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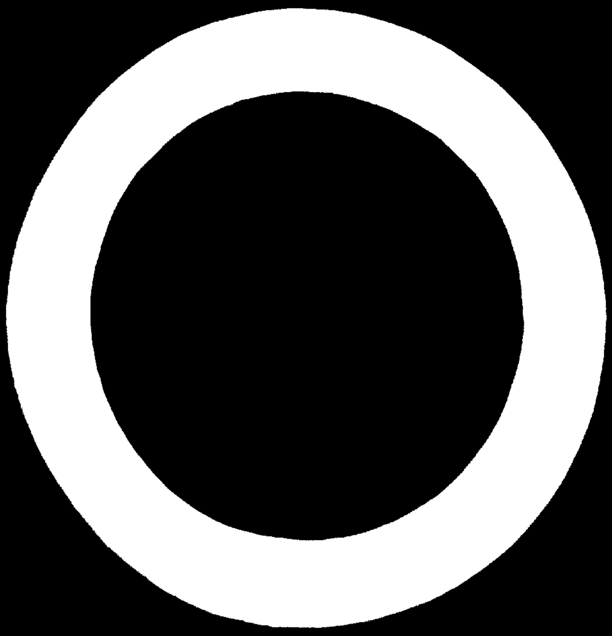
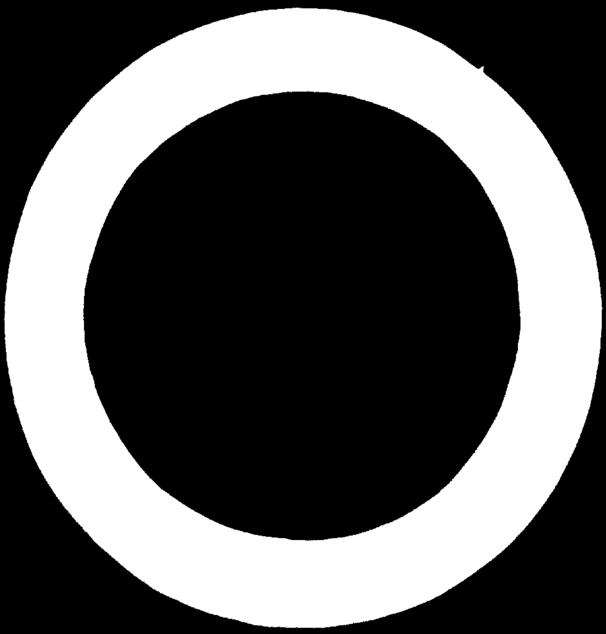
QUALITY CONTROL IN THE TEXTILE INDUSTRY

UNITED NATIONS





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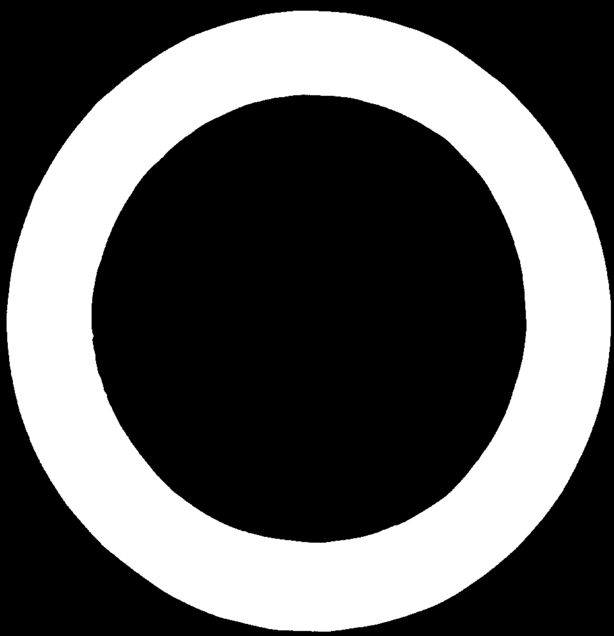

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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
VIENNA

QUALITY CONTROL IN THE TEXTILE INDUSTRY

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PREFACE

This publication consists of two parts. Part I is the report of an Expert Group Meeting on Quality Control in the Textile Industry, held in Budapest in July 1970. The meeting was convened by the United Nations Industrial Development Organization (UNIDO) to recommend suitable ways of assisting developing countries to establish efficient quality control systems in their textile industries.

Among the recommendations adopted at the meeting was one calling for the preparation of a comprehensive study on quality control in the industry to include much of the information contained in papers presented to the meeting and in addition such aspects as the staffing of quality control departments, equipment required, training of mill personnel, preventive maintenance, and the role of statistics in maintaining standards. This study was prepared for UNIDO by Messrs M. Chaikin and J. D. Collins of the School of Textile Technology, University of New South Wales, Australia, and is presented in Part II of the present publication. The views and opinions expressed in the study are those of the authors and do not necessarily reflect the views of the secretariat of UNIDO.

EXPLANATORY NOTES

The following abbreviations are used in this publication:

CV = coefficient of variation

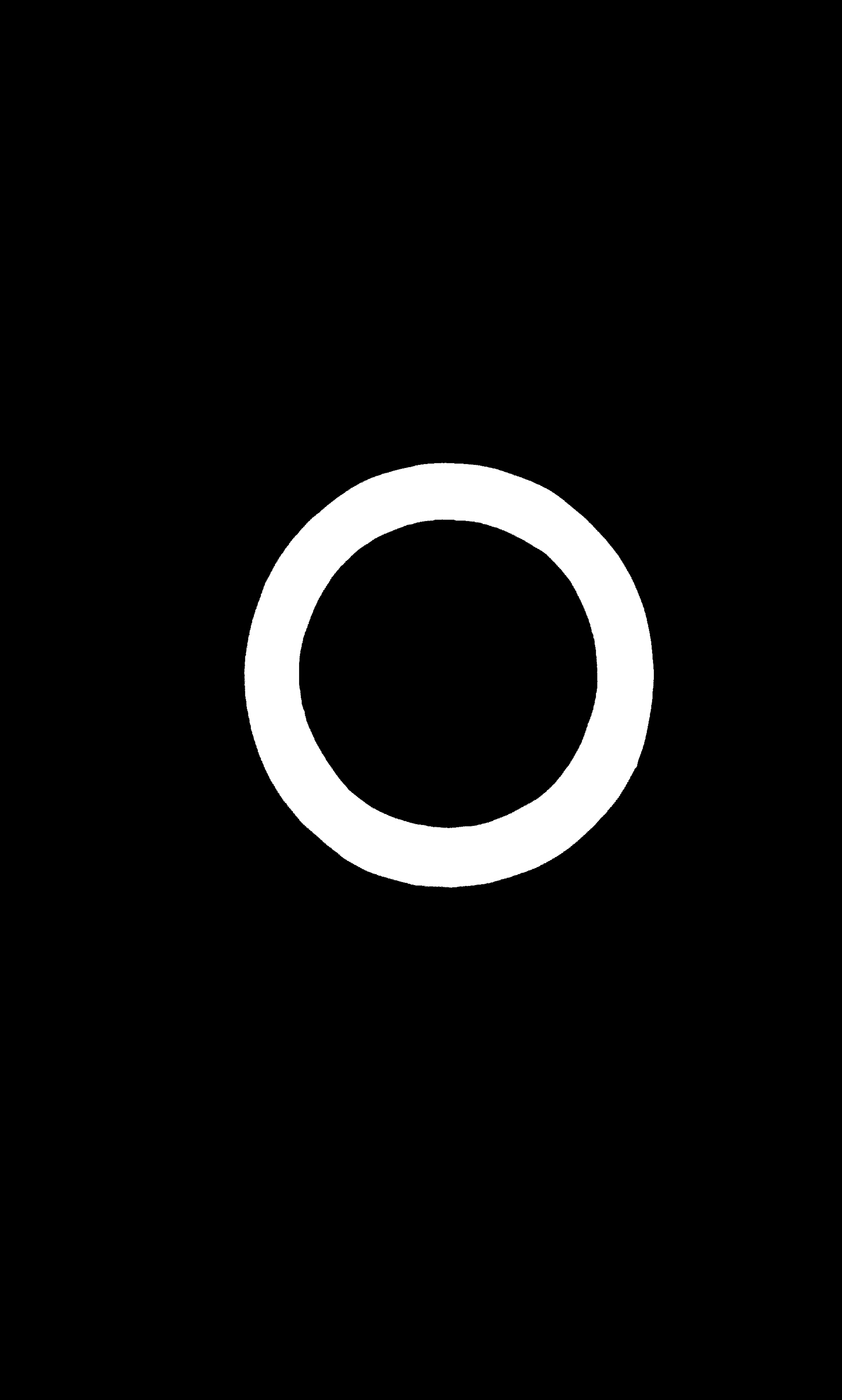
mm = millimetre

U = Uster

pH = hydrogen ion exponent

Part I

REPORT
OF AN EXPERT GROUP MEETING ON QUALITY CONTROL IN THE TEXTILE INDUSTRY



ORGANIZATION OF THE MEETING

1. In accordance with the approved UNIDO work programme for 1970 (ID/B/64/Add.6, para. 15), an Expert Group Meeting on Quality Control in the Textile Industry was held from 6 to 9 July 1970. The purpose of the meeting, which was convened in Budapest at the invitation of the Hungarian Government, was to recommend suitable ways of assisting developing countries to establish efficient quality control systems in the textile industry.

2. Thirteen experts participated in the meeting and there were three observers. Mr. M. Chaikin was elected Chairman and Mr. I. Szabo, Rapporteur. Mr. A. Eräneva represented UNIDO as Officer in Charge of the meeting.

3. The agenda of the meeting is given in annex 1. A number of experts were invited to present papers to the meeting on various aspects of the topics included in the agenda. These papers are listed in annex 2.

4. In addition to the discussion of the agenda items, the programme included visits to the Textile Research Institute, the Institute for Quality Control in the Textile Industry, a special exhibition of textile testing instruments organized by METRIMPEX, and an integrated worsted mill, in Budapest.

DISCUSSION

5. A paper presented by Mr. Barella Miró on statistical methods of quality control consisted mainly of a survey of the various techniques described in trade publications. After dealing with the definitions, the concept of distortions and the methodology involved, the author referred to the principal statistical tests and their applications. The paper also contained an introduction to analyses of variance.

6. Discussion centred mainly around the minimum knowledge required by quality control personnel, their training in the basic concepts of mathematical statistics, the use of non-parametric methods (not dealt with in the paper) and the role that statistics play in the general establishment of a quality control system.

7. The actual organization of quality control in a textile mill was outlined in a paper presented by Mr. Jędryka. The essential factors in the introduction of quality control, the responsibilities and interrelationships between the various mill departments and the problem of the development of new processes and products were dealt with in some detail.

8. As expected, the varying experiences of the participants in the introduction of quality control at the practical mill level highlighted the discussions on the paper, and some useful information was exchanged.

9. The paper by Mr. Chaikin was concerned mainly with the causes and control of waste in worsted spinning, but a number of more generally applicable factors and procedures were mentioned as well. The discussion brought out the very important role that waste plays in the economics of some parts of the textile industry, and, in particular, the special problems that might be encountered in developing countries in this connexion.

