Georgia Institute of Technology
STATE ENGINEERING EXPERIMENT STATION
Atlanta, Georgia

December 14, 1950

Commanding General
Air Materiel Command
Wright-Patterson Air Force Base
Dayton, Ohio

Attention: Materials Laboratory
Engineering Division
MCREXM8

Subject: Progress Report No. 1
Contract No. AF 33(038) - 15624
E. O. No. 602-193 SR-7S

Dear Sir:

Progress to date, (November 15, 1950, through December 14, 1950), has consisted of analysis of the problem and determination of some of the program requirements.

Sections I and II of the program are under way.

Plans for equipment for experimental purposes have been considered, and bid requests have been issued for a blower and related accessory equipment.

A literature survey has been initiated; several reports from the Institute of Textile Technology concerning porosity and permeability are being examined.

Personnel assigned to the project at present include:

Dr. M. J. Goglia, Project Director, Part Time
Mr. H. W. S. LaVier, Research Engineer, Part Time
Mr. G. B. Fletcher, Research Engineer, Part Time
Dr. J. L. Taylor, Research Professor, Part Time
Catherine Widerquist, Research Assistant, Part Time

Respectfully submitted,

M. J. Goglia
Project Director

Approved

Gerald A. Rosselot, Director
State Engineering Experiment Station

Georgia Institute of Technology
STATE ENGINEERING EXPERIMENT STATION
Atlanta, Georgia

January 14, 1951

Commanding General
Air Materiel Command
Wright-Patterson Air Force Base
Dayton, Ohio

Attention: Materials Laboratory
Engineering Division
MCREXM8

Subject: Progress Report No. 2
Contract No. AF 33(038) - 15624
E. O. No. 602-193 SR-7S

Dear Sir:

The analysis of the problem of flow of fluid through a parachute fabric continues. The data of A. F. Robertson's reports from the Institute of Textile Technology on air permeability studies of parachute and open weave fabrics are under examination. An effort is being made to find a correlation between a resistance coefficient and a Reynolds' number based upon a suitable characteristic length.

The receipt of photostatic copies (from AMC) of two theses is acknowledged. These are:

"Development of a Theoretical Formula for Calculating Air Flow through Woven Materials Under Certain Restricted Conditions" by Kenneth W. Longnecker (Lowell Textile Institute) and "The Air Permeability of Woven Fabrics" by Karl Avery Williams, Jr. (Rensselaer Polytechnic Institute). These will be examined for contributions to the problem at hand.

Detailed plans of equipment for holding samples and measuring air flows are being drawn; a motor-blower assembly has been ordered. Delivery is delayed by the present situation, but priority has been applied and procurement will be expedited in every way possible.

A telephone conversation with AMC personnel concerning specifications for standard parachute fabrics has been helpful. Typical samples of the three standard parachute fabrics have been promised; the receipt of one sample is acknowledged. These samples will be examined in accordance with Section III of the program.

There have been no changes in personnel since the last report.

Respectfully submitted,

M. J. Goglia,
Project Director

Approved:

Gerald A. Rosseldt, Director
State Engineering Experiment Station

GEORGIA INSTITUTE OF TECHNOLOGY

THE STATE ENGINEERING EXPERIMENT STATION

ATLANTA, GEORGIA

February 14, 1951

Commanding General
Air Materiel Command
Wright-Patterson Air Force Base
Dayton, Ohio

Attention: Materials Laboratory
Engineering Division
MCREXM8

Subject: Progress Report No. 3
Contract No. AF 33(038) - 15624
E. O. No. 602-193 SR-7S

Dear Sir:

A study of A. F. Robertson's reports* from the Institute of Textile Technology continues. Since these reports do not include the experimental data that would give information relating air flow to variation of fabric geometry under air loading, an opinion of Robertson's method of correlation must be delayed. An attempt is being made to determine if the original data are available for scrutiny. The idea of likening a fabric to a wire screen is subject to a knowledge of the behaviour geometrically of the fabric when subject to air loading. In Robertson's work the variation of the characteristic length parameter used in the calculation of the Reynolds number is neglected; the analysis of the mechanism of air flow through the fabric involves of necessity the inclusion of the variation of fabric geometry. It is thought that a length parameter characteristic of the fabric under air loading might be obtained in an inferential manner similar to a method employed to determine such a parameter for beds of particulate material. This idea is being examined further. In order to verify any conclusion concerning a characteristic length determined in this manner, all fabrics subject to study will be examined under air loading that measurement of changes in fabric geometry might be effected.

The theses by Longnecker and Williams acknowledged in Progress Report No. 2 are being studied by project personnel.

The design of equipment plans is progressing satisfactorily. A rig is being constructed to examine the drag coefficient of sample parachute

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* Air Porosity of Open Weave Fabrics
I Metallic Meshes
II Textile Fabrics

Technical Reports to Office of Naval Research
Contract No. N8-ONR-79801
Project No. NR 033 311
ITT Project 5007

fabrics; these measurements will be made in the three-foot wind tunnel of the Daniel Guggenheim School of Aeronautics at Georgia Institute of Technology.

The Nylon Division (Wilmington) of E. I. du Pont de Nemours & Co. is making available ten pounds each of 30 and 40 denier nylon yarns for warps and twenty pounds of 70 denier for filling.

One sample of parachute fabric has been received from AMC as indicated in Progress Report No. 2; four additional samples are expected as per letter from AMC under date of 10 February 1951.

Satisfactory progress is being made in Sections I and II of the program.

Catherine Widerquist was removed from this project January 22. Otherwise, personnel remain the same.

Respectfully submitted,

M. J. Goglia
Project Director

Approved:

Gerald A. Rosselot, Director
State Engineering Experiment Station

GEORGIA INSTITUTE OF TECHNOLOGY
THE STATE ENGINEERING EXPERIMENT STATION
ATLANTA, GEORGIA

March 14, 1951

Commanding General
Air Materiel Command
Wright-Patterson Air Force Base
Dayton, Ohio

Attention: Materials Laboratory
Engineering Division
MCREXM8

Subject: Progress Report No. 4
Contract AF 33(038) - 15624
E. O. No. 602-193 SR-7S

Dear Sir:

A detailed re-examination of the reports from the Institute of Textile Technology alluded to in Progress Report No. 3 will not be possible as the original data are not available to the personnel of subject project. Accordingly, an opinion is being prepared on the basis of data contained in those reports.

Some preliminary observations have been made on the drag characteristics of the one nylon parachute fabric mentioned in Progress Report No. 2. (The four additional samples promised have not as yet been received.) A sample six inches in diameter was placed in the three-foot wind tunnel at stream speeds of 60, 80, 100 and 120 feet per second. No measurable change in drag coefficient was observed upon the application of a clear lacquer to the fabric. This is in agreement with Jones.* The British R and M 2335 of 1950, indicates, however, that at higher speeds the drag is affected by porosity. A pitot-static survey behind the nylon sample indicates a trend to support this contention. These wind tunnel tests are being conducted to gain some experience with the flow characteristics of the fabrics preliminary to the use of project apparatus.

Through the courtesy of the Nylon Division (Wilmington) of E. I. du Pont de Nemours & Co., the nylon yarns listed below have been made available.

10 pounds	30-10	Type 200	- 7 turns	- sized
10 pounds	40-13	Type 200	- 10 turns	- sized
10 pounds	70-34	Type 200	- 15 turns	- sized
10 pounds	70-34	Type 300	- 10 turns	- unsized
10 pounds	70-34	Type 200	- not twisted	- unsized
10 pounds	70-34	Type 300	- not twisted	- unsized

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*Jones, R., On the Aerodynamic Characteristics of Parachutes. A Comprehensive Account of Researches Incorporated in Various Papers Submitted to the Advisory Committee for Aeronautics (British) R & M No. 862, 1923.

As soon as tests on standard fabrics have progressed sufficiently, sample yardage using the above listed yarns will be prepared for Section IV of contract program.

Progress continues in Sections I, II and VII.

There have been no changes in project personnel since the last report.

Respectfully submitted,

M. J. Goglia
Project Director

Approved:

Gerald A. Rosselot, Director
State Engineering Experiment Station

GEORGIA INSTITUTE OF TECHNOLOGY

THE STATE ENGINEERING EXPERIMENT STATION

ATLANTA, GEORGIA

April 14, 1951

Commanding General
Air Materiel Command
Wright-Patterson Air Force Base
Dayton, Ohio

Attention: Materials Laboratory
Engineering Division
MCREXM8

Subject: Progress Report No. 5
Contract AF 33(038) - 15624
E. O. No. 602-193 SR-7S

Dear Sir:

The work done during the past month is summarized briefly as follows:

Section I. Literature Survey

Reference material continues to be examined and abstracts prepared.

Section II. Development of Equipment

Test equipment has been designed to permit measuring flow parameters such as velocities and pressures as well as the total drag of the test sample. Further, provision is being made for stress-deformation measurements on the fabric. The motor-blower unit is expected shortly so that erection of the wind tunnel should begin late this month.

Section III. Evaluation of Standard Parachute Fabrics

The receipt of four samples of standard parachute fabrics from AMC is acknowledged. These are being subjected to textile analysis and will in turn be examined for permeability in the wind tunnel.

Section V. Variations in Polymers in Yarns

Nylon yarns, as indicated in Progress Report No. 4, are on hand; disposition of these must await observation and conclusions from Sections III and IV (Variations in Fabric Construction).

Section VII. Theoretical and Analytical Studies

Although others have drawn attention to an apparent similarity between fabrics and screens and have employed a characteristic length based on physical measurements from the construction of either, this writer is of the opinion indicated in Progress Report No. 3. Further analysis in defense of this opinion continues.

There have been no changes in project personnel since the last report.

Respectfully submitted,

M. J. Goglia
Project Director

Approved:

Gerald A. Rosselot, Director
State Engineering Experiment Station

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GEORGIA INSTITUTE OF TECHNOLOGY
THE STATE ENGINEERING EXPERIMENT STATION
ATLANTA, GEORGIA

May 14, 1951

Commanding General
Air Materiel Command
Wright-Patterson Air Force Base
Dayton, Ohio

Attention: Materials Laboratory
Engineering Division
MCREXM8

Subject: Progress Report No. 6
Contract AF 33(038) - 15624
E. O. No. 602-193 SR-7S.

Dear Sir:

A summary of work done during the past month is briefly as follows:

Section I. Literature Survey

Reference material is being perused.

Section II. Development of Equipment

The special ducts have been constructed and are on hand. Fabric sample holders and the pitot assemblies are being fabricated. The assembly of the test equipment is under way.

Section III. Evaluation of Standard Parachute Fabrics

A. Textile Analysis

The four samples of standard parachute fabrics received from AMC have been examined. Data from these preliminary tests are summarized in Table I.

B. Wind Tunnel Tests

Samples of each of the above four standard fabrics were subjected to drag measurements in the three foot wind tunnel of the Georgia Institute of Technology. Each sample was arranged in a hoop, six inches inside diameter, and oriented in the test section of the tunnel so as to be subject to a uniformly distributed air loading. Over a range of velocities of from 54.7 to 118 feet per second, an average drag coefficient of 1.33, based on projected area, was determined. These preliminary data show no significant differences in resistance to air flow of the four samples.

Section V. Variations in Polymers in Yarns

The du Pont Company has indicated an interest in making Dacron yarns available to this project. Advantage is being taken of this opportunity.

There have been no changes in project personnel since the last report.

Table I. Data from Preliminary Tests

		Fabric†			
		I	II	III	IV
Actual Width inches		37-1/8	36-3/4	36-1/4	36-7/16
Construction		120x117	126x117	127x76	126x77
Warp Yarns	Denier	30	30	40	40
	Filaments	10	10	13	13
Filling Yarns	Denier	30	30	70	70
	Filaments	10	10	34	34
Weight (ounces per square yard)		1.03	1.05	1.45	1.53
Weight (ounces per linear yard)		1.06	1.07	1.46	1.55
Grab break* (pounds)	Filling	54.5	48.9	86.8	79.3
	Warp	56.1	53.7	74.6	72.4
Elongation* (per cent)	Filling	38.2	38.2	44.9	32.6
	Warp	29.9	25.9	35.3	33.2

*Average of five tests (Scott Vertical Tester)
†The Fabric designations are:
I. White Nylon Rip Stop
Style 200-300 or 118187A
II. Orange Nylon Rip Stop
Style 200-300 or 135744A
(cont.)

Footnotes to Table I. (cont.)

III. White Nylon Twill
Style 000-100 or 131461A

IV. Camouflage Nylon Twill
Style 081-110 or 2695-05B

Respectfully submitted,

M. J. Goglia
Project Director

Approved:

Gerald A. Rosselot, Director
State Engineering Experiment Station

GEORGIA INSTITUTE OF TECHNOLOGY
THE STATE ENGINEERING EXPERIMENT STATION
ATLANTA, GEORGIA

June 14, 1951

Commanding General
Air Materiel Command
Wright-Patterson Air Force Base
Dayton, Ohio

Attention: Materials Laboratory
Engineering Division
MCREXM8

Subject: Progress Report No. 7
Contract AF 33(038) - 15624
E. O. No. 602-193 SR-7S

Dear Sir:

Progress during the past month is summarized as follows:

Section I. Literature Survey

As a result of a meeting with Dr. A. F. Robertson for the purpose of a discussion of his work on air permeability of parachute cloth, some unpublished literature bearing on this project was made available. This material is concerned with the determination of the variation of free area for flow in a cloth as a function of depth below the surface of the cloth; the procedure of using projected area of interstices to determine a length characteristic of a fabric becomes further questionable.

Section II. Development of Equipment

The assembly of test equipment is almost complete; initial operation of the equipment for permeability measurements is planned for late June.

Section III. Evaluation of Standard Parachute Fabrics

Physical testing of the parachute cloths reported last month has been continued and extended.

A visit by Mr. W. A. Corry of AMC with project personnel is gratefully acknowledged. Samples of some sixty different parachute cloths employing various yarn sizes in diverse weaves are to be made available to this project for the purpose of exploiting this group's idea on correlation of permeability data.

Mr. Brooks Metcalfe, as a part time assistant, has been added to project personnel during the past month.

Respectfully submitted,

M. J. Goglia
Project Director

Approved:

Gerald A. Rosselot, Director
State Engineering Experiment Station

GEORGIA INSTITUTE OF TECHNOLOGY

THE STATE ENGINEERING EXPERIMENT STATION

ATLANTA, GEORGIA

July 14, 1951

Commanding General
Air Materiel Command
Wright-Patterson Air Force Base
Dayton, Ohio

Attention: Materials Laboratory
Engineering Division
MCREXM8

Subject: Progress Report No. 8
Contract AF 33(038) - 15624
E. O. No. 602-193 SR-7S

Dear Sir:

The work done during the past month is summarized briefly as follows:

Section I. Literature Survey

Reference material dating back to 1923 has been examined.

Section II. Development of Equipment

Most of the effort during the past month has been devoted to equipment development. The apparatus has been operated; modification of instrumentation is indicated. These changes are being incorporated preparatory to the testing of fabrics for permeability.

Section III. Evaluation of Standard Parachute Fabrics

Preliminary permeability observations have been made on the parachute fabrics on hand.

Photomicrographs of each cloth sample are being taken before and after each is subjected to the permeability tests.

There have been no changes in project personnel since the last report.

Respectfully submitted,

M. J. Goglia
Project Director

Approved:

Gerald A. Rosselot, Director
State Engineering Experiment Station

GEORGIA INSTITUTE OF TECHNOLOGY
THE STATE ENGINEERING EXPERIMENT STATION
ATLANTA, GEORGIA

August 14, 1951

Commanding General
Air Materiel Command
Wright-Patterson Air Force Base
Dayton, Ohio

Attention: Materials Laboratory
Engineering Division
MCREXM8

Subject: Progress Report No. 9
Contract AF 33(038) - 15624
E.O. No. 602-193 SR-7S

Dear Sir:

The work done during the past month is summarized as follows:

Section I. Literature Survey

A technical report dealing with reference material examined is in preparation.

Section II. Development of Equipment

The apparatus for determining the permeability of parachute cloth is now operating on a production schedule basis.

Section III. Evaluation of Standard Parachute Fabrics

Acknowledgement is made of the receipt from AMC of the following items:

1. Fifty-nine rolls of nylon parachute fabrics manufactured by the Bally Ribbon Mills, Bally, Pennsylvania.
2. Five yards Dacron Parachute Cloth S/111 manufactured by the Duplan Corporation.
3. Five yards Orlon Parachute Cloth S/193 manufactured by the Duplan Corporation.

Further, the project is in receipt of four items shipped direct from Cheney Brothers Manufacturers; these are two pairs of parachute fabrics in the greige and finished condition.

These fabrics as well as those discussed in Progress Report No. 6 are being examined for physical properties and permeability characteristics.

During the conduct of the permeability tests the following circumstances exist:

1. Control of the inlet air conditions is that exercised by the building air conditioning system which maintains approximately 88° F dry bulb and 70° F wet bulb corresponding to a relative humidity of 40 per cent.
2. The fabric subject to test is located on the discharge side of the blower; accordingly, air temperatures at the fabric are in the range 110° F to 120° F.
3. The highest static pressure developed by the blower has been noted as 45 inches of water; steps are being taken to raise this to 50 inches.

The permeability data for the four samples mentioned in Progress Report No. 6 indicate that the White and Orange Rip Stop fabrics have essentially the same permeability, whereas the plain white is more porous and the camouflage less porous than the rip stop fabrics. Although the plain white and camouflage appear to be of identical construction, the latter is uniformly approximately 25 per cent less permeable than the former, whereas the rip stop is approximately 10 per cent more permeable than the camouflage. Photomicrographs of these samples are being examined as an aid in attempting to explain these trends.

Mr. D. E. Philpot, a textile technician, has been added to the project personnel during the month as an assistant in the preparation of cloth.

Respectfully submitted,

M. J. Goglia
Project Director

Approved:

Gerald A. Rosselot, Director
State Engineering Experiment Station

GEORGIA INSTITUTE OF TECHNOLOGY
THE STATE ENGINEERING EXPERIMENT STATION
ATLANTA, GEORGIA

September 14, 1951

Commanding General
Air Materiel Command
Wright-Patterson Air Force Base
Dayton, Ohio

Attention: Materials Laboratory
Engineering Division
MCREXM8

Subject: Progress Report No. 10
Contract AF 33(038) - 15624
E. O. No. 602-193 SR-7S

Dear Sir:

The work done during the past month is summarized as follows:

Section I. Literature Survey

The technical report dealing with literature examined is being prepared.

Section II. Development of Equipment

The equipment designed for this work has been operating continuously and satisfactorily. A statistical study has indicated that the manner employed for holding the test sample in the wind tunnel is reproducible; that is, an analysis of the components of variance showed no contribution from the mounting procedure.

Section III. Evaluation of Standard Parachute Fabrics

An important conclusion resulting from the statistical analysis of the test procedure indicated the existence of significant variation in permeability of the cloth in both warp and filling directions. Glaskin ("A Statistical Note on the Variation of Porosity of Nylon Fabric to Specification D.T.D. 556 A." Aeronautical Research Council, R and M No. 2313.) had pointed out the existence of such variation in British cloths. In order to establish a confidence level on the results of this investigation for any one bolt of cloth, nine random samples nine inches from the selvage edge have been subject to permeability study. Accordingly, the mean will be at least within - 7 per cent of the true mean 95 per cent of the time. (Eighteen random samples would have been required to be within - 5 per cent of the true mean.)

The testing of the standard parachute fabrics has been completed.

Section IV. Variations in Fabric Construction

Two different warps of nylon yarn have been obtained from Cheney Brothers; these will be used to prepare fabrics on a single loom under controlled conditions.

Five technicials were added to project personnel to assist in the reduction of data. These were William Gunson, Charles R. Kernan, Felix J. Lyczko, Edward J. Schatz, and Edward H. Liggin.

Respectfully submitted:

M. J. Goglia,
Project Director

Approved:

Gerald A Rosselot, Director
State Engineering Experiment Station

GEORGIA INSTITUTE OF TECHNOLOGY
THE STATE ENGINEERING EXPERIMENT STATION
ATLANTA, GEORGIA

October 14, 1951

Commanding General
Air Materiel Command
Wright-Patterson Air Force Base
Dayton, Ohio

Attention: Materials Laboratory
Engineering Division
MCREX M8

Subject: Progress Report No. 11
Contract AF 33(038) - 15624
E. O. No. 602-193 SR-7S

Dear Sir:

The following is a summary of the progress to date and serves to indicate current activity as well.

Section I. Literature Survey

The literature survey has been completed.

Section II. Development of Equipment

Elimination of the static pressure deficiency indicated in Progress Report No. 9 has been effected by exchanging the blower rotor for a larger one.

In order to examine air permeability characteristics of the cloths when subject to static pressures of 40 pounds per square inch or less, a second wind tunnel has been designed and is now ready for use. This additional equipment was deemed necessary as the data obtained using the 50-inch static pressure tunnel appear to indicate that a fully developed turbulent flow has not been established in the interstices of the cloth. The new tunnel uses compressed air from a laboratory header and the air flow through the cloth is measured by using standard flange-type orifices. The cloth area available to flow is that corresponding to a diameter of 2-1/16 inches.

Section III. Evaluation of Standard Parachute Fabrics

The experimental and calculated results obtained to date for the standard parachute cloths are summarized in the form of three attachments inserted in the body of this report:

Attachment A - A tabular summary identifying the cloths and giving physical and textile properties.

Attachment B - A tabular summary of experimental results relating to porosity and permeability of cloth.

Attachment C - A graphical summary of the porosity and permeability results.

The Bally Ribbon Mills Parachute Fabrics (See Progress Report No. 9.) are currently being tested--the calculated results are not complete at this time.

Attachment A

Physical and Textile Properties of Parachute Cloths

TABLE I

IDENTIFICATION OF CLOTH*

Fabric Number	Source of Supply	Color and Type	Style
1	USAF	White Rip Stop	200-300, 118187A
2	USAF	Orange Rip Stop	200-300, 135744A
3	USAF	White Twill	000-100, 131461A
4	USAF	Camouflage Twill	081-110, 2695-05B
5	Cheney Bros.	White Finished	179362
6	Cheney Bros.	White Greige	179362A
7	Cheney Bros.	White Rip Stop Finished	176498
8	Cheney Bros.	White Rip Stop Greige	176498A
9	Duplan Corp.	White Dacron	S 111
10	Duplan Corp.	White Orlon	S 193

*Fabrics numbered 1 through 8 are nylon cloths.

TABLE II

PHYSICAL AND TEXTILE PROPERTIES

Fabric Number	1	2	3	4	5	6	7	8	9	10
Actual Width (Inches)	37-1/8	36-3/4	36-1/4	36-7/16	36-5/8	39-1/4	37	39-7/8	34-1/8	36-5/8
Construction	120x117	126x117	127x76	126x77	125x74	118x72	122x119	116x117	68x68	51x50
Warp Yarns:										
Denier	30	30	40	40	40	40	30	30	150	200
Filaments	10	10	13	13	13	13	10	10	60	80
Filling Yarns:										
Denier	30	30	70	70	70	70	30	30	150	200
Filaments	10	10	34	34	34	34	10	10	60	80
Weight										
(Oz./Yd.^{2})	1.03	1.05	1.45	1.53	1.49	1.50	1.04	0.98	2.88	2.63
(Oz./Yd.)	1.06	1.07	1.46	1.55	--	--	--	--	--	--
Grab Break: (Pounds)										
Filling	54.5	48.9	86.8	79.3	95.6	64.6	58.8	41.6	146.	109.
Warp	56.1	53.7	74.6	72.4	96.6	73.3	52.	37.5	153.	109.
Elongation (Per Cent)										
Filling	38.2	38.2	44.9	32.6	43.3	27.5	36.5	18.8	26.	20.
Warp	29.9	25.9	35.3	33.2	45.7	31.0	22.2	13.8	30.5	17.5
Twist:										
Filling	1.5	1.5	1.2	1.1	1.0	0.9	0.8	0.7	8.	5.5
Warp	9.0	9.0	8.0	8.5	8.0	8.5	7.0	8.4	8.	6.0

Attachment B

Summary of Experimental Results

In all tests a circular sample of cloth having an area of 0.2 square foot was used in the test apparatus; therefore, in order to calculate air flow through cloth (lbm sec.$^{-1}$) multiply the mass velocity of air upstream of the cloth by 0.2 square foot. The results presented subsequently are the average of nine samples taken from a given bolt of cloth nine inches in from the selvage edge. (See Progress Report No. 10)

TABLE III

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 1			
50	.0753	2.44	7.7
40	.0737	2.1	7.5
30	.0721	1.74	7.2
20	.0702	1.34	6.86
15	.0694	1.11	6.64
10	.0686	.85	6.3
9	.0683	.8	6.23
8	.0683	.74	6.10
7	.0680	.68	6.04
6	.0680	.61	5.88
5	.0678	.54	5.68
4	.0675	.467	5.47

(Continued)

TABLE III (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 2			
50	.0756	2.37	7.4
40	.0740	2.04	7.24
30	.0724	1.7	7.04
20	.0707	1.31	6.68
15	.0696	1.08	6.43
10	.0688	.84	6.15
9	.0688	.725	5.63
8	.0686	.72	5.93
7	.0683	.655	5.76
6	.0683	.60	5.72
5	.068	.535	5.51
4	.068	.458	5.36
Fabric Number 3			
50	.075	2.53	8.04
40	.0734	2.19	7.82
30	.0718	1.85	7.73
20	.0704	1.45	7.48
15	.0694	1.23	7.31
10	.0685	.975	7.19

(Continued)

TABLE III (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.-3)	Mass Velocity of Air Upstream of Cloth (lbm sec-1 ft-2)	Relative Porosity of Cloth (Per Cent)
Fabric Number 3 (Continued)			
9	.0685	.923	7.20
8	.0680	.858	7.11
7	.0680	.80	7.10
6	.0680	.735	7.02
5	.0675	.635	6.93
4	.0675	.590	6.93
3	.0671	.498	6.78
Fabric Number 4			
50	.0758	1.83	5.73
40	.0741	1.59	5.61
30	.0724	1.33	5.48
20	.0707	1.05	5.36
15	.0698	.880	5.27
10	.069	.685	5.04
9	.0688	.640	4.97
8	.0687	.600	4.95
7	.0685	.550	4.86
6	.0684	.500	4.76
5	.0681	.445	4.67
4	.068	.390	4.59
3	.0678	.337	4.56

(Continued)

TABLE III (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 5			
50	.0755	2.11	6.67
40	.0738	1.83	6.52
30	.0721	1.53	6.38
20	.0704	1.21	6.28
15	.0695	1.02	6.14
10	.0687	.801	5.92
9	.0685	.755	5.85
8	.0684	.70	5.82
7	.0682	.645	5.72
6	.068	.585	5.58
5	.0678	.524	5.52
4	.0677	.465	5.45
3	.0675	.393	5.40
Fabric Number 6			
50	.0753	3.77	11.8
40	.0737	3.29	11.7
30	.0721	2.78	11.5
20	.0702	2.20	11.3
15	.0694	1.88	11.3
10	.0686	1.51	11.1
9	.0683	1.42	11.0

(Continued)

TABLE III (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 6 (Continued)			
8	.0683	1.33	11.0
7	.068	1.24	11.0
6	.068	1.14	10.9
5	.0678	1.04	11.0
4	.0675	.920	10.9
3	.0675	.790	10.7
2	.0672	.630	10.5
1	.0669	.427	10.1
Fabric Number 7			
50	.075	2.40	7.58
40	.0734	2.05	7.29
30	.0718	1.72	7.16
20	.0704	1.34	6.88
15	.0694	1.11	6.62
10	.0685	.855	6.33
9	.0685	.800	6.26
8	.068	.745	6.15
7	.068	.685	6.03
6	.068	.625	6.00
5	.0625	.525	5.74
4	.0678	.473	5.57
3	.0671	.409	5.58

(Continued)

TABLE III (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 8			
50	.0754	4.53	14.3
40	.0738	3.93	13.9
30	.0721	3.31	13.8
20	.0703	2.59	14.1
15	.0695	2.19	13.1
10	.0687	1.73	12.7
9	.0685	1.63	12.6
8	.0683	1.52	12.6
7	.0681	1.41	12.5
6	.068	1.29	12.3
5	.0678	1.17	12.2
4	.0677	1.02	11.9
3	.0675	.87	11.8
2	.0673	.685	11.4
1	.0672	.461	10.8
Fabric Number 9			
50	.0756	1.90	5.95
40	.0739	1.72	6.09
30	.0723	1.48	6.11
20	.0705	1.18	6.10
15	.0697	1.02	6.11

(Concluded)

TABLE III (Concluded)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.-3)	Mass Velocity of Air Upstream of Cloth (lbm sec-1 ft-2)	Relative Porosity of Cloth (Per Cent)
Fabric Number 9 (Continued)			
10	.0688	.815	5.99
9	.0687	.765	5.96
8	.0685	.715	5.91
7	.0683	.660	5.84
6	.0682	.600	5.73
5	.068	.540	5.68
4	.0678	.468	5.51
3	.0676	.387	5.23
Fabric Number 10			
50	.0760	2.44	7.63
40	.0743	2.18	7.70
30	.0726	1.86	7.73
20	.0709	1.51	7.75
15	.0701	1.30	7.73
10	.0692	1.06	7.77
9	.0691	1.01	7.82
8	.0689	.935	7.66
7	.0687	.875	7.73
6	.0686	.810	7.70
5	.0684	.725	7.62
4	.0682	.640	7.48
3	.068	.540	7.33

TABLE IV

GURLEY DENSOMETER DATA

Fabric Number	1	2	3	4	5	6	7	8	9	10
Time* (Seconds)	7.53	7.30	5.17	5.46	5.95	3.17	7.84	3.06	6.94	5.34

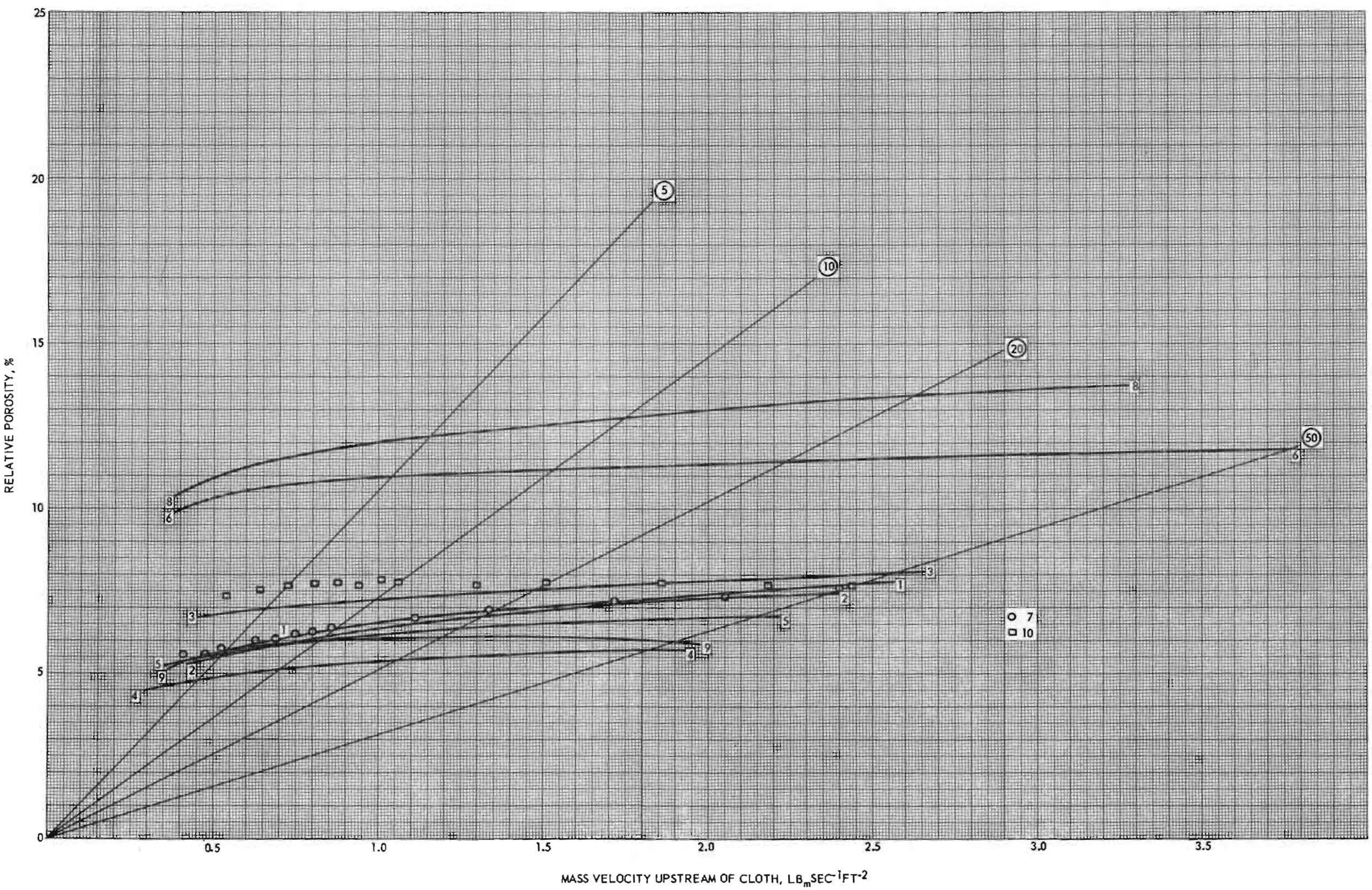
*Time for the passage of 350 cc. of air under a static pressure of 1.22 inches of water guage and with an effective orifice area available to the cloth of 0.1 square inch.

Attachment C

The graphical summary of the porosity-permeability data for the ten fabrics serves to illustrate their relative ordering. The abscissa, mass velocity upstream of the cloth, is a measure of the permeability of the cloth. From the data given in Attachment B the mass velocity can be converted to the usual measure of permeability. The relative porosity is obtained by considering the continuity equation and observing that for small pressure drops (as is the case in this study) the density of the air remains constant as flow through the cloth occurs. Thus the ratio of effective area of interstices in cloth to upstream (or total projected) area of cloth, the relative porosity, becomes equal to the ratio of upstream velocity to effective gas velocity through interstices. The former velocity is directly measureable; the other is calculated. Accordingly, a measure of relative porosity results.

Superimposed on the porosity-mass velocity curves is a set of four straight lines emanating from the origin of coordinates. Each of these is a locus of points for constant static pressure upstream of the cloth; loci for 50, 20, 10 and 5 inches of water are given. Considering the 50-inch locus, one notes that fabric No. 4 is least porous, with No. 9 next, etc., while Fabric No. 8 (intersection of the 50-inch ray with porosity-mass velocity characteristic curve for No. 8 is obviously off the graph) as the most porous of all.

In order to avoid some confusion in the drawing of curves, the characteristics for fabrics numbered 7 and 10 are omitted; the data, however, are indicated.



Graphical Summary of Porosity - Permeability Data.

Section IV. Variations in Fabric Construction

The weaving of parachute cloth under controlled conditions using nylon fibers is under way. Patterns have been selected whose systematic variation from those evaluated in Section III will help appraise the relative merits of construction modifications on permeability characteristics. Two warps of nylon are being employed; the specifications are
(1) 500 yards of Com. 000 (1.6-ounce nylon parachute cloth, twill weave for specification Mil-C-7020, Type II) 40-13-7-Z type 200, 4620 ends sley in loom 37/3 with 42-1/2-inch loom beam setting, and
(2) 500 yards of Com. 10981 (nylon marquisette) 70-34-15-Z, Type 100, 2564 ends sley in loom 48/2.
Filling yarns 30, 40 and 70 denier with different twist, both sized and unsized, will be used.

Subsequent to the weaving and finishing of the cloths they will be examined for permeability characteristics.

Section V. Variations in Polymers in Yarns

Dacron and orlon yarns are being supplied by the Dupont Company in order that the effect of polymer variation on the permeability characteristics of cloth might be observed. The warp specifications requested for the dacron are as follows: 500 yards, 70 denier, 8 to 13 turns per inch, 3800 ends; and, for the orlon, 400 yards 75 denier, 7 to 8 turns per inch, 3600 ends. Dacron yarns for filling will be 40, 70 and 210 denier; orlon yarns for filling will be 75, 100 and 200 denier.

Upon completion of the weaving and finishing of the cloth, the permeability characteristics will be determined.

The services of the following technicians have been terminated: W. E. Gunson, C. R. Kernan, F. J. Lyczko, and E. J. Schatz. The following part time student assistants have been added to project personnel: W. C. Adams, Jr., S. B. Arline, W. C. Boteler, C. D. Brown, D. A. Duke, D. A. Few, and B. A. Williams.

Respectfully submitted,

M. J. Goglia,
Project Director

Approved:

Gerald A. Rosselot, Director
State Engineering Experiment Station

GEORGIA INSTITUTE OF TECHNOLOGY

THE STATE ENGINEERING EXPERIMENT STATION

ATLANTA, GEORGIA

November 14, 1951

Commanding General
Air Materiel Command
Wright-Patterson Air Force Base
Dayton, Ohio

Attention: Materials Laboratory
Engineering Division
MCREX M8

Subject: Progress Report No. 12
Contract AF 33(038) - 15624
E. O. No. 602-193 SR-7S

Dear Sir:

The following is a summary of the progress to date as well as an indication of current activity.

Section I. Literature Survey

The literature survey has been completed as indicated in previous reports.

Section II. Development of Equipment

No changes have been made since the last report.

Section III. Evaluation of Standard Parachute Fabrics

A summary of permeability data and results for the standard fabrics was submitted in Progress Report No. 11. Some preliminary permeability data on the standard cloths are being obtained at static pressures of the order of 40 pounds per square inch in the 2-inch tunnel (See Progress Report No. 11.).

An appendix is attached as part of this report wherein are summarized in tabular and graphical form the data and results for twenty-four of the 59 nylon parachute fabrics. These are products of the Bally Ribbon Mills, Bally, Pennsylvania, and were acknowledged in Progress Report No. 9.

Section IV. Variations in Fabric Construction

Yardage has been woven on a Draper XD loom using the 70-denier nylon warp (Report No. 11). A plain weave pattern has been employed using 40, 50, 60, 70, 80 and 90 picks of 70-denier nylon filling; likewise, other patterns are to be woven.

The 40-denier nylon warp is being set up on a Crompton and Knowles S6 loom.

Section V. Variations in Polymers in Yarns

The warps of orlon and dacron mentioned in Report No. 11 are being beamed for the Draper XD loom; these have not been received as yet. The effect of loom characteristics on fabric construction will be minimized by employing the same loom for different weaves using yarns of approximately the same denier.

There have been no changes in project personnel since the last report.

Respectfully submitted:

M. J. Goglia,
Project Director

Approved:

Gerald A. Rosselot, Director
State Engineering Experiment Station

APPENDIX

NYLON PARACHUTE FABRICS MANUFACTURED BY BALLY RIBBON MILLS

Relative porosity (in. Water)	Item Number	Mill Style	Thread Count Per Inch		Yarn Denier		Weave
			Warp	Filling	Warp	Filling	
17.9	BR-1	7171	138	110	30/10	30/10	Plain
16.8	BR-2	7172	138	120	30/10	30/10	Plain
21.5	BR-3	7173	138	110	30/10	30/10	2/1 Twill
17.4	BR-4	7174	138	120	30/10	30/10	2/1 Twill
18.7	BR-5	7175	138	95	30/10	40/13	Plain
15.8	BR-6	7176	138	105	30/10	40/13	Plain
20.8	BR-7	7177	138	95	30/10	40/13	2/1 Twill
18.5	BR-8	7178	138	105	30/10	40/13	2/1 Twill
17.7	BR-9	7180	120	~~95~~ 85	40/13	40/34	Plain
19.2	BR-10	7181	120	~~105~~ 83	40/13	40/34	Plain
17.7	BR-11	7182	120	95	40/13	40/13	Plain
15.4	BR-12	7183	120	105	40/13	40/13	Plain
10.8	BR-13	7184	120	75	40/13	60/20	Plain
8.25	BR-14	7185	120	85	40/13	60/20	Plain
10.6	BR-15	7186	120	75	40/13	60/20	2/1 Twill
7.72	BR-16	7187	120	85	40/13	60/20	2/1 Twill
11.2	BR-17	7188	100	75	60/20	60/20	Plain
7.38	BR-18	7189	100	85	60/20	60/20	Plain
10.6	BR-19	7190	100	75	60/20	60/20	2/1 Twill
7.03	BR-20	7191	100	85	60/20	60/20	2/1 Twill
22.1*	BR-21	7192	90	68	70/34	70/34	2/1 Twill
18.4*	BR-22	7193	90	78	70/34	70/34	2/1 Twill
22.6*	BR-23	7194	90	68	70/34	70/34	2/2 Twill
18.7	BR-24	7195	90	~~78~~ 71	70/34	70/34	2/2 Twill

SUMMARY OF EXPERIMENTAL DATA

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number BR-1			
30	.0740	4.50	20.1
25	.0714	3.98	18.2
20	.0705	3.47	17.9
15	.0695	3.00	17.9
10	.0688	2.28	16.8
8	.0683	2.00	16.5
6	.0681	1.71	16.4
4	.0677	1.36	16.0
3	.0676	1.17	15.8
2	.0674	0.937	15.6
1	.0672	0.636	15.0
Fabric Number BR-2			
30	.0722	4.25	17.6
25	.0713	3.77	17.2
20	.0705	3.28	16.8
15	.0696	2.73	16.0
10	.0687	2.10	15.8
8	.0684	1.89	15.6
6	.0678	1.61	15.5
4	.0677	1.30	15.2
3	.0676	1.12	15.2
2	.0673	0.912	15.2
1	.0672	0.637	15.0
Fabric Number BR-3			
25	.0712	4.78	21.8
20	.0702	4.22	21.5
15	.0693	3.46	20.6
10	.0686	2.68	19.8
8	.0682	2.36	19.5
6	.0679	1.98	19.2
5	.0677	1.80	18.8
4	.0675	1.58	18.8
3	.0673	1.34	18.3
2	.0672	1.08	18.0
1	.0668	0.742	17.9

(Continued)

SUMMARY OF EXPERIMENTAL DATA
(Continued)

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number BR-4			
30	.0718	4.30	17.9
25	.0710	3.86	17.7
20	.0702	3.39	17.4
15	.0688	2.85	17.2
10	.0684	2.28	17.2
8	.0681	2.01	16.6
6	.0678	1.70	16.2
4	.0674	1.34	15.9
3	.0673	1.14	15.6
2	.0671	0.915	15.2
1	.0669	0.630	13.6
Fabric Number BR-5			
30	.0721	4.58	19.0
25	.0712	4.12	18.9
20	.0703	3.62	18.7
15	.0697	3.07	18.3
10	.0687	2.41	17.7
8	.0678	2.14	17.7
6	.0682	1.82	17.4
4	.0677	1.44	16.9
3	.0677	1.22	16.5
2	.0663	0.995	16.6
1	.0673	0.697	16.5
Fabric Number BR-6			
30	.0716	3.95	16.4
25	.0707	3.54	16.2
20	.0698	3.11	15.8
15	.0690	2.21	13.3
10	.0682	2.08	15.0
8	.0678	1.84	15.1
6	.0675	1.56	16.8
4	.0672	1.26	14.8
3	.0670	1.09	14.8
2	.0668	0.885	14.8
1	.0667	0.616	14.6

(Continued)

SUMMARY OF EXPERIMENTAL DATA
(Continued)

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth ($lbm\ ft.^{-3}$)	Mass Velocity of Air Upstream of Cloth ($lbm\ sec.^{-1}\ ft.^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number BR-7			
30	.0716	5.03	21.0
25	.0707	4.60	21.0
20	.0698	4.04	20.8
15	.0679	3.39	21.0
10	.0682	2.72	19.9
8	.0678	2.40	19.8
6	.0675	2.08	19.9
4	.0671	1.64	19.7
3	.0670	1.41	20.1
2	.0668	1.15	19.3
1	.0666	0.811	19.2
Fabric Number BR-8			
30	.0723	4.60	19.1
25	.0712	4.11	18.8
20	.0704	3.60	18.5
15	.0694	3.05	18.2
10	.0686	2.44	18.0
8	.0683	2.15	17.8
6	.0680	1.84	17.6
4	.0676	1.47	17.3
3	.0675	1.26	17.2
2	.0673	1.02	17.0
1	.0671	0.711	16.7
Fabric Number BR-9			
30	.0718	4.37	18.2
25	.0710	3.93	18.0
20	.0700	3.46	17.7
15	.0693	2.96	17.7
10	.0686	2.36	17.2
8	.0683	2.09	17.1
6	.0678	1.79	17.1
4	.0675	1.45	17.0
3	.0671	1.25	17.0
2	.0659	1.00	16.8
1	.065	0.695	16.7

(Continued)

SUMMARY OF EXPERIMENTAL DATA
(Continued)

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth ($lbm\ ft.^{-3}$)	Mass Velocity of Air Upstream of Cloth ($lbm\ sec.^{-1}\ ft.^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number BR-10			
30	.0719	4.85	20.2
25	.0710	4.26	19.5
20	.0702	3.72	19.2
15	.0694	3.18	19.0
10	.0685	2.58	19.0
8	.0682	2.27	18.8
6	.0678	1.94	18.5
4	.0675	1.57	18.4
3	.0673	1.35	18.4
2	.0672	1.09	18.2
1	.0669	0.756	17.8
Fabric Number BR-11			
30	.0720	4.41	17.8
25	.0711	3.94	17.7
20	.0703	3.49	17.7
15	.0694	2.92	17.4
10	.0681	2.34	17.3
8	.0682	2.08	17.2
6	.0679	1.78	17.0
4	.0676	1.43	16.8
3	.0674	1.22	16.6
2	.0672	0.983	16.4
1	.0671	0.660	15.1
Fabric Number BR-12			
40	.0733	4.58	15.8
30	.0718	3.80	15.8
25	.0708	3.41	15.7
20	.0700	2.98	15.4
15	.0692	2.54	15.3
10	.0684	2.01	14.8
8	.0680	1.78	14.7
6	.0677	1.52	14.7
4	.0674	1.23	14.5
3	.0673	1.07	14.7
2	.0671	0.850	14.8
1	.0668	0.587	13.9

(Continued)

SUMMARY OF EXPERIMENTAL DATA
(Continued)

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number BR-13			
40	.0736	3.17	11.2
30	.0720	2.67	11.1
25	.0711	2.39	10.9
20	.0703	2.11	10.8
15	.0694	1.79	10.7
10	.0686	1.43	10.6
8	.0682	1.27	10.5
6	.0679	1.10	10.5
4	.0676	0.893	10.4
3	.0674	0.770	10.4
2	.0672	0.621	10.6
1	.0671	0.434	10.2
Fabric Number BR-14			
50	.0755	2.79	8.78
45	.0746	2.57	8.61
40	.0738	2.41	8.59
30	.0721	2.03	8.43
20	.0704	1.60	8.25
10	.0687	1.09	8.08
7	.0682	0.907	8.02
4	.0677	0.680	7.98
3	.0675	0.591	8.03
2	.0674	0.489	8.15
1	.0672	0.383	9.03
Fabric Number BR-15			
50	.0746	3.54	11.2
45	.0737	3.32	11.1
40	.0729	3.09	11.0
30	.0712	2.61	10.8
20	.0695	2.06	10.6
10	.0679	1.40	10.4
7	.0674	1.16	10.3
4	.0669	0.861	10.2
3	.0667	0.737	10.0
2	.0665	0.576	9.6
1	.0664	0.393	9.3

(Continued)

SUMMARY OF EXPERIMENTAL DATA
(Continued)

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec^{-1} ft^{-2})	Relative Porosity of Cloth (Per Cent)
Fabric Number BR-16			
55	.0759	2.71	8.1
50	.0751	2.57	8.1
45	.0743	2.41	8.04
40	.0734	2.24	8.00
30	.0718	1.90	7.91
20	.0699	1.50	7.72
10	.0683	1.01	7.51
4	.0672	0.608	7.14
3	.0669	0.520	7.08
2	.0669	0.384	6.36
1	.0666	--	--
Fabric Number BR-17			
50	.0751	3.70	11.6
45	.0743	3.47	11.6
40	.0734	3.23	11.5
30	.0717	2.73	11.3
20	.0701	2.18	11.2
10	.0684	1.48	10.9
4	.0674	0.933	10.9
3	.0672	0.805	10.9
2	.0671	0.664	11.0
1	.0669	0.467	11.3
Fabric Number BR-18			
55	.0759	2.69	8.05
50	.0750	2.45	7.72
45	.0742	2.28	7.65
40	.0733	2.12	7.58
30	.0717	1.79	7.48
20	.0700	1.42	7.38
10	.0683	0.986	7.28
4	.0673	0.623	7.32
3	.0672	0.542	7.37
2	.0670	0.446	7.45
1	.0668	0.331	7.84

(Continued)

SUMMARY OF EXPERIMENTAL DATA
(Continued)

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number BR-19			
50	.0758	3.50	11.0
45	.0749	3.24	10.8
40	.0741	3.06	10.8
30	.0724	2.56	10.7
20	.0707	2.07	10.6
10	.0688	1.42	10.4
7	.0685	1.17	10.3
4	.0680	0.891	10.4
3	.0678	0.776	10.5
2	.0677	0.629	10.4
1	.0675	0.445	10.4
Fabric Number BR-20			
50	.0744	2.31	7.33
45	.0736	2.16	7.27
40	.0727	2.03	7.27
30	.0711	1.71	7.16
20	.0694	1.35	7.03
10	.0678	0.928	6.88
7	.0672	0.773	6.88
4	.0668	0.585	6.92
3	.0666	0.507	6.93
2	.0664	0.423	7.08
1	.0662	0.327	7.75
Fabric Number BR-21			
25	.0712	4.84	22.1
24	.0711	4.74	22.2
21	.0706	4.41	22.1
18	.0700	4.07	22.1
13	.0692	3.44	22.1
9	.0685	2.83	22.0
7	.0682	2.48	22.0
4	.0677	1.85	21.8
3	.0675	1.60	21.7
2	.0673	1.31	21.8
1	.0672	0.917	21.6

(Concluded)

SUMMARY OF EXPERIMENTAL DATA
(Concluded)

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number BR-22			
30	.0717	4.43	18.4
25	.0709	4.03	18.4
21	.0702	3.65	18.4
17	.0696	3.29	18.4
13	.0689	2.84	18.2
10	.0684	2.47	18.2
7	.0679	2.05	18.1
4	.0674	1.54	18.1
3	.0672	1.33	18.1
2	.0671	1.09	18.2
1	.0669	0.757	17.9
Fabric Number BR-23			
25	.0716	4.96	22.6
24	.0714	4.85	22.7
21	.0709	4.52	22.6
18	.0704	4.16	22.6
14	.0697	3.65	22.6
10	.0690	3.06	22.5
7	.0685	2.54	22.4
4	.0680	1.88	22.0
3	.0679	1.62	22.0
2	.0677	1.31	21.8
1	.0675	0.959	22.6
Fabric Number BR-24			
27	.0720	4.29	18.8
23	.0713	3.95	18.8
20	.0708	3.65	18.7
15	.0700	3.14	18.7
10	.0691	2.54	18.6
7	.0686	2.09	18.4
5	.0683	1.75	18.3
4	.0681	1.53	17.9
3	.0679	1.35	18.3
2	.0678	1.10	18.3
1	.0676	7.67	18.0

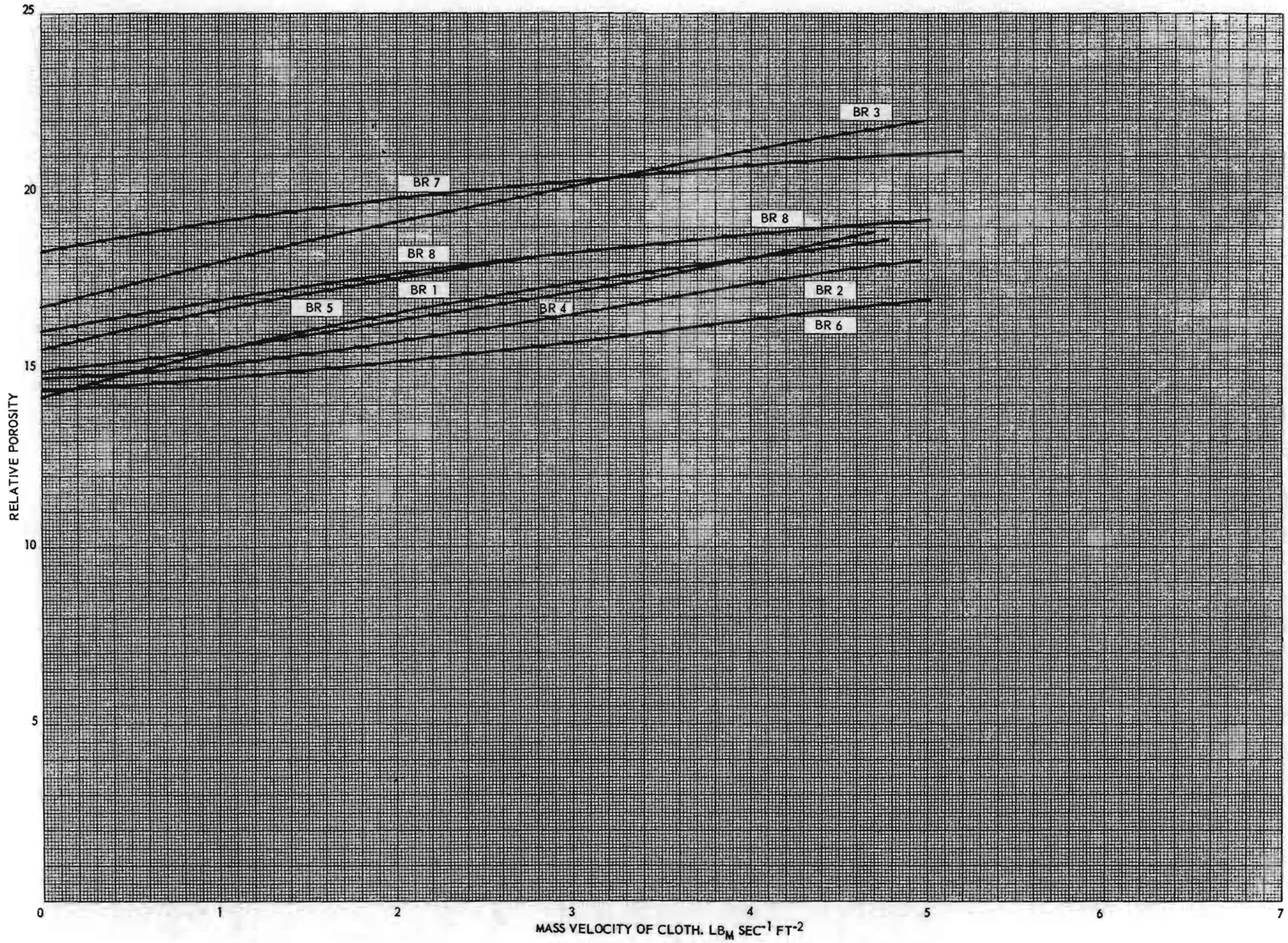


Figure 1. Porosity-Permeability Results, Bally Ribbon Cloths BR 1-BR 8.

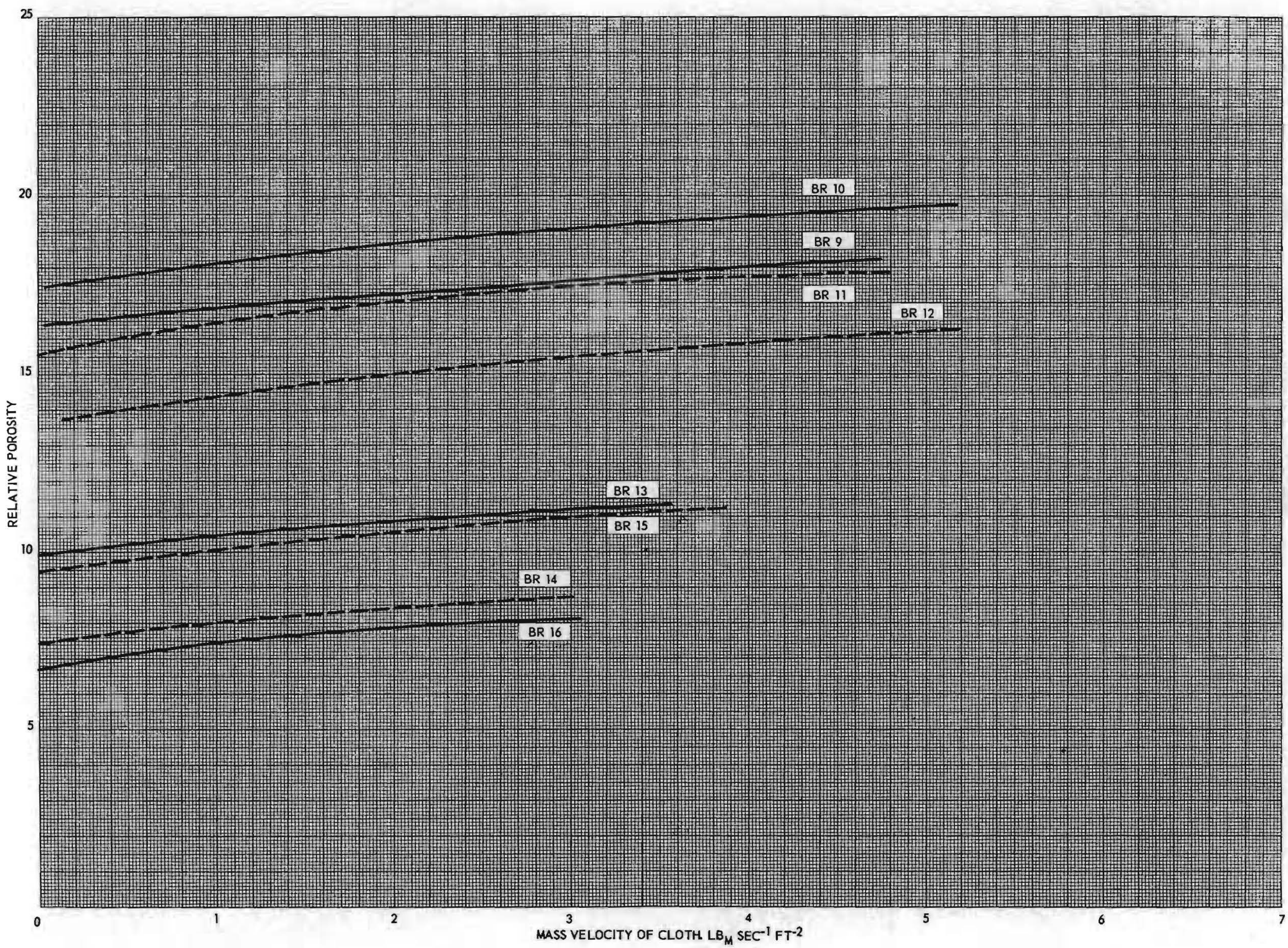


Figure 2. Porosity-Permeability Results, Bally Ribbon Cloths BR 9-BR 16.

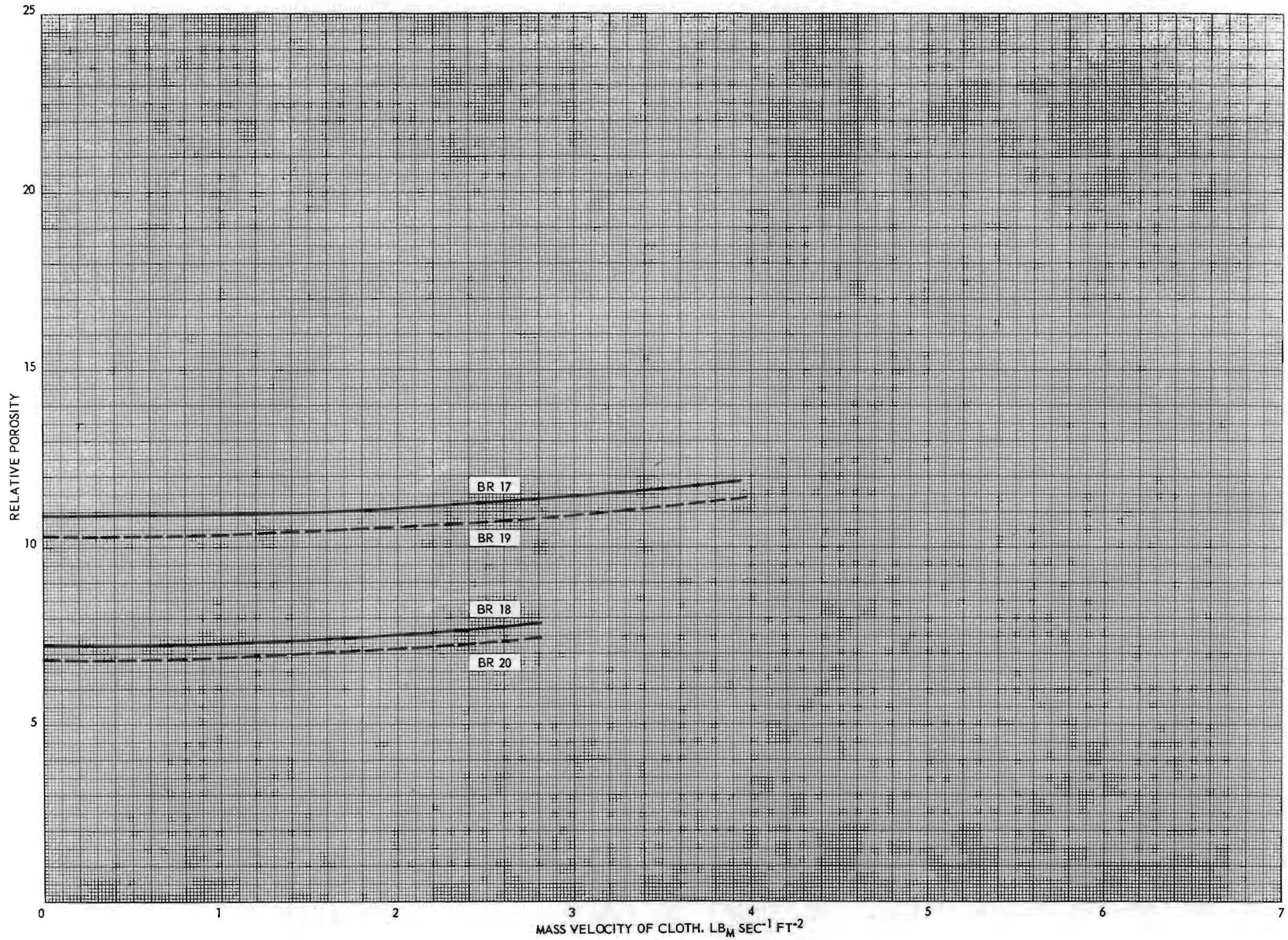


Figure 3. Porosity-Permeability Results, Bally Ribbon Cloths BR 17-BR 20.

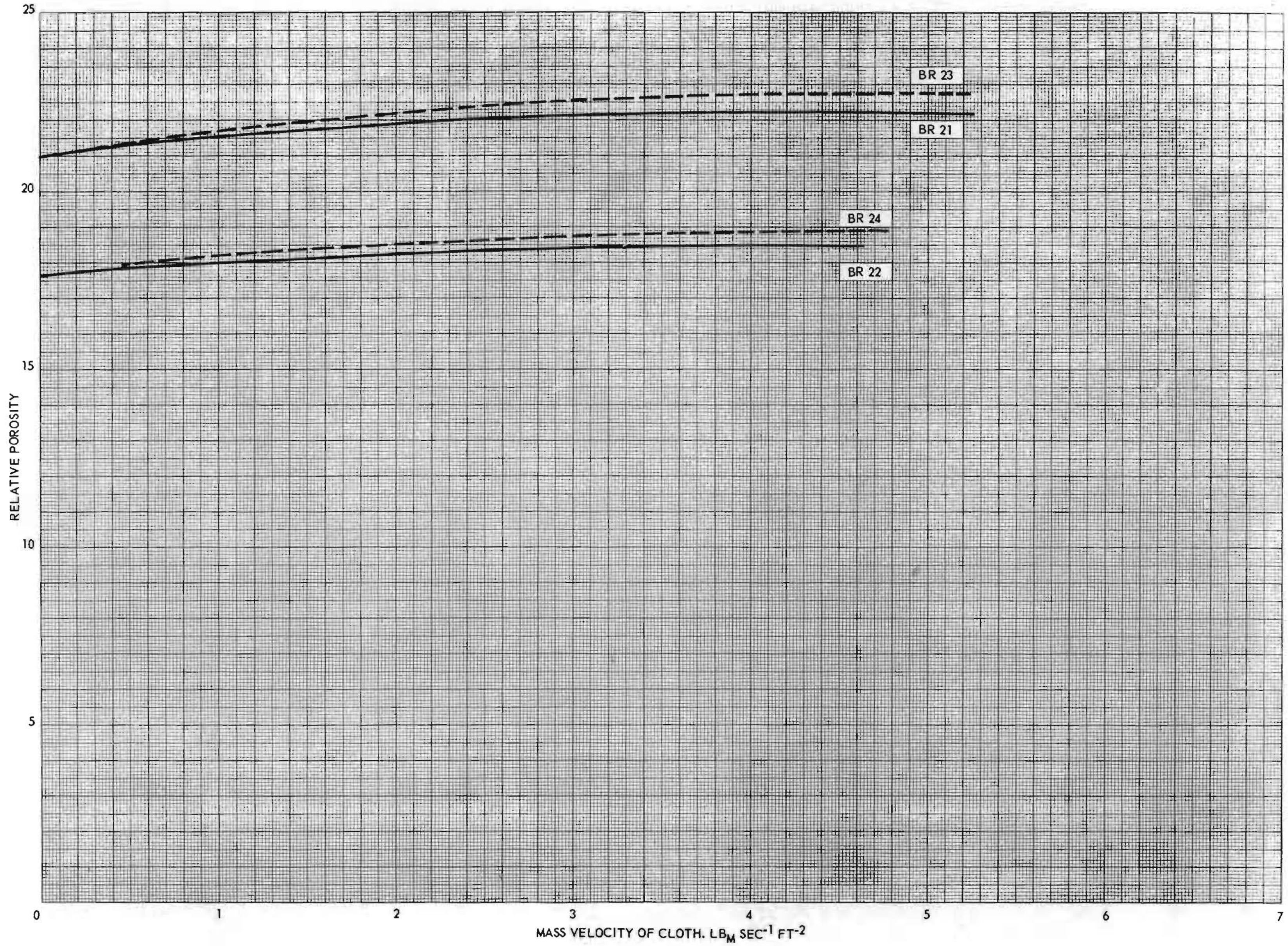


Figure 4. Porosity-Permeability Results, Bally Ribbon Cloths BR 21-BR 24.

Proj. 170

GEORGIA INSTITUTE OF TECHNOLOGY

THE STATE ENGINEERING EXPERIMENT STATION
ATLANTA, GEORGIA

December 14, 1951

Commanding General
Air Materiel Command
Wright-Patterson Air Force Base
Dayton, Ohio

Attention: Materials Laboratory
Engineering Division
MCREX-M8

Subject: Progress Report No. 13
Contract AF 33(038) - 15624
E. O. No. 602-193 SR-7S

Dear Sir:

The following is a summary of the progress to date as well as an indication of current activity.

Section I. Literature Survey

The literature survey has been completed as indicated in previous progress reports.

Section II. Development of Equipment

No changes have been made since the last report.

Section III. Evaluation of Standard Parachute Fabrics

The appendix to this report records in tabular and graphical form the permeability data and results for fourteen additional Bally Ribbon cloths.

Section IV. Variations in Fabric Construction

The following yardage has been woven using the 70-denier nylon warp (Progress Report No. 11) and is currently in the hands of the Franklin Finishing Co. for finishing.

	Yards	Picks Per Inch
Plain Weave	15	40
	15	50
	15	60
	15	70
	15	80
	3*	90**
Satin Weave	15	40
	15	50
	15	60
	15	70
	15	80
	3*	90**

*Approximate value.
**The 90 pick goods cause the selvage to run too tightly.

Weaving is in progress using the 40-denier nylon warp (Progress Report No. 12).

Section V. Variations in Polymers in Yarns

The orlon warp (Progress Report No. 11) has been received and will be put in the Draper XD loom late in December.

The dacron warp is expected early in January.

Mr. W. E. Huie and Mr. A. T. Shawe, graduate student assistants, have been added to project personnel; the services of Mr. B. A. Williams have been terminated.

Respectfully submitted:

M. J. Goglia,
Project Director

Approved:

Gerald A. Rosselot, Director
State Engineering Experiment Station

APPENDIX

NYLON PARACHUTE FABRICS MANUFACTURED BY BALLY RIBBON MILLS

Item Number	Mill Style	Thread Count Per Inch		Yarn Denier		Weave
		Warp	Filling	Warp	Filling	
BR-29	7209	90	68	70/34	70/34	5 Harness Satin
BR-30	7210	90	78	70/34	70/34	5 Harness Satin
BR-31	7211	90	66	70/34	100/34	2/1 Twill
BR-32	7212	90	78	70/34	100/34	2/1 Twill
BR-33	7213	90	68	70/34	100/34	2/2 Twill
BR-34	7214	90	78	70/34	100/34	2/2 Twill
BR-35	7215	90	68	70/34	100/34	5 Harness Satin
BR-36	7216	90	78	70/34	100/34	5 Harness Satin
BR-37	7217	76	57	100/34	100/34	2/1 Twill
BR-38	7218	76	67	100/34	100/34	2/1 Twill
BR-39	7219	76	57	100/34	100/34	2/2 Twill
BR-40	7220	76	67	100/34	100/34	2/2 Twill
BR-45	7225	76	57	100/34	100/34	5 Harness Satin
BR-46	7226	76	67	100/34	100/34	5 Harness Satin

SUMMARY OF EXPERIMENTAL DATA

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number BR-29			
18	.0671	4.84	26.7
15	.0671	4.40	26.7
14	.0671	4.23	26.6
12	.0671	3.91	26.6
10	.0670	3.57	26.6
7	.0670	2.92	26.0
5	.0670	2.49	26.4
4	.0670	2.20	26.0
3	.0670	1.87	25.6
2	.0669	1.57	26.1
1	.0669	1.03	24.2
Fabric Number BR-30			
22	.0702	4.52	22.3
20	.0699	4.32	22.3
17	.0694	3.94	22.2
13	.0687	3.42	22.1
10	.0682	2.99	22.1
7	.0677	2.48	22.0
5	.0674	2.07	21.8
4	.0672	1.84	21.7
3	.0670	1.59	21.6
2	.0669	1.32	22.0
1	.0667	0.895	21.1
Fabric Number BR-31			
58	.0771	2.50	7.21
50	.0758	2.30	7.21
40	.0741	2.03	7.21
30	.0724	1.73	7.21
20	.0707	1.39	7.14
10	.0690	0.955	7.00
7	.0685	0.787	6.93
4	.0680	0.586	6.87
3	.0678	0.502	6.79
2	.0677	0.411	6.79

(Continued)

SUMMARY OF EXPERIMENTAL DATA
(Continued)

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number BR-32			
60	.0779	4.78	13.5
50	.0762	4.29	13.4
40	.0745	3.75	13.3
30	.0728	3.15	13.0
20	.0711	2.46	12.6
15	.0703	2.08	12.3
10	.0694	1.65	12.1
7	.0689	1.35	11.9
4	.0684	1.00	11.7
2	.0681	0.710	11.8
1	.0679	0.152	12.1
Fabric Number BR-33			
60	.0777	2.26	6.33
55	.0769	2.13	6.33
50	.0760	2.01	6.33
40	.0743	1.77	6.25
30	.0726	1.52	6.25
20	.0709	1.22	6.25
10	.0692	0.842	6.17
6	.0686	0.649	6.17
3	.0681	0.416	5.66
Fabric Number BR-34			
60	.0762	1.51	4.30
50	.0743	1.36	4.31
40	.0727	1.20	4.27
30	.0710	1.01	4.22
20	.0694	0.910	4.71
15	.0685	0.678	4.06
10	.0677	0.525	3.90
7	.0672	0.433	3.87
5	.0670	0.369	3.88
3	.0667	0.232	3.16

(Continued)

SUMMARY OF EXPERIMENTAL DATA
(Continued)

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number BR-35			
55	.0753	1.99	5.96
40	.0729	1.66	5.92
30	.0713	1.35	5.66
25	.0705	1.21	5.57
20	.0696	1.06	5.48
15	.0688	0.902	5.39
10	.0680	0.727	5.39
7	.0675	0.604	5.39
5	.0672	0.513	5.39
3	.0669	0.404	5.48
Fabric Number BR-36			
60	.0771	1.44	4.10
50	.0754	1.29	4.11
40	.0737	1.13	4.00
30	.0720	0.941	3.91
20	.0703	0.734	3.79
15	.0695	0.618	3.70
7	.0681	0.395	3.49
5	.0678	0.330	3.46
3	.0674	0.256	3.46
2	.0673	0.205	3.42
Fabric Number BR-37			
42	.0732	3.47	12.1
35	.0721	3.08	12.0
25	.0707	2.60	12.0
20	.0695	2.30	11.9
15	.0687	2.01	12.1
10	.0679	1.59	11.8
7	.0674	1.33	11.8
5	.0670	1.13	11.9
3	.0667	0.880	12.1
2	.0660	0.720	11.9
1	.0664	0.530	12.4

(Continued)

SUMMARY OF EXPERIMENTAL DATA

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number BR-38			
55	.0758	2.67	8.00
50	.0749	2.51	7.94
40	.0732	2.21	7.87
30	.0715	1.88	7.81
20	.0699	1.48	7.62
10	.0682	1.02	7.55
7	.0676	0.841	7.48
4	.0671	0.671	7.94
3	.0670	0.568	7.75
2	.0668	0.457	7.62
1	.0666	0.328	7.75
Fabric Number BR-39			
50	.0752	3.09	9.65
40	.0735	2.69	9.59
30	.0718	2.28	9.49
20	.0701	1.82	9.39
16	.0695	1.61	9.33
12	.0688	1.38	9.27
8	.0681	1.12	9.22
6	.0678	0.965	9.22
4	.0675	0.793	9.33
3	.0673	0.695	9.43
2	.0671	0.555	9.33
Fabric Number BR-40			
55	.0759	1.96	5.86
45	.0742	1.74	5.81
35	.0726	1.51	5.80
25	.0709	1.26	5.76
20	.0700	1.13	5.81
15	.0692	0.955	5.73
10	.0683	0.765	5.66
5	.0675	0.543	5.71
3	.0672	0.410	5.57

(Concluded)

SUMMARY OF EXPERIMENTAL DATA
(Concluded)

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number BR-45			
50	.0755	3.28	10.3
40	.0739	2.87	10.2
30	.0723	2.44	10.1
20	.0706	1.96	10.1
15	.0696	1.68	10.0
10	.0688	1.36	10.0
7	.0683	1.14	10.1
5	.0679	0.960	10.1
3	.0676	0.750	10.2
2	.0674	0.615	10.2
1	.0673	0.445	10.5
Fabric Number BR-46			
60	.0775	2.39	6.78
50	.0759	2.15	6.71
40	.0743	1.89	6.71
30	.0724	1.60	6.63
20	.0707	1.28	6.56
15	.0699	1.09	6.56
10	.0691	0.882	6.48
5	.0683	0.609	6.40
3	.0680	0.480	6.48
2	.0678	0.391	6.48

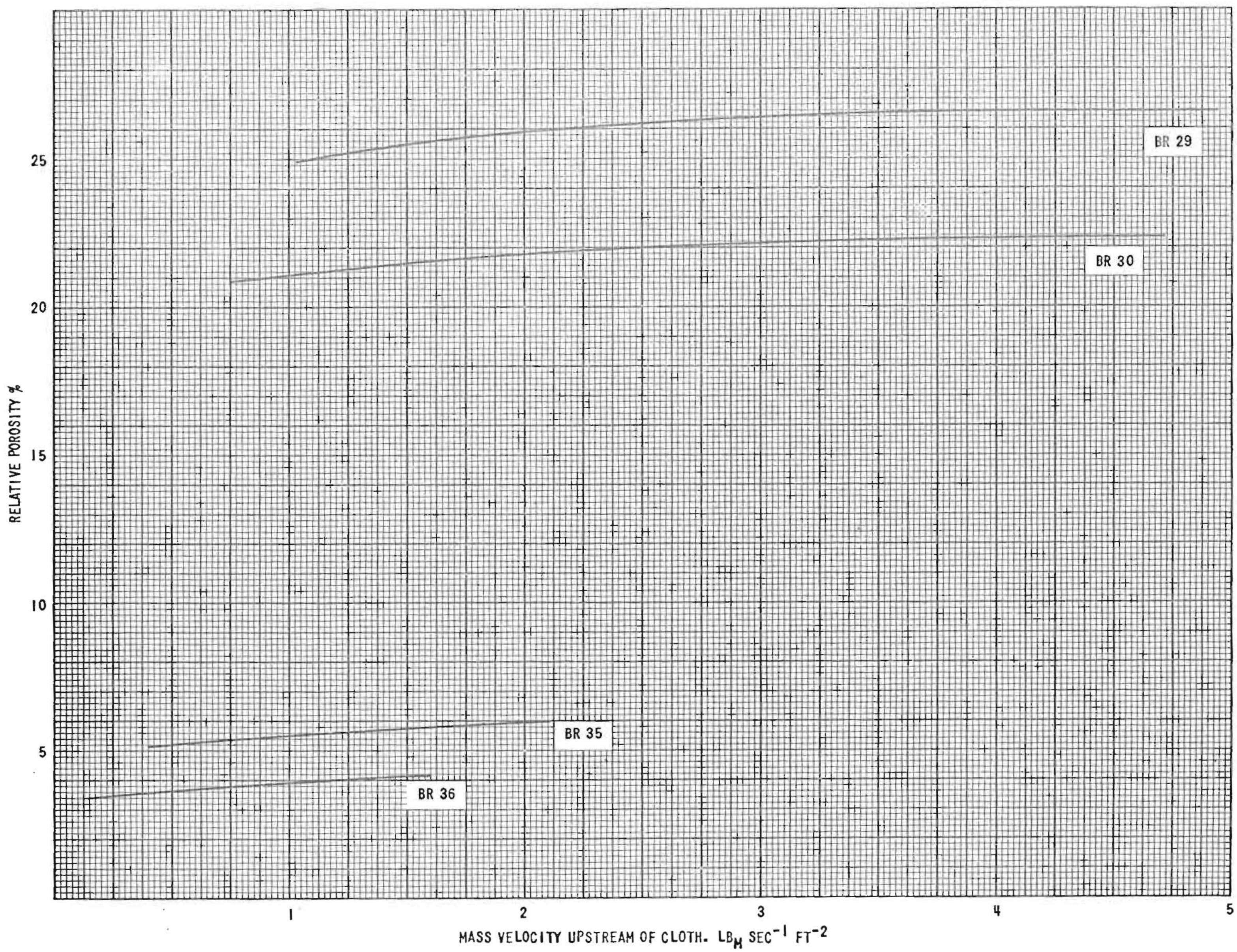


Figure 1. Porosity-Permeability Results, Bally Ribbon Cloths BR 29-30-35-36.

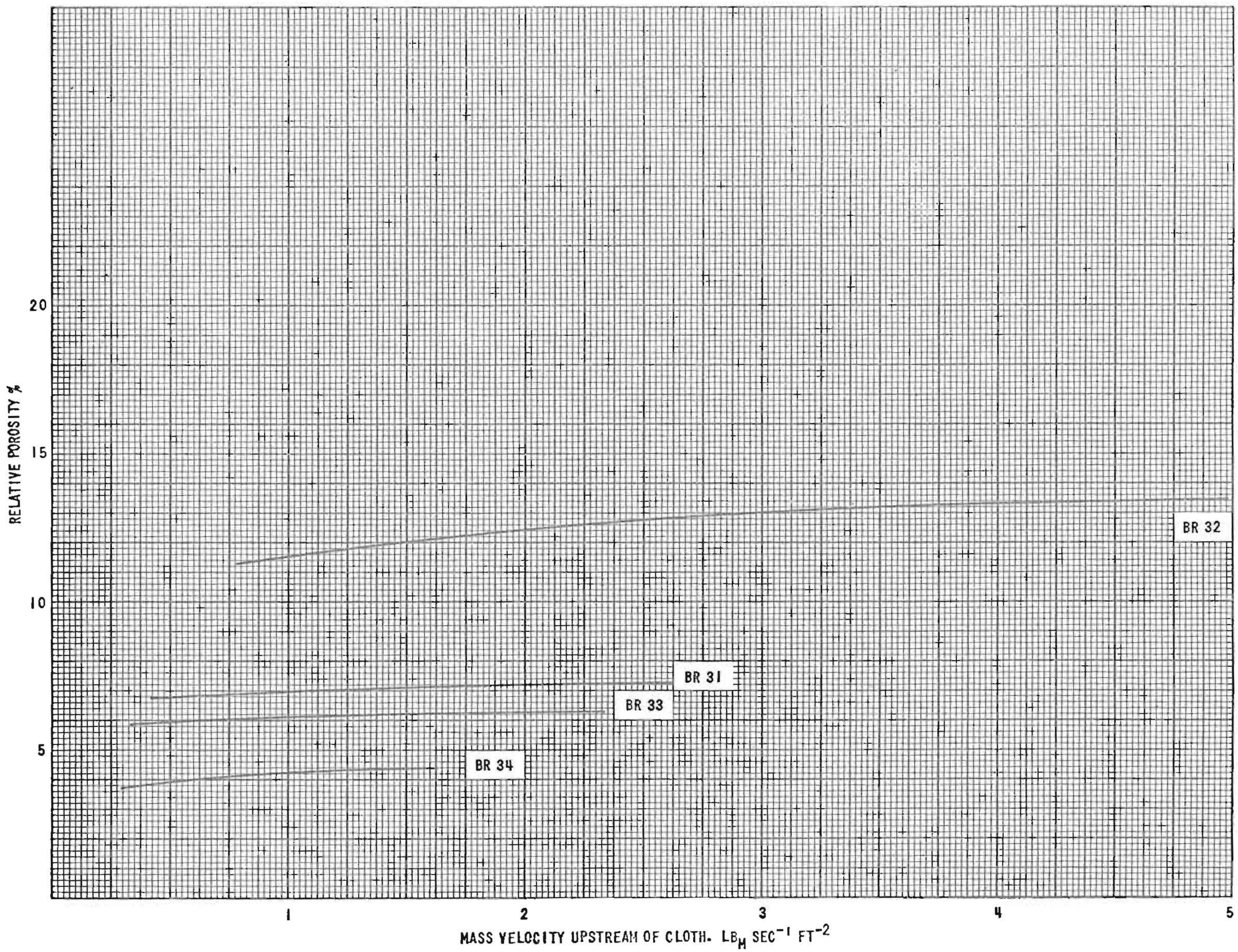


Figure 2. Porosity-Permeability Results, Bally Ribbon Cloths BR 31-BR 34.

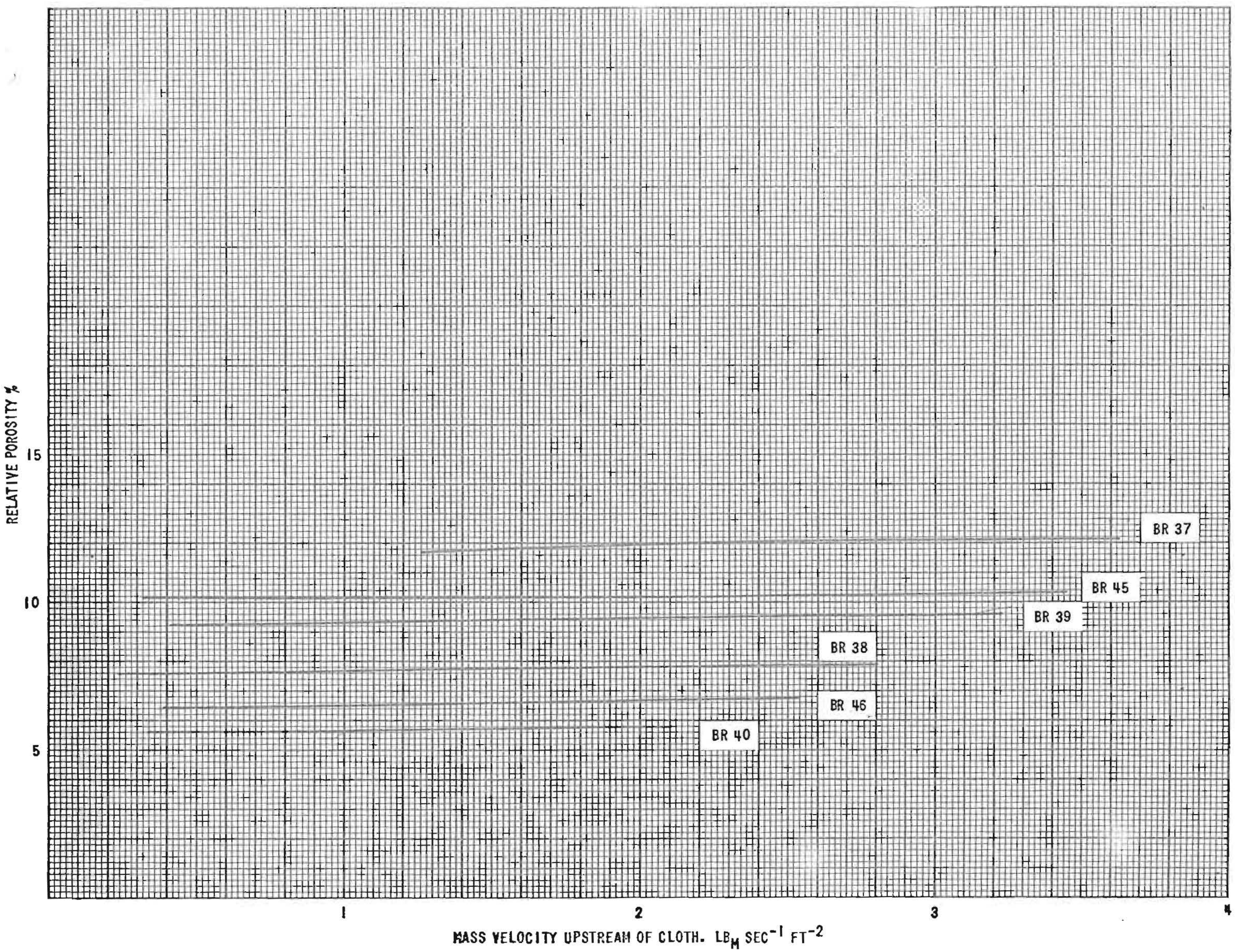


Figure 3. Porosity-Permeability Results, Bally Ribbon Cloths BR 37-38-39-40-45-46.

Georgia Institute of Technology
STATE ENGINEERING EXPERIMENT STATION
Atlanta, Georgia

QUARTERLY REPORT NO. 1

PROJECT NO. 170-117

PARACHUTE FABRIC

By

M. J. GOGLIA and H. W. S. LAVIER

- o - o - o - o -

CONTRACT NO. AF 33(038)-15624
E. O. NO. 602-193 SR-7S

- o - o - o - o -

DECEMBER 15, 1951 to MARCH 15, 1952

Georgia Institute of Technology
STATE ENGINEERING EXPERIMENT STATION
Atlanta, Georgia

QUARTERLY REPORT NO. 1

PROJECT NO. 170-117

PARACHUTE FABRIC

By

M. J. GOGLIA and H. W. S. LAVIER

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CONTRACT NO. AF 33(038)-15624
E. O. NO. 602-193 SR-7S

- o - o - o - o -

DECEMBER 15, 1951 to MARCH 15, 1952

Quarterly Report No. 1, Project No. 170-117

This report summarizes the progress during the quarter ending 15 March 1952. It concerns the high-pressure phase of the research covered by the supplemental agreement to the subject contract.

A. Preliminary Investigation

The low-pressure permeability studies of fabrics woven at Georgia Tech were started during this quarter. Analysis of the test results from these studies, in combination with the results pertaining to Air Force-furnished fabrics, is furnishing data concerning the specific fabric properties to be studied and the magnitude of deformations and internal stresses to be expected in conducting the high-pressure permeability studies.

Equipment for use in the high-pressure permeability studies has been decided upon. Quotations and bids for equipment items including air dryers, after coolers, and a 1,000-cubic-foot air reservoir have been obtained during the past quarter. Plans for the arrangement of test equipment have been completed. A study has been made concerning the instrumentation required for conducting these studies.

B. Deformation of Fabrics Under Load (No Airflow)

Preparing plans for a special testing machine to load and measure the deformation in both warp and filling directions of fabric samples under known simultaneous loadings has required a study of conventional textile grab-break testers and universal-type material tensile testing equipment. It appears unlikely that stock machines can be converted to meet the requirements of this part of the test program. It does appear possible to use grab-jaws and other parts of standard testing machines which will expedite construction of the desired test machine.

