Introduction

The modern idea of Quality Assurance supersedes the old idea of Quality Control, which is now relegated to a subsection of a total Quality System.

Quality Control

The old-fashioned concept of Quality Control is that goods are inspected at various stages in production to determine if they conform to given quality standards so that remedial action (such as mending or reprocessing) can be taken if they do not. Great emphasis is placed on final inspection with sub-standard products possibly being assigned to "second grade" and being sold at lower prices.

This approach was acceptable for simple production systems where

- long runs of a single product could be guaranteed,
- markets were dominated by domestic suppliers who were all competing on a more-or-less equal cost basis, and
- the range and quality of products on sale in various markets were determined by what the manufacturers were prepared to supply.

Quality Assurance

Quality Assurance is designed as a response to much more sophisticated and complicated capital intensive manufacturing technology and much more stringent and internationally competitive markets where the dominant force is consumer choice.

It depends not on the detection and correction of poor quality (however that may be defined within a particular company) but on the positive guidance and control of the product design and production environment so that poor quality is never made. It also stems from the recognition that, in today's production and market conditions, poor quality has a very high cost.

Even though Quality Assurance systems can be expensive, if they are properly applied they will save money in direct costs and they will generate or preserve sales due to enhanced reputation and customer confidence.

Quality Assurance Standards

The technology of Quality Assurance has made great progress in the last decade and much of it has been codified into a series of standards. The most basic and important of these is the ISO 9000 series.

These (and other related) standards will repay very careful study before any attempt is made to try to introduce new Quality Assurance schemes into a mill. However, it should be remembered that the standards represent a rather full statement of complete and very sophisticated Quality Assurance Systems.

Usually it will not be either possible or desirable to attempt to introduce such a complex system wholesale into an operation which may be accustomed to working with traditional routine Quality Control procedures, and which may have no familiarity with Quality Assurance concepts.

It must be remembered also that the standards concentrate on systems and mechanisms. They say very little about the changes in culture and philosophy that are required if a true company-wide Quality Assurance effort is to be successful.

It is very much more important to develop an appropriate attitude and approach to Quality Assurance than to implement complicated theoretical systems.

Objectives of Quality Assurance

A Quality Assurance system has two sides to its major objectives. One side is related to the direct benefits that are expected for the company itself; the other side relates to the needs and expectations of the customer. From the point of view of the company, these can be thought of as internal objectives and external objectives.

The internal objectives of the company are:-

- To eliminate the internal costs associated with sub-standard quality, such as waste, reprocessing, loss of production, and "second grade" selling prices.
- To generate the process control information and knowledge that allows proper control of machinery and processes in the most economical way, consistent with the required quality.
- To generate the product engineering information and knowledge that allows proper prediction of the performance of a given product and, hence, facilitates new product development at minimum cost.
- To generate the knowledge of the critical product parameters and process conditions that allows the Quality Assurance system itself to deliver the ability to continuously reduce the total cost of quality, whilst maintaining the performance of the product at a level that will satisfy the customer.

The external objectives of the company are:-

- To avoid the direct and indirect costs of sub-standard quality in terms of returned goods, lost sales, and marketing claims.
- To build confidence in the customers and reputation in the market, that will assure the retention of customers in difficult times and adequate profits in good times
- To develop a system of feedback from customers that allows advance information about market requirements and ensures that products are made available that actually satisfy a known need.
- To develop a communication system with suppliers so that materials which will critically affect the cost and quality of the company's product are delivered consistently to the required quality specification at the optimum cost.

Components of a Quality Assurance System

An overall Quality Assurance System basically comprises three main elements. These are the Quality Policy, the Quality Targets, and the Quality System. All three are embraced by the Company-wide Quality Culture.

Quality Policy must be set at the highest level of management. It is a statement of what the general attitude of the company is towards the level of quality and the means and resources for obtaining it.

Quality Targets are specific values and tolerances for quality standards to be achieved (e.g. waste below w%, reworking below r%, yarn count tolerances within plus or minus y%, shrinkages below s%)

The **Quality System** is the organisational structure that will be used to implement the policy and achieve the targets (personnel, responsibilities, procedures, resources).

All of the above three elements embody two main perspectives:

1. The average level of quality.

   This defines the position of the company in the market (e.g. Rolls Royce vs. Ford).

2. The general approach towards quality improvement.

   This defines the attitude or the culture of a company.

Most of the additional work and the cost of Quality Assurance are concentrated in the System and so it tends, quite rightly, to get the greatest concentration of effort. However, if the Policy and the Targets are not consistent and realistic, and if the whole workforce does not adequately support them, then even the best organised System will fail to meet its objectives.

Specific Aspects of Quality Assurance

The single most important principle of Quality Assurance is that conditions of manufacturing should be organised so that poor quality is never made. A system that merely emphasises detection and correction of poor quality will be expensive and ineffective in terms of the internal and external objectives given above.

There are three basic tenets that will serve to guide any Quality Assurance system in the right direction.

- It is always more cost-effective to do the job right first time.
- The only performance indicator is the cost of quality.
- The only performance standard is zero defects.

A very good summary of the most critical aspects of Quality Assurance and Total Quality Management has been given by Dale and Oakland in "Quality Improvement through Standards". This book is highly recommended as a general introduction to the subject.

