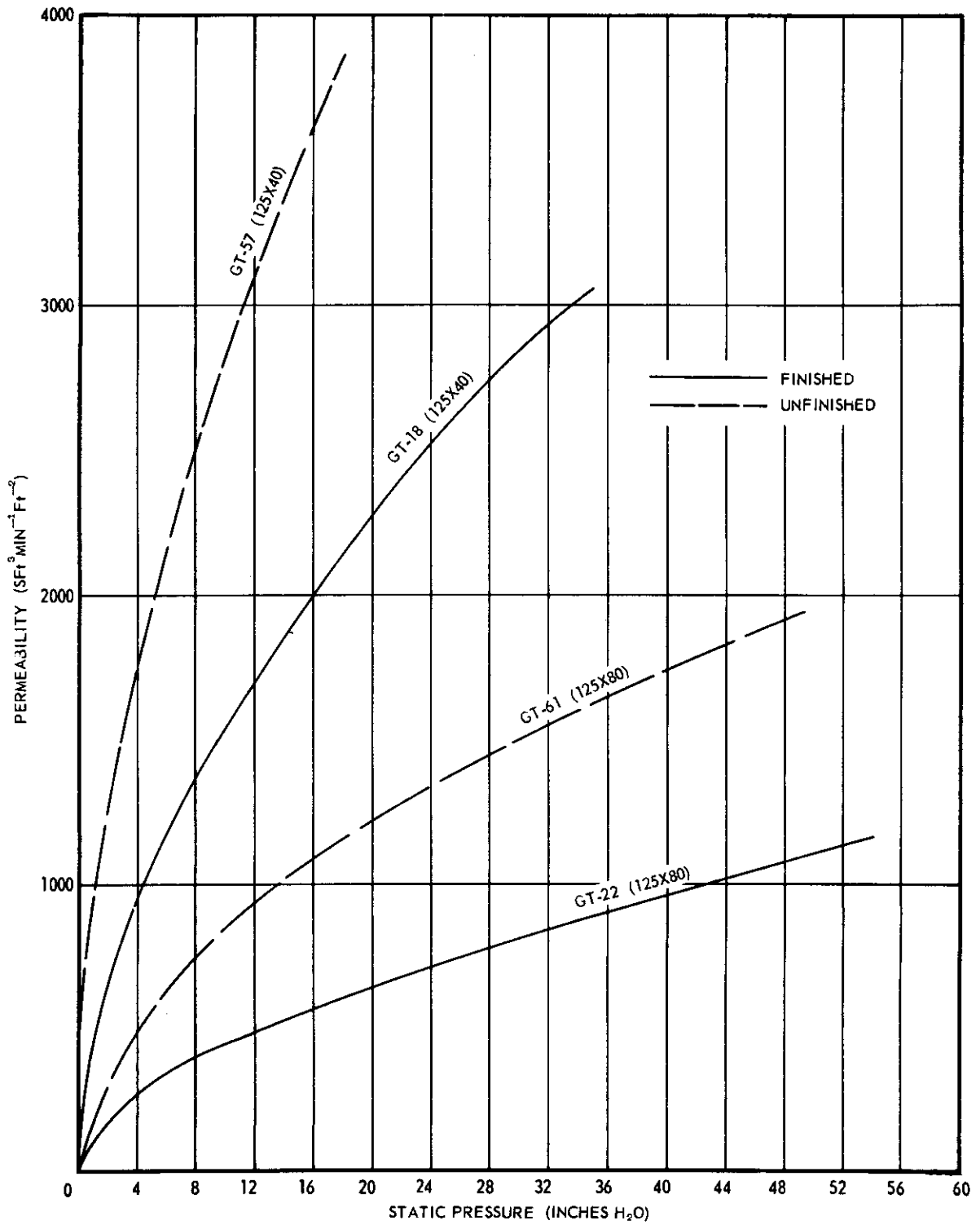


Figure 87. Effect of Finish on Air Permeability.