It is desired to perform these tests and to determine the physical properties under varied conditions of temperature and humidity. The testing machine is being planned to permit its operation within special rooms available that can be controlled to a wide variety of temperatures and humidity. Plans are also made for enclosing the test sample in an insulated box equipped with air-conditioning apparatus to provide variable humidity and temperatures, both hot and cold.

C. Determination of Air Permeability

Current activities under this heading consist of low-pressure air permeability studies of Georgia Tech-woven nylon fabric. This fabric includes various weave patterns based on a 70-denier warp.

D. Analysis and Conclusions

Test results obtained during the past year have been studied. A technical report covering this phase of the work is currently being prepared and will soon be submitted. The first technical report will cover low-pressure permeability studies of Air Force-furnished fabrics including the Bally Ribbon series.

Project personnel during the quarter has included: Dr. M. J. Goglia, Prof. H. W. S. LaVier, Prof. F. B. Fletcher, Dr. J. L. Taylor and Mr. Brooks Metcalfe.

Respectfully submitted:

M. J. Goglia,
Project Director

H. W. S. LaVier,
Research Engineer

Approved:

Gerald A. Rosselot, Director
State Engineering Experiment Station

Georgia Institute of Technology
STATE ENGINEERING EXPERIMENT STATION
Atlanta, Georgia

QUARTERLY REPORT NO. 2

PROJECT NO. 170-117

PERMEABILITY OF PARACHUTE FABRICS

By

H. W. S. LAVIER

- o - o - o - o -

CONTRACT NO. AF 33(038)-15624
E. O. NO. 602-193 SR-7S

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MARCH 15, 1952 to JUNE 15, 1952

Georgia Institute of Technology
STATE ENGINEERING EXPERIMENT STATION
Atlanta, Georgia

QUARTERLY REPORT NO. 2

PROJECT NO. 170-117

PERMEABILITY OF PARACHUTE FABRICS

By

H. W. S. LAVIER

- o - o - o - o -

CONTRACT NO. AF 33(038)-15624
E. O. NO. 602-193 SR-7S

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MARCH 15, 1952 to JUNE 15, 1952

This report summarizes the progress during the quarter ending 15 June 1952. It concerns the low-pressure permeability studies of the fabrics woven at Georgia Tech and the high-pressure phase of the research covered by the supplemental agreement to the subject contract.

A. Low-Pressure Permeability Investigations

During the past quarter warps of nylon, orlon and dacron were woven in the weaving laboratories of the Textile School at Georgia Tech. Two nylon warps, one of 70 denier and the other of 40 denier, were woven with several different filling sizes, several numbers of filling threads per inch and several different weave patterns. A summary of these is included as Table I. Low-pressure permeability studies of these cloths have been made, and the results of this work are presented in Figures 1 through 6.

The orlon warp of 75 denier was woven with similar geometric variations. This cloth was finished by Cheney Brothers Manufacturing Company and is currently being subjected to low-pressure permeability tests.

The 70-denier dacron warp is being woven and will soon be sent to Cheney Brothers Manufacturing Company for the finishing process.

Certain fabrics were furnished by the Air Force during the past quarter. These have been tested on the low-pressure permeability testing apparatus. The results of these tests are presented comparatively in Figure 7. Figures 8 and 9 plot the volume of air flow at standard conditions versus static pressure for these Air Force-furnished fabrics.

B. High-Pressure Permeability Equipment

Equipment (including a 1,000-cubic-foot reservoir, a silica-gel dryer, a Worthington aftercooler and special instruments) has been ordered for use in the high-pressure phase of the subject research. In the interim, pressure tanks and a 12-inch-by-13-inch Worthington compressor are being installed for use in preliminary high-pressure permeability investigations.

The apparatus shown in Figure 10 was used for preliminary tests of several Air Force-furnished parachute fabrics at pressures up to 55 psig (1,504 inches of water). No attempt was made to determine the quantity of air flowing through the cloth. The purposes of these tests were to determine the best means of holding the test sample and to determine the required instrument natural frequency. This latter factor is important in choosing the type of recording device.

Four different fabrics were mounted in a mockup sample holder and installed on the apparatus as shown in Figure 10. These fabrics included a Georgia Tech-woven cloth, K-32 by Textron, a piece of dacron and one of the Bally Ribbon samples. Unfortunately, these tests were of no value other than to indicate necessary modifications of the sample holder. The maximum pressure differential, 55 psig, was attained with the Bally Ribbon sample. However, as in the case of the others, the sample finally pulled loose from the sample holder at the side.

After modifying the sample holder, a piece of nylon orange rip-stop fabric, Style No. 200-300, No. 135744A, was mounted in the test apparatus. This sample failed at an indicated pressure difference of 40 psig (1,107 inches of water). Similarly, a sample of camouflage fabric, Style No. 081-110, No. 2695-05B, failed at a 40 psig pressure differential. During the installation of a second orange rip-stop sample the mounting plate was warped and cracked, resulting in a failure of the wind tunnel. This failure prevents further testing until several modifications of the apparatus are completed.

C. Deformation of Fabrics Under Load (No Air Flow)

The machine to study the deformation of parachute fabrics under simultaneous loads applied in both warp and filling directions is almost completely planned. The tension loads will be measured by Statham Transducers and recorded on either photo-observed milliammeters or potentiometer-type recorders. Likewise, the elongation under load will be measured by a change in electrical resistance and will be similarly recorded. The cloth sample will be held in place and loaded by two pairs of A-5 jaws manufactured by Scott Testers, Inc.

The author is aware of the work being done by Dr. J. H. Dillon of the Textile Research Institute on the development of equipment for studying fabrics simultaneously loaded in warp and filling directions. Dr. Dillon has invited the author to visit his laboratory and to study this apparatus. This visit is planned for about June 15, 1952.

D. Analysis and Conclusions

Dr. M. J. Goglia is completing the first technical report covering the permeability testing of the ten Air Force-furnished fabrics and the Bally Ribbon test series.

E. Personnel

During the past quarter Prof. H. W. S. LaVier replaced Dr. Goglia as Project Director. This change was necessary due to Dr. Goglia's very heavy combined academic and research work load. Also, because of the magnitude of the high-pressure phase of the subject reasearch, it is felt that full-time project direction is warranted. Dr. Goglia will maintain his interest in the subject research by acting in an advisory technical capacity.

Mr. Brooks Metcalf also left the project staff. Project personnel included Prof. G. B. Fletcher and Dr. J. L. Taylor of the Textile School, Prof. Roy A. Martin of the Research Department as Instrument Engineer and Mr. Cecil A. Brown, full-time Research Assistant. The staff is augmented by several part-time student assistants.

Respectfully submitted:

/ Hurlbut W. S. LaVier,
Project Director

Approved:

Gerald A. Rosselot, Director
State Engineering Experiment Station

APPENDIX

TABLES AND FIGURES

TABLE I

ESTIMATED PROPERTIES OF NYLON PARACHUTE FABRICS
WOVEN BY GEORGIA TECH

Item Number	Thread Count Per Inch		Yarn Denier		Weave
	Warp	Filling	Warp	Filling	
GT-1	90	40	70/34	70/34	Plain
GT-2	90	80	70/34	70/34	Satin
GT-3	90	70	70/34	70/34	Satin
GT-4	90	60	70/34	70/34	Satin
GT-5	90	50	70/34	70/34	Satin
GT-6	90	40	70/34	70/34	Satin
GT-7	90	90	70/34	70/34	Plain
GT-8	90	80	70/34	70/34	Plain
GT-9	90	70	70/34	70/34	Plain
GT-10	90	60	70/34	70/34	Plain
GT-11	90	50	70/34	70/34	Plain
GT-12	90	40	70/34	70/34	Twill
GT-13	90	50	70/34	70/34	Twill
GT-14	90	60	70/34	70/34	Twill
GT-15	90	70	70/34	70/34	Twill
GT-16	90	80	70/34	70/34	Twill
GT-17	90	90	70/34	70/34	Twill
GT-18	130	40	40/13	70/34	Plain
GT-19	130	50	40/13	70/34	Plain
GT-20	130	60	40/13	70/34	Plain
GT-21	130	70	40/13	70/34	Plain
GT-22	130	80	40/13	70/34	Plain
GT-23	130	80	40/13	70/34	Satin
GT-24	130	70	40/13	70/34	Satin
GT-25	130	60	40/13	70/34	Satin
GT-26	130	50	40/13	70/34	Satin
GT-27	130	40	40/13	70/34	Satin
GT-28	130	40	40/13	70/34	Twill
GT-29	130	50	40/13	70/34	Twill
GT-30	130	60	40/13	70/34	Twill
GT-31	130	70	40/13	70/34	Twill
GT-32	130	80	40/13	70/34	Twill

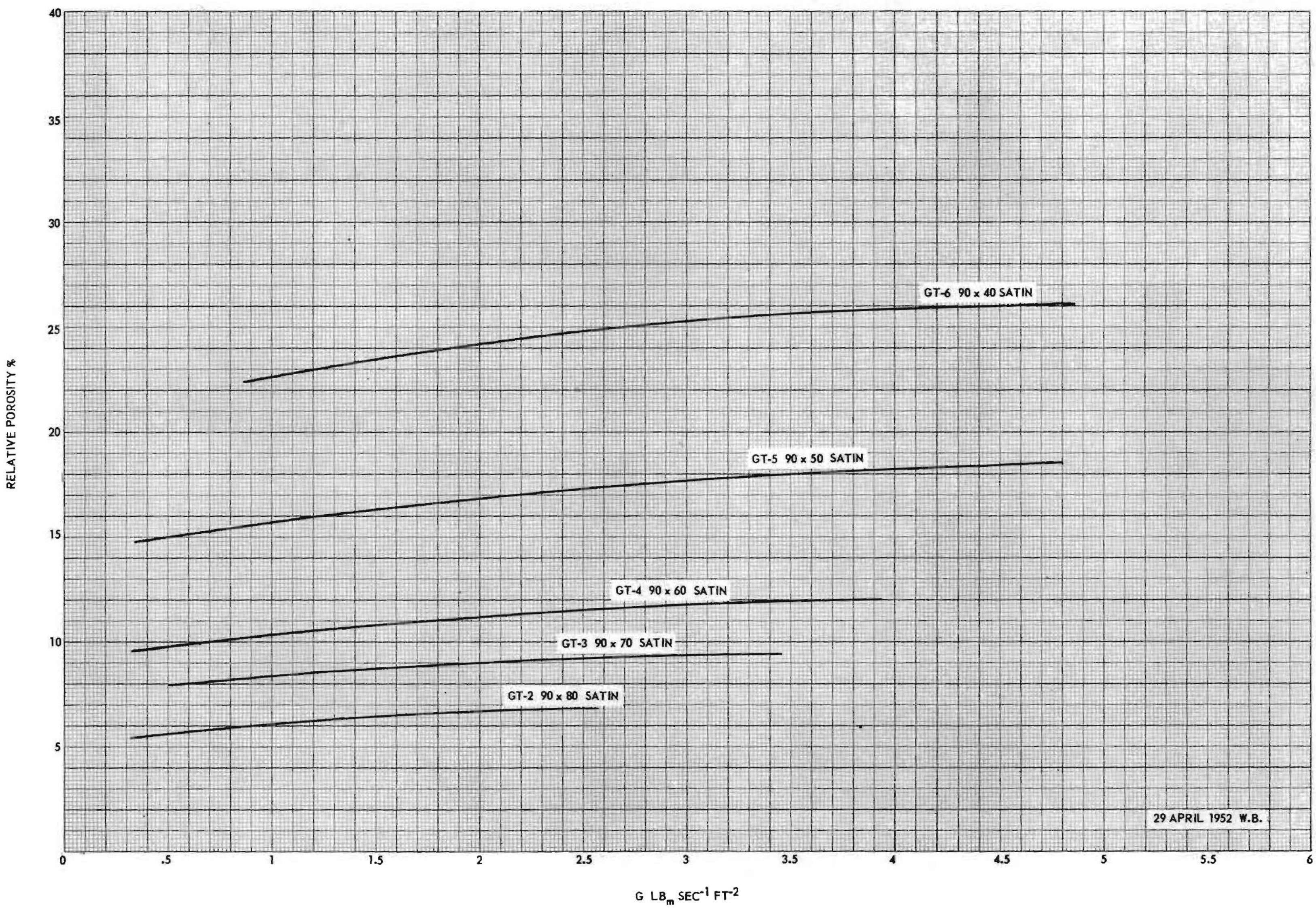

Figure 1. Permeability Data on Georgia Tech-Woven Fabrics.

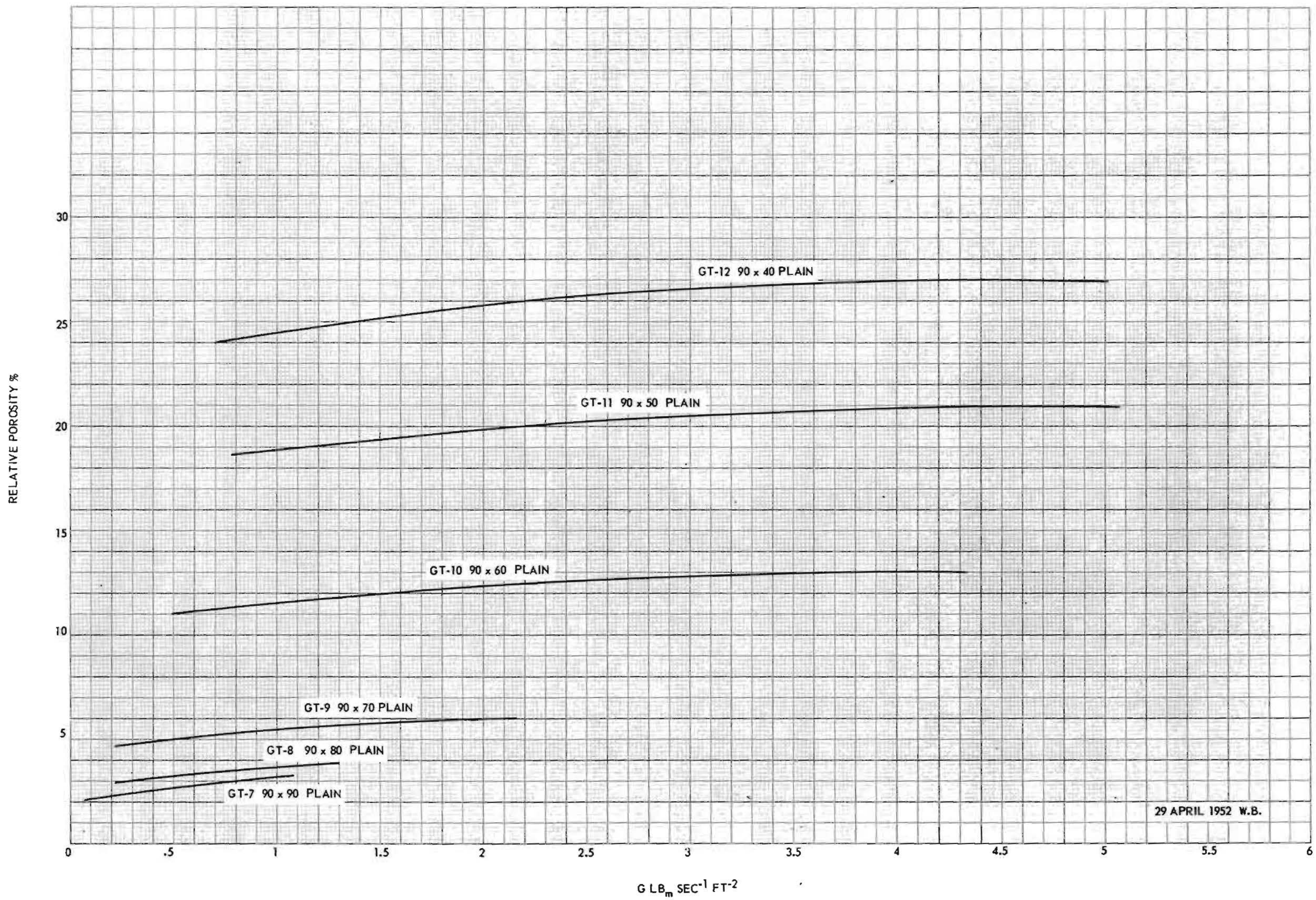

Figure 2. Permeability Data on Georgia Tech-Woven Fabrics

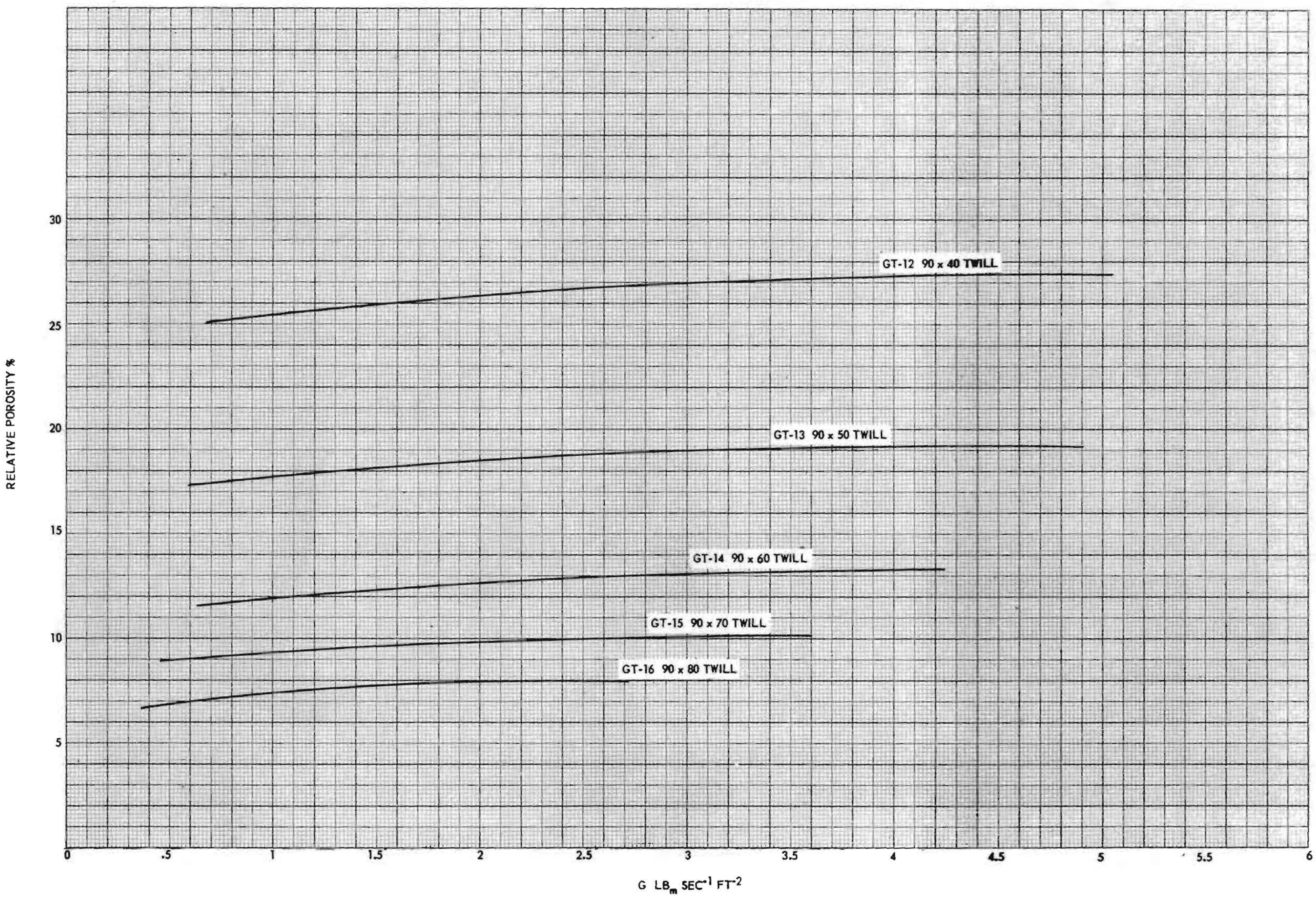

Figure 3. Permeability Data on Georgia Tech-Woven Fabrics.

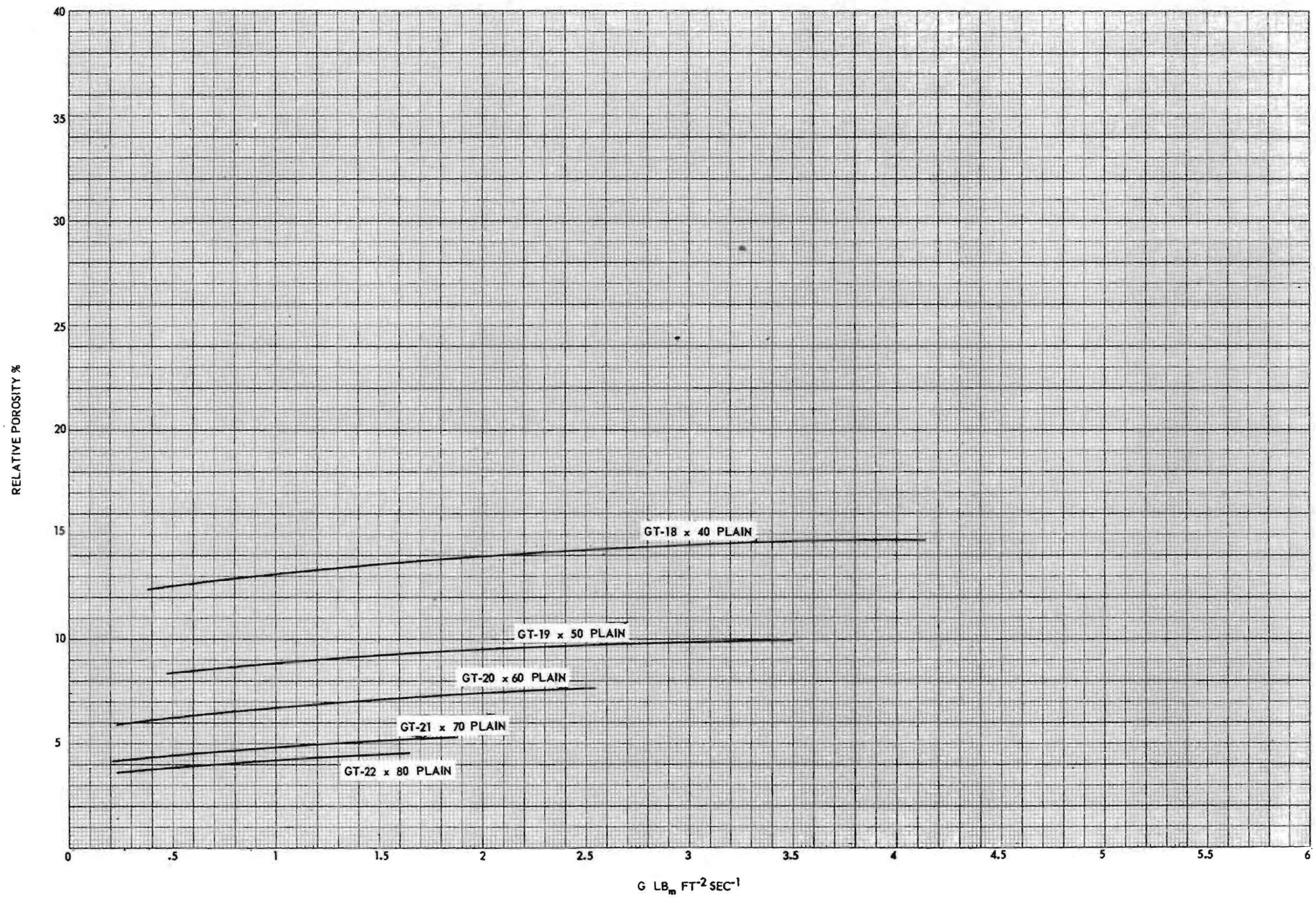

Figure 4. Permeability Data on Georgia Tech-Woven Fabrics

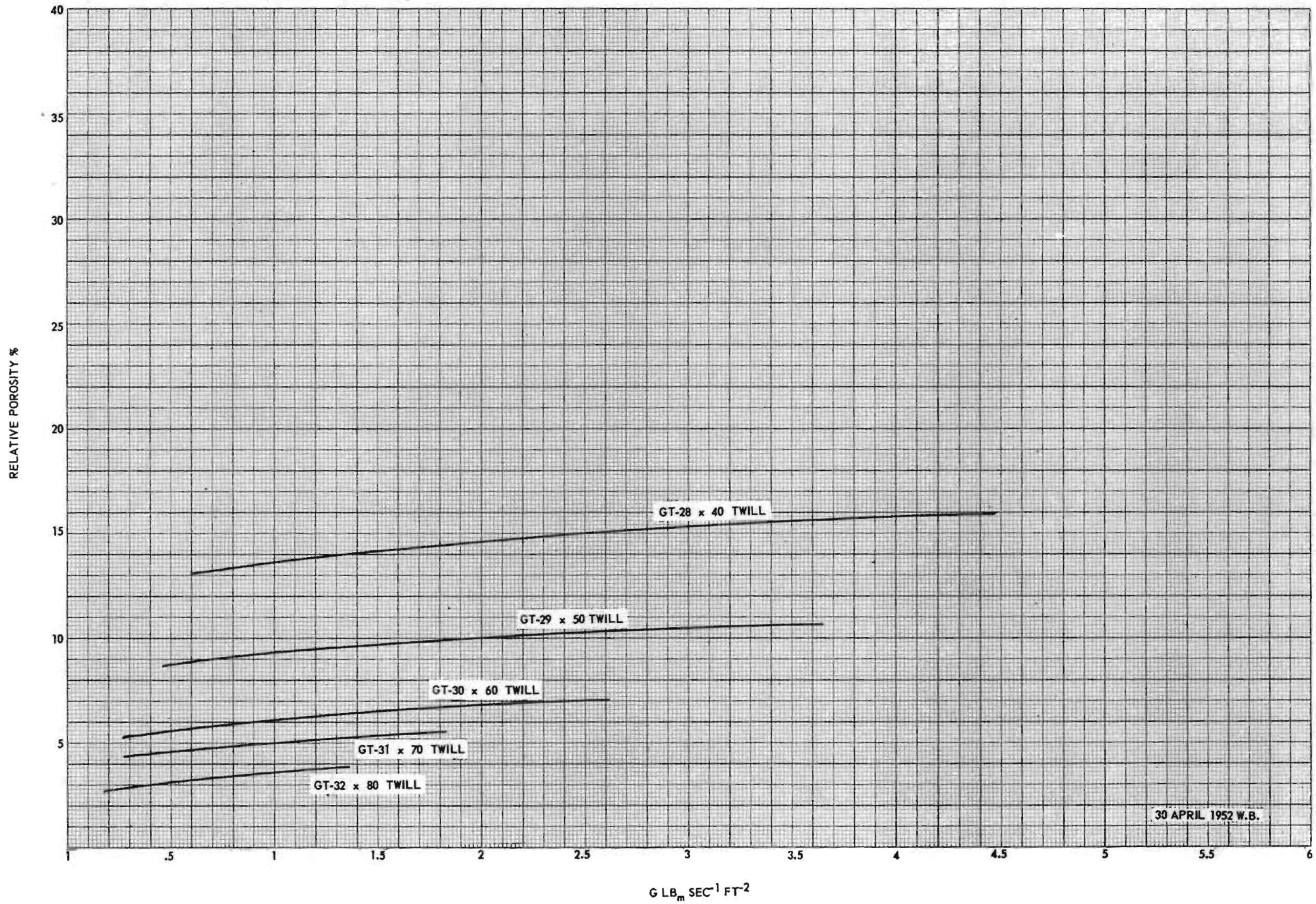

Figure 5. Permeability Data on Georgia Tech-Woven Fabrics

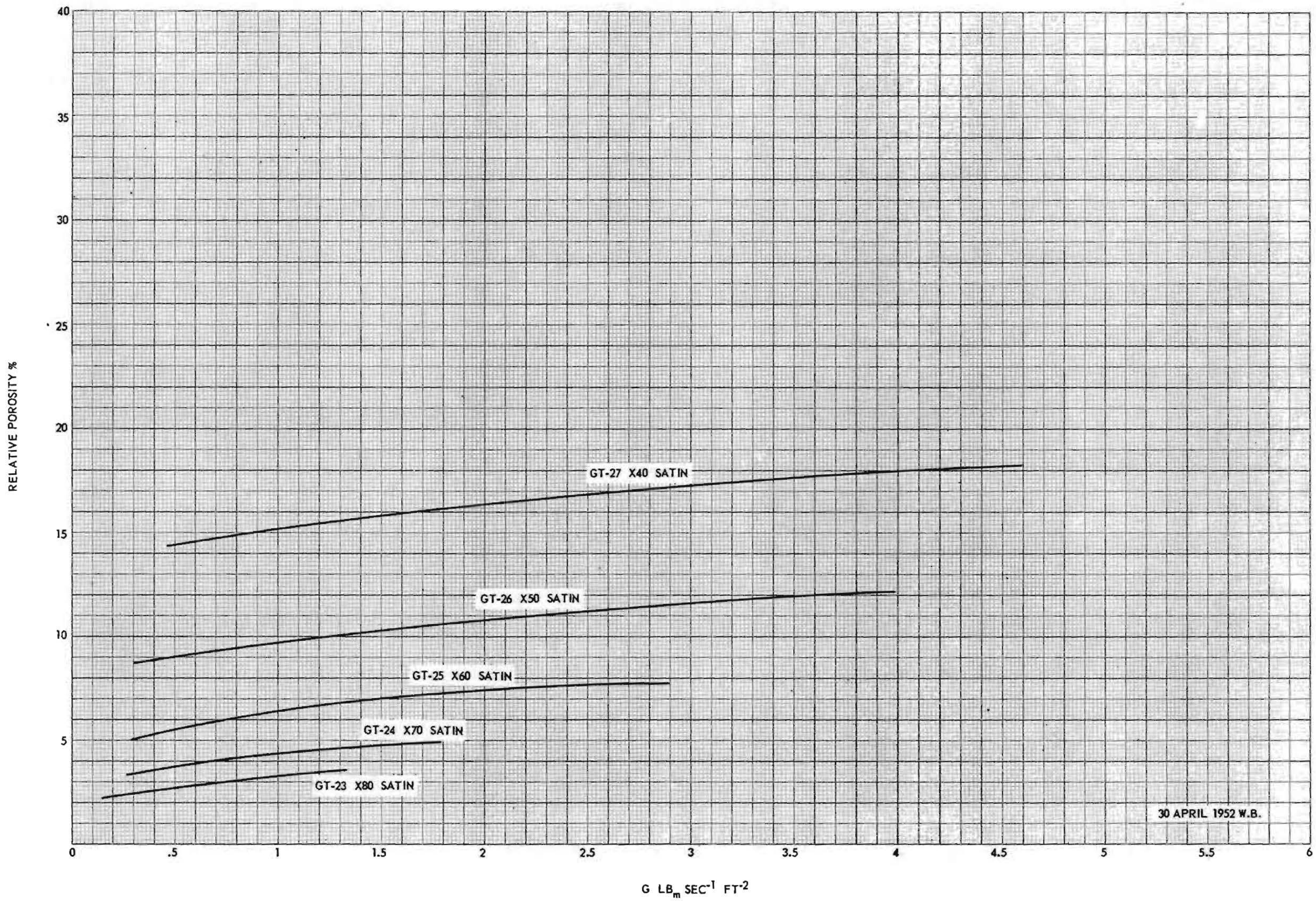

Figure 6. Permeability Data on Georgia Tech-Woven Fabrics

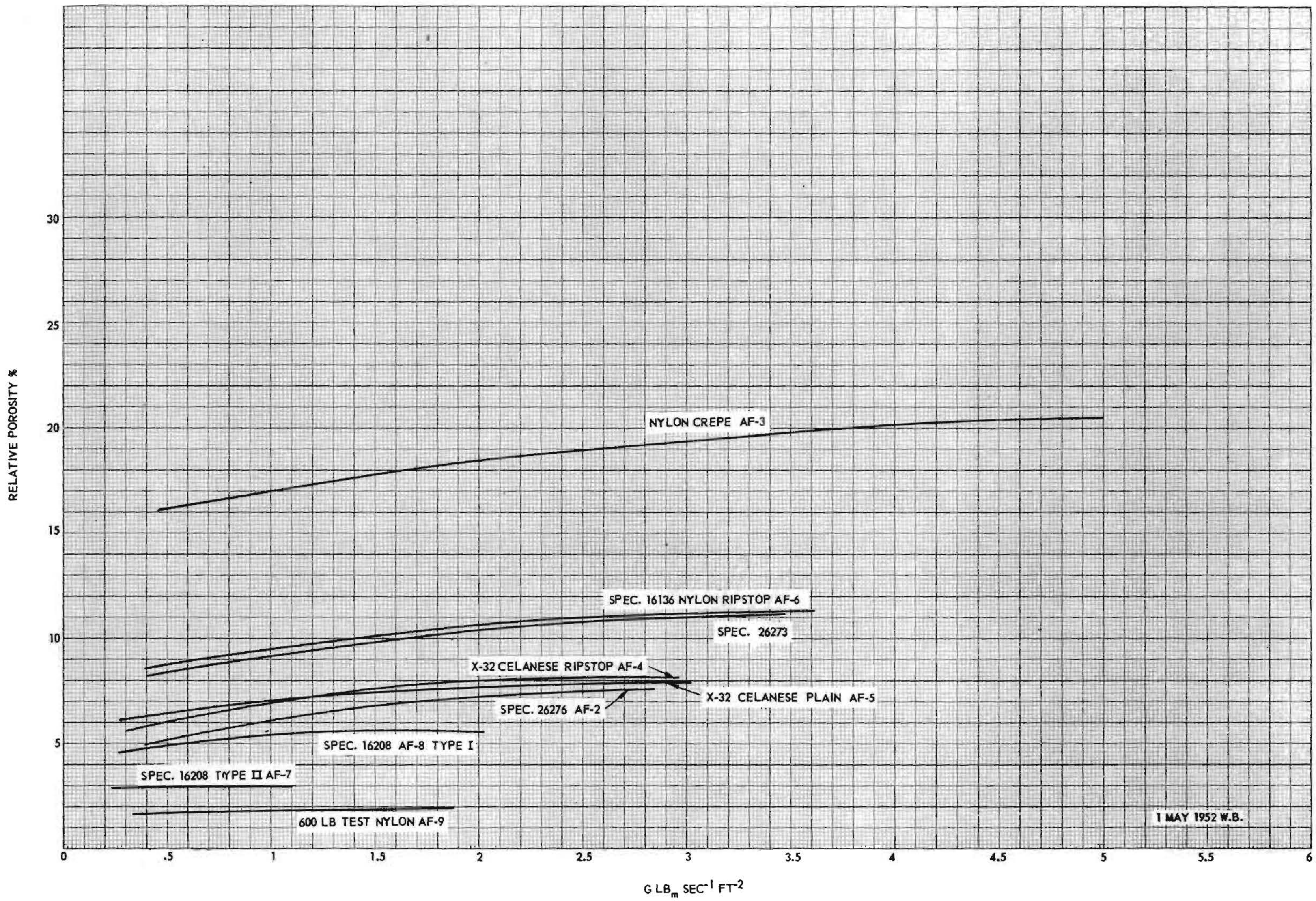

Figure 7. Permeability Data on Air Force-Furnished Fabrics.

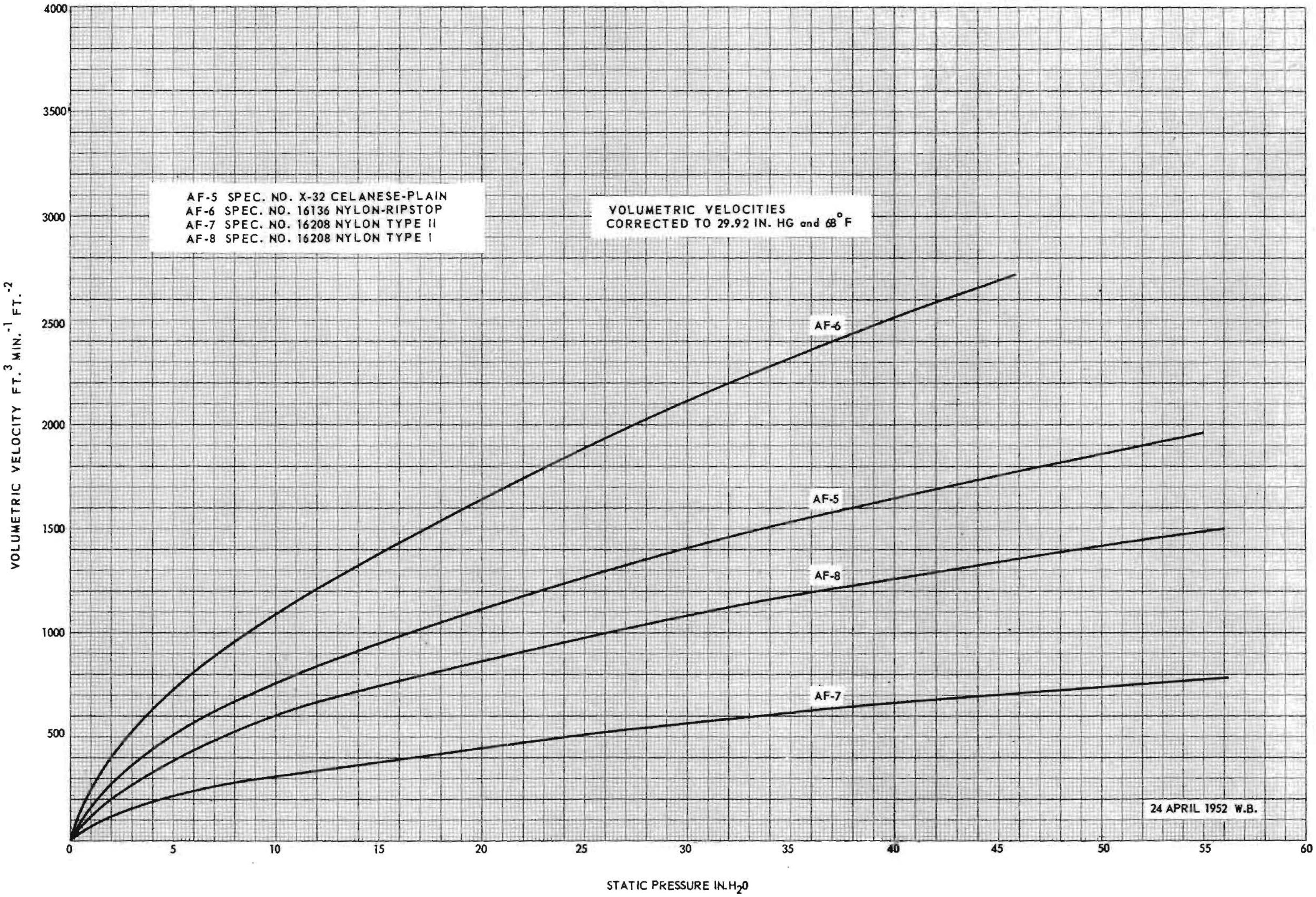

Figure 8. Permeability Data on Air Force-Furnished Fabric

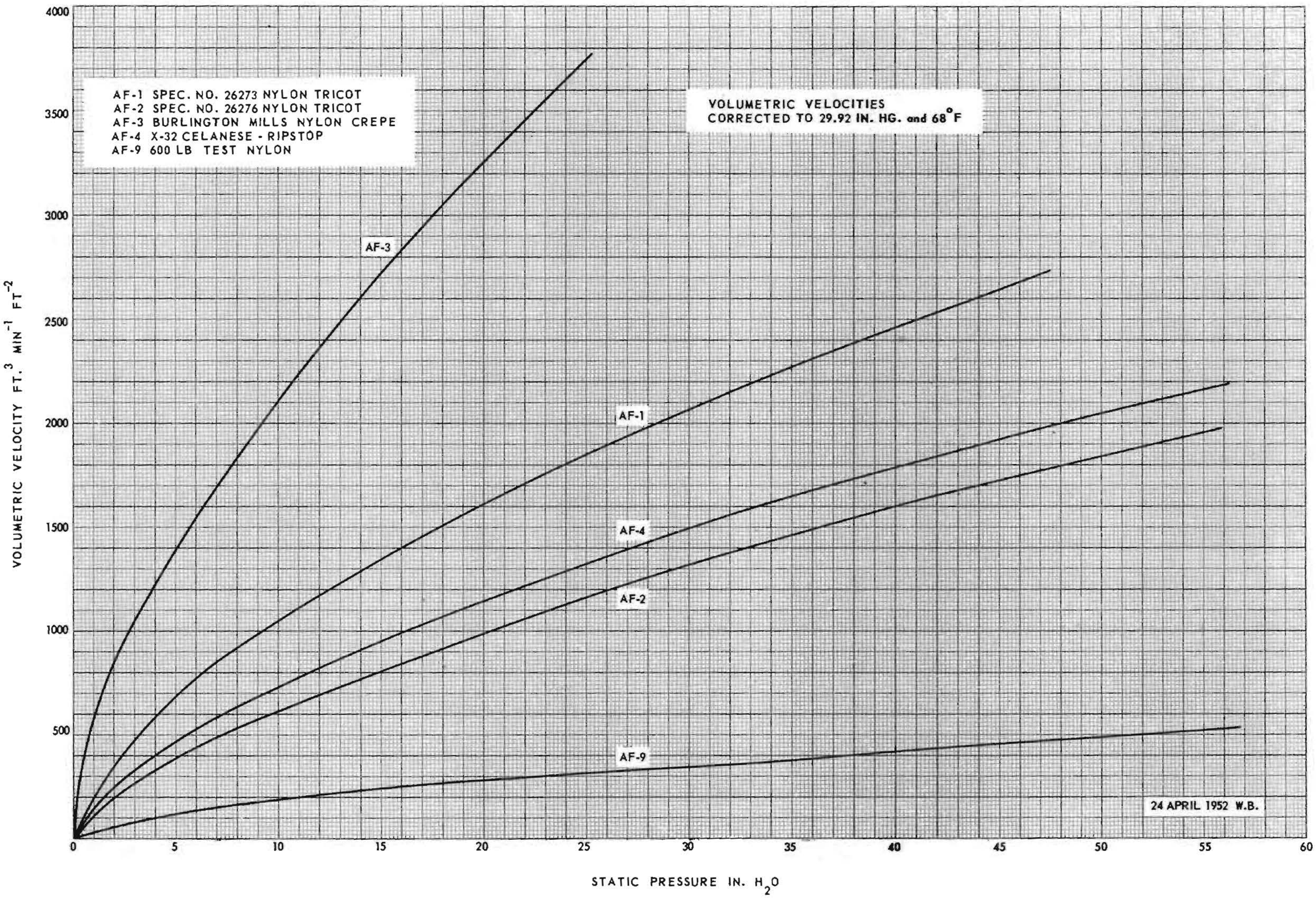

Figure 9. Permeability Data on Air Force-Furnished Fabrics.

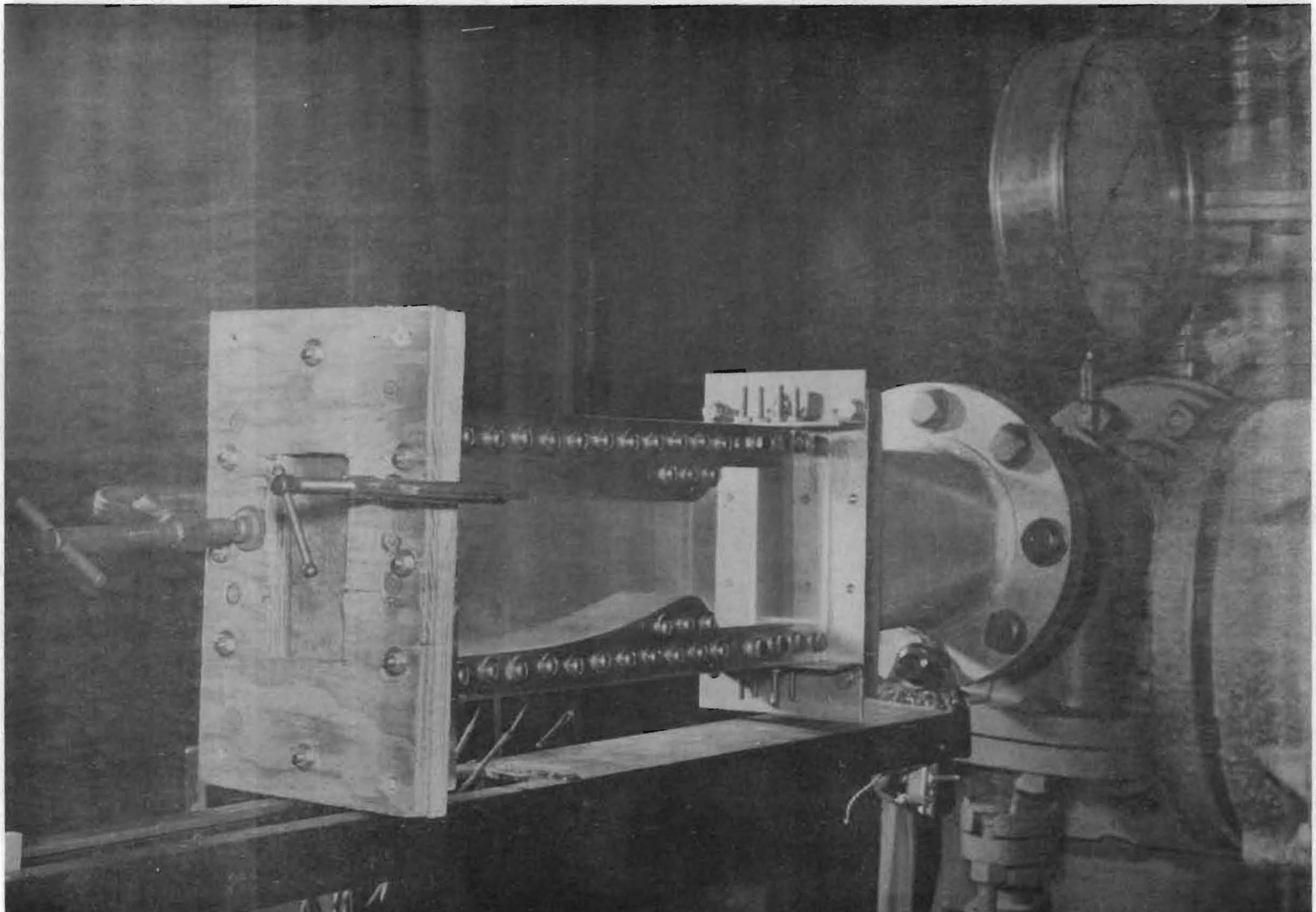

Figure 10. High-Pressure Permeability Apparatus with Mockup Sample Holder.

Georgia Institute of Technology
STATE ENGINEERING EXPERIMENT STATION
Atlanta, Georgia

QUARTERLY REPORT NO. 3

PROJECT NO. 170-117

PERMEABILITY OF PARACHUTE FABRICS

By

H. W. S. LAVIER

- o - o - o - o -

CONTRACT NO. AF 33(038)-15624
E.O. No. R602-198, Project No. 52-660A-41 SR7s
E.O. No. R602-193SR7S, Project No. 52-660A-25

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JUNE 15, 1952 to SEPTEMBER 15, 1952

Georgia Institute of Technology
STATE ENGINEERING EXPERIMENT STATION
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JUNE 15, 1952 to SEPTEMBER 15, 1952

Quarterly Report No. 3, Project No. 170-117

This report summarizes the progress during the quarter ending 15 September 1952. It concerns the completion of the low-pressure permeability studies of the fabrics woven at Georgia Tech. The progress of the high-pressure phase of the subject research is also covered in this report.

A. Low-Pressure Permeability Investigations

During the past quarter Georgia Tech-woven orlon and dacron fabrics were subjected to low-pressure permeability studies. Also, after finishing, the Georgia Tech-woven fabrics were subjected to studies to determine the physical characteristics of the fabrics. Table I includes a comparison of the nominal and finished properties of the 70- and 40-denier nylon. Tables II and III list the same properties for the orlon and dacron fabrics.

The results of the permeability studies for the Georgia Tech-woven nylon, orlon and dacron fabrics are presented in tabular form in Table IV and permeability results for the orlon and dacron fabrics are shown in curve form in Figures 1 thru 6. Table IV contains the permeability data for the Georgia Tech-woven 40- and 70-denier nylon. This data was previously presented in curve form in Quarterly Report No. 2.

Several cloth samples subjected to permeability experiments during the summer of 1951 were recently taken from the filing cabinet storage space, reinstalled in the sample holder and the test procedure was repeated. Figures 7 thru 11 show the 1952 individual sample test results in comparison with the 1951 results for the same sample and also the average of nine samples. The differences between 1952 and 1951 results is within the confidence level for this program as established by the statistical studies.

A standard parachute fabric, No. 135744A orange rip-stop, was placed in the sample holder of the large permeometer and, starting with low pressure differentials across the cloth, the pressures were increased in increments to a maximum of 52 inches of water and then decreased to the lowest possible pressure differential. The sample was left in the sample holder in the large permeometer over night and the same procedure was repeated the next morning. The results of this special test are plotted on Figure 12. Once again, the differences are well within the confidence level.

B. High-Pressure Permeability Equipment

The 12" x 13" Worthington Compressor and aftercooler have been overhauled and are ready for final installation and use. However, difficulty in obtaining 2300-volt electric cable, 3-phase oil-cut-off switches and high pressure steel pipe has prevented use of this equipment.

The silica-gel dryer has been received and will be installed as soon as pipe fittings and valves, now on order, are delivered.

Unfortunately, the steel strike delayed delivery of "header" and "shell" steel to the Richmond Engineering Company. As a result, the tank fabrication has been delayed. The Richmond Engineering Company has not yet indicated their expected delivery date for the 1000-cubic-foot reservior. It is planned to use the interim tanks until the large one is received.

Preliminary instrument tests are being conducted. A Statham Differential Pressure Transducer and two thermocouples were installed on the experimental high-pressure permeability apparatus. It was expected that variations of pressure and temperature would be recorded by a 6-channel

General Electric Recording Oscillograph. However, the preliminary experiments revealed that costly D-C or A-C amplifiers will be necessary. Currently, the availability and characteristics of various amplifiers and transducers are being studied.

It is expected that some temperature control will result from using Freon refrigerant instead of water in conjunction with the Worthington Aftercooler. The special wind tunnel and sample holder to be used in the high-pressure permeability investigations have been designed and are now under construction. Revision of this equipment as the experimental program progresses is to be expected.

C. Deformation of Fabrics Under Load (No Air Flow)

The machine to study the deformation of parachute fabrics under simultaneous loads applies in both warp and filling directions has been designed and is now being constructed. This machine will apply equal and simultaneous deformation in the warp and filling direction. From a simultaneous record of load and elongation, stress-strain diagrams will be prepared. It was decided that the Statham transducer could be replaced by cantilever beams equipped with SR-4 strain gages for load measuring devices. The variation of loading is indicated by sensitive milliammeters and the load versus elongation record is obtained by use of a photo observer.

D. Analysis and Conclusions

The Technical Report No. 1 by Dr. M. J. Goglia and covering the permeability tests of the ten Air Force-furnished fabrics and the Bally Ribbon test series will be ready for distribution on or about September 24.

E. Personnel

During the past quarter project personnel has included Professor H. W. S. LaVier, Project Director, Professor Gerald Fletcher, Textile

Engineer, Mr. Cecil D. Brown, Research Assistant, Mrs. Donna Williams, Project Secretary, Mr. W. C. Boteler, Mr. R. L. Culpepper and Mr. J. L. Smith all Graduate Assistants and Mr. W. H. Carter, Student Assistant.

In addition to completing Technical Report No. 1, Dr. M. J. Goglia was of great assistance to the project staff as a consultant.

Respectfully submitted:

HURLBUT W. S. LAVIER,
Project Director

Approved:

Gerald A. Rosselot, Director
State Engineering Experiment Station

APPENDIX A

TABLES

TABLE I

PHYSICAL AND TEXTILE PROPERTIES OF
GEORGIA TECH NYLON CLOTHS

Fabric Number	1	2	3	4	5	6	7	8	9	10
Width (Inches)	32-1/2	33	33	33	33	33	31-1/2	32	32	32
Construction:	Plain	Satin	Satin	Satin	Satin	Satin	Plain	Plain	Plain	Plain
Nominal	70x40	70x80	70x70	70x60	70x50	70x40	70x90	70x80	70x70	70x60
Finished	77x44	75.5x91	75.5x75	76x63.5	76x55	77x43.5	80x94	78x88	78.5x73	78.5x64.5
Warp Yarns:										
Denier	74.73	74.73	74.73	74.73	74.73	74.73	74.73	74.73	74.73	74.73
Filaments	34	34	34	34	34	34	34	34	34	34
Filling Yarns:										
Denier	80.35	80.35	80.35	80.35	80.35	80.35	80.35	80.35	80.35	80.35
Filaments	34	34	34	34	34	34	34	34	34	34
Weight:										
Oz./Sq. Yard	1.23	1.82	1.50	1.42	1.31	1.17	1.75	1.67	1.58	1.45
Oz./Lin. Yard	1.11	1.67	1.37	1.30	1.20	1.07	1.52	1.48	1.40	1.29
Twist (T.P.I.):										
Filling "Z"	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86
Warp "Z"	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4
Elongation (%):										
Filling	30	36.7	35.6	36.0	30	30.6	35	35.3	36.6	32
Warp	34.5	38.3	38	38.3	32	33.3	36.3	35.9	34	35
Tensile:										
Filling	52	97	81	74	61	37	97	81	80	71
Warp	83	81	74	78	71	65	88	81	80	82

(Continued)

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TABLE I (Continued)

PHYSICAL AND TEXTILE PROPERTIES OF
GEORGIA TECH NYLON CLOTHS

Fabric Number	11	12	13	14	15	16	17	18	19	20
Width										
(Inches)	32-1/2	34	33-1/2	33-1/2	34	33-1/2	33-1/2	33-1/4	32-1/2	32-1/2
Construction:	Plain	Twill	Twill	Twill	Twill	Twill	Twill	Plain	Plain	Plain
Nominal	70x50	70x40	70x50	70x60	70x70	70x80	70x90	125x40	125x50	125x60
Finished	77x53.5	74x42	74.5x53	74.5x63	74x73	75.5x82.5	75x92	137.0x41	139.25x52	140.0x62
Warp Yarns:										
Denier	74.73	74.73	74.73	74.73	74.73	74.73	74.73	43.61	43.61	43.61
Filaments	34	34	34	34	34	34	34	13	13	13
Filling Yarns:										
Denier	80.35	80.35	80.35	80.35	80.35	80.35	80.35	80.35	80.35	80.35
Filaments	34	34	34	34	34	34	34	34	34	34
Weight:										
Oz./Sq. Yard	1.33	1.12	1.29	1.36	1.46	1.57	1.73	1.109	1.317	1.423
Oz./Lin. Yard	1.20	1.06	1.20	1.27	1.38	1.46	1.61	1.024	1.189	1.285
Twist (T.P.I.):										
Filling "Z"	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86
Warp "Z"	15.4	15.4	15.4	15.4	15.4	15.4	15.4	9.8	9.8	9.8
Elongation (%):										
Filling	34.6	30	33.3	32.3	32.6	34.5	37.6	32.0	31.6	33.6
Warp	34.3	36	34.3	36.6	34.3	35.2	37	31.6	30	30
Tensile:										
Filling	61	53	69	80	99	117	117	43	54	72
Warp	85	79	80	81	88	87	84	72	74	74

(Continued)

TABLE I (Continued)

PHYSICAL AND TEXTILE PROPERTIES OF

GEORGIA TECH NYLON CLOTHS

Fabric Number	21	22	23	24	25	26
Width						
(Inches)	32-1/4	32-1/2	33	33	33	33
Construction:	Plain	Plain	Satin	Satin	Satin	Satin
Nominal	125x70	125x80	125x80	125x70	125x60	125x50
Finished	141.5x73.25	142.25x82.25	139.5x84.5	138.75x74.75	139x64	138.25x53
Warp Yarns:						
Denier	43.61	43.61	43.61	43.61	43.61	43.61
Filaments	13	13	13	13	13	13
Filling Yarns:						
Denier	80.35	80.35	80.35	80.35	80.35	80.35
Filaments	34	34	34	34	34	34
Weight:						
Oz./Sq. Yard	1.566	1.679	1.651	1.546	1.443	1.326
Oz./Lin. Yard	1.403	1.516	1.514	1.418	1.323	1.216
Twist (T.P.I.):						
Filling "Z"	.86	.86	.86	.86	.86	.86
Warp "Z"	9.8	9.8	9.8	9.8	9.8	9.8
Elongation (%):						
Filling	35	37.3	36	34	33.6	35
Warp	28.3	30.3	33.3	33.3	33.3	33.3
Tensile:						
Filling	83	100	105	93	81	67
Warp	74	73	83	82	87	82

(Continued)

TABLE I (Continued)

PHYSICAL AND TEXTILE PROPERTIES OF
GEORGIA TECH NYLON CLOTHS

Fabric Number	27	28	29	30	31	32
Width						
(Inches)	33	32-1/2	32-1/2	32-1/2	32-1/2	32-1/2
Construction:	Satin	Twill	Twill	Twill	Twill	Twill
Nominal	125x40	125x40	125x50	125x60	125x70	125x80
Finished	137.5x42.5	139.5x42	140.0x52	141.5x63.75	141.5x72.25	143.5x83.5
Warp Yarns:						
Denier	43.61	43.61	43.61	43.61	43.61	43.61
Filaments	13	13	13	13	13	13
Filling Yarns:						
Denier	80.35	80.35	80.35	80.35	80.35	80.35
Filaments	34	34	34	34	34	34
Weight:						
Oz./Sq. Yard	1.210	1.231	1.337	1.446	1.577	1.697
Oz./Lin. Yard	1.110	1.112	1.207	1.306	1.424	1.532
Twist (T.P.I.):						
Filling "Z"	.86	.86	.86	.86	.86	.86
Warp "Z"	9.8	9.8	9.8	9.8	9.8	9.8
Elongation (%):						
Filling	30	33.3	34	36.6	35	33.3
Warp	33.3	34.0	34.0	33.3	33.6	33.3
Tensile:						
Filling	48	52	66	81	87	94
Warp	80	83	83	86	92	89

TABLE II

PHYSICAL AND TEXTILE PROPERTIES OF
GEORGIA TECH ORLON CLOTHS

Fabric Number	33	34	35	36	37	38	39	40	41	42	43	44
Width												
(Inches)	34-3/4	34-5/8	34-1/4	34-1/4	34-7/8	35	34-7/8	34-3/4	35	34-7/8	35-1/8	35
Construction:	Plain	Plain	Plain	Plain	Twill	Twill	Twill	Twill	Satin	Satin	Satin	Satin
Nominal	100x40	100x50	100x60	100x70	100x40	100x50	100x60	100x70	100x40	100x50	100x60	100x70
Finished	102x41	102x51	104x61	103x70	102x40	102x51	103x61	103x70	102x40.5	100x52	101x60	102x70
Warp Yarns:												
Denier	79.55	79.55	79.55	79.55	79.55	79.55	79.55	79.55	79.55	79.55	79.55	79.55
Filaments	30	30	30	30	30	30	30	30	30	30	30	30
Filling Yarns:												
Denier	80.35	80.35	80.35	80.35	80.35	80.35	80.35	80.35	80.35	80.35	80.35	80.35
Filaments	30	30	30	30	30	30	30	30	30	30	30	30
Weight :												
Oz/Sq.Yard	1.442	1.554	1.668	1.751	1.440	1.525	1.611	1.748	1.397	1.548	1.637	1.751
Oz/Lin.Yard	1.392	1.494	1.587	1.666	1.395	1.482	1.560	1.687	1.358	1.499	1.597	1.702
Twist (T.P.I.):												
Filling "Z"	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Warp "Z"	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6
Elongation (%) :												
Filling	14	13.3	13.6	16	13.6	15.6	15	16.3	14.3	15	13.6	15
Warp	11.6	12.3	11.6	12.3	12	12	12	12.3	11.6	11.6	12	12
Tensile:												
Filling	31.3	36	40.2	36.4	25.4	34.8	38.5	41.5	22.2	30.2	39.3	43.8
Warp	51.9	46.5	53.4	49.2	48.3	53.1	50.2	52.6	46	50.4	56.2	52.1

TABLE III

PHYSICAL AND TEXTILE PROPERTIES OF
GEORGIA TECH DACRON CLOTHS

Fabric Number	45	46	47	48	49	50	51	52	53	54	55	56
Width												
(Inches)	32-1/16	32	32-1/8	32	32-1/16	32	32	32	32-1/2	32-1/4	32	32
Construction:	Plain	Plain	Plain	Plain	Twill	Twill	Twill	Twill	Satin	Satin	Satin	Satin
Nominal	100x40	110x50	110x60	110x70	110x40	110x50	110x60	110x70	110x40	110x50	110x60	110x70
Finished	121x43.5	123x53	122x64	122x75	122x43	123x54	123x66	123x77	122x44	122x56	123x66	123x78
Warp Yarns:												
Denier	77.12	77.12	77.12	77.12	77.12	77.12	77.12	77.12	77.12	77.12	77.12	77.12
Filaments	34	34	34	34	34	34	34	34	34	34	34	34
Filling Yarns:												
Denier	80.78	80.78	80.78	80.78	80.78	80.78	80.78	80.78	80.78	80.78	80.78	80.78
Filaments	34	34	34	34	34	34	34	34	34	34	34	34
Weight:												
Oz./Sq. Yard	1.734	1.874	1.971	2.071	1.740	1.846	1.966	2.100	1.726	1.817	1.983	2.134
Oz./Lin. Yard	1.545	1.666	1.759	1.840	1.550	1.641	1.747	1.867	1.558	1.628	1.762	1.897
Twist (T.P.I.):												
Filling "Z"	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Warp "Z"	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9
Elongation (%):												
Filling	37.3	34	28.8	25	34	30.66	33.9	31.66	29.3	34	36.6	35.3
Warp	27.3	22.6	23.1	23.6	33.3	37	30.66	34	27	31	29.6	33
Tensile:												
Filling	47.8	56.7	61.9	70.3	45	52.4	67	71.8	36.6	56	75.6	83.4
Warp	88.2	91	85.7	78.5	101.1	110.1	96.6	106.9	88	95.4	102.8	108

Summary of Experimental Results

In all tests a circular sample of cloth having an area of 0.2 square foot was used in the test apparatus; therefore, in order to calculate air flow through cloth (lbm sec.$^{-1}$) multiply the mass velocity of air upstream of the cloth by 0.2 square foot. The results presented subsequently are the average of nine samples taken from a given bolt of cloth nine inches in from the selvage edge.

TABLE IV

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 1 (GT)			
16	.0705	4.68	26.90
13	.0702	4.22	27.00
11	.0696	3.85	26.90
9	.0694	3.46	26.80
7	.0691	3.04	26.70
5	.0688	2.53	26.3
4	.0686	2.23	26.0
3	.0683	1.90	25.7
2	.0683	1.53	25.2
1	.0680	1.07	25.0
.5	.0680	.75	24.7
Fabric Number 2 (GT)			
55	.0772	2.24	6.63
45	.0753	1.98	6.57
35	.0737	1.70	6.47
30	.0729	1.55	6.38
25	.0721	1.38	6.28
20	.0713	1.21	6.16
15	.0705	1.02	6.02
10	.0694	.80	5.87
7	.0691	.64	5.62
5	.0686	.50	5.16
3	.0683	.36	4.80

(Continued)

TABLE IV (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 3 (GT)			
50	.0739	2.99	9.49
40	.0721	2.55	9.16
30	.0704	2.13	8.94
25	.0696	1.89	8.78
20	.0688	1.66	8.65
15	.0680	1.40	8.55
10	.0670	1.12	8.33
8	.0668	.98	8.23
6	.0664	.84	8.17
4	.0661	.67	8.02
2	.0658	--	--
Fabric Number 4 (GT)			
45	.0737	3.56	11.9
35	.0721	3.05	11.7
30	.0712	2.76	11.5
25	.0704	2.46	11.3
20	.0695	2.17	11.2
15	.0687	1.82	10.9
10	.0679	1.44	10.7
8	.0675	1.27	10.6
6	.0672	1.08	10.4
4	.0669	.87	10.3
2	.0665	.59	9.90
Fabric Number 5 (GT)			
30	.0715	4.42	18.4
25	.0707	3.97	18.2
20	.0699	3.45	17.9
16	.0694	3.03	17.6
14	.0688	2.80	17.4
12	.0686	2.56	17.2
10	.0683	2.31	17.1
8	.0680	2.03	16.8
6	.0675	1.72	16.5
4	.0672	1.37	16.1
2	.0669	.93	15.5

(Continued)

TABLE IV (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 6 (GT)			
16	.0699	4.51	26.0
14	.0696	4.19	26.0
12	.0694	3.86	25.8
10	.0688	3.47	25.6
8	.0686	3.07	25.3
6	.0683	2.60	24.8
5	.0680	2.35	24.6
4	.0680	2.06	24.1
3	.0678	1.77	23.9
2	.0675	1.43	23.7
1	.0675	1.00	23.5
Fabric Number 7 (GT)			
54	.0755	1.02	3.09
48	.0745	.942	3.04
40	.0732	.832	2.97
34	.0721	.745	2.91
26	.0708	.623	2.81
20	.0698	.523	2.71
16	.0691	.440	2.56
12	.0684	.367	2.48
8	.0678	.278	2.30
4	.0672	.187	2.21
2	.0668	.120	2.01
Fabric Number 8 (GT)			
50	.0754	1.21	3.81
45	.0746	1.13	3.77
40	.0738	1.05	3.70
35	.0729	.955	3.63
30	.0721	.865	3.59
25	.0712	.765	3.51
20	.0703	.665	3.44
15	.0695	.555	3.33
10	.0687	.417	3.06
7	.0681	.333	2.94
5	.0678	.282	2.97

(Continued)

TABLE IV (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 9 (GT)			
50	.0754	1.90	5.97
40	.0738	1.64	5.87
35	.0729	1.56	5.75
30	.0721	1.36	5.74
25	.0712	1.21	5.54
20	.0704	1.06	5.46
12	.0690	.770	5.18
8	.0684	.585	4.84
6	.0680	.478	4.58
Fabric Number 10 (GT)			
46	.0751	3.95	13.0
40	.0740	3.64	12.9
32	.0727	3.18	12.7
26	.0717	2.81	12.6
20	.0707	2.42	12.4
16	.0700	2.13	12.3
12	.0693	1.82	12.2
8	.0686	1.46	12.0
6	.0683	1.25	11.9
4	.0679	1.01	11.9
2	.0676	.699	11.6
Fabric Number 11 (GT)			
24	.0706	4.44	20.9
20	.0699	4.01	20.8
16	.0693	3.56	20.7
14	.0690	3.30	20.5
12	.0686	3.04	20.4
10	.0683	2.74	20.2
8	.0679	2.42	20.1
6	.0676	2.07	19.9
4	.0672	1.67	19.6
2	.0669	1.16	19.4
1	.0668	.810	19.3

(Continued)

TABLE IV (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 12 (GT)			
16	.0696	4.73	27.4
14	.0693	4.40	27.3
12	.0689	4.05	27.3
10	.0686	3.68	27.1
8	.0683	3.27	27.0
6	.0679	2.81	26.8
5	.0678	2.54	26.6
4	.0676	2.26	26.5
3	.0674	1.92	26.1
2	.0672	1.56	26.0
1	.0671	1.08	25.5
Fabric Number 13 (GT)			
30	.0713	4.59	19.2
25	.0705	4.17	19.1
20	.0696	3.69	19.1
15	.0688	3.16	18.9
10	.0679	2.54	18.8
7	.0674	2.09	18.5
5	.0669	1.74	18.3
4	.0669	1.56	18.4
3	.0668	1.34	18.3
2	.0666	1.09	18.3
1	.0665	.755	17.9
Fabric Number 14 (GT)			
45	.0743	3.96	13.2
40	.0735	3.70	13.2
35	.0726	3.42	13.1
30	.0718	3.16	13.2
25	.0709	2.82	13.0
20	.0701	2.49	12.8
15	.0693	2.11	12.6
10	.0684	1.69	12.4
5	.0676	1.17	12.3
3	.0672	.890	11.8
1	.0669	.505	12.0

(Continued)

TABLE IV (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 15 (GT)			
50	.0754	3.22	10.1
45	.0745	3.02	10.1
40	.0737	2.82	10.0
35	.0728	2.62	10.0
30	.0720	2.40	9.96
25	.0711	2.15	9.86
20	.0703	1.90	9.75
15	.0695	1.60	9.56
10	.0686	1.28	9.42
6	.0680	.975	9.32
2	.0673	.555	9.25
Fabric Number 16 (GT)			
55	.0761	2.65	8.44
45	.0744	2.37	7.89
35	.0727	2.06	7.87
30	.0719	1.88	7.81
25	.0710	1.70	7.75
20	.0702	1.50	7.71
15	.0693	1.26	7.55
10	.0685	.995	7.38
7	.0680	.815	7.21
5	.0677	.660	6.93
3	.0673	.505	6.86
Fabric Number 17 (GT)			
45	.0743	2.40	8.05
40	.0735	2.26	8.05
35	.0726	2.08	7.96
30	.0718	1.89	7.85
25	.0710	1.69	7.75
20	.0701	1.49	7.68
15	.0693	1.27	7.58
10	.0684	1.02	7.52
5	.0676	.700	7.39
3	.0673	.540	7.33
1	.0669	.310	7.31

(Continued)

TABLE IV (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 18 (GT)			
35	.0732	3.82	14.6
30	.0724	3.52	14.6
25	.0716	3.18	14.5
20	.0707	2.80	14.4
15	.0698	2.37	14.1
10	.0690	1.88	13.8
7	.0685	1.53	13.5
5	.0681	1.26	13.2
3	.0678	.958	13.0
2	.0676	.772	12.8
1	.0675	.544	12.8
Fabric Number 19 (GT)			
50	.0757	3.15	9.85
45	.0749	2.95	9.80
40	.0741	2.74	9.75
35	.0732	2.54	9.70
30	.0724	2.31	9.59
25	.0715	2.07	9.49
20	.0706	1.82	9.38
15	.0698	1.56	9.27
10	.0689	1.23	9.04
5	.0681	.831	8.70
2	.0679	.544	9.05
Fabric Number 20 (GT)			
55	.0758	2.50	7.47
45	.0741	2.17	7.24
35	.0725	1.87	7.17
25	.0708	1.54	7.07
20	.0699	1.35	6.95
15	.0691	1.13	6.78
10	.0682	.895	6.59
7	.0677	.730	6.50
5	.0674	.605	6.42
3	.0670	.472	6.43
1	.0667	.245	5.81

(Continued)

TABLE IV (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 21 (GT)			
55	.0759	1.71	5.12
45	.0742	1.52	5.08
35	.0725	1.30	5.00
30	.0717	1.18	4.92
25	.0708	1.05	4.83
20	.0700	.925	4.75
15	.0691	.775	4.65
10	.0683	.605	4.47
7	.0678	.493	4.36
5	.0675	.405	4.25
3	.0671	.309	4.20
Fabric Number 22 (GT)			
.54	.0763	1.48	4.45
47	.0751	1.35	4.37
40	.0739	1.21	4.30
34	.0729	1.09	4.23
28	.0719	.965	4.16
22	.0708	.825	4.04
17	.0700	.705	3.95
13	.0693	.610	3.92
9	.0687	.491	3.82
6	.0681	.399	3.81
3	.0676	.291	3.45
Fabric Number 23 (GT)			
55	.0767	1.19	3.52
50	.0758	1.04	3.26
45	.0750	.970	3.25
40	.0741	.890	3.15
35	.0733	.805	3.08
30	.0725	.720	2.98
25	.0716	.640	2.90
20	.0707	.540	2.79
10	.0691	.348	2.51
5	.0682	.235	2.40
3	.0680	.180	2.40

(Continued)

TABLE IV (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 24 (GT)			
55	.0766	1.63	4.86
45	.0749	1.42	4.70
40	.0740	1.30	4.60
35	.0732	1.19	4.53
30	.0724	1.07	4.40
25	.0715	.945	4.30
20	.0707	.820	4.22
15	.0698	.675	4.02
10	.0690	.520	3.83
7	.0685	.410	3.62
5	.0682	.335	3.51
Fabric Number 25 (GT)			
55	.0768	2.58	7.66
45	.0750	2.27	7.53
35	.0734	1.93	7.33
30	.0725	1.74	7.21
25	.0717	1.56	7.10
20	.0708	1.35	6.89
15	.0700	1.11	6.61
10	.0691	.855	6.28
7	.0686	.670	5.91
5	.0683	.535	5.60
3	.0680	.389	5.24
Fabric Number 26 (GT)			
45	.0753	3.61	12.0
40	.0744	3.33	11.8
35	.0736	3.03	11.5
30	.0727	2.74	11.3
25	.0719	2.43	11.1
20	.0711	2.10	10.8
15	.0702	1.76	10.5
10	.0694	1.38	10.2
5	.0685	.922	9.65
3	.0682	.706	9.54
1	.0679	.410	9.49

(Continued)

TABLE IV (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 27 (GT)			
30	.0725	4.40	18.2
26	.0718	4.02	18.0
22	.0711	3.63	17.7
18	.0704	3.21	17.4
14	.0698	2.76	17.1
10	.0691	2.27	16.6
8	.0687	1.99	16.4
6	.0684	1.69	16.1
4	.0681	1.36	15.8
2	.0677	.942	15.6
1	.0676	.661	15.5
Fabric Number 28 (GT)			
34	.0733	4.08	15.8
28	.0723	3.63	15.6
24	.0717	3.30	15.4
20	.0709	2.96	15.2
16	.0703	2.59	14.9
12	.0696	2.20	14.7
10	.0693	1.97	14.5
8	.0689	1.74	14.3
6	.0686	1.48	14.1
4	.0683	1.20	13.9
2	.0679	.835	13.4
Fabric Number 29 (GT)			
50	.0762	3.39	10.6
45	.0752	3.15	10.5
40	.0744	2.94	10.4
35	.0736	2.71	10.3
30	.0727	2.45	10.1
25	.0719	2.19	9.96
20	.0711	1.91	9.77
15	.0702	1.61	9.76
10	.0694	1.29	9.42
5	.0685	.890	9.30
3	.0682	.690	9.31

(Continued)

TABLE IV (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 30 (GT)			
55	.0765	2.31	6.88
45	.0748	2.04	6.78
35	.0731	1.75	6.66
30	.0723	1.58	6.58
25	.0714	1.42	6.45
20	.0706	1.24	6.36
15	.0698	1.02	6.07
10	.0689	.795	5.87
7	.0684	.645	5.74
5	.0681	.520	5.46
3	.0677	.394	5.32
Fabric Number 31 (GT)			
50	.0757	1.70	5.35
45	.0749	1.59	5.28
40	.0741	1.47	5.23
35	.0732	1.35	5.15
30	.0724	1.21	5.02
25	.0715	1.07	4.91
20	.0707	.946	4.86
15	.0698	.789	4.71
12	.0693	.692	4.64
8	.0686	.548	4.54
4	.0680	.381	4.46
Fabric Number 32 (GT)			
55	.0764	1.24	3.70
50	.0756	1.17	3.66
45	.0747	1.08	3.61
40	.0739	1.00	3.56
35	.0731	.919	3.51
30	.0722	.824	3.41
25	.0714	.732	3.35
20	.0705	.621	3.19
15	.0697	.522	3.12
10	.0688	.401	2.95
5	.0680	.272	2.85

(Continued)

TABLE IV (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 33 (GT)			
32	.0726	3.90	15.6
28	.0719	3.60	15.5
24	.0712	3.30	15.4
20	.0705	2.97	15.3
16	.0699	2.63	15.2
12	.0692	2.25	15.1
8	.0685	1.82	15.0
4	.0679	1.30	15.3
2	.0675	.930	15.5
Fabric Number 34 (GT)			
50	.0752	3.05	9.59
45	.0743	2.87	9.61
35	.0727	2.49	9.56
25	.0710	2.08	9.53
20	.0701	1.84	9.49
15	.0693	1.58	9.45
10	.0684	1.27	9.38
7	.0679	1.06	9.37
5	.0676	.890	9.35
3	.0673	.690	9.42
1	.0670	.409	9.65
Fabric Number 35 (GT)			
55	.0774	1.91	5.66
45	.0756	1.70	5.62
35	.0741	1.47	5.58
30	.0732	1.35	5.57
25	.0724	1.21	5.50
20	.0715	1.07	5.43
15	.0707	.895	5.30
10	.0698	.715	5.25
7	.0693	.575	4.89
5	.0690	.495	5.14
3	.0687	.377	5.09

(Continued)

TABLE IV (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 36 (GT)			
55	.0761	1.07	2.81
45	.0744	.950	2.83
40	.0736	.885	2.88
35	.0727	.810	2.93
30	.0719	.745	2.99
25	.0710	.665	3.03
20	.0702	.580	3.10
15	.0693	.489	3.12
10	.0685	.390	3.14
7	.0680	.319	3.16
5	.0677	.268	3.19
Fabric Number 37 (GT)			
40	.0737	3.51	12.5
35	.0729	3.23	12.4
30	.0720	2.95	12.2
25	.0712	2.66	12.2
20	.0703	2.34	12.1
15	.0695	1.99	11.9
10	.0687	1.60	11.8
7	.0681	1.33	11.7
5	.0678	1.12	11.7
3	.0675	.850	11.6
1	.0672	.505	11.9
Fabric Number 38 (GT)			
50	.0751	2.65	8.33
45	.0742	2.49	8.31
35	.0725	2.14	8.19
30	.0721	1.96	8.12
25	.0708	1.75	8.02
20	.0701	1.53	7.91
15	.0692	1.28	7.69
10	.0683	1.01	7.46
7	.0678	.830	7.37
5	.0675	.690	7.24
3	.0672	.530	7.23

(Continued)

TABLE IV (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth ($lbm\ ft.^{-3}$)	Mass Velocity of Air Upstream of Cloth ($lbm\ sec.^{-1} ft.^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 39 (GT)			
55	.0752	1.70	5.12
45	.0735	1.51	5.08
35	.0718	1.29	4.95
30	.0710	1.18	4.92
25	.0702	1.05	4.81
20	.0693	.910	4.72
15	.0685	.765	4.62
10	.0676	.600	4.47
7	.0671	.487	4.35
5	.0668	.406	4.27
3	.0665	.320	4.37
Fabric Number 40 (GT)			
55	.0757	1.27	3.79
50	.0749	1.19	3.77
45	.0740	1.12	3.73
40	.0732	1.03	3.67
35	.0724	.955	3.65
30	.0715	.870	3.63
25	.0707	.780	3.58
20	.0699	.675	3.49
15	.0690	.560	3.35
10	.0682	.438	3.24
5	.0673	.278	2.92
Fabric Number 41 (GT)			
30	.0720	3.84	16.0
27	.0715	3.62	15.9
24	.0710	3.37	15.8
21	.0705	3.13	15.7
18	.0699	2.86	15.6
15	.0694	2.59	15.5
12	.0689	2.29	15.4
9	.0685	1.96	15.3
6	.0679	1.60	15.3
4	.0676	1.29	15.2
2	.0672	.915	15.2

(Continued)

TABLE IV (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 42 (GT)			
55	.0757	3.18	9.51
50	.0749	2.96	9.34
45	.0740	2.77	9.28
40	.0732	2.58	9.24
35	.0724	2.30	9.10
30	.0715	2.17	9.06
25	.0707	1.95	8.97
20	.0698	1.72	8.86
15	.0690	1.46	8.79
10	.0682	1.17	8.65
5	.0673	.810	8.54
Fabric Number 43 (GT)			
55	.0750	2.13	6.40
50	.0742	2.01	6.36
45	.0733	1.89	6.34
40	.0725	1.75	6.28
35	.0717	1.62	6.21
30	.0709	1.48	6.19
25	.0700	1.33	6.14
20	.0692	1.17	6.06
15	.0684	.985	5.94
10	.0675	.795	5.94
5	.0667	.540	5.71
Fabric Number 44 (GT)			
55	.0746	1.70	5.14
50	.0738	1.61	5.10
45	.0729	1.51	5.08
40	.0721	1.40	5.05
35	.0713	1.30	5.01
30	.0705	1.18	4.96
25	.0696	1.06	4.88
20	.0688	.925	4.82
15	.0680	.795	4.82
10	.0672	.605	4.53
5	.0664	.455	4.82

(Continued)

TABLE IV (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 45 (GT)			
35	.0721	3.95	14.7
30	.0712	3.50	14.6
25	.0705	3.21	14.7
20	.0696	2.84	14.7
15	.0689	2.45	14.6
10	.0680	1.98	14.6
7	.0675	1.65	14.6
3	.0671	1.05	14.2
Fabric Number 46 (GT)			
50	.0758	3.20	10.4
45	.0749	3.03	10.3
40	.0748	2.84	10.2
35	.0732	2.65	10.2
30	.0724	2.46	10.2
25	.0715	2.26	10.3
20	.0707	1.97	10.2
15	.0699	1.71	10.2
10	.0690	1.38	10.2
7	.0685	1.15	10.1
3	.0679	.760	10.1
Fabric Number 47 (GT)			
50	.0758	2.25	7.06
45	.0748	2.13	7.11
40	.0741	2.00	7.11
35	.0732	1.88	7.15
30	.0724	1.71	7.11
25	.0715	1.57	7.18
20	.0707	1.41	7.21
15	.0699	1.21	7.21
10	.0690	.980	7.21
7	.0685	.825	7.28
3	.0679	.550	7.45

(Continued)

TABLE IV (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth ($lbm\ ft.^{-3}$)	Mass Velocity of Air Upstream of Cloth ($lbm\ sec.^{-1} ft.^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 48 (GT)			
50	.0758	1.57	4.90
45	.0749	1.47	4.88
40	.0741	1.39	4.95
35	.0732	1.28	4.90
30	.0724	1.19	4.94
25	.0716	1.08	4.96
20	.0706	.965	4.90
15	.0698	.831	4.95
10	.0689	.675	4.81
7	.0684	.565	4.98
3	.0678	.379	5.14
Fabric Number 49 (GT)			
35	.0732	4.22	16.1
30	.0724	3.88	16.1
25	.0715	3.54	16.1
20	.0706	3.13	16.0
15	.0698	2.69	16.0
10	.0694	2.18	15.9
7	.0684	1.80	15.9
3	.0678	1.15	15.7
Fabric Number 50 (GT)			
50	.0771	3.38	10.5
45	.0762	3.19	10.5
40	.0753	2.98	10.5
35	.0745	2.77	10.5
30	.0736	2.56	10.6
25	.0727	2.33	10.6
20	.0719	2.08	10.6
15	.0715	1.79	10.6
10	.0702	1.45	10.6
7	.0696	1.21	10.6
3	.0690	.795	10.7

(Continued)

TABLE IV (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 51 (GT)			
50	.0756	2.26	7.10
45	.0749	2.13	7.07
40	.0740	1.99	7.07
35	.0732	1.86	7.09
30	.0723	1.70	7.07
25	.0715	1.55	7.04
20	.0706	1.38	7.07
15	.0697	1.18	7.00
10	.0689	.950	6.98
7	.0684	.790	6.98
3	.0677	.495	6.71
Fabric Number 52 (GT)			
50	.0762	1.37	4.29
45	.0753	1.28	4.25
40	.0745	1.20	4.24
35	.0736	1.13	4.29
30	.0728	1.04	4.28
25	.0719	.935	4.19
20	.0711	.835	4.28
15	.0702	.720	4.28
10	.0694	.580	4.25
7	.0689	.477	4.19
3	.0682	.319	4.30
Fabric Number 53 (GT)			
30	.0737	4.67	19.2
25	.0729	4.20	19.0
20	.0720	3.69	18.8
17	.0714	3.36	18.7
15	.0711	3.14	18.6
13	.0708	2.91	18.5
10	.0703	2.52	18.4
7	.0697	2.08	18.2
5	.0694	1.75	18.1
3	.0691	1.35	18.1

(Concluded)

TABLE IV (Concluded)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ft.$^{-2}$)	Relative Porosity of Cloth (Per Cent)
Fabric Number 54 (GT)			
40	.0751	3.58	12.6
35	.0743	3.30	12.5
30	.0734	3.02	12.4
25	.0725	2.71	12.3
20	.0716	2.40	12.2
15	.0708	2.04	12.2
10	.0700	1.64	12.0
7	.0694	1.36	11.9
3	.0686	.852	11.4
Fabric Number 55 (GT)			
50	.0764	2.82	8.82
45	.0756	2.65	8.77
40	.0747	2.46	8.69
35	.0739	2.28	8.67
30	.0730	2.08	8.58
25	.0722	1.89	8.58
20	.0713	1.67	8.51
15	.0704	1.42	8.49
10	.0696	1.15	8.40
5	.0688	.810	8.40
3	.0684	.620	8.32
Fabric Number 56 (GT)			
55	.0771	1.47	4.34
50	.0763	1.38	4.34
45	.0754	1.30	4.31
40	.0746	1.21	4.25
35	.0737	1.11	4.22
30	.0729	1.02	4.17
25	.0720	.920	4.20
20	.0711	.810	4.12
15	.0703	.690	4.10
10	.0694	.560	4.10
5	.0686	.394	4.12

APPENDIX B

FIGURES

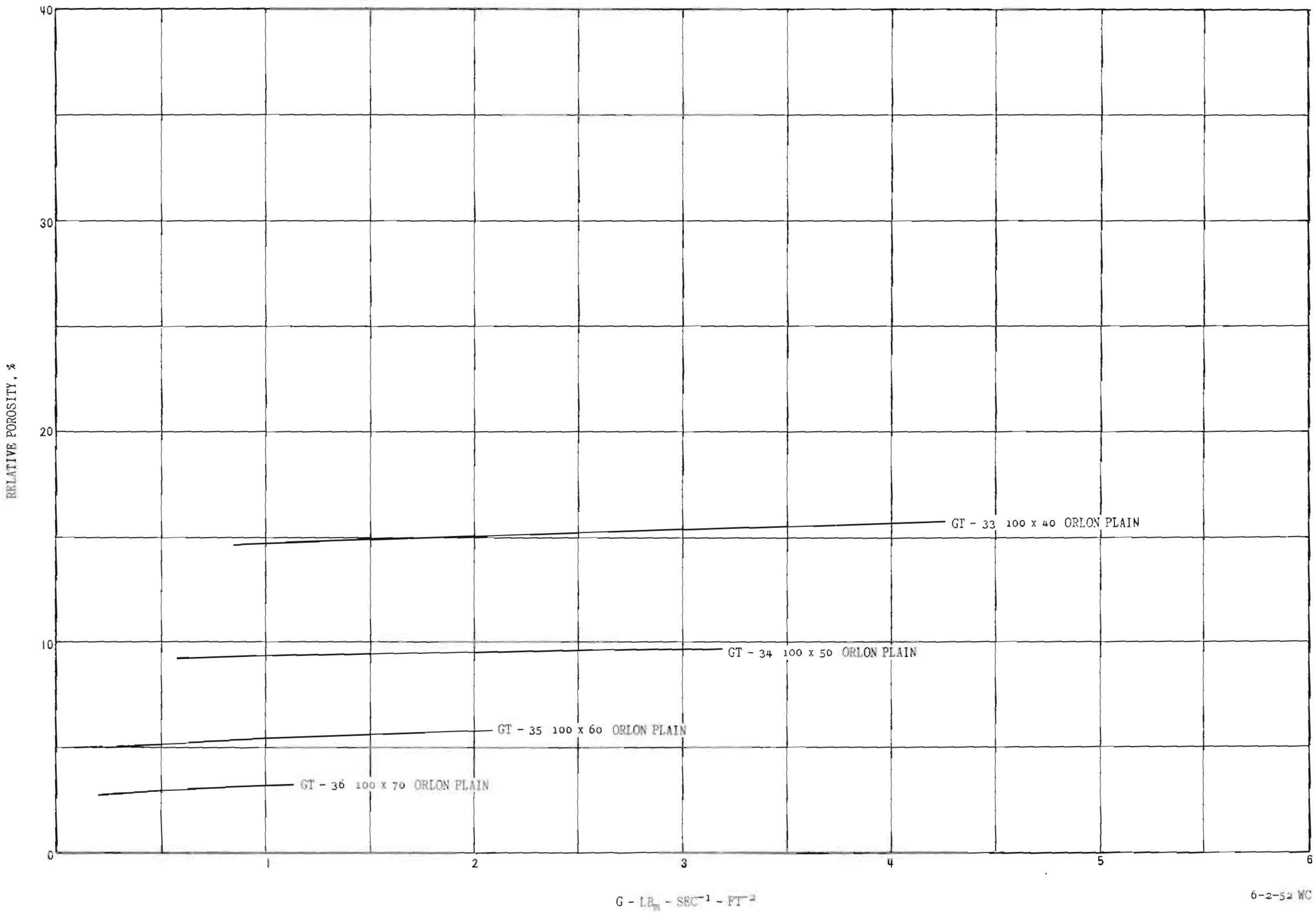

Figure 1. Permeability Data on Georgia Tech-Woven Fabrics.

