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THE EFFECT OF CONSTRUCTIONAL FEATURES ON THE TENSILE STRENGTH OF WOVEN STRUCTURES

THESIS

submitted

by

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IN THE FACULTY OF SCIENCE

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SUMMARY

The main field of enquiry included the effect of interlacing on the tensile strength and the influence of changes in weft particulars on the strength of the warp. The results in all cases are expressed in terms of fabric assistance ratios which are of greater interest when dealing with the influence of component yarns on the fabric than direct strength values. Behaviour of continuous filament yarns and cotton yarns in woven constructions was investigated and considerable differences in the basic pattern were discovered between the different materials.

In addition to the sett and the weave structure it was found that the crimp factor exerted a distinct influence on the ultimate strength value. In this connection it was postulated that of considerable importance in the standard method of tensile strength was the ratio of crimp between longitudinal and transverse components of a fabric.

A trellis type of jaw was constructed to test fabrics under conditions of homogeneous strain with the elimination of "waist" effects and comparisons were made between the two methods of test using identical specimens.

CHAPTER I

GENERAL INTRODUCTION

In order to design a woven fabric having the optimum combination of properties for a given use, it is desirable if not essential to know how each of the properties in question is affected by the changes that can be made in the construction of the fabric. In the present investigation the property in question is the tensile strength.

Tensile strength has been accepted as one of the more important mechanical properties of a woven textile structure. It shows the coherence of the structure in question and without useful degree of coherence, the rest of the properties are really of little value.

Very often a certain minimum strength is required in a variety of woven textile structures made under contract as a guarantee of quality and as a comprehensive check on a number of other points of specification. Manufacturers who attempt to produce such structures are not able to know whether they are meeting the required strength specification until they test a woven specimen. Thus the work is carried out blindfoldedly, especially, when new types of structures are woven. When it is a repetition of a previous specification or where particulars are somewhat similar, the same difficulty does not exist since there is a store of knowledge with regard to its behaviour and characteristics obtained through past experience.

Since the practice in the weaving industry is to order yarn in considerable bulk before the commencement of the weaving process, any mistake in respect of yarn count, yarn twist or fibre quality could be very expensive if the woven structure in the end did not meet the requirements. If there was no previous experience of the structure in question, the manufacturer could only depend on his judgment and broad appreciation of general factors involved, and might err considerably. The tendency might be to err on the high side which could result in the production of a highly priced and therefore uncompetetive fabric.

For these reasons, the general equation relating fabric strength and the yarn particulars could be of considerable value. This relation, as one can expect, will undoubtedly be a very complex one, due to a large number of variables involved and also due to their interaction. This mutual interaction of of variables may, in turn, cause the effect or influence of each variable to change considerably.

The variables which the textile technologist may have to deal with could be listed as follows:

a. Characteristics of the raw material.
b. Yarn particulars - such as count, twist, method of spinning, doubling, irregularity and frictional properties.
c. Fabric particulars - crimp, setting, tension and type of interlacing.
d. Type of finish.

In spite of the complexity of the problem a good deal of guidance can be obtained, however, by changing the above variables singly in one type of cloth, and then studying the changes in fabric strength in relation to the particular variable.

It was realised, of course, that full investigation of all the particulars involved represented a task of considerable magnitude, but it was thought that by concentrating on some particular variables certain definite trends could be discovered.

CHAPTER 2

REVIEW OF LITERATURE

It has long been known that the mechanical properties including the tensile strength of fabrics depend to a large extent on form factors, which are in common use throughout the textile industry. However, there is very little evidence until about 1928 of any systematic research directed towards engineering fabrics for specific end-uses and with specific characteristics. Since 1928 the volume of literature on the subject has grown considerably and the relevant work is reviewed briefly on the following pages under convenient headings.

2.1 - FABRIC GEOMETRY

Peirce[1] was the first to use the classical approach in the field of fabric geometry. He established the fundamental principles of textile structures by generalising the changes in yarn and fabric form factors on the basis of geometric similarity. Afterwards, many research workers [2,3] have made an attempt to develop rapid computing techniques for solving Peirce's equations published in his original paper 'Geometry of Cloth Structure' for yarns of circular cross-section. Pollitt[4] has also stressed the importance of fabric geometry as well as some of the important relations (expressing yarn diameter, crimp and cover factor) formulated by Peirce. Shcherbina[5], in introducing German readers to the Soviet concept of "structure phase" refers to Peirce's work and to its development by Painter[2]. The term "structure phase" states the geometric structure of a fabric in terms of yarn diameters, fabric thickness and the horizontal and vertical distances between warp and weft thread centre lines. In the case of acrylic fabrics which are woven in plain and some other weaves, Haller[6] has recently applied Peirce's equations of fabric geometry and has published graphical solutions to produce tables for count balance, cover factor and maximum sett. In papers by Il'in[7], Decocq[8] and Fujishima[9], the authors also discuss the geometry of woven fabric. In a report issued by the office of the U.S. Quarter-master General, Backer[10] discusses the importance of fabric geometry and shows the relationship between the structural characteristics of the fabric and various functional characteristics, such as breaking strength and elongation, tear-resistance, etc. In other papers, Backer et al.[11,12,13,14] have made a comprehensive evaluation of the relationship between the structural fabric geometry and its physical properties. In designing fabric structures, the requirements of ultimate strength have been discussed by Hamburger.[15] He indicates in the same paper the importance of elastic properties at high strain levels and their variability, as well as form effects in the case of ultimate strength. In this important contribution he discussed, in short, the underlying philosophy of the concept of an engineering approach to the design of textile structure, which includes the effect caused by fibre properties and fabric structure. In an earlier paper,[16] he has stressed the importance of the stress-strain curves of textile materials.

More recently a similar approach has also been adopted to knitted fabrics by a number of different research workers.[17,18]

2.2 EFFECTS OF STRUCTURAL CHANGES ON FUNCTIONAL CHARACTERISTICS

2.21 - Effect of the Characteristics of the Raw Material

Obviously, the total number of fibres in the direction under test and their quality are most important factors. From the integral strength of the fibres in a cross-section of the fabric, the upper limit of the strength that could possibly be expected can be determined. Gregory[19] has predicted that the realised strength of a fabric is only about half of this strength. The effect of fibre fineness on the tensile properties of fabrics was studied by Sands et al.[20] Cotton fabrics were woven with warp and weft yarns having different combinations of fibre finenesses and a range of yarn twists. Then the effects of these combinations on the strip and grab strengths and on the elongation at break were found. The importance of the above experiments lies in the fact that a maximum weft strip break factor was obtained by using a cotton with micronaire reading of about 4.0 in the weft yarns. The same authors,[21] in another paper, have proved that the tensile strength is not dependent on fibre fineness over a range of micronaire values 3.0-4.5. The effect of short fibres on the tensile strength of fabrics has been reported by Tallant.[22] He pointed out that significant changes result from an increase in the percentage of short fibres in the cotton yarns.

2.22 – Effect of Yarn Twist.

Schwab[23] has discussed the possible effect of yarn twist on the strength of cotton and spun rayon fabrics. The given values, however, are valid only for certain types of fabric. The results are intended to form a basis for setting up tables from which, in practice, the magnitude of the effects can be read off in each individual case. Essam[24,25] has also dealt with this feature and has pointed out that elongation of the fabric is influenced by the amount of yarn twist. This can be seen by testing fabrics which have been closely woven with tightly twisted yarns. Such fabrics show apparent loss of extensibility as compared with fabrics woven from low twist yarns. Schiefer et al.[26] have also discussed the effect of twist on breaking strength, elongation and fabric assistance for plain and 2/2 basket weaves. They observed no consistent differences in fabric properties as a result of change in yarn twist direction. However, they have pointed out that as yarn twist multipliers are increased, the corresponding directional breaking strengths of the fabrics increase up to a maximum and then decrease with very high twist multipliers in a manner similar to the behaviour of single yarns. The peak fabric strengths occur at twist multipliers of 4 to 4.75 in the warp and filling. It is convenient at this stage to introduce the definition of fabric assistance given by the same investigators. Fabric assistance is the difference between the strengths of bands of yarns and the same yarns woven into a fabric structure, expressed as a percentage of strength of the band of yarns. They have shown that with an increase in twist multipliers there is a decrease in fabric assistance in general until a minimum is reached, whereupon further increases in twist multipliers are accompanied by greater degree of fabric assistance. The maximum and minimum points of these two curves (fabric strengths versus twist multipliers and fabric assistance versus twist multipliers) occur at the same twist multipliers. Moreover, they have indicated that the cloth elongation increases with higher twist multipliers. The same authors have also attributed the greater fabric assistance in plain weave, as compared to the basket weave, to the greater number of yarn interlacings in the former.

2.23 – Effect of Warp Tension

Morton and Williamson[27] have examined the influence of varying warp tensions on the mechanical properties of plain weave fabrics, varying in cover factor from $(13.2)^2$ to $(16.2)^2$. They have pointed out that with an increase in tension, there is a corresponding increase in the breaking strength of the resultant fabrics. Pickup[28] has also drawn attention to this problem.

2.24 – Effect of Crimp

It is well-known that the amount of crimp affects the measured strength of a strip. Turner[29] has stated that the relatively low strength of a specimen of a heavily sett fabric is due to the unequal removal of crimp during the test. Peirce[1] has also pointed out that if the longitudinal threads are very closely sett, it may be impossible to remove all their crimp because, before this occurs, the crossing threads will have jammed. Schiefer et al.[26] have noted that the elongations of the fabric exceed those of the yarns and this is due to the crimp. Thus, it follows that the plain weave has greater extensibility than the basket weave.

2.25 – Effect of Weave Structure

Due to the difficulty of expressing weave structure quantitatively, there is a limitation to some extent in relating weave structure to specific fabric properties, e.g. to tensile strength. Essam[24,25] was probably the first to find a definite relationship between the breaking strength of a fabric and its structure. He made a study of four weave structures, constructed with four degrees of openness and with yarns of four twist multipliers. He also tested single yarns for breaking strength and then computed the multiple strengths for each system of fabric yarns (unwoven). He compared these values with the actual fabric strength values and attributed the differences to the weave structure, the texture and the yarn twist. The paper by Brown and Rusca[30] discusses the effect of weave structure on fabric properties. They observed that the warp tensile strength decreases for the 3/3 steep twill and 2/2 basket weave, with increases in picks per inch. According to them, this is due to the abrasive action on the warp during weaving. However, the filling is not subjected to the abrasive action in the same way as the warp and hence, the tensile strength increases with increases in picks per inch. These were some of the findings of the investigators when they tried to develop a specialized fabric highly resistant to the passage of water and air and possessing relatively high tensile and tear strength, yet light in weight.

In the case of worsted fabrics, Ananthan and Lang[31] have described the effect of weave structure and sett on the tensile strength. In their programme, they included plain, 2/2 mat and 2/2 straight twills. They concluded that within the limitations of their experiments, the fabric weight was proportional to the sum of the mean warp and mean weft tensile strengths, so long as the sum of the warp and weft fabric assistances was constant. It should be noted at this stage that the above relationship also holds true in the case of cotton and continuous filament rayon fabrics as shown by Jameson, Whittier, and Schiefer.[32] Ananthan and Lang, in the same paper, have also brought some evidence to prove that the effect of yarn crimp on weight is negligible.

More recently, the influence of weave structure on the tensile properties has received attention from various research workers. Schutz and Hunzinger[33] have defined the term "Coefficient of Binding" as a ratio of the fabric strength to the sum of the strengths of the threads in the samples tested. For the range of variations with which they experimented, this ratio increased proportionally to the increasing number of threads per inch. Srinagabhushana et al.[34] have also discussed the effect of weave structure, with constant setting, on the tensile strength. They have observed that in the plain fabrics the weft strip has about twelve percent higher breaking load, whereas the case is reversed in the twill fabrics. Wegener and Winter[35] have examined the dynamometric properties under periodically repeated upper and lower limiting stresses in the case of cuprammonium rayon fabrics. They have found that from the shrinkage in the weft direction of the fabric, it is possible to predict the elongation behaviour. This shows distinct relationship with the number of warp threads to the weave repeat and the number of picks per centimetre. Again, they have also shown that elasticity decreases with the duration of stress and is inversely proportional to the fabric shrinkage. Schiefer et al.[26] have made an important contribution to this topic. Their experiments covered a wide range of weaves in the same construction, viz. 95 x 92 sett, 57's and 60's count. In that paper, they have enumerated and discussed the factors which contribute to strength and tear resistance. The main feature of their investigation is that they have studied the effect of weave on the tensile strength of fabrics having the same weight per square yard. They have summarized that a fabric which is closely woven, firm and has a large number of threads interlacings per unit area and short floats has a greater strength and elongation than a fabric of the same weight which is loosely woven, sleazy, and has a small number of thread interlacings per unit area and long floats. In another paper, Schiefer et al.[36] have pointed out that the fabric assistance increases with the number of yarn interlacings, which confirms the findings of Essam. Turner[29] has also observed the effect of weave structure on the strength of plain cotton fabrics.

2.26 – Effect of Fabric Setting

Schiefer et al.[36] have concluded that the weft and warp breaking strengths increase with the number of weft and warp yarns per inch respectively. Taylor[37] has also drawn the same conclusion.

2.27 – Effect of Loom Abrasion.

Schiefer et al.[36] have also published evidence regarding the effect of loom abrasion on the tensile strength. They have concluded that loom abrasion decreases the breaking strength of the yarns in the fabric. The decrease is proportional to the amount of loom abrasion, that is, to the number of weft yarns per inch since the movements of the loom are directly proportional to the number of weft yarns per inch.

Moreover, they have also observed from the results that the loom abrasion decreases the warp breaking strength at a greater rate as the number of weft yarns per inch is increased than the increase resulting from the increase in the number of interlacings.

2.3 USE OF STRUCTURAL PARAMETERS IN ADVANCE PREDICTION OF FABRIC STRENGTH

In view of the considerable convenience of advance prediction of fabric behaviour prior to actual weaving, especially when attempting to produce new types of fabrics for contract specifications, many workers tried to compute fabric strength from yarn characteristics and other features known in advance of fabric manufacture.

In 1944, Blacke[38] put forward the following relation between the tensile strength of a yarn and the fabric made therefrom.

$$R_f = F \times N \times R_y$$

where R_f and R_y are the dynamometric resistances of the fabric (5 centimetres wide) and the yarn,

N = the number of threads in 15 centimetres,

and F = a variable.

He has listed and discussed fourteen factors affecting the value of F. This value of F has been established by him for a number of listed cases, using Essam's results.

Another approach has been made by Kjellstrand (1935), based on the ratio between specific strength and fabric density.

Satlow and Griese[39] have also given a fabric strength formula as a multiple of yarn strength. The formula includes a variable F, which is a function of the yarn material, weave structure and the method of weaving. They have discussed these three together with other contributory causes and produced tables for F values for different types of yarns, counts and weaves. They have also made a comparison between theoretical and experimental values of F. This value could be less, equal to, or greater than unity and is given separately for warp and weft.

Bouvet[40] has dealt with the factors, e.g. type of yarn, amount of twist, inherent stretchability of individual yarns, relative humidity of the yarns and fabrics and cloth-setting and several others, to be taken into consideration in calculating the strength of a rayon fabric. He has given diagrams to show the effect of twist on continuous filament and spun-rayon vicose yarns and the variations caused by using different staple lengths of fibre. His formula for calculating the fabric tensile strength is as follows:

$$F_s = Y_s \times NE \times V,$$

where F_s = Fabric tensile strength,
Y_s = Yarn strength,
NE = Number of ends (or picks) per inch,
V = Other variable factors (at least 9 in all).

In another article, the same author[41] discusses some "little-known" factors which either increase or decrease the strength of rayon fabrics. The factors which cause the increase include dimensional changes, sizes, finishes and a packing factor, while amongst those which cause reduction are processing damages, warp-length variation, varied types of yarn and crimp.

Freudenthal[42] has presented an empirical formula to predict cotton fabric strength by the grab method. He concluded that the tensile strength increases with an increase in the thread numbers but decreases with an increase in the cotton yarn count. Hence if such an increase or decrease in tensile strength occurs at a constant ratio with a change in thread number and yarn count, the following formula will hold true:

$$\text{Tensile Strength} = \frac{\text{Constant x Thread Numbers}}{\text{Yarn Count}}$$

The above formula, according to the author, holds true on the basis of the available data. He has also compiled two tables to predict the tensile strengths in the warp, and in the weft direction for fabrics made in a large number of constructions and from a particular type of cotton.

Taylor[37] has made an attempt to co-relate the fabric tensile strength, yarn strength, yarn construction and the parameters of fabric construction and suggested the following relationship.

$$\frac{F}{nf} \cdot \frac{100}{100 - c} = r_2 + \frac{br_1\alpha}{NK^2 f}$$

where $\frac{F}{nf}$ = Fabric strength ratio, J,

c = crimp,

N = count of yarn,

K = twist factor of yarn,

f = single-thread strength of yarn

α = a constant.

r_2 = irregularity factor,

r_1 = binding factor,

b = a constant.

He has also given experimental results to illustrate the validity of the theoretical equation. Moreover, he has drawn various graphs plotting $J \times \frac{100}{100 - c}$ against $\frac{1}{NfK^2}$. All these plots show a linear relationship.

Sands et al.[43] have made a statistical evaluation of the effect of yarn properties and fabric structure on the grab breaking strength of fabrics. They have published equations relating grab strength, yarn count, cloth-sett, crimp and skein breaking strength. The regression of grab strength on the four independent variables for the 87 plain woven fabrics has been expressed in the estimating equation as follows:

For warp direction,

$$X_1 = 8.96 - 1.05 X_2 + 0.84 X_3 + 0.31 X_4 + 0.24 X_5 .$$

For weft direction,

$$X_1 = -10.19 - 0.81 X_2 + 1.07 X_3 + 0.41 X_4 + 0.24 X_5 .$$

Similarly, for the 122 fabrics including plain, sateen, twill, and Oxford weaves,

For warp direction,

$$X_1 = -32.24 - 1.50 X_2 + 1.26 X_3 + 1.49 X_4 + 0.47 X_5 .$$

For weft direction,

$$X_1 = -17.80 - 0.82X_2 + 1.17\ X_3 + 0.10\ X_4 + 0.31\ X_5$$

where X_1 = grab strength,

X_2 = yarn count,

X_3 = yarns per inch,

X_4 = crimp,

X_5 = skein breaking strength.

The authors have suggested that since the plain woven fabrics included in the analysis covered the range from tobacco shade cloth to high count lawns and broad cloths, and the other weaves included twills, Oxfords and sateens (some from both carded and combed yarn), these equations can be used for a first approximation of the relationship between grab strength and the various constructional features.

Another method for predicting the fabric strength was put forward by Whittier[44]. His method depends upon the fact that fabric construction has a definite relationship with its weight. He has mentioned a term called "Fabric Strength Factor". This is obtained by dividing the tensile strength of a fabric (in pounds) by its weight (in ounces per square yard). If the fabric strength factor of a cloth having the same particulars, apart from weight, as the unknown is given, the strength of the unknown fabric sample can be predicted by comparison with the known cloth if the weight of the sample of unknown strength is known.

Hotte[45] has also predicted the breaking strength and elongation of combination fabrics, such as were used in balloons. He has found out a co-relation which exists between the sum of the loads thus borne by the individual fabric components and the total breaking load of the balloon combination.

It is worth mentioning at this stage that in the case of 97 two-bar tricot fabrics, Fletcher and Roberts[46] have established a relationship between stitch length, yarn diameter, runner ratios, wales, courses, breaking strength and elongation and bursting strength.

In the case of felts more dense than 0.17 g/cm^3, Baines et al.[47] have suggested that the tensile strength in $lb./inch^2$ is proportional to the density for the given material felted under similar conditions.

The last two examples, however, refer to structurally different materials where simpler relations may exist than in a woven cloth.

2.4 SURVEY OF DIFFERENT APPROACHES TO FABRIC STRENGTH TESTING

2.41 - Relations between Grab, Tear and Strip Tests

The inter-relationships of grab, tearing and tensile strengths have been studied by various authors.[48,49,50] Eeg-olofsson and Bernskiöld[49,50] have shown, both theoretically and experimentally, that the breaking strength by the grab test should differ from the strength by the strip test of the same width by a constant value independent of the width of the clamps and the difference should decrease to zero as the distance between the clamps is reduced to zero. While assessing the resistance of textiles to fungal attack, Russell and Hindson[51] claimed that bursting strength results are not significantly different from tensile-strength results. In a similar field Winkler[52] has modified Sommer's[53] equation to show that the bursting pressure can be derived from tensile strength and elongation. Alberti[54] made a comparison between the strip and grab tensile strength tests, in which he has shown that the grab test gives greater variability and more jaw-breaks than the strip test. Wagner and

Schlenker[55] also made a similar comparison. They have also given the formula for calculating grab breaking load from the strip test. Yasenova[56] in a recent article has suggested a formula for the inter-conversion of fabric tensile test results obtained on different testing machines with different test lengths and speeds of elongation.

2.42 – Biaxial Tensile Testing

Klein[57] has discussed the criteria of biaxial tensile testing, described the instrument for it and reproduced the load-extension curves of a cotton fabric used for the envelope of an airship at different warp-to-weft load ratios.

Clulow and Taylor[58] have also carried out the theoretical and experimental investigation of biaxial-stress-strain relations in a plain weave fabric. Assuming perfectly flexible yarns of unchanging cross-section, they have compared the experimental results for a plain weave fabric with the theoretical stress-strain characteristics, calculated on the basis of fabric geometry. The theoretical changes in dimensions during a cycle were much greater than the observed changes. This lack of agreement between the two was considered chiefly du to the neglect of yarn stiffness in the theoretical approach.

2.43 - Homogeneous Strain

The inherent difficulty in the strip test as it is performed at present is that the strip is not uniformly stressed and therefore it will be expected to break at a lower total load than it would if the stress was uniform. The ideal strip test is one in which the strain in all the elements of the principal thread-directions is the same. Towards this aim of effecting a homogeneous strain, Weissenberg[59] has suggested the use of trellis grips. The specimen is gripped along two lines that represent the directions of the strain invariant in the sample. The lines of zero elongation are found from preliminary trials. This is a practical development of the "trellis model" of Chadwick, Shorter and Weissenberg[60] who considered the production of homogeneous strains in other than the principal thread directions. After that, Shorter[61,62] has published two papers in one of which he dealt with the general theory of the simple form of the trellis model, and in the other, with the experiments on the behaviour of various textile fabrics under the action of simple pulls applied in various directions relative to the fabric structure.

Kilby[63] has investigated in plain woven fabrics the planar stress-strain relationships of a simple trellis, in which the elements are pivoted together at crossing points, but do not pass under and over one another. He has shown that these relationships are identical with those for an anisotropic elastic lamina which does not display a Poisson effect when extended in either warp or weft directions. However, real fabrics do show the Poisson effect when stretched in these directions because of crimp interchange, and it is suggested that a fabric may be regarded as being equivalent to an anisotropic lamina which shows the Poisson effect and with two planes of geometry at right angles to one another.

2.44 - Stress-strain Distribution.

Nosek[64] has published a theoretical paper on stress distribution in a fabric sample. In order to facilitate the mathematics, he has assumed the cloth as being replaced by a thin, extremely flexible plate of similar modulus and Poisson ratio, and then derived the maximum components of thread tension. He has published further work,[65] in which he has derived the equations for the coefficient of lateral contraction and Poisson's ratio for plain weave fabrics.

Padfield and Dickinson,[66] in a preliminary study, have established stresses and strains in an infinitely long elastic sheet under tension applied at two rigid pairs of square jaws. A similar method is used for the purpose of comparison for the analysis of the stress in a strip tensioned by forces applied at rigid jaws extending across the whole width of the strip. This work was carried out as a primary step in the analysis of fabric strength measurement but the results so far obtained are not directly applicable to such strength tests.

CHAPTER 3

EXPERIMENTAL METHODS

In order to make a systematic study of the effects of changes in structural features of fabrics on tensile strength, it is necessary first to produce a wide range of fabrics of varied parameters. All constructions used were woven on two looms each typical for the class of material employed, viz. cotton fabrics were woven on a Northrop loom and nylon on a Saurer loom.

3.1 LOOM SPECIFICATION

3.11 – The Northrop Loom

An automatic pirn-changing cotton loom, model LF/4 was used. The details were as follows:-

Reed space	44.5 inches.
Dobby	20 shaft fine pitch negative.
Box motion	4 box sliding gear.
Picking	Cone under pick.
Reed	Fast.
Let-off	Roper positive type.
Take up	Ratchet type.
Weft fork	Centre.
Warp stop motion	Mechanical.
Temples	9 ring box type (tube mounted with driven cutter.)

3.12 - The Saurer Loom

An automatic shuttle-changing silk loom, type 100 W was used. The details were as follows:-

Reed space	41.2 inches.
Dobby	16 shafts positive working dobby.
Box motion	2x1 cam actuated drop box.
Picking	Cone under pick.
Reed	Fast.
Let-off	Fully automatic positive.
Take up	Regulator type positive.
Weft fork	Centre.
Warp stop motion	Electrical.
Temples	Single pin roller (rubber covered nose.)

3.2 WEAVING CONDITIONS

3.21 - Loom Timing

The timings were obtained by using a loom setting indicator made by Farnworth Engineering Co. Ltd. The appropriate angles for the various events obtained with the aid of the indicator are presented in Table I. Using this data cyclic timing diagrams were constructed for each of the two looms (Figs. 1 and 2.)

Different motions of the looms with reference to the crank position:-

Fig. 1 The Northrop loom timing diagram.

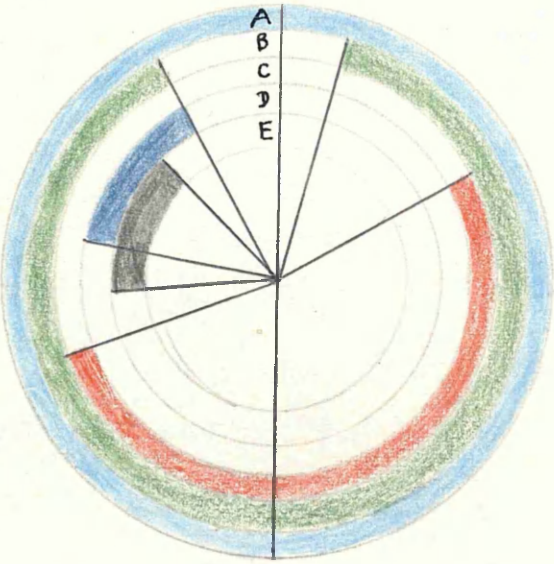


Fig. 2 The Saurer loom timing diagram.

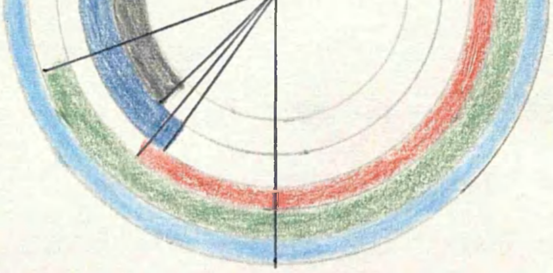


Table I

Loom Timing Sequence.

Circle	Mechanism	Movement	Angle in degrees	
			Northrop	Saurer
A	Sley motion	a. Sley fully back.	0	0
		b. Sley fully forward.	180	180
B	Top shed motion	a. Top shed commencing to move down.	15	35
		b. Top shed steady.	330	250
C	Bottom shed motion	a. Bottom shed commencing to move up.	60	65
		b. Bottom shed steady.	250	220
D	Picking (R.H.S.)	a. Picking stick commences movement.	280	215
		b. Picking stick fully extended	330	270
E	Picking (L.H.S.)	a. Picking stick commences movement.	265	225
		b. Picking stick fully extended.	315	270

3.22 - Loom Drafts

3.221 - Warp

Both the cotton and the nylon warps were obtained on beam, and their particulars were as given in Table II.

Table II

Type of yarn.	Total no. of ends.	width on beam in inches.	Length in yards.
Cotton	2728	39	600
Nylon	3888	40	500

3.222 - Drawing-in

Both the cotton and the nylon warps were drawn-in by hand using 16 heald shafts and a straight draft. The Northrop loom had the slider type twisted wire healds and the Saurer loom had the slider type flat punched steel healds.

3.223 - Sleying

The cotton warp was then sleyed 2 ends per dent in a 72's Stockport reed. The nylon warp was sleyed 2 ends per dent in a 106's Stockport reed.

3.23 - Weaving Personnel

It is essential for research purposes to obtain samples woven under identical conditions in order to ensure that test variations are not due to processing differences. Therefore, it was decided to weave all the samples personally, even though it was very time consuming.

3.3 MATERIALS

3.31 - Yarn Details

Particulars of all the yarns used are presented in Tables III and IV.

Table III

Cotton Yarns

Warp Yarn		Weft Yarn	
Count and type	Twist (T.p.i)	Count and type	Twist (T.p.i.)
2/40's cotton count, mercerised, white, Egyptian cotton.	21.0 (folding twist)	20's cotton count American	13.4 (a) 17.8 (b)
		30's cotton count American	16.4 (c) 21.9 (d)
		2/40's cotton count, mercerised, white, Egyptian cotton. (same as warp)	21.0 (e) (folding twist)

Table IV

Nylon Yarns

Warp yarn		Weft yarn	
Count and type	Twist (T.p.i.)	Count and type	Twist (T.p.i.)
205 denier, 34 filament, white, nylon (syncol sized.)	5 "Z"	150 den.,50 fil.	5"Z"
		"	10 "Z"
		"	15 "Z"
		"	5 "S"
		205 den.,34 fil. (Same as warp)	5 "Z"

3.32 - Cloth Specification

The various fabrics differed in weave construction, weft-sett, weft count, and weft twist. For obvious reasons all possible permutations were not exhausted and the full range of cloths produced is given in Tables V and VI.

