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# QUALITY CONTROL IN THE TEXTILE INDUSTRY 1/

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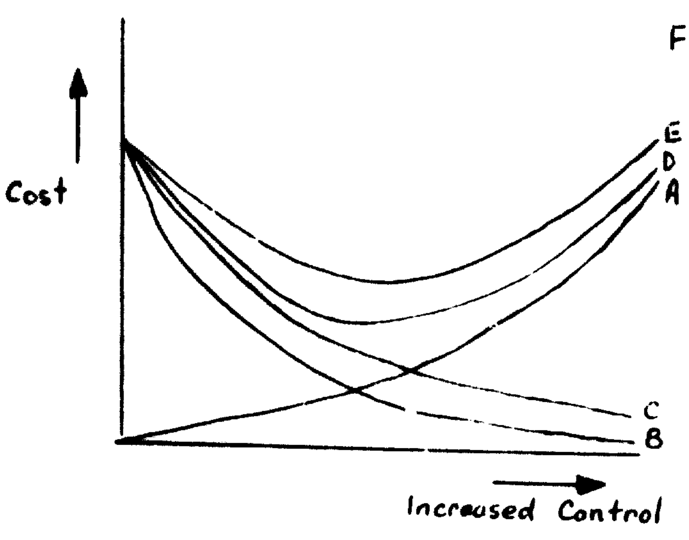
minimum as possible and optimum control will correspond to this minimum (D on figure 1). The optimum represents a compromise since perfect quality is an ideal which is usually not economically worth obtaining.

In practice the achievement of this optimum requires a good costing system which will give a continuous accurate record of the costs of the control scheme and the cost of poor quality. The level of control is varied continuously in the appropriate direction (upwards or downwards) until the minimum is reached. It is worth pointing out here that the presence of poor quality does not necessarily indicate an inadequate control scheme. The optimum position may be where a significant proportion of seconds is being produced e.g. it may be best economically to produce say 10% seconds. It will be necessary, of course, to ensure customer satisfaction by adequately screening the final product before sale, so that these lower quality articles are removed and sold as seconds.

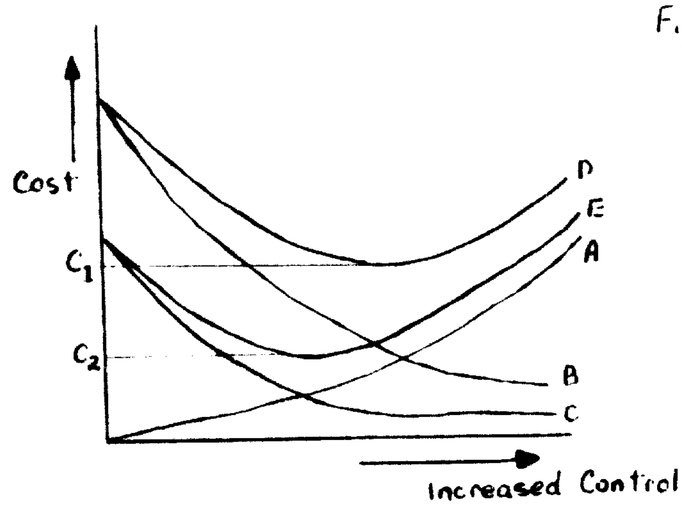
As well as the foregoing type of scheme optimisation, there must also be an effort to gain maximum benefit for a given expenditure on the control scheme. This will mean a careful assessment of the scheme to ensure that the essential testing is carried out whilst unnecessary or superfluous testing is eliminated. The testing scheme must be highly selective in order to obtain maximum benefit, this being particularly so when the added value is low (e.g. knitting) and consequently funds for quality control are limited. Figure 2 indicates diagrammatically the type of effect produced by optimising the control scheme. Curve A is the cost of control whilst B and C are the respective costs of poor quality for an optimum and a non-optimum scheme. The actual costs are indicated by curves D and E, respectively.

Figure 2.



Another factor in the scheme which should be considered is the economics involved in the choice of raw materials, e.g. fibres. Cheaper fibres might give more waste and lead to a lower quality level so that losses may be higher than those for more expensive fibres. Figure 3 indicates the type of effect to be expected where curve A is the cost of control and curves B and C are the respective costs of poor quality for the cheaper and more expensive fibres. The respective actual costs to the mill are indicated by curves D and E.

Figure 3




For the cheaper fibres the optimum scheme will cost $C_1$, whilst for the more expensive fibres the cost will be $C_2$ so that the increased cost for the cheaper fibres will be $C_1 - C_2$. If this difference is smaller than the saving due to the purchase of the cheaper fibres then it will be more economical to use them. It is thus necessary to optimise the choice of fibres to minimise costs.

## 2.2 Obtaining and maintaining optimum processing conditions.

Although there will usually be some guides available for the choice of the raw material and the appropriate processing conditions for a particular product, the conditions for fine control will often differ from mill to mill so that the experience of one mill may not be applicable in another mill. It is thus necessary for each mill to carry out its own experimentation to obtain best conditions. These investigations may be carried out within the general production as well as in separate small scale experiments involving only a small fraction of the processing machinery.

Experiments carried out in general production may be conveniently done using the method of evolutionary operation (EVOP), a special technique for step-by-step improvement of a process until it reaches an optimum level. A series of systematic small changes in levels at which process variables are held is introduced into the daily production, the size of the steps being such that the danger of adverse effects leading to financial loss will be small. After each set of changes the results are reviewed and new changes made, seeking through this evolutionary development to gradually 'nudge' the process into optimum operating levels. Initially it is better to only vary several variables but with experience it may be possible to institute simultaneous changes in a large number of variables. A simple example of the method is where a firm wishes to find the optimum percentage of a cheaper fibre that can be added to a blend without detrimental effects. Suppose, for example, it is known that the use of 15% of this component has no effect. This percentage is then increased in 1% steps until processing is adversely affected. The future level is then set at the highest percentage where satisfactory performance is achieved. Other parameters could be varied to obtain further improvement.

Carefully planned small scale processing experiments where a variety of parameters are altered may be desirable. This is becoming increasingly important in recent times since fashion pressures and the like mean that mills must be prepared for sudden as well as gradual changes in customer demand. In this way the mill should be able to gain experience in newer areas so that changes in production can take place rapidly.

The results of all experiments must be carefully documented so that they may be used as a guide to future production. The behaviour of all lots processed should be carefully recorded noting particularly how the derived conditions stand up in practice and whether changes have been necessary because of processing difficulties. The data from experiments and from previous production in combination will provide the basis for future practice.

The degree to which any particular mill can achieve optimum conditions will vary considerably depending on a wide range of factors including mill size, the degree to which mill production is standardised, lot sizes and the variety produced, types of processes and so on. For example, it would be expected that greater difficulties would be experienced by a small mill producing many small lots in a variety of colours compared with a large mill producing very large all white lots. It will be up to each mill to strive for its own effective optimum conditions.

Previous experience both from experimentation and practice will guide the choice of the processing conditions appropriate for a particular job lot and once these conditions are decided care must be exercised to ensure that these conditions are maintained throughout the processing sequence. Adequate documentation identifying the job and giving processing conditions and other relevant data must be correctly recorded and accompany the lot through processing. At a particular process the relevant processing data must be transferred correctly to the job card or whatever is used to record the data for each machine. The machine must be set up according to these specifications and continuous visual or other checks must be made to ensure that correct conditions are being maintained.

Machine settings if properly adjusted initially should not constitute a problem, but inspection checks must be carried out to ensure that the process is doing what it is supposed to do (e.g. a check on the pattern in weaving). In some processes there will be parameters which can fluctuate or vary with time (e.g. bath temperature, liquor level, pH, chemical concentration and so on) and these variables must be either controlled automatically or checked at intervals depending on the rate at which changes may occur and the relative importance that these changes have in processing. Thus one gives more regular attention to those parameters where large changes can occur in a short period or where even small changes can have a dramatic effect on processing.

2.3 Machine maintenance.

The condition of the available machinery can have a vital bearing on production, quality and waste and hence production costs. To minimise faulty operation and breakdowns it is necessary to implement a comprehensive preventive maintenance scheme. The functions of such a scheme are to:

(i) ensure that machines are regularly cleaned,

(ii) ensure regular lubrication of each machine,

(iii) ensure regular attention to parts where regular replacement or reconditioning is necessary (e.g. lapping on squeeze rollers, roller coverings, blades in slub catchers, parts that require sharpening and so on),

(iv) ensure that the machine is operating correctly (e.g. checking the operation of the various stop motions, builder motions and so on),

(v) ensure that machine settings do not move out of adjustment during operation, and

(vi) ensure that regular inspections are made for worn or broken parts, vibrations, damaged roller surfaces, and so on.

It will be necessary to supply check maintenance and inspection lists for each machine giving the frequency at which each of these functions is to be carried out. Operatives and supervisors should be encouraged to be alert for any unusual operating characteristics so that faults developing between inspections will receive speedy attention. Operatives in particular should be discouraged from making their own adjustments to settings without the supervisor's knowledge. If an adequate scheme is set up and personnel are vigilant, then machinery condition will play only a very small part in the problems encountered.

## 2.4 Operative procedures.

The operator is in direct contact with the material during processing and his or her actions can have a significant effect on productivity, quality and waste. The first parameter to consider is the institution of the best procedures both in staffing and in the duties and operations required of an operative in a particular process. Staffing levels (e.g. machines per operator, spinner patrol cycles) must be established and decisions made as to whether one operator does one job in a sequence or more than one job (e.g. should the same operator do doffing, piecing and creeling within the spinning operation). After jobs have been determined the duties and methods of carrying out these duties for each job must be clearly detailed.

The operative must be taught these procedures being told why the procedures are to be carried out in the designated fashion. This explanation should be geared to the ability of the particular operative to understand the problem and should include knowledge of the importance of this process in the overall production sequence, the consequences of poor quality, excess waste and so on. Operatives must be trained so that production is not achieved at the expense of poor quality and excessive waste. A balanced approach where production, quality and waste get proper attention must be instituted.

The supervisor must continually monitor the work to ensure that the specified procedures are being adhered to correctly. He should be continually alert for deficiencies determining whether these are due to such things as

(i) operative carelessness,

(ii) expecting the operative to do a job outside his or her capabilities,

(iii) poorly defined or ambiguous procedures, or

(iv) some deficiency in the procedures.

It is unlikely that the initially defined procedure will be optimum so that changes will usually be necessary as experience is gained. The mill must be prepared to adopt a flexible approach and experiment with and alter procedures in order to obtain those operating methods which give the best practical results. Psycnological considerations involved in these procedures must be understood and these will be discussed in a later section.

## 2.5 Statistical Quality Control.

### 2.5.1 The testing program.

As well as the foregoing control methods it will be necessary to monitor material characteristics and quality at various control stations throughout the processing sequence. Sufficient checks of objective properties must be made so that the objective and subjective requirements in the final product are met. The first step in this regard should be a thorough systematic analysis of the material properties during the processing sequence. This analysis should include:

(i) A list of all properties which can be assessed or measured during processing,

(ii) The interrelationships between these properties. If a number of properties are related, it may be possible to control all of these by controlling one particular parameter,

(iii) The relative importance of each property on subsequent processing and in the final product. This will include knowledge of the type of variability to be expected, whether large fluctuations are likely and the size of the fluctuation necessary to produce detrimental effects.

(iv) An assessment of the number of measurements required to produce a meaningful result.

(v) The ease and cost of obtaining a meaningful result. This will include a knowledge of the available methods, the instrumentation required, the cost of such instrumentation, the number of people required to take the measurements and so on.

(vi) The time taken to produce meaningful results. The speed at which a result can be produced must be fast enough so that remedial action can be carried out. If the time is excessive then the results may only be useful as a guide in preventing mistakes in future processing.

The aim of the control scheme will be to obtain optimal information with minimum effort. The foregoing data will enable the quality controller to set up a testing scheme giving the control stations the variables to be measured at each control station, the number of measurements required, the frequency of measurement, sampling methods and so on. When the scheme is put into practice it will be necessary to continually review the results so that the scheme can be optimised by changing the frequency of testing of some variables, removing variables from the control scheme, adding others, improving sampling techniques and so on.

2.5.2 The role of statistics.

Although it is sometimes advisable to carry out 100% inspection (e.g. with particular finished products, fabrics, garments, etc.) it is more usual to base decisions on the results of a sample taken from the material. For 100% inspection there is always certainty in any decision made, but as soon as one tests only a fraction of the output of a process any decision based on the test results will have a certain probability of being correct so that there will always be a certain proportion of wrong decisions. It is thus necessary to design procedures so that the chance of making wrong decisions is very small and this design procedure is only possible through the methods of statistics.

