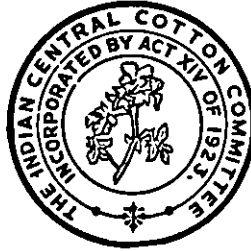


December 1948

Technological Bulletin,
Series A, No. 69.



INDIAN CENTRAL COTTON COMMITTEE TECHNOLOGICAL LABORATORY

—oo0oo—

METHODS OF TESTS ON FIBRE, YARN AND CLOTH AT THE TECHNOLOGICAL LABORATORY

by

D. L. SEN. M.Sc. (Tech.) (Manch.), M.Sc. (Bombay), A.I.I.Sc., F.R.I.C.
Director, Technological Laboratory, Matunga, Bombay.

Price One Rupee

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CONTENTS

| | Page |
|--|------|
| I. Introduction | 1 |
| II. Ginning Tests | 3 |
| Pre-cleaning machines | 3 |
| Gins | 4 |
| III. Moisture Tests | 6 |
| IV. Chemical Tests | 7 |
| (1) Wax content and feel of cotton | 7 |
| (2) Degradation of cotton | 7 |
| (3) Dyeing properties of cotton | 8 |
| V. Fibre Tests | 9 |
| Mean fibre-length | 9 |
| Fibre-length irregularity | 11 |
| Fibre-weight per inch | 12 |
| Stapling Apparatus | 15 |
| Air Permeameter | 15 |
| Fibre strength | 16 |
| Dial reading apparatus for fibre-strength | 17 |
| Bundle strength | 18 |
| Pressley strength tester | 18 |
| Fibre-strength per unit fibre-weight per inch. | 19 |
| Maturity | 19 |
| Maturity coefficient for Indian cottons | 20 |
| Swollen diameter | 20 |
| Fibre-rigidity | 21 |
| Ribbon-width | 22 |
| Convolutions or natural twist | 22 |
| Photoelectric diameter tester | 22 |
| Clinging power | 23 |
| Size of a satisfactory sample for fibre tests | 23 |
| VI. Spinning Tests | 25 |
| (a) Spinning technique | 25 |
| (b) Wastes | 26 |

| | Page |
|--|-----------|
| (c) Spinning processes | 27 |
| (d) Details of machinery | 29 |
| VII. Yarn Tests | 31 |
| Lea Tests | 31 |
| Ballistic tests | 31 |
| Single thread tests | 32 |
| Counts actual | 34 |
| Twist | 34 |
| Evenness | 34 |
| Neppiness | 34 |
| Irregularity | 35 |
| Yarn breakages in the ring frame | 35 |
| Twist standards | 35 |
| Strength standards | 36 |
| Spinning quality of a cotton | 37 |
| VIII. Cloth Tests | 41 |
| 1. Length | 42 |
| 2. Weight per sq. or lineal yard | 42 |
| 3. Width | 42 |
| 4. Thickness | 42 |
| 5. Ends and Picks per inch | 42 |
| 6. Crimp | 43 |
| 7. Count | 43 |
| 8. Shrinkage | 43 |
| 9. Bursting strength | 43 |
| 10. Tensile strength | 43 |
| IX. Conclusion | 44 |

PREFACE

Since the stock of Technological Bulletin (Series A. No. 25) on "Testing of Indian Cottons for Quality at the Technological Laboratory" was exhausted, it has been found necessary to publish a revised edition of this bulletin under the title "Methods of tests on fibre, yarn and cloth at the Technological Laboratory" incorporating various other tests that are introduced in the Laboratory since the publication of the original bulletin. This revised edition has been prepared and compiled with the co-operation of Messrs. Harirao Navkal, A. N. Gulati, V. V. Gupte, V. Venkataraman, Dr. R. L. N. Iyengar, Dr. S. Rajaraman and Mr. H. B. Joshi to whom my thanks are due.

D. L. S.

INDIAN CENTRAL COTTON COMMITTEE TECHNOLOGICAL LABORATORY

METHODS OF TESTS ON FIBRE, YARN AND CLOTH AT THE TECHNOLOGICAL LABORATORY

by

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I. INTRODUCTION

One of the main functions of the Technological Laboratory is to undertake fibre and spinning tests on samples of cotton supplied either by the Agricultural Departments, the trade or the mill industry and to issue reports embodying the results of such tests. The necessity for making tests on agricultural samples lies in assessing, under known and reproducible conditions, the fibre properties and spinning performance of improved varieties before these can be recommended to the farmers for general cultivation. The cotton breeder, who is in a position directly to study the field behaviour of his new types, is naturally anxious to have, at an early stage of his experimentation, reliable information as regards their spinning performance so as to enable him to make his final selection without undue waste of time and labour. Now, experience has shown that although in many cases the spinning performance of a cotton may be predicted with a fair degree of accuracy from a knowledge of its physical and chemical properties, yet in other cases the predicted value differs substantially from the actual performance. A time may come when our knowledge of the relationships between the fibre properties and the spinning performance of cotton may be sufficiently complete to dispense with the necessity of performing the spinning test in each and every case, but until such a time comes the spinning test must remain the most general and satisfactory means of judging the quality of a cotton. In order to make the spinning tests at very early stages of plant breeding, when only the produce of a few plants are available, a new technique of spinning, suitable for Indian cottons, has been evolved at the Laboratory by which tests could be made on as small a quantity as two ounces of the sample. The spinning performance recorded by this method

has been found to be closely correlated with that obtained from the usual test on the large sample and hence this method is a great help to the cotton breeder for selecting suitable strains at an early stage. The importance of making spinning tests on commercial varieties lies in the fact that soon after the marketing of the new season's crop, the trade and the mill industry in general are anxious to have reliable information regarding the spinning quality of the chief commercial types. This information is supplied to the trade in the successive seasons and is useful not only in showing the actual performance of the various types in any one season but also in revealing any steady decline or improvement in the quality of any one type.

Tests on agricultural samples were first undertaken in the Laboratory in 1924, while the testing of trade samples has been in progress since 1930. During this period, more than 10,000 samples have been subjected to the spinning and fibre tests and, as a result, the testing methods and spinning technique employed at the Laboratory have undergone a process of standardisation. In view of the fact that the methods and technique remain substantially the same from year to year, it was decided to describe them in a bulletin, which was published in 1933. Since then, several important changes and additions had taken place in the testing methods or the technique employed at the Laboratory and it was thought expedient to revise and enlarge the same. This has been done in this bulletin.

The methods employed at the Technological Laboratory for measuring the properties of cotton fibre and yarn were selected at the outset with due regard to the type of work which the Laboratory was expected to undertake. Since in most cases the same variety is tested during the successive seasons with a view to ascertaining the effects due to seasonal variation, it is hardly advisable to make frequent or abrupt change in these methods, as such a practice would render invalid a comparison between the results of one season's tests with those of another, unless a great deal of additional work is done in order to link the data obtained for the two seasons. Nevertheless, as the work of the Laboratory progressed, these methods were subjected to a critical examination with a two-fold object, (1) to ascertain in each case the minimum number of tests which is capable of yielding a reliable result, and (2) to find out whether or not the assumptions implied in any one method were valid. Improvements and modifications have been effected from time to time in the light of the results of these critical investigations, suitable supplementary tests were performed, wherever necessary, to determine the magnitude of the correction necessitated by a modification in the method. As a result of these improvements and modifications and the experience gained from numerous tests in the course of the last twenty years these methods have now attained such a state of stability to justify their description in the present Bulletin.

II. GINNING TESTS

Ginning of seed-cotton occupies a very important place in the passage of cotton from fields to the factories. The adjustments of the ginning machines are to be accurately made and the seed-cotton is to be presented in a proper condition in order to obtain satisfactory results. Otherwise the quality of the lint is likely to suffer in the ginning process. The gins generally used are either roller gins or saw gins. While in America 95% of the seed-cotton is ginned in saw gins, in India almost the entire crop is ginned in the roller gins. Before the seed-cotton is fed to the gins, in America, it is dried in dryers, whenever necessary, and is opened and cleaned by means of pre-cleaning machines in order to remove foreign matter in the form of leaf-bits, stalks, hulls, dirt, etc. These pre-cleaning machines are attracting the attention of ginners in India and it is anticipated that their use will increase with time.

The primary concern of the ginning factory is the output, with comparatively less interest on the quality of the ginned lint. It may happen that certain settings and speeds which may increase the output in the case of a particular cotton may impair the quality of lint. The ginning factories which are fully occupied during the busy period and which often lack the necessary equipment and scientific personnel are unable to carry out investigations on the influence of these settings on the fibre quality.

In order to make a systematic study of the processes relating to the pre-cleaning and ginning of Indian cottons, a Ginning Section was added to the Technological Laboratory in 1940-41, and since then experiments have been conducted with different varieties of Indian cottons on the different types of pre-cleaning and ginning machines. The main objects of these experiments have been to compare the efficiency of pre-cleaning machines, to study the effect of such factors as overlap settings, roller speeds etc., in the roller gins and the rate of feed, saw speeds etc. in the saw gins, on the quality of ginned cotton, taking into account such machine factors as power consumption, output per hour, etc.

The Ginning Section is equipped with three kinds of pre-cleaning machines and three types of gins. These will now be described briefly:-

Pre-cleaning machines

(1) *Double Cylinder Seed Cotton Opener (Platts)* manufactured by Messrs. Platt Brothers (England). This machine is 50" wide and is fitted with two spiked rollers besides feed and delivery lattices and a fan for updraft. Its driving pulley has a diameter of 12" and a speed of about 530 R. P. M. The

power required for running this machine, exclusive of that required for shafting, is about $3\frac{1}{2}$ B. H. P. and the output is stated to be about one ton of seed-cotton per hour.

(2) *The Feeding, Extracting and Cleaning machine (F. E. C.)* manufactured by Messrs. J. E. Mitchell & Co., (U.S.A.). This machine is 66" wide and is fitted with brushes to clean the kapas. The driving pulley of this machine has a diameter of 12", the speed of the main pulley is about 350 R. P. M. Ball bearings are provided and the power required for working this machine is 1 B. H. P., and the output is stated to be about 2000 lbs. of seed-cotton per hour.

(3) *The five cylinder I type Cleaning machine No. 2 (H. E.)* manufactured by Messrs. Hardwicke-Etter Co., (U.S.A.). This machine is also 50" wide and is provided with 5 spiked cylinders. It has an attachment of a cleaner screen having mesh of 3 x 3 size which can be changed as and when required. The driving pulley has a diameter of 18" giving a speed of approximately 500 R. P. M. Ball bearings are provided and the power required for working the machine is 3 B.H.P., and the output is stated to be 4,000 lbs. of seed-cotton per hour.

Gins.

(1) *Saw gin* Commander Air Blast type, manufactured by Messrs. Centennial Cotton Gin Co., (U.S.A.). This experimental gin has 40 saws of 12" diameter, and is equipped with a four cylinder ball bearing opener and feeder attachment in which the rate of feed may be varied by operating a lever. The diameter of the fan is 25" and it rotates with a speed of about 2,500 R.P.M. The gin is fitted with a hull extractor, double cylinder battery condenser and also with variable adjustments for adjusting the position of nozzles with respect to saw blades. Normally a pulley of 16" is used on the saw shaft to obtain a speed of about 680 R.P.M. but the saw speed may be varied by using pulleys of different diameters on the shaft of the saw blades.

(2) *Double roller gin*:—New patent double roller gin (Messrs. Volkart Brothers). The driving pulley has a diameter of $7\frac{1}{8}$ " and the gin has a speed of about 925 R.P.M. The rollers are driven by fully encased machine-cut reduction gears. They have a length of 40" and the power consumption of the gin is $3\frac{1}{2}$ B.H.P. exclusive of the power required for shafting. Over-lap settings and the size of the grid could be adjusted according to requirements.

(3) *Single roller gin*:—Double action single roller Macarthy gin manufactured by Messrs. Platt Brothers (England). The length of the roller is about 40" and the diameter of the driving collar pulley for the roller on crank is 5" and its width is 3", fast and loose driving pulleys 7" x 4". The speed of the driving pulley is about 600 R.P.M. which can be changed as

desired and the power required for working the machine is $2\frac{1}{2}$ to $3\frac{1}{2}$ B.H.P. Adjustments can be made in overlap settings and grid size while the speed of the roller may be changed by using suitable pulleys on the roller shaft.

Tests have been made on a number of varieties of Indian cottons using different pre-cleaning machines and their combinations, with different saw speeds and rates of feed in the saw gin and different overlap settings and roller speeds in the roller gins. After careful consideration, it was decided to carry out the pre-cleaning tests on samples weighing about 500 lbs. of seed-cotton, saw gin tests on samples weighing 200 lbs., double roller gin tests on samples weighing 80 lbs., and single roller gin tests on samples weighing 40 lbs., each. Even with these restricted samples several tons of seed-cotton of each variety were required to undertake all the tests. The results of these tests have been published in the form of technological leaflets.