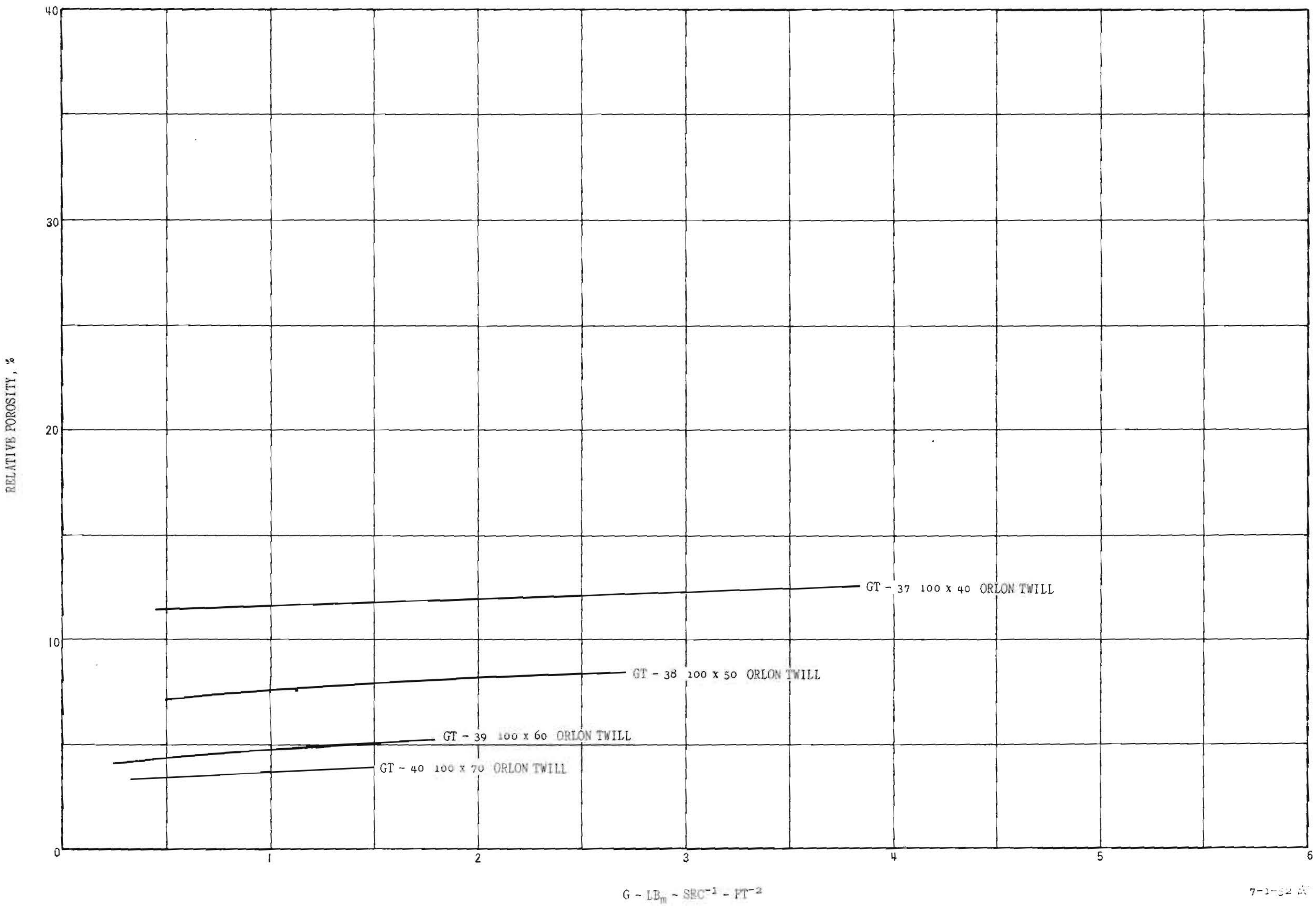

Figure 2. Permeability Data on Georgia Tech-Woven Fabrics.

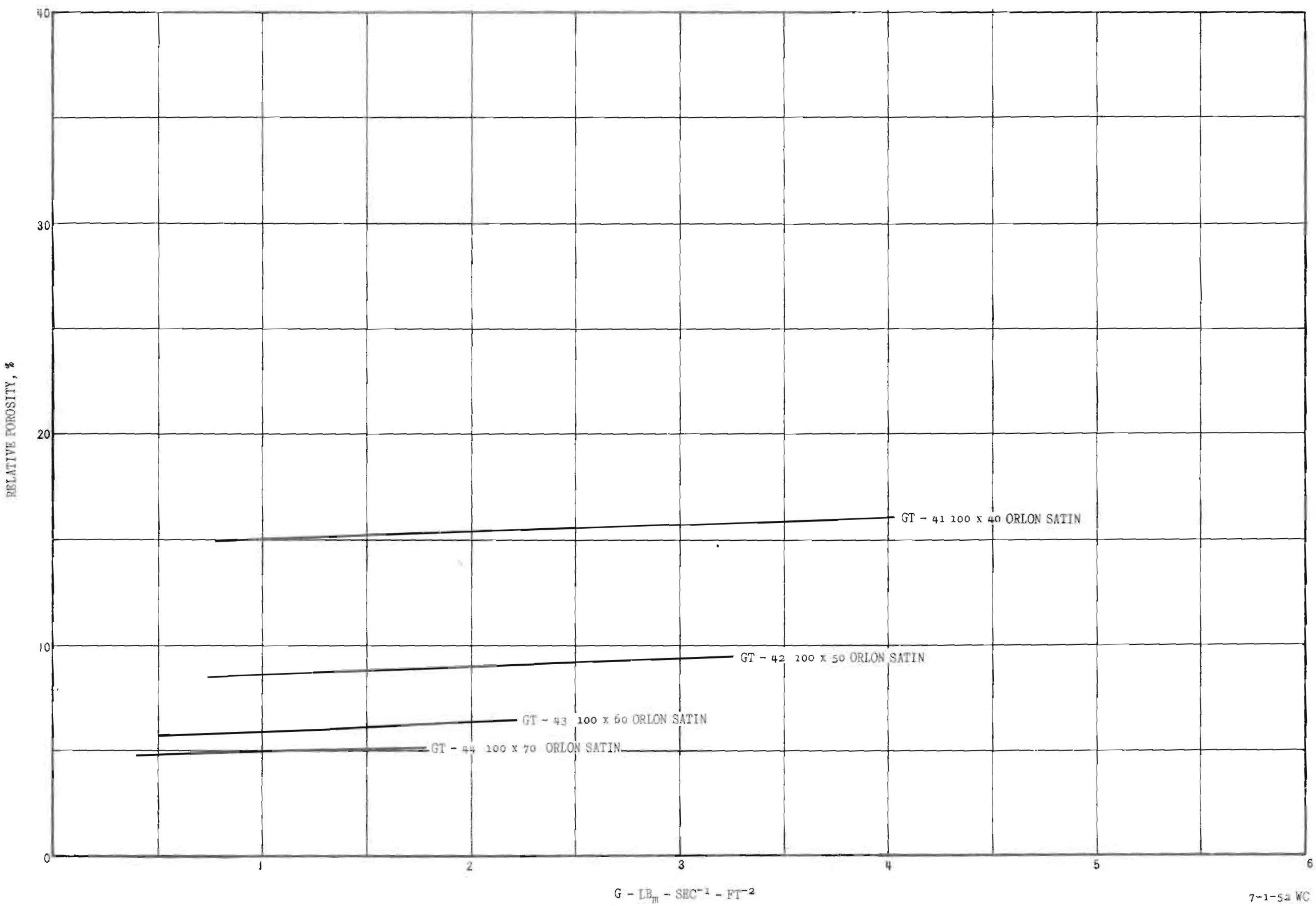

Figure 3. Permeability Data on Georgia Tech-Woven Fabrics.

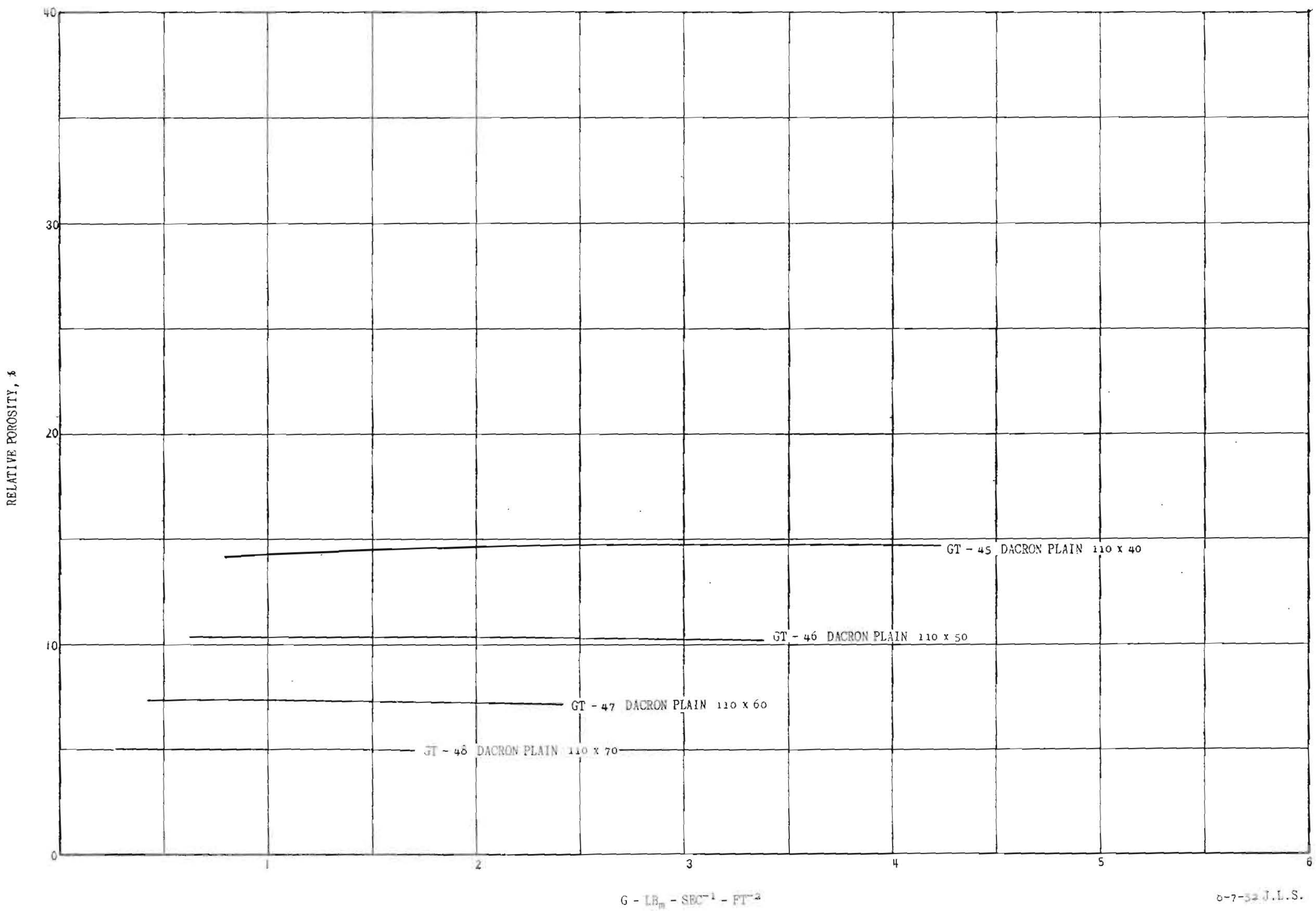

Figure 4. Permeability Data on Georgia Tech-Woven Fabrics.

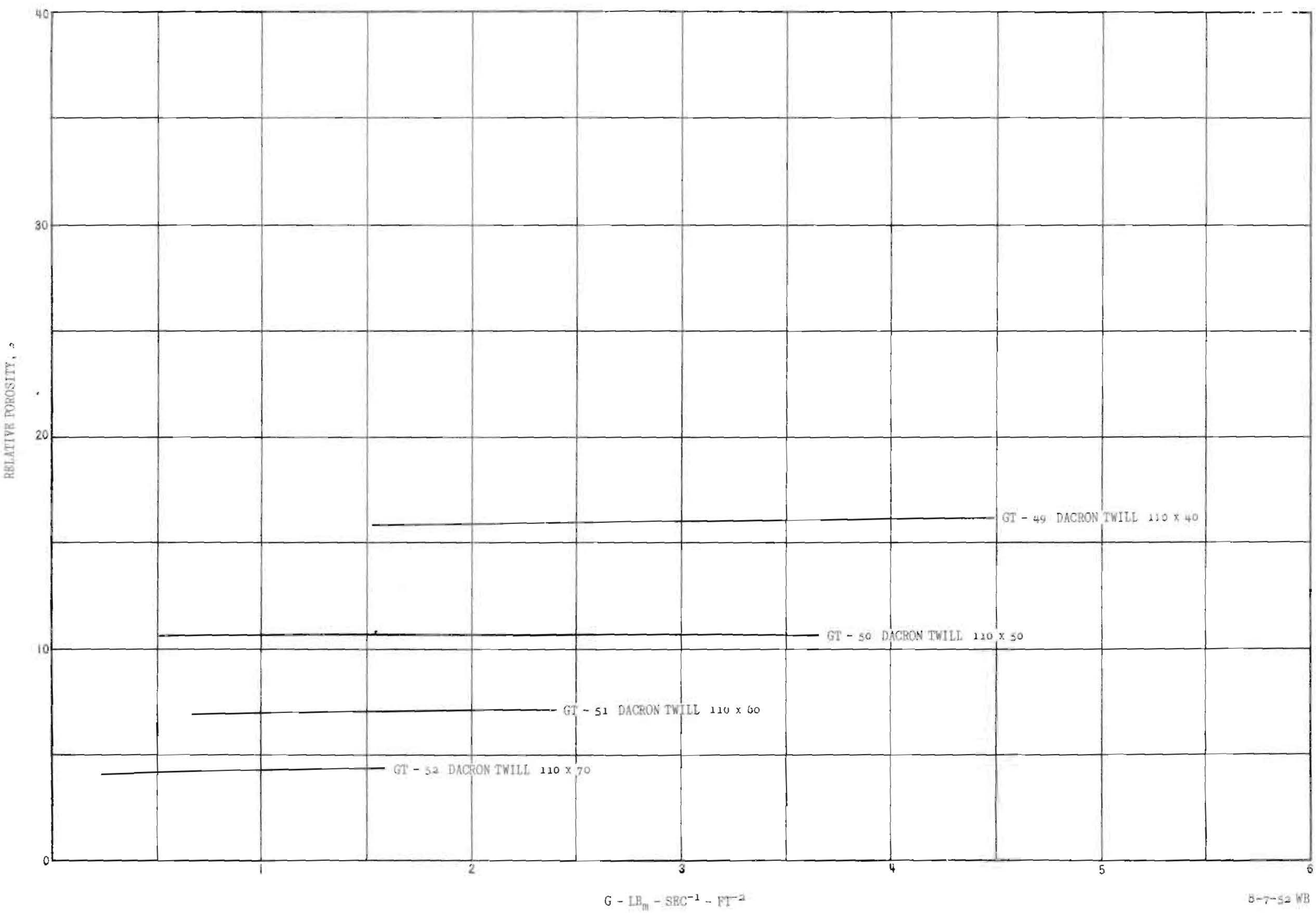

Figure 5. Permeability Data on Georgia Tech-Woven Fabrics.

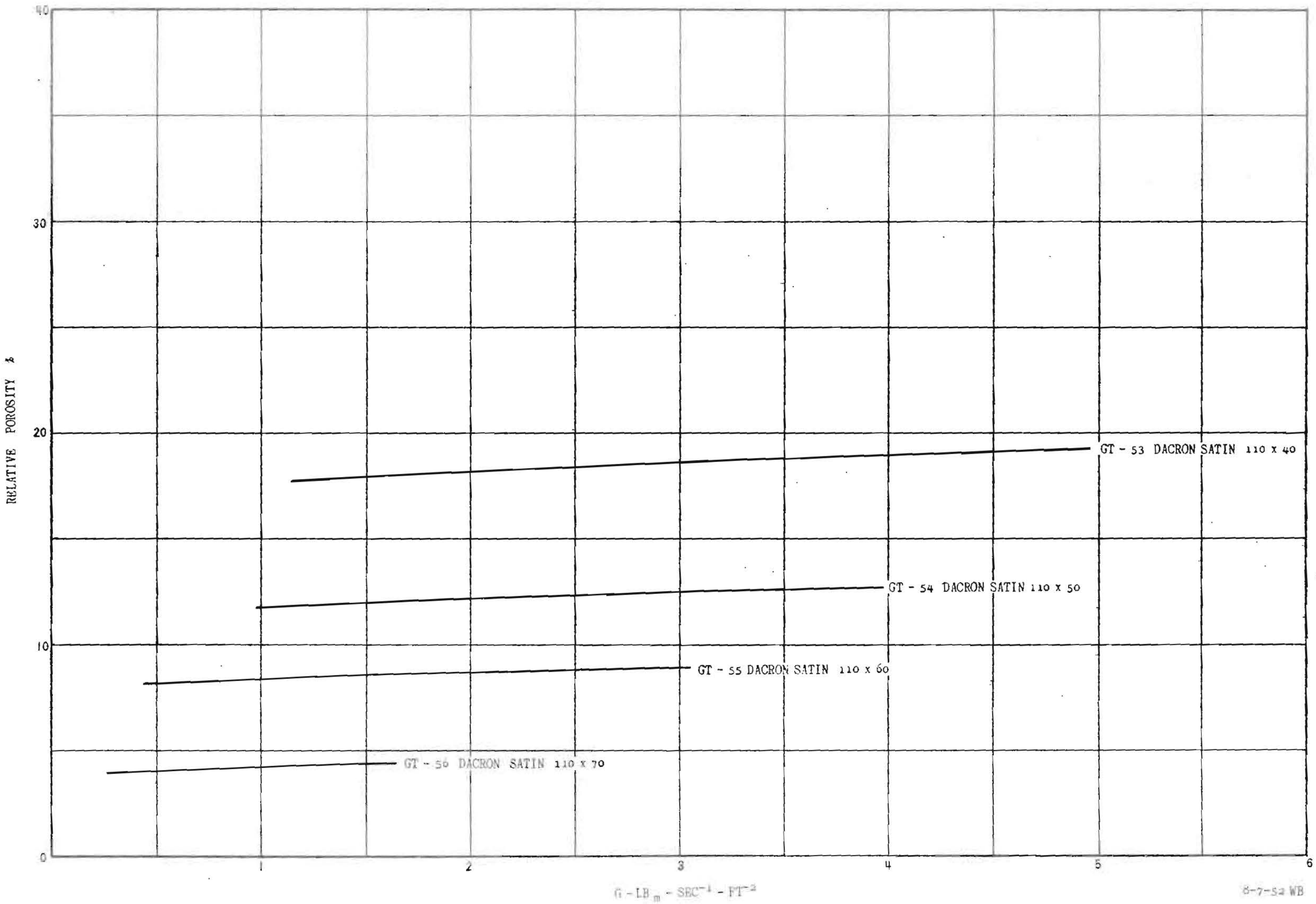

Figure 6. Permeability Data on Georgia Tech-Woven Fabrics.

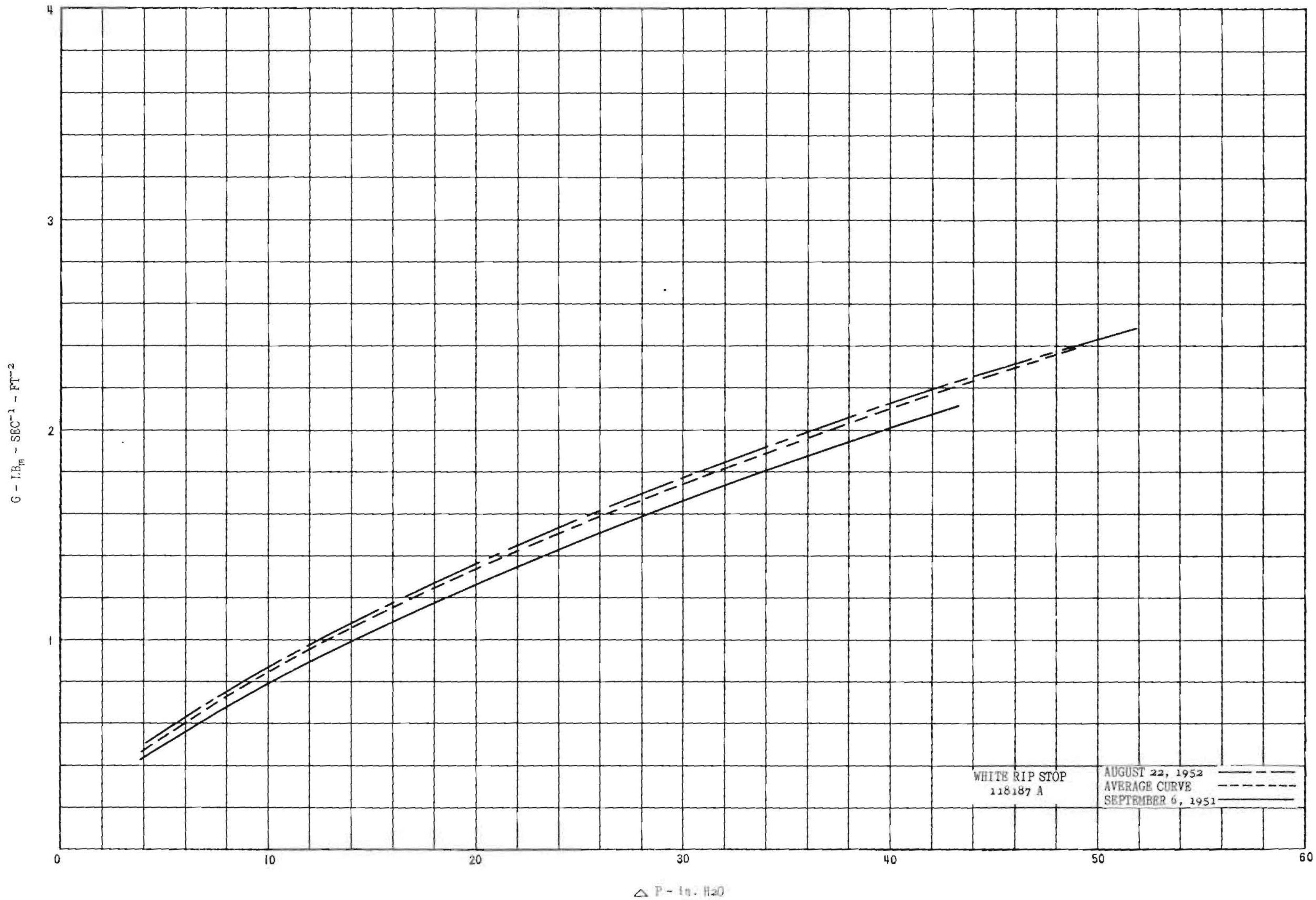

Figure 7. Effect of Ageing on Fabric Permeability.

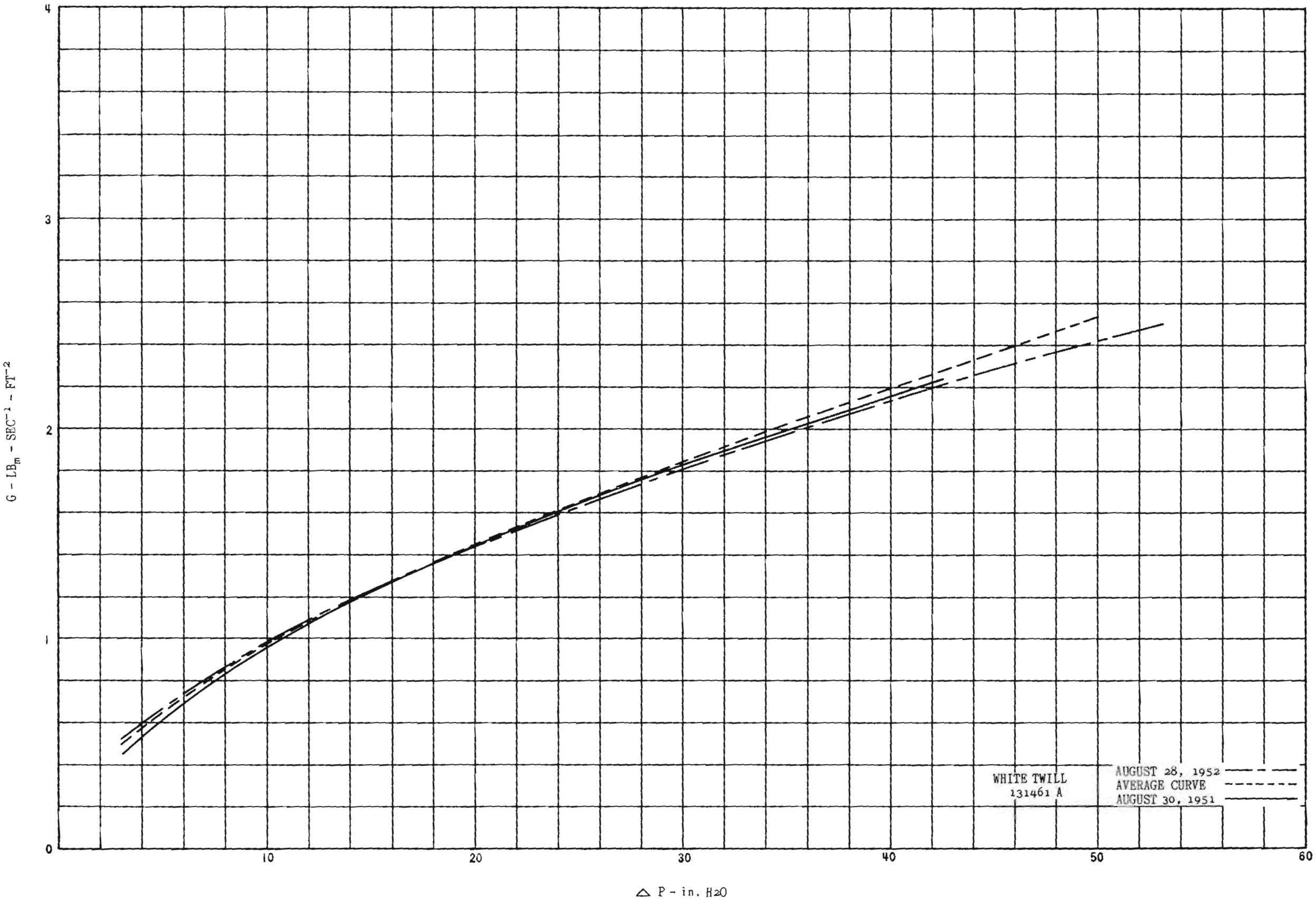

Figure 8. Effect of Ageing on Fabric Permeability.

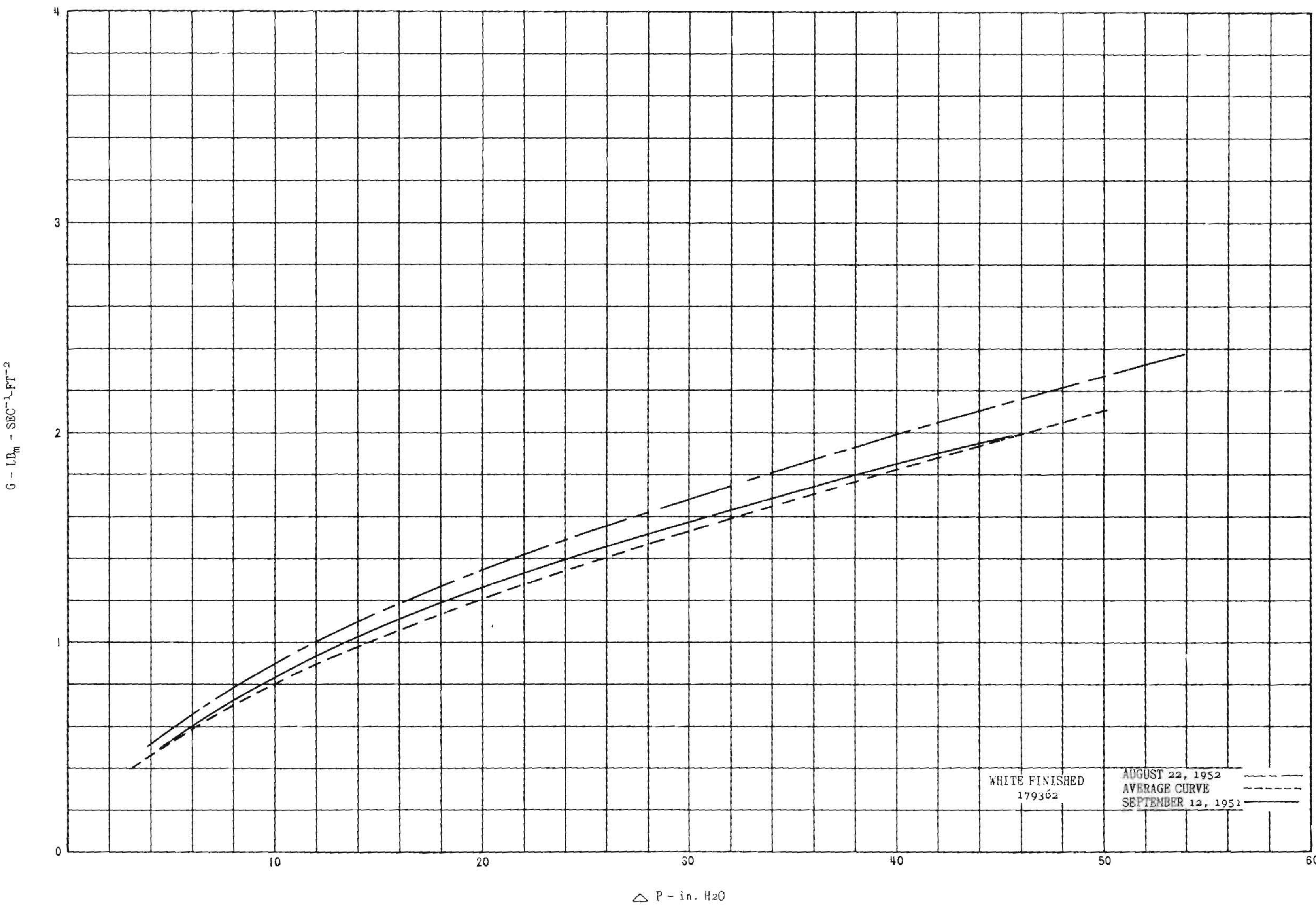

Figure 9. Effect of Ageing on Fabric Permeability.

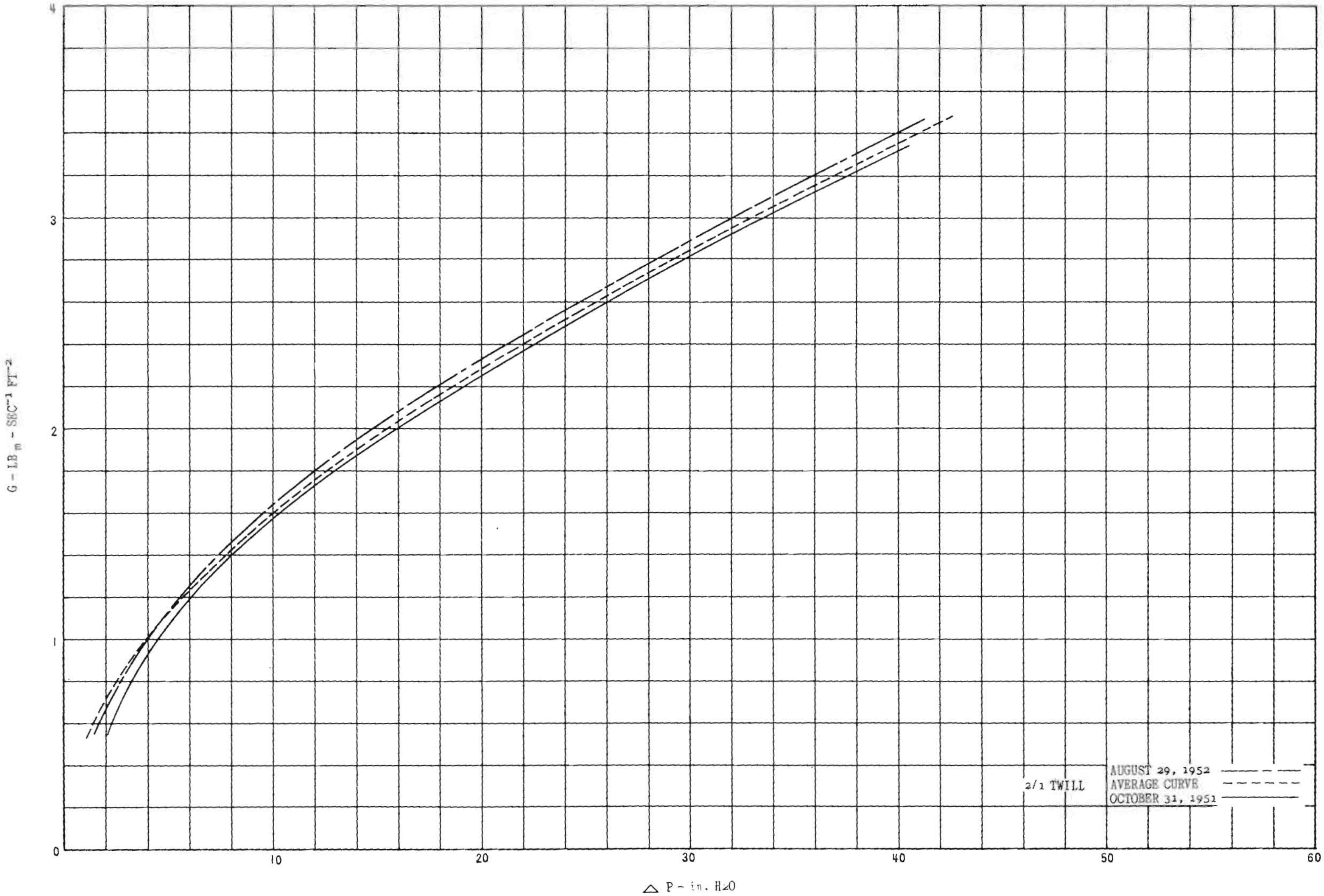

Figure 10. Effect of Ageing on Fabric Permeability.

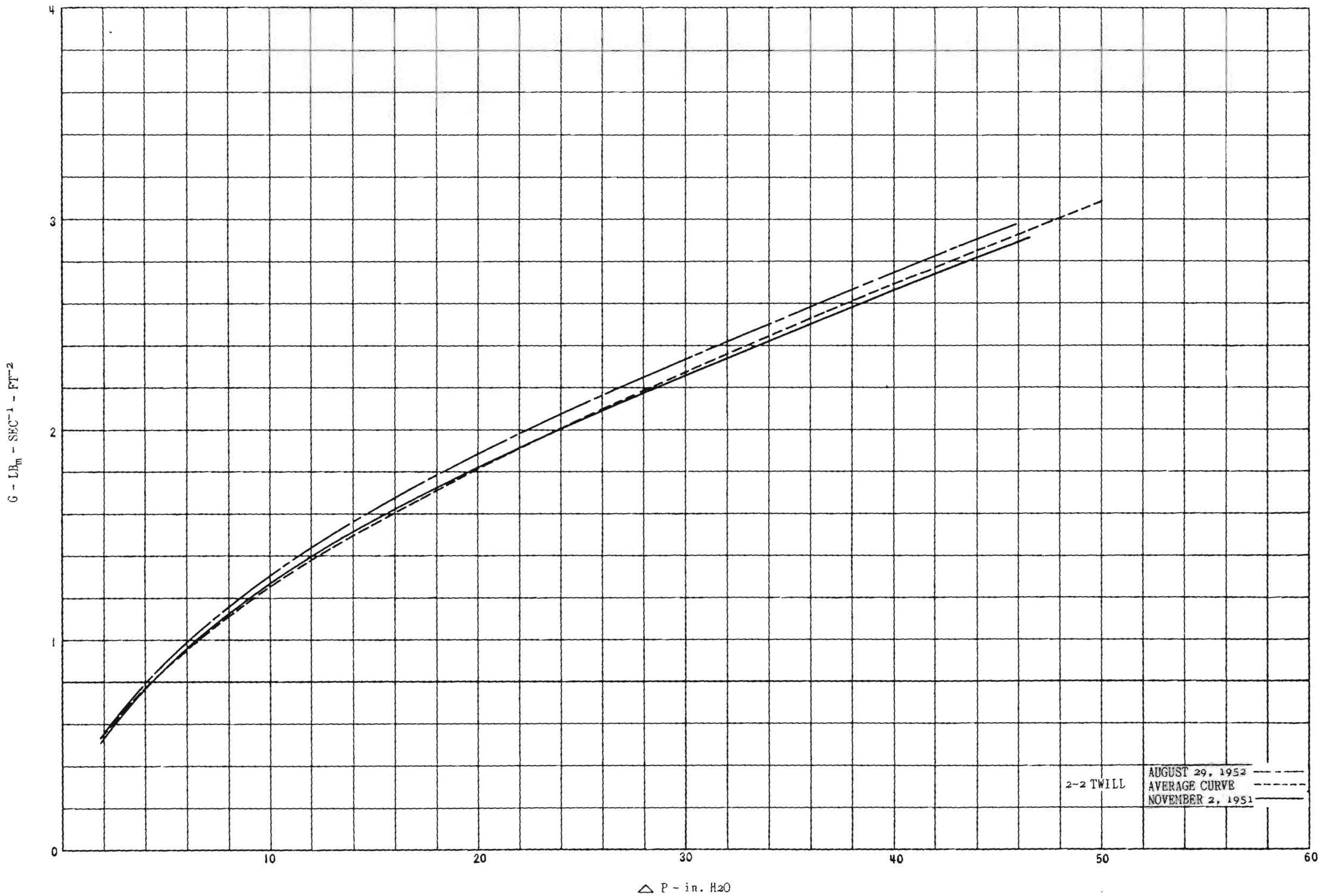

Figure 11. Effect of Ageing on Fabric Permeability.

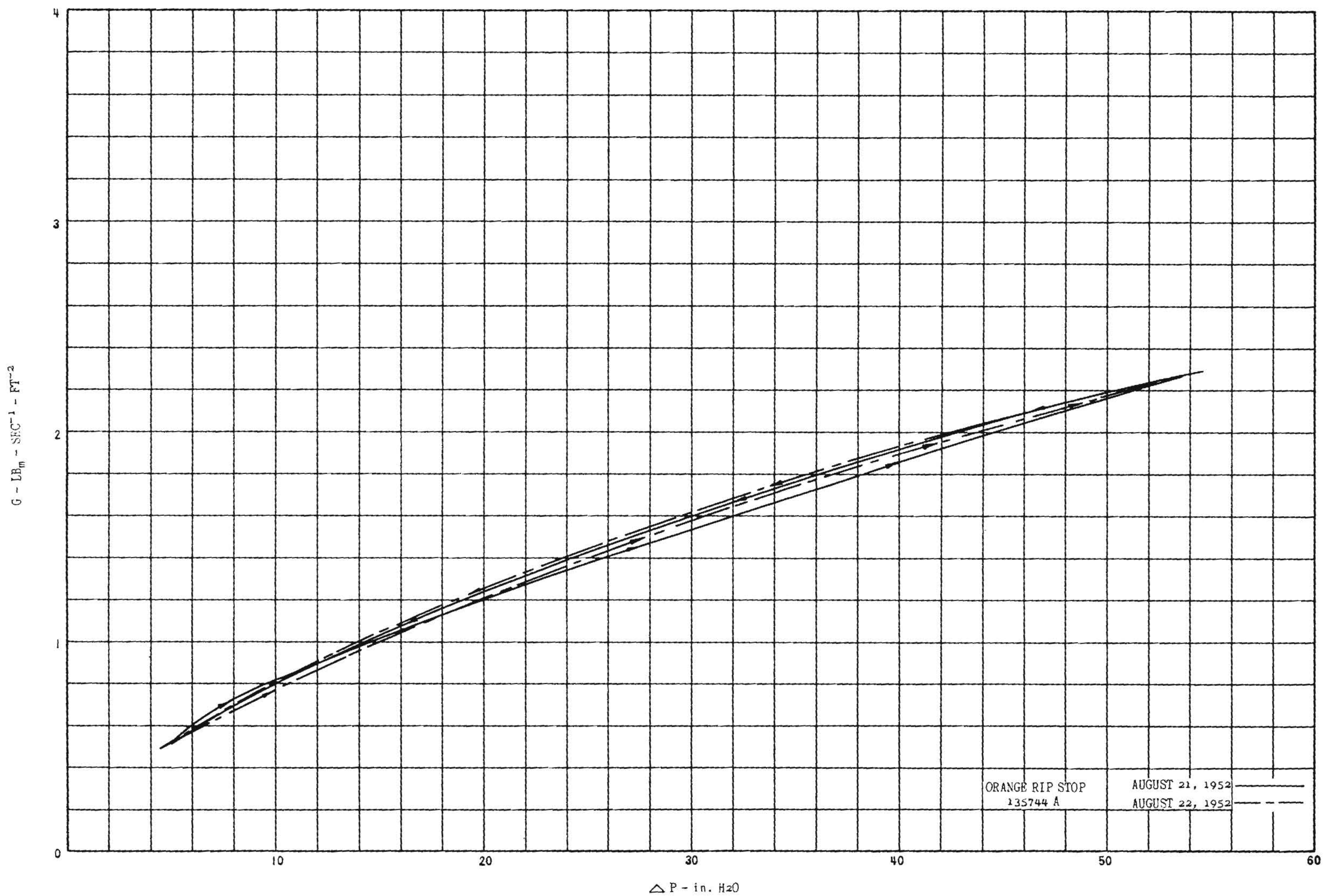

Figure 12. Repetition of Permeability Tests on Georgia Tech-Woven Fabrics.

Georgia Institute of Technology
STATE ENGINEERING EXPERIMENT STATION
Atlanta, Georgia

QUARTERLY REPORT NO. 4

PROJECT NO. 170-117

PERMEABILITY OF PARACHUTE FABRICS

By

H. W. S. LAVIER

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CONTRACT NO. AF 33(038)-15624
E.O. No. R602-198, Project No. 52-660A-41 SR7s
E.O. No. R602-193SR7S, Project No. 52-660A-25

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SEPTEMBER 15, 1952 to DECEMBER 15, 1952

Georgia Institute of Technology
STATE ENGINEERING EXPERIMENT STATION
Atlanta, Georgia

QUARTERLY REPORT NO. 4

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PERMEABILITY OF PARACHUTE FABRICS

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SEPTEMBER 15, 1952 to DECEMBER 15, 1952

Quarterly Report No. 4, Project No. 170-117

This report summarizes the progress during the quarter ending 15 December 1952. It concerns completion of the low-pressure permeability studies of the fabrics woven at Georgia Tech. The progress of the high-pressure phase of the subject research is also covered in this report.

A. Low-Pressure Permeability Investigations

Comparison and correlation of the low-pressure permeability data for the Georgia Tech-woven nylon, orlon and dacron fabrics have been completed. This work is preparatory to the writing of Technical Report No. 2, which will cover the low-pressure permeability studies of Georgia Tech-woven cloths plus some special studies to determine the importance of variables such as humidity, fabric stretch and fabric aging. Technical Report No. 2 is now in process.

Several special nylon cloths were furnished during the past quarter by the Textile Branch. These have been subjected to permeability tests on the large permeometer.

One lot of cloth was camouflage nylon described as "tacky to the touch." This cloth was tested in the "as received" condition, then was washed in distilled water, and after drying it, the permeability tests were repeated. Figure 1 shows, comparatively, the permeability of the camouflage cloth in the "as received" and "washed" condition.

Three nylon parachute fabrics having weights of (a) 1.6 oz/yd^2, (b) 1.1 oz/yd^2 and (c) 0.8 oz/yd^2 were subjected to permeability tests. The results of these studies are shown in Figure 2.

B. High-Pressure Permeability Equipment

Construction and assembly of the high-pressure permeability equipment is well under way. The 1,000-cu.-ft. reservoir and the adsorption dryer have been received. Figure 3 shows the large reservoir and excavation work in progress preparatory to the installation of the tank. The 12-inch-by-13-inch Worthington Compressor, type 2-P Aftercooler and the Kemp dryer are also being installed. Figures 4 and 5 show this equipment in the process of being connected by appropriate piping.

The high-pressure permeability studies will be conducted in a special wind tunnel. A schematic diagram of this tunnel is shown in Figure 6. Many of the parts for this tunnel are now complete. These parts include the transition section, a special gate valve and two types of sample holder. The transition section is shown in Figure 7, and the special gate valve is shown in Figure 8.

Two types of sample holders have been constructed. The first is a simple one similar to the type used in the low-pressure studies. This holder clamps the fabric samples between the two plates. One of the plates is grooved to permit insertion of a rubber tube, which provides additional friction between fabric sample and holder when the plates are tightly clamped together. This sample holder is shown in Figure 9.

A special sample holder designed to measure the tension in both the warp and filling fibers of the fabric sample during the high-pressure permeability test has been constructed. This holder includes four sets of jaws which secure the fabric sample. The jaws are attached to cantilever arms. Electric resistance strain gages attached to the cantilever arms will measure the tension loads in the fabric sample. Figure 10 is a view of this sample holder partially assembled.

C. Deformation of Fabrics Under Load (No Air Flow)

The machine for simultaneous tension loading of a fabric sample in both warp and filling directions is very nearly complete. Only wiring and calibration of the machine remain to be done before actual testing of fabrics can be started. The machine is shown in Figure 11.

D. Analysis and Conclusions

Technical Report No. 2, which will cover the correlation and comparison of the permeability test results of the Georgia Tech-woven fabrics, is now being prepared. In accordance with the suggestion of Dr. Heinrich of the Parachute Branch, this permeability data will be presented in graphical form as volumetric flow (c.f.m.) of air at standard conditions versus the pressure drop (inches of water) across the fabric sample.

E. Technical Discussions and Visits

On September 11 and 12, the writer attended the 19th Symposium on Shock and Vibration held at Wright-Patterson Air Force Base. Dr. M. J. Goglia and the writer visited the Textile Branch at the Wright Air Development Center on October 28, 29, and 30. The purpose of this visit was to discuss with Textile Branch personnel the Technical Report No. 1, written by Dr. Goglia.

F. Personnel

During the past quarter, project personnel has included Professor H.W.S. LaVier, Project Director, Mr. Cecil D. Brown, Research Assistant, Mrs. Donna W. Williams, Project Secretary, Mr. W.C. Boteler, Mr. R.L. Culpepper and Mr. J.L. Smith, all Graduate Assistants, and Mr. W.H. Carter, Student Assistant. Mr. Brown and Mr. Smith resigned at the end of October.

Respectfully submitted:

Approved:

Hurlbut W. S. LaVier,
Project Director

Herschel H. Cudd, Acting Director
State Engineering Experiment Station

APPENDIX A

FIGURES

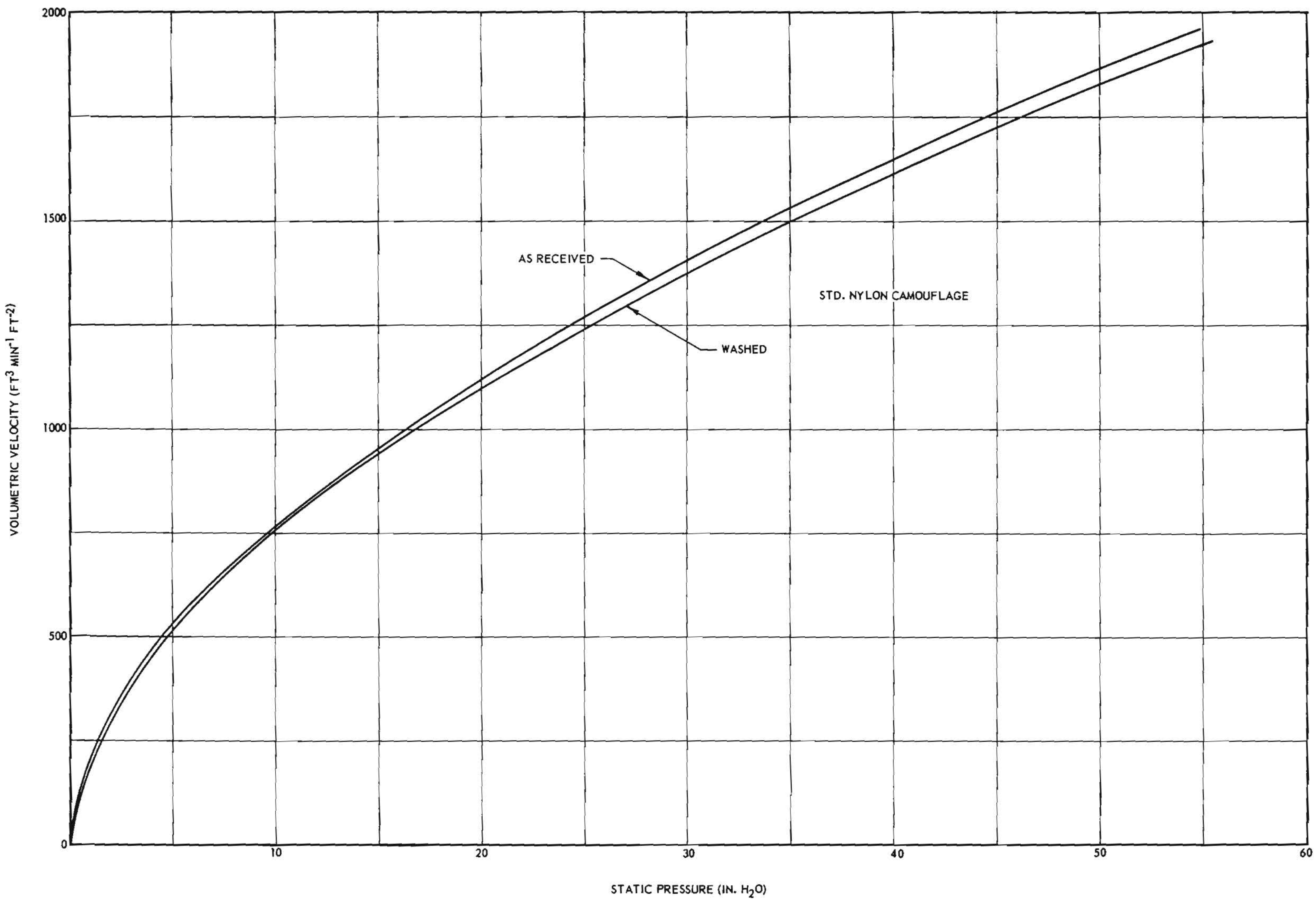

Figure 1. Permeability of Special Camouflage Nylon Cloth.

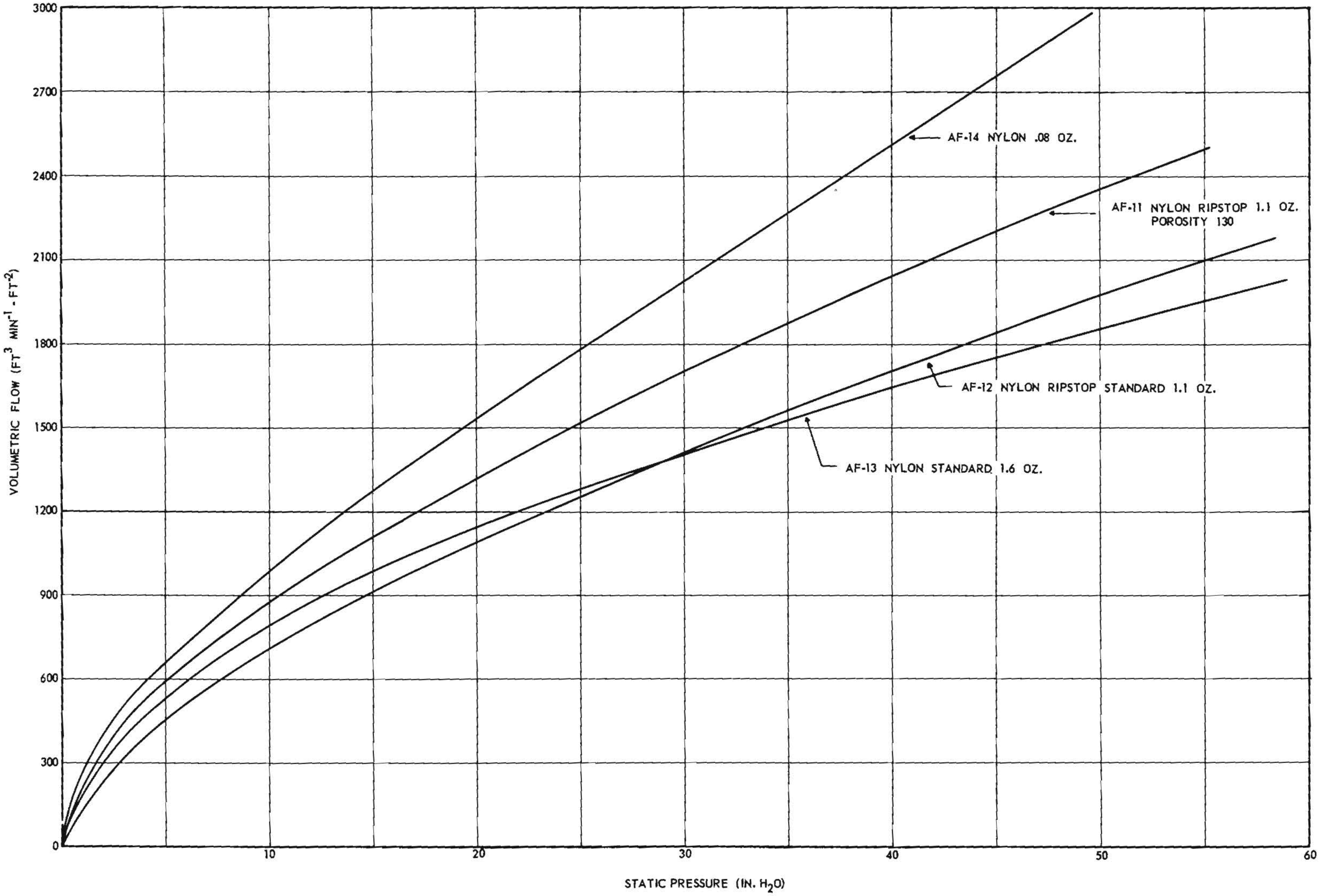

Figure 2. Permeability of Three Special Nylon Cloths.

Figure 3. 1000 Cubic Foot Reservoir and Excavation.

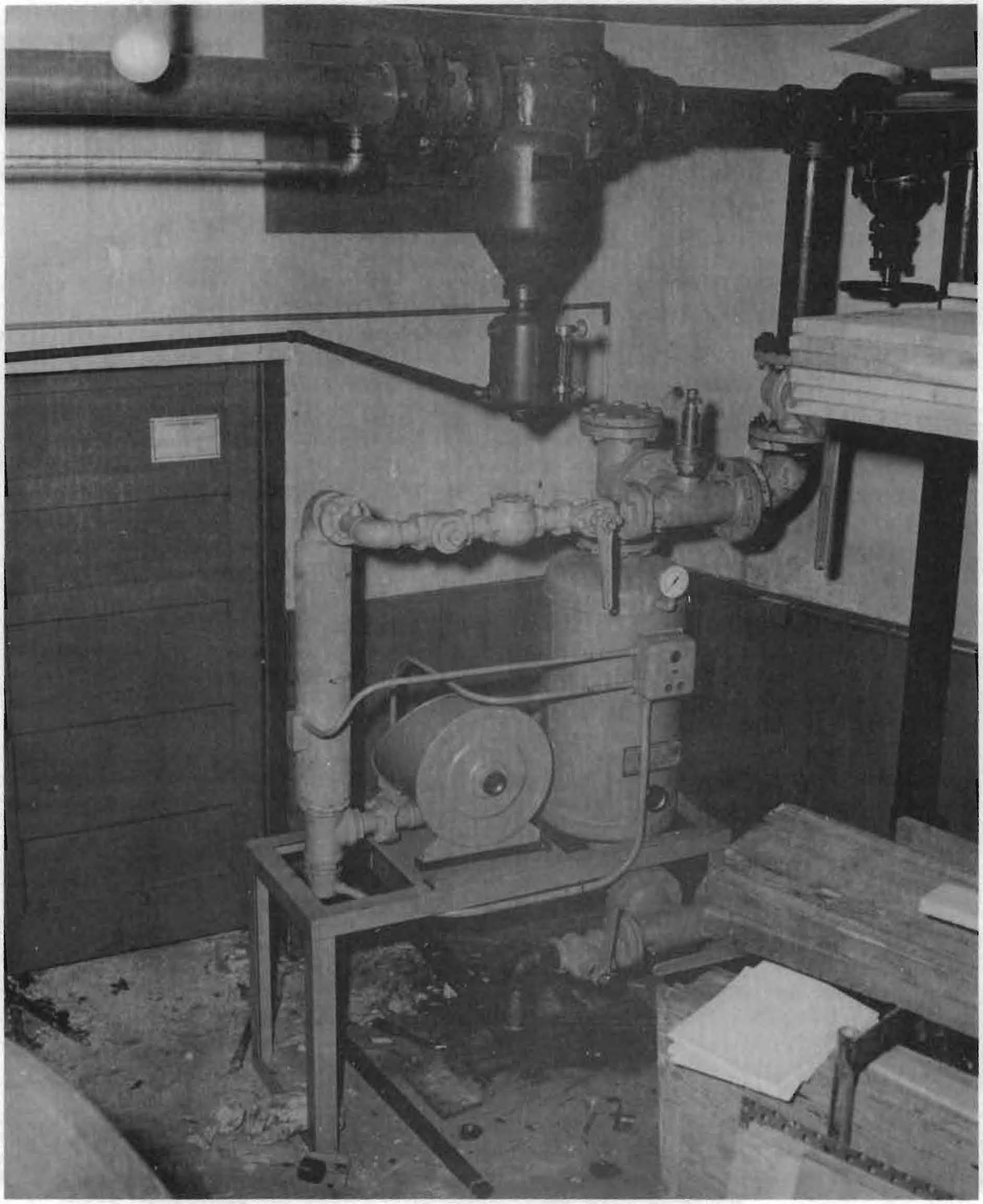

Figure 4. Kemp Adsorption Dryer.

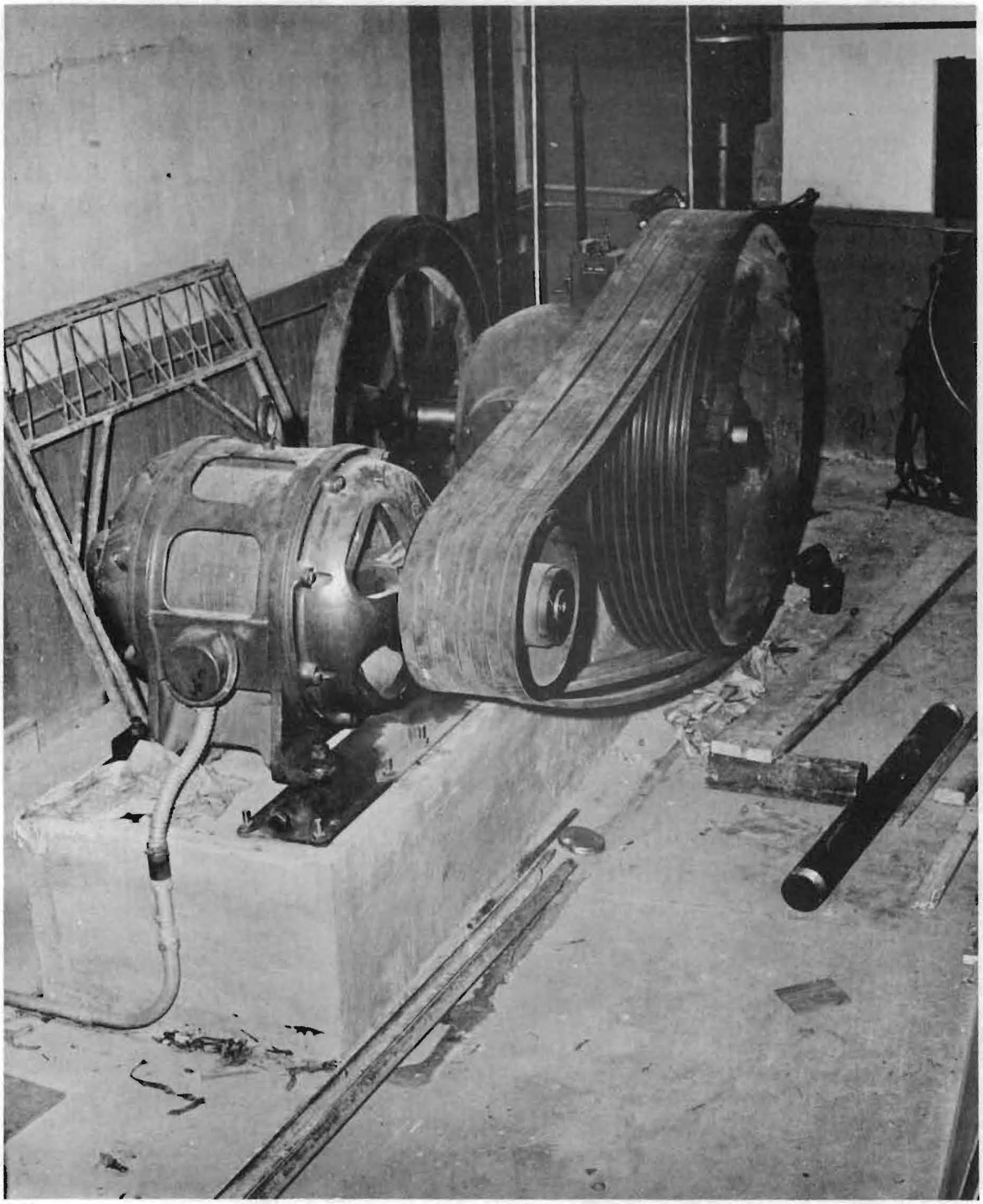

Figure 5. Worthington 12" x 13" Compressor.

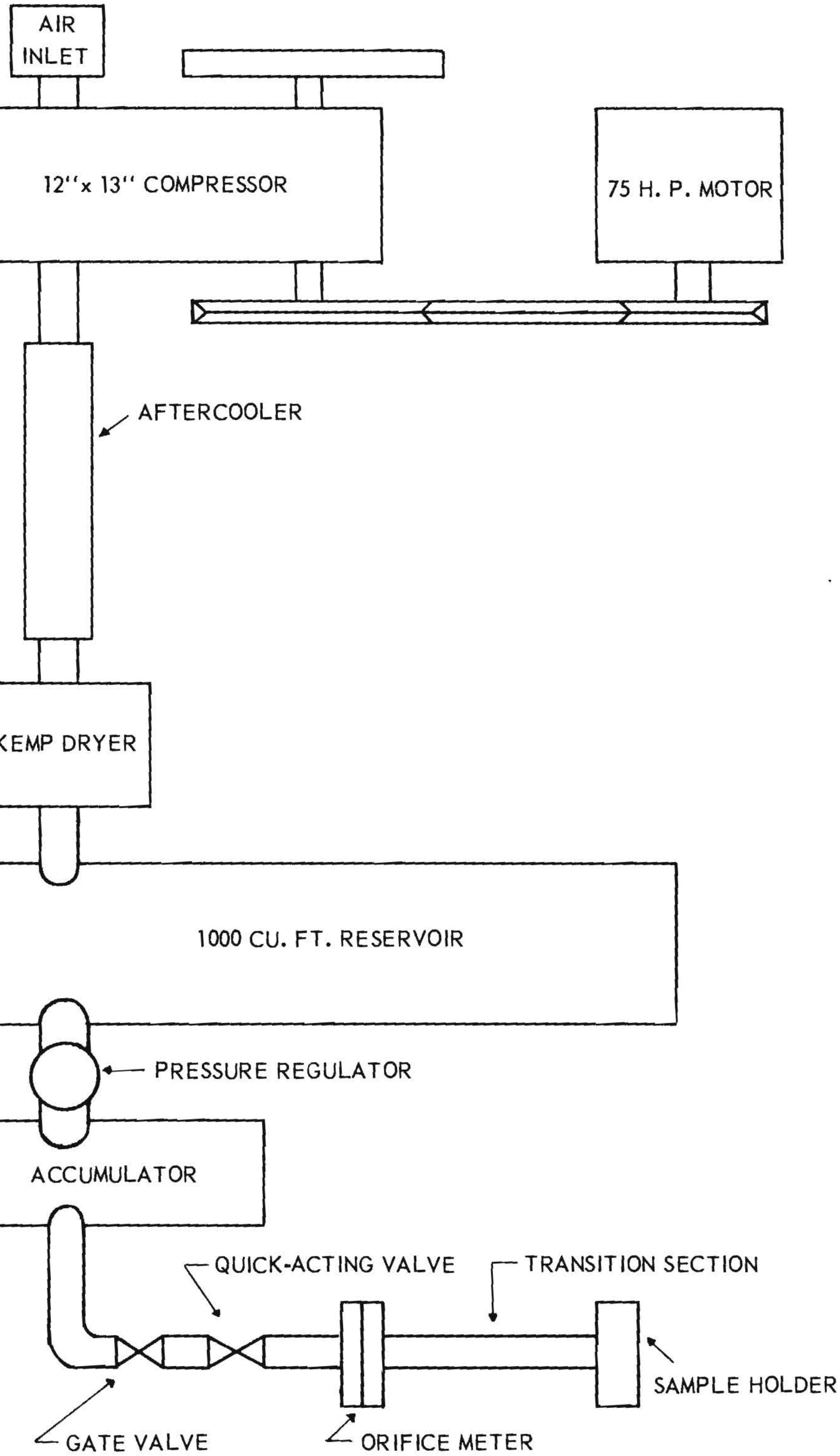

Figure 6 Schematic Diagram of Special High-Pressure Permeometer.

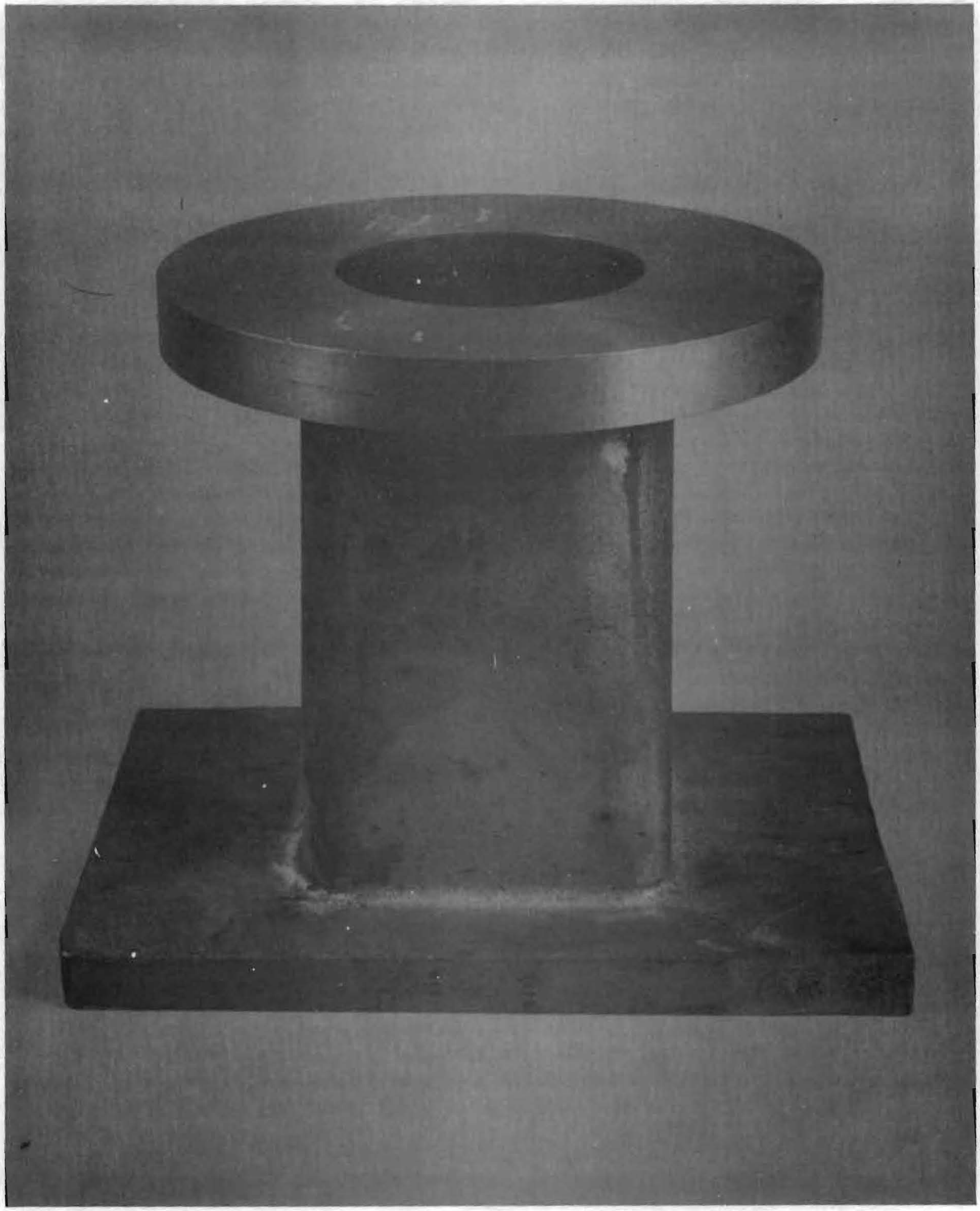

Figure 7. Transition Section.

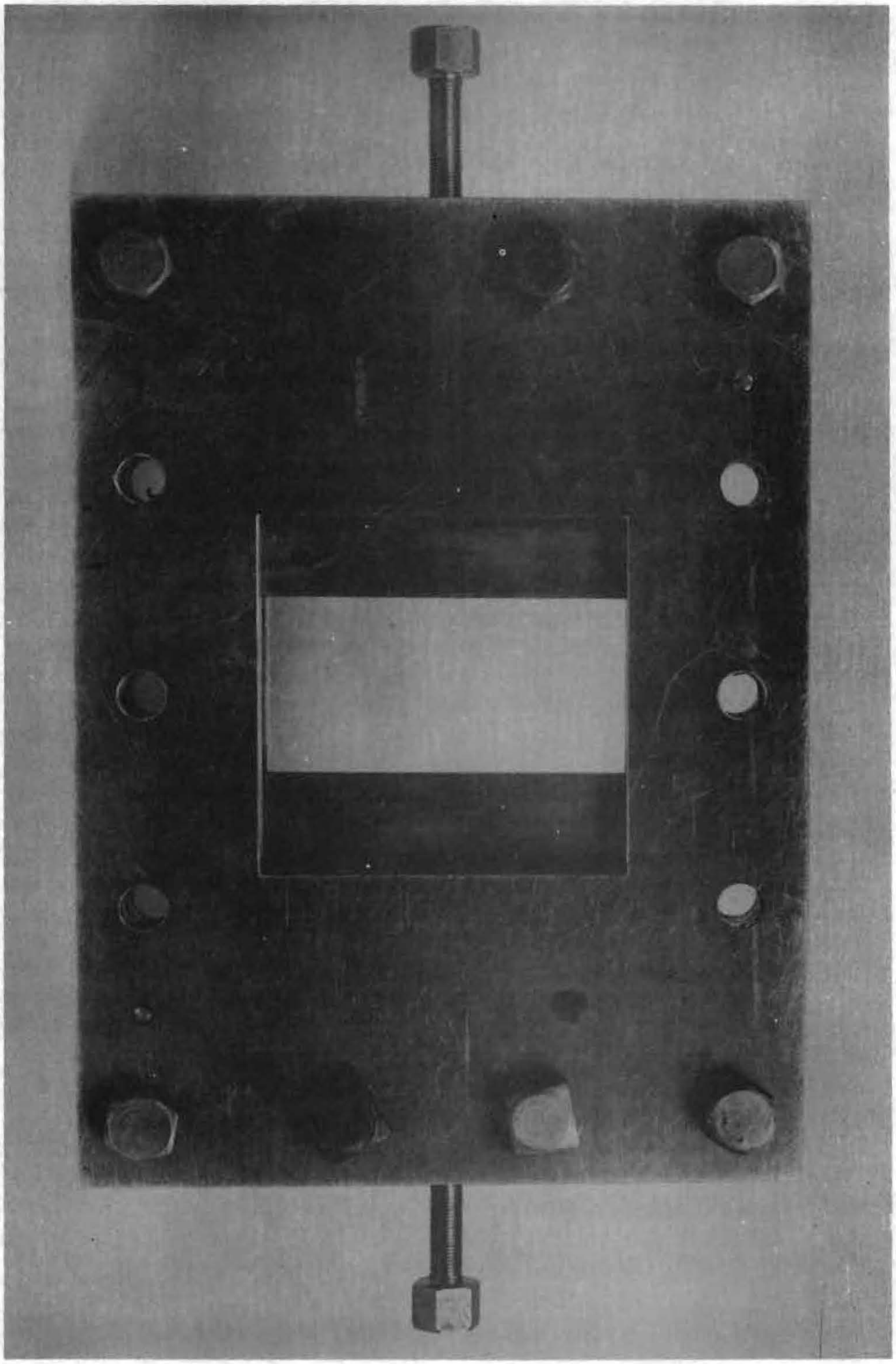

Figure 8. Special Gate Valve.

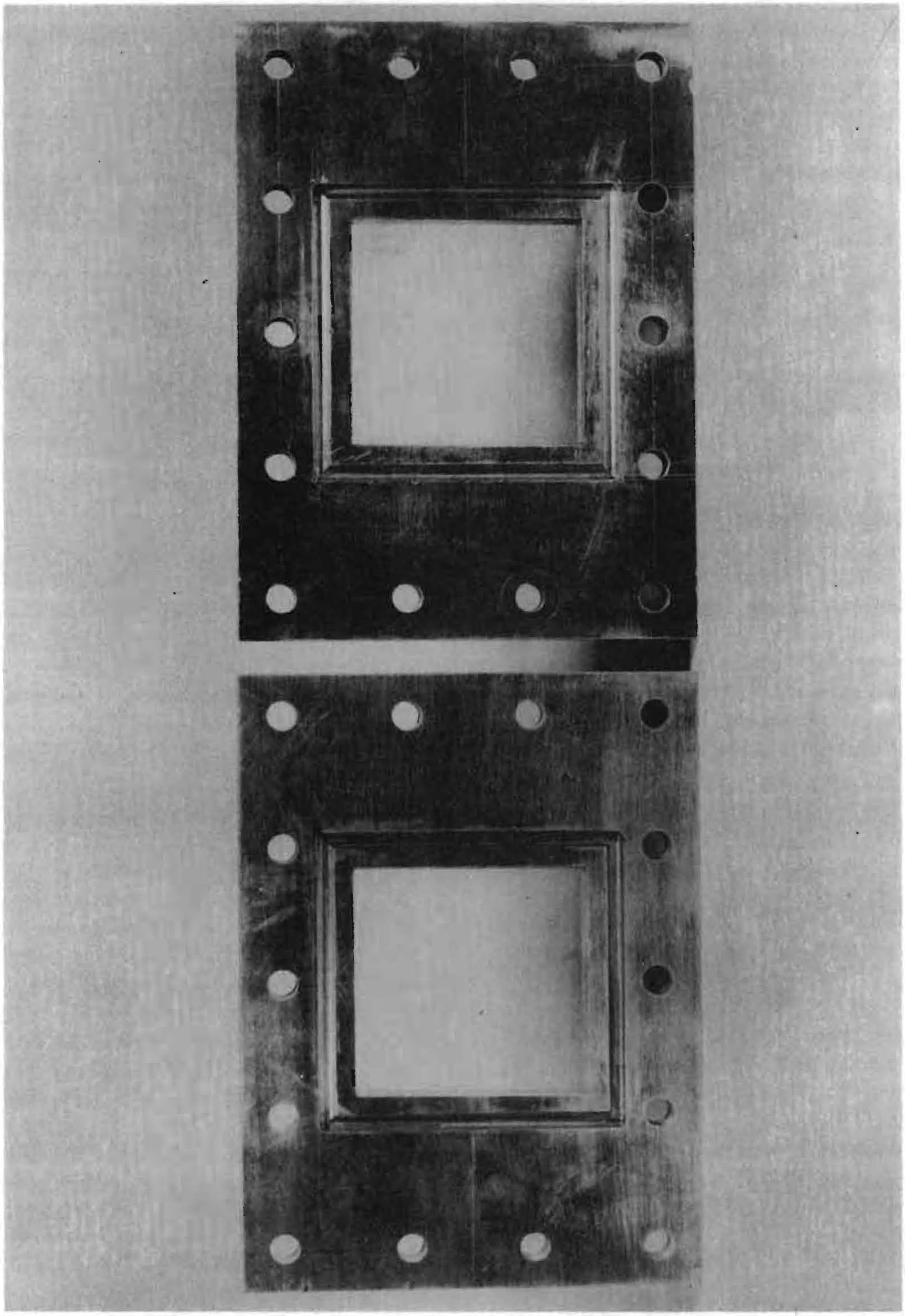

Figure 9. Elementary Sample Holder.

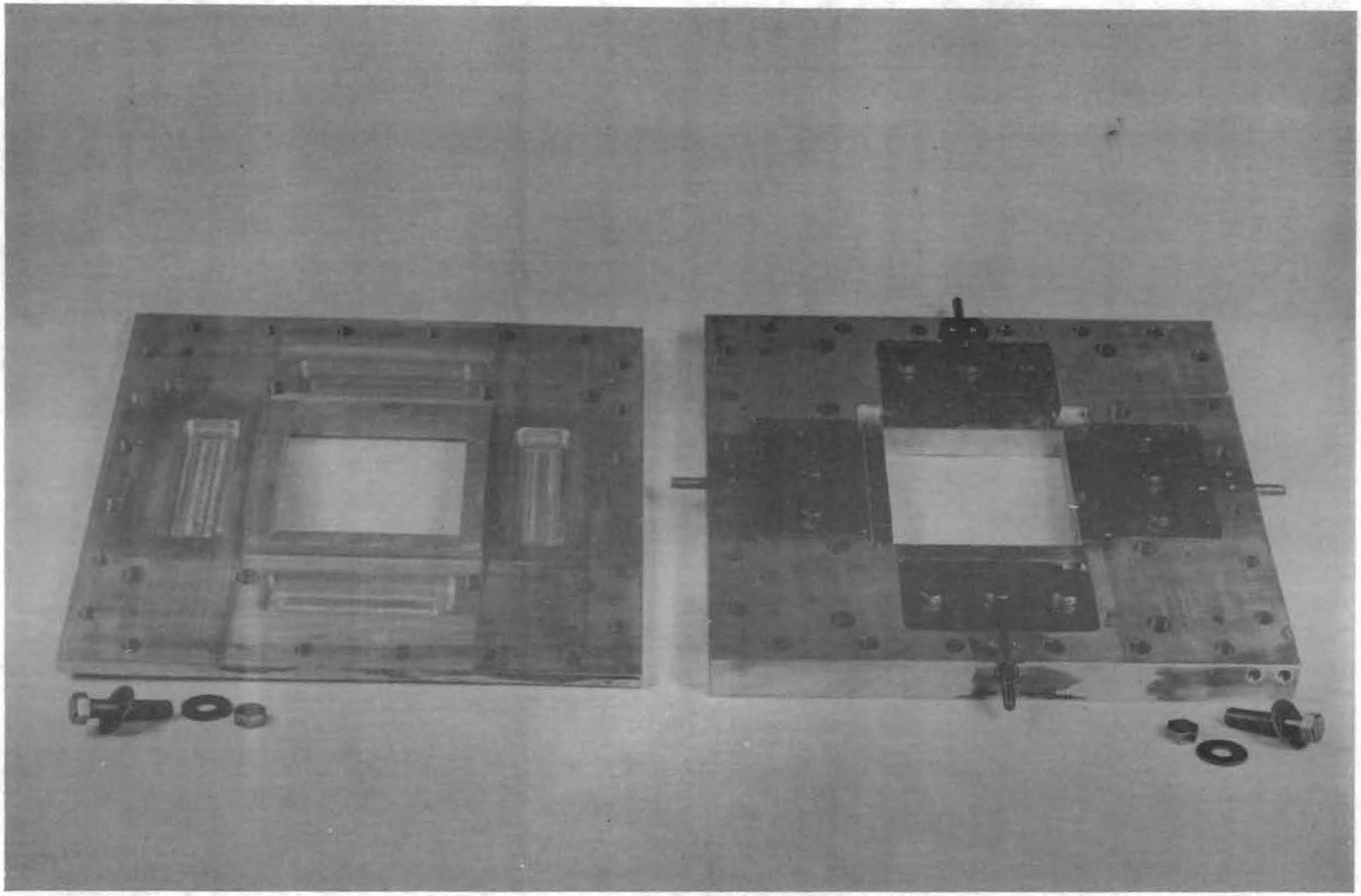

Figure 10. Sample Holder Equipped to Measure Fabric Tension.

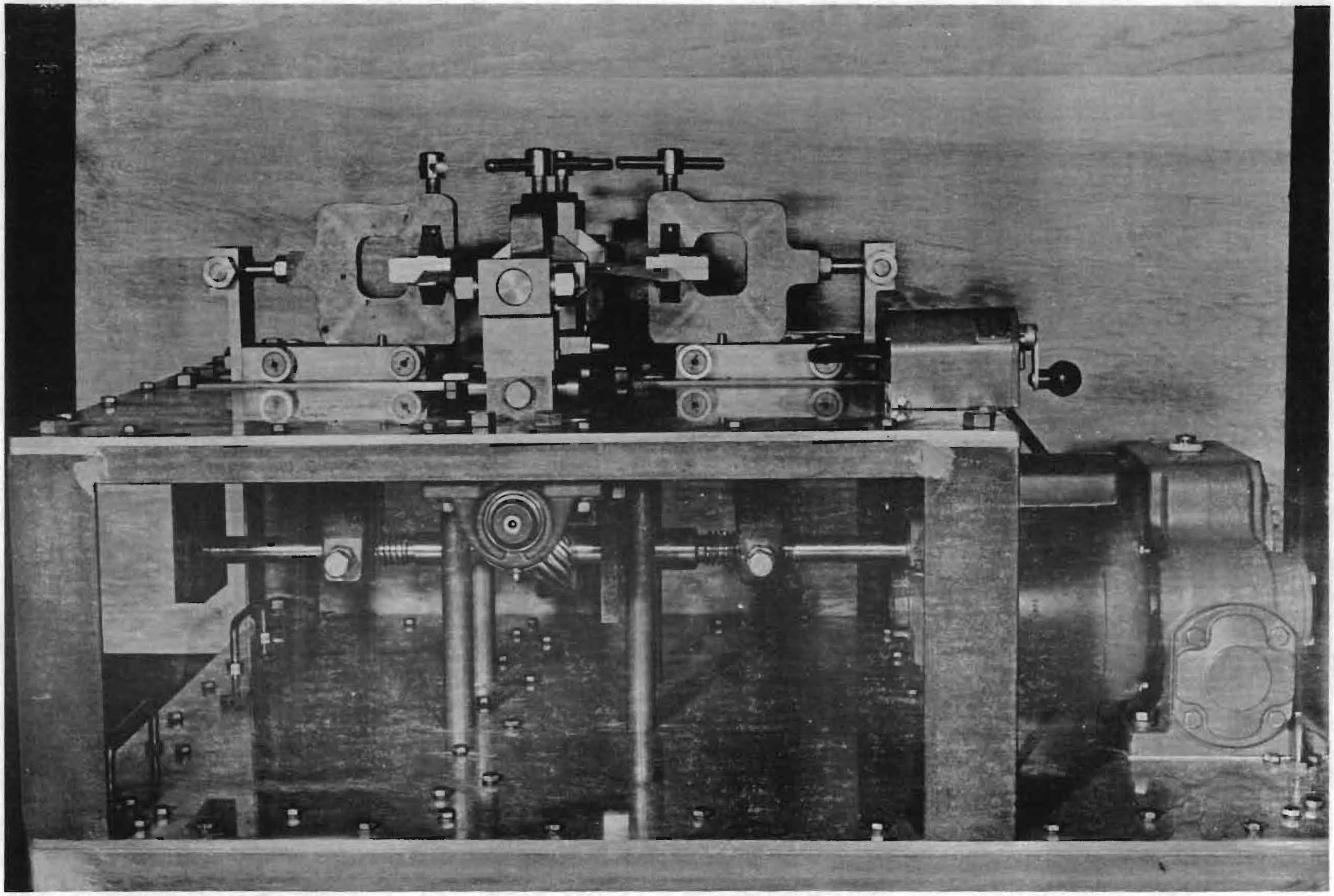

Figure 11. Fabric Tension Tester for Simultaneous Loading in Warp and Filling Direction.

ENGINEERING EXPERIMENT STATION
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Atlanta, Georgia

QUARTERLY REPORT NO. 5

PROJECT NO. 170-117

PERMEABILITY OF PARACHUTE FABRICS

By

H. W. S. LAVIER

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CONTRACT NO. AF 33(038)-15624
E.O. No. R602-198, Project No. 52-660A-41 SR7s
E.O. No. R602-193SR7S, Project No. 52-660A-25

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DECEMBER 15, 1952, to MARCH 15, 1953

ENGINEERING EXPERIMENT STATION
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E.O. No. R602-193SR7S, Project No. 52-660A-25

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DECEMBER 15, 1952, to MARCH 15, 1953

Quarterly Report No. 5, Project 170-117

This report summarizes the progress during the quarter ending 15 March 1953. It concerns completion of the low-pressure phase and progress of the high-pressure phase of the subject research.

A. Low-Pressure Permeability Investigations

The results of the low-pressure permeability studies of Georgia Tech-woven cloths, and Air Force-furnished cloths plus some special studies to determine the importance of variables such as humidity, fabric stretch, and fabric aging are presented in Technical Report No. 2. The manuscript of this report is now complete and has been reviewed by Georgia Tech personnel and personnel of the USAF W.A.D.C. Materials Laboratory Textile Branch. The report has been prepared in accordance with AMC Manual 5-4. The illustrative material for this report is being put in final form. The report will soon be ready for reproduction by the Photo Lab of the Georgia Tech Engineering Experiment Station. Technical Reports Nos. 1 and 2 constitute the final report on the low-pressure phase of the subject research.

B. High-Pressure Permeability Equipment

Construction and assembly of the high-pressure permeometer is very nearly complete. Figure 1 shows the 1,000-cubic-foot reservoir as it has been installed. Installation of the compressor, aftercooler, and adsorption dryer is now complete. A preliminary run to determine any air leakage was made on 12 March 1953.

Due to the short run time (approximately 40 seconds), it is necessary to use pressure- and temperature-sensing or -measuring elements, which will permit recording of such data versus time on a photorecording oscillograph. Planning of such instrumentation requires the selection of appropriate pickup devices, decision as to whether amplification is required or not, and selection of an appropriate galvanometer for the oscillograph. The oscillograph galvanometer is driven either by the pickup directly or by the amplified signal of the pickup device.

Trans-Sonic, Inc., Type-7 Pressure Transducers were chosen as pressure-sensing elements. Figure 2 shows the Type-7 Transducer. A Consolidated Carrier Amplifier, shown in Figure 3, is required to amplify the signal from the transducer and to obtain adequate deflection of the trace on the oscillograph record.

A Six-Channel General Electric Type-PM-10 Recording Oscillograph was obtained for use on this program. However, the galvanometers installed are not sensitive enough for use with either temperature- or pressure-sensing elements. General Electric was not able to promise a satisfactory delivery date for appropriate galvanometers. Therefore, we will use a Consolidated Type 5-116 Nine-Channel Oscillograph on this program. Appropriate galvanometers are available for use with the Consolidated Oscillograph. The Consolidated equipment has been ordered and an early delivery has been promised.

Only the completion of the detail assembly of the high-pressure permeometer and the installation of the special instrumentation remain to be done.

The selection of pressure pickups temperature-measuring devices, oscillographs and galvanometers has required much study. Frequent letter and telephone communication with the vendors was required to obtain early delivery dates. A visit was made to Trans-Sonics, Inc., Bedford, Mass., on

23 January 1953 to expedite early delivery of the Type-7 Pressure Transducers and the resistance-type temperature devices. On 29 January 1953 a visit was made to the Washington office of Consolidated Engineering Corp. Delivery of Consolidated equipment then on order was discussed. Anticipated delivery of the Consolidated Oscillograph and galvanometers was also discussed.

C. Deformation of Fabrics Under Load (No Air Flow)

The machine for biaxial-tension loading of fabric samples is complete except for installation of load- and deformation-measuring devices. The machine is shown in Figure 4. Preliminary runs have been made to test the jaw action and to observe types of fabric failure under biaxial tension. The mechanical operation of the biaxial-tension tester is satisfactory. It is hoped to ultimately record the biaxial loads and stretch on an oscillograph. This will give all necessary data on one record.

D. Analysis and Conclusions

In Technical Report No. 2, fabric permeability data is presented as volumetric flow (c.f.m.) of air at standard conditions versus the pressure drop (inches of water) across the fabric sample. Correlation and comparison of permeability test data, as well as conclusions, are presented in Technical Report No. 2.

