C.P. No. 24
12407
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Porous Properties of Various Materials liable to be used for Making Parachutes

By

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LONDON: HIS MAJESTY'S STATIONERY OFFICE
1950

Price 1s 9d. net.

C.P. No.24

Technical Note No. M.E.31.

March, 1949.

ROYAL AIRCRAFT ESTABLISHMENT

The Porous Properties of Various Materials for Use in Making Parachutes

by

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and
J.F. Holford

SUMMARY

An investigation has been made into the porous properties of paper perforated with round holes, and ribbon meshes with square interspaces. It has been established that the relationship between porosity and the porous area is almost linear for all materials.

An approximately straight line law exists between the logarithm of the porosity and the logarithm of the pressure difference across the sample being tested, whether that sample is a woven fabric or a ribbon mesh.

The value of the index x in the expression $v \propto p^{\frac{1}{2}x}$ is lower for a ribbon mesh than for a woven fabric. Woven fabrics of natural fibres have a higher index value than woven fabrics of artificial fibres.

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1 Introduction

Because of a shortage of silk, it became necessary, during the second World War, to exploit the use of cotton and rayon for manufacture into parachutes. Fabrics made from cotton and rayon yarns were therefore constructed to give approximately the same physical characteristics as those of silk, which was used almost exclusively for parachutes made before 1939. It was found, however, that parachutes made from these new fabrics, behaved very differently from those made of silk.

Wind tunnel and flight experiments showed that the most important fabric characteristic affecting performance of a parachute was its porosity. It was further shown that if parachutes were made from different fabrics, all of the same porosity, then they behaved similarly during opening.

The conditions for measurement of parachute fabric porosity were therefore based on those occurring at parachute opening, and as it was desirable to have standard conditions for testing, a pressure difference of 10 inches of water across the fabric under test was chosen. This pressure corresponds to that developed in a parachute flying at a speed of 209 feet per second, which was then within the normal aircraft operational speeds.

By adopting a standard condition for test it is automatically assumed that, whatever the material, similar parachutes made from fabric which has passed the porosity test will behave similarly over a wide range of speeds. This can only be true, of course, if the porosity/pressure curves for the different materials are similar, particularly at pressures exceeding 2 inches of water.

At one period during the War a requirement arose for the use of paper for making parachutes. As paper is normally manufactured in imporous sheets, it was recognised that some means of venting the parachute canopy would have to be found. One suggestion made was that the paper should be perforated, and hence it became desirable to know what size and number of holes would be required to enable a paper parachute to function as satisfactorily as a similar one made from fabric.

Towards the end of the War it was found that the Germans were using ribbon parachutes. It then became necessary to associate ribbon spacing with porosity, so that the performance of ribbon parachutes could be compared with fabric parachutes.

Some of this information is now required for an investigation which is to be made into the variation of porosity across the width of nylon fabrics. This note has therefore been written to place on record the results of investigations which were made at the end of World War II into the porous properties of (a) imporous materials perforated with round holes and (b) ribbon meshes with square interspaces. In addition, a comparison is made of their properties with those of normal woven fabrics.

2 Imporous materials perforated with round holes

The object of these tests was to determine how the airflow through the perforated material varied, over a wide range of pressure differences across the test sample, with

(a) the thickness of the material,

(b) the size of the hole,

and (c) the number of holes.

Specimens were prepared by cutting discs of $2\frac{1}{2}$ inches diameter from various thicknesses of good quality paper, and also from brass foil. In each material the centre area of $1\frac{1}{2}$ inches diameter was made porous by punching a number of holes of various sizes with a hand punch.

Table I gives the particulars of the specimens tested.

The diameters of the discs and of the porous areas were such that they fitted conveniently over the orifice of the R.A.E. high pressure porosity[1] instrument, with which the porosities were measured. To allow for the effect of burrs caused by punching, the air flow was determined with obverse and reverse sides of the specimens next to the test orifice at a pressure of 10 inches water gauge. The results are given in Tables II, III, IV and V. The relationship between the mean values of the air flow and the porous area is shown in Fig.1.

Using two specimens cut from cardboard 11 thousandths of an inch thick, 8.33% and 25%, respectively, of the areas included in a $1\frac{1}{2}$ inch diameter circle were removed by punching holes $\frac{1}{8}$ inch in diameter. The airflow (v) was then measured at pressures (p) ranging from $\frac{1}{2}$ inch to 17 inch water gauge. Assuming that $V \propto \sqrt{\frac{2p}{\rho}}$, values for V and the percentage porosity $(100\,\frac{v}{V})$ have been calculated and then plotted in Fig.2.

To complete the investigation porosity measurements over a similar range of pressures were made on a standard $\frac{1}{2}$ inch orifice plate. These results have also been plotted in Fig.2.

3 Ribbon meshes with square interspaces

The object of these tests was to determine how the airflow varied with (a) material, and (b) size of interspace between adjacent pairs of ribbons, over a wide range of pressure differences across the test sample. Ribbons of $\frac{1}{4}$ inch width were selected for the tests.

As the test area is small compared with the size of the ribbon, the porous area depends on the relative positions of ribbons and orifice. The two extreme positions are (a) two ribbons at right angles to each other and along two diameters of the orifice, and (b) a space between two pairs of ribbons at the centre of the orifice. These two extreme positions are shown pictorially in Fig.3. They are the easiest to set up correctly over the orifice and also to use for calculation of the porous area.

The porous area over the test orifice was calculated for the two extreme positions using a wide range of ribbon spacings. The results are plotted in Fig.4. Owing to the large width of the ribbons compared with the diameter of the orifice, the porous area does not increase smoothly with an increase in ribbon spacing. Consequently a further calculation was made of the porous area over a very much larger area of mesh. These results are also plotted in Fig.4.

In order to vary the spacing of the ribbons easily and accurately an adjustable frame (Fig.5 (a) and (b)) was constructed. The frame consisted of 4 strips of wood mounted on a plywood base in such a manner that they could pivot about their centres. Ten coiled springs, with crocodile clips attached, were secured by wood screws at equal intervals along each strip. Ribbons were then stretched between opposite pairs of clips. Adjustment of the ribbon spacing was made by rotating the wooden strips, the angle of rotation being read off paper scales pasted on the baseboard. The frame was rigged first with art silk ribbons and then with cotton ribbons, and in each case the porosity was measured on the high pressure porosity instrument at a pressure of 10 inches water gauge. Porosity tests were made with various ribbon spacings in both ribbon-centred and space-centred positions.

In addition, porosity tests were made at a number of different pressures for three spacings in both ribbon-centred and space-centred positions.

The relationship between porosity and ribbon spacing at 10 inch water pressure is shown for the two types of ribbon in Figs.6 and 7. The curves are so similar to those for porous area/spacings in Fig.4 that it was considered sufficiently accurate for practical purposes to draw a curve for porosity/ribbon spacing over a large area assuming that it would have the same shape as the porous area curve, and would occupy the same position relative to the ribbon-centred and the space-centred curves.

Curves of porosity at 10 inches water pressure against porous area have been drawn for the two types of ribbon in Fig.8. They are very nearly straight lines, but do not pass through the origin because of (a) the ribbon porosity, and (b) the leakage between pairs of ribbons at their cross-over positions.

Curves of percentage porosity against V are given in Figs.9 and 10.

4 Normal woven fabrics

In order to compare the behaviour of round holes and square interspaces with a porous woven fabric, porosity tests were made over a range of pressures varying from $\frac{1}{2}$ inch to 17 inches water gauge on woven fabrics made from different materials.

Percentage porosity against V is plotted in Fig.11 and $\log_e v$ against $\log_e p$ in Fig.12.