Besides the abovementioned gins which are used in commercial practice, the Laboratory is equipped with smaller types of gins operated by hand, which are used at cotton breeding stations. These are (1) Bardoli gin, (2) Parbhani gin, (3) table model gin with 5" roller and (4) Platts gin with 12" roller. While the last two gins are of the Macarthy type, the first two are of local make consisting of two rollers each, one made of wood and the other of iron. These two rollers moving in opposite directions catch the fibres between them and pull them out of the seed which is unable to pass through the interspace between the rollers. Sometimes, however, a few weak and immature seeds get crushed and escape between the rollers with the lint. An enquiry was undertaken in order to determine whether any difference was caused in the value of the ginning percentage when the same variety of cotton was ginned in the different gins mentioned above. The mean value for several varieties of cotton indicated that definite differences existed and on that account it was recommended that for standard ginning practice a gin of Platts Macarthy type was most satisfactory.

III. MOISTURE TESTS

The moisture content is defined as the moisture present in a textile material, as determined by definite prescribed methods, expressed as a percentage of the *original* weight. The moisture regain is the moisture present in a textile material, as determined by definite prescribed methods, expressed as a percentage of *oven-dry* weight. The following three methods are used in the Laboratory for the determination of this property.

(a) *Conditioning Oven*

For large size samples, a conditioning oven is employed. The moisture is removed by keeping the sample in an atmosphere of 105-110°C. Generally, $\frac{1}{2}$ lb. of sample is taken for this purpose. As the sample gets drier and drier, the weight of the sample decreases. The weight is determined at intervals of 30 minutes till the difference between successive weighings is less than 0.1% of the weight, when it might be assumed that all the moisture has been driven away. From the initial and the final weights, the moisture content or moisture regain is calculated.

(b) *Brabender Semi-automatic moisture tester*

Moisture content of a sample whose weight is small can be determined by this moisture tester. A sample weighing exactly 10 gms. is kept in an atmosphere having a temperature of 110°C. \pm 0.2°C. A draft in the atmosphere caused by a fan aids the removal of the moisture quickly. The moisture content is directly read on a scale; and the scale reading is taken now and then till a constant value has been obtained. Generally, about one hour is found to be sufficient for this purpose. A battery of 12 samples can be tested at a time.

(c) *Shirley Moisture meter.*

When the moisture regain of a sample of cotton is required quickly, the Shirley Moisture Meter is very useful. It is based on the principle that the electrical resistance of a cotton fibre is closely related to its moisture content. The two terminals in the form of concentric rings, with an insulated annular space in between them, press well against the surface of the cotton sample and the moisture regain of the sample is directly read off on a dial. The average of 5 to 10 readings gives the correct value of the regain. However, as the instrument has been calibrated by the makers at 65°F., some corrections are to be made to the actual value to suit Indian conditions. One is the temperature correction, given by the makers themselves, and the other is the instrument correction, which was determined at the Laboratory by re-calibrating the instrument under conditions obtaining in the Laboratory. With these corrections applied, the value got by Shirley Moisture Meter was found to be equal to that got by the oven method correct to 0.2 per cent. The actual determination takes less than five minutes for a sample. The instrument could also be used for raw yarn samples by merely changing the electrode.

IV. CHEMICAL TESTS

The Technological Laboratory has a well equipped Chemical Laboratory where various types of textile chemical tests are being conducted.

(1) *Wax content and feel of cotton*

The wax occurring on cotton fibre, though present in extremely small quantities, plays an important part in spinning, wetting, dyeing and scouring processes. The feel of cotton as judged by the Cotton Grader from rough to very silky has been found to depend upon its wax content. The following is a broad classification for feel with respect to the wax content of cotton.

| <i>Feel</i> | <i>Wax content (%)</i> |
|----------------|------------------------|
| Very silky | above 0.500 |
| Silky | 0.425—0.500 |
| Slightly silky | 0.350—0.425 |
| Roughish | 0.300—0.350 |
| Rough | below 0.300 |

Method

The method employed in the Laboratory in the determination of the waxy material in cotton is as follows:—

The cotton is well cleaned by hand and its moisture content is determined by heating in a small oven. About 2.5 gms. of this clean cotton of known moisture content is placed in a 'Soxhlet's apparatus' and the wax extracted with hot benzene for 4 hours. The benzene is then filtered hot and distilled. The residual material in the distilling flask is transferred to a tared weighing bottle by washing the last trace with hot benzene. The weighing bottle is kept in an oven at 90°C. for about half an hour to remove benzene completely and is subsequently heated at 100°C. till its weight becomes constant. The increase in the weight of the bottle gives the wax content of the sample. This is corrected for the moisture present in it so as to obtain the value on the dry weight of cotton.

(2). *Degradation of Cotton*

The extent of degradation of cotton is usually estimated either by means of 'Copper Number' or "Cuprammonium fluidity" methods.

- (a) Copper Number is usually determined by the Schwalbe-Braidy's method after Clibbens & Geake. Triplicate tests are done for each sample.

The principle of the method is that the copper sulphate is reduced to cuprous oxide the amount of which depends on *the extent to which the cellulose has been modified*. This oxide is dis-

solved by treating the cellulose with ferric alum solution which is reduced to ferrous condition. When titrated against a standard viz. N/25 Pot. permanganate indicates the weight of copper reduced from the cupric to the cuprous state. By knowing the weight of copper reduced by a known weight of cellulose, the quantity of copper reduced by 100 gms. of dry cellulose from the cupric to the cuprous state in alkaline solutions can be calculated which is termed as 'Copper Number'. Higher the copper number the greater is the amount of the '*modified cellulose*'.

- (b) The 'cuprammonium fluidity' is commonly used for assaying the basic material in cellulose industries as it is regarded as the *most sensitive test* for the degradation of cellulose. The standard method recommended by the Fabric Research Committee of the Department of Scientific and Industrial Research, London is employed to determine the cuprammonium viscosity of the cotton samples. The viscosity measurements are made with 0.5 per cent cellulose solution in a cuprammonium hydroxide solvent containing copper 15 ± 0.1 gms., ammonia 200 ± 5 gms. and less than 0.5 gms. of nitrous acid per litre, at 20°C . and the results are expressed as absolute fluidities in reciprocal poises, when the complete range of cellulose materials covers a scale extending from about 2 to 50 with increasing cellulose degradation.

(3) *Dyeing properties of cotton*

Comparative dyeing properties of cotton is determined by means of a photoelectric colorimeter, using different substantive dyes. The quantity of dye absorbed by a known weight of cotton is estimated from the spent dye liquor by this instrument.

The depth of colour in the dyed cotton is estimated by the Standard Lovibond Tintometer.

Besides these, several inorganic and organic analyses are undertaken in connection with various types of tests of textile materials.

V. FIBRE TESTS

If two small samples of lint are taken at random from different parts of a bale of cotton, it is possible for them to differ appreciably in their fibre-properties. In order, therefore, to eliminate completely the errors due to random sampling, it is necessary to make tests, for each fibre property, on several samples drawn from different parts of the bale. Such a procedure, however desirable it may be from the theoretical point of view, is far too laborious and time-absorbing to be employed for routine work in a testing laboratory where speed is as important a consideration as accuracy. Under these conditions, it is highly important that, for the measurement of any one fibre-property, the sample tested should be truly representative of the bulk, and that the errors due to random sampling should be reduced to a minimum. This object is achieved at the Technological Laboratory in the following manner. Approximately 4 oz. of lint, taken from different parts of the bag containing the cotton under test, is divided into eight or more nearly equal portions, each of which is sampled in five or six different places, yielding thereby forty to fifty small heaps of fibres. These are mixed thoroughly into one mass, which is made into a sliver with the hand without using any machine except a small draw-box which performs the function of parallelising the fibres and making the sliver uniform. This sliver is subsequently used in all fibre-tests. In this way a representative sample is obtained and any possible damage to the fibres by the heavy machinery employed in cleaning or processing cotton is avoided.

The various fibre-properties are determined in the following manner:—

Mean Fibre Length. The "length" of a cotton is a property highly prized by the trade on account of the prevalent and, for the most part, correct idea that, other factors being equal, longer cottons will give better spinning performance than shorter ones. But the "length" of a cotton is an indefinite quantity, as all the fibres in a small bunch of any cotton by no means possess the same length, some being comparatively short, others long. The trade usually obtain their estimate of the "length" of a cotton by "pulling" a small tuft of fibres, with one or both ends somewhat vague, and measuring it against an inchscale. In this operation some of the short fibres may possibly be removed in the act of smoothing the tuft, others may be hidden under the long fibres. The grader's estimate of the "length" of a cotton is, therefore, likely to err and is, in any case, subject to errors of personal judgment, which may assume considerable magnitude with such new and unfamiliar types as result from the work of the Cotton Breeders. In order to furnish them with necessary information, it is essential to adopt a quantity indicative of the staple length which should be definite and a

method for its determination which should be free from errors of personal judgment. It is the practice to select for the former the 'mean fibre-length' of a cotton, which theoretically signifies the arithmetic mean of the lengths of all the fibres present in a small but representative sample of cotton. Obviously, the direct method of determining this quantity by measuring individually the lengths of all the fibres in the representative sample and finding the arithmetic mean is far too tedious to be employed for even a moderately large number of samples. Accordingly, methods, involving the use of special types of apparatus, have been devised by different workers which are capable of yielding results which are close to the arithmetic mean and are more or less free from personal errors. Two of these methods are employed at the Technological Laboratory in order that the results of one method may serve as check upon the other. The methods are (1) Balls Sorter method (2) Baer Sorter method and (3) stapling apparatus.* The first method is based on the principle of mechanically sorting fibres from the sliver mentioned above in order of length and depositing them automatically on an oblong piece of plush, the shortest fibres in the cotton being deposited first and the longest last of all. A calibrated tape, usually marked in divisions corresponding to $\frac{1}{8}$ " length of staple, is fixed alongside of the plush. At the end of a few cycles of operation when a sufficient deposit has been laid, the fibres lying in each length-grade are collected, rid of any plush hairs that may have been removed along with them and weighed on a torsion balance. If W_1, W_2, \dots, W_n , be the weights of the fibre-groups in length-grades l_1, l_2, \dots, l_n , the mean fibre-length L is given by—

$$L = \frac{\sum_{i=1}^n l_i W_i}{\sum_{i=1}^n W_i} \dots\dots\dots(1)$$

Analysis of the results obtained with 15 standard Indian cottons shows that the mean fibre length as found by the Balls Sorter is higher than the true arithmetic mean by a small amount which, however, is practically the same for the different cottons. It may therefore, be said that although the Balls Sorter does not give the true arithmetic mean, it gives a quantity which is highly correlated to it. The Balls Sorter results can, therefore, be used with confidence not only for comparing the staple lengths of different cottons but also in computing the various correlation co-efficients between the length and other fibre properties or spinning quality of cottons.

It will be seen from the foregoing account that besides the mean fibre-length, the Balls Sorter determination gives the percentage distribution by weight of fibres of different length-grades present in any cotton. This data is utilised in constructing Sorter diagrams and in calculating the fibre-length irregularity percentage of cotton.

* Fibrograph is also being used for the determination of fibre-length.

The Baer Sorter works on a somewhat different principle. The hand-sliver is held in a series of parallel combs, separated by intervals of $\frac{1}{2}$ cm. The fibres at one end of the sliver are made to lie along a straight line by removing the protruding fibres with tweezers. Bunches of fibres are then pulled out with tweezers and placed gently on one side on the combs in such a manner that the comb nearest to the operator forms the starting line for the tuft, while at the other end the longest fibres protrude out. The frame supporting the combs is now turned through 180° , the longest fibres are pulled out with the tweezers and laid perpendicular to a base line on a piece of plush. When these fibres are exhausted, one comb is dropped and the fibres next in order of length are similarly pulled out and laid on the plush, all the fibres being carefully spread out to uniform density. The process is continued until the tuft is exhausted and a pattern is obtained. The area of this pattern is measured on a squared sheet of celluloid and the quotient obtained by dividing the area with the length of the base line between the boundaries of the pattern is taken as the mean fibre-length of the cotton. This method is less mechanical and demands greater care on the part of the operator than the Balls Sorter method, especially in spreading the fibres uniformly on the plush which is a necessary condition for the attainment of accurate results.

It is the practice at the Technological Laboratory to make four determinations with the Balls Sorter and eight with the Baer Sorter in case of the standard Indian cottons and one determination with the Balls Sorter and two with the Baer Sorter in the case of the other cottons.

