Research Record No. 69

Some Results From the IIC-Shirley Fineness / Maturity Tester

by

S. Allan Heap

June 1977

Key Words:

Fineness, Maturity, Micronaire, Arealometer, Causticaire, ICCS Cottons.

CONTENTS

NB. This is an electronic version of RR 69. The text was scanned into MS Word and edited to conform to the original. The data tables were then copied into MS Excel and the graphs were re-built from those data. In several cases, this has resulted in slightly different regression equations on some of the figures. In addition, Excel calculates the coefficient of determination (R^2) rather than the correlation coefficient (r), so these are what are displayed on the new figures. The original text has not been altered so there are a few minor conflicts between text and figures.

1 INTRODUCTION

The background to the theory and practice of estimating fineness and maturity of cotton (and other) fibres using air flow instruments has been admirably reviewed and investigated by Lord. His basic work is reported in a series of three papers (1, 2, 3) and summarised in a book (4).

According to Lord, the basic law of flow by a fluid through a porous medium was obtained by d'Arcy from results of experiments on flow of water through sands. It is summarised by the equation:-

$$Q = K . AP / L \qquad (1)$$

where Q is the rate of flow,

A is the area of specimen

L is the length of specimen

P is the pressure difference

Poiseuilles law for laminar flow through a smooth circular tube is taken to be a particular case, which takes the form

$$Q = 1/8 . r^2AP / \mu L \qquad (2)$$

where r is the tube radius and μ the viscosity of the fluid.

This has been extended to non-circular channels, giving

$$Q = 1/K_o \; . \; m^2AP / \mu L \qquad (3)$$

where m is the ratio between the cross-sectional area normal to the flow and the total perimeter presented to the flow. The factor K_o is said to vary generally between 2 and 3 for a wide range of shapes of section.

For a bed of particles, the assumption has been made that this is equivalent to a group of parallel and similar channels whose total internal surface and total internal volume are respectively equal to the particle surfaces and pore volume.

Assuming that the particles are held in a container of length L and section area A, and that

S_o = specific particle surface i.e. surface area per unit volume of material, and

E = porosity i.e. proportion of space not occupied by the material,

then m = *volume of fluid in the channels / surface area presented to fluid*

$= E / S_o(1 - E)$

Furthermore, since the total cross-sectional area of the channels is AE, it follows that equation 3 may be transformed into

$$Q = 1 / K_o \; . \; AP / S_o^2 \mu L \; . \; E^3 / (1 - E)^2 \qquad (4)$$

A correction to equation 4 is required to take account of the tortuosity of the channels. If L_e is the equivalent average increased length of path, then this assumption leads to

$$Q = 1 / K \; . \; AP / So^2 \mu L \; . \; E^3 / (1 - E)^2 \qquad (5)$$

where $K = K_o (Le / L)^2$

For various systems K_o has been found to vary between 2 and 3, K between 4 and 5 but, in practice, the value of the correction factors K or K_o has to be determined experimentally for a given system.

For plugs of fibres in a Micronaire type apparatus, Lord found (1) that K depends upon the type of fibre to some extent and especially upon the porosity. A comprehensive theoretical description of the dependence of K upon porosity and fibre geometry was said not to be possible but empirical relations of the type $y = ax + b$ in the form

$$\log_{10} [KE^2] = a \cdot \log_{10} [1 / (1 - E)] + b \qquad (6)$$

were found. Different values of the constant, a, were applicable to different fibres but the intercept, b, was common to all fibre types, within experimental limits, over a wide range of porosities.

By the method of least squares, applied to the results of five different fibre types, the common constant, b, was estimated to be 0.04434 and hence equation 5 could be re-written as

$$Q = 0.903 \ AP / S_o^2 \mu L \ . \ E^5 / (1 - E)^\alpha \qquad (7)$$

in which 0.903 is the reciprocal of $antilog_{10} [b]$ and $\alpha = (2 - a)$.

For various fibre types, the value of α was found to be as shown below.

Fibre Type	α
wool	1.253
cupprammonium	1.322
silk	1.328
cotton	1.391
viscose	1.403

Equation 7 may thus be regarded as the practical expression of the laws governing air flow in an instrument of the Micronaire type. Note that it is very sensitive to changes in E, the porosity (= density of packing).

From this it is clear that valid and accurate assessments of fibre fineness may be made on well-opened samples of fibres having a circular section by the use of equation 5 (with an assumed value of K depending upon the porosity) or from equation 7 (with $\alpha = 1.32$). But since small changes in porosity cause appreciable changes in flow, experimental calibration of the apparatus is essential.

When the fibre section is not circular, estimates of fineness may still be made from equation 7, provided that the fibre sectional shape is substantially the same in different samples of the same type. In any case, other dimensional features being constant, the rate of flow through the plug will be inversely proportional to S_o^2 and hence directly proportional to such measures of fineness as area of section, and fibre weight per unit length. However, for cotton it should be noted that the relation between S_o, fineness and maturity is of the form

$$S_o = S/v \qquad \text{and} \qquad S = 3.79 / (M.H)^{0.5}$$

where H is the hair weight in micrograms per cm (millitex)

M is the maturity ratio

S is the surface area per gram

v is the specific volume of the whole fibre

v, the specific volume of fibre wall and enclosed lumen, has been shown to have an average value of about 0.75 which leads us to

$$S_o^2 = 25.5 / M H \quad cm^{-2} \qquad (8)$$

Therefore, the rate of flow of air through a plug of cotton should be directly proportional to *MH*, the product of fineness and maturity.

Lord was able to show experimentally that, in general, $MH = aQ + b$ and that for the interesting range of porosity (= packing density of the plug) the constant b was not significantly different from zero, i.e. the air flow was directly proportional to *MH*.

In a later investigation (2, 4) he was able to show that the Micronaire instrument itself was indeed measuring a function of *MH* and for this particular case the best equation was

$$MH = 3.86 X^2 + 18.16 X + 13.0 \qquad (9)$$

where X is the Micronaire value. For this relationship, he quotes a multiple correlation coefficient of $R = 0.9904$.

Presumably, this relationship still exists for current Micronaire instruments.

The IIC-Shirley Fineness/Maturity tester was developed by E. Lord as an attempt to obtain independent estimates of *M* and *H* by making two separate air flow measurements upon the same sample, thus arriving at two separate estimates of *MH*.

Several workers have found that separate estimates of *MH*, made by changing the porosity and / or the pressure and / or the airflow, were biased according to the maturity of the sample. These workers produced empirical correlations of their results with other measures of maturity, but generally the correlations were only moderately good and separate calibrations had to be made for the different types of cottons, e.g. Barbadense vs. Hirsutum. Hence the reason for the IIC-Shirley investigation which had the objective to see whether accurate estimates of fibre maturity could be obtained free from bias with intrinsic fineness by measurements of air permeability at two different test conditions.

The main conclusions of this research are summarised in E. Lord's project report of September 1970 which led to the concept of an instrument which measures the pressure difference at two different combinations of sample compression (porosity) and air flow. It was found that unbiased estimates of fineness and maturity could be calculated from relationships of the form

$$MAT = K_1 . PL^a . (PL / PH)^b \qquad (10)$$

$$FIN = K_2 . 1 / PL . (PH / PL)^c \qquad (11)$$

where K_l, K_2, a, b, and c are empirically determined constants,

PL is the recorded pressure difference at “low” sample compression,

PH is the recorded pressure difference at “high” sample compression.

Evaluation of a prototype machine yielded the following values for the constants.

$K_l = 0.247$

$K_2 = 60{,}000$

$a = 0.125$

$b = 2.0$

$c = 1.75$

Furthermore, it was found that an excellent estimate of Micronaire value could be calculated from

$$MEQ = 0.6 + 850 / (PL + 40)$$

Comparison of the results from this prototype with measures of M and H obtained by the classical methods was made by Shirley Institute as well as by two industrial testing laboratories. All found that the new instrument gave moderate to good estimates of M and H but several modifications to the detailed design were recommended and made. Reports of these evaluations are in the project file.

After the modifications had been made, the resulting instrument was considered ready for production and sale but no comprehensive evaluations of its performance seem to have been made, either with respect to that of the prototype (to see if a change in the value of the five calibration constants was necessary) or in respect of measuring a wide range of cottons. Instead, the procedure adopted was to obtain a supply of the International Calibration Cottons (Micronaire) from the USDA. These ten cottons were measured for fineness, maturity and Micronaire, and the production instruments were calibrated by the manufacturer in such a way (adjusting the volume of the sample holder = changing porosity) that the M and H and Mic estimates obtained were as close as possible to those of the USDA cottons, when using the same constants in equations 10 and 11 as given above.

After each calibration, the ten USDA cottons were re-measured on the FMT instrument in the usual way so that over the past two years or so, a fairly large body of data has become available which can be used to assess the performance and variability of the instruments under ideal conditions.

In addition, we have obtained a set of 22 cottons from the USDA cotton quality lab at Knoxville, Tennessee, together with Micronaire and Arealometer data pertaining to them. These 22 samples have also been measured by Shirley Institute using the standard fineness and maturity tests, and we have made estimates of M, H and Mic using two different FMT machines.

Although this range of cottons is neither as broad or so numerous as that which was used to characterise and calibrate the prototype FMT instrument, it is hopefully sufficient to decide whether present calibration procedures and machine performance are adequate.

2 Results on ICCS Cottons

Some early versions of the FMT were found to give results not sufficiently in line with measurements of M & H obtained by the classical methods and it soon became clear that each instrument would have to be individually calibrated by the manufacturer against a range of standard cottons.

Maintaining a range of standard cottons is a rather expensive business but it is done by the USDA for the purpose of calibrating the Micronaire and Stelometer instruments. The obvious solution was to use the USDA calibration cottons and this procedure was in fact adopted.

Over the past two years, four separate deliveries of these standard cottons have been received and each delivery has been tested by the Shirley Institute for Micronaire, Fineness and Maturity. For each delivery, four replicates of each sample were tested for Fineness and Maturity.

For each delivery except the first, six replicates were tested for Micronaire. For the first delivery, the Micronaire value was assumed to be that declared by the USDA.

The results of these measurements are shown in Table 1 from which it can be seen that the mean coefficients of variation for the classical testing between deliveries were as follows:-

	Mean CV%	**Ranqe**
Micronaire	0.68	0.43 - 1.10
Maturity	1.61	0.56 - 2.88
Fineness	1.67	0.61 - 3.08

These variations are rather low and confirm that the standard cottons are well homogenised and, therefore, pretty reproducible. The variability of results between deliveries does not appear to be related in any simple way to either fineness or maturity although there is a general trend towards better reproducibility with increasing maturity. One may also conclude that the means of the four deliveries will be more representative of the bulk than the results from any one delivery.