Table V

Cotton Fabrics

(Warp sett: 72 E.P.I. in the reed.)

No.	Weave Structure	Weft yarn (Cotton count)	Weft twist (T.p.i)	Weft sett						
				32	40	48	56	64	72	80
1	Plain	20	13.4	▨	▨	▨	▨	▨	☐	☐
2	"	20	17.8	▨	▨	▨	▨	▨	☐	☐
3	"	30	16.4	▨	▨	▨	▨	▨	▨	▨
4	"	30	21.9	▨	▨	▨	▨	▨	▨	▨
5	"	2/40	21.0	▨	▨	▨	▨	▨	▨	▨
6	2/2 twill	20	13.4	▨	▨	▨	▨	▨	▨	▨
7	"	20	17.8	▨	▨	▨	▨	▨	▨	▨
8	"	30	16.4	▨	▨	▨	▨	▨	▨	▨
9	"	30	21.9	▨	▨	▨	▨	▨	▨	▨
10	"	2/40	21.0	▨	▨	▨	▨	▨	▨	▨
11	1/3 twill	20	13.4	▨	▨	▨	▨	▨	▨	▨
12	"	20	17.8	▨	▨	▨	▨	▨	▨	▨
13	"	30	16.4	▨	▨	▨	▨	▨	▨	▨
14	"	30	21.9	▨	▨	▨	▨	▨	▨	▨
15	"	2/40	21.0	▨	▨	▨	▨	▨	▨	▨
16	1/7 twill	20	13.4	▨	▨	▨	▨	▨	▨	▨
17	"	20	17.8	▨	▨	▨	▨	▨	▨	▨
18	"	30	16.4	▨	▨	▨	▨	▨	▨	▨
19	"	30	21.9	▨	▨	▨	▨	▨	▨	▨
20	"	2/40	21.0	▨	▨	▨	▨	▨	▨	▨
21	8-end sateen	20	13.4	▨	▨	▨	▨	▨	▨	▨
22	"	20	17.8	▨	▨	▨	▨	▨	▨	▨
23	"	30	16.4	▨	▨	▨	▨	▨	▨	▨
24	"	30	21.9	▨	▨	▨	▨	▨	▨	▨
25	"	2/40	21.0	▨	▨	▨	▨	▨	▨	▨

▨ Woven setts.

☐ Not available - outwith loom capacity due to high sett.

Table VI

Nylon Fabrics.

(Warp sett: 106 E.P.I. in the reed.)

No.	Weave Structure	Weft yarn (Den./Fil./Twist(T.p.i)	Weft setts 26	32	36	40	48	56	64
1	Plain	150/50/5Z	▨	▨	▨	▨	▨	□	□
2	"	150/50/10Z	▨	▨	▨	▨	▨	□	□
3	"	150/50/15Z	▨	▨	▨	▨	▨	□	□
4	"	150/50/5S	▨	▨	▨	▨	▨	□	□
5	"	205/34/5Z	▨	▨	▨	▨	▨	□	□
6	2/2 twill	150/50/5Z	▨	▨	■	▨	▨	▨	▨
7	"	150/50/10Z	▨	▨	■	▨	▨	▨	▨
8	"	150/50/15Z	▨	▨	■	▨	▨	▨	▨
9	"	150/50/5S	▨	▨	■	▨	▨	▨	▨
10	"	205/34/5Z	▨	▨	■	▨	▨	▨	▨

▨ Woven setts.

■ Not woven.

□ Not available - outwith loom capacity due to high sett.

3.4 TESTING TECHNIQUES

3.41 - Conditioning and Testing Atmosphere

All yarn and fabric samples were conditioned for at least 48 hours at 65 ± 1 per cent relative humidity and at a temperature of 70 ± 2°F before any of the tests were carried out. The testing atmosphere was similar to that in which the samples were conditioned.

3.42 - Yarn Tensile Strength

A standard single-thread testing machine made by James H. Heal & Co. Ltd., of Halifax was used. It was operated at the rate of traverse of 12 inches per minute. The test length was kept constant viz. 12 inches throughout and 20 specimens were tested in each case. All the specimens were drawn directly from cones or bobbins in accordance with the usual sampling techniques prescribed for this type of test. Normal precautions were taken to ensure that the twist was not lost in the specimen.

When the specimen has been mounted, the initial reading of the pointer on the extension scale was noted. Then the lower grip was set in motion. Upon failure of the specimen, the position of the load pointer on the appropriate scale was read and noted. The load required to break the specimen was also auto-recorded. The lower grip was then returned to its initial position. The broken ends of the yarn were removed from the grips and the load arm returned to the starting position.

3.43 - Yarn Frictional Characteristics.

Yarn kinetic friction against steel was measured by using the yarn kinetic friction tester made by Shirley Institute, together with cone-winder, transparent calibration scales, recording ink and circular charts of 4 inches diameter. The yarn was passed at a speed of 60 yards per minute over an arc of clean polished stainless steel, and the steady value of the coefficient of friction was autotraced on the circular paper charts, by using an autographic recorder. The instrument has two ranges. In the present experiment, the lower range viz. 0 to 0.6 was used.

The yarn tested was on either cones or ring bobbins. It should be noted that before the testing sequence was commenced, clean and scoured cotton was run through with a view to remove any traces of grease from the apparatus as this would ultimately affect the test results obtained. Then for each test, sufficient length of yarn was run through the instrument until a complete closed circle was traced by the pen.

The appropriate transparent calibration scale was then superimposed on the circles traced by the pen to obtain the value of the coefficient of friction.

The suggested accuracy of the results by this method is 0.01.

3.44 - Crimp

Tests for warp and weft crimp were carried out according to B.S. 2863:1957 using the W.I.R.A. crimp meter. The principle used is to measure the extension of a thread under a given load from the length it occupies in cloth. The tensions recommended in the above specification were arranged for different specimens.

Ten tests of warp crimp and ten tests of weft crimp were made on threads from specimens cut from each different structure. Each test strip was cut originally a little longer than 10 inches in length. However, when testing actually for crimp, the strips were cut to an exact length of 10 inches and the warp or weft threads were removed one at a time, taking care to see that the twist did not run out of the yarn. To do this, both ends of the thread were eased from the strip by a needle and clamped-in and then the rest of the thread was removed from the strip.

The mean stretched length of the threads was calculated from the results of the ten tests. The percentage crimp was calculated as follows:

$$\% \text{ crimp} = \frac{\text{Mean thread length (straightened)} - 10}{10} \times 100$$

3.45 - Fabric Tensile Strength (standard jaws)

A Denison type T. 42 F Fabric testing machine fitted with standard jaws was used. This machine was used principally on account of the high capacity (1200 lbs.) which it could provide to cover the full range of breaking strengths, from low to very high, which were anticipated in this work.

This machine can work either with a constant rate of loading or a constant rate of traverse. In the present work, the tests were carried out with the constant rate of traverse primarily in order to save time in view of the large number of specimens to be tested. Moreover, due to the wide variety of specimens, it was more convenient to use this method in order to expedite the testing procedure since with the C.R.L. system it would be necessary to pre-determine the rate of increase of the load in order to reach the specified minimum breaking load of the fabric in one minute.

The standard breaking jaws could, if required, be replaced by a variety of fittings, for example jaw holders for webbing tapes, cord, etc. The distance between them could also be adjusted. In the present experiments, the standard jaws were padded with leather. This was found necessary because in the preliminary trials, without this precaution, an excessive number of jaw-breaks have occurred.

A permanent and accurate record of the extension at break of each specimen was made using the autographic recorder in which the horizontal movement corresponds to the extension whereas the vertical movement corresponds to the load applied.

3.451 Capacity of Machine

The capacity of this machine can be altered so that it is 1/2, 1/5, or 1/10th of the maximum capacity, thus increasing the range of sensitivity and acting as four machines of different ranges. This is done by a simple knob adjustment and makes it possible to avoid the unreliable bottom 10% of any scale.

3.452 Testing Procedure

The samples cut for testing were 13 inches in length by 2½ inches in width. They were frayed on both sides so that the centre portion remaining was 2 inches wide. It should be noted that all the specimens prepared were as representative of the fabrics as possible. Weaving defects and other fabric irregularities were not avoided deliberately. The specimens were cut at least two inches away from the selvedge.

A preliminary trial was carried out in order to set the appropriate capacity of the machine. This suggested a use of 240 lbs. capacity for cotton specimens and 600 lbs. capacity for nylon specimens.

Each of the frayed out specimens was clamped first in the top jaw with its other end loose. The latter was then clamped in the bottom jaw such that the specimen was straight and without any folds. The distance between the two jaws was arranged at 8 inches for all the tests.

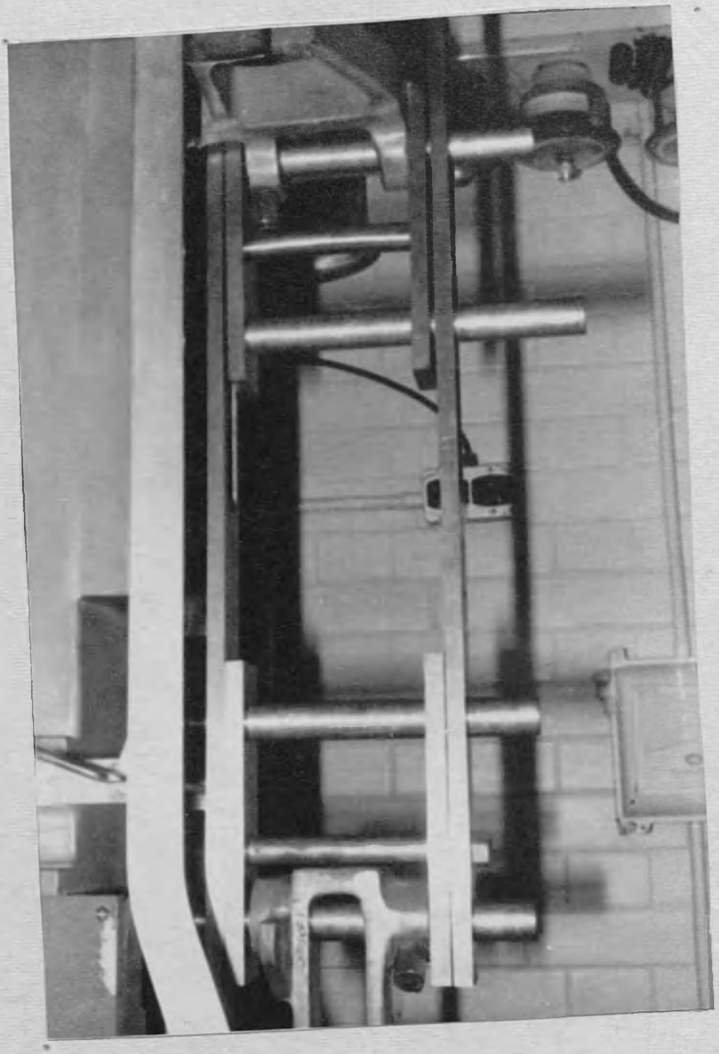
The constant rate of traverse mechanism was operated at a speed of 4½ inches per minute.

The breaking strength was noted from the dial. It should be noted that all the breaks close to the jaw were not taken into account. Five specimens were tested in each direction for each of the woven structures.

3.46 - Fabric Tensile Strength (Trellis Jaws)

As mentioned in previous chapters the standard method of tensile strength testing of fabric strips suffers from a number of inherent errors which may confuse the conclusion and analysis of results especially with regard to the effect of various parameters in respect of the final breaking load. To simplify the analysis it was, therefore, decided to use for some fabrics the trellis system of gripping on the lines specified in the British Patent Specification No. 590,639. The trellis jaws which were specially designed and constructed for this work also required the construction of roller grips for the preliminary determination of lines of zero elongation. Both types of the special jaws were adapted for use in the same Denison testing machine which was also used for the standard tests described above. This machine was only modified in respect of the different weights of jaws which were involved but otherwise the conditions, and the manner of its operation remained unchanged.

Fig. 3



3.461 - Determination of Lines of Zero Elongation

Before any use can be made of trellis jaws it is necessary to determine first the angle at which the fabric must be clamped in order to avoid the "waisting" effect. This angle is determined by the lines of zero elongation which were obtained by the use of the "simple pull" technique achieved in conjuction with roller grips.

The principle underlying the use of roller grips is that the specimen is free to assume the state of strain corresponding to a simple pull. As is well known, such freedom is not enjoyed by a specimen clamped in the standard jaws.

The arrangement used, which was fitted to the Denison testing machine, is illustrated in Fig.3. It consisted of two rollers held in the upper and lower pulling mechanisms of the testing machine such that they were parallel to each other and also, the mid-points of their axes were in line with the direction of the applied pull of the machine.

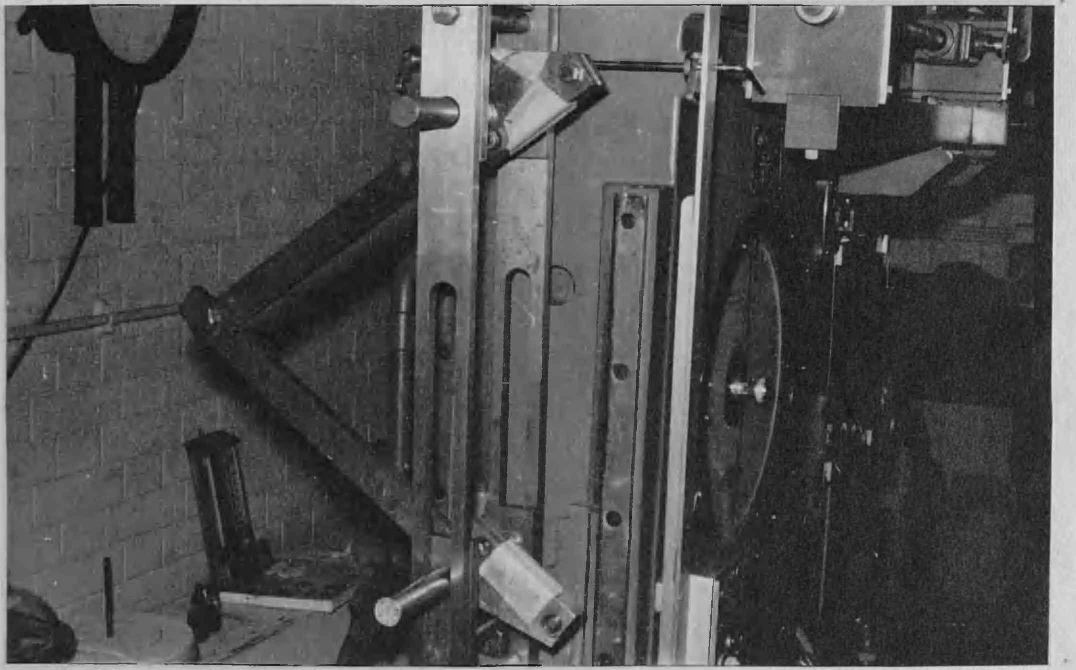
The specimens were prepared in the form of strips, 24 inches in length and 2½ inches in width. They were then frayed to 2 inches in width. This was necessary in order to ensure that the cut was in line with the longitudinal thread. Each specimen was carefully freed from wrinkles and folds and a circle of 2 inches diameter was marked with ink in the centre of the specimen. The two ends of the specimen were then sewn together to form an endless belt and placed round the two cylindrical rollers.

A photographic record was kept of fabric appearance prior to, and after stretching. The stretching was carried to a point just before breakage or disintegration of fabric.

The above procedure was used only for the first specimen of each type. With the rest of the specimens of each group, an aluminium template was put at the back of the stretched specimen and a circle was drawn on the specimen such that the centre of this circle coincided with the centre of the previous one which by now has been pulled into an elliptical shape. This was found to be quite adequate. The common diameters of the circle and the ellipse were drawn. These diameters denoted the "lines of zero elongation".

With this information available, it was now possible to fix the original displacement angle of the

Fig. 4



trellis jaws such that neither "waisting", nor bowing would occur during test.

3.462 - Use of Trellis Grips

As referred to previously [60,61,62] in the review of literature, there are two convenient forms of the trellis jaws for imposing a simple pull. These are namely, the parallelogram grips and the angle grips. In the present investigation, the latter type of jaws were used, and these are illustrated in Figure 4. The angle jaws consist mainly of two clamping steel bars, pivoted at one end with a hinge, and whose axis of pivoting is co-linear with the lines of grip of the bars. The device includes means for adjusting the angle between the arms, and fixing it at any desired value.

The specimens for the trellis were prepared and their dimensions were not less than 24 inches in length and 2½ inches in width. The samples were frayed to 2 inches in width to ensure that the longitudinal thread of the sample was in line with the cut of the specimen. The specimens were then gripped along the lines of zero elongation in the trellis jaws. In all cases, the specimens were tested for simple pulls only i.e. the orientation of the warpway direction was zero.

CHAPTER 4

EXPERIMENTAL RESULTS

In this chapter, it is intended merely to present the results of the experimental work and to provide only such comments as may be necessary to put into proper focus the general trend or any unusual features of the various tests carried out. A full discussion and interpretation of the results obtained will be given in the final chapters.

4.1 RESULTS OF TESTS ON YARNS

4.11 - Tensile Strength and Elongation

Since one of the main objects of this work was to investigate the tensile strength properties of various woven constructions in terms of fabric assistance ratios, it became imperative to know and to specify fully the original single end yarn strengths.

The results of these tests on all the yarns used are given in Tables VII and VIII. With reference to cotton yarns (Table VII), it is interesting to note the different situation arising between the 20's and the 30's count with regard to similar twist factors and their effect on respective yarn strengths. In nylon yarns (Table VIII), the effect of an increase in the twist is followed by the decrease in the tensile strength. At the twist factors used this effect conforms to the generally accepted pattern.

Table VII

No.	Count & Type	Twist (T.p.i)	Breaking load (Ozs.)	C.V. (%)	Elongation at break (%)
1	2/40's cotton count, mercerised, white, Egyptian cotton	21·0	17.76	8.0	4.1
2	20's cotton count Am.	13.4	15.5	6.1	6.7
3	"	17.8	14.0	10.8	5.2
4	30's cotton count Am.	16.4	8.5	15.5	4.2
5	"	21.9	10.7	6.2	3.6

Table VIII

No.	Nylon Denier/filament/Twist(T.p.i)	Breaking load (Ozs.)	C.V. (%)	Elongation at break (%)
1	150/50/5Z	25.2	10.0	20.8
2	150/50/10Z	24.9	6.1	22.9
3	150/50/15Z	23.6	8.8	22.9
4	150/50/5S	25.0	8.9	22.0
5	205/34/5Z	35.3	5.0	15.6

4.12 - Yarn Frictional Characteristics

It appears from the survey of relevant literature that frictional characteristics of yarn component have been very largely neglected as a factor contributing to changes in fabric tensile properties. It was thought, however, that this factor could be of some importance, particularly in connection with stress redistribution and crimp interchange which occur during testing, and therefore friction tests were carried out in anticipation as a preliminary measure.

The results are given in Tables IX and X and whilst all cotton yarns fall within the same range, nylon yarns of higher twist show significant differences.

Table IX

No.	Count & Type	Twist (T.p.i)	Coefficient of friction
1	2/40's cotton count, mercerised, white, Egyptian cotton	21	Betw.0.2 & 0.3
2	20's cotton count, American	13.4	"
3	"	17.8	"
4	30's cotton count, American	16.4	"
5	"	21.9	"

Table X

No.	Nylon Denier/Filament/Twist(T.p.i)	Coefficient of friction.
1	150/50/5Z	Betw. 0.4 & 0.5
2	150/50/10Z	Betw. 0.3 & 0.4
3	150/50/15Z	"
4	150/50/5S	Betw. 0.4 & 0.5
5	205/34/5Z	"

4.2 RESULTS OF TESTS ON FABRICS

4.21 - Crimp

This is an inherent property of woven fabrics and will vary with changes in type of interlacing, density in thread setting and weaving tensions. Since the original crimp value may bear considerably on the crimp interchange phenomena during tensile strength tests on fabrics, it was thought necessary to obtain a full record of this effect for reference purposes. The results are tabulated in Tables XI and XII. On the whole, the warp crimp which is of primary importance in this work shows a regular pattern of increases with the increases in density of weft spacing and the

Table XI

Percentage Warp and Weft Crimps of Cotton Fabrics

(2/40's cotton count, 21 T.p.i. twist as warp yarn, 72 E.P.I. as warp sett)

Weft yarn	Weft sett	Plain		2/2 Twill		1/3 Twill		1/7 Twill		8-end sateen	
		warp	weft	warp	weft	warp	weft	warp	weft	warp	weft
20's cotton count, 13.4 T.P.I.	32	9.6	2.7	6.8	2.6	6.7	2.9	5.3	4.0	3.4	3.0
	40	10.5	2.8	7.7	3.5	7.2	3.6	5.0	4.0	3.0	3.8
	48	13.6	3.6	7.8	4.2	8.1	4.2	5.3	4.3	4.2	3.5
	56	15.3	3.7	8.0	5.6	8.1	5.5	5.0	4.5	4.0	4.0
	64	15.2	7.7	7.4	6.0	8.7	5.7	5.0	5.0	4.5	4.5
	72	14.4	7.3	7.9	6.4	9.1	6.0	5.5	5.1	5.1	4.5
	80	-	-	8.2	8.0	9.3	7.0	5.6	5.1	5.6	4.5
20's cotton count, 17.8 T.P.I.	32	8.1	3.3	5.6	2.7	5.9	2.9	4.5	3.2	3.1	3.4
	40	10.0	3.9	7.0	4.0	5.6	3.3	4.6	4.3	3.0	4.1
	48	12.5	4.7	7.8	4.3	6.5	4.4	4.2	4.0	3.9	4.3
	56	13.5	4.9	7.3	5.0	7.0	5.3	4.4	4.3	4.3	4.7
	64	15.0	4.5	8.4	5.6	8.5	5.3	5.4	4.7	4.6	4.9
	72	12.5	8.4	8.4	6.3	7.7	5.8	5.7	5.3	5.2	5.5
	80	-	-	8.6	6.8	7.9	6.7	5.5	5.5	5.4	5.8
30's cotton count, 16.4 T.P.I.	32	6.5	3.0	4.9	3.3	3.8	3.6	2.8	3.3	2.6	3.9
	40	6.8	2.5	4.7	4.3	4.8	4.0	2.9	3.7	2.9	3.4
	48	7.7	4.3	5.0	4.8	4.6	4.2	3.6	4.0	3.0	4.0
	56	10.0	4.7	4.5	5.7	5.5	5.0	3.9	4.7	3.3	4.5
	64	10.3	6.5	5.3	6.2	5.3	5.2	3.2	4.8	3.3	4.7
	72	11.0	7.8	5.4	6.2	4.8	6.5	4.1	5.5	3.9	5.1
	80	11.9	7.7	5.9	7.3	5.3	6.8	4.0	5.2	4.2	4.7
30's cotton count, 21.9 T.P.I.	32	8.1	3.5	5.0	4.5	4.8	4.4	2.5	3.3	3.0	3.2
	40	9.3	3.9	6.2	4.6	5.1	3.3	3.9	4.0	3.0	4.3
	48	9.3	3.8	4.6	4.5	5.1	4.7	4.0	4.5	3.6	4.5
	56	9.0	4.7	6.5	6.0	6.2	4.5	4.0	6.4	3.0	4.8
	64	10.4	5.3	6.4	6.3	6.8	5.0	4.2	6.6	5.2	5.4
	72	12.3	5.5	6.8	7.9	7.0	6.0	4.3	6.0	3.9	4.9
	80	12.2	7.4	6.9	7.4	5.7	7.9	4.0	5.5	4.0	4.7
2/40's cotton count, 21.0 T.P.I.	32	8.8	2.1	6.3	2.8	5.9	2.7	4.0	2.2	3.0	3.6
	40	12.2	2.3	6.5	2.8	5.9	2.6	4.0	3.0	3.4	3.9
	48	12.4	2.4	7.3	3.6	7.0	2.9	4.3	4.0	3.4	3.9
	56	12.4	3.5	7.6	4.2	6.3	4.2	4.7	4.1	3.5	4.4
	64	14.1	3.6	7.9	5.2	7.5	5.3	4.8	4.7	3.7	4.5
	72	15.3	5.0	7.7	5.0	8.1	5.3	5.6	5.0	4.0	4.6
	80	15.6	5.8	7.9	6.3	7.6	6.2	5.8	5.4	4.6	4.7

Table XII

Percentage Warp and Weft Crimps of Nylon Fabrics

(204/34/5Z as warp yarn, 106 E.P.I. as warp sett)

Weft Yarn	Weft sett	Plain		2/2 Twill	
		Warp	Weft	Warp	Weft
150/50/5Z	26	3.3	2.0	2.4	3.1
	32	2.9	1.9	2.8	2.9
	36			-	-
	40	5.3	1.4	2.7	3.1
	48	7.1	2.0	3.4	3.6
	56	-	-	4.0	4.1
	64	-	-	5.1	5.3
	72	-	-	5.3	5.9
150/50/10Z	26	4.0	3.0	2.4	3.4
	32	5.1	2.1	2.5	3.4
	36	4.5	2.4	-	-
	40	6.7	2.5	3.1	4.0
	48	8.6	2.9	4.0	5.1
	56	-	-	4.3	5.3
	64	-	-	5.0	7.0
	72	-	-	6.5	7.4
150/50/15Z	26	3.3	3.0	2.5	4.8
	32	4.8	3.0	2.6	4.8
	36	4.6	3.4	-	-
	40	6.8	3.5	3.4	5.3
	48	9.1	3.9	4.0	5.5
	56	-	-	5.4	6.2
	64	-	-	6.3	7.1
	72	-	-	6.1	7.1
150/50/5S	26	3.2	1.5	2.2	2.9
	32	4.0	1.7	2.1	3.1
	36	3.7	1.7	-	-
	40	5.5	2.2	2.6	3.7
	48	7.4	1.9	3.4	4.2
	56	-	-	3.8	5.1
	64	-	-	4.1	4.9
	72	-	-	5.5	6.8
205/34/5Z	26	3.8	1.8	2.6	1.5
	32	5.4	2.0	3.3	1.7
	36	4.7	1.3	-	-
	40	7.2	1.6	4.0	1.9
	48	11.0	1.2	5.5	2.1
	56	-	-	6.5	2.8
	64	-	-	7.7	2.7
	72	-	-	9.0	3.1

decreases in float length. It reflects, however, any changes in weaving tension which took place when high weft setts were woven in plain weave construction. As there were no corresponding changes in the warp setts similar pattern could not be established in the weft crimp. In the nylon fabrics, all of which were woven with a very high warp sett, the weft crimp is characteristically low. This is shown particularly well in the case where the heavier denier was used for weft in plain weave construction, the weft lying almost straight with the warp doing most of the bending.

Changes in weft counts produced considerable variation in warp crimp, again in an entirely expected direction, i.e. increased thickness of weft yarn resulted in an increase in warp crimp figures.

Variations in the twist factor of weft yarns had less influence on changes in warp yarn crimp though there was a discernible tendency for the warp crimp effect to increase with the increase in the twist factor. This pattern of behaviour was more marked in the case of nylon yarns and the coarser of the two cotton counts used than in the fine cotton weft yarns.

The rate of crimp increases due to changes of various parameters, was different for different weave interlacings.

4.22 - Fabric Tensile Strength (Standard Jaws)

The results of fabric tensile strength using the standard jaws are given in Tables XIII and XIV. As is known, the fabric relaxes when it is removed from the loom, and this may affect the actual sett of the fabric. It was noted in the present investigation that in low sett fabrics there was no difference between the nominal and the actual setts. This was not the case, however, in high-sett fabrics where some changes did take place in certain weaves. These changes were very small; nevertheless, due cognisance was taken of them in graphical work and though main values in the scales are shown at intervals corresponding to nominal setts the points were plotted in terms of actual setts. For the sake of clarity of presentation only the nominal sett values are shown in the tables.