Some specific aspects are discussed in the following topics

- Definitions of Quality
- Company-wide Culture
- Product Design and Specification
- Suppliers
- Process Control
- Quality Targets and Tolerances
- Resources
- Quality Related Costs

Definitions of Quality

At least three different perspectives can be distinguished, namely Consumer Quality, Market Quality and Manufacturing Quality.

Consumer Quality

So far as the ultimate consumer of products is concerned, Quality simply means performance per unit of price. The problem arises in defining the meaning of performance. There are at least three aspects to performance. These are Objective performance, Subjective perceptions, and Service.

- Objective performance includes tangible physical properties such as colour, weight, handle, shrinkage, durability, garment design, size and goodness of fit, neatness of seams and hems. Some of these properties can be evaluated by the consumer at the point of sale, some manifest themselves only after more or less extended periods of use.
- Subjective perceptions are those intangible aspects that influence the consumer to value a given product more or less highly, regardless of its objective performance. Included are image, lifestyle, fashion, and promotion. It has often been said that a $50 tee shirt is a $10 tee shirt with a $40 logo attached. Whilst this view is perhaps over-cynical, it does illustrate that consumers are influenced by intangible aspects of quality.
- Service relates mainly to the environment in which the product is purchased, combined with previous experience of the product or the environment. A high-class boutique can sell the same objective performance at a higher price than a market stall. Because many of the objective aspects of performance cannot be evaluated at the point of sale (e.g. shrinkage, wash fastness), a consumer will be influenced by previous experience of buying a given product brand, or the general reputation of a given retail store, and its policy in handling complaints.

Consumer Quality is measured in terms of satisfaction. The only reliable indicator of satisfaction is repeat purchases at the asking price.

Market Quality

Market Quality has two faces. One face is directed towards the Consumers, the other is directed towards the Manufacturing Operation.

- On the one hand, Market Quality is the general performance level that a manufacturer or retailer sets for his products, in order to target a particular sector of consumers.

- On the other hand, it is a collection of design and manufacturing targets and tolerances that will be used by the manufacturing operation to develop and deliver specific products.

The manufacturer has to decide what sector of the market he is targeting and, consequently, what levels of Objective, Subjective, and Service performance he will be obliged to provide, and at what price. Once the general performance levels have been decided, they have to be converted into specific product designs, marketing strategies, and objective performance requirements. The objective performance requirements have to be translated into design, engineering, and manufacturing specifications, with appropriate tolerances, for each specific product.

Market Quality is measured in terms of product demand compared to the estimated total demand in the targeted sector.

Manufacturing Quality

So far as the manufacturing operation is concerned, the definition of quality is very simple.

- It is Conformance to the Objective Specification.

More complicated definitions are a distraction from the business of manufacturing.

Manufacturing Quality is measured in terms of the cost of quality as a whole and the cost of non-conformance in particular.

Company-wide Culture

The general approach towards quality improvement defines the attitude or the culture of a company. Three distinct types of Company Culture are summarised below. Most companies contain a mixture of all three types.

Inspection-driven Culture

Traditional systems of Quality Control depend on inspection of the products for defects, followed by corrective action or grading into first and second class quality. Under such systems, the cost of quality is large and is represented by waste, reprocessing, lost production, lost sales, and lost market opportunity.

In general, individual operatives have little or no control over quality; their main emphasis is on production. Managers spend the majority of their time sorting out problems both inside the factory and with customers and suppliers. This kind of system can be thought of as the product of an "Inspection-driven" culture.

The Inspection Driven Culture is basically out of control. The underlying driving force is production. The cost of poor quality is not accurately known, and there are frequent disputes between the production, inspection, quality control, and marketing departments. Unless their domestic markets are heavily protected, such companies will eventually fail under modern international competitive pressures.

Control-driven Culture

A company which has realised that the cost of quality can be reduced by closer control of supplies and processing progresses to a better degree of control. This is achieved by the installation of rigid systems for specifying and checking supplies, more highly automated machinery and the imposition of strict discipline in the operation of machinery and control systems.

Some form of Statistical Process Control may be introduced, along with Quality Manuals and Standardised Quality Procedures (ISO 9000) Operator training may be improved, and there may be some move away from a reward system based purely on productivity bonuses. This kind of system allows for the stabilisation of Quality Levels but does not necessarily reduce the cost of quality by very much, since the new control systems are expensive to operate. This is a "Control-driven" culture. Managers spend a lot of time supervising the system.

The Control Driven Culture always attempts to maintain the status quo. There are seven basic activities in a Control-driven system.

- Choosing objectives for control.
- Selecting the control methods.

- Deciding standards of performance.
- Installing measuring equipment.
- Measuring performance.
- Comparing performance with the standard.
- Acting on the difference.

The underlying driving force is measurement and the preservation of the status quo. The objective is to maintain existing practices and standards. The system has large advantages over the Inspection culture because its result is a greater uniformity and reliability. However, it can become inflexible and cannot easily develop better or more cost-effective ways of operating.