10. Three papers, by Messrs H. K. Krakowian, T. A. Subramanian and L. A. B. Gangli, on various aspects of quality control in spinning were presented. They supplemented each other to cover quite adequately one of the most important areas in quality control. In particular, mean yarn count and yarn irregularity and their significance in process control and product quality were stressed and the various methods discussed. The wide-ranging comments that followed each of these papers indicated the interest they aroused and the considerable amount of work that has been carried out in the past.

11. The papers by Messrs M. C. Paliwal, S. N. Bhaduri and P. Grosberg were received with a great deal of interest since their topics–winding, beaming and weaving, and knitting, respectively–had not received the same amount of attention in

trade publications as some of the other issues. The various techniques involved, the problem of yarn defects, and the control of parameters were outlined. Subsequent discussion extended and amplified the points raised in the papers.

12. "Quality Control in the Finishing of Cotton", by Mr. P. C. Mehta, was presented by Mr. Paliwal, and the discussion indicated the very great interest of the participants in the use of quality control techniques in dyeing and finishing. The paper dealt comprehensively with raw materials and dyestuffs, their purity and compatibility with finishing agents and auxiliaries; it also dealt with aspects of quality control and the control of goods-in-process. The discussion brought out special problems encountered in actual mill experience.

13. The last paper, by Mr. Stiller, on the psychological aspects to be considered when establishing a quality control scheme in a mill, was presented by Mr. Pitre. The participants outlined their experiences in this connexion, and during the ensuing discussion the importance of giving attention to this question was fully recognized.

14. It was agreed that, for the purpose of preparing a composite document on quality control in the textile industry, each author should re-submit to UNIDO corrected copies of his paper and its summary as well as a summary of the discussion relating to it. The authors were further requested to submit as complete bibliographies as possible on the subject matter of their papers, paying special attention to industrial practice.

RECOMMENDATIONS

15. Following the discussion of points raised in the papers, it was agreed that additional papers and/or contributions should be sought covering the following topics:[1]

- *(a)* Quality control in the finishing of wool and wool-blended woven and knitted fabrics;
- *(b)* Quality control in the finishing of man-made fibre products;
- *(c)* Quality control of fibre raw materials;
- *(d)* Quality control in the garment industry; and
- *(e)* Case studies on the establishment of quality control systems with special attention given to the practical results achieved.

It was also agreed that the paper entitled "Quality Control in the Finishing of Cotton" (ID/WG.58/5/Rev.1) should include additional sections on quality control in the finishing of cotton-blended and knitted fabrics.

16. It was recommended that, following the receipt of the additional material necessary to give a reasonably complete picture of the application of quality control in the textile industry, UNIDO should seek the assistance of one or more experts to prepare a composite document recommending the procedures to be followed in instituting a comprehensive quality control scheme in a developing country. This should be followed by the actual implementation of the proposed scheme in a consenting country, and the report on the results achieved should be available for distribution. Model quality control organizations should then be set up in other developing countries.[2]

17. In implementing the programme outlined above:

- *(a)* The practical procedures, including systems and techniques followed in existing textile quality control centres, should be taken into consideration;
- *(b)* If a quality control centre is established, it should in general act as an adviser and consultant to the individual textile mills in the country. It should not be a mere testing house but should become involved in training mill personnel in the use of quality control as a basis for process control. The centre should be encouraged to become involved with firms

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[1] Annex 2 contains a list of the new papers resulting from this recommendation.
[2] Part II of this publication is the comprehensive paper called for in this recommendation.

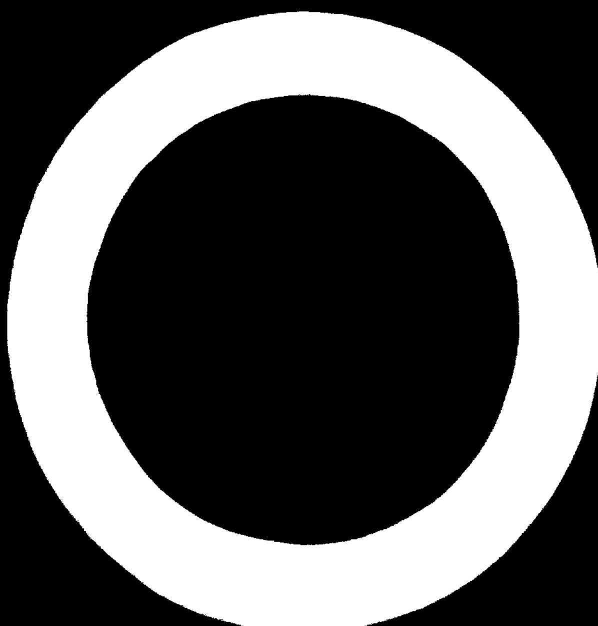
in the development of new products so as to prevent an excessive rigidity in the formulation of standards that could place a brake on technical developments;

(c) Additional expert advice should be sought when necessary; and

(d) The educational and training facilities required should receive the special attention of UNIDO.

18. It was proposed that a series of quality control seminars be held in selected developing countries. An expert group would be asked to organize and provide the background documents for the seminars which would be repeated successively in the various countries concerned.

19. It was recommended that UNIDO co-operate with organizations involved in quality control programmes, with special reference to their activities in the promotion of quality control systems.



AGENDA OF THE MEETING

1. Opening addresses; election of Chairman and Rapporteur.
2. Survey of statistical methods of quality control in the textile industry.
3. General organization of quality control in a textile mill.
4. Causes and control of waste in worsted spinning.
5. Application of quality control methods in worsted spinning.
6. Quality control in cotton spinning, yarn count and uniformity.
7. Quality control in winding, beaming and weaving.
8. Quality control in knitting.
9. Quality control in the finishing of cotton.
10. Psychological considerations for an efficient quality control programme.
11. Recommendations and conclusions.

Annex 2

LIST OF DOCUMENTS[1]

A. Documents presented to the meeting

ID/WG.58/1	The causes and control of waste in worsted spinning by M. Chaikin, University of New South Wales, Australia
ID/WG.58/2	Application of quality control methods in worsted spinning by H. K. Krakowian, International Wool Secretariat, London, United Kingdom
ID/WG.58/3	Survey of statistical methods and concepts to be applied in textile quality control by A. Barella Miró, Director of the Institute for Textiles and Leather, Barcelona, Spain
ID/WG.58/4	Quality control in the knitting industry by P. Grosberg, University of Leeds, United Kingdom
ID/WG.58/5/Rev.1	Quality control in the finishing of cotton by P. C. Mehta, Director of Ahmedabad Textile Industry's Research Association, Ahmedabad, India
ID/WG.58/6/Rev.1	Quality control in cotton spinning, yarn count and uniformity by T. A. Subramanian, A. R. Garde and S. N. Bhaduri, Ahmedabad Textile Industry's Research Association, Ahmedabad, India
ID/WG.58/8/Rev.1	Quality control in winding, beaming and weaving by M. C. Paliwal and S. N. Bhaduri, Ahmedabad Textile Industry's Research Association, Ahmedabad, India
ID/WG.58/9	The organization of quality control in a textile mill: some general aspects and problems by T. A. Jędryka, Textile Research Institute, Łódź, Poland
ID/WG.58/10	Psychological considerations for an effective quality control programme by J. Stiller, Werner Management Consultants, Inc., New York, United States

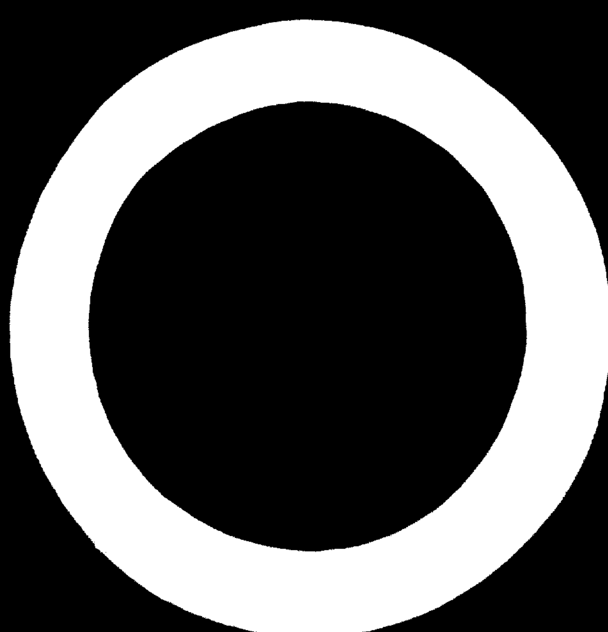
[1] A limited number of copies are available upon request.

	Study of the theoretical and practical relations of spinning plants by L. A. B. Gangli, Textile Research Institute, Budapest, Hungary[2]

B. Documents prepared subsequent to the meeting, as recommended by the Expert Group

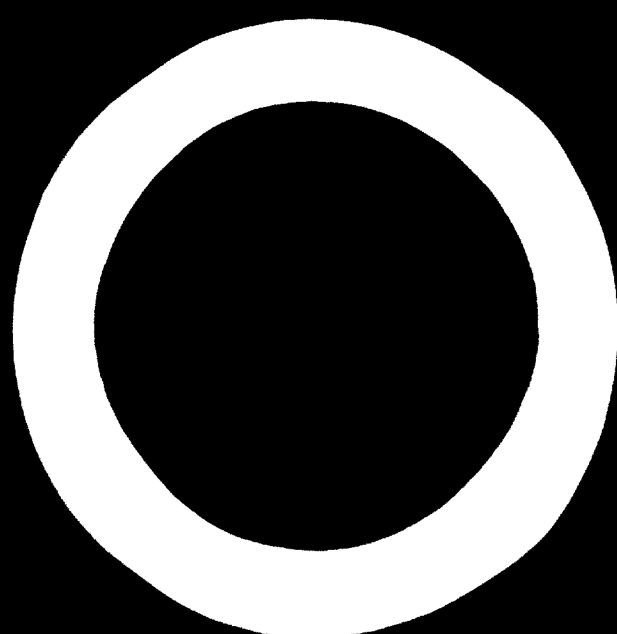
ID/WG.58/13	Quality control in the finishing of fabrics made from blends of cotton with man-made fibres by P. C. Mehta, Director of Ahmedabad Textile Industry's Research Association, Ahmedabad, India
ID/WG.58/14	Quality control in the clothing industry by N. H. Chamberlain, University of Leeds, United Kingdom
ID/WG.58/15	Quality control in the finishing of man-made fibre products by C. Duckworth
ID/WG.58/16	Quality control in the finishing of wool and wool-blended woven and knitted fabrics by C. Duckworth
ID/WG.58/17	Quality control of fibre raw materials by J. D. Collins, University of New South Wales, Australia

[2] Distributed by the author during the meeting and not available for distribution.



Part II

A STUDY ON QUALITY CONTROL



Introduction

The main aim in any manufacturing industry is to maximize profits from the sale of the finished merchandise, which entails minimizing the production costs. A mill purchases raw materials and, through a series of mechanical and/or chemical processes, transforms them into the final product for sale. As this product is required to have certain properties, or meet certain specifications, the raw materials, the processing sequence and the processing parameters must be chosen with these in mind.

For any product there is a minimum hypothetical production cost but the actual cost is usually higher, 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 aim of quality control is to minimize these losses, and there are a number of positive measures that can be taken in this regard. Before discussing them, however, the main parameters affecting the total product cost, which come under the jurisdiction of quality control, will be reviewed.