Fig.11 illustrates the large increase in relative porosity of the woven fabrics, particularly of cotton, in contrast to an almost negligible increase in relative porosity of ribbon mesh of similar porosity. This indicates that if two parachutes are made of cotton fabric and cotton ribbons respectively, and their mean porosities at opening are equal, then the stability of the cotton fabric parachute in a steady descent - that is, at a speed much lower than the opening speed - would be much better than the ribbon parachute. On the other hand, the opening characteristics of the ribbon parachute at high speeds would be expected to be better than those of the fabric parachute.

The percentage porosity of nylon fabric does not increase very greatly with the pressure and the relationship is similar to that of the ribbon mesh.

In Fig.12 a series of linear relationships between $\log_e v$ and $\log_e p$ have been drawn for a number of fabrics and also of a ribbon mesh. The slopes of these lines have been obtained and the values of the index x in the empirical relationship

$$v \propto p^{\frac{1}{2}x}$$

have been calculated. The results are given in Table VI. It will be seen from the results that the value of the index x always exceeds 1 thus confirming earlier work by Duncan[2], and is also dependent on the type of material. Thus fabric made from natural fibres give a higher value of x than fabric from artificial fibres, and ribbon mesh gives the lowest value. The same value for x is obtained when either cotton or artificial ribbons are used.

5 Conclusions

(i) There is a smooth relationship between porosity and porous area of perforated paper, metal foil and ribbon mesh. In the case of ribbon mesh the relationship is linear.

(ii) The percentage porosity of perforated paper, metal foil and of an orifice plate is independent of pressure difference on the two sides of the test piece for the range of pressure difference covered.

(iii) The percentage porosity of a ribbon mesh increases slightly with pressure difference.

(iv) The porosity can be related to the pressure difference by an empirical formula.

(v) The value of the index x depends mainly on the material used. Thus woven fabrics of natural fibres have a higher index value than woven fabrics of artificial fibres.

(vi) The value of x for a ribbon mesh is lower than for woven fabrics. It is independent of the material used in the manufacture of the ribbons.

REFERENCES

Ref.No.	Author	Title, etc.
1	Carling and Leigh	The design of a high pressure porosity instrument. Tech. Note No. Aero.1804. July 1946.
2	Duncan	The cause of the spontaneous opening and closing of parachutes. (The phenomena of "Squidding"). Report No. Aero.1894. December 1943.

TABLE I

Size of Holes

Specimen	Material	Thickness × 10^{-3} in.	Diameter of hole					Porous area punched away %			
			$\frac{1}{4}$	$\frac{1}{8}$	1/16	3/64	1/32	5.55	8.33	11.1	25
1	Paper	4	$\frac{1}{4}$	$\frac{1}{8}$	1/16	3/64	1/32	5.55	8.33	11.1	25
2	"	5			ditto				ditto		
3	"	6			ditto				ditto		
4	Brass foil	7			ditto				ditto		
5	Cardboard	11			ditto				ditto		

TABLE II

Porosity with 5.5% area removed

Specimen \ Size of holes		$\frac{1}{4}$	$\frac{1}{8}$	1/16	3/64	1/32	Mean
1	O*	7.55	7.45	7.65	6.3	7.05	
	M	7.25	7.2	7.0	6.85	7.3	7.12
	I	6.95	6.95	6.4	7.4	7.60	
2	O	7.65	7.3	7.6	8.3	7.45	
	M	7.15	7.05	7.1	7.45	7.65	7.28
	I	6.65	6.8	6.55	6.6	7.85	
3	C	7.8	7.3	7.2	8.1	7.5	
	M	7.4	7.2	7.1	7.55	7.55	7.36
	I	7.0	7.1	7.0	7.0	7.6	
4	O	8.05	8.6	9.8	10.6		
	M	7.7	7.95	9.1	9.75		8.62
	I	7.3	7.3	8.4	8.9		
5	O	7.7	7.7	8.0	8.0	7.55	
	M	7.2	7.25	7.3	7.3	7.9	7.39
	I	6.7	6.8	6.6	6.6	8.25	

* O = obverse side upward, I = inverse side upward, M = mean.

TABLE III

Porosity with 8.3% area removed

Size of holes / Specimen		1/4	1/8	1/16	3/64	1/32	Mean
1	O M I	11.65 11.2 10.8	11.55 11.3 11.1	11.65 11.4 11.15	12.1 11.8 11.5	10.2 10.85 11.5	11.31
2	O M I	11.9 11.4 10.85	12.05 11.55 11.05	12.3 11.95 11.6	13.3 12.75 12.2	10.4 11.0 11.6	11.73
3	O M I	11.95 11.6 11.3	12.55 12.1 11.65	13.3 12.7 12.1	14.1 13.3 12.5	11.0 10.8 10.65	12.1
4	O M I	11.65 11.05 10.45	11.45 11.1 10.75	12.05 11.45 10.85	12.05 11.65 11.25	11.35 11.8 12.25	11.41

TABLE IV

Porosity with 11.1% area removed

Size of holes / Specimen		1/4	1/8	1/16	3/64	1/32	Mean
1	O M I	15.35 14.6 13.8	15.6 14.7 13.8	16.05 14.65 13.25	15.5 14.2 12.85	13.8 14.6 15.4	14.55
2	O M I	15.5 14.55 13.6	15.7 14.7 13.65	16.4 15.0 13.65	16.35 14.7 13.05	14.1 14.8 15.5	14.75
3	O M I	15.6 14.75 13.9	15.6 14.85 14.1	15.7 15.1 14.5	15.7 14.95 14.2	14.9 14.7 14.5	14.87
4	O M I	16.35 15.6 14.85	17.4 16.15 14.9	20.4 18.85 17.3	21.0 19.3 17.6		17.5
5	O M I	15.4 14.5 13.6	15.5 14.55 13.6	16.65 15.2 13.7	16.0 14.75 13.5	15.2 15.9 16.6	14.98

TABLE V

Porosity with 25% area removed

Specimen \ Size of holes		1/4	1/8	1/16	1/32	Mean
1	O	34.95	37.8	43.8	38.3	
	M	35.8	38.8	45.1	40.8	40.1
	I	36.7	39.8	46.4	43.3	
2	O	32.8	34.4	38.1	36.0	
	M	34.6	36.4	40.7	41.8	38.4
	I	36.3	38.3	43.3	47.6	
3	O	31.4	33.0	36.4	34.7	
	M	33.9	35.4	40.5	39.4	37.3
	I	36.5	37.8	44.6	44.1	
4	O	35.4	37.4	47.3	45.8	
	M	36.7	40.0	51.1	50.8	44.65
	I	38.0	42.5	54.8	55.9	
5	O	32.3	34.3	37.5	33.9	
	M	34.2	36.8	42.3	37.8	37.8
	I	36.1	39.4	47.1	41.8	

TABLE VI

Slopes of $\log_e v/\log_e p$ curves

Material	Specification	Slope $\log_e v/\log_e p$	Index x
Art. silk or cotton ribbons	Not known	0.504	1.01
"Celanese fortisan"	DTD.526	0.544	1.09
Nylon, plain weave	DTD.556	0.556	1.11
Viscose	V.7695	0.560	1.12
Silk	DTD.69	0.592	1.18
Cotton (2 fold yarns)	DTD.583	0.588	1.18
	DTD.633	0.620	1.24
Cotton	DTD.524	0.636	1.27
"	DTD.418	0.640	1.28
"	DTD.596	0.700	1.40