Continuous Evolution-driven Culture

The final step in quality and cost control can be taken only when the system is driven by quantitative evaluations of the effect of working methods and production systems upon the quality-related cost of each individual process within the whole chain, from raw materials supply to marketing and customer service. This is a "Continuous Evolution-driven" culture. It recognises that:

- The raw material with the cheapest price is not always that which provides the minimum overall cost. The quality culture in a supplier's factory is of vital importance.
- "Quality and cost improvements cannot be dictated by management; they have to be earned through the hard process of data collection, analysis, and problem solving."
- "The control of quality can only be exercised at the point of production, i.e. by individual operatives."
- Each process is "owned" by a responsible operative. To be a responsible owner, the operative has to have:
  - full understanding of what needs to be done,
  - the means to know what is actually being done, and the cost,
  - the ability to evaluate and regulate his performance.

The Continuous Evolution Culture is always looking for a way to achieve a breakthrough to a different way of operating at a lower cost at the same or better quality. The sequence of activities required for a breakthrough requires eight stages.

- Choosing objectives for breakthrough.
- Convincing colleagues that a breakthrough is needed.
- Identifying the vital few projects.
- Organising for a breakthrough.
- Creation of a project team and a champion to steer the effort.
- Data collection and diagnosis.
- Breakthrough in cultural pattern of working.
- Transition to a new level.

The underlying driving force is reduction in the total cost of quality. The result is a continuous evolution towards higher standards and new practices.

Product Design and Specification

The most important source of new product design information is the customer and he is ultimately the most important person to satisfy. No product will succeed in the long term unless it has been designed to satisfy a specific customer need. However, it should be remembered that many customers are still working under the Inspection-Driven Culture. The following are points to watch.

- the customer often has very short term horizons; be sure that his immediate requests are consistent with long term company policy.

- the customer is in a minority of one; unless he is a very large customer, be sure that at least some other customers are also interested in his ideas and make some attempt to estimate the market size before committing to a new product.
- the customer often is not very good at expressing what he really wants; be sure that any hidden desires or fears are extracted, if possible, and that he is fully aware of the company's capabilities.
- the customer often is not technically trained; be sure that the specified performance is actually achievable and, if not, establish as quickly as possible what is the best compromise.
- the customer is often very hazy about realistic target values and tolerances; be sure that he understands the advantages of fixing required quality standards but that there is bound to be some range in performance. Acceptance levels for performance should be defined in terms of specific test methods that are reliable and are used by both parties in the same way. The Standard Deviation (Confidence Limits) of the test methods should be known on both sides and their significance appreciated.

In summary, it is a fundamental aspect of Quality Assurance Policy that time should be spent with key customers and prospective customers finding out what are their real needs and objectives. Quality Assurance Policy objectives should be led by market requirements as much as by company capabilities.

Suppliers

One of the most important influences on the quality of a company's product is the quality of the supplies that go into it. In the case of the knitter, the prime example is the yarn that he buys; in the case of the finisher it is the grey fabric with which he is supplied.

A Company must spend time with its suppliers in explaining its needs and limitations as well as its expectations. An explicit system of Quality Assurance should be set up between the company and its suppliers to guarantee the quality of their deliveries. Long term, stable relationships with trusted and reliable suppliers are invaluable.

More than half of all sales revenue is spent on purchasing raw materials, services, and supplies. It has been estimated that 50% of a company's problems are caused by purchases that did not meet the required specification and that at least 70% of the blame for this lies with the purchaser.

All of the above is relevant for transactions between sections of a vertical company.

Process Control

There are certain key machines and processes that have a drastic effect on quality if they are not properly understood and controlled. The Quality Assurance System must have at least two objectives in process control.

Firstly, it must ensure that the key operating conditions of particular machines and processes are maintained at the proper levels to guarantee the required quality. The two most obvious examples are the control of Stitch Length in knitting and the control of fabric length and width in finishing.

Secondly, the system must be designed to develop the information that is needed to understand the influence of variation in machine and process conditions upon the final quality and cost of the product. This is required for three reasons:-

- To be able to predict what machine or process settings are required to achieve a particular desired result.
- To identify the most important control parameters, which have to be included as Quality Control Targets, and to eliminate the cost of monitoring redundant parameters.
- To quantify the major quality-related cost elements of the process so that pressure may be brought to bear to reduce these costs.

Quality Targets and Tolerances

Market requirements and production performance have to be translated into specific Quality Targets e.g. weight, width, shrinkage, and tolerances. These targets should be as few as possible in order to satisfy the requirements of process control and product performance.

For example, if a knitter has proper control over his Stitch Length and if the correct yarn has been supplied, and the correct number of machine revolutions (courses) has been knitted then it is not necessary to make any further dimensional measurements on the grey fabric. The correct piece weight and the ultimate fabric weight, width and shrinkages must follow. Other measurements may be made for other reasons (for example yarn Friction to assure good knitting efficiency) but strict control of these three will guarantee the correct dimensions - so far as it is in the power of the knitter to do so.

Additional measurements and control systems represent additional cost without commensurate benefit. Furthermore, the advantage of Yarn Count and Stitch Length as Control Parameters is that they are fixed before the cloth is made and therefore they fulfil the requirement that poor quality has to be prevented, rather than corrected later.