Fibre-Length Irregularity. It has been mentioned above that no cotton is perfectly regular in the sense that its fibres possess the same uniform length. Even a cotton of, say, 1" staple, which is regarded as 'regular' by the trade, will be found, on a close examination, to contain some fibres measuring only $3\frac{3}{8}$ " and others exceeding $1\frac{1}{4}$ " in length. Although the long and the short fibres both contribute towards irregularity in the staple of a cotton, the latter especially are responsible for increasing its waste losses and reducing the strength of its yarns. The relative proportions of short fibres are usually different in cottons having different mean lengths; they may even differ in two cottons possessing nearly the same mean fibre-length, rendering one cotton more irregular than the other. It is important, therefore, that, in addition to the mean fibre-length of a cotton, the degree of irregularity of its staple should also be known. For this purpose, a new statistic called "fibre-length-irregularity" has been introduced. It is defined as the percentage by weight of such fibres in a representative sample of cotton as are shorter than three-fourths of the mode. Thus, if W be the weight of the representative sample, S the weight of fibres shorter than three-fourths of the mode, then fibre-length irregularity, I , is given by—

$$I = \frac{100 S}{W}$$

The mode, it may be explained, is the value of the fibre-length of the group containing the largest number of fibres. In normal distributions the mean and the mode coincide, but in skew distributions, such as exhibited by fibre-length, they are different and the mode is calculated according to the following formula :—

$$\text{Mode} - \text{Mean} = 3 (\text{Median} - \text{Mean})$$

The median, it may be stated, is the particular value of fibre-length above and below which exactly 50 per cent of the fibres lie. The theoretical basis of adopting the above-mentioned procedure for the calculation of fibre-length irregularity and the reasons for selecting the mode instead of the mean are described in a separate bulletin.*

Fibre-weight per inch. This property is to be regarded as a measure of the fineness of cotton fibres, and, next to the mean fibre-length, exhibits the highest correlation with the spinning quality of cotton. In the past it was found by the cutting method, which consisted of weighing 1 cm. lengths cut from a known number of fibres on a sensitive quartz micro-balance. The method, however, is open to two objections. In the first place, it is possible that the fibre-weight per inch varies so much for fibres of different length-grades as to affect the mean value. This point was investigated at the Technological Laboratory, and it was found that although it cannot be accepted as universally true that the fibre-weight per inch is the same for different lengths of fibre, yet the effect of variation of fibre-weight with length grade upon the mean fibre-weight is not so marked as to invalidate the cutting method.† The second objection lies in the possibility of the fibre-weight per unit length being variable along the length of the fibre. In the cutting method, 1 cm. lengths are cut from the middle portion of a bunch of fibres after it is straightened out. It will be seen that this method will only give correct values for the whole fibre if the fibre-weight per inch is uniform along its length. If the central portion weighs more per unit length than the end portions, the results given by the cutting method will be too high, and *vice versa*, if it weighs less, the results will be too low. This point has also been investigated at the Technological Laboratory for standard Indian cottons of two seasons, 1927-28 and 1928-29. The fibre-

* "Fibre-Length Irregularity in Cotton" by Nazir Ahmad and Harirao Navkal, Technological Bulletin, Series B, No. 16.

† "The weight per inch of fibres of different lengths and the numbers of different lengths per seed for each of the standard Indian cottons" by R. L. N. Iyengar and A. James Turner, Indian Central Cotton Committee, Series B, Bulletin No. 7.

weight per inch of the standard Indian cottons of 1929-30 season has also been determined by both methods, and the results of these determinations are given below:—

| Name of cotton | 1929-80 | | |
|-------------------------|---------------------------|---------------------------|--------------------------|
| | $\frac{a}{-7}$ (10 oz) | $\frac{b}{-7}$ (10 oz) | $C = \frac{100(a-b)}{b}$ |
| Dharwar I | 2.09 | 1.90 | 10.0 |
| Jayawant | 2.24 | 1.90 | 17.9 |
| Gadag I | 1.66 | 1.48 | 12.2 |
| Surat 1027 A.L.F. .. | 1.86 | 1.80 | 3.3 |
| Wagad 8 | 2.08 | 1.95 | 6.7 |
| Punjab-American 4F .. | 1.79 | 1.55 | 15.5 |
| Punjab-American 289F .. | 1.47 | 1.42 | 3.5 |
| Mollisoni | 2.98 | 2.72 | 9.6 |
| A.19 | 3.14 | 2.77 | 18.4 |
| K.22 | 2.29 | 2.10 | 9.0 |
| J.N. 1 | 2.87 | 2.29 | 3.5 |
| C.A. 9 | 1.74 | 1.65 | 5.4 |
| Verum 262 (Nagpur) .. | 1.90 | 1.66 | 14.5 |
| Verum 262 (Akola) .. | 1.95 | 1.76 | 10.8 |
| Umri Bani | 1.72 | 1.52 | 13.2 |
| Co. 1 (Cambodia 295) .. | 1.75 | 1.46 | 19.9 |
| Co. 2 (Cambodia 440) .. | 1.72 | 1.86 | 26.5 |
| Nandyal 14 | 1.90 | 1.69 | 12.4 |
| Hagari 1 | 1.92 | 1.75 | 9.7 |
| Hagari 25 | 2.08 | 1.78 | 16.8 |
| Karunganni C7 | 1.96 | 1.81 | 8.8 |
| Mean | | | 11.5 |

a Fibre-weight per inch obtained by weighing 1 cm. lengths.

b Fibre-weight per inch obtained by weighing whole fibres.

It will be seen that in each case the whole fibre method gave a lower value than the cutting method, the percentage difference between the two ranging from 3.3 to 26.5 with a mean value of 11.5. The results of this investigation have necessitated a change in the method of determining the fibre-weight per inch, which is now found by weighing bunches of whole fibres on a quartz micro-balance. Each bunch contains 80-200 fibres depending upon whether the cotton is coarse or fine, the aim being to obtain approximately the same deflection as is produced by a 0.5 mgm. weight. In this way the necessity of calibrating the balance along the entire length of the scale is dispensed with. Altogether some 4,000 fibres are weighed in 28 to 40 bunches in the case of standard cottons and about 1,400 fibres in

8 to 15 bunches in the case of other cottons. Since the total number of fibres as well as their mean fibre-length is known, the fibre weight per inch can be readily calculated. It should be remembered, however, that the values of fibre-weight per inch, as found by the new method of weighing whole fibres, are available only from 1929-30 onwards, the values for the previous seasons being those obtained by the cutting method. In following the seasonal variation in the fibre-weight per inch of cottons for which results are available prior to 1929-30, it should be borne in mind that the new method gives, on the average, some 10 per cent lower results than the old method. The standard deviation for both methods lies between 4 and 9 per cent for most Indian cottons.

The fibre-weight, as found above, will depend to a small extent, upon the temperature and, to a much larger extent, upon the humidity prevailing in the testing room. The variation in temperature inside the fibre-testing room of the Technological Laboratory is so small that no correction is regarded necessary on this account. But as the relative humidity may vary from 30 per cent in the dry weather to 90 per cent during the monsoon, it is necessary to reduce the observed values of fibre-weight to some standard humidity. The standard of humidity adopted at the Technological Laboratory is 70 per cent R.H. Accordingly, the observed values of fibre-weight per inch are reduced to this humidity by using the appropriate correction-factor from the following table, which is based upon the experimental work of Urquhart and Williams.*

Humidity Correction-factors for Fibre-Weight

| Relative humidity | 30 | 40 | 50 | 60 | 70 | 80 |
|-------------------|-------|-------|-------|-------|-------|-------|
| 0 | 1.048 | 1.038 | 1.027 | 1.014 | 1.000 | 0.982 |
| 1 | 1.047 | 1.036 | 1.025 | 1.012 | 0.999 | 0.979 |
| 2 | 1.046 | 1.035 | 1.024 | 1.011 | 0.997 | 0.976 |
| 3 | 1.045 | 1.034 | 1.023 | 1.010 | 0.996 | 0.973 |
| 4 | 1.044 | 1.033 | 1.022 | 1.009 | 0.994 | 0.970 |
| 5 | 1.043 | 1.032 | 1.020 | 1.007 | 0.992 | 0.968 |
| 6 | 1.042 | 1.031 | 1.019 | 1.006 | 0.990 | 0.965 |
| 7 | 1.041 | 1.030 | 1.018 | 1.004 | 0.988 | 0.961 |
| 8 | 1.040 | 1.029 | 1.017 | 1.003 | 0.986 | 0.957 |
| 9 | 1.039 | 1.028 | 1.015 | 1.002 | 0.984 | 0.953 |

For the last few years, fibre-weight and fibre-strength tests are carried out in a room where constant temperature ($85^{\circ} \text{F} \pm 3^{\circ} \text{F}$) and relative humidity ($65 \pm 3\%$) are maintained.

* Journal of the Textile Institute, XVII, 1926 page T 38.

*Stapling Apparatus for determining the mean fibre-length, regularity and fineness of cotton.** Both the Balls Sorter and Baer Sorter methods take a fairly large amount of time. A new apparatus has been designed at the Technological Laboratory, in which the determination of the mean fibre-length and fibre-weight per unit length is made in one series of operations, thus effecting considerable saving of time and labour.

The sliver is matted on a set of combs and the fibres aligned and a small tuft is held between two tweezers and cut into three sections with a special cutter, and these sections are weighed on a torsion balance. From the knowledge of the length of the first two sections and the weight of the first and the third section, the average length can be determined. Thus, if L_3 is the average length of the third section, W_1 and W_3 the weights of the first and the third sections $L_3 = \frac{W_3}{W_1} L_1$. Consequently, L the average length of the tuft is given by $L = L_1 + L_2 + L_3 = L_1 + L_2 + \frac{W_3}{W_1} L_1$. The value of L_1 and L_2 are known from the previous calibration of the instrument.

If fibre-weight is also required, the first section of fibres is held between two glass slides and the fibres are counted under a low power microscope. The middle section is also weighed. Fibre-weight per unit length can be easily calculated. Thus, $W = \frac{W_1 + W_2 + W_3}{NL}$ where N is the number of fibres as given by the counting under the microscope.

The fibre-length distribution of the sample can also be obtained by the help of attachment.†

Air permeameter for the determination of fibre weight per unit length. When air passes through a sample of cotton (under conditions specified below), the resistance it meets during its passage depends on the surface per gram or the fibre weight per unit length. This is the principle on which this instrument operates.

In this instrument, air is allowed to flow through a cotton plug of constant weight and pressed to a constant density. The pressure difference at the two ends of the plug is also maintained constant. The quantity of air passing through the plug of cotton is measured by a suitable device and is indicated by a manometer. The manometer reading is a measure of the fibre-weight per unit length of the sample under test.

* A new method and apparatus for determining the average length and fineness of cotton hairs by Nazir Ahmad and C. Nanjundayya. Tech. Bull., Series B, No. 21.

† A device for determining the proportion by weight of fibres of different lengths in a sample of cotton by Nazir-Ahmad and C. Nanjundayya, Tech. Bull., Series B, No. 23.

Fibre-strength:—Next to mean fibre-length and fibre-weight per inch the property which has perhaps the closest relationship with the spinning quality of a cotton is its fibre-strength. At the Technological Laboratory it is measured by two independent methods viz.: (1) Balls Magazine Hair Tester and (2) Dial Reading Apparatus for fibre-strength. The former is an ingenious device containing a toothed circular plate in which 1 cm. length of individual fibres are fixed with a little sealing wax along the middle of the teeth between the plate and light perforated aluminium eyelets. Some fifty fibres can be thus fixed at a time. The plate is made to rotate slowly in a horizontal plane and each time a tooth comes in front of a suspended hook, the eyelet is caught and gently pulled back. The hook terminates, at the other end, in a fine pointed wire, which faces a vertical plate supporting a circular sheet of tissue paper. A moderately high voltage is established between the point and the vertical plate by means of a small induction coil and the spark produced leaves a trace on the tissue paper. As each fibre is pulled, the tracing point moves in an arc; when the fibre snaps, it springs back to its initial position, the length of the arc traced indicates the strength of the fibre. The mechanism is automatic; each time the horizontal plate advances by one tooth, the circular plate is rotated by a small amount exposing fresh surface of the paper for the new trace, the receding hook, after the fibre is ruptured, comes forward again to grapple the eyelet holding the next fibre. This automatic mechanism helps to reduce the time taken by the test, the instrument can be calibrated once for all and the breaking strength of fibres is read off from the tissue paper by means of a special scale.