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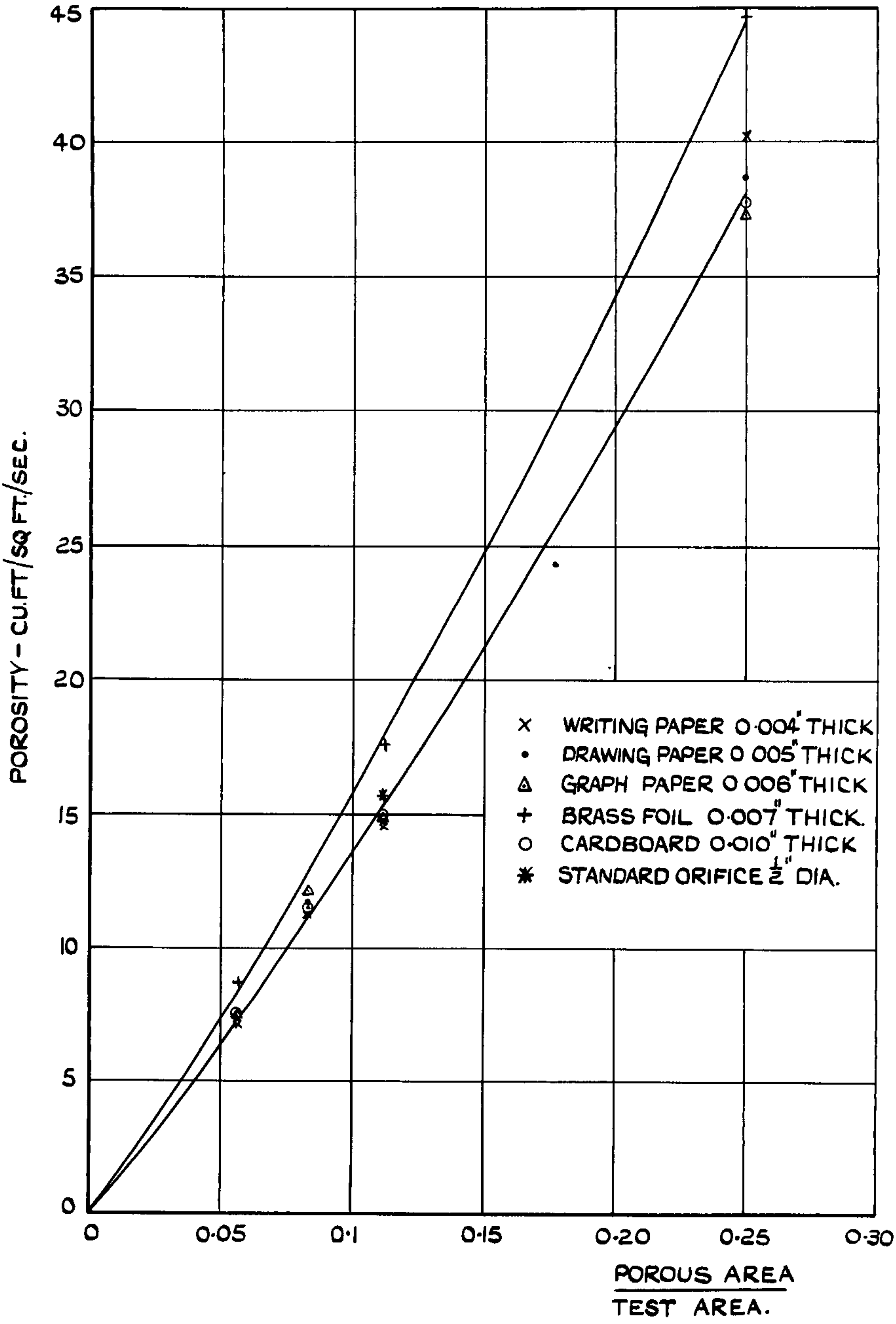


FIG. 1. RELATION BETWEEN POROSITY AND POROUS AREA.

FIG. 2.

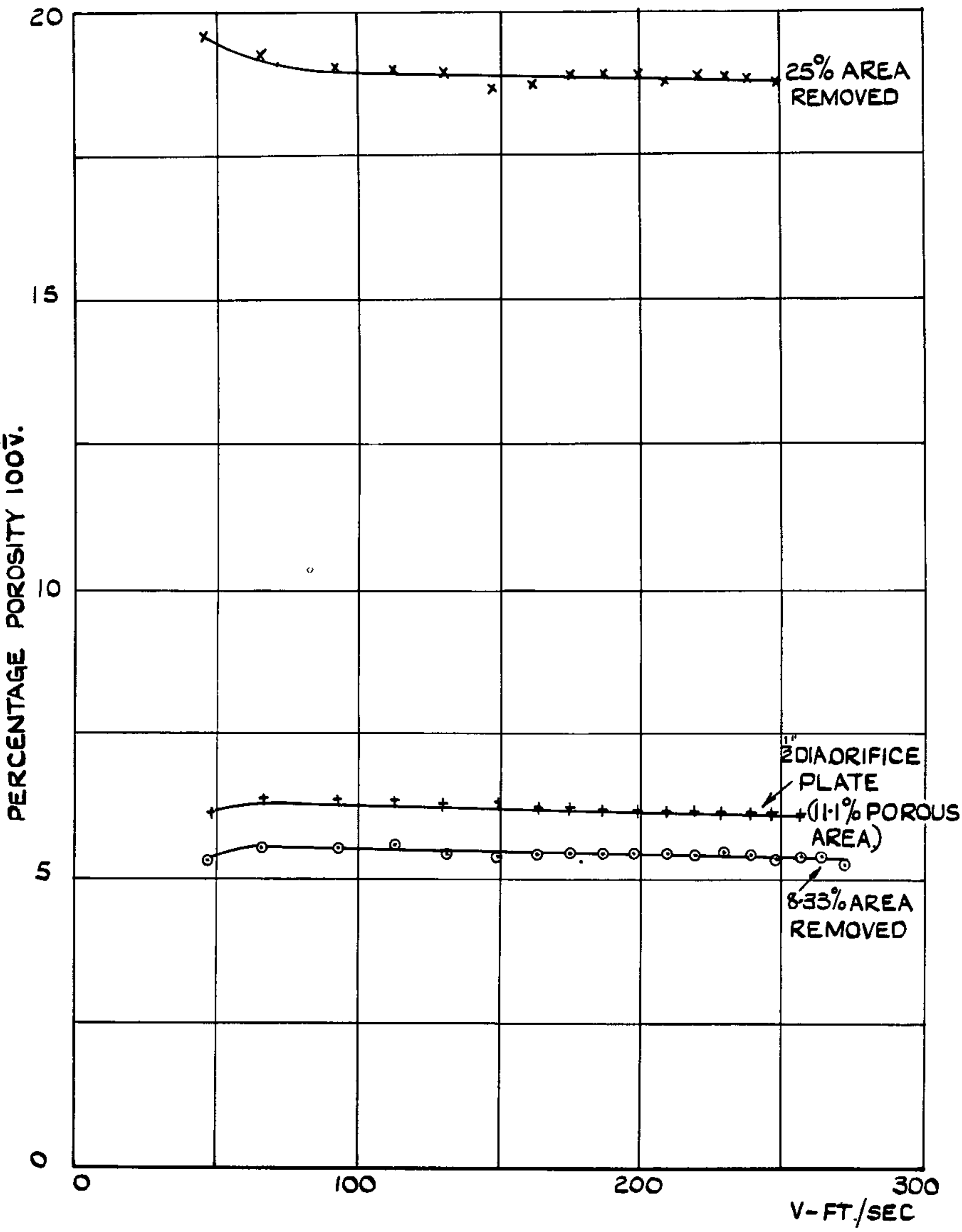


FIG. 2. RELATION BETWEEN PERCENTAGE POROSITY AND V.