Targets and Tolerances must be unambiguously defined, in terms that are easily understood by the workforce, and they must actually be attainable by the installed production regime and measurement system. Individual operators must be properly trained in how to achieve and maintain the targets and should have the means to control their performance. Their remuneration should be influenced strongly by the degree to which they are able to achieve the targets and reduce the overall quality related costs.

When setting targets, it is important to distinguish between Average values and Maximum or Minimum values as the key parameter. A good example is in the setting of Shrinkage Targets. Many customers will demand that shrinkage must not exceed a certain maximum level. This implies that the Target Average level must be lower by about two Standard Deviations in order to guarantee that 95% of deliveries will have shrinkages below the required maximum. This means that close control over the sources of variation in production will be needed, so that the standard deviation stays under control.

There is no point in specifying a level of 5% shrinkage, just because that is what the customer wants, if the basic product design will not allow such a low level at the required weight, or if the finishing equipment is not capable of delivering the required length relaxation. Likewise, there is no point in specifying stitch length tolerances of plus or minus 0.5% when the quality control staff do not have access to properly calibrated electronic yarn length measuring devices.

Appropriate product design changes, machinery investments, and working practices have to be investigated and implemented before improved performance is specified. Targets and Tolerances are not to be seen as either a carrot for the customer or a stick for the workforce, but as a way of achieving control over what is actually possible.

In summary, Quality Targets must be evaluated from the following points of view.

- Is it something that is important to the customer - will the customer want to see quality records for this parameter?
- Is it going to function as a guarantee of good quality, or merely a detector of poor quality?
- Will it help in monitoring the capability or the long-term performance of a key production stage?
- Does it help to understand the technology of the process in the sense that it can be used as a prediction parameter?
- Is it something that can actually be achieved and, if not, what has to be done in order that a desired target can be achieved in the future?

Resources

It is important to remember that:-

- Quality Target Parameters have to be measured in a reliable, consistent and reproducible way.
- Good records have to be kept that are accessible to management in an appropriate form.

- The data have to be used constructively not only in monitoring performance in the short term but in generating the kind of knowledge which leads to improvements in quality, or reductions in cost in the long term.

It is necessary, therefore, to have the appropriate measuring equipment, the appropriate sampling and measuring systems, regular standardisation and calibration of test methods and instrumentation, and well-trained staff.

The people who take the samples and make the measurements may have to be independent from those who are responsible for setting the Targets or running the process. They should be trained in statistical assessment techniques and should be capable of preparing objective, digestible reports for the decision-makers. They should have sufficient confidence in their function that they are under no pressure to "bend" the data. Unreliable data and inadequate evaluation does not help anybody and may lead to a harmful interpretation of the manufacturing operation.

Responsibility for making quality-related decisions on the factory floor has to be well defined, well known to the whole workforce, and supported by an appreciation of the importance of quality as a whole to the future well being of the company.

Quality Related Costs

One of the most important functions of the Quality Assurance System is to measure the cost of quality. It has been estimated that around 25% of total manufacturing costs can be ascribed to poor quality.

Quality Related Costs can be conveniently divided into three parts.

Failure costs

These are costs attributed to scrap, reworking, lost sales, low sales prices, lost production, etc. They represent the cost of non-conformance and are the prime indicator of manufacturing quality

Appraisal costs

The cost of inspection, measurement, testing, and control.

Prevention costs

The costs of supplementary actions taken to investigate, prevent or reduce the risk of non-conformance or defects.

Quality Related Cost Models

BS 6143: Part 1, 1992 and BS 6143: Part 2, 1990 give alternate models for analysing the cost of quality and other recommendations can be found in the extensive literature on Quality Assurance. The various models are not mutually exclusive and may be adapted to local circumstances.

For example,

In a Control-driven Quality Culture, it is often proposed that there is an economic balance in the cost of quality. In other words, total manufacturing costs are lowest at some optimum level of investment in the quality system. When investment levels are low there is a large Failure cost but very low Appraisal and Prevention costs. Investment in prevention and appraisal brings quick rewards in quality level and reduced failure costs but there is a limit to this investment, beyond which the total cost rises.

In a Continuously-evolving Quality Culture, on the other hand, it is claimed that there is no such optimum level of investment in the quality system. This is because the cost of Appraisal and Prevention should eventually begin to reduce as a result of improved working practices and a better understanding of quality related costs. After an initial period of rising costs for appraisal and prevention, progress is made towards a zero defect target with all quality related costs reducing as overall reliability and predictability improve.

It should be emphasised however that there is no need for very detailed attempts to identify every single penny spent on Prevention and Appraisal, or every single dollar lost in Failure costs. Approximate figures will serve, especially in the early stages of a quality costing exercise.

In any event, a continuous effort must be made to evaluate the cost of quality, since it will generally be found that any action that significantly reduces quality related costs will have a large impact on the reliability of the product and the profitability of the enterprise.

The Quality Control Function

Routine Quality Control cannot be avoided but it is expensive. It requires space, capital equipment, time, and above all skilled manpower. The last two especially are scarce resources in most manufacturing operations so the Quality Control operation must be carried out with the utmost cost-effectiveness.