Statistical methods are necessary to provide:

(i) Adequate sampling techniques.

A sample should be chosen in a random manner and should be truly representative of the total production. Sampling methods must be such that operator bias and method bias do not occur and that the properties to be measured from the sample are not affected (e.g. by damage in sampling due to carelessness or due to the method involved).

(ii) An adequate sample size for decision making.

In order to determine the appropriate minimum sample size it is necessary first to know the amount of variation to be expected between measurements of the parameter and the accuracy required of the estimate. The accuracy required will depend on the size of the change in value which will have practical significance. If it known, for example, that a 5% change in the value of a parameter will have a detrimental effect, then it will be important to detect this change (when it occurs) most of the time and the sample size must be designed with this fact in mind. Decisions such as action or no action, change or no change, materials are equivalent or different and so on must be made in such a manner that irrespective of the decision made it will have a high probability of being right. The actual value of this probability will depend on the practical consequences resulting from a wrong decision and will be set at a higher value where these consequences have a more detrimental effect.

(iii) A scientifically valid basis for decision making.

Because of intermeasurement fluctuation it is always possible that any variations measured could have been the result of chance fluctuation and not due to any genuine change. Statistical analysis forms the basis for separating real changes from those produced by measurement variability and a large number of statistical tests are available for a wide range of different types of decision situations.

(iv) A basis for deciding whether it is worth measuring particular variables.

The calculation of the approximate sample size needed for meaningful decisions when coupled with the ease, cost and time of measurement will determine whether there is any real value in taking particular measurements.

Standards and control limits must be set up for use in check procedures and these will be obtained on the basis of previous experience and experimentation combined with statistical analysis. Care must be taken that these requirements are flexible and are designed to be compatible with the performance capabilities of the raw materials and the processes used.

2.5.3 Statistical methods.

In order to determine the value of some characteristic (mass per unit length, strength, shrinkage, percentage impurities and so on), it is necessary to take measurements and a series of measurements will yield a distribution of values, the two parameters of interest being the centre of this distribution (i.e. the estimate of the value of the characteristic) and the scatter or spread of the distribution (this is related to the accuracy of the estimate). These latter parameters may be estimated by the arithmetic mean and the standard deviation, respectively. In order to simplify calculations the median and range are often used instead of the above measures.

The most important distribution is the Normal or Gaussian distribution which applies to a wide range of practical situations. Where errors in measurement which may be regarded as accidental have the properties

(i) a number of different independent sources of variation produce the error,

(ii) the effects of each source are independent, and

(iii) individual effects are small compared with the overall effect,

the distribution may be taken as Normal. The Normal distribution has the property that about 95% of all measurements will be within two standard deviations of the mean whilst almost all measurements will be within three standard deviations of the mean. These properties apply to a wide range of distributions including the Binomial and Poisson distributions.

When a series of measurements are made this is in effect taking a random sample of values from the distribution of all possible measurements. When a series of sets of measurements are obtained and a parameter (e.g. the arithmetic mean) is calculated for each set, it will be found that these estimates will not all be the same, a distribution of values being derived. The spread of these values will decrease as the number of measurements increase, the standard deviation of the estimate being inversely proportional to the square root of this number. The accuracy of the estimate can be expressed as a confidence interval e.g. $\theta \pm$ constant X standard deviation of $\theta$, where $\theta$ is the estimate. A reasonable value for the constant for most distributions is 2 and for this value the interval will have about one chance in twenty of not including the true value we are trying to estimate. If we wish to estimate a parameter to a particular accuracy e.g. $\pm$ 0.0001 then knowing the variability between measurements it is possible to calculate the required number of measurements to achieve this accuracy. When the assumption of normality is justified (the average of a number of measurements is approximately normally distributed) exact confidence intervals can be obtained for the mean or difference between two means (using the t distribution), the standard deviation or variance (using the chi-squared distribution) and the ratio of two variances (using the F distribution).

In hypothesis testing the aim is to be able to make decisions like:

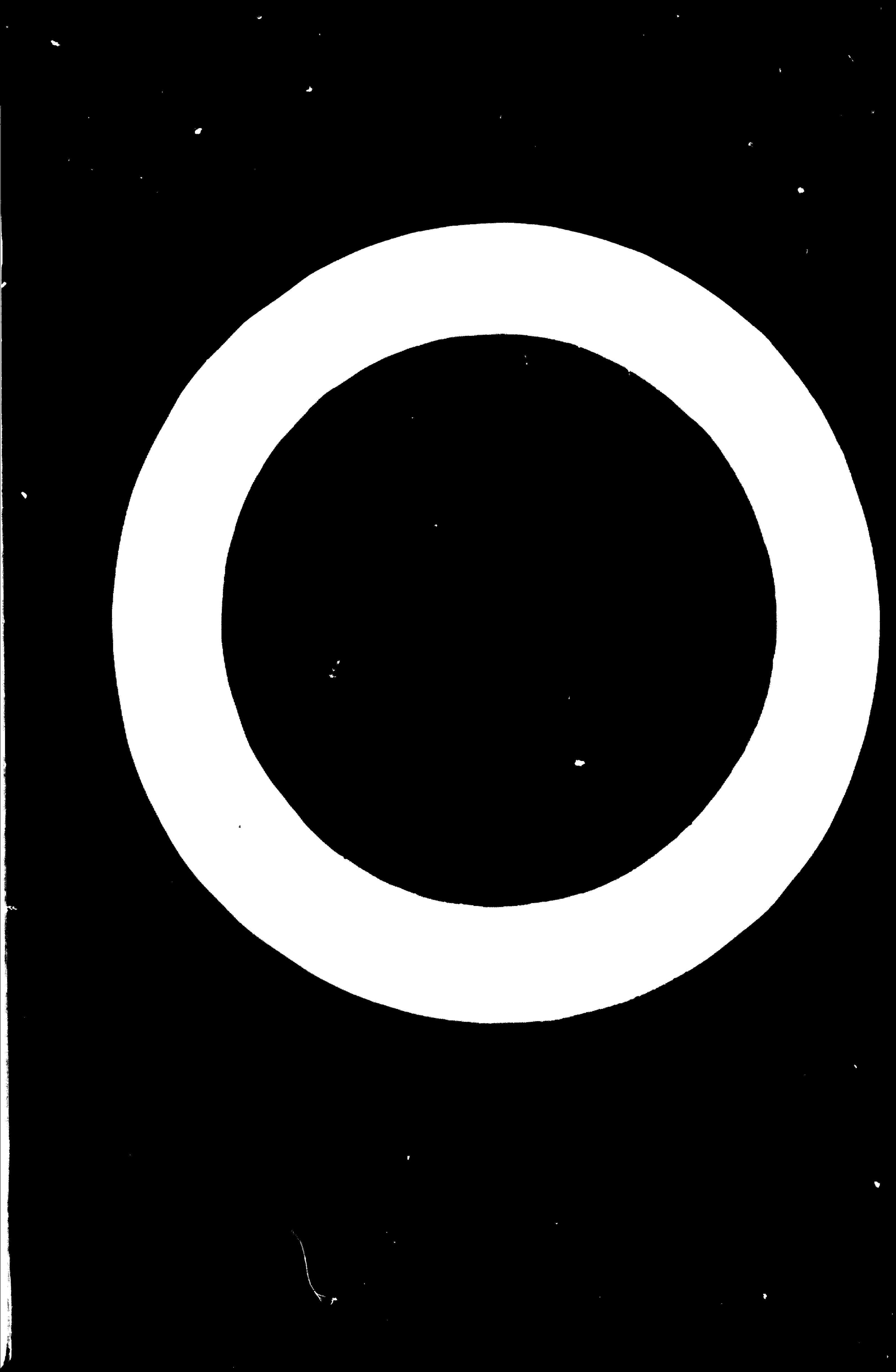
(i) the measured mean is or is not different from some specified value,

(ii) the measured standard deviation is or is not different from some specified value,

(iii) two measured means are the same or different,

(iv) the variances from two samples are the same or different,

and so on. Consider case (i) above, for example. The basic method is to set up the null hypothesis (viz. that the sample mean is equal to some specified value) and test it against some alternative hypothesis (e.g. the average value has increased to some new value). If the null hypothesis is assumed to be true then the distribution of the samplo mean will be known



and hence some upper limit for the sample mean can be set so that it will be unusual to find a value greater than this limit provided the null hypothesis is true. The calculated value is compared with this limit and if it is larger the alternative hypothesis is accepted. If the null hypothesis is true then one wants to make this decision most of the time and the limit is set so that the chance of rejecting the null hypothesis when it is true is small (an error of the first kind). The test, however, is of no use unless it can detect the alternative most of the time when it is true. One therefore designs the test with the required sample size so that the chance of rejecting the alternative when it is true (an error of the second kind) is small.

There are a large number of standard tests available, those where the normality assumption is reasonable including:

(i) testing the value of a single mean or the difference between two means (t tests),

(ii) testing the value of a variance or standard deviation (chi-squared test),

(iii) testing the ratio of two sample variances (F test), and

(iv) comparison of the effect of different levels of one factor or several factors on some characteristic (analysis of variance).

There are a wide variety of other tests which come under the general heading of non-parametric tests since they can be applied irrespective of the type of distribution involved. Correlation methods are also useful in detecting interrelationships between different variables.

Shewart's control charts may be used in regulation control to provide a continuous check on the value of some characteristic. These charts include the value which should be assumed by the parameter and warning and control limits about this value. The warning limits are chosen so that the measured value will be inside these limits most of the time so that a value outside the limits will give a warning of a possible shift in the characteristics value. The control limits are set so that the chance of obtaining a value outside these limits when no change has occurred will be negligibly small. The design of the charts must be such that errors of the second kind are minimised and this entails using the correct sample size (if this is not done a significant proportion of off quality material will be accepted as good). As well as charts based on the mean and standard deviation, charts may be based on the median and range. These latter charts involve little calculation but are less efficient. Cumulative sum charts are useful in indicating trends being more sensitive, quicker to obtain and requiring smaller samples than control charts.

2.6 Waste Control.

The waste problem is quite complex since a large variety of different wasts are produced by a large number of related and unrelated parameters, including raw material variables, processing variables and conditions, operating procedures and operative variables. Waste is often related directly to quality so that maintaining the quality level will minimise waste automatically. Good quality, however, is sometimes only achieved at the expense of extra waste (e.g. combing waste) so a balance between waste and quality is necessary. On many occasions waste and quality are independent so that waste may be treated separately (e.g. starting up and running out wastes in processing). Waste becomes more expensive at later stages in processing and it may be possible to get improvement by a redistribution of waste to earlier processes. In treating the waste problem it is important to take the foregoing into account and hence to consider the problem over the whole processing sequence, rather than in individual units.

The first step in a waste control scheme is to minimise losses incurred by the production of waste and this entails the optimization of the collecting and sale (or reuse) of waste. It is necessary to determine a classification system for waste where separation is based on similarity of properties, value and end-use. The costs of collection, sorting and sale of waste must be balanced against the gains available due to higher sale values to obtain the optimum position.

Waste standards must be set up but it is important that these are realistic. They must be flexible and should be revised regularly (upwards if necessary). Waste should be weighed regularly and the results recorded so that progress can be monitored. Section 2.2 has examined methods of optimising processing and the consideration of waste is an important part of this procedure. Adequate machine maintenance will tend to minimise waste as will the use of correct operating procedures and the training of operators in these methods.

3. Quality Control Organisation.

3.1 The quality control department.

The modern trend is to remove quality control from production management and to make quality control a separate department directly responsible to management. This is to ensure the necessary independence for objective analysis and evaluation and to enable mill management to take the appropriate corrective steps. The organisation must be such as to guarantee smooth co-operation between the quality control and production departments.

The quality control department in its role of testing and evaluating current production and of preparing for future production must set up and co-ordinate the whole control scheme. The duties will include:

(i) Assigning control responsibilities.

Responsibilities for checking, control measurements, collection and weighing of waste and so on must be clearly defined throughout the mill, e.g. the division of responsibilities between the test laboratory and the production staff.

(ii) Setting up and maintaining the testing laboratory.

This laboratory will carry out testing which cannot be carried out in the work place. The laboratory must have the necessary equipment for this testing as well as sufficient qualified staff to carry out the testing procedures. Additional specialised equipment may be required for trouble shooting when production problems arise.