The data from the FMT machines were organised into three batches representing the results from 15 machines, 5 for each of 3 separate deliveries of the USDA standard cottons. Results of the first delivery of standard cottons were excluded because this material was in use before the calibration procedure had been properly systematised and therefore inadequate data were available.

The results from these three batches of machines are presented in Tables 2, 3 and 4. The mean variability of results between machines is given below.

Machine Batch Serial N^{o}s	Calibrated with USDA Delivery	Mean CV%		
		MEQ	MAT	FIN
022 - 026	2	0.46	1.27	1.15
027 - 031	3	0.49	1.12	1.22
037 - 041	4	0.66	0.87	0.97

These results suggest that the variability between FMT machines, for the same cotton, is rather less than that for the classical testing between deliveries.

Instrument, operator, and sampling effects can be essentially eliminated by comparing the mean results of any batch with those of the, Shirley (classical) measurements. Figures 1, 2 and 3 show a graphical comparison of the results from FMT batch 022 - 026 against Shirley results.

Linear correlation coefficients for these data are:-

$r = 0.9996$ for *MEQ* vs. *Mic*,

$r = 0.9706$ for *MAT* vs. *M*

$r = 0.9985$ for *FIN* vs. *H*

The Correlation Coefficients are not materially improved by averaging the Shirley results over the four deliveries and are similar for the other two batches of FMT machines. Furthermore, this degree of correlation is typical for the results from individual FMT machines; the lowest value for *r* observed among all 15 machines was over 0.95. The highest correlation was always observed for *Mic* vs. *MEQ*; the lowest was always for *M* vs. *MAT*. The reason for the lower correlation for Maturity is possibly due, in part, to the persistent inability of the classical test to distinguish between cottons B-15, C-18 and E-2 which are always accorded a maturity ratio of around 0.89, whereas the FMT machine consistently and reproducibly spreads these three over a range of 0.85 to 0.93. One is bound to conclude that the FMT machine is reporting a real difference between these three cottons, which is not discernible by the classical test.

Seeing that the FMT instrument is apparently giving such good estimates of *Mic*, *M* and *H*, it is interesting to check whether the relationship between *Mic* and *MH*, discovered by Lord, still applies and is also built into the FMT instrument as this is an indication of the “self-consistency” of the instrument.

Table 5 shows the measured values of *Mic* or *MEQ* and *MH* or *MAT.FIN* for the Shirley results (averaged over the four deliveries) and for the three FMT batches.

Some of these results are shown graphically in Figures 4 and 5 where the best fit quadratic equations are also indicated (HP 97 Software).

Although the best mathematical expressions of these data are apparently somewhat different, the calculated lines are rather close to each other over the range of interest and are also very close to the line which results from Lord's equation, i.e. $MH = 3.86X^2 + 18.16X + 13.0$. (Figure 6).

The main difference is in the scatter of results which is rather greater for the Shirley (classical) data than for the FMT instruments. Indeed the FMT results show essentially no scatter. Furthermore, it is found that each separate batch of FMT instruments and even, it seems, each individual machine yields essentially the same equation. Thus it was impossible to differentiate the results of the *MEQ* vs. *MAT.FIN* relationship for the three batches of FMT machines, nor was it possible to differentiate these three sets from those obtained later using two different single FMT machines (023 and 010 recalibrated) on the 22 cottons from Knoxville.

At this stage it is not possible to say whether this apparently unique and highly reproducible internal FMT relationship is valid only when the machine is correctly calibrated.

If this does turn out to be the case, it could point the way to a method for a routine check on FMT instruments to ensure that the calibration has not drifted, without the necessity for a series of tests on standard cottons.

For the time being, the best estimate of this numerical expression is probably obtained by averaging the *MEQ* and *MAT.FIN* results over the three FMT batches. This yields the following equation:-

$$MAT.FIN = 2.07\,MEQ^2 + 32.09\,MEQ - 12.68 \qquad (12)$$

which yields a linear correlation coefficient, between measured and calculated values of *MAT.FIN*, of $r = 0.9999$ and a linear regression equation of $y = 1.0007x - 0.33$. In other words, one cannot distinguish the measured values from those predicted.

In conclusion, it can be said that the accuracy and reproducibility of the FMT machines in estimating Micronaire, Fineness and Maturity is impressive when considering results on the ICCS standard calibration cottons. However, it has to be pointed out that this result is entirely to be expected since these are the very same cottons with which the instruments are calibrated.

A much more interesting and relevant evaluation would be one in which a wide range of cottons from an external source were measured and compared with classical test results. Such an evaluation is reported in the next section.

Footnote:

Throughout this report, the convention has been adopted of reporting results from the FMT instruments as

MEQ *for Micronaire equivalent*

MAT *for Maturity estimate*

FIN *for Fineness estimate*

The corresponding abbreviations for the values determined by the classical methods are Mic, M and H.

3 Results on 22 Cottons from Knoxville

By courtesy of Dr. H. H. Ramey Jnr., we received a set of 22 cottons which were samples from a group which are being used by the USDA in their ongoing fibre quality evaluation research programme. The samples were selected mainly on the basis of a wide range of fibre fineness which varies from about 120 to about 330 millitex. The range of maturity is from about 0.74 to about 1.06. A wide range of cotton species are represented as can be seen from the sample identification list in Table 6, although the American Upland type naturally predominates. Results of classical testing on these samples are shown in Table 7, including Arealometer testing carried out at Knoxville.

The samples were tested on two different FMT machines, Nos. 023E and 010D, and as a cross-check on the agreement between the two machines, the USDA/3 calibration standards were re-tested also on these two machines.

The results on the calibration cottons are shown in Table 8 from which it can be seen that there is a good agreement between the two instruments. Table 8 also shows that essentially the same equation has again been found for $MAT.FIN = f(MEQ)$.

The FMT results for the 22 samples are shown in Table 9. Agreement between the two machines is slightly less good in this case and presumably this difference represents sampling differences which are not or scarcely present with the ICCS cottons. The sampling "error" will have to be borne in mind when comparing the FMT results with those of the classical test.

Figures 7, 8, 9 and 10 compare the results from the FMT machines with those from the Shirley classical test. For *Mic* vs. *MEQ* (Figure 7) agreement is excellent and it is mostly not possible to separate the FMT results either from each other or from the classical test.

For *M* vs. *MAT* (Figure 8) there is pronounced scatter in the results. This is presumably because two disturbing effects are operating at the same time. On the one hand are the sampling errors which are approximately reflected in the differences between the two FMT machines. On the other hand is the effect discovered in section 2, whereby the FMT machine is able to detect differences in maturity which are apparently not discernible by the classical method.

The fineness data (Figure 9) suggest that sampling errors may have a smaller effect on the results than is the case for maturity, and the FMT is in serious disagreement with the classical test for only one sample (This FMT result was reconfirmed by re-testing on machine 023).

Figure 10 shows a rather similar picture for *MH* vs. *MAT.FIN* with only one sample (the same) standing out. This figure shows quite clearly how the two FMT machines are in good agreement about the fundamental property of the fibre but yet are often finding differences that the classical test has not seen.

Once again, approximately the same equation for $MAT.FIN = f\,(MEQ)$ was found (Table 9).

There is no evidence from any of these data that the *Barbadense*, or the Asiatic, or the cross-bred types are giving results which are out of the general trend for Upland cottons.

To summarise, we can say that the agreement between the FMT machines and the classical test is excellent for Micronaire, very good for Fineness and *MH*, but only tolerably good for maturity. A part of the reduced correlation in the case of maturity can almost certainly be ascribed to sampling effects and the bulk of the remainder is quite likely to be due to a real difference in the sensitivity of the FMT instrument in picking out differences which are not discerned by the classical test. More work would have to be done to validate these assertions and to discover whether they account for all of the differences.

4 Comparisons with the Arealometer Test

As mentioned in Section 3, the 22 cottons from Knoxville had already been tested in that laboratory with an Arealometer instrument, and the results had been supplied to us.

Starting with the basic Arealometer *A* and *D* values, fibre characteristics can be calculated based upon part-theoretical, part-empirical equations developed by American workers in the past.

Thus, the so-called Maturity index I is given by

$$I = (0.07\,D + 1)^{0.5} \qquad (13)$$

from which the Maturity can be derived via

$$P_m = 150 - 38.1\,I \qquad (14)$$

and

$$M = 1.76 - (2.44 - 0.0212\,Pm)^{0.5} \qquad (15)$$

where P_m is the percent mature fibres (American test method).

Furthermore, the weight per unit length in micrograms per inch is given by

$$W = 0.485\ .\ I\,/\,A^2\ .\ 10^6 \qquad (16)$$

from which the fineness *H* can be calculated by applying the appropriate factor to convert to millitex i.e. g/1000 metres.

The Arealometer *A* and *D* results together with Micronaire values also measured at Knoxville were given in Table 7. Table 10 now shows the corresponding estimates of P_m, *M* and *H* derived by applying the above equations. To identify the results as being derived from the Arealometer, the appropriate abbreviation is preceded by an *A* thus AP_m, *AM* and *AH*. *AM.AH* has also been calculated. For ease of comparison, the Shirley test data are repeated in Table 10 also.

Figures 11 and 12 show the comparison between the Arealometer and the classical tests in graphical form.

It is clear from these figures that, the agreement is only fair and the Arealometer is not better (on this showing) than the FMT in predicting the results of classical testing.

It is noteworthy that the *MH* vs. *AM.AH* correlation is the best of all ($r = 0.929$). This suggests that the basic problem with the Arealometer instrument is that its two *MH* estimates are not adequately resolved into the *M* and *H* components or, at least, not as well resolved as in the case of the FMT instrument. The advantage of the FMT presumably resides in the use of larger samples in the optimum porosity range, as well as the more complex treatment in the empirical regression equations linking the two pressure readings to *M* and *H*.

Finally, it should be remarked that, although they have not been elaborated here, it was found that the Micronaire results obtained at Knoxville correlated almost perfectly with those found at Shirley and also with the FMT MEQ, but with three significant exceptions. These were the same three samples (of coarse fibres) for which the *AH* results had been well wide of the mark, and lends credence to the idea that sampling “errors” had occurred. If the Shirley Micronaire results were substituted for these three, then the correlation with *MEQ* became, for practical purposes, perfect.

Similarly, when these rogues were removed from the fineness comparison, the picture was dramatically improved. However, the improvement in the maturity correlation was negligible.