If a rational Quality Assurance scheme is introduced into an operation which has a low level of quality awareness, then it will usually more than pay for itself through reduced second quality items, lower waste, less reprocessing, and better customer service. It has been estimated that around 25% of total manufacturing costs can be ascribed to poor quality. However, there is an optimum level of investment in simple Quality Control beyond which the additional cost cannot be recovered by savings in manufacturing or gains in marketing. Further cost reductions can only be achieved by changes in processes and systems.

This means that the specific functions of the Quality Control department have to be closely defined, its priorities clearly determined, its operations narrowly targeted, and its costs and benefits well known.

Some of these aspects are discussed in the following topics.

- Focus Priorities
- Identify Key Quality Functions
- Target Testing Priorities
- STARFISH Philosophy

Focus Priorities

One of the most common problems in Quality Control operations is that, due to a lack of focusing of priorities and objectives, large amounts of unnecessary data are gathered by

- making routine measurements, or
- making inspections at the end of the production line,

only for the data to lie filed away in a cabinet because no one ever has the time to study it properly and to draw the obvious conclusions.

Management is confronted with weekly tabulated data sheets which are a mass of figures. These figures neither reveal the underlying trends nor enable rational decisions to be made about whether the manufacturing operation is actually under control, or what action to take. The product is often on its way to the customer before the Quality Control data sheets have been completed.

What is worse, Quality Control tests are often carried out in a way that does not allow the factory either to control its operation or to find out where the source of any deficiencies really lies, so that the effort is completely wasted.

A good example of this is the common practice of measuring the weight per unit area of grey knitted fabric straight from the knitting machine.

This is an almost completely worthless parameter, which does not give any reliable indication of whether the knitting process is under control nor any guide as to how the fabric should be processed. And yet there are many knitting factories that use the grey weight as their main Quality Control tool and their guide to finished dimensions.

It is important to focus on the different reasons for making Quality Control tests and define each one as a separate Quality Function.

- Each identified function should be analysed, to decide what are its Key Control Parameters and what is the minimum amount of testing that has to be done to achieve its objectives.
- A schedule of operations, with corresponding techniques, should be drawn up that will guarantee that the objectives are met.

Time spent on this kind of analysis will be well rewarded by lower Quality Control costs for a better level of reliability of the manufacturing operation.

Identify Key Quality Functions

The following five key functions of a Quality Control operation can be envisaged.

1. To satisfy customer requirements for reporting (or maintaining records) on the achievement of specific Quality Targets.
2. To satisfy internal requirements for routine product monitoring, to ensure that they conform to established internal targets or specifications.
3. To satisfy the requirements of process control, to ensure that the various manufacturing processes are being operated correctly, or are correctly calibrated.
4. To provide the test data required for new product developments.
5. To provide concise and meaningful management information which allows a rapid and realistic overview of the general situation on a continuous basis.

The type and frequency of quality testing is different for each of these different functions, although the first two are often seen as being one and the same.

The customer may have no specific reporting requirements, but the management may deem it prudent to keep some testing records - and even a sample - in each customer file against the chance that goods may one day be returned, or a claim for compensation may be made.

Some large multiple retailers insist that certain quality tests should be undertaken or that certain performance standards should be guaranteed against specific quality testing methods.

Sometimes the only way to know if a product conforms to a certain standard is to install the appropriate test method and carry it out at least on an occasional basis.

The most obvious example for this is the need to obtain precise shade matching in dyeing and a specified level of colourfastness in the dyed fabric. In this case, colour matching and fastness testing will probably be indispensable.

Target Testing Priorities

Whatever the reason for testing, whether to satisfy the customer or whether testing is carried out for internal purposes, it is important not to do more testing than is strictly necessary. A good example is the case of shrinkage testing.

Many companies spend an enormous (and usually unknown) amount of time and money on the routine measurement of shrinkage. However, if the factory is being run according to STARFISH principles, then the Reference Dimensions should be well established for every quality that is being processed.

If the Reference Courses per unit length are known, then it is only necessary to count the courses in the delivered fabric in order to know whether the length shrinkage will be within specification. Similarly, if the Reference Width is known, then it is only necessary to measure the width of the delivered fabric to know whether the width shrinkage is on target.

If the delivered courses and width are correct, if the fabric has been knitting correctly according to the STARFISH specification, and if the wet process route has not been changed since the calibration was established, then it follows that all other dimensional properties of the fabric, such as weight and shrinkage, must also be according to specification.

Thus, so far as the dimensional properties are concerned, the routine Quality Control checks for fabric at the end of the production line need only consist of counting Courses and measuring Width. Since these are also the finisher's manufacturing Control Targets, routine Quality Control is actually built into the manufacturing system.

This does not mean that shrinkage should never be tested but it need not and it should not have to consume such a large proportion of the time and effort of the quality system. Provided that the fabric quality has been properly established in the first place, and the finisher has the appropriate equipment and techniques at his disposal, then limited random sampling plus occasional quality audits should be all that are required to keep the production on target.

Many companies are very proud to insist that they maintain 100% inspection of their products. What they are really saying is that the manufacturing process is not under adequate control.