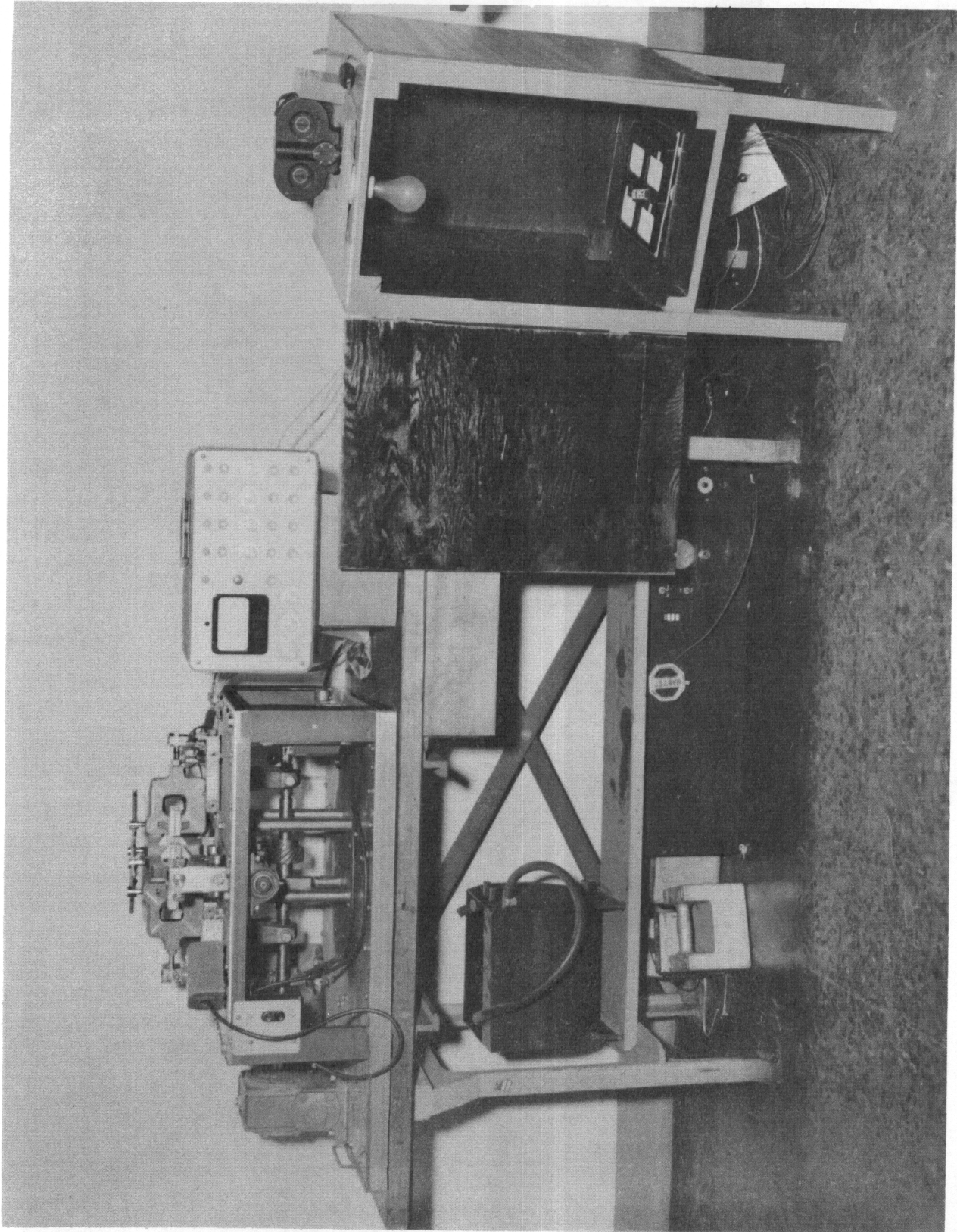


Figure 88. A General View of the Biaxial Fabric Tension Testing Machine.

