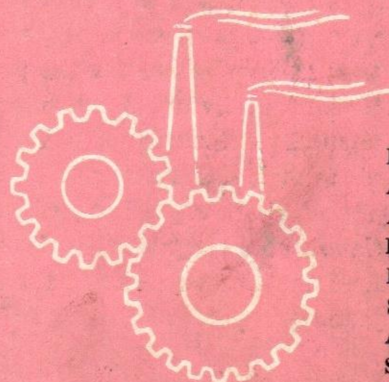
pecial Issue on Quality Control

PRODUCTIVITY

JOURNAL OF NPC



NATIONAL PRODUCTIVITY COUNCIL, INDI

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NATIONAL PRODUCTIVITY COUNCIL

The National Productivity Council is an autonomous organisation registered as a Society. Representatives of Government, employers, workers and various other interests participate in its working. Established in 1958, the Council conducts its activities in collaboration with institutions and organisations interested in the Productivity drive. 44 Local Productivity Councils have been established practically all over the country and work as the spearhead of the productivity movement.

The purpose of NPC is to stimulate productivity consciousness in the country and to provide services with a view to maximising the utilisation of available resources of men, machines, materials and power; to wage war against waste; to help secure for the people of the country a better and higher standard of living. To this end, NPC collects and disseminates information about techniques and procedures of productivity. In collaboration with Local Productivity Councils and various institutions and organisations it organises and conducts training programmes for various levels of management in the subjects of productivity. It has also organised an Advisory Service for industries to facilitate the introduction of productivity techniques.

NPC publications include pamphlets, leaflets and Reports of Productivity Teams. NPC utilises audio-visual media of films, radio and exhibitions for propagating the concept and techniques of productivity. Through these media NPC seeks to carry the message of productivity and to create the appropriate climate for increasing national productivity. This Journal is an effort in the same direction.

The Journal bears a nominal price of Rs. 2.00 per issue and is available at all NPC offices. Annual subscription (Rs. 12.00 to be sent by cheque in favour of National Productivity Council, New Delhi) is inclusive of postage! Subscription for three years, however, can be paid at the concessional rate of Rs. 32.00.

Opinions expressed in signed articles are those of the authors and do not necessarily reflect the views of NPC.

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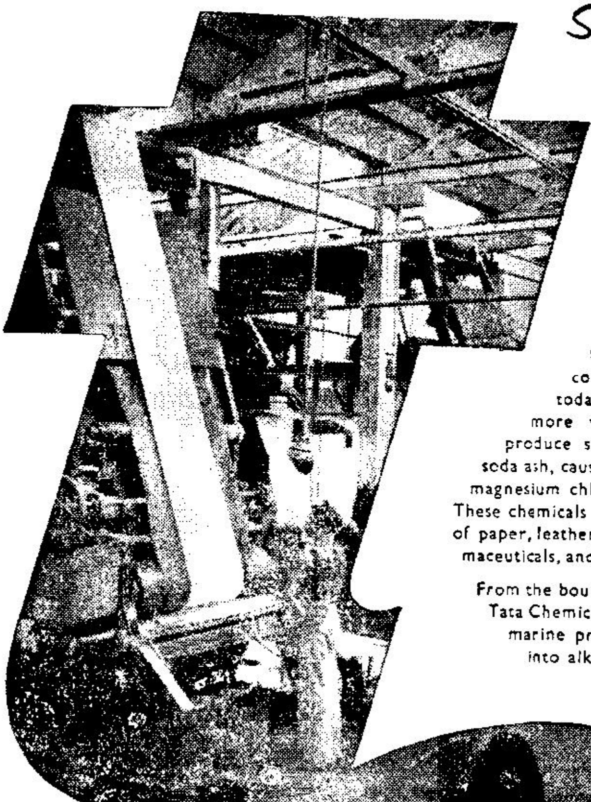

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DALMIA ENTERPRISES IN NATIONS SERVICE

Quality is Productivity*

THIS FIFTH SPECIAL ISSUE OF THE NPC PRODUCTIVITY JOURNAL DEVOTED entirely to the theory and practice of quality control has been conceived in a somewhat wider perspective, as having implications and possibilities far beyond SQC as a productivity technique; for the major handicap of the Indian economy that holds up the very processes of growth is the lack of stability in the quality of goods and services produced. Our countrymen have in historical times produced goods of the highest quality but for reasons which are worth studying it has not been possible to maintain consistently the standards of quality of which we are otherwise capable. We have thus in ourselves the potentialities of a first-class economic power, and it is the burden of this thesis that SQC in its own humble way can make an effective contribution to the realisation of this potentiality. New markets can be created both at home and abroad, for markets are essentially made through quality consistently supplied. Thus we can see broadly the far reaching implications of Statistical Quality Control in terms of foreign exchange, employment opportunities, optimum utilisation of men and materials and machines, workers' education, the quality of management, rationalisation of administrative procedures and so on *ad infinitum.* The fact of the matter is that SQC is in fact being so widely applied. The Government of India in the Ministry of Labour and Employment got an SQC survey done of the functioning of the Works Committees in the city of Bombay.

SQC in the Public Sector

While the example given above is significant in terms of the possibilities of Statistical Quality Control, the normal application of SQC has been in terms of the quality specifications acceptable to the market and building these specifications into the product through materials and process controls. In view however of the ambitious expansion of the Indian economy, it would be probably wiser for us to start with relatively advanced ideas and to understand the market in somewhat wider terms as covering the public sector and the organisation of the public services. There must be some means by which the people judge the quality of the various services that are being done for them by public authorities; and this judgment of the people is fed back into the system to ensure stan-

* The editor cannot sufficiently express his gratefulness to the Indian Statistical Institute for the very generous help they have given in making a very large amount of excellent material available for publication in this special issue of the Journal. It is really their collaboration which has made it possible for the National Productivity Council to bring out this publication.

dards of continuous quality performance. So far, the public sector, particularly the public services, have been considered as above or apart from the market place. SQC may probably help us in bringing a large part of governmental activity within the ambit of the market economy, in a fundamental or classic sense of the word.

Like a Steering Wheel

In a special article published in this issue of the Journal, Dr. Deshmukh has compared SQC to "a steering wheel to an automobile on the road... SQC can be an ever-vigilant and active, scientific ally in closing up the tolerance range, in improving quality...and help decrease production costs..." In the industrial context with which we in NPC are principally concerned, productivity acquires a meaningful significance only in the context of Quality Control, for productivity without quality has no meaning whatever. In reality, quality control includes within itself the two essential attributes of productivity: one which is obvious enough in the very terminology of quality control and the other which it is really designed to ensure, namely, the production of quality goods and services, not only in the most economical manner but also to ensure their continued output by the most economical and at the same time the most effective methods. Quality Control may as well be called the SCIENCE OF ECONOMY.

While the professionals in the field of SQC know the variety of uses that it can be put to, it is otherwise not sufficiently realised that SQC would be of considerable service in the determination of machine capabilities, the isolation of low efficiency factors particularly among machines, the upgrading of worker efficiency through training, selection etc. A case study has been published in this issue of the Journal, which proves by SQC methods the difference between training and lack of training. Probably among the most important results of SQC research would be the realisation among the managerial and administrative classes of the need of worker training and education, if the full possibilities of SQC are to be realised.

Quality and Worker Education

In an article published in this issue of the Journal Dr Lokanathan has drawn pointed attention to this aspect of the problem. One of the reasons why, in his opinion, the quality of Indian goods is low or highly variable is because of the absence of education among the workers and the large body of consumers: "...we have to create conditions in which the worker becomes appreciative of quality, appreciative therefore of the maintenance of quality...In a fundamental sense quality goods can only be produced by quality men...One of the revolutionary changes that has not received sufficient notice is the fact that in the United States a large body of workers are high school boys and girls. Probably the best prospect that we can look forward to is a like transformation of our working force. In fact, that will be the best indicator of social and economic growth."

national productivity council journal

RODUCTIVITY **volume 3 number 3**

SPECIAL ISSUE ON QUALITY CONTROL

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April-May '62

editor DH BUTANI

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PRIME MINISTER ON QUALITY

"...concentrate on improving quality all-over.....but first of all, quality has to be improved in those people who can improve quality in others..."

Jawaharlal Nehru

A Present to the People

Dr Lokanathan has also drawn attention to the rather sad fact that Indian manufacturers in the first instance produce goods of the highest quality, which indicates what is really possible. The first batch of goods creates a market; the second shakes it, and the third destroys it. In fact the history of the Indian economy since the days of Discriminating Protection is the rapid appearance and equally rapid disappearance of markets for new products which showed glittering possibilities in the first instance, followed by almost a meteoric decline, the real cause being loss of faith in the quality of goods produced. The loss in terms of gainful employment for millions of our young boys and girls can only be imagined but is certainly directly traceable to the failure to apply consistently the established techniques of quality control.

Of course there has been progress in this direction for which NPC can claim a legitimate though modest share in the credit for the productive reorientation of the Indian economy. We in NPC cannot, however, claim to have done anything more than a bit of spade work, very much needed of course and something essential to build upon. Probably we would benefit by the NPC Chairman's advice: "...In the context of modern economics, for a build up of large scale markets, it is of the highest public interest that manufacturers should produce goods which may be called a *Present to the People*...it is a present to the people that makes a market."

Statistics and Quality Control

The analysis presented above shows the vast scope and profitability of the application of SQC techniques to the working of industry but a word of caution appears necessary. It has often been seen that either due to fancy or just because an organisation happens to be in command of superfluous resources, statistics come to dominate quality control. This is both an undesirable and a wasteful situation, for the main point is to make statistics as Dr Pabst has put it *'a servant of industrial enterprise'*. There is a real danger that statistics might become *'a cruel and dominating master* involved in its own complexities.' What often happens is that the files of large-scale industrial enterprises become full of a mass of statistical detail which are impossible to use and are infact not used in practice. Statistical methods used must be simple and efficient and must be so designed that action could be rapidly taken on the inferences, which stand out markedly from the presentation of statistics.

Apply SQC to SQC

The main idea of SQC is to tackle problems directly and frontally. If SQC itself means an *ultra-refinement of methods,* we shall need to *apply the principles of SQC to SQC itself.* The techniques associated with statistical quality control originated from the realisation by the managers of industry of the wastefulness and the costliness of the old methods of *inspection "after the event";* and what the fatigued inspector passed, the consumer's wife at home condemned. She did not come back to the counter to register her protest; she just did not come and the market was lost. What the managers of large scale industry were in need of was some economically effective method by which they came to know the quality specifications of the housewives and other large scale consumers of their products, so that by using statistical techniques, they could build in the quality specifications into their products and at the same time ensure by the same statistical techniques that the flow of the products did in fact conform consistently to the quality specifications, designed for the product, within known tolerances. This meant that the whole process from end to end, step by step was productive and maintained at the optimum level of productivity, but *if SQC itself became costly, it would cease to be a productivity technique because its cost-raising attributes would offset its cost-reducing capabilities.* The fact is that SQC must pay and is supposed to pay many times more than what it costs, just like Work Study.

Feigenbaum Theory

This in fact is the idea behind Feigenbaum's Theory of Total Quality Control referred to in an interesting article by Mr Shourie published in this issue of the Journal. Feigenbaum's idea can be briefly stated in his own words:".... the determination of quality—and consequently of quality cost—takes place throughout all stages of the production cycle. *The twin objectives of better product quality and lower quality cost* cannot be achieved by concentrating upon any one phase of the cycle alone—inspection, design engineering, reject trouble-shooting, operator education, or statistical analysis—important as each phase is in its own right. Doing the job adequately requires instead a programme of total quality control. This kind of technically oriented programme integrates, from design through shipment, the many quality elements in the product cycle..." So conceived and operated, total quality control in fact saves two types of costs: *failure costs,* caused by defective materials and products that do not meet the producer's own quality specifications; and *appraisal costs* including expenses for maintaining the producer's quality levels by means of formal evaluations of product quality through a series of inspections etc. The only *bonafide* costs in SQC thus incurred are for the purpose of keeping defects from occurring in the first place. Included here are such elements as quality control engineering, employee quality training, and the quality maintenance of patterns and tools.

An Integrated Productivity Technique

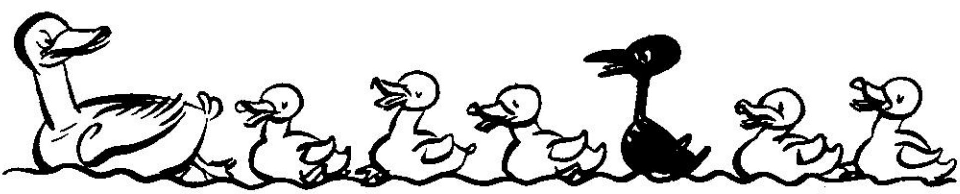
NPC Executive Director's exposition of the system of total quality control gives a simple explanation of how the system works: "...it extends either way into the markets from which a firm buys its materials and machines, to the markets in which it sells its products. And a whole system of feed back is organised by which instead of wasting resources on checking, inspecting and repairing, the requirements of the market are built into the product .... this idea of total quality control also involves fundamentally a general upgrading of the entire range of personnel associated with purchasing, processing and selling. Statistical quality control is thus an all-inclusive fully integrated productivity technique."

Importance of SQC

Quality control has of course acquired great significance in the context of the need to earn foreign exchange particularly in the hard-currency areas and the extension of our markets in neighbouring countries. The hard currency markets are, it is well-known, highly sophisticated markets which have developed standards of quality of their own. If Indian goods are to be saleable in these markets they must conform to the high quality goods of those countries. As Mr Shourie has pointed out, foreign markets can add a new dimension to the Indian economy, thus creating employment for our artisans, craftsmen, young boys and girls who are acquiring new skills and learning new techniques. SQC will enable us to create and capture these markets.

SQC is also important in this country because of the extraordinary variability in raw materials, in machines and above all in the quality of men that use the machines. What we need is not a few high quality men working alongside a large number of persons of varying capacities and attitudes but a marked upgrading of the average quality at the working level, because in the ultimate analysis the raising of living standards in this country would depend not on a few show-pieces of divine quality but a large mass of goods produced for the large mass of the people, of a quality which they can with assurance take for granted. It is only then that the economy will acquire that self-generating dynamism, which is the main objective of the Development Programme.

Quality Control !



Statistical Quality Control

CD DESHMUKH[1]

Statistical Quality Control, or SQC for short, means statistical methods of control developed by industry for the purpose of attaining economic control of quality of product in mass production. It is one of the weapons in the armoury of Productivity Organizations, concerned with factors such as improving uniformity of quality and fitting quality as precisely as possible to uses, rather than directly reducing cost of production. It has been demonstrated, nevertheless, that the institution of SQC leads to a significant reduction in cost, *via* avoidance of rejections and wastage or over-fulfilment of specification as a counterpoise to unequal quality or standard of product. The maintenance of SQC helps keeping the above losses to the minimum. It is *like a steering wheel to an automobile on the road.*

THE CONTROL OF QUALITY involves the specification of what is needed—the production of goods according to specification and the inspection of the goods to test if they satisfy the specification. Statistical techniques, developed during the first-half of the present century, can indicate to a fairly precise extent the limitations on the attainment of uniformity of quality or product; help to attain uniformity as delimited; and, finally, to evaluate the quality of the product in the least wasteful way.

In his book, *Statistical Method fr the Viewpoint of Quality Control,* W ter A. Shewhart, acknowledged as th father of SQC[2], has pointed out how d ing man's known history (includin proto-history and archaeology) stre ing over 1,000,000 years, evidence some conscious attempt to attain quali of implement dates only from sc 10,000 years ago, whereas the techniq

1. The author, known popularly, on account of his long record of distinguished public service, as Sir Chintaman, is really the pioneer of SQC in India, being associated with it from its very commencement. He is even at present intimately associated with the SQC Movement being Chairman of the SQC Policy Advisory Committee. Dr. Deshmukh has held high positions in the service of the State: he has been Governor of the Reserve Bank of India, Finance Minister of the Government of India, Member Planning Commission, Chairman University Grants Commission etc. At present he is Vice-Chancellor of Delhi University and President, India International Centre.
2. It would be a matter of touching interest to the readers of the NPC PRODUCTIVITY Journal that Dr. Shewhart was recently here in India and before leaving for his country, he has sent a special message to this Quality Control issue of the Journal which is printed at the end of this **article.**

of mass production, characterized by interchangeable parts, can be traced back over only the last 150 years. Moreover, the initial efforts, based on exact science, were directed towards the production of piece parts to exact dimensions. The concept of 'tolerance' was introduced only in 1840 and of a range of tolerance in 1870. These concepts were the first-aid in reducing the fruitless cost of trying to do the impossible, that is, trying to produce things *exactly* alike.

Setting limits of tolerance, however, must necessarily be accompanied, to be effective, by methods of inspection which would be the least expensive, that is, the cost of which would not be greater than the savings secured by minimizing the number of rejected product or parts of a product.

Where the manufacturing process consists of the production and final fitting together or transformation into numerous parts, it is clear that statistical inspection must be brought to bear at each stage. This process, indeed, becomes inevitable where the one-and-final tests for strength, chemical composition, blowing-out time (e.g. of a fuse), capacity to explode (e.g. of a hand-grenade) and so on are destructive of the product itself. This consideration necessarily implies the inspection of samples. It is here that statistical techniques, based on the theory of chance or probability, offered a solution, somewhere towards the end of the first quarter of the twentieth century and SQC was born.

What gave a fillip to the movement was the development of industrial standardization organizations all over the world, the consciousness of standards entailing the consideration in an increasingly intensive way of minimizing rejections of sub-standard products as well as minimizing cost of inspection.

SQC relies on the following proposition: that experience in the control of quality provides a practical technique for detecting and eliminating assignable causes of variability in the production process until a state of statistical control is reached wherein predictions based upon the assumption of randomness will prove valid. It helps, by elimination of assignable causes of variability, to make the most efficient use of raw materials, maximize quality, minimize cost of inspection and losses from rejection.

In specifying quality and the range of tolerance, the limitations on commercial conditions of production have to be borne in mind. Moreover, specification, production and inspection have to be coordinated, in the words of Walter Shewhart, so that, 'in fact, the three steps may be thought of as a scientific experiment in which the objective is the attainment of the most efficient use of the available material'. *SQC can thus be an ever-vigilant and active scientific ally in closing up the tolerance range, improving the quality of goods and help decrease production costs.* Its optimum utilization involves, on the one hand, the enlightenment in this respect of the growing generation of industrial leaders, so that they will recognize the potential contributions that statistical theory and techniques have to offer; and, on the other hand, introducing highly trained statisticians into industry, as also 'creating a statistically minded generation of physicists, chemists, engineers and others who will in any way have a hand in developing and directing the production process of tomorrow'.

Despite its theoretical advantages it was not till the time of the Second World War that SQC was seriously adopted and developed for industrial production. Since then it has made considerable headway in the USA and in

Japan and, to a lesser extent, in Europe. In India it attracted little attention, principally because economy and efficiency were at a discount in the sellers' market that prevailed as an aftermath of the War. It was against this background that the Indian Statistical Institute and the Indian Standards Institution invited, under joint sponsorship, Dr. Walter A. Shewhart to India to give an exposition of the importance of SQC in industrial production to industrialists and others interested.

Dr. Shewhart's visit, extending over some months, introduced SQC as a concept and a possible practice to India's industrialists, but hardly any of these realized its significance. An association to promote SQC was established in Calcutta, but for many years this association remained dormant. However, in the meanwhile, a few forward-looking industrial enterprises had introduced some sort of SQC in their organizations and a few Indians, who had studied SQC in foreign countries, were in a position to help in training Indian SQC technicians. The Bombay branch of the Indian Statistical Institute, for instance, started training courses in SQC within a short time of Dr. Shewhart's visit and helped to create some interest in SQC in Bombay's industrial world. The main Institute in Calcutta had been taking active interest in SQC and the application of statistical methods to industry since 1945, when the first training courses on SQC in India were organized by the Institute.

In 1954, on the advice of the Statistical Adviser, backed by the Ministry of Finance, the Prime Minister constituted a Statistical Quality Control Policy Advisory Committee with the writer as its Chairman, in order to promote the movement and to arrange systematically for the training of industrial employees at various levels, as well as technicians, in SQC. The Committee includes as its members both statistical scientists and academicians as well as some prominent Indian industrialists, representatives of the Indian Standards Institution and the National Productivity Council. A year earlier the Indian Statistical Institute had established a SQC unit in Bombay with the help of a special grant from Government. Two more field units were added on the formation of the Committee, one in Calcutta and the other in Bangalore, and a branch of the last one was later added at Coimbatore.

During the last eight years a great deal of promotional work in SQC has been done in India, largely as the direct result of the stimulus given by the Policy Advisory Committee. In January 1955 the Indian Statistical Institute organized a conference in Calcutta for the discussion of technical matters as well as questions of policy and in 1956, when three foreign experts on SQC were available at the Institute, representatives of all the SQC units assembled in Calcutta for a departmental review of the position.

Prof. Barnard of the Imperial College of Science and Technology, who drew up a report on the conference, pointed out at the outset that the term SQC as used in India denotes what is in UK called 'industrial statistics' or 'statistics in industry' and that in UK and also, to some extent, in the USA the phrase SQC refers to certain of the simpler statistical controls, while in the application of statistics, especially in Indian conditions, it is often the more advanced methods that are called for.

Training in SQC was put on a systematic basis as a result of the conference and the publication of its report. The training courses included courses not only for workers and foremen but also for managers, leading technical personnel, engineers and technologists. The importance was recognized of ensuring that those who give instruction in SQC should have continuing first-hand experience of its application. Improvements were also suggested in the academic or scholastic courses in mathematics or statistics.

Towards the end of 1955 a SQC unit was established for ordnance factories by the Ministry of Defence of the Government of India, with functions such as introduction of SQC methods in process control for the ordnance factories, the progressive taking over of their coordination work of the Works Inspection Sections and the investigation of the compatibility of specifications.

Skipping the intervening period, it seems worthwhile referring to the Report of Work and Review for the period January 1959 to September 1961, prepared for the consideration of the SQC Policy Advisory Committee, since this will shed light on a number of important aspects of the development of SQC in India.

To begin with, the results of the SQC promotional work will be clear from the fact that whereas in 1955-56 the number of factories served by the various SQC units (now eight, those in Delhi, Baroda, Madras and Kerala having been added during the last two years) was 32, in 1961-62 it was 78. Inadequacy of trained staff is beginning to appear as the predominant cause of retarding progress in this respect, although the position has been steadily improving in recent years; against the normal workload for a trained technical assistant of 2.5 factories, we have now already only 2.4 factories.

General promotional work consists of the holding of conferences, lectures and talks, followed by visits to top managements in their offices to persuade them of the value of SQC. The holding of training courses for industrial personnel has served to awaken the interest of managements, whilst managers also, convinced of the value of SQC, often influence other managers to give it a trial. *Special set-backs, for instance, a fall in exports, often give an impetus to SQC in the search for remedies.*

Another encouraging feature, concealed in the slow progress of membership statistics, is the building up of their own SQC organizations by factories withdrawing from membership. An analysis of the membership figures following investigation through questionnaires has indicated other remediable causes of lack of interest, such as want of supporting staff in the factory, actual opposition from middle management, lack of sustained management interest generally.

The National Productivity Council has been an increasingly active ally in the spread of SQC as part of its productivity drive. Many foreign experts, supplied under the various technical assistance schemes, have helped to bring more industrial organizations to adopt SQC. Nevertheless, *the total picture is not yet satisfactory from the operational point of view.*

Experience of the working of the SQC units indicates certain priorities for operation and plan purposes, although a more thorough investigation based on prescribed standards for and details of reporting will be necessary before reliable conclusions can be drawn. The problem that comes to notice most frequently is, appropriately enough, the study of quality, and very close to it are others such as dimensional control, process control and process capability. The utilization of resources appears to be of comparable importance, although it is generally regarded more a problem for Industrial Engineering than Quality. Reduction of waste, whether irrecoverable scrap or scrap recoverable by rework, is more traditionally a function of quality control. Problems come up both as a result of reference from managements as points of trouble, as through selection by the staff of the SQC unit as matters of profitable study which are not always recognized as problems by the management. *Incursion by the SQC staff into the field of management accounting, dealing with the broader aspects of business efficiency, would strengthen SQC work,* but this requires both greater confidence by management and greater technical resources on the part of the SQC units.

As for actual techniques used, the most frequent single technique employed is the control chart with which the history of SQC began. The variations of manufacture involve cause and effect analysis and this is followed by indication of appropriate steps for rectification. Work sampling and work study have been used largely in examining the utilization of resources, particularly in textile mills and engineering establishments. Other less common techniques are the 'design of experiments', a matter yet hesitantly supported by engineers and technologists. Work study and operations research have long been in use by the units, although their recognition as highly specialized management techniques is only a recent development in Indian industrial circles.

The SQC units are financed by the Government of India on a deficit budget basis, through a grant-in-aid to the Indian Statistical Institute. The payment for service rendered by industries served is not yet on an economically adequate scale, and the time has perhaps come for placing this matter on a more business-like basis. But this raises the question of a dependable flow of the supply of suitably trained man-power. In the past the rate of expansion of SQC was held up for lack of trained personnel and the position is not much better today, since they are required not only for strengthening the SQC units but also for the basic quality control work in the member-factories advised. Within the last year or two a large number of young men, mostly statisticians, have come forward for specialized training in quality control, but it will be at least three years before these men become really useful either to the units or to industry. For more experienced personnel India continues to be dependent to a certain extent on senior foreign experts, who are hard to come by.

The problems of promotion, payment for services and supply of trained man-power are inter-connected and it is not easy to establish a balance as the work expands. In the USA as well as in Japan, initiative in the adoption of SQC had come from industry itself, though with guidance from scientists and technologists. *In India there is yet little support from industry*—and it is still for the specialists to approach industrialists to convince them of the significance of SQC and to demonstrate and advise. General promotional work such as the holding of conferences or seminars has been and is being tried and in this the NPC or LPCs and the management associations can render yeoman service. There is also a place in promotional effort for the National Society for Quality Control, established soon after Dr. Shewhart's visit, but not active, owing to a number of organizational problems, until recently. It is this body which should undertake the main responsibility for general promotional work through periodical conferences, conventions, exhibitions, discussion groups, lectures by experts, publication of a journal, maintenance of a technical library, ac ing as a clearing house for experience i the application of SQC, production circulation of films demonstrating t application of SQC in Indian indu and the like activities.

The SQC Policy Advisory Commi tee will be holding its meetings in dif ferent industrial cities in India so as diffuse interest in SQC. They have also decided to hold a conference in Bombay next July for the purpose of interesting managements in SQC.

Other decisions for strengthening the SQC movement included coordination of the work of the SQC Policy Advisory Committee with that of the Project Coordination Committee set up by Government with a view to exploring the possibilities of introducing SQC in the public enterprises with which the Coordination Committee was concerned. The Committee recognized that in the initial period the expansion of training programmes and giving to them the necessary tone as well as strengthening the SQC units with personnel of the requisite calibre, would have to depend very largely on Government assistance, but it was felt that this would be a profitable investment in that productivity would be increased and any augmentation of subsidies at this stage was sure to bring benefits to the economy several times over, in due course.

The association of NPC with the Advisory Committee is bound to be a source of increasing strength. There need be no question of overlapping and encroachment and apprehensions on this account. The training programmes of the NPC were usually arranged after consultation with the SQC units and there is room for making closer such consultations and contacts to the mutual advantage of the LPCs and the SQC units.

There is yet a great deal to be done in regard to the collection of information about the function of SQC systems in the Indian factories and to review the whole work. There is no doubt that *progress of SQC in India has been uneven and inadequate because of piecemeal application of statistical quality control methods instead of adopting a comprehensive approach.* By contrast, in Japan it is reported that 60 percent of the factories, having 100 or more employees, have full-fledged SQC programmes in operation. There, SQC consciousness is aroused by lectures, seminars, quality marking schemes, export promotion schemes, all of which call for the maintenance of quality and the employment of refined techniques of SQC. Indeed, unlike the old days, the main emphasis in Japan is on total quality control and the national consciousness has been built up for making 'Made in Japan' synonymous with 'Quality'.

In the world generally there has been an extensive increase in the use of modern quality control techniques and in the development of formal quality control programmes. Side by side there has been a considerable production of literature in this field with respect to specialized applications of statistical methods. Edward M. Schrock in his book, *Quality Control and Statistical Methods*, in the preface to the second edition, says, 'It is becoming apparent that as important as statistical and other specialized techniques may be, they will not in themselves assure the success of a quality control programme. Proper organization and sound administration are essential to the success of such a programme (and most other programmes). Groups attending quality control conventions and conferences have been showing an increased interest in how to start quality control programmes and how to make them effective'. It is very true that optimum results from SQC, as from any other employment of productivity, can only be secured by enlightened and efficient management.

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Walter A Shewhart's Special Message to NPC Productivity Journal Special Issue on Quality Control

IN 1947, SOON AFTER INDIA ACHIEVED HER INDEPENDENCE, I was invited by Professor PC Mahalanobis, Director and Dr. Chintaman Deshmukh, President of the Indian Statistical Institute and Dr. Lal C Verman of the Indian Standards Institution to introduce statistical quality control to India.

During that first visit I travelled all over India visiting dozens of industries, talking to industrialists and businessmen, lecturing and helping to start work at various centres. I stressed the great promise for this technology and its value to a newly developing country setting out to industrialize rapidly.

Statistical Quality Control is a technology to improve and maintain quality and lower costs of manufactured products. Naturally our first efforts must be to train workers. In this, from the very beginning, the Indian Statistical Institute has been playing a notable part in training statisticians to undertake the work. With the establishment of whole-time operational SQC centres at various places, such as Calcutta, Bombay, Bangalore, Baroda, Delhi, Coimbatore, Madras, Ernakulam under the auspices of the Institute, steady advance is being made in spreading the use of SQC in industry. This is very gratifying to me.

This is my fourth visit to India and naturally, I am tempted to survey what has been done and to suggest what I feel should have been accomplished. I am very pleased with the operational units and training centres and their excellent work. I had hoped for even greater progress. In many fields, such as textiles it seems fruitful results have been achieved following the adoption of quality control. There are many other fields where there is great scope for further work and promise of very profitable results. I have a feeling that even the industries in India which claim they use quality control do not make use of the latest developments.

From my experience with the quality control organisation in U.S.A., I believe India would have gained greatly by having a strong national society and a national magazine to provide a common meeting ground and a channel of communicating technical experience to one another.

In a country like India, badly needing foreign exchange, a drive for exports assumes national urgency and importance. But exports can be expanded only on the basis of the assured high quality of the exported products. For a period following the war, when there was shortage of all goods, anything would sell, irrespective of quality. Now it is no more so; there is keen competition to contend with and consistent quality must be maintained to hold the market. Japan is very conscious of this and has made wise use of quality control to assure better quality at a lower cost.

By these remarks I do not mean to criticise India, but rather to make a few helpful suggestions for the improvement of the quality of the products of a country very dear to me. I shall always, therefore, watch with the keenest interest the growth of the productivity and quality control movement in India. May it develop fast and on sound lines.

Sd. (WALTER A. SHEWHART)

Calcutta
12 February 1962.

Dr PS Lokanathan Chairman NPC at Lucknow (Central UP Productivity Council)

Mr John D Thompson awarding certificates, Delhi Productivity Council

NPC Work Study Course in Jute Textiles

Quality Control in The General Perspective of the Indian Economy

PS LOKANATHAN*

Quality Control, or SQC as it is now called due to the application of statistical techniques to the performance of industry, has so far been known only as a productivity technique. It is really a powerful mechanism by which we can create and expand markets, both at home and abroad. The real inhibiting factor in development is the small size of the market in India and the comparative failure to create a sizeable market abroad. Really, Indian industry needs genuine quality control more than any other economy, for expansion along desired lines, whether in the private or in the public sector, depends ultimately upon the markets served by new economic activities. The size as also the nature of the markets are determined by the quality of goods consistently produced by the old as also the new industrial units.

APART FROM THE SOCIAL NEED FOR growth, which SQC as a productivity technique will subserve, it will also serve another national imperative of saving in terms of raw materials. As the economy expands, current shortages which are holding up expansion in several directions will become acuter. It is not sufficiently realized how SQC can go a long way in securing economies of materials all along the line, for it is in essence an anti-waste device, operated with such scientific thoroughness that at less cost in terms of inspection and the like, a larger volume of assured quality goods flow on to the market, fuller utilization of resources being made at every point in the industrial process. The feed back is so systematically organised and statistical charting so simply yet so effectively done at all stages from arrival to despatch of goods that processing gets almost automatically corrected, as it were. In the context of our social and economic circumstances, it looks a somewhat idealistic solution, but any analysis of the economic situation would show that this is exactly what we need; and that it is possible in the short period. It is a Must for survival of private industry both in the context of the emergence of democratic forces, as also the recent upsurgence of competition in several spheres. Quality in that case becomes the condition for survival.

Yet we have to acknowledge that in the industrial sphere, progress in quality control is inhibited by the fact that aggregate demand far exceeds the aggregate supply in practically every sphere of the economy. Inflation is the enemy of quality control. Quality gets short shrift in a market where everything can sell. Standards have there-

* Chairman NPC.

fore to be enforced. We have to build up institutional safeguards to ensure that producers keep to standards. Probably the best safeguard might well be, as it is actually becoming in developed countries, that a firm maintains its own quality control department. The American army, in making its purchases, makes a pretty simple enquiry whether the supplier firm maintains an SQC department of its own. The army has established its own quality standards, which have become world famous and are in fact being applied in civilian industry on a fairly large scale. The big firms in their own turn concentrate their purchases from firms, maintaining quality control staffs, so that a regular movement has been set up. It has become one of the requirements of the market; and firms advertise that they keep to standards and have their own SQC !

It is in the social interest that we in India organise a movement of this character, for the tragedy of the Indian situation is that we in the first instance produce goods of the highest quality, which shows the potentialities of the Indian producer and artisan, but the quality progressively deteriorates. Probably it is not so much now as it was in the inter-war period, when a large number of new industries came into being under difficult political circumstances. Nevertheless, the case of one of the biggest pharmaceutical firms comes to my mind, for it is typical of what used to happen and what yet remains a dark spot on the face of our economy. Several decades ago, a large scale pharmaceutical firm produced goods of the highest quality standards. A market immediately came into being; even an export market developed. In any case the domestic market came to be dominated by indigenous products, British and even Japanese medicines receiving a setback. But the whole market rapidly disappeared because the second and the third and the fourth batch of goods progressively deteriorated till a level was reached when the medicines produced by the pharmaceutical company were really not useable. Things have improved since then but we even now find for example that a company would in the first instance make absolutely first rate blades: the first packet for presentation to the Prime Minister would be of outstanding quality but those to be presented to the public would not be as good and later on, the blades would become unuseable. The fact that the firm had the machinery which co produce blades of quality presentable to the Prime Minister is important because if the firm has the machinery, the technique and the material to produce that quality of goods, there is no reason why that quality should not be made for the people, since in an inflationary market people are prepared to pay even fantastic prices for imported high quality blades. In the context of modern economics, for the build up of large scale markets, it is of the highest public interest that manufacturers should produce goods which may be called a *Present to the People.* A present to the Prime Minister is of course lovely and a matter of grace and charm but it is a present to the people that would make a market.

This brings me to the point which I am particularly anxious to emphasise in the context of our need to earn immediately the largest possible foreign exchange that we can. Our economic and political interests demand urgently that we Replace Aid by Trade; and lack of assurance of quality is a major bottleneck in the expansion of exports. Here also the tragedy is anomalous. The sample shown to the foreign buyer is par excellence; and he is very much attracted. Quality has brought him to our market and it is only quality that will keep him and bring more of his kind; yet the short-run advantages ought by individual suppliers through deterioration of quality have brought about a wholly unnecessary diminution in our export possibilities. Quality assurance through a systematic application of SQC is probably the biggest booster we can provide for our exports. The hard currency areas are highly sophisticated markets with developed standards of quality of their own. If we want to develop export markets, we have to accomplish the same revolution that Japan has done through quality control: namely, a total reversal in the very connotation of Made in Japan. Now it stands for something solid and worthwhile. The very words Quality Control are written in the Japanese law on Standardisation; and it is enforced on exports! We have to do likewise for survival.

The second but not less important field of urgency in respect of quality control is the small industry sector, for the big firm has necessarily to live by its name and the slightest deviation from established quality standards will knock the brand off the market, but it is not so in small scale industry, particularly in our country. Once again, quality is not to be understood in *the handicraft sense of being characteristic of one specimen, but of a continuing flow of goods of assured quality.* It occurs to me and probably it is a very strong point that a very large—probably, very, very large—expansion in the markets of small scale industry can be brought about in the short period, if large scale manufacturers had some institutional safeguards of assured quality supplies (of standard specifications) from small established producers. As the Japanese experience shows, subcontracting is extremely profitable to the big producer, for he finds it a lot more economical, financially and organisationally, to get from outside the large mass of small things that enter into the assembly of a modern product and its packaging. Probably, a very practical course would be for the Small Scale Industry Organisation to provide among the common facilities in the growing industrial estates, a small well-staffed SQC unit, which would in the first instance sell its services cheap or even free but in a time shorter than we can imagine, it will pay its way.

We must now think more deeply. One of the reasons why the quality of Indian goods is low or highly variable is because of the absence of education among the workers and the large body of consumers. We cannot blame them, for our economy has for long periods of time provided little education and hardly a standard of living for the mass of the people. Appreciation of quality is not inborn. It develops. We have to create conditions in which the worker becomes appreciative of quality, appreciative therefore of the maintenance of quality. This is no criticism of the working class. In fact it is a justification indirectly but powerfully of the need to improve working and living standards, if we are going to improve the quality of our goods. Unless workers are used to quality goods, they will not over a long period produce quality goods. In a fundamental sense, quality goods can only be produced by quality men. To expect that quality goods could be produced under dirty working conditions by persons living in dirty surroundings is an expectation that is not only not in good taste but also not realisable in practice One of the revolutionary changes that has not received sufficient notice is the fact that in the United States, a large body of workers are high school boys and girls. Probably the best prospect that we can look forward to is a like transformation of our working force. In fact, that will be the best indicator of social and economic growth.

Simplified Application of Statistics in Industry

William R. Pabst, Jr. *

The achievement of simplicity is almost never a simple thing. In the design of complex products, simplicity is a costly goal that requires great planning as to how to achieve the necessary functioning in the most direct way. In the electronics industry, for example, simplicity and reliability are usually considered to be related and attainable only in the mature design, the models and prototypes being anything but simple. So it is in letter writing and in many of the arts. Simplicity is a product of maturity.

IN STATISTICAL QUALITY CONTROL, simplicity is a desirable goal. It might be expressed in many ways: how to achieve the same degree of control over a process or over a manufacturing establishment in the most direct way; how to achieve the same function with fewer calculations or by using the same information more efficiently; *how to make statistics a servant of the enterprise* that portrays, examines and helps to resolve the problems for the technical decision-makers rather than *a cruel and demanding master involved in its own complexities.*

The goal of simplicity is to make the application of statistical methods maximally useful at minimum cost. This means that the problems to which statistics are applied be the most important from the viewpoint of the enterprise as a whole, that *the statistical methods used be simple and efficient, and that action be taken on the basis of the statistical findings.*

A brief review of the development of simplified statistical tools for use in quality control is presented. These methods have been called by man names: *rough and ready, quick a dirty, and simple but not simpleminded.* There are many other simplified methods proposed under various slogans: "sampling inspection with no calculations", "control charts with no calculations", and many others. If one were to take these captions at their face value one might expect the statistical part quality control to be very simple indeed. This, of course, would be most advantageous if it would help to focus attention on the important problems to be solved rather than on the methods to be used in solving them.

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The published work dealing with simplified methods is so enormous that it is possible in this review to select only a small portion of the available material. The attempt is made to spread this selection over the wide spectrum of tools commonly thought of as appropriate to the broad quality control function. Four general classifications, by no means mutually exclusive, seem appropriate. These are (1) control charts (2) sampling plans for attributes (3) sampling plans for variables, and (4) non-parametric methods.

control charts

Simplification in control charts stems largely from the attempts to use medians and ranges to replace the mean and standard deviation, the use of range being now almost universally practised. Clifford[1] has described these approaches in his article, "Control Charts without Calculations". He proposes control charts in which the values for each item in the sample are plotted and the middle or median value is easily identified and circled. The range of the sample is then measured mechanically by the distance between the highest and lowest plotted points and transferred to a frequency distribution chart for ranges. After a number of samples have been plotted, the median range is determined and control limits for the medians of the samples and for the ranges are established. The method eliminates the usual data sheet and the arithmetic involved in calculating averages and average ranges. The method is also applicable to the identification of strata within the sampled population by proper identification of the individual points. Clifford also discusses the elimination of the usual chart records after a process has been established. The operator is furnished with limits for the median and the range and is allowed to test the conformance of each sample with these limits without plotting. Charts are reinstated, should more than one sample in 20 indicate an out of control point.

Farrell[2] suggests an essentially similar procedure by using the mid-range and range of the samples as well as the median and the range as alternates to the usual $\bar{X}$ and R chart. The mid-range is the average of the highest and the lowest value in the sample. Farrell makes a strong case for efficiency of the mid-range and range method in locating disturbances in the process and wild shots, despite its admitted lower efficiency during a state of statistical control. Simplification of computation is found in the mid-range and range method since only the highest and lowest values in the sample are used, once to measure their difference and once to obtain the average.

Farrell has also proposed control chart methods when the underlying distributions are badly skewed and are not amenable to the usual control chart procedures. In using the range, mid-range method for these badly skewed distributions, semi-log paper is used to replace the arithmetic paper to assist in plotting the geometric ranges and mid-ranges. The advantages in ease of computations apply as in the normal case.

Ott and Mundel[3] in their article entitled, "Narrow-limit Gaging" provide an alternative to the usual variables control charts by setting attribute gages inside the tolerance limits. Operating characteristic curves are provided for different sample sizes n, different acceptance numbers c, and different extents to which the gages have been moved inside the tolerance t. The method follows essentially that developed by Dudding and Jennett. The advantages of the method are primarily in the absence of measurements needed for the sampled units and the ease of record keeping.

1. A Bibliography of all references is given at end of this article.

The method is, of course, much better in efficiency than using attribute gages at the tolerance limits. There are *psychological disadvantages,* however, that might be encountered *in tending to drive a process to unnecessarily tight limits.* The method does provide protection at nearly the variables level without the necessity of measuring individual values or calculating beyond counting.