Table XIII

Tensile Strength (lbs.) of Cotton Fabrics

(Warp yarn: 2/40's cotton count, 21 T.P.I.; Warp sett= 72)

Weft	Weft	Plain		2/2 Twill		1/3 Twill		1/7 Twill		8-end Sateen	
yarn	sett	warp	weft	warp	weft	warp	weft	warp	weft	warp	weft
20's cotton count, 13.4 T.P.I.	32	164	83	171	78	154	72	151	72	164	69
	40	159	105	165	101	148	99	147	98	161	88
	48	152	140	153	128	155	133	152	113	145	107
	56	167	165	159	151	164	151	154	139	150	133
	64	165	203	171	169	166	166	160	164	151	168
	72	156	214	166	199	165	197	158	190	151	188
	80	-	-	165	230	157	222	145	213	147	200
20's cotton count, 17.8 T.P.I.	32	169	60	158	59	166	56	147	53	153	53
	40	159	92	178	77	155	78	143	66	167	74
	48	148	109	163	94	161	90	150	102	157	88
	56	166	133	179	124	163	106	153	101	157	113
	64	160	169	164	134	167	134	146	143	154	138
	72	155	169	161	172	170	165	146	158	159,	151
	80	-	-	159	192	163	194	145	177	165	181
30's cotton count, 16.4 T.P.I.	32	164	43	164	43	163	47	166	44	168	39
	40	145	57	161	58	161	54	159	52	164	48
	48	157	72	173	71	167	74	161	62	159	62
	56	161	97	171	81	169	87	148	75	148	76
	64	162	110	168	99	169	95	151	94	157	86
	72	163	139	163	107	167	116	154	100	154	106
	80	160	171	147	124	162	134	146	100	152	118
30's cotton count, 21.9 T.P.I.	32	177	51	158	44	153	40	145	43	154	43
	40	162	66	155	59	147	57	150	56	154	56
	48	146	84	154	72	164	72	148	74	162	63
	56	160	103	166	93	169	87	148	78	158	83
	64	178	119	170	100	168				170	104
	72	173	140	163	117	165		150	115	157	107
	80	167	164	161	133	163	137	150	130	162	132
2/40's cotton count, 21.0 T.P.I.	32	161	72	168	71	160	71	149	69	157	63
	40	155	90	166	90	159	90	150	85	152	79
	48	160	114	168	102	159	112	151	102	159	99
	56	150	121	170	131	164	128	150	119	158	117
	64	165	156	165	148	165	147	150	139	143	125
	72	159	179	158	167	158	169	147	162	151	152
	80	144	168	163	185	163	190	141	181	155	176

Table XIV

Tensile Strength (lbs.) of Nylon Fabrics

(Warp yarn: 205/34/5Z, Warp sett: 106)

Weft yarn	Weft sett	Plain		2/2 Twill	
		Warp	weft	warp	weft
150/50/5Z	26	502	89	505	79
	32	497	104	518	100
	36	500		-	-
	40	507	127	530	125
	48	509	142	538	155
	56	-	-	538	176
	64	-	-	541	193
	72	-	-	539	231
150/50/10Z	26	526	82	522	77
	32	521	101	532	99
	36	527	101	-	-
	40	525	124	543	122
	48	523	152	545	150
	56	-	-	545	150
	64	-	-	555	202
	72	-	-	546	228
150/50/15Z	26	526	76	529	77
	32	528	96	536	96
	36	520	91	-	-
	40	524	119	536	114
	48	521	145	537	141
	56	-	-	538	160
	64	-	-	551	199
	72	-	-	544	220
150/50/5S	26	516	79	520	82
	32	519	100	534	99
	36	523	99	-	-
	40	521	123	530	122
	48	524	150	540	147
	56	-	-	542	179
	64	-	-	554	208
	72	-	-	545	236
205/34/5Z	26	505	129	525	128
	32	512	155	524	152
	36	517	147	-	-
	40	498	198	529	188
	48	472	234	532	239
	56	-	-	529	270
	64	-	-	538	319
	72	-	-	536	345

From Table XIII, the following points are evident regarding the tensile strengths of cotton fabrics.

a. In spite of the same number of ends per inch in all the structures, it is noted that there is a big difference between their tensile strengths measured in the warp direction. This difference amounts to 27% in terms of the minimum figure, the strength values oscillating between a minimum of 141 lbs and a maximum of 179 lbs.

b. The increase or decrease in warp tensile strength is not varying strictly according to the weft-sett but appears to fluctuate with a certain degree of regularity. The general pattern is of peaks followed by troughs but their occurence is not perfectly synchronised for all structures.

c. Moreover, in general, the warp tensile strength of tight interlacings is higher than that of loose interlacings though within the group of tightly interlaced structures (i.e. plain and four-shaft twills) a frequent reversal of this situation takes place.

d. With regard to tests in the weft-wise direction the strength increases, as expected, with an increase in the number of picks per inch for a particular weave structure. The rate of this increase, however, is not the same for all weave structures, (Figures 5 - 9). As in the case of warp strips, higher strength is again exhibited by the "tighter" weaves.

Referring to Table XIV, where tensile strength performance of nylon fabrics is summarised, the following comments can be made.

a. In spite of the same number of ends per inch, the warp tensile strengths differ considerably - the minimum recorded strength is 472 lbs and the maximum 555 lbs.

b. At maximum weft setts, the warp tensile strength falls.

c. With only one exception, the 2/2 twill structure has a higher warp tensile strength than the plain weave structure.

d. As expected, the strength of weft strips increases with an increase in the number of picks per inch for a particular weave and yarn structure. The divergence in the rate of this increase is not very marked between the plain and the 2/2 twill weave, (Fig. 10 - 14)

e. The structures woven with 205/34/5Z yarn as warp and weft has a very higher tensile strength as compared with other structures, woven with only 205/34/5Z as warp. This is evident from figures 15 and 16.

4.23 - Fabric Assistance Ratios (Fig. Nos. 17 - 26)

The fabric assistance ratios for the cotton and the nylon fabrics are given in Tables XV and XVI respectively.

Table XV

Fabric Assistance Ratios (Standard Method) of Cotton Fabrics

(Warp yarn: 2/40's cotton count, 21 T.p.i.; Warp sett: 72)

Weft	Weft	Plain		2/2 Twill		1/3 Twill		1/7 Twill		8-end Sateen	
yarn	sett	warp	weft	warp	weft	warp	weft	warp	weft	warp	weft
20's cotton count, 13.4 T.p.i.	32	1.03	1.33	1.07	1.25	0.97	1.15	0.95	1.15	1.03	1.10
	40	1.00	1.37	1.03	1.31	0.93	1.29	0.92	1.27	1.01	1.14
	48	0.95	1.54	0.96	1.41	0.97	1.46	0.95	1.24	0.91	1.18
	56	1.05	1.49	1.00	1.36	1.03	1.36	0.97	1.25	0.94	1.20
	64	1.03	1.62	1.06	1.55	1.04	1.33	1.00	1.31	0.95	1.34
	72	0.98	1.50	1.04	1.39	1.03	1.38	0.99	1.33	0.95	1.33
	80	-	-	1.03	1.49	0.98	1.44	0.91	1.38	0.92	1.30
20's cotton count, 17.8 T.p.i.	32	1.06	1.07	0.99	1.05	1.04	1.00	0.92	0.95	0.96	0.95
	40	1.00	1.31	1.12	1.10	0.97	1.11	0.90	0.94	1.05	1.05
	48	0.93	1.29	1.02	1.12	1.01	1.07	0.94	1.22	0.98	1.05
	56	1.04	1.36	1.12	1.27	1.02	1.08	0.96	1.03	1.01	1.15
	64	1.00	1.51	1.03	1.20	1.05	1.20	0.93	1.28	0.97	1.23
	72	0.97	1.34	1.01	1.37	1.07	1.31	0.91	1.25	0.95	1.20
	80	-	-	1.00	1.37	1.02	1.39	0.91	1.26	0.90	1.29
30's cotton count, 16.4 T.p.i.	32	1.01	1.26	1.03	1.26	1.02	1.35	1.04	1.29	1.05	1.15
	40	0.91	1.34	1.01	1.36	1.01	1.27	1.00	1.22	1.03	1.13
	48	0.98	1.41	1.08	1.39	1.05	1.45	1.01	1.22	1.00	1.22
	56	1.01	1.63	1.07	1.38	1.01	1.46	0.93	1.26	0.93	1.27
	64	1.02	1.62	1.05	1.46	1.03	1.40	0.95	1.38	0.98	1.26
	72	1.02	1.82	1.02	1.40	1.05	1.53	0.97	1.31	0.97	1.38
	80	1.00	2.01	0.92	1.46	1.02	1.58	0.91	1.18	0.95	1.39
30's cotton count, 21.9 T.p.i.	32	1.11	1.19	0.99	1.00	0.96	0.94	0.91	1.00	0.98	1.00
	40	1.02	1.23	0.97	1.10	0.92	1.07	0.94	1.05	0.97	1.05
	48	0.91	1.30	0.97	1.12	1.03	1.12	0.93	1.15	0.96	0.98
	56	1.00	1.38	1.04	1.24	1.06	1.16	0.98	1.04	0.98	1.11
	64	1.12	1.39	1.07	1.17	1.05		0.97		1.07	1.21
	72	1.08	1.46	1.02	1.22	1.03		0.94	1.19	0.98	1.11
	80	1.00	1.53	1.01	1.24	1.02	1.28	0.93	1.21	0.95	1.23
2/40's cotton count, 21.0 T.p.i.	32	1.01	1.02	1.05	1.00	1.00	1.00	0.95	0.97	0.98	0.88
	40	0.97	1.10	1.03	1.10	0.98	1.10	0.93	0.96	0.95	0.89
	48	1.00	1.07	1.05	0.95	1.00	1.05	0.95	0.95	1.00	0.93
	56	1.04	0.97	1.07	1.05	1.03	1.02	0.94	0.95	0.99	0.94
	64	1.03	1.10	1.05	1.04	1.00	1.03	0.94	0.94	0.97	0.85
	72	1.00	1.12	1.02	1.04	0.99	1.05	0.92	1.01	0.95	0.95
	80	0.90	0.95	0.95	1.04	0.93	1.07	0.88	1.02	0.92	0.99

Table XVI

Fabric Assistance Ratios of Nylon Fabrics

(Warp yarn: 205/34/5Z, Warp sett: 106)

Weft yarn	Weft sett	Plain		2/2 Twill	
		warp	weft	warp	weft
150/50/5Z	26	1.07	1.09	1.08	0.96
	32	1.06	1.03	1.10	0.99
	36	1.07		-	-
	40	1.08	1.00	1.13	0.99
	48	1.08	0.94	1.15	1.03
	56	-	-	1.15	1.00
	64	-	-	1.15	0.95
	72	-	-	1.15	1.02
150/50/10Z	26	1.12	1.01	1.11	0.95
	32	1.11	1.01	1.13	1.00
	36	1.12	0.90	-	-
	40	1.12	1.00	1.16	0.98
	48	1.11	1.02	1.16	1.00
	56	-	-	1.16	0.99
	64	-	-	1.18	1.01
	72	-	-	1.16	1.02
150/50/15Z	26	1.12	1.00	1.13	1.00
	32	1.13	1.02	1.14	1.02
	36	1.11	0.85	-	-
	40	1.12	1.01	1.14	1.00
	48	1.11	1.02	1.14	1.00
	56	-	-	1.15	0.97
	64	-	-	1.17	1.01
	72	-	-	1.16	1.04
150/50/5S	26	0.99	0.98	1.11	1.01
	32	1.11	1.00	1.14	0.99
	36	1.11	0.88	-	-
	40	1.11	0.98	1.13	0.97
	48	1.12	1.00	1.15	0.98
	56	-	-	1.15	1.03
	64	-	-	1.18	1.04
	72	-	-	1.16	1.04
205/34/5Z	26	1.08	1.13	1.12	1.12
	32	1.09	1.09	1.12	1.08
	36	1.10	0.93	-	-
	40	1.02	1.12	1.13	1.07
	48	1.01	1.10	1.13	1.13
	56	-	-	1.13	1.09
	64	-	-	1.15	1.13
	72	-	-	1.14	1.09

The following points are noted in the case of cotton fabrics from Table XV.

a. The maximum warp fabric assistance viz. 1.12 was obtained in 2/2 twill structure and the minimum viz. 0.88 was obtained in 1/7 twill structure.

b. At low weft setts the assistance ratio is often high; this is followed by a drop, then another peak is reached before the final reduction which invariably occurs at high weft setts. This pattern is evident in all cases although the fluctuations do not occur at the same points with all constructions.

c. Generally, the ratios appear to be higher in the two and four shaft weaves than in the eight shaft weaves.

From Table XVI, the following trends are evident.

a. The fabric assistance of all the structures is greater than one.

b. The minimum fabric assistance is 1.01 (plain weave, 205/34/5Z, 48 weft sett). The maximum is 1.18 (2/2 twill, 150/50/10Z, 64 weft-sett).

c. The plain weave structures woven with 150/50/5S have all almost identical assistance ratios, (Graph No.1).

d. Considerable increase in the strength and in the thickness of the transverse thread element does not appear to have any appreciable influence upon the warp assistance ratio.

Roller Grip Specimens

(Bias angle 0 to warp)

Fig. 27-Unstretched Specimens

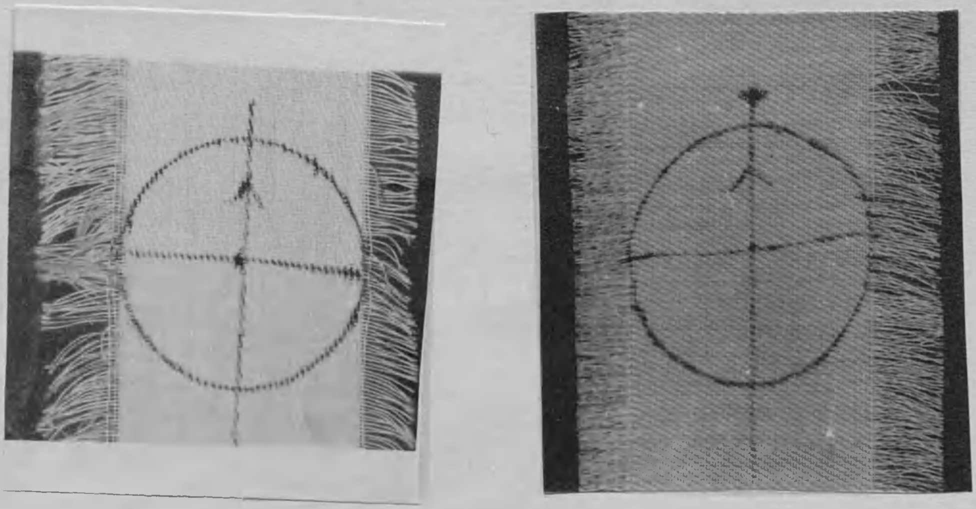


Fig. 28-Stretched Specimens

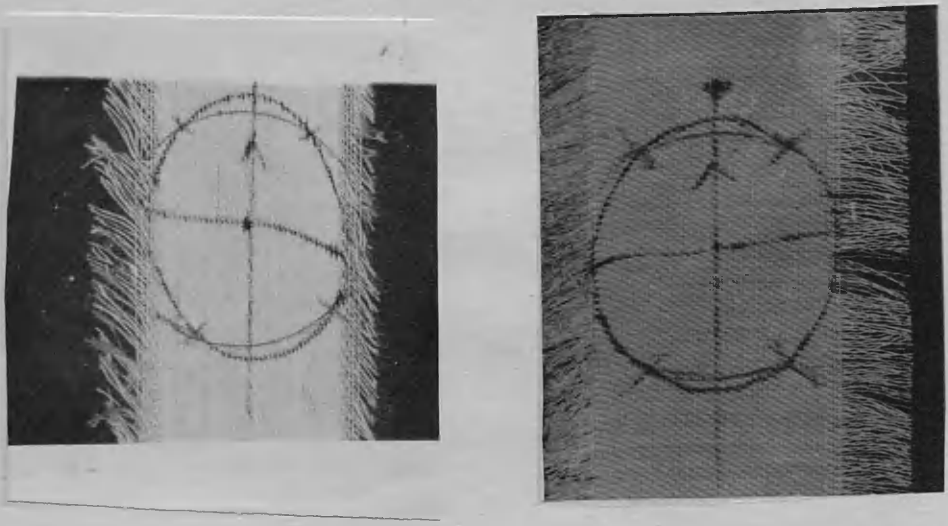
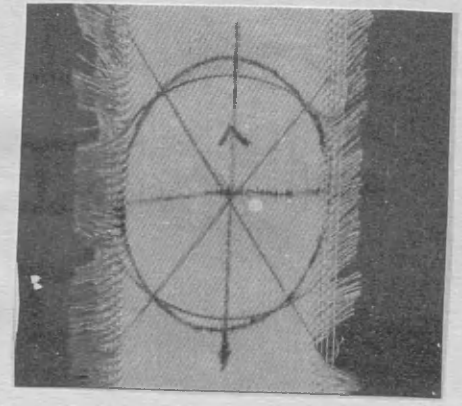


Fig. 29

Lines of Zero Elongation



4.24 - Fabric Tensile Strength (Trellis Jaws)

Figures 27 and 28 show the roller grip specimens in the initial and the final stages respectively. Fig. 29 shows the lines of zero elongation.

Tables XVII and XVIII show values for the tensile strengths of fabrics using trellis jaws for cotton and nylon fabrics respectively. The results are noted against nominal setts, in a similar way as was shown in the Tables XIII and XIV, for the tensile testing of fabrics by standard jaws.

From these two tables, the following points are evident.

a. The tensile strengths obtained by trellis method are higher than those obtained by standard method, in the same fabrics. This was noted by other workers in this field and is in accordance with theoretical expectations.

b. Again, the warp tensile strength figures show a tendency to fall at high weft setts. It should be noted that the warp sett was uniform, in the fabrics studied.

c. The weft tensile strength increases in proportion

Table XVII

Fabric Tensile Strength (Trellis Jaws) of Cotton Fabrics

(Warp yarn: 2/40's cotton count, 21.0 T.p.i.;
Warp sett: 72)

Weft yarn	Weft sett	Plain		2/2 Twill	
		warp	Weft	Warp	weft
	32	180	100	185	90
	40	182	121	190	110
20's cotton count, 13.4 T.p.i.	48	188	161	193	142
	56	189	183	195	177
	64	190	202	200	195
	72	188	225	204	220
	80	-	-	190	240

Table XVIII

Fabric Tensile Strength (Trellis Jaws) of Nylon Fabrics

(Warp yarn: 205/34/5Z , Warp sett: 106)

Weft yarn	Weft sett	Plain	
		warp	weft
	26	600	150
	32	605	185
205/34/5Z	36	610	197
	40	600	220
	48	600	270

with an increase in the weft-sett, (Fig. 30 and 31).

d. The warp tensile strength for the 2/2 twill structure in cotton fabrics is higher than in the corresponding plain weave structure. This is not the case when the results of weft tensile strengths are studied. The weft tensile strengths for the plain weave structures are higher than the corresponding 2/2 twill structures.

4.25 - Fabric Assistance Ratios (Trellis Jaws)

The warp and weft fabric assistance ratios for the cotton and nylon fabrics are shown in Tables XIX and XX. The warp fabric assistances are plotted against picks per inch in Figs. 32 and 33.

The following points are noted from these tables.

a. The warp assistance ratio is higher in nylon fabric than in the two cotton constructions.

b. The warp fabric assistance is greater for 2/2 twill than the corresponding plain weave, in cotton fabrics, (Fig. 32).

c. The weft fabric assistance in both, the cotton and the nylon fabrics increases with an increase in weft sett up to an optimum point whereupon it starts declining. The optimum point is reached earlier with short float weaves than with the longer float weave.

d. In all the cases studied by trellis method the ratio is invariably greater than 1

Table XIX

Fabric Assistance Ratios (Trellis Method) of Cotton Fabric

(Warp yarn: 2/40's cotton count, 21.9 T.p.i.;
Warp sett: 72)

Weft Yarn	Weft sett	Plain		2/2 Twill	
		Warp	Weft	Warp	weft
20's cotton count,13.4 T.p.i.	32	1.13	1.60	1.15	1.44
	40	1.14	1.57	1.18	1.43
	48	1.16	1.77	1.20	1.56
	56	1.17	1.64	1.22	1.59
	64	1.18	1.62	1.25	1.56
	72	1.16	1.58	1.29	1.54
	80	-	-	1.18	1.56

Table XX

Fabrics Assistance Ratios (Trellis Method) of Nylon Fabrics

(Warp yarn: 205/34/5Z , Warp sett: 106)

Weft yarn	Weft sett	Plain	
		warp	weft
205/34/5Z	26	1.28	1.30
	32	1.29	1.31
	36	1.30	1.24
	40	1.28	1.25
	48	1.28	1.27

CHAPTER 5

DISCUSSION

5.1 RELATIONS BETWEEN FABRIC PARAMETERS AND FABRIC TENSILE STRENGTH USING STANDARD STRIP SYSTEM OF TESTING

5.11 - Effect of Crimp

As already commented upon the results **tabulated** in Tables XI and XII show that warp crimp characteristics follow the generally accepted pattern i.e. increases in weft yarn diameter and in the density of weft spacing increase the warp crimp whilst increases in float length decrease the warp crimp value. This is shown graphically in Fig. 34.

With regard to the effect of twist on the crimp it could be observed that in coarser yarns (20's cotton) an increase in the number of turns per inch in the weft yarn produced a significant reduction of crimp in the warp direction due, presumably, to reduction in weft yarn diameter. In finer yarns (30's cotton, 150 denier nylon) this trend was not apparent suggesting that in these cases reduction of yarn diameter did not occur or, if it did, its magnitude was insufficient to affect the result.

It is interesting to note that an increase in the number of turns per inch in the weft resulted invariably in the increase in weft crimp. This is explained by the fact that the higher twist makes the yarn "more springy" and also increases the tension as the yarn unwinds from the pirn in the shuttle the two factors combined augmenting the relaxation power of the weft yarn and, thus, resulting in higher crimp values.

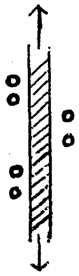
In nylon yarns which have considerably higher elastic recovery factor, weft crimps are distinctly higher with longer float weaves than in plain weave. This is probably due to the fact that in the 2/2 twill the warp being less tightly packed is more accommodating to relaxation pressure exerted by the weft.

No direct relation has been found between the crimp values and the tensile strength performance of cotton fabrics. This is not to say that it does not exist but in this work any changes in crimp have been accompanied by simultaneous changes in other factors which have inevitably masked the effect of the crimp itself. In order to resolve this positively it would be necessary to construct a series of fabrics identical in all respects except for the crimp factor which would have to be deliberately controlled.

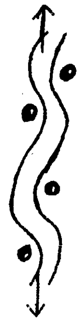
One point, however, has been noticed which may be attributed to crimp value in connection with nylon samples where the effect may be simpler to evaluate since there is no interference from fibre slippage which exists in cotton yarns. The effect can be isolated into two separate channels in the following manner:-

a. Comparison between the plain and the 2/2 twill weaves, and
b. Comparison of effect of the three different twist factors within any weave grouping.

In the case of (a) it is quite clear that warp tensile strength of 2/2 twill fabrics exceeds that of plain fabrics in identical settings. From Table XII it is equally obvious that weft crimps in the same conditions are higher for the 2/2 twill than they are for the plain weave. The warp strength figures appear, therefore, to depend on weft crimp. This assumption seems to be quite a reasonable one since during streching which occurs between the jaws, the longitudinal yarn components can straighten out more readily when greater length of the transverse component is available for the purpose of crimp interchange. Also, the "necking" will be reduced and this straightening out process will proceed further before the transverse yarns commence to jam, resulting in truer tensile strain. In the case in which smaller length of transverse yarn is available the "jamming" will occur sooner preventing the longitudinal component from straightening out and thus introducing a shearing strain element which will tend to reduce the tensile strength value. Admittedly, the tighter interlacing



Longitudinal component straight-tensile strain.



Longitudinal component unable to straighten out-tensile strain and shearing effect.

Fig. 35 INFLUENCE OF CRIMP ON TENSILE STRENGTH IN CONTINUOUS FILAMENT FABRICS.

of the plain weave, combined with higher warp crimp will also contribute to this effect.

This interference of weave and longitudinal crimp difference is not present, however, when considering the second instance (b), where comparisons are made between three 2/2 twill structures which differ from one another only in the twist factors of the weft yarns. From Table XII it can be noted that warp crimps in these three groups of fabrics do not differ significantly but weft crimp values show considerable differences between the 5 T.P.I. weft and the other two, viz, the 10 T.P.I. and the 15 T.P.I. From Fig.36 it can be seen that as the weft crimp increases so does the warp strength. The rate of the strength increase, however, is different at various weft setts. Considering now the situation in general it will be possible to deduce that the effect of weft crimp will be modified by the amount of warp crimp present in the fabric and that best conditions for straightening out of the warp yarn will be obtained when warp crimp is low and weft crimp high. Therefore, other points being equal, warp strength should increase with the increase of the weft to warp crimp ratio.

This point is proved by Fig.37 where four different weft setts are shown. This relationship is not equally clear in all cases but it occurs sufficiently often to be accepted as evidence corroborating the above assumptions.

One proviso must be made before leaving this topic, namely, that the relationship outlined above is liable to increase the strength value in continuous filament yarns only and the possibility exists that where yarns are composed of short fibres the straightening out of the longitudinal component will result in exactly the opposite effect, i.e. reduction in strength due to fibre slippage.

With reference to Fig. 34 which shows the dependance of warp crimp on weft sett and count the curve for plain weave constructed with 20's cotton weft shows a decline at high weft setts. This is due entirely to the fact that in order to construct these very compact fabrics (64 P.P.I. and 72 P.P.I. respectively) it was necessary to increase the tension on the warp. Where it was not necessary to interfere with the weighting of the warp the crimp values show a steady increase with the increase in the number of picks per inch.

5.12 - Effect of the Degree of Twist in Yarns

Since yarn twist affects the strength and dimensional characteristics of yarns it must also be recognised as a major factor contributing to the tensile strength of a fabric.

In fibre yarns an increase in the number of turns per inch for any given count will lead to an increase of strength up to a certain optimum twist value, namely, that which is necessary to practically eliminate fibre slippage. For higher twists than the optimum, the strength decreases because of the torsional stress on the fibres. In continuous filament yarns this is reached very early but in cotton yarns the optimum twist value oscillates about the twist factor of $4.5\sqrt{ct}$ depending primarily on dimensional characteristics of the fibre. In the present investigation these trends are fully reflected and have already been commented upon.

Changes in yarn strength due to twist variations affect fabric strengths in an expected manner where fabric is tested in the same direction as the yarns concerned. This is reflected by all the weft strip tests where fabric strengths vary directly in

Conformity with variations in weft yarn strengths. Changes in the twist factor of weft yarns do not, however, affect the warp strip tests directly, but indirectly the effect of these changes may be considerable since they are almost invariably accompanied by changes in crimp ratios and these influence the fabric strength values to an appreciable extent as already shown in the previous section.

5.13 - Effect of the Direction of Twist in Yarns

This study could only be made in the case of two nylon constructions where fabrics were woven with exactly identical particulars except, that in one instance weft with "Z" twist, and in the other with "S" twist, were used. The warp yarns in all cases had the "Z" direction of twist. From the results in Table XIV it appears that there is no significant difference between strengths of weft fabric strips which is expected in view of their single yarn strengths. In the warp direction, however, higher strengths are registered with "S" on "Z" combination than in the case in which both yarns have "Z" twist. This is thought to be due primarily to the fact that when both elements have the same direction of twist the two sets of yarns at interlacing points will tend to "bed" better since the twist in both elements will run parallel. When opposite twist directions are used the tendency of the two sets of yarns at interlacing points will be to "ride" one on top of another thereby providing greater opportunity for the individual components to move freely as no single filament entanglements are possible between the warp and the weft yarns. Since, as already pointed out in the case of crimp factor, in fabrics composed of filament yarns this freedom to straighten out is essential in order that the fabric achieves its full strength value, higher strength figures are obtained. It must not be overlooked, however, that in fabrics composed of fibre yarns the above relation may be reversed as higher frictional property in such fabrics may mitigate against loss of strength due to fibre slippage.

5.14 - Effect of Single Yarn Strength and Elongation

Any increases in the strength of single components in the longitudinal direction is immediately reflected in the increase of strength in the strip. This increase, though modified by various factors such as crimp, twist and float length, is reasonably proportional to the increase in the strength of single yarns.

However, any strength increases in the single transverse components do not appear to have the slightest effect on strip strength. On the other hand, the elongation of transverse components is of considerable importance and together with crimp will affect the strength figures of the strip appreciably. This is particularly obvious in nylon fabrics where high elongation at break of transverse element tends to increase the strip strength due to an effect already explained in connection with the crimp of transverse threads. In fibre yarns the same clear comparison cannot be drawn mainly due to the fact that elongation at break represents a very unreliable value where distinction between true elastic effect and fibre slippage is not clear.

5.15 - Effect of Loom Abrasion

In the fabric, warp yarns must be considered as more likely to have experienced strains and abrasive wear than the weft because of the nature of the weaving process itself and the preparatory operations. Thus, warp and weft yarn from the same source may show a disparity in specific tensile strength in the same fabric. The evidence of this could best be illustrated by studying the warp and weft tensile strengths of a square-sett fabric having the same type of yarn in warp and weft. In the present investigation, this could be achieved by studying the tensile strengths of cotton fabrics woven by using 2/40's cotton count as warp and weft, in 72 x 72 sett. In all these structures, the weft fabric strength is greater than the warp fabric strength, and this confirms the view that the warp inevitably suffers a loss of strength due entirely to strains of processing. An interesting speculation arises as to the extent of this loss under varying conditions. Studying Fig. 38 it becomes clear that the greatest disparity in strength figures occurs in plain weave and the least in 8-end sateen. This is a situation which could have been predicted considering that with the same or very similar rate of progress of the warp through the loom the loss of strength will depend on the frequency of manipulation and increased frictional contact due to rubbing. The results confirm this prediction though in the case of 1/7 twill the disparity seems greater than the nature of the weave would warrant. This effect may be due to very rapid reduction of crimp as between the four shaft and the eight shaft weaves. An interesting point arises on comparison of warp strength figures of the 1/7 twill and the eight shaft sateen. The higher strength of sateen may be ascribed to lower friction since in this weave adjacent ends are not raised or lowered on successive picks of weft.

To what extent these differences, which oscillate between 0.5% and 10%, are due to processing strains as opposed to changes in crimp characteristics of both, the warp and weft is a matter for conjucture, but further proof could be obtained by careful dissection of the construction after weaving and evaluation of single yarn strengths in both directions. This, however, would require a separate investigation in itself.