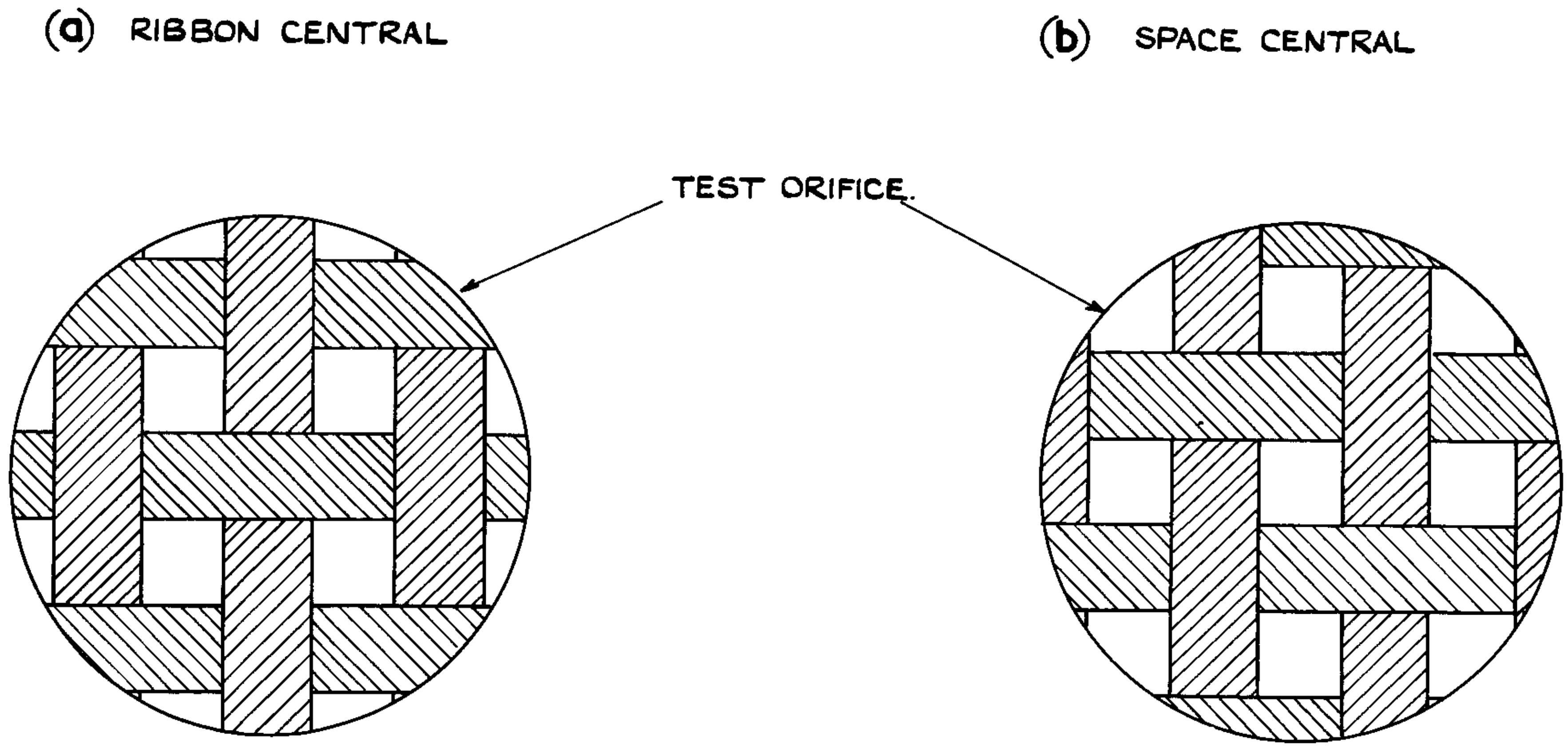


FIG. 3 (a & b) PICTORIAL VIEW OF EXTREME POSITIONS OF RIBBONS RELATIVE TO TEST ORIFICE.

FIG. 3 (a & b)

FIG. 4.

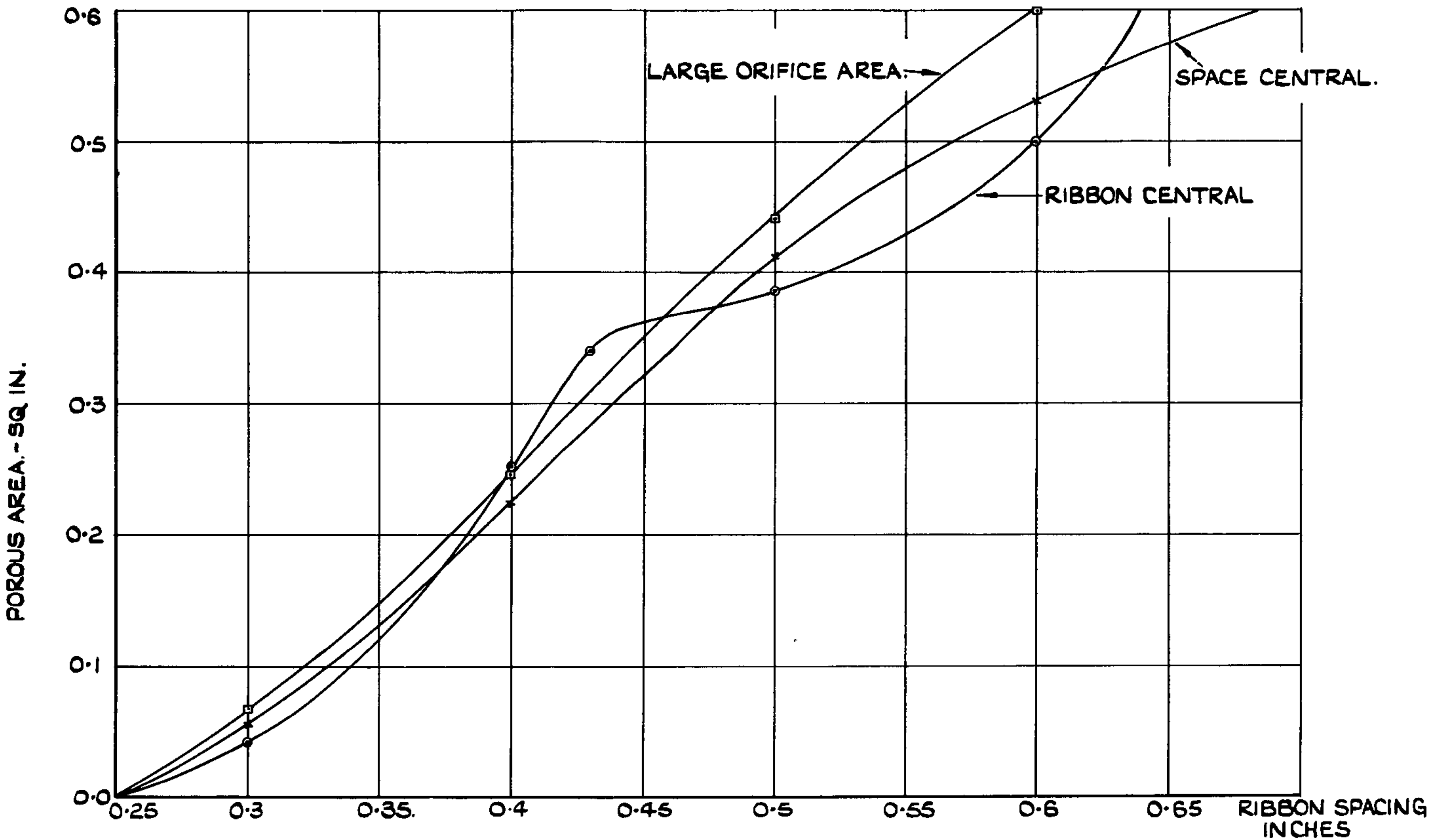
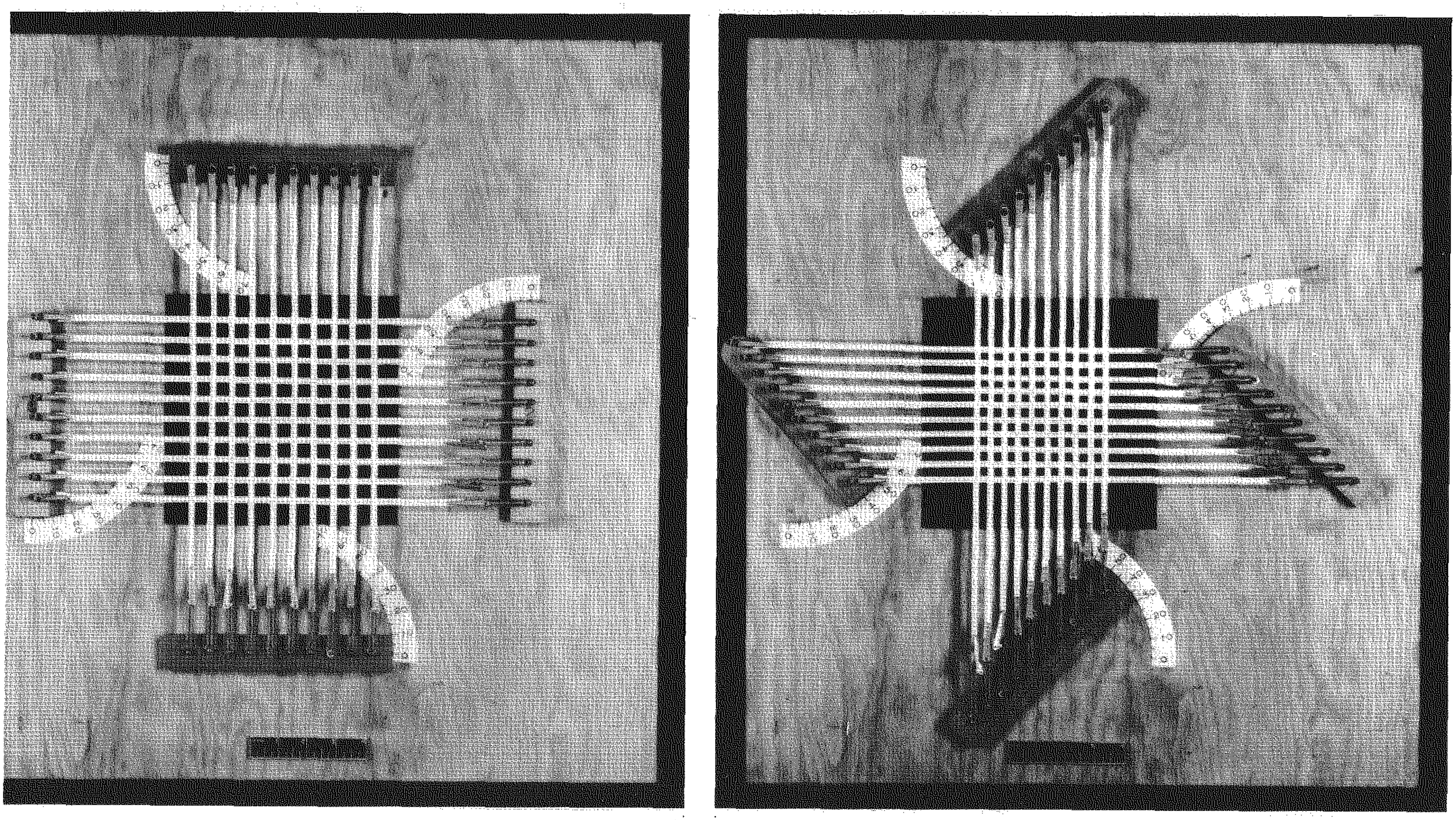