E. Technical Discussion and Visits

The writer visited the Textile Branch at the Wright Air Development Center in December 1952. Instrumentation of the high-pressure permeometer was the subject of this meeting. The manuscript for Technical Report No. 2 was taken to the Textile Branch at W.A.D.C. on 13 February 1953. The manuscript was left with branch personnel for their review and criticism. The writer attended the meetings of the Fluid Mechanics Division of the American Physical Society on 25 January 1953 held on the Harvard University Campus.

F. Personnel

During the past quarter, project personnel has included Professor H. W. S. LaVier, Project Director, Mrs. Donna W. Williams, Project Secretary, Mr. W. C. Boteler, Mr. T. P. Bankston, both Graduate Assistants. Mr. Peter Stanton, Student Assistant, was recently employed.

Mr. Cecil D. Brown left the project staff in November 1952. However, he has returned and resumed his duties as Research Assistant as of 1 March 1953.

Respectfully submitted:

Hurlbut W. S. LaVier
Project Director

Approved:

Herschel H. Cudd, Acting Director
Engineering Experiment Station

APPENDIX A

FIGURES

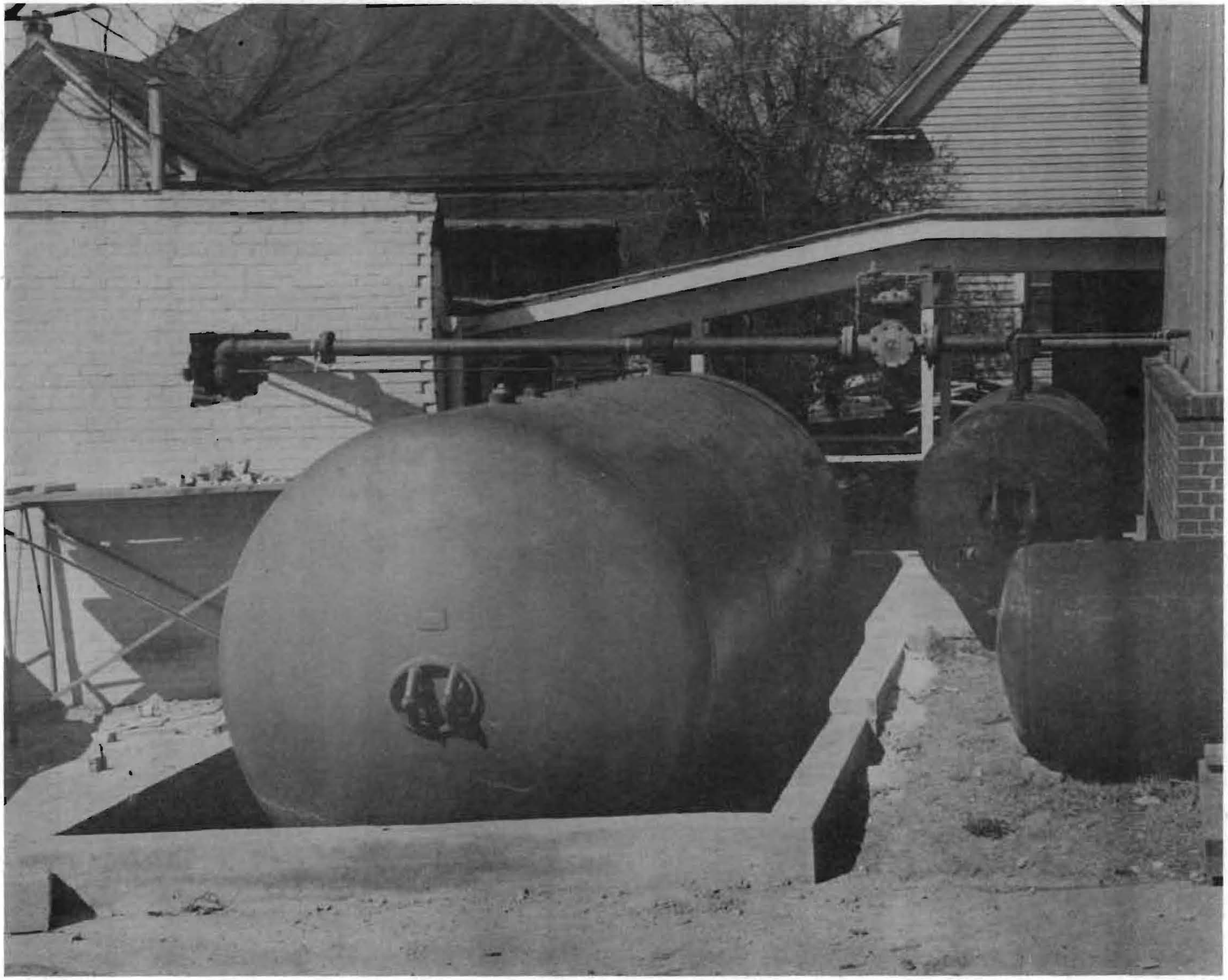

Figure 1. General View of 1000-cu.-ft. Reservior and Pressure Regulator Valve.

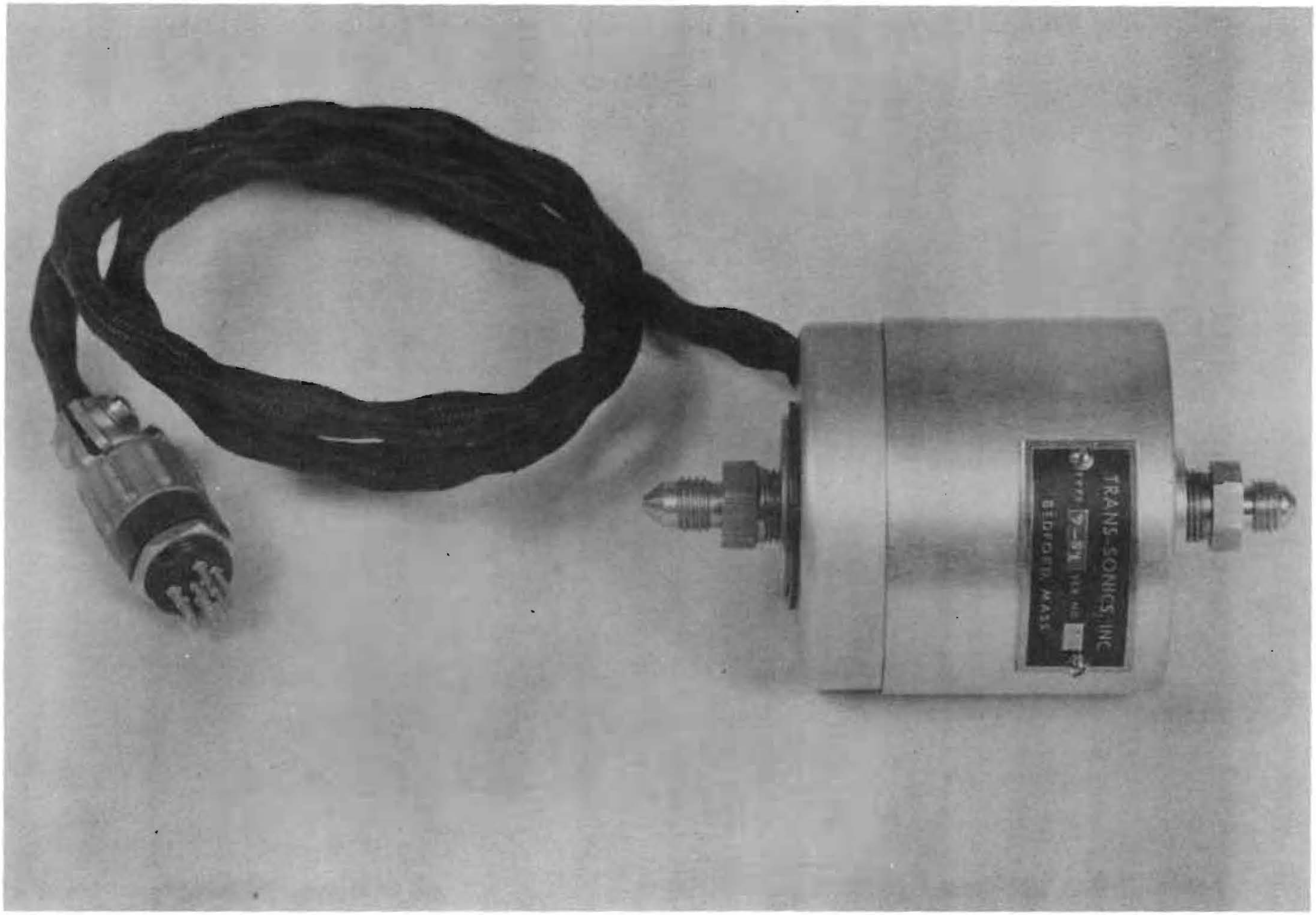

Figure 2. Trans-Sonics, Inc., Type-7 Pressure Transducer.

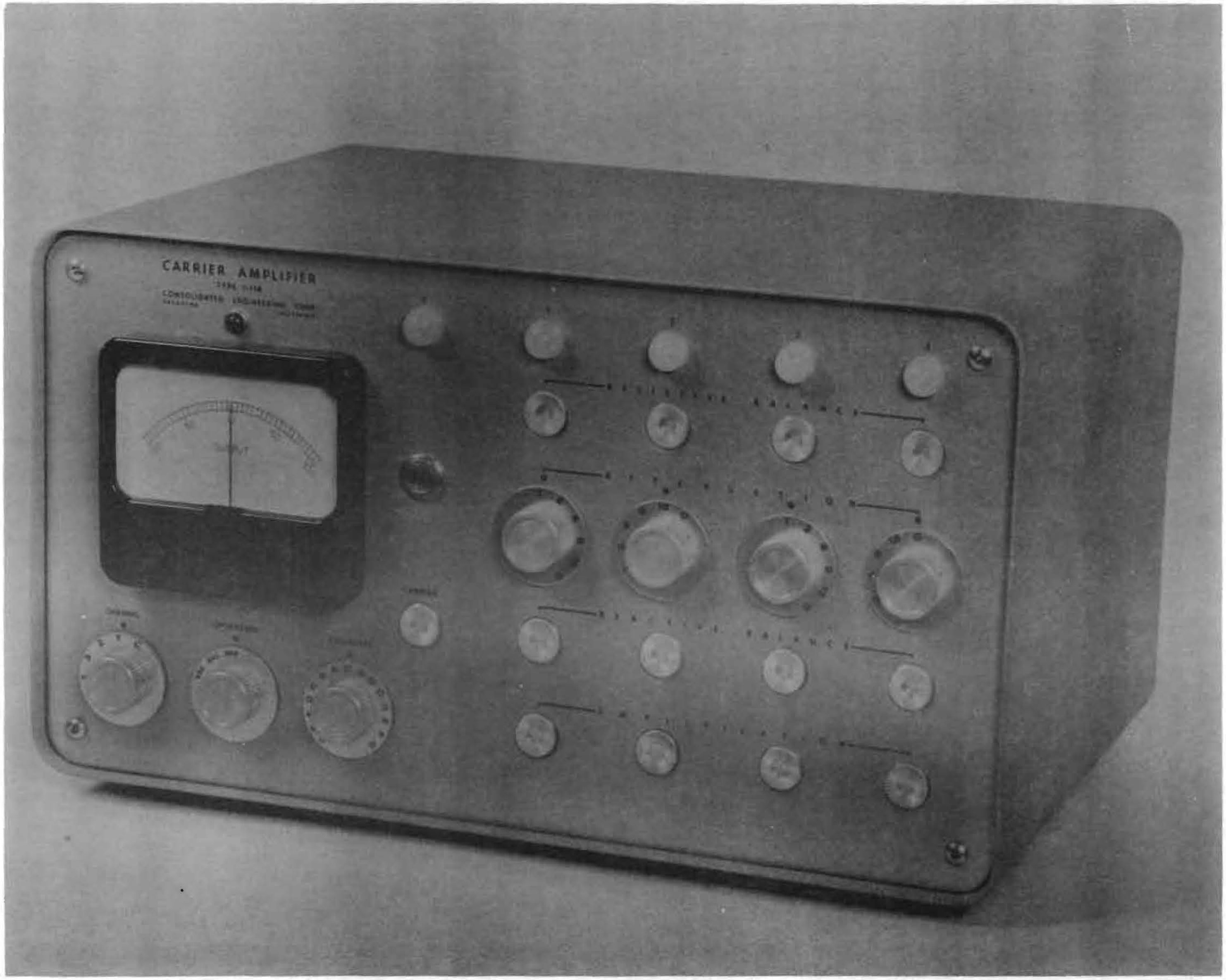

Figure 3. Consolidated Engineering Corp. Type-118-1 Four-Channel Carrier Amplifier.

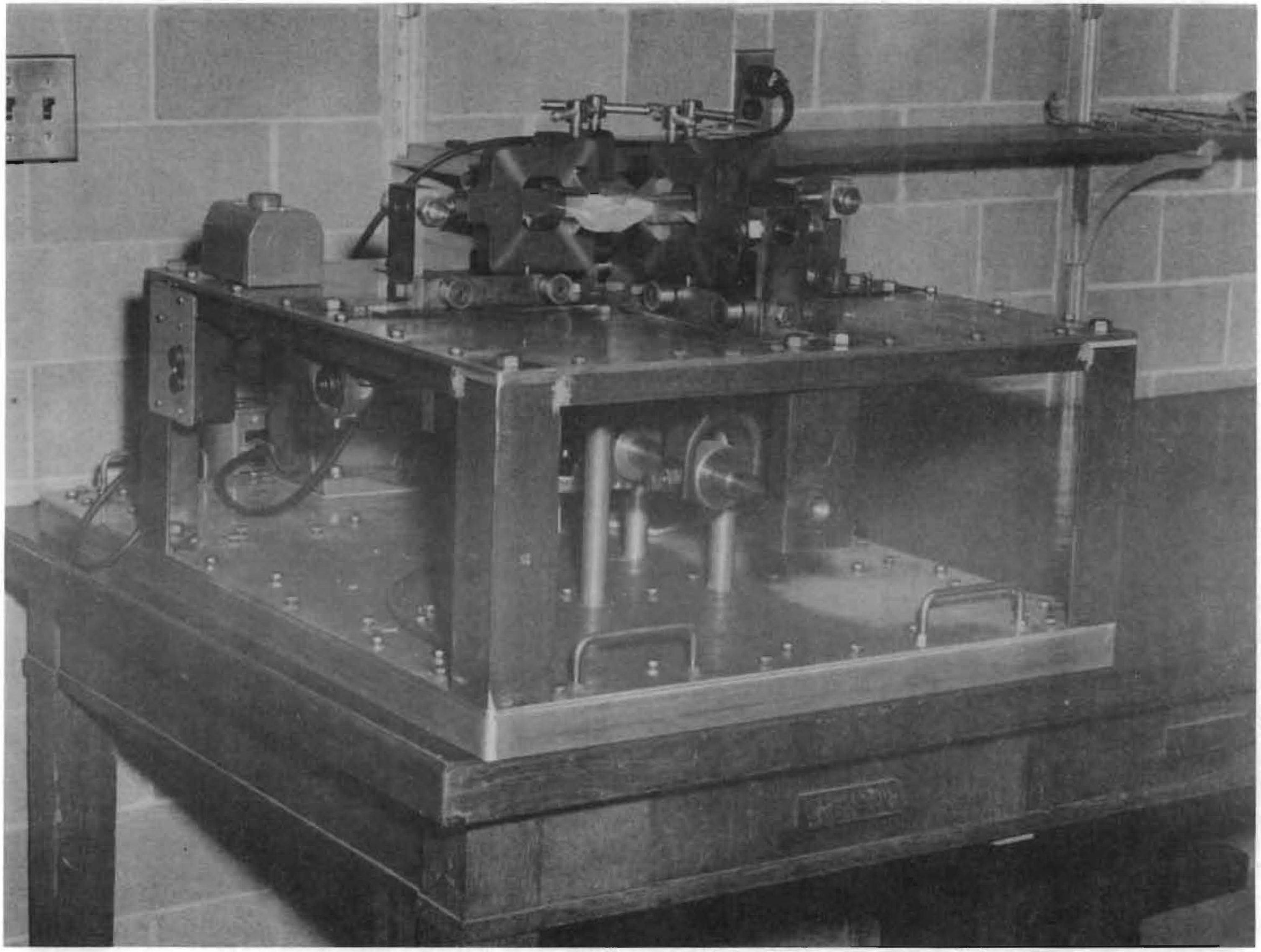

Figure 4. Biaxial Fabric Tension Testing Machine.

ENGINEERING EXPERIMENT STATION
of the Georgia Institute of Technology
Atlanta, Georgia

QUARTERLY REPORT NO. 6

PROJECT NO. 170-117

PERMEABILITY OF PARACHUTE FABRICS

By

H. W. S. LAVIER

- o - o - o - o -

CONTRACT NO. AF 33(038)-15624
E.O. No. R602-198, Project No. 52-669A-41 SR7s
E.O. No. R602-193SR7S, Project No. 52-660A-25

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AUGUST 15, 1953, TO NOVEMBER 15, 1953

ENGINEERING EXPERIMENT STATION
of the Georgia Institute of Technology
Atlanta, Georgia

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AUGUST 15, 1953, TO NOVEMBER 15, 1953

This report summarizes the progress during the quarter ending 15 November 1953. It concerns the preparation for, and conduct of, tests as a part of the high-pressure phase of the subject research. The results of high-pressure air-permeability tests are included in tabular form in Appendix A and graphically in Appendix B.

Results of fabric tests, using the biaxial fabric-tension testing machine, are included in the tables of Appendix A and the figures of Appendix B. The testing machine has required modification to permit testing under a wide range of temperatures.

Preparations for new phases of the subject research have been made. These new phases will include studies of the effects on air permeability resulting from fabric defects and also a wind tunnel study to determine the distribution of fabric stresses throughout the parachute canopy.

I. HIGH-PRESSURE PERMEABILITY TESTS

A. Equipment

The Georgia Tech high-pressure permeometer has required considerable modification during the past quarter. Many of the changes were for improving the instrument installations.

A device for cooling the permeometer air has been installed. This device injects liquid nitrogen into the compressed air stream. Evaporation of the liquid nitrogen reduces the air temperature at the fabric sample. This apparatus is shown on the schematic diagram of the permeometer, Figure 1. The control valves and face of the device are shown in the photograph, Figure 2. Temperatures at the cloth of 0° F. have been obtained. Further development of this apparatus is required. As mentioned in Interim Report No. 2, by shutting off the compressor after-cooler, air temperatures of +175° F. have been obtained at the cloth sample.

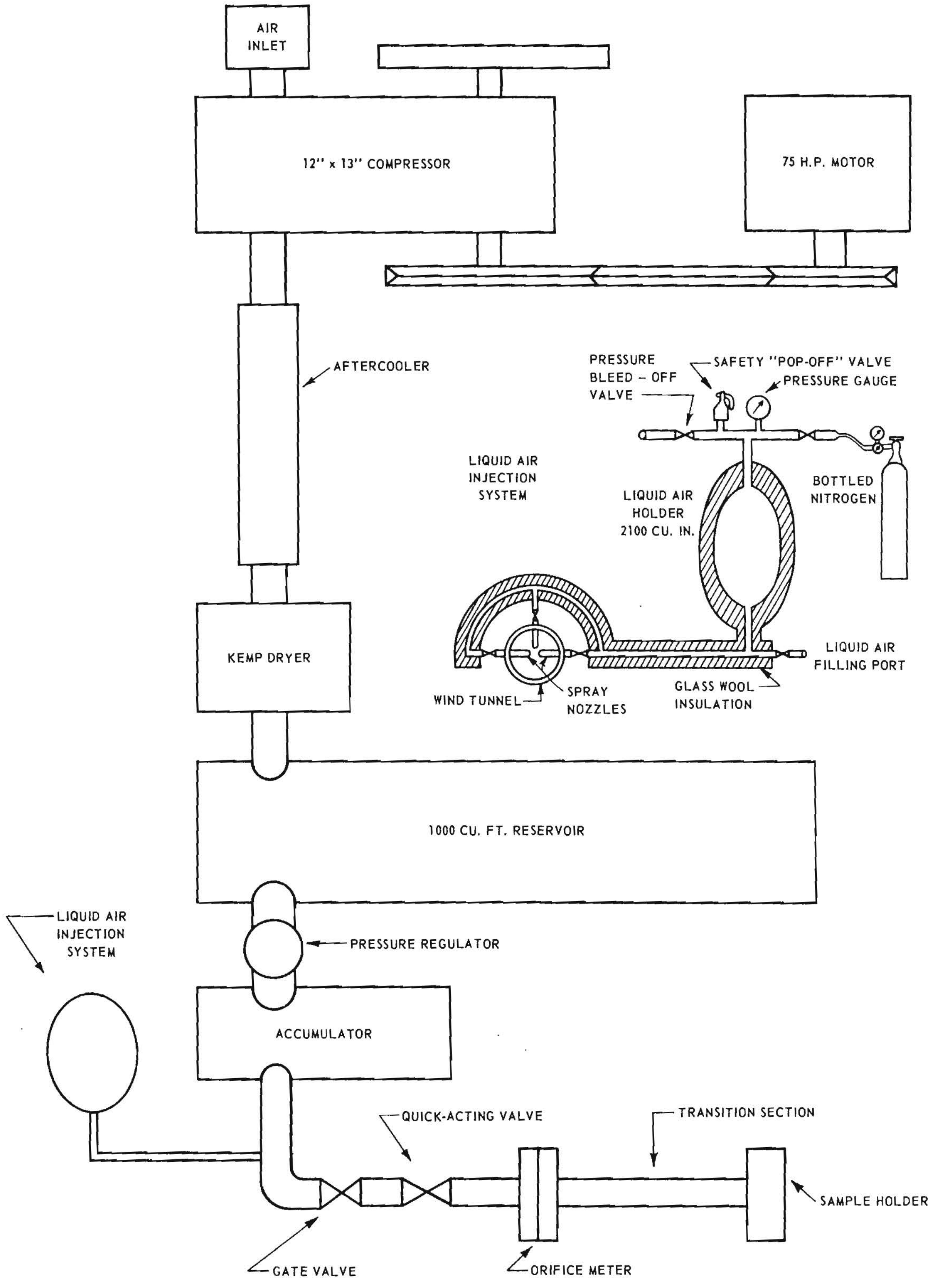

Figure 1. Schematic Diagram of the Georgia Tech High-Pressure Permeometer.

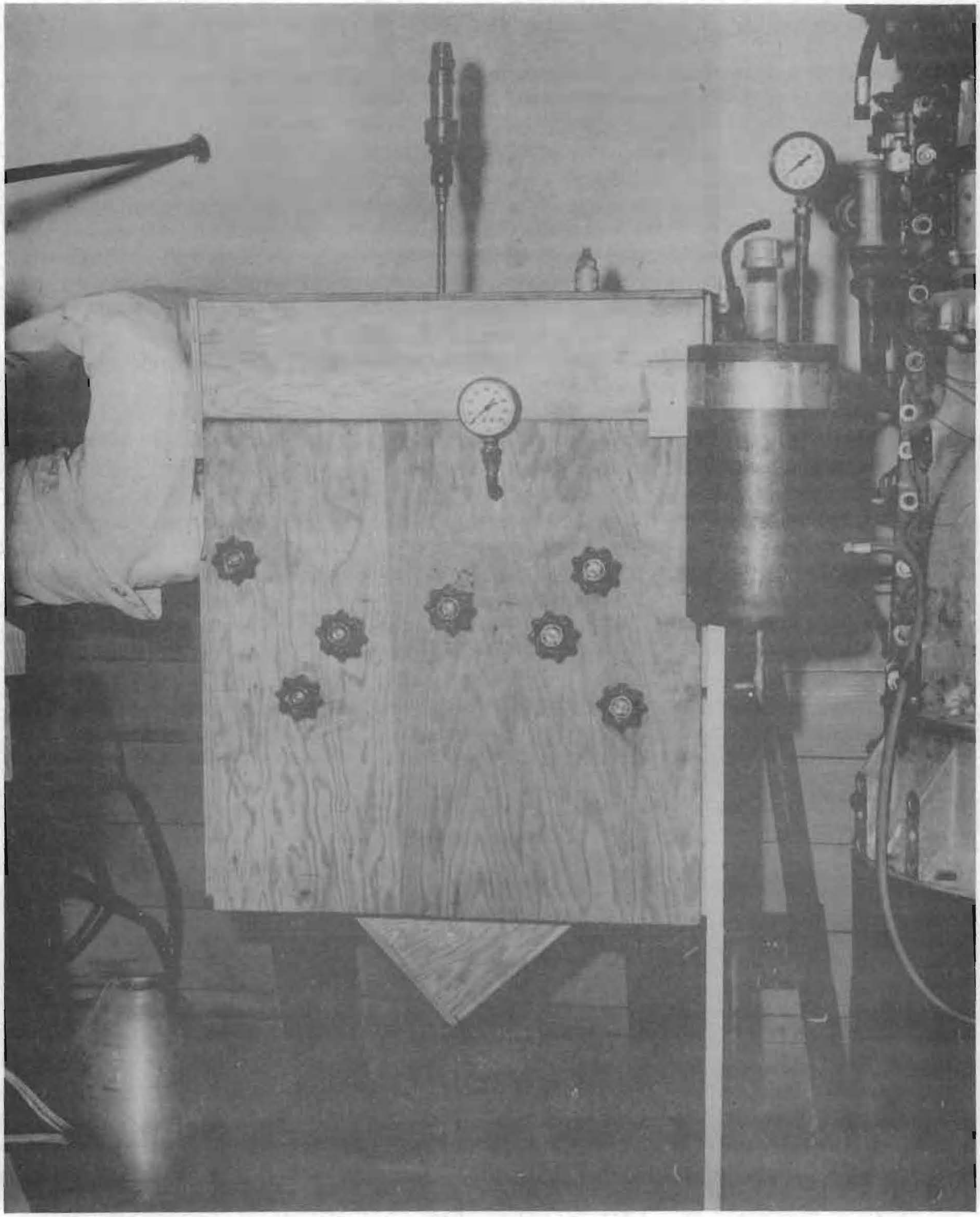

Figure 2. Cooler Controls of the Georgia Tech High-Pressure Permeometer.

The biaxial-tension-load sample holder has required considerable modification. Preliminary tests using this sample holder indicated that observed tension loads were affected by friction between the fabric clamps and the body of the sample holder. It has been necessary to eliminate all possible causes of friction between adjacent parts.

B. Program of Tests

In preparation for Technical Report No. 4, which will be Part III of WADC Technical Report 52-283, representative Air Force-furnished and Georgia-Tech-woven fabrics were selected and listed in Table I, Appendix A of Interim Report No. 2. These fabrics were to be used as the "selected fabrics" for the high-pressure phase of the subject research. Stocks of some of the Georgia-Tech-woven fabrics have been depleted, and it has been necessary to make some substitutions.

We have conducted high-pressure air permeability studies of these fabrics at the machine's operating temperatures (air at the sample approximately +80°F.). The results of these tests are indicated in table form in Appendix A and in graphical form in Figures 4 through 10 of Appendix B. The effects of high temperatures on the air permeability of nylon, orlon and dacron fabrics are indicated in Table I of Appendix A and Figure 11 of Appendix B.

II. DEFORMATION OF FABRIC UNDER LOAD (No Air Flow)

A. Equipment

Further modification of the biaxial-fabric-tension-testing machine has been accomplished during the past quarter. The major portion of these changes involved the insulated hood used in the temperature studies.

Figure 3 shows the biaxial-fabric-tension-testing machine with the insulated hood in place. The hinged cover is shown in the open or raised position. The observation window in the cover can be seen in the photograph.

Figure 3. The Biaxial - Fabric - Tension - Testing Machine with Insulated Hood.

Racks to hold dry ice and a blower system to circulate air through the hood were incorporated. Heating elements will also be provided to produce the high temperatures.

B. Program of Tests

Most of the selected fabrics listed in Table I, Appendix A of Interim Report No. 2, were tested in the biaxial-fabric-tension-testing machine. Because of a depletion of sample stock, it was necessary to make certain substitutions. The entire group of fabrics was subjected to biaxial tension tests at average room temperatures of approximately 80° F. Results of these tests are presented in Figures 12 through 29 of Appendix B.

To prevent slipping of the cloth at the clamps, it was necessary to cover the jaw surfaces with a "gummed-back" paper tape. After taping the jaw surfaces, single-dimension "grab-break" tests of cloth duplicated the rupture test results obtained with the Scott tester.

It was found that elongations based on the extensometer, located in the center of the sample, indicated much less elongation of the cloth under load than that obtained by measurement of the horizontal displacement of the clamps. The results obtained with conventional Scott testers and similar machines usually involve the elongation measurement based upon the horizontal displacement of the test clamps. This seems to indicate nonuniform elongation throughout the sample length. It also points out the necessity for using an extensometer having a gage length of at least one inch rather than using a smaller gage length and running the chance of indicating only the local elongation rather than an average value for the sample.

In accordance with ASTM Specification for "grab-break" tests, five samples of each fabric to be tested were submitted to the biaxial fabric-tension tests, and from these five tests an average curve of load versus elongation was prepared.

III. ADDITIONAL RESEARCH PHASE

A recent amendment to the subject contract calls for a study of the effects of fabric defects on air permeability. Also the low- and high-pressure air permeabilities of cotton, rayon and viscose fabrics, as well as nylon, orlon, and dacron cloths, are to be studied. A third part of the additional research phase involves the use of the wind tunnel for testing model parachutes to determine the distribution of fabric loads throughout the parachute canopy during deployment and at the time of the opening shock.

So far, investigations have been started to obtain the necessary sample material. Drawings of the standard parachute types have been requested, and from these drawings, model parachutes will be prepared. We have located several potential makers of the model parachutes.

Respectfully submitted:

Hurlbut W. S. LaVier
Project Director

Approved:

Herschel H. Cudd, Director
Engineering Experiment Station

APPENDIX A

TABLES

TABLE I

HIGH-PRESSURE PERMEABILITY TEST RESULTS
FOR GEORGIA-TECH-WOVEN FABRICS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ft.$^{-2}$)	Volumetric Velocity (cfm ft.$^{-2}$)
Fabric Number 2 (GT)			
55	.0837	4.92	3730
97	.0914	6.17	4470
165	.1040	7.50	5100
230	.1160	8.78	5640
360	.1400	11.80	6900
485	.1630	14.50	7880
595	.1830	17.50	8960
665	.1970	19.10	9430
730	.2080	20.90	10000
795	.2200	22.40	10450
Fabric Number 8 (GT)			
130	.0974	4.59	3220
260	.1220	6.84	4290
390	.1460	9.18	5260
520	.1700	11.50	6110
650	.1940	13.90	6900
780	.2180	16.60	7780
830	.2290	17.70	8110
Fabric Number 9 (GT)			
140	.0920	7.37	5330
210	.1040	9.09	6180
280	.1150	10.80	6960
350	.1270	12.33	7560
420	.1390	13.95	8190
550	.1630	17.10	9270
620	.1750	18.72	9810
700	.1870	20.34	10300
760	.1990	22.05	10800
830	.2100	23.85	11400
900	.2220	25.88	12000
Fabric Number 12 (GT)			
210	.1100	14.90	9860
280	.1220	18.90	11800
350	.1350	22.64	13500

(Continued)

TABLE I (Continued)

HIGH-PRESSURE PERMEABILITY TEST RESULTS
FOR GEORGIA-TECH-WOVEN FABRICS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ft.$^{-2}$)	Volumetric Velocity (cfm ft.$^{-2}$)
Fabric Number 12 (GT) (Continued)			
420	.1480	26.12	14900
490	.1600	29.81	16300
Fabric Number 15 (GT)			
30	.0776	3.19	2500
97	.0897	5.62	4110
240	.1160	10.30	6650
375	.1400	14.30	8280
500	.1620	18.20	9340
615	.1830	22.30	10300
745	.2060	26.40	11200
825	.2210	29.20	11800
875	.2300	31.10	12200
1000	.2540	35.40	13000
Fabric Number 27 (GT)			
80	.0870	10.17	7550
190	.1060	14.40	9670
260	.1190	16.65	10570
360	.1380	20.25	11950
430	.1510	22.59	12710
530	.1690	26.19	13960
610	.1830	28.53	14600
730	.2050	32.31	15600
Fabric Number 28 (GT)			
55	.0960	7.31	5170
110	.1080	10.59	7090
170	.1190	13.53	8590
220	.1310	16.32	9880
280	.1430	18.95	10970
330	.1550	21.64	12030
390	.1660	24.32	13160
440	.1780	26.98	14000
Fabric Number 30 (GT)			
41	.0760	1.58	1250
97	.0860	3.63	2700

(Continued)

TABLE I (Continued)

HIGH-PRESSURE PERMEABILITY TEST RESULTS
FOR GEORGIA-TECH-WOVEN FABRICS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ft.$^{-2}$)	Volumetric Velocity (cfm ft.$^{-2}$)
Fabric Number 30 (GT) (Continued)			
180	.1000	5.77	4000
230	.1100	7.01	4620
315	.1230	9.01	5620
370	.1330	10.44	6260
440	.1450	12.33	7090
490	.1540	13.95	7790
560	.1670	16.11	8630
610	.1750	17.46	9150
Fabric Number 36 (GT)			
160	.1000	7.38	5110
240	.1140	8.42	5450
315	.1280	9.53	5830
395	.1430	10.51	6090
475	.1570	11.42	6310
550	.1710	12.40	6540
635	.1860	13.66	6930
720	.2010	14.65	7150
745	.2060	15.10	7290
Fabric Number 40 (GT)			
90	.0880	2.72	2000
160	.1000	3.52	2430
225	.1130	4.41	2870
290	.1250	5.32	3290
355	.1370	6.37	3770
420	.1480	7.45	4240
485	.1600	8.52	4670
545	.1710	9.76	5170
610	.1820	10.85	5570
Fabric Number 44 (GT)			
66	.0820	3.67	2810
130	.0930	4.27	3060
175	.1010	4.81	3320
245	.1130	5.76	3730
315	.1250	7.00	4340

(Continued)

TABLE I (Continued)

HIGH-PRESSURE PERMEABILITY TEST RESULTS
FOR GEORGIA-TECH-WOVEN FABRICS

Static Pressure Upstream of Cloth (Inches Water)	Air Density Upstream of Cloth (lbm ft.$^{-3}$)	Mass Velocity of Air Upstream of Cloth (lbm sec.$^{-1}$ft.$^{-2}$)	Volumetric Velocity (cfm ft.$^{-2}$)
Fabric Number 44 (GT) (Continued)			
350	.1320	7.73	4670
390	.1390	8.27	4850
435	.1470	9.27	5300
480	.1550	10.53	5860
Fabric Number 52 (GT)			
140	.0990	6.87	4790
260	.1210	8.55	5410
390	.1450	10.53	6050
515	.1670	12.78	6840
645	.1910	15.12	7580
765	.2140	17.46	8260
890	.2360	20.34	9170
1020	.2590	23.49	10100
1145	.2830	27.18	11200
Fabric Number 56 (GT)			
140	.1000	5.11	3550
265	.1230	7.77	4850
390	.1460	10.35	5930
515	.1690	13.59	7240
640	.1420	17.01	8505
765	.2150	20.70	9700
890	.2380	24.39	10940
1015	.2620	28.53	12200

APPENDIX B

FIGURES

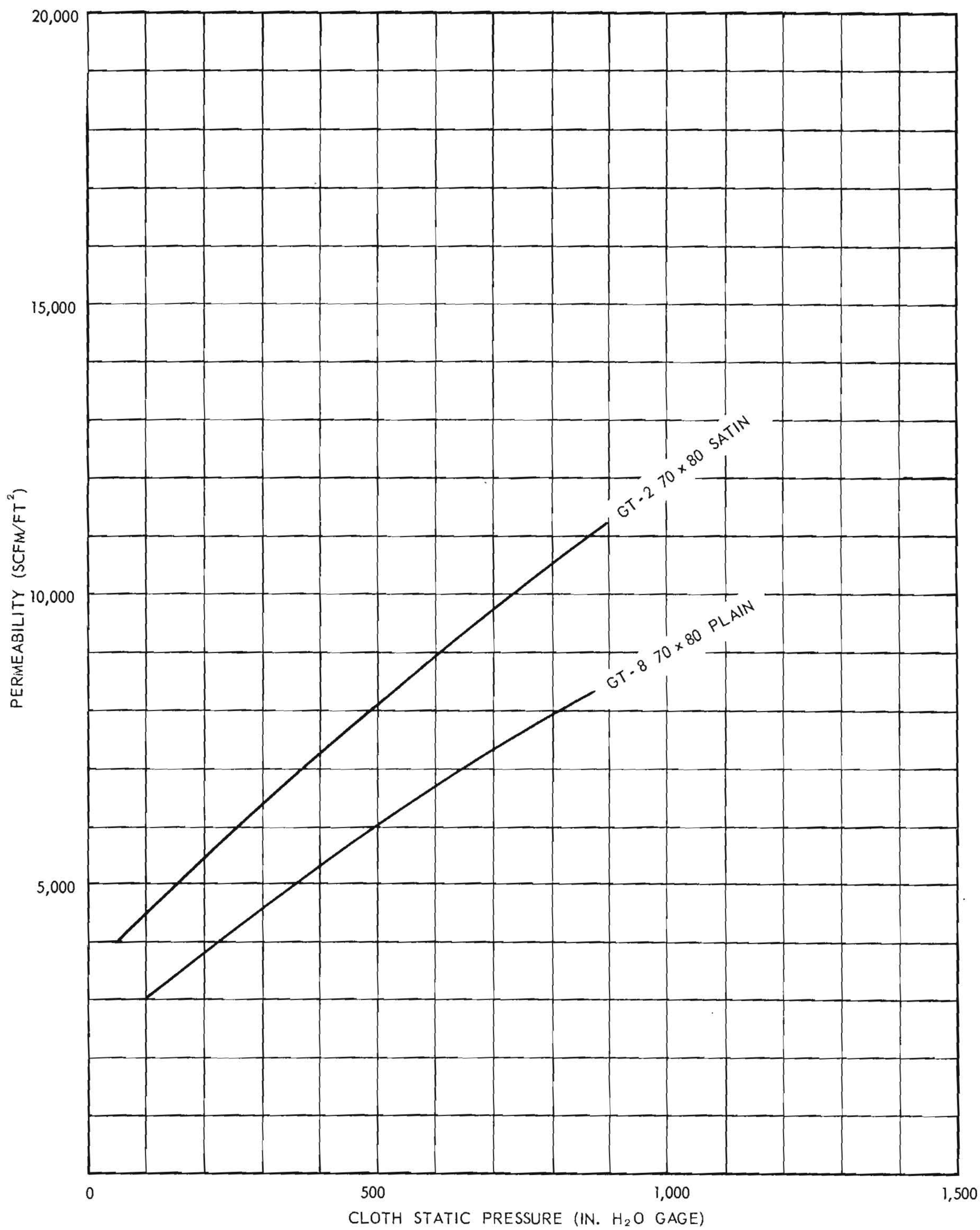

Figure 4. High-Pressure Permeability Test on Nylon.

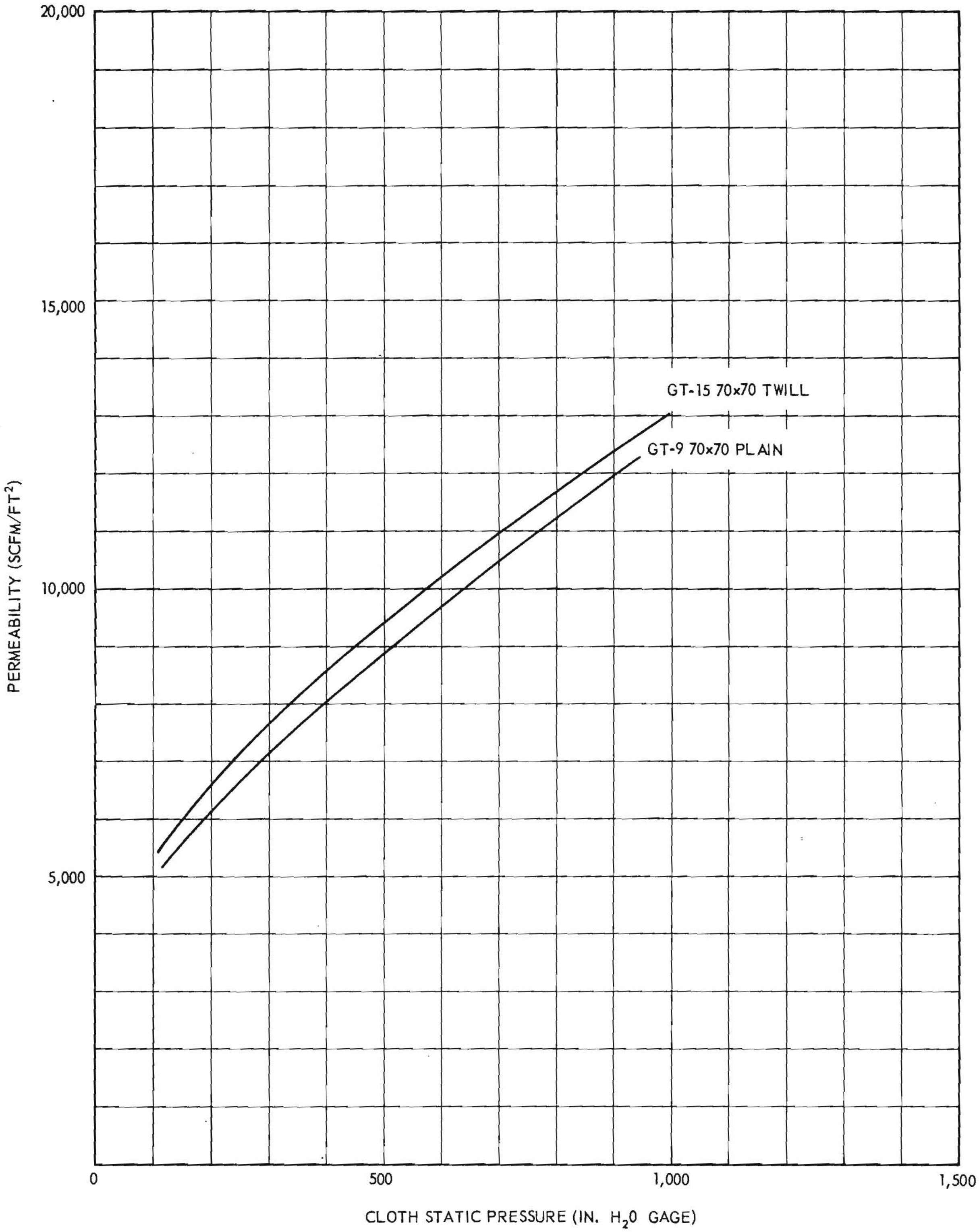

Figure 5. High-Pressure Permeability Test on Nylon.

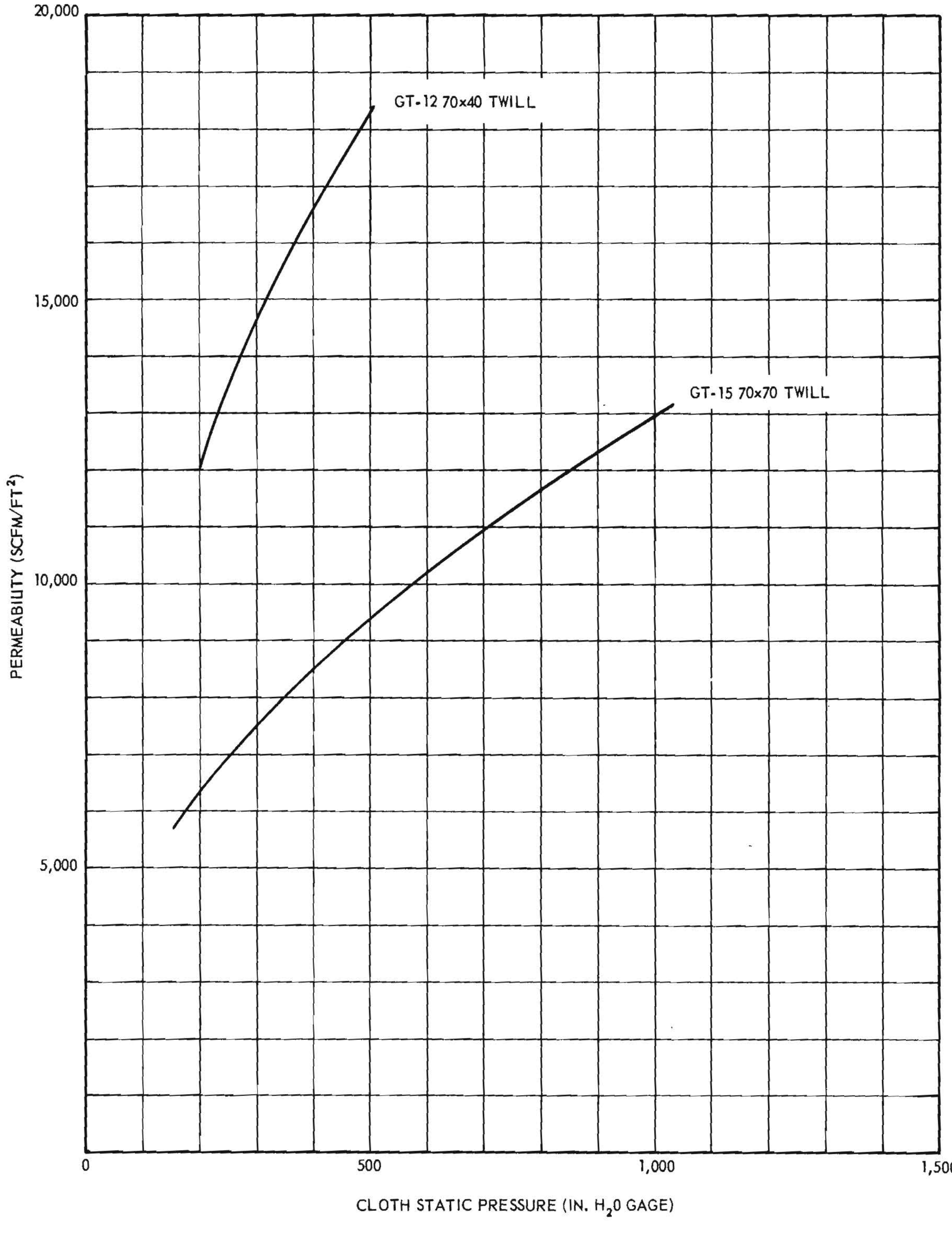

Figure 6. High-Pressure Permeability Test on Nylon.

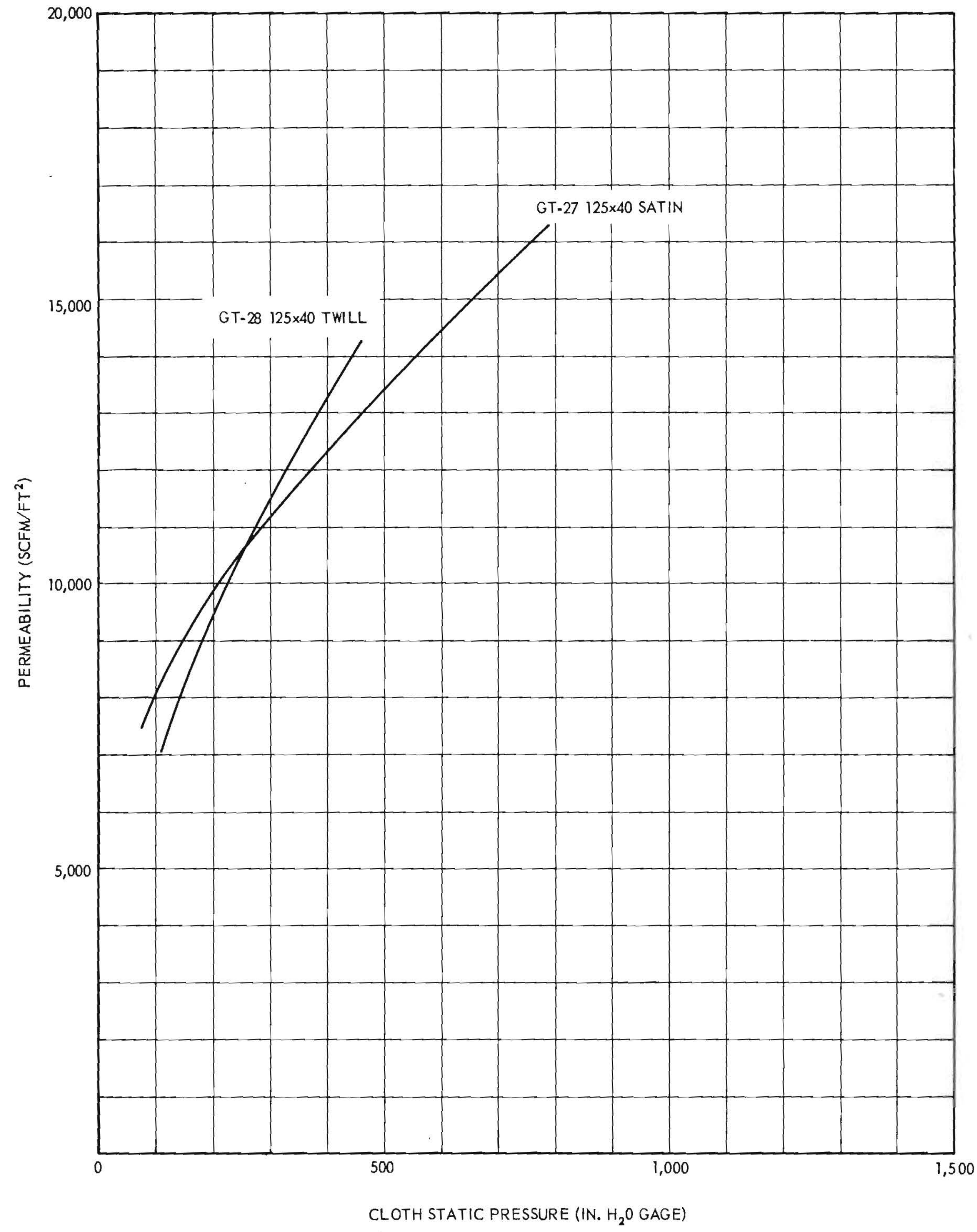

Figure 7. High-Pressure Permeability Test on Nylon.

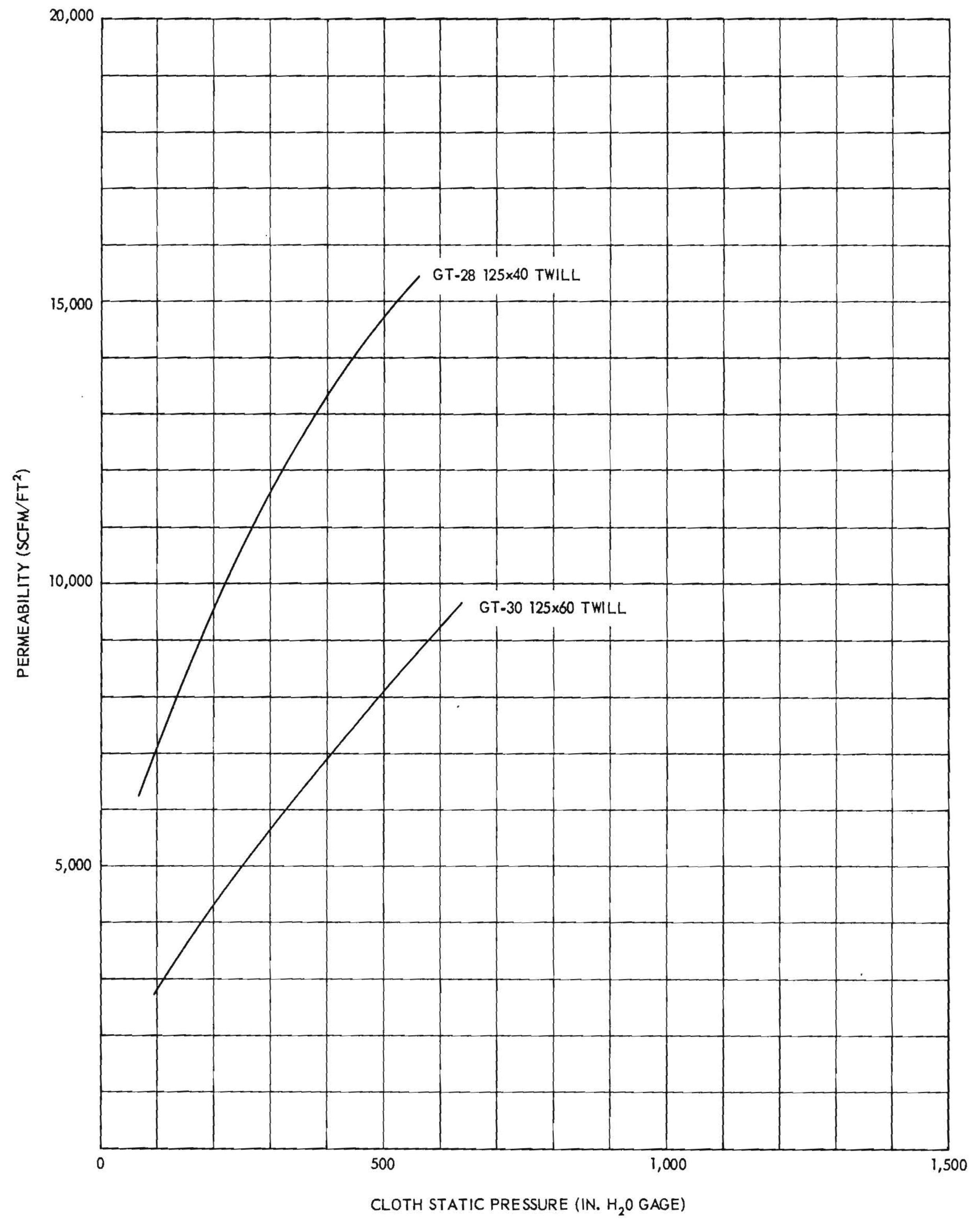

Figure 8. High-Pressure Permeability Test on Nylon.

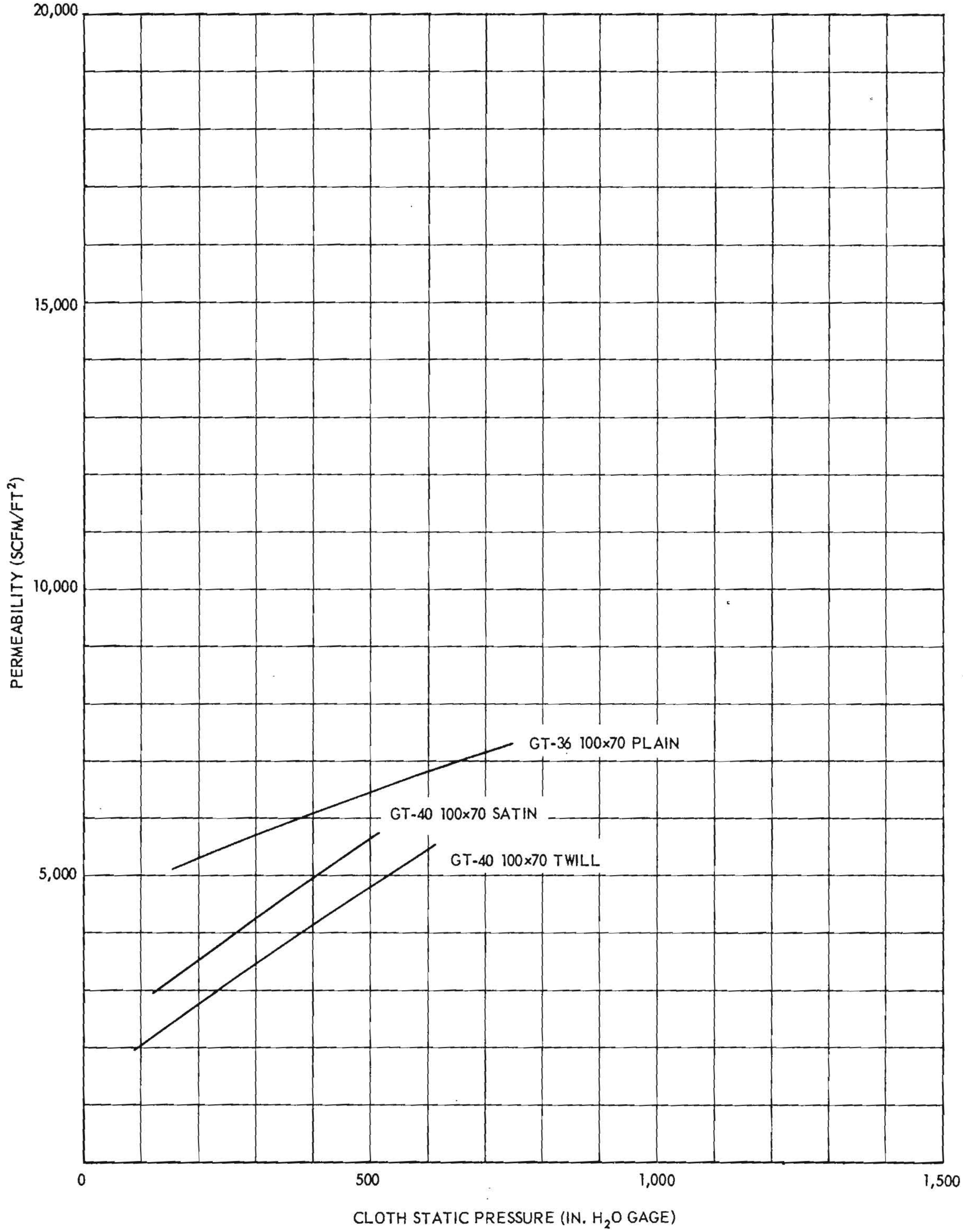

Figure 9. High-Pressure Permeability Test on Orlon.

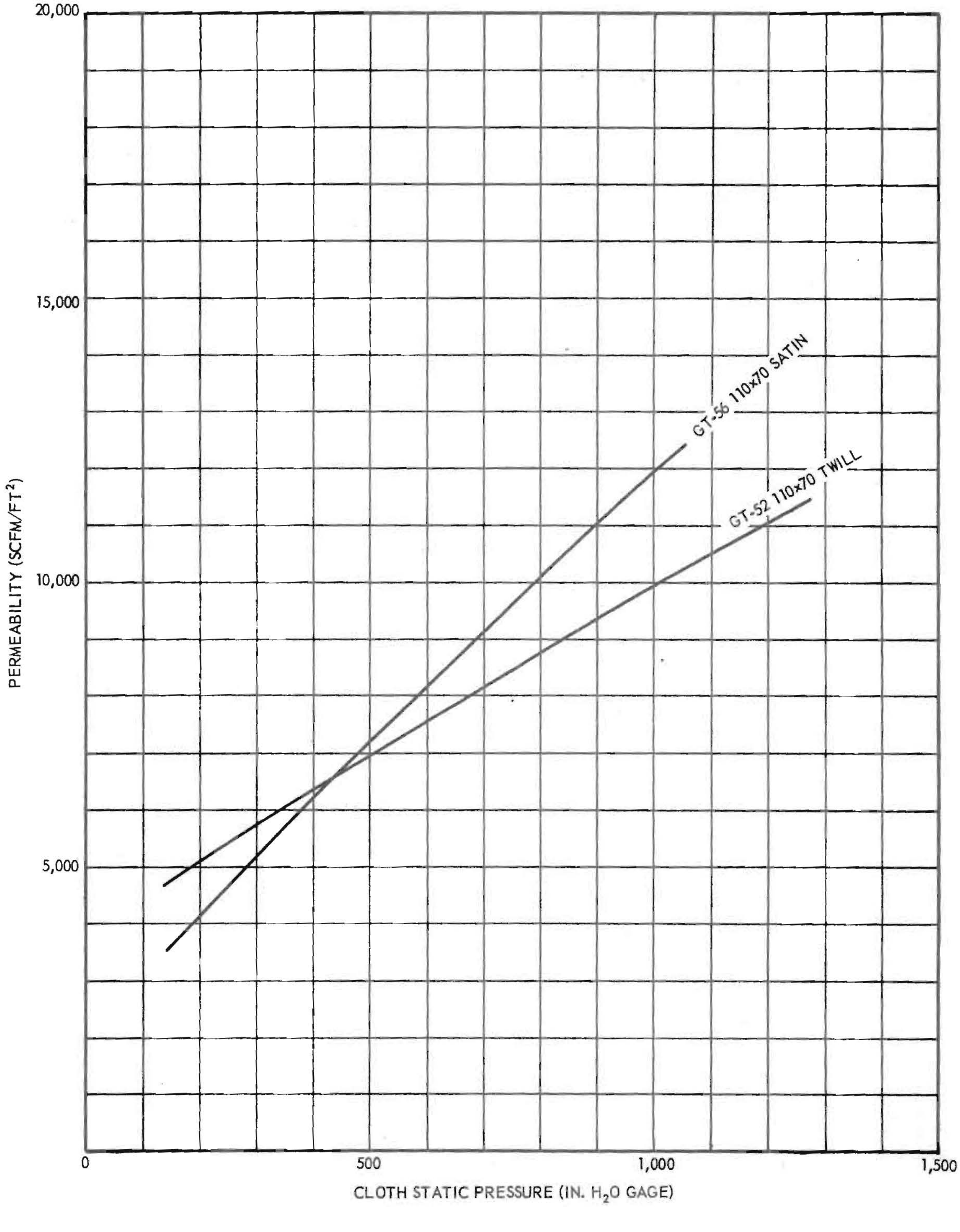

Figure 10. High-Pressure Permeability Tests on Dacron.

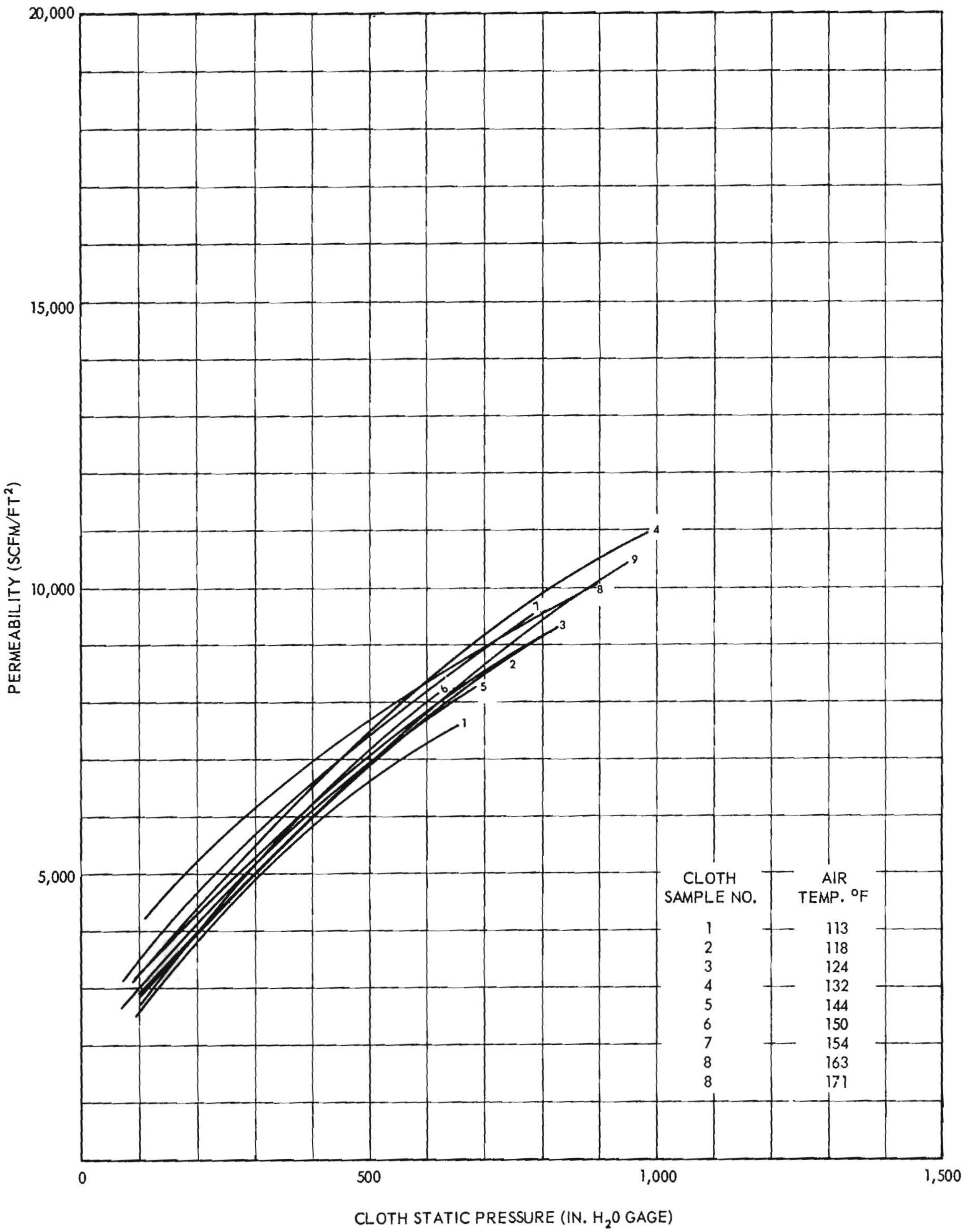

Figure 11. Effect of Variation of Air Temperature on Cloth Permeability (GT-22 125x80 Plain Nylon).

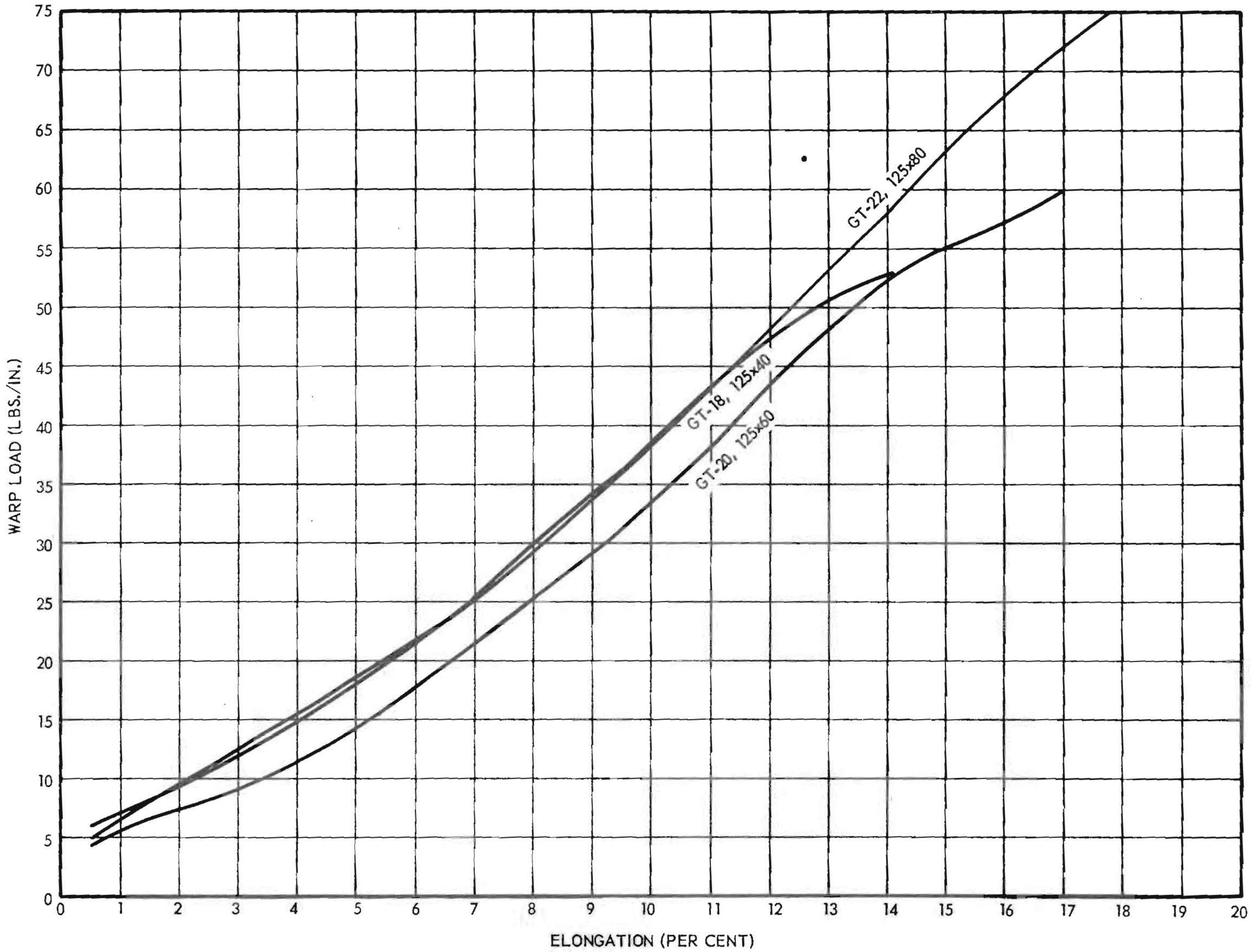

Figure 12. Biaxial Fabric-Tension Test on Effect of Varying Numbers of Picks for Plain Nylon.

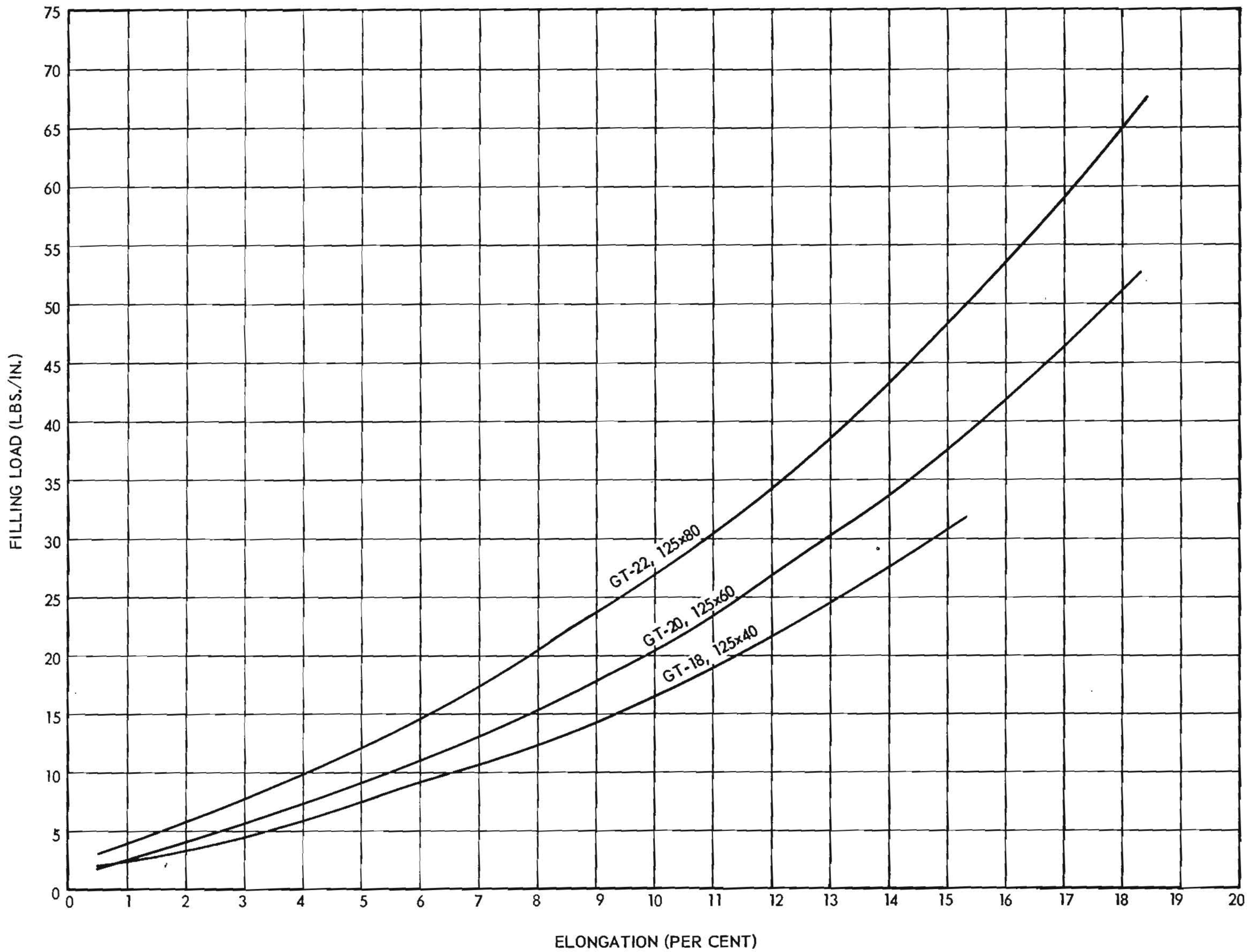

Figure 13. Biaxial Fabric-Tension Test on Effect of Varying Numbers of Picks for Plain Nylon.

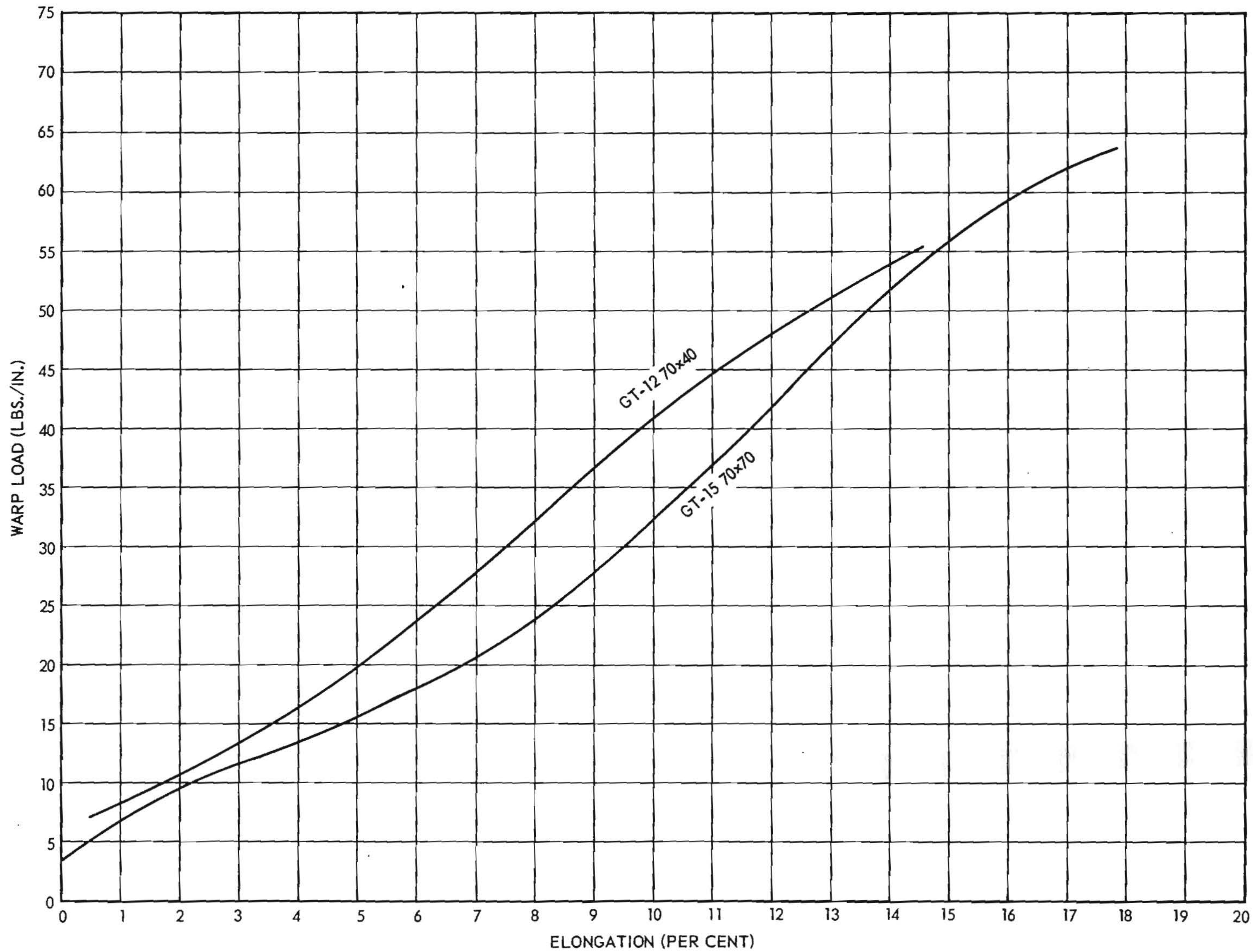

Figure 14. Biaxial Fabric-Tension Test on Effect of Varying Numbers of Picks for Nylon Twill.

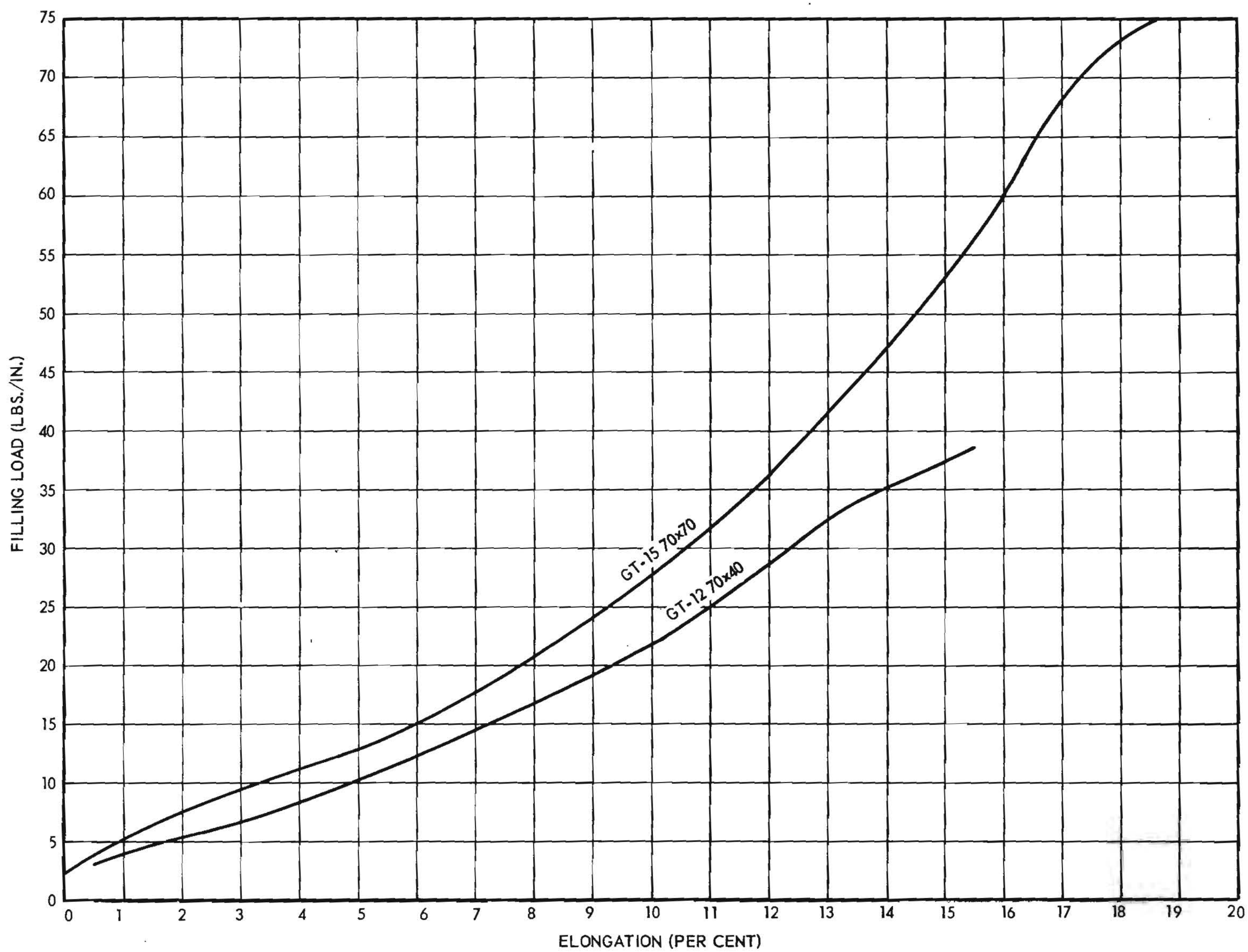

Figure 15. Biaxial Fabric-Tension Test on Effect of Varying Numbers of Picks for Nylon Twill.

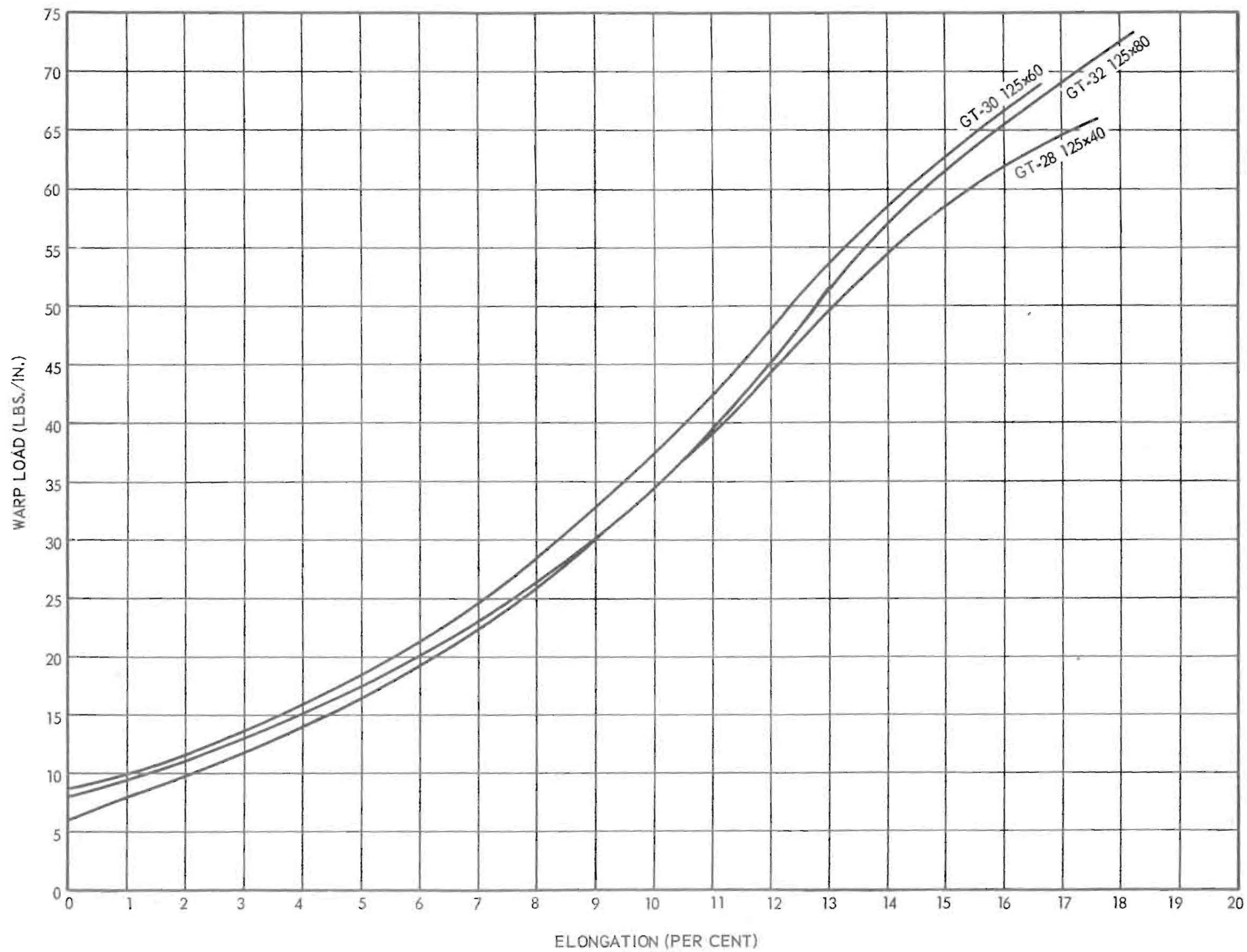

Figure 16. Biaxial Fabric-Tension Test on Effect of Varying Numbers of Picks for Nylon.

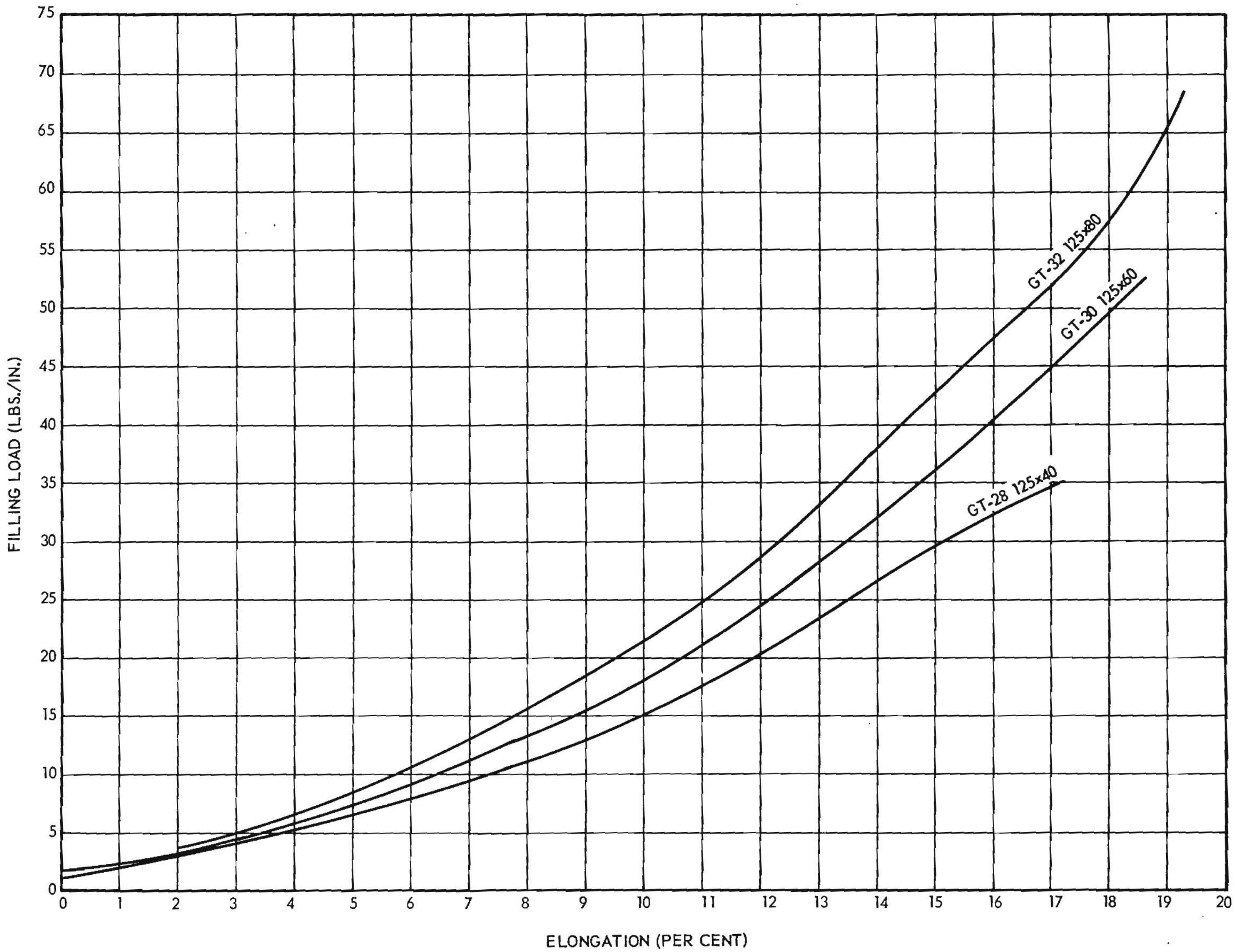

Figure 17. Biaxial Fabric-Tension Test on Effect of Varying Numbers of Picks for Nylon Twill.