(iii) The appropriate training of mill personnel.

(iv) The provision of an adequate documenting system.

Forms for recording measurements, calculations, summaries of measurement changes with time, control charts and so on must be designed and provided at the relevant points within the mill. The prompt distribution of completed documents must be arranged.

(v) Ensuring that the correct action is taken.

It is necessary to define precisely the checking of measurements against standards, to determine if control is being maintained and the procedures to be applied when control is inadequate (e.g. what action is necessary, who should be told, etc.). This must be co-ordinated in such a way that minimum time between the discovery of faulty operation and corrective action is achieved.

(vi) Assessing the scheme's effectiveness.

The effectiveness of the scheme must be reviewed regularly and changes made where necessary.

3.2 Staffing of the quality control department.

The main problem here is to obtain a suitably qualified person to run the department. This person should have a background and training to enable him to be analytical in his thinking. He must be able to develop good contacts and elicit co-operation and he should have a sense of humour and be able to talk the shop language. There are two ways to secure such a man and these are:

(i) to employ a man already in the company, who knows the personnel and processes but who knows nothing of modern quality control methods. Such a man must be taught these methods and this may involve attending specialised courses and/or the use of consultants,

(ii) to employ a man outside the company who is experienced in quality control methods. Such a man must become acquainted with the shop personnel and processes.

Much depends on the man, but a general observation is that an insider can learn quality control methods quicker than an outsider can acquire knowledge of processes and the confidence of the shop personnel.

A job specification for the quality control engineer might be as follows:

(i) Formal training - a degree in engineering, textile engineering or textile technology - courses in industrial management, engineering economics, methods and procedures, cost accounting and human relations are desirable - specialised training in statistics, quality control and analysis of data would be a distinct advantage.

(ii) Experience - three to five years in the textile industry preferably dealing with trouble shooting, methods work, process engineering or quality control.

(iii) Personal characteristics - proved integrity and the ability to deal smoothly with people - habit of reaching conclusions from facts, not opinions.

(iv) Duties - to organise and run the department along lines discussed in section 3.1.

The control engineer will control a staff whose number and qualifications will depend to a large extent on the particular mill involved. In a large vertical mill it may be necessary to have a separate control engineer responsible for control in the individual departments (e.g. spinning, weaving and finishing) and ultimately responsible to the department head. The testing laboratory may require a manager who may be a physicist, chemist or engineer depending on the type of mill and the testing required (e.g. in dyeing and finishing a chemist would be more appropriate). Separate clerical staff will deal with the paper work and suitable laboratory will be required to carry out the testing function.

## 3.3 The testing laboratory.

A large number of fibre, sliver yarn and fabric tests are affected by moisture so that it is necessary to provide controlled humidity conditions in the testing laboratory. The facilities and equipment provided in the laboratory will depend on the control scheme considered economically appropriate for the particular mill as discussed in previous sections. Where costs limit the equipment available for routine testing and trouble shooting, it may be possible to call on outside agencies for assistance. These agencies (Universities, testing authorities, etc.) are of importance in providing specialised equipment and testing outside the scope of the quality control department.

## 3.4 Training of mill personnel.

Mill personnel at all levels must be taught the principles of quality control, the explanation being geared to the level within the mill. Top management must be acquainted with the gains to be had from an efficient control scheme as well as the general methods of control. In order to keep management on side it will be necessary to demonstrate the advantages in real money terms that they understand. Very few top officials wish to incur expenses for scientific ways merely because these ways are demonstrably scientific.

In teaching supervisors what quality control means it is more important to teach principles rather than the mathematical theory behind these principles. The emphasis will be on using a new tool for solving old problems. There should be an understanding of process capabilities, the nature of variation, controlled and uncontrolled variation, averages, dispersions, the control chart and sampling. It will be useful to indicate how some practical problems have been solved. The solution of actual problems by the supervisors will be a major help in the training program and it is important that the training not get ahead of practical problem solving.

Training of operatives is best carried out on the job by the respective supervisor. The training should be geared to the workers' ability to understand the problem and should include an explanation of the position of their process in the overall processing sequence, how to recognise poor quality and the effect of this on later processing.

3.5 Psychological aspects.

There is usually more than one way to achieve the desired results and the human element is often the most significant factor. It is dangerous to consider this latter element as being less important in a more automated industry since people still play the major role in decision making. Quality control depends on the decisions of personnel at all levels from top management down.

In every task there is always the possibility of human error and it is important to understand how the person's behaviour pattern affects the production of errors and how the behaviour pattern can be changed to minimise errors. The performance depends to a large extent on the physical environment, the information on tasks given to the employee and the degree to which the employee identifies with the organisation's goals. It is wrong to assume that most human performance properties related to quality can be cured by improved motivation since it may be that motivation is in the wrong direction (e.g. production at the expense of quality).

Crash programs to improve attitudes and motivation tend to be limited and transitory and programs involving better screening, selection and training of employees often do not have the desired impact. More permanent improvement may be had by developing and evaluating new equipment, materials, techniques, operator aids, etc., the improvement being brought about by changes in the job itself.

There is often confusion as to what constitutes acceptable and unacceptable quality and when quality is borderline this employee confusion is particularly apparent. It is essential that standards are set which clearly define limits for acceptability and that these standards are communicated to the operator.

In employee selection, tests should be used to gauge the employee's potential and ability to do the job whilst a personal interview can determine his or her drive and ambition. The employee should be trained so as to feel part of the company and he should understand his place in the processing sequence. It is important to emphasise the [illegible]t methods for quality rather than methods for speed and quantity. Records of his progress should be kept and regularly reviewed with him. Proper training and supervision will result in reduced labour turnover, reduce absenteeism, better morale, increase production and improved quality.

When quality falls below standard, before blaming the operator, the supervisor should determine if the proper tools were available, if the instructions were correct, was the employee trained properly, was the product correct when it reached the work station, etc. A systematic approach to problem solving should be employed, viz. identify the problem, pinpoint the cause, determine the solution, take the necessary action and follow up to check that the correction has been made.

The quality controller must be aware of the ability, sensory perception, agility and motivation of the employee, whether the quality performance level is realistic, whether the right equipment is available (e.g. lighting, space) and the consequences of off-standard quality. The quality control organiser must ensure that the skills to achieve acceptable quality coincide with the employee skills, that auxiliary aids are available, that the right information and standards are provided, that suitable control personnel are selected and that quality awareness is developed.

It is management's duty to establish an atmosphere of quality awareness whilst the operators are in direct contact with the process and the quality performance. The supervisor is the middle man responsible for ensuring quality production at each process and implementing any changes necessary. His role is to work through people towards company goals and objectives.

The transition away from crafts has meant that the role of experience is less important. If the skills are adequately taught then experience becomes less of a factor in determining quality. The employee must have the desire to learn and be prepared to build on present skills and management must inform him of his progress.

It is important to examine the job and assign responsibility fairly. It may be possible to resolve a quality problem by changing the job especially where the job role is monitoring rather than causitive. Effective supervision automatically leads to high motivation levels in the subordinates. Employees must be given a sense of responsibility, a sense of achievement and a means to challenge himself to improve his performance.

## 4. Quality Control in Spinning.

### 4.1 Control of fibre raw materials.

In the choice of fibre raw materials, it is necessary to decide on the minimum fibre property requirements necessary in the particular end product. Fibres are selected so as to meet these requirements and losses will result if either inferior fibres are used or if fibres are too good for the proposed application (these fibres will be more expensive to buy). It is important to base prices paid for fibres on the clean fibre yield so that accurate knowledge of moisture contents and the amounts of impurities or additives is necessary.

Various fibre parameters are of significance in processing and end-use and fibres with the required properties must be purchased and processing must be adjusted to adequately accommodate these properties. Finer fibres can be spun to finer counts, give more uniform, stronger yarns for the same count with less processing difficulty. They impart greater flexibility and softness to the assembly, give lower abrasion resistance, increase the heat insulation and are more liable to nep formation. Fibre diameter is also important in dyeing behaviour. Fibre length affects the choice and adjustment of machinery and is particularly important in producing uniform strong yarns with less ends down in spinning from low staple length fibres such as cotton. Length affects yarn compactness, smoothness and hairiness. Length variability is important and there is usually an optimum amount of variability for best processing. Length diameter relationships are of significance in blends where migration behaviour can affect the yarn properties.

The mechanical behaviour of the fibres affects processing and the mechanical behaviour of the end product, strength and strength variability being particularly important in determining the amount of fibre breakage. Fibre crimp is responsible for increased bulk and softness in yarns and fabrics and can affect the spinning process. Fibre immaturity in cotton leads to inferior spinning performance and lower quality yarns and fabrics. Colour is important since the presence of discoloration has a detrimental effect on dyeing. Foreign matter must be removed and difficulties increase as the proportion of this material increases. Fibre entanglement and fibre damage also reduce the value of the fibre to the spinner.

Classification by grading attempts to classify fibres according to the most important properties from a processing and end-use point of view. Cotton is assessed according to length, colcur, grade (impurities present), preparation and character. Wools are classified by breed, type, quality number and grade and the yield is assessed. This subjective assessment has a number of disadvantages (e.g. variation from country to country, inter-classer variability, the drift of assessments with time) so that objective measurement methods are necessary.

Fibre length may be measured by measuring each fibre or by sorting techniques but these are very slow and for control purposes tuft methods (such as the fibrograph, WIRA and almeter) are preferred. Fineness can be determined gravimetrically, microscopically, using air-flow methods, vibroscopically, using particle sizecounting and by several other techniques, air-flow methods being the most appropriate for control use. Cotton fibre maturity may be estimated microscopically, but the best method for control purposes is using air-flow (the arealometer). Bundle strength tests are common and colour can be measured using a colorimeter. The trash content of cotton is determined using the Shirley Analyser whilst the wool yield is derived by scouring, drying and removing the vegetable matter by dissolving the wool in caustic soda or by using a modified Shirley Analyser.

In order to determine a particular property, correct sampling techniques are required. A representative sample is obtained by taking a number of samples at random over the material volume. If sampling is to take place from only some of the bales within a lot then those to be sampled must be randomly chosen and a convenient method is to use random number tables. Within bales it is important to spread samples over the whole volume. In selecting samples method bias and individual bias must be eliminated. When the combined sub-samples give too large a sample, the zoning technique may be used to reduce the sample size.

The design of the sampling scheme must be such as to ensure sufficient accuracy in the estimate. When sampling from a number of bales the optimum numbers of samples within bales and bales tested will depend on the variabilities within and between bales and the costs involved in the sampling. In zoning sampling the estimate error will be reduced by testing more fibres from more zones.

Quality control assists in the selection of fibres, the verification of fibre properties, the selection of the appropriate processing sequence and the blending of fibres. In order to determine the fibres to buy it is necessary to carry out experimentation along the lines discussed in section 2.2.

The testing scheme will be affected by a number of different parameters. High cost raw materials and the associated higher quality end products will justify a more comprehensive scheme whilst if the added value is low the scheme will have to be restricted. The available data on the fibres and the reliability of this data will also affect the size of the scheme. The parameters tested will depend on the type of fibre, e.g. wool, cotton, etc. The availability of a suitable low cost and rapid test method

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will influence the chosen scheme. The relative cost of a scheme will depend on the test volume and hence the mill size. The presence of a centralised testing laboratory will be of assistance, particularly in developing countries.

Future developments are likely to be towards presenting the buyer with a 'guaranteed' product where objective test measurements are available. There are automatic test lines for cotton and similar lines are planned for wool. The object will be to have the characteristics of each bale (or group of bales) measured and stamped on the bales before sale. The fibre user will derive considerable benefit from such a service since the need for further testing will be greatly reduced and the available data will allow more accurate purchasing and optimum use of the raw materials selected.

4.2 Control in cotton spinning

The aim in spinning is to produce a yarn of specified count and required quality at the lowest price, adequate quality being necessary to ensure that the product performs well in subsequent processes and that the final end product is acceptable. This quality is determined by the yarn uniformity, tensile strength, elongation, etc. and freedom from imperfections, the relative importance of these factors depending on subsequent processes and the final product.

Count and count uniformity are basic characteristics since yarn is designated by count and count and its uniformity affect strength and strength variability, the performance in later processes and the fabric appearance. One of the prime functions in spinning is the control of count and its variability. Measurement of these factors is based on average weight and variability of weight per unit length. The so-called B (L) curve which gives a description of the overall irregularity is obtained by plotting the coefficient of variation of weight for different lengths of yarn against length. In practice, the variability for short lengths is found with capacitance evenness testers whilst long term variability (100 metre lengths) is found by weighing. These variabilities represent the extremes of the B (L) curve and if these are kept low then this will tend to keep the whole curve at lower variability values. Overall control consists of maintaining the average count as specified, ensuring that the count variation (short term and long term) is satisfactory and minimising thin spots, thick spots and neps.