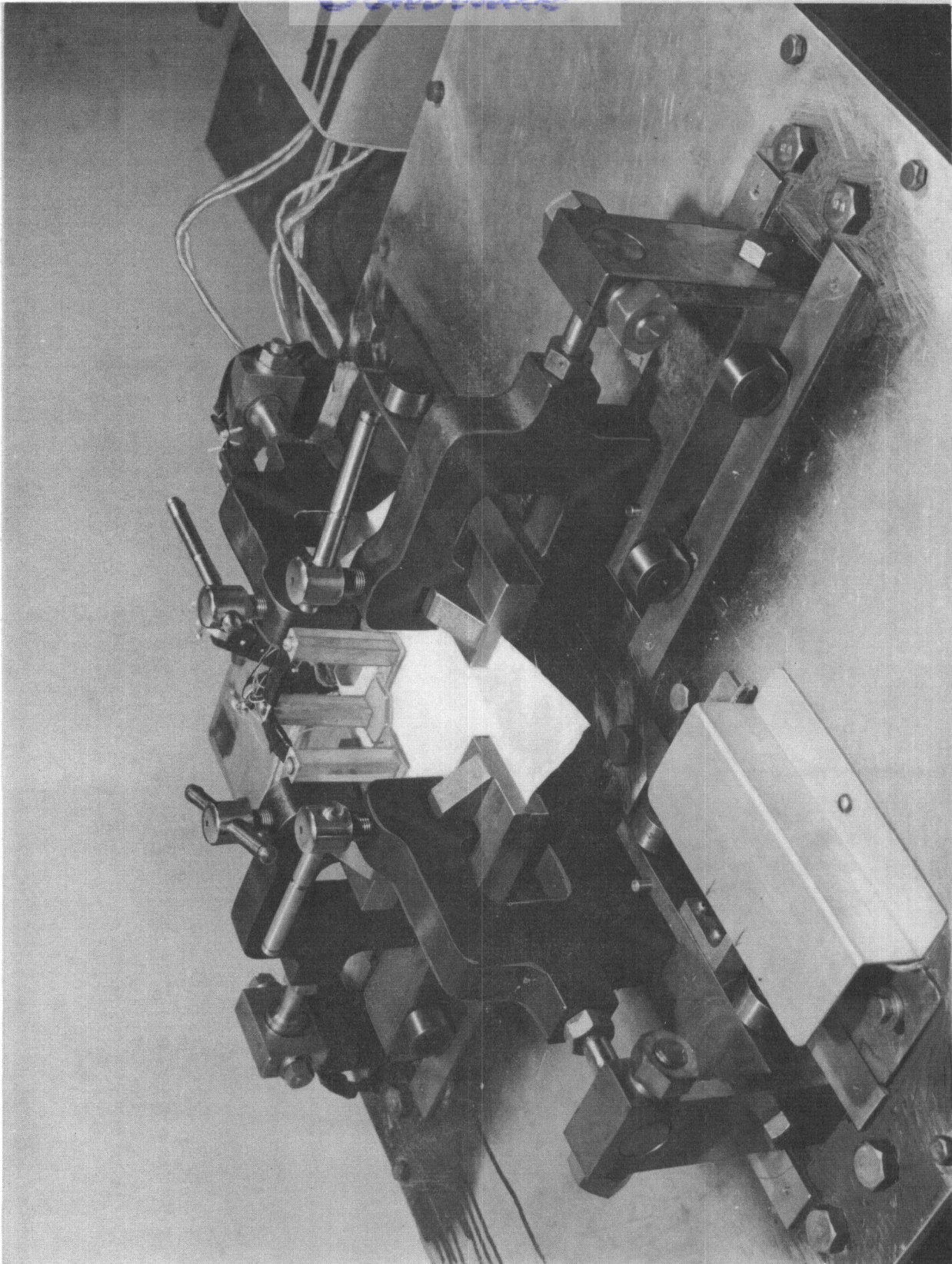


Figure 89. A General View of the Biaxial Extensometer in Place on the Test Fabric.