Madison and Ostle[4] have developed a chart in which the individual sample values are plotted, following in part the work of Howel[5]. This chart is called the Maytag Double Line Chart. The chart has two sets of limits, the outside limits being the specification limits, and the inside limits being measured from the specification limits by a multiple of the estimated standard deviation. The following two conditions apply: the process is considered satisfactory when (1) all the sample values fall within the specification limits and (2) when they do not all fall in the interval on one side between the inner and outer limits. The method is an interesting application of the modified control chart procedure. Madison and Ostle provide a comparison for power with usual control charts. Although this method does not agree closely in power with the mean range charts under conditions of control and for large shifts in process average, it does have desirable qualities in ease of application and understanding.

Control charts have also been applied in a two-way classification for the control of a process having two closely correlated characteristics. Weis[6] provided an example of such an application to the re-set time and trip time of circuit breakers, where control charts previously applied on each characteristic tended in the correction of process for one factor to throw it off for the other. The charts developed are parallelograms and the average points are not plotted in time sequence as in the normal control chart, designation of the order of points being necessary if analysis by time is to be retained. Jackson[7] has also explored the subject of the control charts for correlated variables and uses a control ellipse set at a given probability level (in this case 95%). It is pointed out the result obtained is the same as in Hotellings' T^2 control charts, in which one over-all measure is obtained for each pair of sample values. Behnken[8] suggests some interesting and simplified approaches in the use of control charts for trends.

sampling by attributes

The simplest procedures for sampling by attributes are identified with Binomial Probability Paper (BIPP), first introduced by Mosteller and Turkey[9]. This is a special kind of graph paper by means of which sampling plans by attributes can be determined, attribute tests of significance made, and comparison between observation and specification resolved. Use of the paper is based upon the observation that distances from any point are measured directly in standard deviation units. Given any point it is possible to directly determine its difference from assigned standard in standard deviation units and by means of usual tables to convert these standard deviation units into significance levels.

Hicks[10] has given five typical problems that can be solved by means of BIPP paper as follows: a. To determine whether an observed number of defective items in a sample is significantly different from an assumed process average. b. To determine confidence limits for a population fraction defective p'. c. To construct a p chart with varying sample sizes. d. To design a single sampling plan. e. To compare two variances to substitute for the F test in analysis of variance. Obviously there are many other problem types such as the comparison of two fractions defectively that can be solved simply by use of this device.

It must be pointed out that considerable simplicity has already been introduced into the attributes side of quality control through the use of collections of sampling plans such as the Dodge Romig tables and the Mil Std 105 tables. For most problems where attribute sampling is applicable, it is easy to find by use of the presented operating characteristic curves to find an attributes plan suitable for the purpose even where the administrative framework of the Mil Std is not used. Once the plan is adopted, only a comparison between the observed number of defectives and the acceptance and rejection numbers need be made.

Note must also be made of the continuous sampling procedures for inspection by attributes as developed by H.F. Dodge and his colleagues. These plans are based upon a procedure wherein the fraction inspection of the items presented is reduced on the basis of the quality of material presented. These plans have been studied and extended by others. Ireson and Biedenbender[11] presented the background and development of the Inspection and Quality Control Handbook H-106 entitled "Multi-level Continuous Sampling Procedures and Tables for Inspection by Attributes." These plans provide for a reduced amount of sampling when the process is better than that established as acceptable.

sampling by variables

Tables for sampling by variables have been available for a long time. Their use requires calculation of the sample mean and the sample standard deviation or an estimate of it. As in the case of variables control charts, the range has come to be used increasingly as the basis for estimating the standard deviation. The Bowker and Goode tables were first available, and those of Ordnance Standard 80 were developed as a simplified version. In developing the Army tables for Ord-M608-10 Storer and Davison[12] presented a complete set of variables tables based on the range. They reported on this under the title "Simplified Procedures for Sampling Inspection by Variables". Both the Navy and Army plans have now been superseded by the Mil Std 414 (Sampling Procedures for Inspection by Variables for Percent Defective) which presents a complete set of plans comparable to those of 105 based both on range and on standard deviation (both known and not known) with alternative means of calculation.

Many attempts have been made to simplify the use of variables inspection plans. Greenwood[13] has developed a mechanical device for using sampling by variables. The machine makes possible a decision in accordance with the new Mill Std. 414 without need for computation of the acceptance criteria. In using the device to judge the conformance of a lot with assigned AQL, a sample is selected from the lot and measured in accordance with established practice. The mean of the sample is then determined and the standard deviation is determined usually from the ranges of subsamples of five. The mean and estimated standard deviation are then plotted with the help of moveable scale arm to determine whether the results fall within the preplotted acceptance region for the assigned AQL. The device can be used equally well for single and for double-sided specification limits. It saves computation steps and the comparison with acceptance criteria furnished in the tables of Mil Std. 414.

Another effort at simplification of variable acceptance plans has developed from the use of normal probability paper. This has been dramatized by

Chernoff and Lieberman[14] in their paper, "Sampling inspection by variables with no calculations". The NO-CALC procedure is essentially one in which the variable measurements observed in testing a sample are plotted on a normal probability chart first in order above the zero axis, and then plotted spread out across the chart on axial points depending upon sample size. If the plotted points fall on a straight line, the population is judged to be normally distributed, the standard deviation is determined from the slope of the line and the median from its midpoint. Tables are provided for various sample sizes showing the maximum percentage of defectives allowing the acceptance of lots of given quality.

The Jetec-11 (Joint Election Tube Engineering Council Committee on Sampling Procedure)[15] has developed a median quasi-range method of variables acceptance sampling. This method has appeared in many of the election tube specifications. Acceptance limits are given in the specification for the median based on the desired upper and lower limits for the lot average. Similar limits are also given for the quasi-ranges based upon the desired lot standard deviation. The particular quasi-ranges (highest minus lowest, next to highest minus next to lowest, third highest minus third lowest) used are those with the greatest efficiency for the given sample size. The operations for each lot involve making an array of the sample data, so that the median can be quickly identified and the quasi-range computed by one subtraction. These are then compared with the limits to determine the acceptability of the lot.

The Hamilton Standard Lot Plot plan introduced by Shanin[16] was developed as a simplified version of variables acceptance plans and was intended to be distributed free, in that the decision to accept or reject the lot was dependent upon the type of parent distribution selected. In the operation of the plan a sample of 50 pieces is selected from the lot, and the sample is divided into a number of subsamples and a histogram is constructed. Depending upon the appearance of the histogram, the limits of the population are derived from the calculated mean and standard deviation and are compared with the tolerance limits to determine the acceptance of the lot. This method has been widely used in the aircraft industry. The plan is easily explained and used and is appealing in its visual portrayal of the sample histogram. Its statistical characteristics have not been well explored. Shaffer[17] has developed the operating characteristic curves for plans of this type for normal distributions including the special case selected by Shanin.

Various methods have been presented to simplify the operation of the lot plot plan. One of these is the lot template method given by Hill[18] in which lot distributions for different degrees of non-normality are prepared for use by the lot histograms. Another method is called a "Mechanical Lot Templet" developed by Ellis[19] which provides a series of 121 possible 50-piece distributions each with a different degree of skewness. The histogram from the lot in question is matched with one of these prepared distributions, and from it the lot limits are determined. If the lot limits are outside of specification limits, the percent outside limits is immediately read from a table. The accuracy of the templet method has not been determined, although comparison with the lot plot method using means and ranges suggests no great difference.

non-parametric methods

Recently a whole new class of simplified methods have been made available to quality control practitioners under the general title of *"quick and dirty"* methods. These methods usually involve only the ranks of the observations or the signs of the observations. Ranks involve arranging the observations in algebraic order and assigning the highest one a rank of one, the next highest a rank of two, and so forth. Signs involve only determining whether one observation is higher or plus rather than lower and minus, or, when observations are not numerical, whether one object is better or poorer than another. These methods are easy to apply compared with the standard variable procedures of the test or the analysis of variance. They also involve no assumptions concerning the normality of the underlying distribution from which the term "non-parametric" stems. It has been increasingly clear from the theoretical work that these methods are never much poorer than the standard methods even when an assumption of normality is tenable, and that they are sometimes much superior especially when the distribution is non-normal or unknown. Most often they deserve the title "quick and clean".

These methods are described by Wallis[20] in "Rough and Ready Statistical Tests" and by Bradley[21] in his two articles entitled, "Some notes on the theory and application of rank order statistics". Dixon and Massay[22] have an excellent chapter in their *Introduction to Statistical Analysis* as do Wallis and Roberts.[23] The literature is extensive as Siegel[24] indicates in his organization of this material.

A thumbnail sketch of some of the methods is given as follows:

signs: Two materials, inspectors, conditions or other characteristics are to be compared. Pairs of observations are available under similar conditions for the two objects covering the range of conditions for which the comparison is to be made. A count is made of the positive and negative differences between the two things being compared. If the number of plus and minus signs are equal or nearly so, there is no reason to believe that the population from which the pairs are drawn are not equal. If they are different, the significance of the difference can be determined. Tables are available to test the significance of the difference for the number of pairs involved. For instance, on 28 lots of materials the company inspectors found more defectives than the government inspectors in parallel samples on seven lots, whereas government inspectors found more defectives on the other twenty-one lots. The probability of this difference happening by chance alone is found to be between one and five percent so that the hypothesis that the company inspectors are as observant as the government is rejected. This test has many important applications in determining in a plant where more intensive controls will be useful.

runs: A series of observations is examined to determine whether the arrangement is random, differences between the successive observations being scored as plus or minus. A run is counted as a number (one or more) of like signs together. A number of runs greater or less than critical values is evidence of non-randomness. This test may be used in detecting trends up or down in the series. The series of observations may be observed with respect to time or some other characteristic. For instance, a number of white and black balls may be arranged in order by size; each series of white or blacks (including a series of only one) being considered a run. If the whites are bigger than the blacks, they will tend to be grouped together and the number of runs will be small. For instance, in a sample of ten whites and ten blacks, a count of seven or fewer runs would be evidence of such a difference at about the 5 percent level.

rank: The white and black balls can also be compared by ranks, scoring a rank of one for the smallest, two for next smallest and so forth. The sum of the ranks of the white balls can be compared with the sum of the ranks of the black. Tables show that the chance of the sum of the white ranks being less than or equal to 79 is .026, or being equal to or greater than 134 is .026. Thus, if the rank sum is less than 79 or greater than 134, the white population is different from the black at about the 5 percent level of significance. A similar test, the H test, can be applied when there are more than two classifications or groups of objects and is essentially similar to the analysis of variance.

life of equipment

Goodman[25] in "Methods of measuring useful life of equipment under operational conditions" describes a simple method for comparing the longevity of two or more objects or equipments. The method depends upon a replacement policy for worn-out items by switching. Suppose, for instance, that it is desired to compare the service obtained from light bulbs of two manufacturers. When the bulb of one manufacturer fails, it is replaced by one of the alternate manufacture, and vice versa. If the system is started with an equal number of bulbs of each manufacture, then the relative longevity after a sufficient period of replacement is given simply by the proportion of bulbs of that manufacture in use at a given time. After the replacement policy has been in use for a sufficient period of time, the result is independent of the form of life distribution of the equipment and is hence nonparametric. For instance, if *switch policy* is utilized in a factory having a total of thirty bulbs in use, and it is found after a period of time that 11 of manufacture A are in place and 19 of manufacture B, then the relative longevity of A is $11/30 = .367$, and that of B is $19/30$ is .633. The significance of these estimates can be compared with their standard error which is given as approximately $\sqrt{(.367)(.633)/30} = .088$. If the total number of replacements is known, then it is also possible to estimate the length of time of service of each item. The fact that it is not necessary to identify or keep records of the individual items when the switch policy is utilized makes it easy administratively.

simplified approaches

The question now is posed as to where simplified methods relate to the development of a quality control system.

During 1958 in India I had the opportunity of working in conjunction with the Indian Statistical Institute with more than a hundred of the newly developing enterprises in that country. This afforded a workshop in quality control that covered some thirty different industries and the entire subcontinent. The objective was to lay the foundation for the development of effective use of statistical quality control methods to assist in increasing the productivity of Indian industry. *In nearly every plant we visited, a potential increase in productivity of 10 to 40 percent was considered attainable through effective quality control and in many cases these expectations were realized in actual fact.*

The procedure adopted consisted primarily of survey visits to the plants with follow-up letter reports detailing the particular ways in which quality control methods might be applied or improved. A positive approach was taken. A check off list indicating those areas where quality control had been effective in the United States; namely, in the reduction of scrap, elimination of rework, defect prevention, maintenance improvement, control of incoming material quality, control of outgoing quality levels, was used not so much to indicate where quality controls might be used, as to find where they might do the most good. With limited resources of quality control skills available, it was desirable to make the biggest gains first. In fact the emphasis was more on *the problems to be tackled than on the methods to be used*, since these in most cases were indeed obvious. The measure of success of the quality control procedures were their contribution to the increase in productivity, and not merely in the use of the methods themselves. Some one described this as *applying quality control methods to quality control itself.*

Typical cases where quality control might be effectively applied were found repeatedly in nearly every plant. The most typical situation involved a difference in scrap, output, productivity, or rework between parallel productive units. For instance, among ten contractor units in a foundry, the acceptance rate for one contractor group averaged about 92 percent for a six month period in contrast to less than 60 for some of the other groups. Incidentally this information was available from payment records but had not previously been utilized in a positive way to *bring up the level of the lower group to that potentially available.* It is easy to see that the production of the entire foundry, using the same men materials and plant might have been increased by as much as 25 percent by bringing the lower group up to the attainment of the upper one. Therefore, the quality control effort was directed to the metallurgical, psychological and training needs required to balance these parallel resources. In the jute mills differences in individual weaver efficiency focused attention on the need for training and incentives to raise the productivity of the lower group. In the jute mills, too, differences among the spinning frames in "ends down" provided a starting point for corrective action. Assembly and subassembly lines in the sewing machine factory were found to have greatly different scrap rates; so did the different heads on the automatic glass machines. Sign and rank tests are invaluable for making judgments of this kind.

Another typical problem was the difference in inspection standards among the different inspectors. It was easy to spot the inspector on one side of the conveyor belt throwing away twice as many defectives as his partner, *even after their positions were shifted.* One inspector in the sewing machine plant rejected four times as many completed machines over a period of months as another in the group of ten final inspectors. *In general, inspection seemed to be more poorly engineered than any other production operation.* Multiple comparison charts are nearly always necessary in getting reasonable consistency among inspectors.

In most plants the best starting point for a quality control operation seemed to be the evaluation of outgoing product. For it was possible to thread back cause-effect relations through the production process to isolate the major causes of trouble. This starting point has many advantages in that it tends to focus controls at those process points where greatest gains can be expected. For instance the sewing machines has more than five hundred parts, but among these less than a dozen were found to be the most troublesome in contributing to rejectable machines. By correcting these and bringing them under control, it was possible to make significant gains in productivity, whereas a *broadside attempt to use control charts* on the thousands of dimensions would have exceeded quality control resources and tended to *focus attention on methodology rather than on results.* Similar practices applied on incoming materials of course extended the chain of control back through the suppliers of material.

Another starting point was the scrap and reject pile, for the information here could be almost immediately used to isolate causes and to establish controls at the strategic points in the production chain. This approach was especially important in the foundries, the soap factories and the potteries.

Quality control and statistical developments where they had been started were not always free from disproportion. For in some plants beautifully designed experiments had satisfactorily found the maximum operating conditions for temperature in glass annealing only to be followed by simpler processes that led to scrap rates of more than 25 percent. In the soap industry great attention had been paid to the control charting of laboratory results where data were easily available, only to be followed in the manufacturing plant by poor handling and cutting techniques that caused more than half the product to be returned to the soap kettles. When attention was focused on these larger simpler problems, rapid and effective gains could quite easily be made.

The widespread use of control charts was not always effective. In one plant the hundreds of control charts used in the machine shop which was followed by sampling inspection did not prevent the flow of defectives to the assembly line, but rather seemed to *immobilize the search for basic causes and corrective actions.*

These basic problems are more fully described elsewhere.[26] They point to the need for *simplicity in approach as well as simplicity in method.* Interestingly the problems of one plant in an industry to which quality control techniques might be applied appeared to be essentially similar to the other plants in the industry. Thus, quality control approaches for several jute mills were generalized into one that might serve all the plants in the industry. This general approach was presented in the form of briefs outlining a step by step procedure by which quality control might be initiated. Emphasis was placed on problems to be tackled and the results that might be expected, with less attention given to methodology. These briefs did serve the purpose of *starting the use of quality control in many areas on the simplest terms* leaving the more advanced applications to await the growth in maturity arising from experience. Simplified methods were used where they could be readily understood but standard practices were most often employed.

Were this Indian experience isolated and unique, it would not merit much attention; but for every problem encountered in Indian industry, a parallel on perhaps a different level can be found in the American experience of the last decade. Indeed the American groups of statisticians and engineers with whom I have reviewed this experience have been struck by the similarities with their own.

conclusion

An enormous bag of simplified tools is available for use in quality control applications. Within the framework of an operating quality control system, it is possible to use these effectively to reduce the amount of paper work and to reduce costs of the quality control system. The dangers are that the simplest system may be none at all, and the advantages of a quality control system may be lost, the *simple methods may degenerate into simple-minded ones.*

The quality control system is like the complicated machines under development. The first attempts to construct the machine, the breadboard model, is like the initial attempt at organization of the data flow and the determination of the basic quality control practices. As the machine is developed, improvements can be made in many of its components to simplify the operation without sacrifice of function or performance. As each part of the machine is simplified and developed, an overall simplicity is achieved. Depending upon the machine, this may take years of effort. Similarly with a quality control system, the first concern is with an overall framework where *approach and purpose are more important than method.* It is after this framework has been stabilized, that useful gain can develop from the application of simplified method. This is the aspect of simplicity that needs to be developed in the quality control area for too little attention has been paid to the *organization of these simplified tools into a simplified system.*

The workshop opportunity in India indicated that these simplified tools especially the sign test and the ranking methods were extremely useful in *spotting weaknesses* within the plants and directing attention to them. The methods were also useful in *avoiding the situation of over-concentration on small and specialized problems* that were more interesting from a statistical viewpoint than to that of longrun company advantage. However, the first attempts at application utilize standards methods for the most part firming the foundation upon which simplification can develop.

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Total Quality Control

HD Shourie*

Recent productivity literature is full of a new idea that is being popularised by Armand V Feigenbaum as Total Quality Control. It is a new concept of integrated quality control engineering, which seeks to build-in quality into the product from end to end; that is to say from a sampling of incoming materials on a scientific basis through all the processings to the final handling and transportation. Actually, this field of total quality control extends much farther at both ends; it extends either way into the markets from which a firm buys its materials and machines, to the markets in which it sells its products. Instead of wasting resources on checking, inspecting and repairing, the requirements of the market are built into the product that is processed, and further back, the product specifications determine categorically the level of acceptability of materials. Total quality control is therefore a system by which the specifications of the market travel back by an organised method and are translated into the specifications of the materials that enter into the product and the machines that process the product. Further this idea of total quality control also involves fundamentally a general upgrading of the entire range of personnel associated with purchasing, processing and selling. Statistical quality control is thus an all-inclusive fully integrated productivity technique.

It would be rather awkward for us to claim that NPC has put forth this concept of total quality control, for the idea of quality is inherent in productivity. Production of defective materials is certainly the very opposite of productivity; and mere inspection is certainly not quality control. Quality control essentially means a systematic reduction of costs incurred on the production of defective materials and also the economising of costs incurred on police or clerical inspection, all along the line from the unloading of materials to the loading of products. Quality control is a productivity technique which seeks to economise on both these types of costs.

It is also a productivity technique because it is the only method of expanding the market, making it more profitable than it ever was and keeping it consistently profitable. It is a preventive productivity technique in the sense that its sole objective is to *avoid defects occuring in the first instance.* It is thus very obvious that while the idea of total quality control might look very advanced, as it actually is, it is the idea that Indian industry needs both for survival as well as for prosperity; for the main defect with which Indian industry has been faced is that while it has the capacity to produce goods of the highest quality, goods of varying qualities get produced alongside and means are not being adequately adopted by which a reasonable quality can be maintained.

Indian manufacturers have been famous since historical times for producing goods of historical quality but

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the problem has been how to build-in this quality into mass-produced goods and to maintain that quality throughout the flow of goods from the factory to the market. The Indian consumer or the consumer of goods abroad is really not sure whether he is getting the goods that he has seen at one time. The damage to the economy in terms of limited markets within the country and export markets abroad can only be imagined in terms of the national interest. SQC thus becomes a most powerful instrument for expanding the market both within the country and abroad. Equally, it becomes the most powerful instrument for expanding employment opportunities, for fundamentally it is the small size of the market that limits employment opportunities. If Indian goods become acceptable to the people because they conform to the quality of which they approve, the market acquires altogether a new dimension of dynamic potentialities. Foreign markets can by themselves add a new dimension to the Indian economy, for the demand for Indian products of quality in countries of high purchasing power is really incredible and it can create any amount of gainful opportunities of employment for our artisans, craftsmen, young boys and girls who are acquiring new skills and learning new techniques. SQC will enable us to create and capture these markets.

This dial doesn't do anything—we just put it in for something to fiddle with when the boss is around!

Quality Control: Some Principles

DJ DESMOND*

Although I am delighted to contribute to the special Quality Control issue of "Productivity", I am unable to give a case study of any of the work I did in India owing to lack of data here in the UK. Further, any description of what was done over four years ago would not necessarily be the best today with improvements in technology and a wider understanding of what Quality Control means. I think my best contribution would be to outline some of the principles which I tried to teach during my two visits to India.

QUALITY CONTROL IS A TECHNIQUE OF scientific management which has the object of improving industrial efficiency by concentrating on better standards of quality and on controls to ensure that these standards are always maintained. It *never had a major objective of providing a cheap form of inspection* although it often resulted in both cheaper and more reliable inspection. It is *not intended to show what is wrong with current technology* but rather to establish what can be achieved with existing methods when they are operated correctly. If such achievement will not satisfy service requirements, then quality control methods can be used to determine optimum operating conditions with a minimum of experimentation.

The principles of statistical control can be demonstrated by a crude procedure. Take a sample of any convenient size direct from the process you wish to control and measure the characteristic of each item constituting the sample. More than one characteristic may be measured if you are interested in more figure which is representative of the sample. In some cases it may be convenient to have more than one summary measure and the procedure should then be applied to all of them. Plot the summarised measure on a simple chart with its magnitude shown by a numerical scale drawn vertically on the left of the chart. The horizontal scale will show the time and date of taking the sample.

Repeat this procedure on a number of occasions using the same sample size and the same method of summarising the data. The overall results will then show a picture similar to the figure printed at the end of this article. Now scrutinise the pattern and decide if it "looks right", that is, whether the group of points look as though they belong to a single family without any "strangers". Even if they look right, there will be some variation in the magnitude of the summary measure and then this variation is likely to arise from a single basic cause. Such a cause would be the lack of perfection in the manufacturing technique and the pattern would look right if this imperfection remained appreciably constant over the whole period of the study.

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SQC Expert (1954—1958) Indian Statistical Institute, by whose courtesy this and the following article are published.

If this condition is satisfied, draw two parallel bounding lines which just contain all the plotted points and then the region within this boundary will give a measure of the variation which is inherent in the process being investigated. Note that there is an implicit assumption that all the observed variation is here due to chance so that the high, medium and low values are all of the same quality. Now project these lines into the future and continue to take samples, measure and summarise the results and plot on the same chart. It may then be assumed that the future quality is the same as the initial quality if *all* the plotted points continue to lie within the boundary limits and the process can then be said to be under control.

In many cases it will be found that one or more of the initial plotted points do not "look right" relative to the pattern of the remainder. On such occasions, it is safe to infer that these points arose when the process was not under proper technical control although it *cannot* be stated in what respect the technical control has slipped. A pair of boundary lines which just contain nearly all the plotted points can then be considered as defining the quality which is achievable even though it was not achieved for the whole of the initial study. The projection of the limit lines and plotting of further results can still be carried out with the same implications of quality as above.

When one of these additional points falls on or beyond either limit line, it is indicative of a change in quality. This is usually, but not always, a deterioration which can be restored by appropriate technical action. Such a condition is usually described as "lack of control". It should be particularly noted that control may have been lost at any time previous to the sample violating the limit lines and it can no longer be assumed that control exists for all samples falling within the limits. Further, the presence of a run of points within the limits after such violation is not evidence of the restoration of control *unless* suitable technical action has been taken.

This crude procedure illustrates the principles of statistical control but a successful application would require correct decisions in a number of subjective judgments. These include the size of sample, the summary measures and the positions of the limit lines. Statistical methods of analysis enable these decisions to be made objectively. They also show the effect of changing the sample size and the summary measure. Further, they are used to determine whether a set of data are self consistent in which case they will "look right". Finally they show the positions of the limit lines for any proposed risk.

The most common statistical analysis uses the average and range of samples of four or five items as the summary measures. Since each sample gives a set of summary measures, we ultimately obtain a series of averages and a series of ranges. We expect that each series arises from constant technical conditions and, if this is so, each series will be self consistent. This can be tested by statistical theory.

The distribution of ranges in samples of constant size is determined completely by the average range so that if the average range is computed, it is easy to see whether any individual range in the same set of data is consistent with the known average. It is usual to accept all ranges which are smaller than the limiting value which arise by chance only once in 1000 samples and reject any higher ones as having occurred when technical control had not been maintained.

The distribution of sample averages depends on the grand average and also on the variation within the samples.

The latter quantity is determined by the average range and then again it is easy to decide whether each individual average is consistent with the data as a whole. In this case it is also usual to accept all averages which are closer to the grand average than the limiting values which would arise by chance only once in 1000 samples and reject all more extreme averages as having occurred when technical control had not been maintained.

The one in 1000 chance corresponds to much British practice although some workers use other probability levels. My own personal preference is a one in 200 chance for most applications. American practice differs somewhat in using a criterion based on the variation in the theoretical distribution of the summary measure. They use a three-sigma limit which is substantially the same as that used in Britain for dealing with averages or any symmetrical distribution but it differs substantially for unsymmetrical distributions.

It can be seen that this formal method assumes that all normal variation in averages occurs through the variation within the samples and that no further variation should occur from sample to sample. This conflicts with the crude procedure used to illustrate the principles. The latter poses the question "does the pattern of the averages look right without any reference to any other source of variation?" In many cases, the answer is "yes" even though examination by the formal method would show that the variation among the averages cannot be explained by the variation within the samples. The two different methods of approach give differing results and both of them cannot be correct. Failure to reconcile the answers has led to many difficulties in the use of quality control methods so much so that many people believe they are useless in their particular industry.

More sophisicated methods of analysis provide the reconciliation. They divide the total variation into two parts; the first is contributed by the variation within the samples and the second by the variation from sample to sample. A physical interpretation can then be given to these two contributions and usually both will exist in a process and will continue to exist unless some technical innovation takes place to reduce the second to zero. The variation within the samples is due mainly to the lack of complete repeatability of the machine. This is always accepted as being inevitable and it produce the differing ranges observed within the samples.

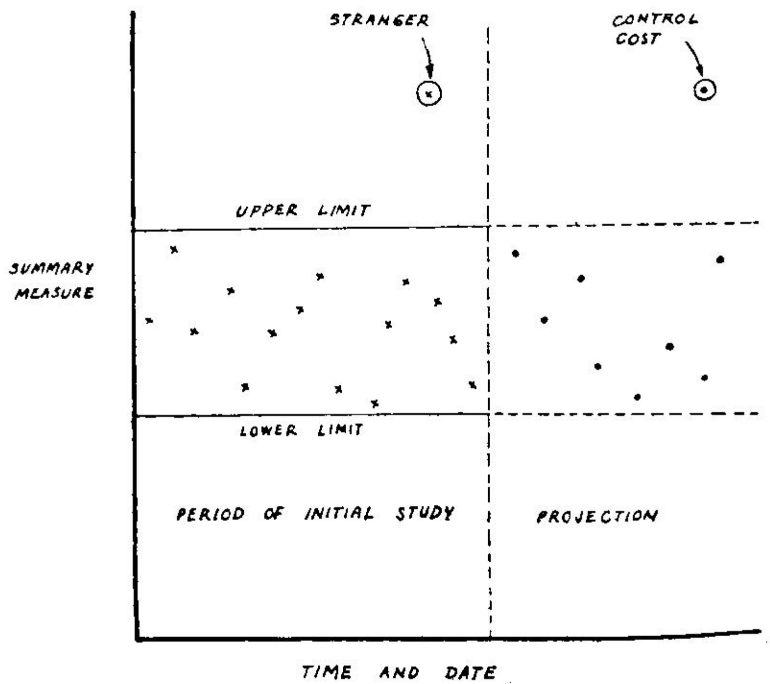
Variation from sample to sample will include the variation within the samples but any variation caused by the material or the operative will be superimposed on it. Ideally the operative will adjust the working conditions so that he will balance exactly the variation imposed by the material but he would have to make such adjustment *before* working on the material. This is impossible so that variation due to material is just as inherent in the process as the acceptable variation due to the machine. However, the magnitude of this variation can be controlled by ensuring that all sample averages fall within limits computed from the more sophisicated analysis carried out on the initial study results.

Statistical techniques such as analysis of variance and regression analysis certainly form a part of quality control. They enable the total variation to be divided into technical "components" each of which is due to its own basic cause. They can also be used to show how much of the variation in one process will affect a succeeding process. By such means they provide a guide to the technologist and process planner in the development of better methods.

Although these techniques require more elaborate analyses than those used with the normal interpretation of control charts, they ultimately produce a control chart which has the same appearance as the charts computed in the simpler manner. However, the limits will be in different positions and, if they are accepted by shop floor personnel, the implications of control will be exactly the same.

The result of all these preliminary analysis is the evaluation of a Quality Standard for the process. A more reliable standard is obtained by the more elaborate analysis but on some occasions the increased reliability does not justify the increased work. Every case must be considered on its own merits.

The quality standard is determined solely from the process and represents the best quality which can be achieved by the process. This quality must then be compared against the customer's requirements and if it will satisfy them, continual control at this level will suffice. However, if the quality standard is inadequate, the current processes must produce some rejects. These may be removed by complete inspection but it is preferable to develop better processes so that customer requirements will be satisfied merely by proper control during manufacture. The investigations leading to these developments will be of a technical nature but statistical analysis of the results is vital to avoid misleading inferences. If the whole investigation is planned with this in mind, then considerable reductions in experimental effort will be achieved. This is the way quality control helps the technologist to produce better quality.



SQC: Some Observations

Ellis R. Ott*

There are different techniques, some statistical and some non-statistical, which have been combined with a system of thought to provide the basis for a new industrial science or methodology called Statistical Quality Control. Techniques which are accepted as basic to the practice of Quality Control include: (a) Shewhart control charts, (b) acceptance sampling plans, (c) design of experiments applicable in all stages of product design and manufacture, as well as in reserach and development, (d) regression and correlation techniques. India was the first nation to request and host a United Nations Technical Assistance Administration Team on Statistical Quality Control (1952). Subsequently, India has steadily developed the variation and effectiveness of these methods and principles. It has been my privilege to remain associated with this programme of development and also to be host to five Indian SQC practitioners studying both theory and application at Rutgers University in the USA.

The development of SQC requires a two cycle advance, alternating between efforts to interest management, and efforts to provide professional practitioners who can produce results for them. The development of management's interest will continue to warrant attention ; similarly, we must develop more and more SQC practitioners competent to apply the science effectively.

Statistical Quality Control is a scientific method of indicating important differences in manufacturing plants: differences, which are often missed by standard methods. SQC cooperates with technical and management personnel to locate and remedy the causes of avoidable imperfections. Although based in part on theory, statistical and mathematical principles, the industrial applications are effected with simple methods which can and must be understood and applied by plant management.

There are several advantages which SQC has to offer: these differ from plant to plant. One plant, for example, has applied it to eliminate bottlenecks caused by inspection ; another to reduce rework ; a third to minimize scrap ; a fourth to improve the product quality to meet desired standards ; another to reduce machine downtime ; another to increase productivity while using the same machines and materials ; another to provide assurance of product quality. In all these cases it may be noted that the underlying purpose is to operate the plant processes more economically by saving materials and time, by increasing productivity, and by producing quality products.

How are these advantages to be realized ? Only by developing within a plant an organization concerned with these objectives, and the development would be faster and more effective if assisted by a competent, experienced SQC practitioner. The plant organization must develop routine methods of making inspection data and control charts data available to appropriate production foremen. It can also supply a specialized

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SQC "trouble-shooting" group. The SQC practitioner begins a programme within a plant, with management's initiative or approval, by giving various types of training in the basic concepts and methods of Quality Control to plant personnel. Some of these training sessions will be only for an hour ; others will be longer. The SQC practitioner is useful to the plant in so far as he can help organize its own quality system and help improve specific plant problems.

The successful SQC practitioner will team with the technical expert both to cure the trouble as well as to locate its source. Sometimes this is possible by an analysis and interpretation of data in hand, but it will usually require the design of a practical study, involving perhaps the use of sampling techniques, to identify the nature of the assignable causes. These techniques should be included in quality control training at least in the advanced phase ; their analysis can be introduced as extensions of control charts.

Control Charts This is a simple chart characterized by three horizontal lines, a central line to indicate a standard, and an upper and/or lower line to indicate control limits, determined on the basis of simple probability concepts. By plotting results from small samples taken periodically at frequent, regular intervals, it is easy to watch the chart for indications of gradual or abrupt shifts in the level of performance or in its variability. Thus control charts are important both to prevent or reduce the manufacture of sub-standard product, and to indicate unsuspected traits of the process. Such indications have been the signal to instigate investigations of the process in many industries—ranging from chemical plants to textile mills, to foundries, to machine shops, to steel mills. There is always variation in a process, no matter how well devised in theory or how modern the equipment ; the control limits are a simple basis for deciding whether the variation between samples may be attributed to those differences of material, temperature, or other small changes which are inherent in the process, or whether the variation indicates some major source of disturbance which warrants an investigation by an engineer, chemist, or production supervisor. When a sample point falls outside the lines, we investigate for sources of assignable cause ; when a sample point falls inside, we are well advised to make no adjustment on the process because such adjustments introduce variation. The control charts are also a means of indicating what the process is capable of producing, both the average level of the process and its inherent variability. Thus, control charts constitute powerful tools which provide management with logical bases for guiding and adjusting important processes.

Scientific acceptance plans In purchasing parts from an outside vendor ; in transferring sub-assemblies from one stage of assembly to another ; in checking on the effectiveness of a 100% inspection operation—in each of these it is common practice either to do no inspection or go to the other extreme of 100% inspection. Let us confine our discussion to quality characteristics of an attribute character rather than a variable measurement. For example, a glass bottle has a nick in it or it does not ; an electric lamp will light or it will not ; there are many quality characteristics of this nature where measurements are impossible or impractical. (It is certainly not sensible to do 100% test when the test is destructive.) Individual items in a shipment or a lot of such items thus are defective or are non-defective depending on whether they possess a certain characteristic. Even when 100% inspection is possible, it may be very uneconomical unless a large percent of the product has the undesirable characteristic. Thus it is often appropriate to use lot-by-lot sampling inspection. Such a sampling plan might be :—if the number of items in a lot is more than 1000 but less than 1800 select at random a sample of $n=75$ items. If more than some designated number such as $c=1$ of defective items are observed in the sample, then reject the entire lot and return it for 100% inspection or other appropriate action.

There are complete acceptance sampling table which have been prepared and published. Those prepared by H.F. Dodge and H.G. Roming, formerly of the Bell Telephone Laboratories, USA, have had very wide use by industries in many countries with major usage beginning about 1944. The tables have been designed very carefully with different percents as the accepted basis for decision ; :n the quality is very good, the lots are ually accepted without the expense in y and time to do 100% inspection. hen the quality is very bad, the entire lots rejected without other evidence. When quality is borderline, some "good" lots ll be returned for inspection, and some 'undesirable" lots will be accepted. On average, the established percent of ndesirable units will be maintained at a ubstantial saving over 100% inspection. urthermore, detailed information is recorded on these samples, and is the basis for mation to feed-back to manufacturing as to improve the quality of subsequent

Process Control There are many nciples and other techniques which are ng used to aid the engineering and production people to improve the quality of duct during production itself. These itute the methods of process quality trol which are considered by some to be onymous with SQC. We prefer to ide modifications of these techniques help identify the sources of difficulty or provement whose existence is indicated control charts and acceptance sampling ans. A specific example will illustrate the nciples, although the variations and fications in industry usage are legion.

Quality Control or a redesign of the ?

The design of experiments and production dies have often been described with nples from agriculture and the chemical ustries. It is often advantageous to use y of the same concepts in the electrical, ronic, and mechanical fields. The lowing example represents a small production study which was carried out three times in three days.

A particular electrical-assembly was well-designed in the sense that the performance of those units which passed the final electrical test was very satisfactory. However, there were more rejects than was considered tolerable and the possible need of an engineering redesign was being considered.

There is no question but that there are many engineering ways of improving the design of almost any product and it is often an appropriate approach to manufacturing problems: perhaps a redesign of certain components, a change of materials, or other redesign. However, there is an alternative method, too frequently ignored or overlooked which is to determine whether the components, the assembly operators, and the existing facilities *are being utilized to their maximum effectiveness.*

In the assembly operations where there are many stages and miscellaneous routing of parts, it is not unusual to come across some operations or machines or other similar factors that are sources of the assignable causes of trouble. If these could be discovered and eliminated substantial improvements are possible. Suitably designed experiments are an invaluable aid in this trouble shooting. It is not difficult to design an experiment to include all the possible factors for study ; but in practice, it is preferable to study not more than two or three factors at a time. This would enable the experiments to be carried out quickly according to the design without too much difficulty.

The electrical assembly in question consisted of four operations and there are inspections of the assembled product. These will be designated as A, B, C, D and E. Two operations, A and C, were chosen for detailed study in this case. There were four operators at A each with his own particular machine designated A_1, A_2, A_3 and A_4. All the four operator-machine combinations were included in this study.* There were three assemblers at operation C performing a hand operation. The performance of all the three assemblers were also sought to be studied. The three assemblers will be designated C_1, C_2 and C_3. If each of the four A's would be associated with each of the three C's then there would be $4 \times 3 = 12$ combinations.

The following experiment was carried out. 480 components were chosen at random from a common source and divided into 12 samples of 40 each. Each sample was put in a separate tray and routed through the assembly line in such a way that the 12 samples between them covered each of 12 planned combinations. Attached to each tray was a routing card. For example, the routing card of tray 1 would be as follows (fig. 1).

Routing Card—Tray 1

Operation	*Position*
A	A_1
B	Mech B†
C	C1
D	OP D†
E	Ins S†
No of units inspected	40
No of rejects found	0

Date : 4/9 S

Sd/-Inspector.

Fig. 1

Of the 40 units assembled and inspected from tray 1, that is from the units prepared by A_1 and C_1, there were no rejects. The results of each of the 12 combinations are presented in fig. 2. There were 14 rejects from the 40 units prepared by A_2 and C_2, 7 rejects from the 40 units prepared by and C, and so on.

	A_1	A_2	A_3	A_4	Total
C_1	0	1	7	3	11
C_2	2	14	8	5	29
C_3	1	5	2	6	14
	3	20	17	14	D=

Fig. 2

120 items of each of A_1, A_2, A_3 and have been examined ; of these 40 each ha been produced by the three C s . In o words the performance of A_1, A_2 etc. ha been obtained after adjusting for t differences if any, among the C s. Similar the performance of the C s have been obtai after adjusting for the differences among A Therefore the rejection percent of the thr C s and the four A s are comparable themselves.

The total rejects from $C_1 = 11$, so $\bar{C}_1$ $11/160 = 0.07$ similarly $\bar{C}_2 = 0.18$, $C_3 = 0.0$ and $\bar{A}_1 = 0.025$, $\bar{A}_2 = 0.17$, $\bar{A}_3 = 0.14$ $\bar{A}_4 — 0.12$. Could the observed differen arise due to fluctuations of sampli Apparently C_2 produced more rejects tl C_1 and C_3, and A_1 produced the rejects of the four operator machine combi tions. The differences appear quite la and no further analysis may be need Since, however, not all test results are self evident, a general method of analysis n be adopted as follows.

The best estimate of overall propor of rejects produced is given by

$$\bar{p} = \frac{\text{Total Rejects}}{\text{Total assembled}} = \frac{54}{480} = 0.112$$

If the sample proportion be denoted P its standard deviation αp is given

$$\alpha p = \sqrt{\frac{\bar{p}\ (1-\bar{p})}{N}} = \sqrt{\frac{(0.112)(0.8}{N}}$$

Where $N = 3 \times 40 = 120$ when compa the As

* As this was an exploratory study it was felt that the difficulties of interchanging operators and machines would not be commensurate with the possible advantages. If, say, one particular combination was found to give excessive rejections the data would not tell us whether it was due to the operator or the machine, but the technical expert would have to begin his corrective analysis. That was why the operators and the machines were, to use a statistical jargon, confounded deliberately.

† Same for all 12 trays.

and $N=4\times 40=160$ when comparing Cs

If we were to have a control chart for the control limits would be given by

$$\bar{p} \pm h_{\alpha}\, \sigma p$$

Where α denotes the level of significance. ı control charts of this nature it is usual draw the control limits such that, if there ·e no real difference, not more than 5 or of the observations will exceed the limits. ;e are called 5% (or 0.05) and 1% · 0.01) levels of significance. Thus there so little likelihood of an observation falling the control limits that, when it does ır, it pays to assume existence of the ˙gnable causes and hunt for the same.