In the control of within and between bobbin variation it is first necessary to examine the processes to eliminate the causes of increase in these variations. Processes up to and including carding have little effect on within boobin count variation. The most important single cause of this latter variability is defective drawframe drafting due to such things as rollerslippage and excessive web or creel draft. Improper regulation of bobbin speeds in fly frames can lead to irregular stretching and where a trend in the amount of stretch is found, this will significantly affect within bobbin variability. In ring frames the stretch between the creel and the back roller, irregular movement in self-weighted top rollers and within doff tension variations on the spindle affect the irregularity.

Between bobbin uniformity may be improved by regular control of blow room weights, by ensuring waste levels and drafts in carding and combing are kept constant, by maintaining draft uniformity in drawing and roving, by avoiding trends in the hank of intermediate over the bobbin, by correct use of back and front row bobbins in creeling and by keeping ring frame draft constants identical.

After attending to the above points and reducing the variation within and between bobbins, it is necessary to maintain minimum levels by routine wrappings. Here the important aspects to consider are where to test, how often to test and how many tests to make and accurate humidity control is essential to ensure meaningful results.

Yarn uniformity is measured as U% or CV% and the measured values are compared with norms (from intermill surveys or past performance) to see if action is necessary. The set of norms supplied by Uster are a result of international surveys and these may not be applicable in developing countries where higher values will usually be found due to raw material differences and lower levels of sophistication of the machinery.

Yarn irregularity is either random, periodic or quasi-periodic. Random variation is always present and there is a minimum possible irregularity depending on fibre fineness and yarn count. Periodic fluctuations may arise whenever roller speeds vary or nipping positions move and these may be produced by such things as roller eccentricity, roller vibration and roller slippage. A yarn may have an acceptable U% but be ruled out because of periodic variation which produces barriness in the fabric. The wave-length which gives information on the origin and thus the cure of the fault determines the type of fabric defect produced whilst the amplitude is related to the seriousness of the fabric defect. Periodic variation may be detected by wrapping on a blackboard (only for a limited wavelength range) or using the spectrogram attachment for the Uster evenness tester. Quasi-periodic variation (amplitude and wavelength varies) is usually a result of faulty fibre control in ring frame drafting and such drafting waves may be minimised by better fibre control.

The fibre raw material may have a large effect on yarn irregularity and the choice of the cotton to be used depends on the end-use and the money received for the end product. Inferior cotton may be used where labour is cheap (developing countries) since high end break rates may be tolerated. The level of sophistication of machinery is most important in the ring frame, to a certain extent in the fly frame and of marginal importance in the drawframe when yarn irregularity is considered. Processing parameters which affect yarn irregularities are such things as room humidity, production rates and settings in carding, the level of waste and production rates in combing and fly and ring frame drafts. Machinery condition is another important determining factor.

Imperfections (leading to poor yarn and fabric appearance and process difficulties (e.g. in knitting) may be detected by the Uster imperfection detector. Fibre parameters such as length uniformity (more short fibres lead to more thick and thin spots), the presence of immature fibres (neps) and the trash content (counted as neps) and various processing parameters affect the number of imperfections.

Poor performance (in terms of yarn irregularity and imperfections) is often due to processing parameters and machine conditions and it is essential to carry out regular routine checks of processing parameters and to inspect and maintain the machines correctly. These checks will often detect or prevent a defect long before it is detected by measurement.

## 4.3 Control in Worsted Spinning.

### 4.3.1 General.

Developments in worsted spinning have led to shorter processing sequences and, as a consequence of this, more highly trained technicians are required to exercise control and evaluate the raw material through to the final product. Productivity has increased due to faster machine operation and more vigilance is required to prevent faulty operation. Systematic testing is required to establish standards and limits of tolerance and it is important that all testing should be carried out at controlled temperature and humidity. In setting these standards it should be noted that only a limited regularity can be achieved in practice and that standards must not be too rigid being compatible with the machinery, processes and fibre raw materials.

Worsted quality control is usually at the top, roving and yarn stages. Assessments which were once the sphere of the skilled classer are now based more on accurate objective measurements. It is common to buy tops by diameter (microns), length (m.m.) and C.V. of length and short and long term variation and mean strength and its variability of yarns are often specified. Machine makers often now specify fibre parameter limits for the operation of their machines.

Control at the top stage involves checks on fibre fineness (the dominant factor), fibre length, nep and vegetable matter and the regularity of weight per unit length. Colour and crimp may be examined visually. Fibre fineness (the deciding factor in manufacturing possibilities and in the value of the finished product) may be measured microscopically using the projection microscope or by the air-flow method, this latter method giving quick results so that it is preferred for routine testing. Fibre length is important since it affects end-use, conversion costs and the character of the yarn and the fabric. Originally the comb sorter was used to obtain the barbe and hauteur but modern developments have led to very rapid and automatic electronic instruments which yield the same quantities.

The amount of neps and pieces of vegetable matter may be obtained by counting within known weights of fibres, 1 nep per gram of fibre often being taken as the standard by mills. Improvement, however, may be had by basing the standard on the fibre length being examined. The main weight per unit length variation for tops occurs as differences between the inside and outside of balls and when this occurs it is more prevalent in large balls and can be minimised by the use of smaller balls.

Sliver and yarn irregularity measurement (by electronic capacitance testers) is necessary as a control measure to ensure that the various processes are working correctly. The modern trend towards reduced doublings has meant there is more chance of an accident (previously corrected by doublings) and hence more frequent (daily) inspection of rovings and yarn is necessary. The index of irregularity, the ratio of the actual C.V. of irregularity to the limiting C.V. of irregularity, is a useful method of assessing rovings and yarns. Experience indicates that this index should be less than 2 for rovings to give reasonable end breakage rates in spinning but a decrease much below 2 does not give any practical advantage. Capacitance evenness testers give the short term non-uniformity and the variability between 100 metre lengths is measured. Here the C.V. of weight between 100 metre lengths should not exceed 2 to 3% (4 to 5% C.V. will lead to bars in woven or knitted fabrics). Control charts may be used in this count control (100 metre lengths).

Yarn tensile strength analysis may be carried out using an automatic dynamometer which yields the average breaking load, the minimum breaking load, the C.V. of breaking load as well as information on yarn extensibility. The effectiveness of the twisting process should be tested regularly by measuring twist and its variability. Slub and impurity control is important and a count of fault types picked up in clearing can be useful in reducing future faults.

#### 4.3.2 The causes and control of waste.

The production of waste represents a signifioant factor in spinning economics and the problem is becoming increasingly important because of the larger relative costs of raw material and labour, the larger capital investment in machinery (requiring higher operating efficiencies) and competition from other firms (improved efficiencies are required in order to compete effectively). The constant changes in production due to such factors as fashion have also highlighted the waste problem. The cost of producing waste depends on a number of factors including the raw material cost, processing cost, handling cost, the reduction in efficiency, the loss in selling profit and the reprocessing cost or sale value. Losses are greater for later stages in production so there is more to be gained by reducing waste in later processes.

The study of the factors which affect waste production is complex since a large variety of wastes with differing properties are produced by a large number of related and unrelated causes. The problem is accentuated by the fact that the amount of waste may increase as the quality increases or decreases or be completely independent of quality.

Raw material variables can affect the amount of waste produced, fibre diameter being the major factor since for the same count less waste will result when finer fibres are used. An increase in fibre length (up to a certain point) will reduce waste whilst length variability is important since low variabilities (square tops) are hard to spin and high variabilities lead to more fly waste (due to short fibres). Stronger fibres resist breakage and hence result in less waste whilst specific weaknesses such as staple tenderness and tip weathering damage lead to increased waste.

Preliminary processing produces considerable fibre breakage and hence fibre waste. Significant factors in such breakage are fibre entanglement, damage and residual grease content in scouring, hook formation, machine settings, lubrication and fibre regain in carding and lubrication and fibre regain in combing. Top dyeing, backwashing and the use of blends with man-made fibres all introduce waste problems.

The room relative humidity and the fibre regain must be maintained at optimum values (depending on the system) in order to minimise waste; low humidity conditions give static problems whilst under high humidity conditions fibres tend to stick to the drafting rollers. Oil and anti-static agents reduce the need for accurate relative humidity control, the optimum amounts depending on the system and whether blending with synthetics. Ambient condition fluctuations can be large and the automatic control of temperature and humidity may result in worthwhile (economically) savings in the cost of anti-static agents.

In processing drafts and doubling affect waste, higher drafts requiring better fibre control to avoid excessive waste. Ratch settings and roving twist influence fibre breakage and hence waste. The problem of fly waste is becoming more important because it accumulates much more rapidly with modern high speed machinery. In spinning factors such as twist, draft, roving irregularity, winding angle and spindle speed all affect end breakage and thus thread waste. Modern machinery produces significantly less waste than older machinery and machinery condition can also be of significance.

When the operatives are considered it is found that excess waste may be a combination of inefficient operating procedures, inadequate training, poor supervision, lack of operator skill and/or operator carelessness. In spinning the amount of thread waste and waste due to faulty packages is controlled by the spinner patrol cycle rate and the end breakage rate. The presence of trainees and absenteeism can also lead to more waste, especially in smaller mills.

Small batch sizes coupled with variety production introduces problems in that more types of waste and more handling are involved, frequent processing changes are required and running in and running out wastes are increased. In general, waste increases as the lot size decreases and the variety increases.

When considering the control of waste an overall approach must be made since savings in one area may mean increased losses elsewhere. Because of the cost structure it may be better in a particular case to increase the overall waste by increasing the amount of waste in earlier processes if this brings about a smaller but sufficiently large decrease in waste in later processes. Subsequent processes must be considered since economies in spinning may lead to adverse effects later.

A major step in any control program is to optimise processing conditions and waste should be one of the parameters considered in the experimental program (see section 2.2) conducted by the mill. Correct spinner cycle times and allocations must be established by balancing the extra labour cost against the savings due to waste reduction. The number of patrols will depend on the count ranges being produced since coarse counts produce waste at a faster rate and hence an increase in labour may be justified in order to reduce this waste.

A waste control program may be initiated by bringing in a waste consultant, but if this is not possible, then a mill can institute its own program by carrying out the appropriate steps. The problem is first explained in terms of cost, quality and job security to all key supervisors in order to obtain their co-operation. The locations of, reasons for and remedies for particular waste problems are examined and supervisor conferences where each person discusses his own problems can be helpful.

A classification and sorting scheme for waste must be set up where separation is done on the basis of similarity of properties, values and end-uses. The amount of sorting in a particular case will depend on the gains to be had by further separation of waste. A systematic plan for weighing and recording wastes is necessary. Standards, important for comparative purposes, must be flexible, not too harsh and should be revised regularly.

When training operatives in waste control methods it is important to use a rational approach rather than pressure tactics. It must be emphasised that waste is a natural by-product of each process and that the important factor is excess waste which may appear small to the operative but which is a significant cost factor to the mill. It is necessary to build up interest, awareness and desire in the operator whilst supervisors must maintain close supervision with regular checking. The aim must be to maintain quality and production whilst reducing waste and incentive bonuses may not be a good idea particularly where one of these objects only is emphasised.

Developing countries may require special consideration since cost structures are different (e.g. lower labour costs) and increased labour to reduce waste may be justified. Classification procedures for waste are likely to differ, mills will usually be smaller with smaller batch sizes, fashion pressures may be comparatively absent, less modern machinery may be available and air-conditioning may be a problem. Optimisation of processing is likely to be much more difficult. Waste control personnel may require overseas training whilst training of personnel will depend on cultural and other differences.

## 5. Quality Control in Fabric Manufacture.

### 5.1 Control in weaving.

The objectives of quality control in cloth production are to achieve a specified or better quality with minimum waste whilst optimum labour and machine productivities are maintained so that profits are maximised. Quality standards and productivity norms are laid down by management and it is the weaving superintendent's job to exercise control to maintain or improve fabric quality whilst meeting the production norms. Design specifications determine the fabric properties and there is a need to meet these specifications inasmuch as these can be controlled from winding to weaving. The superintendent must also ensure a fabric free from yarn faults and defects originating in looms and/or preparatory processes.