The O'Neill Hair Tester is much simpler in design and can be constructed readily at a nominal expense, but requires more time than the Magazine Hair Tester to test an equal number of fibres. The fibre—again 1 cm. length—is held between two perforated light eyelets. One eyelet is passed through a book attached to a lever, the other through another hook at the end of a float in calcium chloride solution. The concentration of the solution, which is kept in a cylinder with an outlet and a stopcock near the base, is so adjusted from day to day that its vapour pressure is equal to that of the moisture in the air. In this manner the fibres are always broken in an atmosphere of known humidity. The solution is slowly let out in a beaker until the crinkles in the fibre are removed as shown by the tilting of the lever. The stopcock is closed, the beaker is exchanged with a measuring jar, and the solution is again run out slowly. The float sinks, pulling the fibre until the latter snaps. The volume of the solution collected between the tilting of the lever and the rupture of the fibre corresponds to

its breaking strength. The apparatus can be calibrated once for all by attaching the float to one pan of a balance and noting the weights required to counterpoise the pull produced by letting out known volumes of the solution.

Dial Reading Apparatus for fibre-strength.—There are several defects in the O'Neill apparatus as modified by Mann & Pierce. The speed of working is low. Secondly, after each reading, time is spent in pouring the solution back into the cylinder. A new apparatus was devised in the Laboratory which is free from these defects. It consists essentially of three parts, (1) a 'U' tube in which two floats are suspended in a solution of appropriate density (2) a device by which the fibre is suspended which makes an electric contact when a fibre is straightened out and (3) a mechanism for lifting one of the floats at a uniform rate and automatically recording the tension applied to the fibre. The fibre is suspended from a hook fixed to the device mentioned above, when making the tests, in which an electric circuit is completed as soon as the fibre is straightened out. The other end of the fibre is attached to a float in one arm of the 'U' tube, while the tension on the fibre is applied by raising the second float, which acts as a counterpoise, by winding a string on a pulley driven by a small electric motor. The same gear arrangement which lifts the float also records the tension, applied to the fibre, on two calibrated dials. The mechanism for applying and recording the tension is also connected with the electric circuit made by the device used for suspending the fibres, and works only so long as the circuit is complete. When the fibre breaks, the electric circuit is interrupted, and both the pointer and the counterpoise come automatically to rest. The instrument can be used either for recording the strength of individual fibres or the aggregate strength of a given number of fibres. In the second case, it acts as an integrating machine, and adds up automatically the strength of several fibres.

It is the practice at the Technological Laboratory to test 300 fibres with the Magazine Hair Tester and an equal number with the O'Neill Tester in the case of the standard Indian cottons. The standard deviation for most Indian cottons is found to lie between 40 and 60 per cent.

The strength of a cotton fibre is also affected by the humidity prevailing in the testing room. As in the case of the fibre-weight, the observed values are corrected to 70 per cent. relative humidity by using the appropriate correction-factors from the following table, which is based upon results obtained at the Technological Laboratory:—

Humidity Correction-factors for Fibre Strength

| Relative humidity | 40 | 50 | 60 | 70 |
|-------------------|-------|-------|-------|-------|
| 0 | 1.176 | 1.111 | 1.053 | 1.000 |
| 1 | 1.170 | 1.105 | 1.047 | 0.995 |
| 2 | 1.163 | 1.099 | 1.042 | 0.990 |
| 3 | 1.156 | 1.093 | 1.036 | 0.985 |
| 4 | 1.149 | 1.087 | 1.031 | 0.980 |
| 5 | 1.143 | 1.081 | 1.026 | 0.976 |
| 6 | 1.136 | 1.075 | 1.020 | 0.976 |
| 7 | 1.130 | 1.070 | 1.015 | 0.976 |
| 8 | 1.124 | 1.064 | 1.010 | 0.976 |
| 9 | 1.117 | 1.058 | 1.005 | 0.976 |

The correction-factor for relative humidities above 75 per cent. is taken the same as for 75 per cent. R.H. and the determination of fibre-strength is suspended when the relative humidity exceeds 85 per cent.*

Bundle strength. A small tuft of fibres is passed through a series of combs so that the stray fibres and impurities are removed. Its ends are fixed between two pairs of paper strips by means of some good adhesive. The test-length is kept exactly 1 cm. The number of fibres in the bundle is obtained by counting them by using a low power microscope. Care is taken to see that this number lies between 80 and 120. The paper strips are inserted in the jaws of a Schopper Testing machine and the bundle is broken in the usual manner. The fibre-strength that is recorded here is divided by the number of fibres in the bundle to obtain the strength per fibre. It may be mentioned that the strength obtained this way is usually between 40% and 60% of the fibre-strength obtained by methods which involve testing of only one fibre at a time.

Pressley Strength Tester. In the Pressley's Strength Tester, a cleaned flat bundle (or ribbon) is fixed between two clamps. Sufficient pressure to prevent slippage is applied by turning the screws attached to these clamps. The protruding fibres are removed by a sharp edge so that the bundle has a definite length of 0.464". The two clamps are held together and inserted in the two jaws of the machine and the arrangement is such that the ribbon is broken more or less along the central line. The lower jaw is fixed and the tension on the upper jaw is gradually increased by the sliding of a heavy weight along a beam. This weight stops as soon as the ribbon is broken; and the position of the weight on the beam which is calibrated gives the strength in pounds to break the ribbon. The strength so obtained is divided

* See the foot-note on page 14.

by the weight of the ribbon is milligrams to get the strength index which is expressed as pounds per mgm.

The strength index is comparable to the intrinsic strength; and it may be stated that, generally, the greater the intrinsic strength, the higher the strength index.

By making certain assumptions it has been found that if S is the tensile strength expressed in thousand pounds per square inch and p is the Pressley strength index,

$$S=10.8 p.$$

Thus, a strength index of 6 lbs per mgm. will be equal approximately to a tensile strength of about $65 \times 1,000 \frac{\text{lb}}{\text{in}^2}$.

Fibre-strength per unit fibre-weight per inch:—The strength of a cotton fibre will depend partly upon the intrinsic strength of the material (mostly cellulose) constituting it, partly upon the number and intensity of 'weak spots' on its surface and partly upon the amount of cellulose present per unit volume. Mainly owing to the last-mentioned factor, the coarser cottons generally give higher values for fibre strength than the finer ones, though their intrinsic strength may be less. In order, therefore, to compare the intrinsic strength of two cottons, it would be necessary to eliminate, so far as possible, the effect of different amounts of cotton associated with a unit volume. This may be done by dividing the observed fibre-strength by the fibre-weight per inch which is regarded as proportional to mean cross-sectional area of the fibre, assuming that the density of cotton is the same for all varieties of cottons. The value of fibre-strength per unit fibre-weight per inch thus obtained is proportional to the intrinsic strength of the cotton and is found to exhibit a higher correlation with its spinning quality than fibre-strength.

Maturity:—A thin tuft of cotton fibres is drawn by means of tweezers from a sliver held in Baer Sorter combs. Its thickness is regulated such that about 100 fibres are spread in a parallel array over a width of an inch; and thus each fibre can be examined separately under the microscope. The tweezer end of the tuft is clamped first on the narrower strip of the fibre mounting device called the maturity slide and are spread across the glass slide on which the overlapping fibres are again separated with the help of a mounted needle. The free ends of the fibres are then held in the clamp on the second strip of the maturity slide, which is adjustable to stretch the fibres.

The fibres are then irrigated with 18% caustic soda solution and covered with a suitable strip of cover glass. The slide which is now ready for ex-

amination is placed on the mechanical stage of the microscope and examined. Beginning at one edge of the tuft all fibres are classed into three categories, namely, mature; half-mature and immature: The mature fibres look straight and fairly solid, the half-mature fibres have a lumen (canal) wider than the thickness of one side wall of the fibre and immature fibres have extremely thin walls.

Such examination is carried out on 4-8 slides and the classified fibres are added for each of the 3 groups. Percentages for the total number of fibres examined are then struck and results are presented as percentages of mature, half-mature and immature fibres in a sample.

Maturity Coefficient for Indian Cottons:—Fibre weight per unit length is the most easily determinable character for estimating the fineness of fibres in a sample of cotton. However, its efficiency as a criterion of fineness is vitiated by changes in the fibre maturity of the sample. Allowance for these changes could be made by using a factor called the Maturity Coefficient, which is a unitary expression signifying the multiple character of fibre maturity usually represented by the percentages of mature, half-mature and immature fibres. In order to calculate the maturity coefficient for Indian cottons, constants were derived by undertaking an elaborate investigation employing a new technique. For each fibre swollen in 18 per cent. caustic soda solution the maturity class, the fibre diameter, D , and the lumen diameter, d , were determined. From the mean value of the expression $\frac{D^2-d^2}{D^3}$ for the fibres falling within each maturity class and from the value of mean fibre weight per unit length of the sample, the value of the constant for each maturity class was derived. By examining 22 cottons covering a wide range of fibre maturity it was found that the maturity coefficient, M_c is given by

$$M_c = \frac{M + 0.6H + 0.4 I}{100}$$

where M , H and I represent the percentages of mature, half-mature and immature fibres respectively in the sample. The values of these constants were directly verified by actually weighing cm. long raw cotton fibres separated out into the three maturity classes by using polarised light technique and finding the ratios of the weights of half-mature and immature fibres to the weight of mature fibres:

*Swollen diameter** :—The sliver is placed on Baer Sorter combs and a small bunch of fibres is withdrawn from it by means of a tweezer, cleaned of stray fibres and placed on a maturity slide, and the fibres are spread and carefully separated from one another with a blunt needle. The fibres are

* Swollen wall-thickness is also measured in some special cases.

straightened and then irrigated with 18% caustic soda solution by placing a few drops on a cover slip and slowly dropping it from one edge on the bunch of fibres, thus avoiding air bubbles. In about ten minutes the slide is ready for examination. Swollen diameter measurements are made on a micrometer scale in the eyepiece of a microscope and one reading near the middle of the fibre is taken and about 75 fibres are examined in this manner per slide. At least 2 slides should be examined making a total of about 150 fibres for each cotton. The measurement is carried out only on the mature and half-mature fibres.

The fibre-properties described above appear to have the most intimate relationship with the spinning quality of a cotton. They may, therefore, be regarded as the major fibre-properties. Besides these, the spinning quality of a cotton must depend, to some extent at least, upon such other physical and chemical properties, such as the number of natural twists per inch, the ribbon-width, the rigidity, the extensibility, the wax content, the clinging power, etc., of its fibre. Among these the number of natural twists per inch, the ribbon-width and the fibre-rigidity have been measured in the past for all the standard Indian cottons of each season. It has been found that their contribution to the spinning quality of a cotton is extremely small as compared with that of the major fibre-properties, and their determination, as part of the routine tests, has therefore been discontinued from the 1932-33 season. However, since the values of these minor fibre-properties obtained for the previous seasons have been included in the issues of the Technological Reports on standard Indian cottons and since it may become necessary at any time to determine one or more of these properties in special cases, the methods adopted for their determination are briefly described below:—

Fibre-rigidity:—As the rigidity of cotton fibre is extremely susceptible to changes in humidity, the fibres are tested inside a closed box in which the atmosphere is maintained at a constant relative humidity of 70 per cent. This is achieved by placing inside the box calcium chloride solution of such a strength that 100 parts of it contain 27 parts by weight of anhydrous calcium chloride. The fibres are suspended from a horizontal beam and each fibre supports at its mid-point a small aluminium rod which is half an inch long. This small rod is made to oscillate in a horizontal plane and the time of oscillation, T , is noted by a stop-watch. Knowing its moment of inertia, I , the rigidity n of the fibre is calculated from the formula :

$$n = \frac{8 \pi^3 I l}{T^2} \quad \text{where } l \text{ is the length of the fibre.}$$

The value for each sample is the mean of 150 tests and the standard deviation lies between 60 and 120 per cent. for most Indian cottons.

Ribbon-width.—The ribbon-width is read directly with a microscope with a micrometer scale in the eyepiece. The width of the broadest part of the fibre between two successive convolutions is measured. As ten observations are made on each fibre and 150 fibres are examined in all, the value of the ribbon-width for each sample is the mean of 1,500 observations. The standard deviation, as estimated for a few Indian cottons, appears to lie between 10 and 14 per cent. Upto 1925-26, only 50 fibres of each cotton were examined for ribbon-width but as this number was regarded insufficient, it was subsequently raised to 150.

Convolution or natural twist.—The number of convolutions per inch is obtained from measurements made with a microscope on 150 fibres of each cotton. The standard deviation for this property lies between 30 and 45 per cent. for most Indian cottons. Upto 1925-26, only 50 fibres were examined for convolutions but subsequently the number was raised to 150 fibres.