The following factors are significant in the final production cost:

(a) Raw material parameters;

(b) Processing conditions;

(c) Operating procedures; and

(d) Machinery.

Raw material parameters. There are a number of factors that must be considered when choosing fibres for a specified end product. The fibre's performance in processing and end use will be affected by its fineness, length, length and diameter variability, mechanical properties, crimp, maturity (cotton), colour, the presence of foreign matter, and the degree of entanglement or damage. In practice, there will be some minimum requirement in terms of these properties and the purchase of inferior fibres may give rise to processing problems, excessive waste and substandard merchandise, leading to large profit losses. If a firm obtains better fibres than are necessary for the purpose (usually at a higher purchase price), this too will lead to a loss in profits. As fibres such as cotton and wool are often sold with substantial amounts of impurities present, it is essential, in order to avoid paying too much for the raw material, to assess accurately the clean fibre yield. When choosing fibres for a specific end use it is necessary to balance quality against price in order to obtain the optimum purchase.

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

Textile mills use many other raw materials, such as chemicals, dyes and sizes, and if these are not up to specification in terms of strength, purity etc., they may lead to processing problems with a consequent rise in production costs. Certain materials, such as dyes, may be available from a number of suppliers at apparently different prices, but these prices will, in effect, be directly related to the strength of the dyes. The correct choice of raw material depends on the effective price and quality factors associated with the material.

Processing conditions. The specifications for a given final product determine the processing sequence and the relevant processing parameters that will provide optimum manufacturing conditions. However, even when 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, and production rates); process parameters (e.g. temperature, time, doublings, and pH); fibre conditioning (e.g. regain, relative humidity, oil, and anti-static agents); and the state of the material entering the process (fibre parallelization, sliver mass per unit length, twist etc.). Because of the inherent complexities involved, it is difficult for a mill to obtain optimum conditions and, therefore, the degree to which the actual conditions approach the optimum that determines profitability. As the conditions depart from the optimum, processing difficulties and waste increase and lower-quality products are turned out.

When a set of conditions is specified it must be maintained, since gradual or sudden changes will, if they go unnoticed, lead to financial loss. Errors are also made when lots from different sources are mixed inadvertently (e.g. through incorrect processing), when conditions are misinterpreted, when the information is incorrectly transferred (e.g. one person to the next, one piece of paper to another) and so on, and these may have a dramatic effect on the final product.

Operating procedures. An operator may carry out his or her duties in a variety of ways, and each way affects the production rate, product quality, quantity of waste and, hence, profitability. There is an optimum method (or methods) that tends to maximize profits. However, a problem that often arises in this respect is that, even if the operating sequence is clearly defined, the operative may diverge from it if he is poorly trained, poorly supervised, lacking in skill, or just simply careless. Psychological factors also have an important bearing on this problem.

Machinery. The capabilities of its machinery determine the ability of a mill to meet product specifications, but if these specifications are set near the limits of the machines, processing difficulties may increase. The age and sophistication of the machinery affect profitability, since, in general, the more modern the machinery is the more efficient it is, presenting less processing difficulty, less waste and, hence, lower production costs.

The majo factor affecting the performance of the machinery is the condition in which it is ke . Poorly maintained equipment has an adverse effect on profitability.

The aim of a quality control programme is to eliminate, as far as possible, factors that lead to increased production costs and lower profitability. Control of raw materials, processing conditions, product properties at various stages of processing, waste and operating procedures, in addition to regular machine maintenance, are essential to ensure a final product that meets the required specifications, with minimum waste for minimum production cost. Chapter 1 discusses some of the more important aspects of quality control while later chapters deal with its application to the textile industry. The role, the special problems, and the significance of quality control in developing countries are analysed in Chapter 7, as well as the question of setting up quality control centres.

Chapter 1

PRACTICAL QUALITY CONTROL METHODS

The economics of quality control

Costing is one of the most important factors in quality control, since the extent to which control is exercised depends on the relative cost of the control scheme compared with the cost of poor quality owing to waste, processing difficulties, rejects, seconds, returns etc. A general cost/quality control relationship is indicated in figure 1. As the control effort is increased, there is a corresponding 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) is the sum of the costs of the control scheme and of poor quality.

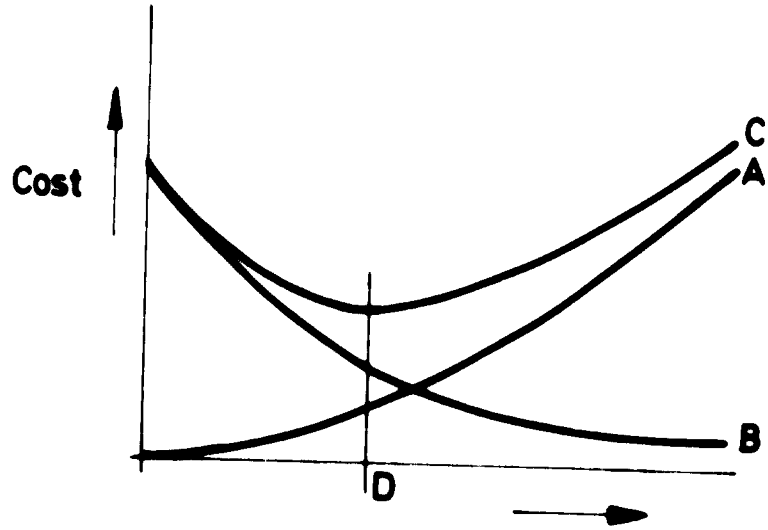


Figure 1. The cost of quality control

As the amount of control is increased, the actual cost decreases to a minimum and then increases again for a greater quality control effort. The aim of a control scheme is to operate as close to this minimum as possible, and optimum control (D) also corresponds to this minimum. The optimum represents a compromise, since perfect quality is an ideal that is usually not economically worth obtaining.

In practice, the achievement of this optimum requires a good accounting system that gives a continuous, accurate record of the costs of the control scheme and the cost of poor quality. The level of control is varied continuously, either upwards or downwards, until the minimum is reached. It is worth pointing out here that poor quality does not necessarily indicate an inadequate control scheme. The optimum may be that stage at which a significant proportion of seconds is being produced. For example, it may be best, economically, to produce 10 per cent seconds. It is necessary, of course, to ensure customer satisfaction by adequately screening the final product before sale. Lower-quality articles should then be removed and sold as seconds.

As well as implementing the foregoing optimization scheme, an effort must be made to gain maximum benefit for a given expenditure on the control scheme. This means a careful assessment of the scheme to ensure that the essential testing is carried out, while unnecessary or superfluous testing is eliminated. The testing scheme must be highly selective in order to obtain maximum benefit, particularly when the added value is low (e.g. knitting) and funds for quality control are consequently limited. Figure 2 indicates diagrammatically the effect obtained by optimizing the control scheme. Curve A is the cost of control while 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.

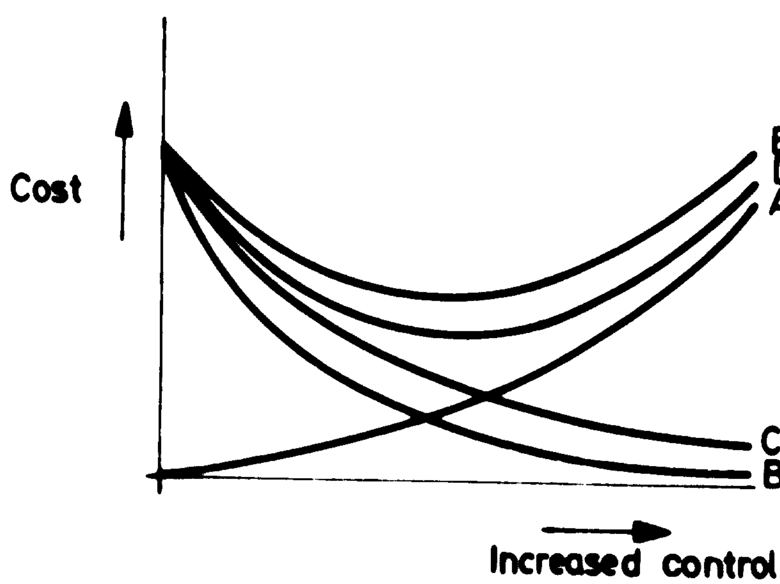


Figure 2. The effect of quality level on the cost of quality control

The economics involved in the choice of raw materials, such as fibres, represent another factor in the scheme that is worth considering. As cheaper fibres lead to more waste and a lower quality level, losses may be higher than when more expensive fibres are used. Figure 3 indicates the effect to be expected where curve A is the cost of control and curves B and C are the costs of poor quality for the cheaper and more expensive fibres, respectively. The respective actual costs to the mill are indicated by curves D and E.

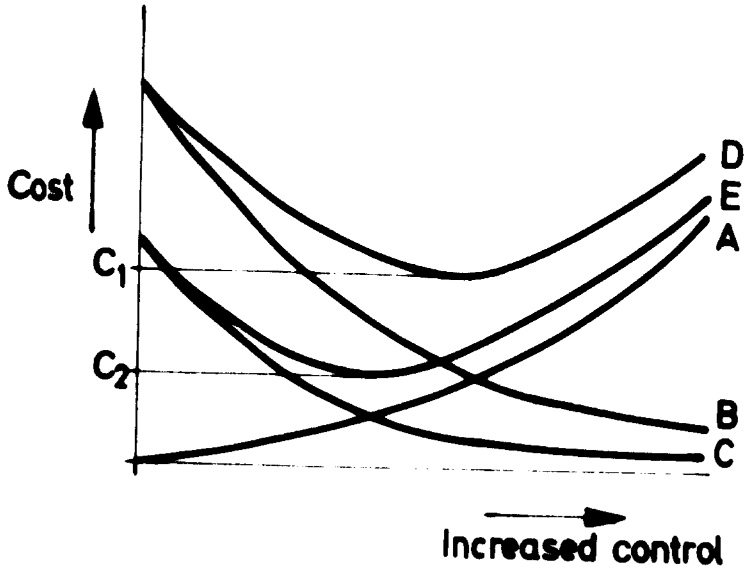


Figure 3. The effect of the quality of raw material on the cost of quality control

For the cheaper fibres, the optimum scheme costs C_1, while for the more expensive material the cost is C_2: therefore, the increased cost for the cheaper fibres is $C_1 - C_2$. If this difference is smaller than the saving from the purchase of the cheaper fibres, it will be more economical to use them. It is thus necessary to optimize the choice of fibres in order to minimize costs.

Obtaining and maintaining optimum processing conditions

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

Experiments in general production may be conveniently carried out by using the "evolutionary operation" (EVOP) method, a special technique for the step-by-step improvement of a process up to the optimum level. A series of small, systematic changes, in levels at which process variables are held, is introduced into the daily production, the size of the changes being such that the danger of adverse effects leading to financial loss is slight. After each set of changes, the results are reviewed and new changes made. Through this evolutionary development, the process is gradually "nudged" into optimum operating levels. At the outset it is better to change only a few variables, but as experience is gained it may become possible to institute many changes simultaneously. A simple example of the method is provided by a firm wishing to find the optimum percentage of a cheaper fibre that can be added to a blend without detrimental effects. The firm knows that the use of 15 per cent of this component has no effect. The amount is increased in steps of 1 per cent until processing is adversely affected. The future level is then set at the highest percentage where satisfactory performance has been achieved. Other parameters may be varied to obtain further improvement.