Control methods at each point must be viewed in the overall context; weaving accounts for most of the cost so that in the preparatory processes the emphasis should be on quality (to the extent that it affects loom quality and productivity) rather than quantity. There must be no compromise in the quality of preparation since this can affect loom productivity. Quality and productivity are sometimes opposed and a fine balance is needed in these cases.

At each process quality depends on process parameters, the condition of the machines and work practices. Process parameters are based on experience and large scale controlled trials and only minor adjustments should be required. When these parameters are optimised quality depends on how well the mill sticks to these parameters, mechanical maintenance of the machines and the quality of work practices. The approach of the superintendent should be to a regular program of process control and checks, preventive maintenance, training of operatives, statistical quality control and waste control.

In winding the aim is optimum removal of yarn faults (which lead to fabric defects and breakage in later processing) and the production of good packages (poor quality packages lead to increased yarn waste and breakages). The slub catcher removes thick places whilst the tension removes weak spots. Thin spots can be removed using electronic clearers but these are little used in developing countries. The unwinding tension and catcher setting affect fault removal and need regular checking whilst the condition of the slub catcher should be inspected for changes in the blade position (operator tampering), wear, disturbance of calibration setting (oscillating blade type), free blade movement and so on. A good practice is to have a spare set of blades and to rotate these regularly. The positioning and alignment of the bobbins can increase tensions leading to breakage and regular examination is desirable. Proper training is necessary to prevent operatives tampering with the slub catcher and to ensure good knots.

A variety of package defects can be caused by such things as a defective broken thread stop motion, improper setting of the winding spindle with respect to the winding drum, non-alingment of the tension bracket with the drum, the mecnanical knotter condition and incorrect work practices.

In warping the objective is to produce beams of the correct density which will unwind well in sizing and in which breakage is minimised. Yarn breaks in warping are undesirable since these reduce productivity and are a potential source of later breaks and fabric defects. During stoppages yarn abrasion may occur and improper mending may be done due to negligence or the inability to trace the yarn end. Yarn tension and package alignment should be checked regularly and the guide roller examined for eccentricity. The package quality is affected by the condition of the beam flanges, uneven tensions and the warp stop motion and control must be exercised in these areas.

Sizing aims at giving a uniform smooth protective film to the yarn so that strength and abrasion resistance are improved without significant losses in yarn extensibility. The yarn strength gain depends on the size recipe, the ingredient quality and the amount picked up by the yarn, the recipe being a result of experience and trials, whilst ingredient quality is maintained by control checks. Accurate control of the maximum amount of stretch in all zones within sizing is necessary to minimise yarn elongation reduction in the sized yarn and regular checks of actual yarn elongation should be made. It is necessary to determine the optimum size pick-up and to verify actual values by beam weighing and laboratory desizing. Control of the depth immersion in the sizing paste, the paste level and the temperature of the paste and examination of squeeze roller bearings for wear should be made. Overdrying must be avoided and the correct package density with no cut ends should be achieved in winding.

Fabric defects in weaving arise from preparatory process defects, incorrect loom settings, poor work practices and end breakages (due to poor preparation and/or unsatisfactory loom maintenance). Regular data on the

## PREFACE

A number of experts were invited to present papers to an Expert Group Meeting on Quality Control in the Textile Industry held in Budapest from 6th to 9th July, 1970. The papers presented at that conference were:

1. The organisation of quality control in a textile mill: some general aspects and problems, by T.A. Jedryka.
2. Survey of statistical methods and concepts to be applied in textile quality control, by A. Barella.
3. Psychological considerations for an effective quality control program, by J. Stiller.
4. Quality control in cotton spinning, yarn count and uniformity, by T.A. Subramanian, A.R. Garde and S.N. Bhaduri.
5. Application of quality control methods in worsted spinning, by H.K. Krakowian.
6. The causes and control of waste in worsted spinning, by M. Chaikin.
7. Quality control in winding, beaming and weaving, by M.C. Paliwal and S.N. Bhaduri.
8. Quality control in the knitting industry, by P. Grosberg.
9. Quality control in the finishing of cotton, by P.C. Mehta.

It was agreed at the Meeting that papers on a number of other aspects involving textile quality control should be sought and arrangements were made for the preparation of the following additional papers.

10. Quality control of fibre raw materials, by J.D. Collins.
11. Quality control in the finishing of fabrics made from blends of cotton with man-made fibres, by P.C. Mehta.
12. Quality control in the finishing of wool and wool blended woven and knitted fabrics, by C. Duckworth.
13. Quality control in the finishing of man-made fibre products, by C. Duckworth.
14. Quality control in the clothing industry, by N.H. Chamberlain.

The Meeting also recommended that a composite document covering the whole field should be prepared. It was subsequently proposed that, as well as the condensation and integration of the available material, the document should be expanded to include a number of other aspects such as the role of statistics in maintaining standards, staff requirements for type and incidence of defects is necessary so that the relative emphasis can be placed on preparation and weaving and in order to locate specific areas of action. Weaving defects arise due to such things as faulty setting of the anti-crack motion, incorrect setting and timing of shedding, faulty battery scissors and temple cutters, incorrect feeler motion and battery settings, let off and take up motions, the box plate setting and cleanliness and the warp stop motion (the most important single factor). A number of loom factors lead to more end breaks and fabric defects and these include shedding faults, warp tension, reed spacing, heald eyes and shuttle condition. It is important to bring about a quality awareness in the worker and sytematic supervision, training and incentives for quality reduce the occurrence of defects. In supervision it is worth inspecting fabrics on each loom each day and to point out the defects to the appropriate cause (i.e. operator or loom maintenance section).

In order to meet design specifications, a check on counts, the correctness of weave, the end and pick density, cloth width and piece length needs to be kept. In difficult designs a useful aid is to keep a piece of fabric for checking purposes. The correct dimensions are obtained from past experience with settings and regular dimension inspections should be made.

5.2 Control in knitting.

Quality control is the regulation of the degree of conformity of the final product to its specification and in knitting this specification is often subjective and difficult to define. The aim of control will be to check sufficient objective properties to meet both the objective and subjective specifications required of the fabric. Fabric objective properties can be grouped as geometric (e.g. the average loop shape and variability of loop shape, the colour design, the property retention after wet treatments), mechanical (e.g. load-extension, shear and bending) and retention (abrasion resistance, pilling resistance, colour fastness). The mechanical properties are important in subjective properties such as drape and handle whilst the hysteresis of mechanical properties during wear affects the fabric shape retention.

The simplest control plan would be to test all fabric properties but this is uneconomical due to waste and the amount of testing required. A better plan involves acceptance testing of the yarn, some checks on processing variables and final fabric checks. Here sufficient properties are examined so that adequate control is achieved.

Work on fabric geometry has shown that the control of stitch length is essential in the control of fabric dimensions and that fabrics tend to relax to a state governed by stitch length. With bulked yarn or felted fabrics stitch length is still the most important factor except that this stitch length is shorter than the initial stitch length as knitted. This length depends on the felting properties of felted fabrics whilst for bulk yarn fabrics the collapsed stitch length depends on the yarn crimp rigidity.

Excess spirality in a fabric may be produced by twist-lively yarn and the use of twist relaxed, twist balanced or alternate course of S and Z twist must be considered. Spirality in circular knitted fabrics can become unacceptable when the feeders are too close together.

The appearance of individual loops depends on the spacing of the individual needles and the variation in count and twist from loop to loop. The effect is reduced as the fabric is relaxed, except in cases where the yarn is plastically deformed during knitting.

In positive yarn feeds the stitch length is governed by the rate of yarn feed (which depends on yarn speed and input tension) and the rate at which loops are formed. Elastomeric yarns in particular must have accurately controlled tension and yarn speed to ensure a constant input rate whilst with bulked yarns sufficient tension must be applied to remove all crimp. Positive feeds are used in warp knitting and in simple circular weft knitting, but are considered too complicated for jacquard circular knitting and flat-bed knitting. Operatives in weft knitting do not like positive feeds due to the difficulties of threading up after a break and unless closely supervised will try to bypass the feed.

The stitch length depends on a number of factors including tensions, feed rates, cam positions and shape and yarn to needle friction. Besides controlling feed rates and input tensions, it is necessary to control the cam height position. The maximum tension must be monitored since too high values lead to press-offs and broken loops.

Our knowledge of the mechanical properties is limited, but bending and shear of the yarn and the stitch length appear to be the main factors. In the long term retention properties (abrasion, resistance, pilling) there are so many factors that the only reasonable test is to examine the finished fabric and this applies equally to dimensional stability.

The choice of factors to test can be grouped into yarn testing, process variable control and final fabric testing. These will now be examined.

(i) Yarn variables.

The yarn count (together with the stitch length) affects the cover factor but more importantly the count affects the economics of the system since yarn is bought by weight and cloth is sold by area. Thus a 5% increase in count will increase the raw material cost by 5% with no equivalent increase in profit. Checks on count are needed as a basis for claims and measurement of yarn irregularity and checks on slubs, knots and thin spots are desirable.

The crimp rigidity of bulked yarns should be uniform or streaks will appear in the fabric. Yarn strength and strength variability needs to be controlled to prevent press-offs and broken loops, but this is usually only important in low strength yarns (e.g. wool). Yarn extensibility is important in elastomeric yarns whilst dynamic extensibility is significant in stocking manufacture.

Twist liveliness can be easily examined by a quick visual check of the tendency to snarl whilst only at most occasional spot checks of twist and twist variability are required. Yarn friction affects the tendency to break and the stitch length (for negative feeds) and some check of dynamic friction is desirable. The yarn bending modulus depends on the diameter of the fibres used and it is common to check fibre diameters when wool yarns are used.

(ii) Process variables.

The stitch length can be examined by using a yarn speed meter and a yarn length counter. A number of tension testers are available which give relative tensions and it is important to use the same type of instruments for comparative purposes. Input tension and stitch length checks should be done at least once a day and at the same time it is desirable to visually inspect the fabric to check for correct pattern selector operation. It is worth pointing out that the common practice of using measurements of courses per inch in knitted fabrics for stitch length checks is unreliable, misleading and results in many difficulties in existing schemes.

(iii) Fabric variables.

Abrasion, pilling and dimensional stability tests prevent the sale of substandard merchandise and are useful data for determining future practice. Final inspection for irregular stitches and dropped stitches and rough dimensional checks are routine, some mills relying entirely on this for quality control, a highly undesirable situation.

The amount of testing carried out depends on the costs involved and since in the knitting industry there is a relatively low added value for many knitted products, costs must be minimised (the scheme must be highly selective). Mills rarely do acceptance testing of yarn for economic reasons but yarn count checks are still desirable as these affect profitability. The minimal control scheme would include yarn count checking, control of processing variables and the final fabric inspection with occasional spot checks of colour fastness and dimensional stability. There will be many intermediates between the minimal scheme and the complete scheme and the final choice will depend on the type of fabric, the added value and the state of the industry.

6. Quality Control in Finishing.

In finishing, the fabric from the loom or knitting machine is subjected to a series of chemical and physical processes in order to confer on the fabric the appropriate desirable properties for a particular end-use and the aim is to do this so that quality is maintained and costs are kept down. The fabric must be finished so that it meets the subjective standards related to drape, softness, firmness, lustre, cover, solidity of shade and so on, the objective properties such as matching of shade and uniformity of shade, weight per unit area, fabric construction, width, length, tensile strength, colour fastness and dimensional stability and any special property required of the fabric in end-use (flammability, showerproofing, air permeability, etc.). The specifications required of a particular fabric are often quite detailed especially if associated with the defence department, government departments, registered trade marks, brand names or the like. As well as meeting the specifications finishing must be carried out so as to keep to acceptable levels the number of faults present in the finished fabric (strings per 1000 yards), the percentage of seconds and the occurrence of fabrics not fit for normal sale.

There are a number of different functions involved in quality control in finishing and these may be treated under the following headings:

(i) The control of raw materials,

(ii) The selection of the finishing sequence and control of process parameters,

(iii) The control of fabric specifications.

(iv) Inspection of fabrics (before, during and after processing)

Control of raw materials is desirable since expenditure on raw materials represents a significant fraction of costs and often the decision for purchase from a particular supply is based on price, quality of the material not being considered. This is a mistake since quality factors such as strength influence the effective cost which is a combination of the material strength and the sale price and these latter factors must be balanced to obtain the most economical costs. In a mill large quantities of materials are purchased so that the test load must be chosen with some discrimination in order that the scheme is economical. In this regard the first materials which should be tested are those which contribute most to the expense (possible savings in material costs) and those whose effect on processing is most critical (possible savings due to less defective fabric).