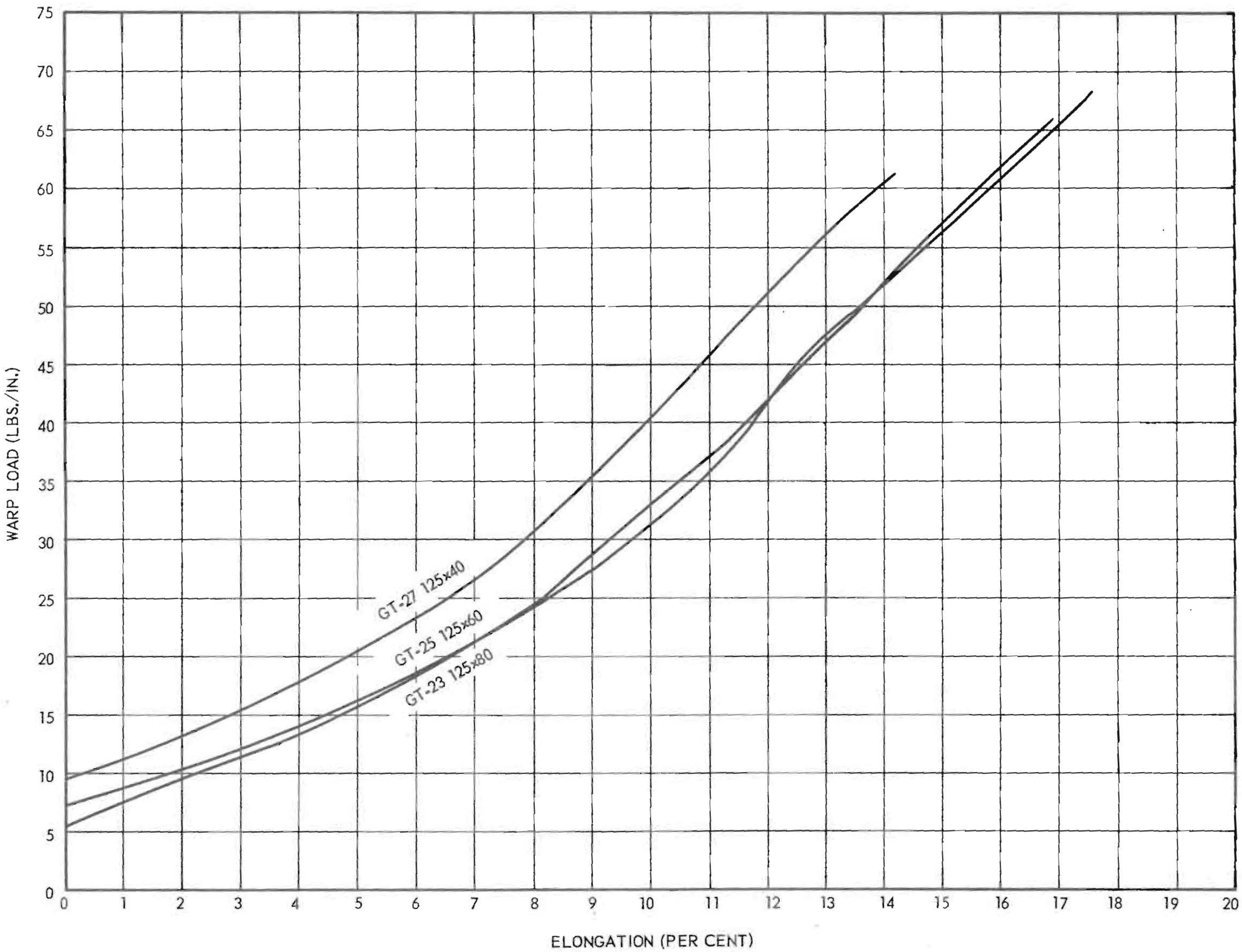

Figure 18. Biaxial Fabric-Tension Test on Effect of Varying Numbers of Picks for Nylon Satin.

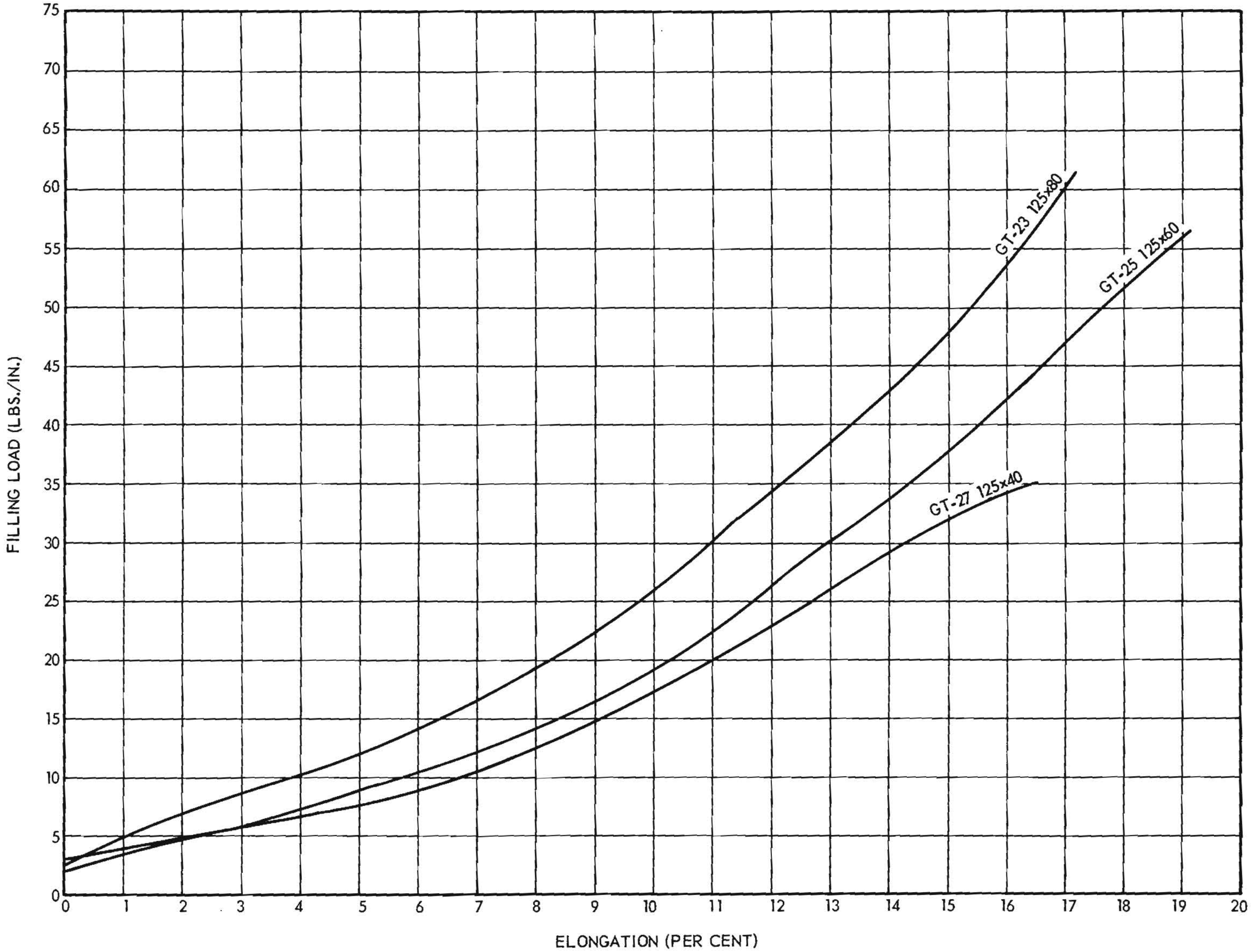

Figure 19. Biaxial Fabric-Tension Test on Effect of Varying Numbers of Picks for Nylon Satin.

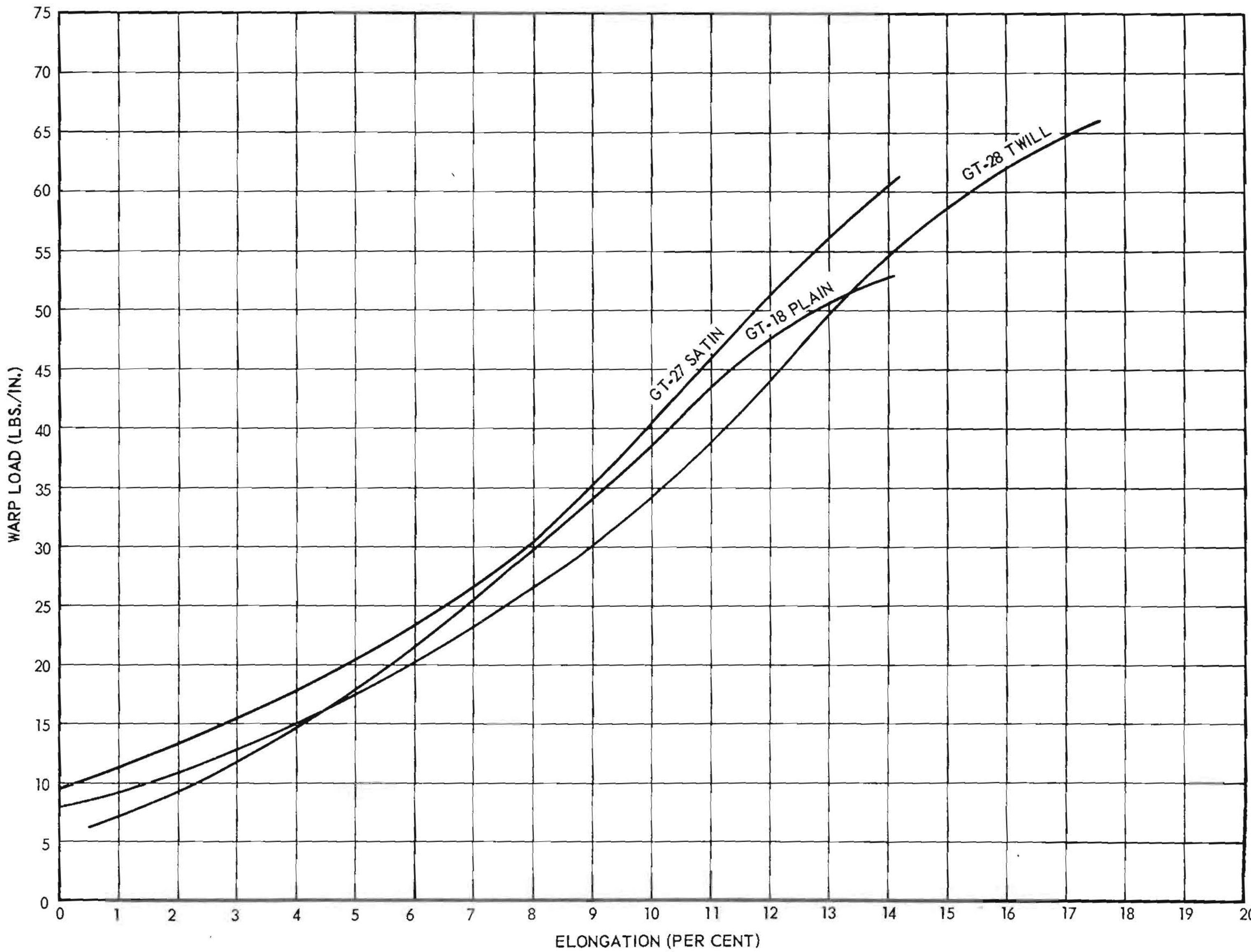

Figure 20. Biaxial Fabric-Tension Test on Effect of Varying Weave Pattern of Nylon (125x40).

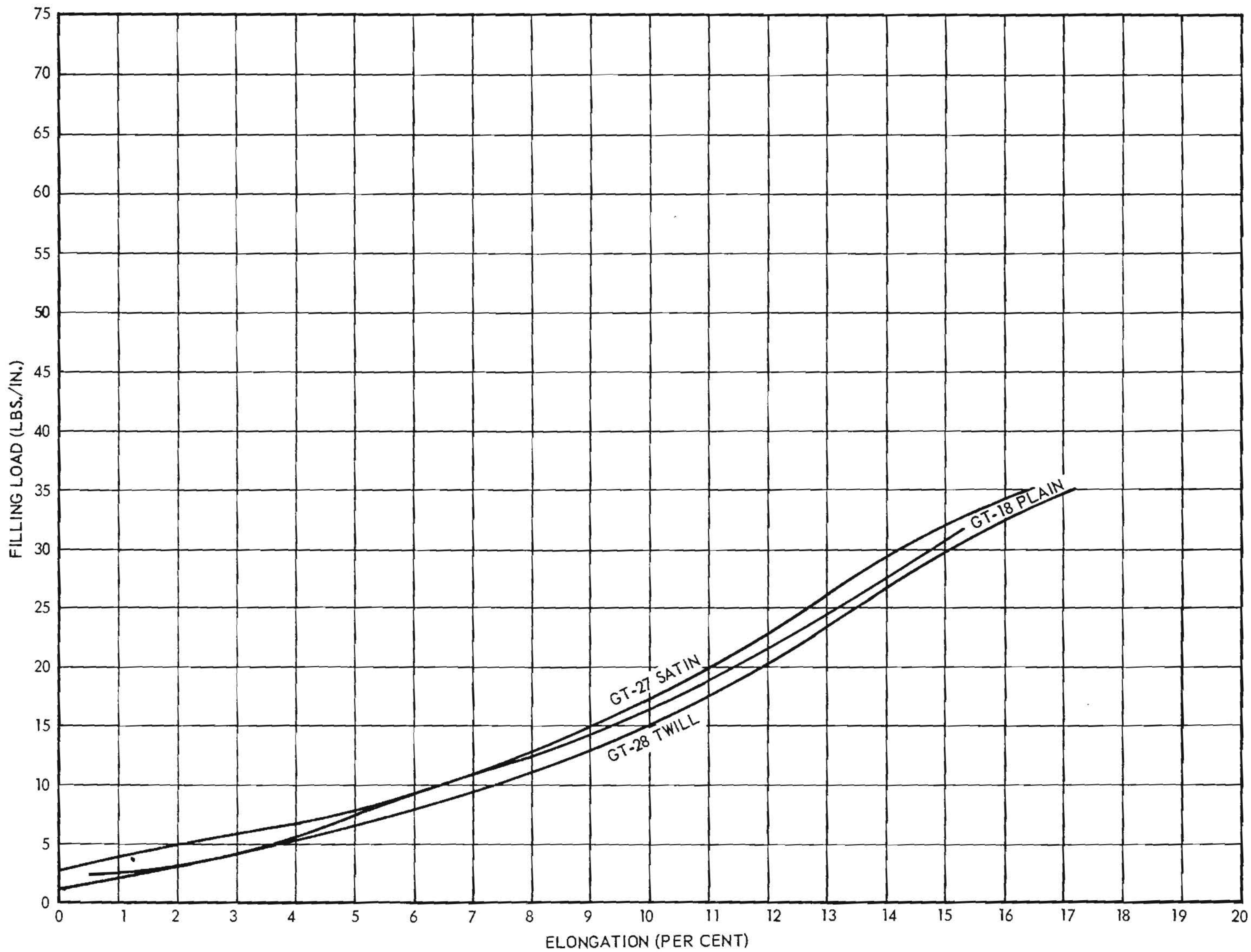

Figure 21. Biaxial Fabric-Tension Test on Effect of Varying Weave Pattern of Nylon (125x40).

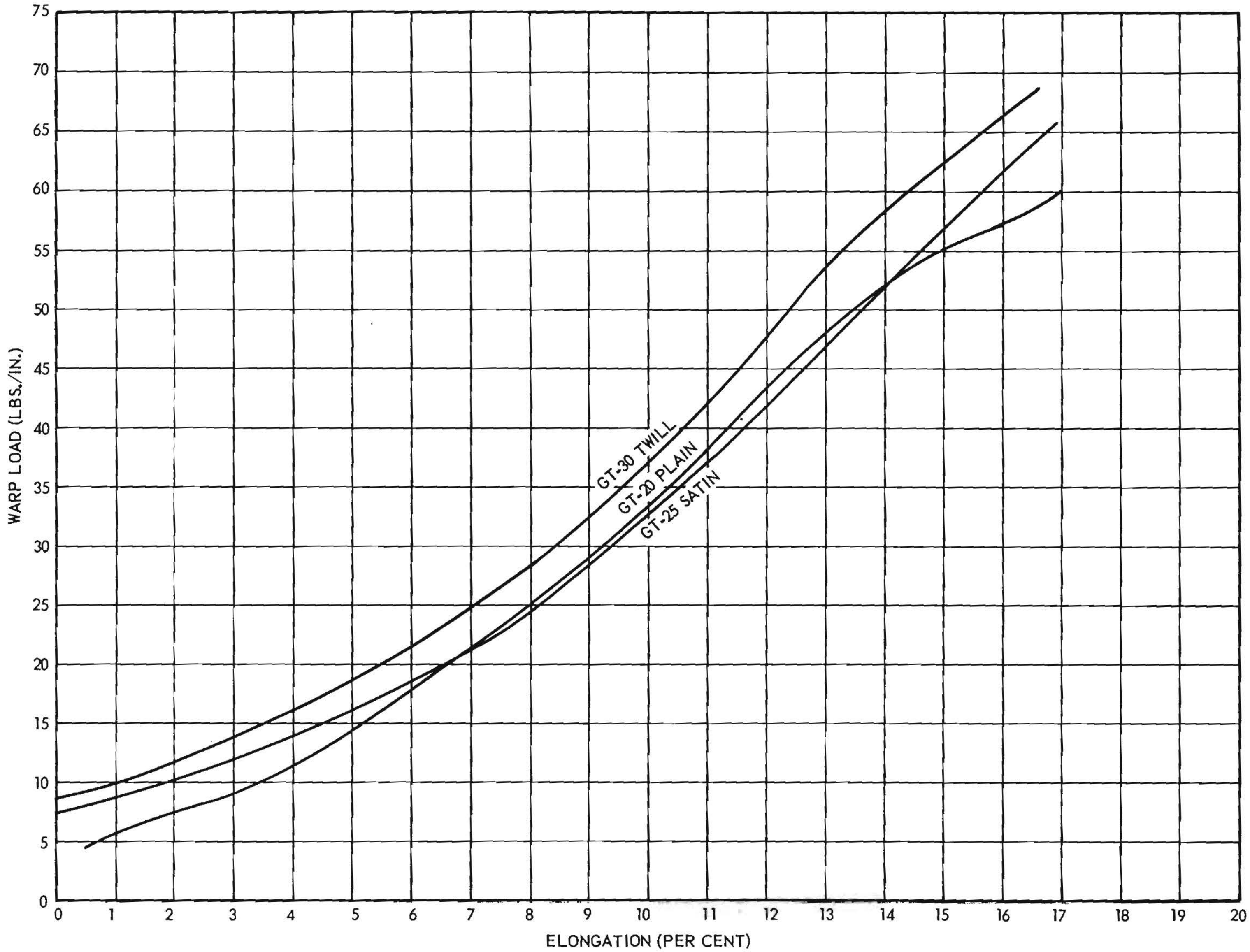

Figure 22. Biaxial Fabric-Tension Test on Effect of Varying Pattern of Nylon (125x60).

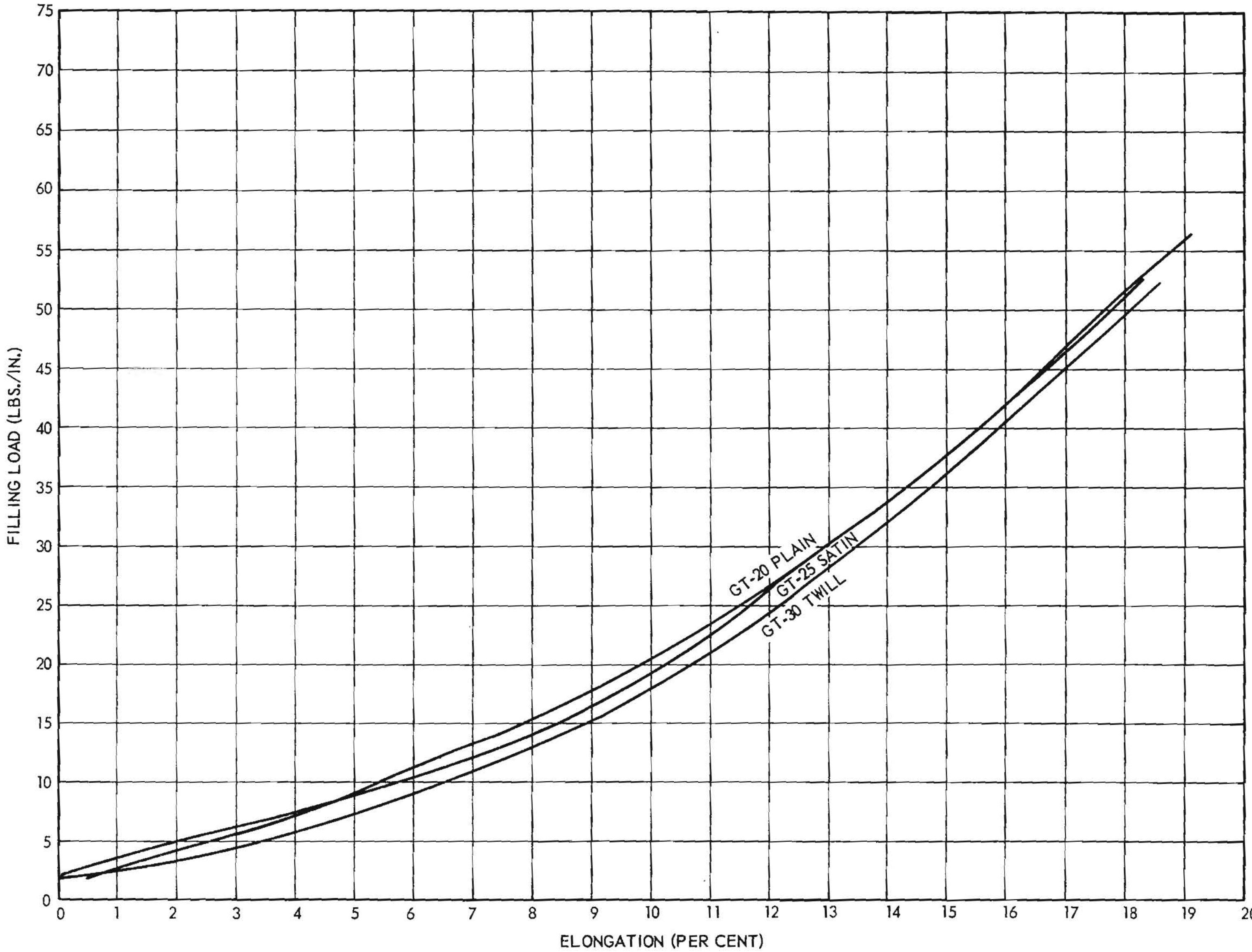

Figure 23. Biaxial Fabric-Tension Test on Effect of Varying Weave Pattern of Nylon (125x60).

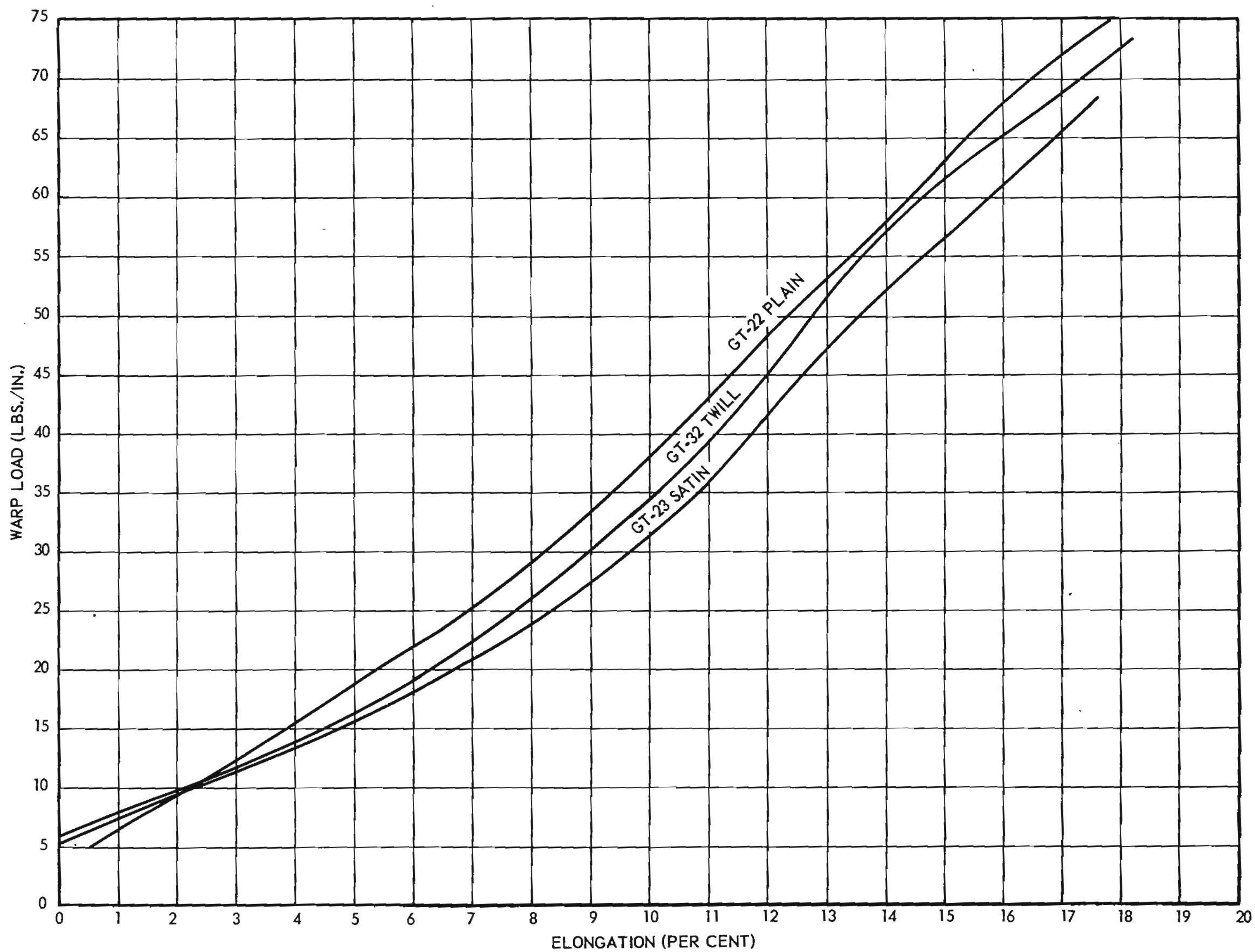

Figure 24. Biaxial Fabric-Tension Test on Effect of Varying Weave Pattern of Nylon (125x80).

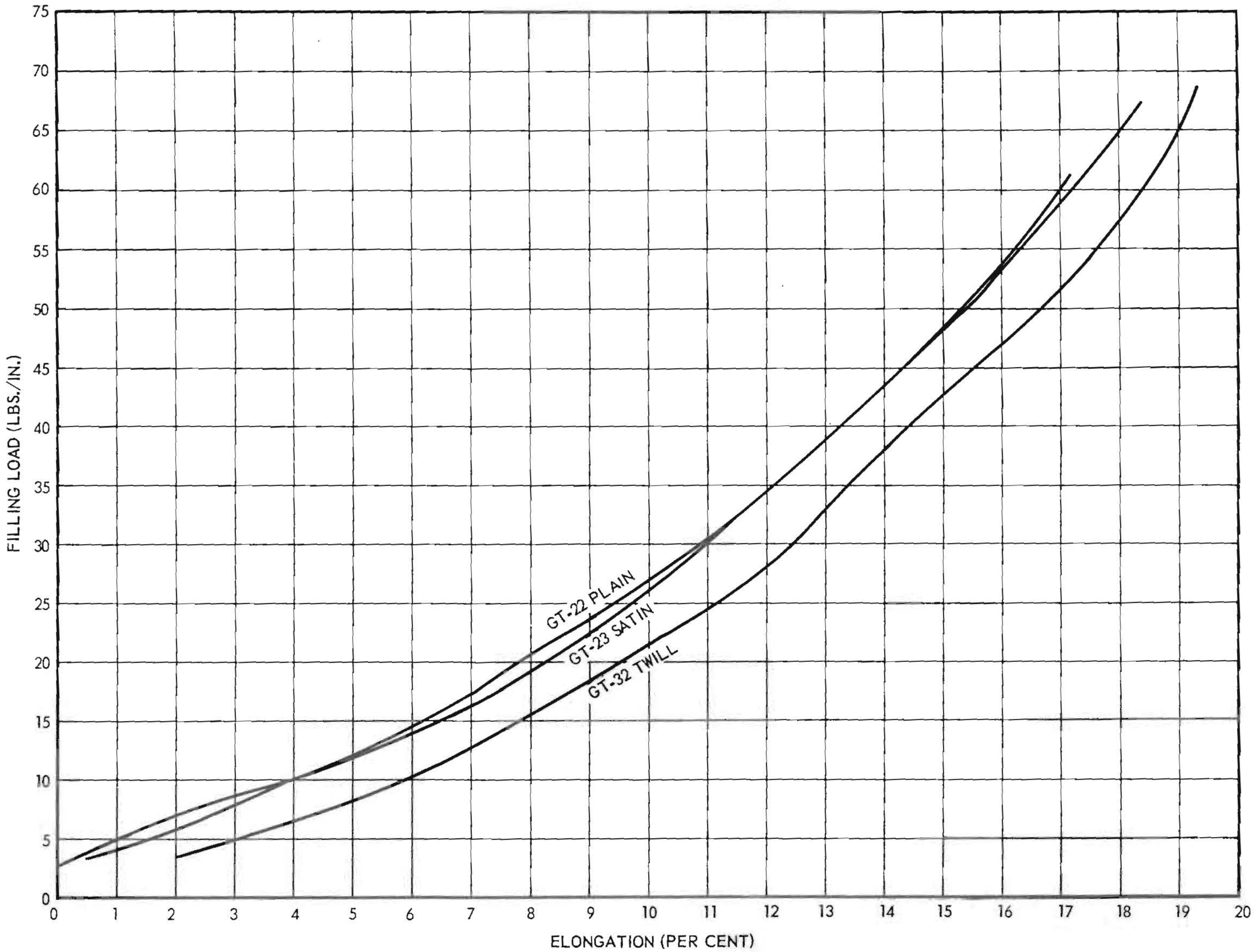

Figure 25. Biaxial Fabric-Tension Test on Effect of Varying Weave Pattern of Nylon (125x80).

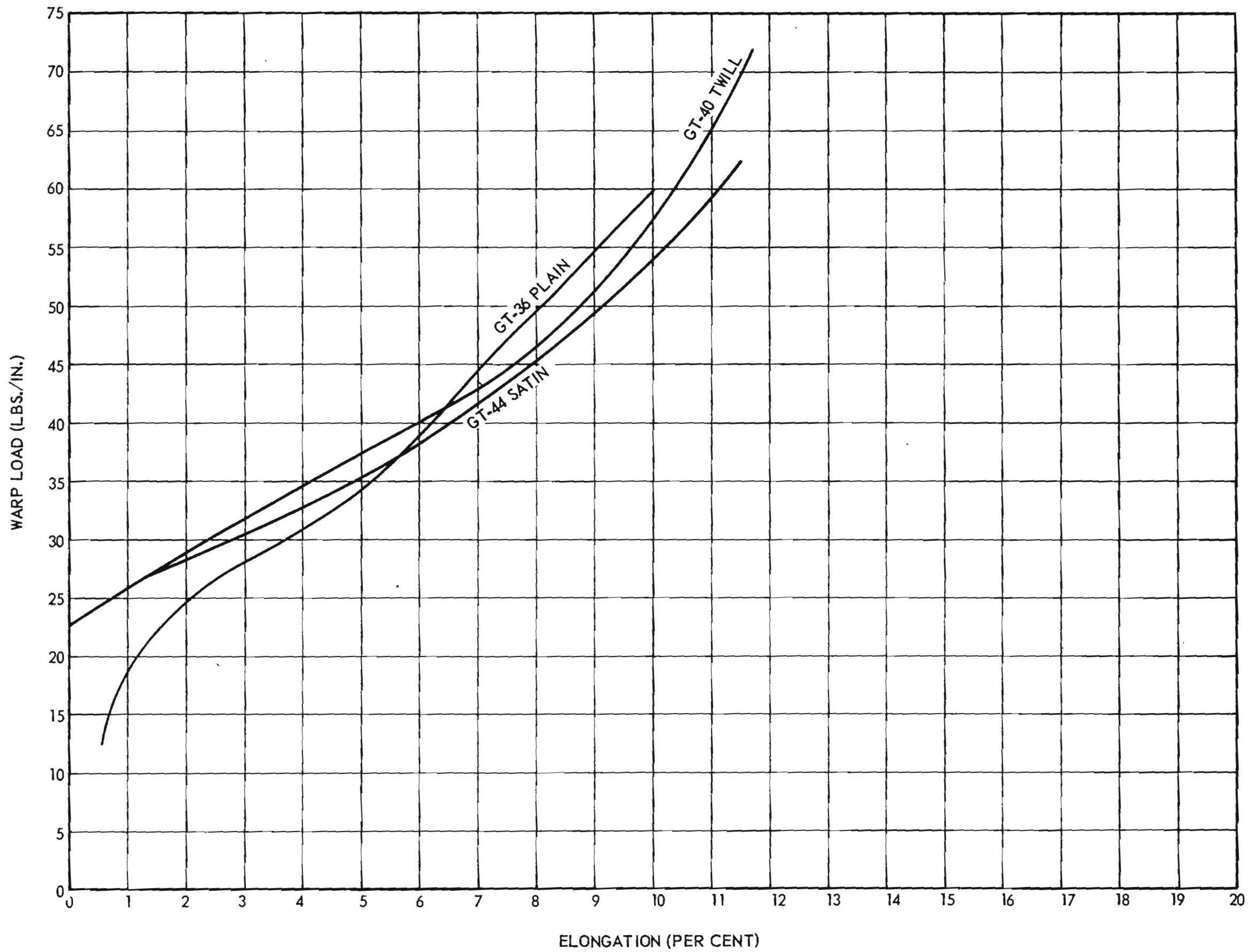

Figure 26. Biaxial Fabric-Tension Test on Effect of Varying Weave Pattern of Orlon (100x70).

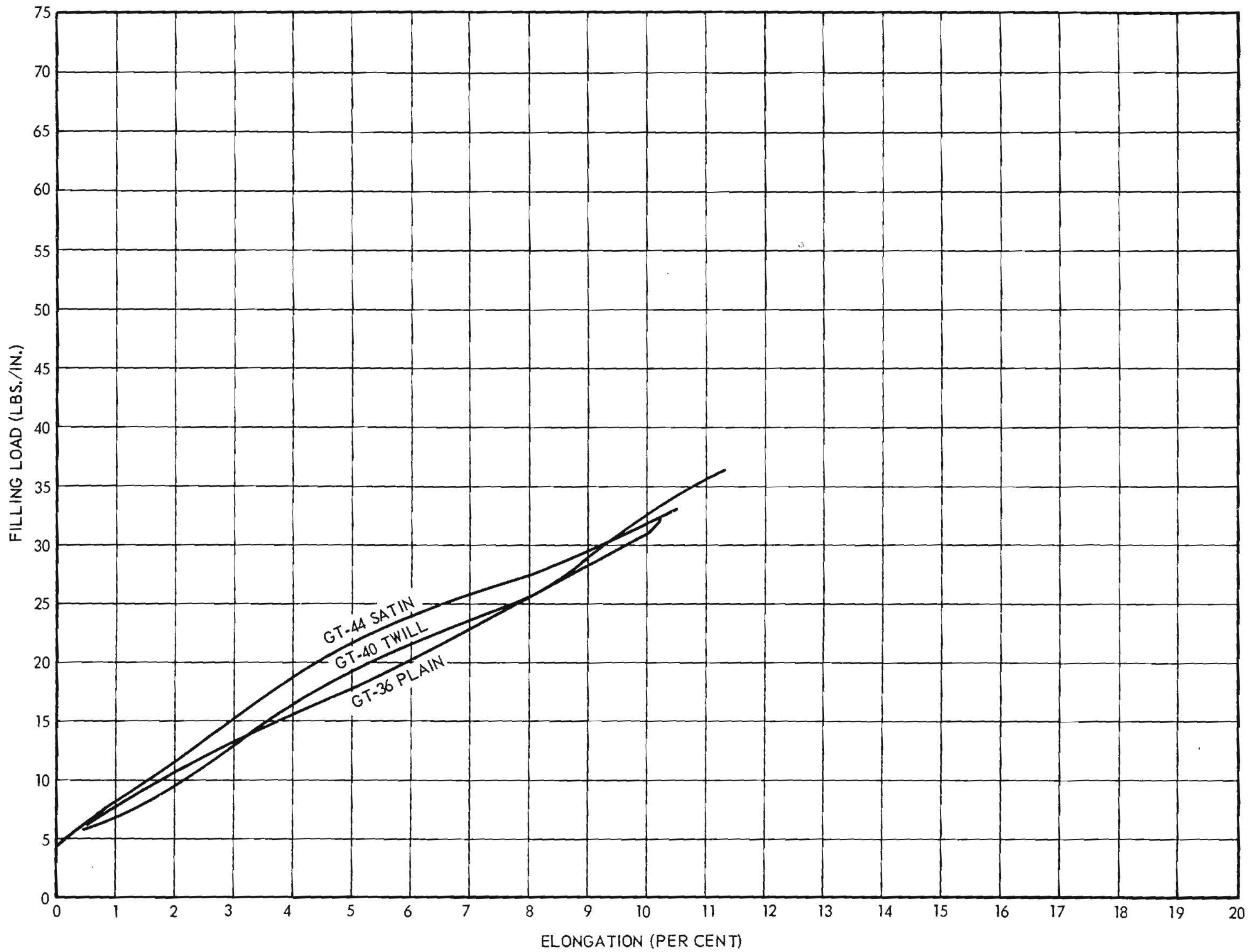

Figure 27. Biaxial Fabric-Tension Test on Effect of Varying Weave Pattern of Orlon (100x70).

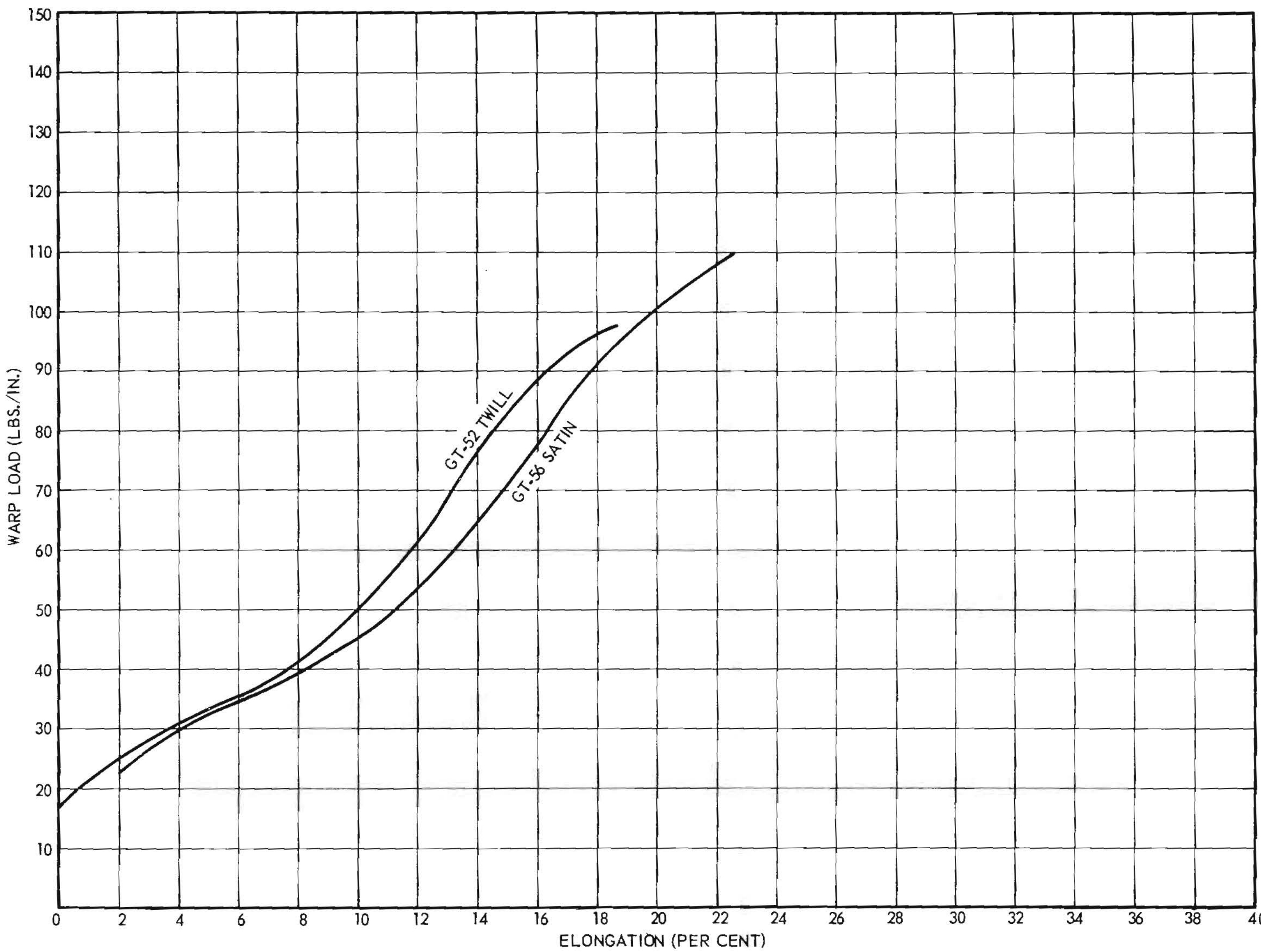

Figure 28. Biaxial Fabric-Tension Test on Effect of Varying Weave Pattern of Dacron (110x70).

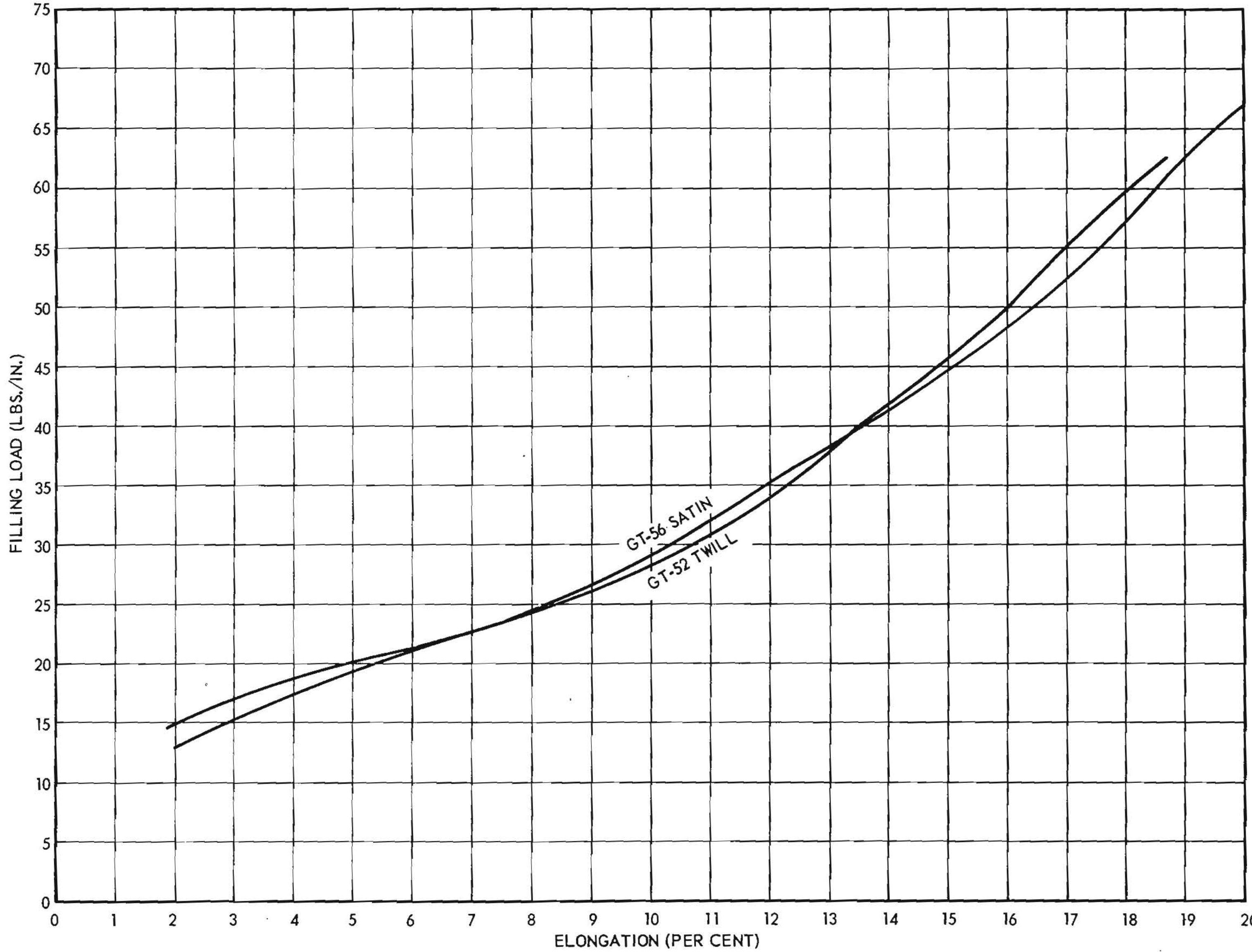

Figure 29. Biaxial Fabric-Tension Test on Effect of Varying Weave Pattern of Dacron (110x70).

ENGINEERING EXPERIMENT STATION
of the Georgia Institute of Technology
Atlanta, Georgia

QUARTERLY REPORT NO. 7

PROJECT NO. 170-117

PERMEABILITY OF PARACHUTE FABRICS

By

H. W. S. LAVIER

- o - o - o - o -

CONTRACT NO. AF 33(038)-15624
E.O. No. R612-12 SR7z

- o - o - o - o -

NOVEMBER 15, 1953 TO FEBRUARY 15, 1954

ENGINEERING EXPERIMENT STATION
of the Georgia Institute of Technology
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NOVEMBER 15, 1953 TO FEBRUARY 15, 1954

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This Report Contains 29 Pages

This report summarizes the progress during the quarter ending 15 February 1954. It concerns the preparation for additional high-pressure permeability tests. The results of previously obtained high-pressure permeability data, corrected to consider the effects of elastic deformation of the fabric, are presented in tabular form in Appendix A and graphically in Appendix B.

Discussion and conclusions resulting from the biaxial-fabric-tension tests are included. The Technical Report No. 3, devoted to the biaxial-fabric-tension tests of selected fabrics, has been submitted in draft form for Air Force approval.

Low-pressure permeability tests have been conducted in order that the effects of fabric weaving defects on air permeability could be studied. The results of these tests are presented graphically in Appendix B.

Preparations continue for the model parachute tests to be conducted in the Georgia Tech nine-foot wind tunnel.

I. HIGH-PRESSURE PERMEABILITY TESTS

A. Equipment

During the past quarter, the Georgia Tech high-pressure permeometer has not been in use. A short circuit damaged three of the Trans-Sonics, Inc. pressure transducers. These have been repaired by Trans-Sonics and were returned to Georgia Tech on 12 February 1954.

Preliminary high-pressure permeability tests indicated that the 0 to 150-psi-range pressure transducer, used to measure the pressure drop across the orifice meter, was not sensitive enough during the portion of the test run when the volume of flow was low. Therefore, a 0 to 25-psi-range transducer was ordered for use with the orifice meter. Originally, delivery of the pick-up was scheduled for December 23, 1953, but actual delivery was made February 1, 1954. The transducer has now been installed, and the defective 0 to 150-psi transducers have now been replaced by equivalent CECO, Inc. pressure transducers. The high-pressure permeometer is now ready for operation.

B. Program of Future Tests

The high-pressure permeability tests, to be conducted during the next quarter, will be made for the purpose of testing the selected fabrics that will be reported in Technical Report No. 4. After the selected fabrics have been tested, the high-pressure permeometer will be used to conduct air-permeability evaluations on all of the various test fabrics at hand. These evaluations will be reported in Technical Report No. 5.

C. Effect of Elastic Deformation on Air Permeability

The possibility of the fabric sample stretching or deforming under air load was not considered in the high-pressure permeability data presented in Quarterly Report No. 6. It is planned to incorporate, for use in future high-pressure permeability tests, a device to indicate the amount that the fabric sample stretches during the test.

In the meantime, an approximation has been devised and tried. This approximation is based upon the assumption that the rupture-elongation data obtained by grab-break tests represents the maximum possible stretch of the fabric sample under the conditions of the high-pressure permeability tests. If biaxial-tension elongation data are available, they could be used in the same way and in place of the grab-break data used here. Using the grab-break elongation data, a maximum-area-increase factor was obtained by squaring the unit elongation for warp or filling, whichever is the lowest. A graph is then constructed of an area-increase factor (f) versus pressure differential across the sample. At zero pressure differential, the area factor is assumed as unity, and at the rupture pressure differential, the maximum-area-increase factor is assumed. Between these limits, a straight-line variation is presumed. In computing the volume flow per unit area through the cloth at any pressure differential, the basic sixteen-square-inch-sample area is multiplied by the area-increase factor for that pressure differential as taken from the graph (a typical example of the graph is shown in Figure 1). Figure 2 shows, comparatively, the plots of high-pressure permeability versus pressure differential for the fabric sample neglecting fabric stretch, and, also, corrected to consider stretching of the fabric sample. Also shown on the same graph are the low pressure-permeability test results for the same fabric. It is obvious that the low-pressure permeability data will fall into the corrected high-pressure test results. Values of effective porosity are computed using volume-flow values corrected for fabric stretch.

The two high-pressure test points, that appear to be off the curve, occur at low-flow conditions. It was in this range that it was difficult to obtain an accurate measure of the pressure differential across the orifice meter, using the 0 to 150-psi-pressure transducer. For this reason, the 0 to 25-psi transducer will be used in future high-pressure permeability tests.

Correcting for the effects of fabric, elastic deformation under air load will generally result in a curve of effective porosity versus pressure differential similar to that shown in Figure 3. However, in the case of porous fabrics such as GT-2 shown in Figure 4, the effective porosity value will decrease with increasing pressures. This indicates that under the effect of air load each yarn stretches causing the interstice area to increase which lets more fluid through the opening accompanied by a reduction of ratio of interstice velocity divided by approach velocity.

Volume flow and effective porosity data, corrected to indicate the effect of stretch for fourteen fabrics are presented in tabular form in Appendix A and graphically in the curves of Appendix B.

The procedure for evaluating high-pressure permeability of fabrics consists in applying successive and increasing air-pressure differentials to a fabric sample until rupture occurs. Each pressure application is rapid peak pressure occurring 0.10 seconds after the permeometer cut-off valve is opened. This is to represent air-blast effects.

II. DEFORMATION OF FABRIC UNDER LOAD (No Air Flow)

A. Equipment

The biaxial-fabric-tension testing machine is being modified by the addition of the two "X-Y" type recorders. These will permit simultaneous plotting of load-versus-elongation curves while the fabric-tension test is in process. The recorders have been tested, and the cables and connectors have been ordered but have not been received.

The elongations of fabric under load, as reported in Technical Report No. 3, were measured with use of the specially designed biaxial extensometer. This device has been previously described in Interim Report No. 2. The extensometer, actuated by the fabric stretch, causes relative displacement of orienting needles located in the feet piercing the fabric. This method of measuring the elongation has been advocated by experimenters at Textile Research Institute and Fabric Research Laboratory. After conducting the tests reported in Technical Report No. 3, it is the opinion that use of this type of extensometer results in elongation measurements generally too small in magnitude. It appears that a measurement of the relative displacement of the test jaws, as is done in the case of conventional Scott testers, would be better. A device has been designed to use the displacement of the jaws rather than the extensometer for measuring the elongation in future tests. Parts for this device are also on order but have not been received.

B. Program of Tests

As soon as the "X-Y" recorders are hooked up, biaxial-fabric-tension tests of the other test fabrics will be conducted. It is proposed to conduct these tests at room temperature, since the problem of varying temperature and absolute humidity have been reported in Technical Report No. 3.

III. ADDITIONAL RESEARCH PHASE

The model parachutes, for use in studying the load distribution in the canopy, are being designed. After they are constructed and instrumented, they will be tested in the Georgia Tech nine-foot wind tunnel. Mr. J. H. Ross of the W.A.D.C. Textile Branch has offered to help in obtaining some 0.80-ounce-per-square-yard nylon cloth to use in making these model parachutes. It is expected that these tests will be conducted in June because of other commitments for the Georgia Tech nine-foot wind tunnel.

Respectfully submitted:

Hurlbut W. S. LaVier
Project Director

Approved:

P. K. Calaway, Acting Director
Engineering Experiment Station

IV. APPENDIX

APPENDIX A

TABLES

TABLE I

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches of Water)	Relative Pososity of Cloth (Per Cent)	Volumetric Velocity (scfm $ft.^{-2}$)
AIR FORCE FURNISHED FABRICS:		
Fabric Number 4 (ES-4)		
550	4.79	4520
500	4.88	4360
450	4.93	4190
400	5.00	4010
350	5.05	3790
300	5.12	3550
250	5.15	3260
200	5.13	2910
150	5.02	2470
100	4.46	1790
90	4.20	1600
GEORGIA-TECH-WOVEN FABRICS:		
Fabric Number 2 (GT)		
795	6.01	6770
731	6.15	6680
668	6.23	6480
596	6.53	6350
485	6.75	5910
360	7.29	5550
231	8.01	4870
163	8.97	4600
97	10.6	4200
55	12.1	3590
Fabric Number 8 (GT)		
831	3.99	4620
778	4.05	4540
651	4.23	4330
521	4.54	4140
391	4.90	3880
260	5.37	3470
127	6.38	2890

(Continued)

TABLE I (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches of Water)	Relative Porosity of Cloth (Per Cent)	Volumetric Velocity (scfm ft.$^{-2}$)
Fabric Number 9 (GT)		
900	5.57	6680
831	5.64	6540
761	5.86	6480
693	6.05	6390
623	6.31	6340
554	6.61	6240
415	7.33	5990
346	7.79	5790
277	8.39	5590
208	9.05	5220
138	10.1	4760
Fabric Number 12 (GT)		
457	15.7	13500
428	15.9	13300
398	16.4	13200
339	17.4	12800
309	18.0	12600
279	18.6	12400
220	19.9	11800
190	20.6	11400
131	22.6	10300
101	23.5	9510
71	25.3	8540
Fabric Number 15 (GT)		
1000	7.54	9560
875	7.83	9260
823	7.91	9090
743	8.01	8730
615	8.36	8290
496	8.55	7610
374	8.77	6800
241	9.27	5750
97	9.85	3880
30	11.1	2450

(Continued)

TABLE I (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches of Water)	Relative Porosity of Cloth (Per Cent)	Volumetric Velocity (scfm ft.$^{-2}$)
Fabric Number 27 (GT)		
526	11.7	10800
452	12.3	10500
402	12.8	10200
327	13.6	9800
277	14.2	9420
203	15.1	8650
154	16.0	7930
79	17.2	6130
Fabric Number 28 (GT)		
443	11.8	10020
388	12.2	9690
332	12.6	9230
277	13.2	8810
222	13.8	8230
166	14.5	7490
111	15.3	6460
55	16.5	4920
Fabric Number 30 (GT)		
612	5.91	5850
562	5.99	5690
488	6.07	5360
438	6.09	5100
366	6.24	4770
313	6.22	4410
233	6.40	3900
180	6.54	3490
97	6.50	2560
42	4.74	1230

(Continued)

TABLE I (Continued)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches of Water)	Relative Porosity of Cloth (Per Cent)	Volumetric Velocity (scfm ft.$^{-2}$)
Fabric Number 40 (GT)		
609	4.13	4080
548	4.15	3890
484	4.11	3630
423	4.14	3390
358	4.12	3110
291	4.12	2800
227	4.21	2540
159	4.41	2220
91	5.00	1910
Fabric Number 44 (GT)		
482	4.96	4360
435	4.86	4060
388	4.85	3810
352	4.97	3740
313	5.02	3550
244	5.12	3210
175	5.58	2950
130	6.15	2810
66	8.23	2690
Fabric Number 52 (GT)		
892	5.04	6040
767	5.15	5720
643	5.44	5510
515	5.82	5260
391	6.24	4930
263	7.19	4700
139	9.42	4440

(Continued)

TABLE I (Concluded)

SUMMARY OF EXPERIMENTAL RESULTS

Static Pressure Upstream of Cloth (Inches of Water)	Relative Porosity of Cloth (Per Cent)	Volumetric Velocity (scfm ft.$^{-2}$)
Fabric Number 56 (GT)		
889	5.65	6730
765	5.73	6330
640	5.76	5850
515	5.83	5300
391	5.88	4650
266	6.27	4080
139	6.85	3240

APPENDIX B

FIGURES

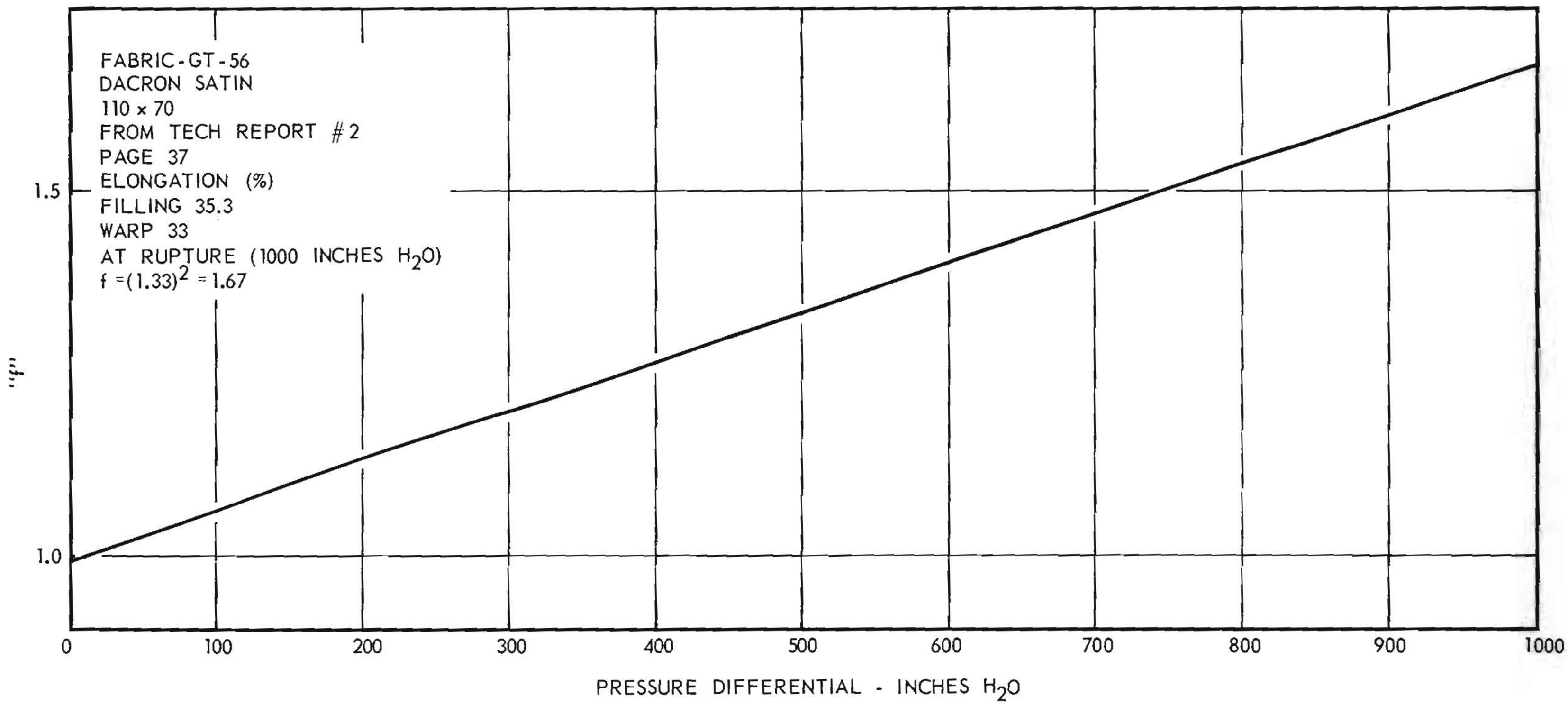

Figure 1. Typical Area Increase Factor (f) Curve Based on Grab-Break Data.

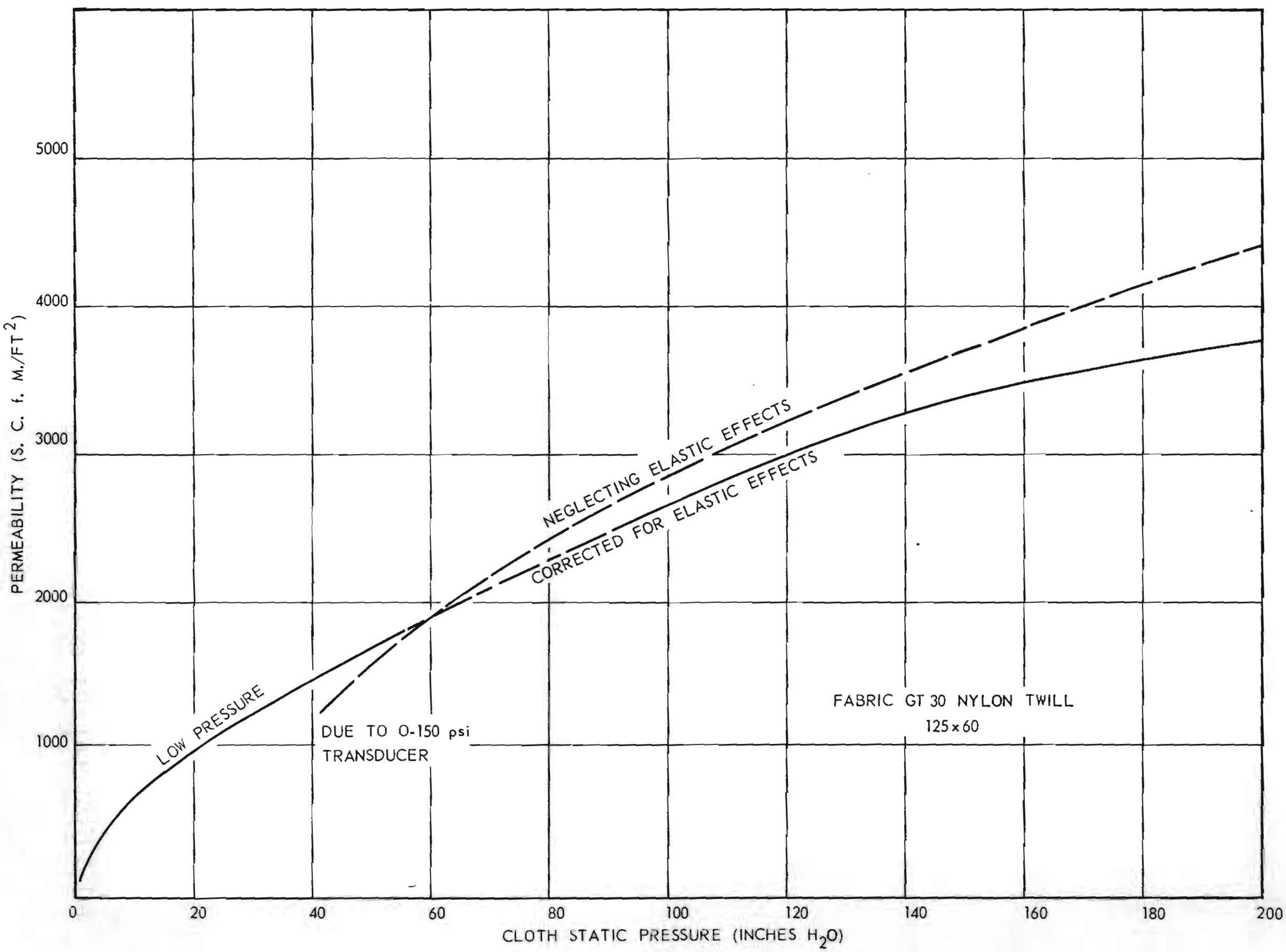

Figure 2. Effect on Air Permeability at High-Pressure Differentials Correcting for Elastic Effects.

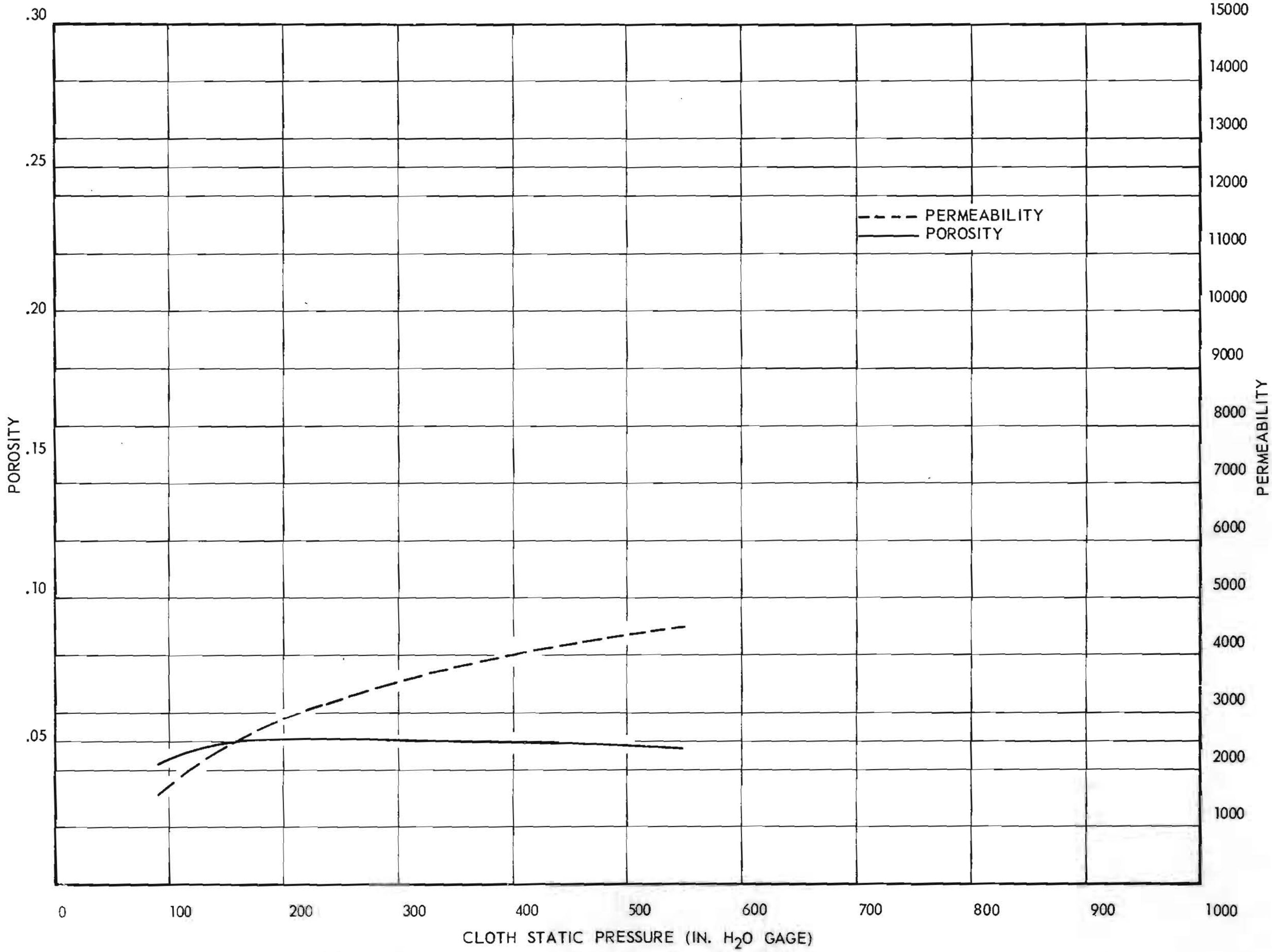

Figure 3. Fabric ES-4, Nylon Camouflage Twill Construction 126 x 77.

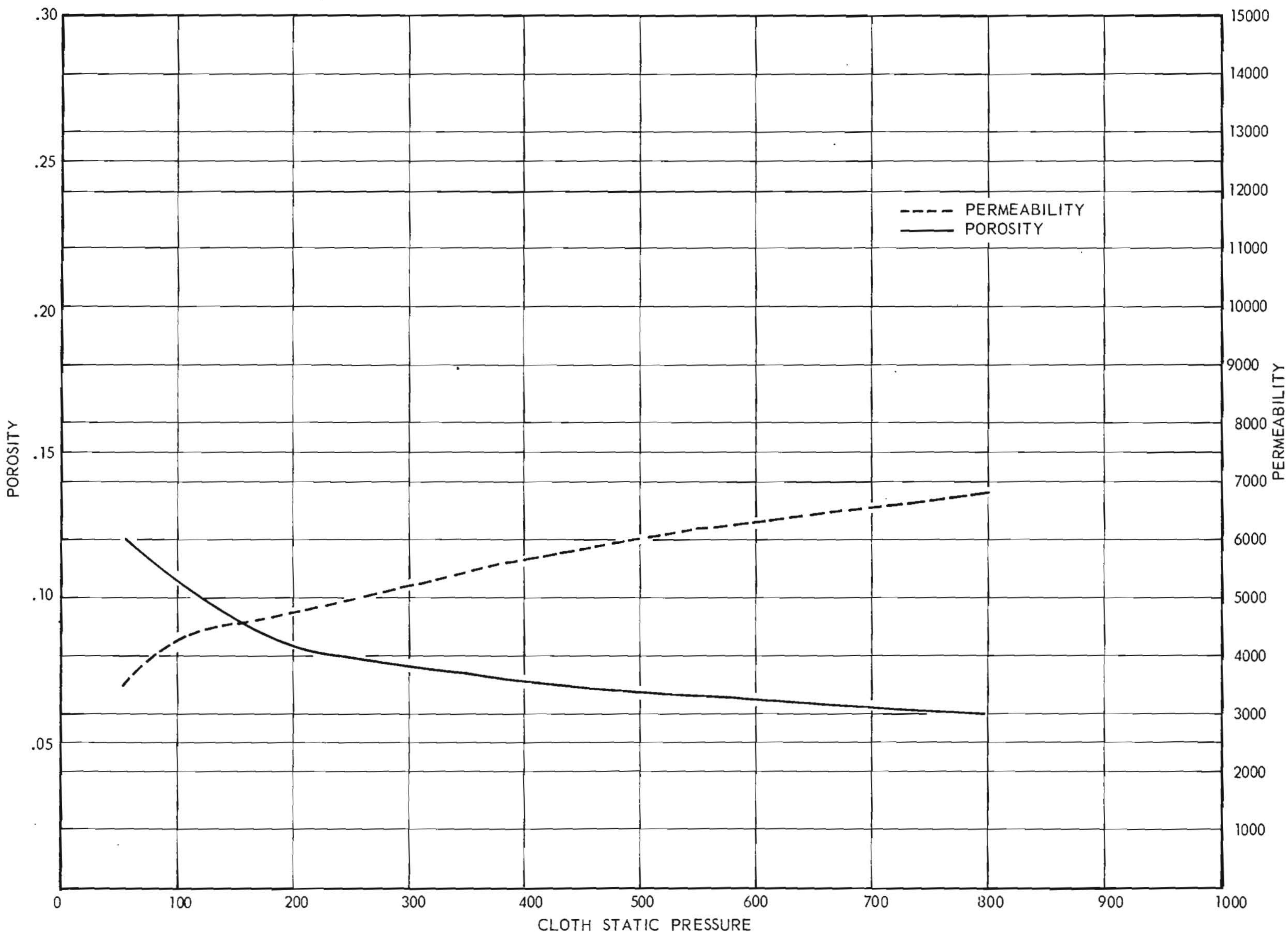

Figure 4. Fabric GT-2, Nylon Satin Construction 70 x 80.

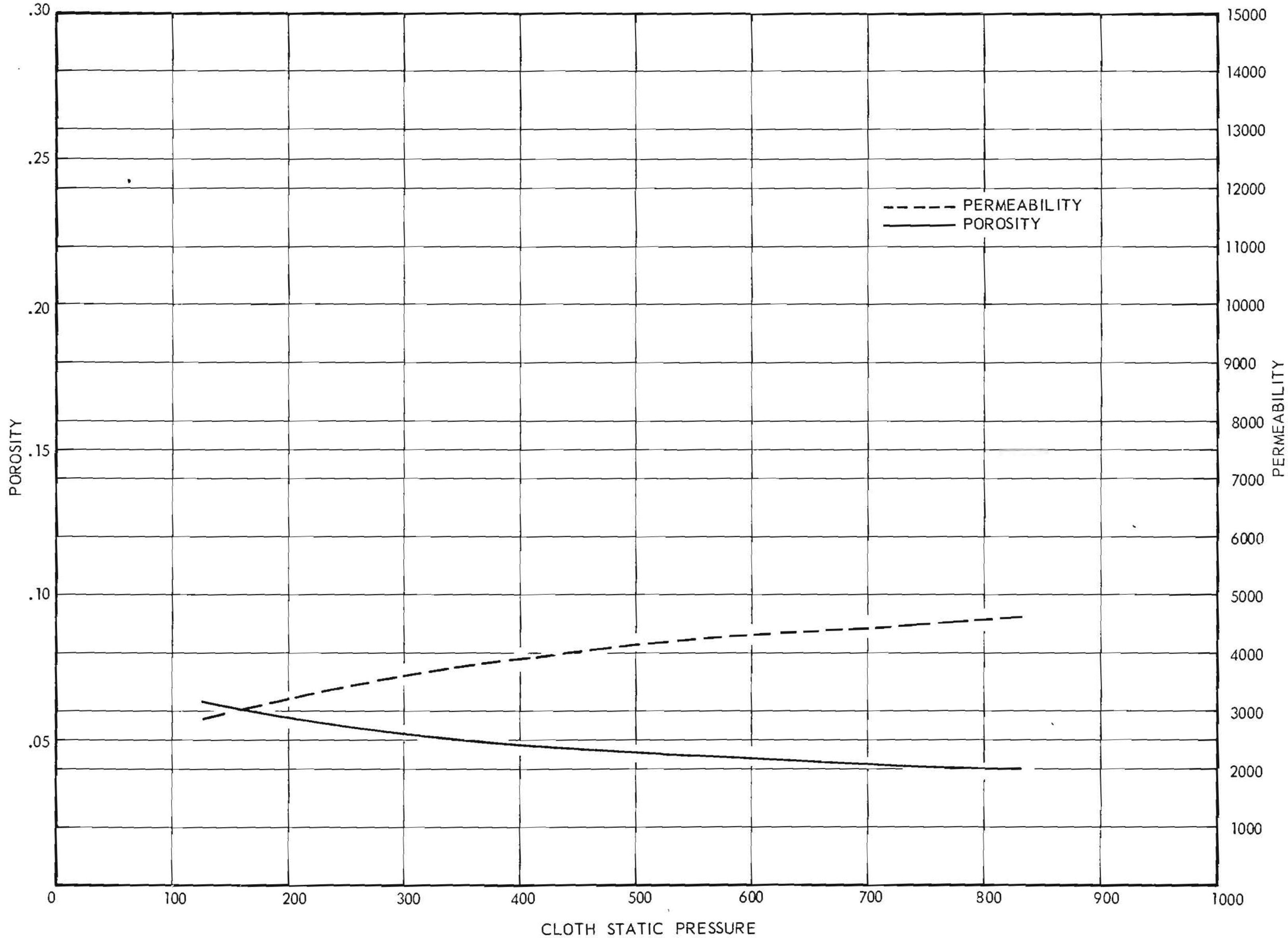

Figure 5. Fabric GT-8, Nylon Plain Construction 70 x 80.

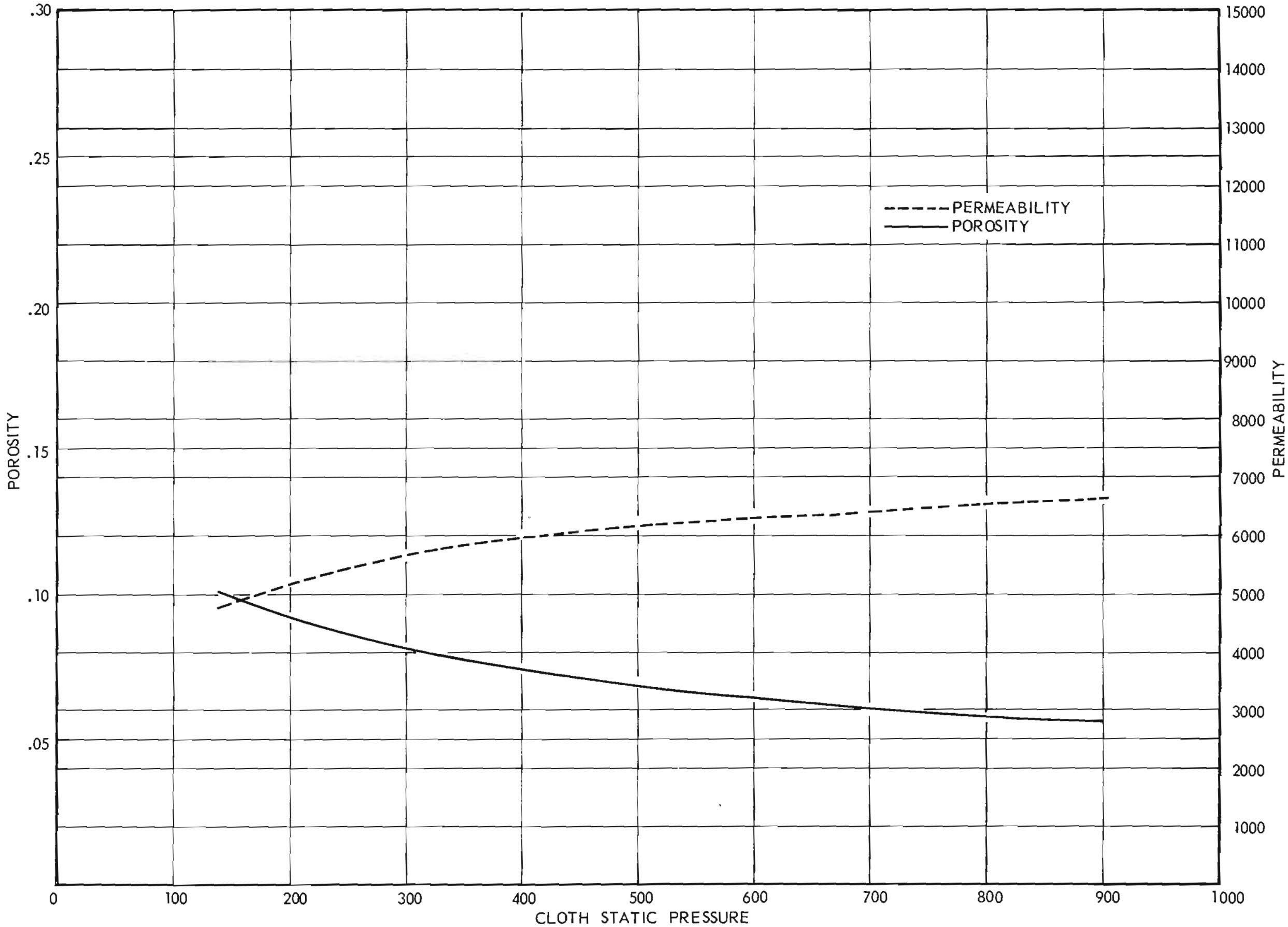

Figure 6. Fabric GT-9, Nylon Plain Construction 70 x 70.

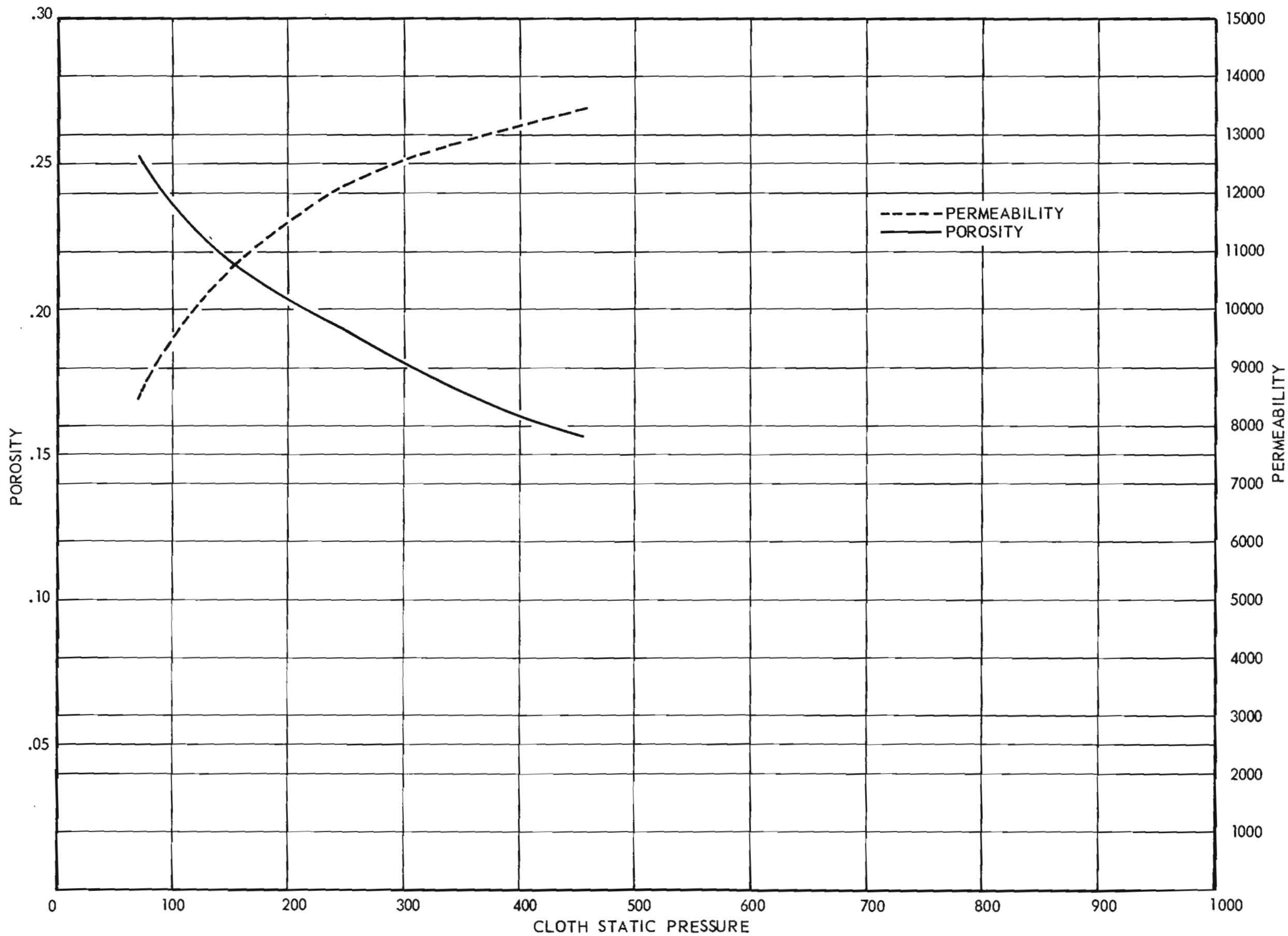

Figure 7. Fabric GT-12, Nylon Twill Construction 70 x 40.

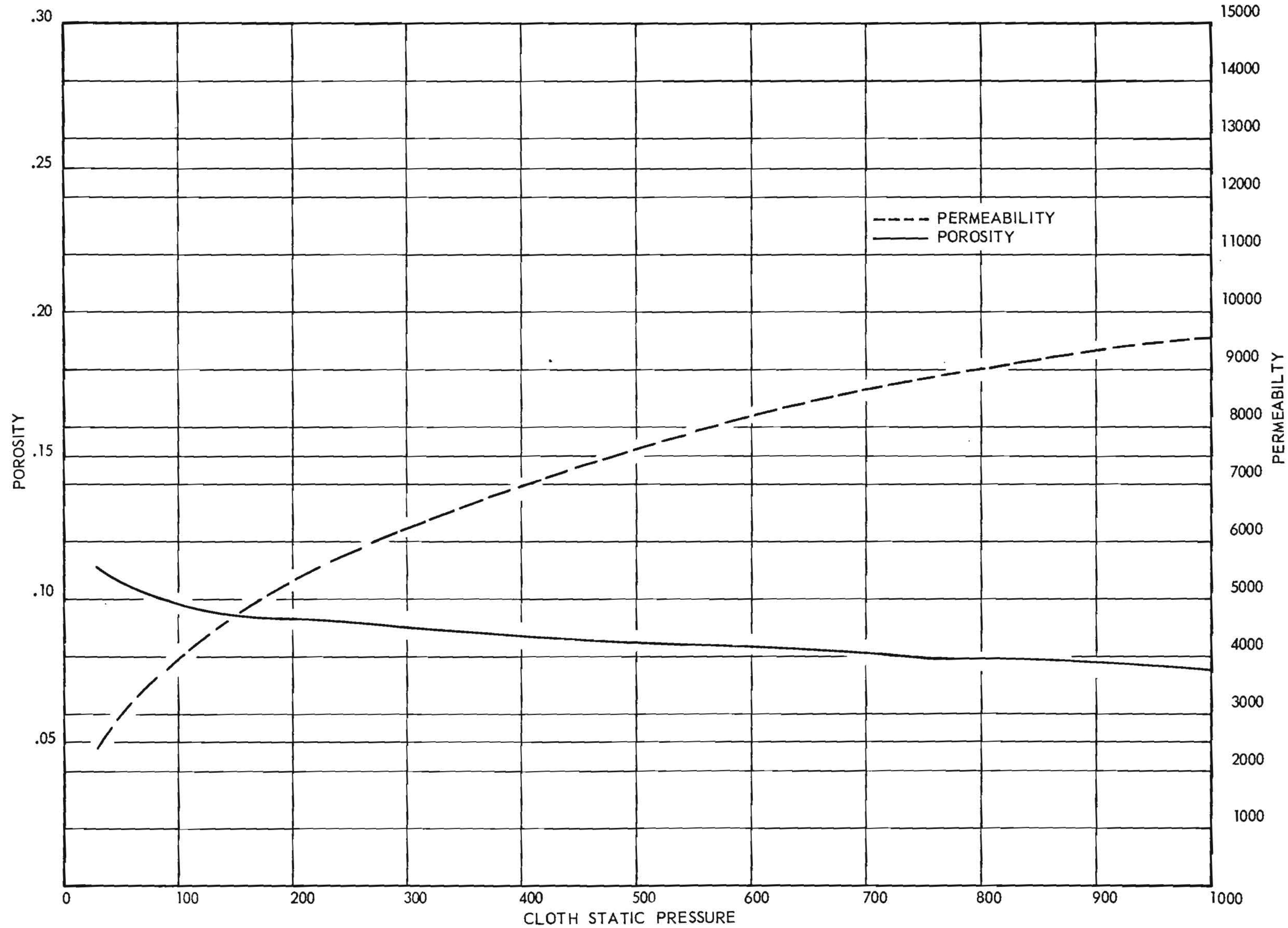

Figure 8. Fabric GT-15, Nylon Twill Construction 70 x 70.

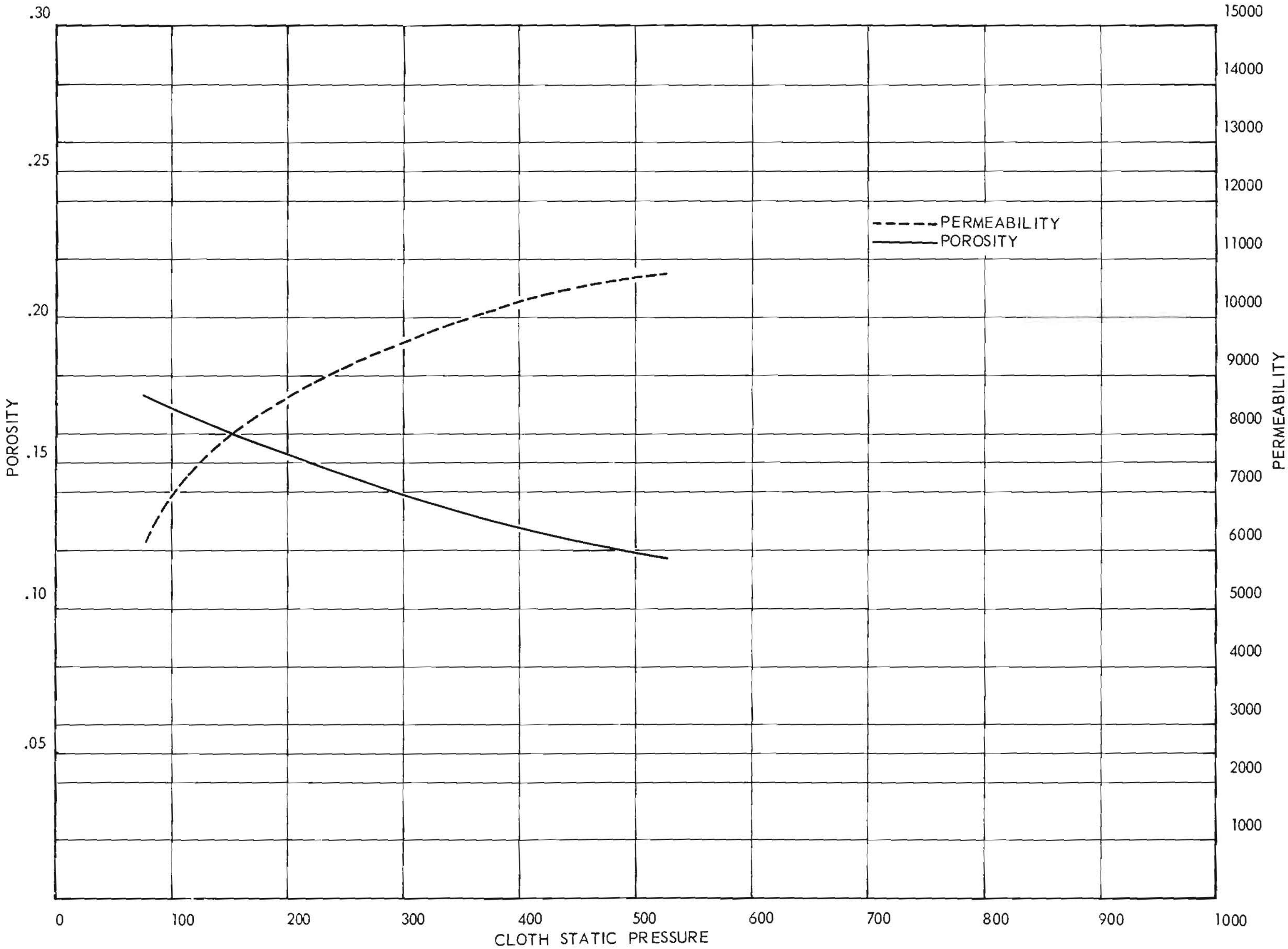

Figure 9. Fabric GT-27, Nylon Satin Construction 125 x 40.