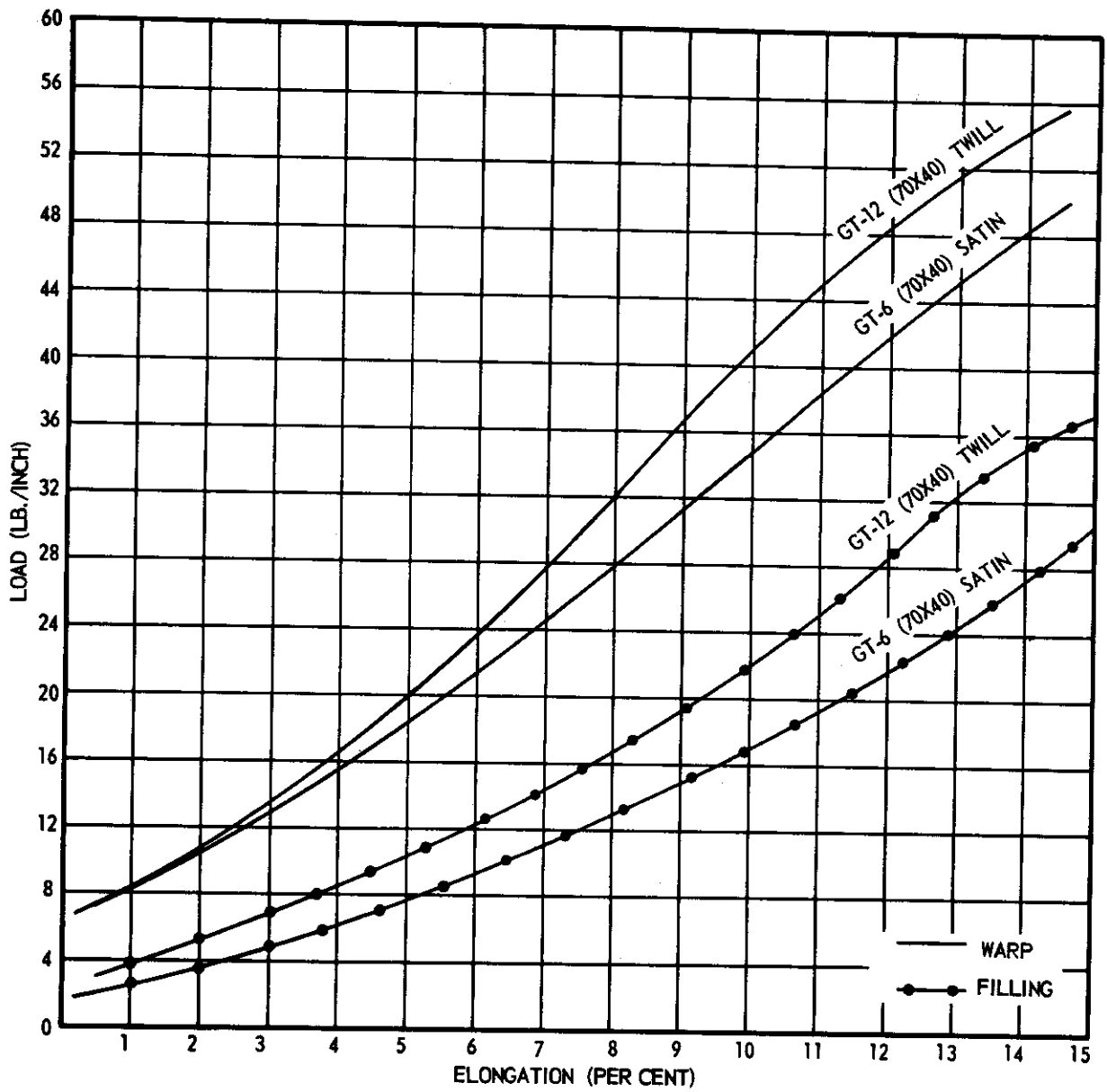


Figure 90. Effect of Weave Pattern on Cloth Elastic Properties (No Airflow).

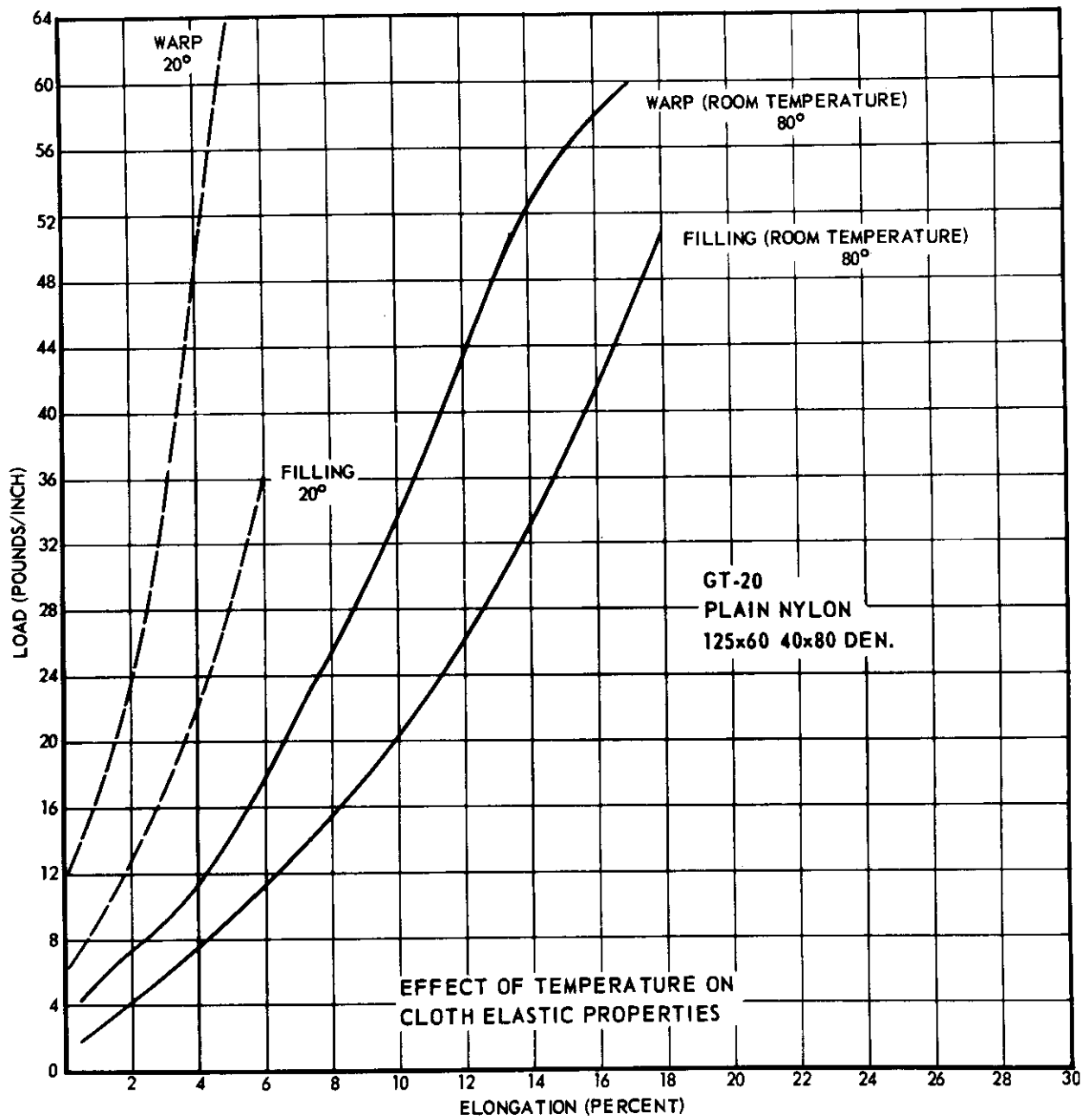


Figure 91. The Effects of Temperature Variation on the Elastic Properties of a Plain Weave Nylon Cloth.