Commercial dyestuffs are usually a mixture of pure dye plus some additives, there being no standardisation of the relative proportion of these components. The dyestuff supply may be unreliable particularly if there is a shortage (a factor common to developing countries). The dye strength may be assessed by standard dyeing since the depth of dyeing is directly related to the strength. In order to compare dyes from different suppliers, concentrations of dyes are varied to obtain matching shades so that the relative strengths are determined (and hence the effective price). The disadvantages of this method are that differences of less than 5% cannot be detected and tone difference may interfere with the depth assessment and other methods for more accurate assessment may be used if required. It is important to know whether the supplied dye is pure or a mixture of dyes and simple chromatography techniques may be used to separate components. Dye compatibility is required since in practice dyeing is done with mixtures of dyes and checks on relative dyeing rates and migration of dyes may be carried out by test dyeing procedures.

Starch based finishing agents usually contain starch plus softeners or stiffening agents. The starches rarely require testing but the viscosity of a test paste should be checked. The softeners and stiffening agents may be assessed by finishing trials. Chemical finishing agents such as resins require testing for free formaldehyde (embrittlement of the fabric and offensive smell), for percentage of active ingredient and possibly qualitative identification.

The fibres to be finished are often in blends and identification of the components with their relative proportions may be necessary in order to ensure effective dyeing. Since the dyeing behaviour is affected by the relative concentrations of fibres in a blend, test control of blend uniformity will be necessary to minimise the chance of uneven dyeings due to this factor.

Auxiliaries include desizing agents, wetting agents, dispersing agents and levelling agents. The strength of desizing agents may be estimated by measuring the reduction in viscosity of a standard starch paste, the wetting efficiency produced by wetting agents may be checked by sinking tests for standard hanks, the effectiveness of the dispersion can be evaluated with a simple filter paper test whilst levelling agents may be examined by test dyeings. Other major chemicals (e.g. sodium hydrosulphite, caustic soda, common salt, soda ash, sodium nitrite, hydrogen peroxide, acids, bleaching powder, etc.) may be checked by standard analytical procedures.

The water quality is important since hardness affects scouring and dyeing, the presence of iron is undesirable in bleaching and impurities must be minimised when water is used in boilers. Knowledge of hardness, alkalinity, dissolved solids and total solids is essential and the appropriate treatment must be applied so that the water is suitable for the particular application envisaged.

The selection of the appropriate processing sequence and processing parameters depends on the type of fabric, the properties required and to a large extent on the fibres used. The sequences may vary considerably depending on whether the fabric is made of cotton, wool, a cotton synthetic blend, a wool synthetic blend or a pure synthetic fibre. Particular processes may have to be modified to suit a particular fibre or fibre blend and more careful control may be necessary to reduce faults. It is worth mentioning here that good machine maintenance, oleanliness and tidiness are essential features irrespective of the sequence. Damage to fabrics due to poorly maintained machines (seized rollers, rough spots in dyeing and finishing machines, faulty nip rollers, etc.) and to oil and other contaminants being picked up from machines and during transit may be minimised in this way.

The treatment of various fibre combinations may now be considered.

(a) Processing of cotton.

Periodic determination of residual size after desizing is necessary since inadequate desizing or uneven desizing affects scouring efficiency, dyeing and the application of some finishes. Scouring removes impurities and makes the fabric absorbent. High absorbency is essential (checked by a drop test) and periodic testing of residual wax content and nitrogen content may also be required.

In bleaching the object is whiteness without degradation and testing the whiteness (against a standard white) and the fluidity is necessary. Bleaching depends on the pH, the concentration and the temperature and these must be adequately monitored. After neutralising with acid, the pH of the fabric should be checked (universal indicator paper) to ensure acid is not present during drying.

In mercerising the concentration of alkali should be controlled and the finished fabric examined for absorption increase and lustre. Residual alkali should not be excessive as this promotes yellowing and oxidation.

Starch based finishes should be checked for paste viscosity and temperature and the squeezing action of the mangle should be examined. Subjective evaluations of drape and stiffness are desirable and the fabric whiteness may be monitored to verify the effectiveness of optical brightening agents. For easy-care finishes the resin stability, the pH and absorbency of the finished fabric and the evenness of resin fixation should be assessed.

In dyeing careful recipe preparation is essential and temperature and bath exhaustion tests are required. The fabrics to be dyed must be absorbent, free from impurities and uniformly packed. In printing the paste recipe, the thickener viscosity, the print stability, the printing roller pressures, roller settings and the ager condition should be checked.

The finished fabric should be examined for dye or print fastness to light and washing. Rubbing fastness (when pigments are used), fastness to perspiration, dry cleaning etc., residual shrinkage (preshrunk articles) and the effectiveness of easy-care and durable press finishes may require testing.

(b) **Processing cotton-synthetic mixtures.**

When synthetics are incorporated with the cotton, processing sequences and processing parameters will require modification.

Cotton-polyester fabrics should have soiling and oil stains removed in the loom state fabric since removal is very difficult later. Sizes used will differ due to the hydrophobic nature of the polyester and the greater hairiness of blended yarns. There is more danger of fabric (impregnated with desizing solution) drying out and thus leading to difficulties. In scouring, alkali damage to the polyester is controlled by the time, concentrations and temperature. Heat setting required to set the polyester giving dimensional stability requires accurate temperature control to avoid adverse effects and changes to the fabric stiffness and drape. The control of the set is assessed by shrinkage tests, crease angle tests and handle tests. Pilling control by singeing is preferable after rather than before dyeing. Optical brightening agents will be different for each fibre and anti-static finishes may be necessary. Since dyeing is essentially different for each fibre, more accurate controls are needed.

In processing of cotton-viscose blends modification is necessary since viscose is weaker when wet, is much more extensible when wet, is more affected by alkali and dimensional stability is poor. Pressure scouring is not recommended and because of the cleaner nature of the blend shorter scouring times may be used. In mercerising hot water is required to wash off the alkali and it is desirable that alkali concentrations be lower and that extra care is taken in removing residual alkali. Processing must be carried out under low tension particularly when the proportion of viscose is high. Package dyeing may be difficult due to the large swelling of the viscose fibres.

Heat setting is required for cotton-polyamide mixtures where the amount of polyamide exceeds 30%. Sodium hydrosulphite is necessary in scouring to prevent discoloration of the polyamide. Careful selection of dyes (vat) is necessary and laboratory matching is desirable before bulk dyeing is carried out. In dyeing the exact conditions of temperature and pH should be maintained. The harsh handle after resin treatments can be avoided by thorough after-washing treatment.

For acrylic-cotton blends, temperatures and alkalinity must be minimised to prevent damage to the acrylic (the conditions are determined by laboratory trials). Excessive stretching must be avoided during chemical processing and pressure, temperature and stretch in processing must be controlled. In dyeing temperature control is very critical.

(c) Processing of wool.

Inadequate setting during crabbing can lead to cockling or design distortion during rope scouring or piece dyeing. Too high a tension and the wrong pH (very important) can lead to fabric weakening. In rope scouring an excessive load on the dolly nip or high temperatures can lead to rope marks, design distortion and excessive shrinkage. Inadequate scouring leads to dyeing difficulties and control of residual fat, soap and alkali is necessary.

In milling excessive roller pressures and overloading of the machine must be avoided whilst in carbonising uniform saturation with acid is essential to minimise unevenness. In winch dyeing attention should be paid to the correct dye selection and application method. Overfilling leads to uneven dyeing and temperature control is very important.

Overraising will lead to a weak fabric and uneven raising can be produced by creases, uneven moisture content and the presence of residual chemicals. Curling of the selvedges and too intensive raising will lead to defects and the condition of the card wire is important. In shearing the fabric back must be done first to avoid holes and attention must be paid to the sharpness of the cutter and the blade orientation. Even tension and wrapping is essential in steam decatising and wet steam must be avoided (stains). Faults in pressing arise due to non-uniform preconditioning, overstretching the fabric and failure to keep the fabric flat during feeding.

For knitteds dimensional stability is a problem, correct stretching during finishing being essential. This will tend also to prevent snagging during wear.

(d) Processing of man-made fibres.

When processing continuous filament and staple fibres these must be adequately separated to minimise contamination. Fibre Makers' Manuals give processing sequences, recommend specific techniques, points to watch and faults encountered during finishing.

In the control of fabric specifications it is necessary to carry out testing and this requires that the appropriate test instruments should be available. Testing of such things as weight per unit area, pilling resistance, abrasion resistance, the effectiveness of finishes, fabric quality control departments, equipment requirements, training of mill personnel and preventive maintenance in a quality control scheme.

Although it is believed that the topic has been covered comprehensively bearing in mind the tremendous scope of the subject, readers are urged to refer to the original papers cited above whenever additional information is required.

strength, etc. and check of the design, the colour and so on may be necessary.

Inspections are carried out in the grey state at particular intermediate steps (e.g. after piece dyeing) and after finishing is complete. The bulk of the strings in a finished fabric is due to yarn and weave imperfections and the grey mending room is a main control point and guide as to the quality standard which may be ultimately expected. For the more expensive wool fabrics mending of faults is carried out whilst for cotton and synthetics little mending is done and the inspection is less critical. Final inspection is necessary to prevent the sale of inferior merchandise. The results of inspections should be carefully tabulated in terms of output, % seconds, % not fit for normal sale and the strings per 1000 yards so that control measures can be immediately applied if faults are excessive. Records of faults, with fabric samples and the results of trouble shooting investigations should be kept to assist in future fault finding.

Quality control for commission dyers and finishers has different problems and the emphasis will be on different aspects. These latter organisations do not own the fabrics, process a larger variety of fabrics, have more customers with a greater range of end-uses, have a larger output than vertical mills, have smaller orders which are more split up and have greater problems in production planning to meet delivery deadlines. Initial inspection tends to be infrequent since the firm usually assumes the fabric is right. A proportion, however, should be checked (based on past records, knowledge of supplier's reputation, etc.) and full width samples kept as a reference (this is helpful in determining whether faults are due to finishing or earlier processes). Perching is usual after dyeing (or drying if only scoured and finished) and fabrics are passed or directed back for reprocessing. The aim is to keep the faults at the final inspection low. Fault analysis is a vital feature in a commission works and charts and graphs should be constructed to keep a running record of trends occurring. The final quality depends on the number of strings and the percentage of damaged fabric retained by the mill (charged to the finisher by the customer).

## 7. Quality Control in the Clothing Industry.

Quality control in the clothing industry is less clear cut for a number of reasons. The clothing manufacturer must deal with a wide variety of raw materials (fabrics) whose properties depend on the fibres used, the properties of the yarns, fabric manufacture parameters and finishing variables. Production thus begins with an inherently variable raw material. The selection of parameters to specify a given garment is difficult since a large number of properties cannot be measured quantitatively. Size of the whole garment or of individual parts can be specified but here the size measured will depend on the method used. Subjective parameters such as 'style' and 'cut' vitally affect the value of the garment but methods of examination are limited to visual assessment.

Quality control can be divided into three areas, viz. acceptance testing, performance testing and product inspection. Acceptance testing incorporates the testing of all raw materials used including the basic fabric and auxiliaries such as buttons, zippers, press studs, hooks and eyes, elasticated waist band fabric, stiffenings, tapes, interlinings, pocketings, linings, paddings and sewing threads.

Fabrics are specified by counts and twists of the yarns, fibre composition, ends and picks per inch (or courses and wales) weight per unit area, width, thickness (raised or napped surface fabrics), conformity to shade and freedom from structural faults. The relative importance of each of the above will depend on the fabric and its usage so that the important factors only are examined. It is usually only possible to test a sample of fabrics so the testing scheme must be designed so that the chance of a defective fabric passing into production is fairly small. One difficulty encountered is that sampling must usually be carried out at the fabric end which may not be representative of the fabric as a whole. The most effective method of control is to concentrate on types of fabrics which are more liable to contain faults. Thus for some types reperching of every piece may be desirable whilst with others testing may be only on a small fraction of the pieces , e.g. linings or pocketings may be tested for weight and width on, say, every tenth piece.

Acceptance testing on accessories should be concentrated on articles which show the greatest variation from lot to lot. Each component should be taken separately and the appropriate testing scheme for this article set up. Some components, such as buttons, are easily assessed (dimensions, weight, colour, surface finish) whilst others like zippers are more difficult to evaluate. For these latter fasteners it is best to sample each batch and inspect for size, faults in materials or workmanship and for free and satisfactory action.