FIG. 4. RELATION BETWEEN POROUS AREA AND RIBBON SPACING OVER A $1\frac{1}{2}$ INCH DIAMETER ORIFICE.

FIG.5



a FIG.5. FRAME FOR ADJUSTING RIBBON SPACINGS b

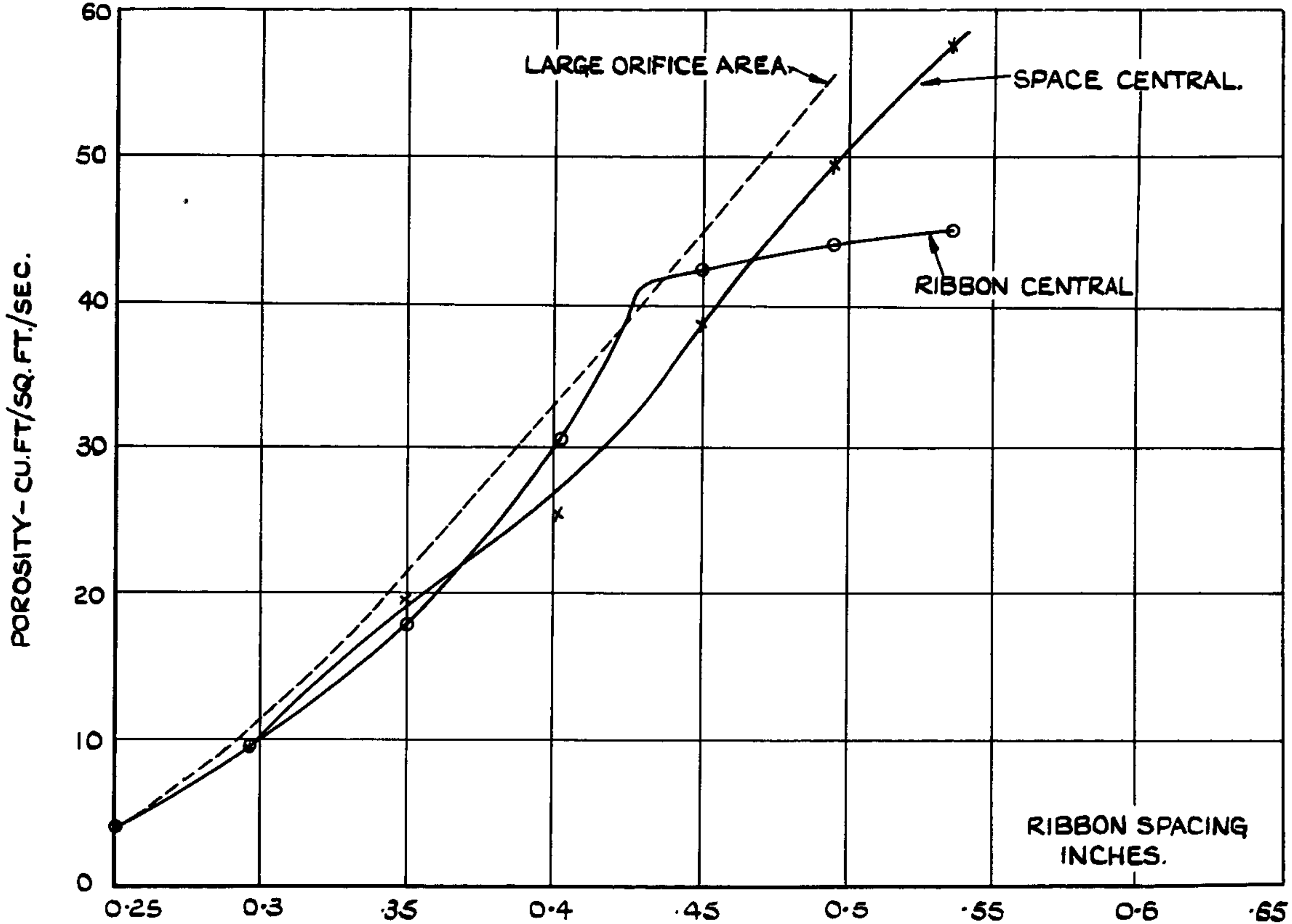


FIG 6 RELATION BETWEEN POROSITY AND SPACING OF ARTIFICIAL SILK RIBBONS OVER A $1\frac{1}{2}$ INCH DIAMETER ORIFICE.

FIG. 6.