The factor h_{α} depends on the level of ;nificance as well as the number of means) to be compared and are given in the ble below

Table : Values of h α*

(Standard to be computed from data)

k	h_{05}	h_{01}	k	h_{05}	h_{01}
	1.39	1.82	10	2.66	3.12
	1.93	2.39	15	2.83	3.29
	2.15	2.62	20	2.95	3.39
	2.29	2.76	30	3.09	3.53
6	2.40	2.87	40	3.19	3.62
8	2.56	3.02	60	3.31	3.73

Halperins (ct al) statistic for df=α ; see (2)
Modification of entries in t table with df=α

for comparing differences among A s $K=4$, $h_{05}=2.15$, $h_{01}+2.62$ so the control limits are

$\bar{p}\pm h_{05}\ \sigma p=0.112+0.062$ or 0.174 and 0.050 ;

$\bar{p}\pm h_{01}\ \sigma p=0.112=0.076$ or 0.188 and 0.036

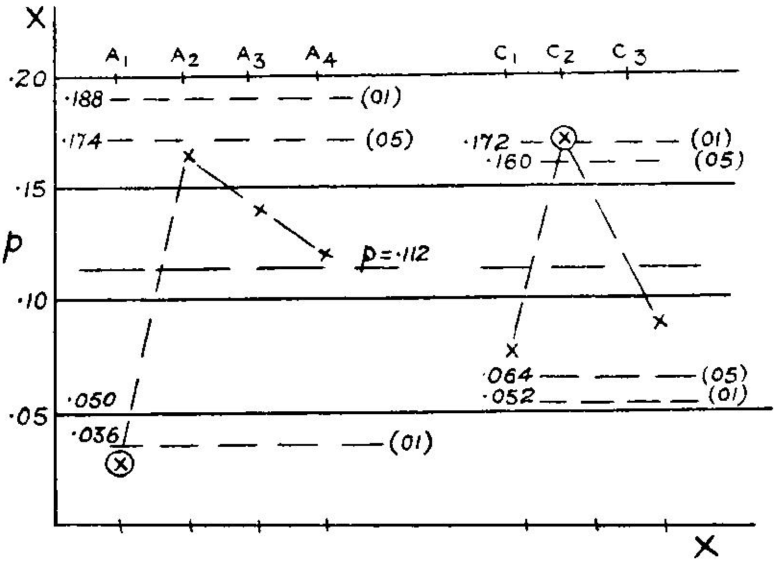
For comparing differences among C s $k=3$, $h_{05}=1.93$, $p_{10}=2.39$, so the control limits are

$\bar{p}=h_{05}.\ \sigma p=0.112\pm 0.048$ or 0.160 and 0.064

$p+h_{05}.\ \sigma p=0.112\pm 0.060$ or 0.172 and 0.052

The control chart with the two sets of control limits is given here.

Any point which falls outside the decision line is classified as being significantly different ; that is, the difference is not explained by the small variations inherent in the system. The risks associated with this decision have been selected at the .05 and .01 levels. Thus, since the point corresponding to A_1 is below the (01) line, there is less than one-chance-in-a-hundred that the



sample data are attributable to chance causes: i.e., it is important to study the machine-operator combination A_1 to find the reasons for the excellent performance.

Similarly, the point corresponding to C_2 is above the (01) line and its performance offers an opportunity for improvement.

There are other ways of considering these data, but this was the one actually used. This type of analysis has several advantages ; in this case it showed that the differences were of practical significance as well as statistical significance. On the basis of differences indicated by this study, certain adjustments were recommended by engineering and manufacturing. Then the 12-tray study was repeated the following day, and additional clues obtained and improvements made. On the subsequent day, the study was repeated with the following results.

	A_1	A_2	A_3	A_4	Σ
C_1	0	0	0	1	1
C_2	0	0	3	1	4
C_3	0	0	0	1	1
Σ	0	0	3	3	D=6

This new $P=6/480=.012$ compares the original $\bar{p}=.112$ which had led considering an expensive redesign to redu rejects.

The improvement was based u changes made by the management in study ing reasons for the differences indicated b this study. It is clear that a redesign was no necessary.

The particular results of this study unimportant: it has been included to stre the importance of simple production stud and to illustrate this useful method o analysis.

IN A MINUTE, YOU'LL HAVE THE KING DIVING

An American millionaire (from Taxas, no doubt) sat next to the Royal Box at the Henley Regatta. The people in the Royal Box were throwing pennies into the Thames, for which small boys dived. The millionaire started throwing twenty-dollar gold pieces. An English friend grabbed him and shouted, "Don't, don't! In a minute you'll have the King diving!"

SQC : Operations Research

LLOYD A. KNOWLER *

One of the important scientific techniques available for Productivity and Management is Statistical Quality Control: Operations Research. It is often defined as the use of probability and statistics in the manufacture of a *useable* product or the rendering of a *useful* service at the least cost with due regard to the conservation of materials. Emphasis is upon the words *useable* and *useful*. The objective is to have the *least cost* for the items and the services which can be *used*.

STATISTICAL QUALITY CONTROL: OPERATIONS Research is helpful in research and development, design and specifications, acceptance of materials, inventory of raw materials, inspection, maintaining quality of outgoing materials, inventory of manufactured materials, distribution and sales, determining consumer reaction, which in turn affects research and development.

In Statistical Quality Control, Operations Research, emphasis is placed upon *production*. Efforts are made to maintain the process (men, machines, and materials) so that the manufactured product is made of satisfactory quality. It is realized that sorting, sometimes called 100 percent inspection or even 200 percent or 300 percent inspection, is not effective. Furthermore, in a sorting operation a considerable loss of material often results in addition to the loss of machine time and the waste of power. That is, Statistical Quality Control, Operations Research places the emphasis upon *making the product right in the first place*.

The usual statistical techniques used in production are: control charts, acceptance sampling, design of experiments and statistical inference. These techniques are not mutually exclusive. The use of control charts on the process, placed on the machine accessible to the supervisor or overseer and within view of the worker, is proving to be very effective in numerous manufacturing operations. The supervisor or overseer makes use of the control chart to observe whether or not the process is consistent, in control. If the process is erratic or chaotic, as easily determined

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* Chairman of the Department of Mathematics and Astronomy, State University of Iowa. The author has served in a consulting capacity in connection with actuarial and quality control programmes of several industrial organizations, educational institutions and governmental agencies. He has served as co-director of each of the 16 intensive courses in Quality Control by Statistical Methods: Operations Research at the State University of Iowa; as a member of the staff on similar courses at the University of California at Los Angeles, University of Colorado, University of Illinois, Northwestern University, Purdue University, and Chicago Association of Commerce and Industry. He is one of the official representatives who organized the American Society for Quality Control.

by the control chart, then the technician (including the supervisor or overseer) can take corrective *action* when he has the greatest chance of success. What is also important is that the worker can *and does* observe the control chart to help him with the operation at hand.

The use of a control chart in snap readings with respect to maximum utilization of machines is effective. It is *possible to isolate the machines which are working at low efficiency.* The technical staff can make maximum use of their time and efforts by concentration upon these machines of low efficiency to get them operating at a higher level. A similar procedure can be used to select the workers who are doing a good job.

The results of the use of control charts are very useful to *determine the machine capabilities,* needed by the engineer in design and in setting specifications; also, for planning the flow of work so as to use the appropriate machine to produce a product at the most economical level. The machine capabilities can be useful to the purchasing agent and often to the sales staff.

It is important to keep the machine running to make a useable product. It may be desirable to engage some extra workers to achieve this objective—perhaps a "stand by" crew to be on call or a "roving patrol" to be used where and as needed; it may also be desirable to shift some personnel through the elimination of unnecessary operations which slow down the work of the machines.

The control chart gives evidence of the optimum life of a setting or a tool. It is frequently reported that the life of a tool has been extended by 20 to 40 percent by means of a trend chart; also, that the time between overhaul has been increased thereby reducing the portion of down time. A control chart on the process gives an immediate feedback—a most desirable feature.

Once a satisfactory quality level has been obtained it is important to *maintain* the economical level. That is, statistical quality control: operations research is a *continuous procedure.* Good quality does not remain indefinitely; it must be maintained and when economical, it should be improved.

Control charts are quite useful in connection with short runs and in job shops. In fact, one chart on a process with one person at a single machine with variable material is equivalent to a one-man factory whether it be in a large organization in an industrial centre or in a small cottage industry. The percentage improvement, not rupee value, may very well be higher in a small factory than in a large one. The application of statistical methods upon which to base decisions appears to be universal.

It appears that Statistical Quality Control: Operations Research is growing in India. Management, supervisory staff, and workers find that it is beneficial to each of them. It may be in order to report that on February 16, 1946, seventeen official representatives met in New York, USA, and formed the American Society for Quality Control. Fifteen years later this Society has about twelve thousand members from virtually every kind of business and industry—public and private—in the United States. This represents one of the most spectacular growths, if not the most spectacular one, which has ever been enjoyed by a professional society.

The results of several studies support the hypothesis that as quality improves the production of useable products increases.

The use of probability and statistics

are most useful, if not necessary, in those factories which have variation in raw materials, variation among machines, and variation among men. The greater the variation the greater the need for Statistical Quality Control: Operations Research.

In order to have the most effective use of Statistical Quality Control: Operations Research it is desirable to have a well trained and competent person in charge who reports directly to top management, who must take *appropriate* and *immediate* ACTION.

One of the most important things to any country, to any state, to any factory, to any person is *quality*. It has been stated that "Quality is Remembered Long After the Price is Forgotten". Its responsibility is that of *everybody*.

One of the primary aims of Statistical Quality Control: Operations Research is to manufacture a product or render a service to sell, not to sell a product or a service which might be manufactured or rendered. The objective is: TO PRODUCE TO SELL, NOT TO SELL TO PRODUCE.

IN TIME FOR THE RESURRECTION

Abe Lincoln, one of whose slogans was to have "anything for a laugh," once hired a horse from a liveryman who opposed him politically. The liveryman provided Lincoln with a slow horse, hoping that he would not reach his destination in time to deliver a scheduled speech. On the return journey Lincoln plotted revenge. Surrendering the horse, he blandly inquired if the liveryman reserved that particular animal for funerals. Assured that such was not the case, Lincoln continued, "Well, I'm glad of that! If you did, he'd never get a corpse to the grave in time for the Resurrection."

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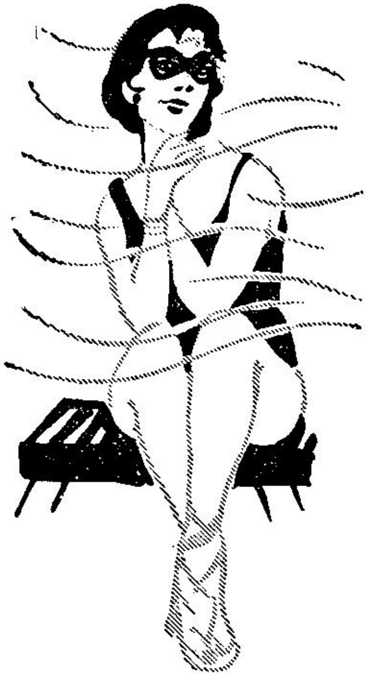

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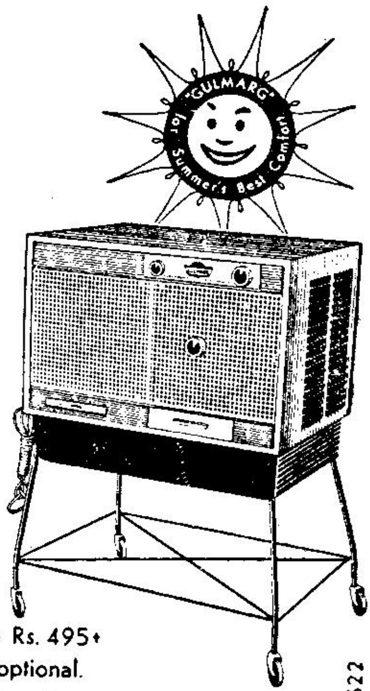

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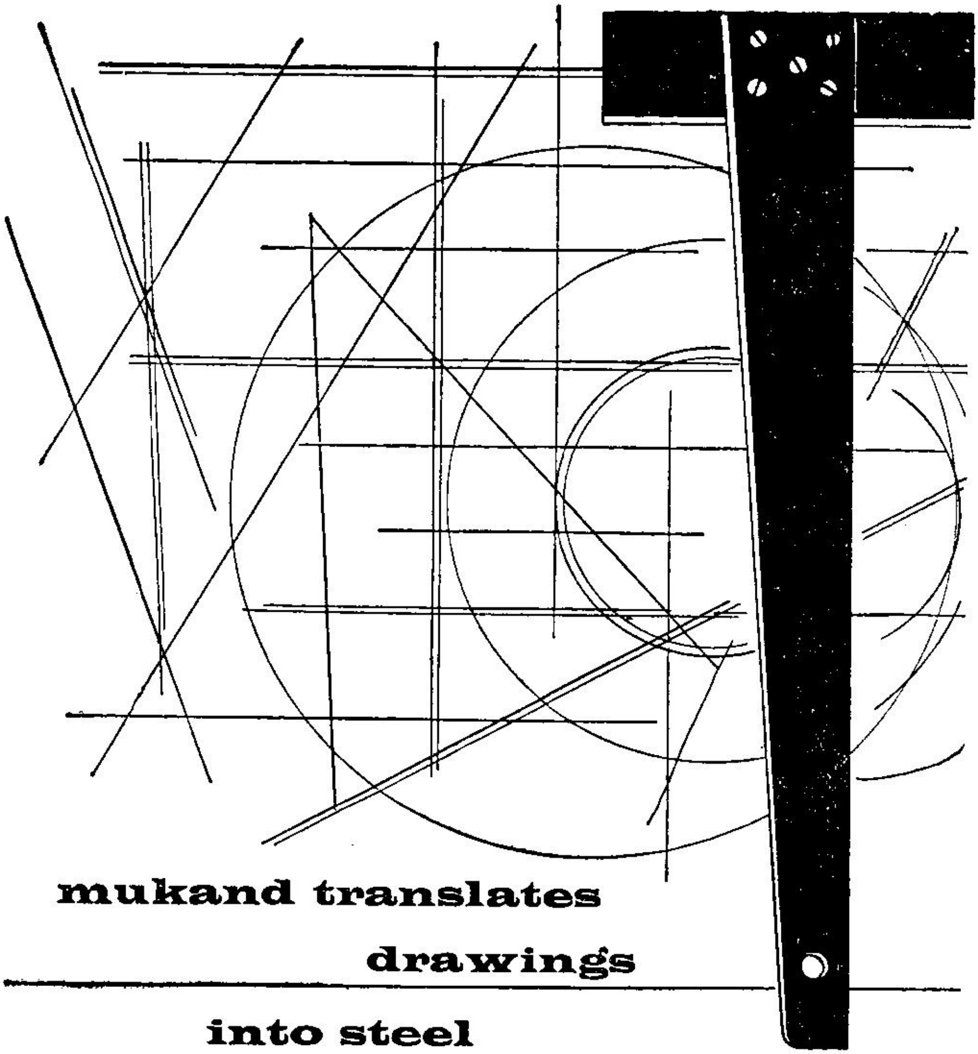

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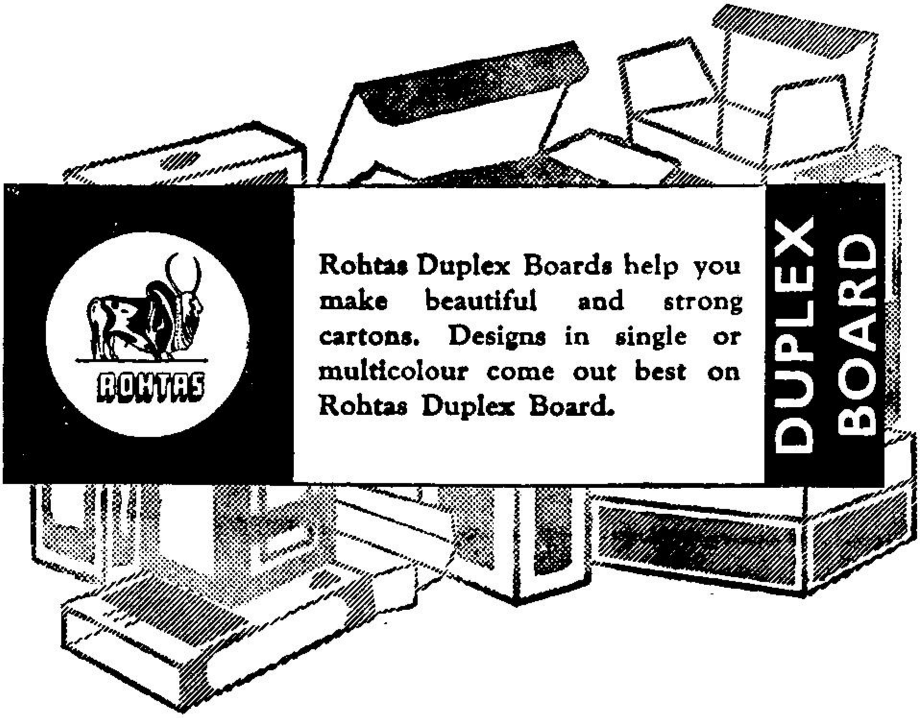

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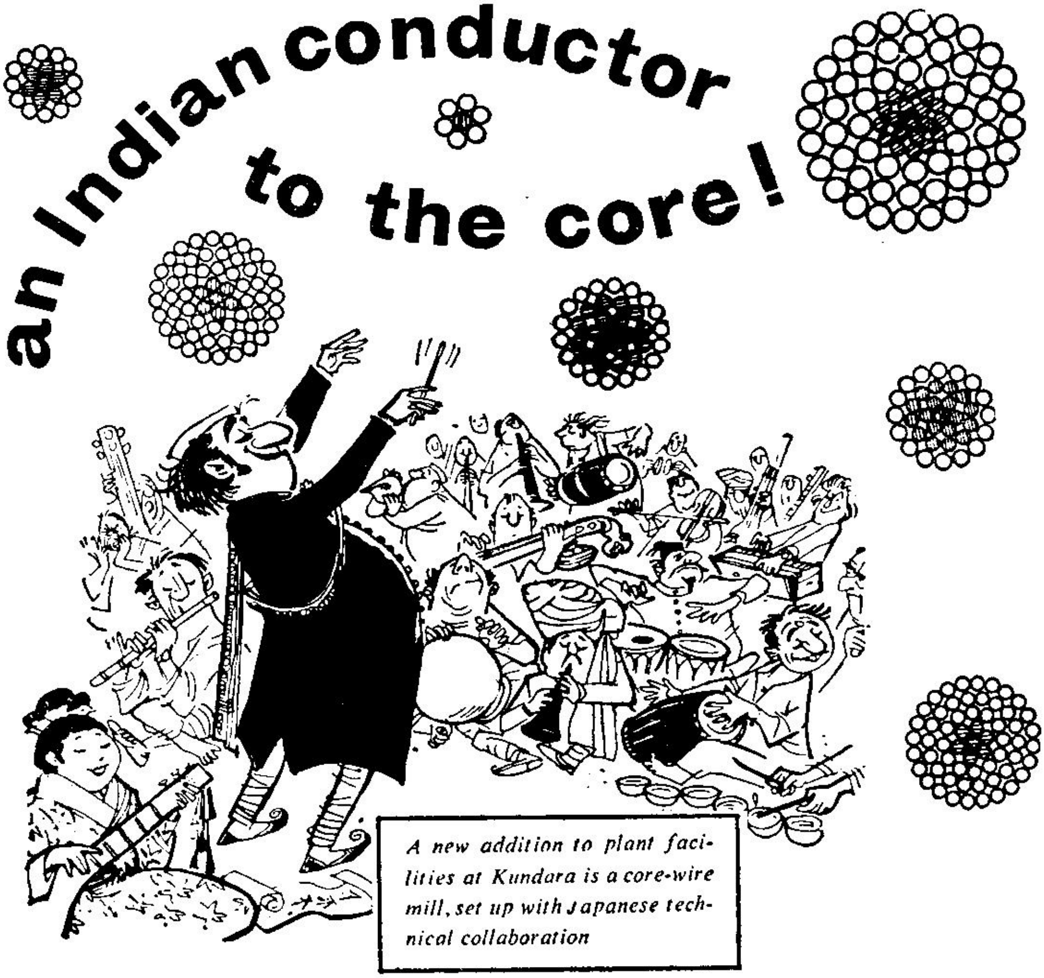

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SQC in Textiles*

Quality Control is not a fresh entrant into the field of cotton textile industry. Quality as well as its control have played a very prominent part in textile manufacture since ancient times. In fact, they have devised routine procedures for control by inspection not only of the final product but also during different stages of the processing of cotton, like control of lap weight and hank, and draw frame sliver, comber wastes, yarn quality, production and wastes as well as fabric quality over which 100 percent inspection is not uncommon. However, such controls are primarily based on standards evolved from experience rather than from any systematic scientific approach which becomes essential on account of the admittedly large inherent variability in the raw material itself and in the varied processes to which it is subjected before the fabric emerges ready for the market. For a rational control of such variability by evolution of proper standards, the use of statistics which may be called the science of variation, must be pressed into service, if the standards are to be realistic and conclusions from collected data are to be reliable. It is here that the modern system of SQC helps in a rationalisation of the entire system of control. The use of statistical principles aids in the evolution of proper standards of quality with tolerances scientifically obtained and in the maintenance of such standards from day to day, besides assisting in increasing productivity and reducing wastes, thus also reducing cost of production. While in most cases so far quality control is achieved by inspection and sorting the acceptable from unacceptable and re-processing the latter, if necessary, or finding alternative use therefor; the new approach attempts to build quality into the product itself, right from the raw material through all the processes and allied factors. As every stage of processing is optimally controlled by scientific methods there is an automatic assurance of the quality of the finished product which incidentally now demands least inspection. In this paper an attempt is made to explain how the different SQC techniques can be applied in the field of textiles. For this purpose it is necessary as a first step to evolve operational standards for each process (both for quality and production as well as wastes) or atleast for the processes that are strategically important in terms of quality and economy. Some of the results of the application of SQC techniques to cotton textiles have been so striking that we might as well start the exposition with telling figures.

IN ONE MILL FOR EXAMPLE THE APPLICATION of the mean-range control chart enabled the mill to reduce wheel changes in drawing from 103 to 12 per month. In another group, control chart assisted in bringing to light and correction of the rogue frames. Another interesting use of the control chart was in the bundling and packing section where it was profitably and in time applied to the date on the inventory turnover.

A technique of considerable importance frequently employed with profit-

* The Indian Statistical Institute has done very valuable work in the field both of cotton as also jute textiles. The studies printed from this page to 480 are published by the courtesy of the Institute.

able results is the snap survey. In simplified terms it refers to a series of snap pictures of a shed taken at random intervals in sufficiently large numbers so that the results integrated together give an average overall picture of the working of the section.

It is a quick and powerful means of bringing home the different causes responsible for production losses either due to material, machine or operative. Our experience is that a survey of this type conducted in any mill would yield quite surprising results. The figures of machine utilisation (alongside analysis of causes/stoppages) often come as a revelation and enable remedial action being taken. Surveys of a similar type in a loom shed have revealed how production losses are sustained by machine stoppages due to gaiting, beam shortage, weft shortage, weaver gone out, spare parts of stores not available, and breaks etc. An increase of 5—6 percent in efficiency by prompt measures consequent on snap surveys and the maintenance of these improved conditions is not uncommon. Snap surveys in spinning frames have given valuable information to the supervisory staff enabling them to take prompt action and bring down loss due to idle spindles, idle frames, ends down etc. Quoting from actual experience, bonda waste was reduced from 4.4 to 3.9 percent by the use of this technique and idle spindles from 2.2 to 0.8 per frame, thus increasing production. The snap technique is not necessarily confined to machine utilisation studies only. It can be applied to operative utilisation as well as for example, to estimate the proportion of time operatives actually work, to the proportion of time spent by them in performing different elements of work, to spot-light operatives below or above , to assess how the non-working portion of operatives' time is spent, so that thought may be given to reduce the same without increasing workload or fatigue.

designed experiment

While control charts are effectively used for the maintenance of standards of performance and snap surveys to secure reliable factual information in quick time at low cost, the most powerful method for evaluating optimum conditions of processes and for securing improvement in standards is designed experiments. Regular SQC work in a number of mills has clearly indicated that in the processes some factors are more critical than others in their influence on the performance of machines or quality of products or the productivity of the processes. For example the size of tensors or travellers, the break drafts used, roller settings, roving or yarn twists, pressure on rollers, type and size of aprons, type and condition of top rollers, are fairly critical factors that exert considerable influence on spinning performance qualitatively and quantitatively. Often the technologist is guided by past experience and his technical knowledge to aid him in fixing these factors. The actual conditions differ very much from mill to mill on the one hand and between theory and practice on the other that projection of a previous experience into a fresh one does not always prove fruitful. Sometimes the performance of a machine is suspected either because of age or other cause and management is confronted with the problem of deciding whether to replace it or continue with it. Sometimes it may be a simpler problem of purchasing a new type of bobbin or drafting equipment. In combing, for example, the optimum waste to be extracted or in spinning, the draft distribution either one frame or between two processes after a number of alternatives. Technology combined with experience readily rejects a good many alternatives but even amongst the final few the choice is still a matter of a trial and error only. It is here that planned experimentation proves a powerful ally to the technologist in giving a clear answer to the alternatives in quick time in a most economical manner. Statistics provides an efficient means of designing an experiment taking all the possible factors into consideration so that the best combination of the involved variables can be known for the optimum quality and productivity. Results of a statistically designed experiment not only recommends the optimum level but also provides us with a measure of the risk run by adopting the method. In a number of cases in different mills such experiments conducted on processing details have shown the necessity to make changes in the use of either tensors or travellers, break drafts, draft distribution, aprons etc. resulting in greater evenness of yarn or higher production or waste reduction etc. In many cases end-breaks have also been reduced with better yarn strength. Standardising winding tensions and speeds as well as loom speeds have been made by the use of this technique. This also enables fixing up optimum size percentages, temperatures and concentration of dying and finishing baths and the like.

quality assurance

In order to make quality assurance doubly sure at the point of despatch of the material to the consumer, tests are made on samples taken according to a systematised procedure so that the final assurance is obtained that the out-going quality conforms to expected specified levels. In many cases such investigations have also led to considerably economies. It provides answers to problems of the following nature:

(1) The average excess length given away to the consumer in each bundle or piece of cloth (2) The actual average count of a lot of yarn despatched (3) Average lea strength of the yarn at the despatch point (4) Visual defects per 100 yards of length of yarn or piece of cloth as it leaves the godowns (5) Mixing up of knots in bundles or different varieties of cloth in a bale (6) Percent of bundles or bales carrying wrong labels (7) Percent of defective cones in a box.

management applications of sqc

SQC does not confine itself to the production processes. Its sphere of influence and action is more comprehensive. In many important fields of management functions like inventory control, preventive maintenance, sales analysis, customer complaints, market research, cost control etc. a systematic method of measurement and analysis of relevant facts is provided by SQC approach. Statistical methodology helps to maintain inventory at an optimum level with minimum risks of hold up due to shortages or lock up of funds by over-stocking of goods. In the field of preventive maintenance, by providing a systematic analysis of data on frequency and causes of break-down, maintenance costs etc., it assists in reducing machine time lost and also in formulating a rational policy for machine replacement. Statistical analysis of data on sales reveals useful trends and assists management in taking decisions and in formulating plans of action for development. Analysis of customer complaints enables measures being taken to prevent their recurrence and thereby increase customer satisfaction. Consumer needs can be estimated and changes and trends in fashion and demands for different types of goods predicted by market surveys to enable planning of production programmes so as to capture future markets. SQC has also penetrated into administrative sections to standardise their outputs and efficiencies as well as quality. Even in regard to costing, the principle of natural variation has been introduced to discover significant, variations in costing.

Scope and Utility of SQC in Textiles

Textiles has been one of the few industries in which Statistical Quality Control has been applied extensively in India. It would not be wrong to say that SQC commenced its career in India with Textiles. Thanks to the pioneering efforts of ATIRA in this field and the successful applications made by the SQC units and the textile research organisations considerable experience has been built up during the last few years. As a consequence it has been possible to locate the strategic points where application of these techniques would yield maximum results.

THE FIRST STEP TO EFFECTIVELY ORGANISE SQC in a mill is to evaluate the current methods of processing, standards of quality and production. Such a survey which usually involves some or all of the following steps: helps to categorise specific procedures and methods so that in due course each one of them could be specifically looked into:

(1) Programme of mixing including mixing of wastes (2) Weights of laps and tolerances (3) Weights of lap rods (4) Card room practices, (5) Draw frame wrappings (6) Scrutiny of stop motions, (7) Checking up speeds in fly frames and ring frames (8) Wastes in all processes, (9) Checking of gears and wrapping practices (10) Production standards at each stage. Such surveys require only a few days for completion and it is a profitable practice to repeat it periodically, say once in six months or a year.

wrapping control

Statistical methodology helps in rationalising the entire wrapping procedure so that the method of sampling and the frequency of readings are properly defined, and even more important, the tolerance limits within which action should not be taken and beyond which action should promptly be taken, can be worked out scientifically. This is one of the principal aspects of SQC as against the existing practices of routine control in which there is a danger of wrong action or inaction. The lap weight tolerances should be worked out on the basis of process capability studies instead of on ad hoc basis and on the spinning quality required.

carding

While it is generally difficult to control wrapping in card room owing to inherent difficulties of variations in the conditions of working of the cards caused by stripping, grinding etc. it would be profitable to assess the working of every card on a cyclic basis to assure that each one of them functions up to given standards regarding sliver quality as well as wastes. It takes time to standardise card room procedure, but once done it could be strictly followed and cards checked up on a cyclic basis at the time of feeding a fresh lap. If the sliver quality deviates from standard, the cause can be found out and the cards set properly to yield standard values. Similarly with reference to waste control.

combing

Standardisation of wastes between combers and between different heads in a comber is of great importance. Tests for production as well as sliver quality like eveness and neps should be a standard practice.

drawing

Most of the mills have a practice of collecting 5 yd. wrappings from each of the deliveries of the finisher head of all the draw-frames, twice or thrice a shift. A pinion change is made on a frame whenever the average value of these wrappings taken from all its deliveries crosses some limits which are usually set at ±3 or ±4 grains from the standard. It appears that the guiding criterion in fixing these limits is the expected change that would occur when the pinion is changed by one tooth. The flaw in such a procedure for making pinion changes is that the inherent variability of the process is not taken into account in fixing the limits. This usually leads to undue pinion changes which, though well intended, lead to increased variation in the sliver. The modified form of $\bar{X}$-R charts, which allow for the pinion effect as well, have been found helpful in providing a rational basis for making pinion changes. These charts are so simple that the wrapping clerk could be easily trained to maintain them. An immediate effect of installing these charts is elimination of all unnecessary pinion changes and increased uniformity of sliver. To start with, it has been found sufficient to take one set of wrappings per shift. However, when the charts show that the draw-frames run for days together without any pinion changes, it becomes possible to cut down the frequency of wrappings and also only half of the deliveries need be wrapped (with corresponding change in the limits on the charts).

fly frames

It is now generally recognised that control over wrappings should either be exercised at the drawing stage or at the final stage in ring spinning. Once the speeds in fly frames are adjusted, it becomes unnecessary to collect any wrappings from the frames and to make pinion changes. It is therefore advisable to stop collecting wrappings from fly frames if that has not been done so far. Some mills however need the fly frame wrappings to calculate the production in lbs. from the hank. For this purpose, it is enough to use the expected wrapping weight as the standard for calculating production.

ring spinning

The ultimate aim of wrappings control at different stages is to maintain the counts spun at the desired standards. With a given mixing, to spin coarser count than the specified means loss of cotton and to spin finer does not add to the value of yarn spun. It is necessary therefore to have an efficient procedure for wrapping control at the spinning stage. A suitably designed statistical investigation into the sources of variation in lea-count helps answer a number of questions. To give an example: In a mill spinning 28s count, it was decided to determine the optimum number of wrappings and the control limits to satisfy the following conditions: (a) The average count spun should be 27.75 for the mixing in use. (b) If the count being spun is one count coarser or finer, the change should be detected once in two wrappings. The inherent variability—(σ) was 2.07 grains and a back-roller change shifted the average level by about 0.5 count. These conditions led to a sample size of 16 wrappings and control limits of ±1.2 grains around the standard of 26 grains for the average of 16 wrappings. The usual practice in the mill was to sample two bobbins from each frame in a group and this resulted in excessive wrappings where the group size was more than 8 and inadequate wrappings when it was less than 8. The limits used were ±0.5 count irrespective of the group size and this gave rise to a number of pinion changes in smaller groups in particular. The control charts on the averages of 16 wrappings with limits set as shown above showed immediate reduction in pinion changes and the overall count variation.

From results achieved in a project on reorganization of entire wrapping procedures, it was seen that substantial reduction was possible with respect to (i) number of pinion changes, (ii) number of wrappings and, (iii) work-load of the wrapping staff. All these could be achieved without affecting the yarn quality-in-fact, improving the long-term variation due to elimination of undue pinion changes.

waste control

Waste in a textile mill is usually classified in the following categories : (a) saleable waste comprising of the waste extracted in blow-rooms, carding and also the sweeping collected from the spinning department ; (b) soft or usable waste comprising of lap pieces, sliver pieces, bonda and comber-waste ; (c) hard-waste—waste in yarn form. For similarity in treatment, damages in cloth are also considered here as the fourth category of waste. The methods found useful in reducing each of the above types of waste are discussed below.

saleable waste

For a given mixing, the saleable waste is mainly made up of waste extracted in blow-room and carding. While ordinarily it is not possible to reduce the waste extracted in blow-room, considerable scope often exists for experimentation of carding. For instance, in a medium count mill, the initial survey showed that on a fairly large number of cards of a particular make, the flat speeds were as high as 4.8" per minute. Suitably planned statistical experiments showed that the flat-speed could be reduced to 2.25" per minute without affecting the percent trash in card sliver and the quality of yarn. This change brought about 1.2% reduction in flat-strips waste which meant nearly 1800 lbs reduction per month in saleable waste in a section of about 50 cards. Another profitable area for experimentation in carding is concerned with improving the efficiency of cleaning under the licker-in screen and the cylinder. Sometime the licker-in and/or cylinder fly waste is found to contain a fairly high proportion of white waste. In one mill about 20% of the cards of a particular manufacturer gave this trouble. Improvement was possible only after intensive experimental work was carried out to correct the existing licker-in screens and the settings which almost eliminated good cotton dropping with the fly waste. Finally, a routine procedure for examining four cards, preferably guaged on previous day, has been found quite useful in keeping a continuous watch on the carding performance. The cards are observed both for quantity and quality of waste and the amount of waste extracted under each category compared with control limits fixed on the basis of the variation possible when different laps are processed on the same card under the same setting.

comber waste

In combing, the usual practice is to remove 8 to 15%, the actual standard being fixed either by experience or by knowing the proportion of fibres in the mixing below a certain specified limit. The question is 'What happens if the waste extracted is about 1% less than the specified standard' ? The answer is never readily available and under such circumstances it has been found useful to carry out a series of experiments, preferably using the modern and simple concepts of evolutionery operation, to arrive at an optimum standard of waste extraction. In addition to the above experimental work, routine procedures are also established to detect head to head variation with regard to the waste extraction and also deterioration in the overall performance of combers from the desired standard of sliver quality and waste percentage. The control limits for this purpose are determined on the basis of a suitable statistical study conducted earlier. It should be of interest to the readers to note that when actual tests are conducted in almost all cases considerable variation in waste percentage is found between combers of same make and age processing same material, and between heads, even as much as 2%.

soft waste

In most of the mills, the problem of soft waste is considered minor mainly because it is normally re-used in mixing. From the point of view of quality however, reduction in soft waste is desirable as it has been shown that mixing soft waste into raw cotton adversely affects the quality of yarn spun.

The major portion of soft waste produced in a mill arises from bonda waste, roving ends, and the sliver pieces and lap pieces in combing. The incidence of these categories of waste is largely attributable to the operative's negligence and therefore presents a problem, mainly of a supervisory nature. Sometimes statistical studies have been used for locating ring frames and/or tenters giving high rates of bonda waste, if nothing else atleast to visually demonstrate to the operatives so that they may improve. Stricter supervison and operative training seems to be the best ways of reducing soft waste.

hard waste

The hard waste mainly comprises of the yarn left over on warp and weft bobbins in winding and weaving departments. The unsized yarn waste in the sizing department arising from unequal length of yarn on warpers' beams is also an important part of the hard waste. Both these types of waste could be reduced in many mills if systematic data were collected using simple statistical principles. For instance, in a mill where it was felt that the incidence of hard waste due to unsized yarn was high, simple collection of data was started on the length of yarn left over on each of the beams when a sizing set was completed. The data were collected for about 25 sets, clearly identifying the warping machines which produced the beams. It was found that the number of yards of unsized warp left over varied considerably from one beam to another on the set—the maximum being 130 yards. It was also found that the sizing operation was often stopped even before a single beam was exhausted. On the average, about 45 yards of warp were left over per beam per set. This simple investigation led to strategic inspection and correction of clock dials on the warping machines thus ensuring that the warpers produced beams with a fairly uniform length. Consequently, the unsized waste was reduced from about 45 yards warp to 24 yards per beam. In another mill, a simple cause-wise analysis of the weft returns from the weaving shed showed that nearly 26% of the pirns thrown out carried considerable usuable weft, and most of these were either full or half full. Further, nearly 45% of the rejected pirns were either badly built or had sloughed off during use. A subsequent study helped in locating the weft ring frames which were responsible for giving a high proportion of such defective pirns.

damage in cloth

Damages in cloth form the most serious type of waste in a textile mill. The overall present damages at the grey inspection stage shows the strategic importance of efficiency in the loomshed. It is possible to eliminate the defects such as weft cracks and to some extent undrawn ends and floats which arise due to weavers' negligence by adopting the snap reading technique. According to this technique the weaving supervisor goes round the loomshed as many times as possible and inspects about 10" to 12" of cloth visible on the loom to see if the defects are repaired by the weaver or not. The looms with unrepaired damages are noted down on a suitable data sheet and the weavers of these looms are asked to repair the damages on the spot. In a mill where this procedure was adopted, the weaving damages could be reduced by about 20% of its original value within a period of one month.

A peculiar type of hidden waste arises at the final cutting stage in some mills, due to the very method of cutting the cloth pieces. If the method of cutting and matching for 'two pieces' is not optimum from the point of view of the recovery of good pieces, the proportion of good pieces of a specified length recovered from a continuous stretch of cloth is less and in his anxiety to match the 'two pieces', the operative often ends up with a greater proportion of 'seconds and fents', It is found that the optimum method of cutting the cloth is to cut where the defect is noticed and the matching for two pieces should be done independently at the end of the day. In one mill where the method of cutting was modified in this way, the recovery of good pieces in one type of shirting cloth increased by 4%.

control

It has now become a fairly common practice in a textile mill to use the statistical technique of snap readings (work sampling) to assess the loss in machine utilisation. In spinning, the survey may cover the preparatory and the ring spinning sections simultaneously to bring to light any imbalance between different sections. It can help locating rogue frames behaving differently from others in idle spindles. On winding machines, the technique helps in judging if the existing allocation of spindles per winder is proper from the point of view of machine utilisation. However the snap survey should be used with care because when it comes to taking action. It is sometime found that no direct action is possible on any of the contributory causes due to inherent difficulties or other causes. For example, in normal mills, the loss in utilisation due to warp breaks is of the order of 8% and this usually is the most important contributory factor. As such an overall improvement is possible only if warp breaks are reduced and this can be done if the yarn supplied to the loom shed is improved. In this way one is led to experimentation with tension weights and guages in winding and with size percentage at the sizing stage. In one mill, it was found that increased tension weights at winding helped minimize the warp breaks in loomshed which in turn increased the efficiency of the set looms running on the particular sort. In others, rewinding of dyed cheeses under proper tension weights solved the problem of low efficiency on coloured sorts in the loomshed.

Another simple yet fruitful approach is that of statistically analysing the production records. For example, in one loomshed when data on 22 looms running on a particular sort, were analysed statistically, it was possible to classify the looms into three groups, namely good average and bad, depending upon their production performance. By suitable technical actions such as elimination of mechanical faults, reduction in slipage, training of weavers etc., it might be possible to increase the average production of looms to A category. This might well mean a sizeable increase in over-all output.

store and inventory control

A suitable inventory policy based on simple statistical principles is helpful in cutting down the stock level and simultaneously meeting the demand. To give an example: in one mill where a cyclic system of inventory control involving a safety stock and a target stock level was introduced, it was possible to cut down the average inventory held of eight important products having a procurement period of one month from about 20 to 64 percent of its original value.

organisation

The success of SQC in any plant, not excluding textiles, depends fundamentally on a proper organisation. *If SQC fails it is not the failure of the technique but the failure arising from inept organisation.* In a plant SQC section must be an independent one, assisting the production but not necessarily subordinate to it. Normally it is advisory in character and its duty is to prompty point out how the process functions and to intimate to the production personnel without loss of time when the process crosses the safety limit. It will then be the duty of the production personnel to take action without delay. It is also his duty not to interfere with the processes till the installed controlled system indicates the necessity for action. The so called intuition (which has its place in the scheme of things) cannot be a substitute for scientific processes. Effective organisation for reliable collection of vital data, their quick analysis and feed back of information followed by prompt action is essential. Otherwise SQC cannot produce results or yield profits. In this connection, the importance of taking people into confidence particularly the shift supervisors, jobbers and fitters in SQC work cannot be overemphasised.

"... between us (Mark Twain and Kipling) we cover all knowledge; he knows all that can be known, and I know the rest."

SQC in a South Indian Mill

AN INTENSIVE SQC PROGRAMME WAS UNDERTAKEN in a large South Indian mill under the guidance of SQC consultants. The first step was to train the supervisory staff after which an SQC section was organised in the mill. The overall benefits to the mill from this programme of quality control as assessed by the management are shown below.

department	quality characteristics	before	after
Blow Room	Lap rejection	10.0%	0.6%
	Yard to yard variation	3.0%	1.2%
Carding	Sliver weight variation (30s mix)	4.9%	1.6%
	Neps per 100 square inches (30s mix)	30.0	20.8
Drawing	Sliver weight variation	2.0%	1.1%
	Wheel changes	Once in 3 days	Once in a month
Spinning	Idle spindles (in the whole shed)	57	25
	Ends down	4.0%	1.8%
	Fieldon & Walker yarn unevenness (30s count)	20%	61%
Cone Winding	Cones meeting specification	20.8%	86.8%

Apart from the programme of routine quality control, several special studies which were undertaken helped to reduce the waste, increase yarn strength, improve yarn evenness and increase the overall production. Studies on the consumption of oil, packing materials, bobbins etc. showed how considerable savings could be achieved in these fields also by the application of SQC techniques.