In view of the fact that the Arealometer test is a rather difficult and time consuming one to carry out, there seems to be absolutely no reason to prefer it to the FMT instrument.

5. Comparisons with the Causticaire Test

A detailed assessment of the standard Causticaire test was published by Lord in 1956 (3). He concluded that the use of the recommended regression equations, for converting Micronaire-type measurements on untreated and mercerised samples into estimates of the percent mature fibres (P_m), led to biased estimates of maturity. In this publication, he established that, whereas Micronaire values on untreated cottons are a function of *MH*, the corresponding values on mercerised material are related to $H.(M)^{0.5}$ and he found an empirical regression equation of the form

$$H.(M)^{0.5} = 8.73\, X_m^2 - 55.15\, X_m + 186.7 \qquad (17)$$

where X_m is the Micronaire reading for the mercerised material.

He also showed that the Causticaire Maturity Index (*CMI*) was only moderately well correlated with P_m ($r = 0.814$) and that a better prediction could be made by taking the Causticaire reading on the untreated material (*U*) into account.

Thus the expression

$$P_m = 2.944\ CMI - 1.097\ U - 81.7 \qquad (18)$$

gave a correlation coefficient of $r = 0.920$.

These findings seem to have been ignored by the advocates of the Causticaire test since the recommended procedure for the ASTM Causticaire method is still to use the simple equations developed by the original workers who estimate P_m as

$$CMI = 100\ U / T \qquad (19)$$

where U and T are the Causticaire scale readings for untreated and mercerised samples respectively.

In the case of the Causticaire fineness estimates, however, either the standard regression equation had been changed since 1956 or Lord had made an error (or there was a misprint) because he quotes the following equation for the fineness estimate

$$D = 1.185 + 0.00075\ T^2 - 0.020\ CMI \qquad (20)$$

whereas the ASTM equation is quoted as

$$D = 1.785 + 0.00075\ T^2 - 0.020\ CMI \qquad (21)$$

where D is the fibre fineness in microgram/inch.

Application of the appropriate factor converts D into F, the fineness in millitex.

The use of equation 21 for the fineness estimate has presumably not disturbed Lord's conclusions about improving the maturity estimate by the use of equations 17 and/or 18, since these were derived by reference to measurements of M and H made by the classical techniques, and by estimates of P_m derived from M via the previously-established regression.

$$P_m = 100\ (M - 0.2)\ (1.565 - 0.471M) \qquad (22)$$

For the present purposes, Causticaire measurements were made on the USDA/3 calibration cottons as well as most of the Knoxville samples. These tests were carried out on the Micronaire instrument at Bolton Technical College by IIC staff (who are not experienced in this test method).

The results are shown in Tables 11 and 12, as well as in Figures 13, 14, 15 and 16. Table 13 shows the values of P_m obtained by applying equation 22 to the M and MAT figures obtained earlier for these same cottons.

Figure 13 shows that the Bolton Micronaire instrument was correctly calibrated, although there is some scatter in the results, presumably due to operator effects.

Figure 14 shows that, if two very wild results on low maturity samples are excluded, then the Causticaire Maturity Index is a fair estimator of P_m, especially when it is remembered that these tests were carried out by inexperienced (for this test) technicians. Thus the scatter in the results is not a great deal worse than that in Figure 8 where MAT is compared with M.

In Figure 15, however, the scatter is considerably greater than that for the FMT instruments (Figure 9) and it is clear that the Causticaire fineness figure is unreliable. It is interesting to note that the ICCS/3 samples appear to exhibit a rather good curvilinear relationship in Figure 15 which leads one to suspect that the Causticaire test is susceptible to further improvement, as Lord implied.

In both Figures 14 and 15, there is a suspicion that the two groups of samples are behaving somewhat differently. In fact, the two groups were tested on different occasions and we may be seeing some operator effect, which has increased the scatter.

Figure 16 shows a comparison of the Causticaire and FMT results for maturity.

Although this graph is not strictly relevant, it has been included because Hadwich has published (5) a comprehensive comparison of FMT and Causticaire results, in which he demonstrates a fairly good correlation between the two, but with some dependence on the cotton variety.

It was found that Lord's equation 18 did not improve the Causticaire estimate of P_m - quite the contrary. Since it is inconceivable that Lord has made two major blunders in one paper, we have to assume that the Causticaire test has in fact been changed since 1956 and is now giving better results.

It would be academically very interesting to discover if Lord's contention, that the Micronaire value of mercerised material is related to $H.(M)^{0.5}$, rather than MH, is still borne out and to modify the Causticaire system accordingly. Presumably the development of the FMT renders this interesting little piece of research redundant.

The Causticaire test is a fairly long-winded one which is said to require a fair degree of skill and experience on the part of the operator, and one can find no reason to prefer the Causticaire test to the FMT from these results. This conclusion was not changed by studying the more comprehensive (and expert) results of Hadwich (5).

6. Conclusions

1. Under ideal conditions (i.e. with sampling and operator effects removed), the FMT instrument is capable of giving excellent estimates of Micronaire, Maturity and Fineness.
2. There is apparently very little difference in the performance of individual FMT machines, one compared to another, at least among the machines studied here.
3. The FMT will produce a practically identical Micronaire estimate to that obtained from a correctly calibrated Micronaire instrument.
4. There is a strong suggestion that the FMT instrument is more sensitive to maturity differences between samples than is the classical caustic soda swelling test. This is presumably an inherent advantage, but it does mean that apparently low correlations between *MAT* and *M* are inevitable, and “evaluations” of FMT machines based upon only a few samples may be misleading.
5. The ICCS samples are apparently very suitable for calibrating the FMT machines. However, it would be as well to recognise that it may be impossible (because of the effects noted in point 4) to simultaneously match cottons B-15, C-18 and E-2 for *MAT* and *M*. Maybe it would be wise to accept that only one of these can be matched (C-18?) and either to exclude the other two or to accept the “historical” *MAT* values as being correct.
6. When sampling and operator effects are brought into the picture, the FMT machine still produces a very good estimate of fineness ($r = 0.96$), an estimate which is probably better than that obtained from the Arealometer instrument and almost certainly better than the Causticaire fineness estimate. The FMT estimate of maturity under these conditions is only moderately good ($r = 0.85$), but this is also at least as good as, and probably better than both Arealometer and Causticaire systems. In addition, the lower correlation could

be partly caused by real differences in what the two tests are reporting, as discussed under point 4.

7. When the time and expertise required for testing is considered there can be no question that the FMT is to be preferred over any other system considered. (The French Maturimetre may be competitive) when an estimate of maturity is required.
8. When absolute precision of results is the main criterion (fundamental research) then presumably the classical methods have to be preferred, since they are direct measures, but the penalties in time and cost are enormous. For this reason, the Arealometer and Causticaire tests are most commonly used for all but the most basic of researches. After a series of comparative studies, there is no apparent reason why the FMT should not take over this function, since its results seem to be at least as reliable and are much quicker and simpler to obtain.
9. The FMT system seems to be based upon a unique relationship between *MEQ* and *MAT.FIN* analogous to that between *Mic* and *MH* first discovered by Lord. It is very close to that found by Lord, but not identical and it is obeyed to a very high degree of precision ($r = 0.999+$) by all instruments so far checked. This fact may be useful in the calibration of FMTs or in checking for drift but further work would be needed to establish this, for example by doing a wide series of tests on deliberately "de-calibrated" machines.

1. References

2. E. Lord; *Airflow through Plugs of Textile Fibres. Part 1 - General Flow Relations*; Shirley Institute Memoirs, Vol. XXVII, 1954, pp 309-331.
3. E. Lord; *Airflow through Plugs of Textile Fibres. Part 2 - The Micronaire Test for Cotton*; Shirley Institute Memoirs, Vol. XXVIII, pp 289-320.
4. E. Lord; *Airflow through Plugs of Textile Fibres. Part 3 - The Causticaire Test for Cotton*; Shirley Institute Memoirs, Vol. XXIX, pp 135-149.
5. E. Lord; *Manual of Cotton Spinning. Vol. 2, Part 1 - The Characteristics of Raw Cotton*; The Textile Institute, Manchester 1961, second reprint 1971.
6. F. Hadwich, Melliand Textilberichte Vol. 57 (1976) No.9.

Table 1

Measurements of *Mic*, *M*, and *H* made by classical methods at the Shirley Institute upon four separate deliveries of ICCS cottons.

		1	2	3	4	Mean	s.d.	cv%
A-8	*Mic*	(5.54)	5.59	5.58	Replaced	5.57	0.026	0.48
	M	0.995	0.985	0.994	by	0.991	0.006	0.56
	H	213	217	216	A9	215	2.08	0.97
B-15	*Mic*	(4.60)	4.71	4.69	4.64	4.66	0.05	1.07
	M	0.915	0.885	0.885	0.860	0.886	0.023	2.54
	H	188	190	188	190	189	1.16	0.61
C-18	*Mic*	(3.52)	3.49	3.50	3.52	3.51	0.015	0.43
	M	0.925	0.890	0.885	0.905	0.901	0.018	1.99
	H	142	151	144	150	147	4.43	3.02
D-2	*Mic*	4.02	3.97	3.99	3.98	3.99	0.022	0.54
	M	0.985	0.970	0.960	1.00	0.979	0.018	1.79
	H	139	143	142	144	142	2.16	1.52
E-2	*Mic*	(3.02)	2.98	2.98	2.94	2.98	0.033	1.10
	M	0.905	0.890	0.90	0.875	0.893	0.013	1.48
	H	119	122	124	122	122	2.06	1.69
F	*Mic*	(7.08)	7.14	7.06	7.11	7.10	0.035	0.49
	M	1.01	1.02	1.00	1.04	1.018	0.017	1.68
	H	320	315	310	310	314	4.79	1.53
G-5	*Mic*	(2.70)	2.64	2.68	2.65	2.67	0.028	1.03
	M	0.690	0.680	0.645	0.675	0.673	0.019	2.88
	H	118	122	124	127	123	3.78	3.08
H-2	*Mic*	(6.11)	6.14	6.19	6.18	6.16	0.037	0.60
	M	1.02	0.995	1.024	1.025	1.016	0.014	1.39
	H	239	240	248	250	244	5.56	2.28
I-11	*Mic*	(4.93)	4.97	5.03	4.96	4.97	0.042	0.84
	M	-	0.935	0.945	0.93	0.937	0.008	0.82
	H	-	205	207	208	207	1.53	0.74
K	*Mic*	(7.40)	7.43	7.41	7.42	7.42	0.013	0.17
	M	1.055	1.04	1.04	1.06	1.05	0.010	0.98
	H	326	318	327	324	324	4.03	1.25