On the whole, there seems to be no doubt that this is a factor to be seriously considered especially when comparing the effect of higher weft sett on the strength of warp. It would be reasonable to assume that between, say, 72 weft sett and 32 weft sett the warp strength will deteriorate by the value corresponding to the difference, i.e. in the case cited, 40 rubs of the reed and an equal number of rubs by the healds and the adjacent yarns.

5.16 - Effect of Density of Yarn Spacing

Theoretically, an increase in the warp and weft sett should improve the fabric tensile strength because of improved fibre binding. However, this is not always the case as pointed out by Peirce[1]. He has mentioned that if the longitudinal threads are very closely set, it may be impossible to remove all their crimp because, before this occurs the crossing threads will have jammed.

The problem dependent on the factor of yarn spacing must be considered from two different view points:

a. Effect of changes in longitudinal sett.

b. Effect of changes in transverse sett.

The former point presents no difficulty until the situation described by Peirce is reached. In normal circumstances any increase in the number of longitudinal components will increase the strip strength. This is shown by Figs. 6 - 15 which are relating to changes in weft sett against weft strip strength. A linear relationship is established though it can be observed that the ratio of the increase is not the same for all weaves.

The latter effect is considerably more difficult to analyse and must be approached in a different manner when dealing with fibre yarn fabrics as opposed to filament yarn fabrics.

In filament yarn fabrics an increase in transverse sett should have very little influence on the strength of the strip as long as the longitudinal component is capable of straightening out to such an extent that the shear element is of no practical importance. Normally such circumstances do not arise and changes in the density of transverse thread setting will have considerable bearing mainly due to changes in the crimp factor of both the longitudinal and the transverse components - a point already described earlier.

In fibre yarn fabrics an altogether different situation will arise because of the presence of another factor in the form of fibre slippage. This feature, speaking in terms of tensile strength effect, is at odds with the shearing effect, i.e. in order to arrest the tendency of fibres to slip the greatest possible number of transverse yarns should be introduced, but, in order to reduce the considerable effect of shearing the fewest number of transverse yarns should be employed. Obviously, a compromise situation will be achieved at some points. From the results in Figs. 17 and 21, it appears that the point at which any tendency towards fibre slippage would be arrested, is achieved very early even with the comparatively short fibre yarn such as cotton. The exact position of this point will vary depending on the fibre length and regularity, on turns per inch and the float length in the construction. In most cases this has been reached with the lowest transverse sett of 32 picks per inch and the exceptions in the form of long floated weaves rather seem to confirm the above assumption. Indeed, with short floated weaves, this point may have been reached before and even the high value at 32 picks per inch may represent a decline compared with, say, 24 or 20 picks per inch. The decline from the high value mentioned above may, therefore, represent the effect of shearing overriding the advantage of any further arrestment of fibre slippage. This theory explains the original peak value followed by a trough but it does not cover the fact that, particularly in tight weaves, the tendency is for the strength value to recover before final decline. This recovery may be due to the situation observed by Peirce and mentioned earlier, namely, that with high transverse sett crimp interchange will be arrested early during the test due to "jamming" and this will reduce the "waist" effect thus bringing greater number of the longitudinal threads to bear the strain simultaneously. The final decline occurs due to increased shearing strain at even higher transverse setts when no further longitudinal elements can be brought to assist.

5.17 - Effect of Weave Structure

From Tables XIII and XIV it is evident that the order of thread interlacing has considerable effect on tensile strength of fabrics. Some difficulty arises in co-relating the weave with the tensile strength of fabric because it is not easy to express the term "weave" in quantitative terms. From the review of the literature on the subject it appears that some authorities refer to "an average float length" irrespective of the order of lifting and the order of alignment of warp and weft. Thus, they tend to reduce, e.g. 4/4 twill, 1/7 twill and 8-shaft sateen to exactly identical group by regarding each of the above as having an average float length of four. This type of simplification does not appear to be useful and may be grossly misleading as it gives an impression that like structures are compared whilst this is far from truth. The better method appears to be that suggested by Taylor[37] namely, to classify fabrics according to the length of float between plain intersections. This could be extended by specifying, for instance, the length of maximum float between minimum float etc. Some further distinction would have to be applied to differentiate between, say, 1/7 twill and 8-shaft sateen which otherwise would be grouped together.

Considering nylon fabrics which were woven with high warp sett, using plain and 2/2 twill weaves, it can be observed that weft strip strengths do not differ significantly between the two constructions at equal conditions. This point was already mentioned when discussing the crimp factor and appears to be dependent on the combination of crimp with the weave effect in so much as in the plain weave there is low longitudinal crimp, high transverse crimp and less freedom for crimp interchange whilst in the 2/2 twill the situation is opposite, i.e. there is high longitudinal crimp, low transverse crimp but greater freedom for crimp interchange. This factor of freedom for crimp interchange appears to equalise adequately the unfavourable arrangement of the other two crimp factors in the twill as opposed to the plain cloth. A different situation arises in the case of warp strip strength. There the twill cloths show superior strength results and the above argument applies in reverse, i.e. more favourable ratio of crimps (longitudinal: transverse) exists in the twill than in the plain weaves; further, the weave factor (or crimp interchange factor) operates adversely against the plain weave, hence lower strength of plain weave strips in the warp direction. It is significant that the differences diverge more in higher transverse setts confirming the above views.

In cotton fabrics the effects of weave were largely summarised in the discussion of the effect of the density of spacing. On the whole, the shorter the float length the higher the strength due to superior fibre binding. This was particularly evident in the case of weft strips where singles yarns were used. In the warp strips the situation was frequently reversed due to interference factor arising out of changes in the density of spacing in transverse yarns. The same argument applies here as that advanced in the previous section and Figs. 5 to 26 corroborate the views expressed earlier.

5.18 - Fabric Assistance Ratios

The term fabric assistance ratio has come into prominence to designate the difference between the direct yarn strength and the resultant fabric strength. This ratio is the outcome of a complex set of factors and, therefore, it is obvious that it may change irregularly according to the changes in the structural geometry of the fabric. The ratio will depend upon the way in which the mean single thread is expressed and the various workers have expressed this in one of the following ways:-

a. The mean strength of single threads tested individually.

b. The mean strength of single threads, tested in groups of approximately the same number as in the test sample.

c. In the case of a warp or a weft, the mean strength of groups of threads which have been given processing strains viz., by treating as a warp or a weft in the absence of the other.

In the present investigations the fabric assistance ratio has been calculated according to the first method viz. by taking into account the average single-thread strength.

Thus the fabric assistance ratio

$$= \frac{\text{Fabric strength}}{\text{Average single-thread strength X no. of longitudinal threads in the specimen}}$$

The correctness of this method as opposed to the other two could be argued but it represents a convenient approach which has been used by sufficient number of workers in this field to offer comparisons. The various form factors affecting the strength performance of woven fabrics have been already separately discussed under sundry headings in the preceding sections. It will now be appreciated that some of these factors will improve, others will depreciate the strength values. It has also been shown that a complete reversal of the role of any one factor is also liable to take place if conditions under which it operates change sufficiently. In view of this complex interplay of a number of variables it is not surprising to note that the assistance ratio may in some cases be negative, i.e. less than unity, in other instances positive, i.e. more than unity. It is generally accepted that the poorer the performance of single longitudinal elements in the sample the greater will be the influence of fabric assistance. In continuous filament yarns where there is no fibre slippage the value of this element should be neglible, it should also be insignificant when two fold yarns form the longitudinal components. These two premises were put to test by considering warp strip assistance ratios where the above two conditions applied for both the nylon and the cotton warps. In both cases the value of assistance was investigated through a range of changes in transverse thread setts and in yarn counts.

In nylon cloths the ratio seems to average about 1.10 oscillating slightly depending on crimp values of both the longitudinal and the transverse yarn components - a point mentioned earlier. Greater degree of assistance exists in twill than in plain weave fabrics. This was accounted for in previous sections by unfavourable crimp relationship and introduction of shearing strains. Considering the value of assistance in this type of fabric it is surprising to note that it is positive throughout the series of changes. From earlier postulates it might appear that best results would be obtained if a band of threads were tested without incorporating any transverse element. This, however, is only partially true since in a band of threads the weak ones would reduce the overall value and further, some ends, depending on their original tension value, would not participate at all for certain periods of time during stretching. The value of assistance, therefore, appears to depend on the possibility of enlisting the support of transverse elements to take the strain or to bind the weak points thus ensuring more uniform distribution of stress over the largest possible number of longitudinal yarn components.

Similar remarks could be applied to weft assistance ratios in nylon fabrics which are, on the whole, slightly lower than the warp ratios averaging about 1.00. It is noticed that where the weft ratio is negative, i.e. below unity, this is due to adverse crimp relationship. In the case in which the warp and the weft are identical in denier very little difference exists between the two ratios except in plain weave where again there is a considerable disparity in warp to weft crimp ratio.

With regard to assistance ratio of cotton warp strips, these, as mentioned earlier consisted of two fold yarns, and the low average of about 1.00 is in keeping with earlier stipulations. The influence of the transverse sett is apparent and higher ratios are obtained with weaves composed of shorter floats.

From Table XV referring to weft assistance ratio it is seen that the assumptions made earlier are quite correct. Yarns which are weak as single units obtain a very considerable degree of assistance from the interlacing in the form of additional binding and support which materially reduces fibre slippage. As would be expected greater support is obtained with tighter weaves. This is natural since in a transverse sett of 72 used throughout, plain weave will give 36 binding points per inch, whilst 8-shaft sateen will provide only 9. Increased sett of longitudinal components produces an improvement in assistance ratio until very high setts are reached which cause a drop in the ratio due to torsional and shearing effects nullifying the increased binding properties. A point of considerable significance arises in connection with the twist factor of the two singles yarns. The assistance ratios for the low twist yarns are higher than for the high twist yarns. This again confirms the view that greater interlacing assistance will be invariably obtained with components showing poorer strength characteristics prior to weaving. The weft assistance ratio in the case of two fold yarns is very similar to the warp ratio of the same yarns and any discrepancies arising are due to different crimp factors in the two directions.

5.2 COMPARISONS BETWEEN RESULTS OBTAINED IN TENSILE STRENGTH TESTS USING STANDARD JAWS AND TRELLIS JAWS

5.21 - Tensile Strength Values

As already observed tensile strength values obtained with the trellis jaw exceed considerably the values in standard jaw tests using identical specimens. A further very important observation can be made with regard to pattern of behaviour of the longitudinal element when sett changes are made in the transverse component, namely, that in the standard jaw tensile test the strength value will fluctuate twice with fibre yarn fabrics but using the trellis jaw only one peak is apparent. In the former technique, it has been postulated, that the first strength peak occurs when all fibre slippage has been eliminated; the second, when additional longitudinal components are brought in to bear the strain both declines being due to shearing effect. In the latter method due to the homogeneous strain all longitudinal components are involved from the beginning and, therefore, a single incline in the curve, representing reduction of fibre slippage, is followed by a single decline, showing an area in which the shearing effect predominates over any further arrestment of fibre slippage. In this respect the results obtained with the trellis jaw appear to confirm fully the theory advanced earlier to explain the apparently unruly behaviour of curves showing the strength/transverse sett relationship using ordinary jaws.

In continuous filament fabrics where the factor of fibre slippage does not exist the strengths obtained with the trellis jaw follow the same pattern as those of the standard jaw except that the values are considerably higher and more even distribution of stress improves the performance considerably at high transverse setts and shearing stress influence is levelled out.

Considering the respective levels of strength values between ordinary and trellis jaws it appears, that ensuring that all longitudinal elements bear the strain is worth between 10% - 15% more in cotton fabrics, whilst the bonus in nylon fabrics seems to oscillate between 15% and 20%. The higher gain in nylon fabrics is probably due to the fact that with the more elastic material the Poisson ratio is greater in the original system of testing, therefore, complete elimination of the waisting will produce greater benefit.

For ease of comparison the results are shown pictorially in Figs. 39 and 40.

5.22 - Fabric Assistance Values

The growth of strength values is accompanied by an equal growth in fabric assistance ratios. The ratios shown in Tables XV and XVI for one method, and Tables XIX and XX for the other, emphasise again the detrimental value of Poisson effect encountered in all standard strip tensile strength tests. This is shown by comparing in turn the warp assistance ratio against weft ratio in cotton fabrics and warp assistance ratios between the cotton and the nylon fabrics. In the former comparison high gain in the warp direction reflects correctly the high Poisson effect in existence during the standard tests in that direction as opposed to low Poisson effect in the weft direction (due to warp strength and high warp sett) where only slight differences exist in

assistance [illegible]

trellis method of test. In the latter comparison the high Poisson effect of nylon fabrics show high gains when employing trellis jaw and the much lower "waisting" of cotton fabrics is indicated by lower gains.

CONCLUSIONS

CONCLUSIONS

The main difficulty encountered in this work was connected with the large number of variables and their mutual, complicated relationships. This is a problem encountered in most fields of technological research and though it is felt that artificial simplifications are futile in helping to assess the situation, it is considered that a series of less comprehensive studies with higher degree of concentration on single parameters might be more fruitful in providing the hard facts needed for systematic analysis.

Relations Between Form Factors and Tensile Strength

Different conditions apply to continuous filament fabrics as opposed to fabrics composed from yarns consisting of short fibres. In a filament yarn fabrics the crimp factor, and particularly the ratio of crimp in the longitudinal and transverse components, will have considerable bearing on strength values. Due to an element of shear, increase in crimp, or stabilisation of crimp, will reduce the tensile strength. This observation is corroborated by Bouvet's[41] work on rayon fabrics.

The shear effect is also present in fibre yarn fabrics but it is more confused there due to conflicting influence exercised by the fibre slippage factor.

The twist factor is of importance mainly because it affects yarn strength and crimp - it does not appear to have an intrinsic effect on strength and it seems that many workers tend to ascribe to it greater influence in this direction than is warranted.

Categorical statements concerning the value of the number of interlacings with reference to both the weave and the sett cannot be made without serious qualifications. The value of the short interlacing considered by some to have a predominant role in improved strength performance has been over estimated by a number of workers mainly due to the fact that they do not appear to have gone far enough to have felt the over-riding influence of the shearing effect at maximum setts. It is admitted, of course, that under conditions favourable to itself a "tight" weave or sett will give higher readings than a loose one.

The assumptions made that higher fabric assistance ratio is obtained with low quality yarns is fully corroborated and, in fibre yarn fabrics, the significance of frequent interlacing is, in this connection, acknowledged.

Comparisons Between the Standard and the Trellis Jaw Techniques of Testing

The reducing factor produced by the well known effect of "waisting" in ordinary tensile tests is fully exposed by comparing the results of this method with the homogeneous strain introduced with the hinged trellis jaw. This factor appears to operate particularly adversely in fabrics which exhibit high Poisson ratio. This is thought to be due to the fact that under such conditions comparatively few longitudinal members of the sample bear the strain simultaneously.

In spite of the undoubted superiority of the trellis model it is thought that involved techniques concerned with the determination of lines of zero elongation and high wastage of fabric associated with this method will mitigate against its general adoption. It will remain, however, a useful research tool which, due to its high accuracy and the simple nature of the stress, may provide some insight

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into the exact mechanics of fabric failure. High reproducibility of results was a particularly commendable feature of the system and the very low spread of results should also be of assistance in result analysis

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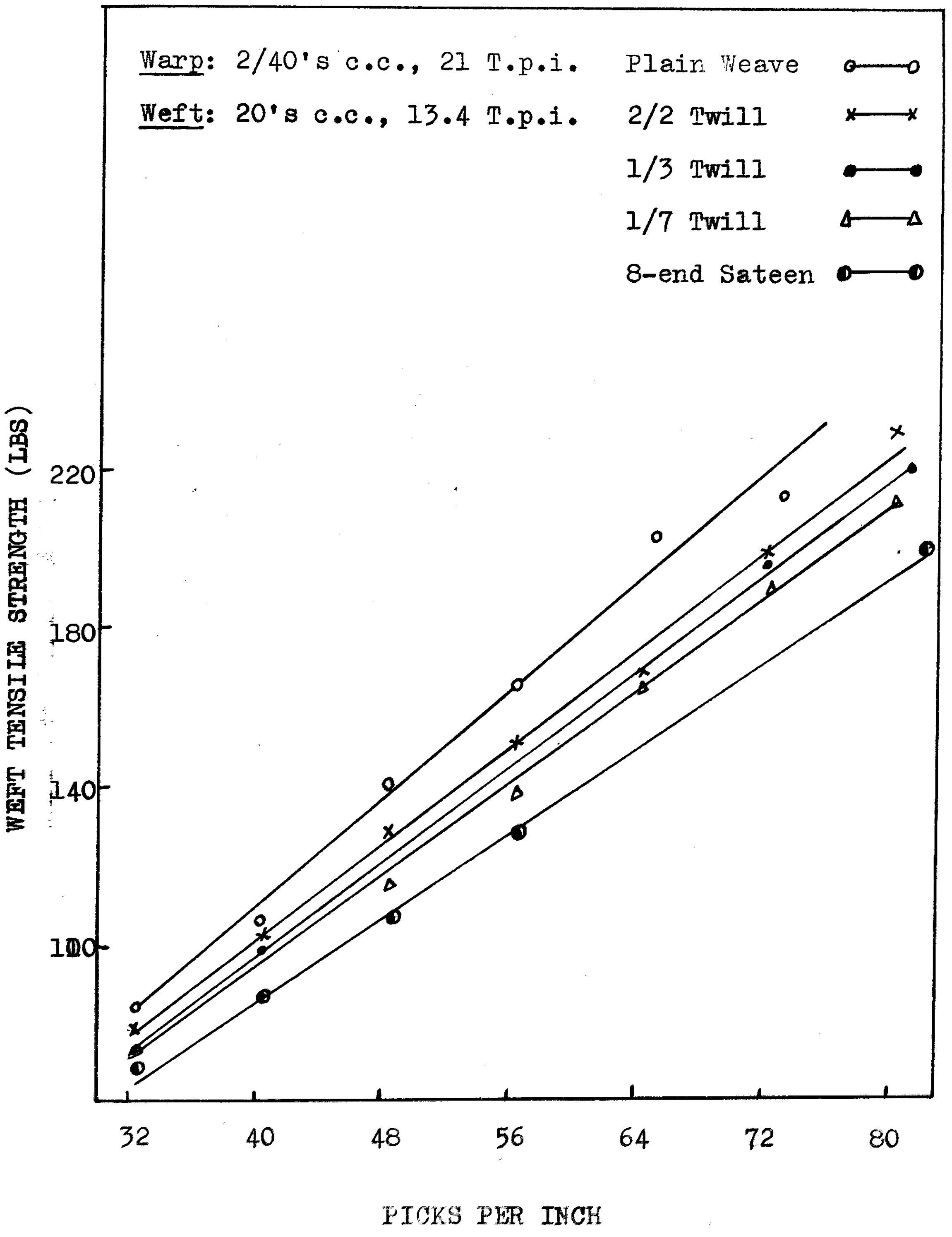

Warp: 2/40's c.c., 21 T.p.i.
Weft: 20's c.c., 13.4 T.p.i.
Plain Weave o—o
2/2 Twill ×—×
1/3 Twill ●—●
1/7 Twill △—△
8-end Sateen ◐—◐
WEFT TENSILE STRENGTH (LBS)
220
180
140
100
32
40
48
56
64
72
80
PICKS PER INCH

FIG. 5

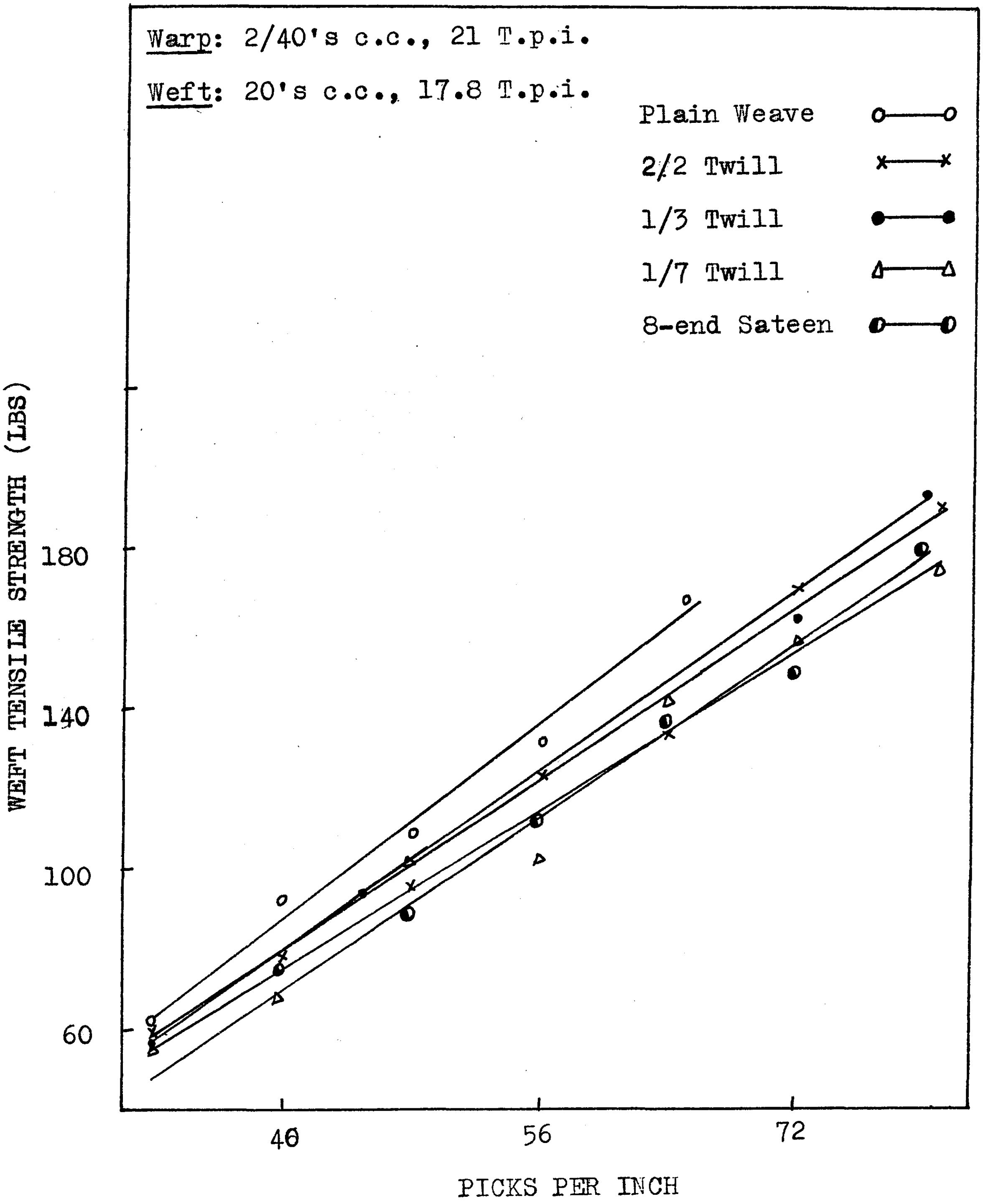

Warp: 2/40's c.c., 21 T.p.i.
Weft: 20's c.c., 17.8 T.p.i.
Plain Weave
2/2 Twill
1/3 Twill
1/7 Twill
8-end Sateen
WEFT TENSILE STRENGTH (LBS)
180
140
100
60
40
56
72
PICKS PER INCH

FIG. 6

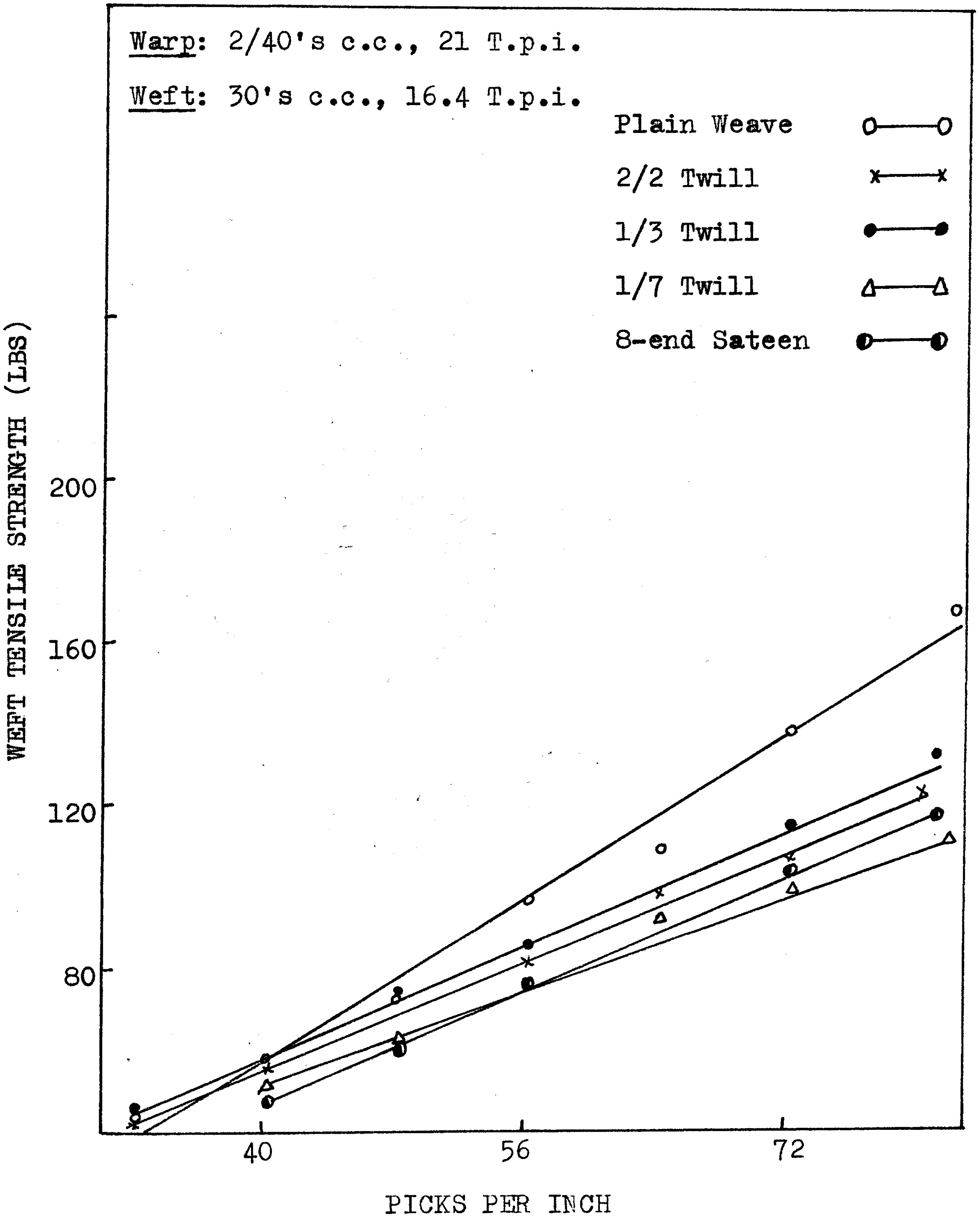

Warp: 2/40's c.c., 21 T.p.i.
Weft: 30's c.c., 16.4 T.p.i.
Plain Weave
2/2 Twill
1/3 Twill
1/7 Twill
8-end Sateen
WEFT TENSILE STRENGTH (LBS)
200
160
120
80
40
56
72
PICKS PER INCH