In a large spinning mill, spinning medium counts, the following benefits were obtained from a programme of SQC

The Technical Director of a large composite cotton mill reported the following results, as a result of the application of SQC : (1) increase in spinning efficiency from 83 to 86% ; (2) reduction in bonda waste by 8% ; (3) reduction in idle spindles from 1.2 to 0.5% ; (4) increase in production by 3.3 lbs. per frame per shift (by eliminating frame differences) ; (5) reduction in the wheel charges at drawing from 103 to 12 per month. A similar result was also achieved in the case of spinning frames ; (6) reduction in the variation (C.V.%) of sliver hank from 2.2 to 0.9%.

	before	after
Lap rejection	8%	5%
Variation in weight per yard (C.V.%)	2.5%	1.4%
Waste in cards	4.4%	4.0%
Variation in weight of (2 yards) card sliver (C.V.%)	3.4	2.5
Variation in yarn count (C.V.%)	5.5	3.8
Variation in lea strength (C.V.%)	15.0	13.0
Uster Unevenness (%)	19.0	17.4
End Breaks per 100 spindle hours	50	37
Idle spindles per 1000	5.3	0.9
Ends down per frame	11.0	8.8
Production per spindle in ozs (per 8 hours)	5.4	6.3

A fine count cotton mill showed the following results

department	quality characteristics	before	after
Blow Room	Lap rejections	10%	3%
	Yard Variation (C.V.)	3.1%	1.6%
Carding	Variation in sliver weight (C.V. of 2 yard wrapping)	10.9%	4.6%
Spinning	Ends down per frame	18.0	11.3
	Bonda waste	4.2%	2.9%
	Idle spindles per frame	2.2	0.8
	Average production per spindle (per 8 hours)	1.26 oz.	1.35 oz.

A special experiment designed to study the optimum tension required at winding was very helpful in reducing the yarn breakages at winding as well as at the subsequent stages. Consequently the winding production went up by 16%, end breakages in warping (per 1000 yards per 400 ends) came down from 9.4 to 5.9, and the time for warping 1000 yards was reduced to 7/8 of the original figure. Further, the weaving efficiency also increased due to reduction in the number of missing ends in weavers beams. Special studies in cone winding helped to bring down the OHP by 20%.

individual processes

While the above gives a comprehensive view of results and benefits of SQC in a mill as a whole, some applications to individual processes are detailed below: (*a*) *Blow Room*: Process capability studies followed by appropriate action enabled a mill not only to reduce the lap weight tolerance from ± 16 ozs. to ±8 ozs., but also to reduce the lap rejections from 16.5 to 3.5%. Action taken on the basis of the study included (*a*) Adjustment of resting bar to make room for the free movement of pedals (*b*) Resetting of pedal motion (*c*) Resetting of the stripping rail (*d*) Air perforations in beater opener.

(*b*) *Cards*: Statistically designed experiments helped in the standardisation of card speeds and consequently reduced the card waste by as much as 1.3%. The financial benefit to the mill by this application was estimated at Rs. 60,000/- per annum. A planned study on the performance of the different makes of card enabled reallocation of cards to different mixes which resulted in reduction of waste in expensive foreign cotton from 5.5 to 4.0%. A study on the effect of using sliver compressors revealed that the unevenness was increased by as much as 1.5% in a 100s mixing. Further, when spun, the yarns gave a higher lea strength without compressor than with it. This drew the attention of the management to give a second thought to the programme of fitting compressors on all the cards in the mill. In a mill having ACS continuous stripping fitted to all the cards the stripping frequency was once a shift. Studies made to find the effect of extending the period between consecutive strippings enabled fixing the stripping frequency as once a shift for the doffer and once in three shifts for the cylinder. It is needless to say that such an action brought down the stripping waste on all the cards. Even in a mill where roller stripping was employed the stripping frequency was changed from 1½ hours to 2½ hours with a consequent reduction in the stripping waste obtained without affecting sliver or yarn quality.

(*c*) *Drawing*: An important function of the draw frame is to reduce sliver unevenness. Delivery differences were observed in a mill on a short term basis and traced to differences in the back material. To reduce this a rational scheme of feeding the cans at the back of drawing frames was worked out. According to this procedure six full cans are fed at the same time to a delivery. Thus one doff (6 cans) of the first head is fed to the first delivery of the second head at one time. On the next feed for the second head all the 6 cans of a doff are fed to the second delivery of the second head and so on. As a result of this change in the feeding system the value of average range of sliver weight for a wrapping came down from 11.0 to 9.0. The mill also reported an increase of 4% in the overall efficiency of the drawing frames.

(*d*) *Comber*: Statistically designed experiment conducted in a mill to evolve the optimum waste extraction in combing made it possible to bring down the waste extraction from 14 to 8% without any deterioration in the quality of yarn or the performance in the first combing stages of production. While the comber waste was reduced by as much as 6%, the CSP of yarn, the yarn evenness, neps and foreign matter in yarn and the variation in count and lea strength of yarn did not differ significantly for the two levels of waste extraction in combing.

(*e*) *Slubbing*: In one particular mill, study on end breakages in slubbing frames processing 20s mix showed that the average breakage rate was 38 for 100 spindle hours: rather a very high value judging by normal standards. An investigation into the causes and the places of occurrence of breakages was taken up. Analysis of data showed that nearly 60% of the breaks occurred at the funnel behind the back rollers. On a close examination it was found that the bore in the funnel was too narrow compared to the sliver material, thus causing breakages on a number of occasions. Modified funnels were fitted to a dozen spindles on a trial basis which completely eliminated this type of breakage. All the funnels of the frames were then modified suitably. This action resulted in bringing down the end breakage rate from 38 to 18 per 100 spindle hours. The result was an increase in frame production from 4.9 to 7.0 hours per shift.

(*f*) *Spinning*: A mill was confronted with the problem of poor performance of a group of spinning frames, compared to another group of different technical particulars processing the same back material which gave comparatively better results. A planned experiment was, therefore, conducted to arrive at the optimum operating conditions. Following a discussion with the technical staff, it was decided to take three factors into consideration as follows

1 break draft	D_1	:	1.22 (existing)
	D_2	:	1.47
2 tensors	T_1	:	No. 4
	T_2	:	No. 5 (existing)
3 dead roller weights	W_1	:	4¼ lbs.
	W_2	:	4¾ lbs.
	W_3	:	5¾ lbs. (existing)

The characteristics studied were count, strength, evenness and end breaks. Results of the experiment showed that the combination D_1 W_1 T_1 gave the best results. The table given below presents a comparison of the performance under existng and changed conditions of operation as regards break draft, tensors and dead roller weights.

	EXISTING		CHANGED	
	Break draft	1.22	Break draft	1.22
	Tensor Number	5	Tensor Number	4
	Dead roller weight	5¾ lbs.	Dead roller weight	4¼ lbs.
C.S.P.		1279		1442
End breaks per 100 spindle hours		113.1		30.6
Unevenness % (Fieldon & Walker)		23.3		19.1

Such designed experiments with actual mill operating conditions have yielded very positive results.

(*g*) *Winding*: In the winding section of a cotton mill processing cones for export it was found that only 20.8% of the cones met the specification regarding weight. Studies on operator differences and control charts for weight of cones helped to increase the percentage of satisfactory cones to 86.8%.

An example of how even a simple, well conducted experiment in a mill can yield very beneficial results is illustrated here. This is a case of determining the desirable tension weights in winding. Since the breaks at winding were numerous and the winding efficiency was low something had to be done. After some preliminary observations it was decided to compare the performance of existing weight of 554 grains against a lower weight of 474 grains. The results are given in the table below :

	TENSION WEIGHT	
	existing 554 grains	modified 474 grains
End breaks in winding (per 100 bobbin changes)	36	25.4
C.S.P. of yarn after winding	1437	1474
End breaks in warping (per 2000 yards)	13.5	10.6
Warping efficiency (%)	71.1	76.6

While the low tension has naturally reduced end breaks in winding, contrary to expectations, the breaks in warping have also been reduced and the warping efficiency increased by 5.5%.

(*h*) *Weaving*: The loom shed is a fruitful place for the successful use of snap survey technique in increasing loom utilisation and shed efficiency and reducing fabric defects. In one loom shed which had a low efficiency of 44.2% it was raised up to 79.5%. The results of the survey picked out the troublesome looms in which either the shuttle change or the weft fork or other mechanisms were not functioning properly. Action taken following this study resulted in an increase in production of 12.1 yards per loom per shift.

In the case of loom shed working with plain looms (4 looms per weaver) such surveys helped in reducing the loom stoppages from 15.7 to 10.2% in the course of one month and after three months the loom stoppage was stabilised and held in control at 8.4%. As a result the shed efficiency rose from 83.2 to 90.4%. Further the looms running with defects in cloth came down from 6.3 to 2.4%.

Another instance of the useful results of a SQC programme in a weaving establishment is given below

department	quality characteristics	before	after
Winding	End breaks per 100 bobbin changes	29.0	17.7
Warping	End breaks per 1000 yards	14.6	8.0
	Warping efficiency	55.8%	68.3%
Loom shed	Production in yards per shift	1073	2134
	Looms weaving defective cloth	62.0%	2.6%

(*i*) *Cutting piece lengths*: Analysis of data on piece lengths of 4 yard dhoties showed that on an average for each dhoti as much as 7 inches of cloth was given away in excess of the specified length. An analysis of the distribution of the length indicated the possibility of reducing the average excess length to 3 inches without a single dhoti being less than 4 yards.

(*j*) *Accessories*: Analysis of data on life of roller coverings gave a rather low value of only 78 shifts. Cause-wise analysis indicated groove formation as a major cause for roller casualty. An investigation traced it to the poor condition of the flannel layer beneath the leather covering. Action taken in this regard gave the roller coverings a longer life. A study on the life of shuttles revealed that it varied from 0 to 1200 shifts with an average of 376 shifts. The results of the study enabled the management to standardise their purchase policy with an assured longer life for the shuttles and better performance of the loom shed.

"Never handle firearms carelessly. The sorrow and suffering that have been caused through the innocent but heedless handling of fire-arms by the young! Only four days ago, right in the next farm-house to the one where I'm spending the summer, a grandmother, old and grey and sweet, one of the loveliest spirits in the land, was sitting at her work, when her grandson crept in and got down an old, battered, rusty gun which had not been touched for many years and was supposed not to be loaded, and pointed it right at her, laughing and threatening to shoot. In her fright she ran screaming and pleading toward the door on the other side of the room; but as she passed him he placed the gun almost against her very breast and pulled the trigger! He had supposed it was not loaded. And he was right—it wasn't...'"

(Mark Twain)

Diagnostic Survey of Coimbatore Cotton Mills

RATNAM, RAMAKRISHANAN AND RANGANATHAN

In the textile industry the introduction of SQC presents certain problems, the main one being the high variability in the raw material, which has to be processed in a continuous manner through several stages of production, varying in their objectives. The control of raw material is difficult, partly because of the difficulty of being able to buy cotton at standard specifications, and partly because of the lack of testing equipments in the mills. Improvements achieved as a result of introducing quality control are quite often offset by deterioration in the quality of the raw material. It also becomes difficult to assess the exact benefits of quality control in terms of increased production or improvement in quality or reduced waste. This results in a certain amount of scepticism on the part of the management about the utility and effectiveness of quality control.

EXPERIENCE HAS TAUGHT SITRA that different units need different types and degrees of assistance. In order to achieve fairly substantial results over a short period of time a diagnostic survey of some Coimbatore mills was conducted by a specially trained staff for period of 6 to 8 weeks, covering the following aspects A. quality of the product B. waste extracted and cleanliness in relation to the raw material C. production at various stages of processing.

Special emphasis was placed on getting-facts about the technical conditions of machines and a list of recommendations were given for each section. In some of the older and larger units, having a variety of machines and running a number of counts, such a survey is particularly helpful in highlighting the major causes of poor quality and efficiency.

A. quality of the product

When the raw material has been chosen, maintenance and improvement of quality depends upon the machines and the methods of processing. The key point for maintaining a yarn of good quality is to control the amount of neps in blow room and cards, and the long and short term variations in the material at various stages of processing. The amount of neps in cotton was assessed at different stages in blow room in order to detect the sources that introduce neps. In carding, the web was observed for neps and variation was noted between cards. Cards giving excessive neps were found to have some easily rectifiable defects Suggestions were given to modify the settings and speeds for reducing the total number of neps.

In the survey the material was inspected at each stage, in order to locate the sections introducing variation in the product. Particular emphasis was given to the inspection of product in blow room and drawing, as the variations in these two departments decide to a large extent the yarn irregularity. One of the main points noted in the blow room was that the tolerance limits fixed for the acceptance of the lap and effecting a change in the machine are generally decided arbitrarily, without taking into consideration the capacity of the machine. In most of the cases the limits set are found to be too tight for the machine to cope with and this results in frequent adjustments on the machine. Adjustments should correct only persistently long-term trends, and be delayed until it is clear that the departure from the standard weight is consistent. It is essential to study the natural limits of variation of the process and fix the limits on the basis of the same. If, however, the process variation is higher than the desirable tolerance limits, steps should be taken to investigate the causes of such a high variation. The survey revealed that because of the tight tolerance fixed and defects in the machine and methods of processing, *as high as 40 to 50 percent of the total product produced in the blow room were rejected.* Excessive rejection of the material would first of all affect the production. Also reprocessing of the material would result in damage to fibres, and thereby affect the yarn quality.

Significant differences were found to exist, between machines in the average weight as well as the variation in the product. This was traced back to differences in the draft change wheels and defects in the machine. Whenever a number of doublings are done the variation is expected to reduce progressively, but there is a limit to it, depending largely on the variation introduced by the machine. The variation in the final product was separated into two categories, namely variation introduced by the machine and that by the back stuff. In drawing, particularly, the short-term variation was found to be high and differed significantly between deliveries.

Also the long-term variation was not found to be reduced progressively. One of the main reasons for this was found to be due to fixing tolerance limits arbitrarily. In ring spinning routine test results are generally used by the mills only to study the average, and the variation part is neglected. It was found possible to obtain much useful information from these results in determining trends and spotting within, and between machine variations. The study revealed many useful features such as certain frames spinning consistently finer or coarser counts, and certain frames spinning yarn of low strength. Lack of proper upkeep of machinery, and settings and drafts not suitably adjusted for the material processed were found to be some of the main causes for the excessive variation introduced by the machine.

B. study of waste, cleanliness etc.

Cleanliness in one of the important characteristics of a good yarn. It is determined largely by the quality of raw material, and the methods of processing in blow room and cards. Representative samples from the raw material at various stages of cleaning and that from different machines processing the same material were tested for trash content and fibre properties. The performance of the process was judged on the basis of the experience gained by SITRA, as a result of conducting studies of a similar nature in a number of mills. The following are some of the findings: (*a*) some of the cleaning units are not set properly, resulting in loss of good material and poor cleaning. (*b*) in certain cases the number of cleaning units were found to be in excess, resulting in damage to the fibre and loss of good cotton. (*c*) in certain mills, more number of cleaning units have to be introduced to effect a better cleaning. (*d*) the quality as well as waste differs significantly between machines. By taking corrective action it was found possible to effect a considerable reduction in the loss of good material in the waste and at the same time, in some instances, improve the overall cleaning effected. A comparison was made on a set of machines processing the same material, and it was noticed that there was practically no relationship between the quantity of waste extracted and the amount of cleaning achieved. This would mean loss of good cotton in some machines which were subsequently reset. It was found possible to cut down the waste by 2 to 3 percent, without effecting the quality, and thereby effecting an annual saving of Rs. 50,000/- to the mills.

C. processing

Particular emphasis was given on the scope of increasing production at various stages of processing, without affecting quality or, effecting any major change or introduction of new machinery. Machine utilisation in the different departments was quite low, the main causes being excessive rate of end breaks, machines waiting to receive attention, shortage of back material and other accessories. A study on the rate of end breaks and causes of machine stoppages in various sections revealed that a majority of the stoppages were caused by defects in the machines, improper machine adjustments etc. The number of ends down, apart from affecting production, deteriorrates the quality also.

The number of machines at various stages of processing was not found to be properly balanced, thereby increasing the machine unproductive time due to shortage of back-material. Generally, importance is given by the mills to maintain the production in ring spinning at the maximum level, the machines in the preparatory sections being so adjusted to ensure a continuous supply of material. In order to study the extent to which production could be increased, the standard production was estimated in ring spinning after giving due allowance for unproductive time due to causes which are either unavoidable or cannot be reduced below a certain minimum. The actual production was found to be 15 to 20 percent less than the standard, the main reasons being (*a*) the speeds maintained in some of the machines not conforming to the standards specified (*b*) variation in twist and consequently production between machines (*c*) improper balancing of production (*d*) machines waiting for receiving attention (*e*) spindles idle.

implementation

Once a diagnostic survey is conducted, the second step should be to implement the remedial measures for improving the quality and increasing production. The third stage is to take measures which aim at maintaining the remedied situation. It is never pleasant for the technicians to read a report pointing mainly the faults in machinery and techniques. For quality control to become a success it is necessary to make sure that the irritation caused by critical remarks is kept to the minimum. Quite often for many of the pitfalls and shortcomings, the technicians may not be responsible at all. *The implementation of a regular quality control programme would be greatly eased if it is preceded by a detailed diagnostic survey.* This would enable the mills to decide the departments that need immediate attention. The survey also acts as a powerful aid to impress upon the management and technicians about the effectiveness of statistical methods in solving problems of production, quality and waste. In view of the diversity of the processes adopted and the large human element involved, *a constant and a continuous vigil* on the product at various stages of processing is necessary for efficient running.

Reduction of Card Waste

An important factor to be considered in assessing the performance of a cotton spinning mill is the total waste produced during the processing of cotton into yarn, through the several stages. It is common experience that the waste contains, apart from trash, a considerable quantity of spinnable cotton fibres. Since the raw material cost constitutes a good proportion of the cost of manufacture of yarn, it is important to see that, consistent with the required yarn quality, the waste produced is minimum. The present study narrates, how a routine SQC programme in the carding section led to sizeable reduction in card waste without affecting the yarn quality.

In the mill where this study was conducted, a large number of cards were engaged on the processing of 40s mixing. As part of the routine SQC programme, data were collected on (i) percent waste extracted by each card (ii) particulars of speeds and settings (iii) quality of 'web' (36 sq. in.) ; number of neps and foreign matter. An analysis of these data disclosed that the level of waste extraction for the different cards was not uniform, and, further, that the values tended to cluster around two different averages. This fact could not be ascribed to any differences in settings but could be correlated with the flats speed ; two different levels were found being maintained in the shed. The flat waste, constituting the bulk of card waste, was found to be higher for cards running with the higher level of flats speed. The nep and foreign matter count was, however, no higher for the group of cards with low flats speed.

It was decided to investigate whether by standardising the flats speed at the lower level, waste could be reduced without yarn quality being adversely affected. For this purpose the cards with high flats speed and an equal number with low flats speed were chosen. The sliver was followed through the several stages of spinning and all important characteristics of silver yarn were recorded. Attempts were made to maintain uniform conditions to ensure valid comparisons. In particular, differences due to machines, and variations due to humidity were sought to be eliminated if not minimised by inter-changing the flats speeds on the two groups of cards and by recording observations simultaneously for both speeds.

For instance, after half the required number of observations at carding were made, the allotment of cards to the two speeds was reversed—after processing one half of the required material, the draw frame deliveries and subsequently, the fly frame spindles processing each material source, were interchanged to complete the experiment. At spinning on the same side of a selected ring frame half the spindles were allotted to material from the cards with low speed and the remaining to material from the cards with high flats speed. The allotment to the sets of spindles was interchanged after processing half the experimental material. At each stage the following observations were made : (i) Count of neps and foreign matter in card web—for the two grouping cards (ii) Total waste at carding, (iii) Lea count and strength of yarn, (iv) Evenness of yarn (Uster) ; strength of yarn (Uster) (v) Breakage rate of yarn, (vi) Appearance.

The yarn appearance test during the final phase was made as follows :

Three specimen yarns were taken, two from experimental speeds (2.25″ per minute flat speed processed yarn, 3.75″ per minute flat speed processed yarn) and one from normal production. Those three were wound on black wooden strips and were given to five judges for ranking according to their appearance. The results o the study are summarised in Tables 1 and 2.

Table 1: Carding quality characteristics

flats speed	waste extraction %		neps and foreign matter (36 sq. in.)	
	flats waste	total waste	neps	foreign matter
low (2.25″ per min.)	2.1	4.9	9.9	8.3
high (3.75″ per min.)	4.3	6.5	9.6	8.7

Statistical analysis showed that the quality of the web is not significantly different for the two speeds. Waste extracted however is significantly lower for the low speed. Thus it is advantageous to have a low flat speed at carding. As regards the quality of yarn, Table 2 given below shows the CSP and lea strength for the two speeds.

Table 2: Yarn quality at spinning

quality characteristic	flats speed	
	low	high
count strength product	1367	1316
corrected lea strength in lbs.	33.5	33.1
variation in lea count (c.v.%)	5.45	5.43
variation in lea strength (c.v.%) in lbs.	9.30	9.85
uster unevenness—v%	21.4	21.4
uster single thread strength— average	160.4	159.7
standard deviation	25.0	25.3
end breaks per 100 spindle hours	41	45

Also the yarn appearance, as judged by five senior staff of the mills, was said to be practically the same for all the three specimens.

It can be seen from the foregoing results of the investigation that there was no deterioration in quality at spinning as a result of the reduction of flats speed from 3.75 in. per minute to 2.25 in. per minute. On the other hand, a considerable reduction in the waste extracted occurred. It was therefore recommended that reduction in the flats speed of the cards would be advantageous to the mill. This recommendation was implemented and it was reported that an annual saving of Rs. 60,000/- occurred to the company.

A man wanted to sell Charles Schwab a cow. "Pedigree?" asked Schwab. "I don't know," answered the farmer. "How much milk per day?"... "Can't even tell you that, but I tell you one thing. She is a good-hearted and good-natured old cow, and if she, got any milk, she'll give it to you."

Snap Survey in a Loomshed

An attempt is made in this article to describe how a textile mill had advantageously employed the technique of snap survey (work sampling) in its loom shed to increase production and reduce defects in cloth.

In the mill in which this study was carried out there are 200 plain looms, running on plain sorts. Snap rounds in the shed were made regularly twice a shift. During each round, the looms that were found stopped were noted down together with the cause of stoppage. Simultaneously, the defects observed in cloth were also recorded with appropriate identifications. At the end of each round, the information was summarised in a suitable form and was given to the respective jobbers so as to focus their attention on the stopped looms. At the end of the month, the results of the survey were consolidated and discussed with the mill technical staff. Based on this, appropriate standards for loom stoppages as well as for some of the important causes of stoppage were laid down and suitable control procedures were developed. Control charts were maintained for the total stoppages as also for some of their important causes. Thereafter, whenever the control charts, indicated lack of control, an analysis was immediately made to isolate the causes responsible and this information was fed back to the appropriate technical personnel for appropriate action.

As a result of sustained controls exercised, gradual but sustained improvements occurred. The average loom stoppage declined from 31-38 in July to less than 17 in November. Under each cause also stoppages showed a steady downward trend. The shed efficiency also rose correspondingly from 83.2 in July to 90.4 in November. Simultaneously the quality also improved. The number of looms running with defects in cloth decreased from 12.50 in July to 4.84 in August and remained steady around 7.5 in the subsequent months.

It would be worth narrating how the above improvements in performance were achieved. Causewise summary of July data showed that the major stoppages were due to single and multiple warp breaks, shuttle change and weaver busy on another loom. This was brought to the notice of the technical staff of the mills. For reducing the number of single warp breaks, they suggested a change in the size mix and this was tried with remarkable success. The stoppages due to this cause decreased considerably. Careful observation revealed that multiple warp breaks occurred mostly as a result of undrawn warp ends left loose on the warp sheet by the weaver, which got entangled with other ends in the warp sheet. The extra tension thus created resulted in breaking a number of ends in the warp. Simultaneously proper instructions given to the weavers and strict supervision led to a reduction in multiple warp breaks as well as to a reduction in cloth defects due to missing ends.

For reducing the frequency of stoppages due to shuttle changes, it was decided to put more weft in the pirns. Also, pirns having less than the standard quality of weft were not issued to the weavers. This action made it possible to bring down the loom stoppages due to shuttle change from 5.00 in July to 2.66 in November. A natural consequence of the reduction in loom stoppages due to the above three major reasons was a reduction in the stoppages due to interference—that is loss due to waiting for attention of the weaver busy on another loom. This was reduced to nearly half its original value. Last but not the least was the psychological effect that the snap survey had on the weavers responsible for the other improvements. For instance, the number of stoppages due to 'weaver gone away' came down from 1.58 in July to 0.38 in November. Thus the introduction of a routine system of information gathering, analysis and action had helped the mill to achieve improvements in performance.

The guide was showing some Americans around a museum. There he showed them two skulls and said, "The smaller one is the skull of Alexander as a boy, and the larger one is the skull of Alexander as a man."

A Case Study in Excess Weight

THIS ARTICLE NARRATES how a cotton spinning mill used simple SQC techniques to reduce the average excess weight given away in bales of 40^s yarn at despatching. Yarn is packed in bundles of 10 lbs. and a bale comprises of 40 bundles. The usual practice is to pack the yarn slightly heavy at bundling so as to allow loss in weight due to evaporation in storage and transport. For this purpose, an excess of about 5 lbs. was felt necessary as a safeguard. A snap check of the mill records on bale weight for a month showed that on an average, an excess of about 10 lbs. was given away over the standard of 400 lbs. (net weight). The variability in the weight of individual bales also was found to be large. Careful observation showed that the two predominant causes contributing to excess weight in bales were: (i) inappropriate blending of of the heavy and light knots at bundling stage; (ii) excessive variation in the weights of individual knots due to variation in count at spinning.

The study to reduce the excess weight was carried out in two stages. To start with an overcheck was installed at the bundling of yarn to control the bundle weights; the bundle weight and bale weight being inter-related and inseparable the ultimate objective of minimising the excess weight in bales can thereby be achieved.

The practice followed by the mill at the packing stage prior to the installation of SQC was as follows: Old type of spinning frames were employed for spinning 'heavy' count, new types of frames were used for spinning 'light' count. Knots made out of the yarn from these two types were stacked in separate heaps in the packing section. The operator was instructed to assemble light and heavy knots at random to form a bundle such that it weighted a minimum of 10 lbs. It was observed that the operator was always prone to give too much in excess of the standard weight. The SQC section decided to set up a control chart on his activity to watch his performance and to provide him an objective guidance in performing his function. This was done as follows: One bundle was selected at random from each of 5 presses immediately after packing to form a sample of 5 bundles and the weights of these bundles were recorded in terms of the deviation from the standard weight of 10 lbs. Four such samples were collected each day for about 20 days. The averages and ranges of these samples were plotted on a control chart provided with action limits. The operator was instructed to exercise care and caution whenever a point violated the action limits on the chart.

The average weight of a bale was thus reduced by about 6 lbs. and the variability from bale to bale was also considerably reduced. But the control chart maintained at the blending stage, although it helped to reduce the excess weight, created bottlenecks at the packing stages due to piling of heavy or light knots that occurred as a result of excessive variation in the weights of knots. It was, therefore, decided to tighten up the prevalent controls at spinning. Accordingly separate $\bar{X}$-R charts were set up on the lea-weight to control the yarn count. The supervisors were trained to use the charts intelligently. Action on pinion changes was based on the charts in all the three shifts. As a result, unnecessary pinion changes were avoided. It was found that variation in lea-weight was due to misplacement of rove bobbins of heavy count from adjacent frames in some cases. This could be detected with the help of range chart. Suitable instructions were given to the rove boys to prevent the incidence of such misplacements. Actions at spinning resulted in greater uniformity in weights of knots. This improvement eliminated the bottlenecks at the packing stage completely. As a result of the controls at spinning and packing stages, a reduction of 7.25 lbs./bale was obtained entailing a saving of about Rs. 3500/- per month to the company.

SQC in Indian Jute Mills

The SQC Units of the Indian Statistical Institute have been concerned with providing consultative service to over 15 jute mills in the Calcutta region since 1955. The activities included routine quality control in mills which became members of the servicing scheme; and special project works in non-member mills on specific problems. In the course of these activities the unit had to grapple with a variety of problems relating to most of the stages of jute processing. The use of statistical quality control techniques has helped to increase productivity in the jute mills by evolving and operating control procedures over the factors influencing the quality of the product or performance; and providing objective information to facilitate timely and appropriate management decisions. An attempt is made in this article to bring together some of the experiences accumulated so far.

JUTE FABRICS ARE IMPORTANT FOREIGN exchange earners for the country, and the customers do prescribe standards of quality. In view of growing competition from Pakistan and other developing economies the need for complete customer satisfaction cannot be overemphasized. It is not unusual to come across instances where the goods have been shipped back at supplier's cost or accepted at very reduced prices. The Jute Commissioner's Office often receives complaints from abroad about the poor quality of fabrics supplied by Indian mills. Secondly, the cost of raw jute constitutes the major part of the cost of the finished fabric. Therefore, great care has to be taken to see that the specifications prescribed by the customer are met by an economic use of raw materials. The third factor naturally would be to maximise the utilisation of all the facilities so as to reduce cost of production. Thus an SQC programme in a jute mill should start from three basic considerations: control of outgoing quality to customers' specifications, control on consumption of raw materials and control of utilisation at spinning and weaving. The emphasis might, however, vary from mill to mill. For example, if the major production is broad loom carpet backing, greater emphasis would be given to outgoing quality to start with, whereas if the production is mostly sacking quality, the other two aspects would receive greater attention in the first instance.

Customers have developed quality grading systems. One of the most important of these operates as follows: A. A bale is opened at destination and each of the cuts is weighed, and measured. The weight per yard (original indicated weight divided by measured yardage) is computed for each out. A score for the bale is determined from the number of cuts below specified weight, no credit being given for cuts above the specified weight. B. Four cuts from the bale are examined in detail for the following: porter (three determinations each cut); shot (three determinations each cut); width (three determinations each cut); faults determined from complete reinspection of each cut, including weft breaks, warp breaks, double weft, snarls, float, ghaw, hard beats, low beats, bias and reed marks; and selvage condition scored as excellent, good, fair and poor. A number is then assigned to each type of fault depending on its seriousness. Cuts with more faults will receive higher scores. The average and range of the total scores for the cuts in the sample checked are plotted on a control chart. Looms or weavers responsible for faulty cuts can be picked from out of control points on the chart for corrective action.

Quality Check Sampling: either bales may be removed from godown for quality check or material sampled just prior to baling. If bales are to be removed from the godown for quality sampling at least two bales per day should be selected at random and surveyed as above. If many types of products are made by a mill, random sampling should be modified to include at least one bale of each type per week in the product sampled. Sampling prior to baling is recommended, however. Product may be surveyed after lapping and just before baling in order to save the cost of opening bales and rebaling. For this purpose a sample of 32 cuts from the day's production should be selected at random, and weight per yard determined with care, in accordance with 'A' above. From this initial sample of 32 cuts, at least two cuts of each type of cloth produced should then be examined in accordance with 'B' above.

The moisture content of the fabric also have an important bearing on the quality since cloth baled with heavy moisture content gets damaged after lapse of time. Sometimes it has resulted in heavy losses to the manufacturer. Although no specification in respect of moisture content is laid down by the purchasers, it is desirable to bale the fabric at safe levels of moisture percent. Checks in respect of this characteristic could be made on the samples along with other characteristics. A control chart could be used for control purposes.

Recording and utilising data from check inspection of outgoing product: the data obtained is a sample from which outgoing quality of all material may be estimated. The data will need to be summarised from day to day in the form of charts, summary reports, or in other manner suited to executive action. Charts on the (1) number of cuts below standard, (2) number of measurements below width, (3) number of defects per cut should be recorded on a daily basis for each type of fabric produced. Control limits should be placed on these charts to show the departure from desired standards to signal unwanted changes in the production process. Information obtained above should be the basis for any or all of the following types of action: process correction, downgrading of the product or no action. Many types of defects can be traced through the process back to their point of causation. Selvage irregularities, differences in porter, and many faults can be pin-pointed at their source. Action to correct these difficulties may require combined efforts on the part of many of the staff. Once troubles are detected, they should be corrected to prevent similar troubles in the future. If the troubles cannot be corrected economically, then acceptance of these as non-correctable troubles is patently given and the consequences accepted. Weight per yard data from the cuts should also be analysed as to the reason or cause of the underweight: weft, warp, and forth. Action may be taken to segregate the underweight material, or to study the means of weight control and correction. If product is below levels acceptable to customers, product might be down-graded to lower grades, or possibly segregated before baling into acceptable and non-acceptable classes. The importance of unbiased and scientific knowledge about outgoing quality is that the wisest management action can be taken (1) with the material in hand and (2) with the process of producing future material.

Process control: the information from the outgoing quality check may provide the guide line as to where within process controls are vitally needed. *Standard product can usually be produced as easily and cheaply as non-standard,* once the sources of trouble have been located.

Quality check of finished cloth in a mill revealed that the majority of defects were warp breaks. A study of the yarn strength available from laboratory tests revealed that they were at the desired level. Some changes were then made to the dressing practice. This led to not only to an improved quality but also increased efficiency at weaving. The major cause in another mill was revealed to be snarls. Actions at winding helped to reduce the incidence of this defect substantially.

In addition to this tracing back through the process of those points suggested by the outgoing quality evaluation there is need to *keep control on some specific characteristic as part of good technical practice.* These are regularity and strength of yarn. The test laboratories usually provide enough information on these characteristics. In many mills they have not been treated with the consideration they deserve. If control charts for averages and ranges could be maintained on these characteristics it will be possible to know reasonably early the likely effects of a change in mix or other processing factors on the final product so that appropriate remedial measures can be set in motion.

consumption of raw materials

Optimum mix: The margin between the selling price of jute cloth and the cost of the raw materials necessary to make them is so little that great care must be used in successful jute making in the selection of economic raw material mixes. The aim is to use the cheapest materials that will spin well in making any grade of fabric. One method for controlling the raw material mixture is to compute the batch cost for each type of yarn made and to relate this to spinning and weaving efficiencies. The data to be collected is the daily batch price, say for hessian and sacking warp and the daily spinning efficiencies for spinning and weaving associated therewith. This provides the basis for a series of informative charts: spinning efficiency per unit cost versus time, weaving efficiency per unit cost versus time, spinning efficiency by batch cost, weaving efficiency by batch cost, spinning versus weaving efficiency. The movement over time of the efficiencies should measure the progress made in improving raw material cost situation. The relation between batch cost and efficiency should be positively correlated, other things equal, since the higher the batch cost, the better the spinning efficiency should be. Where this relationship does not hold, then investigative action should be taken to find out why; if efficiency is relatively low, poorer raw material or incompatible raw material may be costing more than it adds to the mix, etc.

The cost should be standardised and related to a particular period because raw material prices tend to fluctuate widely from period to period. Unless the unit costs and batch costs are standardised the comparisons are likely to be misleading.

One of the most beneficial effects of keeping these charts would be to reveal that although a better batch would produce higher efficiency, for any given batch the process efficiency might vary by as much as 20% thus showing up that with appropriate process controls a reasonably good batch can yield very high efficiencies. When once the batch is fixed the efforts would be directed at achieving the quality requirements with minimum jute consumption through process controls.

Two important characteristics for this purpose are moisture and equivalent weights. Jute is a highly hygroscopic materials. It absorbs or desorbs moisture depending upon the humidity of the surrounding atmosphere. The usual measure for the amount of moisture in jute at any stage of production is 'moisture regain percentage' which is defined as $R = \frac{G-D}{D} \times 100$ where R= moisture regain percentage, G=Gross weight of a given quantity of jute and D=Weight of the given quantity after complete drying. Meters are available which can read off moisture regain directly from the jute. At various stages of the process it is essential to maintain the level of moisture regain percentage within certain tolerances. To achieve this the normal practice is to add water to the material at 3 different stages: softening, yarn dressing, and cloth damping. Some mills also attempt to achieve over moisture in the jute while in process by installing artificial humidifiers in their plants. In spite of all these attempts, wide fluctuations in moisture regain persist at almost all stages of manufacture. The effect of variation in moisture regain can be seen from the following illustration. Suppose the dollop weight is fixed at 32 lb and the moisture regain in jute at the feeding end of the breaker card is 27 percent. The yarn produced out of this material has, let us assume, an observed grist of 9 lb under a given combination of intermediate machine settings. Now, if level of moisture regain changes to 18 percent with all other things remaining equal, the observed grist will be about 9.7 lb i.e. the yarn will be about 8 percent heavier. The importance of maintaining regular check on moisture is, therefore, a matter of the utmost concern. The most practical way of tackling this problem would be to instal control charts on moisture regain on the outgoing material at softening, yarn dressing and damping. Suitable control procedure for setting up $\bar{X}$ and R chart on individual machine or a group of machines can be worked out for the purpose.

Control on moisture regain will help to keep the variation under reasonable control at softener, dressing and beaming and damping. To maintain control over the consumption of jute consistent with the specification requirements, the weight of yarn and fabric will require to be controlled. The regularity of sliver and yarn and grist are usually sought to be controlled through gross weights. As the weight of the fabric will be influenced to a large extent by the moisture the above procedure is not likely to be very beneficial. As an illustration, the specified grist of yarn is 10 lbs., at 15 percent moisture regain. It can be shown that the gross weight would be 9.6 lbs. at 10 percent moisture regain and 10.5 lbs. at 20 percent moisture regain. In other words, if the uncorrected weight meets specification requirements there is no guarantee that the real weight will also be as desired and vice versa. These pitfalls could be avoided if equivalent weights (weights at a standard moisture regain) were used as the criterion for control.

Let S=the standard moisture regain (%)
R=the recorded moisture regain
G=the recorded gross weight of a given length of sliver, yarn or fabric
E=equivalent weight at S% moisture regain.

Then, $E = G \times (100+S)/(100+R)$

It is needless to point out that if the equivalent weights are in control at any stage the jute consumption at that stage is also under control and vice versa. The stages where this would be useful are

finisher card	:	weight of sliver
finisher drawing	:	weight of sliver
spinning	:	weight of yarn

ex-loom : weight of fabric
finishing : weight of fabric.

A suitable sampling procedure can be devised for each stage and control charts for averages and ranges maintained.

Waste control: wastes in a jute mill consist mainly of droppages under machines in the form of fluff or caddies and yarn waste at weaving and beaming operations. Difference in droppage may be observed between machines doing similar operation or between periods within a machine or group of machines. Such differences could arise due to mechanical causes: machine setting, change in material, working procedure of individual operators etc. Systematic collection of data on droppages would help to detect avoidable waste. Routine control procedure may also be installed for each machine or groups of machines to keep a continuous check on droppage. Experience has shown that there is considerable variation in yarn waste between beaming machines and between looms. Such variations are generally due to the fact that some operators tend to waste more yarn than others. Systematic collection of data helps to detect negligent operators. In the loomshed linewise, charts on percentage of waste of weft yarn have been found to be useful for motivating the line *sardars* in keeping a check on the weavers under their control.

In addition to cost of jute fibre and the operation cost, the consumption of many store items such as batching oil, shuttle, picks etc. also add to the production cost of the jute fabric although in a minor way. There is, therefore, some interest for the management to exercise control on the consumption of such items. Standards and control limit for lives of items like shuttles, pickers, etc., could be obtained by experimentation. A log-book for issues to individual looms could be maintained and records used for keeping control on issues. An issue necessitated by life of shuttle much lower than the lower control limit for shuttle lives will be indicative of some technical fault with the loom. It may be necessary that different working limits are obtained for every supply. Consumption of batching oil or soap higher than the expected highest would indicate increased waste of emulsion provided the weight of jute processed remains at the required level. There is need to gather further experience in this field in the jute industry.

control of process efficiency

Two vital points in a jute mill from the point of view of process efficiency are the spinning frames and the looms. Indices of efficiency computed as

$$\frac{\text{Actual production}}{\text{Rated production}} \times 100,$$

are commonly employed to compare performances. These indices, though useful, take a long time to compute and do not often offer a basis for remedial action. If the standards of speed are properly set the utilisation studies based on snap reading or work sampling technique offer an effective basis for routine control. These may now be discussed.

The object in the spinning section is (a) to achieve stable and satisfactory level of the process by taking corrective action on the poorer frames and develop routine procedures to maintain these levels. For this purpose, the first step is to obtain a periodic count of the number of ends down per frame. After data on several rounds are available a comparison of the average ends down of the frames working on the same quality may be made using a control chart. The control chart will indicate the frames needing special attention. Studying the number of end breaks on each spindle of the poor frames in a given period of time enables locating the spindles giving excessive breaks. Usually it is found that about a quarter of the frames need to be set right and among these frames about four or five spindles might be causing the most damage. If no spindle differences are found in respect of end breaks, action is indicated over the whole frame. The initial corrective action helps to improve the overall performance. If this level is satisfactory, steps for routine control may be taken up.

Routine control at spinning: snap reading rounds may be taken 4 times in a shift for about a week after the poorer frames have been set right. The number of ends down in each frame observed during a round may then be recorded in a suitable form. It is not unusual to find spindles idle for reasons other than end breakages e.g. sliver shortage and breakage, mechanical trouble etc. The number of such idle spindles with their causes should also be noted. When the entire frame is found stopped at the time of observation for causes such as doffing, mechanical breakdown, sliver shortage, bobbin shortage, routine maintenance etc., this may be indicated by suitable codes. The data can be analysed and control charts installed for the average ends down for each round. Experience has shown that for control chart purposes the frames in most cases may be classified into four broad groups: hessian warp, hessian weft, sacking warp and sacking weft. Thus, normally, 4 sets of control charts will cover the utilisation aspect of all the spinning frames. When the ends down tends to increase it may be due to any or a combination of some of the causes like change in batch quality, sliver irregularity, moisture regain in sliver, mechanical fault, poor performance of spinners, etc. Procedures for detailed investigation can be worked out to pinpoint the causes for remedial measures.

Normally there should be no loss due to sliver or bobbin shortage and, when they are spotted, could be set right. A weekly and monthly summary of the snap reading data help to reveal the extent of these causes. In fact, these summaries should be very useful to the management. Doffing often accounts for much higher loss in utilisation than is imagined or is reasonable. The weekly and monthly summaries should be carefully watched for any increasing trends in losses due to this cause.

Weaving: loomshed efficiency measures the effect of controls at all the stages. Here too quality control methods should be first used to attain the best possible levels and then maintain these levels. Snap check data may be used along with the efficiency figures to decide on the first step. If in a particular type of fabric, the efficiency figures are lower than the utilisation, say, by more than 5 percent then, provided the standards for speeds have been properly set, the existence of slippage may be suspected. The snap check data would then be used to locate the looms giving low utilisation, which would be marked out for special attention. At the third stage the data would be summarised to give loss in utilisation causewise. These summary sheets are very useful in deciding on the appropriate point for attention. For example, such a table may draw attention to warp breaks, mechanical troubles etc. When once the utilisation has reached a satisfactory level, there is need to establish routine control.

Horace Greeley, once editor of the New York Tribune, said of himself that he was "so rocking in his gait that he walks down both sides of the street at once."