Photoelectric Diameter Tester.—The method of determination of fibre diameter mentioned above involves several individual microscopical measurements. Besides, the value of the diameter at only a single point on the fibre is measured. A new method was evolved at the Laboratory whereby the average value of the diameter of a large number of fibres over a wide region along the length of the fibre is obtained. In the apparatus designed for this purpose a beam of light of uniform intensity emerging out of a rectangular slit falls on a photoelectric cell producing a photo-electric current I_1 which is accurately measured. A parallel bunch of mercerised fibres, dyed black and with as little over-lapping as possible, is interposed in the path of the beam perpendicular to the length of the slit. The current gets reduced to the value I_2 the deficit being proportional to the area of light cut off, which depends upon n , the number of fibres and d , the average diameter of fibres. If the intensity of illumination is the same in both cases

it can be easily shown that
$$d = \frac{l}{n} \frac{I_1 - I_2}{I_1}$$

where l is the length of the slit. The assumptions made here are (1) that the photoelectric current is proportional to the area of illumination of the photoelectric cell, (2) that the fibres are opaque to light and (3) that there is no appreciable overlapping. The first two conditions were experimentally verified to hold true. The third condition was satisfied by the use of a new slide that was designed for this purpose. By its use not only is the overlapping reduced to a minimum but the mounting of fibres is also made very simple and quick. The overlapping of a few fibres that still remain over is

removed by observing the portions through a pair of binocular glasses and teasing the fibres out with a needle and a pair of fine forceps.

It may be mentioned that the diameter obtained in this case is on the dry mercerised fibre and this value is approximately 0.6 times swollen diameter described on page 20.

The method has been found to be accurate and quick so that it could be used for routine testing of a large number of samples for fineness of diameter. The instrument could also be used for the determination of the projected diameter of other fibres, hairs, filaments, fine wires etc.

It is proposed to improve the sensitivity of the instrument by the addition of a matched photoelectric cell and to make the equipment portable by amplifying the photoelectric current.

Clinging Power:—The methods used for the determination of clinging power consist of pulling one fibre or a group of fibres of a cotton between pads made from the parallelised fibres of the same cotton subjected to a known pressure. The pads are 3½" wide. The force is applied and measured by an arrangement used in the O'Neill Fibre Tester. Three methods are being followed in this Laboratory. They differ only in the number of fibres taken and in the nature of the application of the pressure. Two of these are described in detail in the Bulletins Series B, No. 8 and Series B, No. 25. The third one is being tried here and a full description of it will be published later, if the new method is proved to be more advantageous than the other two.

Size of a satisfactory sample for fibre-tests:—In view of the fact that fibre tests are usually made on a mere handful of cotton, it is necessary to know the minimum number of tests which will give results representative of a bulk sample. "What" we may ask ourselves, "is the minimum number of tests which will yield a reliable value for a given fibre-property?" The answer to this question is definitely available as a result of an investigation carried out at the Technological Laboratory. The full details of this investigation will be found in a series of Technological Bulletins entitled "Studies in the Sampling of Cotton for the Determination of fibre-properties." The following table based on the tests carried out on Surat 1027 A.L.F., which is taken from Part III of this series,* shows the degree of reliability which can be placed in the mean value of a given number of tests for any one of the fibre properties.

Range (% of the mean) for which the odds are as shown that the mean of a random sample will lie therein.

* "The size and reliability of a satisfactory sample" by Ram Saran Koshal and A. James Turner, Indian Central Cotton Committee Technological Laboratory, Series B., Bulletin No. 10.

| Fibre property | Odds. | Number of fibres tested | | | | |
|----------------|-------|-------------------------|-----|-----|-----|-----|
| | | 200 | 300 | 400 | 500 | 600 |
| Fibre-length | 20.1 | 18 | 16 | 13 | 11 | 9 |
| Fibre-width | 20.1 | 4 | 2.7 | 2 | .. | .. |
| Convolutions | 20.1 | 30 | 24 | 20 | 19 | 18 |
| Fibre-strength | 20.1 | 40 | 23 | 17 | 15 | 13 |
| Fibre-rigidity | 5.1 | .. | 60 | 55 | 48 | 44 |

It will be seen from this table that in the case of ribbon width the odds are 20 : 1 that the mean of observations on 200 fibres, chosen at random, will lie within 2 per cent. on either side of the mean value for a large sample; while for convolutions the range of deviation is 15 per cent. on either side of the mean for the same odds and the same number of observations.

More recently the minimum number of tests for fibre-maturity and swollen diameter have also been calculated. For fibre-maturity † it was found that for $P=.05$, the extreme variation due to random sampling between two samples of 500 fibres would be about 9%. In the case of swollen diameter ‡ the extreme variation for $P=.05$ which may be expected between two cottons due to random causes is about 5% for the mean values based on 150 tests and about 4% for those based on 200 tests.

† Fibre-Maturity in relation to Fibre and Yarn characteristics of Indian Cottons—by A. N. Gulati and Nazir Ahmad. Tech. Bulletin, Series B., No. 20.

‡ The Determination of the Swollen Diameter of Cotton Fibres—Effect of size of sample on the significance and reliability of the results.—by R. S. Koshal and Nazir Ahmad. Tech. Bull. Series B, No. 27.

VI. SPINNING TESTS

The Technological Laboratory is equipped with all the necessary machinery for cleaning, processing and spinning of cotton, including five ring frames, one of them a weft-ring frame and a comber set. The primary object of the spinning test being to ascertain the performance of a cotton, when spun in bulk *under mill conditions*, from tests on a small sample, the usual mill practice is closely followed in the handling and processing of the samples submitted for tests. Nevertheless, owing to the special nature of the work, the spinning technique employed at the Laboratory differs in some respects from the general mill practice. These differences mainly arise on account of the fact that whereas in a mill a large quantity of a mixing is available for a considerable length of time, at the Technological Laboratory, samples of different cottons follow each other with great rapidity. Consequently, in a mill the necessity of making frequent changes in the speeds and settings of various machines does not often arise. At the Technological Laboratory where samples of different cottons are tested, it may be regarded advantageous to make the necessary alterations in speeds and settings for each sample, but such a practice would result in the loss of a great deal of valuable time. It was, therefore, necessary at the commencement of the work to adopt tentatively certain standards which should be appropriate for a fairly wide range of counts, and in order to preserve a uniform basis of comparison, to adhere to them except when a cotton falling outside the usual range is tested or when the results of an investigation definitely point to the desirability of making a change. As the work of the Laboratory progressed, investigations were undertaken from time to time in order to test the validity of the technique employed at the Laboratory which in almost all cases was justified by the results of these investigations. In this connection it should be borne in mind that the value of the spinning test as a means of comparing the quality of two cottons is unaffected by any minor differences in the Laboratory technique and the average mill practice. The importance of this observation lies in the fact that a great deal of the work of the Laboratory centres round the comparison of the quality of various types either as between themselves or from one season to another, and for this purpose all that is necessary is that the tests should be carried out under as nearly the same conditions as possible.

(a) *Spinning Technique*—The treatment given to a cotton in the blow-room should, strictly speaking, take into account both the quality of its staple and amount of foreign matter present in it so as effectively to remove the latter without injuring the former, and should, therefore, vary suitably with different cottons. However, in the case of most samples tested at the Laboratory, the impurities are found to lie within a fairly narrow range and

hence a normal treatment has been decided upon which is modified only in exceptional cases. This normal treatment consists in passing the cotton through Hopper-bale-breaker; Horizontal cleaner; Crighton opener, Dust trunks; Cage exhaust and Hopper feeder. This machine deposits the material on the feed lattice of the scutcher. At this point the first difficulty in the handling of a small sample is encountered. Since a uniform supply of the cotton cannot be maintained in the hopper feeder, it gradually thins out as it is deposited on the lattice of the scutcher. In order to avoid the resulting irregularities in the scutcher lap, the material is carefully evened out and in the case of samples weighing at least 10 lbs., four equal laps are prepared. These are unfolded one above the other on the scutcher lattice, passed through the scutcher, and another four equal laps are prepared. These are again unrolled by hand one above the other on the scutcher lattice, passed through scutcher and, finally, one lap is made for the next (carding) process. The three passages through the scutcher correspond to the opener, intermediate and finisher scutcher in a mill, and the repeated doubling of the laps helps greatly in reducing the irregularities present in them. In the case of samples weighing 5 lbs. or less (upto 2 lbs.) it has not been found possible to prepare four scutcher laps; consequently a single lap is made which is divided into four equal lengths on the lattice itself. This process is repeated twice, giving in all three passages through the scutcher, and, finally, a single lap is prepared for the next (carding) process. It has been found that both the card-room loss and the yarn strength results are higher for samples weighing less than 10 lbs. A special spinning technique to deal satisfactorily with samples weighing 2 lbs. has also been evolved. Spinning technique to deal specially with micro-samples weighing about 60 grams to 150 grams or 2 to 5 oz. is being tried with a view to test samples obtained in the early stages of breeding work.

Since, in spite of the precautions taken, the two ends of the scutcher lap are likely to be somewhat more irregular than the middle portion, the leading and trailing ends of the card sliver prepared from the lap are rejected and the test bobbins on the slubber, intermediate and roving frames are made only from the middle portion, which is fairly regular and representative of a bulk sample.

(b) *Wastes*.—The blow-room loss percentage is reckoned on the initial weight of cotton. The card loss is calculated on the net weight of the finished lap obtained in the blow-room. The invisible card loss is not found out. The card loss with a small sample is naturally higher than with a bulk sample. Losses after the carding point are not taken into account because they do not give a fair comparison with mill losses at these points. They are likely to be misleading in some cases due to the fact that in a mill the opera-

tive minds a large number of spindles whereas in the Laboratory he has to attend to only 12 spindles.

(c) *Spinning processes*:—The middle portion of the card sliver is ordinarily given two instead of three heads of drawing, the latter practice prevailing in most mills in India. In order to test the validity of giving only two heads of drawings, tests were made on eight standard Indian cottons and two American cottons, with one, two and three heads of drawing respectively. The detailed results of these tests have been described in a *Technological Bulletin*.^{*} They showed that whereas the yarns obtained with one head of drawing were definitely weaker than those with two or three heads of drawing, there was, on the whole, very little difference in strength between the yarns spun with two and three heads of drawing respectively. Consequently, the practice of using two heads of drawing has been adhered to in majority of cases. However, when samples, spinnable into 20s and counts above 20s, are being tested on payment of fees, they are given three heads of drawing to conform to the mill practice and also to obtain more regular yarns from such samples.

Ordinarily, 24 bobbins are prepared on the slubber and the intermediate and 12 on the roving frame. Eleven of the roving bobbins are used in spinning yarn from single roving for yarn tests, while the twelfth roving bobbin in the case of all except the agricultural samples and the eleventh ring bobbin are preserved for a possible reference in the future. The approximate hanks most commonly employed in the roving are as follows:—

Approximate Roving Hanks

| Counts | 6 | 8 | 10 | 12 | 14 | 16 | 20 | 24 | 30 | 40 |
|-------------|-----|-----|-----|------|------|-----|------|-----|------|------|
| Roving Hank | 1.8 | 1.7 | 1.9 | 2.37 | 2.74 | 3.0 | 3.45 | 4.0 | 4.50 | 4.90 |

As two or more counts are often spun from the same hank roving by merely changing the draft in the ring frame it may be objected that unbalanced drafts are used in the case of other than the medium counts and that this unorthodox practice may vitiate the value of the results obtained for these counts. In order to test whether or not this is the case tests were performed on eight standard Indian cottons using balanced and unbalanced drafts. The results of these tests which are described in detail in a *Technological Bulletin* † show that no appreciable difference in the quality of yarn spun from pure cottons is caused by using unbalanced drafts within the range employed at the Laboratory. The advantage of such an arrangement is obvious; it results in a considerable saving of time as it avoids frequent

^{*} *Technological Bulletin*, Series A, No. 11, "The effect of using either one head or two heads of Drawing instead of three heads of Drawing in the spinning preparation for spinning tests" by A. James Turner.

† *Technological Bulletin*, Series A, No. 8 "The effect of using unbalanced drafts instead of balanced drafts in the spinning preparation for spinning tests" by A. James Turner.

changes in the preparatory machines and the testing of wrappings for each individual count.