Carefully planned small-scale processing experiments in which a variety of parameters are altered are desirable and are becoming increasingly important nowadays, since sudden shifts in fashion and the like mean that mills must be prepared for rapid as well as gradual changes. Through these experiments a mill gains 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, and note taken particularly of how the derived conditions stand up in practice and whether changes have been necessary because of processing difficulties. The combined data from experiments and from previous production provide the basis for future practice.

The degree to which a mill can achieve optimum conditions varies considerably, depending on a wide range of factors that include its size, the degree to which its production is standardized, lot sizes and the variety produced, types of processes and so on. For example, a small mill producing many small lots in a variety of colours experiences greater difficulties than a large mill producing very large lots of the same colour. It is up to each mill to strive for its own effective optimum conditions.

Experience gained through experimentation and practice influences the choice of processing conditions for a particular job lot. However, once these conditions are decided, care must be exercised to ensure that they are maintained throughout the processing sequence. Adequate documentation, identifying the job and giving processing conditions and other relevant data, correctly recorded, should accompany the lot through processing. For a given process the relevant processing data must be transferred correctly to the job card (or whatever recording system is being used) for each machine. The machine must be set up according to these specifications and continuous checks, visual or other, must be made to ensure that the conditions are being followed.

Machine settings, if properly adjusted initially, should not constitute a problem; however, 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). Parameters for some processes may fluctuate or vary with time (bath temperature, liquid level, pH, chemical concentration and so on), and these must be either controlled automatically or checked at intervals, depending on the rate at which the changes occur and their relative importance in processing. Thus, attention should be paid to those parameters where great changes may occur in a short period or where even small changes may have a dramatic effect on processing.

Machine maintenance

The condition of the machinery has a vital bearing on production, quality, waste, and thus production costs. In order to minimize faulty operation and breakdowns, it is necessary to implement a comprehensive preventive maintenance scheme. The functions of such a scheme are to ensure:

(a) That machines are cleaned regularly;

(b) Regular lubrication of each machine;

(c) Regular attention to parts that need replacement or reconditioning (lapping on squeeze rollers, roller coverings, blades in slub catchers, parts that require sharpening and so on);

(d) That the machine is operating correctly (checking the operation of the various stop motions, builder motions and so on);

(e) That machine settings do not move out of adjustment during operation; and

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

It is necessary to supply maintenance and inspection check lists for each machine, giving the frequency at which each of these functions should 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 should be discouraged, in particular, from making adjustments to settings without the supervisor's knowledge. If an adequate scheme is set up and personnel are vigilant, problems with machinery can be kept to a minimum.

Operative procedures

As the operator is in direct contact with the material during processing, his or her actions may have a significant effect on productivity, quality and waste. The first parameter to consider in this respect is the institution of the best known 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 whether one operator does one or more jobs in a sequence (e.g. should the same operator carry out doffing, piecing and creeling within the spinning operation). After jobs have been determined, the duties for each job, and methods of carrying them out, must be clearly detailed.

The operative must be taught these procedures and told why they are to be carried out in the designated fashion. This information should be geared to the ability of the operative to understand the problem and should include an explanation of the importance of the process in the over-all 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 quality. A balanced approach must be instituted whereby production, quality and waste get proper attention.

The supervisor must continually monitor the work to ensure that the specified procedures are being adhered to correctly. He should be constantly alert for deficiencies and when they are found, should determine whether they are owing to:

(a) Operative carelessness;

(b) Expecting the operative to do a job that is beyond his capabilities; or

(c) Poorly defined or ambiguous procedures.

As it is unlikely that the initially defined procedure will be optimum, 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 develop operating methods that will give the best practical results. The psychological considerations that are involved in these procedures must be understood. They will be discussed in a later section.

Statistical quality control

The testing programme

Besides developing control methods, it is 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:

(a) A list of all properties that can be assessed or measured during processing.

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

(c) The relative importance of each property on subsequent processing and in the final product. This includes 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.

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

(e) 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.

(f) 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, the results may be useful only as a guide in preventing future processing mistakes.

The aim of the control scheme is 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, such as the number of measurements required, the frequency of measurement and sampling methods. When the scheme is put into practice it will be necessary to review the results continually so that the scheme can be optimized by changing the frequency of testing some variables, removing variables from the control scheme, adding others, improving sampling techniques and so on.

The role of statistics

Although it is sometimes advisable to carry out a complete inspection (e.g. of finished products, fabrics and garments), it is more usual to base decisions on a sample taken from the material. There is always certainty in a decision made on the basis of a complete inspection, but when only a fraction of the output of a process is tested, the decision will have less probability of being correct. This means that there is always a certain proportion of wrong decisions. It is thus necessary to design procedures that will minimize the possibility of making wrong decisions. Such a procedure must be based on statistical methods.

Statistical methods are necessary to provide:

(a) Adequate sampling techniques. A sample that is truly representative of the total production should be chosen. Sampling methods must be such that operator and method bias do not occur and that the properties to be measured from the sample are not affected by damage in sampling (owing perhaps, to carelessness or the method being used).

(b) An adequate sample size for decision making. In order to determine the appropriate minimum sample size it is first necessary 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 that will have practical significance. If it is known, for example, that a 5-per cent change in the value of a parameter will have a detrimental effect, it will be important to detect this change most of the time; the sample size must be designed with this fact in mind. Decisions such as whether to act or not, whether to change or not, whether materials are equivalent or different must be made in such a manner that they will have a high probability of being right.

(c) A scientifically valid basis for decision making. It is always possible that variations measured may result from a chance fluctuation in inter-measurement and not from a genuine change. Statistical analysis offers a means of separating real changes from those produced by measurement variability. Statistical tests that cover a wide range of decision-making situations are available.

(d) A basis for deciding whether or not it is worth measuring certain variables. The calculation of the approximate sample size needed for meaningful decisions, coupled with the ease, cost and time of measurement, determine the value of taking 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.

Statistical methods

It is necessary to take measurements in order to determine the value of a characteristic (mass per unit length, strength, shrinkage, percentage impurities and so on). A series of measurements yields 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 its scatter or spread (which is related to the accuracy of the estimate). These parameters may be estimated by the arithmetic mean and the standard deviation, respectively, though, in order to simplify calculations, the median and range are often used instead.

The most important form of distribution is the Normal, or Gaussian, method which applies to a wide range of practical situations. The distribution may be regarded as Normal when errors in measurement, which may be regarded as accidental, conform to the following:

(a) They derive from a number of different sources of variation;

(b) The effects from these sources are independent of each other; and

(c) Individual effects are small compared with the over-all effect.

A characteristic that is also common to a number of distributions, including the Binomial and Poisson systems, is that about 95 per cent of all measurements are within two standard deviations of the mean, while all measurements are within three standard deviations.

Making a series of measurements 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 the results vary. The spread of these values 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 θ, where θ 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 that is sought. When estimating a parameter to a particular accuracy, e.g. $\pm$ 0.0001, and 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 testing the hypothesis, the aim is to be able to make decisions on whether, for example:

(a) The measured mean is, or is not, different from a specified value;

(b) The measured standard deviation is, or is not, different from a specified value;

(c) Two measured means are the same, or different; and

(d) The variances from two samples are the same, or different.

In the case of *(a)* above, for example, the basic method used is to set up a null hypothesis (the sample mean is equal to some specified value) and test it against an alternative hypothesis (e.g. the average value has increased to some new value). If the null hypothesis is assumed to be true, the distribution of the sample mean will be known, and an upper limit can be set in such a manner that it will be unusual to find a value greater than this limit. The calculated value is compared with this limit and if it is greater, the alternative hypothesis is accepted. If the null hypothesis is true, then it is desirable to make this decision most of the time and the limit is set so that the chance of rejecting it 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. The test is therefore designed to 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 many standard tests available, and those which assume reasonable normality include:

(a) Testing the value of a single mean or the difference between two means (t tests);

(b) Testing the value of a variance or standard deviation (chi-squared test);

(c) Testing the ratio of two sample variances (F test); and

(d) Comparing the effect of different levels of one or several factors on a certain characteristic (analysis of variance).

A wide variety of tests come under the general heading of "non-parametric" 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 charts may be used in regulation control to provide a continuous check on the value of a characteristic. These charts show the value that should be assumed by the parameter, together with the value's warning and control limits. The warning limits are set so that the measured value will be inside them most of the time and a value that goes outside them will give a warning of a possible shift in the characteristic's value. The control limits are set so that the chance of obtaining a value outside them, when no change has occurred, will be negligible. The design of the charts must be such that errors of the second kind are minimized, which entails using the correct sample size. If this is not done, a significant proportion of inferior quality material will be accepted as good. Charts may also be based on the median and range. These charts involve little calculation but are less efficient. Cumulative sum charts are useful in indicating trends. They are more sensitive, easy to obtain, and require smaller samples than control charts.

Waste control

The waste problem is a complex one, since a great variety of wastes are produced by a large number of related and unrelated parameters, including raw material variables, processing variables and conditions, operating procedures, and operative variables. As waste is often directly related to quality, maintaining the quality level will automatically keep it down. Sometimes, however, good quality is only achieved at the expense of extra waste (e.g. combing waste) and a balance between waste and quality is necessary. On other occasions waste and quality are independent of one another and the waste may be treated separately (e.g. starting up and running out wastes in processing). Waste becomes expensive at advanced stages of processing, but this might be offset somewhat by its redistribution 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 minimize losses incurred by the production of waste. This entails the optimization of the collecting and sale (or re-use) of waste. A classification system should be established, based on similarity of properties, value and end use. To obtain the optimum position, the costs of collecting, sorting and selling the waste must be balanced against the gains that might be obtained from higher sale values.

Standards must be set for the waste, but it is important that these be realistic. They must be flexible and should be revised regularly (upwards, if necessary). Waste should be weighed regularly and the results recorded in order to monitor progress. Adequate machine maintenance helps to minimize waste as does the use of correct operating procedures and the proper training of operators.

Chapter 2

QUALITY CONTROL ORGANIZATION

The quality control department

The modern trend is to remove quality control from production and make it a separate department directly responsible to management. This ensures the independence necessary for objective analysis and evaluation and enables mill management to take the appropriate corrective steps. However, the organization must guarantee smooth co-operation between quality control and the 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:

(a) 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.

(b) Setting up and maintaining the testing laboratory. This laboratory will carry out testing that cannot be done in the work place and should have the necessary equipment and qualified staff. Additional specialized equipment may be required for trouble shooting when production problems arise.

(c) The training of mill personnel.

(d) 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.

(e) Ensuring that prompt corrective 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 elapses between the discovery of faulty operation and corrective action.

(f) Assessing effectiveness of the scheme. The effectiveness of the scheme must be reviewed regularly and changes made where necessary.

Staffing of the quality control department

The main problem in staffing the department is finding a suitably qualified person to run it. This person should have the background and training to analyse problems and deal with them effectively. 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. Two feasible ways to fill such a post are:

(a) Employ a person already in the company, who knows the personnel and processes, but who knows nothing of modern quality control methods. Such a person must be taught these methods, and this may involve his attending specialized courses and/or the temporary use of consultants; or

(b) Employ a person from outside the company who is experienced in quality control methods. This person must become acquainted with the shop personnel and processes.