Increasing Output from Spinning Frames

It is well known that other things remaining constant it is the spindle speed that determines the volume of production that can be obtained from a spinning frame. The present note explains how an investigation on the acceleration of spindle speed led to an increase of output by as much as 8 percent.

IN THE MILL IN WHICH THIS study was made, 12 of the spinning frames were processing 60s yarn. As a part of the routine SQC programme in the mill, data on end breaks and snap survey on idle spindles and ends down were recorded daily. The ancillary technical particulars such as spindle speed, front roller speed etc. were also noted.

Analysis of routine data on end breakage rate showed that the average breakage was about 14 per 100 spindle hours. This was considered to be a good performance according to past experience in the mill as well as standards currently prevailing in the industry. In addition, the results of snap survey of spinning showed that the ends down for the frames processing 60s were only 4 per frame, which was considered to be a very good performance. The results also indicated that the performance being more than average the spinning piecers might not be fully occupied. A snap study of these piecers was accordingly conducted and it was found that they were occupied only 63% of the total time. Compared to the normal standards of workload this was considered to be under-utilisation of their time.

As the workloads of different categories of workers in the mill is based on agreements for the industry as a whole it is not possible to increase the number of spindles assigned to each operator. In these circumstances it was *natural to think of raising the speed of the machine*, for even if this were to result in a higher rate of end breaks it would still be within the normal capacity of the piecers to attend to the spindles allotted to them. This led to a study of the effect of raising the spindle speed to the maximum extent considered feasible within the mechanical limitations.

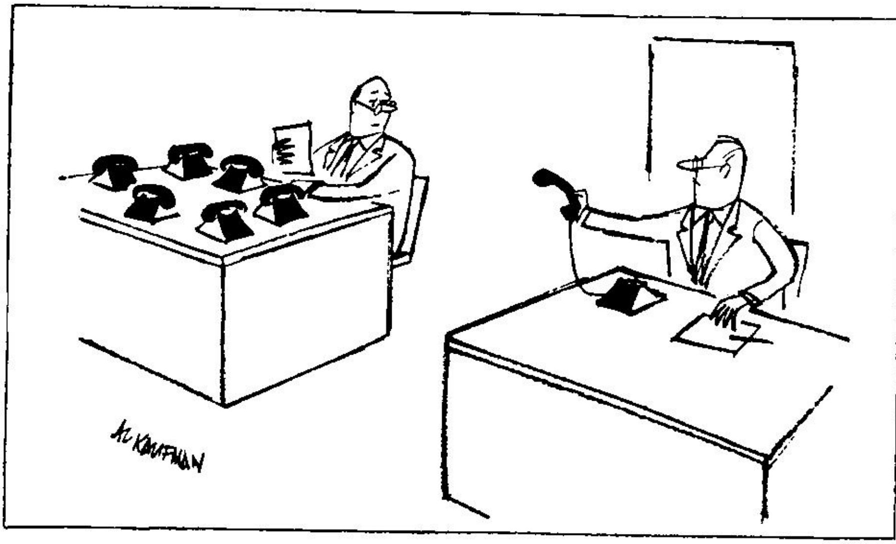
For the purpose of the study two frames of the same make and in the same condition spinning 60s were selected after ensuring that no significant difference existed between the two as regards production and yarn twist. The two frames were checked for spindle speed and it was observed to be 10,400 rpm in both. The higher spindle speed for the purpose of this investigation was chosen as 11,200 rpm. The following characteristics were studied in the experiment conducted with both the speeds on the two frames chosen. (a) Production (b) End breaks (c) Count strength Product (d) Count variation (e) Strength variation.

A summary of the results is presented on Table 1 below.

	characteristic	spindle speed 11,200 rpm	spindle speed 10,400 rpm
1.	production (in ozs. per spindle per shift)	1.47*	1.36
2.	end breaks per 100 spindle hours	10	7
3.	average count strength product	1961	2001
4.	count : c.v. %	3.92	3.31
5.	strength : c.v.%	9.46	8.54

*Indicates statistical significance at 1% level.

For each of the characteristics considered in the experiment separate statistical tests of significance were carried out to determine if the observed numerical differences in their values corresponding to the two spindle speeds were real or could occur from chance causes. The results of statistical analysis showed that (i) there was a significant difference between the output corresponding to the different speeds—the higher speed led to higher production (ii) the differences for the other characteristics were not statistically significant. The accelerated spindle speed resulted in increased production of the order of 7.8%, without adversly affecting the yarn quality. For the piecers also the workload was not increased but there were opportunities to get more production bonus because of increased production. In view of the above advantages, it was recommended that the spindle speed for the frames spinning 60s be raised to 11,200 rpm. This was implemented and as a result the daily production increased by about 6 lbs per frame. This meant an increase of 1800 lbs per month on this count of yarn alone.



QC : Productivity Tool in Textile Manufacture

SN Bahaduri *

Far too often in the past Quality Control has been identified in the public image with Statistical Quality Control (SQC), which in reality is only a small part of the technique of Quality Control. To the average production engineer the SQC technique appears to consist principally of plotting points, representing any given product quality on charts drawn after mysterious calculations by the statistician. If any point falls out of the sacrosanct limits drawn up by the statistician, all hell seems to break loose and the engineer is asked the reason why. He also comes in time to wonder how this technique can be of help to him in improving quality or productivity. The purpose of this article is to show that there is more in the technique than meets the casual eye and properly used Quality Control can be a potent aid to the management and to the production engineer. The technique of Quality Control will be discussed here only in relation to the manufacture of cotton textiles or those made from out staples of manmade fibres.

THE QUALITY OF A PRODUCT AT ANY STAGE of manufacture e.g. yarn may vary from time to time on account of several factors, chief among which are: variations in (i) cotton quality (ii) quality of material fed to the ring frame (iii) processing parameters on the ring frame (iv) atmospheric conditions in the department (v) quality of work done by the workers and (vi) unknown and uncontrollable factors which may have a bearing on quality. It is evident that in order to control the quality of yarn it is necessary to control as many of these variable factors as possible. By quality of yarn may be meant any one or more of the measureable properties of yarn such as count, tensile strength, evenness, number of week points (of which yarn breakages during processing is an index) or so on. It is of course not possible to control all the variable factors mentioned above within desirable limits, and therefore a certain degree of variation in quality will always manifest itself in normal processing even when major factors such as cotton quality and machine factors are held constant. Another difficulty in trying to control the quality of important products such as yarn or fabric is the fact that these products are the culminating products of a series of processes, each of which may affect the outgoing product characteristics at that process and the quality at subsequent processes. With this multi plicity of processes and product characteristics involved it becomes difficult to

* Atira.

decide on which processes and characteristics to concentrate ones efforts. This discrimination can come only with accumulated knowledge and experience, on the part of the quality control engineer, of the effect of the interplay of the various factors on yarn of fabric quality. Theoretical considerations and practical experience show that the most important factors affecting yarn strength and short term evenness, and number of weak points are (i) cotton quality (ii) quality of carding (and of combing for combed yarn) and (iii) processing factors at the ring frame itself. For long term yarn regularity, the variation in weight per unit length of the product at the drawing and intermediate stages are also very important. The fabric quality is primarily determined by the (i) quality of yarn, (ii) quality of sizing and chemical processing and (iii) certain processing factors at the preparatory machines and looms. Such knowledge is of great help in keeping down the volume of quality control work to manageable proportions. Very often unnecessary effort is directed towards the control of processes or quality characteristics which are relatively unimportant.

The quality of yarn and fabrics is greatly dependent on that of the cotton, and all attempts to maintain quality will fail if unsuitable cottons are used. Further, cotton cost constitutes 45 percent to 50 percent of the total cost of the fabric, and possibilities of monetary savings are very great if proper care is exercised in the selection of cotton. While certain general relationships between fibre properties and yarn quality are known, it requires several years of experience and study to determine the precise quality characteristic of cotton to suit the particular requirements of given end products. Apart from staple length, tensile strength, fibre fineness, maturity and trash content in cotton are important characteristics which should be checked regularly. Often cost considerations preclude the purchase of higher priced cottons; but even for a given cost, it is sometimes possible, by a combination of laboratory tests and inspired guess work, to select cottons which would give better quality of yarn and fabrics than others in the same price range.

Let's now take the example of the carding process and see how the technique can be applied. Several quality and process characteristics can be considered here, chief among which are (i) neps and quality of web and (ii) cleaning efficiency. These are found to depend on cotton, production rate settings, speeds and condition of machine. All of these factors have a bearing also on waste extracted at the process. The standards of acceptable quality have again to be determined from experience and experiments. Thus it will be found that production rate may be increased upto a certain maximum or waste level may be reduced upto a certain minimum without any adverse effect on yarn quality, and the machines can be set accordingly. One very important point has to be borne in mind here which is characteristic of most quality control operations, and is the basis of the SQC technique. This will be illustrated with reference to control on waste which affects the cleaning efficiency and neps in sliver. Let us assume that the required level of waste is 5 $\pm$ .5 percent set from technological considerations. If by a series of observations on a card working under invariant conditions of processing, we set the limits of natural variation at 5 percent and 6 percent waste, then no action need be taken if wastes are between these levels. If waste exceeds 6 percent or is less than 5 percent it may be assumed that some "assignable" factor has intervened to produce the departure from the normal pattern of variation. The cotton may have been changed and new standards may have to be set up. However, if cotton has not been changed, then we would be justified in taking the necessary corrective action e.g. changing relevant speeds, settings etc. which may have been altered.

In the example given above the natural limits of variation or the "control" limits for the process were conveniently taken to be the same (5.0 and 6.0 percent) as the "specification" limits. This, of course, does not always happen. For example, in the drawing process the control limits for the weight per yard of the outcoming product (sliver) may be found from statistical considerations to be 50 $\pm$ 5 grains, whereas from technological considerations the specification limits may be 50 $\pm$ 2.5 grains, if the final product (yarn) is to be reasonably uniform. If action is taken only when product quality is outside control limits, then obviously the final yarn quality will be unacceptable. It is no use also, if weight per yard of sliver exceeds 52.5 grains or is less than 47.5 grains, to take action and set the machine to give a lighter or heavier weight respectively since in any case, because of the natural variation of the machine for a considerable proportion of the product the sliver weight per unit length will be outside specification limits. The action in such cases becomes mandatory and consists of overhauling and correcting machine defects (mainly relating to rollers, roller weighting, draft distribution etc.) till the required precision in working is attained.

Other cases may arise when a process is in control, and the control limits are satisfactory as far as the range of variations about the mean is concerned, but the mean level itself is unsatisfactory. Such situations are of two types (i) where the correction can be made by routine adjustment e.g. where the weight per yard of drawing sliver can be made to conform to specifications by change of draft pinion (ii) where the corrective action is not so simple. The latter type of situation is quite common and is indeed the bugbear of the Quality control engineer. The quality control section cannot rest by determining whether quality is satisfactory or not; it must help in finding out the conditions of processing which will lead to best quality. It must determine by careful experimentation optimum backdraft, total draft, twist, settings, speeds, minimum tolerable roller eccentricity etc which will ensure the highest quality of product. The same general principles apply in weaving. For example, the quality control section should not only report that stoppages per loom hour have increased but should as far as possible indicate the causes for such working. These causes may relate to inferior yarn, bad preparation, change in size mixing, improper working practices such as bad piecings or knots and so on. It should also indicate optimum conditions of processing which will result in best quality.

The scope of Quality Control as envisaged here is a far cry from the old concept that Quality Control can be carried out by appointing a statistician who will collect data on waste and product quality and report these to management from time to time. It is the experience of the author that this is the surest method of making the function of Quality Control ineffective. For one thing this method of operation is sure to estrange the statistician from the production department chiefs who come to look upon the Quality Control section as a spy of the management. For another it soon degenerates to a frustrating routine of collection of ineffectual data and engenders a contempt for Quality Control on the part of the production people. Quality Control must be a production tool in the hands of the production people. Under the normal set up in most mills, the production departments do not have staff or facilities enough to keep a continuous check on important quality and process characteristics at various stages. Nor do they always have a precise idea of quality of cotton being used. They do not have the time or the equipment to experiment and to arrive at optimum processing conditions which very often are different for different cottons and types of yarns or fabrics manufactured. They cannot therefore always relate changes in product or process quality to specific causes. Indeed quite often they are not aware that changes in product or process quality have taken place until it is too late to do anything. It is the purpose of the Quality Control section to provide the production people with all this information and to act as their "eyes and ears".

Often the question is asked whether the establishment of a Quality Control section is economically worthwhile. The answer is an emphatic 'Yes'. A reasonably effective quality control section can be set up in a mill with a staff of seven or eight assistants and a Quality Control Engineer. The latter may either be a textile technologist with some training in statistical methods or a statistician with training in testing methods and a long experience of textile processing. The total monthly expenses on salary would be in the region of Rs. 3,000/- while the capital investment equipment would cost approximately Rs. 75,000/- The direct advantages of Quality Control would be manifested in improved and steady quality of products. Not only would precise information be available on existing quality characteristics at important stages, but warnings would be available when quality of processing or products is about to deteriorate so that timely action could be taken. Many other advantages would accrue in real terms. Taking a small example, an average mill (600 looms working 2 shifts on medium counts) may buy cotton worth more than Rs. 50/- lakhs per year. Even a small occasional saving on purchases of lots of cotton can amount to thousands of rupees per year. Similarly the saving of 1 percent of waste, which is generally quite easily achieved can save upto Rs. 50,000/- per year. Cutting down on rejects (fents and seconds) arising out of improved quality and continuous checks on process quality can also save the mill a very sizeable sum annually. The institution of Quality Control also often acts as a catalyst in toning up the general working of the department.

CANN'T AFFORD TO KEEP A COW!

A Tennessee distiller, on Christmas, sent a gift of whiskey to an improvident acquaintance who lived in a cabin up in the hills. The beneficiary and his family dropped in on the distiller toward the end of January, and intimated that if the distiller was so inclined, the family could use a little more liquor. "Aren't you rather overdoing things?" inquired the distiller. "It's been less than five weeks since I gave you a whole keg." .... "Well, Colonel," explained the hillbilly. "You got to remember that a kag of licker don't last very long in a family that cann't afford to keep a cow."

QC in Textiles

MS SRINIVASAN*

The consumers of textile goods in India are becoming increasingly quality conscious. The pattern of consumption also shows a trend towards larger offtake of quality goods. The consumer's choice of textile fabrics depends on many quality factors such as initial impression created, the price, utility and lasting properties. The psychological factors that influence the choice include the becomingness, fashion, sentiment and the reputation of the producers. In international markets too, the force of competition is determined by the quality superiority as between competing goods besides the element of price differentials. In this context both for internal and international markets, quality control in textile industry assumes high significance.

THE OBJECTIVE OF QUALITY CONTROL IS TO check unacceptable variation in the product and to keep it within stipulated standards by an integrated system of inspection and control at various stages or processes. Acceptable quality in products can be defined in terms of desired characteristics physical, intrinsic or serviceability. In the case of textile industry, quality can be defined in terms of certain basic elements: (1) physical appearance, uniformity of yarn and weave, smoothness to touch, density and (2) intrinsic and service values: chemical properties, lasting qualities, colourfastness, shrinkage proofing, crease resistance, mercerising, moth and insect proofing etc.

Besides securing quality, a quality control system achieves simultaneously two other results: (1) improvement in the performance efficiency by an integrated system of inspection and (2) routine control of works and defectives at different stages. The control is exercised over the contributory factors of raw materials to be worked upon, the atmospheric conditions, the performance of machines and workers' efficiency. Technically, the cause for poor quality are traceable to such factors as defective raw materials, incorrect specifications, poor workmanship and handling, wrong tools and equipment, defective machinery, bad design and time elements. The installation of quality control system to operate through the processes of production would not only increase productivity through improvement in work efficiency but also result in better quality. There is really no need to imagine that higher quality of output necessarily means expensive materials, labour and equipment. Best quality in finished product is achieved through a proper combination of material, labour, equipment and specifications.

Inspection, which is the primary medium in quality control technique, extends from raw materials through the processes to the end product. The quality of cotton maintains its influence through the entire line of production,

* Inspecting Officer, Textile Commissioner's Office, Bombay.

Once the programme of production is determined, the raw material qualities and quantities are to be decided upon correspondingly. The actual supplies of cotton are to be tested for spinning values and suitability. Instead of depending on the rough and ready methods of cotton graders, it has been possible to develop instruments such as balls sorter, baer sorter and gutter-webb sorter to examine the properties of cotton such as structure, strength, elasticity, moisture content, lustre and durability. These properties determine the spinnability values and from experience it has been noticed that particular fibre length properties in cotton are eminently suited for certain counts of yarn.

Sample testing to evaluate products at each process is to be arranged to ensure uniformity in quality besides eliminating defects before further costs are incurred. Samples of laps from the blow room, slivers from the carding process and the sliver ropes from the draw frames are to be examined and the inspection is to be carried through the slubbing, roving and drawing processes. Where any defects are noticed, it would be necessary to investigate and discover the causes such as wrong speeds, maintenance defects, spare part needs, stores and wrong-handling problems.

At the ring frames stage, it would be essential to have elaborate testing of yarn samples for qualities of count, evenness, uniformity and strength. Equipments have been designed to test the qualities of yarn; these include special yarn balance, hand wrap reel, uniformity analyser, and goodbrands lea tester. Though it may not be practicable to have elaborate test on all properties of yarn —viz. evenness, uniformity, tensile strength, elasticity etc— it should be possible to have tests for atleast uniformity and strength. As the weaving efficiency and fabric quality entirely depend on the yarn quality, the need for quality control to produce quality yarns can never be overemphasized.

In composite units, where most of the yarn is produced for internal consumption, the defects in yarns are not publicised. But they would nevertheless exhibit themselves as defects in the woven cloth. Cloth samples are to be tested for properties such as composition, weave, reed marks, defects in weaving, strength and weaving qualities. The standard type goodbrands machine is gaining in popularity with the textile mills. Besides this, other useful equipments include the wear and tear tester and the bursting strength tester. In many of the progressive mills, as an important part of fabric inspection, entire pieces of cloth are run at low speed, and weaving defects are noted and flagged.

Whatever defects escape the naked eyes at the grey stage, expose themselves prominently during the processing stages, and processing defects also aggravate the quality variation. Patches, discolouration, damages and holes make themselves visible after dyeing and processing.

It is the function of quality control to trace out the points where the quality has swerved from the standards and then have an investigation into the causes. The damages sustained by textile goods are classificable into three groups as mechanical damage, chemical damage and operational faults. Faults arising from wrong setting of machines may result in creases, rule marks, frequent breaks, and punctured holes. The chemical damage arises in bleaching, dyeing and processing operations. Operational faults arise from wrong speeds and poor maintenance of plant and equipment. Inspection procedures as a part of quality control programme are intended to bring about a coordination between the processes in maintaining quality standards.

Quality control yields definite economies in the form of savings from reduced number of defectives, spoilages and wastes. It helps to trace out the defects in products even at the processing stage and enables rectification and prevents further costs from being incurred on the production of defectives. Besides helping in securing better prices and profit margins, the system helps to minimise losses from delays and stoppages of machines for rectifying defects, and intangible looses such as customer's complaints and decline in morale of the staff because of frictions between the departments.

In the textile mills, the quality check on cotton ensures a proper supply of raw materials with good results in processing. The testing and checking of lap weights in the blow room, the card sliver for nep count, the wrappings in draw frames and fly frames, the yarn from ring frames are helpful in controlling the quality of process products and thereby result in standard products. The quality check of stores to eliminate defects such as vibrating bobbins, and poor quality shuttles in stores consumed in spinning and weaving operation would help in improving operating efficiency. Speeds of operation, correct setting of gauges, tension weights, pinion changes and the control of such other factors in running machines ensure uniformity in product quality.

The predetermination of control limits is a challenge to the statistician. A high degree of precision not only involves high costs of production but, it is not also a practical necessity in many cases. The limits within which the variations in quality can be tolerated are determined with due reference to the economics of quality control. The remaining phases of fixing schedules and conducting investigations are to be incorporated into the factory organisation.

The importance of quality control for Indian textile industry can never be overemphasised. There is *no need to labour under the feeling that higher quality always means higher costs; quality is the complementary part of performance efficiency* and it is always possible to have high quality consistent with low costs. The quality control technique yields benefits of high quality of products, better process control, improved reputation and sales for product, reduced raw material losses, failures and rejections, fewer production delays, improved processing efficiency and improved worker attitudes. Thus it is an excellent source of increased over-all productivity.

Two rustic sports were uncertainly flivvering their way home from the county seat. "Bill", said Henry, "I wancha to be very careful. Firs' thing y'know you'll have this car in a ditch."... "Me?" said Bill in astonishment. "Why, I thought you was drivin."

DCM System of Quality Control

THAKUR & RAMAKRISHNAN

The first step in the direction of Quality Control was taken by DCM in 1943 when they established a testing laboratory with a few instruments and a Research Advisory Board to guide its work. The advice given to the research staff by Lala (Sir) Sri Ram was significant: *"Study all problems in fields where practical and monetary advantages could be obtained easily and quickly"*. In 1946 the laboratory was enlarged and in 1952 quality control section was added to it. Now DCM is able to tackle its operational problems through SQC. There is practically no branch either of purchasing, manufacturing or marketing where in some way or the other the laboratory has not played its role by supplying adequate information for guiding the decisions on vital issues involving cost and quality.

THE FUNCTION OF THE TEXTILE RESEARCH laboratory is to spotlight deviations from standards and pinpoint areas where action is needed through analysis on the spot and periodical reports reviewing the progress. The head of the laboratory is responsible directly to the general manager and is on par with other production managers. He has in turn two senior officers working under him, one for quality analysis and the other for quality control and assurance. Each of the two officers has in turn three sections staffed with investigators, assistants etc. Under the quality analysis officer there is a pilot plant for grading of raw materials, a testing laboratory for inspection of raw materials, material in process and finished goods; also a process inspection division for collection of data on various characteristics that help process control. The main division of quality control has quite a number of functions: design of experiments; diagonostic studies; economic studies; process capability; analysis of data; statistical methods; sampling plans; training in SQC and development of new products. In the same division there is a section dealing with quality assurance: quality audit; reinspection of finished products; comparison of market quality level etc. Between the general manager, the production departments and the laboratory, the broad line of communication is that the laboratory submits directly to the general manager summary reports and recommendations involving policies and costs; and the general manager communicates his decisions on these matters to the production departments. But there is also a direct line of communication between the laboratory and the production departments which refer their problems directly to the laboratory. The line of communication for routine matters is between the officer incharge of the routine quality control and the section incharge concerned. All reports on quality control and special investigations are discussed on a monthly basis at the level of heads of departments wherein problems for special investigation on the basis of routine QC are decided.

The laboratory, however, operates against the background of standards which have been evolved on the basis of past performance and market requirements, taking into consideration the process capabilities. Committees have been set up to review these standards in the light of market trends and changes in process. The membership of these standards committees varies but it includes one or more of the superintendents of various sections: spinning, weaving, dyeing printing, folding, marketing, besides of course the head of the laboratory and the quality control officer.

The achievements of quality control cannot be measured in purely statistical terms. But a few instances may be given, such as a 50 percent reduction in one category of waste, a 10 to 20 percent reduction in process waste in another department; reduction of one or two processes in spinning preparatory with resultant doubling of productivity without any adverse effect on quality. Special diagnostic surveys have been carried out by the laboratory, and action taken on its recommendations has increased productivity from 93.4 percent to 98.0 percent.

"I'm sorry, Johnson, but we simply had to cut down on vice-presidents."

A BTRA Case Study

Member mills refer their day-to-day problems to BTRA (Bombay Textiles Research Association) on all items of mill work. These are investigated and reports thereon, embodying such suggestions for improvement as are feasible, are sent to the mills concerned. Some of these problems are of a general nature, while others are of particular interest to the individual mills. In order to make the results, obtained on the former type of problems, available for the benefit of all member mills, it was decided some time ago that these reports should be summarised and published as case-histories without mentioning the name of the mills. In implementation of this decision BTRA published a compendium, containing six case-histories of studies on Statistical Quality Control carried out in the mills by BTRA under the supervision of Dr MK Vagholkar, Statistician, assisted by Mr DS Borwankar, Junior Scientific Officer (Statistics) and their staff. The editor of this Journal had the opportunity recently of discussing with Dr. Nanjundayya (the man behind BTRA) the excellent work being done by this organisation in the field of Quality Control. One of their case-studies printed below would be found interesting and significant.

IN A MILL, ABOUT 10 PERCENT OF THE PIRNS, on an average, returned by the weaving shed to the winding department, contained unused yarn. In most pirns which were returned with unused yarn, 1/10th of the yarn was left as cop bottom waste. It was ascertained from the weaving master and a number of weavers that the main cause of returning partly used pirns to the winding department was that, there were excessive weft breaks while unwinding from the cop bottom. The snap studies for loom stoppages had earlier revealed that the loss in efficiency due to weft breaks was about 1.8 percent which was rather high.

Examination of the pirns showed a chase length of 2". This, being rather high, was thought as the probable cause of numerous weft breaks. It was, therefore, recommended that the performance of 1½" chase length might be compared with that of 2" chase length. On an examination of the diameter of the different rewound-pirns with a standard gauge, it was noticed that there were variations and the larger ones did not fit well in the shuttle. The three types of pirns of 30s weft, therefore, were collected for experimentation in the weaving shed. They were

1) pirns of 1½" chase length with standard diameter, 2) pirns of 2" chase length with standard diameter and 3) over-sized pirns of 2" chase length.

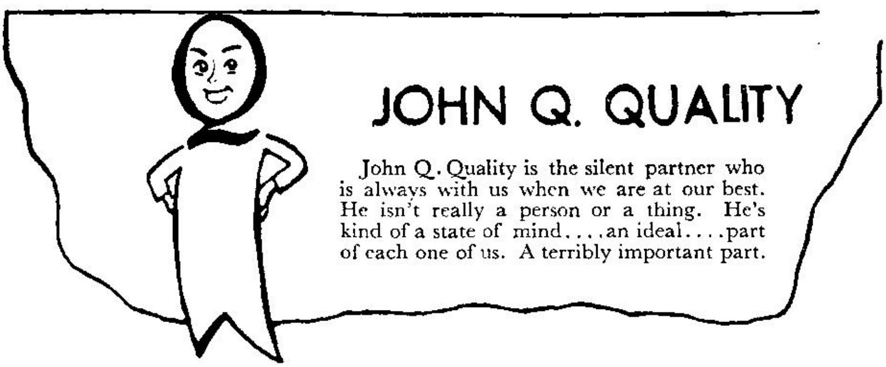
These three types of pirns were worked on four looms selected at random on three consecutive days noting down the number of weft breaks and the position at which the break occurred.

Pirns with 1½" chase length gave significantly less weft breaks than those with 2" chase length, pirns of both types having the standard diameter. Out of the over-sized pirns of 2" chase length, a small fraction gave too many weft breaks almost at the top. This led to the conclusion that among the over-sized pirns there were some which were excessively over-sized, and these were the ones that caused large number of weft breaks.

The following recommendations were made 1) a strict check in the weft-room might be kept so as to prevent the extra over-sized pirns from being passed on to the weavers. 2) 1½" chase length might be tried on a larger scale since the studies showed that this worked better than 2" chase length.

Pursuant to recommendation 2) stated above, a statistically well-designed experiment on a large scale was conducted, having introduced the pirns of 1¾" chase length in addition to those of 1½" and 2" chase lengths. Precautions were taken to keep only chase length as the only variable factor in the incidence of weft break. The experiment confirmed the previous conclusion that 1½" chase length worked better than 2" chase length and that 1¾" chase length gave the best performance. Chase length of 1¾" was, therefore, recommended instead of 2".

Subsequently, the mills reported that weft breaks were considerably reduced by implementing the recommendation, viz., employing chase length of 1¾" instead of 2" which had caused trouble. It would be seen from this case study how beneficial BTRA's investigation was to the mills.



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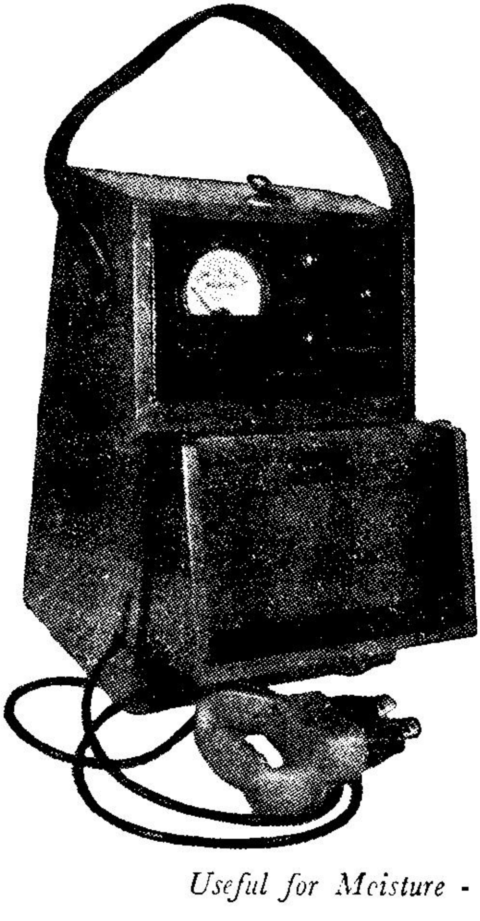

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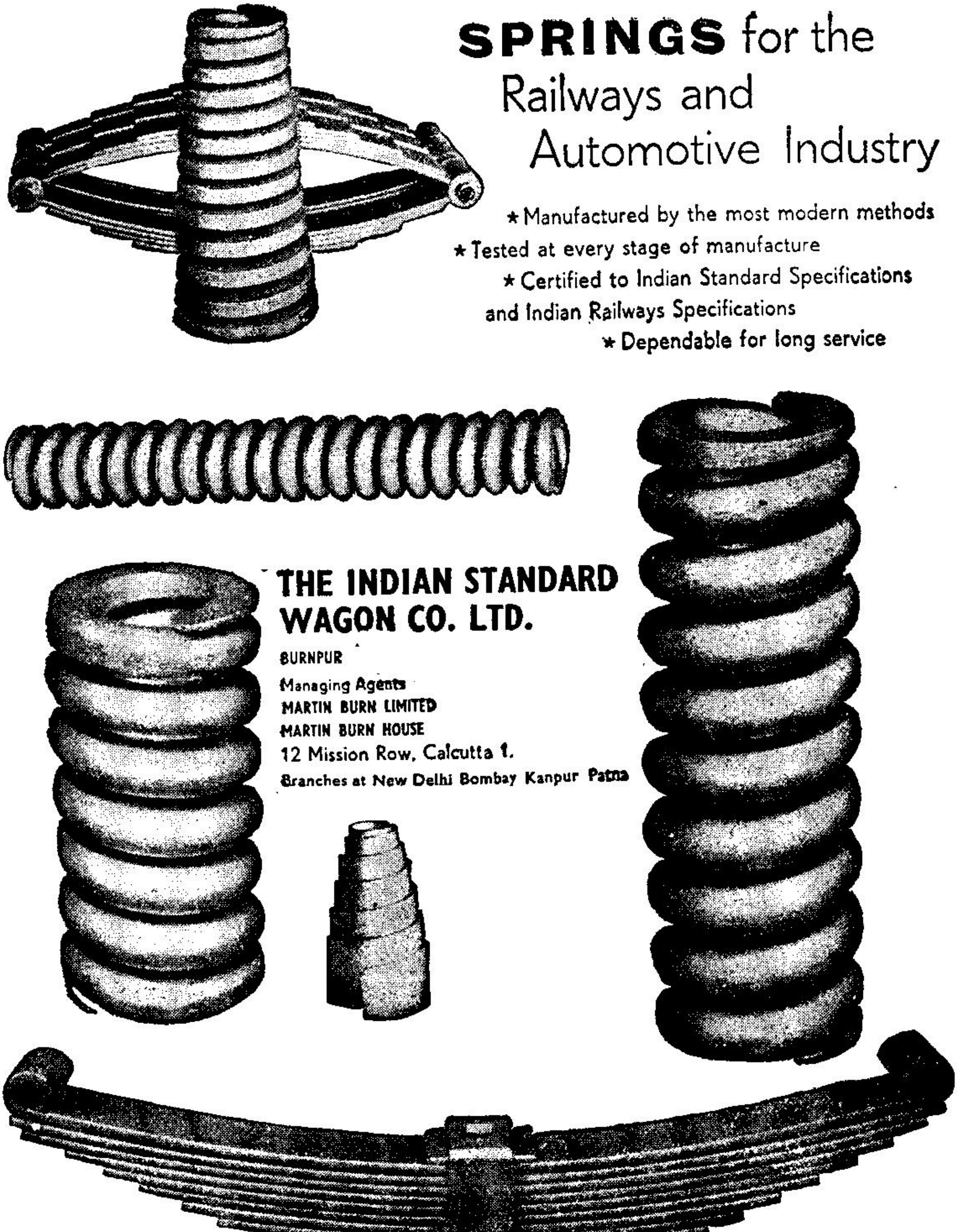

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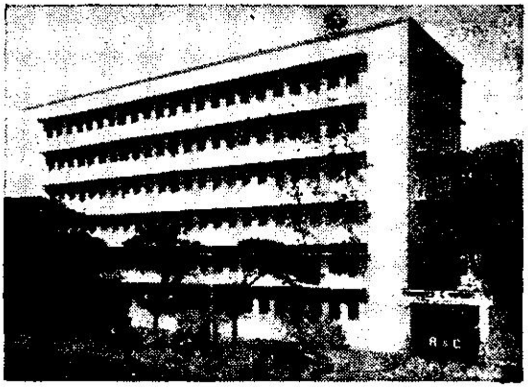

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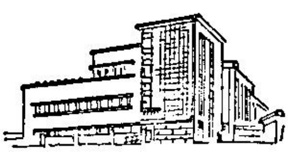

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SQC in JYOTI FOUNDRY*

KULKARNI, RAO and VARADACHARI

A foundry is really a multiple job system involving not only the usual three variables of men, materials and machines, but also a fourth variable: difference between jobs. This renders the task of SQC particularly difficult; yet this case study shows that considerable results can be achieved: in four months, the average percentage rejection came down from 20-25 to 11-12; and the overall foundry efficiency increased from 54 to 61. In the context of the development that is taking place in heavy industry, these results are particularly significant, for foundry is the basis of modern engineering industry. Further, modern mass production methods have created a demand for foundry products. SQC alone can ensure a continuous plan of quality products from foundries at reduced costs. This case study also shows the importance of operative skills and the need for training.

THE SQC UNIT, BARODA, WAS SET a question by the management of the Jyoti Foundry: "Is it possible to get everyday a minimum of 90 good castings out of every 100 castings made?" The Unit was rather sceptical because the rejection rates on some items were as high as 60 to 80 percent. It was not that the foundry was not doing good work or was incapable of improving its quality. In fact developments consequent on SQC showed that quality work was almost immediately possible. The unit started systematically grouping various categories according to rates of rejection. Those parts for which the rejection rate was high (more 30 percent) were taken up for immediate action. The information tabulated below speaks for itself:

Part	*Before Action* No. made	Rejection	*After Action* No. made	Rejection	Action taken
CTF_4 Shelter	77	83%	135	7%	Change of pattern
4" L_3 Impeller	22	70%	44	19%	Composition of sand changed
CTF_8 Body, CTF_{10} Body	34	30%	21	0	Change of Moulder
Starter Cover	50	78%	76	6.6%	Use of good boxes and correct pins

* The three articles published in this section on Foundries have all been received from the Indian Statistical Institute.

The SQC unit then proceeded on a somewhat firmer basis. In fact simultaneously a simple recording procedure had been set up for collection of data of castings made and rejection. A classification of the causes of rejection was worked out, and it was found that the largest number of rejections were due to tackle, pattern and certain miscellaneous causes. Attention to these major factors resulted in substantial reduction in rejection. Miscellaneous defects due to breakages in transit, handling etc were remedied by attention to MOULDER'S PSYCHOLOGY. In this, the technician played a crucial role. It was essential that he should have a fair amount of training in all branches of foundry work such as pattern making, moulding technology, core practice, cupola operation, etc. The question of relations between the quality control technician and the supervisory staff is important, for the former's function is not only to pinpoint the difficulties but also to convince the latter of the need of immediate attention.

Control charts are of course very helpful and can play a good part in the successful operation of SQC. In this foundry too efficiency charts are maintained, one on a weight basis, the other on percentage defective number basis. The efficiency chart on weight basis shows the trend of quality in heavy castings whereas the other shows the trend in lighter castings. The foundry then maintains weekly bar charts on each of the processes, metal, pattern, sand, moulding, core, tackle etc. These are intended to detect the processes which lack control for individual moulders/machines. Process control charts are maintained to keep the moulder informed of the work done by him. Besides there are job history sheets which are a permanent record of the actions taken, improvements achieved, giving information regarding machine, particulars of job, quality of work done in the past, nature and causes of defects etc. How useful these control charts are is proved by contrasting the usual analyses which we were making of carbon, silicon, manganese, phosphorous and sulphur in iron melted-byes, and analysis according to SQC techniques done subsequently. We have also now been maintaining sand control charts, for the permeability of and moisture in sand can affect the quality of castings.

Summing up we have obtained the following advantages from SQC: improvement in efficiency; reduction in rejections; improvement in quality; better coordination between different sections; increase in production; reduction in production cost; awakening of quality consciousness in the supervisory staff; improvement in labour morale; incentive to search for better methods of production; better human relations etc.

STAND CLOSER TO THE RAZOR

Sergeant: Private Doakes, did you shave this morning? Doakes: Yes, sir, Sergeant. Sergeant: Well, next time stand closer to the razor.

Statistical Quality Control in a Steel Foundry

PRAKASH NATH

The author has shown from practical experience how in the various sections of a foundry—raw materials, furnace, the foundry proper and the machine shop—the principles of SQC yield substantial results.

THE APPLICATION OF SQC TO THE PURchase of raw materials presented several interesting aspects. Formerly, we were accepting due to practical difficulties of supplies etc., practically all materials as received though we had the means of testing all consignments for relevant, physical and chemical characteristics. We had the test records but it was only SQC which enabled us to use them to our advantage, as for example, with regard to limestone.

Limestone is used as a flux in the manufacture of steel. There are two important characteristics: calcium oxide and insoluble matter. The quality of limestone is vitally important in steel making. For our works we require limestone containing a *high* percentage of calcium (minimum 45 percent) and a *low* percentage of insoluble matter (maximum 8 percent). On the basis of our laboratory test on the consignments of various suppliers, we found that a given supplier called B sent us consignment of limestone which on the average contained a higher percentage of calcium oxide and a lower percentage of insoluble matter. The price being practically the same, we decided to buy a major part of our suppliers from B. We have, therefore, found it profitable to keep a regular check on the quality of new consignments; hence we are able to get better basic slag than in the past and it has become easy to control sulphur and phosphorus below maximum allowable limits.

In the furnace section, there was considerable loss because the results of chemical analysis could only be known after the liquid steel had been made into ingots or castings. The application of SQC enabled us to control two important characteristics relating to manganese and carbon, as shown below:

	Carbon		Manganese	
	Average	*Variation*	*Average*	*Variation*
Before Control	1.36	± .36	13.00	± 4.2
After Control	1.25	± .20	12.25	± 2.2

Apart from the considerable reduction in variations, we found that the heats going out of specifications were, after control, only about half the previous figures.

In the foundry section, it is very important to have a control on moisture, permeability and strength of sand used for moulding purposes and the mould hardness. In an investigation it was found that the average for these charactertistics fluctuated widely from time to time. It was therefore decided to have a regular check. In addition to this, special studies were undertaken in the case of castings showing high rejection. A study conducted on one type of casting, in which there was high fettling cost and high rejections. A preliminary study to assess the situation gave about 22 percent rejection of which gas holes at the rim accounted for about 20 percent. In addition to this all the castings were found to be affected by fins (extra metal). Technical staff attributed this rejection to entrapped gases and it was decided to give more top vents. It was also expected that this would reduce the incidence of fins. An assessment study after the technical action revealed that there were only about 10 percent rejections and only 24 percent of the castings were found to be affected by fins. We are making further studies to improve the position. In the near future we intend to start sampling inspection at knockout stage and fettling stage so that the information regarding high rejection or high rectification would be available without much delay.

A brakeman, who used to be a chaplain in the army, asked me if I had seen the cannon they had just cast for West Point. I told him I hadn't. "How does it work?" "Well, it carries the biggest ball—"... "How does it work?"... "They shot the cannon off the other day but the ball was so large that it stood right still and the cannon went twelve miles."

Quality Control in a Foundry

Quality control in a foundry has the main object of reducing the rejection rate and supplying good quality castings to machine shops, both with respect to surface defects and dimensional characteristics. To achieve this goal, it is necessary to evolve an effective system in which information on quality of raw materials, of operating characteristics of sand, core, mould, metal etc., and of castings produced is collected, analysed and fed-back continuously to the foundry technicians, who would take corrective measures wherever necessary. While attempting to do this, a number of problems peculiar to Indian foundries crop up. These are discussed here with special reference to typical medium-sized foundries.

ONE OF THE ESSENTIAL FEATURES OF any good quality control scheme is an efficient feed-back system designed to minimise the time lag in the cycle of manufacturing, testing and correcting the process. It is here that a foundry poses its first problem. The delay between pouring and inspection varies from 12 to 48 hours depending upon the swiftness with which the knocking-out and sand-blasting operations are carried out. Fettling of castings may take additional time and some of the defects may be visible only after fettling. Machining of the castings may take place a few days later and information on blow-holes and cavities which appear only after machining will not be available till then. Further, many of our foundries are of a short-run nature producing a large variety of castings. The run lengths are usually so short that the job is over by the time the rejections are analysed and information fed-back.

Because of the short-run nature of our foundaries, it is often argued that control should be exercised process-wise as it is not practicable to do so on individual type of castings. Such an approach has paid handsome dividends in some cases but it has not been found to be adequate in a number of other situations. In the latter cases, although the many operating characteristics have been found to be alike, different types of castings are prone to different types of defects and rejections have been reduced only as a result of individual attention to the types giving poor quality performance. This, therefore, raises another problem, that of ensuring continuous vigil over the performance of individual types.

Before developing a system of routine rejection analysis and feed-back, it is found useful to conduct a pilot survey to locate obvious technical anomalies and eliminate them. This type of control, which does not depend upon any collection and statistical analysis of data before action is taken on the processes, may be termed as open loop control. In foundry, survey of this nature, conducted with the help of a foundry technician brings to light the moulding boxes that have wrapped or deformed, the bushes and closing pins that do not fit well and so on. Such defective equipment should be immediately ear-marked for repair or replacement which should be undertaken as early as possible. Pending this, sometimes it is possible to set apart the boxes in perfect condition for dimensionally critical castings, and the jobs not quite sensitive to mould box defects may be cast in the other boxes. It is also useful to examine the method of storing patterns and modify it if necessary to ensure adequate protection for the patterns against being damaged during storage.