The Technological Laboratory is at present equipped with five ring frames, each containing 48 spindles. Ring Frame No. 1 is fitted with the ordinary three roller system on both sides, while ring frames 2, 3 and 4 are fitted with a high draft system on one side and the ordinary system on the other. Ring frames 1 and 2 have band drive arrangement and are similar in construction; ring frames 3 and 4 are each of a different make, but both have tape drive arrangement; ring frame No. 5 is a weft frame with four roller high draft system on both sides. The spindles are driven with tape. The spindles on the five frames are serially numbered, and in order to reduce the intra-spindle effects to a minimum, test bobbins are always spun on the same 22 spindles of each ring frame. All the five ring frames are driven by individual motors with arrangement to change their speeds. Details of drafts, twist, front roller speed, spindle speed, etc., in the ring frame are invariably given in the tables of spinning test results accompanying the reports issued from the Laboratory, from which other data relevant to any particular count may easily be calculated. For instance, although the figures for production for each count are not included in the tables referred to above, these may readily be arrived at by the use of the following formula:—

$$\begin{aligned} \text{Theoretical production} & & \pi \times D \times R \times 60 \times 10 \times 16 \\ \text{per spindle per 10 hrs.} & = & \frac{ }{C \times 840 \times 12 \times 8} \text{oz.} \\ & = & \frac{\pi \times D \times R}{C} \times \frac{20}{63} \text{oz.} \end{aligned}$$

where D is the diameter of the front roller, R is its speed (r.p.m.) and C the count-number of the yarn spun. The actual production will, of course, be less on account of yarn-breakages, idle bands, the milling effect and time lost in doffings etc.

Only one more point needs mention. The rings employed in the spinning of all counts upto 50s have the same diameter, viz., 1-5/8" whereas in most mills the practice prevails of using rings with diameters varying from 2" for 6s counts to 1 1/2" for 40s. It may be thought that this practice, which is adopted for the sake of saving time, is rather more favourable to low class cottons and less favourable to the better class types, but results of comparative tests obtained elsewhere* show that no appreciable difference in the count-strength product of 28s warp spun with 4.75 twist multiplier is caused by using rings varying in diameter from 1 1/2—2 1/4 inches.

* "Tests to determine the effects of humidity, ring size and spindle speed on the strength of yarn" by J. J. W. Cooper, Miscellaneous Scientific Papers of F. P. Sheldon & Son, 1926. Providence, R. I., U. S. A.

(d) *Details of Machinery*:—Details of machinery employed in spinning tests are as follows:—

Blow-Room Machinery.

1. Hopper-bale-breaker connected to and driven from 2.
2. Horizontal cleaner—cylinder speed = 550 r.p.m.
3. Crighton opener : Beater speed 750 r.p.m. (Range 500 to 1,500).
4. Dust trunks—5 sections.
5. Cage exhaust : Fan speed 950 r.p.m.
6. Hopper feeder—driven from 7.
7. Scutcher : 3 bladed beater : beater speed—900 r.p.m. beater setting to feed roller—3|8". Beater shaft directly coupled with the motor. (Range of beater speed 675 to 970).

Card room Machinery

Revolving Flat Card—Cylinder speed = 160 r.p.m. Doffer speed = 9 r.p.m. on No. 1 card, and 12.5 r.p.m. on No. 2 card. Flat speed = $2\frac{1}{8}$ " per minute (Note. No. 1 card is used for cottons spinnable into 34 or counts above 34s. No. 2 is used for all other cottons).

Drawing Frame

Front roller speed = 370 r.p.m. Front roller diameter = $1\frac{3}{8}$ " also spares of $1\frac{1}{4}$ " and $1\frac{1}{8}$ ". Draft = about 6.

Slubbing Frame

In two sections of 16 spindles each

Section I : Front roller dia. = $1\frac{1}{8}$ "; Front roller speed = 216 r.p.m.

Section II : Front roller dia = 1"; Front roller speed = 244 r.p.m.

Spindle speed = 675 r.p.m.

Intermediate Frame

In two sections: one of 24 and the other of 20 spindles.

Section I : Front roller dia = $1\frac{1}{8}$ "; Front roller speed = 164 r.p.m.

Section II : Front roller dia = $1\frac{5}{8}$ "; Front roller speed = 196 r.p.m.

Spindle speed = 780 r.p.m.

Roving Frame

In two sections: one of 32 spindles and the other of 24 spindles.

Section I : Front roller dia. = 1"; Front roller speed = 145 r.p.m.

Section II : Front roller dia. = 7|8"; Front roller speed = 176 r.p.m.

Spindle speed = 1150 r.p.m.

The second sections of the above speed frames are used for cottons spinnable upto 20s or coarser counts; the first sections being used for other cottons. It is contemplated to convert the second section into Casablanca high draft system.

Jack Roving

56 spindles: Front roller dia. = 1". Front roller speed = 158.
Spindle speed = 1280 r.p.m.

Ring Frames

No. 1 to No. 4. Twist ring frames with 48 spindles each. Lift $5\frac{1}{2}$ "; Front roller dia. of No. 1 to No. 3 = $7\frac{1}{8}$ ". Dia. of rings upto 50s counts = $1-5\frac{1}{8}$ ", for 60s and above = $1\frac{1}{4}$ ".

Traveller Counts

9 for 6; 77 for 8; 5 for 10s; 3 for 12s; 1 for 14s; 1|0 for 16s; 3|0 for 20s; 4|0 for 24s; 7|0 for 30s; 9|0 for 34s and 12|0 for 40s.

Spindle Speeds

6s—6000; 8s—6800; 10s—7800; 12s—8400; 14s—8900; 16s—9400; 20s and above—9700 on No. 1 and No. 2 frames and 11000 on No. 3 frame.

Ring Frame No. 1

Three roller drafting system on both sides; Band driven spindles.

Ring Frame No. 2

One side with three roller drafting system; the other side with Casablanca High Draft system; Band driven spindles.

Ring Frame No. 3

One side with three roller drafting system, the second side can be fitted with four roller High Draft System. Tape drive for spindles. Also spares for single Apron high draft system.

Ring Frame No. 4

One side with three roller drafting system, the second with four roller High Draft System. The front roller dia. = $1\frac{3}{8}$ " Tape driven spindles.

Ring Frame No. 5

Wet ring frame. 4 Roller High draft system on both sides. Tape driven spindles. The angle of inclination of roller stands on one side can be varied from 25° to 35° . Ring dia. = $1\frac{1}{4}$ " spare sets of $1\frac{1}{8}$ ", $1\frac{1}{2}$ " and $1-3\frac{1}{8}$ " dia. rings.

Comber Set

It consists of :—

Sliver lap machine

Ribbon lap machine and

New Model Nasmith Comber with two heads.

VII. YARN TESTS

For purposes of routine tests, all the samples received at the Laboratory are spun on Ring frame No. 1. Even so, as there may be some variation from spindle to spindle, all the spindles on the four ring frames have been numbered serially and yarn tests are made on bobbins spun upon spindle Nos. 1-10 for one lot and Nos. 73-82 for the other. These twenty spindles belong to ring frame No. 1. Since the same spindles are used to provide the test bobbins for every sample received for routine tests and each test bobbin is numbered to show the spindle on which it has been spun, it is possible to study the variation from spindle to spindle and also to check if the spindle is properly working or not from the day-to-day data of tests obtained for each bobbin. In this manner, possible variations in the quality of yarn due to 'spindle effect' are reduced to a minimum. As the standard Indian cottons are spun in duplicate lots while others are spun in single lots, 20 bobbins are available for tests on each count in the case of the former and 10 in the case of the latter.

The details of yarn tests and the manner in which they are carried out are described below :—

Lea tests:—Ordinarily, 5 leas are reeled from each bobbin and are broken on a Goodbrand Lea Tester of suitable capacity. These machines are electrically driven with a rate of traverse of its lower grip at 12 inches per minute and can register a maximum load of 150 lbs. 200 lbs. or 250 lbs. For the coarse counts, only 2 or 3 leas are broken so that for each lot the value obtained is the mean of 50 tests in the case of medium and fine counts and 20 or 30 tests in the case of coarse counts.

Ballistic tests:—The results of these tests have been given in the publications of the Laboratory. The test itself consists of measuring the work done in breaking half a lea (or quarter of a lea) by means of a heavy pendulum which is supported on steel knife-edges or ball bearings and swings in a wide arc against a graduated scale. This principle is embodied in the Goodbrand's Ballistic Testing Machine which is used in these tests. As the maximum reading on the machine, 150 inch-pounds, is often exceeded by the work of rupture of a full lea, half leas are broken in the case of fine and medium counts and quarter leas in the case of coarse counts. In view of the fact that both ends of the strands in the half or quarter lea are knotted to prevent slippage, the threads break almost simultaneously and the work of rupture is directly proportional to the number of threads in the half or quarter lea. The observed value is multiplied by two or four in order to obtain the value for the full lea, which for each count, fine or coarse, is the mean of 50 tests.

Lea and Ballistic tests are carried out on alternate leas and half-leas (quarter leas in the case of the coarse counts) from each bobbin. Where the test is commenced with a lea test, the half or quarter lea for the ballistic test is kept aside and the ballistic tests are made immediately after the lea tests. Where the test is commenced with the ballistic test, the half lea or quarter lea for this test is kept aside and broken after the lea test. The material or yarn in the bobbin is not entirely free from variation in strength and count at different portions in it and while the average may not differ much from the top, centre and bottom portion of the bobbin yet when it is found necessary to correlate certain properties with different types of tests, e.g. single thread tests, lea tests and ballistic tests, the correlation could be better done when the different types of tests on the same bobbin are done from the top, centre and bottom than when a particular lea or single thread or ballistic test is done from top, centre and bottom respectively of a bobbin. In order therefore to obtain a good average the following method of testing is adopted at the Technological Laboratory when all the three types of tests (single thread, lea and ballistic tests) are carried out on one and the same bobbin.

Single thread tests:—These tests are made on 20 or 10 successive lengths of yarn, each 12 inches long. The 200 or 100 tests are divided into 2 groups of 100 or 50 tests each (10 or 5 from each bobbin). The first 100 or 50 tests are made before the lea and the ballistic tests while the second 100 or 50 tests are made after the lea and the ballistic tests. The values for each count is, therefore, the mean of 200 or 100 tests. In taking consecutive lengths, small clips are used to ensure that partial untwisting of the yarn does not take place. In addition to strength, these tests indicate the extensibility of yarn and, therefore, serve not only as a check upon the lea test results, but also as a means for providing information with respect to a property of yarn which is very important in the weaving operations. The machine employed, Goodbrand's Single Thread Tester, can register a maximum load of 64 oz., and its rate of traverse of the lower grip is adjusted to equal 12 inches per minute, *viz.*, the same as in the case of the lea tester. Single thread tests are also carried out on other machines such as the Moscrop single thread tester, the Schopper tester or the Scotts inclined plane tester whenever necessary.

The relative merits of the three above-mentioned methods of determining yarn-strength and the extent to which their results show a general correspondence have been discussed in a Technological Bulletin.* It may be remarked here that the lea test, though widely used in practice, is open to a number of serious objections. In the first place, the manner of testing

* "A study of comparative results for lea, single thread and ballistic tests on yarns from standard Indian cottons"—by A. James Turner and V. Venkataraman, Indian Central Cotton Committee, Technological Bulletin, Series B, No. 12.

yarn for lea strength does not correspond to any of the subsequent operations of winding, warping, beaming, etc., in which yarn is never used in the form of a lea or a hank, the only noteworthy exceptions being hank sizing, hank bleaching, hank mercerising and hank dyeing. Secondly, it gives no indication whatever of the extensibility and elastic properties of a yarn, which are highly important in the weaving operations. Thirdly, the rupture of a single thread at a weak place affects the result for the whole lea, which is contrary to what we have in actual practice in warping, beaming, weaving, etc., where yarns are individually subjected to tension and the rupture of one thread leaves the others unaffected. These objections are to some extent absent in the single thread tests, but here unfortunately the sampling error is large on account of the very short length of yarn tested. This will be seen from the following illustration. The total length of yarn on a bobbin containing say, $1\frac{1}{2}$ oz. of 20's yarn is 1,575 yards. Of this, 600 yards are reeled for 5 lea tests, while only $6\frac{2}{3}$ yards are required for 20 single thread tests. The ballistic test does certainly involve a much smaller sampling error than the single thread test and has the additional advantage of taking into account the elastic properties of a yarn, but as the test stands at present, no distinction is made between the extension within the elastic limit, which is all-important, and the extension beyond it, which is relatively unimportant. On the whole, therefore, it may be said that in the present state of our knowledge all the three tests are useful inasmuch as the results of one supplement and reinforce those of the other.

It has been stated above that the results of the single thread test serve as check upon those of the lea test. This point has been investigated at the Technological Laboratory, using the data obtained from tests on 144 carded and combed yarns spun from 16 standard Indian cottons into counts ranging from 6's to 80's.* It is found that if we define the 'lea ratio' of a yarn

as $\frac{\text{lea strength (lbs)} \times 100}{160 \times \text{single thread strength (lbs.)}}$, then the results of the two tests show fairly good agreement provided the lea ratio lies between 67 and 77; if the lea ratio is below 67 or above 77, the correspondence between the results of the two tests is generally poor, the difference between them amounting sometimes to 30 per cent or more. Thus, it is not possible to use the results of single thread test as a check upon the lea test results in all cases, but only in those for which the above-mentioned condition is fulfilled. The lea testers are fitted with stress-strain attachment for checking the tests and, if necessary, for finding out the extension of the yarn.