NB. *Mic* figures for Series 1 are the USDA standard values

Table 2

FMT Measurements on ICCS/2 cottons for Machines 022E – 026E

		022E	023E	024E	025E	026E	Mean	s.d.	cv%
A-8	*MEQ*	5.44	5.46	5.45	5.46	5.47	5.46	0.011	0.20
	Mat	0.982	0.997	1.006	0.997	1.006	0.998	0.010	0.98
	Fin	227	225	222	225	223	224	1.95	0.87
B-15	*MEQ*	4.66	4.63	4.65	4.64	4.66	4.65	0.013	0.28
	Mat	0.925	0.939	0.927	0.920	0.933	0.929	0.007	0.80
	Fin	196	191	195	196	194	194	2.07	1.07
C-18	*MEQ*	3.53	3.54	3.53	3.53	3.54	3.53	0.005	0.15
	Mat	0.888	0.877	0.894	0.877	0.906	0.888	0.012	1.38
	Fin	143	146	142	145	141	143	2.07	1.45
D-2	*MEQ*	3.91	4.00	4.02	3.94	3.93	3.96	0.047	1.20
	Mat	0.986	1.003	1.021	0.982	l.002	0.999	0.016	1.56
	Fin	148	151	149	151	147	149	1.79	1.20
E-2	*MEQ*	2.94	2.97	2.94	2.93	2.96	2.95	0.016	0.56
	Mat	0.846	0.846	0.828	0.843	0.871	0.847	0.015	1.83
	Fin	119	121	121	119	117	119	1.67	1.40
F	*MEQ*	7.09	7.08	7.09	7.06	7.06	7.08	0.015	0.21
	Mat	1.007	0.988	1.007	0.996	0.998	0.999	0.008	0.80
	Fin	316	320	316	317	317	317	1.64	0.52
G-5	*MEQ*	2.57	2.56	2.53	2.54	2.59	2.56	0.024	0.93
	Mat	0.682	0.693	0.695	0.672	0.718	0.692	0.017	2.49
	Fin	121	119	117	121	117	119	2.00	1.68
H-2	*MEQ*	6.07	6.10	6.05	6.10	6.08	6.08	0.021	0.35
	Mat	1.041	1.030	1.039	1.038	1.051	1.040	0.008	0.73
	Fin	248	252	248	251	247	249	2.17	0.87
I-11	*MEQ*	4.95	4.96	4.92	4.95	4.96	4.95	0.016	0.33
	Mat	0.943	0.935	0.957	0.960	0.965	0.952	0.013	1.32
	Fin	208	210	204	204	204	206	2.83	1.37
K	*MEQ*	7.42	7.48	7.47	7.44	7.43	7.45	0.026	0.35
	Mat	1.056	1.040	1.038	1.032	1.035	1.040	0.009	0.90
	Fin	323	331	331	331	330	329	3.49	1.06

Table 3

FMT Measurements on ICCS/3 cottons for Machines 027E – 031E

		027E	028E	029E	030E	031E	Mean	s.d.	cv%
A-8	*MEQ*	5.45	5.42	5.46	5.44	5.44	5.44	0.015	0.27
	Mat	0.989	0.999	1.004	0.997	1.000	0.998	0.006	0.56
	Fin	226	222	223	223	223	223	1.52	0.68
B-15	*MEQ*	4.63	4.63	4.65	4.65	4.62	4.64	0.013	0.29
	Mat	0.909	0.930	0.908	0.915	0.907	0.914	0.010	1.04
	Fin	197	193	198	197	197	196	1.95	0.99
C-18	*MEQ*	3.49	3.47	3.51	3.48	3.46	3.48	0.019	0.55
	Mat	0.852	0.866	0.860	0.871	0.853	0.860	0.008	0.95
	Fin	146	143	146	143	145	145	1.52	1.05
D-2	*MEQ*	3.95	3.90	3.93	3.93	3.94	3.93	0.019	0.48
	Mat	0.970	0.985	0.983	0.989	0.965	0.978	0.010	1.06
	Fin	152	148	150	149	153	150	2.07	1.38
E-2	*MEQ*	2.96	2.93	2.93	2.94	2.93	2.94	0.013	0.44
	Mat	0.820	0.833	0.827	0.849	0.831	0.832	0.010	1.29
	Fin	123	120	121	119	120	121	1.52	1.26
F	*MEQ*	7.11	7.06	7.11	7.03	7.015	7.07	0.044	0.63
	Mat	0.987	0.992	0.973	1.003	0.984	0.988	0.011	1.11
	Fin	323	318	327	313	318	320	5.36	1.675
G-5	*MEQ*	2.58	2.56	2.55	2.59	2.55	2.57	0.018	0.71
	Mat	0.668	0.690	0.660	0.681	0.650	0.670	0.016	2.39
	Fin	124	119	123	122	125	123	2.3	1.88
H-2	*MEQ*	6.06	6.05	6.08	6.05	6.04	6.06	0.015	0.25
	Mat	1.028	1.029	1.020	1.036	1.016	1.026	0.008	0.77
	Fin	250	250	125	248	252	251	1.95	0.78
I-11	*MEQ*	4.94	4.88	4.90	4.93	4.86	4.90	0.033	0.68
	Mat	0.921	0.953	0.935	0.920	0.935	0.933	0.013	1.44
	Fin	211	202	206	211	204	207	4.09	1.98
K	*MEQ*	7.43	7.41	7.47	7.39	7.35	7.41	0.045	0.60
	Mat	1.035	1.026	1.03	1.030	1.018	1.028	0.006	0.62
	Fin	330	331	332	328	329	330	1.58	0.48

Table 4

FMT Measurements on ICCS/4 Cottons for Machines 037E- D41E

		037E	039E	038E	040E	041E	Mean	s.d.	cv%
A-9	*Meq*	5.45	5.40	5.45	5.45	5.41	5.43	0.025	0.46
	Mat	1.008	1.017	1.010	1.015	1.011	1.012	0.004	0.37
	Fin	222	217	221	220	219	220	1.92	0.88
B-15	*Meq*	4.68	4.64	4.65	4.64	4.65	4.65	0.016	0.35
	Mat	0.929	0.924	0.903	0.933	0.930	0.924	0.012	1.31
	Fin	196	195	199	193	194	195	2.30	1.18
C-18	*Meq*	3.52	3.51	3.55	3.55	3.49	3.52	0.026	0.74
	Mat	0.879	0.869	0.883	0.891	0.874	0.879	0.008	0.96
	Fin	144	145	145	144	143	144	0.837	0.58
D-2	*Meq*	3.99	3.89	3.96	3.99	3.94	3.95	0.042	1.05
	Mat	0.978	1.010	1.004	1.014	0.996	1.000	0.014	1.42
	Fin	153	144	149	148	149	149	3.21	2.16
E-2	*Meq*	2.97	2.94	2.98	2.96	2.93	2.96	0.021	0.70
	Mat	0.862	0.854	0.851	0.861	0.845	0.855	0.007	0.83
	Fin	119	118	120	118	118	119	0.894	0.75
F	*Meq*	7.07	7.08	7.10	7.05	7.08	7.08	0.018	0.26
	Mat	1.020	1.027	1.034	1.019	1.026	1.025	0.006	0.59
	Fin	311	310	309	310	310	310	0.707	0.23
G-5	*Meq*	2.59	2.55	2.62	2.59	2.58	2.59	0.025	0.97
	Mat	0.687	0.679	0.678	0.691	0.677	0.682	0.006	0.91
	Fin	122	120	125	121	122	122	1.871	1.53
H-2	*Meq*	6.13	6.09	6.06	6.08	6.01	6.07	0.044	0.72
	Mat	1.030	1.032	1.027	1.028	1.031	1.030	0.002	0.20
	Fin	254	251	250	251	247	251	2.51	1.00
I-11	*Meq*	5.00	4.92	4.93	4.94	4.91	4.94	0.035	0.72
	Mat	0.950	0.948	0.954	0.957	0.933	0.948	0.009	0.98
	Fin	209	205	205	205	208	206	1.95	0.94
K	*Meq*	7.46	7.37	7.47	7.46	7.41	7.43	0.043	0.58
	Mat	1.050	1.022	1.048	1.040	1.030	1.038	0.012	1.15
	Fin	327	329	328	330	330	329	1.30	0.40

Table 5

***Mic* and *MH* for Classical and FMT Results**

		Shirley tests*	FMT tests				Predictions**	
			022-026	027-031	037-041	Mean	Shirley	FMT
A-8	*Mic*	5.57	5.46	5.44	5.43	5.44		
	MH	213	224	223	223	223	221	223
B-15	*Mic*	4.66	4.65	4.64	4.65	4.65		
	MH	167	180	179	180	180	170	181
C-18	*Mic*	3.51	3.53	3.48	3.52	3.51		
	MH	132	127	125	127	126	121	125
D-2	*Mic*	3.99	3.96	3.93	3.95	3.95		
	MH	139	149	147	149	148	139	146
E-2	*Mic*	2.98	2.95	2.94	2.96	2.95		
	MH	109	101	101	102	101	103	100
F	*Mic*	7.10	7.08	7.07	7.08	7.08		
	MH	320	317	316	318	317	328	318
G-5	*Mic*	2.67	2.56	2.57	2.59	2.57		
	MH	83	82	82	83	82	95	83
H-2	*Mic*	6.16	6.08	6.06	6.07	6.07		
	MH	248	259	258	259	259	259	258
I-11	*Mic*	4.97	4.95	4.90	4.94	4.93		
	MH	194	196	193	195	195	186	196
K	*Mic*	7.42	7.45	7.41	7.43	7.43		
	MH	340	342	339	342	341	354	340

* Shirley results averaged over all four deliveries.