Much depends on the person chosen, but an insider generally can learn quality control methods more quickly than an outsider can acquire knowledge of processes and the confidence of the shop personnel.

A typical job specification for a quality control engineer reads as follows:

Formal training. A degree in engineering, textile engineering or textile technology is essential. Courses in industrial management, engineering economics, methods and procedures, cost accounting and human relations are desirable. Specialized training in statistics, quality control and the analysis of data would be a distinct advantage.

Experience. Three to five years in the textile industry, preferably in trouble shooting, methods work, process engineering or quality control.

Personal characteristics. Proven integrity and the ability to deal smoothly with people. The habit of reaching conclusions from facts, not opinions.

Duties. To organize and run the department in such a way to obtain maximum efficiency while maintaining a smooth working relationship with the production departments.

The control engineer supervises a staff whose number and qualifications depend to a large extent on the size and type of mill. In a large vertical mill it may be necessary to have a separate control engineer for each department (e.g. spinning, weaving and finishing) who would be ultimately responsible to the department head. The testing laboratory may require as a manager 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).

The testing laboratory

As a large number of fibre, sliver yarn and fabric tests are affected by moisture, it is necessary to control the humidity in the testing laboratory. The facilities and equipment provided in the laboratory depend on the control scheme considered economically appropriate for the particular mill, as discussed in previous sections. Where a mill cannot afford all the equipment needed 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 specialized equipment and testing outside the scope of the quality control department.

Training of mill personnel

Mill personnel at all levels must be taught the principles of quality control, and the explanation should be geared to the function of the employee within the mill. Top management must be convinced of the gains to be had from an efficient control scheme as well as the general methods of control, and in order to achieve this, it will be necessary to demonstrate to them the advantages in terms of hard cash. Very few top officials wish to support science merely for its own sake.

In teaching supervisors what quality control means it is more important that they be taught principles than the mathematical theory behind the principles. The emphasis should 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), averages, dispersions, the control chart and sampling. It is useful to indicate how some practical problems have been solved. The solving of actual problems by supervisors is a major help in a training programme and it is important that the training does not get ahead of this practical aspect.

Training of operatives is best carried out on the job by the supervisors. 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 over-all processing sequence, how to recognize poor quality and the effect of this on later processing.

Psychological aspects

There are many factors involved in achieving the desired results in quality control, and the human element is often the most significant of these. It is unwise to underestimate the importance of the human element in 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.

As every task carries the possibility of human error, it is important to understand how a person's behaviour pattern contributes to the making of errors and how this pattern can be changed to minimize errors. An employee's performance depends, to a large extent, on his physical environment, the explanation given to him regarding his task, and the degree to which he identifies with the goals of the organization. It is wrong to assume that human performance with regard to quality can be improved by increased motivation, since motivation itself may be in the wrong direction (e.g. production at the expense of quality).

Crash programmes aimed at improving attitudes and motivation tend to be limited and transitory and those that involve better screening, selection and training of employees are often unsatisfactory. More permanent improvement may be achieved by developing and evaluating new equipment, materials, techniques, operator aids etc., and applying them to the job.

There is often confusion on the part of the employee as to what constitutes acceptable, and what unacceptable, quality; when quality is border-line this confusion is particularly apparent. It is essential that standards be set clearly defining limits for acceptability and that these standards be communicated to the operator.

When selecting an employee, tests should be given to gauge his potential and ability to do the job and a personal interview should be conducted to determine his drive and ambition. The employee should be trained to feel part of the company and he should understand his place in the processing sequence. It is important to emphasize the correct methods for quality rather than methods for speed and quantity. Records of his progress should be kept and reviewed with him regularly. Proper training and supervision result in reduced labour turnover, reduced absenteeism, better morale, increased production and improved quality.

Before blaming the operator when quality falls below standard, the supervisor should determine if the proper tools were available to him, if his instructions were correct, if he was trained properly, if the product was in order when it reached his work station etc. A systematic approach to solving problems 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, and the consequences of off-standard quality. The quality control organizer must ensure that the skills necessary to achieve acceptable quality coincide with those of the employee, 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, while the operators are in direct contact with the process and the quality performance. The supervisor is the middleman 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 a diminishing of the importance placed on experience. If the skills are adequately taught, experience assumes a smaller role in determining quality. The employee must have the desire to learn, to be prepared to improve his 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 description, especially where the job is monitorial rather than causitive. Effective supervision automatically leads to high motivation levels in subordinates. The employee must be given a sense of responsibility, a sense of achievement and the incentive to improve his performance.

Chapter 3

QUALITY CONTROL IN SPINNING

Control of fibre raw materials

When choosing fibre raw materials, it is necessary to know the minimum fibre property requirements essential to the particular end product. Fibres should be selected to meet these requirements for losses will result *(a)* if inferior fibres are used or *(b)* if fibres are too good (and therefore too expensive) for the proposed application. Prices paid should be based on the clean fibre yield; an accurate knowledge of moisture contents and the amount of impurities or additives is therefore necessary.

Various fibre parameters are of significance in processing and end use, and fibres with the required properties should be purchased and processing adjusted to accommodate these parameters adequately. Fine fibres can be spun to fine counts, giving more uniform, stronger yams for the same count, with less processing difficulty than inferior fibres. They impart greater flexibility and softness to the assembly, offer lower abrasion resistance, increase the heat insulation, and are more liable to nep formation. Fibre diameter is also important in dyeing behaviour. Fibre length determines 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 is also related to 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 may 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 discolouration has a detrimental effect on dyeing. Foreign matter must be removed, and difficulties in removing it increase in proportion to the quantity present in the fibre. Entanglement and damage also reduce the value of the fibre to the spinner.

Grading is a means of classifying fibres according to their most important properties, from a processing and end-use point of view. Cotton is assessed according to length, colour, 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, such as variation from country to country, inter-classer variability, the drift of assessments with time, so that objective methods of measurement are necessary.

Fibre length may be determined either by measuring each fibre or by using sorting techniques, but these systems 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 (arealometer) methods, vibroscopically, using particle size counting, and by several other techniques; air-flow methods are the most appropriate for control use. Cotton fibre maturity may be estimated microscopically, but the air-flow method is best for control purposes. Bundle strength tests are common and colour can be measured using a colorimeter. The trash content of cotton is determined by using the Shirley analyser. 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 random samples from the volume of material. If only some of the bales within a lot are to be sampled, they must be chosen at random; a convenient method is to use random number tables. When sampling bales it is important to spread samples over the whole volume, being careful to avoid individual and method bias. When the combined sub-samples give too large a representative sample, it may be reduced by using the zoning technique.

The sampling scheme must be designed to ensure sufficient accuracy in the estimate. The optimum numbers of samples taken from a bale and the number of bales tested, depend on the variabilities within and between bales and the costs involved in the sampling. In zoning sampling, the estimate error may 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 what sort of fibres should be bought, it is necessary to carry out experimentation along the lines discussed in chapter 1.

The testing scheme will be affected by a number of different parameters. Expensive raw materials and the corresponding better-quality end products justify a comprehensive scheme, whereas if the added value is low, the scheme should be restricted. The available data on the fibres and the reliability of this data also affect the size of the scheme. The parameters tested depend on the type of fibre (e.g. wool or cotton). The availability of an inexpensive but rapid method of testing influences the choice of scheme. The relative cost of a scheme depends on the test volume and hence the mill size. The presence of a centralized testing laboratory is of assistance, particularly in developing countries.

Future developments are likely to be directed towards presenting the buyer with a "guaranteed" product, with objective test measurements available. Automatic test lines are available for cotton, and similar lines are planned for wool. The object will be to have the characteristics of each bale (or group of bales) identified and stamped on it 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.

Control in cotton spinning

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

Count and count uniformity are basic characteristics of spinning since yarn is designated by count and both characteristics affect strength and strength variability, the performance in later processes and the appearance of the fabric. 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 over-all 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 while long-term variability (100-metre lengths) is found by weighing. These variabilities represent the extremes of the B (L) curve and, if they are kept low, tend to keep the whole curve at lower variability values. Over-all control consists of maintaining the average count as specified, ensuring that the count variation (short- and long-term) is satisfactory and minimizing thin spots, thick spots and neps.

In order to control or eliminate the causes of variation increase within and between bobbins, it is first necessary to examine the processes. Processes up to, and including, carding have little effect on count variation within the bobbin. The most important single cause of this type of variation is defective draw frame drafting owing to such things as roller slippage and excessive web or creel draft. Incorrect regulation of bobbin speeds in fly frames may lead to irregular stretching, and a trend in the amount of stretch has a significant effect on variation within the bobbin. 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.

Uniformity between bobbins may be improved by regular control of blow-room weights, by ensuring that 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. 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 inter-mill surveys or past performance) to see if action is necessary. The set of norms supplied by Uster are based on international surveys and may not be applicable in developing countries which usually have higher values owing to differences in raw material and less sophisticated 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 occur whenever roller speeds vary or nipping positions move. 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 wavelength which gives information on the cause, and thus the cure, of the fault determines the type of fabric defect produced, while 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 by using the spectrogram attachment for the Uster evenness tester. Quasi-periodic variation (amplitude and wavelength) is usually a result of faulty fibre control in ring-frame drafting. Such drafting waves may be minimized by better fibre control.

The fibre raw material may be accountable for a great deal of yarn irregularity; the choice of the cotton to be used, therefore, depends on the end use and the value placed on the end product. Inferior cotton may be used where labour is cheap (e.g. in 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 draw frame when yarn irregularity is considered. Processing parameters that affect yarn irregularities include 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 such as those leading to poor yarn and fabric appearance and causing processing difficulties (e.g. in knitting) may be detected by the Uster imperfection detector. Fibre parameters such as uniformity of length (the more short fibres, the more thick and thin spots), the presence of immature fibres (neps), the trash content (counted as neps), and various processing parameters determine the number of imperfections.

Since poor performance (in terms of yarn irregularity and imperfections) is often due to processing parameters and machine conditions, it is essential that routine checks of processing parameters be carried out regularly and that the machines be regularly inspected and maintained. These checks will often prevent a defect long before it is detected by measurement.

Control in worsted spinning

General

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

Quality control of worsted usually takes place 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 (mm) and CV of length; short- and long-term variation, mean strength and variability of yarns are often specified. Machine makers nowadays often specify fibre parameter limits for the operation of their machines.

Control at the top stage involves checks on fibre fineness, 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 by a projection microscope or by the air-flow method. The latter method is preferred for routine testing since it gives quick results. Fibre length is important since it affects end use, conversion costs and the character of the yarn and fabric. Originally the comb sorter was used to obtain the barbe and hauteur, but automatic electronic instruments have been developed that yield the same qualities very rapidly.

The amount of neps and pieces of vegetable matter may be ascertained by counting within known weights of fibres, 1 nep per gram of fibre often being taken as the standard by mills. Improvement, however, is possible 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 it is more prevalent in large balls and can be minimized by the use of smaller balls.

Measurement of sliver and yarn irregularity using electronic capacitance testers is necessary as a control measure to ensure that the various processes are working correctly. The modern trend towards reduced doublings means there is more chance of an accident and hence more frequent (daily) inspection of rovings and yarn is necessary. The index of irregularity, the ratio of the actual CV of irregularity to the limiting CV 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 CV of weight between 100-metre lengths should not exceed 2 to 3 per cent (4 to 5 per cent CV will lead to bars in woven or knitted fabrics). Control charts may be used in this count control (for 100-metre lengths).