* Examination of a proposed relationship between the lea test and the single thread test results—by V. Venkataraman and Nazir Ahmad, Indian Central Cotton Committee, Technological Bulletin, Series B, No. 15.

Counts actual :—The leas, half-leas and quarter leas, broken on the lea and the ballistic testers, are weighed individually on a suitable Yarn Balance for determination of the actual counts. In each case, therefore, the value of the actual count obtained represents the mean of 50 determinations for medium and fine counts and 20 or 30 determinations for coarse counts. The ten 1-foot lengths removed from a bobbin in each of the two groups for the single thread tests are weighed collectively on a torsion balance and the mean of the twenty weighings is shown in the reports issued from the Laboratory.

Twist :—The actual number of turns per inch inserted in a yarn is found by means of a Twist Tester employing the untwist-retwist principle. The measurements are made on 10-inch lengths of grandrelle yarns, a few layers of which are laid on top of each test bobbin after the cotton under test has been spun thereon. The method of preparing these grandrelle yarns and the experimental details of the twist tests are fully described in a Technological Bulletin.* Five lengths of yarn are examined from each of the ten bobbins, and the value for any single count is therefore the mean of 50 observations. Here, as in the case of the single thread tests, due care is taken that yarn is not partially untwisted during the tests. Twist tests on single yarns are carried out on the Rockbank single yarn twist tester or are tested on the ordinary twist tester on $\frac{1}{2}$ " length. The mean of 200 tests is usually taken for twist tests on single yarns.

Evenness :—Evenness of a yarn is an important asset in view of the fact that fabric prepared from an uneven yarn, however strong, will not appeal to the eye. At the Technological Laboratory, the yarn under examination is wound on a drum covered with black velvet, its degree of evenness is estimated visually and expressed by means of a numeral indicating one of the following seven classes :

1. Very even.
2. Very even to even.
3. Even.
4. Even to fairly even.
5. Fairly even.
6. Uneven.
7. Very uneven.

Neppiness :—The number of neps present in a yarn is counted at the same time as it is examined for evenness. The count is made on forty portions of yarn, each 3.6 inches long, ten portions being taken from a bobbin. Neppiness is expressed as the average number of neps per yard of yarn.

* The determination and variation of Twist in ring-spun cotton yarns—by D. F. Kapadia and A. James Turner, Indian Central Cotton Committee, Technological Bulletin, Series B, No. 18.

Irregularity :—In addition to the above characteristics, which are either measured directly with the help of mechanical appliances or estimated visually, two yarn characteristics are calculated from the results of these measurements. The first is the “percentage strength irregularity” denoted below by I_s which should be regarded as a measure of the number of weak places in a yarn. Its significance lies in the fact that in such operations as winding, warping and weaving in which single threads are subjected to variable stresses, the mean strength plays a relatively less important part than the frequency of ‘weak spots’, where breakages are likely to occur. It is calculated from the following formula.

$$I_s = \frac{M - M_1}{M} \times 100$$

M is the mean of all the strength results and M_1 the mean of those which are less than M . In the same manner as described above, percentage extension irregularity is calculated.

As the practical man may find it difficult to grasp clearly the conception of irregularity, another statistical measure named “weakness percentage” has been introduced. This simply represents the percentage of the results in the single-thread test which are less than three-quarters of the mean.

Yarn breakages in the ring frame :—The strength, extensibility, evenness, and neppiness of a yarn are qualities which come into prominence after a cotton has been spun. But the behaviour of a cotton in the spinning process is also a matter of considerable importance, especially from the economic point of view. If the number of yarn breakages in the ring frame should become excessive, the cotton would claim more than its due share of attendance on the part of the operatives, raising thereby the labour charges, and the yarn obtained under such conditions of spinning would suffer in strength and appearance owing to frequent piecings. The number of yarn breakages in the ring frame can in some cases be reduced by inserting more twist; but this method is not entirely satisfactory as, besides making the yarns hard, it will lower production. In view of the importance of the spinning behaviour of a cotton, the number of yarn breakages in the ring frame per 100 spindles running per hour is given for each count in the reports issued from the Laboratory.

Twist standards :—In a given count, the strength of a yarn will depend, to a large extent, upon the degree of twist inserted in it. It is well known* that yarn strength at first increases with the twist, attains a maximum value and then steadily diminishes. This is especially so in the case of comparatively long staple cottons as is shown by the results of tests on Cambodia

* e. g. “Empirical relationships between count, twist and strength of cotton yarns” by Nazir Ahmad and V. Venkataraman, I.C.C.C. Technological Bulletin, Series A, No. 48.

and Mollisoni which are described in a Technological Bulletin.† As one of the primary objects of the spinning test is to compare the performance of the same varieties in the different seasons, it is necessary to adhere to certain standards of twist in order to maintain a uniform basis of comparison. At the Technological Laboratory, the standard selected is that represented by the twist multiplier * 4, which corresponds to a medium degree of twist.

For the routine tests, each lot is generally spun into three different counts, though occasionally this number may be increased to four or cut down to two. Before assigning these counts to a cotton, a preliminary test is made by spinning it into a suitable count. On the strength results of this test, the particular counts into which the cotton is to be finally spun are decided upon. If the cotton has been tested before at the Technological Laboratory, then, in order to facilitate comparison, at least two of the three counts are made identical with those spun from it in the previous season. The third count may or may not be different, depending upon whether the cotton has maintained its quality or shows large seasonal variation.

Strength Standards:—Various standards oflea-breaking strength have been proposed from time to time for different counts of moderately twisted warp yarn. Although these standards are more or less arbitrary, they, nevertheless, take into account the average quality of the types of cotton to which they are intended to apply. Thus, the standards for Egyptian cottons are somewhat higher than those for American cottons, the standards for combed yarns are more severe than for carded yarns. The standards adopted at the Technological Laboratory, together with the corresponding count-strength products, are shown in the following table:—

Table of Strength Standards for Various Counts.

| | Count | Breaking strength | Count-Strength Product |
|------|-------|-------------------|------------------------|
| Upto | 14 | 90 | 1,260 |
| | 16 | 81 | 1,296 |
| | 18 | 78 | 1,814 |
| | 20 | 67 | 1,840 |
| | 22 | 62 | 1,864 |
| | 24 | 58 | 1,892 |
| | 26 | 54 | 1,404 |
| | 28 | 51 | 1,428 |
| | 30 | 48 | 1,440 |
| | 32 | 46 | 1,472 |
| | 34 | 44 | 1,496 |
| | 36 | 42 | 1,512 |

† "Limit Spinning Tests on Cambodia and Mollisoni Cottons" by R. P. Richardson and A. James Turner, Indian Central Cotton Committee Technological Bulletin, Series A, No. 17.

* The twist multiplier is a factor which, when multiplied by the square root of the counts being spun, gives the number of turns per inch.

| Count | Breaking strength | Count-Strength Product |
|-------|-------------------|------------------------|
| 38 | 40 | 1,520 |
| 40 | 39 | 1,560 |
| 50 | 38 | 1,650 |
| 60 | 28 | 1,680 |
| 70 | 25 | 1,750 |
| 80 | 28 | 1,840 |
| 100 | 20 | 2,000 |

A yarn spun with a moderate degree of twist and having the lea-breaking strength specified in the above table corresponding to its count will be referred to as "standard warp" yarn.

It will be seen from the table that the lea-breaking strength for 40s yarn is nearly 60% of that for 20s yarn and that the count-strength product increases steadily with the count. In actual practice, neither of these two conditions is realised for any cotton. If the lea-breaking strength of 20s yarns of a medium quality cotton is 67 lbs. the lea strength of its 40s yarns will be considerably less than 39 lbs., and vice versa, if the lea strength of 40s yarns of a good quality cotton is 39 lbs., the lea strength of its 20s warp will be much higher than 67 lbs. Furthermore, if the cotton be spun into two or more counts, the count-strength products will be found to decrease with increasing counts. The scale, therefore, is purely hypothetical and does not represent any single case met with in actual practice.

It follows that if a cotton which, according to the adopted scale, is capable of yielding 20s standard warp yarns, is also spun into 30s or 40s warp, the strength of these latter yarns will fall short of that specified in the scale and, therefore, the cotton will be adjudged unsuitable for spinning higher than 20s standard warp. In other words, in order to obtain finer yarns which should conform to the standards of strength adopted at the Laboratory, a cotton of much better quality must be used. The reason for making the standards of yarn strength more rigorous for finer yarns is that these are required for manufacturing better class of fabric and are subjected to greater tension than coarse yarns in the weaving process. If they are prepared from a low quality cotton, then on account of excessive warp breakages and the consequent piecings, the cost of production will mount up and yet the fabric will be poor in quality and uninviting in appearance.

The spinning quality of a cotton.—The method of indicating the spinning quality of a cotton in terms of the scale given above will be clear from the accompanying diagram, Fig. A. It has already been stated that whereas the values of count-strength products in the scale increase with the count number, those actually obtained with any one cotton behave in exactly the opposite manner. Consequently, if a cotton be spun into two or more

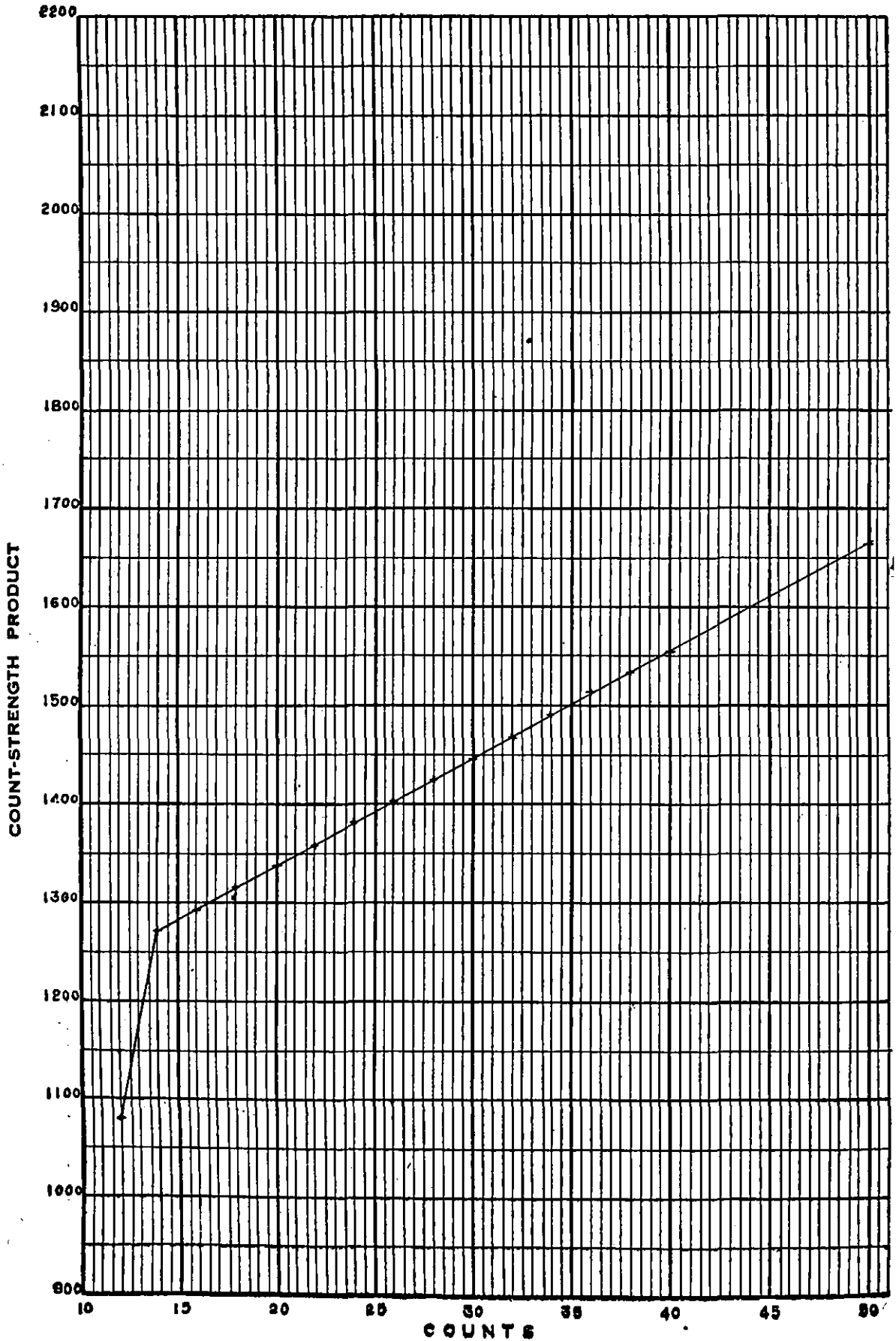


Fig. A—Relation between count and count-strength products.

counts and the observed values of count-strength products be plotted and joined by a line on the same graph as contains the line passing through the hypothetical values, the two lines—one rising upwards, the other sloping downwards—are bound to intersect in a point. The particular value of the count given by the point of intersection is taken as a measure of the spinning quality of the cotton and is termed “the highest standard warp count” for which the cotton is adjudged suitable.