It is not quite uncommon to find in many foundries that the patterns—(not prototypes)—are found to be defective only after they have been used to make castings which on inspection get rejected due to pattern faults. To obviate such a situation, it is advisable to introduce a suitable system of inspection of patterns before they are issued to the shop for use. This is purely an organisational matter involving setting up of a suitable agency for pattern inspection and repair and designing a convenient pattern inspection form to systematise the procedure.

Most of the foundries have a laboratory where moisture, permeability and compression strength of sand and physical and chemical properties of metal are tested on a routine basis. Rarely however one finds that these test results are viewed with the seriousness compatible with the expenditure incurred in carrying out the tests. This is perhaps due to the fact that it is almost impossible in routine practice to correlate the sand and metal characteristics with the rate of rejections ; it is also true that other factors, such as condition of patterns, quality of equipment, moulding and pouring practices, temperature of metal at the time of pouring, gating practices etc., are so very predominant in affecting the rejection rates that the effect of variations in sand and metal characteristics from the standards is difficult to assess.

Under such circumstances the only positive attitude towards these tests in a quality control programme appears to be to take it for granted that control over sand and metal characteristics is a part of good foundry practice and it should be exercised in the best possible manner. Once this principle is accepted, statistical control charts prove to be the best way of inter- ng the test results for action.

Other things remaining the same one of : characteristics which is found to have important bearing on the quality of the :ings is 'mould strength.' Control charts averages and ranges serve as a useful of the performance of the process and ive been found to be particularly helpful in maintaining specified standards at machine moulding. Although the control charts at hand moulding cannot be operated in the conventional way in the sense that remedial measures are difficult when a point falls outside the control limit they have been found to be very helpful in keeping the moulders informed of their performance in relation to the desired standards.

Again, a good many of the defects could be eliminated if steps are taken to see that only good cores are supplied to the moulding section. If a control chart for fraction defective is installed at the core making section and results of sample checks of cores plotted on the chart operatorwise it will help to show up operators giving significantly worse quality and then suitable remedial measures can be planned. When the number of operators is large it may be uneconomical to keep a large number of control charts. In such cases it may be better to keep 2 or 3 control charts for broad groups of cores but the data may be kept operator wise and analysed periodically for operator differences.

The purpose of inspection is not sorting good castings from the defective ones. It is to provide a closed loop control in which data are collected, analysed and the most vital information is fed-back which in turn is used to improve the process. In many foundries, the technicians have a standard chart showing the types of defects that could arise due to various operating factors such as pattern, equipment, sand, metal moulder etc. According to this chart, there are about 100 different ways in which a rejected casting can be classified. This method of classification of defects though praise-worthy for its technical elegance, is too unweildy to be used on a routine basis. Depending upon the past experience it is always possible to prepare a list of about ten important and unambiguous defects which commonly occur in a particular foundry. The castings, after knock-out and sand blasting, are inspected carefully and the defectives are classified according to such a list.

The inevitable delay between production and inspection, the short run lengths of the jobs cast, the need for keeping watch on performances of individual jobs and all such factors lead to the conclusion that some provision has to be made for permanently recording all the relevant particulars of each of the jobs cast in a foundry. This is sought to be achieved with the help of a job history card on which is recorded the nature and cause of defects found, both in foundry and machine shops, actions taken, improvements achieved and so on. The card also gives information regarding men and machines used and serves as a necessary guidance for future work. Along with the job history card, it has been found useful to keep another card showing the standard practices adopted for casting the job. These practices include specifications on moulding and core sands, the types of boxes to be used for moulding and the moulding machines to be used in the order of preference. A rough sketch of gating practice recommended is also given. Any change in future in the standard practices is recorded on this card. Thus, a job-history card together with the standard practices card provides a permanent and continuous record of all relevant data for each of the jobs.

Daily after completing the postings on job history cards, the rejections for the day are compared for each of the jobs with the previous cumulative evidence available on the cards. The cards for jobs which have shown abrupt deterioration over their past performance (after a statistical test for significance) are picked up and a special bulletin—named *Red-list* items report is prepared for the foundry technicians to take immediate action.

Sometimes a particular type of castings may be subject to heavy rejections and special efforts are required to reduce rejections. A very useful first step in such cases is to divide a casting into a few homogeneous zones on the basis of technical considerations and obtain the incidence of defects zone-wise in a two way classification may be that there is heavy incidence of core cracks in zone C and crushed mould in zone E. Other defects do not appear to be important. It may now be possible for the technical people to visualise why core crack and crushed mould invariably occur in zones C and E respectively and plan suitable remedial measure. This approach is particularly useful in the case of large and medium type castings.

By far the most important role that a job-history card has to play in the short-run type foundries is in helping to plan for quality in advances. Every week-end when the production programme for the following week is available, the job-history cards for all the jobs scheduled are scrutinised. The cards of the jobs which have poor quality history are picked out and the precautionary measures are decided upon at joint meeting of the foundry technicians concerned. Actions are taken wherever possible and in other cases the technicians are prepared *a priori* for high rates of rejections and this helps them make additional provision for cores and moulding capacity. In this way planning for production and quality go hand in hand with the help of the job-history cards.

control charts on percent rejection

The p-charts maintained on daily percentage rejection provide an excellent method of pictorially viewing the foundry performance on a continuous basis. The steady improvements brought about by a successfully operating quality control programme shows up on these charts as a downward trend in percent rejection. When the rejections are brought down at a satisfactory level, the statistical control limits on the p-charts become really helpful in detecting an overall deterioration in the performance over the standard achieved. To achieve closer controls, it is often helpful to group the castings into three or four homogeneous groups and maintain separate control charts for each group. This is because in a foundry producing a large varieties of castings, the overall percent rejection is likely to be affected by the relative proportions of different types of castings being produced.

The problem regarding the dimensional

characteristics in foundries is usually concerned with the provision of machining allowances on the castings. Sufficient care is usually exercised in this regard at the time of making prototypes. However it is not an uncommon experience to find that the castings weigh much more than the standards calculated originally. In addition to creating trouble during machining, this also makes the finished product heavier than desired. To obviate such a situation, it is necessary to systematise the prototype inspection and also to make it a routine practice to examine a random sample of (say) 10 different types of castings for machining allowance every week. In this way, the wear and tear of patterns if any and the variations in core dimensions would be continually detected.

Perhaps, a foundry is an ideal place for investigations to improve the quality of its products. It is surprising however that in foundries not much work in the field of statistical experimentation has been recorded, particularly in this country. Some of the areas in a foundry where statistically designed experiments can be fruitfully carried out, are listed below.

(1) Developing specifications for moulding and core sand (2) Studying the effect of laddle-additions on specified types of castings (3) Developing gating practices best suited for particular job (4) Fixing optimum temperature for pouring (5) Developing metal composition to achieve desired physical properties (6) Optimum conditions of annealing.

I may truly say that I owe much of my success in life to this inward craving, this constant yearning for something better.... I am in favour of anything and everything—of temperance and intemperance, morality and qualified immorality, gold standard and free silver. I've tried all sorts of things and that is why I want to try the great position of ruler of a country. I have been in turn reporter, editor, publisher, author, lawyer, burglar. I have worked my way up and I wish to continue to do so.

—From Mark Twain's Speeches

...YOUR PROBLEM GIVEN
DELICATE, LOVING CARE BY
OUR STAFF OF SKILLED EXPERTS...

SQC at the Sarabhais

Kanak R Ravel*

The Sarabhai Chemicals started a regular programme in SQC with the help of the Indian Statistical Institute at Baroda in May 1958. A pilot survey indicated the potential of SQC in the following directions: the use of scientific sampling procedures for incoming and outgoing materials; the maintenance of uniformity of dosage of medicaments at the desired standards by installing proper inspection and control chart procedures; minimisation of the incidence of rejection on various operations; above all, the designing of appropriate experiments in research etc.

In the first instance, the SQC unit helped us in the orientation of staff in the principles of quality control: then they helped us in the collection and analysis of the necessary data. We have regular monthly meetings in which the works manager, production manager and chief of quality control sit down with the representative of the SQC unit and review the past month's activity. The results have been so encouraging that we have set up a permanent SQC section. The control chart techniques have been applied to (a) the filling of ointments in collapsible tubes (b) capsule filling (c) cost control etc. Not only have the applications been successful but also rewarding in a number of ways, because our medicaments are costly, patent, of small dosage and the quality specifications are fairly stiff. Statistical sampling procedures and control charts for defectives have been used in respect of (a) antibiotics vials (b) strip packaging (c) raw materials etc. We were experiencing considerable difficulty with regard to vials of domestic manufacture; hence we arranged a conference with the manufacturers' representatives, who met our quality control and manufacturing experts. At this conference, defects were classified and a suitable sampling plan taken from MIL-STD 105A was adopted. Further it was decided that the supplier will maintain SQC charts on the properly identified consignments supplied to us and we in turn will subject them to statistical sampling and inspection treatment and feed them back the data we get.

In strip packaging, we found in the case of our fast moving products that the average rejection rate amounted as much as 6 percent. Through causewise analysis followed by appropriate action, the rejection rate was brought down to 3 percent. After strip packaging, the strips are attached to catch-covers by heat sealing. Here also, there was an overall rejection of over 4 percent. This has been brought down to 1 percent. The efficiency charts technique has through very simple adjustments enabled us to reduce the rejection rate of bottles for liquid filling to 0.5—1.0 percent, compared to 6.7 percent bottles being rejected due to caps getting torn and re-working of 8.9 per-

* Sarabhai Chemicals, Baroda.

It is obvious that the establishment of standards and the construction of Control Charts for the processings described above would present problems of a somewhat unusual character, also their filling and packaging ; yet this Firm has succeeded in applying SQC principles, gaining substantial advantages therefrom. By controlling excess weight as well as number of tablets, the *Hamdard Dawakhana* has achieved a saving of Rs. 20,000 per year on one type of tablet only.

So we tried it . . . on the dog

Recently a new product was brought up to Macy's Bureau of Standards for testing—called "Doggie-Co. 'Way-Kwik" or something like that. Pretty obvious what it was.

With our myriad of retorts, reagents and Bunsen burners, we could have easily enough analyzed this product, and come up with a weighty report that it contained so many mgs. of HCHO, a well-known dog-repellent according to such-and-such sources.

We tried it on a dog.

The dog loved it. He wallowed in it. He lapped it up. So we rejected it. True, may be one dog doesn't make a Summer, so to speak, but we don't think you want even one dog wallowing around in your "Doggie-Co. 'Way-Kwik."

Macy's Bureau of Standards has as many machines, as much scientific know-how as the next fellow. But fundamentally it knows you aren't going to use a rotary motor on your pillows, a breaking machine on your Nylons, a Fade-O-Meter on your curtains. We've got wind and water machines for testing umbrellas, but we leave a few out on our roof to see what soot-covered rain does to 'em. If a customer complains that her pressure cooker gave her potatoes "a funny taste" we cook potatoes in the cooker and eat them. We've even been known to slather on mosquito repellent and seek out wild and wooly mosquitoes in their own habitat just to make sure our product Had Something. And one of our men is still trying to get lint off his walls that accrued from a somewhat dubious paint roller.

Better lint on his walls than on yours.

There's more than one kind of thrift, more than one way of skinning a cat, more than one way of saving money. Macy's Bureau of Standards is concerned, not with "how little do you pay ? ", but with "how much do you get ? "......

SQC IN CERAMICS*

From several points of view, the Ceramics Industry in India is probably one of the most promising fields for SQC. The Indian Statistical Institute is, therefore, to be complemented on including this area for the application of SQC techniques. The characteristics of quality in ceramics being mostly visual, it is a field in which SQC techniques have to be applied to inspection itself; and the compulsion of economic circumstances is pressing for the application of quality control to the line. Though it has so far been a protected market due to foreign exchange restrictions and a good seller's market due to shortages against the background of sharply increasing purchasing power, particularly among low-income groups, domestic competition is likely to emerge as a serious factor in which quality producers are bound to earn a large premium and low quality goods might well rot on the shelves. On the other hand, there is the excellent prospect of capturing neighbouring markets, if we can produce goods of quality. A complicating factor is the small size of most manufacturing concerns in the line.

SOME OF THE RESULTS ACHIEVED by SQC Units of the Indian Statistical Institute are really remarkable. In a period of 18 months, a Ceramics factory manufacturing potteries and electrical items was able to effect a 40 percent increase in output at the biscuit kiln alone. Systematic maintenance of data at different stages of production, reorganisation of inspection etc., enabled the factory to increase its overall yield of marketable quality by 10 percent. The rejection rate which for six items ranged between 11 to 27 percent before SQC came down to between 2 to 15 percent then after; and the methods employed to locate and remove defects were pretty simple. In some cases, the dyes used for pressing were repaired or changed; or a few alterations were made in the method of pressing. Some unexpected economies were achieved alongside improvement in quality. A reduction, for example, in the kiln temperature in a particular zone by 35°C improved not only the quality of finish but also saved the management a good deal in the cost of fuel. Reverting again to marketable quality; while the percentage for various items of manufacture before SQC was between 57 to 79 percent, it went up after SQC to between 65 to 90 percent; and what is still more significant the whole of the demand curve in 1961 shot up not only at a few points but was lifted bodily over the whole range of demand for 1960. It is thus obvious that the efforts of the Indian Statistical Institute in the line have yielded high dividends; hence an analysis of the industry from the SQC point of view would be valuable.

Most of the defects which make an item unacceptable relate to attributes visual in character, eg cracks, warpage, glaze defects. The sorters are likely to differ among themselves in their decisions unless specifications of acceptability have been established in advance for each of the defects and the *sorters have been trained to* adhere to these

* Indian Statistical Institute.

specifications. For example, in the sorting of insulators by two different groups of inspectors in the same company the rejections were 45 and 30 percent respectively. *When these sorters were interchanged the rejection rate changed to about 30 percent in the first unit and 45 percent in the second unit!* Such large differences would naturally result in the quality received by the customers being highly variable. A quality assurance scheme should prevent this. Quality assurance schemes would, incidentally, also provide for *feed back of information* for improving the quality of manufacture and thus increase the proportion of acceptable products.

The first step in the installation of a good quality assurance scheme would be to establish well-defined specifications of quality and to instruct and train the sorters to inspect to these specifications. For each type of defect samples of the worst among the good and the best among the bad can be kept and the sorters encouraged to refer to these in cases of doubt. The second step would be to inspect thoroughly a few randomly chosen items from the sorted products at regular intervals for all possible defects against a check off list and record this information in a suitable data sheet. Statistical analysis of the data so collected on about 500 pieces would indicate the current quality of the sorting as also the direction in which quality improvement efforts may be most usefully expended as for example, better training of sorters especially for discrimination in respect of warpage.

Along with appropriate remedial measures suggested by these conclusions the third step would be to develop a *demerit score for the observed defects* depending upon the *importance and the intensity of the defect* such that the demerit scores for individual items would follow a predictable pattern when assignable causes do not operate at the sorting stage. This can be achieved from technical considerations either by trial and error or by the use of more sophisticated statistical techniques like *discriminant functions*. Thus each item examined will receive a demerit score depending upon its defects. This will be an objective measure of its quality: the larger the score the worse the quality.

It would now not be difficult to develop a control chart for average demerit. The charts can be maintained by plotting the averages of the scores of a sample of 4 or 5 pieces. In the case under consideration, the average demerit at the beginning was 9.3. After the scheme was in operation for 6 months the average demerit score had come down to 7.5 indicating an improvement of about 20 percent in the outgoing quality.

process control

In the ceramics industry the cost of firing constitutes the major element of cost. The scrap after firing cannot be recovered or reworked. The management would naturally be interested in maximising the recovery of acceptable products from the firing. The quality assurance schemes described above are of some help in this direction. Further improvements can be obtained by process control. A piece which is defective at the green stage cannot obviously come out as a good one after firing. It is, therefore, essential to ensure that only good pieces are passed from one stage of manufacture to the next, so that ultimately only *good green pieces are sent for firing*. Installation of number defect control charts have been found to be extremely helpful towards this end. Some of the stages where such charts may be maintained on a routine basis are releasing from moulds; finishing; joining operations; bisque sorting; stamping; and decoration.

As an illustration of the process control programme a procedure for maintaining control chart at releasing stage is discussed below. Similar procedures, with appropriate adjustments, can be applied at most of the stages enumerated above. Suppose there are 5 dryers; corresponding to each, there is a set of workers who are moulding same or different types of wares. After completing a drying cycle the pieces are released from the moulds by a worker whose function includes rejection and rectification of pieces depending upon the nature and intensity of certain visual defects. In order to ensure that only good pieces are sent on the next stage it is essential to maintain a strict control on the number of defective pieces passed by the releasing operator. For this purpose a system of patrol inspection on the outgoing product would be most effective. After enough data has been collected through systematic petrol of inspection it would be possible to analyse the currency performance and take appropriate remedial measures if the situation is unsatisfactory. After the situation has been remedied a number of defective chart can be set up with appropriate standards and suitable sample size. When once standards have been established it would be better to have one control chart for all dryers making similar wares. If the chart shows lack of control analysis of the data pertaining to the corresponding period can be made with a view to locating the defaulting dryer. The data accumulated over a month can be summarised and discussed at a monthly staff meeting for purpose of coordination. The above approach is useful for controlling the defects occurring at all the prefiring stages. Both glost firing and decoration firing introduce some defects and these also have to be reduced.

control of scrap

From the point of view of economy it is very important to keep down rejections at the firing stages, because by then, practically *all the elements of cost will have entered* into the product. At the pre-firing stages the scrap can be reused; but nothing can be retrieved if a piece turns out to be a rejectable one after firing. The seriousness of the problem may be realised from the fact that post-firing rejections have been found to vary from 15 to 45 percent for various types of wares.

Some of the important causes of rejection at the firing stages are crack, dunt, warpage, chip, spot, glaze defect, stuck, grog, firing defect, etc. To reduce rejections, the first task is to assess the relative importance of the various causes. For this, systematic record has to be maintained on rejection classified according to cause. For some types of products, eg, large sanitary wares, it will be useful to record also the *position of occurrence of defects.* The data accumulated over a period of time may then be analysed to *rank the causes* according to their contribution to the overall percentage of rejection. On the basis of the information thus obtained actions have to be taken starting from the causes which are more serious or which are easy to eliminate.

It has often been found that rejections due to some of the causes, like chip, glaze defect, stuck, grog, etc., can be *substantially reduced by improved supervision alone.* For example, chippings may be reduced by ensuring more *careful handling;* stuck and grog can be reduced by ensuring stricter adherence to the loading norms. For such causes as warpage, dunt, crack and spots technical actions of a more fundamental nature may have to be taken either at the kiln or at the back processes.

A prominently displayed graphical presentation of the causewise analysis of the daily rejection percentages has been found to be effective in creating awareness and better objectivity among the production assistants. This may be done in the form of bar diagrams with different shades or colours used for various defects.

Though the problem of rejection at green stages is of lesser importance from the cost aspect, it creates serious difficulties sometimes. Excessive rejection at pre-firing stages may result in under-loading of kilns and create imbalance in the production schedule. One of the most important causes of rejection in the green stage is occurrence of cracks, during drying. Cracks may develop from a variety of causes attributable to the operator, machine or the material. Special studies can be conducted to pin-point the real cause so that appropriate remedial actions could be taken. In this connection, two illustrations may be cited.

A pottery was manufacturing a certain type of bowl but was falling behind in its supply commitments owing to a very high rate of rejections at the green stage. Production records showed that about 45 percent of the pieces moulded were developing cracks during drying. Systematic data was collected over 3 days and analysed. It showed that (a) there was no operator difference in respect of rejections (b) of the 45 percent cracks, more than 40 percent were occurring at the centre of the pieces. When this information was given to the production in-charge, he immediately suspected that this may be due to use of blunt profile cutting tool. Steps were taken to ensure that blunt tools were not used and thereafter the percentage of rejection came down to about 7 percent.

In the manufacture of stone-ware cups it was found that rejection due to cracks which developed at firing was of the order of 20 percent. Data was collected in a way so designed as to show separately the effects due to preparation of clay, moulders, drying and firing. The existing variation in all the factors other than the moulders did not show any significant effect on the incidence of cracks. There were 3 moulders, drying and firing. The existing variation in all the factors other than the moulders did not show any significant effect on the incidence of cracks. There were 3 moulders and there was significant differences among them. Only about 9 percent of the cups made by two moulders needed to be rejected due to cracks after firing, whereas about 40 percent of the cups made by the third moulder were rejected for the same cause. This moulder was studied and his method of moulding corrected resulting in a reduction of rejection due to cracks by about 10 percent. Similar trouble shooting studies have been found to be very helpful in reducing the bottlenecks at the different stages by reducing scrap and rework.

special investigations

Quite often special investigations are necessary to study some aspect or other of the quality. Such studies would benefit considerably if based on statistical design to experiments and correlation analysis. For example, one enterprise is trying to manufacture a certain type of light crockery. Obviously there must be some relationship between the weight before firing and that after firing. The first step would, therefore, be to obtain a measure of this relationship by means of regression analysis. There will be some variation in the final weight of the pieces even if their weight before firing is the same. The best equation depicting the relationship between the weight before firing (x) and the weight after firing (y) for the above data is found to be $y = -7.66 + 1.00 \times x$, and the variation introduced by the firing operation is $\pm$ 5.88 units. If this is considered large from the technical point of view steps should be taken to improve the glazing and firing operations. If not, controls should naturally be placed at moulding or casting. There is need then to decide at what levels the several factors like density of slip, setting time, have to be kept or how the moulding operations have to be performed. The next step would, therefore, be to consider the factors responsible for the variation in weight at the green stage and to determine their magnitude. A suitably designed experiment would show up the best levels at which these factors may be controlled to obtain the optimum results. Similar studies can be carried out for determining the optimum operating conditions at the kilns and at the slip house.

There are many areas of management interest other than those described in the preceding paragraphs, that would benefit by a statistical approach. For example, it is necessary that the value of the average daily recovery after final firing should not be below a certain level for the company to make reasonable profits. The management would like to get a running picture of the extent of fulfilment of these target and a chart for daily index of recovery can be maintained on a routine basis. When the charts are first introduced it is sometimes found that the targets are not being maintained and there are wide fluctuations from day to day. Usually this has led to better co-ordinated efforts to improve the loading because of the keen interest shown by top management.

I HATE TO BE INTERRUPTED

Rabbi Wise of Chicago was scheduled to make a speech during a great labour controversy. He received many insulting letters, some threatening letters, and several even threatened to shoot him if he made the speech. So to illustrate the point that speakers must have courage, the Rabbi started his speech by holding his hands aloft and said, "If anybody in this crowd intends to shoot me, I wish he would do it now and not wait until after I get started because I hate to be interrupted."

Scratching More Profits

MK Vasuraj

The author has shown the valuable results obtained by the application of SQC principles to his own particular line coated abrasives. Manufacture of coated abrasives, on a mass production basis, is a highly specialised process. So many variables are inherent in the making process that adequate control of uniformity is extremely difficult. If the producers are to reach their goal of capturing a large share of the coated abrasive market, it is imperative for them to apply certain techniques like Statistical Quality Control to obtain high quality products at minimum cost.

OUR DIFFICULTY WAS THAT WE HAD RELIED largely on what might be called *educated guesses*. Unsatisfactory products produced were rejected after manufacturing time had been spent on them. Semi-faulty material had to be either corrected or reworked, which meant extra cost, and 100 percent inspection—a procedure which is costly and seldom entirely satisfactory. Any curative action was possible only after the trouble had arisen. We therefore decided to apply the scientific methods of SQC, as described below:

Spot checks are made by Quality Control Inspector during manufacture to maintain the correct adhesive viscosity, temperature, weight of grain and adhesive and the percentage of moisture etc. Apart from these checks during the different stages of manufacture, Quality Control carries out performance and other tests on finished goods for quality determination. After careful study of the manufacturing process and analysis of the inspection data, control charts were put up to control the important variables during manufacture and to study the quality trend of the finished product.

Of the three components of a coated product, the most difficult to control is, undoubtedly, the adhesive. This is applied hot and, in order to ensure that its temperature and, more particularly its viscosity, does not vary, it is constantly pumped through a system of pipes connecting the adhesive trough with a heated reservoir. As the coating machine operates, the temperature and the viscosity of the fluid vary with consequent variation in adhesive qualities. We were able to control these variations with the help of SQC techniques, particularly through control charts.

The results of the application of SQC were substantial. We were able to get out products of better and more uniform quality. In the past, we had found it advisable to put in extra raw material just to be on the safer side of specifications; nevertheless, the quality was unsatisfactory so that we lost at both ends. Test data on the finished product showed us conclusively the improvement in quality. The average for wear of the abrasive had lowered and the variation fluctuated between narrower limits. In our case, most of the tests on the finished products are destructive. SQC has enabled us to economise on the samples by nearly 40 percent.

One of the greatest savings that can be made through quality control is in connection with scrap. Our accounts department tells us the annual scrap cost for the company. The inspection department is provided with a printed form giving the different kinds of defects that are caused during manufacture. The rejects from each lot are analysed and listed separately in the appropriate column. If any defect shows outstanding rejection it is likewise controlled by intimating the department foreman concerned to take action, who in turn sets up methods and ways to correct these causes at its origin. I should have mentioned it earlier that the incoming raw material is also tested by drawing samples from small lots and testing them for different qualities, alongside a master sample of our standard material. We have also been able to effect a reduction of 85 percent in the re-working cost through the application of the principles of quality control.

Mr. SHAKESPEARE WROTE THE BIBLE ?

"Does Mr. Shakespeare live here?" No, sor. I think he be dead." "Well, do many people come to see his grave?" "Oh, yes, sor." "What did he do to make these great crowds visit his house and the church where he is buried?" "I've lived here all my life," said Hodge, scratching his head in great perplexity, "but I don't know exactly, but I think he writ something." "Well, what did he write?", "I think," said Hodge solemnly, "it was the Bible."

SQC at the TEXMACO

NP Basu

This firm has been particularly lucky in the intake of SQC as it had the good fortune of the direct advice of Dr Pabst, who himself suggested a couple of experiments, when the firm was in difficulty regarding the breakage of spindle blades, while in operation. It is interesting in the retrospect to recall the small beginnings of SQC in Texmaco, when in the first instance a clerk was appointed to take two-hourly snap reading. Rapid progress was made till standards for all the machines in the different departments were established. The idea of SQC as a tool for controlling the quality of products gradually began to take shape with the firm's membership in the SQC Unit of the Indian Statistical Institute.

To start with, the technicians from the SQC unit conducted various experiments on our different problems. Real difficulties were caused due to the attitudes of inspectors, operators and production supervisors, mainly because of ignorance about the subject. As a first step, the SQC assistants in the factory and the SQC unit's technicians took up the job of explaining the aim and utility of SQC to the operatives. As we progressed, certain very useful studies on production processes were made which created some interest in the subject in the minds of the staff and operatives. Soon we began to achieve results. We were able to reduce the percentage defective in the Single Flang Ring by about 10 per-cent and attain a steady quality of the product.

The results were so satisfactory that we decided to establish a fullfledged SQC department and integrate the inspection department with it. We also sent out a technical assistant and a chargeman of the inspection department for training in SQC. When we got the trained hands we began the maintenance of control charts which reduced the workload on final inspectors, who could now be utilised for SQC work. Control charts also helped the operators and particularly the piece-rate workers to produce more good articles and thus increase their wages. They realised that control charts always helped them to know the instantaneous position of the production process, so that action could be taken as soon as any defect occurred.

SQC techniques have been particularly useful in improving the quality of a number of components that enter into the Ring Spinning, Frame manufactured by the firm. For instance, in roller leather, the percentage of rejection has been reduced from 6.4 to 1.9 per-cent, the average eccentricity having through SQC techniques fallen from 0.0023" to 0.0016". Texmaco has felt so much encouraged by the successful application of SQC techniques that it was decided to extend SQC to the Jute machinery section and the CI foundry.

A Case Study in Sewing Machines

SUBIR DATTA

This is an extremely interesting case study, based on the actual experience of the Jay Engineering Works. It is a telling commentary on the reliability of 100 percent inspection. It shows how with the *application of SQC principles to inspection itself*, this firm was able to effect a very considerable reduction in rejections, alongside a substantial improvement in consumer satisfaction.

IN JAY ENGINEERING WORKS, ALL MACHines assembled were inspected on a 100 percent basis by two groups of inspectors: sound testers and stitch testers. The return percentage was as high as 35 percent; hence the management was naturally anxious to enquire into the reliability of inspection, as it was not based on any measurement but was determined by personal judgment. An inspectorwise analysis showed a range of 10 to 30 percent return of machines from this very same flow, on grounds of defects in sound. In case of stitch inspection the return percentage varied from 1.5 to 10 percent. The next step was to split the total return according to different causes and compare the inspectors within each of the causes. This study enabled the setting up of standards for acceptances and rejection and listing the order of inspection for different forms. The setting up of standards was a different engineering job but ultimately with the help of a team of technicians, two machines were selected which could be considered just passable or just rejectable, for each of the major defects. These constituted a sort of standard machines, which were, of course, replaced at certain intervals because standards tended to change. The check list on the other hand ensured that inspection was done in a systematic manner and that the same machine had not to return to the assembly line for one defect, then another and so on. The company also found that the inspection work was best done under conditions of specialisation. Formerly, the inspector was himself a repairer on a small scale. It was also decided to have a sampling inspection of minor defects on a proper basis.

The *systematisation of final* inspection was, however, only a part of the problem considering the whole factory. Data now obtained were reliable enough to be fed back to the process. So intensive study in the form of dimensional control was taken up for some of the key components in the machine shop and in the assembly. The results speak for themselves: within six months, the average weekly return from sound test inspection came down from 15 to 5 percent; and for stitch test, from 22 to 14 percent.

BACKLASH SLIVERS

T Bose *

This paper presents a case study on the procedure and results on an experiment undertaken jointly with Indian Statistical Institute under Prof. ER Ott, to study the causes and means of eliminating or reducing "backlash slivers", referred to in the text. In this experiment no statistical analysis was made. It was a sort of dynamic experiment and quick action taken on basis of results obtained.

One of the common alloys produced at Belur Rolling Mills of the Indian Aluminium Company, Limited is a 2 percent alloy of Magnesium in Aluminium. Large quantities of sheets of this alloy are rolled annually. The sheets are subjected to screening for physical properties, surface defects and dimensional tolerances before being sent to customers. One major cause for rejection is "backlash slivers". The loss on this account sometimes went as high as 4 percent. The origin of "backlash slivers" be linked up with black patches found at the time of casting ingots. Black patches, presumed to be primarily Oxide of Magnesium, occurred on the body of ingots. This was most pronounced at the bottom and less on sides and surfaces. As against black patches at the bottom, on the surface those were less difficult to handle, as they could be removed by machining. What happened was that during hot rolling small particles of the dark coloured, hard and brittle substance, from the bottom of ingots, were picked up with roll coating and then transferred on to the surface at regular distance. These black patches on subsequent rolling develop "backlash slivers".
A detailed investigation was undertaken. Results of this investigation indicated

1. Black patches developed with the roughness of the ingot surface which increased as more ingots were poured off a mould.
2. Black patches were reduced with external cooling of moulds possibly due to higher rate of cooling as compared to internally cooled moulds.
3. Maintenance of smooth surface during the pouring process either by occasional wire brushing or by application of whiting or preferably by both, minimised the formation of black patches on ingots.

NO NEED FOR TWO OF US TO LIE AWAKE

An old lady in England had stood the bombings with amazing grit. When asked the secret of her fortitude she replied: "Well, every night I say my prayers and then I remember 'ow the parson told us God is always watching, so I go the sleep. After all, there's no need for two of us to lie awake."

(The Christian Century)

* Indian Aluminium Co. Belur.

Some Experiences in SC

SB Deo

SQC is *as essential to industry as education to human beings.* As quality living is not possible without education, so quality production in industry is not possible without SQC. The author has in support of his thesis cited a number of practical examples from experience.

We had a problem in the production of 5/8" BS stud, for which there was a monthly demand of 10,000. The major difficulty was one of getting grinding accuracy (0.002") on turning operation. $\overline{X}$ and R charts were put up on the machine to guide the operator to work at the desired level and within the specified limits. This gave a solution for the parts of smaller diameter required for 5/16" studs, which were in a still larger demand at around 75,000 per month. With the help of SQC charts, we were able to produce the same quantity with the same quality in the same time and at less cost, making grinding capacity available for other parts.

We applied SQC principles also to our inventories. In this, we made use of Sequential Sampling Inspection as applied in the US arms and as elaborated by Norbert L. Enrick. We were also able to help our suppliers through the application of quality control principles to the supplies received from them. We started sending them frequently distributions of the characteristics for which a lot would be rejected.

For continuous production jobs, we have put in practice the scheme known as "Continuous Sampling at Minneapolis—Honeywell". The scheme is as follows: we have to inspect 100 percent till we get continuous 'i' jobs OK. Then we go in for sampling, inspecting a fraction 1/k of the production. As this goes on, we plot a graph of cumulative numbers rejected against cumulative numbers, inspected. With our AOQL fixed beforehand, we plot two lines on the graph dividing it into three regions: acceptance, and 'in between', a region of 'continuous sampling'. As long as the point is in the 'continuous sampling' region, the fraction inspection is continued. As soon as the point touches the rejection line or falls in the rejection region, we revert to 100 percent inspection till we get continuous 'i' jobs free of defects.

As already referred to, we have with great benefit used SQC in controlling our inventories. We felt that the value of our inventories was very high compared to our output. This problem was referred to the SQC section. It was found out that 250 out of 5,000 bins carried 70 percent of the total stock value. After selecting these 5 percent items for control, the limits were calculated on the basis of relevant considerations, and the stock position for each item laid down. The result was that the ratio of the value of these selected items, (covering 70 percent of the stock value) to the billed value for that month came down from 2.35 to 1.24 and it is likely that we shall be able to bring it down to 1 percent. It is clear that the application on statistical quality control to inventories is likely to yield substantial results in the Indian economy and *release locked up capital for productive use.*

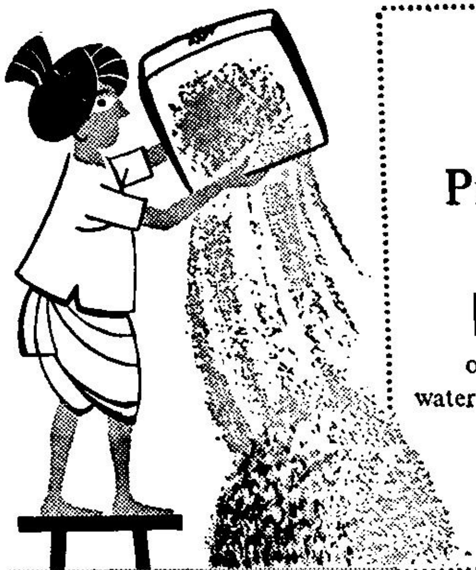
How Coal Consumption was Reduced

A Case Study

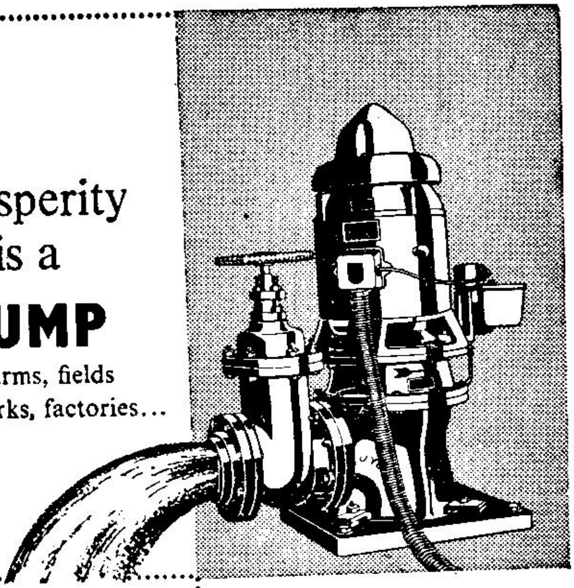
This describes how coal consumption in the boiler house of a certain pharmaceutical concern has been reduced using simple statistical techniques. The records maintained in the factory were found inadequate to permit any assessment of the reasonableness of coal consumed. It was, therefore, considered necessary to introduce suitable systems of recording in order to have a check on coal consumption.

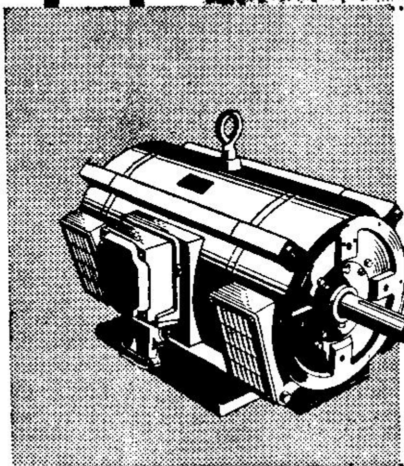
UNLIKE VERY BIG PLANTS, where load is stable all through the day, the load in this case varied considerably from day to day and even during the day. It was therefore necessary to have some *measure of the workload.* Quantity of water converted into steam was taken as a measure of workload for simplicity. Arrangements were made for weighment of coal and a water meter was provided to record the consumption of water.

After 30 working days, the data were analysed. Average consumption of coal per day was 1728 Kgms and that of water was 974.6 gallons. Consumption of coal varied by $\pm$ 686 Kgm from day to day. Through analysis of covariance technique, the variation in quantity of water consumed was taken into consideration and it was found that if the load were stable and same quantity of water consumed every day, the quantity of coal consumed would vary by only $\pm$ 453 Kgms. The mathematical relation between consumption of water and coal was found to be $Y=384.1+1.3789\ X$ where Y is the quantity of coal consumed in Kgms and X is the quantity of water used in gallons. This means that for converting 1000 gallons of water into steam 1763 Kgms of coal would be consumed, on an average. On any single day the actual consumption could be anything between 1310 and 2216 Kgms. On February 8, 1961 the consumption of coal was very high. For simplicity and for the benefit of fireman, coal consumption in Kgms per 100 gallons of water consumed was worked out for each day. This varied from 133 to 289 Kgms. Incidentally, this extreme consumption happened to occur on two successive days. It was however confirmed that record was correct. Also, coal just could not be of bad quality on 8 February, 1961, and of good quality on 7 and 9 February 1961. These results were discussed with technical personnel and firemen. Both were of the opinion that variation was high and the cause was attributed to poor planning in feed of coal. Simultaneously it was thought that through proper planning it would be possible to avoid high consumption. Thus every one was optimistic about the scope for reduction in coal consumption, as also in its variation through the use of an appropriate control chart. The boiler man was encouraged to plan things for himself and to break coal to desirable size for proper combustion. A control chart was simultaneously initiated with average consumption of 160 Kgms per 100 gallons of water. In a couple of days, a rapid fall in coal consumption was noted. The data collection and plotting of chart were continued. By the end of March 1961, the latest data were analysed to establish the new standards. This time the average consumption of coal was 113 Kgms per 100 gallons of water consumed. The initial variation of $\pm$ 453 Kgms from day to day when quantity of water consumed was maintained at same level reduced to $\pm$ 220 Kgms only. The mathematical formula relating to coal consumption and quantity of water converted into steam had changed to $Y=361.1+0.7842\ X$. A saving of about Rs. 12,000/- has been estimated per year. For reasons of space, it has not been possible here to give full statistical details of the real economies achieved. Briefly it would be significant to state that the consumption of coal per 100 gallons of water which was 181 Kg on 19 January '61 and rose sometimes to much higher level thereafter, declined to 119 Kg by 31 March '61 and on most days of this month, was in fact must lower.

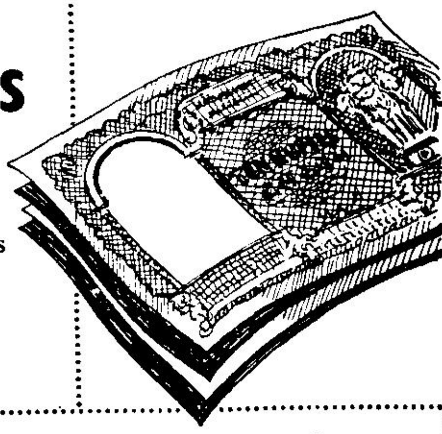


Prosperity
is a
PUMP
on farms, fields
water works, factories...





MOTORS
mean
money
in a myriad uses



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JY. 393 EVEREST

Television At Mitcham

THIS CASE STUDY OUTLINES SOME PECULIARITIES OF STATISTICAL QUALITY CONtrol methods in television manufacture, and in the inspection of in-coming goods, at Philips' Mitcham works. The quality control engineer was asked to consider what more could be done to reduce the amount of defective work. As most trouble was found during alignment, the first step was to obtain a record of performance at this stage. A chart was designed with all likely meter readings and faults pre-printed, and each test operator was asked to plot her results by putting crosses in the appropriate sections of the chart. This procedure takes very little time and shows the pattern of variation at each test table. This pattern, which should be similar for all test tables, provides the basis for prompt action if quality is deteriorating. Formerly action took place only when it was noticed that fault-finders were overloaded with sets awaiting repair.

In addition, if one chart departs from the general pattern shown by the others it suggests that something is wrong at that particular test table. This has proved to be a most useful feature in revealing faulty test gear. It is feasible to make a full check on test gear only once a week, but the charts now provide a continuous commentary from which faulty test gear may be detected at any time. Previously, alignment faults were not noticed until final inspection, by which time more sets had become involved. The results obtained from this scheme prompted an extension of the same ideas to mechanical inspection. The result has been a higher and more uniform standard of mechanical inspection. The production charge-hands, by keeping an eye on the charts, can see accurately what faults are prevalent at any time, and take immediate steps to eliminate them.

MAJOR MOSES

The young recruit was the victim of so many practical jokes that he doubted all men and their motives. One night while on guard, the figure of one of the officers loomed up in the darkness. "Who goes there?" he challenged. "Major Moses," replied the officer. The recruit sensed a joke. "Glad to meet you, Moses," he said cheerfully. "Advance and give the Ten Commandments."