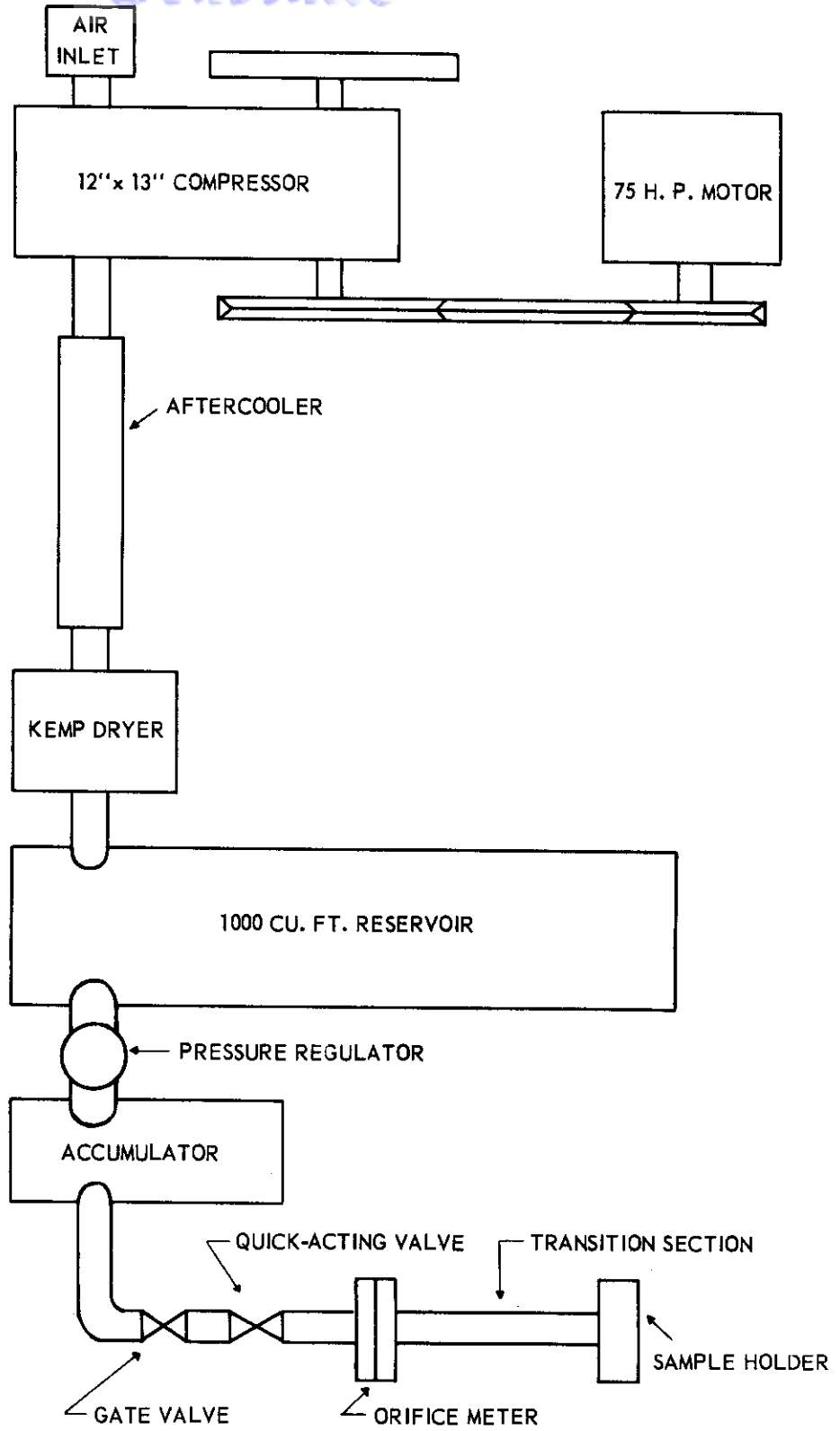


Figure 92. A Schematic View of the High-Pressure Permeometer.