FIG. 7

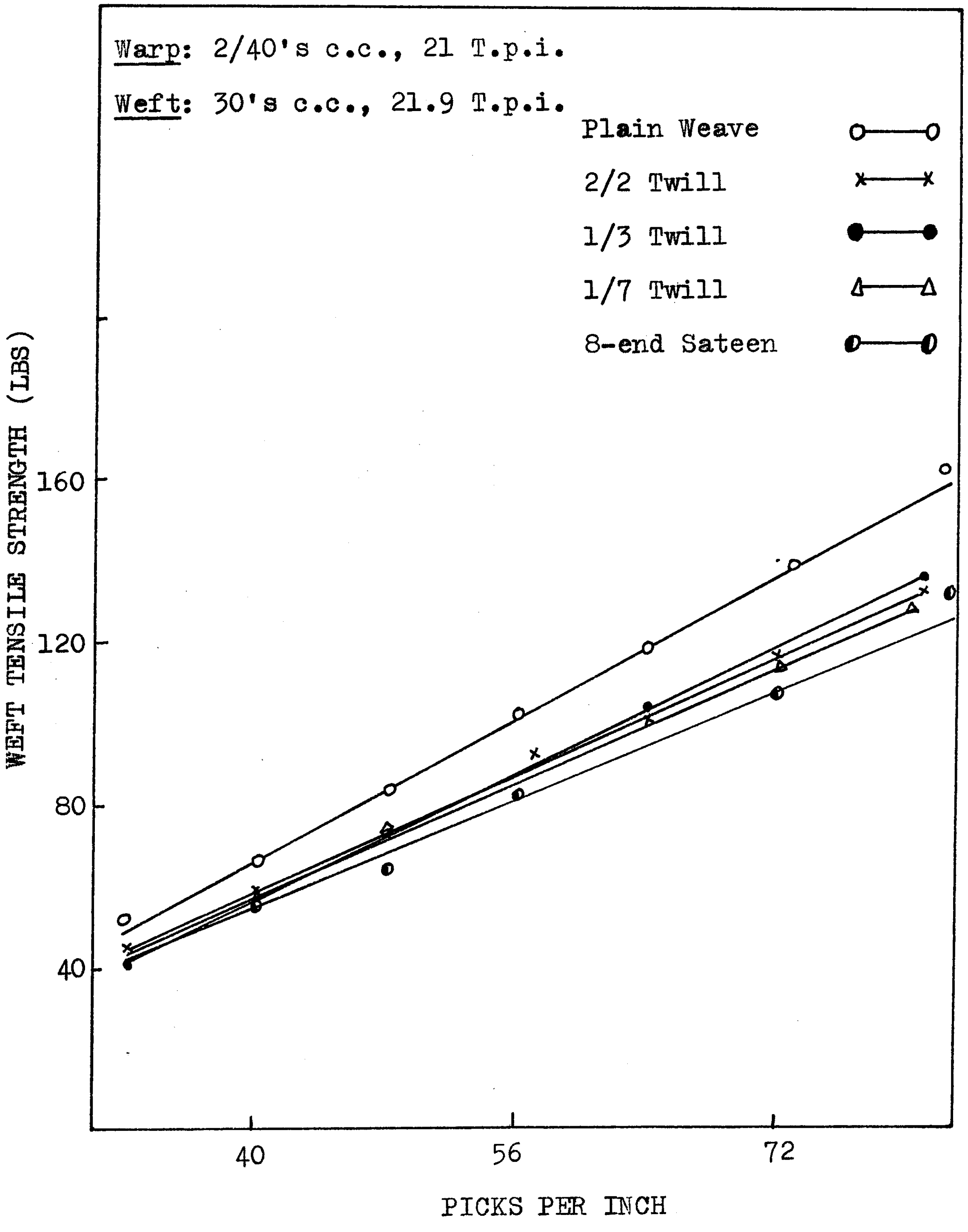

Warp: 2/40's c.c., 21 T.p.i.
Weft: 30's c.c., 21.9 T.p.i.
Plain Weave ○—○
2/2 Twill ×—×
1/3 Twill ●—●
1/7 Twill △—△
8-end Sateen ◐—◐
160
120
80
40
WEFT TENSILE STRENGTH (LBS)
40
56
72
PICKS PER INCH

FIG. 8

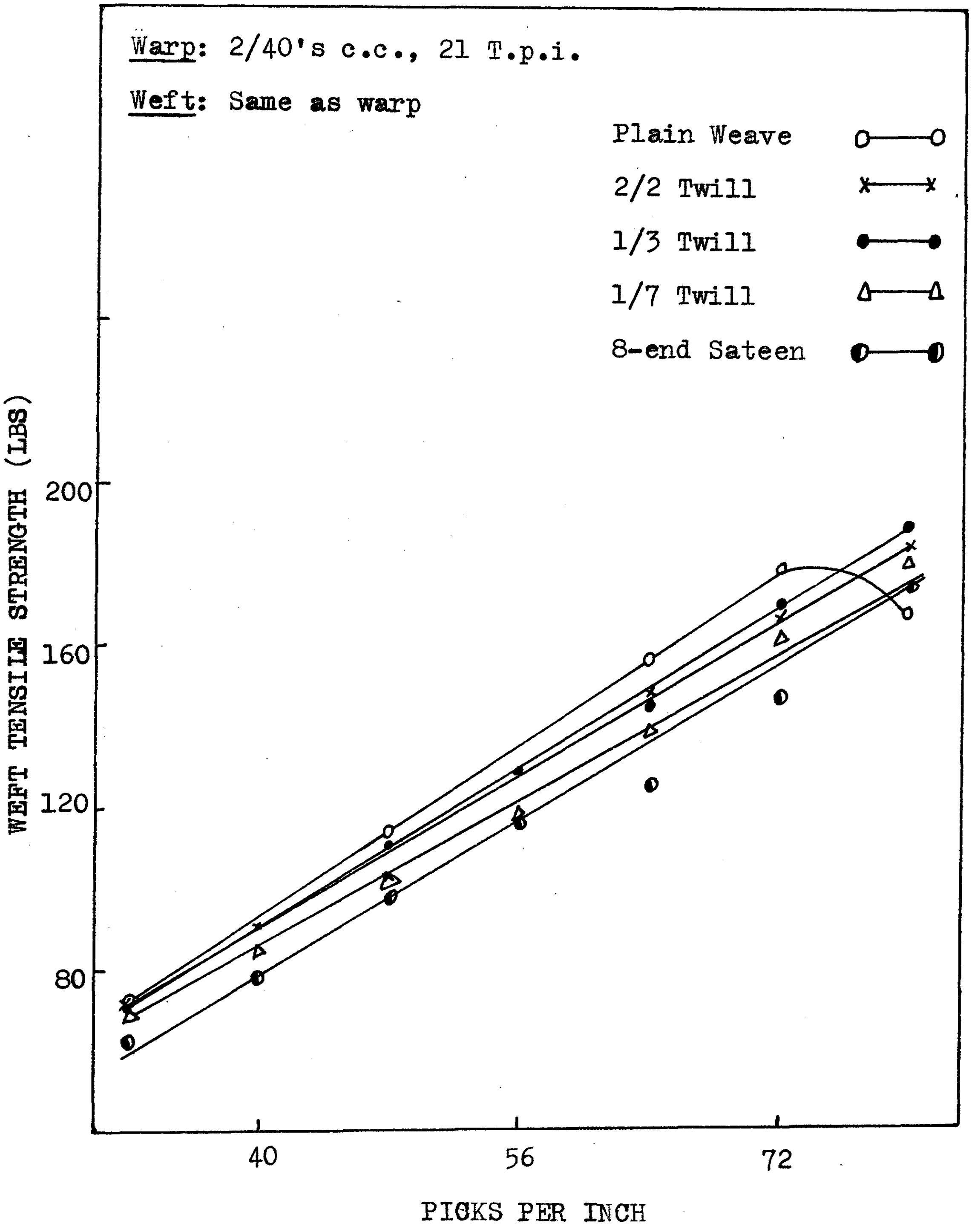

Warp: 2/40's c.c., 21 T.p.i.
Weft: Same as warp
Plain Weave
2/2 Twill
1/3 Twill
1/7 Twill
8-end Sateen
WEFT TENSILE STRENGTH (LBS)
200
160
120
80
40
56
72
PICKS PER INCH

FIG. 9

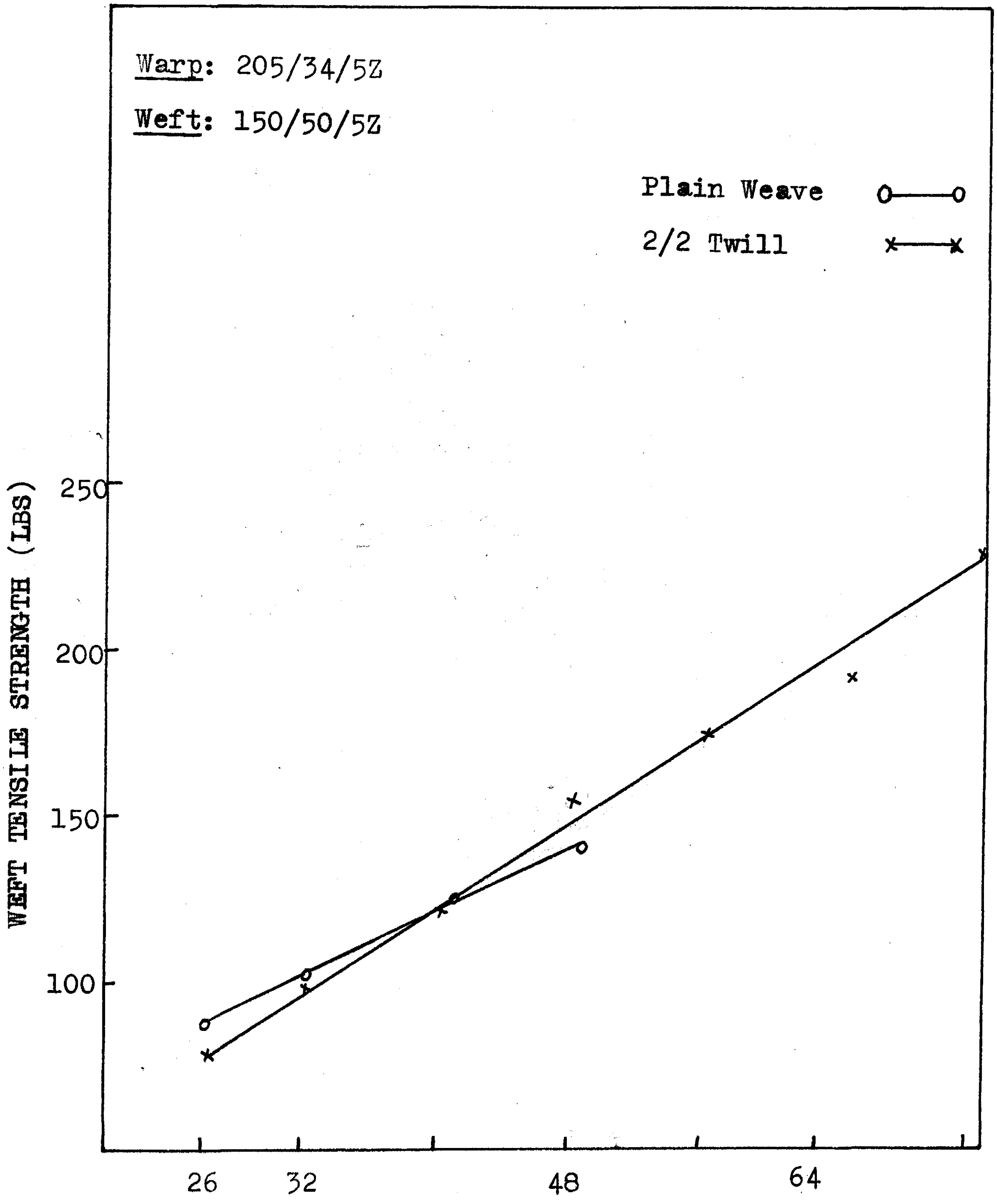
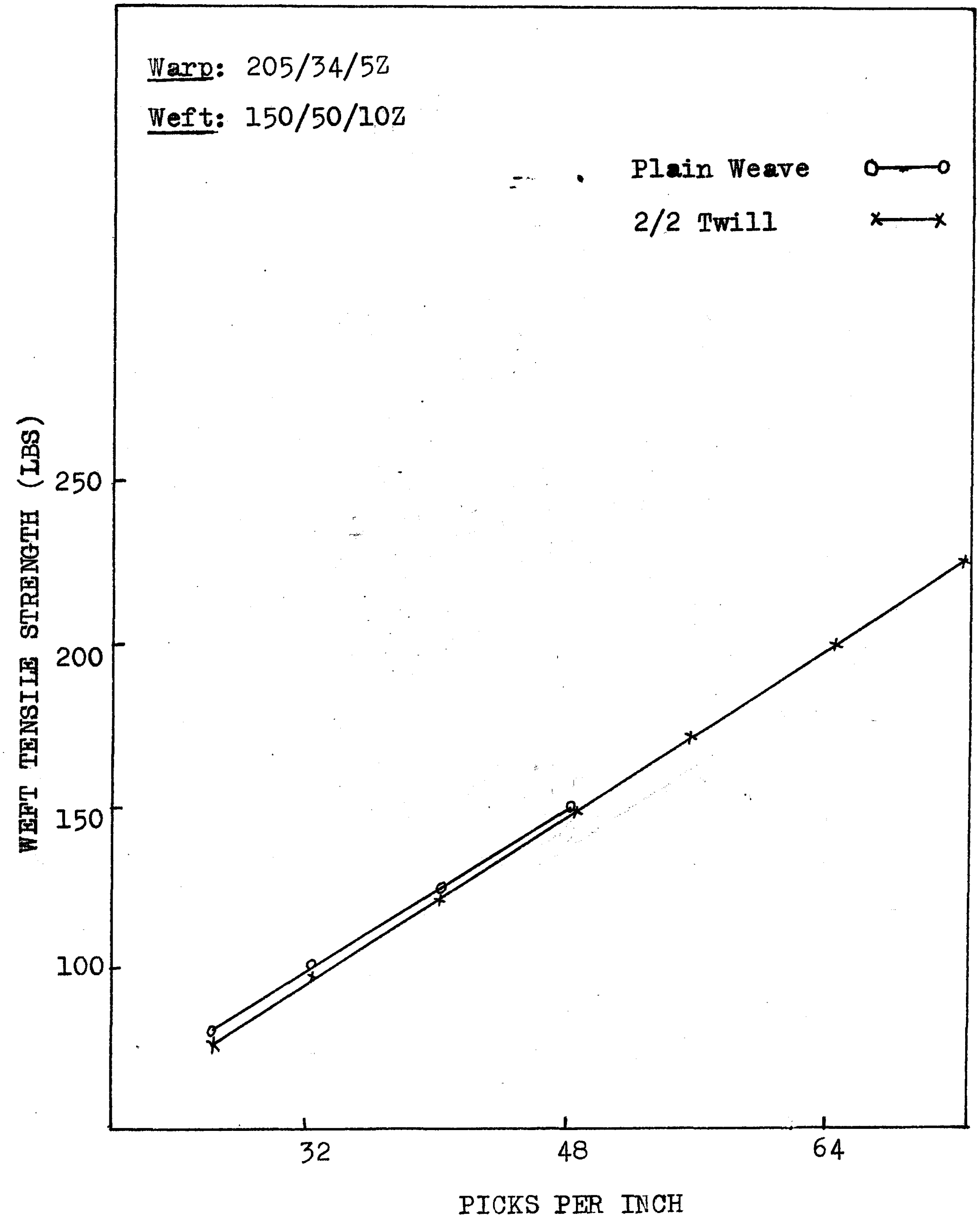

Warp: 205/34/5Z
Weft: 150/50/5Z
Plain Weave
2/2 Twill
WEFT TENSILE STRENGTH (LBS)
250
200
150
100
26
32
48
64
PICKS PER INCH

FIG. 10



Warp: 205/34/5Z
Weft: 150/50/10Z
Plain Weave
2/2 Twill
WEFT TENSILE STRENGTH (LBS)
250
200
150
100
32
48
64
PICKS PER INCH

FIG. 11

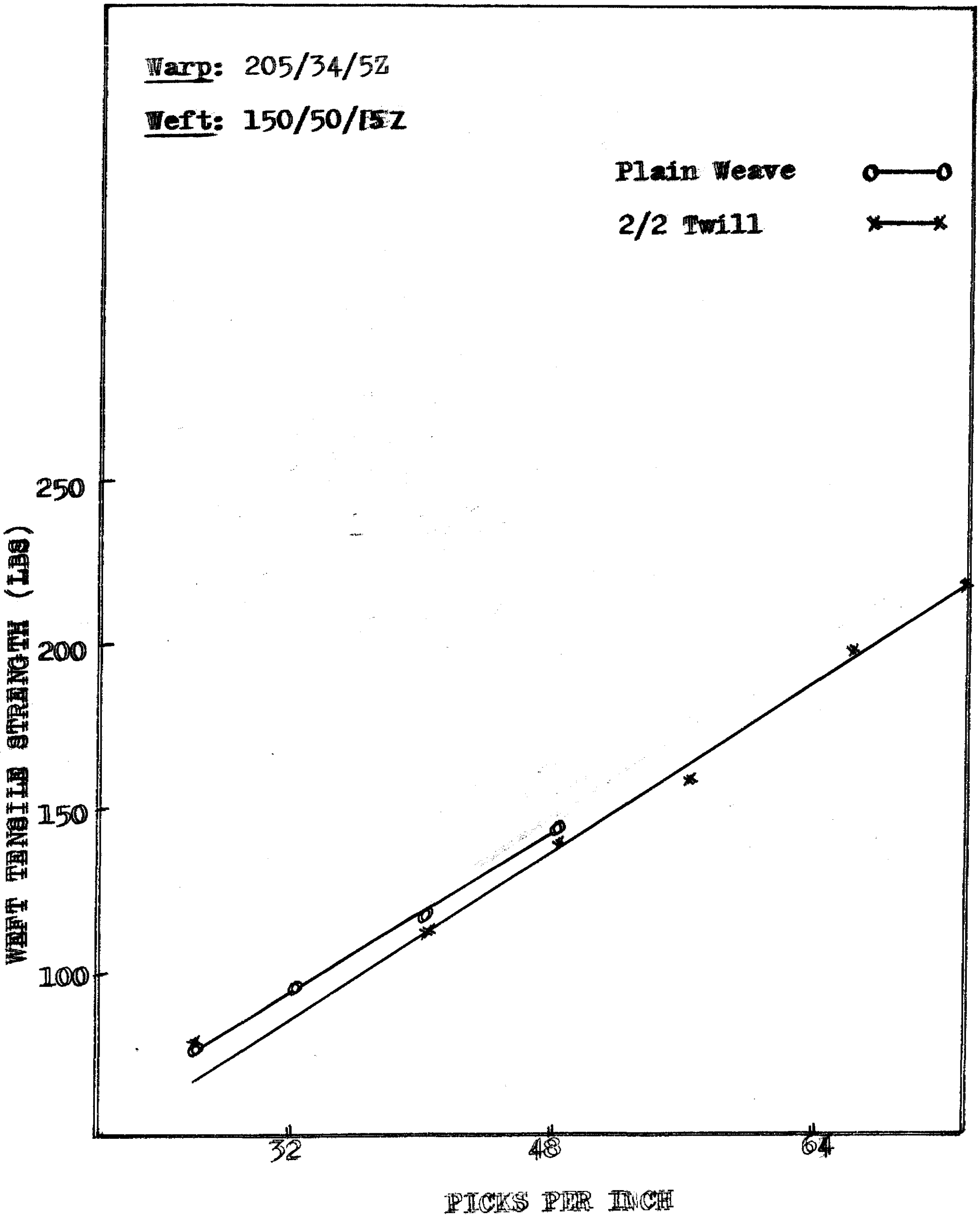

Warp: 205/34/5Z
Weft: 150/50/15Z
Plain Weave
2/2 Twill
250
200
150
100
WEFT TENSILE STRENGTH (LBS)
32
48
64
PICKS PER INCH

FIG. 12

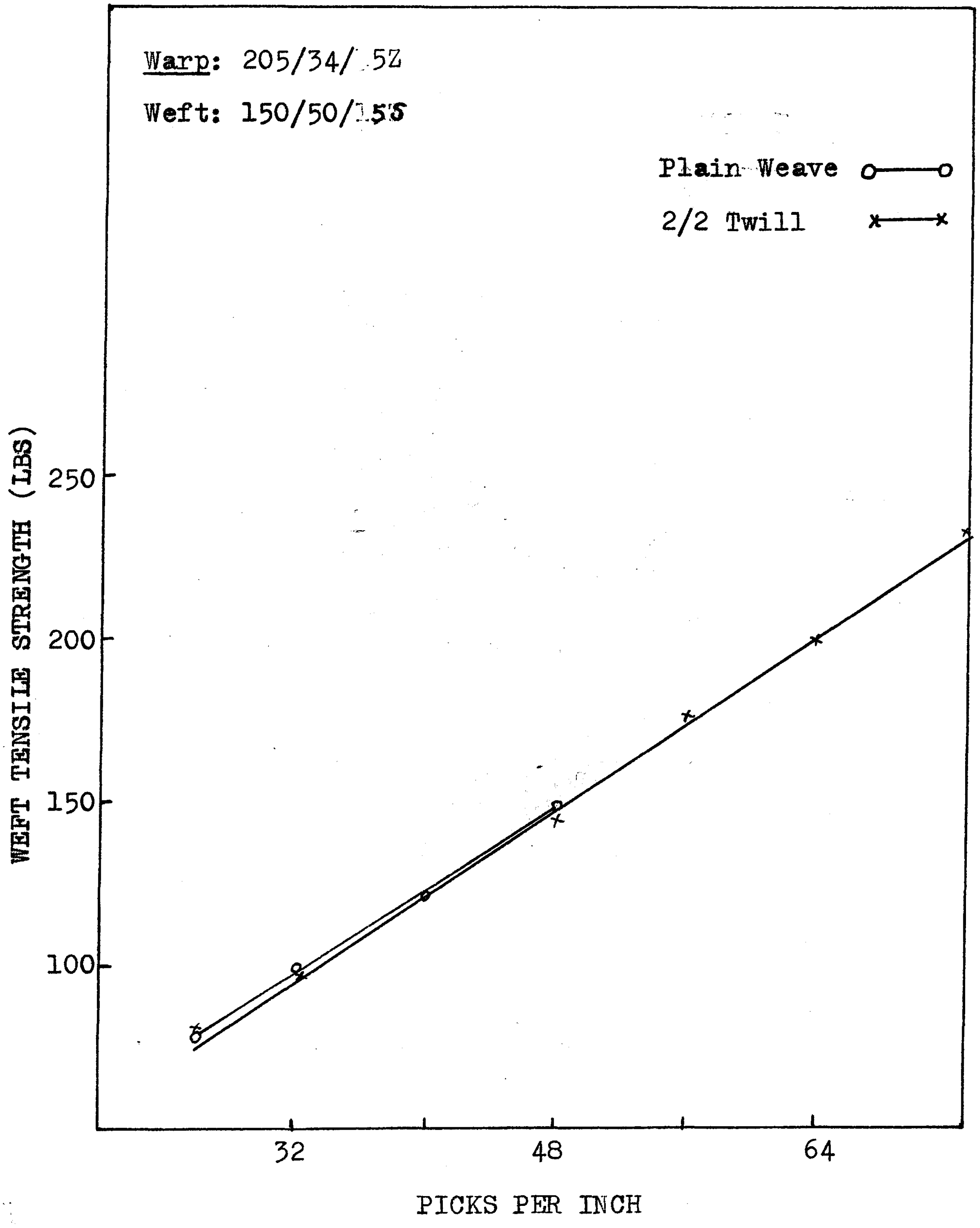

Warp: 205/34/.5Z
Weft: 150/50/15S
Plain Weave
2/2 Twill
WEFT TENSILE STRENGTH (LBS)
250
200
150
100
32
48
64
PICKS PER INCH

FIG. 13

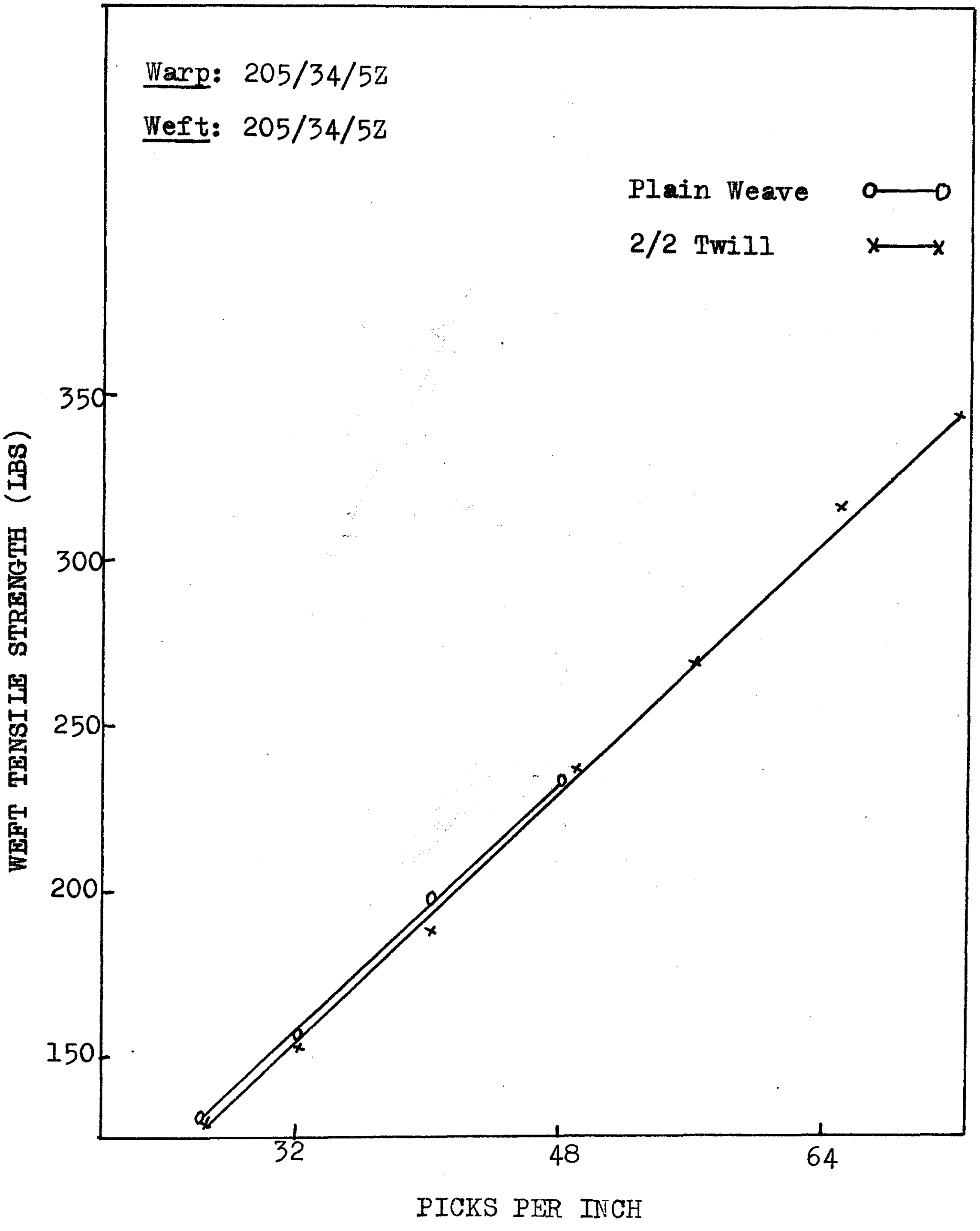

Warp: 205/34/5Z
Weft: 205/34/5Z
Plain Weave
2/2 Twill
WEFT TENSILE STRENGTH (LBS)
350
300
250
200
150
32
48
64
PICKS PER INCH

FIG. 14

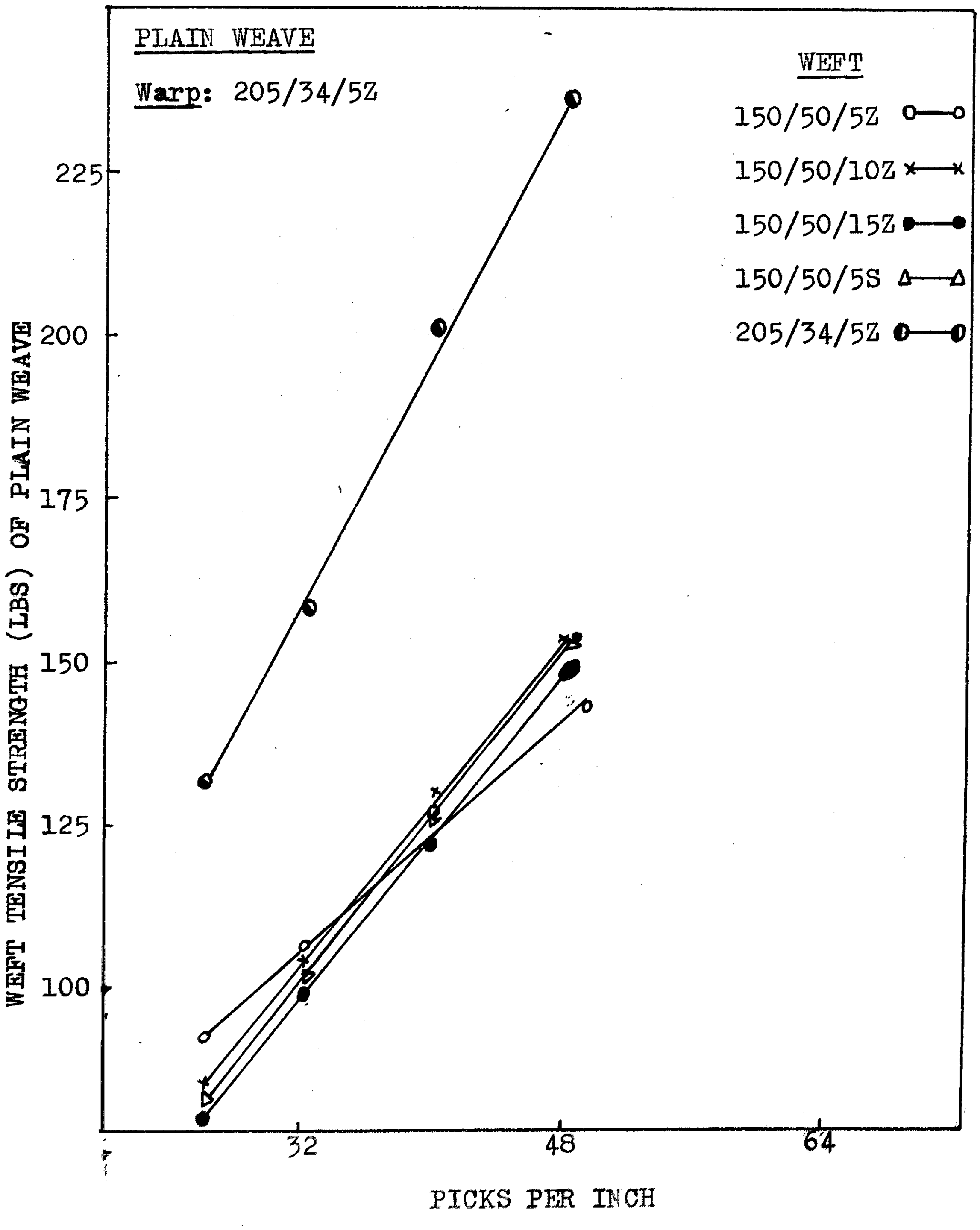

PLAIN WEAVE
Warp: 205/34/5Z
WEFT
150/50/5Z
150/50/10Z
150/50/15Z
150/50/5S
205/34/5Z
225
200
175
150
125
100
WEFT TENSILE STRENGTH (LBS) OF PLAIN WEAVE
32
48
64
PICKS PER INCH