** Shirley: $MH = 6.03X^2 - 6.14X + 67.98$, $r = 0.9964$

FMT: $MAT.FIN = 2.07X^2 + 32.09X - 12.68$ $r = 0.9999$

Where *X* is *Mic* or *MEQ* respectively

Table 6

Sample	Identification	Remarks
1	SO68 NRA HAC 668	Hopi Introgression
2	SO57 Pope	Upland
5	CS57 Deltapine 15 Dryland	Upland
8	LU68 Western Stormproof	Upland
12	PH70 Pima S-2	Barbadense
14	SC57 Acala 1028	Barbadense Introgression
15	SO57 DES 1000	Upland
16	SO57 Stoneville 3202	Upland
18	LU57 Blightmaster	Upland
19	SO68 DeRidder	Upland
20	U57 DES 726	Asiatic
21	SC57 Deltapine 15	Upland
22	SO57 A2-47	Asiatic
24	SO68 Ferguson 406	Upland
25	CS57 136B (Irrigated)	Upland
26	U57 Tanguis	Barbadense
27	U57 Lengupa	Barbadense
28	RL57 TH 150-7-1	Triple Hybrid
36	FL58 Earlistaple	Barbadense
39	SO67 Deltatype Webber	Upland
40	SO67 Delfor 9169	Upland
41	SO67 Delfor 531C	Upland

Table 7

Classical Testing of the Knoxville Cottons

	Shirley				Knoxville		
	Mic	***M***	***H***	***MH***	***Mic***	***A***	***D***
1	5.61	1.02	217	221	5.45	364	19
2	4.18	0.85	173	147	4.20	427	24
5	4.14	0.94	177	166	4.06	454	30
8	3.06	0.735	162	119	3.41	510	46
12	3.30	1.01	117	118	3.46	513	32
14	4.16	0.935	174	163	4.05	464	35
15	4.85	0.935	199	186	4.83	416	33
16	4.70	0.93	207	193	4.58	427	31
18	3.07	0.785	167	131	3.84	467	36
19	-	0.94	210	197	5.74	368	29
20	7.19	1.005	338	340	6.18	328	20
21	4.34	0.875	189	165	4.35	442	31
22	6.98	1.015	330	335	6.95	301	16
24	5.36	1.065	195	208	5.25	382	22
25	4.84	0.97	178	173	4.64	405	21
26	5.66	1.03	205	211	5.42	381	27
27	6.11	0.975	242	236	6.80	321	23
28	4.32	0.96	184	177	4.20	423	26
36	3.79	0.87	156	136	3.90	466	37
39	2.95	0.79	148	117	2.86	559	56
40	3.40	0.87	156	136	3.25	521	46
41	3.11	0.82	148	121	3.06	538	48

Table 8

FMT Measurements on ICCS/3 Cottons: Machine 023 vs Machine 010

	MEQ		***MAT***		***FIN***		***MAT.FIN***	
	023	010	023	010	023	010	023	010
A-8	5.46	5.45	0.947	0.98	235	226	223	221
B-15	4.61	4.67	0.924	0.93	194	194	179	180
C-18	3.53	3.55	0.874	0.88	145	145	127	128
D-2	3.97	3.95	0.947	0.97	157	151	149	146
E-2	3.03	3.10	0.840	0.89	124	122	I04	109
F	7.11	7.10	0.971	0.98	328	325	318	319
G-5	2.62	2.63	0.683	0.74	124	115	85	85
H-2	6.08	6.22	1.002	1.06	258	252	259	267
I-11	4.93	4.97	0.933	0.95	209	207	195	197
K	7.40	7.49	0.991	1.02	339	337	336	344
y=a+bx								
a	0.0002		0.0997		-4.629		-1.584	
b	1.0000		0.9222		1.0035		1.019	
r	0.9995		0.9770		0.9991		0.9992	

for 023: $MAT.FIN = 1.89\ MEQ^2 + 33.43\ MEQ - 14.84$

for 010: $MAT.FIN = 2.36\ MEQ^2 + 28.94\ MEQ - 5.50$

Table 9

FMT Measurements on Knoxville Cottons

	MEQ		*MAT*		*FIN*		*MAT.FIN*	
	023	010	023	010	023	010	023	010
1	5.49	5.50	1.115	1.08	205	212	229	229
2	4.24	4.21	0.931	0.94	173	169	161	159
5	4.13	4.10	0.922	0.96	169	162	156	156
8	3.17	3.15	0.736	0.74	147	146	108	108
12	3.43	3.33	0.926	0.97	133	124	123	120
14	4.21	4.21	0.886	0.96	179	167	159	160
15	4.80	4.82	0.921	0.98	204	195	188	191
16	4.71	4.68	0.934	0.97	196	188	183	182
18	3.95	3.95	0.818	0.88	177	166	145	146
19	6.13	6.14	0.962	1.00	269	260	259	260
20	7.25	7.31	0.948	0.97	343	340	325	330
21	4.28	4.28	0.937	0.96	174	170	163	163
22	7.35	7.10	0.948	1.00	349	318	331	318
24	5.29	5.26	1.075	1.07	201	200	216	214
25	4.90	4.80	1.065	1.09	184	176	196	192
26	5.62	5.56	1.030	1.00	227	228	234	228
27	6.20	6.16	1.023	0.99	260	264	266	261
28	4.42	4.31	0.985	0.99	173	167	170	165
36	4.07	3.91	0.916	0.90	167	161	153	145
39	3.00	2.98	0.763	0.76	134	133	102	101
40	3.51	3.47	0.822	0.86	152	144	125	124
41	3.15	3.16	0.830	0.80	132	137	110	110
y=a+bx								
a	-0.004		0.113		3.527		0.715	
b	0.992		0.899		0.955		0.986	
r	0.9985		0.9443		0.9924		0.9982	

for 023: $MAT.FIN = 1.51\ MEQ^2 + 37.21\ MEQ - 23.74$ $r = 0.9998$

for 010: $MAT.FIN = 1.72\ MEQ^2 + 34.92\ MEQ - 17.69$ $r = 0.9997$

Table 10

Fineness and Maturity Derived from Arealometer *A* and *D*

Compared with Classical Test Results

	Maturity			Fineness		Product	
	AP_m	***AM***	***M***	***AH***	***H***	***AM.AH***	***MH***
1	92	1.056	1.02	221	217	233	221
2	88	0.995	0.85	172	173	171	147
5	83	0.934	0.94	163	177	152	166
8	72	0.803	0.735	150	162	120	119
12	81	0.915	1.01	150	117	137	118
14	79	0.887	0.935	165	174	146	163
15	81	0.906	0.935	201	199	182	186
16	82	0.925	0.93	186	207	172	193
18	78	0.877	0.785	165	167	145	131
19	84	0.945	0.94	245	210	232	197
20	91	1.044	1.005	275	338	287	340
21	82	0.925	0.875	174	189	161	165
22	94	1.097	1.015	308	330	338	335
24	89	1.022	1.065	208	195	213	208
25	90	1.033	0.97	183	178	189	173
26	85	0.964	1.03	224	205	216	211
27	88	1.006	0.975	300	242	302	236
28	86	0.975	0.96	179	184	175	177
36	78	0.873	0.87	166	156	145	136
39	65	0.734	0.79	136	148	100	117
40	72	0.803	0.87	144	156	116	136
41	70	0.786	0.82	138	148	108	121
y=a+bx							
a		0.159		29.43		0.428	
b		0.836		0.844		0.959	
r		0.7852		0.8913		0.9289	

Table 11

Causticaire Results on the ICCS/3 Cottons

	Micronaire		Causticaire			
	X	*Xm*	*U*	*T*	*CMI*	*F*
A-8	5.73	6.78	75.3	85.0	88	213
B-15	4.70	5.73	65.3	75.0	87	169
C-18	3.48	4.43	51.5	62.8	82	122
D-2	4.25	4.75	58.3	66.0	88	130
E-2	3.15	4.18	46.0	59.8	77	114
F	6.80	7.65	86.3	93.0	93	252
G-5	2.73	3.40	37.5	50.3	75	87
H-2	5.98	6.95	77.5	88.0	88	229
I-11	5.00	6.63	68.5	83.3	82	210
K	7.40	7.70	90.5	93.0	97	248

Table 12

Causticaire Results on the Knoxville Samples

	Micronaire		**Causticaire**			
	X	***Xm***	***U***	***T***	***CMI***	***F***
1	5.62	7.02	74.3	87.0	85	227
2	4.17	6.20	59.8	79.3	75	197
5	4.05	5.75	58.5	75.0	78	175
8	3.02	3.97	43.5	56.5	77	104
12	3.40	4.20	50.0	60.0	83	111
14	4.20	5.80	60.0	75.5	80	176
15	4.87	7.25	67.5	89.8	75	249
18	3.85	5.90	56.5	77.0	73	188
21	4.27	5.60	61.0	74.0	82	167
24	5.30	6.65	71.0	83.5	85	209
25	4.90	6.50	67.0	82.3	81	206
26	5.50	7.60	73.0	92.5	79	261
27	6.30	7.90	80.0	95.5	84	273
28	4.35	6.17	61.5	79.0	78	193
36	3.85	5.60	56.5	74.0	76	172
39	2.95	5.80	42.5	75.8	56	196
40	3.40	5.20	50.3	90.5	71	161
41	3.20	4.90	47.0	67.3	70	149

Table 13

Pm from M and MAT for the ICCS/3 and Knoxville Cottons via Equation 22

	Shirley P_m	FMT 010 P_m
A-8	87	88
B-15	79	82
C-18	79	78
D-2	85	86
E-2	80	75
F	88	88
G-5	56	62
H-2	89	89
I-11	83	83
K	90	89
1	89	93
2	76	83
5	83	85
8	66	66
12	88	85
14	83	85
15	83	86
18	67	78
21	78	85
24	92	92
25	85	94
26	90	88
27	86	87
28	85	87
36	77	80
39	70	68
40	77	77
41	73	71