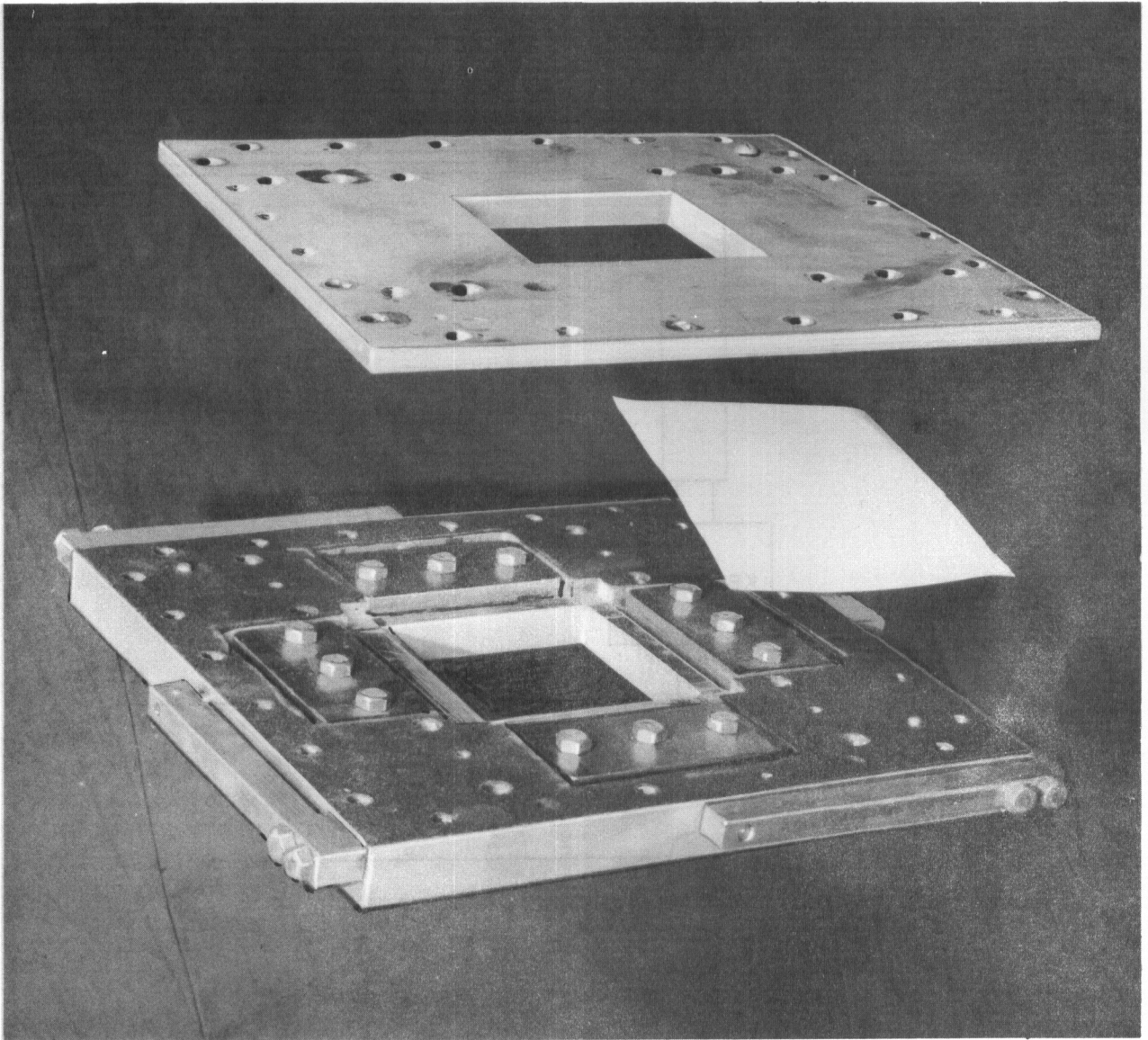


Figure 93. A Special Biaxial Tension Measuring Sample Holder.