The tensile strength of yarn may be analysed by using an automatic dynamometer which gives the average breaking load, the minimum breaking load, the CV of breaking load, and 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 may be useful in guarding against future faults.

The causes and control of waste

Waste is a significant factor in the economics of spinning and represents a problem that is becoming increasingly important because of the growing costs of raw material and labour, the large capital investment needed in machinery, and competition from other firms. Constant changes in production owing to the demands of fashion have also highlighted the waste problem. Waste losses are relative to a number of factors, including the cost of the raw material, the cost of processing, handling cost, inefficiency, small profits, and the reprocessing cost or sale value of the waste material. As losses are greater at advanced stages in production there is a lot to be gained by keeping waste to a minimum in later processes.

The study of the factors that contribute to waste is complex since a wide variety of wastes with differing properties are produced by numerous related and unrelated factors. The problem is compounded by the fact that the amount of waste may increase with either increases or decreases in quality, or it may be completely independent of quality.

Raw material variables may determine the amount of waste produced; fibre diameter is the major factor here since, for the same count, less waste results when finer fibres are used. An increase in fibre length (up to a certain point) reduces waste. Variability in length is also important since low variabilities (square tops) are hard to spin and high variabilities lead to more fly waste (owing to short fibres). Strong fibres resist breakage and produce little waste, while specific weaknesses such as staple tenderness and tip weathering damage lead to increased waste.

Preliminary processing may be responsible for considerable fibre breakage and waste. Among the causes of such breakage are fibre entanglement, damage and residual grease content in scouring, hook formation, incorrect 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 contribute to the production of waste.

The relative humidity of the room and the fibre regain must be maintained at optimum values (depending on the system being employed) in order to minimize waste; low humidity conditions give rise to static problems while high humidity tends to make the fibres stick to the drafting rollers. Oil and anti-static agents reduce the need for precise humidity control, the optimum amounts depending on the system being used and whether blending with synthetics is being carried out. Where there are wide fluctuations in atmospheric conditions, automatic control of temperature and humidity may result in worth-while savings in the cost of anti-static agents.

During processing, drafts and doubling also contribute to waste; higher drafts require better fibre control in order to avoid excessive waste. Ratch settings and roving twist cause fibre breakage and waste. The problem of fly waste is becoming more important because the waste 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, provided it is kept in good condition.

Excess waste may also result from 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 from faulty packages is controlled by the spinner patrol cycle rate and the end breakage rate. Absenteeism and the use of trainees in positions that call for experience also contribute to waste, especially in smaller mills.

Small batch sizes, coupled with variety production, introduce 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 as the variety increases.

An over-all approach must be made to the control of waste since savings in one area may mean increased losses elsewhere. Because of the cost structure it may be better to increase the amount of waste in early processes in order to bring about a decrease in the later, more costly processes. Subsequent processes must be considered since economies in spinning may lead to problems later.

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

A waste-control programme may be initiated by bringing in a waste consultant, but if this is not possible, a mill may institute its own programme. The first step is to explain the importance of waste in terms of cost, quality and job security, to all key supervisors, and obtain their co-operation. The locations of, causes of, and remedies for particular waste problems are examined. Supervisor conferences at which each person discusses the problems in his own area may also be helpful.

A classification and sorting scheme for waste must be set up, with separation based on 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, which are important for comparative purposes, must be flexible, not too harsh, and should be revised regularly.

When training operatives in methods of waste control, a rational approach, rather than pressure tactics, should be adopted. It must be emphasized that waste is a natural by-product of each process, but that excess waste, though it may appear small to the operative, is a significant cost factor to the mill. It is necessary to build up the operator's interest, awareness and pride in his task. Supervisors must maintain close supervision through regular checking. The aim must be to maintain quality and production while reducing waste. Incentive bonuses may not be a good idea where only one of these objects is emphasized.

Waste control in developing countries involves a number of factors that deserve special consideration:

(a) As labour costs are usually lower, the hiring of additional waste-control personnel may well be justified;

(b) Classification procedures are likely to be different, since mills and batch sizes are usually smaller than those in developed countries;

(c) Pressures owing to changing fashion may be almost non-existent;

(d) Machinery may not be very modern;

(e) Adequate air-conditioning may not be available;

(f) Optimization of processing is likely to be much more difficult;

(g) Waste-control personnel may require training overseas; and

(h) Training of personnel will be affected by cultural and other differences.

Chapter 4

QUALITY CONTROL IN FABRIC MANUFACTURE

Control in weaving

The objectives of quality control in cloth production are to achieve a specified quality with minimum waste, and maintain optimum labour and machine productivity so that profits are maximized. Quality standards and productivity norms are laid down by management, and it is the weaving superintendent's job to maintain or improve fabric quality in order to meet these norms. Design specifications determine the properties of the fabric, and there is a need to meet them inasmuch as they 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 context of the over-all operation; 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 on quantity. There must be no compromise in the quality of preparation since this can affect loom productivity. Sometimes a fine balance must be struck between quality and productivity.

At each stage, quality is determined by the parameters of the process, the condition of the machines, and work practices. As process parameters are based on experience and large-scale controlled trials, only minor adjustments should be required. When these parameters are optimized, quality depends on how well the mill sticks to them. It also depends on proper maintenance of the machines and the quality of work practices. The aim of the superintendent should be a regular programme 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 while tension removes weak spots. Thin spots can be removed by using electronic clearers, but these are little used in developing countries. The unwinding tension and catcher setting are instrumental in detecting and need regular checking. The slub catcher should be inspected for changes in the blade position (owing, perhaps, to operator tampering), wear, disturbance of calibration setting (oscillating blade type), free blade movement, and so on. It is a good practice to have a spare set of blades and to rotate them regularly. As the positioning and alignment of the bobbins may increase tensions, leading to breakage, regular examination of the bobbins is desirable. Proper training is necessary to prevent operatives from 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-alignment of the tension bracket with the drum, poor condition of the mechanical knotter and incorrect work practices.

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

Sizing aims at giving a uniformly smooth protective film to the yarn that will improve strength and abrasion resistance while avoiding significant losses in yarn extensibility. The improvement in the strength of the yarn depends on the recipe used for the size, the quality of its ingredients, and the amount picked up by the yarn. The recipe is found by trial and experience; ingredient quality is maintained by control checks. Accurate control of the maximum amount of stretch in all zones of the sizing machine is necessary in order to minimize elongation reduction in the sized yarn. To this end, 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. The depth immersion, level, and temperature of the sizing paste should be controlled and the squeeze roller bearings examined regularly for wear. Overdrying must be avoided and the correct package density (with no cut ends) should be achieved in winding.

Fabric defects in weaving arise from defects in the preparatory process, incorrect loom settings, poor work practices and end breakages (because of poor preparation and/or unsatisfactory loom maintenance). Regular data on the type and incidence of defects are necessary so that the proper emphasis can be placed on preparation and weaving and that corrective measures can be taken. Weaving defects result from 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, incorrect let-off and take-up motions, wrong box plate setting, lack of cleanliness and incorrect setting of the warp stop motion (the most important single factor). A number of loom factors lead to more end breaks and fabric defects; these include shedding faults, warp tension, reed spacing, heald eyes and shuttle condition. Supervisors should inspect the fabrics on each loom every day and point out the defects to the operator or loom-maintenance worker.

In order to meet design specifications, a check must be kept on counts, correctness of weave, end and pick density, cloth width, and piece length. A piece of fabric for checking purposes is a useful aid in the weaving of difficult designs. The correct dimensions will be known from past experience with settings, but they should be inspected regularly.

Control in knitting

Quality control is the regulation of the degree of conformity of the final product to its specification, but in knitting, this specification is often subjective and difficult to define. Therefore, control should aim at checking sufficient objective properties to meet both the objective and subjective specifications required of the fabric. Objective fabric properties can be termed geometric (e.g. shape and variability of the average loop, colour design, property retention after wet treatments); mechanical (e.g. load-extension, sheer and bending); and retentive (abrasion resistance, pilling resistance, colour fastness). The mechanical elements are important in subjective properties such as drape and handle, while the hysteresis of mechanical properties during wear affects retention of shape in the fabric.

The simplest control plan would be to test all fabric properties; however, this would be uneconomical because of waste and the amount of testing required. A better plan involves acceptance testing of the yarn, checks on processing variables, and final fabric checks. In this way, sufficient properties to achieve adequate control are examined.

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

As excess spirality in a fabric may be produced by twist-lively yarn, the use of twist relaxed, twist balanced or alternate courses of "S" and "Z" twist must be considered. Spirality in circular knitted fabrics may 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 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 in order to ensure a constant input rate. Sufficient tension must be applied to bulk yarns to remove all crimp. Positive feeds are used in warp knitting and in simple circular weft knitting, but these are considered too complicated for jacquard circular knitting and flat-bed knitting. Weft knitting operatives do not like positive feeds, because of the difficulties of threading up after a break, and unless closely supervised they 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 position of the cam. The maximum tension must be monitored since if values are too high they lead to press-offs and broken loops.

Bending and shear of the yarn and the stitch length appear to be the main factors influencing the mechanical properties of the fabric. Long-term retention properties, such as abrasion resistance and lack of pilling, involve so many factors that the only reasonable test is an examination of the finished fabric; this applies equally to dimensional stability.

The factors that should be tested are: yarn variables; process variables; and fabric variables. These will now be examined.

Yarn variables

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

The crimp rigidity of bulked yarns should be uniform; otherwise streaks appear in the fabric. Yarn strength and strength variability need to be controlled in order to prevent press-offs and broken loops, but this is usually only important in low-strength yarns such as wool. Yarn extensibility is important in elastomeric yarns, while dynamic extensibility is significant in stocking manufacture.

Twist liveliness can be easily examined by a quick visual check. Only occasional spot checks of twist and twist variability are required. As yarn friction contributes to breakage and is a determining factor in the stitch length (for negative feeds), some check of dynamic friction is desirable. The yarn bending modulus depends on the diameter of the fibres used and for this reason it is common to check diameters when wool yarns are being used.

Process variables

The stitch length may be examined by using a yarn speed meter and a yarn length counter. A number of tension testers are available that give relative tensions, but it is important to use the same type of instruments for comparative purposes. Checks on input tension and stitch length should be carried out at least once a day. At the same time, the fabric should be inspected visually for correct pattern selector operation. It is worth pointing out that the common practice of using measurements based on courses per inch for checking the stitch length in knitted fabrics is unreliable, misleading and is the cause of many difficulties in existing schemes.

Fabric variables

Tests for abrasion, pilling and dimensional stability prevent the sale of substandard merchandise and provide useful data for determining future practice. Final inspection for irregular and dropped stitches, and rough dimensional checks, are routine. Some mills rely entirely on these checks for quality control, a practice that is highly undesirable.

The amount of testing carried out in the knitting industry depends on the costs involved; however, as there is a relatively low added value for many knitted products, the scheme must be highly selective in order to keep costs to a minimum. For economic reasons, mills rarely do acceptance testing of yarn but yarn count checks are still desirable since they affect profitability. A minimal control scheme includes yarn count checking, control of processing variables, and the final fabric inspection, with occasional spot checks for colour fastness and dimensional stability. There are many intermediates between a minimal scheme and a complete one and the final choice must depend on the type of fabric, the added value and the state of the industry.