Figure 1: ICCS Cottons Tested on Machines 022-026

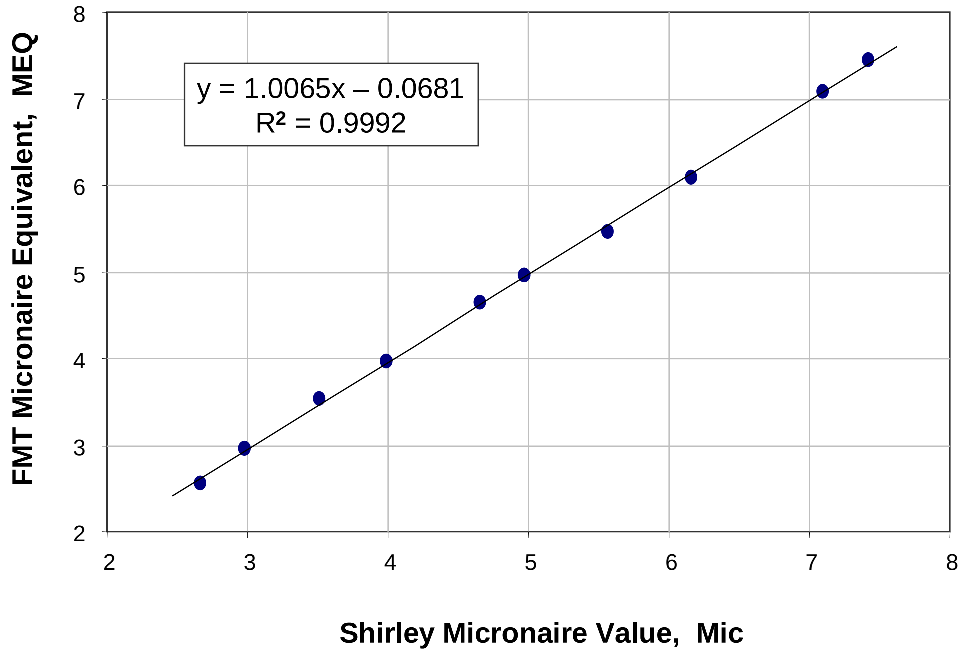

Figure 2: ICCS Cottons Tested on Machines 022-026

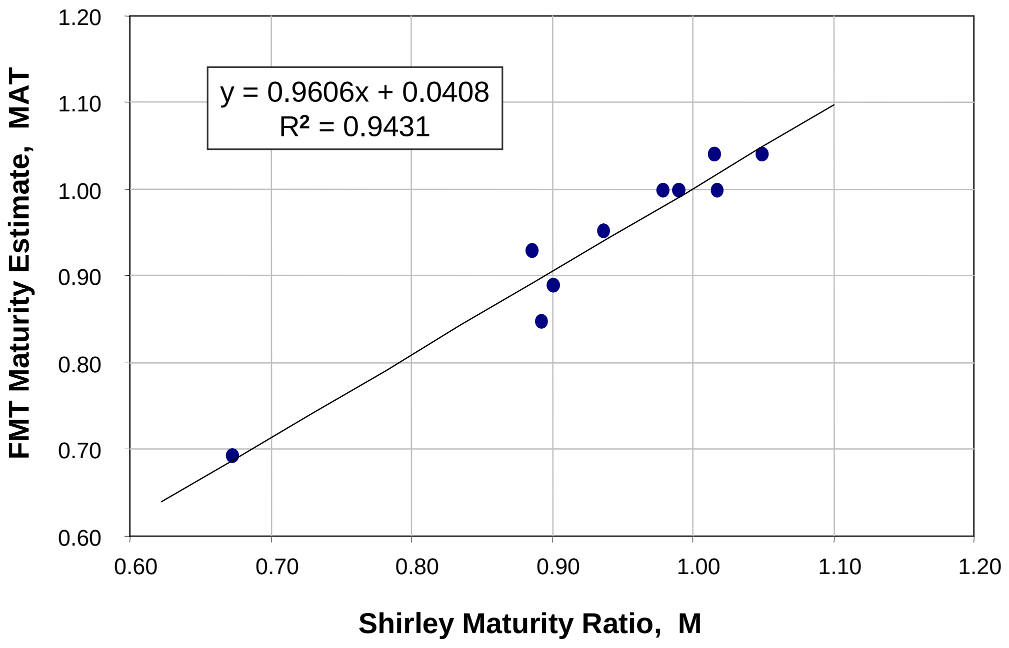

Figure 3: ICCS Cottons Tested on Machines 022-026

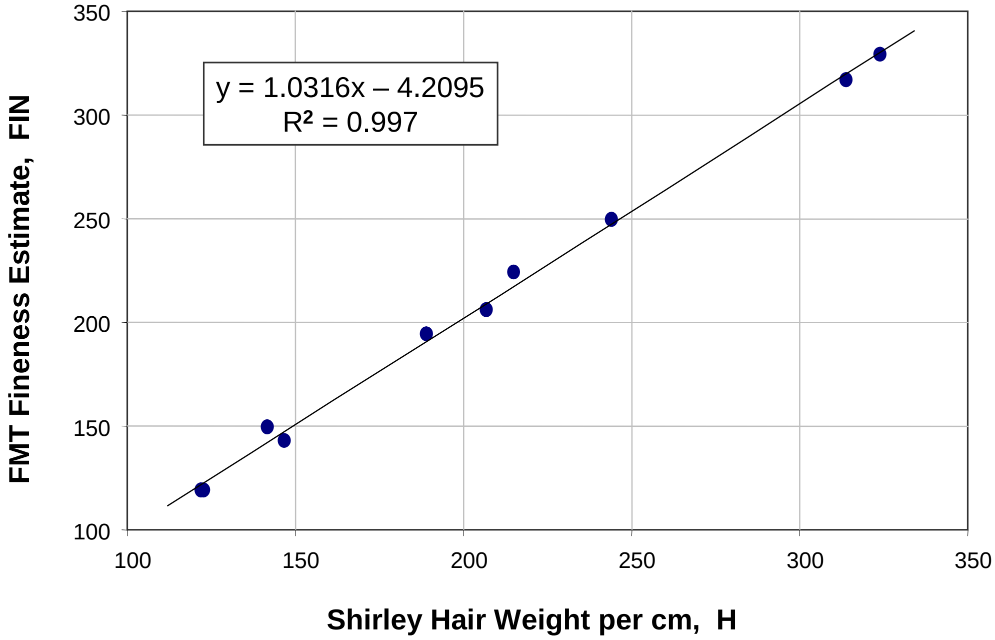

Figure 4: ICCS/2 Cottons Tested by Shirley Institute

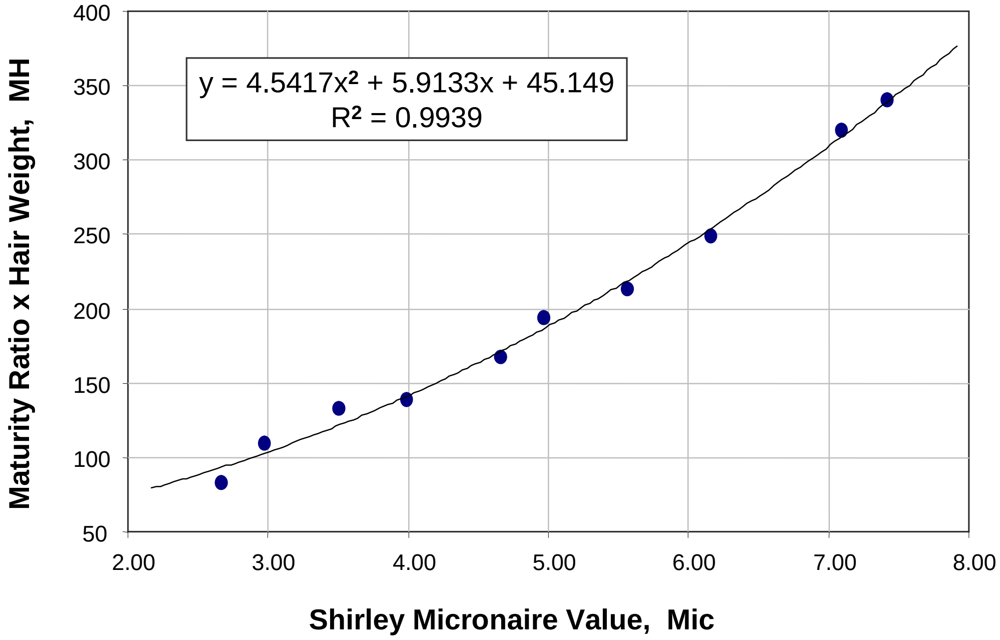

Figure 5: ICCS/2 Cottons Tested by FMT 022-026

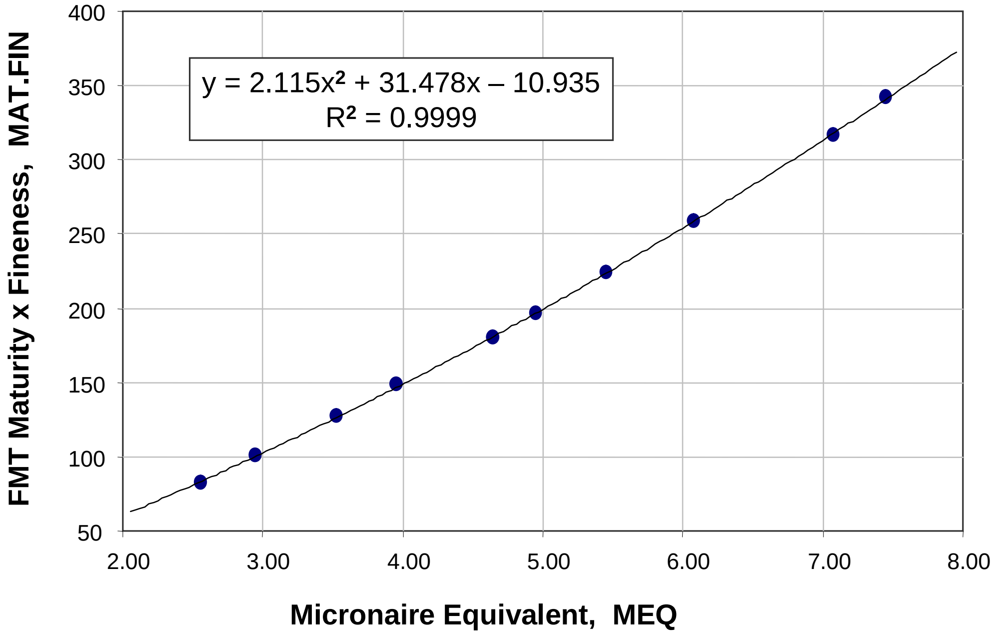

Figure 6: Comparison with Lord's Equation