FIG. 15

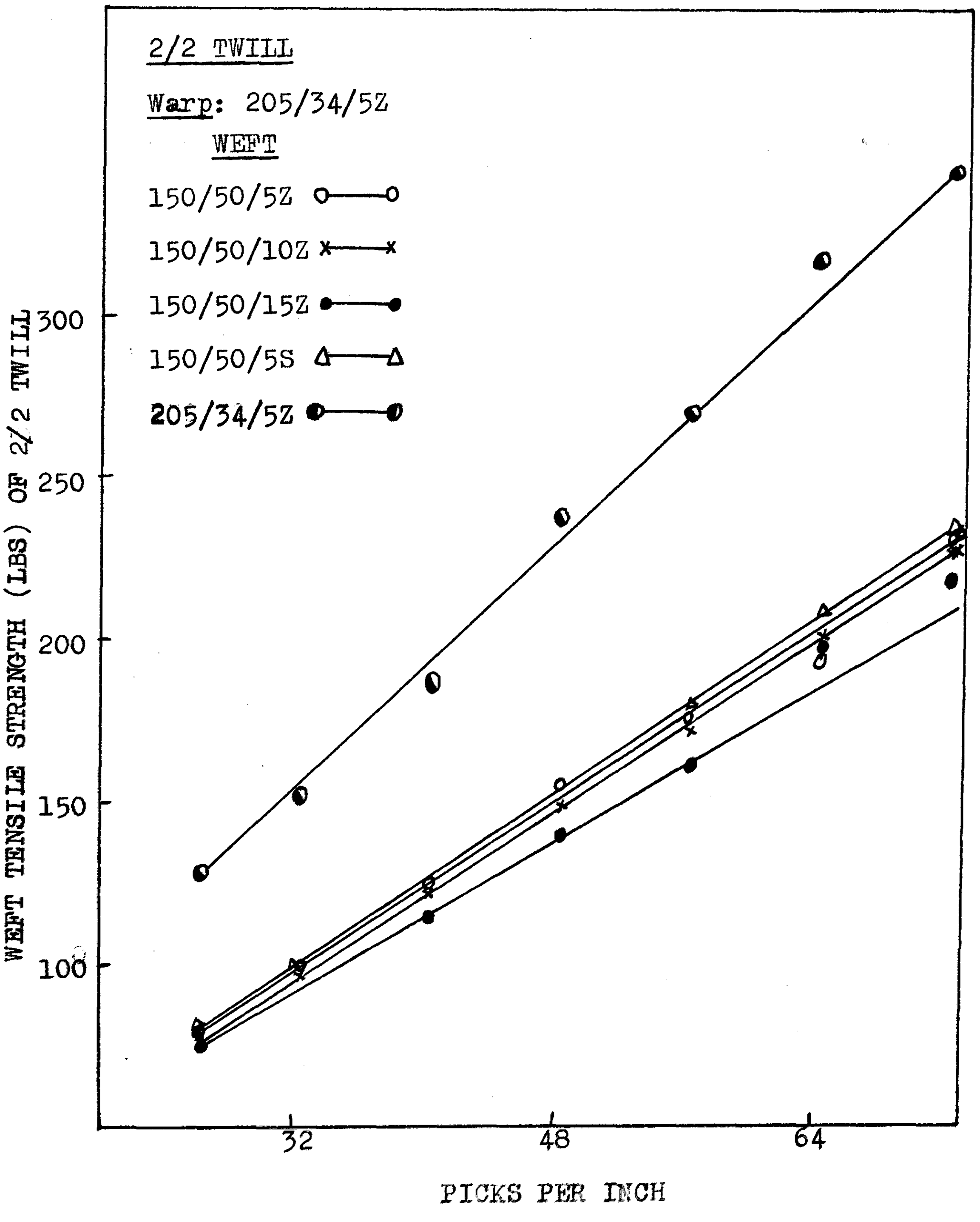
2/2 TWILL
Warp: 205/34/5Z
WEFT
150/50/5Z
150/50/10Z
150/50/15Z
150/50/5S
205/34/5Z
WEFT TENSILE STRENGTH (LBS) OF 2/2 TWILL
300
250
200
150
100
32
48
64
PICKS PER INCH

FIG. 16

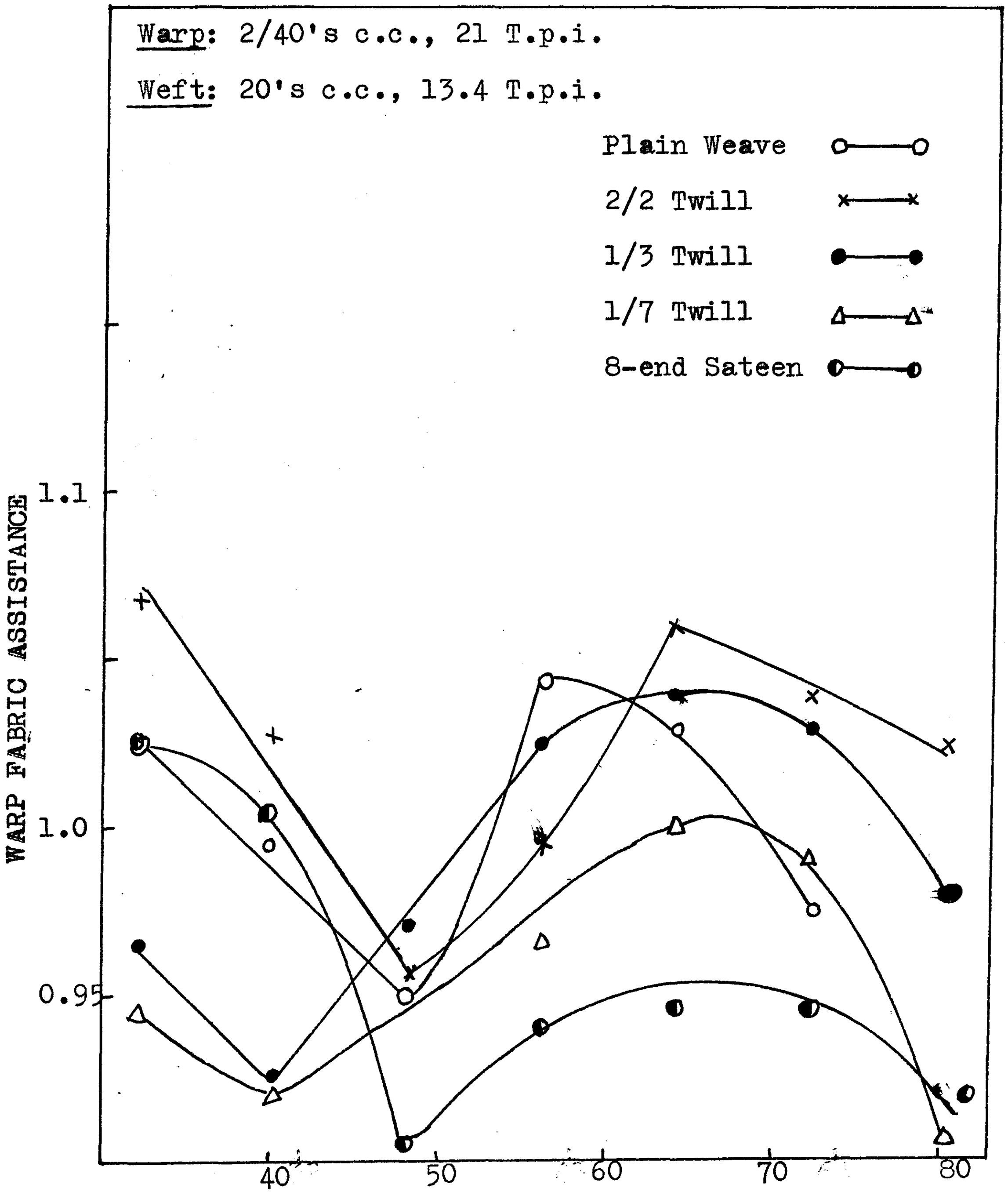

Warp: 2/40's c.c., 21 T.p.i.
Weft: 20's c.c., 13.4 T.p.i.
Plain Weave
2/2 Twill
1/3 Twill
1/7 Twill
8-end Sateen
WARP FABRIC ASSISTANCE
1.1
1.0
0.95
40
50
60
70
80
PICKS PER INCH

FIG. 17

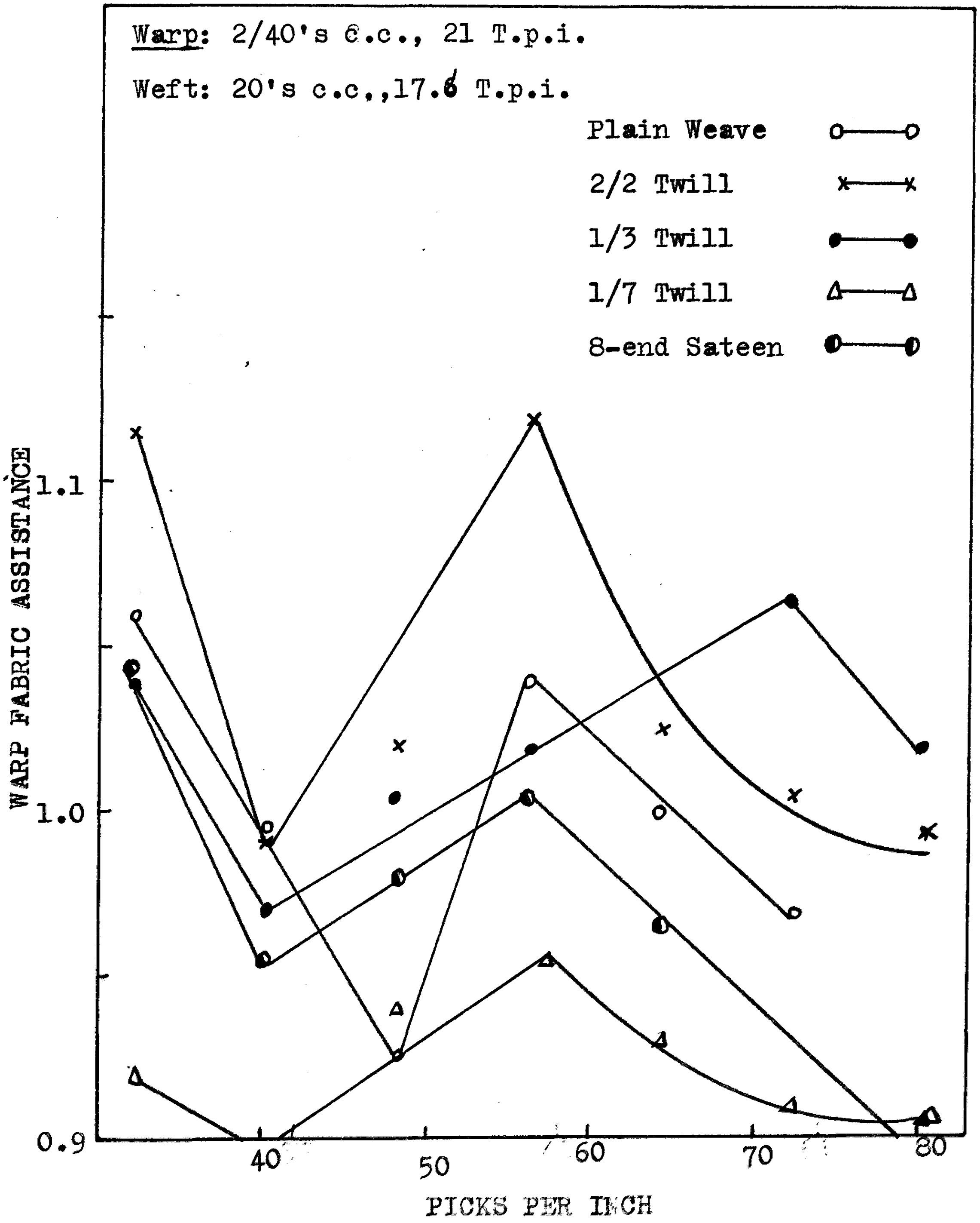
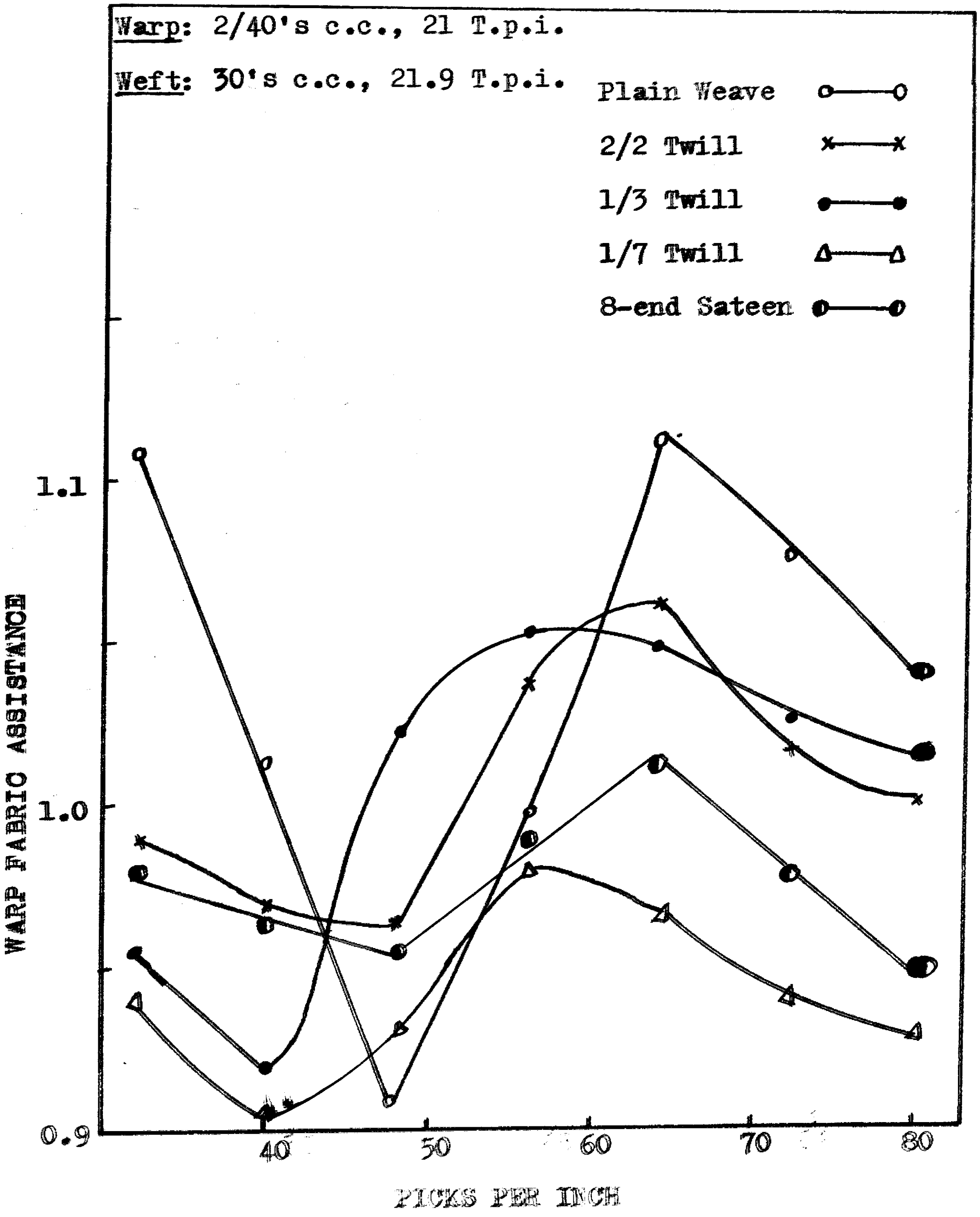

Warp: 2/40's c.c., 21 T.p.i.
Weft: 20's c.c.,17.6 T.p.i.
Plain Weave ○—○
2/2 Twill ×—×
1/3 Twill ●—●
1/7 Twill △—△
8-end Sateen ◐—◐
WARP FABRIC ASSISTANCE
1.1
1.0
0.9
40
50
60
70
80
PICKS PER INCH

FIG. 18



Warp: 2/40's c.c., 21 T.p.i.
Weft: 30's c.c., 21.9 T.p.i.
Plain Weave
2/2 Twill
1/3 Twill
1/7 Twill
8-end Sateen
WARP FABRIC ASSISTANCE
1.1
1.0
0.9
40
50
60
70
80
PICKS PER INCH

FIG. 20

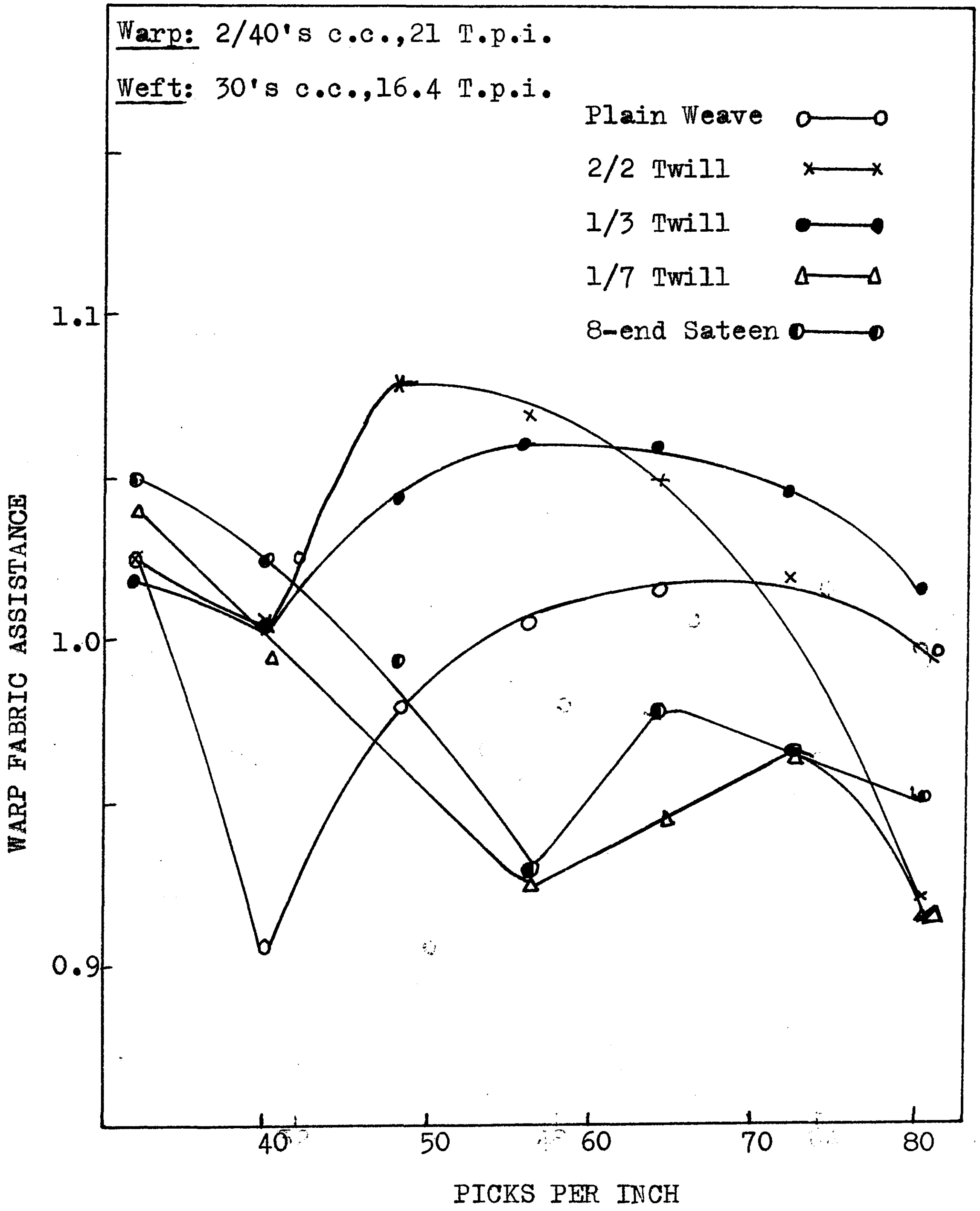

Warp: 2/40's c.c.,21 T.p.i.
Weft: 30's c.c.,16.4 T.p.i.
Plain Weave
2/2 Twill
1/3 Twill
1/7 Twill
8-end Sateen
1.1
1.0
0.9
WARP FABRIC ASSISTANCE
40
50
60
70
80
PICKS PER INCH

FIG. 19

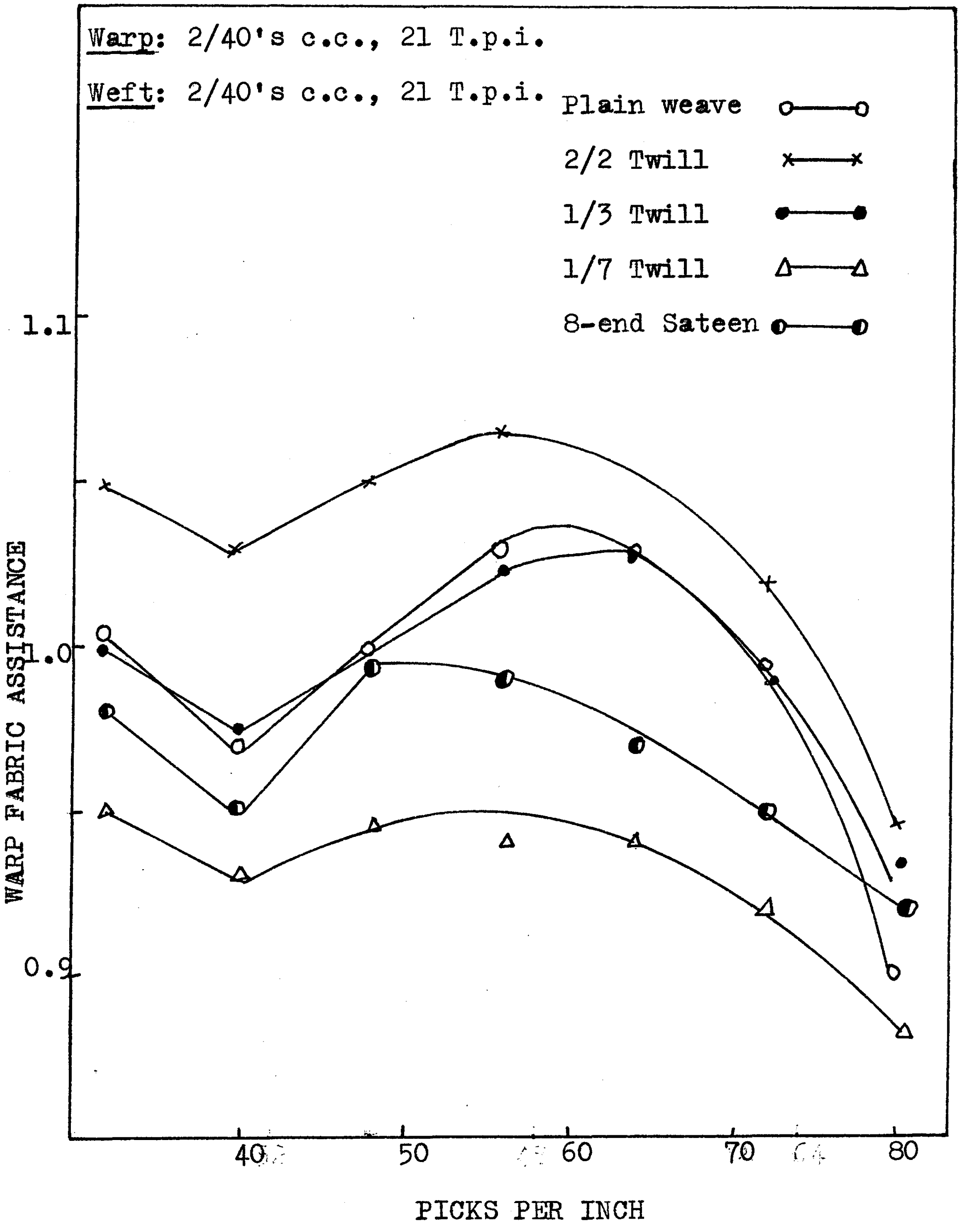

Warp: 2/40's c.c., 21 T.p.i.
Weft: 2/40's c.c., 21 T.p.i.
Plain weave
2/2 Twill
1/3 Twill
1/7 Twill
8-end Sateen
1.1
1.0
0.9
WARP FABRIC ASSISTANCE
40
50
60
70
80
PICKS PER INCH

FIG. 21

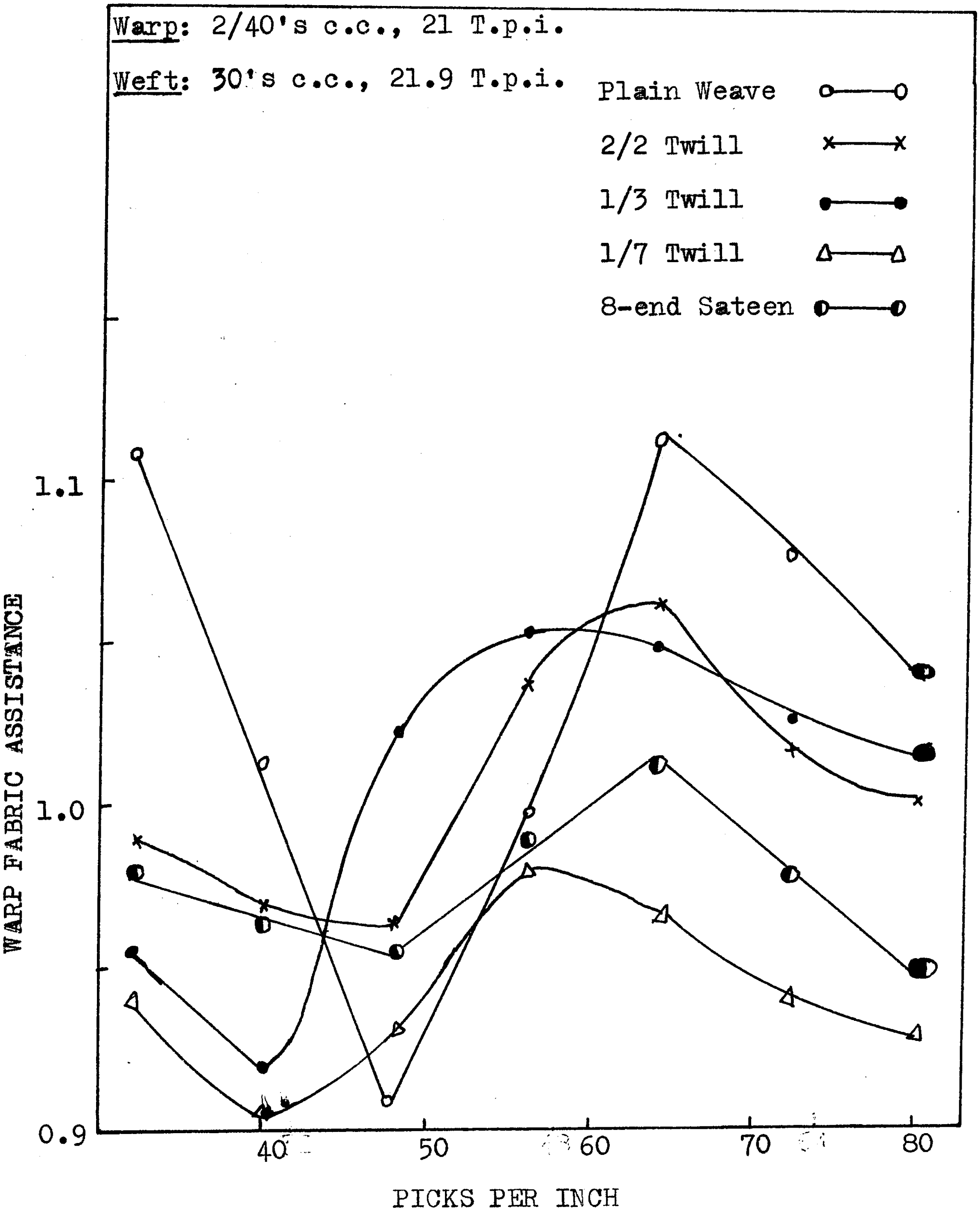

Warp: 2/40's c.c., 21 T.p.i.
Weft: 30's c.c., 21.9 T.p.i.
Plain Weave
2/2 Twill
1/3 Twill
1/7 Twill
8-end Sateen
WARP FABRIC ASSISTANCE
1.1
1.0
0.9
40
50
60
70
80
PICKS PER INCH