The foregoing method of ascertaining the spinning quality of a cotton from its count-strength products, instead of lea-breaking strength values, offers two advantages. In the first place, no matter what precautions are taken, the actual counts of yarns tested are bound to differ somewhat from the nominal counts. This may be due to varying conditions of humidity in the spinning and the testing rooms or to lack of uniformity in the roving. The departure from the nominal counts will affect the breaking strength of a yarn, it will be high or low according as the actual count is finer or coarser than the nominal count. In order, therefore, that the results for different yarns may be rendered strictly comparable, it would be necessary either to reduce the observed values of strength to those for nominal counts in each case or, what amounts to the same thing, to employ count-strength products. This procedure assumes that, within the small range of deviation of actual from nominal counts, strength of a yarn will vary sufficiently regularly to allow the principle of proportionality to be applied. A method has been described * by which the observed values of strength of actual counts can be

reduced to those of the nominal counts. The formula is $S_2 = \frac{C_1 S_1 - (C_2 - C_1) K}{C_2}$

where C_1 and S_1 are the actual counts and the actual strength, C_2 is the nominal count, S_2 is the strength of the nominal count and $K = 0.7(74 - C_2)$. This correction is generally applicable for carded yarns ranging from 6s to 50s counts when spun with moderate twist. A formula has also been evolved which is given in this bulletin to calculate the strength of any count (which is not spun) from the known strength of another into which an Indian cotton had been spun. The second advantage in plotting the count-strength products in preference to strength-values lies in the fact that changes in humidity affect the counts and the breaking strength of yarns in opposite directions; increase in humidity lowers the count-number but increases the strength of a yarn. If, therefore, the count-strength products are used in comparing the performance of two cottons, the effects of small changes in humidity are smoothed out. The effects due to large changes still remain, and in order to make an allowance for them, certain corrections, based upon results obtained at the Technological Laboratory, are applied to count-strength products wherever necessary. This point has been explained in

* Empirical relationships between count, lea strength and staple length of Indian cottons by V. Venkataraman and Nazir Ahmad, Technological bulletin, Series A, No. 42.

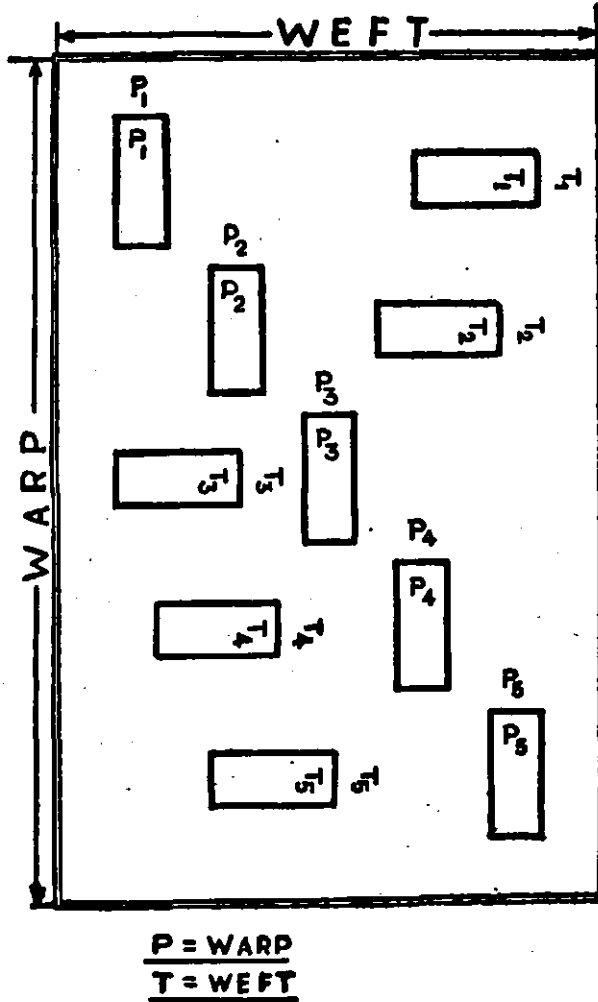
detail to avoid any misunderstanding that might be caused with respect to the method adopted at the Laboratory for ascertaining the spinning quality of a cotton.

It must not be concluded from the preceding remarks that it is not possible to spin a cotton into finer yarns than that specified by its highest standard warp count or that the strength of its yarns in any one count must necessarily be the same as or less than that shown in the table of strength standards. It has already been mentioned that the strength of a yarn depends not only upon the quality of its raw material and the treatment to which it is subjected but also upon the degree of twist inserted in it. Therefore, in order to obtain from a cotton, stronger yarns in any given count or finer yarns than that for which it is adjudged suitable, all that is necessary is to insert more twist in it during the spinning operation. If breaking strength were the only criterion of yarn quality, this method would work up to a limit beyond which even strength is found to diminish with increasing twist. But the insertion of high twist lowers production, makes the yarns uneven and lustreless and adversely affects their sizing and dyeing qualities, consequently, it cannot be recommended as the most satisfactory means of obtaining stronger yarns. It should be clearly understood that the statement that a cotton is suitable for a given highest standard warp count simply means that yarns of that cotton, spun into the assigned count with a twist multiplier of 4, will give the lea-breaking strength shown for that particular count in the table of strength standards.

The method described above of indicating the spinning quality of a cotton has certain definite advantages over the alternative method of expressing it directly in terms of the breaking strength of yarns of one single count. In the first place it is not always easy to choose one single count which should be suitable for the different varieties composing the Indian cotton crop. If coarse counts are selected, the treatment would hardly be fair to the long staple cottons; on the other hand, if fine counts are decided upon the short staple cottons would be spun much above their spinning capacity with disastrous results. The method adopted has a wide application, as it is equally well suited to long and short staple Indian cottons. Furthermore, it gives more accurate information and is capable of revealing fine shades of distinction between the spinning quality of two cottons.

VIII. CLOTH TESTS

The Laboratory usually receives cloth samples from mills, firms, individuals and at times from Government Departments for various tests to be carried out on them on payment of charges. Care is being taken to see that the result of such tests is the average of several tests taken from different places in the sample and is truly representative of the sample tested. As far as possible, in all cases, the following sampling method is adopted.



The figure shown above shows the different places in the sample from which portions, both in the warp and weft, the necessary strips may be cut

or yarns unravelled out, or ends and picks counted for carrying out of one or the other test, such as tensile strength of strips, counts, strength, elongation, crimp and twist of yarns extracted from cloth, number of ends and picks per inch and such other tests.

In short, the diagram of sampling in a cloth piece shows that each test is from a different portion of the cloth which does not have the same warp or weft yarns.

The advantage of such a sampling system is that it is easy to locate the place in the sample from which the test was made, should it become necessary to investigate the cause of an abnormal result since the portion from which the strip is cut or the material taken out for tests is marked 1P, 2P, 1T, 2T, etc., where P stands for warp and T for weft—the numerical figure indicating the test number. The tests are carried out under standard condition of 65% ($\pm 2\%$) R.H. at a temperature of 80°F ($\pm 4^\circ\text{F}$).

Below is summarized the method usually adopted for the testing of some of the principal properties of cloth.

1. *Length*.—The fabric is laid across a smooth flat table, measuring four yards in length, without applying extra tension to the cloth than is necessary to make it lie straight and flat; one side of the table, lengthwise, is marked in yards, ft. and inches and the cloth is measured in lengths of 3 yards and the balance of less than 3 yards is read off on the scale provided on the table. Measurement shall be correct to half an inch.

2. *Weight per sq. or lineal yard*.—Wherever possible, two pieces of cloth 18" x 18" are weighed separately on a suitable balance and the weight per sq. or lineal yard is calculated and the average of two tests, in ozs, is given as the weight per sq. or lineal yard.

3. *Width*.—The width of a sample is measured at five different places uniformly distributed along the full length of the sample with a measuring scale placed at right angles to the selvedge, care being taken that the cloth is laid across a smooth flat measuring table without applying extra tension than is necessary to make it lie straight. The result is expressed in inches or fractions of an inch and the measurement made to the nearest 1/16 inch. The average of five measurements shall be the width.

4. *Thickness*.—Five measurements are taken at different places in the sample with a thickness measuring micrometer having an interchangeable upper pressure foot of different diameters. The diameter of the upper pressure foot is usually 1" and the pressure applied to it is 1 lb. per sq. inch. The result is expressed in thousandth of an inch.

5. *Ends & Picks per inch*.—The number of threads per inch is counted at five different places each in the warp and weft direction with a one

inch micrometer thread counter. For 25 or fewer threads per inch a three inch gauge length is used. The counting of warp threads is carried out after leaving at least one inch of cloth from the selvedge. The average of five tests is the number of ends or picks per inch.

For samples of small width, 3 inches or less, the entire width is taken for counting the threads and the result given as the "total number of ends in the sample."

6. *Crimp*:—Two parallel lines are marked on the fabric at least 6 inches apart and four threads are ravelled out beyond each mark. These threads are straightened without undue tension. Generally a load (in grams) equivalent to $156/c$ where c is the approximate count of the yarn is applied for straightening the yarn taken out of the cloth. The difference between the final length of the thread (after ravelling and straightening) and its original length in cloth expressed as a percentage of the original length is known as the crimp.

7. *Count*:—Yarns are taken out of the cloth and straightened with the minimum load necessary to remove the crimp ($156/c$ gram where c = approximate counts), their length measured and finally weighed. The count is calculated from the length and weight of these yarns and the average of several readings of yarns taken out from different places in the cloth is the average count of the yarn in the cloth.

8. *Shrinkage*:—Shrinkage is determined by cutting out test pieces measuring slightly more than 20 inches by 20 inches and marks 20 inches apart are made at three different places in the warp and weft directions with indelible ink or marking ink. The test piece is laid flat for 2 hours in cold distilled water and then allowed to dry on a flat surface. The distance between the mark at all three places each warp way and weft are measured under plate glass. The difference in distance between the marks expressed as a percentage of 20 inches is given as the shrinkage. The average of tests on two pieces are given wherever possible.

9. *Bursting strength*:—Specimens 9" square are cut from cloth after seeing that the specimens do not contain the same central threads. These specimens are laid centrally over the rubber sheet of the bursting strength tester after ensuring that all bubbles are removed and wrinkles carefully smoothed out. The specimen is clamped on the rubber diaphragm and pressure steadily applied. The bursting strength is observed on the pressure gauge and noted. The average of three tests is given as the average bursting strength of the cloth.

10. *Tensile strength*:—For finding the tensile strength of the cloth, the sample is laid flat on smooth table and the portions from which the strips are

to be cut in the warp and weft directions are marked out as shown in the diagram on page 41. Five strips are cut in the warp direction and five in the weft direction about $\frac{1}{2}$ inch wider than the specified effective width required for the actual test and then each strip is ravelled out, on either side equally, to the specified width. The projecting transverse threads are allowed to remain. The strip is then broken in a testing machine of suitable capacity having a constant rate of traverse of 18" per minute, after fixing the longer length of the strip at right angles to the jaws. The average of five tests each way is the tensile strength of the cloth. The result is expressed in pounds.

Tests are also carried out for wear tests, porosity to water, air permeability, dye fastness, pliability, friction tests, compressibility, etc. according to standard methods and conditions after proper sampling.

IX. CONCLUSION

The foregoing account describing the methods employed at the Technological Laboratory for ginning tests, moisture tests, chemical tests, fibre tests, spinning tests, yarn tests and cloth tests carried out on Indian cottons and their manufactures applies strictly to only one phase of the activities of the Laboratory, viz., carrying out of routine tests. Besides this, the Laboratory has undertaken, ever since its inception, fundamental research on a variety of subjects related to the properties of the raw material and the influence of mechanical treatment on the quality of yarns spun from it. It is beyond the domain of possibility to set down methods of research which should be applicable to the various investigations which the Technological Laboratory has undertaken in the past or may do in the future. These are described in their proper place in the Technological Bulletins embodying the results of these investigations, which are issued from time to time from the Laboratory.

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