An important part of acceptance testing is the recording and filing of results. These should usually be retained for the probably garment life so that they may be referred to if a complaint is received.

Performance testing involves special tests on properties important to particular types of fabrics. These tests include showerproofing for rainwear, flammability of children's garments, fabric to fabric adhesion in fusible interlinings, air permeability in windproof fabrics and so on. A showerproof fabric should be effective after successive wetting and drying and the finish should be stable to dry cleaning. Tests are available but due to reproducibility difficulties between laboratories are not entirely satisfactory and relative measurements only can be obtained.

Flameproofing of children's nightwear is required by law so that testing must be done as a matter of routine. The air permeability of weatherproof fabrics may be measured using the Cambridge instrument but testing is rarely carried out except where weather extremes will be encountered, e.g. fabrics for the Arctic. Abrasion resistance measurement is desirable on fabrics which are subject to wear extremes (e.g. pockets, linings) and the Martindale tester is the most common test instrument. The tests are comparative rather than absolute and since four fabrics can be tested concurrently, a useful method is to test two samples of satisfactory wear behaviour and two samples where the abrasion resistance is required and to compare the results.

For a number of reasons many fabrics change their dimensions on steaming and since the number of steamings during making up may be as high as twenty, it is important to examine this factor. Where a fabric has been overstretched to obtain the correct width a considerable redistribution may occur on steaming leading to dramatic size changes. The usual test involves steaming whilst allowing freedom to shrink, a particular example being the W.I.R.A. test.

Drape and handle are difficult to quantify and when required are best done by comparison with standard fabric. Various tests are available for crease recovery and crease resistance. In laminates the requirement is good adhesion stable to dry cleaning, flexing, etc. and tests are available but none are as yet regarded as standard.

The sewability problem, highlighted by the advent of synthetics, involves seam damage by needles in sewing, seam distortion or puckering and the seam strength. Because of the large variation between fabrics often of unknown composition, it is desirable to include sewability tests as part of the control scheme.

There is a complicated array of processes (e.g. cutting, assembling and so on) before the final product is produced and a system of product inspection is required to remove processing faults. Inspection during production ensures that further work is eliminated on already faulty garments and the final inspection prevents the sale of faulty garments. Inspection may be 100%, but it is usual to examine only a sample and to concentrate on styles and types which are known to be fault prone. The amount of inspection will depend on the type of garment, the quality and the price range.

Checks for size are necessary since the intended size may not be obtained in practice and reclassification may be required. Faults such as distorted or damaged seams, uneven hemlines, mismatched checks and stripes, wavy fronts or backs, badly set sleeves, pockets and lapels and so on must be detected since the presence of any one fault would justify rejection in high quality garments. The final judgment is made by the customer and a useful method of control is to offer to exchange any faulty articles with no arguments. Although this method is open to abuse, it is helpful in picking out faults which should be remedied.

In conclusion, it should be stated that the clothing industry offers a rather difficult field for the application of quality control systems. This is mainly because of the operation of two factors, viz. the variability of input raw materials and the large range and short production runs of the product. Economic considerations dictate the amount of time and labour that can be allocated to quality control in a particular factory producing a stated range of garments and it then becomes a question of dividing up these resources among the three types of testing, in such a way as to exercise the maximum degree of control over the quality of the final product. Normally, when a quality control system is first set up, emphasis is placed initially on acceptance testing, with product inspection used to monitor the effectiveness of such tests. Performance testing comes later, except where required by law.

The clothing industry is one in which the goodwill and reputation associated with a certain brand or name count for a very great deal with the buying public. It is precisely in the maintenance and enhancement of such goodwill that quality control, despite the difficulties, has a great part to play.

## 8. Quality Control in a Developing Economy.

### 8.1 General aspects.

For many years manufacturers in the developed and advanced countries have had to compete with each other, with importers within their own country and with overseas competitors when exporting. As a result consumers have been faced with a wider and wider choice in making their purchases and a major criteria for selection has been the product quality. People have been educated to demand high quality and a supplier who does not meet these specifications will not be able to sell his product. Because of the increased competition price in addition to quality is a deciding factor in purchasing, so that internal quality control within the mills has become an essential and will become more important in the future.

Developing countries, however, are in quite a different position since, in general, quality standards are low and consumers have not been exposed to high quality goods, have not developed a quality awareness and usually have not had the money to pay for this quality even if it were available. With increased economic and technical development of the country, the public begins to demand goods of better grade. Imports are received from the advanced and developed countries and this arouses in the customer a curiosity and interest and develops consumer demand for quality goods.

Competition in export markets will be a key factor in the pressure to improve quality. A country with a limited range economy must export to survive. Sometimes there are natural markets in the immediate area which do not demand quality goods, but usually the country will be forced to compete with the high quality products of the developed countries. An important point worth noting here is that the first objective must be to improve the overall internal quality level within the country before improving the quality for export. Industry must become accustomed to quality production methods so that the maintaining of continually changing export quality can be facilitated.

In the developed countries a firm is subjected to a relatively slower change in quality demand since the quality of production will already be of a reasonable standard. Developing countries generally have a low quality standard at present, but in the future an accelerated quality growth will be required if the social and economic level is to be raised. This creates numerous problems and it may be useful here to discuss the factors which may or may not be important in assisting the developing country to raise its quality standards.

A large factor in this regard is likely to be the type of assistance given to the industry by the government. In order to raise manufacturing standards the industry will require highly trained technologists and engineers to organise production, there being a need to produce these within the country rather than importing them. The government should therefore strive to increase assistance to existing tertiary education establishments and to create new institutions so that the training and information programs of such places can be expanded.

The various firms will need help in establishing modern quality control methods and as a first step here plant management must be acquainted with and made aware of the importance of quality control both to themselves and the country as a whole. Management must be taught how to organise proper control systems and an extensive promotion and training program will be required to make mill personnel quality minded. Manufacturers must be made aware of changing quality requirements and a comprehensive and reliable information system to provide production personnel and management with complete data on the nature of the products required and the products actually manufactured should be set up. Encouragement must be given to firms to institute properly designed control and inspection systems to improve the overall quality.

Governmental policies may be of importance in realising the goal of quality improvement. In most developing countries there will usually be a system of tariff protection for local industry to enable them to compete with overseas imports. In order to raise quality standards it would be desirable to carry out a well-planned and extensive program where these protections are progressively removed so that an internal quality increase is necessary to meet the increased competition of imports. Adequate protection against dumping would have to be provided. Some restrictive agreements may be desirable provided they lead to rationalisation of production and marketing, the improvement of products and the assurance of their quality. Legislation to regulate and standardise weights and measures may be necessary, the definition of export standards must be provided and some means of checking and controlling of exports is required.

Various other governmental assistance schemes might be considered. Measuring instruments are an essential part of inspection schemes and aid in this area could be to make instruments cheaper (e.g. by subsidies, by a rental scheme, etc.), to provide central testing facilities for firms who cannot afford to set up their own, to standardise the use and calibration of measuring instruments, to provide a calibration and maintenance service for the instruments and so on.

The consumer is extremely important in that a demand for higher quality must be generated. The government (and especially such departments as defense) is usually a large consumer of goods and is thus in a position to insist that product quality be an essential criterion when purchasing. Standards for all governmental purchases should be established and rigidly controlled. Retail chains have a valuable role in the general consumer education and they need encouragement to sell high quality goods at reasonable prices, to collaborate with manufacturers on specifications and quality standards, to avoid suppliers who fail to give suitable and consistent quality, to educate the public to appreciate attractive, high quality products and to encourage customers to return unsatisfactory merchandise.

8.2 Central quality control centres for the textile industry.

8.2.1 The functions of these control centres.

The setting up of central quality control centres will contribute greatly to the aim of lifting quality standards in developing countries. The range of functions of a particular centre will depend on the needs of the local industry and would include some or all of the following:

(i) General technical assistance and advice.

With the rapid advances and changes within the textile industry it is becoming increasingly difficult to keep up with technological advances within the industry. A central quality control centre could play a valuable role in this area by keeping abreast of latest overseas developments and trends and by giving advice on all matters pertaining to the running of a textile mill as a viable enterprise. Consultation on such matters as the correct choice of raw materials, the conversion methods for different raw materials, optimum processing requirements, efficient staffing, purchase of new machinery and equipment, future mill development, standards required for export, management and costing, etc. might be provided.

(ii) Specialised advice on quality control and waste control.

The centre could supply specialists in quality and waste control who would go into the mill, investigate the situation already existing in the mill and supervise the institution of an overall scheme in the mill. The centre might also provide training courses for senior mill staff to promote quality awareness and to indicate the methods of obtaining quality goals.

(iii) Training mill personnel in quality control and waste control.

The type of service could include specialised training courses for supervisors where, among other things, the training of operatives is discussed. Specialists could be provided to go into mills to assist in on-the-job training of supervisors and

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# QUALITY CONTROL IN THE TEXTILE INDUSTRY

## 1. Introduction.

In any manufacturing industry the main aim is to maximise profits from the sale of the finished merchandise and this entails the minimising of the production costs in producing the article. The mill purchases raw materials and through a series of mechanical and/or chemical processes produces the final product for sale. This product is required to have certain properties or specifications and the raw materials, the processing sequence and the processing parameters are chosen in such a way that these specifications are met in the finished article.

For any particular product there will be a minimum production cost but in practice the actual cost will be higher than this owing to such factors as excessive waste production, processing difficulties, inferior products (rejects and seconds) and product returns by the customer (with the subsequent risk of customer loss). The role of quality control is to minimise losses due to the foregoing factors and there are a variety of functions necessary in this regard. Before discussing these, however, it would be desirable to review briefly the main parameters, affecting the total product cost, which come under the jurisdiction of quality control.

The following factors are significant in the final production cost:

### (i) Raw material parameters.

In choosing fibres for a specified end product there are a number of factors which must be considered. Properties such as fineness, length, length and diameter variability, mechanical properties, crimp, maturity (cotton), colour, the presence of foreign matter, the degree of fibre entanglement and the presence of fibre damage will affect the fibres' performance in processing and end-use. In practice there will be some minimum requirement in terms of these properties and if inferior fibres are purchased then there is a danger of processing problems, excessive waste and sub-standard merchandise leading to large profit losses. If a firm obtains better fibres than are necessary for the purpose (usually at a higher purchase price) then this too will lead to a loss in profits. Since fibres such as cotton and wool are sold in the presence of often substantial amounts of impurities it is essential to base prices paid on accurate assessments of the clean fibre yield in order to avoid paying too high a price for the fibre raw material. When choosing fibres for a specified end-use it is necessary to balance fibre 'quality' against price in order to obtain the optimum purchase.

Even after the fibres required have been specified there is still the problem that the purchased fibres may differ in specification from the optimum since fibres tend to be bought more on the basis of subjective assessment than measured properties. Accurate knowledge of particular properties is usually necessary to enable the spinner to adjust processing conditions to obtain the best result where waste, processing difficulties and low quality end products are minimised.

Textile mills use many other raw materials (e.g. chemicals, dyes, sizes, etc.) and if these are not up to specifications (strength, purity, etc.) then this may lead to processing problems with a consequent rise in production costs. A particular material (a dye for example) may be available from a number of suppliers at apparently different prices and the 'effective' differences in prices will depend on the relative strengths of the dye from the different suppliers. The correct choice of raw material will depend on the effective price and quality factors associated with the material.

(ii) Processing conditions.

The specifications of a given final product will lead to a choice of the processing sequence and the relevant processing parameters in an attempt to provide optimum manufacturing conditions. Even if the optimum processing sequence is clearly defined the efficiency of each process is affected by machine settings (e.g. ratch settings, roller speeds, spindle speeds, production rates, etc.), process parameters (e.g. temperature, time, doublings, pH, etc.), fibre conditioning (e.g. regain, relative humidity, oil, anti-static agents, etc.) and the state of the material entering the process (e.g. fibre parallelisation, sliver mass per unit length, twist, etc.). Because of the inherent complexities involved, it is doubtful if any mill could ever obtain optimum conditions and it is the degree to which the actual conditions approach the optimum which determines profitability. As the conditions depart from the optimum, processing difficulties and waste will increase and lower quality products may eventuate.

When a set of conditions is specified there is still the problem of maintaining these conditions, since there may be gradual or sudden changes in conditions which, if unnoticed, will lead to financial loss. Errors may also be made when lots from different sources are mixed inadvertently (incorrect processing), when conditions are misinterpreted, when the information is incorrectly transferred (one person to the next, one piece of paper to another, etc.) and so on and these may dramatically affect the final products.