Paper at Aylesford

QC IN THE MANUFACTURE OF KRAFT PAPER and newsprint at the Aylesford Mills of Albert Reed is almost a model compendium of precision mechanics. Among the properties which are tested are substance (weight); tensile strength, bursting strength; tearing resistance; caliper thickness; sizing (degree of resistance to moisture); and gloss. Other tests of a special nature (e.g., air resistance) are carried out wherever necessary or required by the customer. Current practice is to perform quality control tests on the end of each reel of paper, but the company is attempting to apply sample testing to other parts of the reel. The results of the tests are sent back to the appropriate foreman so that he can make adjustments to the producing machinery if this should prove to be necessary.

For substance tests sample pieces are taken across the reel and down the length of the reel. The pieces are cut out, using a template, and then weighed. The results, when plotted on a control chart using statistically-calculated limits, indicate if it is necessary to make any alteration to the total quantity of papermaking stock going on to the machine (stuff gate adjustment) or to the distribution of stock going on to the wire of the machine (slice adjustment). A profile *Beta*-ray gauge is also used for obtaining cross-machine substance variation—the findings being recorded on a profile chart in terms of percentage variation. By this means it is possible to pin-point the position at which any adjustment is necessary. The bursting test, which is used for all products, is mainly carried out by a pneumatic testing machine, but for products liable to be subjected to damp conditions hydraulic pressure tests are used. The caliper test is a straightforward one of measuring samples by means of a thickness gauge, while the sizing test is made by subjecting the sample to penetration by a fixed quantity of water for a period of sixty seconds. The tearing test is carried out by a recording mechanism working on the pendulum principle. It was designed to cause the recording needle to stop at whatever value the paper tears. The dynamic tensile test works on a broadly similar principle, but with more complicated mechanism. Trials are still in progress to decide the most satisfactory gloss test. Hitherto this has been an optical test, and therefore subject to human variability. The company is experimenting with an instrument using a photo-electric cell which records its own findings.

Eventually statistical quality control methods will be used in testing all properties. Within recent years, papermaking has tended to change from a craft to a science, and the need to ensure rigorous control at whatever level is specified by the producing organisation is becoming more and more apparent. Quality control techniques in this industry have also shown the necessity for close customer-manufacturer cooperation. In the past, a customer has asked for good, medium or low-quality paper. Quality control has shown the desirability of specifying for protection against particular hazards e.g., bursts and/or tear and/or moisture absorption.

A Footwear Case

Freeman, Hardy and Willis of Leicester were one of the first in the footwear industry to apply statistical quality control. Before the method was introduced, however, preliminary discussions were held with the British Boot, Shoe and Allied Trades Research Association (SATRA), which had evolved a scheme of a general nature, not hitherto put in practice. Traditionally, inspection in the footwear industry is carried out at the end of a departmental process. As there are some three hundred operations involved in making a shoe, the effectiveness of inspection by the traditional methods is almost bound to be impaired by monotony experienced by the inspectors.

Before the scheme was installed a meeting of the works manager, the quality supervisor and the shop stewards was held. The reasons for wishing to adopt it were put to the shop stewards, who were given the opportunity of suggesting improvements to the proposals. Full approval was given, and enthusiasm for the system has been maintained ever since its introduction. One of the main reasons for this is the realisation by operatives that they can now place greater reliance than before on the materials with which they work. The firm has also noticed a resurgence in pride of work among operatives wherever quality control has been introduced. Considerable interest is shown in quality results charts displayed outside the foreman's office. These are a summary of the number of defective shoes, and show the relative positions of the morning and afternoon shifts

It is of interest to note that although only 0.7 percent of the shoes passing any one control point are subjected to inspection the overall effect has been to cut down by an appreciable amount delays in rectifying faults. Under the former system of inspection up to two complete days could have elapsed between completion of all operations in a department and the time the fault was discovered, and this could have meant two days' work being entirely wasted. Quality control ensures that a rectifiable fault can be detected within a very short time, and certainly no longer than half a day will elapse between finding it and taking corrective action.

One result of the introduction of quality control has been to change the emphasis on the responsibility of foremen. The "taskmaster" attitude has virtually disappeared as responsibility for output at any operating process point has passed to the individual operative. The foreman, on the other hand, now has the opportunity to perform the administrative part of his duties, and to put his practical experience into effect by suggesting methods of preventing faults from recurring.

London Bricks

London Brick Company Limited operates twenty-nine works, twenty-six of them producing Fletton bricks and three hollow clayware. The total output of bricks is approximately 2,000 million a year. The company's interest in quality control began shortly after the end of the war, coinciding with the introduction of a new British Standards Institution specification for the size of common bricks.

One of the difficulties encountered in brick production is variation in the physical properties of the raw material and, allied to that, the moisture content of the clay. An important factor in laying down control limits, therefore, is the ability to assess material conditions, and this is largely based on geological surveys carried out by boring and at the clay face before digging begins.

Quality control charts were first used for checking by sample the sizes of bricks as delivered. Any persistent failure to measure up to standard sizes might mean a change in the raw material or in the drying and firing of the bricks. The use of quality control charts leads to a technical investigation of the cause of change in size.

green bricks

Later, quality control charts were instituted for control of the production of green bricks (i.e., after pressing into shape, but before firing in the kiln). Control limits have been set by the research department, and operatives plot samples on the charts provided. Any deviation from the limits or any marked trends are instantly brought to the notice of the fitters, who make the necessary machine adjustments. When millions of bricks are being dealt with, a small increase in size represents a very large tonnage of material to be processed, so that the control system is useful not only for ensuring that bricks are produced within the standard limits but also for helping to keep down cost of production.

An example of the saving which quality control can achieve is indicated in this connection. For some time the company had been dissatisfied with the rate of grinding in a section of one of its plants. As a consequence, plans were prepared for installing a new type of pan which, it was hoped, would have the effect of increasing output, but at the most by only a relatively small amount. Before the new equipment was produced, however, five small samples were taken every half-hour over a period of some weeks, and from these it was deduced that the fault lay not in the pans themselves but in the feeding mechanism. All that was necessary was a modification to this mechanism, and as a result output has risen far more than would have been made possible by the installation of a new type of pan.

The application of quality control is the responsibility of the research department, whose job it is to lay down standards and to provide means for keeping within the specified limits. The use of control charts not only means that the causes of variation are identified but also ensures that everybody's attention is drawn to the technical problems involved in keeping within the desired standards. As a final analysis of the quality of bricks and other products of the company, charts are kept of such properties as their crushing strength, weight, water absorption and so on. In the initial stages, random sample checks showed wide variations but, attention having been drawn to these through the quality control charts, there is now a significant levelling out of the variations.

Here, then, is an industry not concerned with the fine dimensional tolerances which apply in sections of the engineering industry. Standards of quality and the necessity for producing at as low a cost as possible apply with equal force, however.

Samuel Fox

SAMUEL FOX OF STOCKSBRIDGE, produces large tonnages of alloy and stainless steels, besides certain finished steel parts. It has an established reputation for the high quality of all its products. The safeguarding of this reputation is an important part of company policy. Approximately 6,500 people are employed by the company and the strength of the inspection department is 160. All educational courses arranged for supervisory grades include lectures on "Quality Control" and also "The Inspection Function." Quality control methods of presenting "quality information" are used, particularly the histogram method. A histogram is prepared, for example, of the thickness measurements on strip delivered to the world's largest razor blade manufacturers. The customer is supplied each week with information in this form. The same method is used to control the thickness during pressing of a watch spring catchpiece. A sample of 30 catchpieces is measured every two hours and a chart is built up and displayed at the press. A variability board has been designed by the firm's inspection department to check the strength of internal combustion engine valve springs which are produced in the company's light spring department. The board carried lines of steel pins, each line corresponding to a load reading obtained by compressing the springs to a specified length. The load range rollers, and the belt can be moved to suit the load range of the particular springs being sampled. A sample of approximately 20 springs is load tested and each of the 20 is hung on its appropriate peg, thus forming a histogram of the sample.

Quality Control in Brewing

THE BREWERY OF ARTHUR GUINNESS at Park Royal occupies what is possibly a unique position in British industry, for it is concerned with the manufacture of only one product and, unlike its competitors, does not control any of the retail outlets through which this single product is distributed. Although it is a matter of some conjecture which firm was the first to apply statistical quality control, there is no doubt that Guinness, by introducing the technique at their Dublin brewery at the beginning of this century, were among the pioneers. Gossett, who wrote under the pseudonym of "Student", in 1899 joined the Dublin brewery, where he ultimately built up the statistical department. He was the first head brewer at Park Royal when that brewery was opened in 1936. Gossett's work on the variation in the mean values derived from small samples is the cornerstone of this branch of statistics. Statistical information and analysis is regarded by the company as an essential service to the production staff in their efforts to secure a constant product of high quality.

Quality control is applied to the raw materials—malted barley, flaked barley, hops and water, all of which are examined by means of systematic sampling. Control of the process is achieved principally by the use of various methods, including laboratory analysis, although measurements and subjective judgment made on the plant are still important. An example of the use of visual inspection in process control is to be found in the operation of barley roasting (incidentally, it is the roasted barley which gives the characteristic Guinness colour); the operative in charge of the roasting cylinders samples the "make" periodically and by visual inspection decides on the progress of the roasting process.

It will be appreciated that the brewing of a standard product using barley and hops that vary from season to season requires a careful selection of the raw materials. Standardization of the product is assisted by extensive mixing of one batch with another at all points along the line of the process. The effectiveness of these actions is susceptible of statistical examination.

Formal control charts are not used extensively. Nevertheless the principles underlying the control chart are used in laying down limits by which is judged the significance of those measurements which are made either in the laboratory or by operatives on the plant. In fact, the control chart, as such, is used, for example, in an examination of the use of steam by each of the 23,400-gallon coppers where hops are added to the wort and the liquor is boiled to extract the hop resins.

The final product is always examined, test being carried out on various attributes which include condition, temperature, brightness, pressure and flavour (this last being a taste test carried out by a panel). The assessment of flavour is purely subjective and for this purpose the brewery use both tasting and drinking panels. Usually these tests are carried out so that the results lend themselves to statistical analysis.

The methods of quality control are applied to other activities than those concerned with the raw materials, process and product. For example, such methods are used extensively in work in connection with the hop farms, casks, transport, barley breeding etc. From time to time the methods of control adopted are examined and may be changed or indeed abandoned if changed circumstances justify such action.

SQC Off the Shop Floor

THE GENERAL ELECTRIC COMPANY'S Switchgear Works, Birmingham, has operated its present system of quality control since May, 1955. The policy has been to keep it as simple as possible, in order that it can be understood by all operatives. Technical jargon—and *even the term "statistical quality control"—is kept off the shop floor.* Despite certain initial scepticism, the company was able to go ahead fairly rapidly with its application of quality control. One of its most successful results was the drawing up of a revised scale of tolerances for all machining operations. This was based on an analysis of the machine shops' statistical control records. A meeting was then called with the heads of the various machine shops and the subject was discussed without bias. Incidentally, the revision did not mean that all tolerances were tightened; in a number of instances it was found that the former tolerances were too close and could be effectively loosened without any loss of quality.

In order to obtain a wide appreciation of the value of the technique the company decided to use the "guinea pig" approach. The job chosen for the purpose was the production of an important mass-produced electrical component, where the degree of rejections was sufficiently high to encourage a study of the problem. The use of quality control charts soon narrowed the cause of the defects down to certain elements in the assembly. Modifications were made to the inspection sequence and inspection was concentrated at certain stages of assembly. Closer attention was paid to this aspect of production and, as a result of these measures, rejections are now down to under one-tenth of the figures of eighteen months ago. Furthermore, the number of inspectors in the department has been reduced by one-fifth. As other companies have found, GEC Switchgear Works discovered that psychology has played a large part in the successful application of quality control. No man or woman will produce faulty work when he or she can equally well produce good work.

Quality is Everybody's Business

STATISTICAL TECHNIQUES ARE ONLY part of the overall quality problem. There should be a compaign for quality mindedness all the way through the organisation and since all departments are in one way or another responsible for quality, their co-operation must be obtained and their responsibilities underlined. There should be a plan to organise this cooperation and the formulation and running of this plan is the prime responsibility of the quality control department, with of course the full backing of top management. It is essential that the manager of the quality control department has the managerial ability to initiate, organise and maintain the quality programme.

the quality programme

1. *What level of quality is required*: A luxury limousine or a popular cheap car ? This is a top management decision based on information on (i) probable sales (sales department) (ii) available supplies (buying department) (iii) available equipment (engineering department) and labour (personnel department) (iv) available capital (accounting department) (v) and an appreciation of the main points in paras 2-5 printed below.

2. *Determining the magnitude of the quality programme*: (i) cost of avoidable defects, and of rectification (quality, accounting, production) (ii) estimated cost and effect of a programme of defect prevention (quality, engineering, accounting).

3. *Achieving adequate supplies of material of the correct quality*: (i) Choice of a good supplier (buying and inspection) (ii) Adequately specified requirements (design, quality, production) (iii) Supplies adequately verified on arrival, for conformance to specifications (Inspection).

4. *Design*: Good product design can ensure (i) an article of good quality and serviceability (ii) components are such that they cannot be incorrectly assembled. (Where this cannot be done in the product, the jigs for assembly may be designed to prevent incorrect assembly). (Design, Industrial Engineering).

5. *Setting realistic specifications*: (i) Product requirements (design, research, development, sales and customer) (ii) process capabilities (production, quality). There is little sense in setting specifications which cannot be met, set realistic specifications (bearing in mind the market at which the product is aimed). It is essential that information about process capabilities gleaned from control charts should be passed on to the departments responsible for product specifications and for production planning.

6 *Obtain equipment with the correct degree of precision*: (i) When the specifications cannot be widened and cannot be met by present equipment, it is usually most economical to obtain equipment which can meet them. This may be new equipment, or an additional process, which may be inspection, although this is usually not advisable. (ii) This equipment, in fact all production equipment, should be adequately maintained. (engineering and maintenance).

7. *Provide adequate testing equipment*: (i) To ensure that the operator can varify the

quality of his product, and (ii) To ensure that the inspector is able to test the product correctly. (iii) Site the equipment and staff so that inspection can be done in time to prevent the continued production of defective work. (iv) Maintain the testing equipment. (maintenance, gauge room).

N.B. Ensure that the characteristics being checked are really the important ones. (sales, production, inspection, quality, design, engineering, accounting).

Wherever an operator can verify his own workmanship this should be arranged in order to *introduce a pride of craftsmanship,* a real interest in quality.

8. *Provide adequate training for* (i) Production staff in the use of equipment for both production and also quality checking. (ii) Inspection and quality staff in the use of quality checking equipment, and also in the simple uses of quality control charts.

9. *Stimulus*: A stimulus and drive to carry through the quality programme should be provided at all levels by the provision of incentives, either financial or psychological, or both. (top management, production, quality).

10. *Quality reporting*: The amounts of defective work, scrap, rectification, guarantee returns, and customer complaints must be reported by the quality department. The value of these quantities should be determined by the accounting department. It is desirable that a periodic report of the quality control activities should be submitted to higher management—to provide them with the necessary incentive to extend or modify the quality programme. (quality, accounting).

Quality Analysis!

Quality Control in Aircraft Industry*

The objectives of Inspection and Quality Control in any industry which caters to the requirements of the consumer's market is primarily governed by considerations of cost. In the aircraft industry, however, quality is a '*must*' and is required to ensure the safety of the operating personnel as well as the public. The quality control system in the aircraft industry is therefore required to be directly responsible to top management and is independent of production or works departments.

FOR YEARS, THE AIRCRAFT INDUSTRY HAS employed 100 percent inspection procedure to the problem of detection and correction of defectives in the finished product. Recognising the inability of 100 percent inspection to cut out all defectives, it has frequently been resorting to repetitive inspections, sometimes amounting to 200 percent or 300 percent inspection. Gradually, over the years, control functions have become added responsibilities of the inspection department and as a result, the present day composite function is actually one of quality control, of which inspection is but a part.

Through the inspection of materials, parts and assemblies etc. and separation of those lying within the standard from those which are not acceptable, the desired quality is attained, but not necessarily the desired 'quality control', even though such separation is very necessary in the aircraft industry when considered from the safety point of view alone. Quality control activity in the aircraft industry is directed towards restraining, governing and directing the three M's—Materials, Machines and Men—of the manufacturing processes to ensure that more and more acceptable work is produced efficiently and economically. Quality control is a work-in-process control. In fact, it starts with materials control. Purchase orders for and semi-finished materials like castings, forgings etc., in addition to specifying compliance with appropriate standards or specifications, *stipulate evidence of such compliance in* the form of actual test reports from approved laboratories etc. Samples of the materials received are again sent to the test laboratory for confirmatory check for material composition, condition and properties. Examination in the test laboratory—which is but a quality control activity—may consist of tests for chemical composition, mechanical and metallurgical properties. On receipt of satisfactory laboratory test reports, raw materials are colour coded and batch-numbered. Colour coding helps to identify the material specification at the time of issue. Batch number is cross-referenced to the incoming inspection documents, which helps to trace the complete history of the part, in case it is found to be defective later.

Recourse is made to the use of all modern precision measuring instruments and tools and checking gauges and also of functional testing equipments for the various systems like electronic, hydraulic, pneumatic, fuel systems. These activities, which are rigidly

* Hindustan Aircraft Bangalore.

followed at every stage, are laid down in the form of standard inspection procedures and thereby the control of the production and assurance and maintenance of quality to the desired specifications and standards of acceptance are attained.

In the strict interpretation of the word, only one type of machine is literally controlled, viz. the spot or resistance with the applicable specifications. control department certifies spot welding machines for each gauge and material combination to be welded, the certification involving process control, laboratory investigation and test in accordance with the applicable specifications. Similarly, a significant degree of control of many other machines is being exercised by application of statistical quality control techniques. Aircraft production operations lend themselves least easily of all classes of manufacture to the basic techniques of SQC, because of the complexity of the alloys, processes, heat-treatments and other operations involved and mainly because of the extremely short run of_batch productions. However, as it is an accepted fact that quality is built into the product during manufacture and not be inspected into it, SQC techniques are utilised in the several manufacturing operations as a weapon against waste, rejections, mistakes or carelessness.

For purposes of control, the several electroplating baths and chemical cleaning baths in the finishing department, as also the heat-treatment furnaces are all regarded as "machines", and proper process controls are exercised in all these cases. Each heat-treatment furnace or bath is certified by the quality control and process laboratory prior to approval for production use. These certifications require a temperature survey of each specific furnace to assure temperature stabilisation throughout the furnace. Further, physical tests are conducted on representative samples of the furnace load to determine that the desired physical properties of the materials are attained. Test pieces and parts are given heat numbers for easy identification. Continued periodic re-checks are conducted on these furnaces or baths to assure proper atmospheric control, accuracy of temperature control etc. and thus a fair degree of positive process control is being always maintained.

The quality control department, has instituted a system of tool control aiming at a planning maintenance of all tools, gauges and measuring equipments to the desired accuracy. Each cutting tool used in the machine shop or tool room is meticulously inspected after any regrinding to ensure that the right tool in the right condition is always available to the operator. A similar assurance is made possible by the quality control function known as "precision tool and gauge control", by virtue of which all precision tools in use in the facility, including micrometers, height gauges, calipers, 'go and no go' gauges etc. are all checked and re-checked for accuracy in the "standards" room. Similarly, a system of recheck and control is also established for the several assembly and sub-assembly jigs and fixtures at specified intervals for the accuracy of the important attachment points etc. Tensile testing machines, weighing machines etc. are all periodically checked and calibrated against "reference standards" to ensure continued accuracy of each equipment or machine.

The last of the three M's—'MAN' is the most difficult to control. However, certain positive degrees of control are attained over men operating in specified categories of work. For example, each welder employed in the airframe production must be certified in accordance with the specific government regulations. These certifications are the responsibility of quality control and process laboratory. On successfully passing the certification tests, each welder is issued with a certificate, which describes the material he is authorised to weld and the type of welding approval. He is also assigned an approved welder's stamp to identify all welds made by him. At intervals, his work is examined to verify his performance. Similar approval and certification is also made in the case of operators, who are required to swage and splice cables for the control systems of the aircraft. Further, a degree of control on inspectors is maintained by careful study of the jobs passed by them and assessing their efficiency by the quality control group. The inspection section which is the verification section of the quality control organisation furnishes through the data obtained in its daily operations, vital information relative to the adequacy of the present controls, the necessity for new or additional controls, as well as quantitative knowledge, relative to the performance of men, machines and materials of the various manufacturing operations and processes in the industry.

Another most important appraisal activity of the quality control department is the "analysis of field complaints" or "defect investigations". This assumes a greater importance when viewed from the point of view of the safety of equipment and men involved in their operation, as also the public. A systematic approach is made for the investigation, review and analysis of all the complaints, defects or service failures of any detail part, sub-assembly, assembly, unit or system of the aircraft, aero-engine or their accessories. The investigations include the most detailed and minute examination of such defective parts, units or assemblies and all possibilities like faulty materials, incorrect specification or size, improper methods of fabrication, improper installation or assembly, malfunctioning of the system and operating conditions etc. are taken into account and the actual causes for the failure are determined after careful analysis. All defective investigations, specify remedial and corrective action are taken on all similar parts to prevent occurrence of such defects or failures. Simultaneously the concerned design engineering department is coordinated and wherever necessary, modifications are issued specifying repair or rectification action on all such existing parts and/or replacement of such parts by new designs. In all this activity, assurance of quality is the main factor. In conclusion, it is but proper to say that there has been a planned system of quality control in the aircraft industry and the same has been and is being instituted and implemented in stages, wherever possible in the industry. A considerable impact is already felt for quality product in the aircraft industry by this type of total quality control programme. However, opportunities are still manifold for additional control developments.

When a man gets talking about himself, he seldom fails to be eloquent and often reaches the sublime.

QC in a Railway Workshop

MM LUTHER*

Quality control in manufacturing industries has been widely dealt with in all its aspects by various authors and many methods of inspection in the manufacturing industry have been devised. This includes individual inspection either by sight or automatically with the help of electric gadgets. In a jobbing workshop, however, the problem is slightly different, particularly where it involves repairs to components or assemblies where the quantum of work required to carry out repairs may have to be determined in each case. In this short article, it is intended to briefly describe procedures followed for quality control in certain important stages of repairs to railway coaches.

QUALITY CONTROL IN ALL INDUSTRIES dealing with transport of men and materials like railway rolling stock, aircraft industry, automobile industry etc. becomes particularly important on account of the sanctity attached to human life and the possibilities of heavy claims of damages in cases of accidents as far as freight traffic is concerned. The Central Railway Carriage & Wagon Workshops at Matunga started, according to a decision taken by the Railway Board, an intensive drive to introduce incentive scheme in the workshop in 1958. Simultaneously with method study and work measurement, it became essential to make a scientific study of the end use of components and assemblies and service conditions for each as also the usefulness of the repair techniques followed to maintain the stock in a safe and presentable condition in order to lay down inspection procedures. This was considered necessary to ensure that the increase in productivity which was expected by work study followed by incentives did not result in a lowering of standards of quality.

The quality control procedures adopted were considered under three heads (a) Prerepair inspection (b) Stage inspection (c) Final inspection. The repairs to coaching stock broadly cover (i) bogie repairs (ii) structural repairs to the body (iii) structural repairs to the underframe and (iv) painting.

Prerepair inspection

As the coaches are received in the workshops for repairs, they are inspected jointly by the supervisor of the subshop dealing with the repairs to the body of the coaching stock and by a qualified inspector. Separate prerepair inspection forms for different types of stock indicating all possible repair operations necessary for each have been designed and the results of the inspection are indicated in these forms. In order to make it easy to indicate allowed time for carrying out repairs to a particular coach, the allowed time for

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each operation is preprinted in the prerepair inspection sheet. The shop supervisor has been made jointly responsible for the prerepair inspection with the object of exercising a dual technical check on the repairs to be carried out. This procedure also ensures that the technical unit carrying out the repairs to the coaching stock is not absolved completely of the responsibilities of determination of the extent of repairs necessary for a particular coach keeping in mind: (a) the number of days that the coach is expected to spend in the shops and (b) the repairs that have to be carried out (i) to make the coach safe for traffic till atleast the next periodical overhaul and (ii) to ensure that in service the stock does not deteriorate to an extent which will make it unpresentable to the travelling public.

Stage inspection

After the body repairs have been completed and the top panels put in place, it is not possible to check the work that has been done by the staff on the structural members below the panels. Stage Inspectors have, therefore, been provided to check the quality of work during the pendency of the repair operations. The Stage Inspectors mark on the inspection sheets the results of their inspection and advise the supervisors and workmen concerned if a particular operation has to be carried out either in a manner or to a quality different from what is being done. This aspect deserves particular attention in the initial years of working under incentives to help the workers in not only working to allowed times but also gaining some bonus by following correct practices. If the men are not guided properly and they continue to lose time for three or four months, particularly when they have to correct the jobs which have not been done to the standard laid down principally because of incorrect tools or methods, it sets up a psychological reaction and the men disheartened if not cheated because inspite of putting on hard (though not entirely productive) work, they do not get any additional emoluments. The supervisors and the administration are then hard put to explain to the men that they had to work hard because in the first instance. the job was not done correctly. The importance of bearing in mind the psychological reactions of the workers while taking any decision cannot be overemphasised. In India where majority of the factory workers are still illiterate, more guided by either their emotions or impressions or by what their colleagues may choose to tell them than by facts which may be presented by the administration, the necessity of ensuring as far as possible a receptive frame of mind amongst the workers is particularly great.

Bogie repairs

The bogies of coaches represent the most important assembly in the coaching stock from the point of view of safety and riding comfort and particular care is taken to carry out the prerepair inspection, the stage inspection and the final inspection of the bogies, on the lines indicated under: at prerepair inspection stage all wearing components of bogies are checked up with the help of gauges and those which require replacement or repairs stripped if necessary. All the components like springs and wheels are stripped and separately tested and if necessary repaired in other ancillary shops. A senior inspector is responsible for the final inspection of the bogies which includes checking up of all clearances.

Carriage repairs

This section also deals with complete repairs as well as inspection of all the vacuum brake fittings and brake gear and draw gear. Whereas in the case of carriage repairs, the repair work is not standardised on account of its intricate nature, an effort has been made to standardise the jobs in bogie repairs so that all the trolleys of a particular type leave the shops to the same standard of safety and operational efficiency.

Underframe repairs

When the coaches are received, all members of the underframes of carriages are checked and those which need either replacement or repairs singled out by the Inspector. If the underframe needs heavy repairs, the wooden super-structure is lifted, kept on the trestles and the underframe removed to a different shop for the necessary repairs. There again stage inspection is given high priority to make sure that the process of carrying out the repairs is correct. This does not, however, apply to integral coaches of the type built in Integral Coach Factory, Madras, where the metal body of the coach is integral with the underframe.

With the advent of modern designs of bogies with shock absorbers, silent block fittings etc. special steps have to be taken to see that all the components are individually and thoroughly checked and made fit to run for atleast the next one year. This is particularly more important because it is difficult to carry out any major repairs to them while they are in service between periodical overhauls in workshops.

Painting

While it is comparatively easy to set inspection standards in case of components or assemblies, the quality control functions in paint work present a difficult problem. The coaching stock broadly have two types of finishes, the exterior is always painted and the interior is either french polished or painted according to the class of the coach. The condition of the paint and polish is examined by the prerepair inspector while the carriage is still in the carriage repair shop. As in the case of the carriage repair shop, prerepair inspection sheets with pre-printed timings for each operation laying down the allowed time for each operation are available and the inspector indicates the operations to be carried out on each coach on these sheets. Before the coaches reach the paint shop, the rate fixer in the paint shop totals up the allowed time for operations on a particular coach and arrives at the total allowed time for the various painting or polishing operations on the coach.

Stage inspection

In the case of painting and polishing operations, it is possible to get a certain degree of finish with varying quantums of work carried out on the panels. The difference arises in the life of the paint. If the intermediate operations before the final coat is put on, are not fully or properly carried out the life of the paint will be relatively short and this will expose the metal surface to corrosion and of course also it spoils the appearance of the coach. Great importance is therefore laid on the stage inspection to make sure that each stage of painting and polishing operations is fully and properly carried out and the inspector makes suitable endorsement in his records. Each stage has to be passed by the inspector before the next stage is started by the workmen.

In the absence of definite quantitative methods for measuring the finish of various coats, sample approved panels indicating the finish required after each stage of painting have been prepared for the guidance of the inspector. With age, these panels are likely to vary in their appearance and the sample panels are inspected by the inspecting officer every week to make sure that the samples retain the quality that is desired on a coach being freshly painted. If necessary, fresh samples are prepared and approved by the inspecting officer.

Final inspection

As in the case of the stage inspection, sample panels have been prepared for comparing the finished surface of the coach to the desired standard of painting. A device to measure the finish of the painted surface is now being developed and it is hoped that some qualities of the painted surface can atleast be quantitatively checked when this device is available.

The editor of this Journal had the occasion recently to visit the Works of which the author is the Works Manager. An extract from the *editor's diary* may be of interest: "...It appeared to me that the best focus for the productivity drive is the public sector. In this connection I visited the Central Railway Workshop at Matunga. Formerly it used to repair wagons and coaches; now it is also manufacturing them. This Workshop has an annual budget of over Rs. 2 crores and employs over 7000 workers. The devotion with which the technicians work, their integrated application of a large variety of productivity techniques (work study, production scheduling, quality control etc.) in which their professional competence is so very obvious, their devotion to the public interest and the very obvious lack of conflict with the basic interests of the working class are all advantages....The public sector illustrates in a very interesting way the differences in the application of the State policy of rationalisation without tears....in the public sector as exemplified by the Workshop at Matunga, the workers know that public officers have no interest in rationalisation in the sense of retrenchment of workers or economising on the wage bill. Yet the application of productivity techniques does mean employment of less manpower, other things being equal. That is why a purely repair workshop has moved into a regular manufacturing process. A large number of workers are being progressively brought on incentive and by July 1962 practically all the direct workers will be on incentive. Quality Control is simultaneously, intelligently applied, alongside scrap control. In short, you have a sort of a model productivity Workshop with an integrated application of various productivity techniques..." in the context of these impressions, the editor made a personal request to the author for an article on the working of quality control in his Works. Sri Luther has been good enough to send his article, showing how productivity techniques in his Works are operated in an integrated way. He has along with his article sent a note on the importance and significance of quality control which is of general interest: "...Today, in India, the market belongs to the seller. In view of the needs of various industrial goods in a majority of the cases being in excess of the capacity of the various industries, private industry very often ignores the quality aspect of their products. This does not apply to certain major concerns which have used SQC techniques in their own industry as a whole, but *in the case particularly of small scale industries, quality control is woefully ignored.* While the ISI has done immense service to the industry by drawing up standards of inspection, their follow up mainly depends on the industry itself. It is essential in the national interest that the small scale industries follow the ISI standards or in their absence the accepted standards laid down by other institutions like the BSI. As industry develops and there is keener competition, a name for quality established at this stage would perhaps stand them in good stead in time to come..."

Quality Control in Shoe Industry

RS GUPTA*

The shoe industry, like many other industries, has become more quality conscious in recent years. The interest in quality problems has grown in two directions. The first phase is to build additional quality features into the product by using better components and materials. This has, however, led to increased cost of manufacture, and under the pressure of competition in home as well as in foreign markets, the problem of balancing the extra quality and its price has become a formidable task for the industry. This concern about costs, with the development of statistical and other advanced methods of quality control, has stimulated more interest in the second phase of the quality problem, namely, the question of how best to organise quality control function so that the specified and often more exacting quality requirements are attained in bulk production with the maximum of efficiency at a lower cost.

THE DEMAND FOR QUALITY FOOTWEAR at home and elsewhere is not solely a demand for sheer durability. In shoe making one can also go a longway in quality styling, design and appearance. There is a similar relationship between comfort (another facet of quality) and durability. Thus aesthetic enjoyment and prosaic facts of serviceability, and durability are all elements in quality.

The assessment of components and raw materials from the point of view of quality and suitability for the intended process at the planning stage is, for a number of reasons, a formidable task. First of all, the shoe is made of an unexpectedly large number of widely different types of materials and components and within each there is a wide range of choices. Consider leather for an example. Sole leather should have durability, waterproofness, flexibility; it is also relevant how it will react to heat, perspiration, oil etc. Upper leather should have in addition fastness of finish and strength. It is hardly ever possible to assess the individual quality attributes by simple visual inspection. Very often a laboratory test requiring specialised equipment is necessary merely to obtain a reasonably reliable assessment. As regards wearing properties of leather or rubber, the conditions to which a shoe will be subjected in wear cannot be simulated in the laboratory with complete success.

For these and other reasons it is wholly impracticable for an average firm to depend on its own resources to assess the quality attributes and the process suitability of new components and materials. It, therefore, necessitates the establishment of a central research association, to work out definite specifications for the guidance of the suppliers and purchasers.

Until a few years ago, the only form of inspection in the average shoe factory was final screening inspection at the end of the manufacturing process

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and sometimes also at a few intermediate points. The main object of this inspection is to locate rejects and defective shoes. It is a common practice in the shoe industry for the screening examiners at the intermediate stages to do a certain amount of repairs. This medieval method of working may be contrasted with a case in which process control, with all the SQC techniques of control charts etc., was installed: Since most of the inspection in shoe industry is by attributes, two types of control charts have their application in controlling the quality percent defective chart and number of defects per unit chart. The illustration of the former control chart is given here. When this chart was applied in the 'Lasting' stage in one of the shoe factories, the average percent defective were around 38 percent. It was decided to start with 5 control charts. One chart was maintained for each of the four defects and the fifth chart was kept for total percent defective. Prompt attention to 'out-of control points' on some of the charts resulted in substantial improvement in the average quality, and total effectives were reduced from 38 to 21 percent. After the charts had been in operation for two months, it was decided that separate charts for individual defects could be abandoned except for two defects which were still giving a good deal of trouble. After another three months the total defective level was reduced to 5 percent. At this point all control charts for individual defects were abandoned. Only a single control chart for total defective has since been maintained. Whenever any deterioration in quality is indicated by this chart, the evil is immediately nipped in the bud.

SQC in Ordnance Factories

PV KRISHNA IYER[1] and MN BHATTACHARYA[2]

The authors have done good work in the field of SQC in the defence sector. This article, however, discusses on the 'basis of the authors' experience, relative advantages and disadvantages of $\bar{X}$ and R charts, as compared to L—S charts. The Ordnance factories where a large number of defence and civilian stores are manufactured provide ample scope for the application of SQC and sampling inspection techniques. Unlike other industries, however, hundred percent inspection of all the items of manufacture is in vogue in the ordnance factories. It cannot be easily dispensed with as the nonconformity to the specifications may be harmful to the user himself. If SQC is to be applied extensively in the ordnance factories without appreciable increase in the existing inspection cost, a method of SQC much simpler than the usual $\bar{X}$ and R charts for measurable characteristics, has to be found out.[3]

WE CONDUCTED AN EXPERIMENT FOR controlling a process which was entirely out of control by the help of the L-S chart and $\bar{x}$ & R charts and compared the efficiencies on the basis of the corrective steps suggested by both the methods. The job selected for study was a component of a store manufactured by a single spindle automatic machine in an ordnance factory from coiled brass rods of diameter 0.1876 inches. The characteristic studied was the total length of the component. The reasons for selecting this characteristic were, ease of measurement, high tolerance and technical importance. When the length of the component is low, the store is likely to function prematurely and thus prove dangerous to the users and hence it is a critical defect. On the other hand when the length is high, the store will not function and thus it is a major defect. We undertook an investigation lasting for twenty three days. Samples of consecutive five jobs were taken at a regular interval of half an hour. Each component was measured carefully with a micrometer after proper cleaning and removing of bars, if any. The measurements were recorded on a data sheet. Any adjustments of the machine were noted in the remarks column of the sheet.

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1. Defence Science Laboratory.
2. Army Statistical Organization, New Delhi.

3. Different simplified methods of SQC have been discussed in the statistical literature and their efficiencies have been theoretically discussed by various authors. Stevens (1946), after some elaborate investigations, concludes that the control of the mean and standard deviation can be done by the control charts of (c—a) and (c+a) respectively, where a is the number of articles passing the smaller gauge and c is the number failing to pass the larger gauge. The sizes of the gauges are so fixed that under normal conditions the upper gauge will not allow a fixed percentage of articles to pass through it while the lower gauge will allow another fixed percentage of articles to pass through. This method is as efficient as the control by ($\bar{X}$ & R) charts provided ten articles are gauged in place of eight exactly measured. For want of sufficient supply of gauges, control by gauging does not appear to be feasible in the Indian factories. Howell (1949) has investigated the merits of the $\bar{X}$ & R charts with the L—S chart, where L and S stand for the largest and smallest values of the sample. He finds that the L—S chart is as efficient as the $\bar{X}$ & R charts for all practical purposes. The L—S chart adpears to be well suited for adoption in the Indian factories. Before this is recommended, however, a critical examination of the two methods should be made. An investigation regarding the relative merits of the two methods of SQC, namely the $\bar{X}$&R charts and L—S chart, has been described in the text of the article.

For each sample the largest and smallest values were plotted on a graph against the tolerance limits given in the specification. Similarly the mean and range of each sample were calculated and plotted on the respective control charts. The new pair of control limits were calculated as the quality improved. The corrective steps suggested by the L-S chart were followed. As a result of control the percentage of defectives went down appreciably.

(1) *L-S chart detects lack of control almost equally efficiently as the $\bar{X}$ & R charts.* Throughout this investigation the process was controlled by taking corrective steps as suggested by the L-S chart. This was checked with the $\bar{X}$ & R charts. The results of the interpretation of both the charts were substantially the same.

(2) *In L-S chart a simple comparison of the control limits with the tolerance limits ensures economic control while in $\bar{X}$ & R charts such assurance requires further calculation and comparison.* If the two control limits of the L-S chart are within the tolerance limits, so long as the process is within control we are fairly sure that the job will meet the specifications. This is not so obvious in the case of $\bar{X}$ & R charts.

(3) *In some cases quicker diagnosis of the assignable cause may be possible with the L-S chart.* The last sample (vide SQC Chart) indicates lack of control on both sides of the control limits. This suggested the adjustment of the position of the stopper and the feeding arrangements. But according to $\bar{X}$ & R charts the range only was out of control and thus indicated that the variation had increased. This might have been either due to irregular feeding or sudden shift of the stopper. Similar situations were noticed with few other samples in such cases the L-S chart suggests definitely the nature of corrective steps while the $\bar{X}$ & R charts keep us in doubt.

(4) *L-S chart is much simpler.* In the case of $\bar{X}$ & R charts the mean and range are to be calculated and plotted. In L-S chart, only the largest and smallest values are to be noted and plotted. Hence the L-S chart is much simpler than the $\bar{X}$ & R charts and takes much less time to maintain.

(5) *L-S chart is readily explainable to the machine operator.* The machine operator is more accustomed with individual measurement and the tolerance on it than with the sample mean and range which are confusing to him and therefore he can more easily understand the L-S chart than the $\bar{X}$ & R charts.

SEE THAT THE TROUBLES ARE FIXED

A veteran foreman was asked several years ago to express his ideas about what a quality control programme should do. "Well, that's an easy one," he told his questioner. "It ought to find out what quality troubles there are, then see the troubles are fixed so that they don't happen again."

Quality Control in Heavy Electricals

R SUBBIAH *

The application of Quality Control to the Heavy Electricals at Bhopal is a matter of national importance, because its products form the capital equipment of industries generating, transmitting and distributing electric power. Defects in this equipment can cause not only inconvenience but widespread loss and even catastrophe. The quality of the Bhopal equipment, however, can only be measured by performance over a long period of time. It is the next generation of engineers who will be the judges of the real quality of Bhopal Heavy Electricals.

WE APPEAR TO HAVE STARTED WELL though we have no national standards of our own. We are establishing them with the help of the Indian Standards Institution. Further we have access to the designs, specifications and processes of the *Associated Electrical Industries*, the largest British electrical manufacturing firm, with long experience and a large research and development organisation. Assurance of quality, however, is bound to be a somewhat expensive process, because it has to be supported by research and knowledge of the behaviour and designs of materials under varying conditions in a country of continental size. This research and development work and the systematic compilation of data arising from service experience is an exceedingly expensive business, for which there is often no immediate financial return. Certain tests are of course carried out on every equipment made. Additional prototype tests are carried out on a proportion of the output: in these the most severe conditions which can occur are simulated. For example transformers are given a 'heat run' to check the effect of operation under severe loads, and an 'impulse test' to check the effect of an abnormally high voltage surge—such as a lightening flash. In quality control specially on incoming materials our large well-equipped and well-staffed laboratory is a great help; so also in manufacturing processes, for example, in the check up of welded steel fabrications (made out of mild steel) for physical and chemical properties such as carbon content, tensile and bend tests. We have besides, an independent inspection department reporting to the Chief Executive. This again is fully equipped with precision measurement equipment, regularly checked and calibrated in an air conditioned gauge room.

As this is a new industry, quality control on incoming materials and components has certain very interesting features. In fact our engineers are helping in the establishment of nascent ancillary industries. Our engineers visit their works to check their facilities and practices; our laboratory facilities are also at their disposal.

* Works Manager, Heavy Electricals, Bhopal.

Quality Control in Glass Industry

JS Sodhi *

Today, glass makers are able to produce glass lighter than cork or almost as heavy as iron; glass as fragile as a egg-shell or as strong as steel; glass as soft as cotton or as hard as precious stone; glass resistent to intense heat or the strongest acids; glass that transmits or absorbs infra-red, ultra-violet and x-rays; glass that will either conduct or insulate against heavy charges of electricity. Glass is the tool of the scientist, with the aid of which he explores the innermost fastnesses of matter and the farthest reaches of space. Obviously, glass is the ideal field for quality control.

In spite of very many developments and gradual mechanization, the quality of indigenous glassware still needs improvements in certain respects. Unfortunately, the industry, like several others, faces a number of difficulties: high cost of raw materials in India, their uninterrupted availability etc. Further, the range of articles produced is rather wide. The first and foremost requirement, however, is that the glass itself should be of good quality.

One of the methods by which uniformity in quality and reduction in the cost of production has been achieved in the industrially advanced countries is the introduction of quality control. So far, with the exception of some testing of raw materials and finished goods practised only in a few works, quality control has not been introduced as a regular feature in the Indian glass industry. It appears necessary to emphasize that quality control not only brings increased reputation to the manufacturer's products but gives the factory staff satisfaction in knowing how to produce good glassware. In order to make a steady and continuous improvement, both in the quality of glassware and in the quantity of the output, every single factor in the process of glass production, from the unloading of raw materials through storage, batch mixing, melting, refining, glass formation, annealing packing and transportation, put under proper observation and careful control.