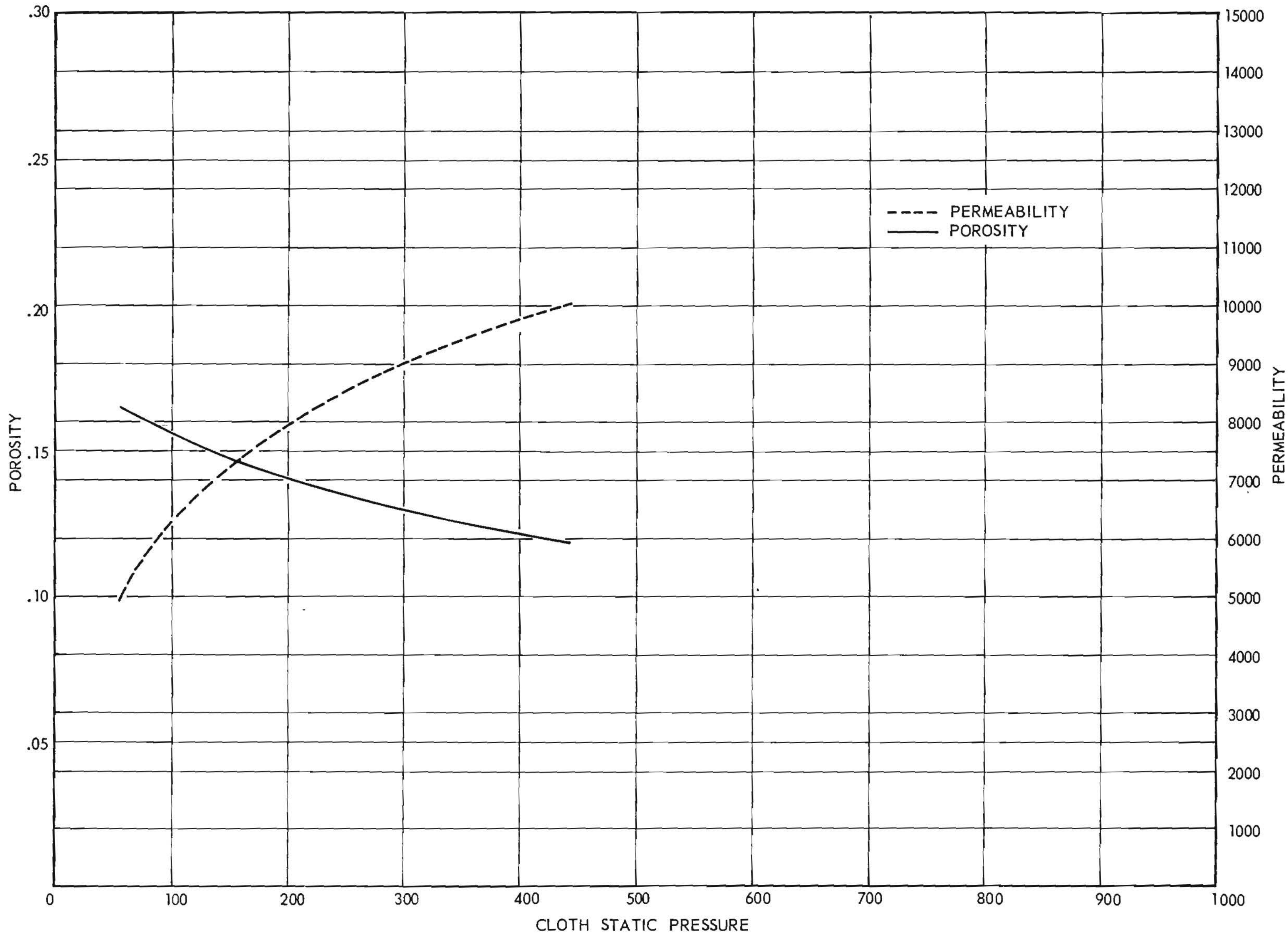

Figure 10. Fabric GT-28, Nylon Twill Construction 125 x 40.

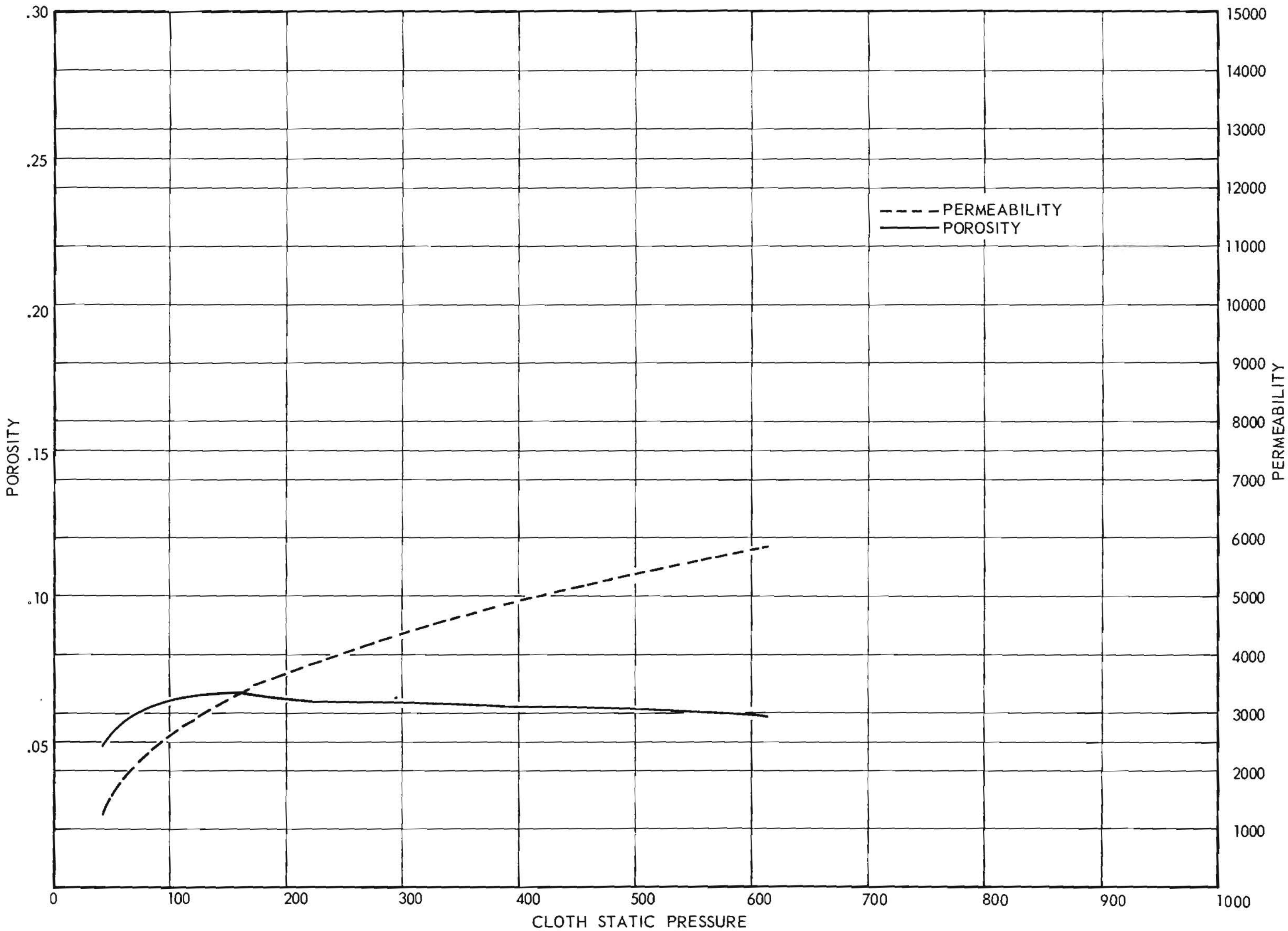

Figure 11. Fabric GT-30, Nylon Twill Construction 125 x 60.

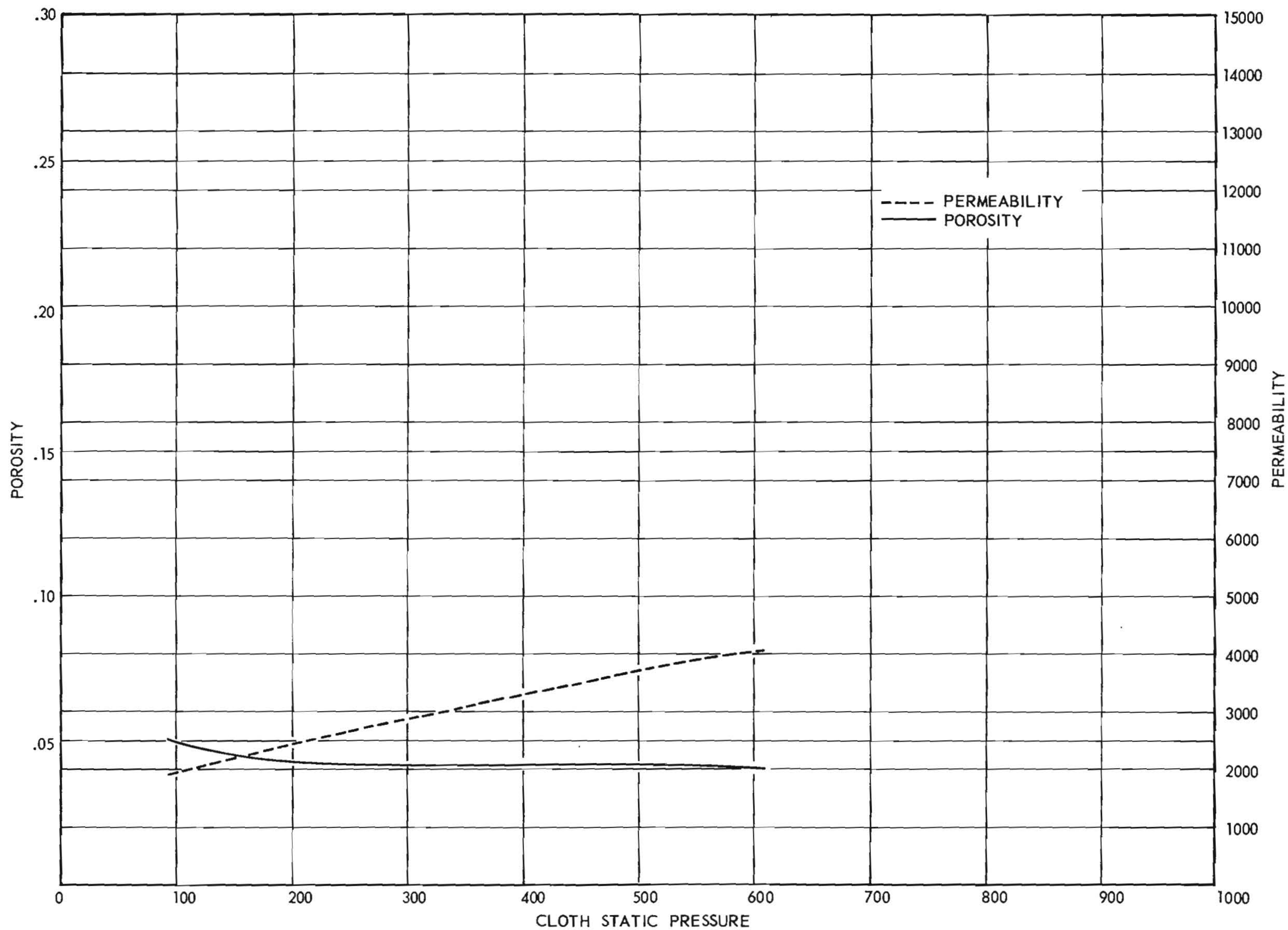

Figure 12. Fabric GT-40, Orlon Twill Construction 100 x 70.

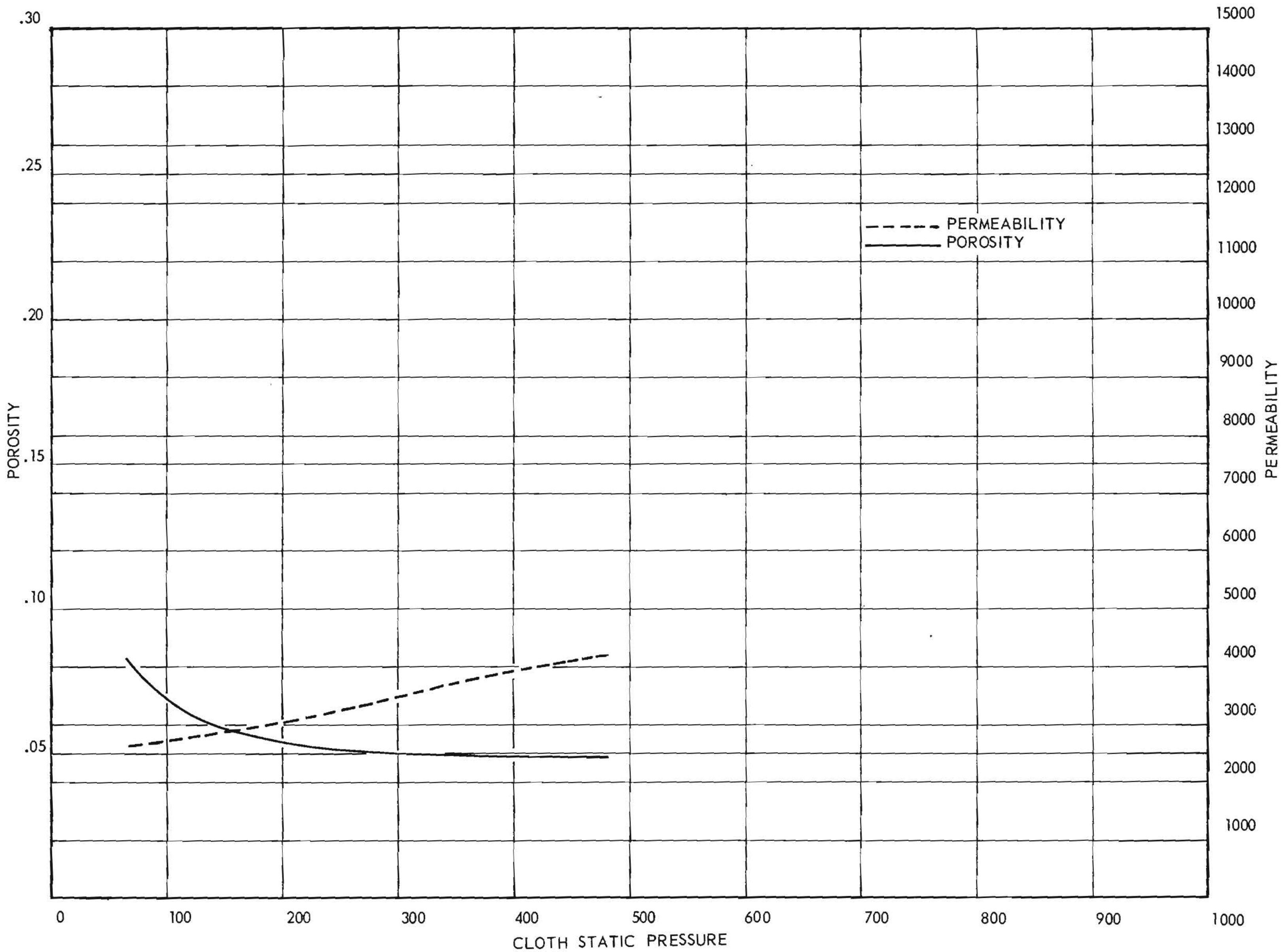

Figure 13. Fabric GT-44, Orlon Satin Construction 100 x 70.

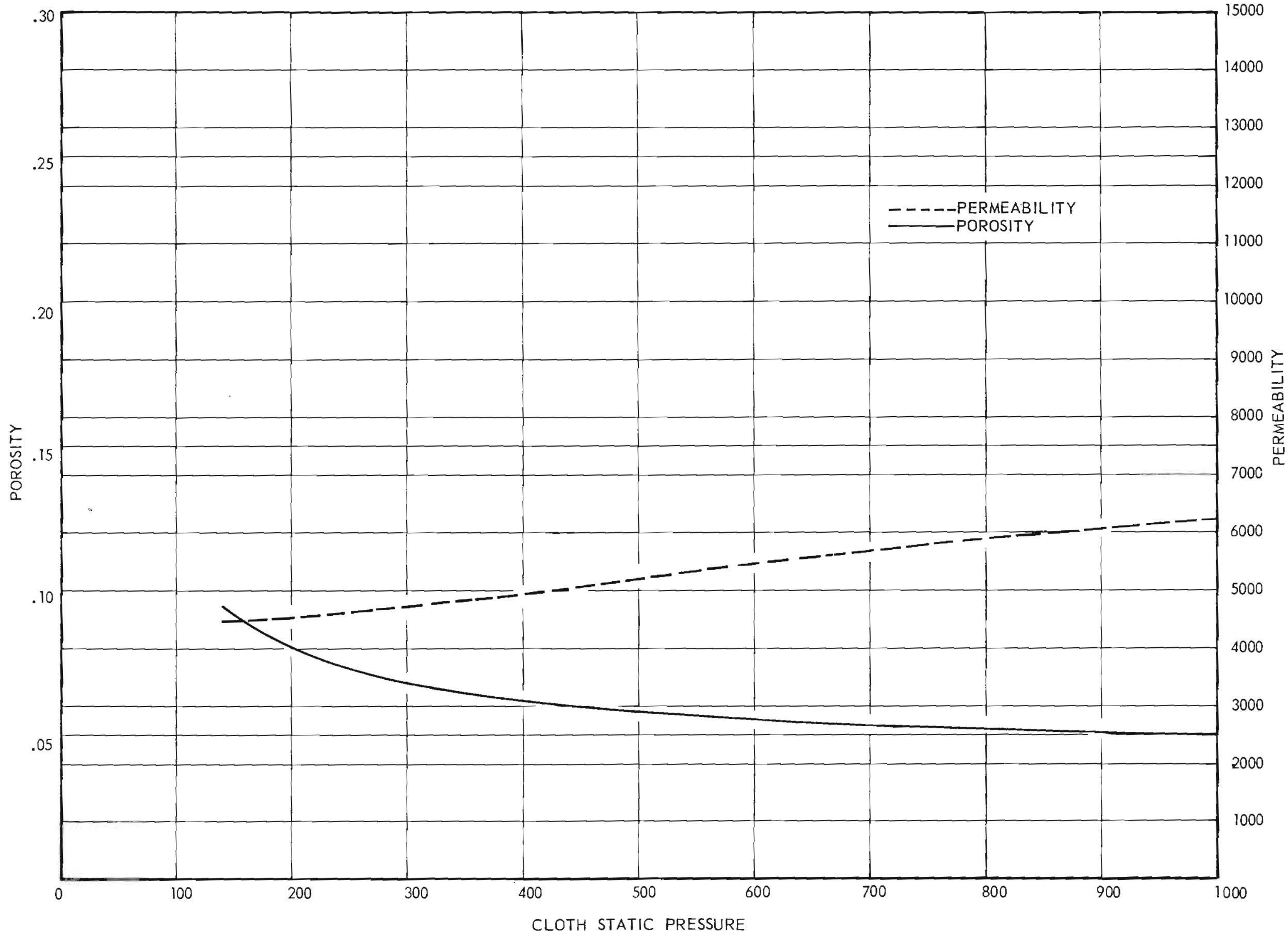

Figure 14. Fabric GT-52, Dacron Twill Construction 110 x 70.

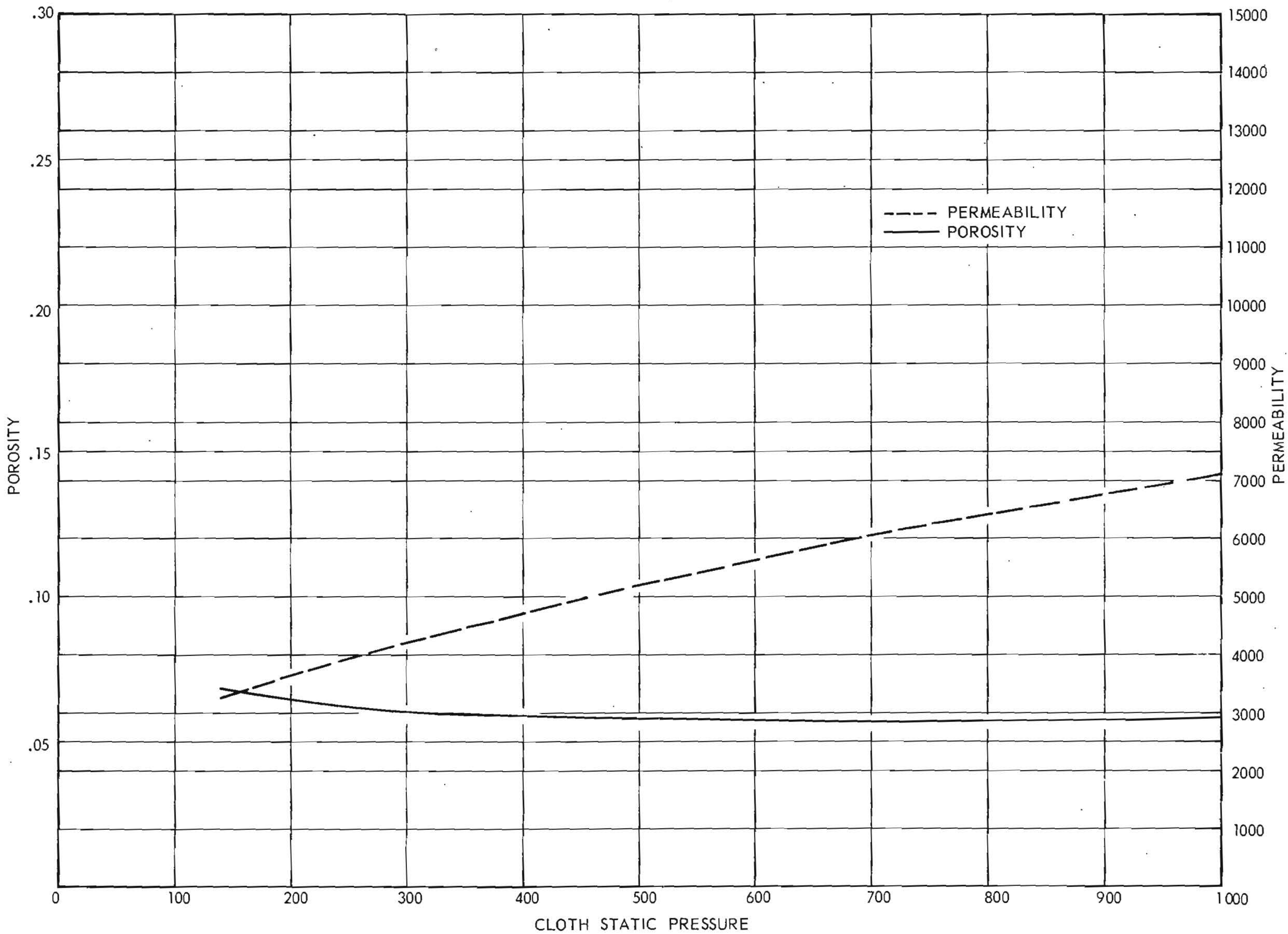

Figure 15. Fabric GT-56, Dacron Satin Construction 110 x 70.

ENGINEERING EXPERIMENT STATION
of the Georgia Institute of Technology
Atlanta, Georgia

QUARTERLY REPORT NO. 8

PROJECT 170-117

PERMEABILITY OF PARACHUTE FABRICS

By

H. W. S. LaVIER

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Contract No. AF 33(038)15624

R. D. O. No.R-612-12 SR-12

PROJECT NO. 53-660-25

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February 15, 1954 to June 15, 1954

ENGINEERING EXPERIMENT STATION
of the Georgia Institute of Technology
Atlanta, Georgia

QUARTERLY REPORT NO. 8

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R. D. O. No.R-612-12 SR-12

PROJECT NO. 53-660-25

- o - o - o - o -

February 15, 1954 to June 15, 1954

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LIST OF FIGURES

LIST OF FIGURES (Concluded)

This report summarizes the progress during the quarter ending 15 June 1954. It concerns the conduct of high-pressure air permeability evaluations of selected parachute fabrics. During the period further development of the Biaxial Fabric Tension Testing Machine was accomplished.

Air-permeability evaluations were made of several parachute fabrics to demonstrate the effect of weaving defects on air permeability. Also low-pressur evaluations have been made to demonstrate the effect on air permeability due to varying the calender loading.

Preparations continue for later phases of the subject research. These include plans for a wind-tunnel study to determine the distribution of fabric stresses throughout the canopy of a model parachute.

I. HIGH-PRESSURE PERMEABILITY TESTS

A. Equipment

The Georgia Tech high-pressure permeometer has performed satisfactorily during the past quarter. Failure of several of the Transonics Inc. transducers and their repair delayed the high-pressure evaluations during February and March. However, subsequently the equipment was returned, replaced and the test program was conducted.

A device for cooling the permeometer air by introducing liquid nitrogen into the high-pressure air stream has given some trouble. It has been necessary to modify this equipment by the addition of screens in an attempt to cause turbulence and, thus, diffuse the liquid nitrogen causing a more efficient cooling. This work has only been recently completed.

B. Program of Tests

WADC Technical Report 52-283, Part 4 was completed in draft form during this quarter. The report is now in the process of being edited by Air Force personnel.

Low-pressure permeability evaluations have been conducted on yellow, blue and black cotton muslin, specification MIL-C-4279. The results of these tests are presented in table form in appendix A, Table I, and in graphical form in Figures 1 through 3 of appendix B.

The effect of weaving defects on air permeability of parachute fabrics at low-pressure differentials is demonstrated graphically in Figures 4 through 20. The air-permeability values of samples containing defects are compared with the average value of the same flawless fabric. Table I of appendix A also contains the permeability values at various pressure differentials for the normal fabric only. Insignificant differences in air permeability were observed in comparing the evaluations for samples with flaws and samples without flaws. It is not expected that these weaving defects will seriously impair the strength or air permeability of these fabrics at high-pressure differentials.

Experiments were conducted to demonstrate the effect of varying the calender pressure and heat treating on the air permeabilities of a nylon parachute-type cloth. The seven experimental fabrics investigated were obtained from a piece of MIL-C-7020 Type I (1.1 ounce) nylon ripstop parachute fabric woven on one warp in same loom and totaling approximately 330 yards. All the samples were cut from this original piece. The cloth was sewed together after grey calendering, and all finishing and dyeing operations thereafter were performed on the sewed piece.

Sample No. 6 was heat treated on a tenter frame at 420^{o}F for 7-1/4 seconds and in a Morrison cylinder-type machine at 420°F for 9 seconds. The sample received two consecutive heat-treating operations; the first time, on the tenter, to set the desired width and the second to further stabilize the cloth and to eliminate any tendency toward lack of complete setting of the selvages, which sometimes results because of the cooler tenter-frame-clip exposure.

The permeability of MIL-C-7020 Type I fabric may be decreased by 34 per cent at 50 inches of water by increasing the calender pressure from 0 to 100 tons. About 20 per cent of this decrease occurs when the calender in the pressure is increased from zero to 19 tons. Changing the pressure from 19 to 50 tons results in an additional decrease of 10 per cent, while increasing the pressure from 50 to 100 tons produces an additional decrease of only 4 per cent. Samples 2, 3, 4 and 5 are within the limits of 80-120 at 1/2-inch pressure drop as specified by Specification MIL-C-7020 - Type I., indicating that very close control of permeability between specified limits is possible by variation of calendering pressure.

Heat treatment of the piece calendered at 19 tons produced an increase in permeability ranging from 5-1/2 per cent at 10 inches of water to 3 per cent at 30 inches of water. A decrease in percentage variation with an increase of differential pressure is to be expected, since as the interstices open up, the flow is less dependent upon the size of the yarn. In other words, the larger the interstice is in relation to the yarn, the smaller will be the percentage variation due to a change in width of the yarn.

High-pressure permeability, biaxial tension and impact pressure tests are being conducted on these fabrics and a complete analysis of the results will be presented in a future report.

Table II of appendix A explains the identification of the specially calendered Cheney Bros. fabric. Physical properties of this fabric are presented in Table II. The magnitude of the air-permeability variation due to changing the calender weight is summarized in Table III. Figures 21 through 24 of appendix B show graphically the effect of varying the calender load on the air permeability of the fabric. Figures 24 and 25 show the effect on air permeability and effective porosity due to heat treatment.

A study using the high-pressure permeometer to determine fabric bursting pressure was conducted. Table IV of appendix A presents a comparison of impact and gradual bursting pressures for several Georgia Tech fabrics. Figure 27 of appendix B illustrates the impact bursting process. The gradual break occurs during the normal high-pressure permeability test. The pressure is gradually increased until a break occurs, and data are recorded at all intermediate pressures. It is noted in Table IV that the gradual rupture pressure is higher for some fabrics while the impact rupture pressure is higher for others. This indicates that the differences between the impact and gradual rupture pressures are principally due to the variability of the fabric from sample to sample. It is not unusual for the breaking point of fabric to vary 30 per cent from one sample to the next. Impact rupture pressure for standard Air Force fabrics will be presented in part 5 of AF Technical Report 52-283. The standard Air Force fabrics Mil-C-16208, Types I, II, III and Mil-C-7350, Type I, could not be broken at the maximum tank pressure of 100 psi.

II. DEFORMATION OF FABRIC UNDERLOAD

(No Air Flow)

A. Equipment

The Bristol "X-Y" type recorders have been installed on the Biaxial Fabric Tension Testing Machine during the past quarter. This installation has required the construction of accessory equipment in the form of strain-gage power sources, variable resistances and a calibrating circuit. The work has just been completed, and there has not been time to conduct any tests using the new recorders.

III. ADDITIONAL RESEARCH PHASE

A model parachute is now in the process of construction. Special strain gages have been located for use in making the stress-distribution measurements. Some difficulty in scaling down the canopy mass weight is being experienced.

Preparations are now being made to conduct additional high-pressure permeability evaluations of the specially calendered cloth and of the defective fabrics.

Respectfully submitted,

/ Hurlbut W. S. LaVier
Project Director

Approved:

Paul K. Calaway, Acting Director
Engineering Experiment Station

IV. APPENDIX

APPENDIX A

TABLES

TABLE I

LOW-PRESSURE PERMEABILITY RESULTS FOR MIL-C-4279

Cloth Static Pressure	Air Density Upstream of Cloth	Mass Velocity Air Upstream of Cloth	Permeability
(Inches of Water)	(lb_m ft.$^{-3}$)	(lb_m sec.$^{-1}$ ft.$^{-2}$)	(cfm ft.$^{-2}$)
Yellow Cotton Muslin			
3	0.0653	0.900	770
5	0.0666	1.20	1,019
7.5	0.0670	1.52	1,281
10	0.0674	1.79	1,503
15	0.0682	2.27	1,900
20	0.0690	2.69	2,236
25	0.0700	3.07	2,533
30	0.0708	3.42	2,812
32.5	0.0711	3.57	2,928
Black Cotton Muslin			
3	0.0670	0.980	830
5	0.0673	1.34	1,135
7.5	0.0678	1.71	1,442
10	0.0682	2.04	1,713
12.5	0.0686	2.34	1,958
15	0.0690	2.60	2,165
17.5	0.0694	2.84	2,365
20	0.0699	3.07	2,545
22.5	0.0703	3.30	2,728
25	0.0708	3.49	2,872
27	0.0711	3.64	2,985
Blue Cotton Muslin			
2	0.0672	0.605	509
5	0.0677	1.10	922
8	0.0682	1.48	1,240
12	0.0689	1.93	1,610
16	0.0697	2.32	1,920
20	0.0704	2.64	2,180
24	0.0711	2.94	2,410
28	0.0719	3.22	2,630
33	0.0728	3.55	2,880

(Continued)

TABLE I (Continued)

LOW-PRESSURE PERMEABILITY TEST RESULTS
FOR CHENEY BROS. FABRICS

Cloth Static Pressure (Inches of Water)	Air Density Upstream of Cloth (lb_m ft.$^{-3}$)	Mass Velocity Air Upstream of Cloth (lb_m sec.$^{-1}$ft.$^{-2}$)	Permeability (cfm ft.$^{-2}$)
Fabric Number 1			
3	0.0680	0.585	491
7	0.0687	1.02	851
11	0.0694	1.35	1,124
15	0.0701	1.65	1,363
19	0.0707	1.93	1,591
23	0.0714	2.18	1,785
27	0.0721	2.41	1,966
32	0.0729	2.67	2,163
37	0.0738	2.92	2,348
42	0.0751	3.14	2,507
Fabric Number 2			
4	0.0676	0.545	458
10	0.0687	1.00	836
15	0.0696	1.29	1,070
20	0.0704	1.56	1,290
25	0.0713	1.80	1,480
30	0.0723	2.04	1,660
35	0.0731	2.26	1,830
40	0.0739	2.46	1,990
45	0.0750	2.66	2,130
50	0.0758	2.83	2,250
Fabric Number 3			
5	0.0681	0.595	498
10	0.0690	0.930	776
15	0.0700	1.24	1,020
20	0.0708	1.50	1,240
25	0.0717	1.75	1,430
30	0.0727	1.98	1,600
35	0.0736	2.19	1,770
40	0.0744	2.40	1,930
44	0.0753	2.56	2.050
48	0.0759	2.71	2,140

(Continued)

TABLE I (Continued)

LOW-PRESSURE PERMEABILITY TEST RESULTS
FOR CHENEY BROS. FABRICS

Cloth Static Pressure	Air Density Upstream of Cloth	Mass Velocity Air Upstream of Cloth	Permeability
(Inches of Water)	(lb_m ft.$^{-3}$)	(lb_m sec.$^{-1}$ft.$^{-2}$)	(cfm ft.$^{-2}$)
Fabric Number 4			
5	0.0670	0.515	437
10	0.0679	0.805	675
15	0.0687	1.08	897
20	0.0695	1.32	1,090
25	0.0705	1.53	1,260
30	0.0714	1.74	1,420
35	0.0722	1.93	1,570
40	0.0730	2.12	1,710
45	0.0743	2.30	1,850
49	0.0745	2.43	1,950
Fabric Number 5			
5	0.0680	0.491	414
10	0.0685	0.775	649
15	0.0694	1.02	848
20	0.0704	1.25	1,030
25	0.0715	1.45	1,190
30	0.0724	1.66	1,350
35	0.0730	1.84	1,490
40	0.0739	2.02	1,630
45	0.0750	2.20	1,760
50	0.0760	2.37	1,880
Fabric Number 6			
3	0.0670	0.515	437
5	0.0672	0.680	575
10	0.0681	1.05	881
15	0.0690	1.35	1,123
20	0.0699	1.64	1,354
25	0.0707	1.90	1,564
30	0.0717	2.14	1,748
35	0.0727	2.35	1,910
40	0.0736	2.55	2,053
45	0.0746	2.74	2,197
46	0.0747	2.77	2,221

(Continued)

TABLE I (Concluded)

LOW-PRESSURE PERMEABILITY TEST RESULTS
FOR CHENEY BROS. FABRICS

Cloth Static Pressure	Air Density Upstream of Cloth	Mass Velocity Air Upstream of Cloth	Permeability
(Inches of Water)	(lb_m ft. $^{-3}$)	(lb_m sec.$^{-1}$ft.$^{-3}$)	(cfm ft. $^{-2}$)
Fabric Number 7			
5	0.0679	1.40	1,180
7.5	0.0684	1.76	1,470
10	0.0688	2.08	1,740
12.5	0.0694	2.37	1,970
15	0.0700	2.63	2,170
17.5	0.0704	2.86	2,360
20	0.0710	3.09	2,540
22.5	0.0714	3.29	2,700
26	0.0722	3.57	2,910
29	0.0728	3.79	3,070

TABLE II

PHYSICAL AND TEXTILE PROPERTIES OF

1.1-OZ NYLON RIPSTOP PARACHUTE CLOTH OG-106

Fabric Number	Width	Construction	Warp Yarns	Filling Yarns	Weight	Twist		Elongation		Tensile Strength	
						Filling	Warp	Filling	Warp	Filling	Warp
	(Inches)		(Denier/ Filament)	(Denier/ Filament)	(Oz/Sq.Yd.)			(%)	(%)		
1	36-1/8	126x119	30/10	30/10	1.11	1.5	9.0	44	34	45	47
2	36-5/8	124x119	30/10	30/10	1.09	1.5	9.0	39	32	40	47
3	36-1/8	126x119	30/10	30/10	1.10	1.5	9.0	44	32	42	47
4	36-1/2	125x118	30/10	30/10	1.08	1.5	9.0	40	33	42	46
5	36-1/4	126x119	30/10	30/10	1.08	1.5	9.0	39	31	42	45
6	36-3/4	124x118	30/10	30/10	1.07	1.5	9.0	33	34	43	47
7	39-1/2	116x115	30/10	30/10	.98	1.5	9.0	36	30	41	42

(1) No grey calendering, no heat treat, finished.
(2) Hot calendered in grey, 19 tons, no heat treat.
(3) Hot calendered in grey, 25 tons, no heat treat.
(4) Hot calendered in grey, 50 tons, no heat treat.
(5) Hot calendered in grey, 100 tons, no heat treat.
(6) a. Hot calendered in grey, 19 tons, no heat treat.
b. Heat treat on tenter frame at 420°F, 7.½ sec.
c. Heat set on Morrison at 420°F, 9 sec.
(7) Grey sample, no finish or heat treat - as woven.

TABLE III

PERCENTAGE RELATIONS BASED ON SAMPLE NO. 1

Static Pressure (Inches of Water)	10		20		30	
	Value	Percentage	Value	Percentage	Value	Percentage
1. Finished						
Permeability	1,050	100	1,650	100	2,450	100
Effective Porosity	0.085	100	0.092	100	0.0970	100
2. Finished - 19T						
Permeability	825	78.6	1,290	78.2	2,000	81.6
Effective Porosity	0.065	76.5	0.072	78.3	0.078	80.4
3. Finished - 25T						
Permeability	790	75.2	1,250	75.8	1,930	78.8
Effective Porosity	0.062	72.9	0.0695	75.5	0.0760	78.4
4. Finished - 50T						
Permeability	675	64.3	1,180	66.2	1,710	69.8
Effective Porosity	0.054	63.5	0.061	66.3	0.068	70.1
5. Finished - 100T						
Permeability	650	61.9	1,025	62.1	1,640	66.9
Effective Porosity	0.051	60.0	0.0585	63.6	0.065	67.0

Static Pressure (Inches of Water)	10		20		40	
	Value	Percentage	Value	Percentage	Value	Percentage
1. Finished						
Permeability	1,050	100	1,650	100	2,450	100
Effective Porosity	0.085	100	0.092	100	0.0970	100
7. Grey						
Permeability	1,730	165	2,520	153		
Effective Porosity	0.138	162	0.142	154		
2. Finished - 19T						
Permeability	825	100	1,290	100	2,000	100
Effective Porosity	0.065	100	0.072	100	0.078	100
6. Finished - 19T Heat Treat						
Permeability	870	105.5	1,350	104.7	2,060	103
Effective Porosity	0.069	106.2	0.076	105.6	0.082	105

(Continued)

TABLE III (Continued)

PERCENTAGE RELATIONS BASED ON SAMPLE NO. 1

RELATIVE CHANGES IN PERMEABILITY

Static Pressure (Inches of Water)	10 (%)	20 (%)	40 (%)
Finished	100	100	100
Finished - 19T	-21.4	-21.8	-18.4
Finished - 25T	-24.8	-24.2	-21.1
Finished - 50T	-35.7	-28.5	-30.2
Finished - 100T	-38.1	-37.9	-33.1

RELATIVE CHANGES IN EFFECTIVE POROSITY

Static Pressure (Inches of Water)	10 (%)	20 (%)	40 (%)
Finished	100	100	100
Finished - 19T	-23.5	-21.7	-19.6
Finished - 25T	-27.1	-14.5	-21.6
Finished - 50T	-36.5	-33.7	-29.9
Finished - 100T	-40.0	-36.4	-33.0

RELATIVE CHANGES

Permeability

Static Pressure (Inches of Water)	10 (%)	20 (%)
Finished	100	100
Grey	+65	+53

Effective Porosity

Finished	100	100
Grey	+62	+54

Permeability

Static Pressure (Inches of Water)	10 (%)	20 (%)	30 (%)
Finished - 19T	100	100	100
Finished - 19T (Heat Treat)	+5.5	+4.7	+ 3

Effective Porosity

Finished - 19T	100	100	100
Finished - 19T (Heat Treat)	+6.2	+5.6	+ 5

TABLE IV

COMPARISON OF GRADUAL AND IMPACT RUPTURE

Fabric Number	Gradual Rupture Pressure 60 sec, 0 to break	Impact Rupture Pressure (psi) 0.10 sec, 0 to break
GT-15	36.2	26.8
GT-18	13.4	17.1
GT-27	19.0	21.9
GT-28	16.0	19.6
GT-30	22.1	29.1
GT-40	22.0	20.8
GT-44	17.4	25.5
GT-52	41.4	33.8
GT-56	36.7	34.8

APPENDIX B

FIGURES

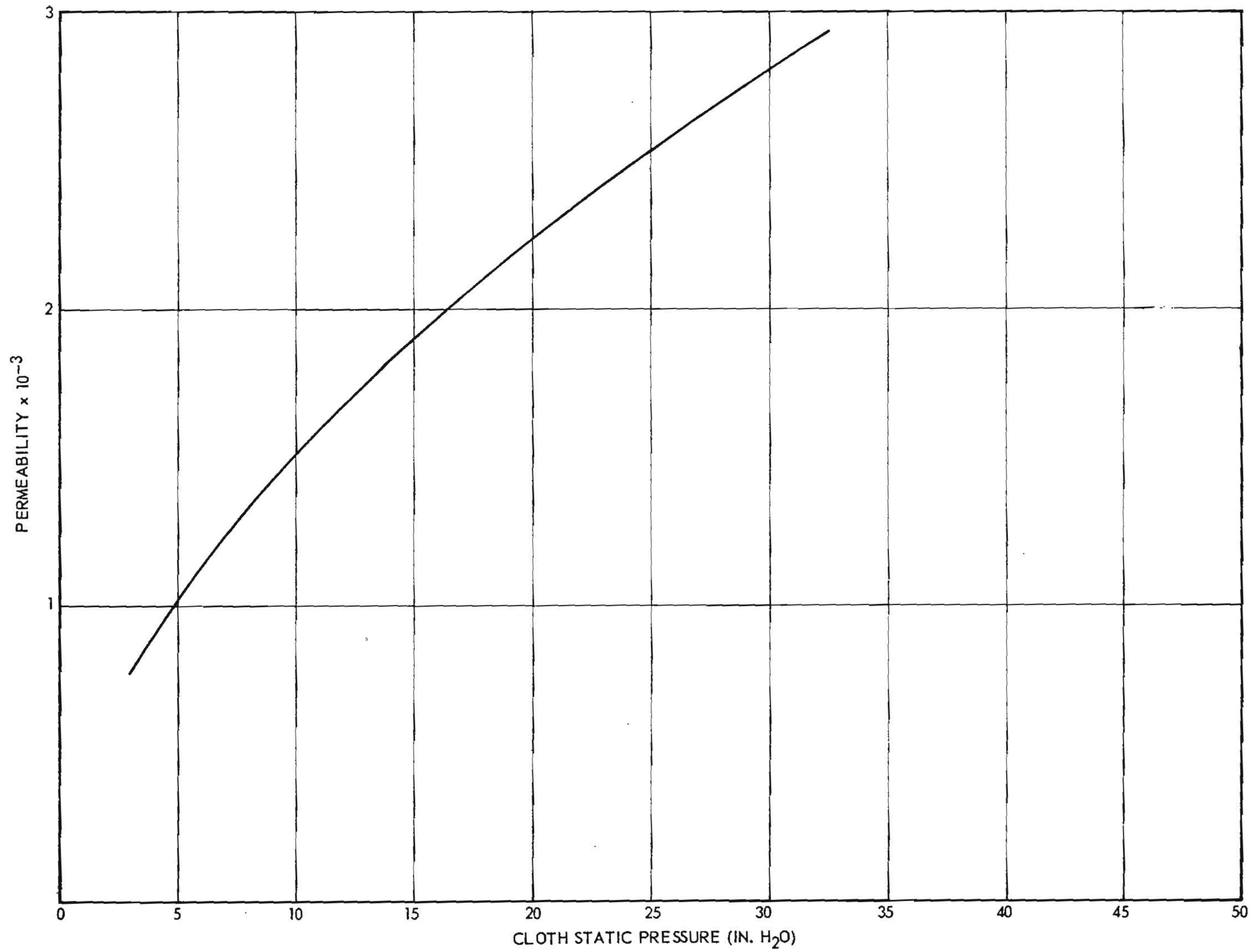

Figure 1. Yellow Cotton Muslin Spec. Mil-C-4279 59 x 59 Construction Cargo Parachute Cloth.

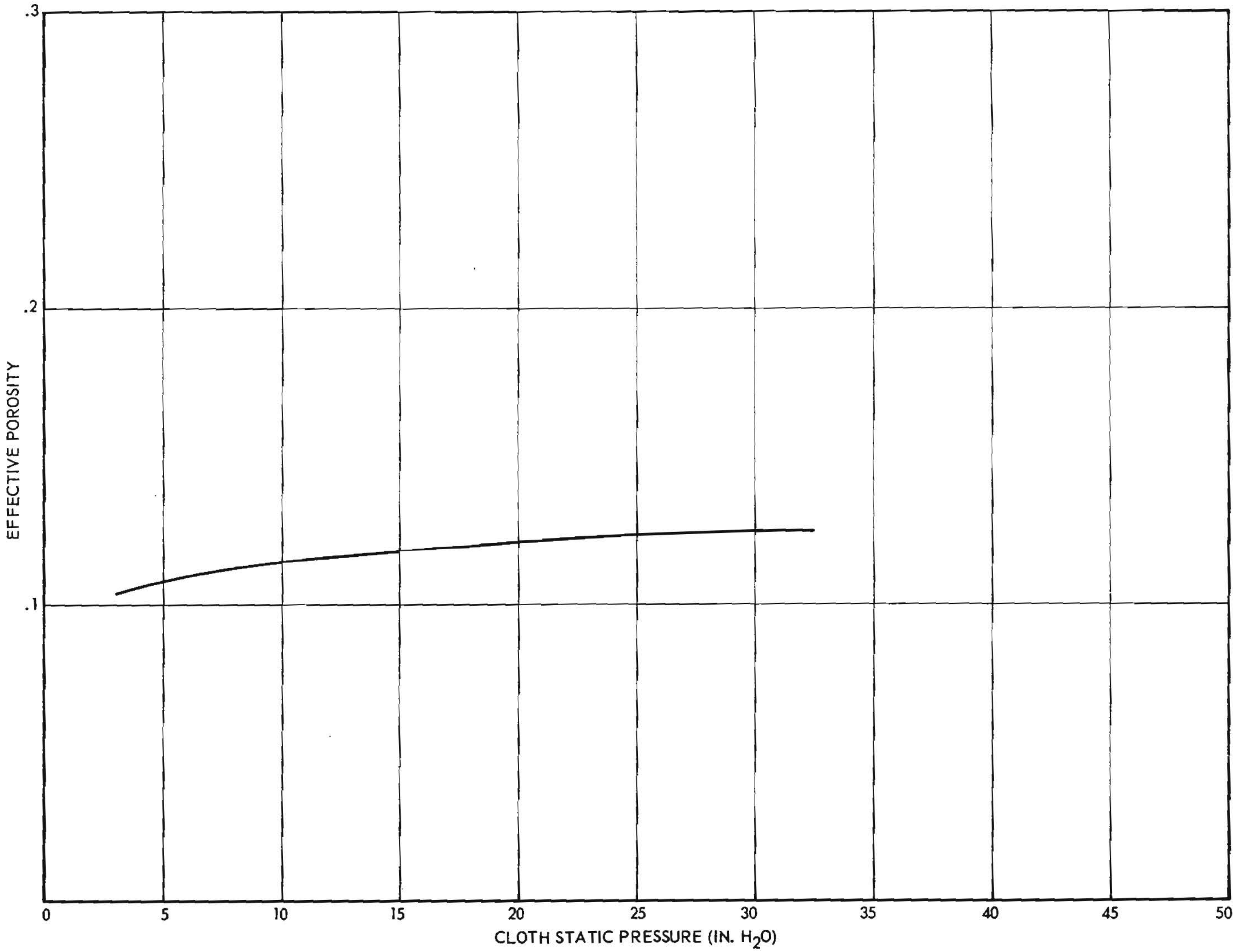

Figure 1A. Yellow Cotton Muslin Spec. Mil-C-4279 59 x 59 Construction Cargo Parachute Cloth.

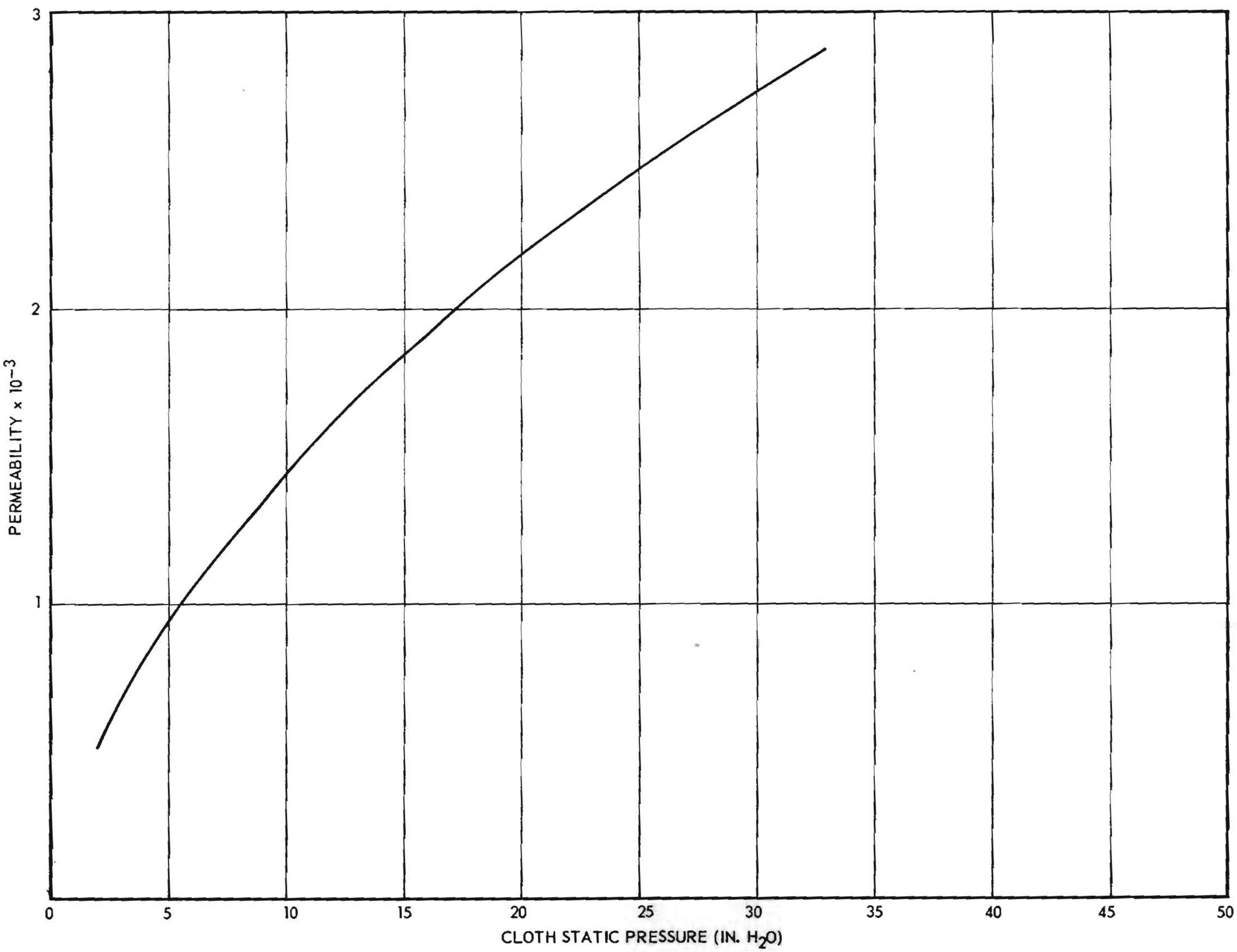

Figure 2. Blue Cotton Muslin Spec. Mil-C-4279 59 x 59 Construction Cargo Parachute Cloth.

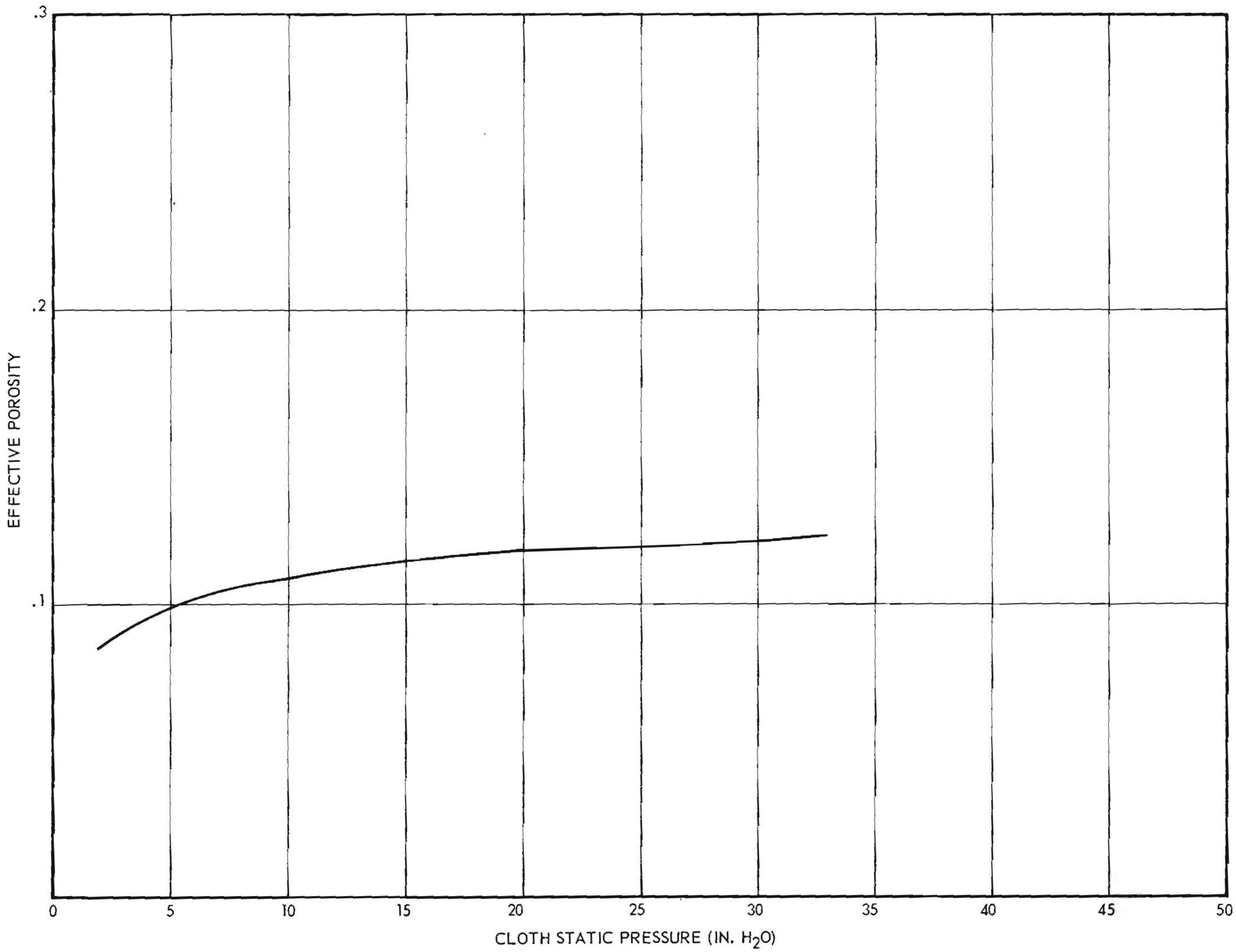

Figure 2A. Blue Cotton Muslin Spec. Mil-C-4279 59 x 59 Construction Cargo Parachute Cloth.

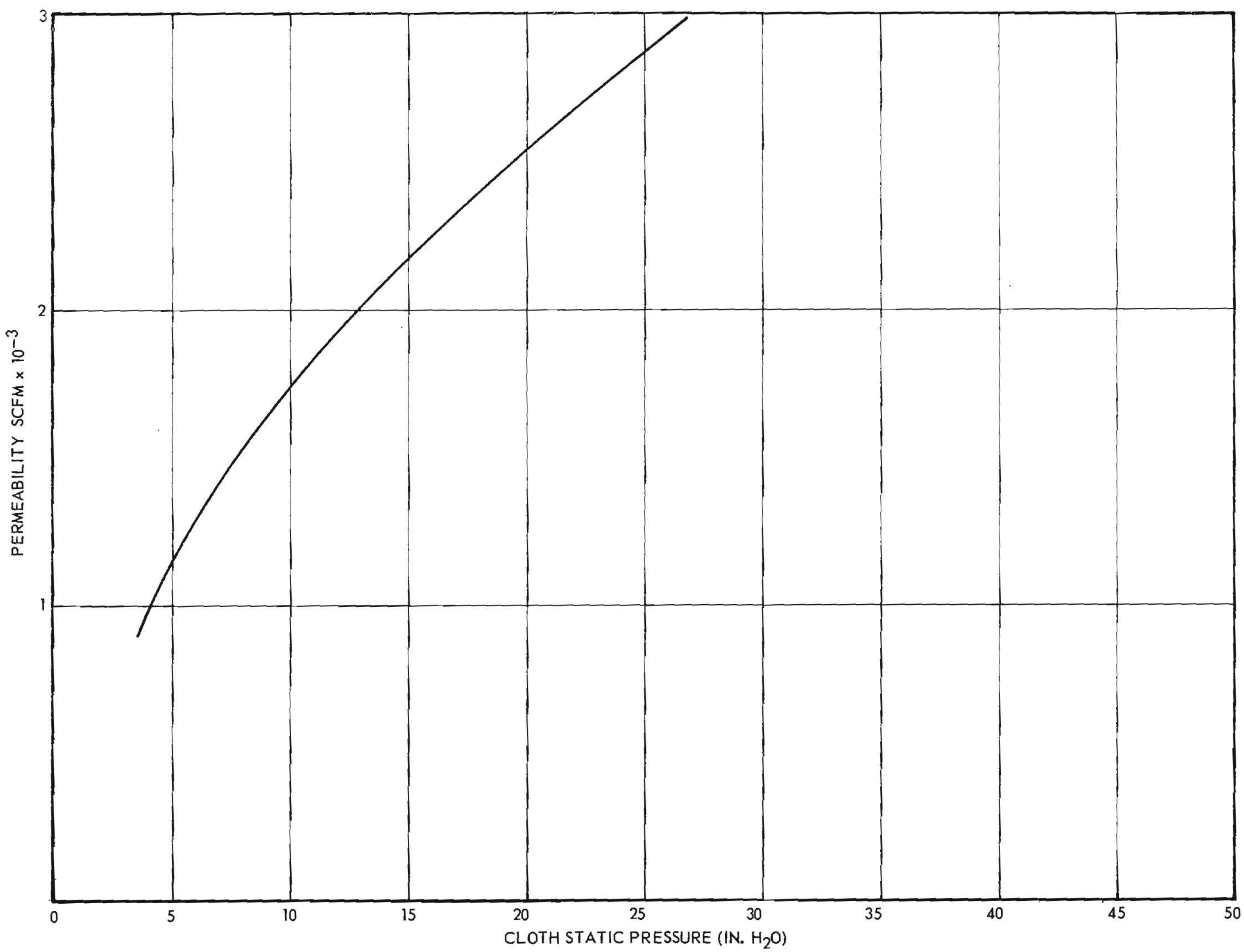

Figure 3. Muslin Cotton, Black Spec. Mil-C-4279 Construction 59 x 59 Cargo Parachute Cloth.

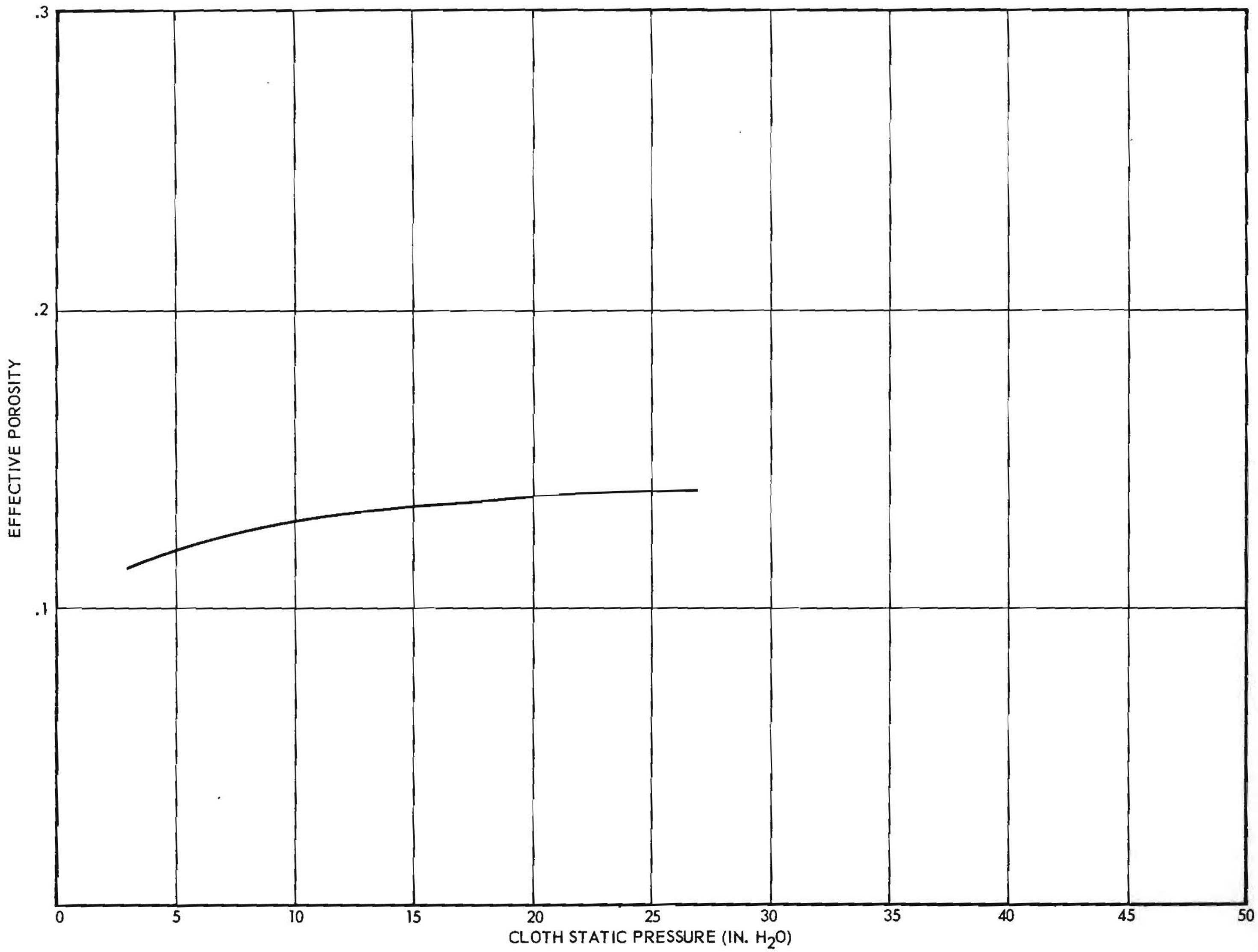

Figure 3A. Black Cotton Muslin Spec. Mil-C-4279 59 x 59 Construction Cargo Parachute Cloth.

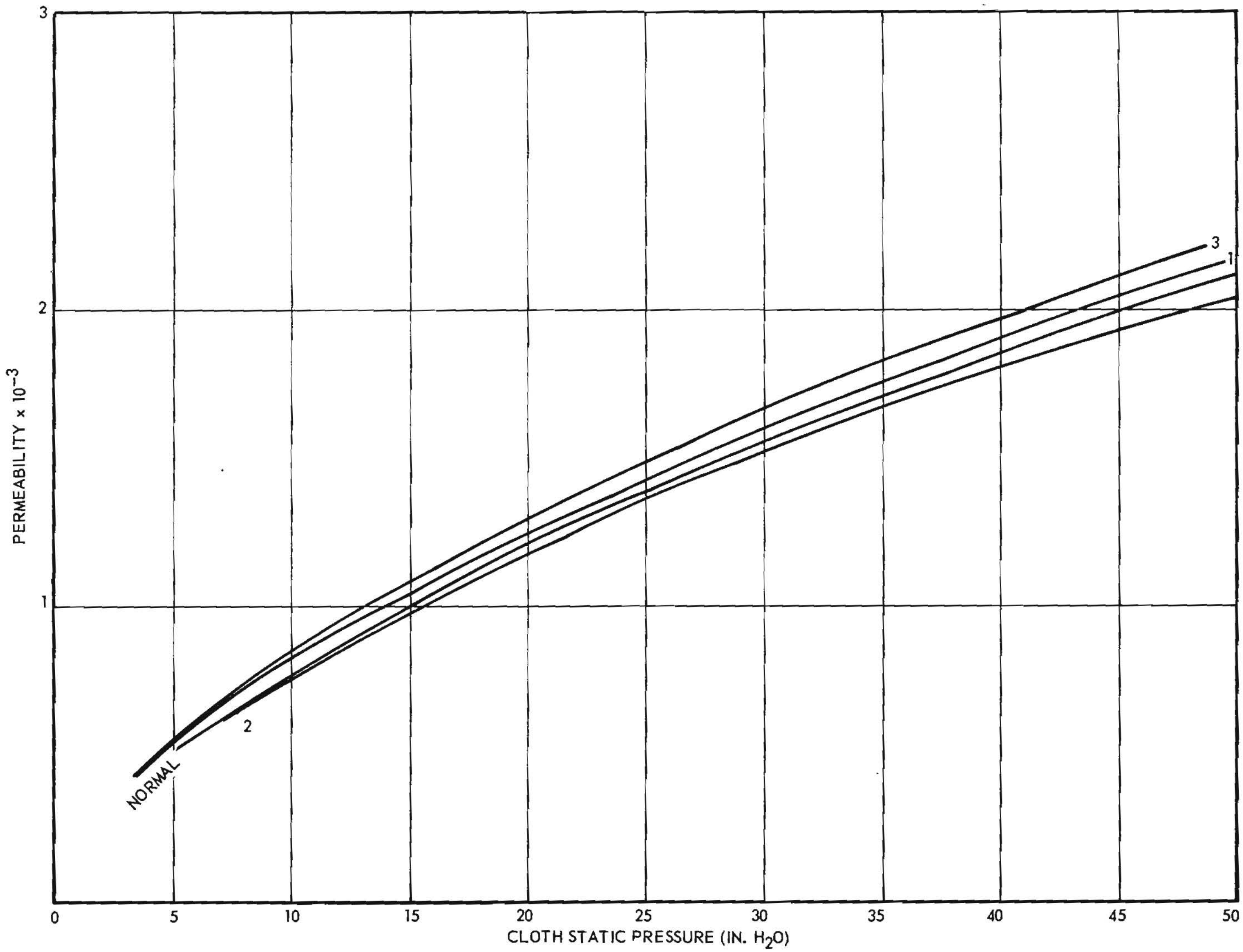

Figure 4. Effect of Wrong Draw on Permeability of Mil-C-7020 Type I Fabric.

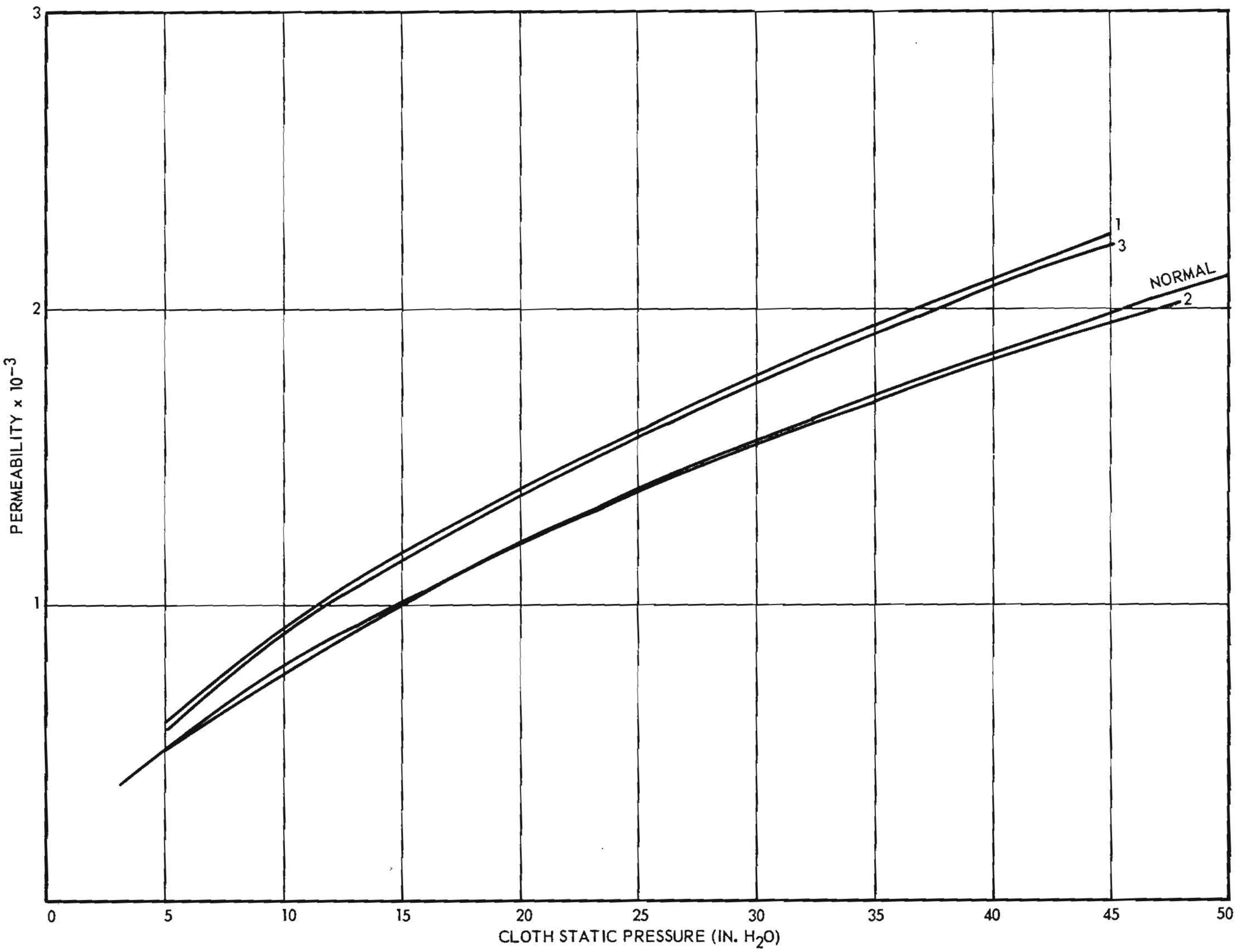

Figure 5. Effect of Mispicks on Permeability of Mil-C-7020 Type I Fabric.

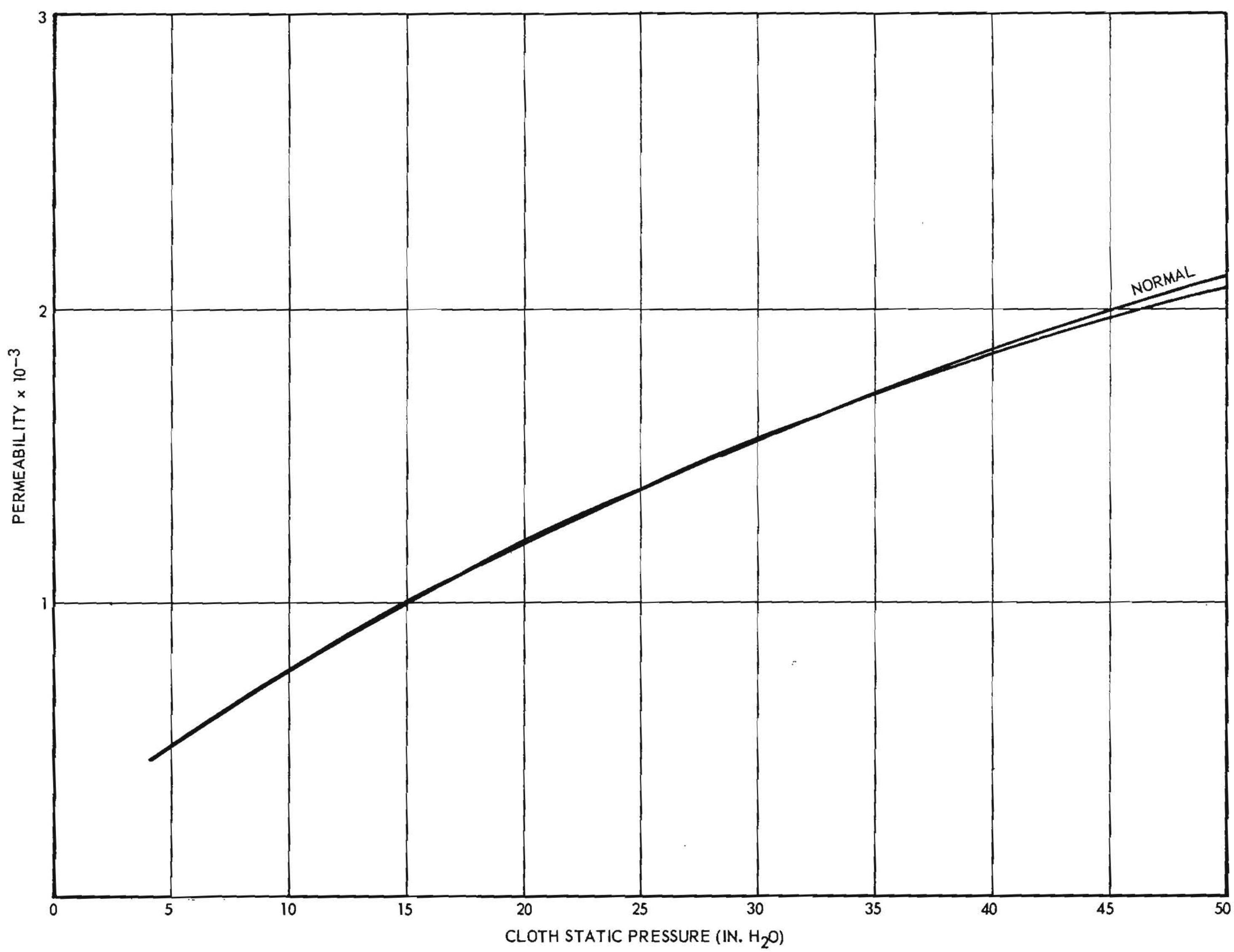

Figure 6. Effect of Threads Out on Permeability of Mil-C-7020 Type I Fabric.

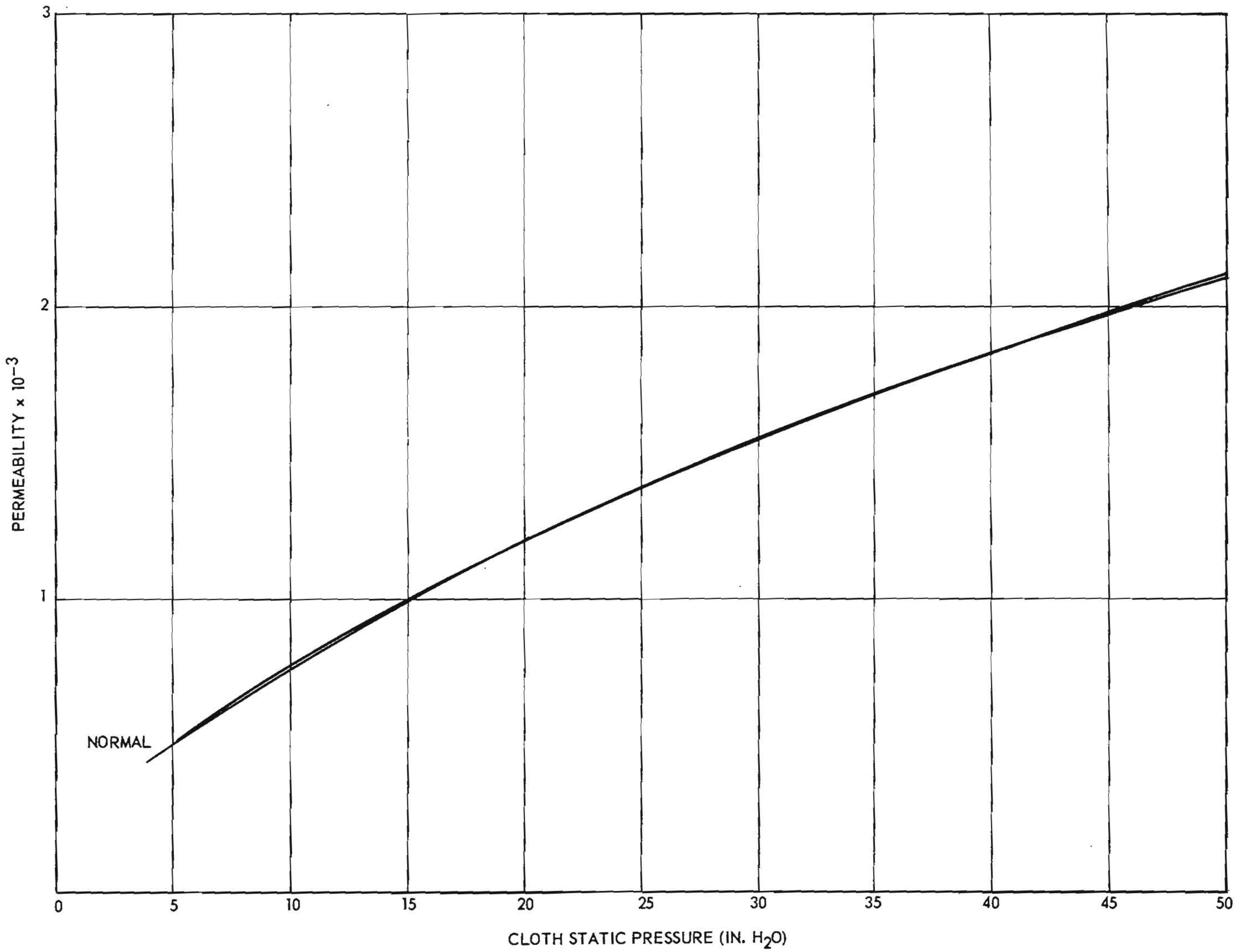

Figure 7. Effect of Light Start and Broken Threads on Permeability of Mil-C-7020 Type I Fabric.

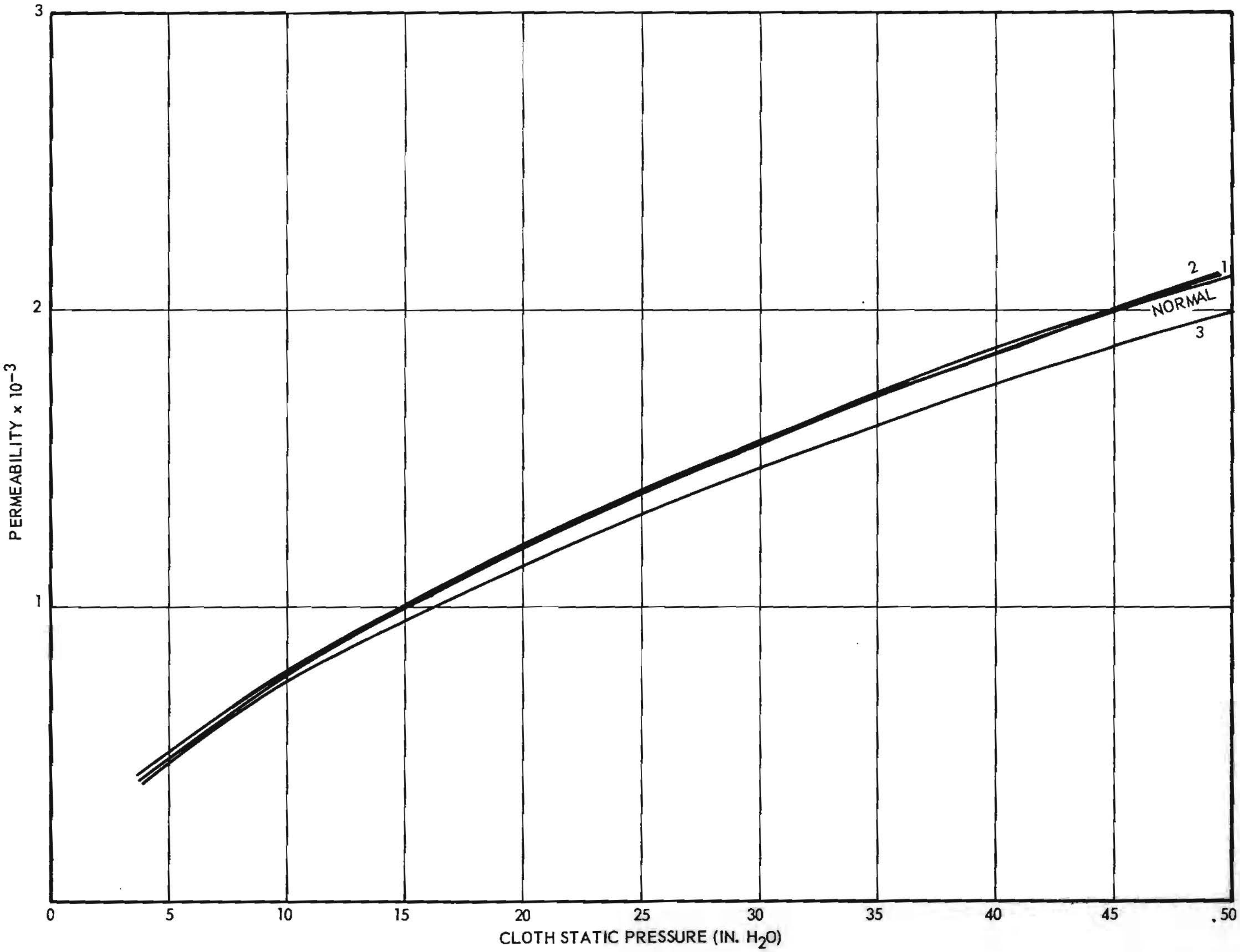

Figure 8. Effect of Floats on Permeability of Mil-C-7020 Type I Fabric.

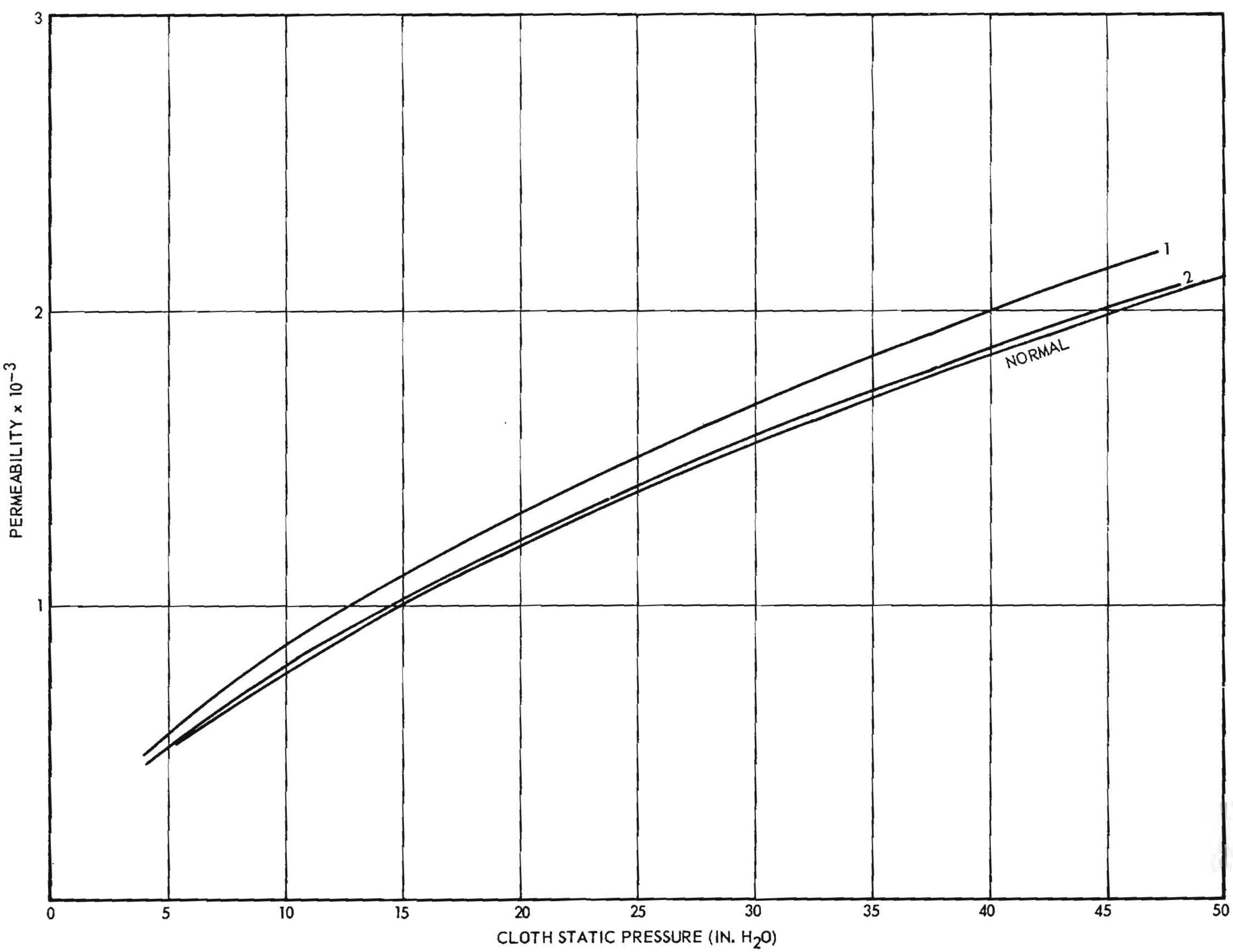

Figure 9. Effect of Broken Picks on Permeability of Mil-C-7020 Type I Fabric.