Chapter 5

QUALITY CONTROL IN FINISHING

During the finishing operation, the fabric from the loom or knitting machine is subjected to a series of chemical and physical processes designed to give it the properties needed for a particular end use. This should be done in such a way that quality is maintained while costs are kept down. The fabric must be so finished that it meets the subjective standards related to drape (softness, firmness, lustre, cover, solidity of shade), the objective properties (such as matching 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 for a particular fabric are often quite detailed, especially when they are set by a defence department, a government department or when the material carries a registered trade mark, or brand name. Besides meeting the specifications, finishing must be carried out so as to keep the number of faults present in the finished fabric (strings per 1,000 yards), the percentage of seconds, and the occurrence of fabrics not fit for normal sale to acceptable levels.

Quality control at the finishing stage involves a number of different functions and these may be classified under the following headings:

(a) Control of raw materials;

(b) Selection of the finishing sequence and control of process parameters;

(c) Control of fabric specifications; and

(d) Inspection of fabrics (before, during and after processing).

Control of raw materials is desirable, since they represent a significant fraction of costs. Often the decision to purchase them from a particular source is based on price rather than on quality. This is a mistake, for quality factors, such as strength, influence the effective cost which is based on material strength and sale price. These factors must be balanced in order to obtain the most economical costs. Since a mill may purchase large quantities of materials, the test load must be chosen with some discrimination to ensure that the scheme is economical. Careful testing of the raw material is particularly important in cases where its cost is a major factor in the costs of the final product, and where its behaviour in processing is critical.

Commercial dyestuffs are usually a mixture of pure dye plus some additives, and there is no standardization of the relative proportion of these components. Supplies of dyestuff may be unreliable, particularly if there is a shortage (a possibility common to developing countries). The strength of the dye may be assessed by measuring its depth since there is a direct relationship between the two. In order to compare dyes from different suppliers, concentrations are varied to obtain matching shades. From these, the relative strengths (and hence the effective price) are determined. The disadvantages of this method are that differences of less than 5 per cent cannot be detected and tone difference may interfere with the depth assessment. Other methods are available if more accurate assessment is required. It is important to know whether the supplied dye is pure or a mixture of dyes, and this can be ascertained by using simple chromatography techniques to separate the components. Dye compatibility is necessary, since, in practice, dyeing is carried out with mixtures of dyes. Checks on relative dyeing rates and migration of dyes may be carried out by test dyeing procedures.

Starch-based finishing agents usually contain an amount of softeners or stiffening agents. The starches themselves 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 (the cause of embrittlement of the fabric and offensive smell), for percentage of active ingredient, and possibly for qualitative identification.

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

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 efficiency of wetting agents may be checked by sinking tests for standard hanks. The effectiveness of dispersing agents may be evaluated through a simple filter paper test, and 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, and bleaching powder) may be checked by standard analytical procedures.

Quality of the water is important, since hardness affects scouring and dyeing. The presence of iron is undesirable in bleaching, and impurities must be kept to a minimum when water is used in boilers. Knowledge of hardness, alkalinity, dissolved 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, on 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. Processes may have to be modified to suit a particular fibre or fibre blend and more careful control may be necessary to reduce faults. Good machine maintenance, cleanliness and tidiness are also essential features of quality control in finishing.

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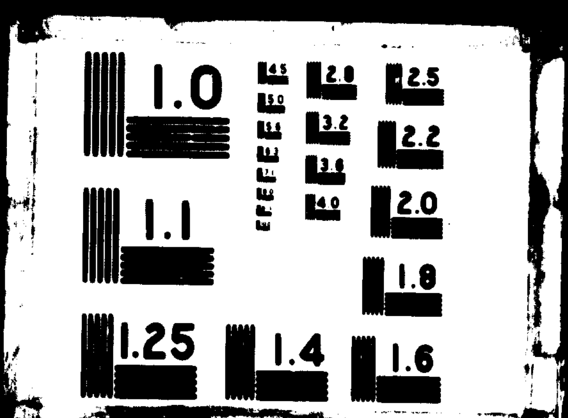

Processing of cotton

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

The object in bleaching is whiteness without degradation and comparison testing of 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 neutralizing with acid, the pH of the fabric should be checked, by universal indicator paper, to ensure that no acid is present during drying.

In mercerizing, 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. 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 preparation of the recipe is essential, and temperature and bath exhaustion tests are required. The fabrics to be dyed must be absorbent, free from impurities and uniformly packed. Items to be checked in the printing process are: paste recipe; thickener viscosity; print stability; roller pressures; roller settings; and the condition of the ager.

The finished fabric should be examined for resistance of the dye or print to light and washing. Tests may be required for resistance to rubbing (when pigments are used), perspiration, dry cleaning, and residual shrinkage (pre-shrink articles). The effectiveness of easy-care and durable press finishes may also require testing.

Processing cotton-synthetic mixtures

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

Cotton-polyester fabrics should have soil and oil stains removed at the loom stage since their removal is very difficult later on. Sizes must be appropriate to the hydrophobic nature of the polyester and the greater hairiness of blended yarns. As these fabrics are impregnated with desizing solution, there is more danger of their drying out, which also leads to difficulties. In scouring, alkali damage to the polyester is controlled by time, concentrations and temperature. The heat setting required to give the polyester dimensional stability requires accurate temperature control in order to avoid adverse effects and changes to the stiffness and drape of the fabric. 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 are different for each fibre and anti-static finishes may be necessary. Since dyeing is essentially different for each fibre, more accurate controls are needed.

Modification is necessary in the processing of cotton-viscose blends since viscose is weaker and much more extensible when wet. It is also affected to a greater degree by alkali, and its 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 mercerizing, hot water is used to wash off the alkali. Concentrations should be kept low and extra care 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 owing to the extensive swelling of the viscose fibres.

Heat setting is required for cotton-polyamide mixtures where the amount of polyamide exceeds 30 per cent. Sodium hydrosulphite is necessary in scouring to prevent discolouration 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 kept to a minimum to prevent damage to the acrylic. (The conditions are determined by laboratory trials.) Excessive stretching must be avoided during chemical processing. Pressure and temperature must also be controlled. Temperature control is very critical in the dyeing operation.

Processing of wool

Inadequate setting during crabbing may lead to cockling or design distortion during rope scouring or piece dyeing. Too much tension and the wrong pH may weaken the fabric. In rope scouring, an excessive load on the dolly nip, or high temperatures, may cause rope marks, design distortion and excessive shrinkage. As inadequate scouring leads to dyeing difficulties, control of residual fat, soap and alkali is necessary.

During the milling process, excessive roller pressures and overloading of the machine must be avoided. Uniform saturation with acid is essential to minimize unevenness in carbonizing. In winch dyeing, attention should be paid to the correct selection of dyes and methods of applying them, since over-filling leads to uneven dyeing. Temperature control is also very important.

Over-raising will lead to a weak fabric. Uneven raising may be produced by creases, uneven moisture content and the presence of residual chemicals. Curling of the selvedges and too-intensive raising lead to defects. The condition of the card wire is important. In shearing, the fabric back must be done first if holes are to be avoided, and attention must be paid to the sharpness of the cutter and the orientation of the blades. Even tension and wrapping are essential in steam decatizing. Wet steam must be avoided as it causes stains. Faults in pressing may result from non-uniform preconditioning, overstretching the fabric, and failure to keep it flat during feeding.

Dimensional stability is important in knitteds. Correct stretching during finishing is essential and helps to prevent snagging during wear.

Processing of man-made fibres

When continuous filament and staple fibres are being processed, they must be kept adequately separated in order to minimize contamination. Fibre-makers' manuals give processing sequences, recommend specific techniques, list points to watch and discuss faults encountered during finishing.

Testing is necessary in order to control fabric specifications, and the appropriate test instruments should therefore be available. Testing of such properties as weight per unit area, pilling resistance, abrasion resistance, the effectiveness of finishes, fabric strength, design and colour may be necessary.

Inspections are carried out at intermediate steps in the grey state (e.g. after piece dyeing) and after finishing is complete. Most of the strings in a finished fabric are caused by yarn and weave imperfections. The grey mending room is a main control point and guide to the quality standard that may be ultimately expected. While faults in the more expensive wool fabrics are mended, little mending is done on cotton and synthetics, 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, percentage of seconds, percentage not fit for normal sale, and the strings per 1,000 yards in order that control measures may be applied immediately if faults are excessive. Records of faults, samples of faulty fabric, and the results of trouble-shooting investigations should be kept to assist in future inspections.

Quality control problems for independent commission dyers and finishers are different from those of the vertical mills: they do not own the fabrics, though they process a larger variety of them; they have more customers with a greater range of end uses; they have a larger output but receive smaller orders, which are in turn divided into groups; and they have greater problems in planning production 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 owing to finishing or earlier processes.) Perching is usual after dyeing (or drying, if only scoured and finished) and fabrics are either passed or directed back for reprocessing. The aim is to keep the faults low at the final inspection. As fault analysis is a vital feature in a commission works, charts and graphs should be constructed to keep a running record of trends.

Chapter 6

QUALITY CONTROL IN THE CLOTHING INDUSTRY

Quality control in the clothing industry is not very clear-cut, for a number of reasons. The clothing manufacturer must deal with a wide variety of fabrics, the quality of which depends on the fibres used, the properties of the yarns, the manufacturing parameters, and the 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 the size measured depends 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 may be divided into three areas: acceptance testing; performance testing; and product inspection.

Acceptance testing

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, elasticized 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. As the relative importance of each of the above depends on the fabric and the use for which it is intended, the important factors only are examined. It is usually only possible to test a sample of fabrics, and therefore the testing scheme must be designed so well that the chance of a defective fabric passing into production is fairly small. A difficulty is presented by the fact 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 that are more liable to contain faults. Thus, reperching of every piece may be desirable for some types, while for others testing may only be required 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 that show the greatest variation from lot to lot. Each component should be taken separately and the appropriate testing scheme for it set up. Some components, such as buttons, are easily assessed (dimensions, weight, colour, surface finish), while others, like zippers, are more difficult to evaluate. Each batch of zippers should be sampled and inspected for size, faults in materials or workmanship and for free and satisfactory action.

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

Performance testing

Performance testing involves special tests on properties important to particular types of fabrics. These tests include showerproofing for rainwear; inflammability of children's garments; fabric-to-fabric adhesion in fusible interlinings; air permeability in windproof fabrics and so on. A showerproof fabric should continue to be effective after successive wetting and drying, and the finish should stand up to dry cleaning. Because of the difficulties of reproducing the same testing conditions in different laboratories, these tests are not entirely standardized and only relative measurements may be obtained.

As flameproofing of children's nightwear is required by law, testing must be done as a matter of routine. The impermeability of weatherproof fabrics may be measured using the Cambridge instrument but testing is rarely carried out unless the fabrics are intended for areas where weather extremes will be encountered, e.g. the Arctic. Measurement of abrasion resistance is desirable in fabrics that are subject to heavy wear (e.g. pockets, linings) and the Martindale tester is the most common test instrument for this purpose. The tests are comparative rather than absolute and since four fabrics can be tested concurrently, it is useful to test two samples giving satisfactory wear and two that require treatment for abrasion resistance, and to compare the results.