(iii) Operating procedures.

There is usually a variety of ways in which an operator can carry out his or her duties and each will affect the production rate, product quality and the quantity of waste and hence profitability. There will be an optimum method or methods which will tend to maximise profits. Another problem which often arises is that even if the operating sequence is clearly defined the operative may diverge from this sequence due to poor training, poor supervision, lack of skill, carelessness and so on. Psychological factors can also assume considerable importance.

(iv) Machinery.

The capabilities of the machinery available will determine the ability of the mill to meet the product specifications and if these specifications are near the limit of the machinery capabilities, then processing difficulties could increase. The relative sophistication of the available machinery compared with the latest modern machinery will affect profitability since, in general, the more modern machinery will be more efficient, give less processing difficulty and less waste and hence should lower production costs.

Given a particular machinery set the major factor affecting the performance will be the condition of the machinery, since well maintained machines will be superior to poorly maintained equipment. In the latter case it might be expected that machinery faults would have an effect on profitability.

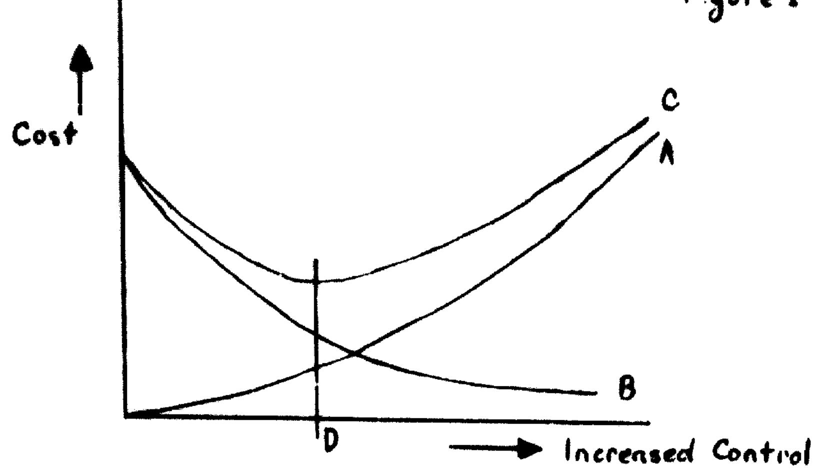
The aim of any quality control program is to eliminate (as far as possible) these foregoing effects which lead to increased production costs and hence lower profitability. Control of raw materials, processing conditions, product properties at various stages of processing, waste and operating procedures and regular machine maintenance must be carried out in order to ensure a final product which meets the specifications with adequate quality and minimum waste for minimum production cost. The following section describes some of the important factors in quality control and later sections deal with quality control as applied to the various sections of the textile industry. The role, the special problems and the significance of quality control in developing countries will then be analysed and the question of the setting up of central quality control centres will be examined.

## 2. Practical Quality Control Methods.

### 2.1 The economics of quality control.

One of the main factors in quality control is costing since the extent to which quality control is carried out will depend on the relative cost of the control scheme compared with the cost of poor quality (waste, processing difficulties, rejects, seconds, returns, etc.). The general type of cost relationship is indicated in figure 1. As the control effort is increased there will be a continual increase in the expenditure on the control scheme (curve A) and a corresponding decrease in the cost of poor quality (curve B). The actual cost to the firm (curve C) will be the sum of the costs of the control scheme and of poor quality.

Figure 1




As the amount of control is increased the actual cost will decrease to a minimum value and then increase for a greater quality control effort. The aim of the control scheme must be to operate as close to this

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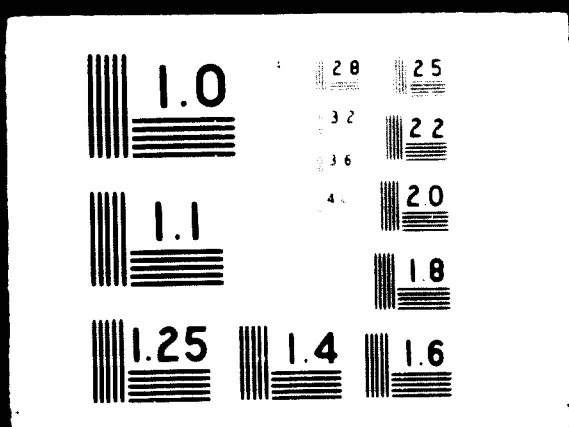


operatives.

(iv) Providing specifications and policing these specifications.

Standards are required for export goods and the centre could act as a control to see that only high quality merchandise is exported. The centre could also provide a check on the specifications of other merchandise. As part of this service the centre might provide recognition of good quality by introducing quality labels for such merchandise to assist in their sale.

(v) Quality control and testing for the industry.

In certain areas of quality control it will not be economical for mills to carry out their own measurements. This occurs particularly in the testing of fibre raw materials where methods available to mills are time consuming and expensive (particularly where the volume of testing required is small). A centre with volume throughput could take advantage of the latest automatic equipment to surmount this difficulty.

The centre could provide facilities for all the types of tests applicable to the mills it services to cater for such things as checking the accuracy of a particular mill, calibration of measuring instruments, teaching mill staff how to use the equipment, providing testing in areas where a particular mill does not have the appropriate equipment, etc.

(vi) Trouble shooting for the industry.

Mills often face processing difficulties where they are not equipped themselves to investigate the causes of their problems. The assistance of some outside agency where specialised equipment and manpower is available would be a great advantage. The type of problem for which service is provided could range from reasonably straight forward fault finding (using the centre's laboratories) to a full scale investigation of some serious processing problem within the mill itself.

(vii) Teaching and research.

If the centre is attached to a University or some similar tertiary institution, then it could be developed to provide textile technology degree and diploma courses. The centre would thus cater for the long-term needs (the supply of trained personnel) of the local industry as well as needs .. a more immediate nature. A centre developed in this fashion could carry out research programs on a wide range of problems relevant to the local industry.

(viii) Other functions.

The centre might assist in a variety of other ways, possibly including some of the following:

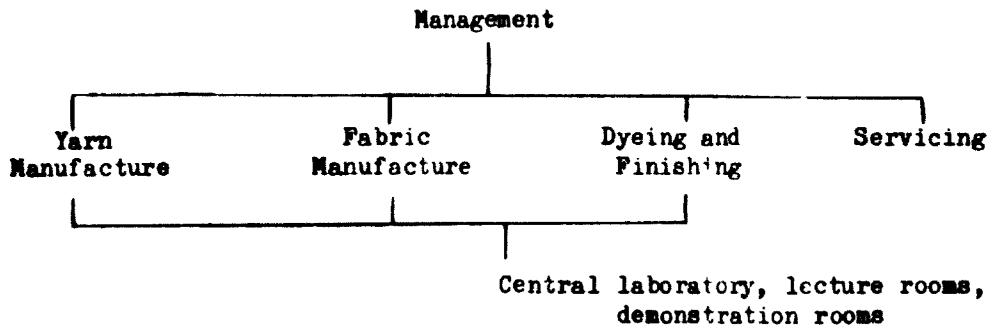
- assistance in new product development.
- carrying out wearing or other evaluation trials on new products.
- advising export companies on the latest overseas standards.
- giving technical advice in disputes.
- assisting in the correct use of goods by supervising care labels which give such things as washing and ironing instructions.
- providing a well equipped library with translation services.
- providing news on current developments in the world textile industry by means of some regular publication.

In setting up a particular centre it would obviously not be practical to institute all of the above at once. The centre must initially concentrate on relatively narrow fields of activity and gradually expand into the relevant areas. The establishment for example, could start more as a testing centre for the industry and expand from there or alternatively the basis could be a Textile School with testing facilities. The latter approach might be more desirable for the long term future of the local industry.

8.2.2 Staffing and equipping the cen.re.

Only a rough guide can be given here since much will depend on the size of the establishment, the functions assigned to the centre and the work load. A possible structure for a smaller centre is shown in figure 4.

Figure 4:




The management would consist of the centre director and office staff and each of the three textile sections (viz. yarn manufacture, fabric manufacture and dyeing and finishing) would be in charge of a textile technologist, who is an expert in the particular area. The three textile technologists would be responsible for general quality control and other problems arising in their own sphere of influence.

The servicing section would provide expert assistance in engineering and statistical matters to the textile sections. A textile engineer would be required to provide general engineering advice in such things as mill layout, purchase of machinery, air-conditioning, lighting, machine maintenance, etc. whilst a specialist engineer would be required to give advice in methods engineering and operations research. A statistician would be required as a consultant in statistical quality control.

The central laboratory staffed by a laboratory manager and sufficient laboratory assistants, attendants, etc. would provide a testing service for the three sections. Lecture rooms and demonstration rooms would also be available.

For larger centres it would be desirable for each textile section to have its own laboratory facilities, each with a laboratory manager and sufficient support staff. This would entail doubling up on particular equipment so that efficiency is not impaired.

The centre would require laboratories for various functions including chemical, processing, testing (accurately controlled temperature and humidity), dyeing and finishing and microscopy laboratories. General equipment would include chemicals, stains, glassware, balances (torsion and Mettler [100 gm and 2000 gm]), drying ovens, microscopes (simple, hot stage, projection, stereo, polarising, interference; camera attachment for microscopes), an Instron tester (suitable for fibres, yarns and fabrics, with the appropriate attachments). This general equipment would cater for many of the tests carried out.

The following is a list of the more specific specialised equipment which would be required assuming that cotton, wool and man-made fibres are to be catered for and that testing of raw wool and cotton is necessary.

(i) Cotton fibre testing.

Cotton standard samples for classing and calibration; Shirley analyser for trash content of cotton (and wool); Comb sorter (Suter-Webb, Shirley or Uster) for fibre length; Fibrograph for fibre length; Arealometer (or micronaire or fibronaire) for fibre fineness and maturity; Stelometer or Pressley tester for bundle strength; Cotton Colorimeter for the colour of cotton (and wool).

(ii) Wool fibre testing.

Core sampling equipment; W.I.R.A. single fibre length apparatus; Almeter for fibre length; W.I.R.A. airflow tester (or the new C.S.I.R.O. sonic fineness tester) for fibre fineness; laboratory scale scour for yield determination; Soxhlet extraction apparatus for grease content; rapid grease extraction apparatus for grease content; C.S.I.R.O. rapid regain tester (with a range of sample containers).

(iii) Man-made fibre testing.

Vibroscope for denier determination.

(iv) Fibre identification.

Infra-red spectrometer.

(v) Fibre processing and fabric manufacture.

Micro-spinning plants for cotton, worsted and wool; sample loom; sample knitting machines.

(vi) General mill testing.

Yarn speed indicator; mean yarn tension meter; peak yarn tension meter; electronic yarn tension meter; tachometer; stroboscope; roller eccentricity instrument; sound level measuring instrument; illumination measuring instrument; heat absorption and transmission measuring instrument; static electricity measuring equipment.

(vii) Yarn manufacture and yarn testing.

Nep counting templates with classification photographs; Uster evenness tester with the tester and recorder, the integrator, the spectrogram and recorder, the imperfection meter and the Uster statistics; wrap block for roving mass/unit length; wrap reels, balances and girth measuring apparatus for yarn count; twist meters of the parallel fibre method type, the twist, untwist type and the continuous type; friction testers (Shirley autographic and Shirley banjo); Uster dynamometer with automatic bobbin changer for yarn strength; wrapping board machine with standard photographs for yarn faults.

(viii) Fabric testing.

Fabric appearance standards; yarn crimp tester, piece glasses, needles, line gratings for fabric structure; bursting strength tester; Elmendorf ballistic tearing strength tester; cantilever-type drape meter, crease recovery tester; bending length tester; fabric thickness tester; abrasion testers (Stoll and Schiefer); templates for fabric weights.

(ix) Finishing and finish testing.

Laboratory dyeing and finishing equipment; fadeometer for light fastness; fading cabinets for daylight fading; launderometer or washwheel for wash fastness; domestic washing machine; crockmeter for rubbing fastness; press for pressing fastness; shrinkage tank for relaxation shrinkage; cubex washing machine; spectrophotometer for transmission and reflectance measurements; colorimeter, colour matching instrument; water baths (temperature controlled); mixers, shakers, centrifuges; flammability tester; waterproofing testers (hydrostatic head and shower testers); air permeability tester.

(x) Garment testing.

Sewing machines (domestic and industrial); crease sharpness tester.

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