Glass is liable to suffer from a multitude of defects owing to numerous difficulties which attend its production. Unless, therefore, we know the various stages where such defects occur, we cannot proceed with proper investigations, in order to eliminate those. The principal defects are

1. *Defects when glass is molten:* lack of homogeneity; presence of stones, cords blisters, seeds, bad colour, etc. 2. *Defects during working of glass:* breakage, crizzles,

* Secretary, All India Glass Manufacturers Federation, New Delhi.

cracks, strains, uneven thickness, dull-surface, discolouration, etc. 3. *Annealing Defects:* deformation, fitting and entry of dirt, cracking, breaking, filming, blooming, discolouration, etc. 4. *Afterworking Defects:* devitrification, filming, blooming, formation of bubbles and seeds, annealing defects, etc. 5. *Storage Defects:* sweating, cracks and breaks under slight mechanical shocks and temperature changes, etc. 6. *Defects during use:* defective composition, fracture due to strain in glass, poor durability, splintering, discolouration of surface, etc.

With a view to improving the quality, it is equally important for the manufacturer to know the qualities which a good glass should possess. Some of these qualities are here enumerated.

i) Good appearance if the glass, including brightness, colourlessness and absence of seeds, stones, cords, etc. ii) freedom from defects during shaping, such as, inclusion of gathering blisters and stones, etc.; crizzles or dapple marking due to unsuitable procedures when operating with tools, moulds, etc. iii) uniformity of weight and capacity; distribution of the glass in the walls and bottom of the object; absence of sharp edges. iv) satisfactory annealing. v) conformity to chemical and physical requirements according to the purpose for which the article was designed.

In judging quality, some standard is also needed. In the case of appearance, dimensions and defects during shaping, the manufacturer can make a start by selecting some really satisfactory samples of his own manufacture by which his inspectors should judge the rest. He might, of course, on occasion take some competitor's good bottle as the standard he wishes to attain. In any case, at the outset, it is advisable to start with a standard that seems reasonably attainable and later, after some improvement has effected, to raise standard.

It is claimed that control chart technique increases the value of inspection and fulfills a function not possessed by the more usual inspection schemes. It is advisable to closely associate such control charts with the relevant production units, because they have become a common language for all concerned, from operator to chief executive. Control charts create interest for the operator, but the operator need not understand their construction. Similarly, it is not essential that the senior management should be acquainted with the theory on which the construction of charts is based, in order to be able to *interpret* them and encourage their use as part of the production routine.

The technical testing department is often a neglected section of a factory, since it is not actually engaged in production. This department is often classed with the sorting department, another non-producing section, which too is generally looked on as regrettable necessity; whereas, on the other hand, both of these departments need be maintained by all good glass units. The work of the sorting department is to find and isolate faulty ware; while the testing department plays its part in condemning faulty ware —its main effort is to look forward in an endeavour to prevent the formation of faults by adequate study and control of the manufacturing process. Further, it checks the work of sorting by means of spot tests and guides the sorters as to rejection limits.

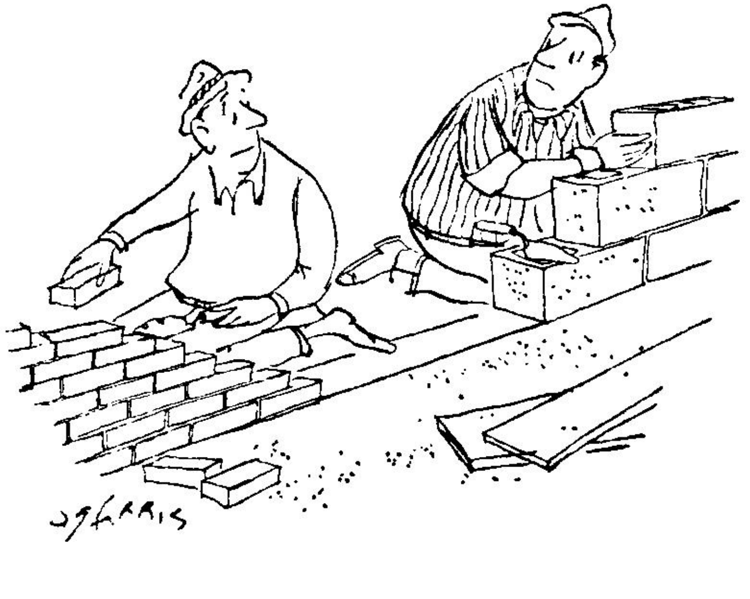
In order that a timely warning could be given in case any of the operatives went wrong, it is necessary to work out tests which could give enough indication, so that corrective measures could be adopted without incurring losses. In order to be effective, the tests have to be simple, speedy, meaningful and easy of interpretation. The mere carrying out of tests on individual pieces of glass takes from individual articles, or the carrying out of tests on individual articles or on sets of articles, is not of permanent value unless the results of the tests are properly recorded and preserved in some form which allows of quick reference. Tests which give direct information about glass quality and about glass distribution are important because they can be related directly to the quality of the articles produced. But all testing is expensive and should, in my opinion, be cut down to the minimum necessary to give information which will enable defects to be traced to their causes or origins, so that such causes can be eliminated. Each factory must decide for itself how much can be spent on tests to control the quality of the articles it produces and must choose its tests accordingly, selecting those which will give information and be of most direct value.*

A good glass container which will be acceptable to most peculiar customers would be impossible to make without some kind of batch and composition control. The first essential of a successful programme for control is to select a glass property which can be measured rapidly; is sensitive to small changes in the composition; is suitable for statistical treatment; has a stable operation, permitting good responsibility of job set-ups and has a higher consistent per-

* The author had given in his original manuscript an extremely rich description of various testing techniques, which had to be omitted for reasons of space.

cent back. Another necessary supplement to control the composition of glass is the control of raw materials for best chemical composition and particle-size distribution. It is important to know the analyses of raw materials, so as to be able to guide suppliers toward uniformity of the material, and to ensure a supply of materials with variation no greater than can be tolerated. Further, it is not possible to obtain glass of consistent quality unless furnace operation, as also batch ingredients, mixing etc., are consistent. Homogenization of glass is directly connected with the convection currents which occur in the glass melting tank furnace. Maintenance of regular convection currents result in a fairly regular wear of the refractories. A changing load or changing temperature would naturally upset these currents, as indeed will be changing of the cooling to the outside of the tank blocks.†

† The author's original manuscript contained excellent and exhaustive technical details not only regarding good furnace operation and melting control but also a long list of practical suggestions covering the whole range of glass manufacture.



Quality Control in Rubber

GP Dutta*

Unlike many industries viz. light engineering, textile, chemicals etc., most of the operations, save a limited few, in the tyre and rubber industries do not take place under constant cause systems and hence restrict the scope for the application of Statistical Quality Control. But where the operations do come within the scope of constant cause systems, SQC can work well, viz. in tube and tread extrusion, fabric calendering, bead wire measurements etc. In sampling inspection in the stores, SQC principles prove extremely useful. In investigational jobs SQC charts provide a clearer picture of the subject under study leading to definite conclusions.

Of the different fields of SQC application the most remarkable results have been obtained in calender operation. SQC boards installed near the calender have proved very helpful to the operators, and as a result calendered fabric weight variation and conformity to process mean have greatly improved. Besides ensuring better quality, this has also reduced costs.

Conformity to mean
(taking process mean = 100)

1959	—	115
1960	—	113
1961	—	110

Tyres, tubes, belting and cycle rim, which constitute the bulk of manufacture, are subjected to a very arduous treatment in service, hence the importance of the highest degree of control beginning from the raw materials till the products take the final shape. No source that may have any influence on quality remains unexplored. Every consignment of raw materials, received from approved and established suppliers only, is tested and only those meeting the specification requirements are allowed to go into production. Products in the different phases of manufacture are sampled and tested in the laboratories; in some cases the sampling is 100 percent, no risk being taken, as subsequent stages of manufacture would otherwise be adversely affected. The process control division acts as a sentinel on manufacturing operations. Finished products are also sampled periodically and subjected to machine and service tests. They are in fact inspected twice :—100 percent inspection on shop floor and a sampling inspection in the the stores prior to despatch. The latter inspection is carried out solely as the customer's risk inspection.

The regular sampling check on the weight of the components and finished products by the material economy section provides control on the consumption of materials in relation to process weights.

It is our experience that if the quality informations that are gathered daily at different stages are summed up together, giving each stage its relative influence on quality, not only a ready index of quality is obtained but it also serves the purpose of a rank correlation. This helps foster an interdepartmental competition in respect of bettering the quality index figures. The following figures speak for themselves:

Quality Assessment Score

1959	=	100
1960	=	118
1961	=	141

This improvement correlates well with the service performance data.

*The author is Quality Control Superintendent of Dunlop, whose interest in SQC goes as far back as 1952 when they utilized the opportunity of having one of their technical staffs trained in SQC under a training programme sponsored by the United Nations Technical Assistance Administration and the Government of India. They have been connected with the Indian Society for Quality Control since then. Also, recently one of their senior technical staff received training in SQC under the training scheme of the Indian Statistical Institute.

SQC in Kiln Production

BEFORE INITIATING SQC STUDIES, past records on quality, waste and production were scrutinised and this was helpful in deciding the starting point. The records revealed that the product quality obtained was satisfactory inasmuch as the specifications for silica content and loss on ignition were being adhered to. However, the daily production (saleable grade) fluctuated widely from 5.25 tons to 10.14 tons and averaged 7.37 tons only per kiln although the installed capacity was stated to be 10 tons of saleable grade. Such fluctuations offered difficulties in forecasting production and introduced an element of irregular working in the subsequent sections. SQC studies were, therefore, directed towards the standardisation of the daily production and exploring possibilities of attaining the stated capacity of 10 tons.

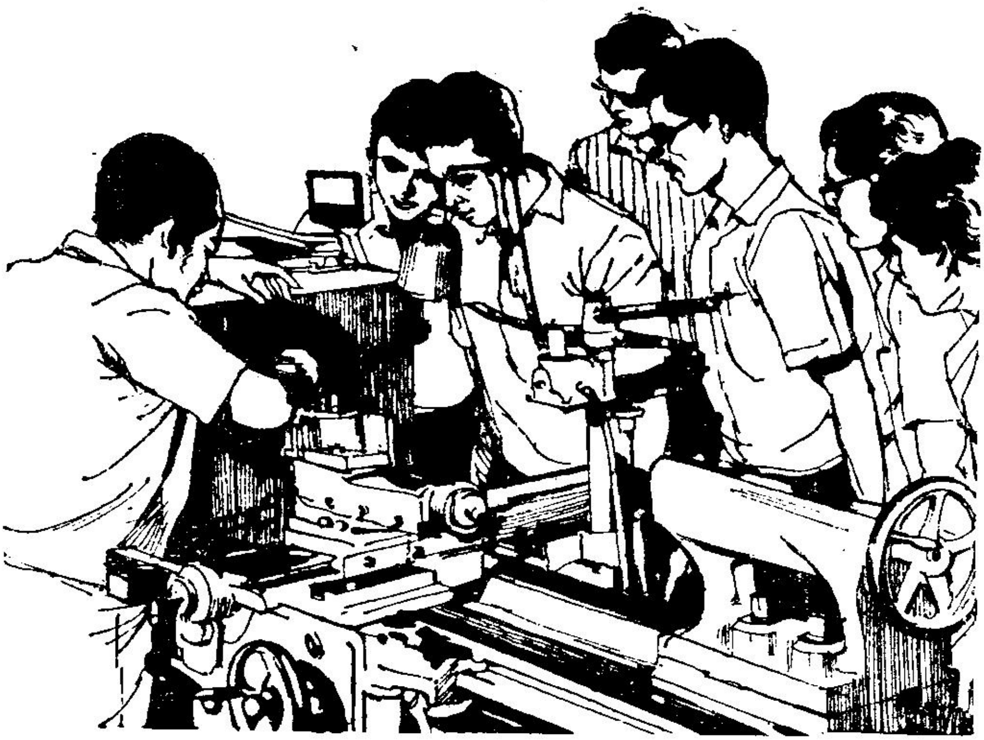
A study of the practices and procedures in vogue in the kiln section showed that the quantity drawn at a time from the kiln was left to the discretion of the operators. Also the material was being drawn more often from a particular pair of opposite doors (situated on the same sides as the burners) than the other pair, as it was contended that comparatively lesser time would suffice for proper calcination for the material near the burner. With a view to standardising production at the stated capacity, a series of planned experiments were carried out in the kiln section. The results speak for themselves. An experiment in 'fixed quantity per draw' resulted in an increase in 'saleable' by 7.4 percent. In another experiment, the reduction in 'uncalcined' suggested the possibility of reducing the 'hardburnt' by increasing the quantity drawn at a time. The latter in itself increased the 'saleable' by about 7%, being the direct result of increased quantity drawn. Shiftwise fluctuation in the percentages of hardburnt and uncalcined has narrowed down after standardisation of oil consumption. At the same time, the percentages of hardburnt and uncalcined have themselves come down from 14.24% to 7.74% and from 3.99% to 0.76% respectively.

The overall effect of fixing the levels of factors such as frequency of draws, quantity drawn and furnace oil consumption has been the increase in production from an average of 7.37 tons to more than 9.57 tons per day per kiln, i.e., an increase of 29%.

* Salem Magnestie, Salem

"There must be at least five hundred million rats in the United States; of course, I am speaking from memory."

Tomorrow's Experts



Metal Box is today assisting 200 young men to develop management tools and to qualify in the many specialist skills of modern packaging :

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Inspection Why and How

KENNETH C JASPER *

In practice a managering director very seldom has the opportunity to set up or organize inspection or quality control department in its entirety; because some phase or portion of the system may already exist. We can best see the basic and vital steps which must be taken, if we approach the establishment of an inspection department as though nothing existed at any point. So let's start from scratch.

THE FIRST STEP IS TO SET UP GOALS ON objectives: so that we may plan how to gain the objectives and check up, periodically, to determine how well we are doing. The following eight basic objectives for the quality control (inspection) department may be sufficient or we may in some cases wish to add our own:

(1) *To detect and isolate faulty materials:* before they enter the process, to prevent waste (2) *to protect the customer:* against paying for faulty, substandard or defective goods or services (3) *to discover and bring defects to the attention of those concerned* before they become serious (4) *to ensure that operators are paid only for good work and production* (5) *to remove, and prevent further* work being performed on parts or material already in-correctly made or defective (6) *to promote interchangeability* and to eliminate selective assembly (7) *to detect sources of weakness or trouble in the final product*, and report these to management for correction (8) *to promote and maintain the reputation* for complaint by affording customers, minimum cause for complaint.

When the objectives are finally set up, management must then determine how and by whom the objectives are to be implemented, if we accept the basic principle of organisation: *"That the checking up must be separated from the doing"*. We will have our head-man of the production department. The production people willingly deviate from standard to uphold production quotas. Their basis is always, "that it does not make any difference". However their willingness to take chances is often biased in favour of quantity, not quality. By separating the functions we shall help to defining responsibility and authority and channelize it. As part of setting up the inspection department, organisationally, we must determine those points or places in the process where the greatest effectiveness with minimum personnel can be achieved. To a large degree the determining factors are two fold. First: the complexity and precision of the product, secondly the value or cost of the product. With this in mind we can easily see that the production from a foundry will require a somewhat different inspection set up and less personnel than a plant, whose product is precision gear boxes.

Further, we need to make sure that, through a study of the parts, the process and tooling, we determine the

* Expert, George Fry Team attached to NPC.

points that are of prime importance and provide checks or inspection, both before and at the *point of no return:* the point where there is no possibility of salvage or where the adding of high costs to defective work are to be avoided. An effective type of organization for this plant would provide the following services of checks.

1. *In coming materials* certification.
2. *First piece inspection* to verify that the first piece of each newly set up operation is correct and to specification.
3. *Roving or floor inspection* during the operations, men will periodically, at random, check the part to determine that it is being done properly and to specification. Normally these men have the authority to shut down any machine not producing parts to tolerance. They also remove known defective product from the work area.
4. *Departmental inspection,* charged with the responsibility of making certain that only good, usable product leaves the department and in the quality required. They make certain that the workers are only paid for good product. This is especially important in shops using incentive plans.
5. *Final inspectors* who will finally recheck and in addition make certain that all the specifications have been met and that the part is functionally right. This function is normally in a separate area away from the shop proper.
6. *Gauge and tool inspectors* who are responsible for the maintenance and certification of all tools, jigs, fixtures and inspection gauges. The area of responsibility is normally limited to determining that the tool or gauges are dimensionally correct and that they will produce a part within the tolerance specified this function is extremely important because by checking dies, tools etc. we can often relax the inspection at other points, at least rely more on spot check instead of a 10 percent inspection of every part.

Many managements look on inspection or quality control as an item of expense, whereas in reality it is a cost saving tool which will pay its own way. The reduction in waste, the reduction in assembly time plus a savings in misapplied man hours and materials make the control of quality pay its own way and in most plants profits can be traced directly to this function.

When the quality control function is properly organized, manned and given the responsibility and the very necessary authority to perform its function; when management sets objectives and defines policies of operation, plant efficiency will climb and customer acceptance of the product will be reflected in increased sales and market security.

If I took a taxi in New York, I would often find that the driver was a Ph.D., who would start arguing about philosophy at imminent risk to himself and me.

—BERTRAND RUSSELL.

Inspection in Rayon Silk

VINAY BHARAT RAM & AC DAS GUPTA*

The authors have obviously considerable experience in textile manufacture. They not only know intimately the difficulties experienced in the classification of cloth attributes, subjectivity of judgment etc; but they are also conscious of the losses to manufacturers caused by fresh goods being classified as mill-seconds, erroneous discounts, market dissatisfaction and the like. They, therefore, conducted a series of experiments in which they were successful in reducing the usual subjective criteria to a relatively objective scale of judgment.

UNDER THE OLD SYSTEM CLOTH WAS RECEIVED in the folding department on rolls, each containing about 200 yds. This material was given a preliminary inspection by folders, who also cut it into lengths not exceeding 24 yards. The actual length of the pieces cut was determined by the interval between major flaws. The folders then graded the pieces into fresh, X and Y; X and Y refer to market discounts on defective pieces. Cut pieces (fents, rags and chindies) of course were collected and weighed separately.

Our problem now was to find the frequency of misclassification by the folders. But this presumed the solution of a much more difficult problem. How were we to know the true quality levels corresponding to fresh, X and Y ? We began by drawing up an arbitrary scheme in which all defect *irrespective of their source* were given demerit ratings according to length of a defect or the greatest distance between two defects per one yard fold. Thereafter certain pieces were examined yard by yard and the defects noticed were rated according to the scale. Each defect was weighted (multiplied) by its corresponding demerit rating and the yard by yard demerits were totalled for the entire piece-length. Finally the average demerits per yard per piece were calculated, thus yielding a numerical index of quality. As each piece was examined it was given to four persons to grade individually. These four persons—two from marketing and two from production—gave their personal evaluations in a set form. The agreement between the subjective personal evaluations and the numerical SQC ratings was very encouraging indeed. After a fairly large number of samples were taken in each quality, a meeting was called to decide on the quality standards for fresh, X and Y. For example, it was decided that X should fall between .75 and 1 and so on.

An objective scale for testing quality levels was now available. The next problem was one of arriving at a random sample size which would give a reliable

* Delhi Cloth & General Mills

check on the percentage of errors made by the folders while grading.

This was estimated in the following manner

$\bar{p} = 0.03$

$p^1 = 0.08$

$$S\bar{p} = \sqrt{\frac{N-n}{N-1}} \sqrt{\frac{\bar{p}(1-\bar{p})}{n-1}}$$

$$= \sqrt{\frac{200-n}{200-1}} \sqrt{\frac{(.03)(0.97)}{n-1}}$$

$N = 200$

$Z = 1.7$ (confidence level of about 90%)

$n = ?$

$\bar{p}$ is the actual error rate observed.

$S\bar{p}$ is the estimate of the true standard deviation.

N is the average number of pieces folded every day.

p^1 is the upper tolerance limit of the error rate.

N is the sample size which will give a 90% assurance that the true error rate does not exceed 8%.

$$Z = \frac{p^1 - \bar{p}}{S\bar{p}}$$

$$p^1 - \bar{p} = Z \; S\bar{p}$$

$$.05 = (1.7) \sqrt{\frac{200-n}{200-1}} \sqrt{\frac{(0.03)(0.97)}{n-1}}$$

$$\left(\frac{.05}{1.07}\right)^2 = \left(\frac{200-n}{199}\right) \left(\frac{.0291}{n-1}\right)$$

$$n = 29.79$$

Thus it was found that a daily random sample of 30 pieces would give a fair assurance that the outgoing quality leval of the product was upto the mark and the error rate of the folders was within the specified control limit. Experience of course showed that the error rate actually varied on account of changes in the kind of material folded or increased worker-negligence. To counter this the sample size was linked functionally with the error rate, that is, whenever the error rate went up, other things equal, the above formula assured us, that the sample size would increase appropriately.

In a city in which consumers of gas still receive gas through quarter-in-the-slot meters, the gas company hired a new collector. "Here's a master key," said the manager. "Go around and empty all the coin boxes. Get all the quarters." The new collector was gone two weeks. Then he walked into the office and said: "Can I have another key? I lost the one you gave me." "Sure," said the manager. "But where've you been? Last Friday the cashier stayed here till seven o'clock in the evening to give you your wages." .... "Wages?" said the new collector. "Do I get wages, too?"

Research in Visual Inspection

Ackoff & Arnoff*

Some years ago a large manufacturing company approached Ohio State University with a request for a research project to investigate the factors affecting visual inspection performance. Below is printed an interesting and significant account of an inter-disciplinary research, indicating that Quality Control really connotes a lot more than the words signify and proving that attitudes are more important than techniques.

The company was anxious to discover the means for improving quality and reducing the cost of the visual inspection of one of the parts which they manufactured for use in their product. The inspection task involved a 100 percent visual inspection of the product for flaws and defects, many so small as to be hardly visible, at a relatively high rate of speed. The large number of parts produced and inspected each year (somewhat over 2 billion) and the importance of the quality of these parts, both to the company's reputation and the satisfaction and safety of their customers, combined to create a problem of considerable magnitude and importance.

The project was accepted, and the company detailed their Director of Quality Control as project administrator. The University assembled a research team consisting of a research optometrist, a psychologist, and the author, an industrial engineer and statistician. It was agreed that the research be directed toward the discovery of those factors having a significant effect on visual inspection performance.

One year was spent in the University's laboratories investigating various aspects of the problem. The optometrist studied the correlation between visual inspection performance and various types and intensities of illumination, measures of keenness of eyesight among inspectors, and types of eyemovement patterns. The psychologist studied motivational problems, job satisfaction factors, and fatigue problems. The industrial engineer was concerned with the effects of various types of designs of inspection equipment and with the statistical analysis of the experimental data.

An imposing array of scientific techniques was used, ranging from physiological optics through aptitude measuring tests. The interchange of viewpoints and techniques among the three disciplines represented contributed greatly to the success of the venture. One of the most difficult problems involved in the whole study was the definition of a satisfactory measure of visual inspection performance. Those measures which had been used by the company were found to be generally unsatisfactory. Before the experiments were completed eight new

* Operations Research Group.

methods of measuring visual inspection performance were devised. The previous lack of valid and reliable measures of performance had caused untold difficulties in earlier investigations of the inspection problem by the company and by others.

The studies showed that there were a number of factors affecting visual inspection performance, by far the most important of which was *the attitude of the inspector*. It was further concluded that under optimum conditions the inspection rate on this operation could be increased by 300 to 400 percent with a considerable improvement in the quality of the job being done.

With these results in hand, the research team and the company's coordinator made an in-person report to the company's top management. The company was urged to undertake a vastly expanded programme of research in order to discover means for translating our findings into practical procedures for improving their inspection operations. The company's management, a very conservative group, was at first skeptical of the whole investigation, but by the close of our meeting they were highly enthusiastic and decided to proceed with the study on an even larger scale than had been recommended.

As the next phase of our investigation, it was decided to undertake an intensive study of conditions and procedures in the inspection department in the plant. A variety of interesting observations resulted from this study, two of which are particularly important: Since a number of the defects which the inspectors were supposed to detect on the surface of the part were quite minute, the company had equipped each inspection device with a magnifying lens. The team's research optometrist was, however, to prove that the logical analysis of problems as complicated as this one is likely to be quite subtle. He, however, discovered that every single inspector in the department was using the magnifying lens, not as a magnifier, but as a corrective lens. In other words, they were using the lenses, not to make the object look larger, but to relieve eyestrain. After study of the problem he was able to design a new lens which combined the effects of magnification and correction; at the same time the new lens reduced some of the eyestrain caused by the necessity for changing the eye's depth of focus as it lodged from one area of the surface to another. As a result, inspection performance was improved significantly.

Another interesting case concerned the investigation or worker attitudes. Immediately after approval of the request for an expanded investigation, the team approached management for permission to conduct a survey of worker attitude among the personnel of the inspection department. They replied that they were *not interested in workers' attitudes, only in worker production*. Since preliminary investigations had indicated that workers' attitude was probably the primary determinant of visual inspection performance, the team persisted in its request. Management indicated that they did not wish to proceed with such a study because they felt certain that the workers would make the proposed survey an occasion for demanding higher wages. Thus, it became apparent that management's reluctance was not due to their indifference to workers' attitude, but to their feeling that they knew exactly what the workers' attitude were ("We're not being paid enough!") Finally, management acceded to the team's request and it proceeded to conduct an attitude survey.

It should be noted at this point *that attitude determination is a very tricky business, and one that should be entrusted only to competent professionals.* The problem was complicated in this case by the fact that the inspection department consisted entirely of women. An analysis of the results of the interviews brought to light some most interesting facts. First, out of the 150 girls surveyed, only three even mentioned wages; two of these had volunteered the information they thought the job paid quite adequate wages, and only one complained that wages were too low. At the same time, 136 out of the 150 girls complained that the chairs were very uncomfortable. To say that these results were a surprise to management is a gross understatement. When they had recovered from their state of pleasant shock, they immediately had samples of a wide variety of chairs placed in the inspection department with instructions that the employees were to select the one which they liked the best. One week later, the entire inspection department was equipped with new chairs. It goes without saying that management and the inspection force developed a mutual admiration never before known in this company. In addition to the complaints about the chairs, the attitude survey brought to light several other situations which, though they appeared to be trivial matters on the surface, were actually the cause of considerable employee unrest and dissatisfaction.

The next phase of our investigation involved setting up a "pilot plant" in which we could carry out experiments under conditions approximating those obtaining in the plant. The team hired and undertook the training of a random sample of 12 girls. Although the inspector training programme had not been slated to be a subject for investigation in this project, the necessity for training 12 new inspectors provided an opportunity to review established training procedures. Making use of the principles of the psychological theory of learning, the team was able to devise a new training programme which was tested on behalf of the group of new inspectors. The results showed that the new procedure required only half the training time needed by the procedure then used in the plant. The new procedure was put into effect with the result that new inspectors are now productive and "earning their way" in half the time previously required.

A further and even more important result accrued from the use of the new procedure. The contract between the company and the union calls for a probationary period of a specified duration for all new employees. During this period the company has the right to discharge the employee for any reason whatsoever, but after the expiration of the probationary period the employee becomes a member of the collective bargaining unit and can be discharged only for those reasons covered by the union contract. It so happened that the old training procedure required more time than the length of the probationary period, and also it was known that performance during the training period was a very unreliable measure of "on the job" performance. Thus, it had been almost impossible for the company to weed out potentially mediocre and poor inspectors before the termination of the probationary period. The new training procedure changed this situation completely; there was sufficient time during the probationary period to complete training and to get a good evaluation of the inspector's capabilities through "on the job" measurement of performance. Thus, the company was able, over a period of time, to improve the general level of competence among inspection personnel.

An analysis of the eye-movement photographs showed that the average inspector was actually seeing considerably less than 100 percent of the surfaces of the parts which she was inspecting. This meant that, even if she recognised and removed all the parts that she saw had defects, she would be doing considerably less than a perfect job of inspection. Based on scientific knowledge of the capabilities and limitations of the human eye, it was possible to devise a new inspection device and undertake a programme of training the inspectors in the use of efficient eye-movement patterns, thus effectively eliminating the former difficulties. Applying the basic laws of optics to the problem at hand, a new and improved lighting fixture was designed which, by insuring that the right amount of the right kind of light was being transmitted to the inspector's eye, allowed her to do an even more efficient job.

The team's investigations indicated that the difficulty of the inspection task varied with the percentage of defective parts in a batch. The team proposed that the conventional fixed-speed inspection device be equipped with a variable-speed drive, the speed to be under the control of the inspector so that she could vary the speed of the inspection operation in accord with the proportion of defective items in the batch being inspected and in accord with her own individual capabilities. There was considerable initial resistance to this idea on the part of the company. They feared that putting the control of the speed of the inspection operation in the hands of the inspector would give her an opportunity to cut down on production. Eventually, such a device was installed and tested. The result was an increase rather than a decrease in over-all production rate with a substantial improvement in the quality of the inspection job.

Perhaps the most interesting aspect of the investigation centers around the problem of motivation. The other results which were obtained were facilitative in nature, i.e., they improved the physical and visual aspects of the inspection task to the point where the inspector could, if she wanted to, inspect at a much higher rate of speed and with greater accuracy. The problem was how to get the inspector to "want to".

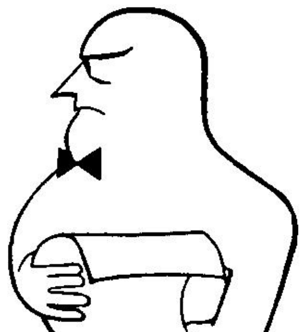
The logical approach to the problem would be through the installation of some type of monetary incentive plan. This was the approach proposed and favoured by management and such a plan was installed and studied. The improvement in the production rate was substantial, but the team was convinced from its capability studies that the inspectors were capable of achieving even higher levels of performance. The logic behind conventional incentive plans is simple and direct: more pay for more work. However, the logical analysis of this problem, as in the case of the magnifying glasses, turned out to be a little more complicated.

A review of the case histories and interview results from the experimental inspectors and those in the plant showed that only a small percentage of them depended on their wages as a primary source of support. Most of the women were either young girls just out of high school, living at home and working until they got married, or married women working to supplement their husbands' incomes. From a careful study of the value systems indicated by the data, it was concluded that *extra time would be much more valuable to the inspectors than extra money*. To test these conclusions *a "time-off" incentive system was set up*. A weekly production quota was established, and when an inspector reached the quota she could go home for her work. Under this system production increased dramatically, and a number of the girls were able to complete 5 days' work in 2 or 2½ days. This represented almost three times the production rate normally achieved in the plant.

Investigation of the use to which the inspectors put their time off revealed that a number of new and powerful sources of motivation had been tapped. One woman, for example, wanted the additional time to spend at home with her children. The top inspector, who by far outstripped all others, was revealed to have a husband who worked on the night shift. It was deemed that no further investigation into the source of motivation in this case would be required. In short, it was found that, contrary to popular opinion, money was not the most important of the available incentives for motivating this group of workers.

The new incentive system, while extremely successful in increasing the rate of production, created another problem. The previously used checking and quality control system was not adequate to maintain the desired quality level in the outgoing product. Therefore, the team set about the task of scientifically developing a new procedure for checking and quality control. Through the use of some fairly involved statistical procedure the team was able to arrive at a scheme in which the average inspector would *earn the greatest amount of time off when producing at a quantity and quality level which minimized the total cost to the company.* The team was thus able to achieve that rarely attainable objective —*a situation in which what was best for the worker was also best for the company.*

When You Call Me That, Smile!



The Visual Assessment of Finish

E. Summerscales*

One of the most difficult tasks facing an inspector is to pronounce on the acceptability of standards of finish where there is no means of measurement. In the machining field, the problem has been solved by the development of surface measuring instruments. The use of these instruments is now commonplace in the engineering industry and a standard method is laid down for the interpretation and communication of results. When one engineer speaks of a finish of 15 micro-inches C.L.A., all other engineers know just what he means. Unfortunately, many finishes cannot be assessed so specifically. If one thinks of the polishing and plating of metal, of painting, of finish on moulded plastics or rubber, of the finish of glassware, etc., one realises that the assessment of the standard of finish is subjective.

This case study describes an attempt to overcome this problem in the case of plated zinc-base die-castings. The method is not free from the use of subjective judgment. There will always be differing opinions about finishes of the non-machined kind. The method applied to the data is quite exact, though, it is stressed that whatever standard of finish is derived, the criteria for its durability must be satisfied as the prime requirement.

Judgment operates from the outset in the selection of, say, seven specimens of the product. Presumably this will be done by a single responsible member of the organization, usually the Chief Inspector. The sample comprises: one unit well below the standard of acceptability; one specially produced unit of high standard (or of selected high standard).

These two specimens clearly limit the upper and lower boundaries. The lower one is at a level which would injure a company's name for quality, whilst the production cost of the upper one is outside the price being paid by the customer and would, therefore, spell economic ruin.

Five units with varying degrees of finish, but all of marginal acceptability. In the case of a plated die-casting this could be a combination of brightness of plate, smoothness of plate, freedom from base-metal defects resulting from casting and polishing, freedom from uncovered nickel and, certainly, freedom from blistered plate.

A panel of responsible and interested members of the production unit should be asked to pronounce on the specimens. Experience shows that it is wise to let each person make judgment in isolation because there is almost bound to be collusion otherwise. Having confirmed that reliance can be placed on the trust worthiness of the panel's findings, the final ranking can be determined from the individual row totals in terms of "marks" awarded.

benefits from the approach

1. An assessed opinion has been established and samples of average, and below average can be retained as typical of their class. They can be used for routine reference in keeping a standard in the mind's eye of those carrying out inspection. 2. Secular process deterioration can be detected. 3. The psychological factor of a group effort banishes the inspection "tyranny". 4. A firm basis has been established for price/quality negotiations. 5. Samples are of great value when communicating standards to sub-contractors who are getting work for the first time.

* Chief Quality Engineer of Joseph Lucas (Electrical) Ltd.

Application of SQC Methods

AV Sukhatme*

Applications of Statistical Quality Control technique is now so widespread in western industry, that it is no longer necessary to sell the idea that *statistical techniques provide a useful tool for taking executive decisions.* The collection and compilation of operation data for analysis and its interpretation, as an aid for management, is now almost accepted as a routine in many progressive industrial establishments. Their adoption in India is however still in its infancy.

SQC methods are useful for increasing productivity in many ways. The main elements of a control programme are (1) setting up standards, (2) comparing actual performance with the standard set, (3) analysing the difference or determining the cause of variance, and (4) applying corrective action. This procedure reduces waste and ensures optimum results at minimum cost, and thus increases productivity. Various aspects of operations such as production, yields, rejects, services, manhours etc can be brought under a control programme. The basic concepts of such a programme, under the four heads indicated above, remain unaltered and statistical methods provide the necessary tools for setting up of standards or analysing relevant data.

The best known statistical method in industrial application is the control chart method. Control chart method expresses the inherent characteristics of a system. The nature of its variation is indicated. Limits of variation can be set by a study of back data and forward specifications can be established. A trend towards one or the other limits can be investigated before out-of-control situations develop. The performance can be measured not only of products but also of other factors to be controlled such as manpower, absenteeism, safety records, clerical errors etc. One advantage of the control chart system is that *it catches errors at inception rather than at inspection.* An intelligent study of the process will reveal a point at which a control check should be exercised which will allow correction of defects before the piece is finished. This eliminates waste and reduces rejects.

Statistical analysis of customer complaints leads to tracing sources of weakness in the manufactured product and improvement in quality. A thorough sifting of data reveals whether the complaint arises due to (1) faulty specification, (2) faulty product or, (3) faulty inspection procedure.

In India the measures for prolonging equipment life is a matter of some urgency. Statistical treatment of equipment failure and frequency distribution of repairs establishes a preventive maintenance programme as a check on the equipment before serious trouble develops. The probable life can be evaluated and the most economic way of using an equipment can be established.

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There is another aspect of equipment life can be analysed statistically. In certain cases, as in life of rolls in a steel mill or life of O.H. fces., the condition of the equipment reflects on the quality of the products, in which case it is possible to work out statistically the optimum equipment life.

Judging association between operation practice and the quality of the product is of great interest to supervisors. Generally such associations are assumed on some theoretical reason or sometimes at best by a guess. The statistical correlation-regression technique provides a good method for working out such associations on actual data obtained. Extensive use of this technique has been made in steel industry for judging the effect of various factors influencing steel manufacture as regards their chemical and physical properties. This would help setting limits for operation practice as it would enable us to determine the optimum limits of the factors under examination for best practice.

There are several other techniques well known to statisticians, as tests of significance, analysis of time series, statistical inference, X^2 tests, binominal distribution of variables etc. which have applications to industry for control purposes. Each one of these methods can be usefully applied but the following warning, sounded by Dr. Juran* in regard to applying the use of statistical methods in Industry by an academic statistician are worth mentioning :—

1. Statistics is not an end in itself but only an adjunct in applying the scientific method.
2. The practitioner of statistical methods must be aware of the broader programme of managerial endeavour of which his specially is only one element.
3. Application of statistical methods must commence on a small scale and must grow with due regard for the time needed to grow solidly.
4. The statistical methods must be sold by all the arts of salesmanship. They cannot be forced on the executives of industry.
5. The intricate methodology must be kept in the background for use by the statistician only ; the simple methodology may be introduced into the shop for use by the shop personnel.
6. The statistical practitioner must learn of the technology of management and not expect that the managers will want to learn of the techniques of statistics. They will want to learn only how these techniques can aid them to carry out longstanding management objectives.

*Dr. Juran—"Application of statistics to the Science of Management". *Mechanical Engineering* April '49.

Robert M. Hutchins, former president of the University of Chicago, is reported to have said in a commencement address, "I understand that Harvard University is making its diplomas larger or smaller. I have forgotten which. This is a step in the right direction!"

Applications of Statistics to Industry

SP VASWANI *

There is a general impression that improvement in quality is usually accompanied by an increase in the cost of manufacture. Statistical controls provide techniques, which when properly applied, have been observed to reduce the cost of manufacture simultaneously with improvement in the quality. The Statistics Division of the NC Corporation has been giving Statistical Service to many organisations in the public and private sectors. In the industrial field, this Division has *inter alia* helped many factories to reduce wastage, rework and scrap; improve the quality of manufactured product and the efficiency of machines and operatives and increase material utilisation by establishing statistical controls at various stages of manufacturing processes. Their techniques have also helped in controlling stores, inventories and in-process stocks. A few of the many results obtained in some of the member organisations of the Corporation have been summarised below. In these case histories, no attempt has been made to assess the economic advantages achieved with the help of SQC techniques. The Statistics Division of the Corporation generally leaves it to the managements of its member organisations to make such assessments, who have informed from time to time about the considerable monetary savings effected by them after taking appropriate action on the basis of the techniques introduced by the Corporation.

STATISTICAL CONTROLS WERE INTRODUCED in the stores of a member organisation in 1958. The ratio of the total money value of the stores as on March 31 to the average monthly nett billed value during the year ending March 31, was 4.6 and 4.8 in the preceding two years. After controls, this ratio decreased to 3.1 in the year 1958-59, and further decreased to 2.24 in the year 1960-61. In the year 1960-61, a proportion of the stores had been deliberately built up, as the factory had decided to manufacture a new product. Excluding this portion of the stores, the value of the ratio in the year 1960-61 was 2.05.

Training of operatives

The Statistical Division of the NC Corporation among other things, gives training to operatives with the help of statistical techniques. Some elementary principles of Statistics are explained to the operatives and efforts are made to make them quality-conscious. Appropriate charts are also installed on the machines or at some other suitable places. Such training has invariably resulted in very significant improvements in the quality of work or product, com-

* Dr. Vaswani is a Director of the NC Corporation Private Ltd. (Stadium House, Bombay). One Division of this Corporation, namely, the Statistics Division, gives Statistical Quality Control Service to various organisations in industry, trade and administration, including the Government of India. The author desires that the text of the article printed in this Journal should not be reproduced without obtained prior permission of the Corporation.

bined with an increased rate of production. This is illustrated in the case of a machine shop in which eight operatives who were producing a large proportion of parts requiring rework were given training. After training, each of these operatives was able to reduce the incidence of parts requiring rework, as shown below:

Parts requiring rework

(As percent of total parts produced by each operative)

Operative Number	SQC Before %	SQC After %
1	22.1	0.1
2	18.7	0.8
3	24.6	3.6
4	24.1	5.2
5	24.8	3.9
6	28.8	12.9
7	15.8	6.5
8	26.2	8.6

The first three operatives had been given training for seven months and the last five for four months. Further, as a result of these improvements, this component which was previously in shortage in the assembly, actually became a surplus part thus eliminating completely the hold-ups in the assembly which had previously occurred due to the shortage of this part.

Manufacture of batteries

Controls exercised on the manufacture of one type of zinc cans helped the member organisation to reduce the incidence of defective cans from 13 to 1.5 percent in one machine, from 11 to 3 percent in second machine and from 12.6 to 0.8 percent in the third machine. The overall incidence of defective cans decreased from 12.2 to 1.7 percent. In this member organisation, statistical controls *inter alia* helped in improving the evenness of wall and bottom thickness also. The result was that the average thickness in the case of wall as well as bottom could be reduced without violating the minimum desirable specifications. The bottom thickness was reduced by 15.4 percent of its original value, while the wall thickness was reduced by 3.3 percent of its original value. The average weight per can consequently declined by 3.6 percent of its original value, which was an important achievement, particularly in view of the fact that zinc was an imported material.

Works in progress

In SQC investigations conducted on the movement of works in progress in two member organisations, the movement of lots of cloth was studied from the time they were sent for processing to the time they were ready for despatch. On the basis of the data collected thus, it was possible to take corrective action in such a way as to expedite the movement of the works in progress. It was possible to reduce the average number of days per lot from 52 to 35 in one member organisation, and from 32 to 24 days in another member organisation. These techniques thus helped the member organisations to release considerable amount of locked-up capital and to speed up the turnover of their finished product. In the case of one member organisation, for instance, the works in progress carried by the factory before controls were installed, were equivalent to more than 54 days' production. These stocks were reduced to about 25 days' production after controls.

The loom-shed case

In the loom-shed of a member organisation, SQC techniques yielded the following results: defective cloth reduced from 10.2 to 5.1 percent; idle loomshifts from 3.8 to 2.2 percent, and loss in machine utilisation from 27.1 to 22.1 percent. The rate of production of piecers at the same time increased from 7,600 to 8,600 ends per piecer per shift. In the loom-shed of another member organisation, systematic SQC investigations help-