For a number of reasons the dimensions of many fabrics are altered by steaming and, since the number of steam treatments applied during making up may be as high as twenty, it is important to examine this factor. When a fabric has been overstretched in order to obtain the correct width, a considerable redistribution, leading to dramatic size changes, may occur on steaming. The usual test involves steaming while allowing freedom to shrink. (The WIRA test is a typical example.)

Drape and handle are difficult to quantify and this, when required, is best done by comparison with standard fabric. There are various tests for crease recovery and crease resistance. The requirement in laminates is good adhesion that will withstand dry cleaning, flexing etc., but though tests are available, none are regarded as standard as yet.

The sewability problem, which involves damage caused to the seams by needles during sewing, and distortion, puckering, and strength of the seam, has been compounded by the advent of synthetics. Because of the large variation between fabrics, often of unknown composition, sewability tests should be included as part of the control scheme.

Product inspection

As the garment goes through a complicated array of processes (cutting, assembling and so on) before the final product appears, a system of product inspection is required to remove processing faults. Inspection during production ensures that no further work is done on garments already classified as faulty, and the final inspection prevents their sale. A full inspection may be carried out, but it is usual to examine only a sample and to concentrate on styles and types that are known to be prone to faults. The amount of inspection depends 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 must be detected since the presence of any one of these faults justifies rejection in high-quality garments. The final judgment is made by the customer and an offer to exchange any faulty articles without arguments is a useful incentive to control. Although this method is open to abuse, it is helpful in picking out faults that 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. There are two main reasons for this: *(a)* the variability of input raw materials, and *(b)* the large range and short production runs of the product. Since economic considerations dictate the amount of time and labour that can be allocated to quality control in a factory producing a certain range of garments, it becomes a question of dividing up these resources among the three types of testing. This should be done 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 on acceptance testing, product inspection being used to monitor the effectiveness of such tests. Unless it is required by law, performance testing usually comes later.

The clothing industry is one in which the goodwill and reputation associated with a certain brand or name count for a great deal with the buying public. Quality control, despite its inherent difficulties, has a great part to play in maintaining and enhancing this goodwill.

Chapter 7

QUALITY CONTROL IN A DEVELOPING ECONOMY

General aspects

For many years manufacturers in the developed countries have had to compete with each other, with importers within their own countries and with overseas competitors when exporting. As a result, consumers have been offered a wider and wider choice to pick from and product quality has become a major criterion for selection. People have been educated to demand high quality and a supplier who does not meet their standards will not be able to sell his product. Because of this increased competition, price is also a deciding factor in purchasing. Quality control within the mills has therefore become an essential part of the drive to keep quality high while keeping prices down.

The situation in developing countries, however, is quite different. Local quality standards are generally low. Consumers have not been exposed to better-quality goods, have not developed a quality awareness and normally would not have the money to pay for this quality even if it were available. With increased development of the country and improved standards of living, the public begins to demand goods of better grade. Imports are received from the developed countries and this arouses in the customer a curiosity and interest, and develops consumer demand for quality goods.

Competition in export markets is a key factor in the pressure to improve quality. A country with a limited range of manufactures must export in order to survive. Sometimes there are natural markets in the immediate area that do not demand quality goods, but, as a rule, a country is 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 over-all quality for the domestic market before improving the quality for export. Industry must become accustomed to quality production methods so that the quality of goods for the continually changing export market may be maintained.

Firms in developed countries are subjected to relatively little change in quality demand, since the quality of their production has already been established at a reasonable standard. Developing countries, generally, have low quality standards at present, but in the future an accelerated growth in quality 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 that may, or may not, be important in assisting the developing country to raise its quality standards.

The type of assistance given to the industry by the government is likely to be a key factor in this regard. In order to raise manufacturing standards, the industry will require highly trained technologists and engineers. This personnel should be trained within the country rather than imported. The government should therefore strive to establish new institutions and increase assistance to existing tertiary education establishments so that their training and information programmes can be expanded.

The various firms will need help in establishing modern quality control methods and, as a first step, plant management must be acquainted with, and made aware of the importance of, quality control, both to themselves and to the country as a whole. Management must also be taught how to organize proper control systems. An extensive promotion and training programme 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. Firms should be encouraged to institute properly designed control and inspection systems to improve the over-all quality.

Governmental policies may be of importance in realizing the goal of quality improvement. In most developing countries there is a system of tariff protection to enable local industry to compete with overseas imports. However, in order to raise quality standards, a well-planned and extensive programme for the progressive withdrawal of these protections should be carried out. This would necessitate an increase in internal quality to meet the increased competition of imports. Adequate protection against dumping should be provided. Some restrictive agreements may be desirable, provided they lead to rationalization of production and marketing, the improvement of products and the assurance of their quality. Legislation to regulate and standardize weights and measures may be necessary. Export standards should be defined, and some means of checking and controlling exports is required.

Various other governmental assistance schemes might be considered. Measuring instruments are an essential part of inspection schemes and aid could be given in this area by providing subsidies, or a rental scheme, by supplying central testing facilities for firms that cannot afford to set up their own, by standardizing the use and calibration of measuring instruments, by providing calibration and maintenance service for the instruments and so on.

The consumer sets the standards for quality. Governments (and especially their defence departments) are usually large consumers of goods and are thus in a position to insist on product quality 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 should be encouraged 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.

Quality control centres for the textile industry

The functions of the centres

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

(a) *General technical assistance and advice.* It is becoming increasingly difficult to keep up with the rapid technological advances and changes taking place within the industry. A quality control centre could play a valuable role in this respect, by keeping abreast of the 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.

(b) *Specialized advice on quality and waste control.* The centre could supply specialists in quality and waste control who would go into a mill, investigate the situation, and supervise the institution of an over-all scheme for improvement. The centre might also provide training courses for senior mill staff, to promote quality awareness and to indicate the methods of reaching quality goals.

(c) *Training mill personnel in quality and waste control.* This service could include specialized training courses for supervisors in which, among other things, the training of operatives would be discussed. Specialists could be provided to assist in on-the-job training of supervisors and operatives.

(d) *Providing and monitoring 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 special labels for such merchandise that would assist in their sale.

(e) *Quality control and testing for the industry.* It may not always 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 tests applicable to the mills it services. It could also offer services such as checking the calibration of measuring instruments, teaching mill staff how to use the equipment, and carrying out tests for mills that do not have the appropriate equipment.

(f) *Trouble shooting for the industry.* Sometimes mills experience processing difficulties but are not equipped to investigate the causes of their own problems. The assistance of an outside agency offering specialized

equipment and manpower would be a great advantage. The service provided could range from reasonably straightforward fault finding (using the centre's laboratories) to the full-scale investigation of a serious processing problem.

(g) *Teaching and research.* If the centre is attached to a university or a similar tertiary institution, it could be developed to provide degree and diploma courses in textile technology. By training personnel, the centre would thus cater to the long-term needs of the local industry, as well as those of a more immediate nature. A centre developed in this fashion could carry out research programmes on a wide range of problems relevant to the local industry.

(h) *Other functions.* The centre might assist in a variety of other ways, including, perhaps, some of the following:

Providing assistance in new product development;

Carrying out wearing or other evaluation trials on new products;

Advising export companies on the latest overseas standards;

Arbitrating in cases of disputes over quality;

Assisting in the correct use of goods by monitoring labels that give instructions on such things as washing and ironing;

Providing a well-equipped library, with translation services; and

Providing news on current developments in the world textile industry by means of a regular publication.

When a centre is being set up, it is obviously not practical to institute all of the above means of assistance at once. The centre must concentrate initially on relatively narrow fields of activity and gradually expand into the relevant areas. It could, for example, start as a testing centre for the industry and expand from there, or alternatively, it could start as a textile school, with testing facilities. The latter approach might be more desirable as a long-term arrangement for the local industry.

Staffing and equipping the centre

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

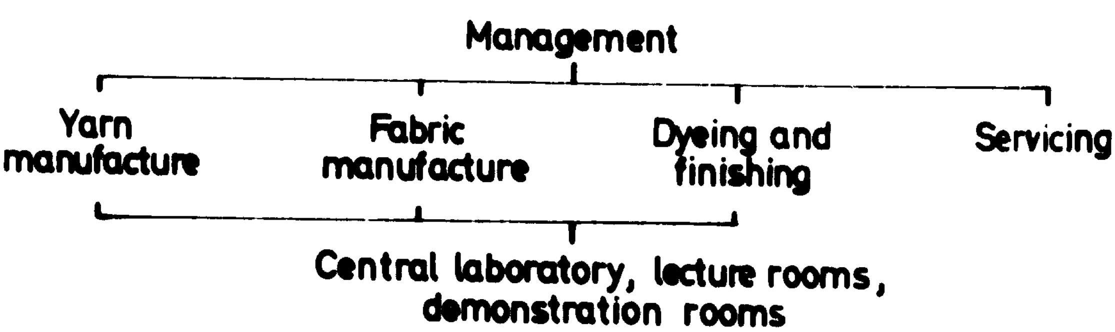

Figure 4. Organization chart for a small quality control centre

The management would consist of the centre director and his office staff. Each of the three textile sections (yarn manufacture, fabric manufacture, dyeing and finishing) would be in charge of a textile technologist, 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 on mill layout, purchase of machinery, air-conditioning, lighting, machine maintenance etc., while an industrial engineer would be needed to advise on methods engineering and operations research. A statistician would be required as a consultant in statistical quality control.

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

In larger centres each textile section should have its own laboratory facilities, with a laboratory manager and sufficient support staff. This would entail doubling up on certain equipment in order not to impair efficiency.

The centre would require laboratories for such functions as chemical and physical testing, control of temperature and humidity, and microscopy. General equipment would include chemicals, stains, glassware, balances (torsion and Mettler (100 g and 2,000 g)), drying ovens, microscopes (simple, hot stage, projection, stereo, polarizing, interference) camera attachment for microscopes, and an Instron tester, suitable for fibres, yarns and fabrics, with the appropriate attachments. This equipment would be used for many of the tests carried out.

The following is a list of the equipment and material needed in the processing of cotton, wool and man-made fibres, and in the testing of raw wool and cotton.

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 cotton and wool.

Wool fibre testing. Core sampling equipment; WIRA single fibre length apparatus; Almeter for fibre length; SIRA airflow tester (or the new CSIRO 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; CSIRO rapid regain tester (with a range of sample containers).

Man-made fibre testing. Vibroscope for denier determination.

Fibre identification. Infra-red spectrometer.

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

General mill testing. Yarn speed indicator; mean yarn tension meter; peak yarn tension meter; electronic yarn tension meter; tachometer; stroboscope; roller eccentricity instrument; instruments for measuring sound level, illumination, heat absorption and transmission, and static electricity.

Yarn manufacture and testing. Nep counting templates with classification photographs; Uster evenness tester complete with tester, recorder, integrator, spectrogram, imperfection meter, and Uster statistics; wrap block for roving mass/unit length, wrap reels, balances and girth measuring apparatus for yarn count; twist meters (parallel fibre method, twist, untwist, and continuous); 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.

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 (Stool and Schiefer); templates for fabric weights.

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.

Garment testing. Sewing machines (domestic and industrial) and crease sharpness tester.

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