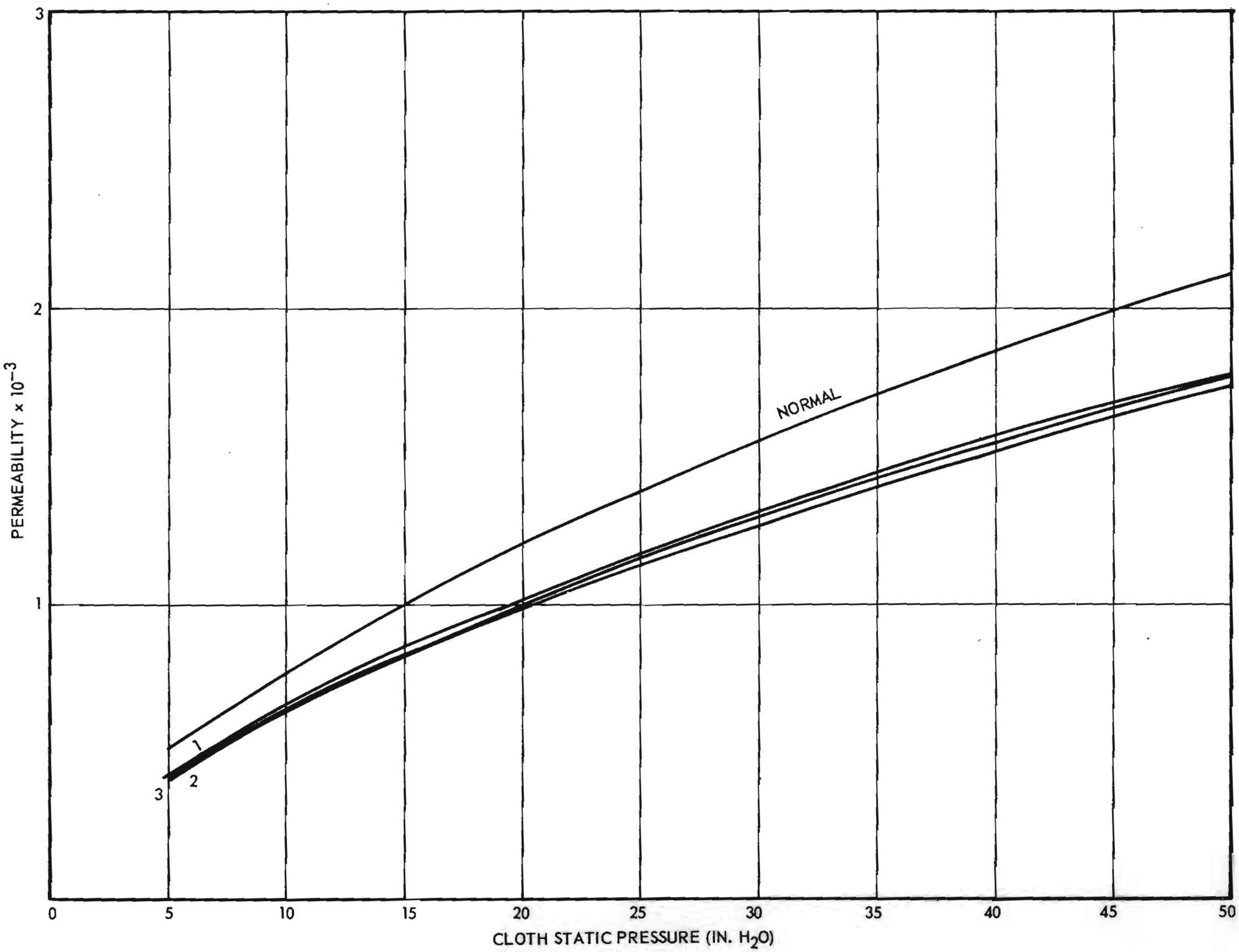

Figure 10. Effect of Heavy Start on Permeability of Mil-C-7020 Type I Fabric.

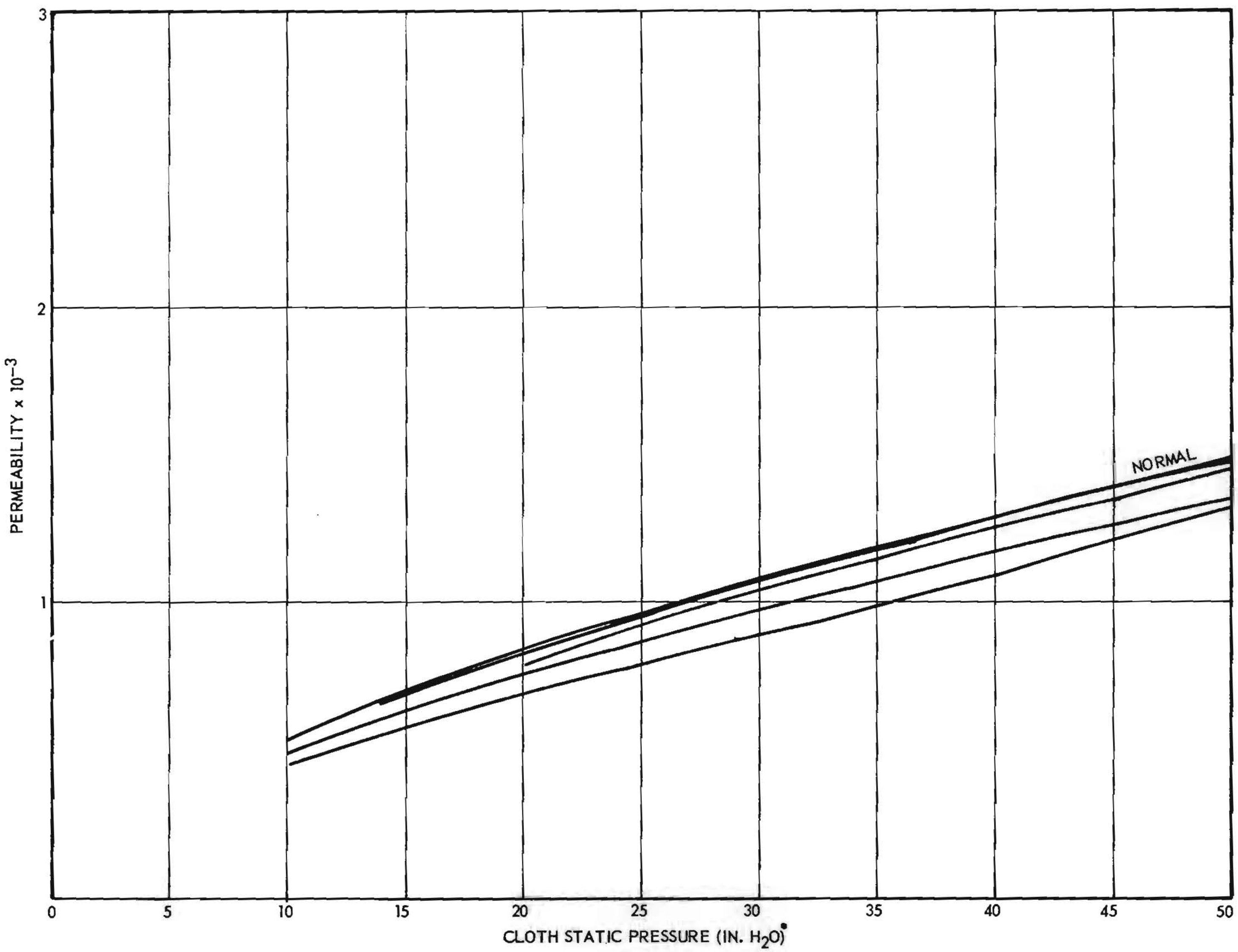

Figure 11. Effect of Heavy Starts on Permeability of Mil-C-7020 Type II Fabric.

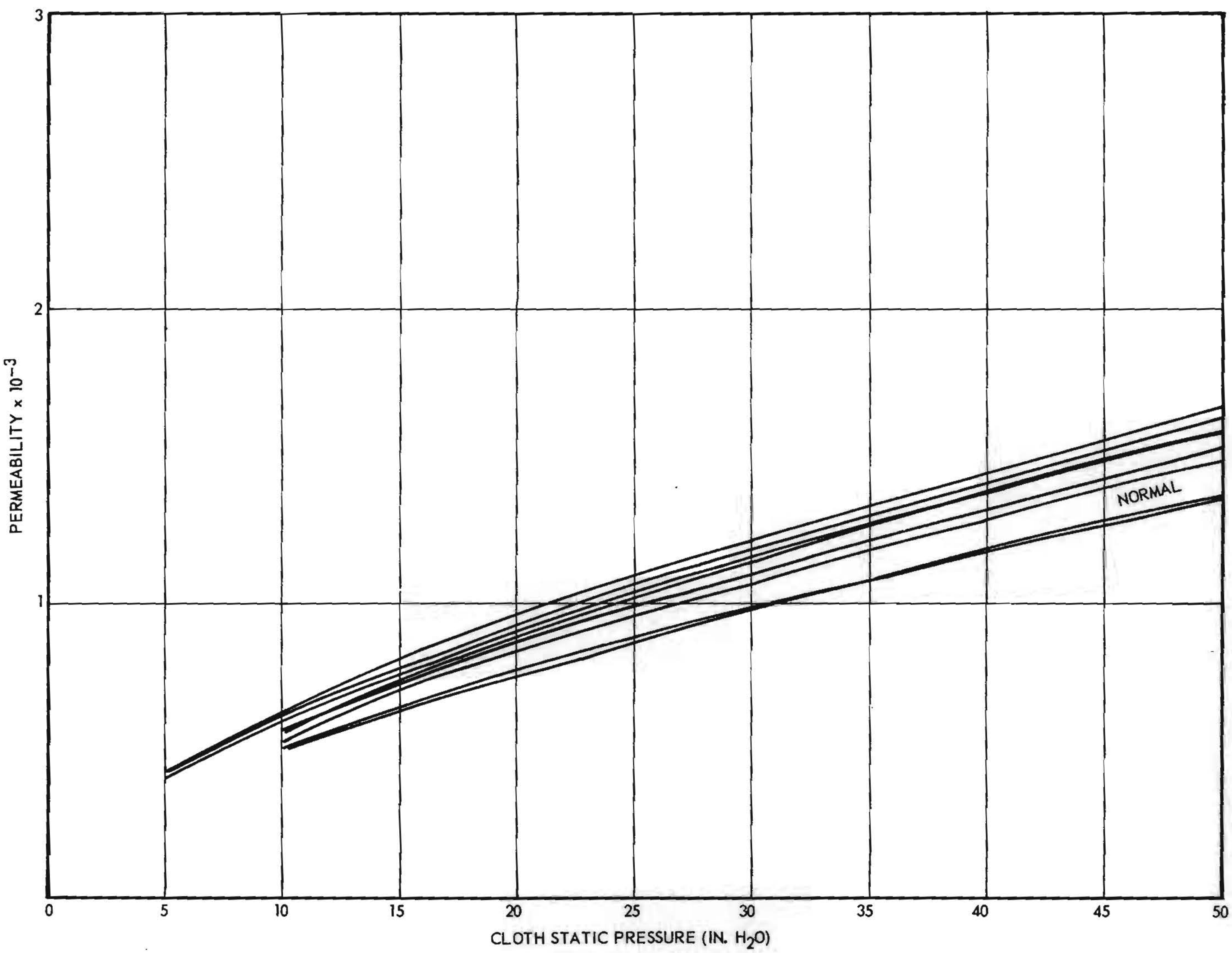

Figure 12. Effect of Mispicks on Permeability of Mil-C-7020 Type II Fabric.

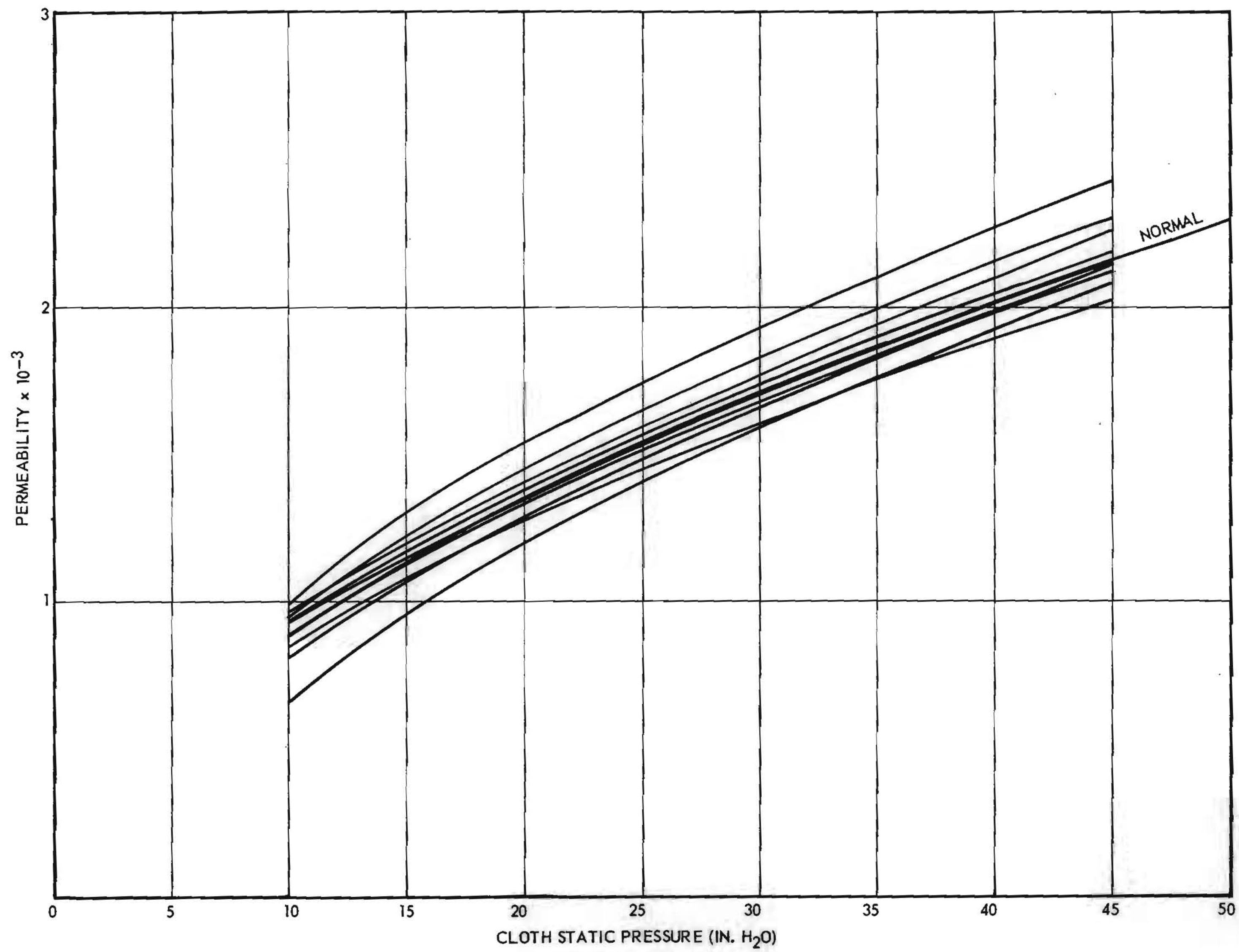

Figure 13. Effect of Mispicks on Permeability of Mil-C-7020 Type II Fabric.

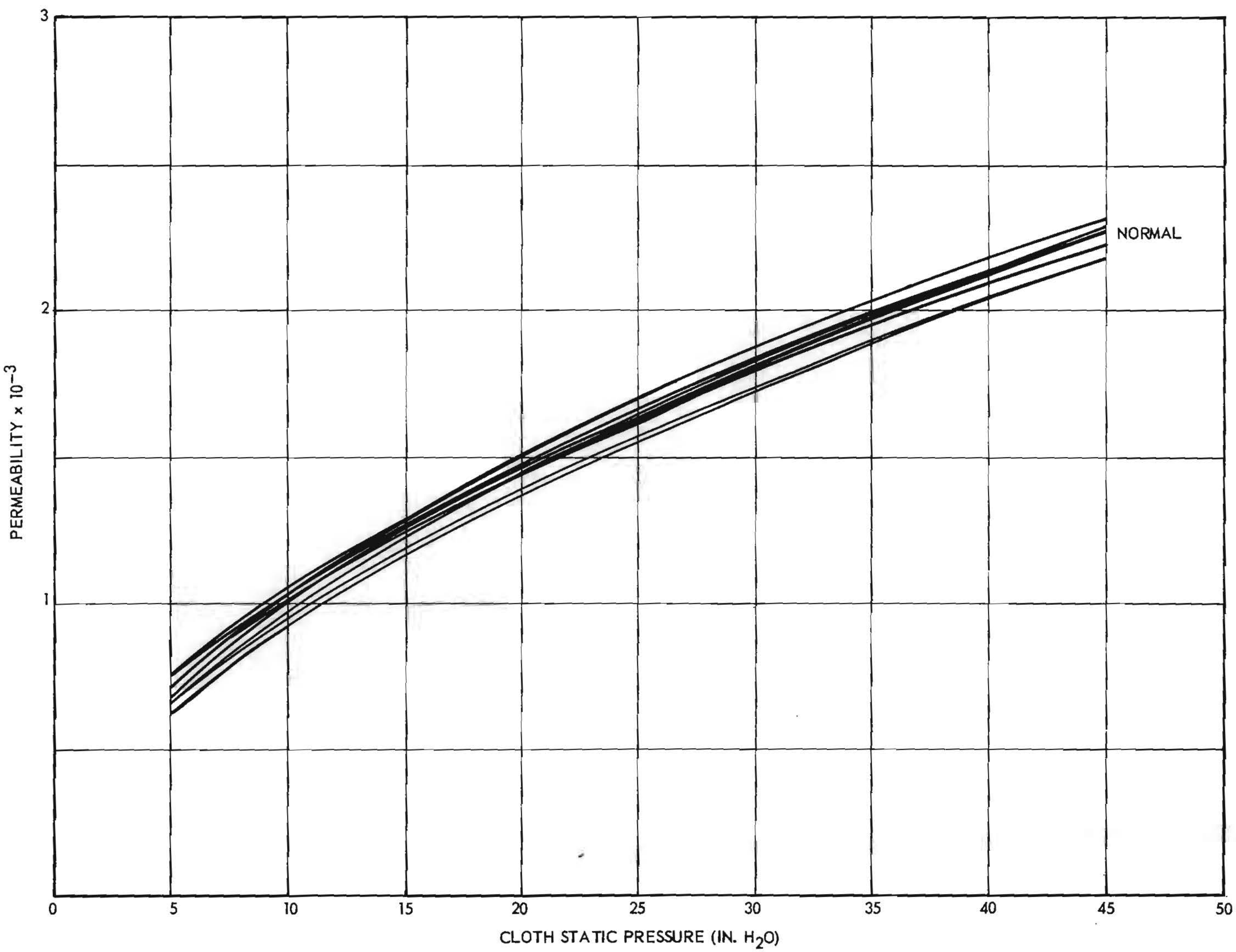

Figure 14. Effect of Floats on Permeability of Mil-C-7020 Type II Fabric.

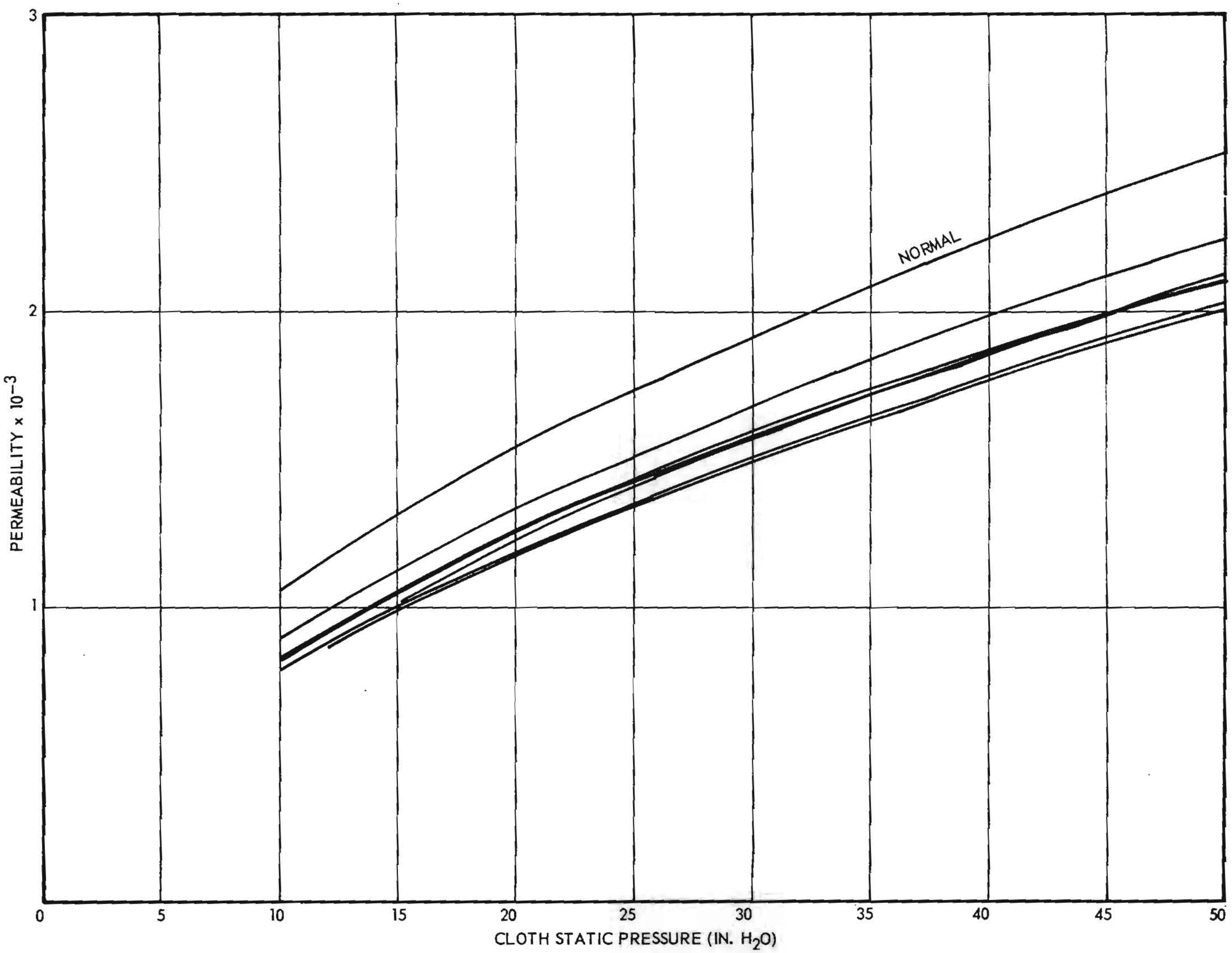

Figure 15. Effect of Shift Marks on Permeability of Mil-C-7020 Type II Fabric.

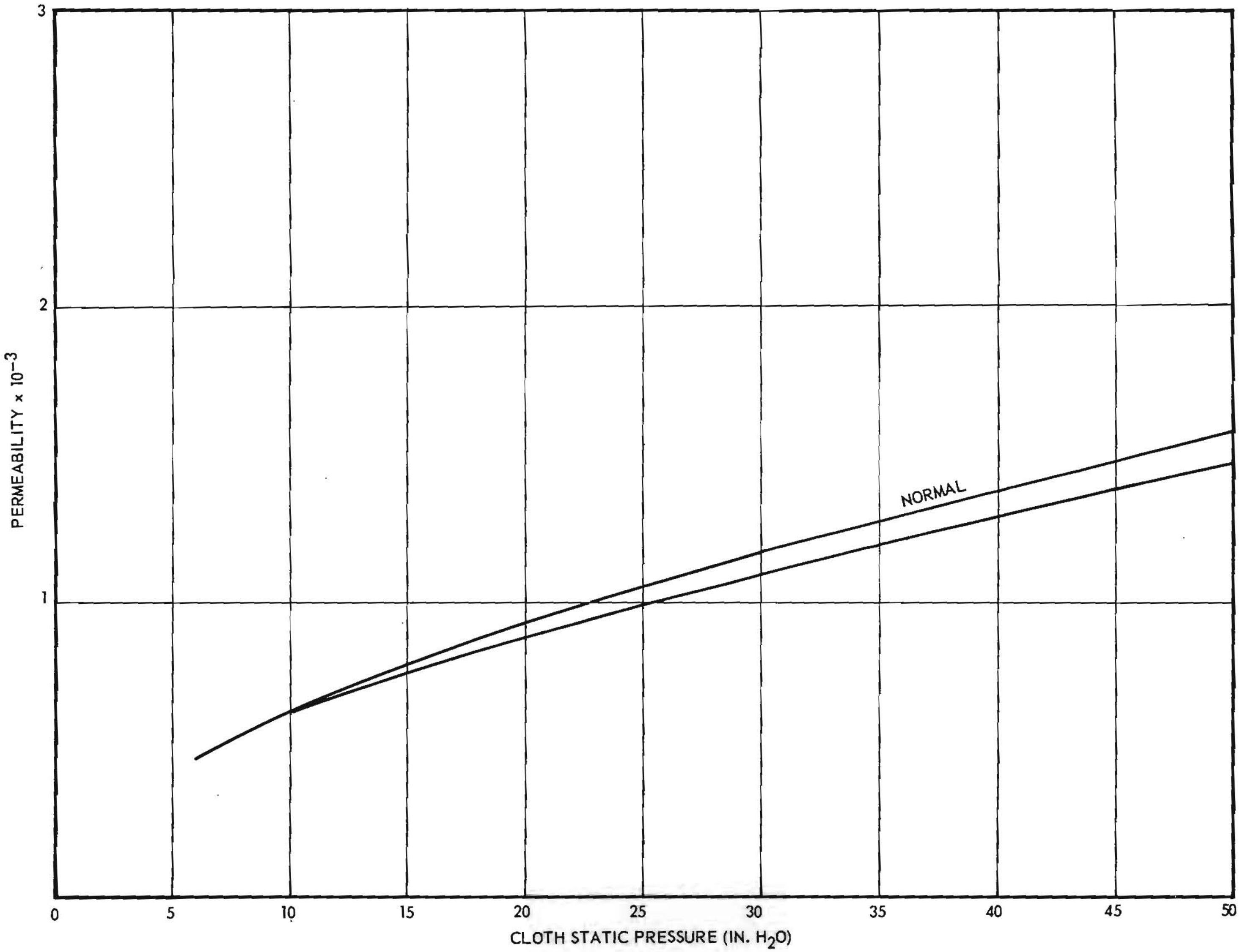

Figure 16. Effect of Light Start on Permeability of Mil-C-7020 Type II Fabric.

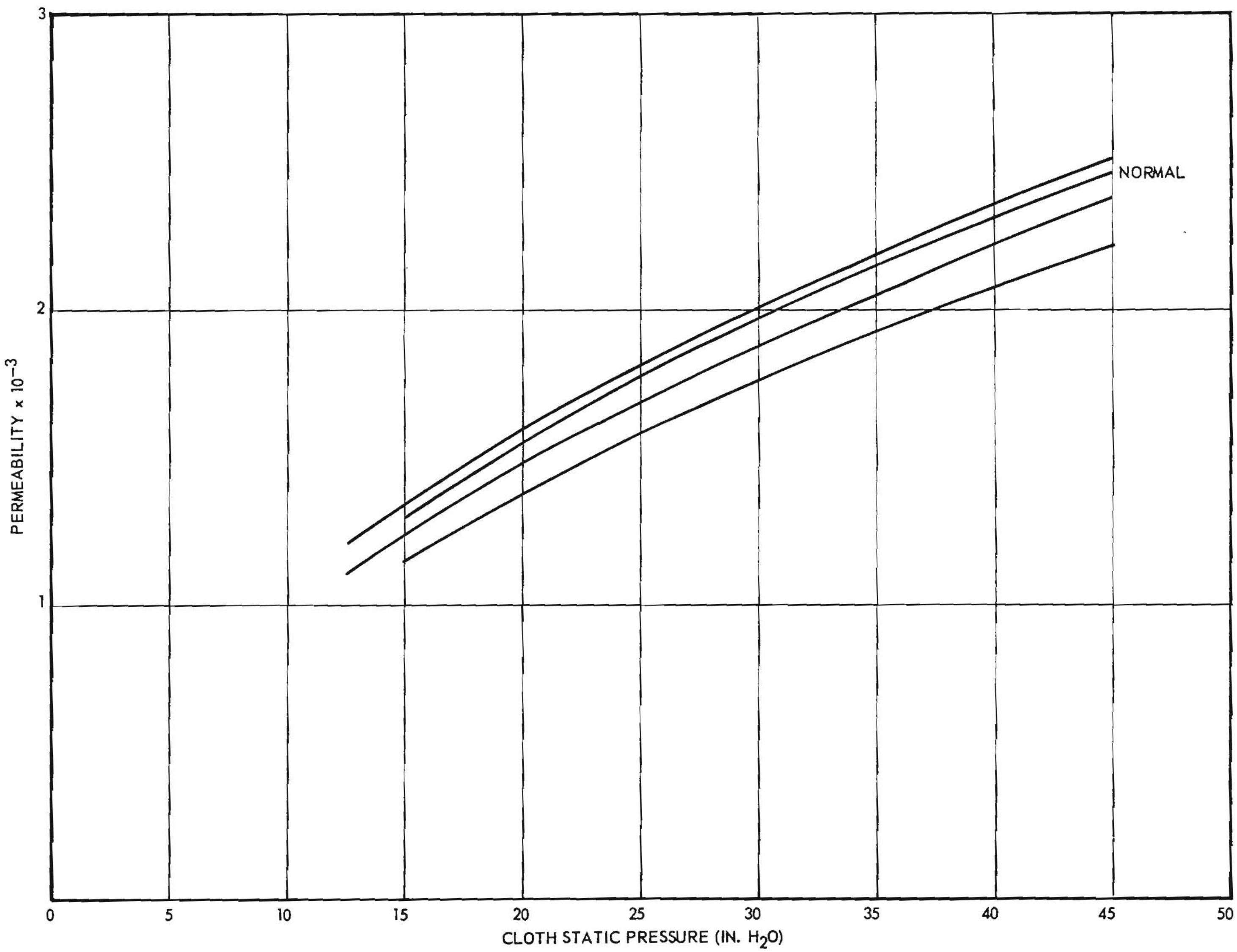

Figure 17. Effect of Mispicks on Permeability of Mil-C-7020 Type I Fabric.

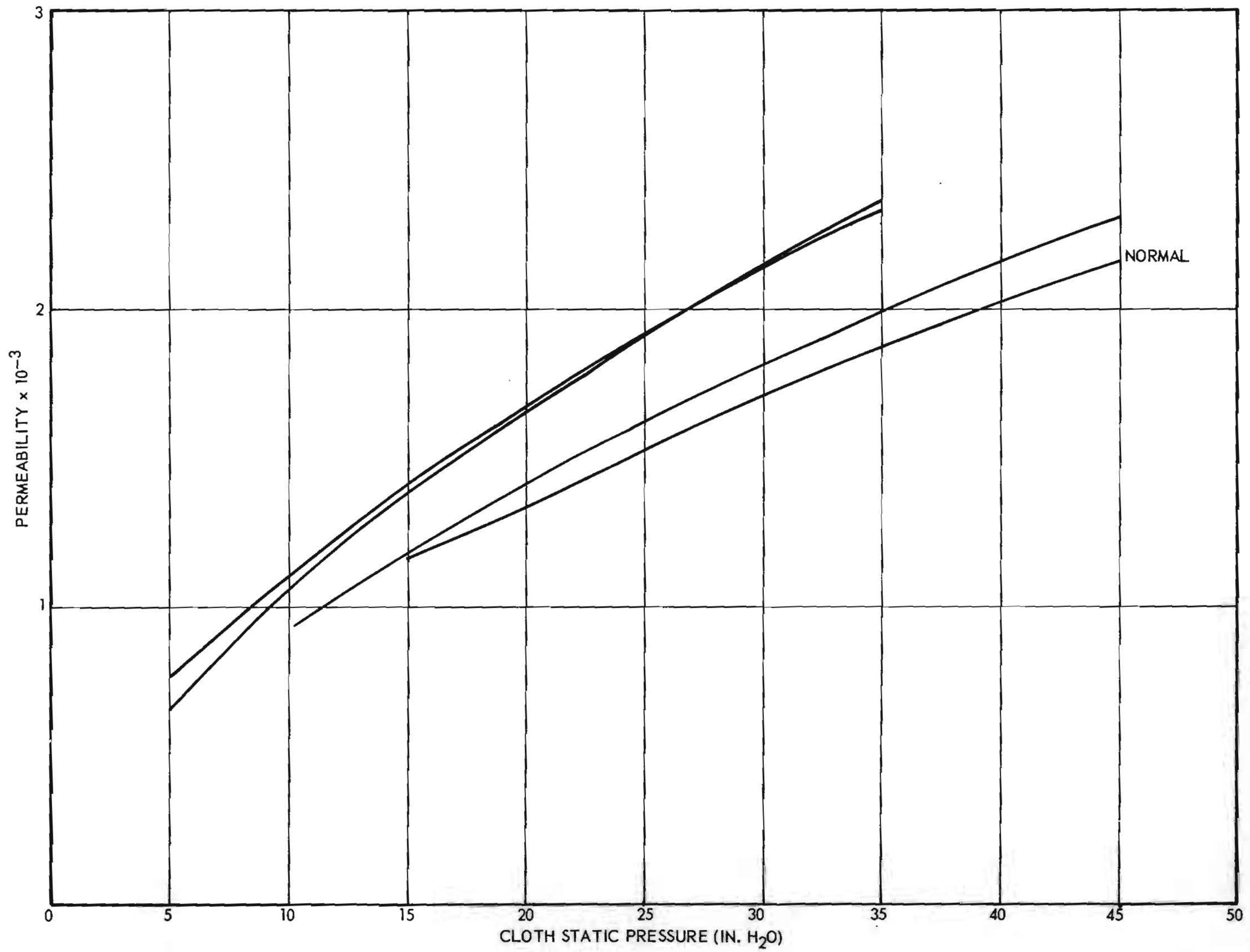

Figure 18. Effect of Mispick and Floats on Permeability of Mil-C-7020 Type I Fabric.

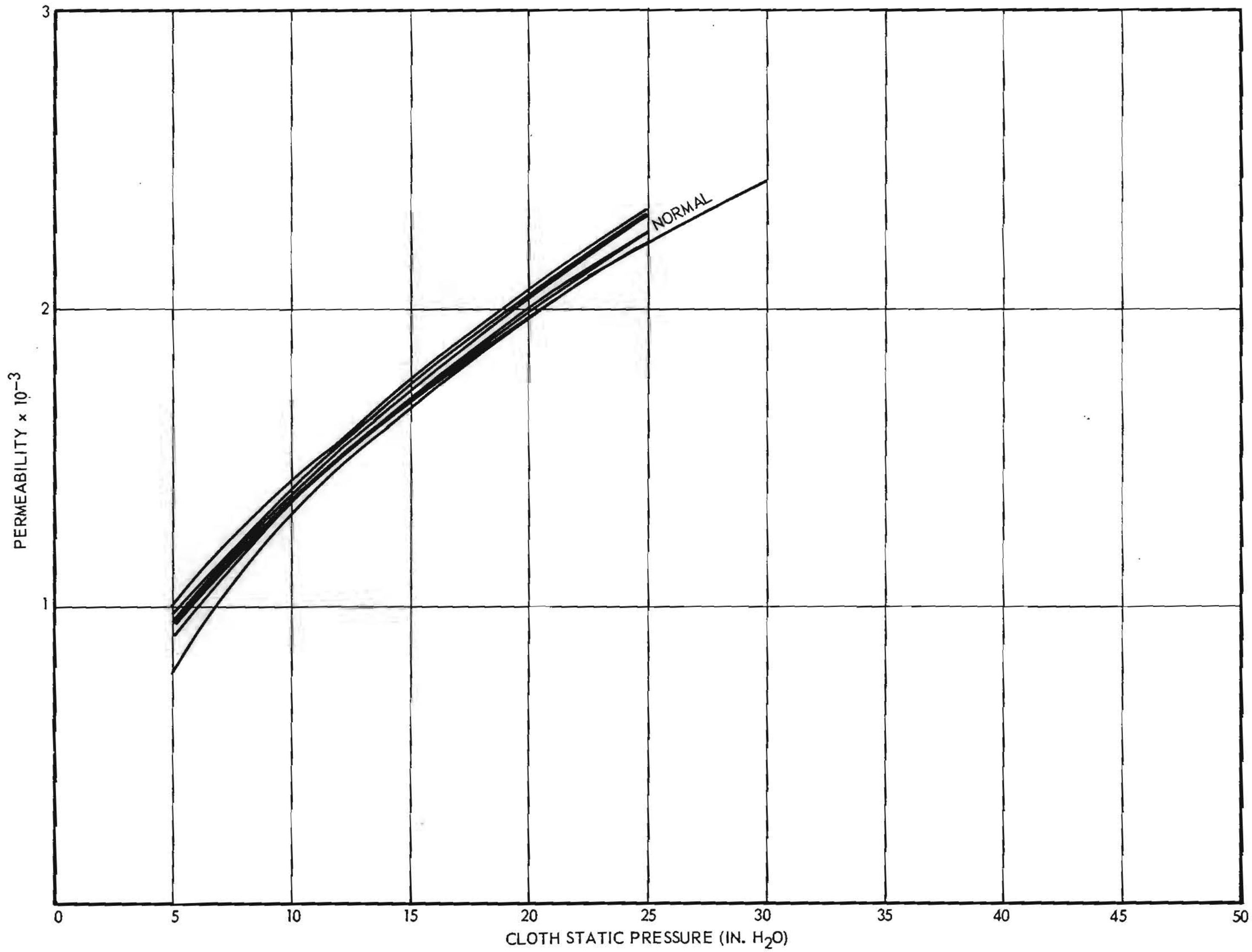

Figure 19. Effect of Shift Marks on Permeability of Mil-C-7350 Type I Fabric.

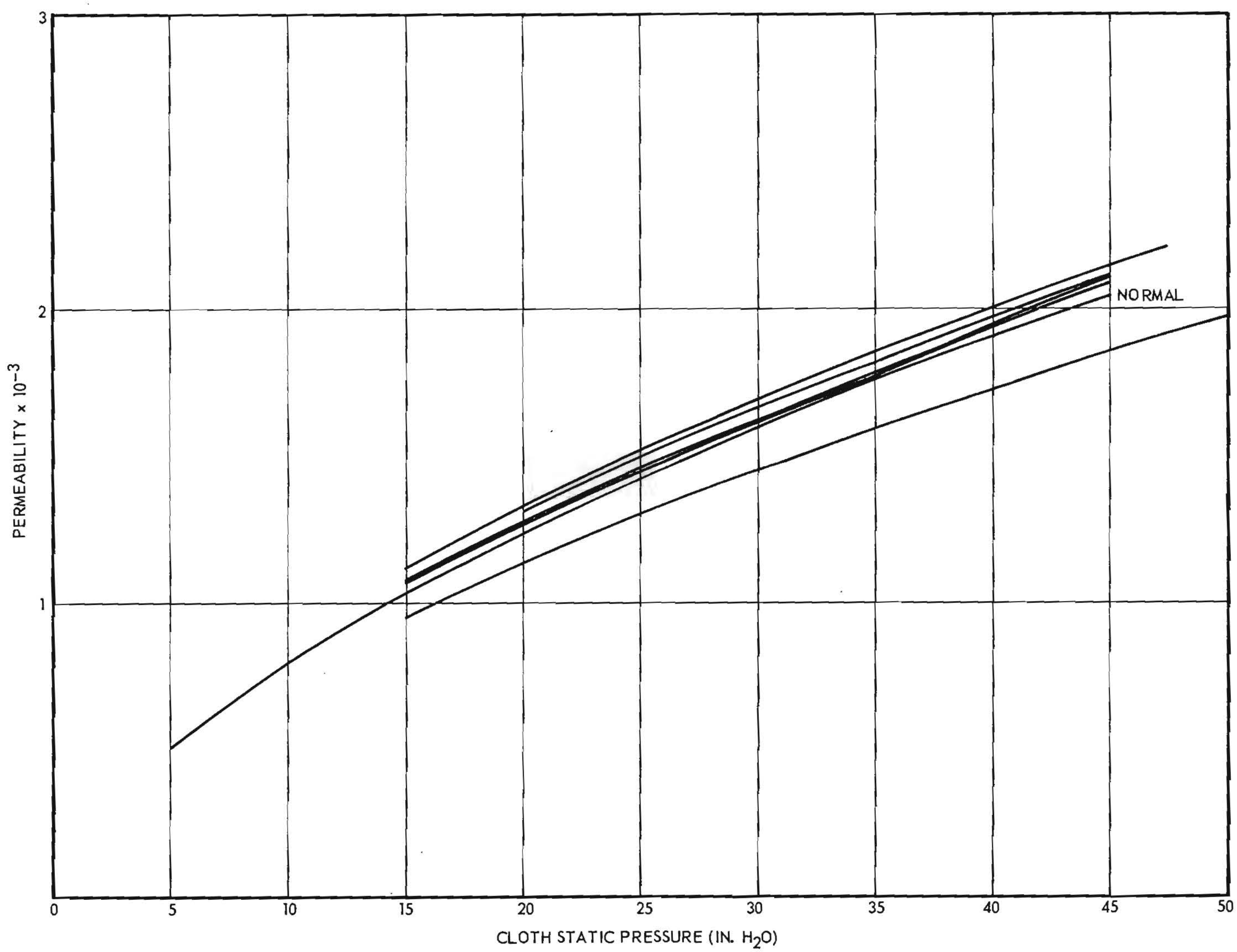

Figure 20. Effect of Light Joining on Permeability of Mil-C-7020 Type I Fabric.

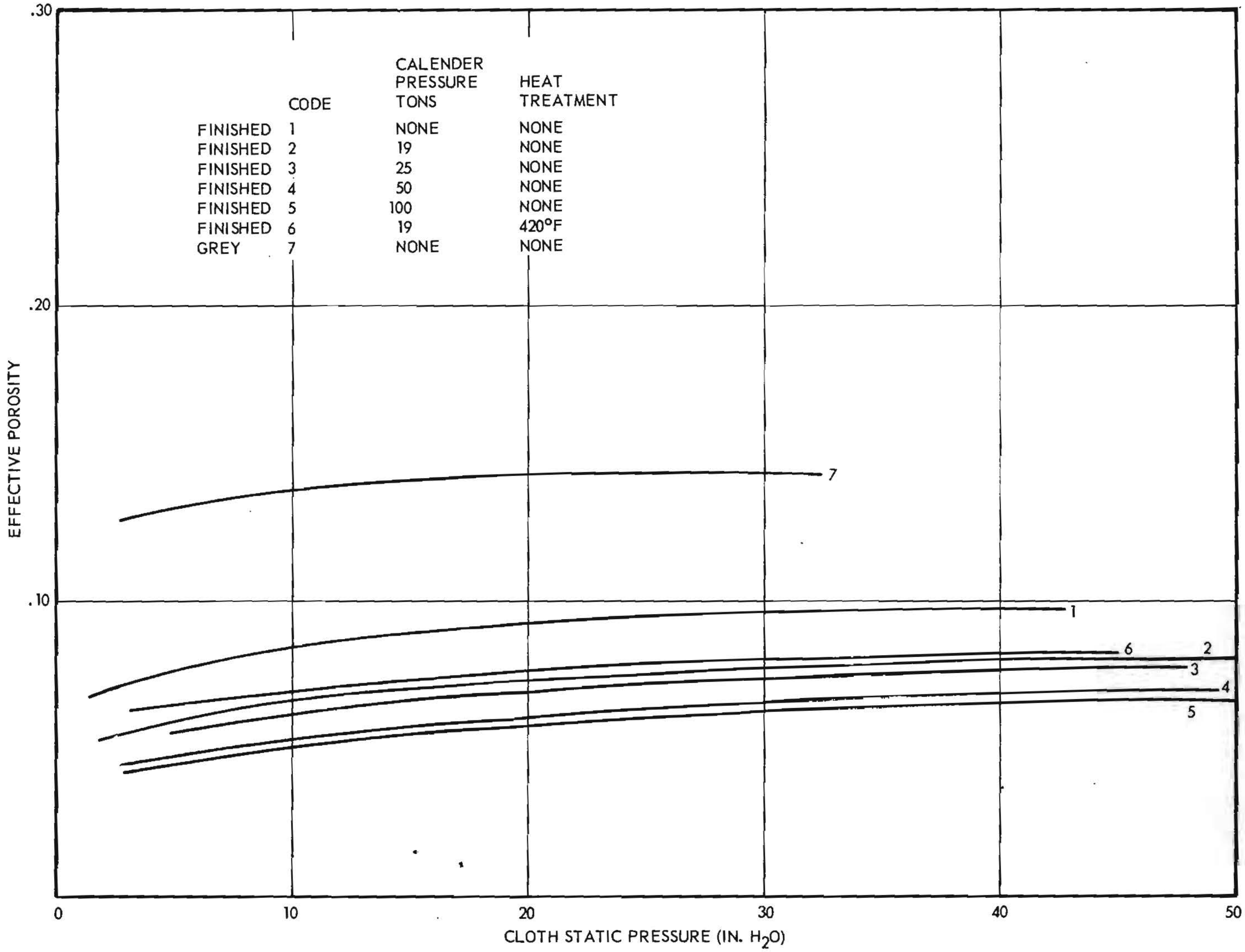

Figure 21. Effect of Variation of Calender Pressure on Effective Porosity of Mil-C-7020 Type I Fabric.

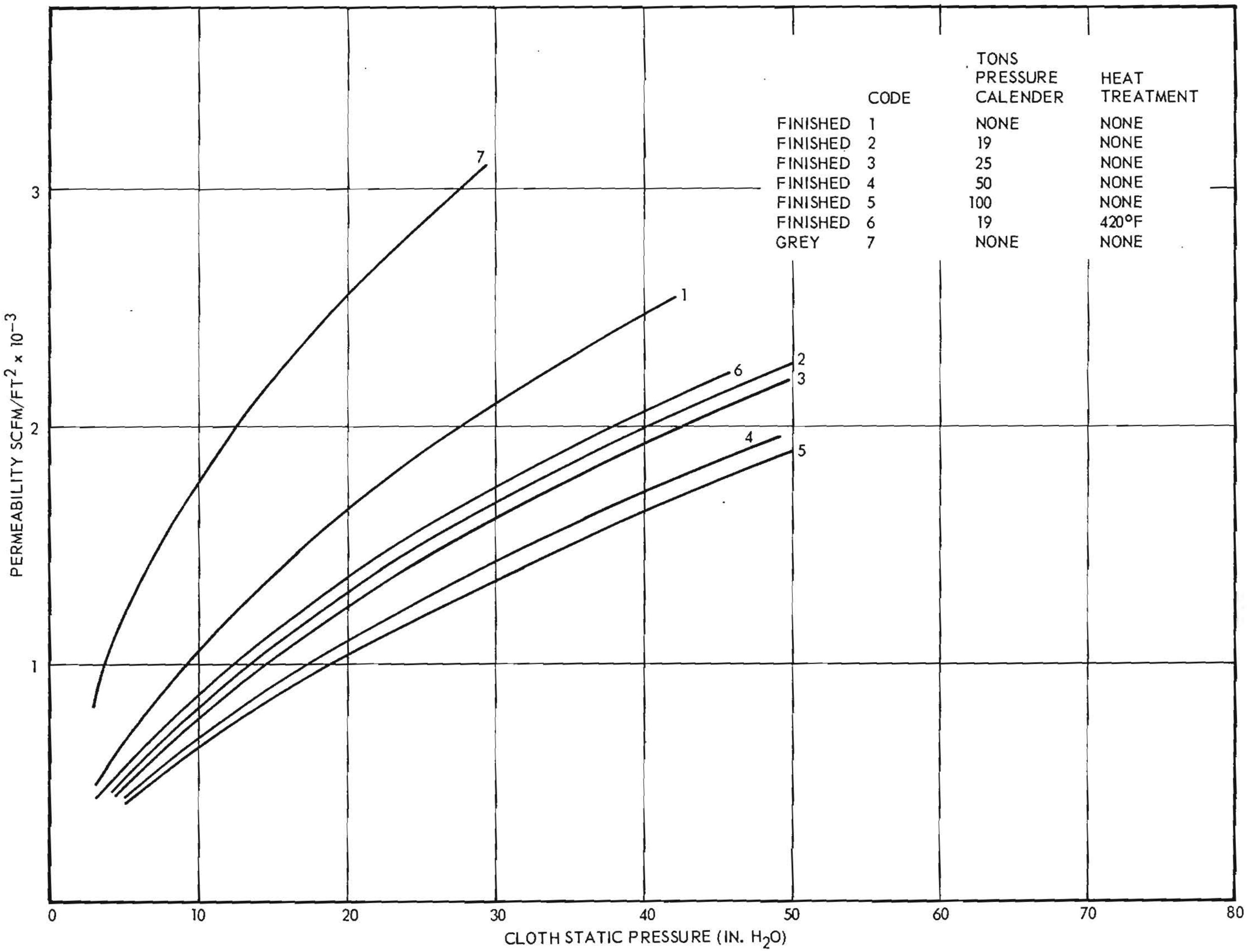

Figure 22. Effect of Variation of Calender Pressure and Finishing on Permeability of Mil-C-7020 Type I Fabric.

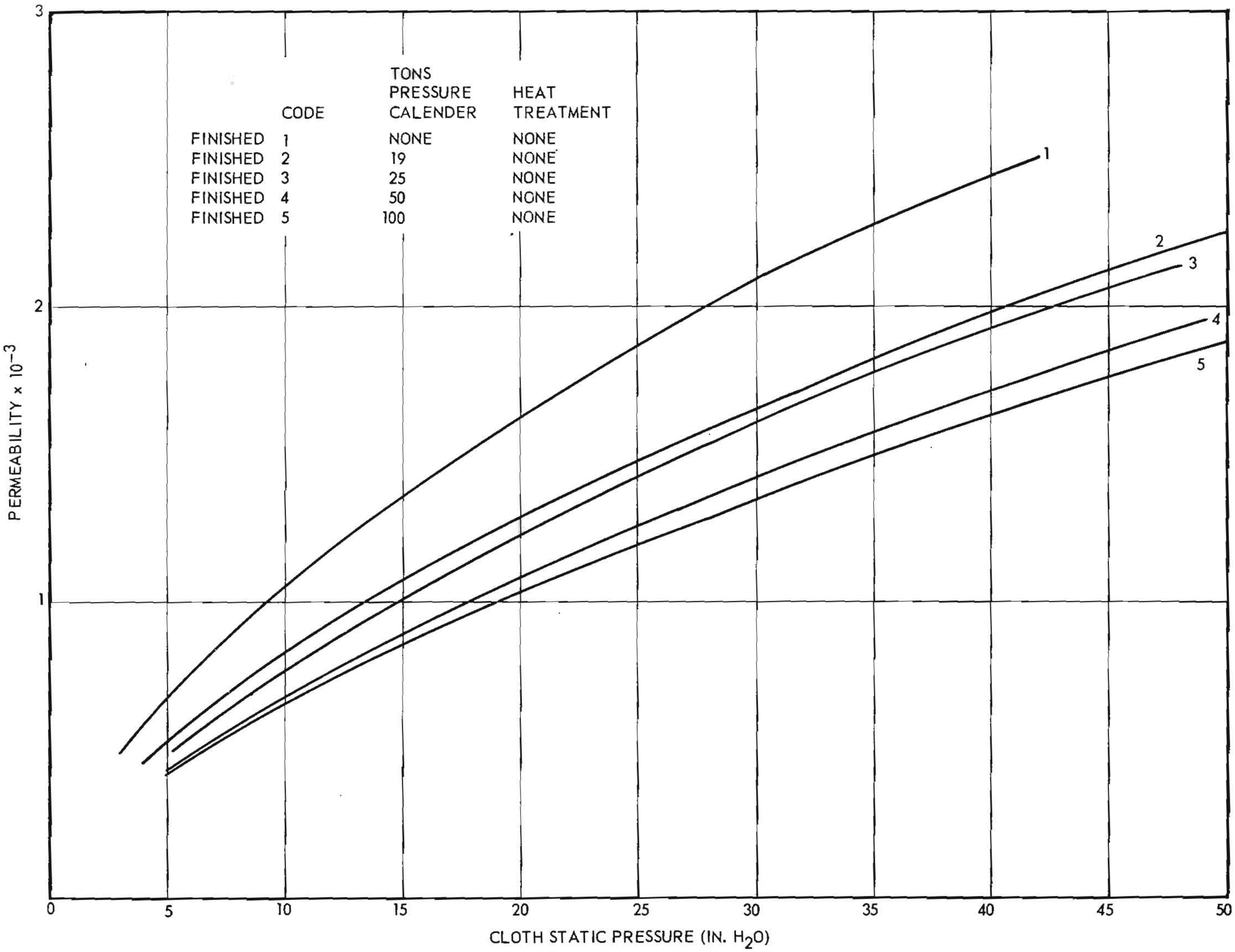

Figure 23. Effect of Variation of Calender Pressure on Permeability of Mil-C-7020 Type I Fabric.

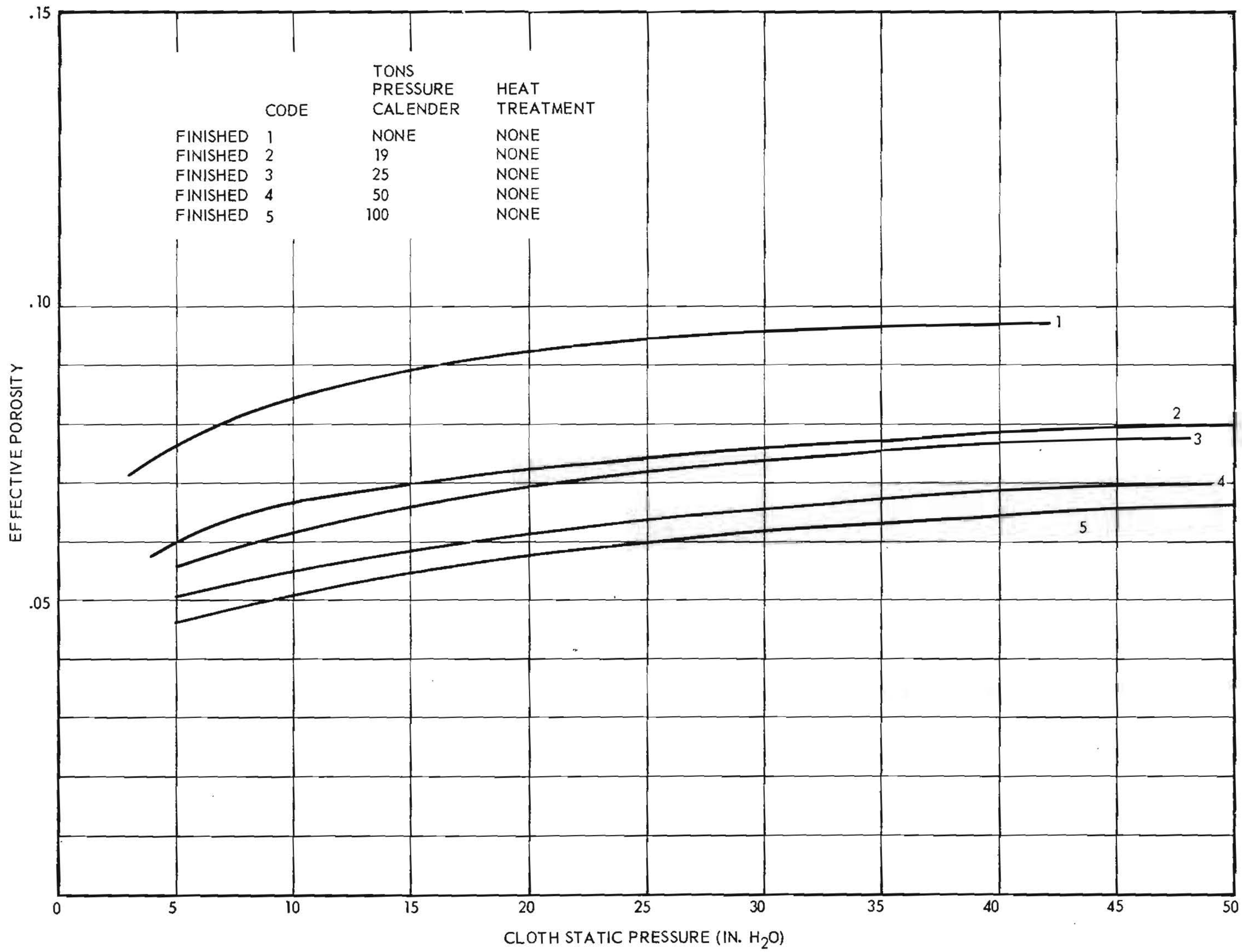

Figure 24. Effect of Variation of Calender Pressure on Effective Porosity on Mil-C-7020 Type I Fabric.

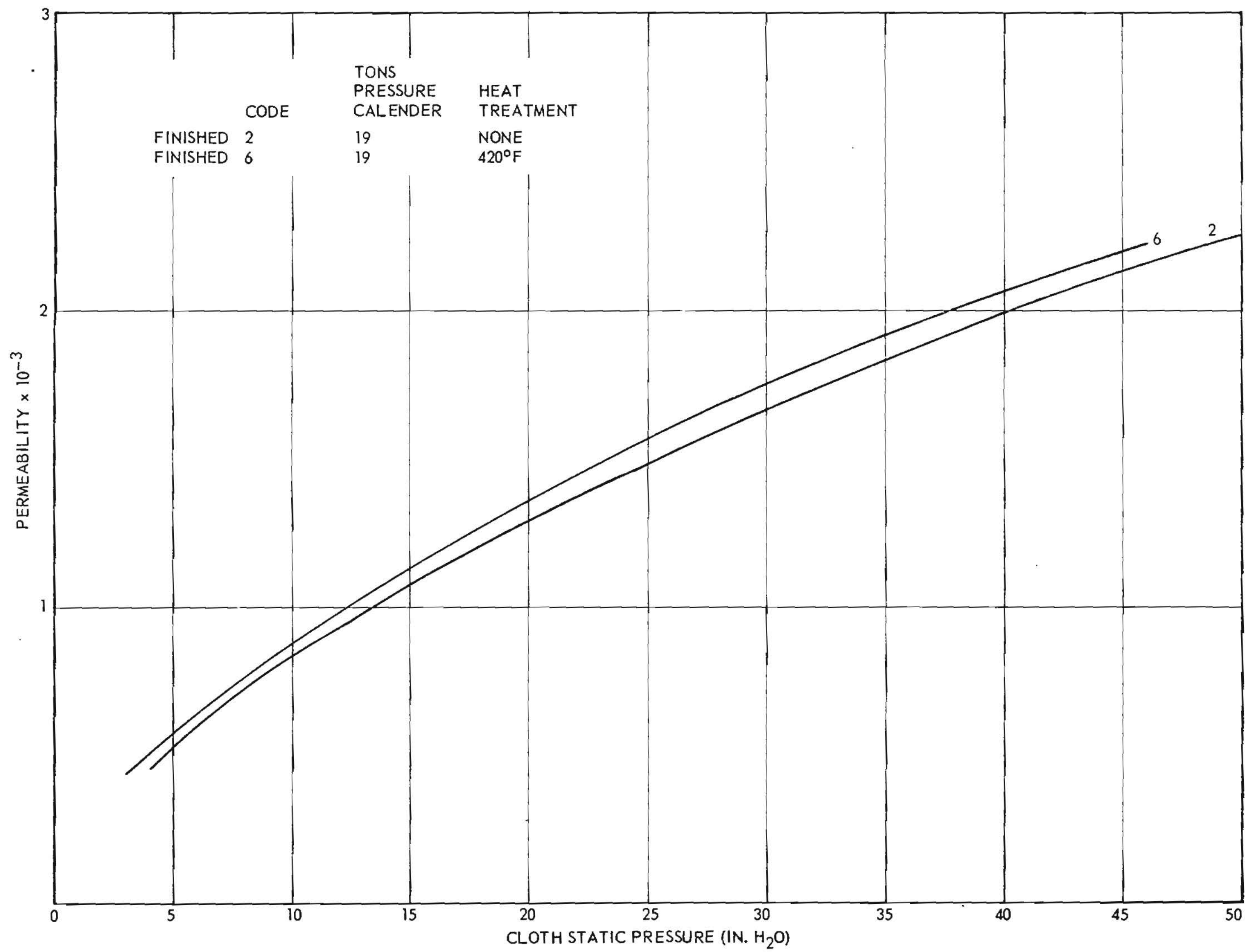

Figure 25- Effect of Heat Treatment on Permeability of Mil-C-7020 Type I Fabric.

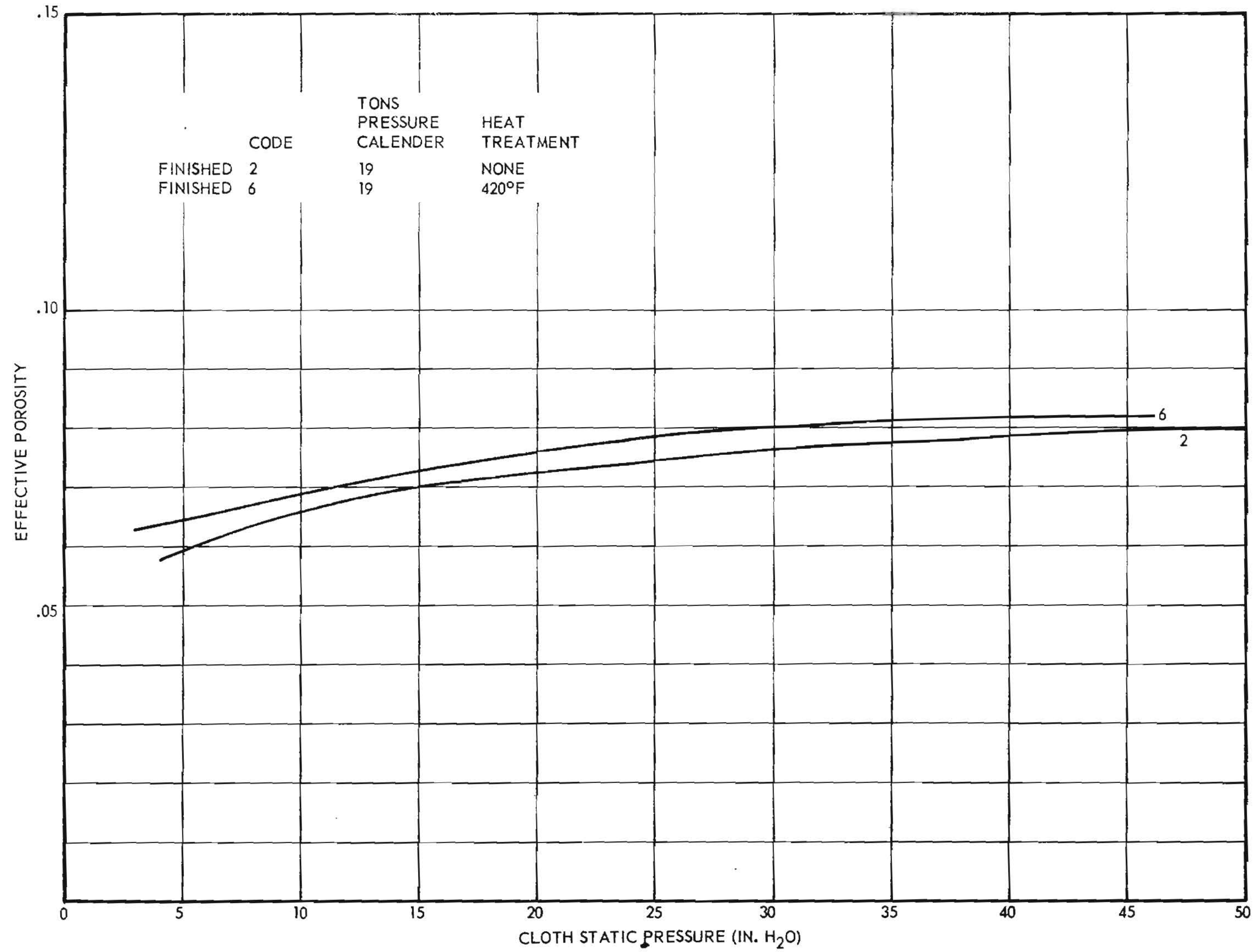

Figure 26. Effect of Heat Treatment on Effective Porosity of Mil-C-7020 Type I Fabric.

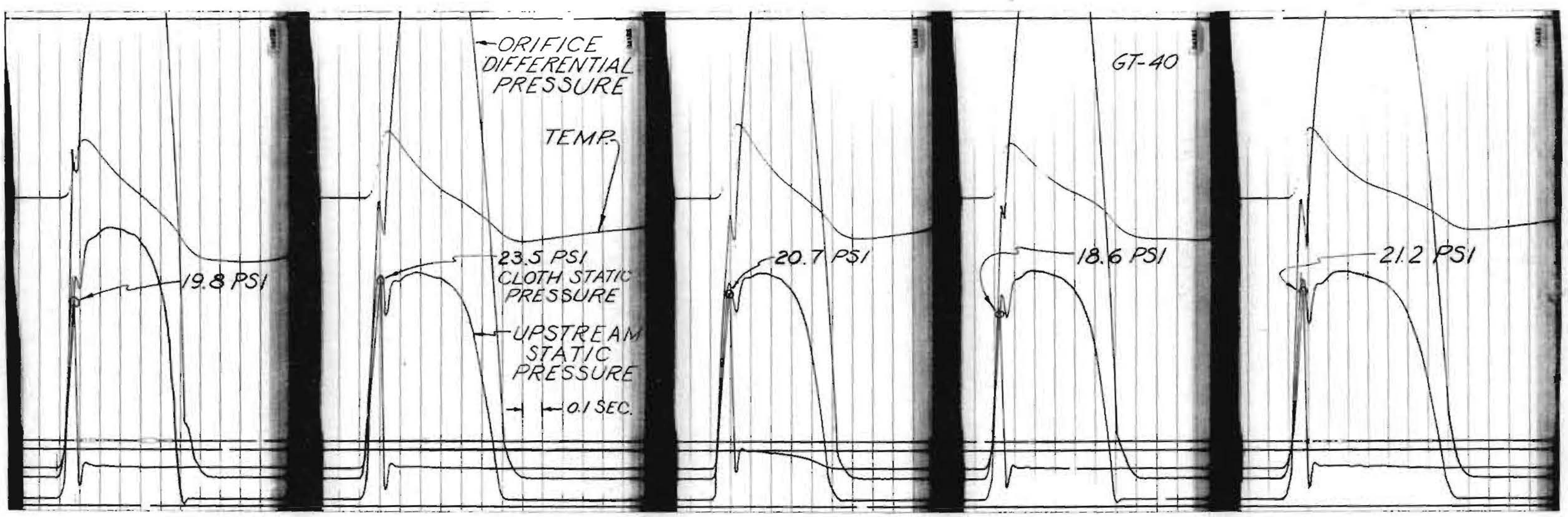

Figure 27. Photograph of the Oscillograph Records for the Impact Bursting of GT-40 100 x 70 Twill Orlon Fabric. The Breaking Point is Circled for Emphasis. The Cloth Static Pressure may be Easily Identified since the Trace Drops Immediately to the Zero Output Position. Chart Speed was 2 Inches per Second.

170-

ENGINEERING EXPERIMENT STATION
of the Georgia Institute of Technology
Atlanta, Georgia

INTERIM REPORT NO. 1

PROJECT NO. 170-117

PERMEABILITY OF PARACHUTE FABRICS

By

H. W. S. LAVIER

- o - o - o - o -

CONTRACT NO. AF 33(038)-15624
E.O. No. R602-198, Project No. 52-660A-41 SR7s
E.O. No. R602-193SR7S, Project No. 52-660A-25

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MARCH 15, 1953 to MAY 1, 1953

ENGINEERING EXPERIMENT STATION
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E.O. No. R602-193SR7S, Project No. 52-660A-25

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MARCH 15, 1953 to MAY 1, 1953

Interim Report No. 1, Project 170-117

This report summarizes the progress during the period from 15 March 1953 through 1 May 1953. It concerns the preparation and conduct of preliminary tests for the high-pressure phase of the subject research.

A. High-Pressure Permeability Equipment

During this period, the construction of the high-pressure permeometer was completed. Figure 1 is a general view of the permeometer. We have received the third transducer and two resistance temperature devices from Trans-Sonics, Inc. Also, the galvanometers and Type 5-116 oscillograph were delivered by Consolidated Engineering Company. These deliveries permitted the completion of the permeometer instrumentation.

An unfortunate accident resulted in silica-gel's being drawn from the C. D. Kemp Dryer into the cylinder and valve system of the Worthington Compressor. This necessitated a complete dismantling of the compressor and a thorough cleaning of the cylinder, piston and valves. Some delay in conducting the preliminary tests was caused by this accident.

The first of the group of preliminary tests was for the purpose of evaluating the two sample holders. Some modification of these parts was required to insure proper retention of the fabric in the sample holder. Figure 2 is an exploded view of the basic sample holder.

A special sample holder was designed to measure the biaxial tension loads in the fabric sample during the time of air flow. An idea of the construction details of this sample holder may be obtained through the exploded view, Figure 3, of the Biaxial Tension Load Sample Holder.

Preliminary biaxial tension tests with air flow through parachute fabrics were successful. Some alterations of the sample holder and techniques of operation were required.

An orifice meter has been incorporated in the high-pressure permeometer. To insure accuracy of measurement with this device, studies were made to compare orifice pressure differential and temperature to tank pressure and temperature, relative to time. By means of the record of tank pressure and temperature variation with time during blow down, an accurate computation of the weight rate of flow may be made. This is then compared with the flow data obtained by use of the orifice meter in the usual manner. A part of the calibration has been a comparison of flow rate versus time as obtained from the tank conditions and as from the orifice meter.

Several fabrics were run in the basic sample holder and preliminary high-pressure air permeability data was obtained. The procedure of testing each fabric involved setting first a low-pressure differential across the cloth by adjusting the pressure-regulating valve. The instruments were started and the quick-acting air valve was opened suddenly. This applied a shock load to the test sample. The run was continued until the pressure stabilized. Then the regulator valve was adjusted to give a higher pressure across the fabric sample, and the procedure above was repeated. The pressure differentials were adjusted higher and higher during successive runs until the fabric sample failed or until the limit of the apparatus was obtained.

Figure 4 is a typical air permeability curve for the high-pressure shock-loading type of investigation for ES-4, 126 x 77 Twill, 40/70-denier nylon. Air permeability testing of parachute fabrics under simulated shock loading conditions is new. Therefore, it will require careful consideration of the best way of reproducing the data and curve for the most convenient use of those who will apply the results of the subject research.

A close-up view, Figure 5, is shown of the Consolidated Type 5-116 Nine-Channel Oscillograph and the Type 118 Four-Channel Carrier Amplifier used in this program. Figure 6 is a photograph of a portion of a typical oscillograph record. Dew point of the stored air is measured by the General Electric Dew Point Indicator.

B. Deformation of Fabric Under Load (No Air Flow)

The machine for biaxial tension loading of fabric samples is now complete. The photo observer for recording the load-elongation data is also complete. A special device to transmit the bidimensional fabric elongation to the photo observer is shown in Figure 7. A general view of the Biaxial Fabric Tension Testing Machine with the Four-Channel Carrier Amplifier and the photo observer is shown in Figure 8. Typical average load versus elongation curves for an ES-4, 126 x 77 Twill, 40/70-denier nylon parachute-type fabric are shown in Figure 9.

An insulated housing, to cover the top area of the machine in the region of the sample and tension jaws, is now being constructed. This housing will be equipped with a blower and heaters needed to obtain elevated temperatures. Ice and dry ice will be used to obtain the low temperatures. A device to vary the humidity will be incorporated in this housing.

C. Analysis and Conclusions

The low-pressure phase is complete with the issuing of Technical Report No. 2. The preliminary tests of the high-pressure phase have been devoted to evaluating the equipment, developing research techniques, and determining the best ways to present research results.

D. Technical Discussions

The writer visited the Textile Branch at Wright Air Development Center on 2 April 1953. Progress of the research and permeability testing for Fabric Research Laboratories, Inc., was the subject of this visit. On 10 April 1953, the writer presented a paper, "Results of Permeability Studies on Parachute Fabrics," at the Fourth Annual Southeastern Regional Conference of Student Branches of the Institute of Aeronautical Sciences held at Mississippi State College.

E. Personnel

During the period 15 March through 1 May 1953 project personnel has included Professor H. W. S. LaVier, Project Director, Mrs. Donna W. Williams, Project Secretary, Mr. Cecil D. Brown, Research Assistant, and Messrs. W. C. Boteler and T. P. Bankston, both Graduate Assistants. Mr. Peter Stanton was a Student Assistant.

Professor George K. Williams, a specialist on electric resistance strain gage devices, assisted the project staff during this period.

Respectfully submitted:

Hurlbut W. S. LaVier
Project Director

Approved:

Herschel H. Cudd, Acting Director
Engineering Experiment Station

APPENDIX A

FIGURES

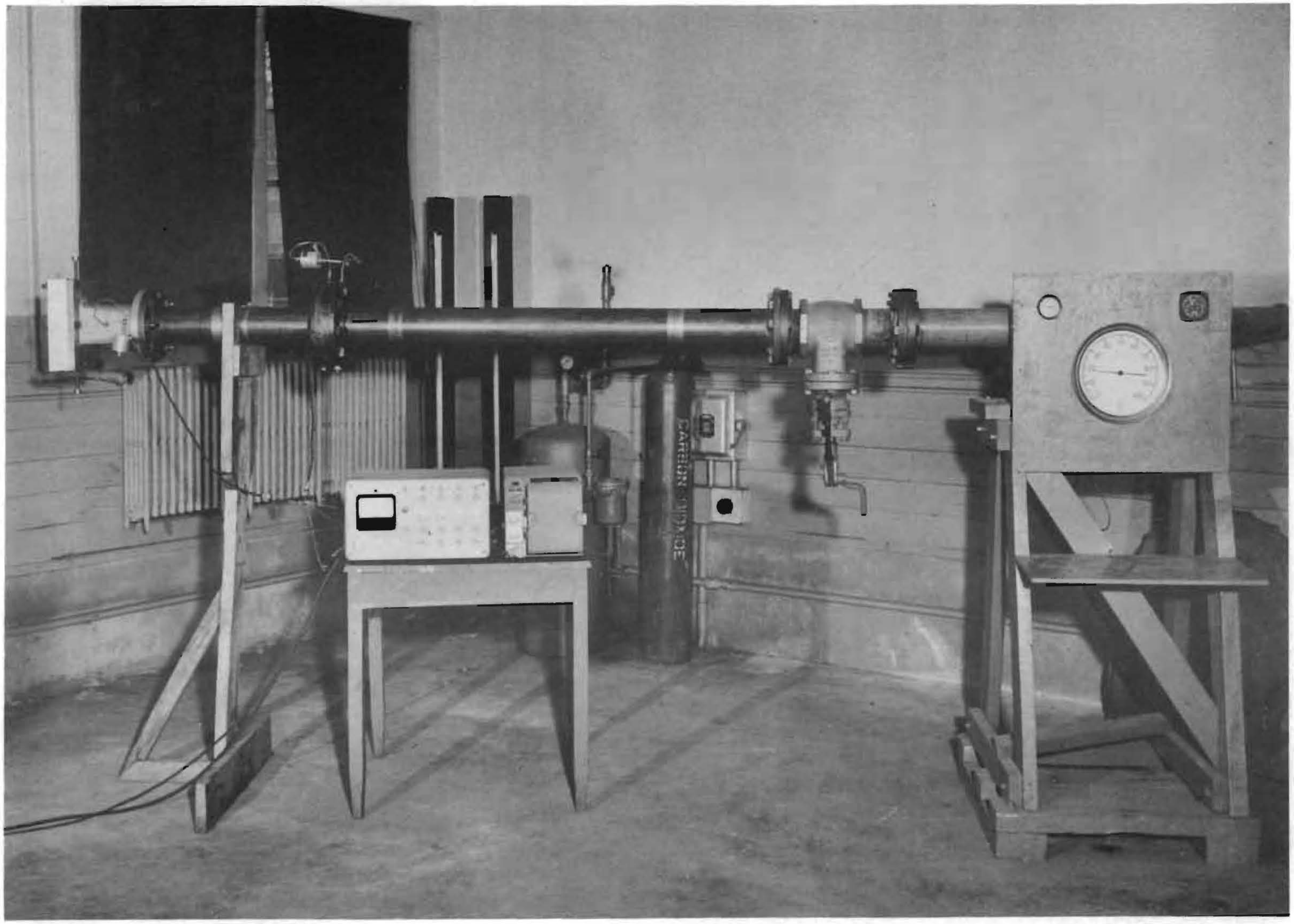

Figure 1. General View of the Ga. Tech High-Pressure Permeometer.

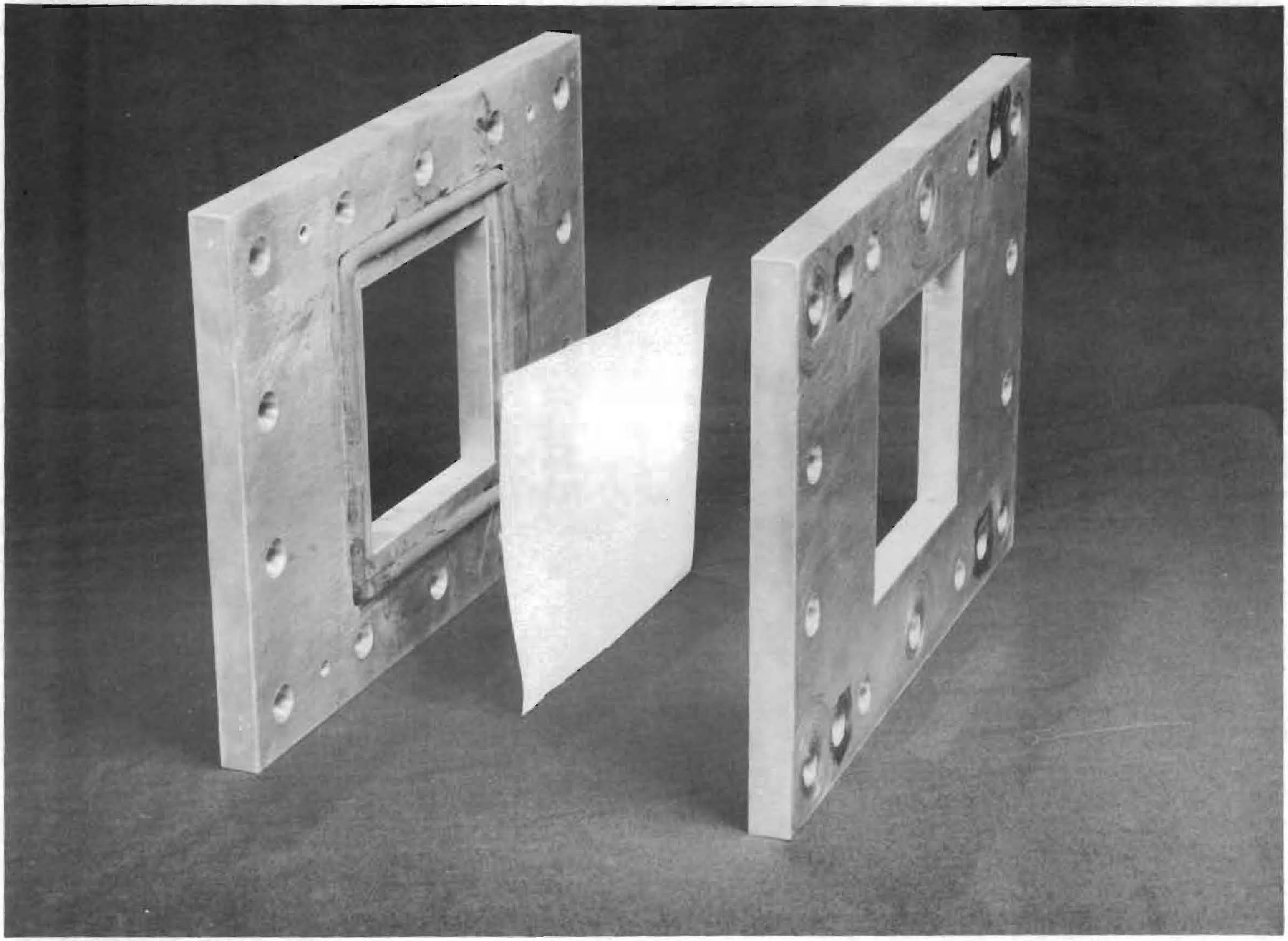

Figure 2. Exploded View of Simple Sample Holder.

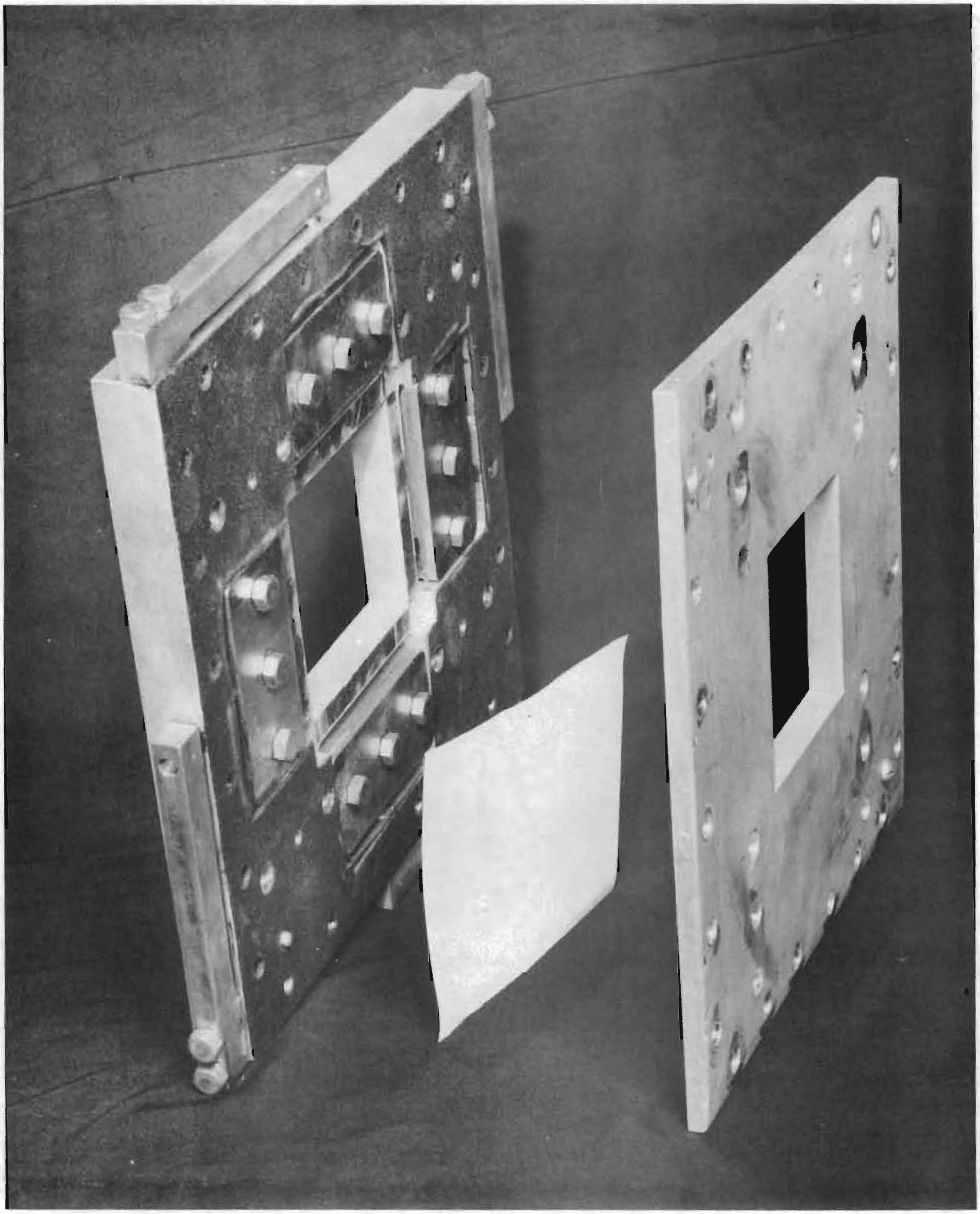

Figure 3. Exploded View of Biaxial Tension Sample Holder.

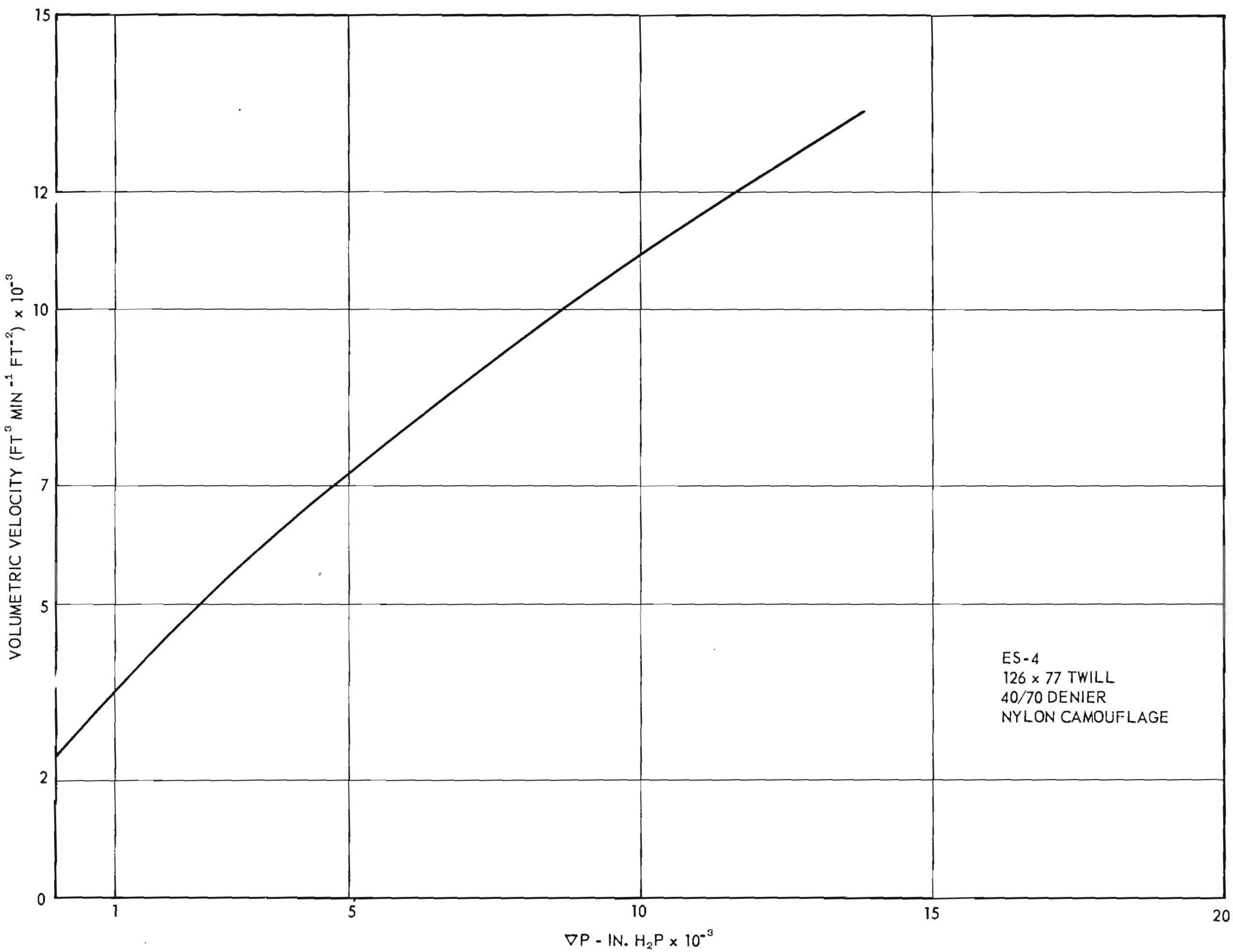

Figure 4. High Pressure Air Permeability Curve.