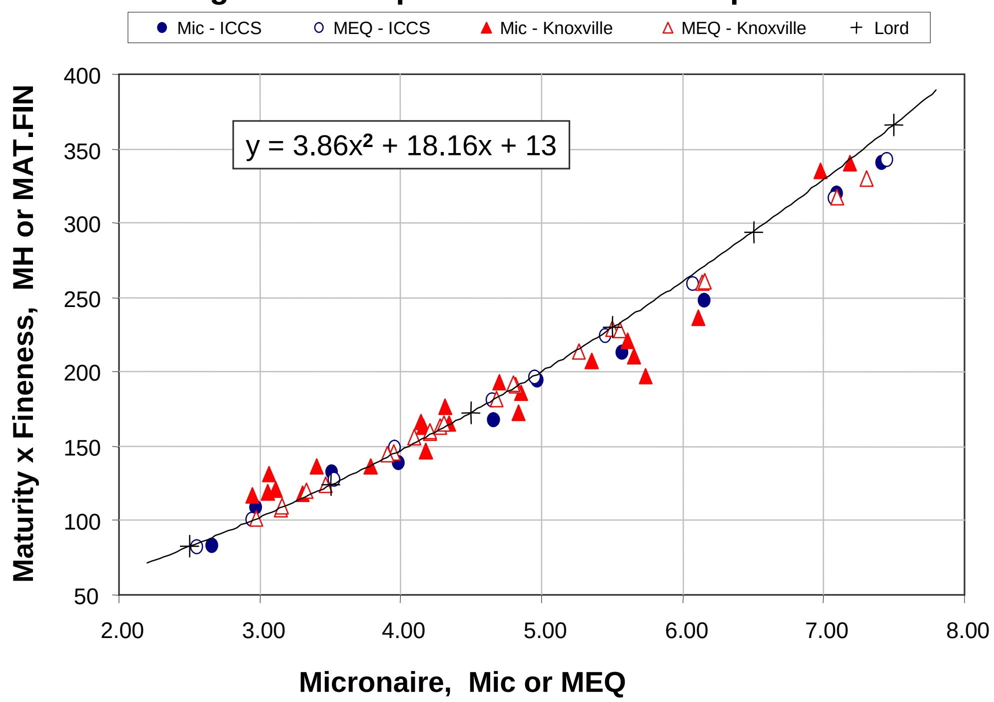

Figure 7: Knoxville Cottons - Mic vs MEQ on Machines 023 and 010

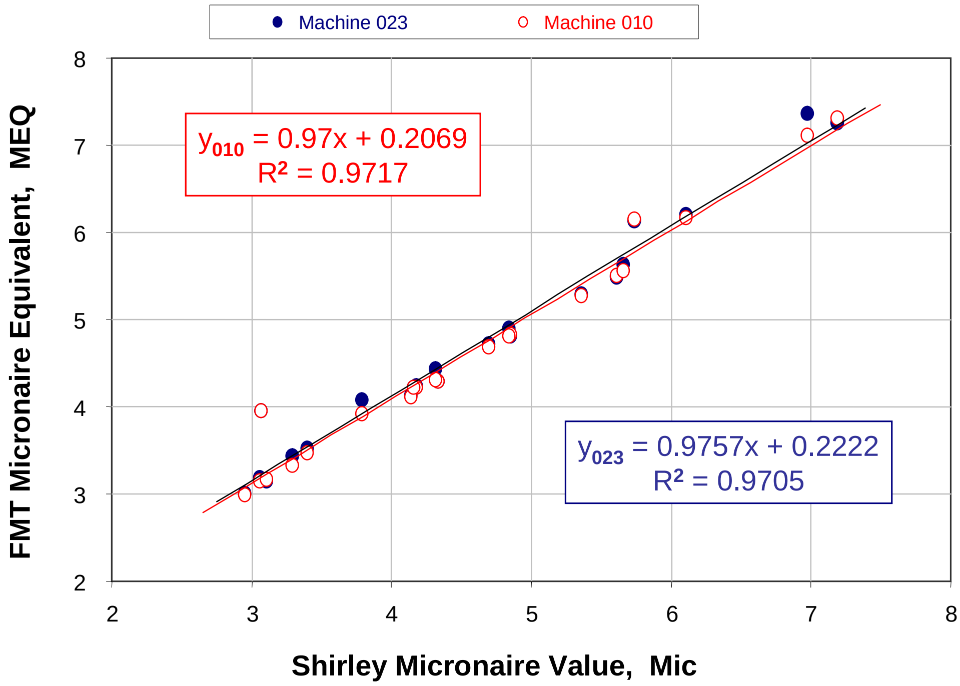

Figure 8: Knoxville Cottons - M vs MAT on Machines 023 and 010

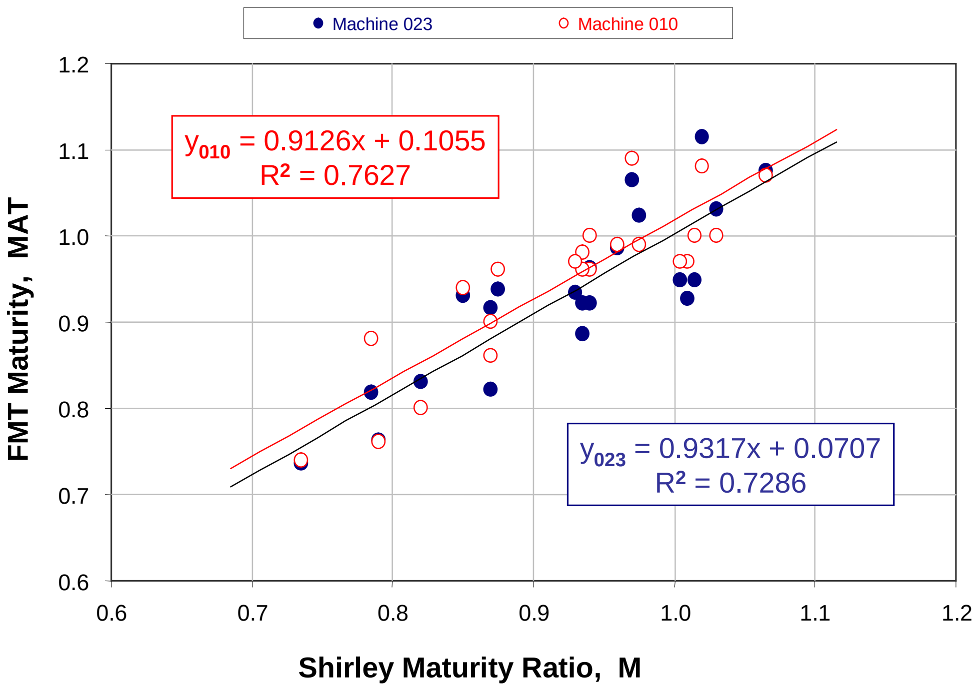

Figure 9: Knoxville Cottons - H vs FIN on Machines 023 and 010

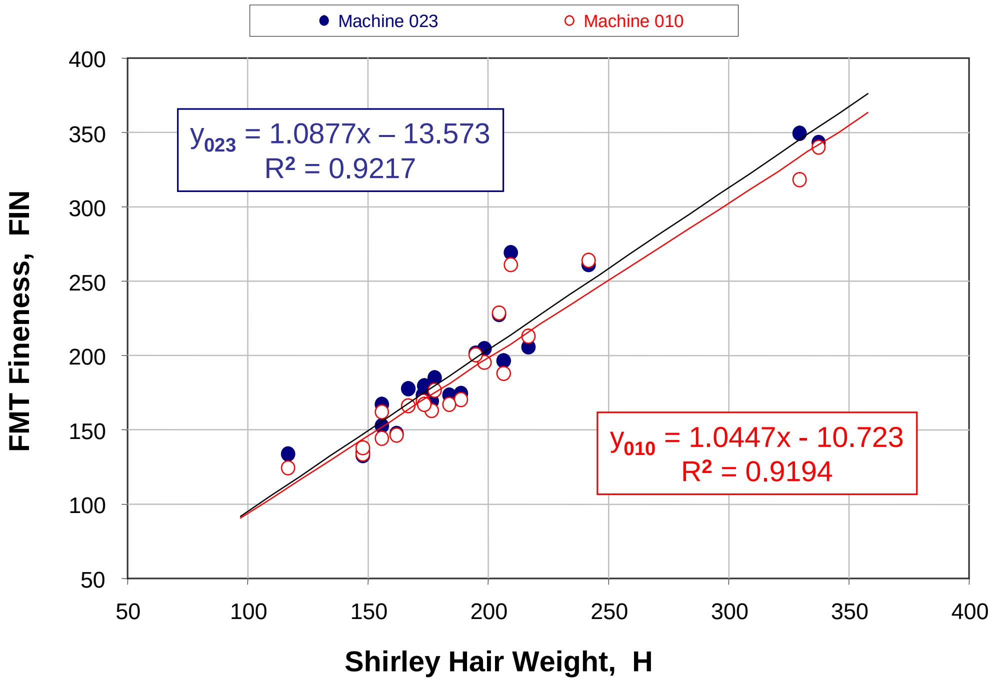

Figure 10: Knoxville Cottons - MH vs MAT.FIN on Machines 023 and 010

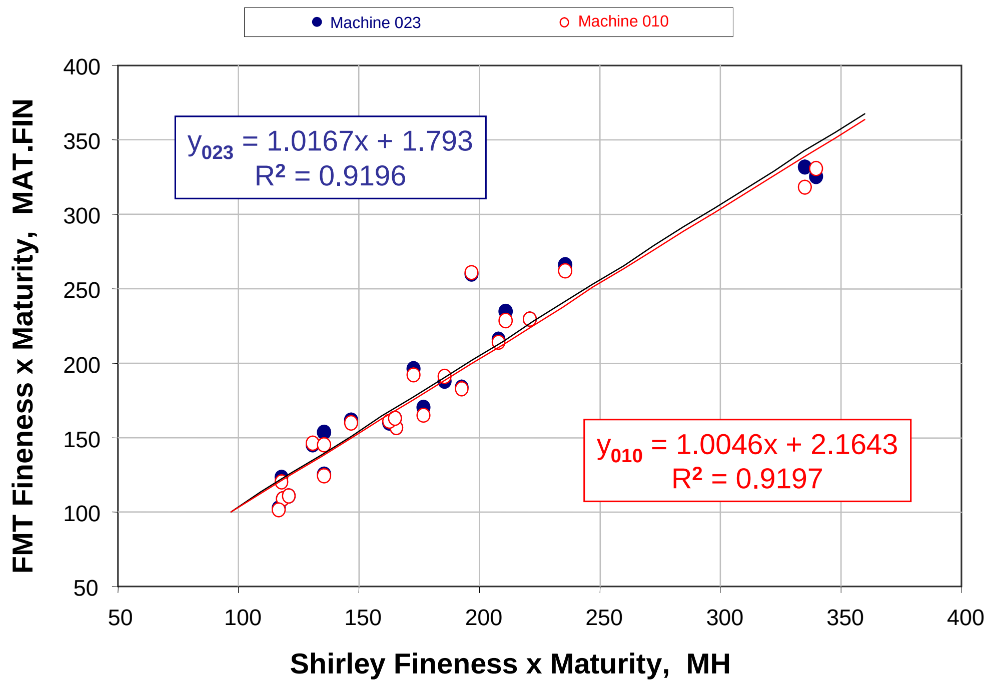