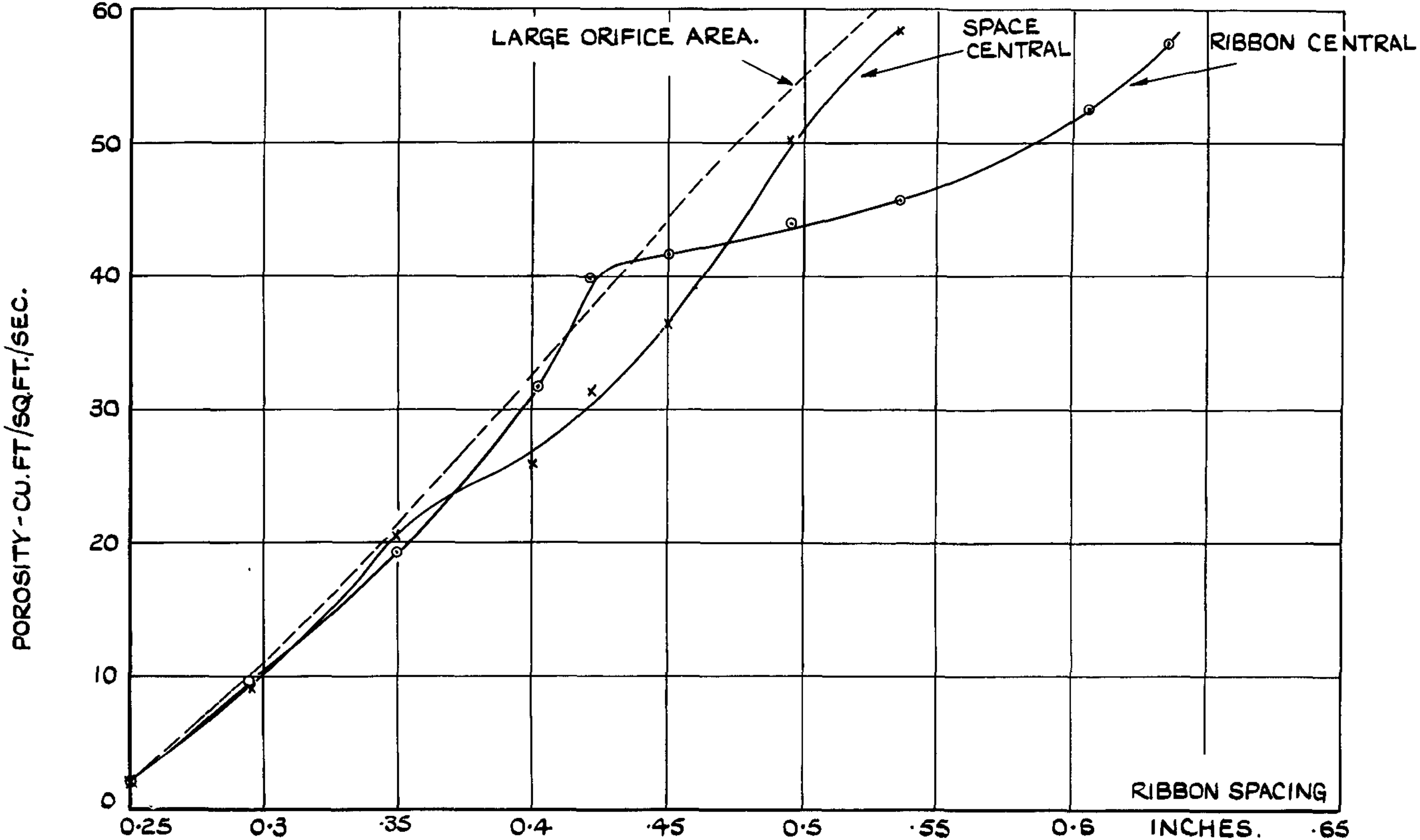


FIG. 7. RELATION BETWEEN POROSITY AND SPACING OF COTTON RIBBONS OVER A $1\frac{1}{2}$ IN. DIAMETER ORIFICE.

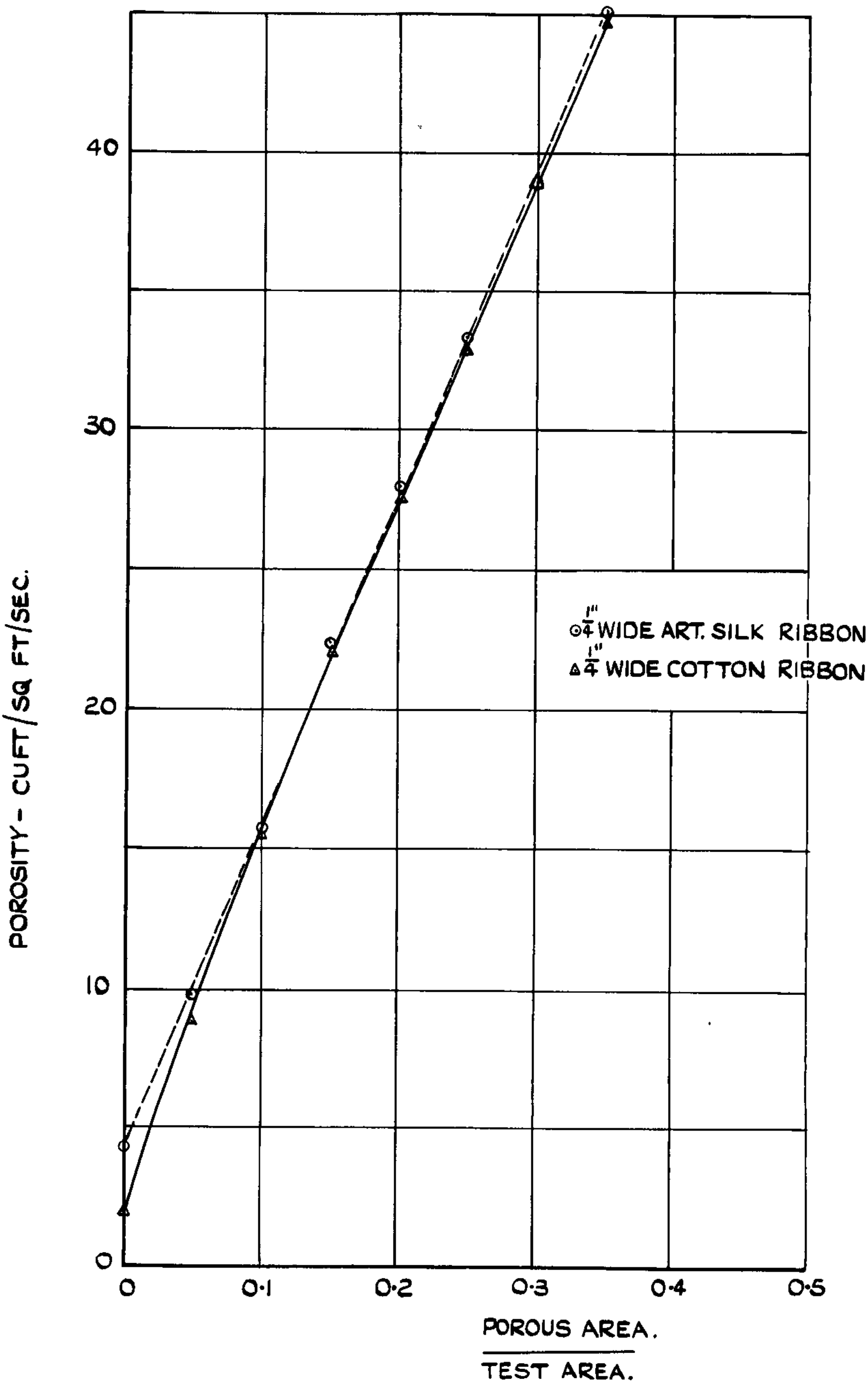


FIG. 8. RELATION BETWEEN POROSITY AND POROUS AREA OF RIBBON MESH.

FIG. 9.