On the other hand, when a new product is being introduced, or when new wet processing equipment is being commissioned, then the testing should be rigorous and comprehensive. For the new product, it is essential to establish what are the average Reference Dimensions with a good degree of certainty, so that the correct finishing Control Targets can be issued to the finisher. For the new equipment, it is essential to know whether the Process Calibration has been changed and, consequently, whether any existing products will have to be re-engineered to make allowance.

In both of these cases, a few samples are not enough to establish reliable averages. Even so, there is no need to measure everything about the fabrics. The essential parameters are the Reference Courses and Wales and these should be gathered as quickly and as comprehensively as possible.

It may also be necessary to establish whether the relationship between the Reference Dimensions and the dimensions after the normal routine QC relaxation test are different. If this is the case then a series of comparative relaxation tests should be carried out also.

Other properties, such as the relaxed weight may have to be determined but these are all subsidiary to the Reference Courses and Wales, and can be established at a slower pace.

STARFISH Philosophy

The STARFISH principle is that quality testing should be a precision tool that is directed at specific product parameters and at specific locations in the manufacturing process. It should never be simply a blanket method for creating records or for grading products into first and second class quality. In this context, it is the **process control** function that has the highest level of importance.

The STARFISH philosophy is that product quality must be guaranteed by design and by control from Start to Finish. If all of the manufacturing processes are correctly set up and correctly controlled, (and there is no change in raw materials purchased) then the quality must be correct at the end of the line. Therefore, the major functions of a quality system are to:

- Identify the critical manufacturing stages.
- Establish the correct control parameters for each of those stages, and the appropriate Target Values and Tolerances for each parameter and for each product.
- Set up written procedures for maintaining the control parameters at the correct levels during manufacturing of specific products.
- Make sure that the process operatives fully understand about the critical parameters, are properly trained in how to carry out the control procedures, and are given easy communication channels when they feel that the process is not under control, or when they are experiencing difficulties.
- Develop appropriate and cost effective quality testing procedures to ensure that the control parameters are being correctly monitored.
- Set up written procedures, which outline the corrective action that has to be taken when it is discovered or suspected that a particular critical stage is going out of control.

Quality Charts

Once the important control parameters have been identified, and the required Target levels have been specified for a given product and manufacturing stage, they have to be monitored continuously. This must be done in such a way that any drift in the control parameters away from the specified levels can be quickly detected, so that the appropriate action can be taken before the drift is sufficient for second grade quality to be made.

One of the most useful and powerful tools for monitoring the process is the Quality Chart.

Quality Charts are important because they can be made to focus very precisely on single, simple parameters. They can be used to control not only the Average levels but also the Variability of a process. They illustrate what level of performance is practically attainable, and they provide an instant and instantly understandable picture of how the level of control stands in a specific area. Thus, they serve to focus management attention on the current capability and state of control in the factory and, hence, on exactly where further investment is needed - whether it be in the form of manpower, training, or capital investment.

Quality Charts, often known as Control Charts, or Shewhart Charts, form part of the quality system known as "Statistical Process Control". The total system is rather complex, but the basic concept of control charts is rather simple, is easy to introduce into the factory, and can be a very valuable aid to Quality Assurance.

Some of the different types of Quality Chart are discussed in the following topics.

- Types of Quality Charts
- Simple Control Charts
- Sample Average Control Charts
- Range Control Charts
- Cusum Control Charts
- Monitoring Design and Control Limits

Types of Quality Charts

Four different types of control chart are worth considering.

- Simple Control Charts
- Sample Average Control Charts
- Range Control Charts
- Cusum Control Charts

To construct these charts, three sets of data items are required, namely:

- the Target Value,
- the Normal Tolerances, and
- the Action Tolerances.

The **Target Value** is the specification value for the control parameter, for example the Target Stitch Length to be knitted on a given machine for a given quality, or the Yarn Count that is supposed to be delivered by the spinner.

The **Normal Tolerances** represent the range of values for the parameter within which the process can be assumed to be operating within its normal capability. The usual way to determine the Normal Tolerances is to calculate the Standard Deviation (or the Standard Error) of a run of measurements, when the process is known to be under control. Usually about 25 values are needed to get a good idea of the standard deviation. Then the Target Value plus two standard deviations is the Upper Normal Tolerance, and the Target Value minus two standard deviations is the Lower Normal Tolerance. When the process is operating normally, 95 out of every 100 measurements should lie within the Normal Tolerance range.

The **Action Tolerances** represent the range of values outside which the process can be assumed to be out of control. When such values are recorded some positive action must be taken to find out what is going wrong and, if necessary, to adjust the process or the Quality Assurance procedures. The Action Tolerance is usually taken as three standard deviations (or standard errors) from the Target Value. When the process is operating normally, 99 out of every 100 measurements should lie within the Action Tolerance range.

Note:

Control Tolerances are an objective indication of the actual current state of control of the particular process. They should not be confused with the most desirable tolerance or tolerances for Performance Targets that have been requested by customers. Control Tolerances reflect all of the variations due to materials, equipment and operators, which affect the actual performance of the process. The process cannot deliver a better result under current conditions.

There is no point in simply setting Control Tolerances at less than two standard deviations, in an attempt to achieve better control – this is an exercise in futility. If the current performance is not good enough, then steps have to be taken to identify the sources of variation and to bring them under better control. Only after the standard deviations have been successfully reduced can the Control Tolerance range be narrowed.