FIG. 20

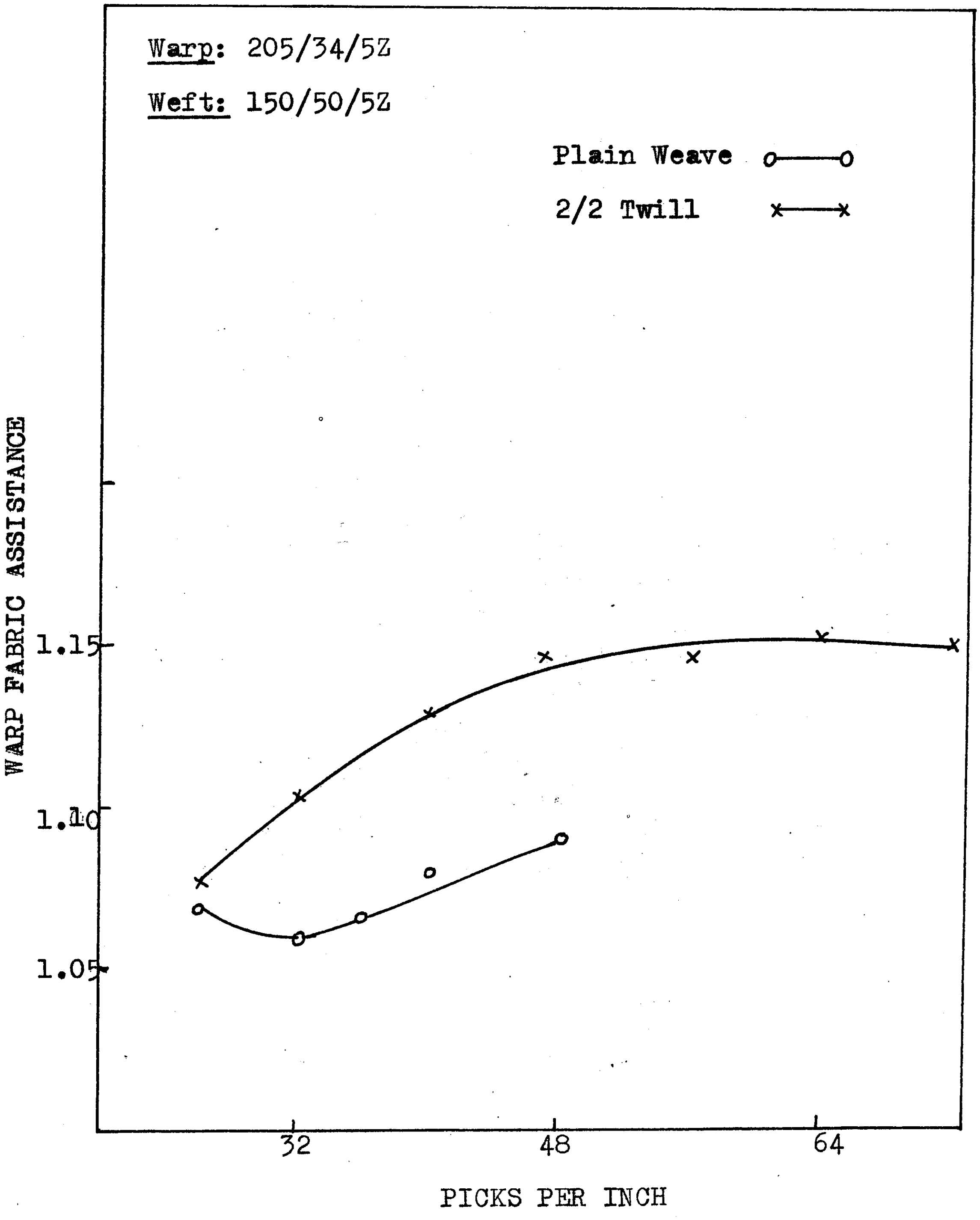

Warp: 205/34/5Z
Weft: 150/50/5Z
Plain Weave
2/2 Twill
WARP FABRIC ASSISTANCE
1.15
1.10
1.05
32
48
64
PICKS PER INCH

FIG. 22

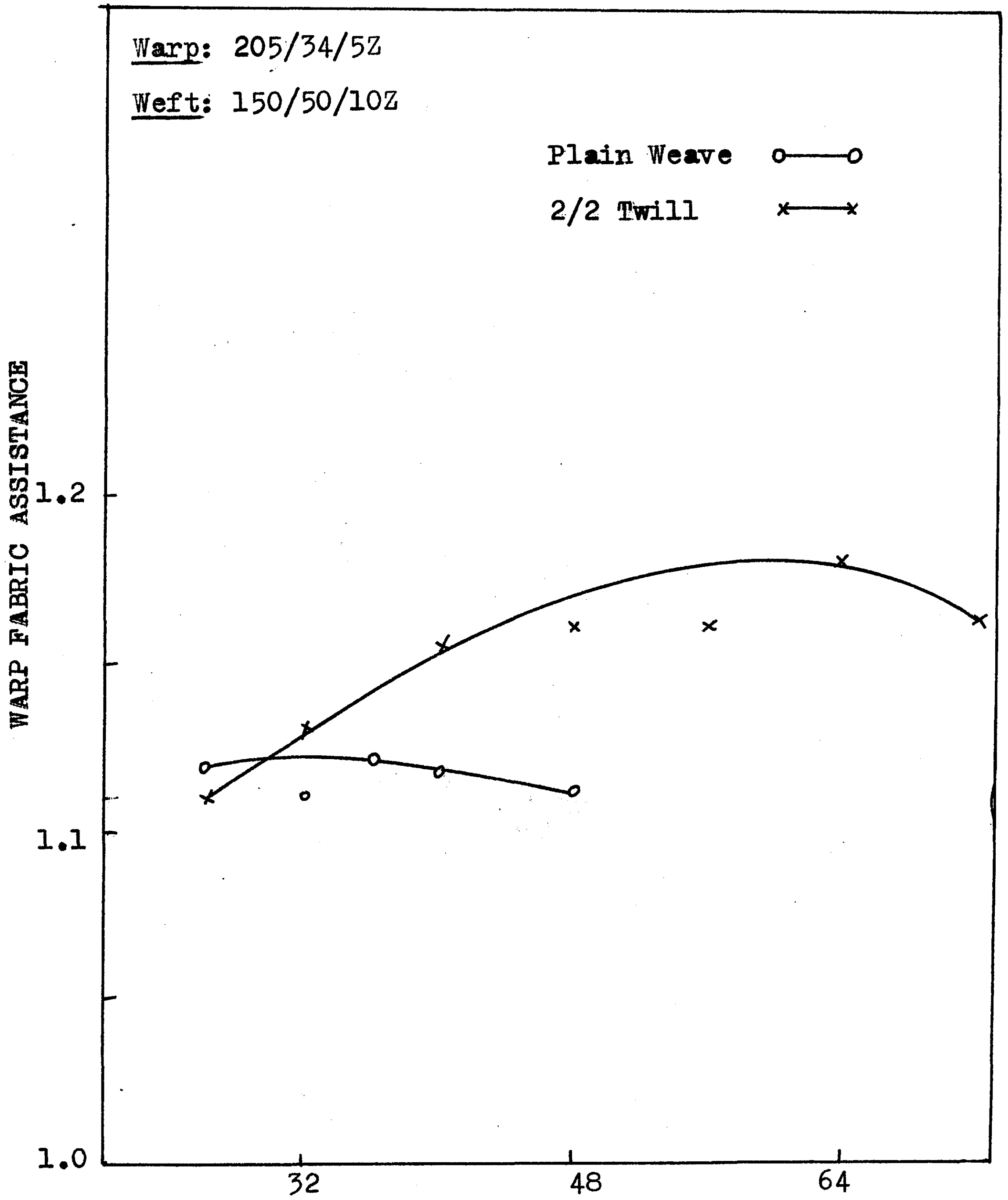

Warp: 205/34/5Z
Weft: 150/50/10Z
Plain Weave
2/2 Twill
WARP FABRIC ASSISTANCE
1.2
1.1
1.0
32
48
64
PICKS PER INCH

FIG. 23

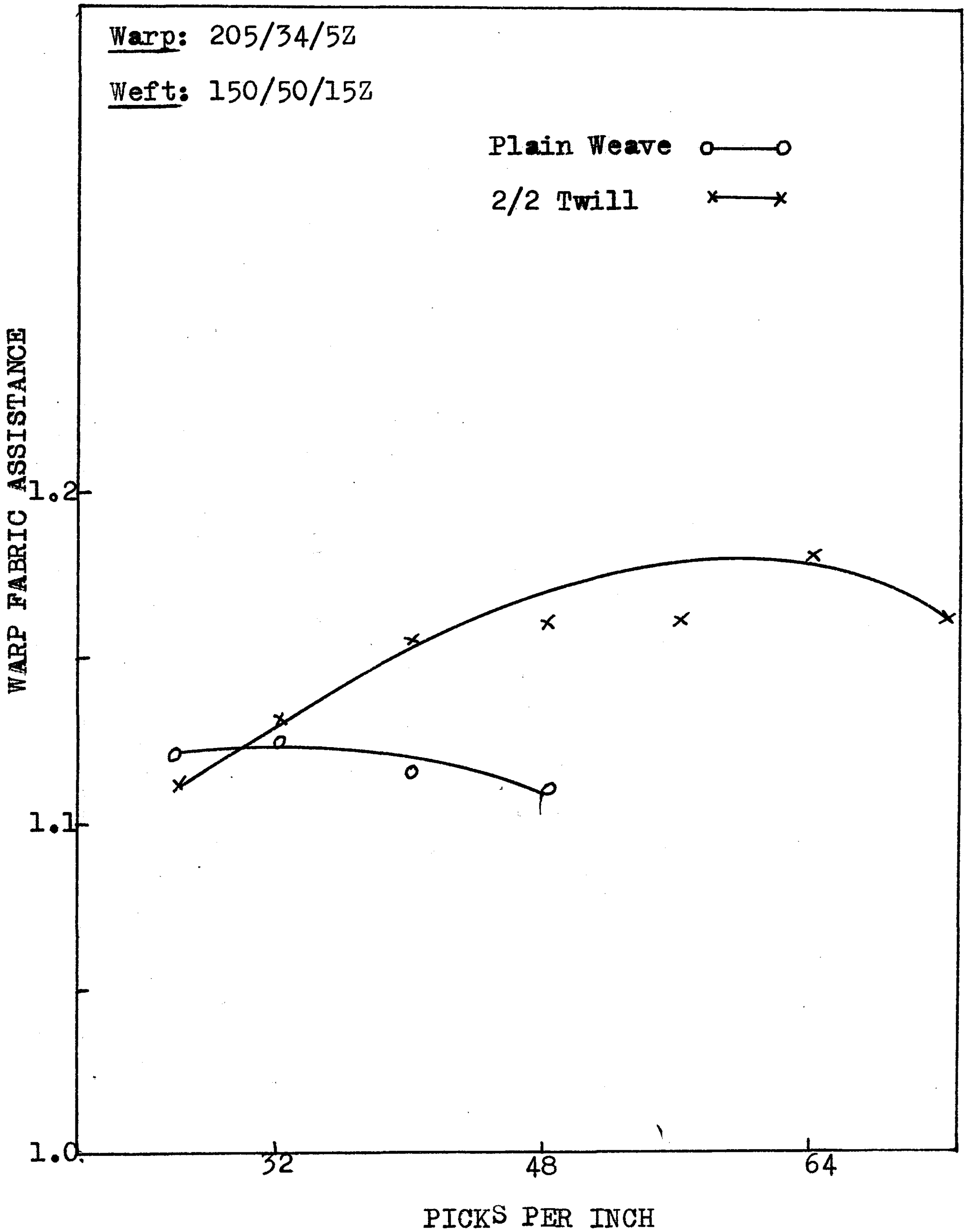

Warp: 205/34/5Z
Weft: 150/50/15Z
Plain Weave o——o
2/2 Twill ×——×
WARP FABRIC ASSISTANCE
1.2
1.1
1.0
32
48
64
PICKS PER INCH

FIG. 24

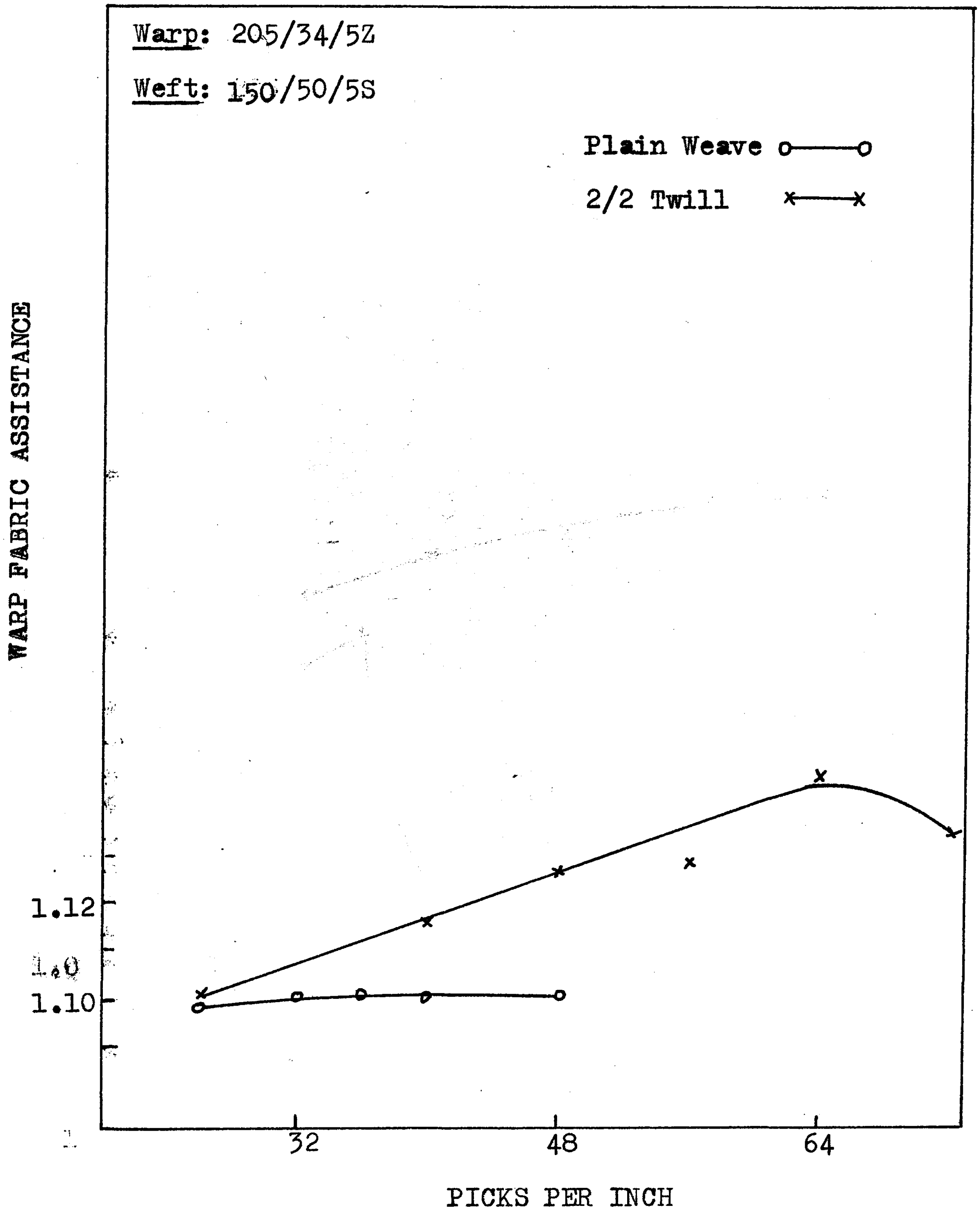

Warp: 205/34/5Z
Weft: 150/50/5S
Plain Weave
2/2 Twill
WARP FABRIC ASSISTANCE
1.12
1.0
1.10
32
48
64
PICKS PER INCH

FIG. 25

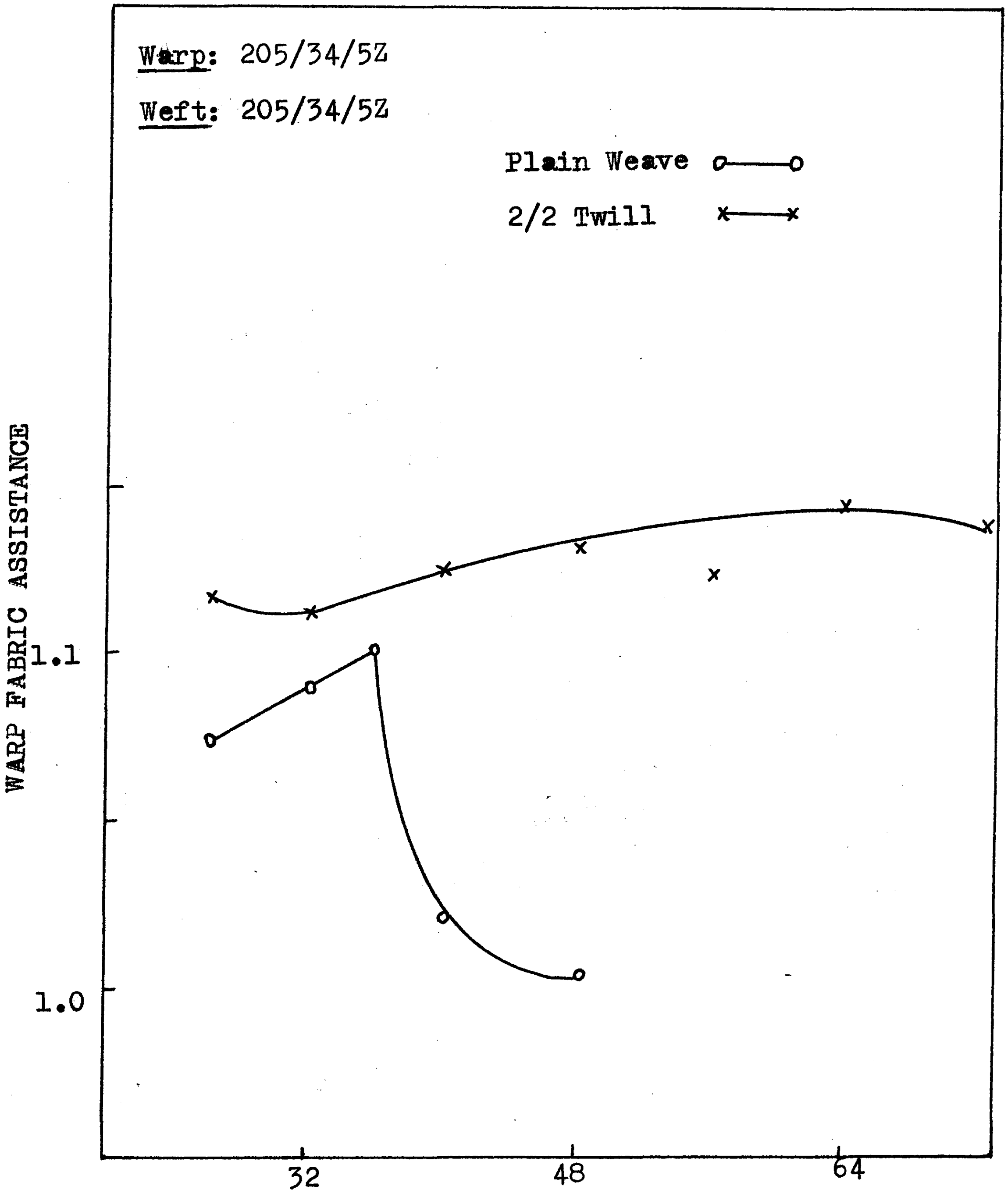

Warp: 205/34/5Z
Weft: 205/34/5Z
Plain Weave
2/2 Twill
WARP FABRIC ASSISTANCE
1.1
1.0
32
48
64
PICKS PER INCH

FIG. 26

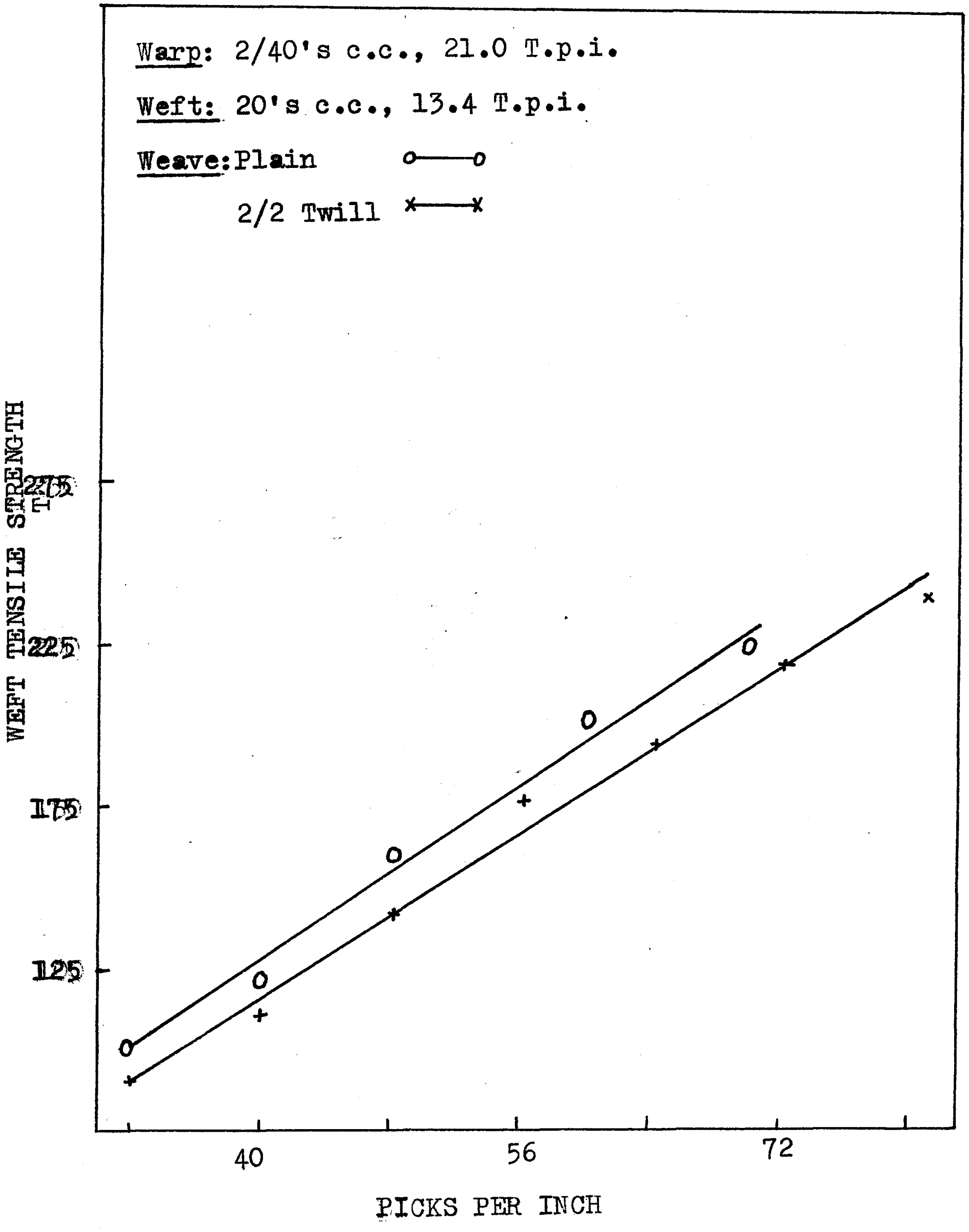

Warp: 2/40's c.c., 21.0 T.p.i.
Weft: 20's c.c., 13.4 T.p.i.
Weave: Plain
2/2 Twill
WEFT TENSILE STRENGTH
275
225
175
125
40
56
72
PICKS PER INCH

FIG. 30

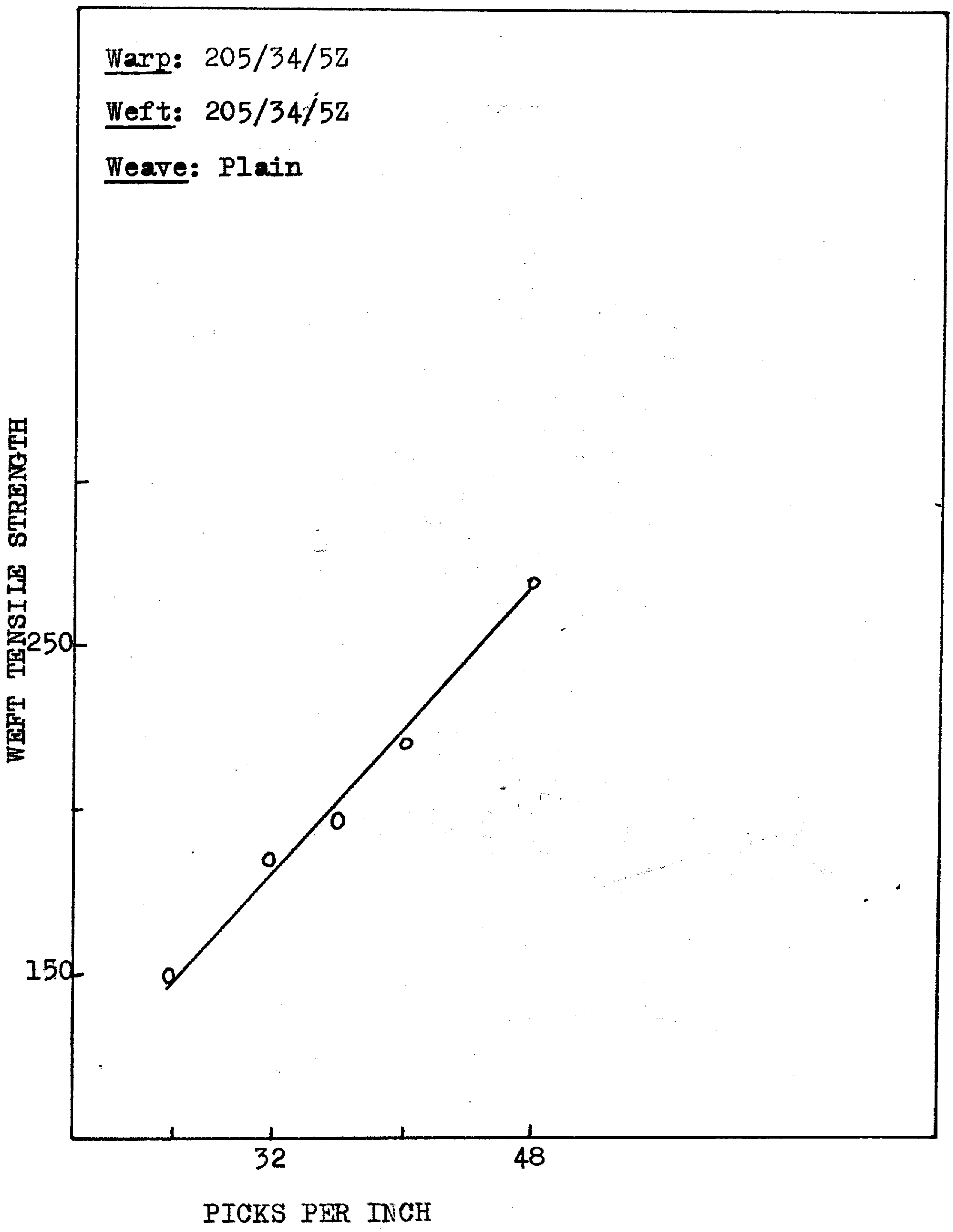

Warp: 205/34/5Z
Weft: 205/34/5Z
Weave: Plain
WEFT TENSILE STRENGTH
250
150
32
48
PICKS PER INCH