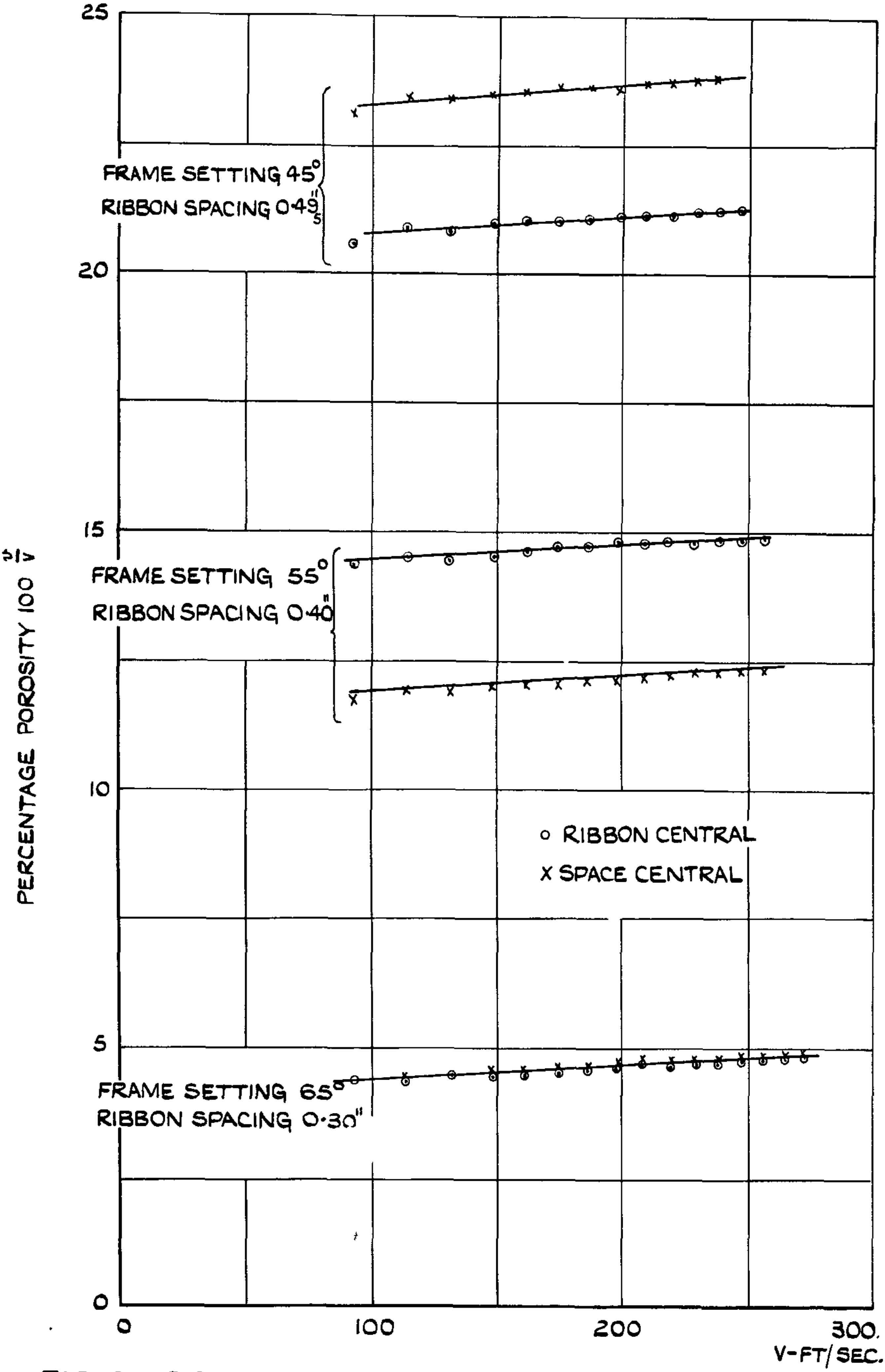


FIG. 9. RELATION BETWEEN PERCENTAGE POROSITY AND V USING ART SILK RIBBON MESH.

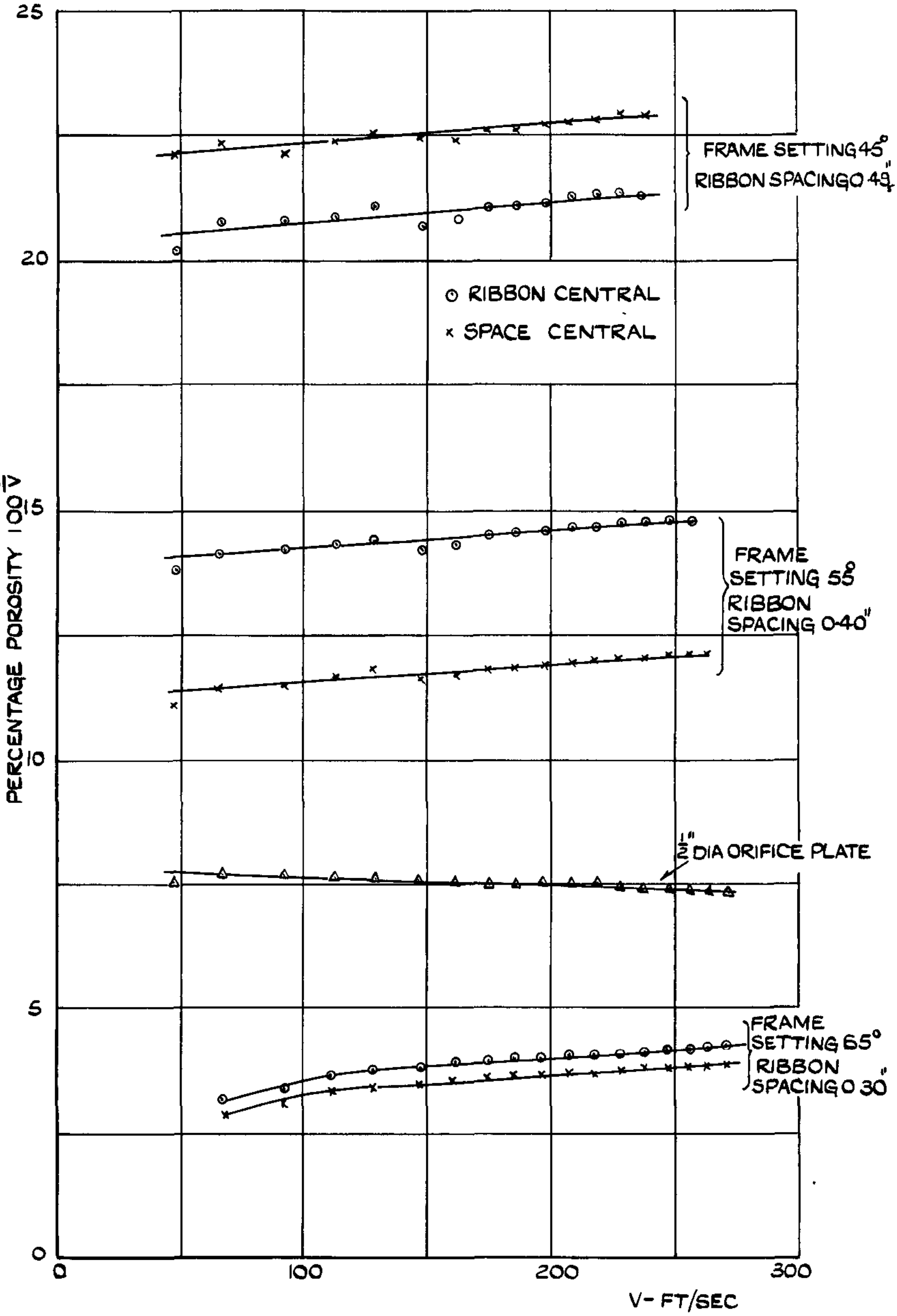


FIG. 10 RELATION BETWEEN PERCENTAGE POROSITY AND V USING COTTON RIBBON MESH.

FIG. 11.