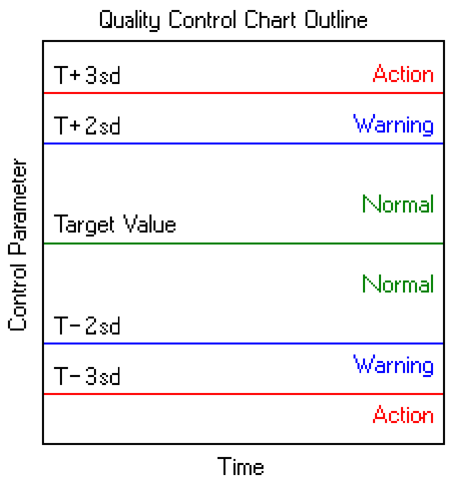
Simple Control Charts

The Simple Control Chart is the most direct and easiest type of control chart to deal with. It is suitable for the case where one or two simple parameters are responsible for the control of an operation, each of which have specified Target Values, and where the operation is self-contained in the sense that the values for the control parameters are used only to control that operation. The objective is to ensure that, for example, the knitting machines are indeed being properly set up to the right quality and that this is being maintained over time and across different machines.

For a simple Control Chart for Stitch Length, checks on the stitch length can be recorded on every new roll, for a given machine running a given quality, and compared with the Target value. After about 25 values have accumulated their Standard Deviation can be calculated so that the Normal Tolerances and the Action Tolerances can be calculated. Once the Tolerances are known, then the rate of checking can be reduced to once a shift, once a day, or even once a week, depending on circumstances.

- Constructing a Simple Control Chart
- Limitations of Simple Control Charts
- Interpreting Simple Control Charts
- Advantages of Simple Control Charts

Constructing Simple Control Charts



A chart is set up with,

- a vertical scale representing the control parameter,
- a central horizontal line set at the Target Value,
- two further horizontal lines above the Target Value set at distances representing two and three Standard Deviations, respectively, and
- two further horizontal lines set at corresponding distances below the target line.

The chart is now divided into six horizontal bands. The two middle bands represent the Normal Tolerance range, an area where, in principle, the control parameter is allowed to lie. This is because a normal random distribution of measurements is expected. This means that 95% of measurements will lie within plus or minus two standard deviations of the mean and the long-term average will correspond to the Target Value.

The actual measured values for the control parameter should be more or less equally distributed above and below the Target line, with more of them lying close to the Target line than towards the upper and lower edges of the bands (which represent the upper and lower Normal Tolerances).

The two outer bands which lie between the Normal Tolerances and the Action Tolerances are Warning bands; areas where only about 5% of measurements of the control parameter should occur. Action is not required if only the occasional measurement (one in twenty) falls into the upper or lower Warning bands, and if such occasional entries are equally shared between the upper and lower bands.

If the number of entries in only one of the warning bands is more frequent than expected, then the average value of the control parameter has probably drifted away from the Target. If the entries in both of the outer bands are more frequent than expected, then the variability of the control parameter has grown. In either case this is an indication that action should be taken to get the control parameter back on target or to reduce its variation.

If the control parameter lies outside the Action Tolerances, then action is clearly indicated because this should happen only about once in 300 observations under normal circumstances.

Limitations of Simple Control Charts

The main problem with the Simple Control Chart is that each observation is treated independently. Looking at a series of single observations is not a very sensitive way to detect a gradual drift in process control because the natural variability of single, independent observations can obscure the underlying trend.

For this reason, two simple additional guidelines are usually adopted as indicators for taking action.

- If there are two consecutive observations that fall in one of the outer Warning bands,
- If there is a run of seven observations that all lie on one side of the Target line.

The first action to be taken is simply to make a further series of measurements, to confirm that the "run of seven", or the "consecutive two" are not simply a statistical freak.

It is important not to make frequent, unnecessary adjustments to equipment because this only causes a greater level of variation. Therefore, some effort has to be devoted to ensuring the soundness of the diagnosis.

If the new measurements confirm that the process is running out of control, then an immediate investigation should be launched to find the source of the deviation.

Interpreting Simple Control Charts

When measurements confirm that the process is running out of control, an immediate investigation should be launched to find the source of the deviation. Generally, it will be found that there are three main types of reason for deviations.

Equipment

The machinery may require adjustment or maintenance - for example the Positive Feed unit on a knitting machine has become contaminated with wax and Fibre Fly. and is not functioning properly. In such cases, the reasons why the fault has arisen should be carefully considered. It may be that a new delivery of yarn has excessive wax or generates unusual levels of Fibre Fly. The yarn supplier should be consulted.

In any case, action should be taken to reduce the likelihood of the fault occurring again. Standard written procedures may need to be modified and operatives may need to be re-trained. If the machine actually needs mending then preventive maintenance schedules should be reviewed. For example, it is very bad practice to wait until excessive numbers of faults begin to appear before replacing all of the knitting needles.

Materials

A change in the in-going material will usually cause a corresponding change in the product. For example, a change in the Reference Courses or Wales after finishing is most likely to have been caused by changes in the knitting, or in the yarn supply.