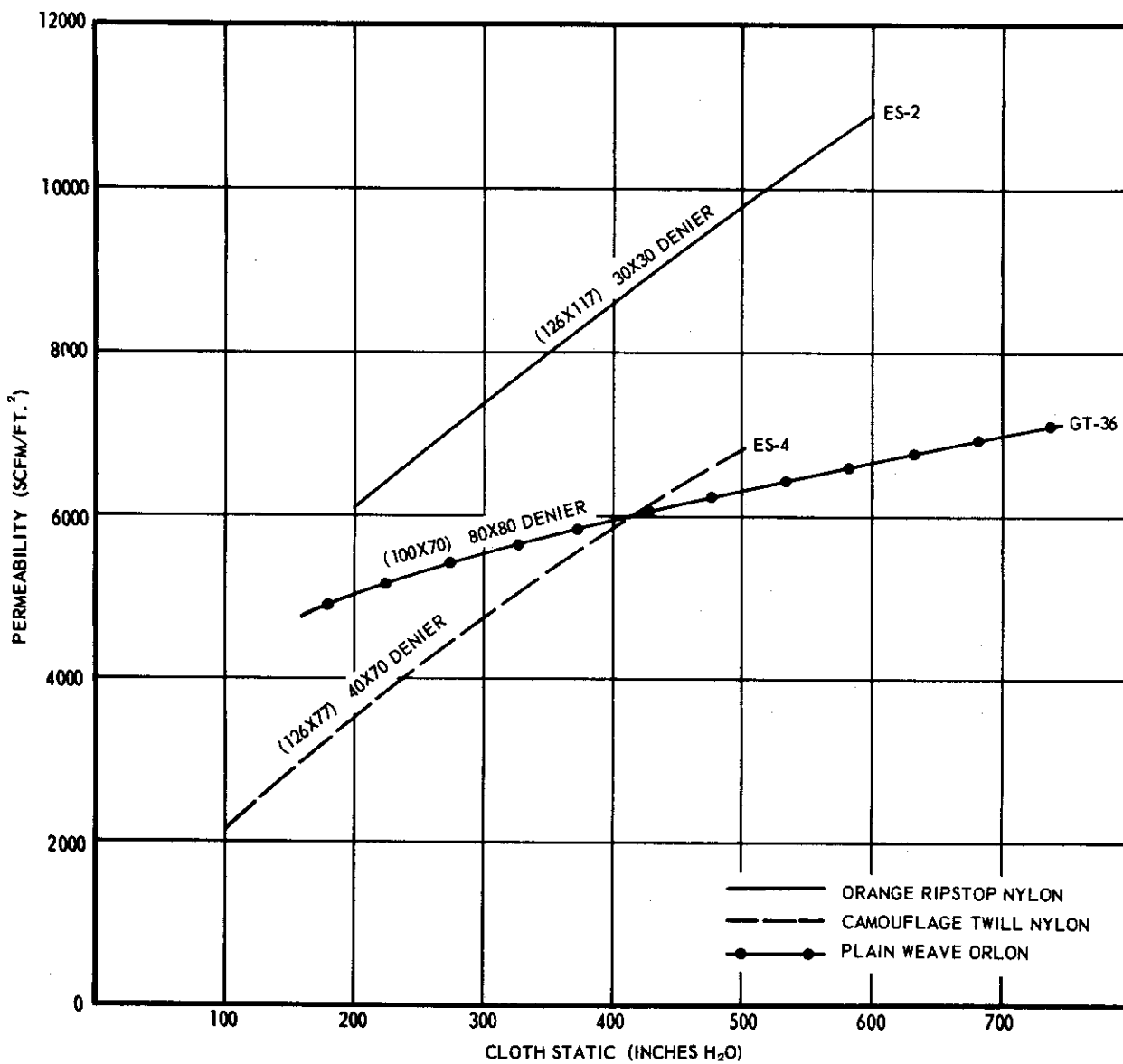


Figure 94. High Pressure Air Permeability of Several Parachute Cloths.