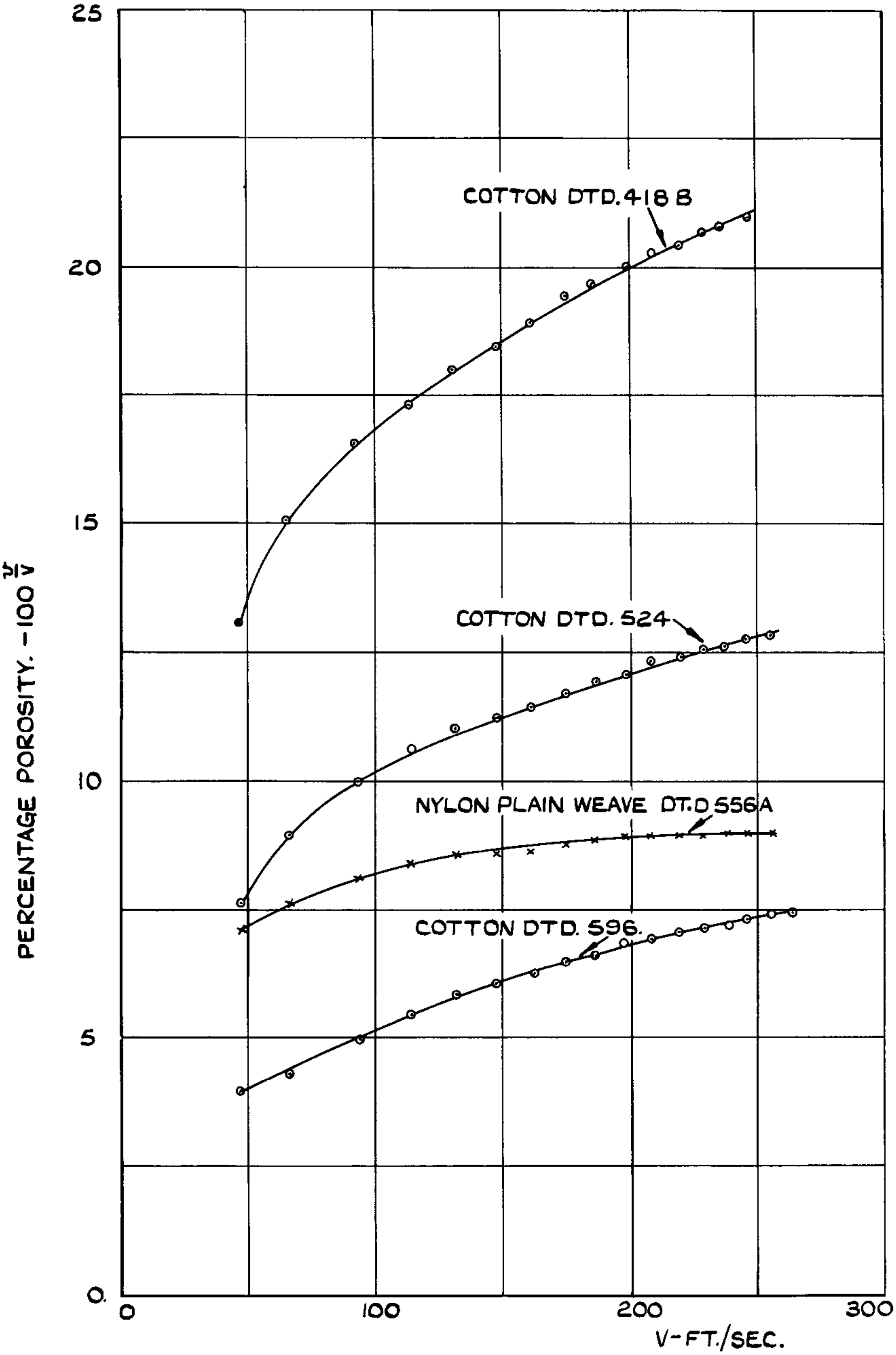


FIG. 11. RELATION BETWEEN PERCENTAGE POROSITY OF WOVEN FABRICS AND V.

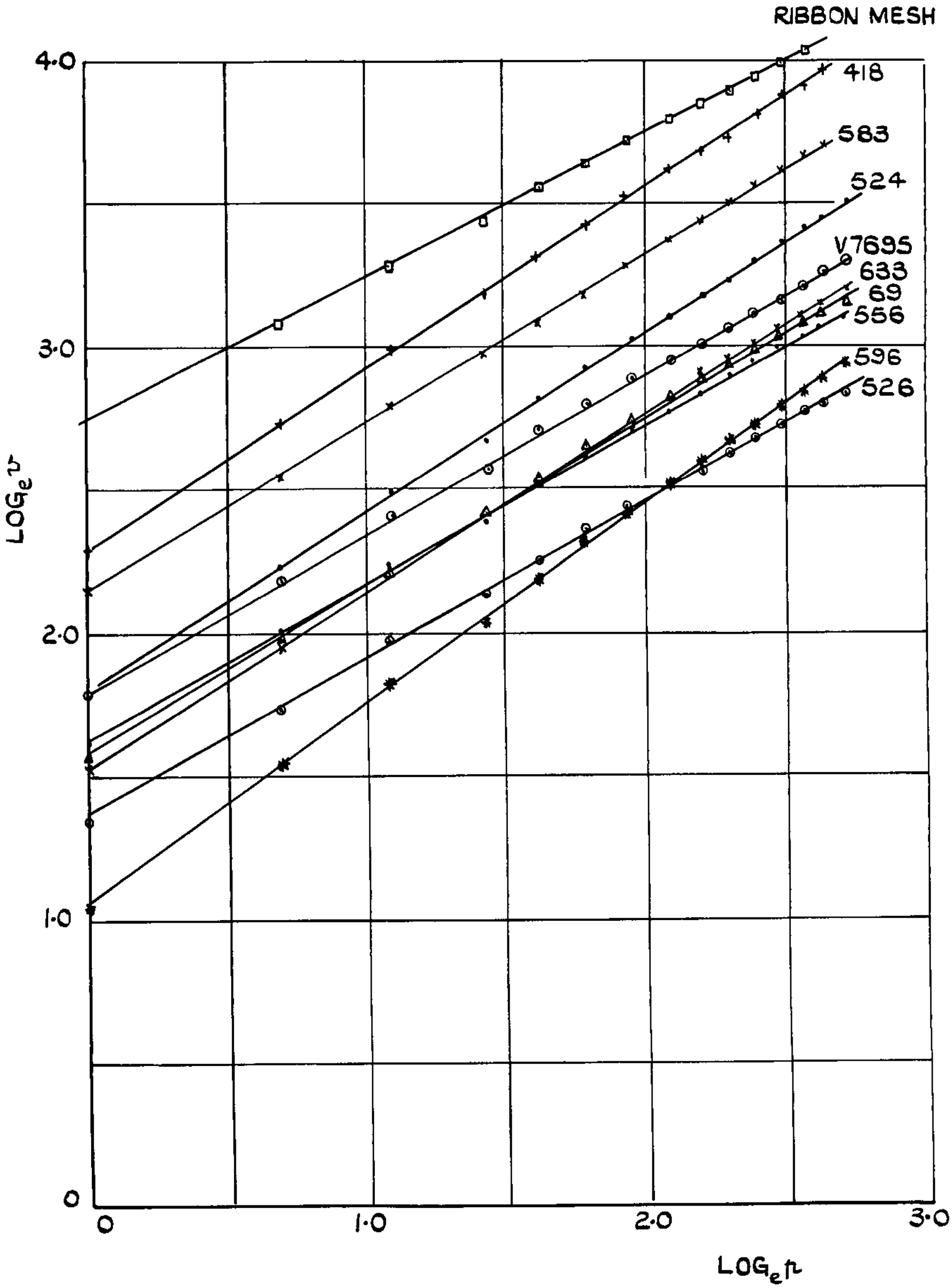


FIG. 12. RELATION BETWEEN POROSITY AND PRESSURE ACROSS FABRIC TEST AREA.

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