FIG. 31

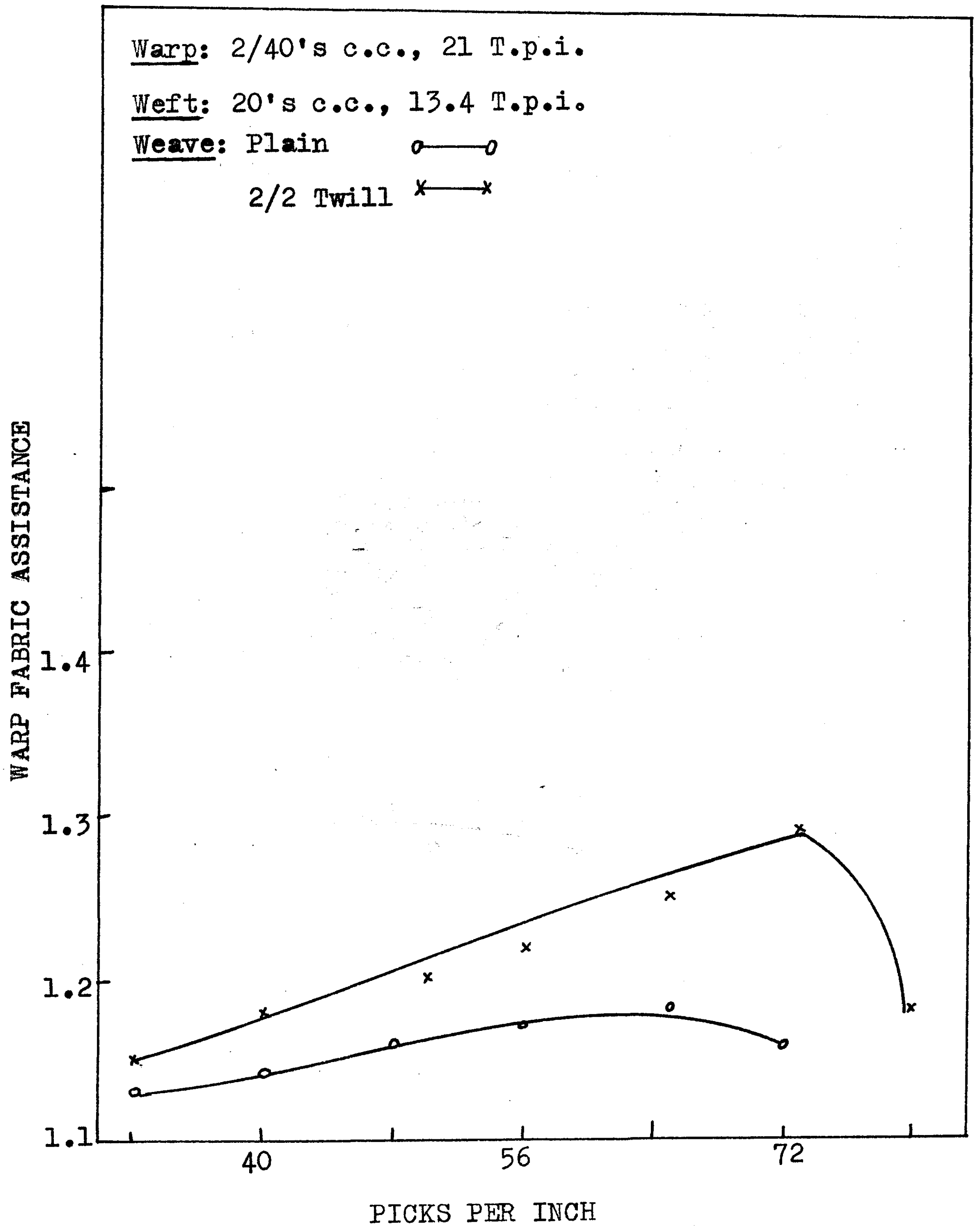

Warp: 2/40's c.c., 21 T.p.i.
Weft: 20's c.c., 13.4 T.p.i.
Weave: Plain
2/2 Twill
WARP FABRIC ASSISTANCE
1.4
1.3
1.2
1.1
40
56
72
PICKS PER INCH

FIG.32

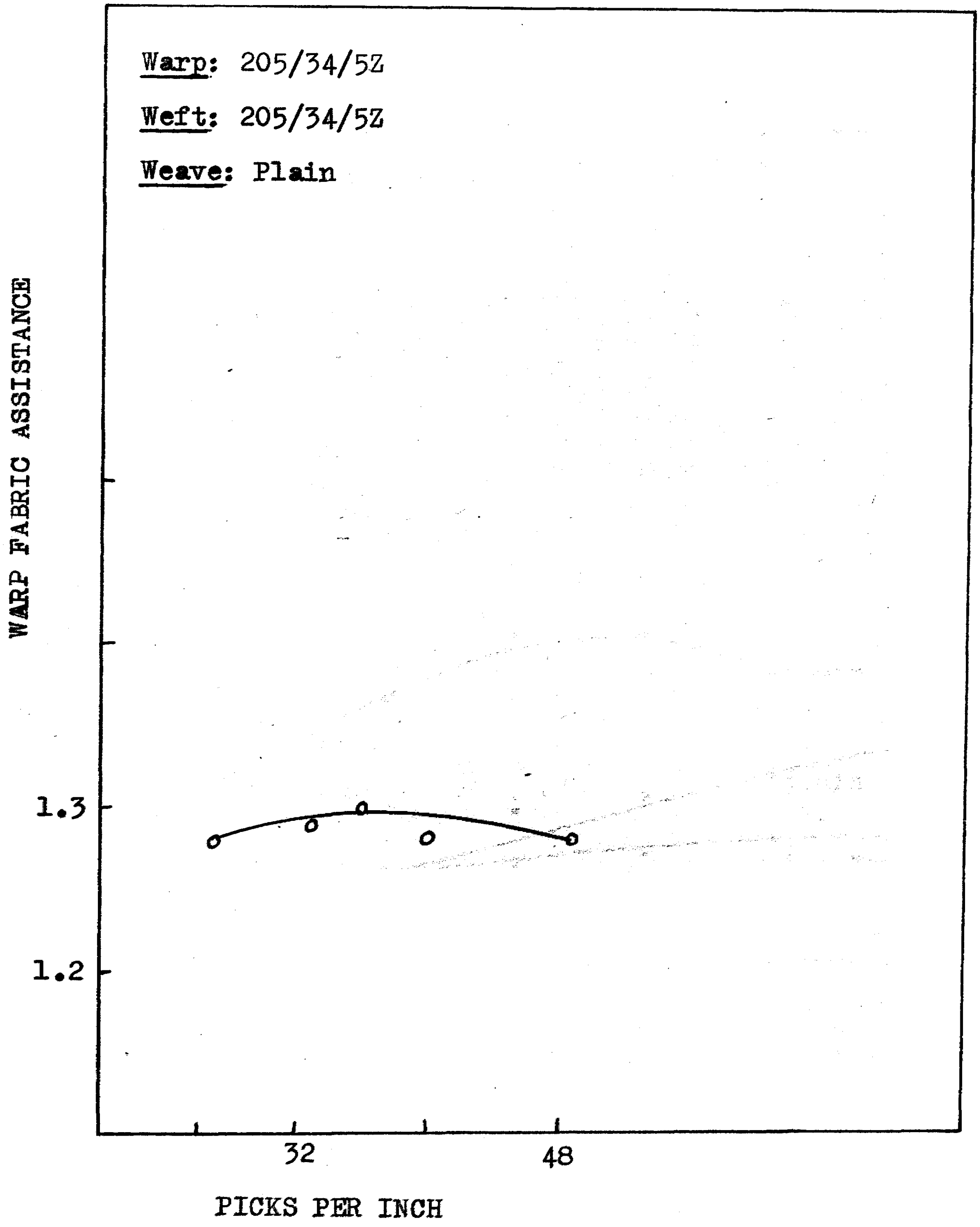

Warp: 205/34/5Z
Weft: 205/34/5Z
Weave: Plain
WARP FABRIC ASSISTANCE
1.3
1.2
32
48
PICKS PER INCH

FIG. 33

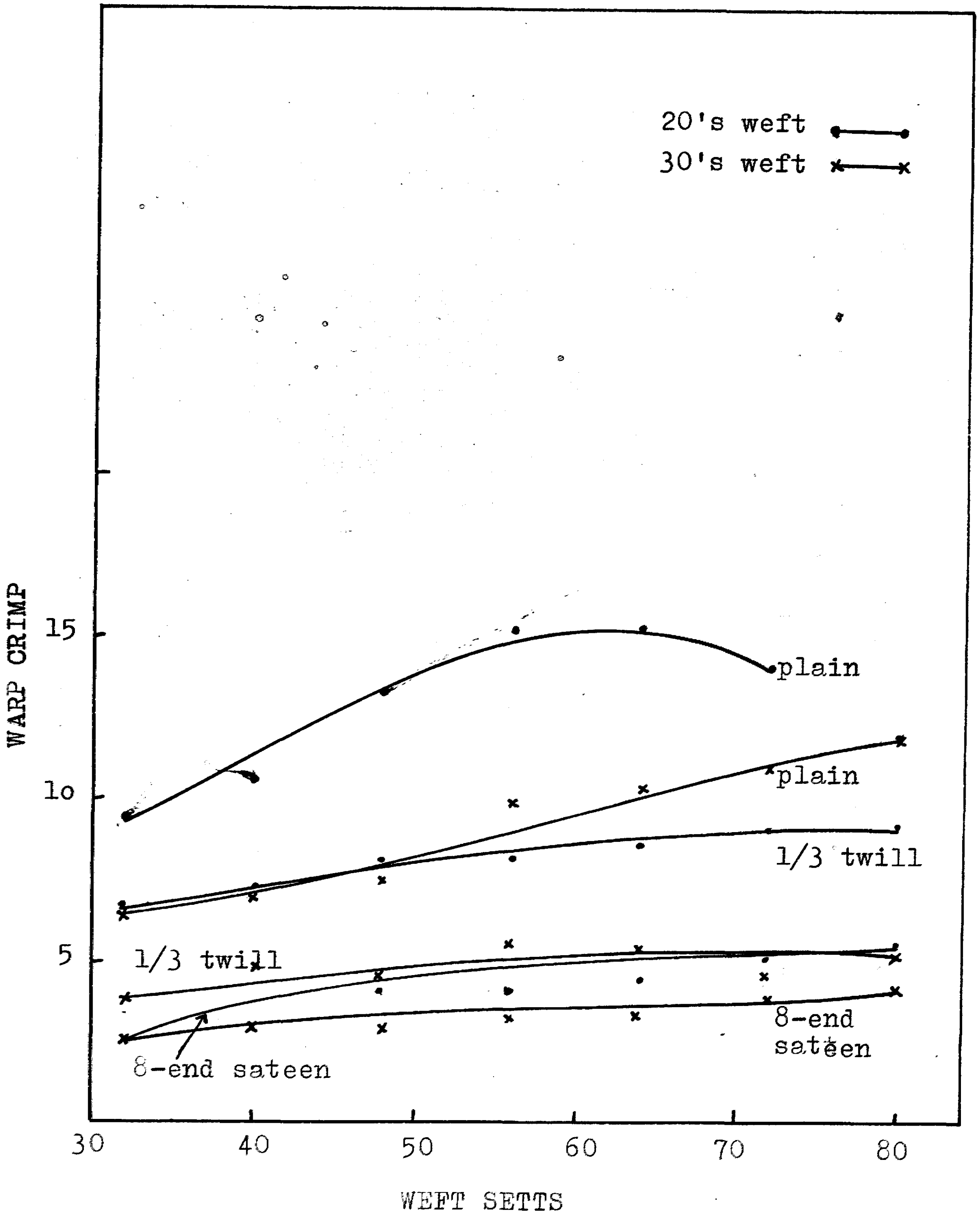


FIG. 34 DEPENDENCE OF WARP CRIMP FIGURES ON WEFT SETT AND WEFT COUNTS.

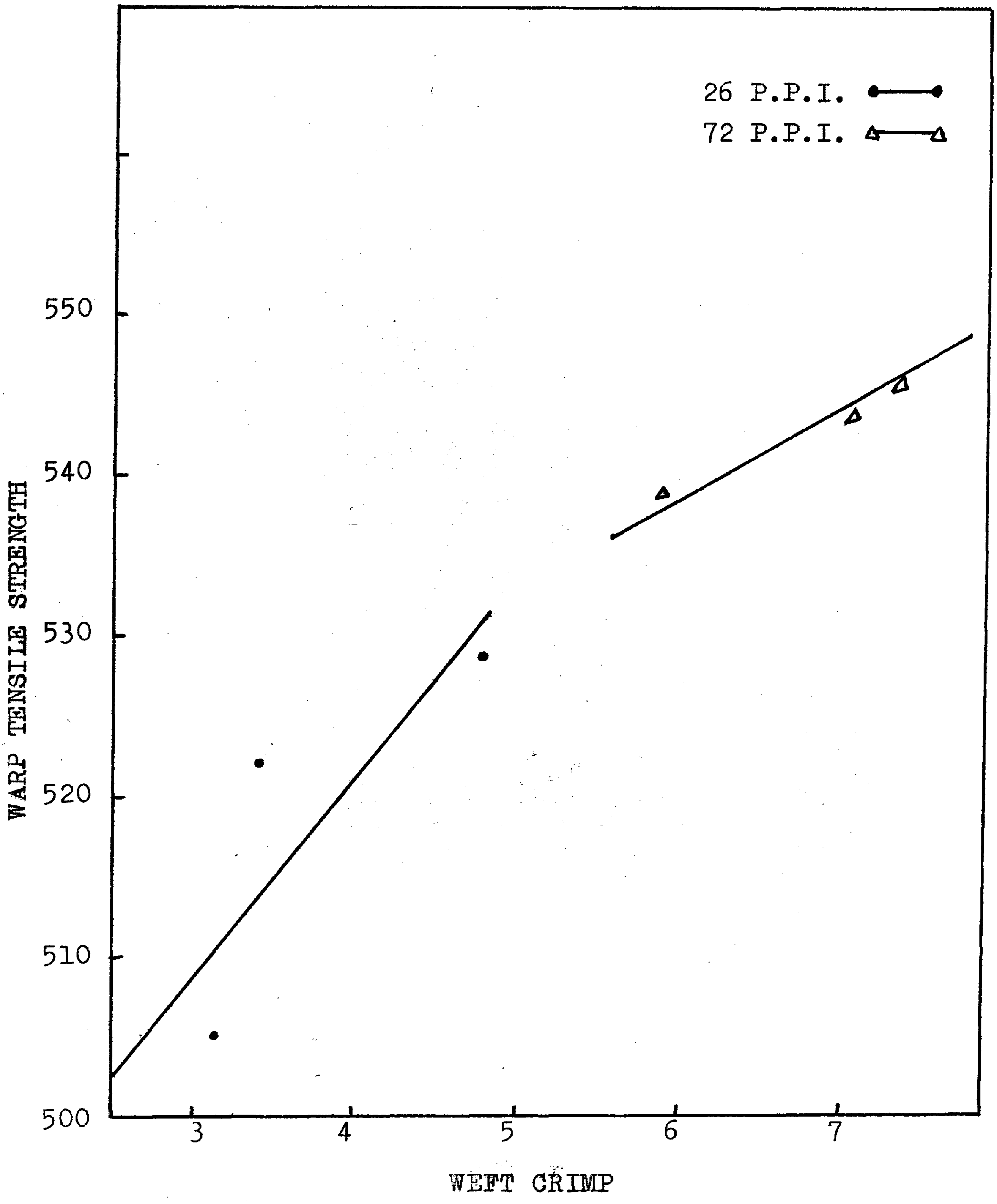


FIG. 36. RELATIONS BETWEEN WARP STRENGTH AND WARP CRIMP VALUE.

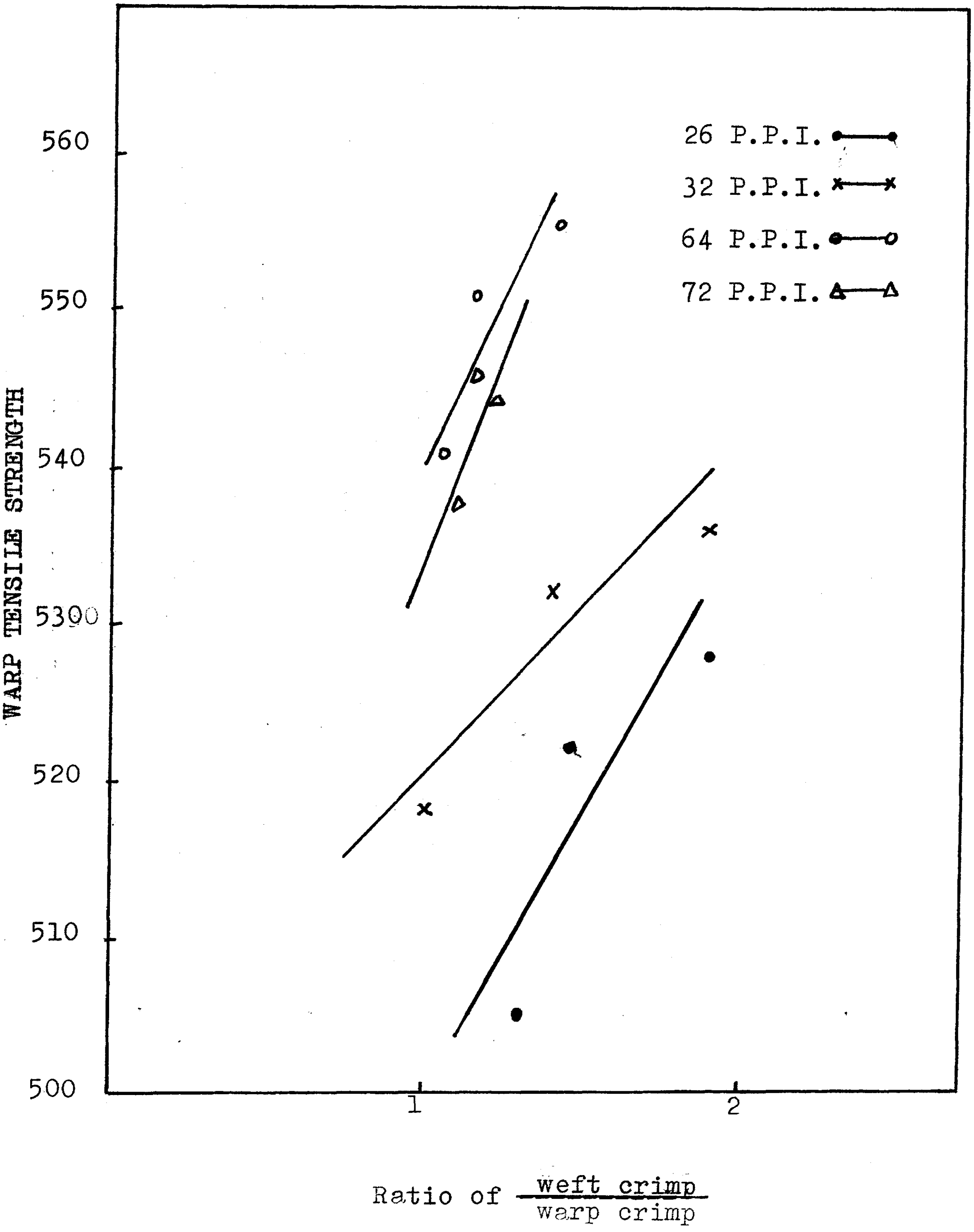


FIG. 37. RELATIONS BETWEEN WARP STRENGTH & WEFT & WARP CRIMP RATIO.

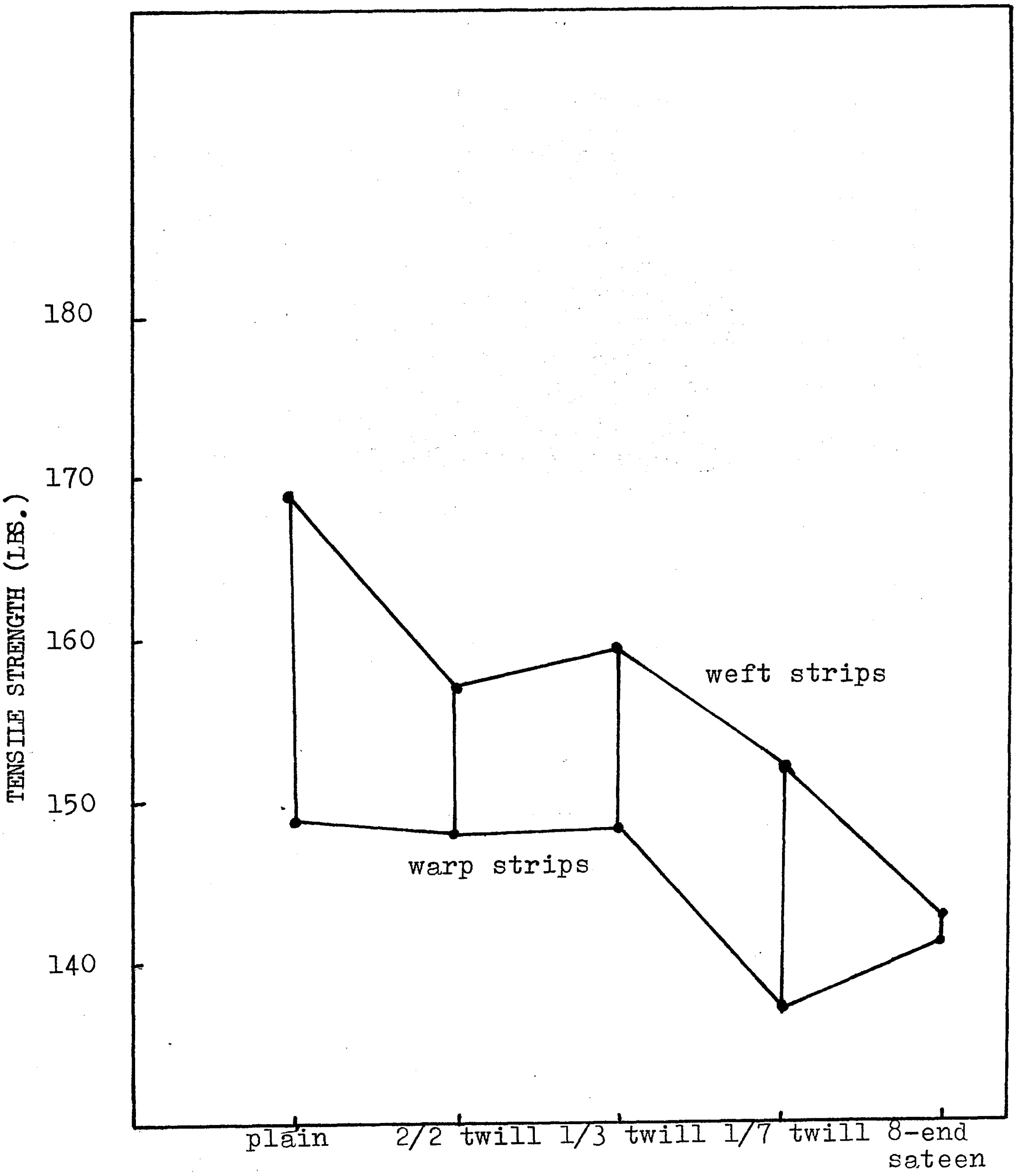


FIG. 38. EFFECT OF LOOM ABRASION.

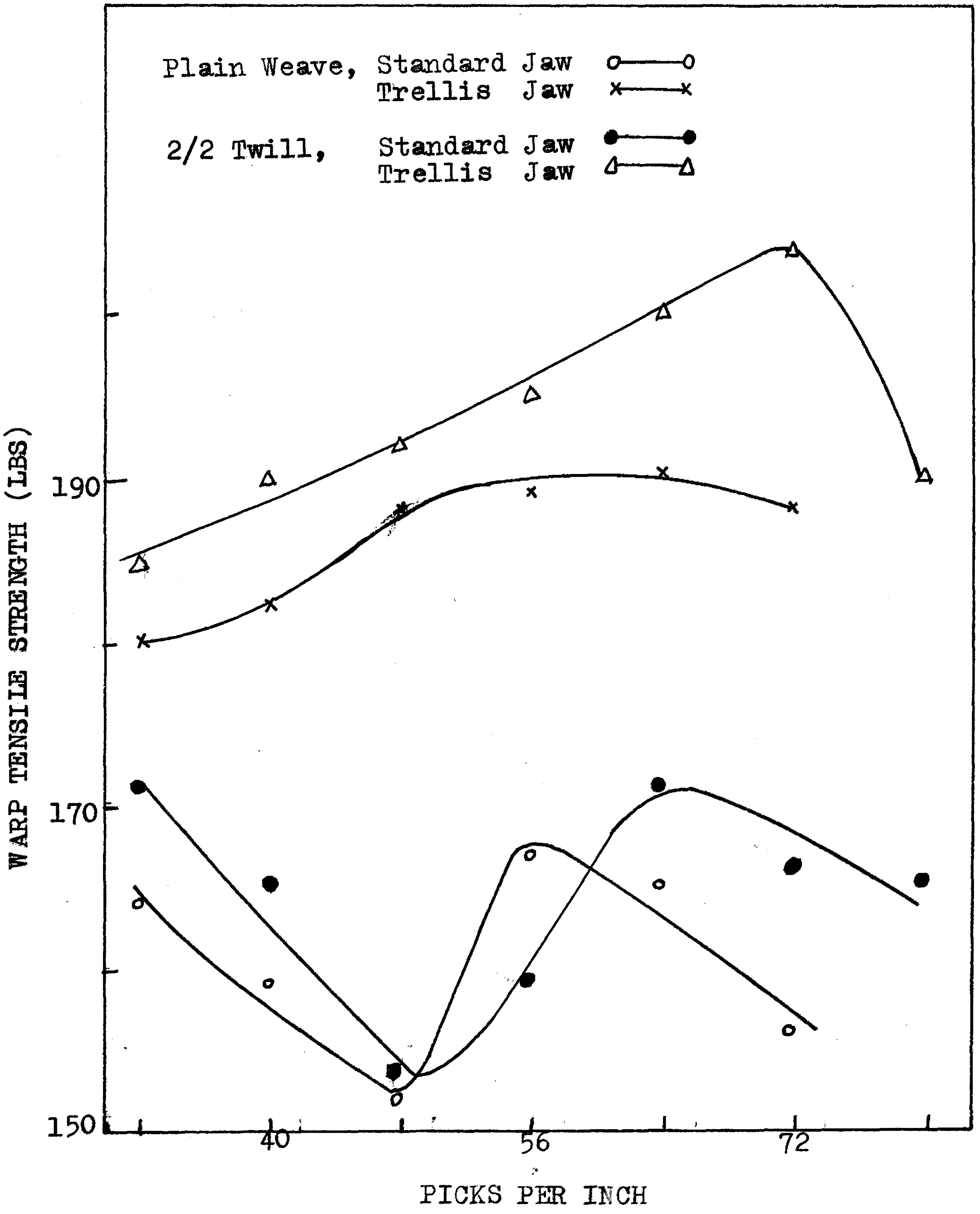


FIG. 39 COMPARISON OF TENSILE STRENGTH VALUES ACHIEVED WITH THE TWO TYPES OF JAW IN COTTON CLOTHS (WARP STRIPS)

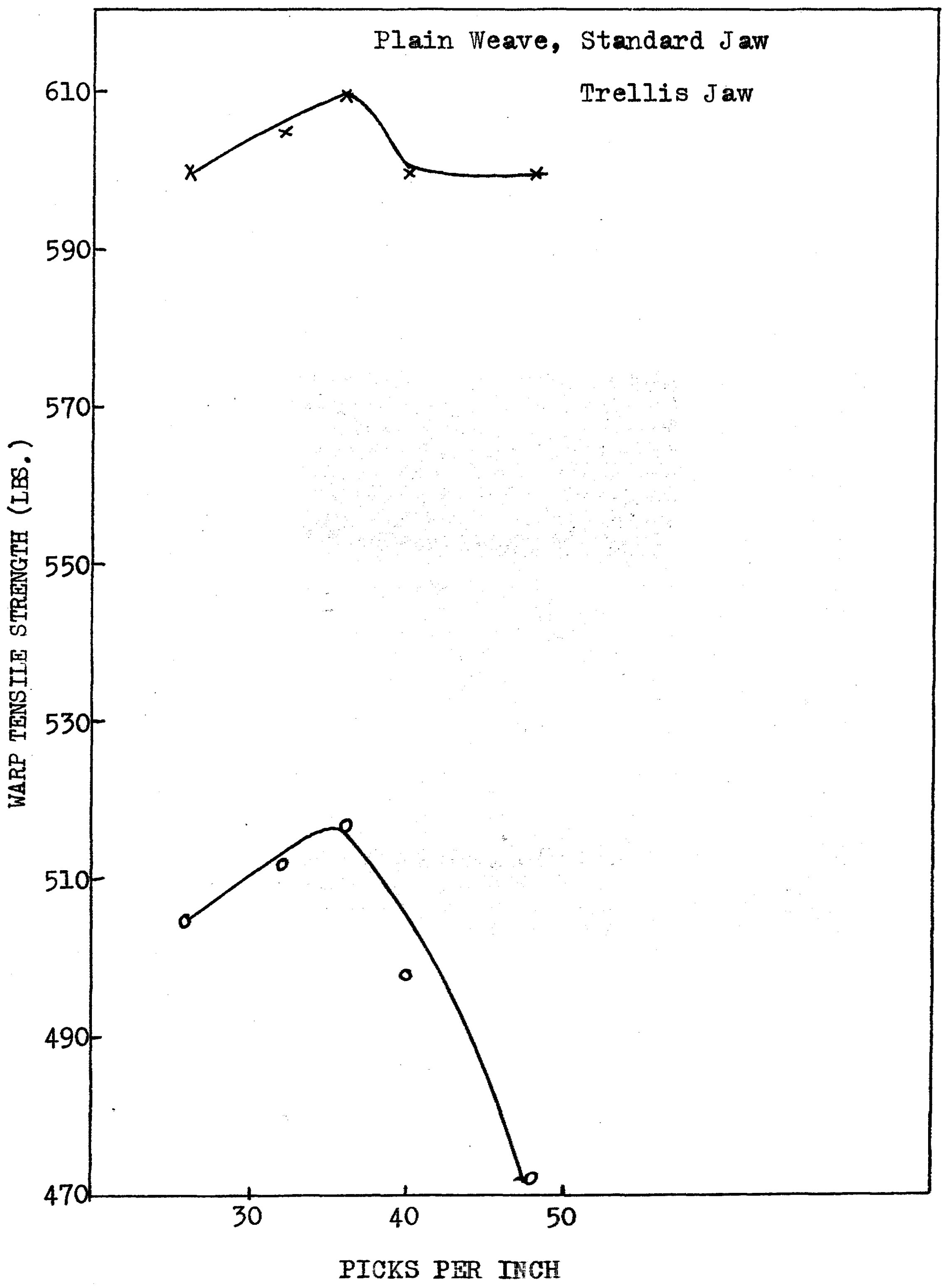


FIG. 40 COMPARISON OF TENSILE STRENGTH VALUES ACHIEVED WITH THE TWO TYPES OF JAW IN NYLON CLOTHS(WARP STRIPS).