Figure 11: Knoxville Cottons - Maturity vs Arealometer Maturity

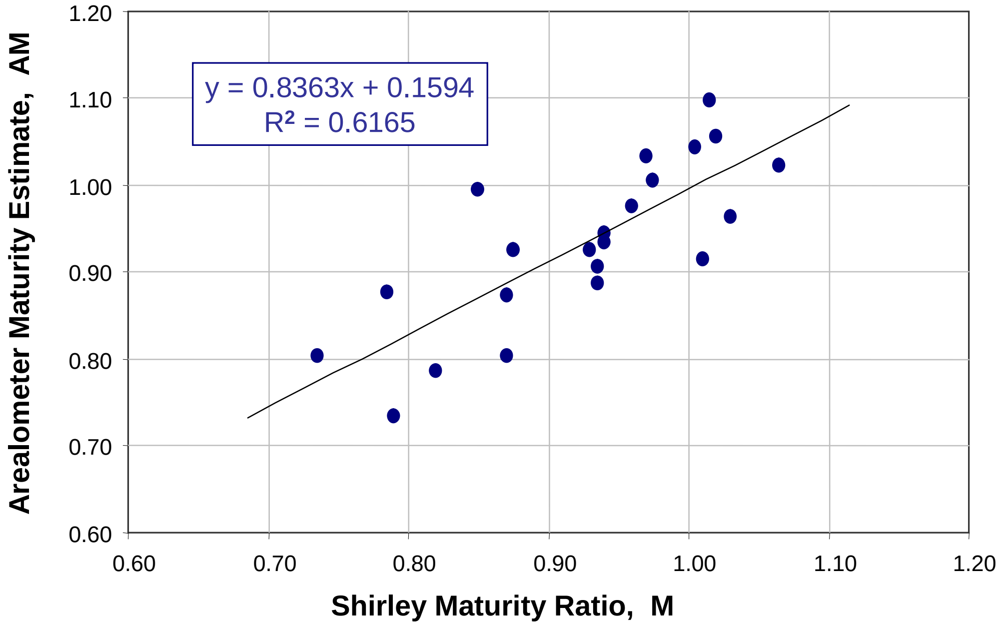

Figure 12: Knoxville Cottons - Hair Weight vs Arealometer Fineness

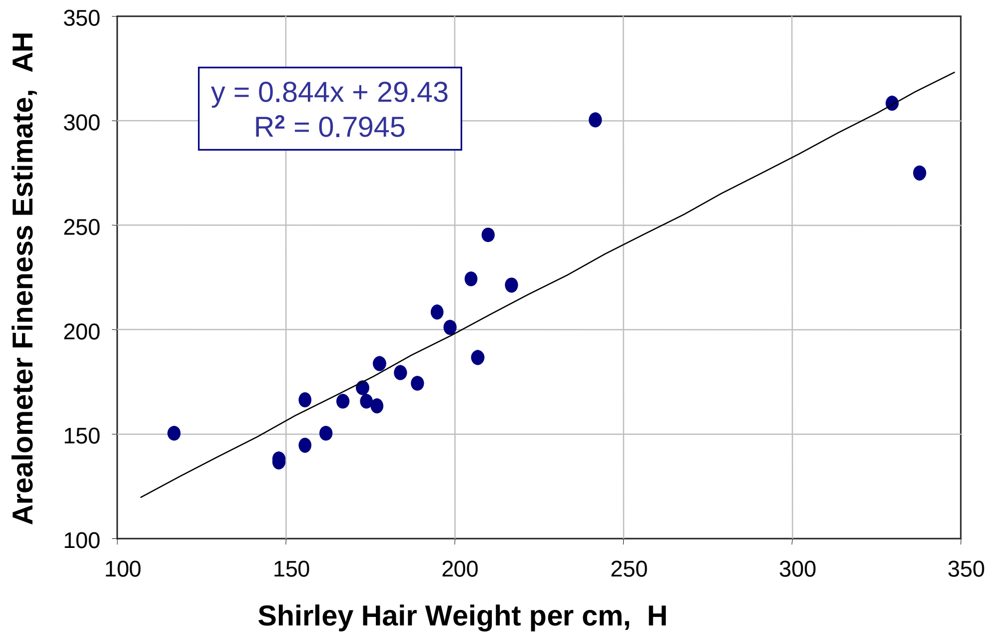

Figure 13: ICCS Cottons Tested at Bolton

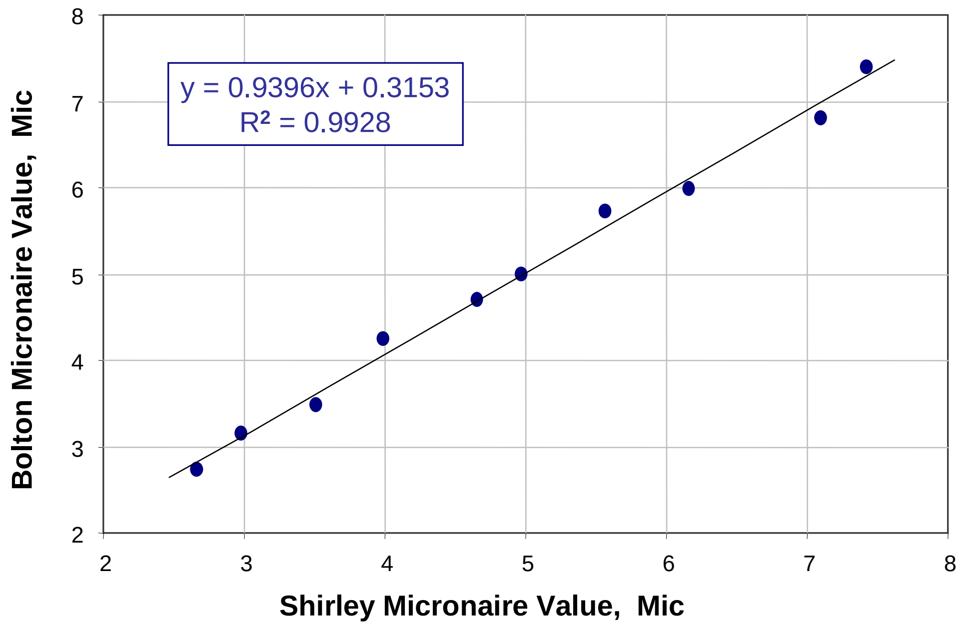

Figure 14: Causticaire vs Classical Test - Maturity

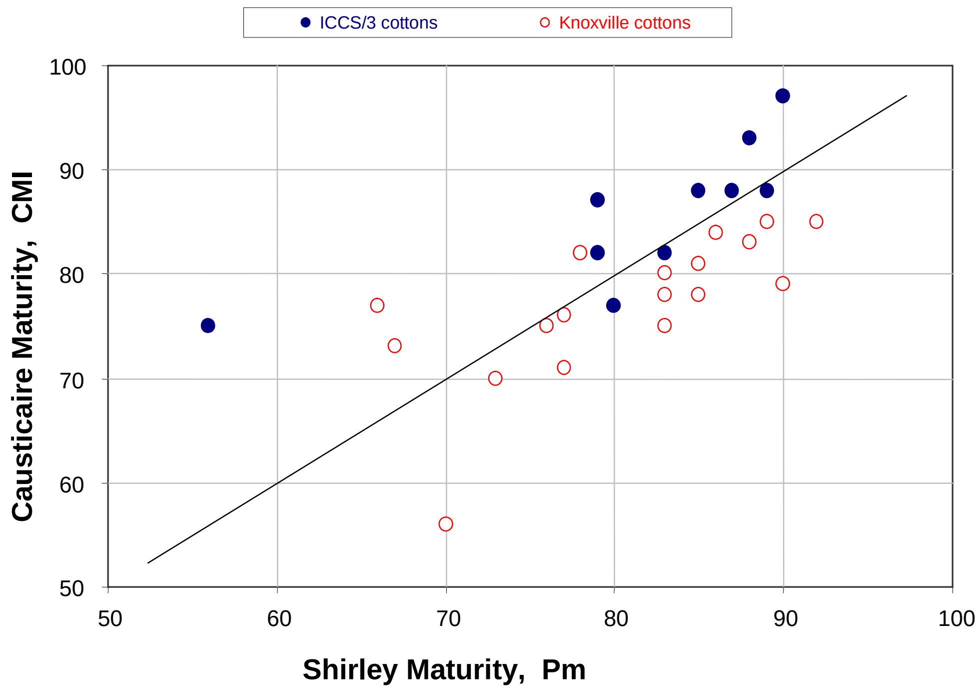

Figure 15: Causticaire vs Classical Test - Fineness

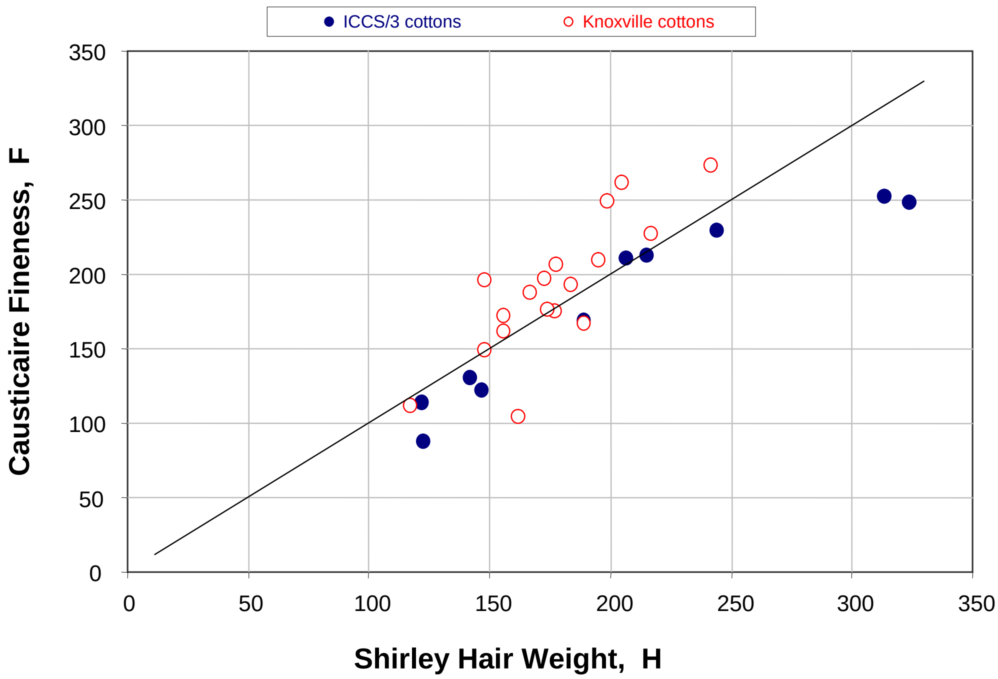

Figure 16: Causticaire vs FMT 010 - Maturity