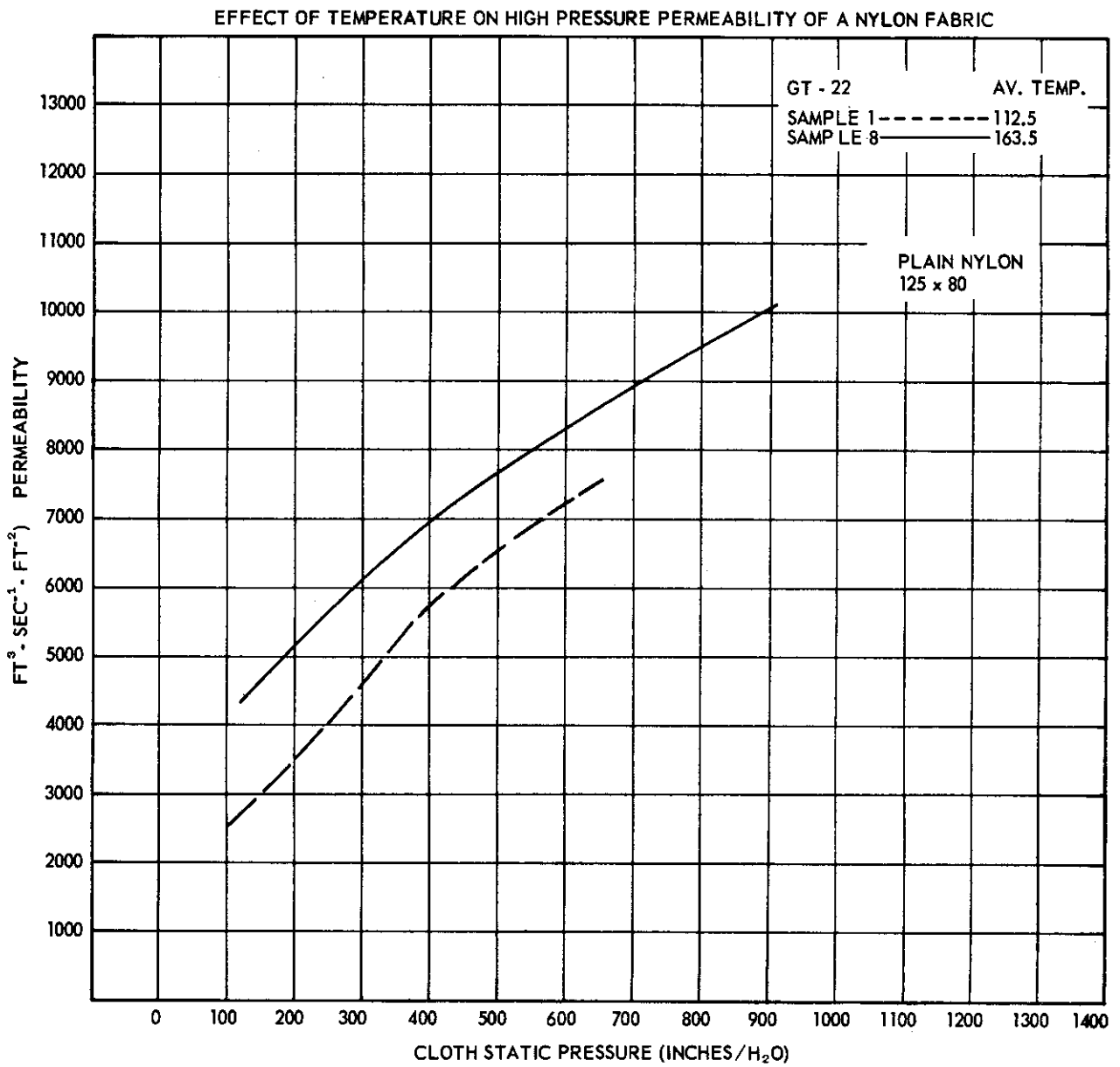


Figure 95. The Effect of Temperature on the High-Pressure Permeability of a Plain Weave Nylon Cloth.

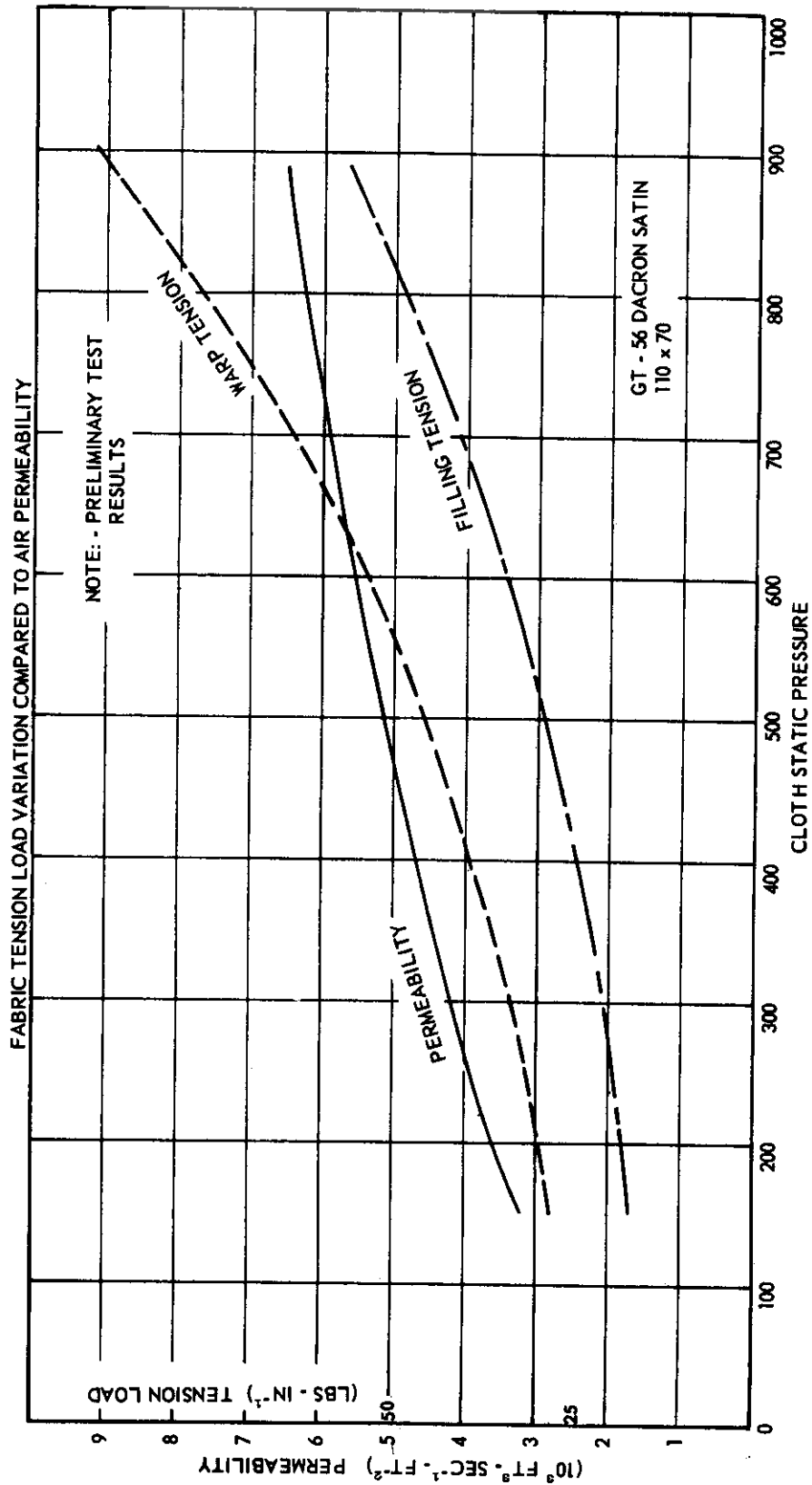


Figure 96. The Fabric Tension Load Variation with Air Permeability Under the Effect of High-pressure Differentials Across the Cloth.