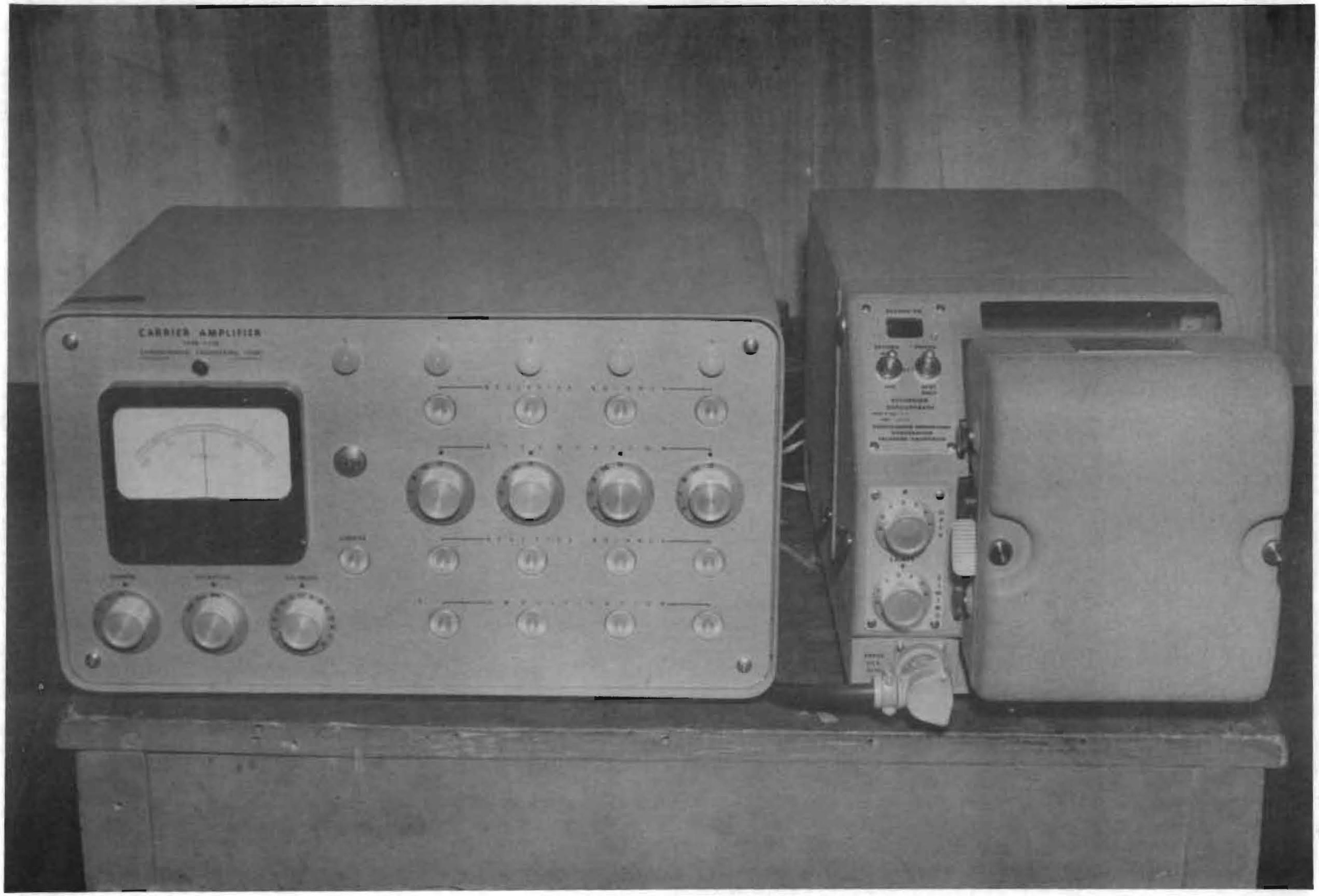

Figure 5. Carrier Wave Amplifier and Recording Oscillograph.

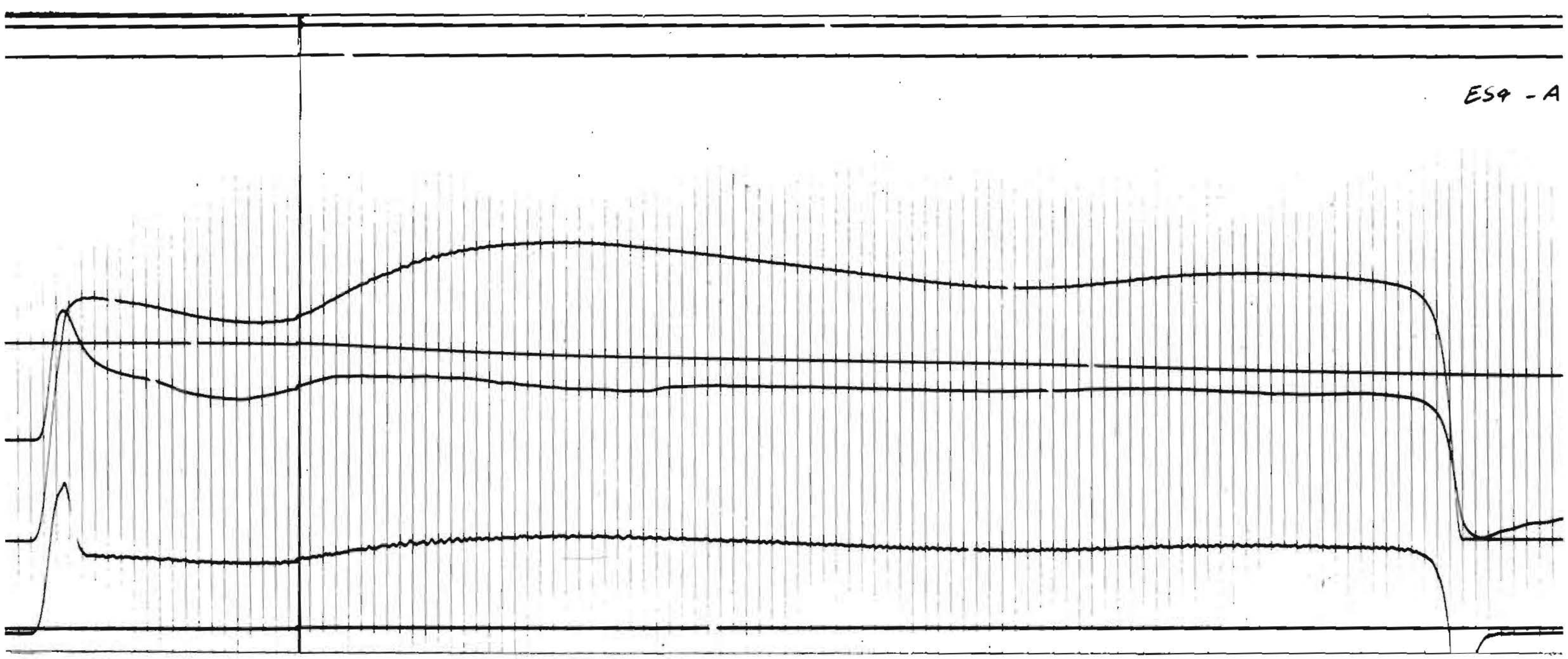

Figure 6. A Photograph of a Portion of a Typical Oscillograph Record.

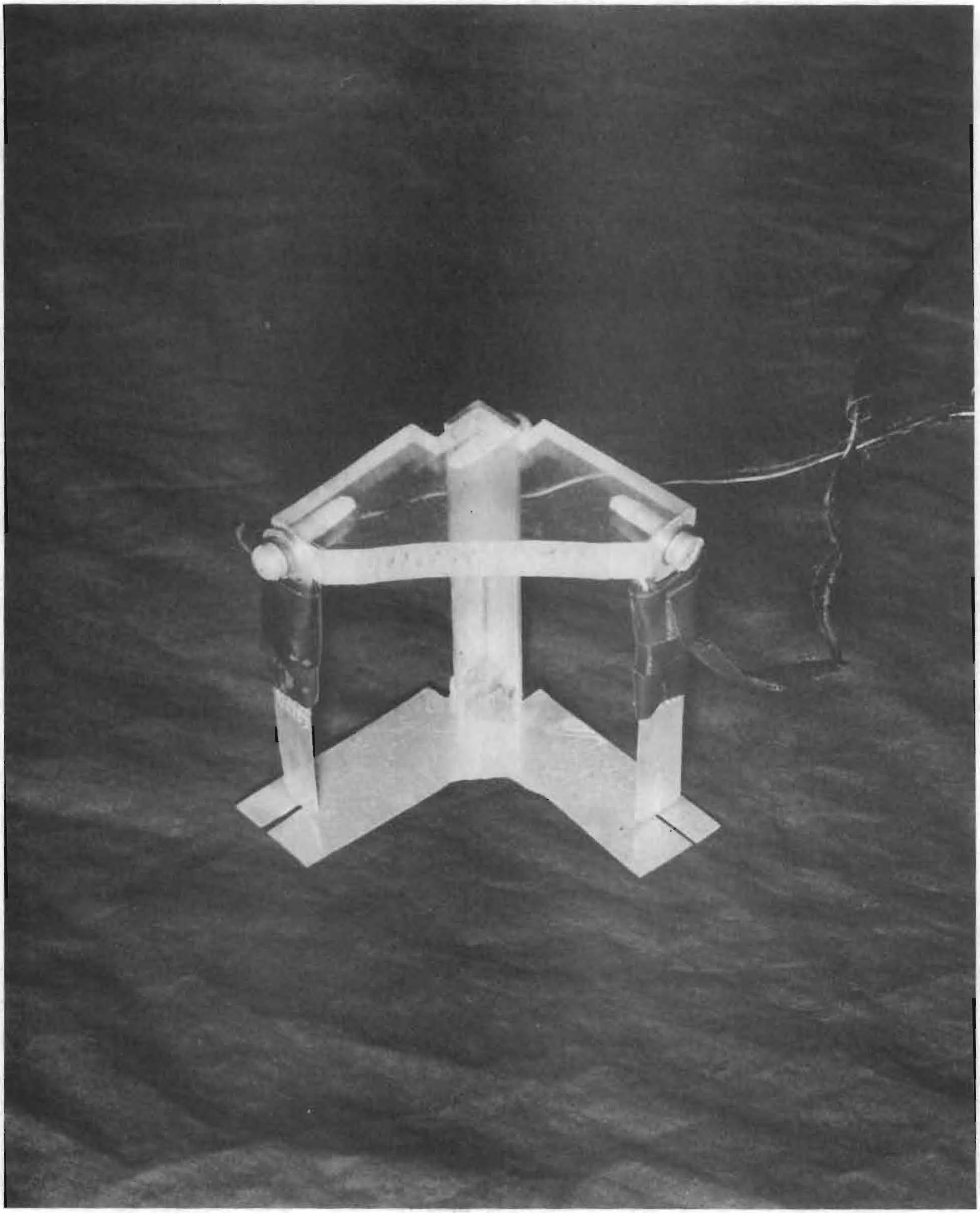

Figure 7. Special Fabric Extensometer.

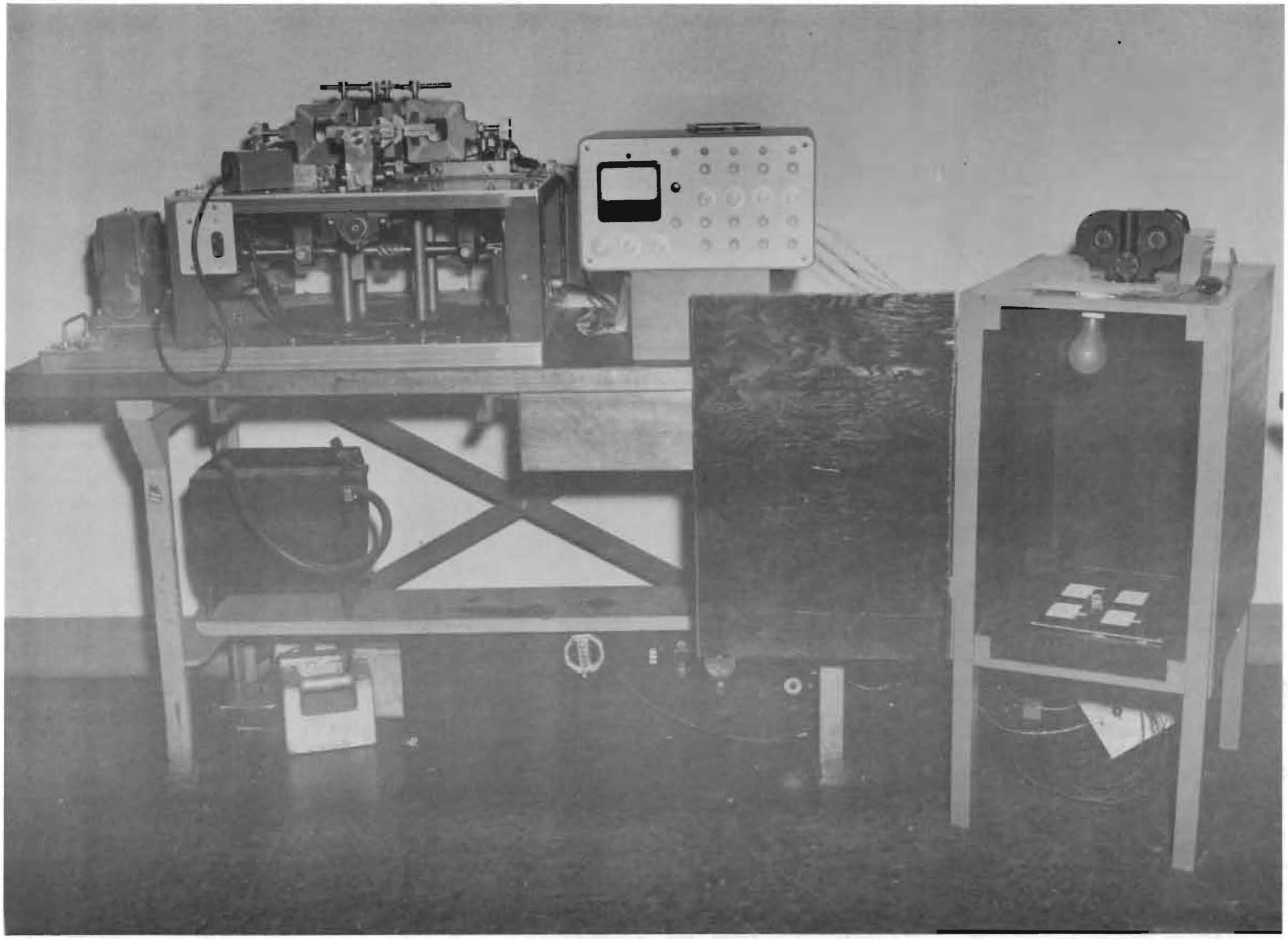

Figure 8. General View of the Biaxial Fabric Tension Testing Machine.

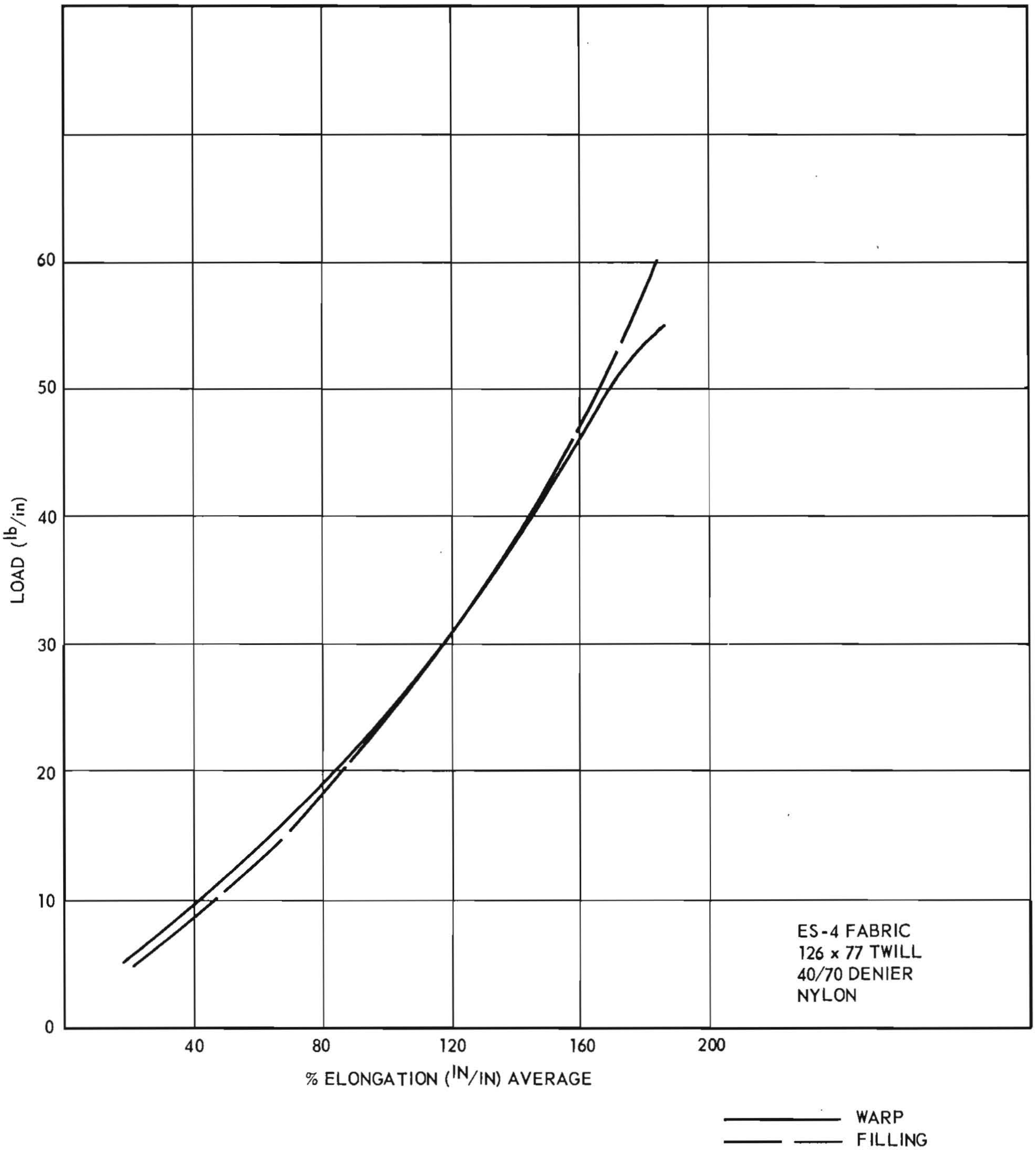

Figure 9. Typical Biaxial Fabric Tension Load vs. Elongation Curve.

ENGINEERING EXPERIMENT STATION
of the Georgia Institute of Technology
Atlanta, Georgia

D5

INTERIM REPORT NO. 2

PROJECT NO. 170-117

PERMEABILITY OF PARACHUTE FABRICS

By

H. W. S. LAVIER

- o - o - o - o -

CONTRACT NO. AF 33(038)-15624
E.O. No. R602-198, Project No. 52-669A-41 SR7s
E.O. No. R602-193SR7S, Project No. 52-660A-25

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JUNE 1, 1953 THROUGH JULY 1, 1953

ENGINEERING EXPERIMENT STATION
of the Georgia Institute of Technology
Atlanta, Georgia

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JUNE 1, 1953 THROUGH JULY 1, 1953

This report summarizes the progress during the period from 1 May 1953 through 1 July 1953. It concerns the preparation and conduct of tests as a part of the high-pressure phase of the subject research. Prior to this period, project activities were largely devoted to the construction of special research equipment and the development of appropriate research techniques. High-pressure permeability test results for three fabrics are presented in Table II of Appendix A. The same results are shown graphically in Figures 12 through 14 of Appendix B. Numerical values of load versus elongation for biaxial tension load tests of three fabrics are presented in Table III of Appendix A. Curves of these results appear in Figures 15 through 17 of Appendix B.

I. HIGH-PRESSURE PERMEABILITY TESTS

A. Equipment

Further development of the Georgia Tech high-pressure permeometer was found to be necessary during the period subsequent to that covered by Interim Report No. 1. The Biaxial-Fabric Tension-Load Sample Holder, after minor modifications designed to eliminate the effects of friction, was used in all of the permeability tests except those for the first fabrics. Figure 1 is a view of the Biaxial-Fabric Tension-Load Sample Holder.

In regard to steady-state conditions, the orifice meter has been proved reliable over the entire pressure differential range of 0-54 psi. Some further calibration is required to ascertain the accuracy of the orifice meter when the flow is varying immediately after opening the valve. The orifice meter can be seen in the general view of the Georgia Tech high-pressure permeometer, Figure 2.

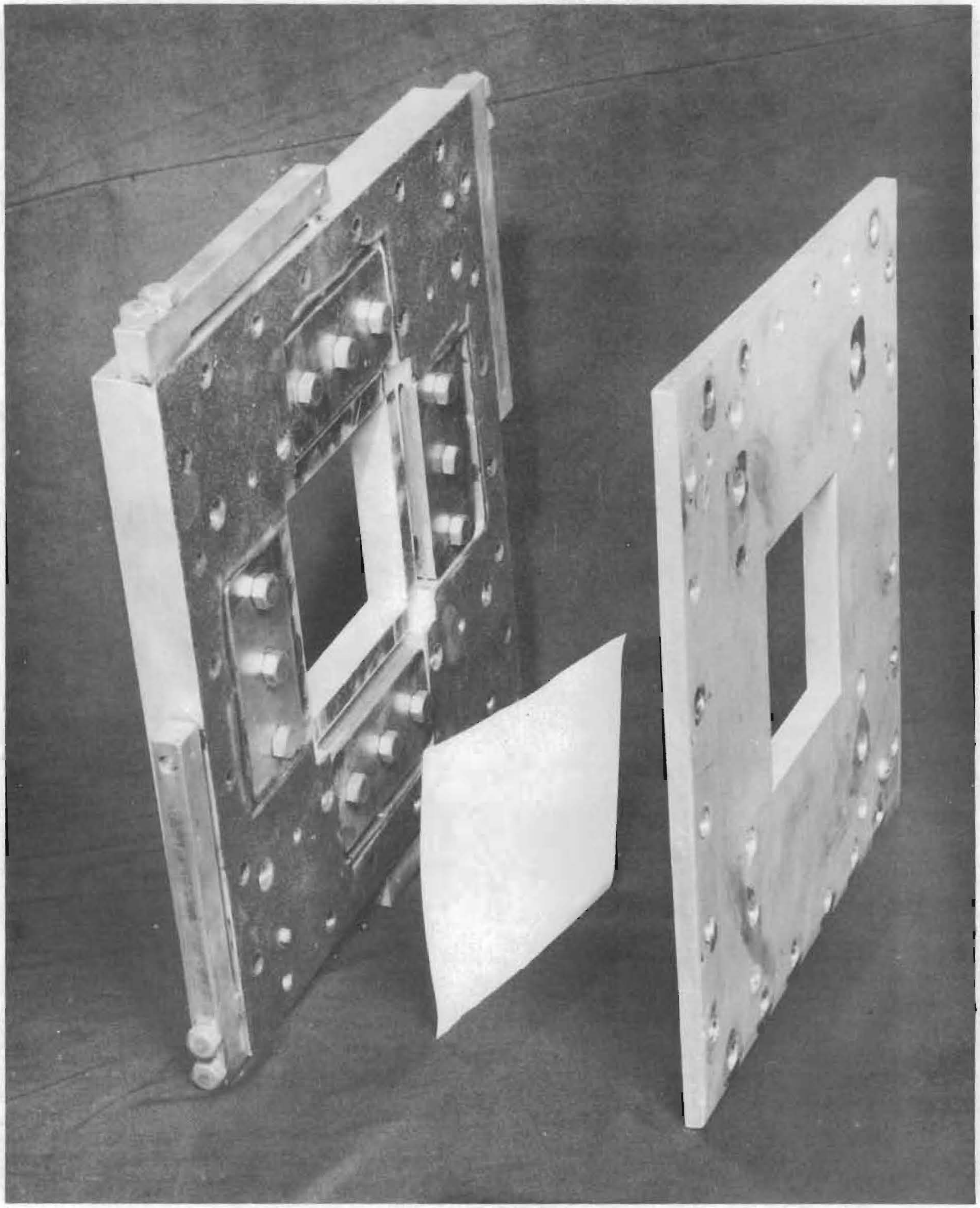

Figure 1. Exploded View of Biaxial Tension Sample Holder.

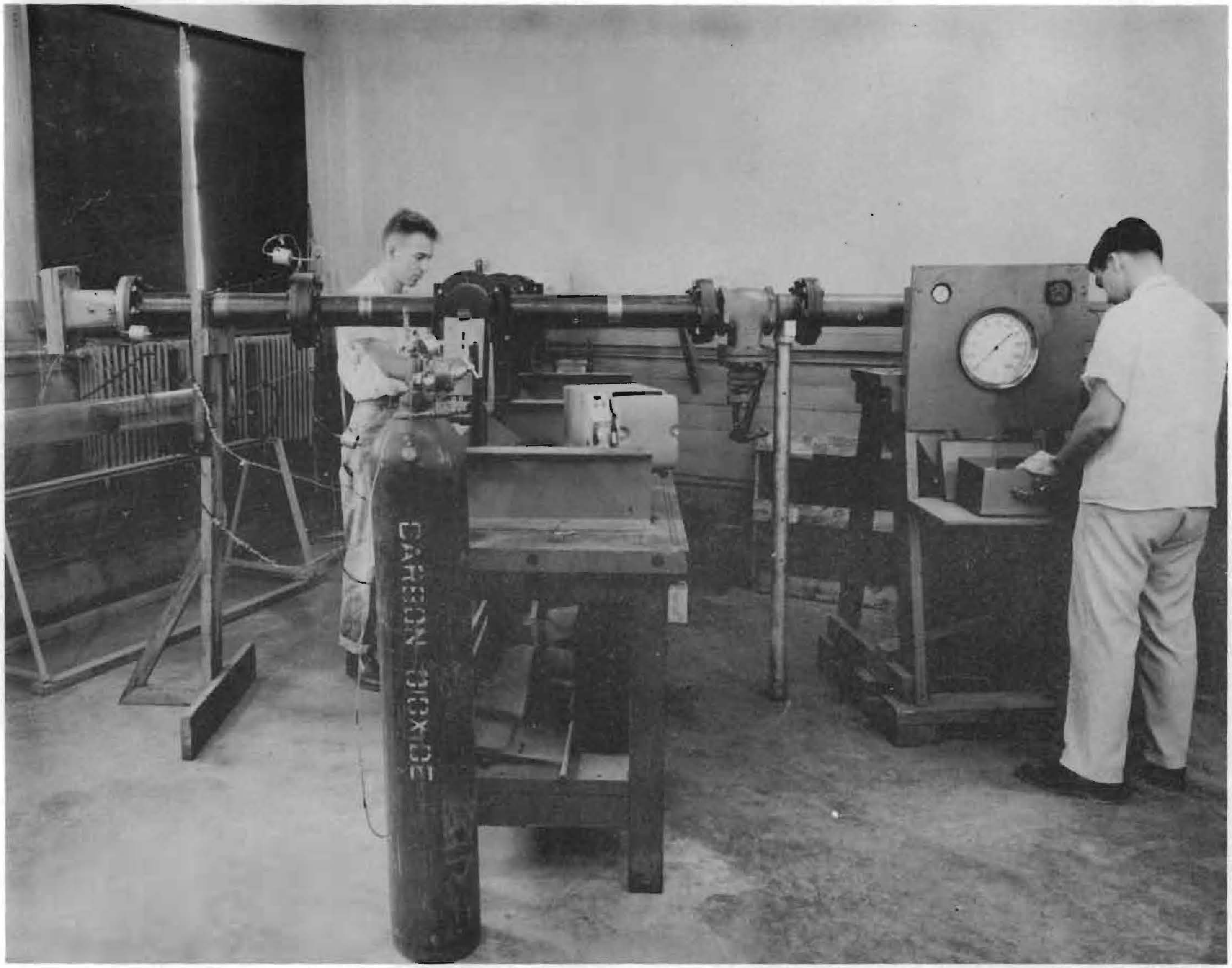

Figure 2. General View of the Georgia Tech High-Pressure Permeometer.

Variation of the air temperature is obtained by controlled operation of the compressor aftercooler and also by use of a special cooling device. High temperatures are obtained by using the hot compressed air as it comes out of the compressor and C. M. Kemp dryer and without using the water cooling of the aftercooler. This aftercooler is shown at the top of Figure 3, a general view of the Kemp Dryer. For low temperatures, cooling the compressed air as it passes through the high-pressure permeometer is accomplished by introducing liquid air upstream of the cut-off valve and just downstream of the pressure regulator valve. This equipment and its location are shown in Figure 4, a schematic view of the Georgia Tech high-pressure permeometer. By controlled use of the aftercooler and the liquid air-cooling equipment, a temperature range of from -30° F. to 130° F. should be obtained. Because of a delay in the delivery of valves and fittings, the cooling device is not yet complete. Therefore, tests presented in this report were all conducted at ordinary machine-operating temperatures (compressor aftercooler operating); some being obtained with the aftercooler coolant shut off. A high temperature of 168° F. was obtained.

It was felt that insulation around the reservoir and surge tanks might be required. However, further study revealed that normal insulation coverings would not be adequate to hold stored-air temperatures constant. Therefore, the exteriors of valve tanks and piping that are out of doors were painted with aluminum paint to minimize radiation effects of the sun. Figure 5 shows the tanks and piping as they appeared after painting.

The Trans-Sonics, Inc., transducers and thermocouples are used in conjunction with the Consolidated Engineering Corporation's Nine-Channel Oscillograph to measure the pressures and temperatures.

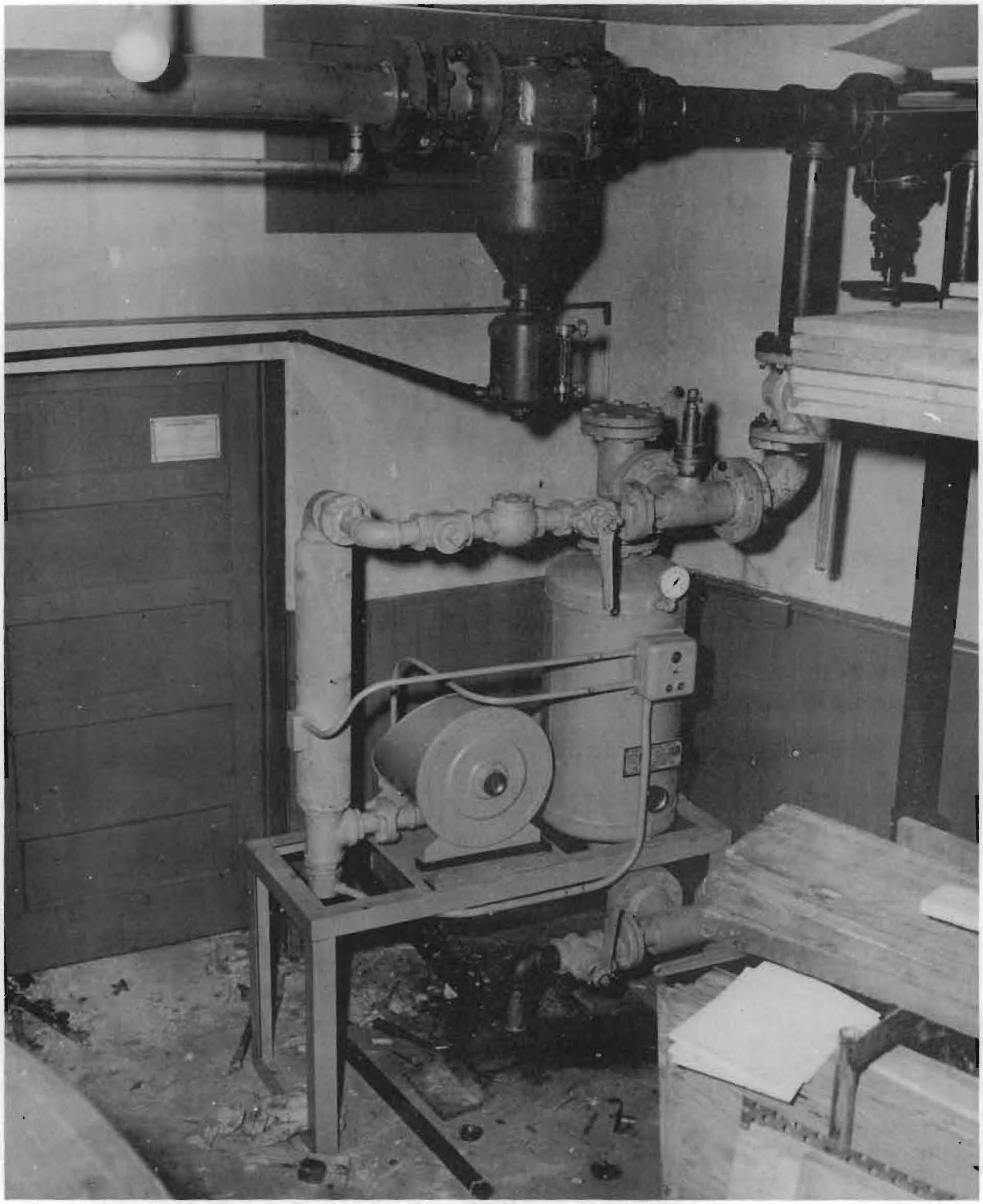

Figure 3. Kemp Adsorption Dryer.

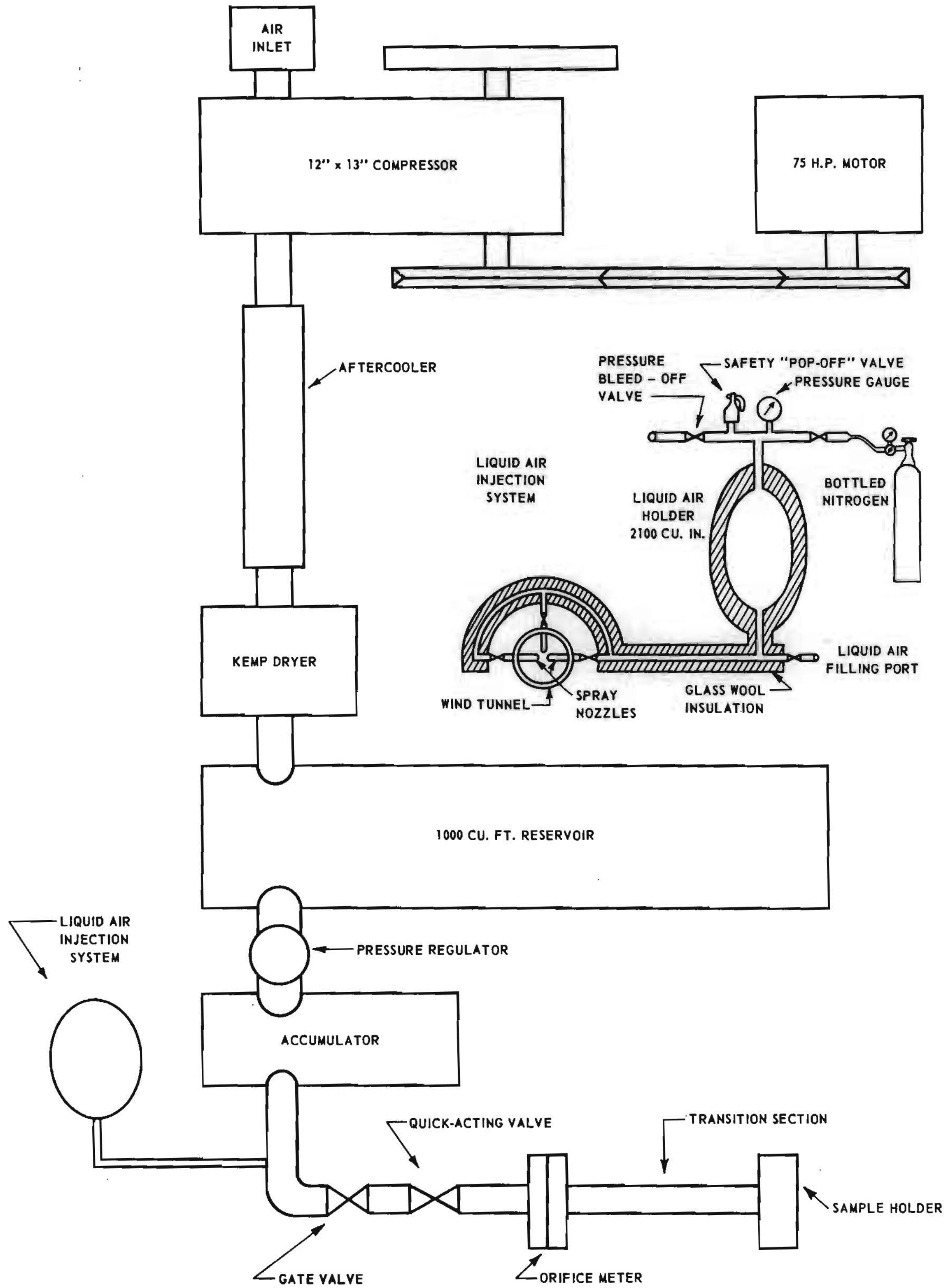

Figure 4. Schematic Diagram of Special High-Pressure Permeometer.

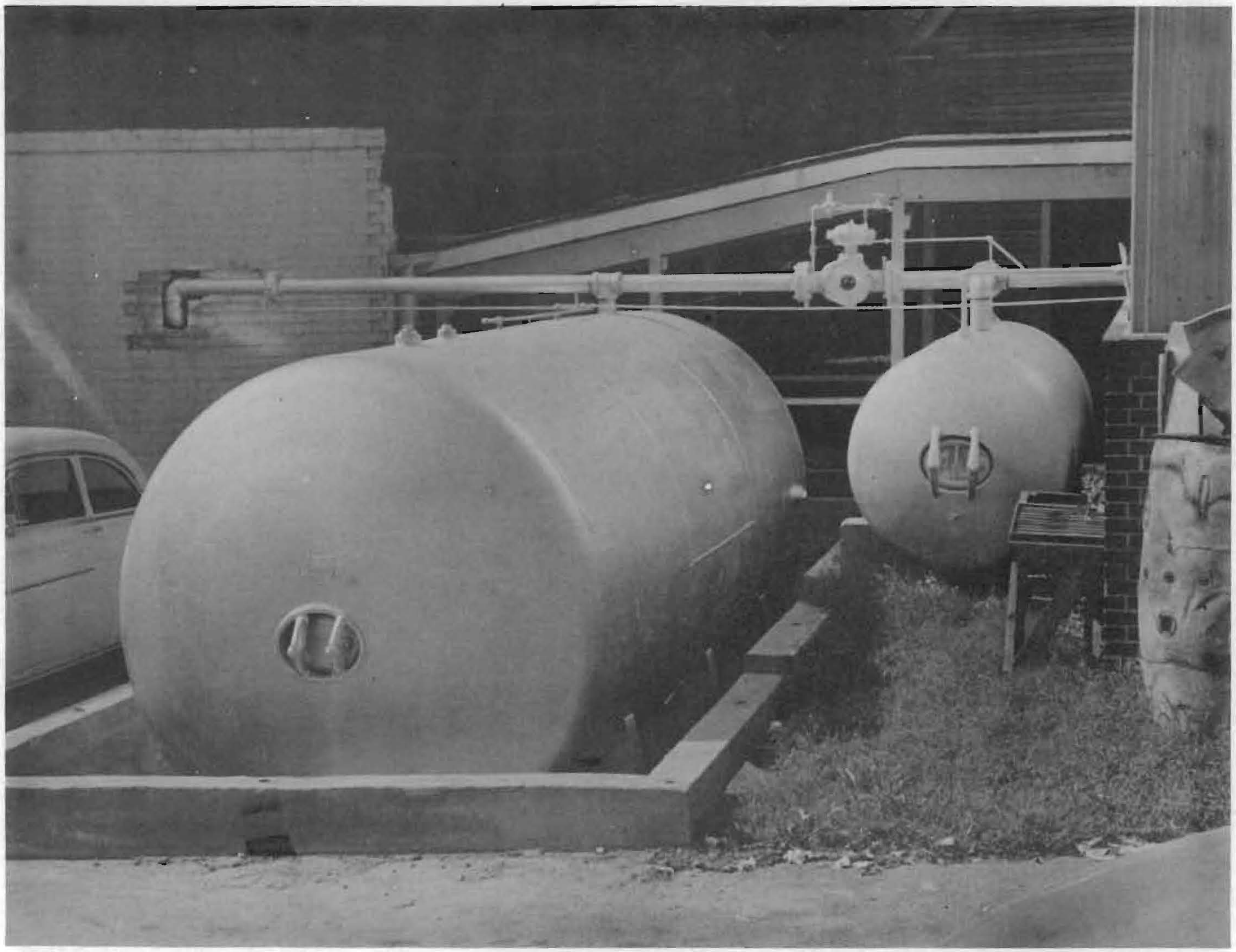

Figure 5. General View of Reservoir and Pressure Regulation System.

B. Program of Tests

The selected fabrics to be used in the high-pressure phase of the subject research are listed in Table I. This selection was suggested by Georgia Tech and approved by the Air Force.

Cloth from all three groups (Table I in Appendix A) has been tested at ordinary machine-operating temperatures and dry-air conditions (-30° F. dew point). Test results have been corrected to represent standard conditions of temperature and pressure (based on 59° F. and 29.92 inches of mercury).

The effect of high temperatures (approximately 130° F.) and low temperatures (approximately -30° F.) on air permeability will be demonstrated by use of representative plain-weave nylon, orlon, and dacron fabrics chosen from groups (a) and (b) of Table I. Because of the small amount of fabric available, it is not possible to study the effect of temperature on the air permeability of the special Cheney Brothers Manufacturing Company nylon fabrics listed in group (c) of Table I. These fabrics were designed to show the effect of twist on air permeability.

As described in preceding paragraphs, certain modifications of the Biaxial-Tension-Load Sample Holder were found to be necessary. This necessitated conducting these permeability tests using the Simple Sample Holder shown in Figure 6. However, the modifications are now complete and the biaxial-tension loads will be recorded as well as the pressure differential across the cloth and the quantity of air flow through one square foot of the fabric.

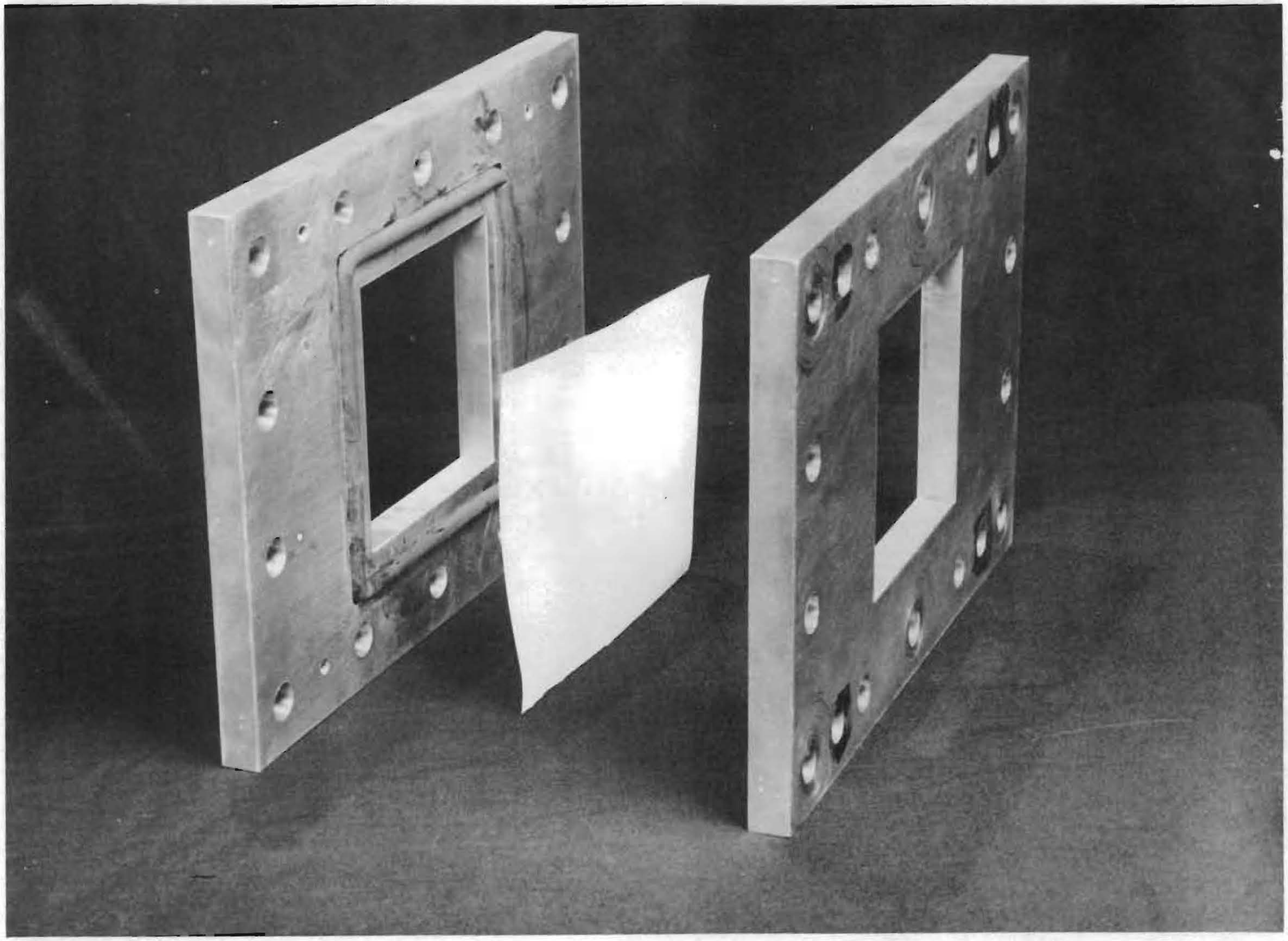

Figure 6. Exploded View of Simple Sample Holder.

C. Method of Handling Data

For these initial high-pressure tests, the data were handled in a manner similar to that used in conjunction with the Low-pressure (0-55 inches of water) Permeometer. Figure 7 is a sample of the Master Data and Result Sheet. Figure 8 is a sample of the Data and Result Sheet for a typical fabric. The Master Data and Result Sheet has been revised, since it first appeared in Georgia Tech Technical Report Nos. 1 and 2 (WADC Technical Report 52-283, Part 2), to present the permeability data in terms of volumetric flow per unit area ($cu^2/min/ft^2$) versus static pressure drop across the cloth in terms of equivalent pressure in inches of water (inches H_2O).

D. Test Results

Table II in Appendix A presents the numerical values of permeability versus pressure drop for three fabrics from groups (a), (b) and (c) of Table I which have been tested thus far. Most of the Georgia Tech woven fabrics have been tested at normal permeometer conditions. The test results are plotted in Figures 12 through 14 in Appendix B.

Figure 9 shows the permeability test results for the ES-4 fabric as tested on both permeometers. The volumetric flow per unit area versus pressure drop across the cloth was plotted on log-log paper. All average experimental points fall closely along the same straight line. This shows good correlation between the two permeometers. It also indicates that the flow characteristics throughout the pressure range are approximately the same.

MASTER DATA AND RESULT SHEET

Item No.		Dimension
1.	Barometer (Data)	in. Hg.
2.	Barometer (0.491 x item 1)	$lb_f\ in^{-2}$
3.	Cloth Static Pressure (Data)	psig
4.	Cloth Static Pressure (item 2 + item 3)	psia
5.	Cloth Static Pressure (item 3 x 27.7)	in. W.G.
6.	Temperature, T, (Data)	°F abs.
7.	$2.71 \div T$, (From Curve)	
8.	Orifice Pressure Drop, ∇P_o, (Data)	psi
9.	Air Density at cloth, ρ_c, (item 4 x item 7)	$lb_m\ ft^{-3}$
10.	$\nabla P_o \rho_c$, (item 8 x item 9)	
11.	$\sqrt{\nabla P_o \rho_c}$, (item 10)$^{1/2}$	
12.	Estimated Flow, W_e, $\beta = .60$; (2.03 x item 11)	$lb_m\ ft^{-3}$
13.	$\frac{C}{\mu}$ (From Curve) $\beta = .60$; C = 9335; μ = Viscosity in cp	
14.	Reynolds Number at throat, N_{Re}, (item 13 x item 12)	
15.	Corrected Orifice Coefficient, K_c, (From Curve)	
16.	Upstream Static Pressure, P_1, (Data)	psig
17.	KP_1, (1.4 x item 16)	
18.	$\frac{\nabla P_o}{KP_1}$, (item 8 $\div$ item 17)	
19.	Expansion Factor, Y_1, $\beta = .60$ (From Curve)	
20.	$Y_1 \times W_e$, (item 19 x item 12)	
21.	$\frac{K_c}{K}$, (item 15 $\div$ 0.65) = (item 15 x 1.5385)	
22.	Corrected Flow, W_c, $\frac{Y_1 W_e K_c}{K}$, (item 20 x item 21)	
23.	Mass Velocity at cloth, G, (9.00 x item 22)	$lb_m\ sec^{-1}\ ft^{-2}$
24.	$\sqrt{\rho_c}$, (item 9)$^{1/2}$	
25.	219 x G, (219 x item 23)	
26.	Permeability, $G/\sqrt{\rho_s \rho_c}$, (item 25 $\div$ item 24)	$scfm.\ ft^{-2}$

Figure 7. Master Data and Result Sheet.

DATA AND RESULT SHEET

Cloth Identification		Ref: Log Sheet
Style No. ES-4	Color Style Camouflage	Run No. #3
Fiber Content Nylon	Piece No.	Page No.
Weave Pattern Twill		Computed by C.M. White

Item Number	Test Number						
1.	29.12	29.12	29.12	29.12	29.12	29.12	29.12
2.	14.30	14.30	14.30	14.30	14.30	14.30	14.30
3.	4.23	4.13	7.89	12.10	16.40	21.87	25.50
4.	18.53	18.43	22.19	26.40	30.70	36.17	39.80
5.	117.2	114.4	218.6	335.2	453.2	605.8	706.4
6.	546.7	546.7	546.7	546.7	546.7	546.7	546.7
7.	.00496	.00496	.00496	.00496	.00496	.00496	.00496
8.	0.41	0.41	1.00	1.92	2.92	2.92	4.10
9.	.0919	.0914	.1101	.1309	.1524	.1794	.1974
10.	.0377	.0375	.1101	.2513	.4450	.5238	.8093
11.	.194	.194	.332	.501	.667	.724	.900
12.	.394	.394	.674	1.017	1.354	1.470	1.827
13.	501700	501700	501700	501700	501700	501700	501700
14.	197700	197700	338200	510300	680000	737500	916600
15.	.652	.652	.651	.650	.650	.650	.650
16.	4.56	4.53	8.90	13.97	19.00	24.58	29.20
17.	6.38	6.34	12.46	19.56	26.60	34.41	40.88
18.	.064	.065	.080	.098	.110	.085	.100
19.	.971	.970	.964	.955	.950	.961	.954
20.	.383	.382	.650	.971	1.286	1.413	1.743
21.	1.003	1.003	1.002	1.00	1.00	1.00	1.00
22.	.384	.383	.651	.971	1.286	1.413	1.743
23.	3.46	3.45	5.86	8.74	11.57	12.72	15.69
24.	.303	.302	.332	.362	.390	.424	.444
25.	757	755	1283	1914	2535	2785	3436
26.	2498	2500	3865	5287	6500	6569	7738

Figure 8. Sample Data and Result Sheet.

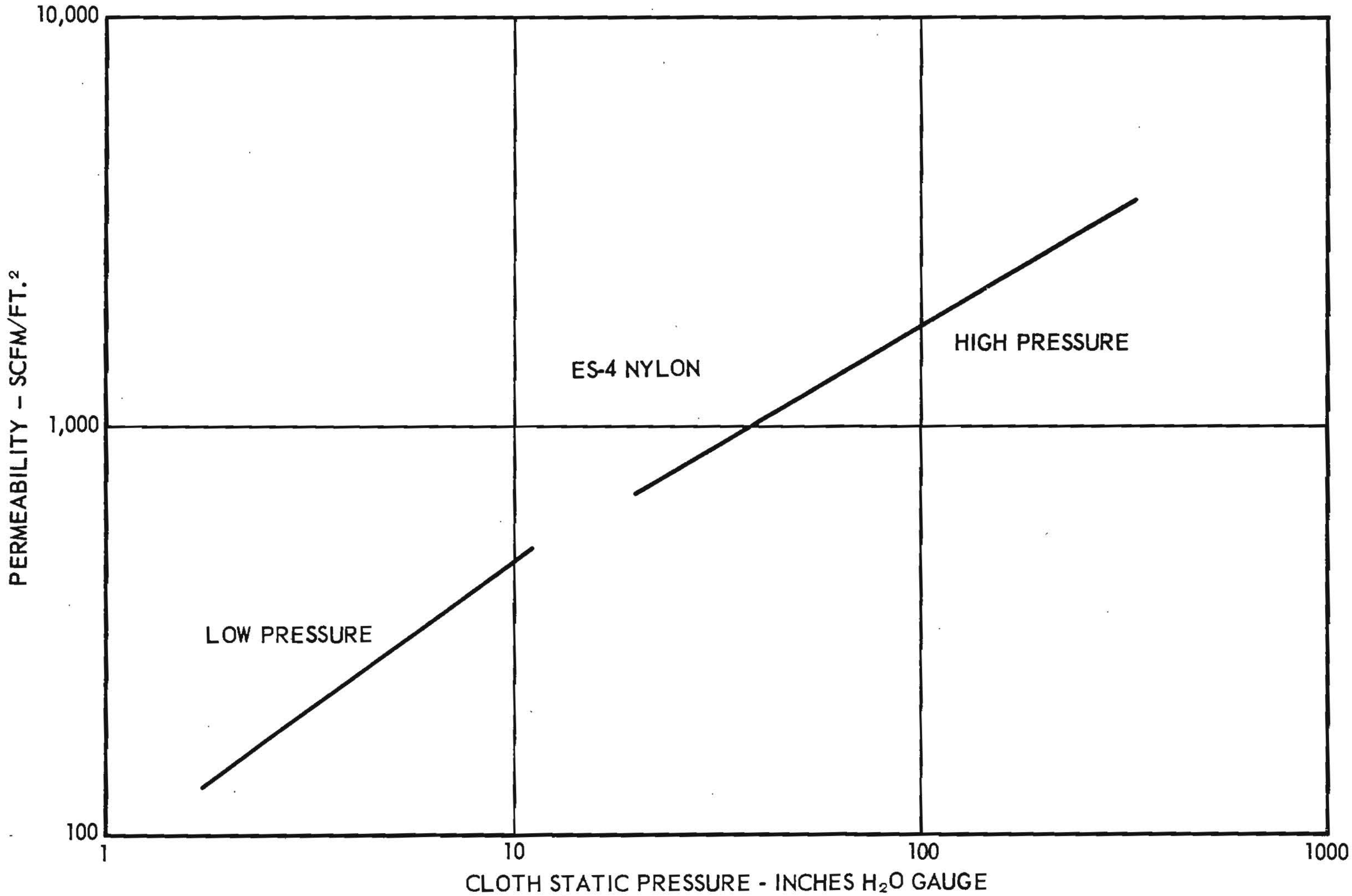

Figure 9. Comparative Plot of Low Pressure and High Pressure Data.

II. DEFORMATION OF FABRIC UNDER LOAD (No Air Flow)

A. Equipment

The Biaxial-Fabric Tension-Testing Machine has required minor modifications. This machine with the associated Four-Channel Carrier-Type Amplifier and photo observer is illustrated in Figure 10. Extension or stretch of the fabric under load is measured by a special Biaxial Extensometer. This device, shown in Figure 11, involves needle-point-equipped light-gage metal arms. Stretching of the fabric in the warp and filling directions will cause the arms to flex, which will, in turn, vary the internal electrical resistance of the gage arms. The strain gages, acting through the carrier-type amplifier and the oscillograph, record a measure of the fabric extension or displacement on the photo-observer film record.

An insulated hood has been made to cover the upper portion of the machine. As yet, the hood has not been equipped with the heating elements. On completion of the hood-heating provisions, temperatures at the sample up to 130° F. will be possible. By use of dry ice under the hood, low temperatures may be obtained.

B. Program of Tests

Fabrics described in groups (a), (b) and (c) of Table I will be subjected to tests at room temperatures in the Biaxial-Fabric Tension-Testing Machine. Representative plain-weave fabrics of nylon, orlon, and dacron will be used under the hood to demonstrate the effect of high and low temperatures on the load-elongation properties of these synthetic materials.

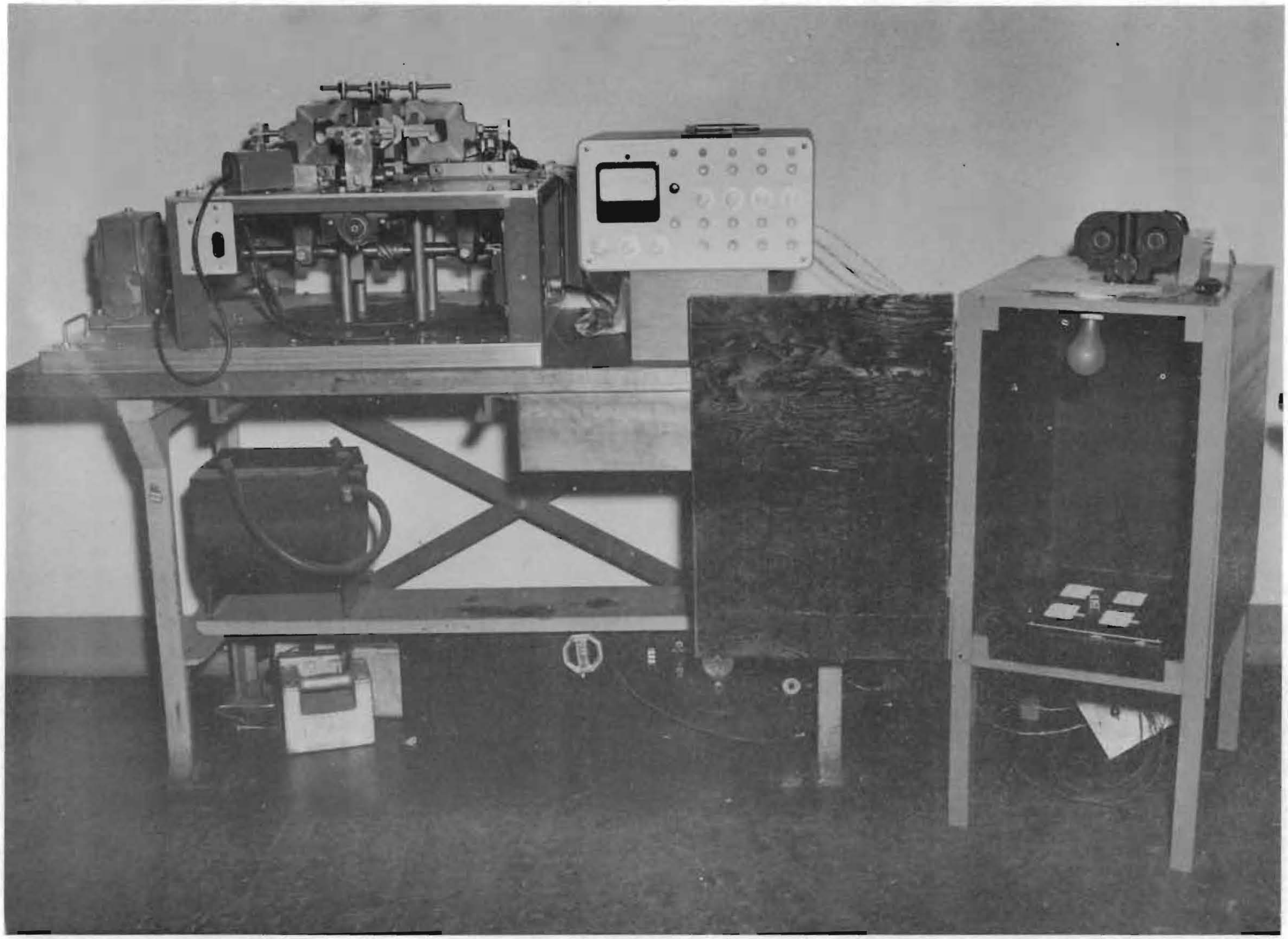

Figure 10. General View of the Biaxial Fabric Tension Testing Machine.

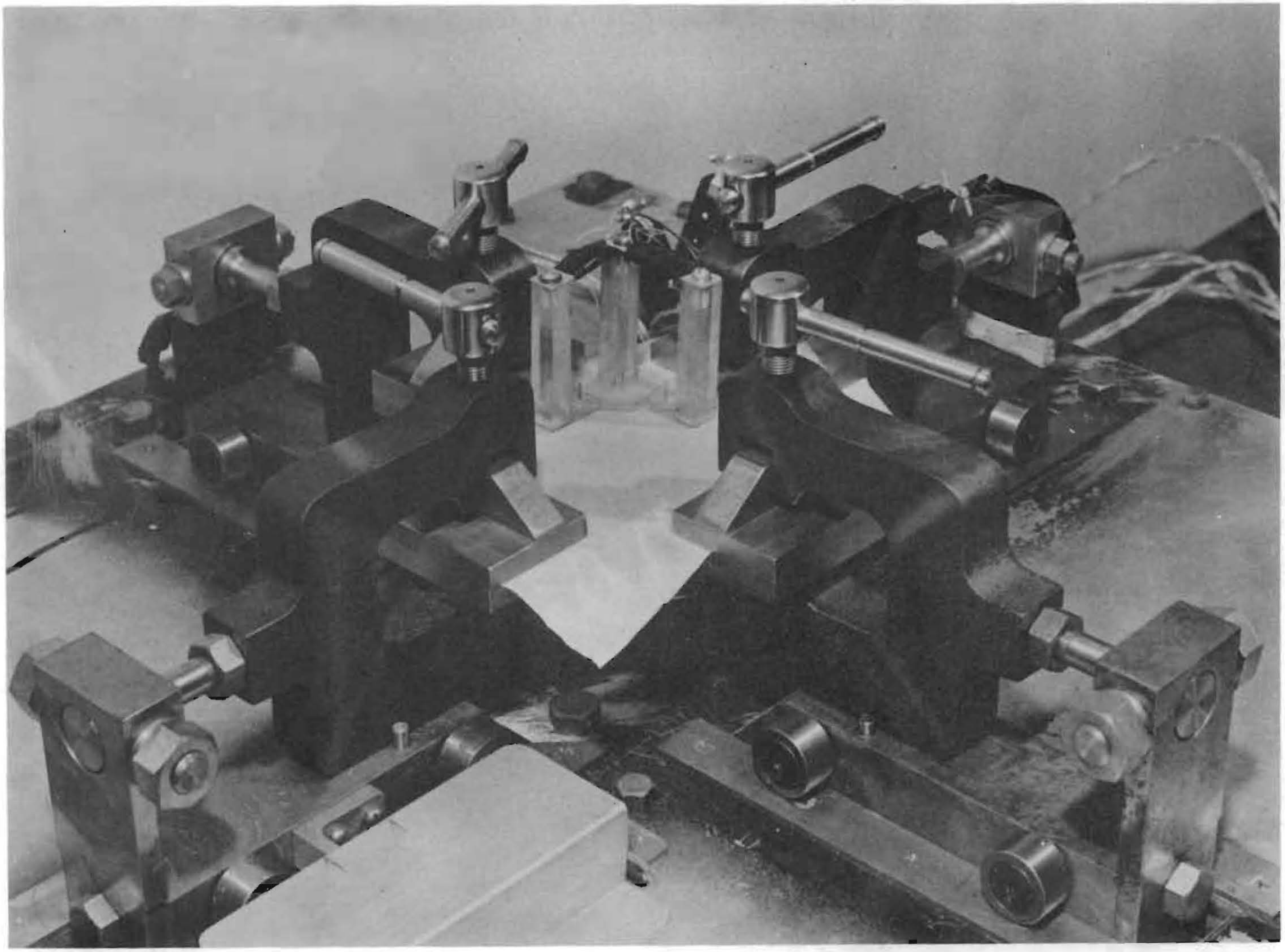

Figure 11. General View of the Biaxial Extensometer in place on the Test Fabric.

C. Method of Handling Data

The four ammeter readings will be reduced to indicate tension load per inch of sample width in both warp and filling direction and extension in inches per inch of sample width in each of these directions. From this data, load-versus-elongation curves will be prepared. Development of correlation methods, perhaps in the form of stress-strain diagrams, will be based upon these data.

D. Test Results

Table III of Appendix A shows the numerical values of load and elongation at respective time intervals. All of the Georgia Tech-woven fabrics have been tested, and the test results for three cloths are presented here. Figures 15 through 17 of Appendix B contain plots of biaxial-tension load versus elongation data for the fabrics tested so far.

Respectfully submitted:

/s/ Hurlbut W. S. LaVier
Project Director

Approved:

Herschel H. Cudd, Director
Engineering Experiment Station

APPENDIX A

TABLES

TABLE I

GEORGIA TECH SELECTION OF FABRICS
FOR HIGH-PRESSURE AIR PERMEABILITY STUDIES

Fabric Designation	Construction	Denier W	Denier F	Weave	Material	Style or Color	Reference
AIR FORCE-FURNISHED FABRICS:							
Fabric No. 2	126x117	30	30	Ripstop	Nylon	Orange	Tech. Rpt. #1, p. 60
Fabric No. 4	126x77	40	70	Twill	Nylon	Camouflage	Tech. Rpt. #1, p. 60
GEORGIA TECH FABRICS:							
Fabric No. 1	70x40	75	80	Plain	Nylon	White	Tech. Rpt. #2, p. 31
Fabric No. 6	70x40	75	80	Satin	Nylon	White	Tech. Rpt. #2, p. 31
Fabric No. 12	70x40	75	80	Twill	Nylon	White	Tech. Rpt. #2, p. 32
Fabric No. 7	70x90	75	80	Plain	Nylon	White	Tech. Rpt. #2, p. 31
Fabric No. 9	70x70	75	80	Plain	Nylon	White	Tech. Rpt. #2, p. 31
Fabric No. 18	125x40	40	80	Plain	Nylon	White	Tech. Rpt. #2, p. 32
Fabric No. 20	125x60	40	80	Plain	Nylon	White	Tech. Rpt. #2, p. 32
Fabric No. 22	125x80	40	80	Plain	Nylon	White	Tech. Rpt. #2, p. 33
Fabric No. 36	100x70	80	80	Plain	Orlon	White	Tech. Rpt. #2, p. 36
Fabric No. 48	110x70	80	80	Plain	Dacron	White	Tech. Rpt. #2, p. 37

	Plain Weave			Ripstop
CHENEY BROS. FABRICS	7N* 1/2	7C**1/2	10N 1/2	7N 1/2
	7N* 7	7C**7	10N 7	7N 7
	7N* 35	7C**35	10N 35	7N 30

*N = Not Calendered
**C = Calendered

TABLE II

SUMMARY OF HIGH-PRESSURE PERMEABILITY TEST RESULTS

Static Pressure Upstream of Cloth (Inches Water)	Volumetric Velocity (scfm/ft.^{2})
AIR FORCE-FURNISHED FABRICS:	
Fabric Number 4 (ES-4)	
100	2136
150	2836
200	3511
250	4156
300	4773
350	5343
400	5869
450	6338
500	6806
550	7171
600	7243
650	7515
700	7850
Fabric Number 2 (ES-2)	
200	6100
300	7390
400	8590
500	9890
600	10900

TABLE III

SUMMARY OF BIAXIAL FABRIC
TENSION TEST RESULTS

Tension Load (lbs./in.)	Elongation Filling (Per Cent)	Elongation Warp (Per Cent)
GEORGIA TECH-WOVEN FABRICS:		
Fabric Number 12 (GT)		
2	0.30	1.00
3	0.50	1.40
5	0.80	2.25
7	1.10	3.00
10	1.60	4.00
15	2.45	5.35
20	3.30	6.55
25	4.18	7.50
30	5.10	8.30
Fabric Number 20 (GT)		
2	0.20	2.40
3	0.40	3.25
5	0.90	4.60
7	1.60	5.75
10	3.00	7.30
15	5.45	9.40
20	7.95	11.10
25	10.55	12.50
30	13.20	13.70
Fabric Number 36 (GT)		
2	0.10	0.75
3	0.15	1.15
5	0.25	1.95
7	0.40	2.85
10	0.60	4.25
15	1.10	6.90
20	2.70	10.10

APPENDIX B

CURVES

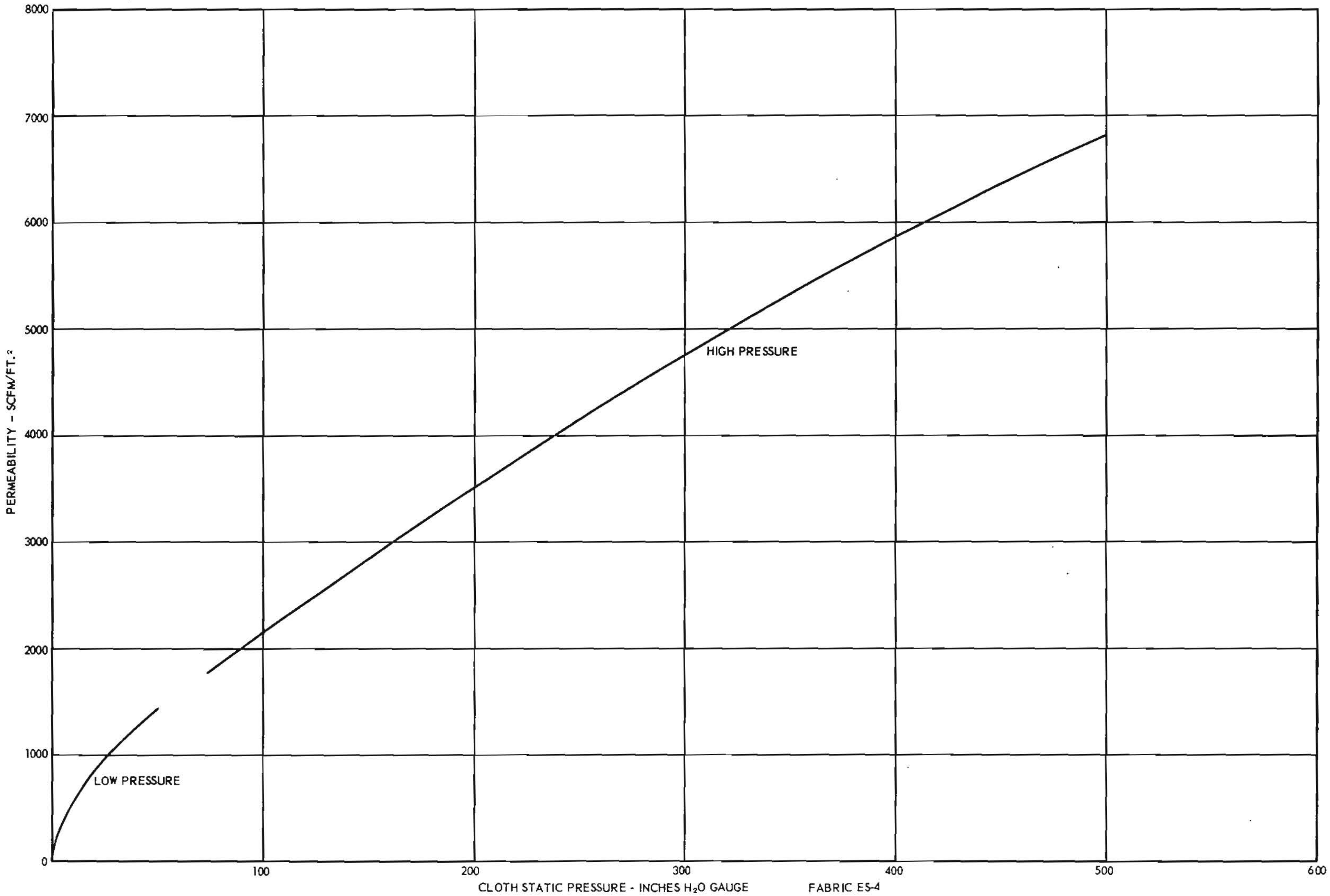

Figure 12. High Pressure Permeability Test Results of ES-4 Camouflage Nylon.

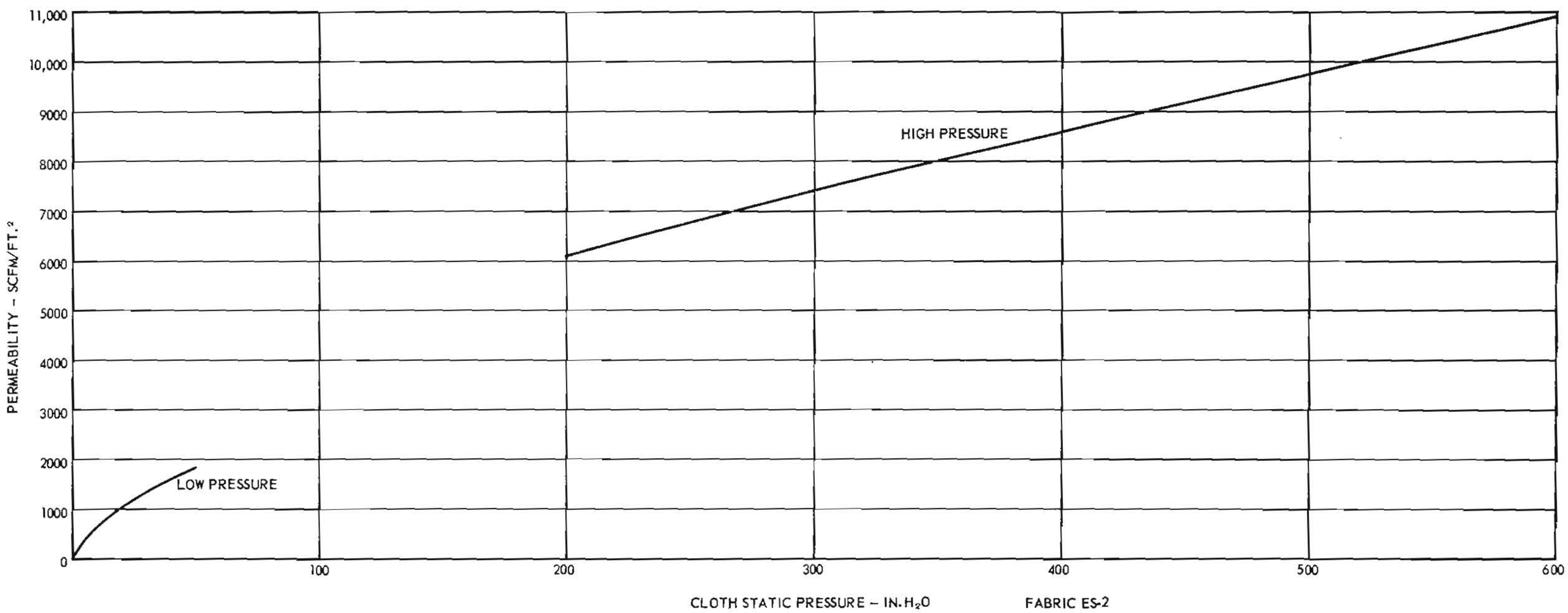

Figure 13. High Pressure Permeability Test Results of ES-2 Orange Ripstop Nylon.

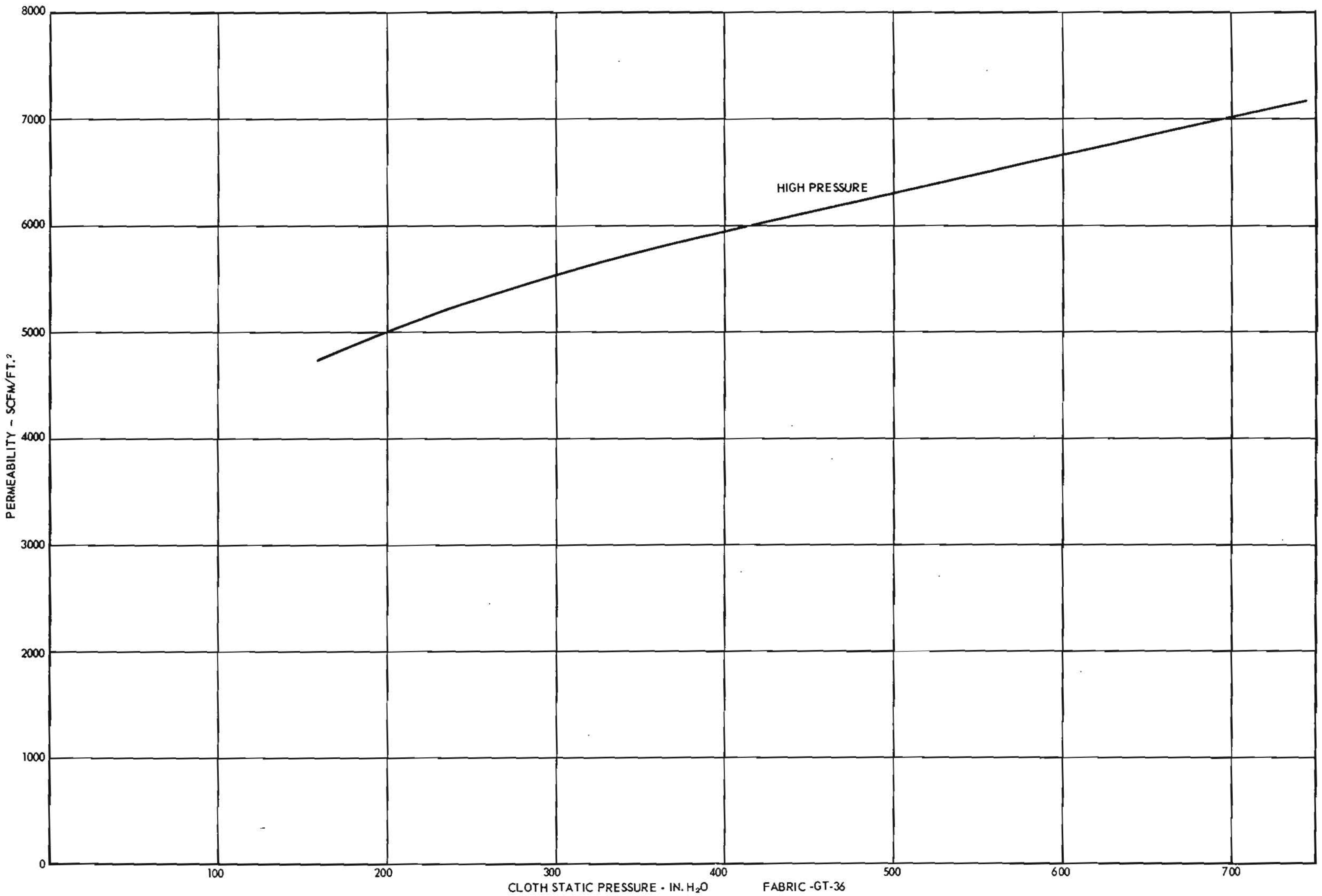

Figure 14. High Pressure Permeability Test Results of GT-36 Orlon 100x70.

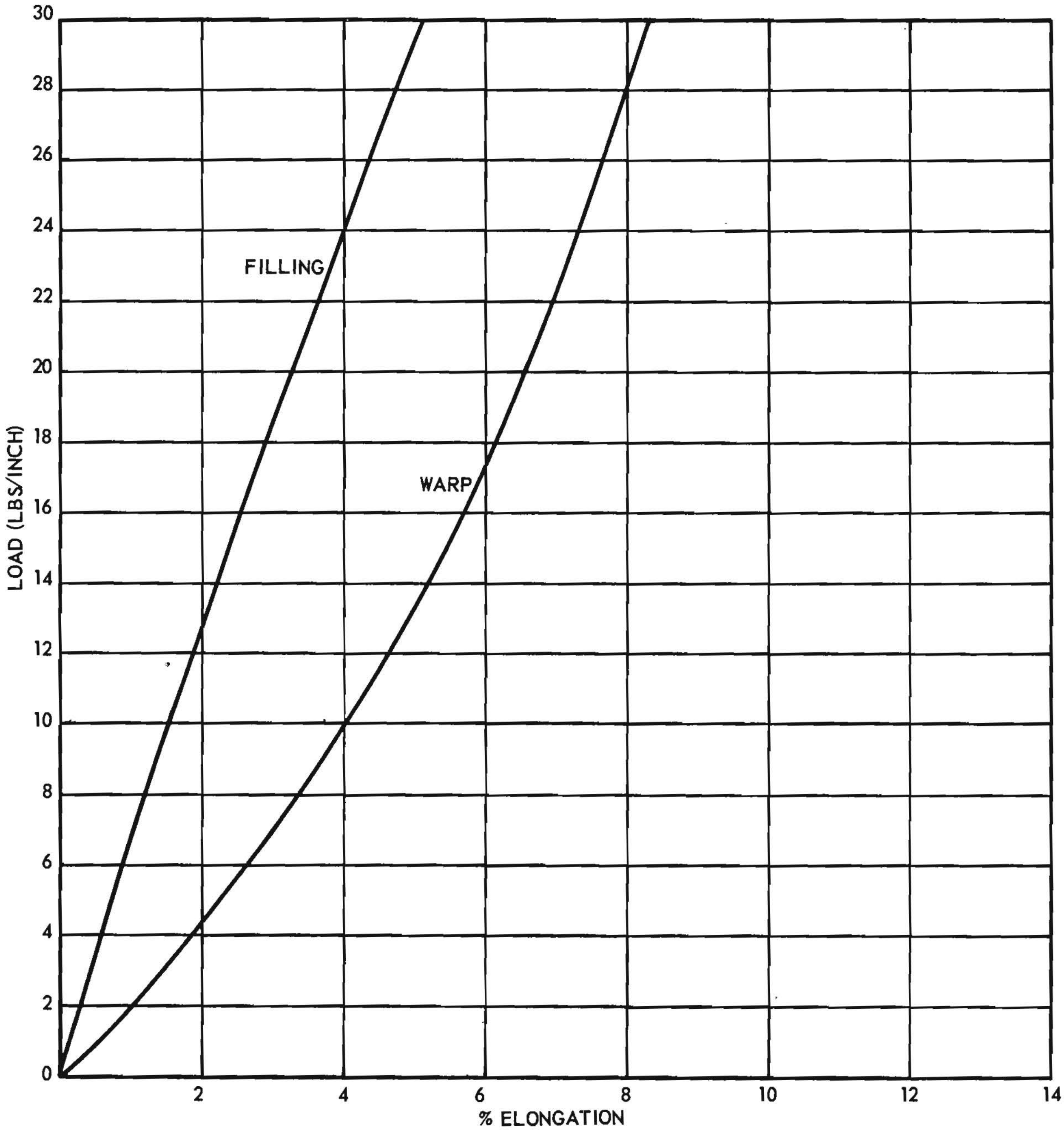

Figure 15. Biaxial Fabric Tension Test of GT-12 Nylon 70x40.

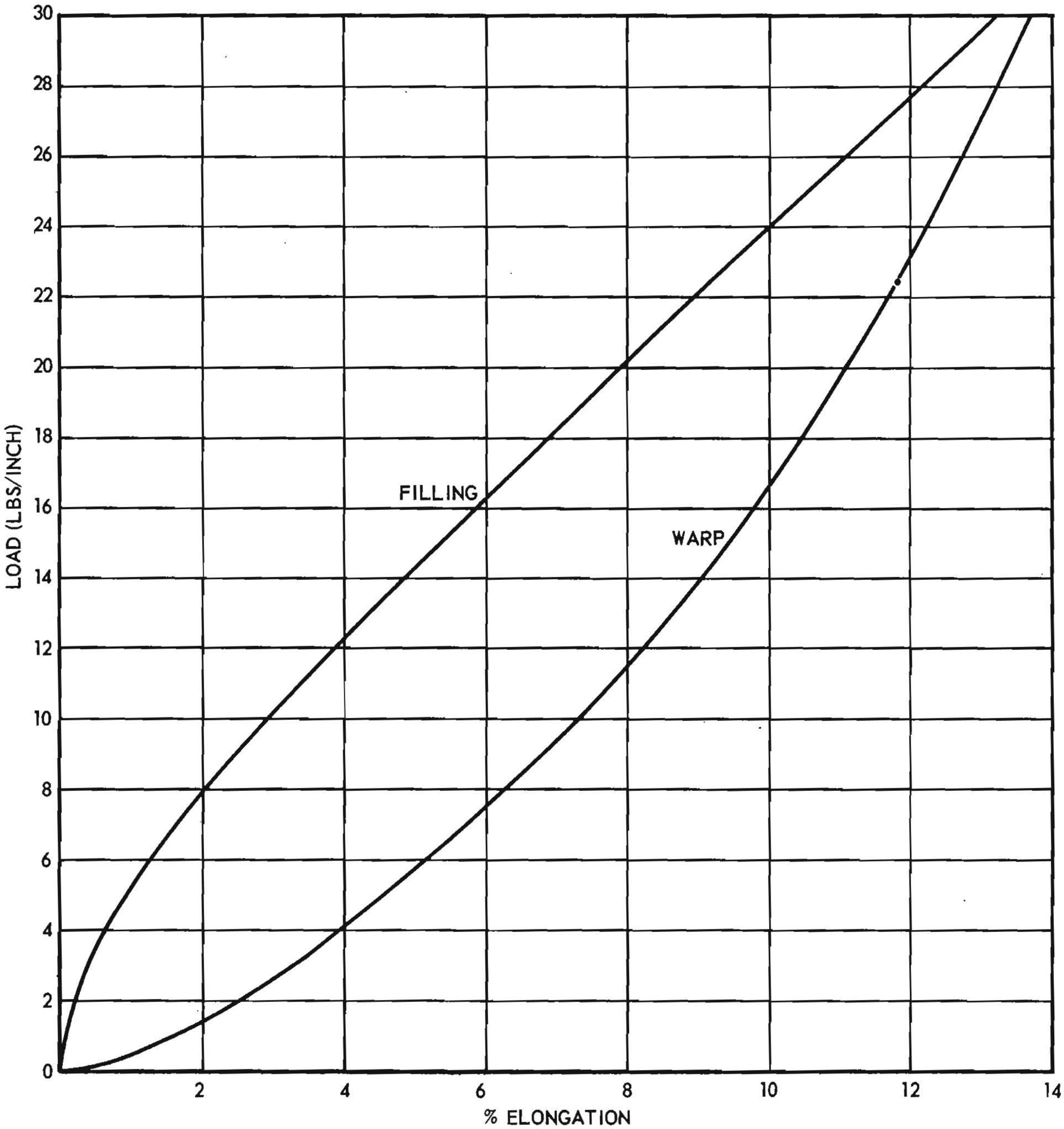

Figure 16. Biaxial Fabric Tension Test of GT-20, Nylon 125x60.

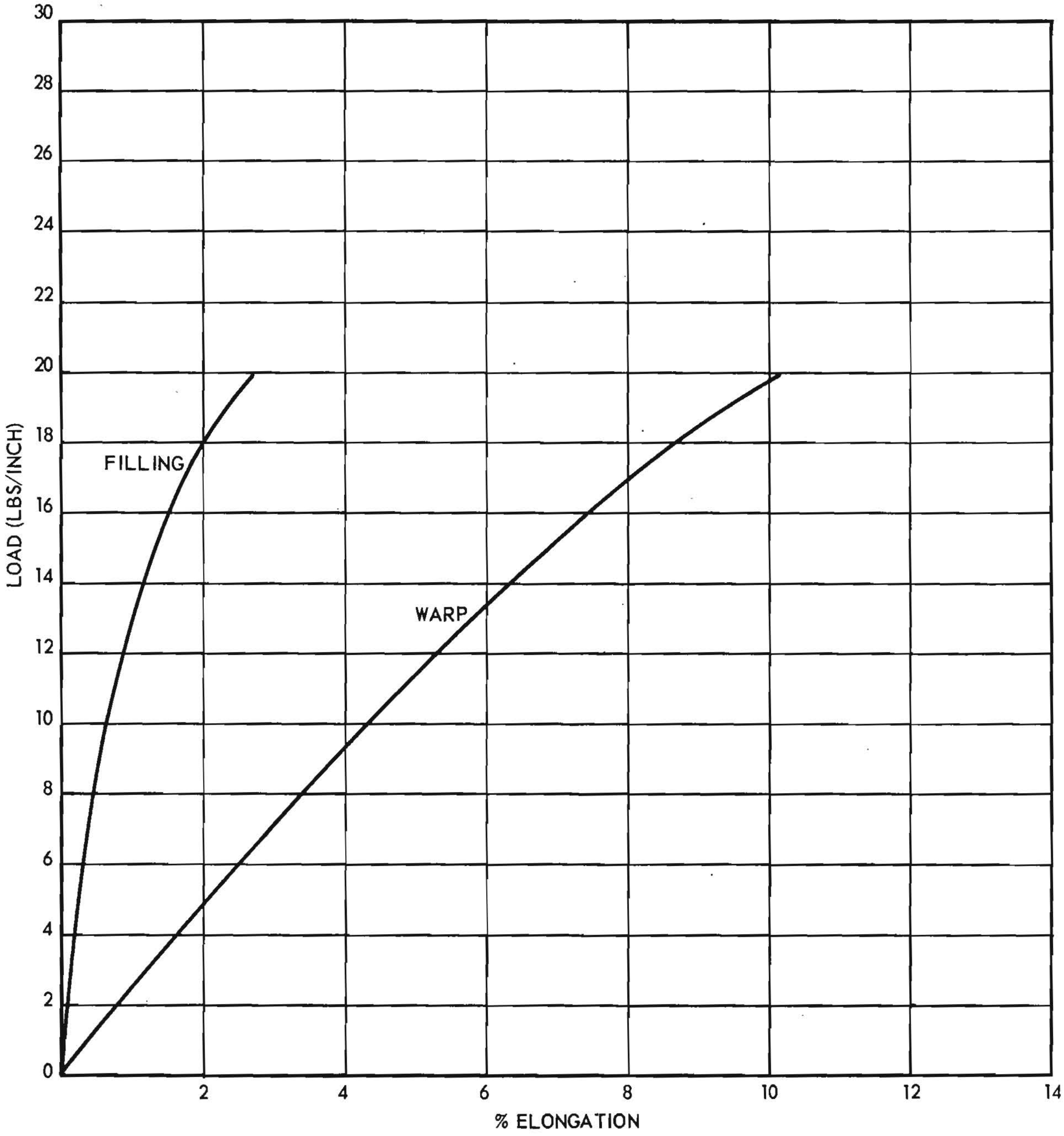

Figure 17. Biaxial Fabric Tension Test of GT-36, Orlon 100x70.