When a new yarn supplier is adopted, the influence of his material on the final product should be thoroughly tested so that appropriate adjustments can be made, if necessary, or the new supplier can be advised to modify his deliveries (for example the level of twist may be different). Special attention should be paid to the level of variation in yarn quality, not just the average values.

Operator

It is too easy to blame the operator when problems occur, but research has shown that over 80% of failures are for reasons that are not under the operator's control. Any operator can make a mistake from time to time but if he is not keeping the process under adequate control over a period, or is generating an unusually large number of faults, then the reasons should be investigated. Most often it will be found that the operator does not have sufficient understanding of exactly what is required of him, or his morale is low.

The solution is communication and retraining. Training of operatives, and the maintenance of good morale, should be regarded in the same light as the upgrading and maintenance of capital equipment - both are vitally important to continuous production of good quality products. Training should be thorough and clear, with the operative encouraged to supply his own ideas about how the job could be done better.

Advantages of Simple Control Charts

The great advantage of the Simple Control Chart is that it is very quick and easy to maintain. Large deviations from target can be spotted immediately so that causes can be discovered quickly. Small drifts need less immediate attention and can be left to alternative techniques. It is often a good idea to display a control chart in a prominent position so that the workforce can see at a glance how the process (and they themselves) is performing.

A point to remember, however, is that the use of the pre-existing Standard Deviation to calculate the Normal and Action Tolerances exerts no pressure on the operatives and the procedures to reduce the variability of the Control Parameter or to improve the process. The pressure is directed primarily at maintaining the average at the specified level and preventing the variability from increasing.

Therefore, separate steps have to be taken to ensure that the variation in the control parameter is already as low as is technically and economically feasible. Whenever the variation has been successfully and consistently reduced then new Normal and Action levels should be established to ensure that the variability does not begin to drift upwards again.

As new data are collected over the weeks and months, the grand mean and the overall standard deviation can be continually recalculated over longer time intervals - say monthly - so that even longer term drifts can be detected. This is especially important when the control chart approach is used to monitor the calibration level of a wet finishing process. In this case, the control parameters are the Reference State values of courses and wales that will be used to set Finishing Control Targets or to calibrate the STARFISH model. A time interval of longer than one month is probably not useful for data that is collected daily or weekly.

Sample Average Control Charts

The Sample Average Control Chart is used to monitor over longer time intervals, or when the measurements reported are not individual, independent observations but the means of small numbers of samples. The sample means are much less variable than the individual observations, so that the way of calculating Normal Tolerances and Action Tolerances is slightly different, being based on the Standard Error of the mean rather than the Standard Deviation.

The standard error is simply the standard deviation of the independent, individual observations divided by the square root of the number of observations that were used to calculate the sample means.

For example, whenever a delivery of yarn is received, at least twenty packages (depending on the size of the delivery) will be tested for Yarn Count and the average will be calculated and checked against the specification. After a few deliveries have been made, the overall standard deviation of the individual measurements can be established. The averages can be plotted on a control chart with the Warning lines at Target Value plus or minus two standard errors, and the Action lines at plus or minus three standard errors. This allows the chart to accommodate longer time intervals and smoothes out the random day-to-day effects so that they do not obscure the underlying picture. The Action criteria are essentially the same as for the simple control chart but the response time is likely to be slower. It may be necessary to treat the deliveries from different yarn suppliers separately.

The sample mean approach can also be used to make groupings of quality data. For example, if a given quality of fabric is being knitted on more than one machine, then the results for the individual machines can be averaged to provide an indication of the overall mean for the quality as a whole. In this case, the standard error is a measure of the effectiveness with which different machines are being set to the same target. This approach can even be extended to grouping different qualities by normalising the data. For the different qualities, each determination of, say, the Course Length is divided by the Target Value for that quality. The global Target Value then becomes 1.00 and the standard error represents the state of control of a whole sector of the operation - say all Plain Jersey qualities, or the whole of the night shift.

Such an approach is often the preferred one provided that there is sufficient confidence in the day to day running of the operation, or when individual observations are expected to be rather variable. It is also usually a more useful tool for management information since it is capable of summarising a relatively large amount of data into a small and easily interpreted diagram. Combined with a random sampling procedure, it is also a good way of monitoring the general Quality Level of outgoing products.

Range Control Charts

The range is simply the difference between the highest and the lowest value within the group of observations that form a sample. Range Control Charts are used for groups of small numbers of samples, and to control the variability of a process independently of the average value of the control parameter.

For example, the average values of Course Length will be different for the different machine diameters that are knitting fabrics for a set of body-widths, but the range (or especially the percentage range) will be about the same. The range is often used in preference to the Standard Deviation because it is quicker and easier to calculate.

In this case, the Target Value, the Normal Tolerance, and the Action Tolerance have to be calculated by referring to a table of factors that depend on the sample size. These tables can be found in British Standard No. 600. For example, if the average range of the individual observations is R, then for a sample size of five, the Target value is R, the Normal Tolerance is 1.81 x R, and the Action Tolerance is 2.34 x R.

The Range chart can also be used to discover when a significant improvement has been made to the variability of the process. For a sample size of five, if the Mean Range consistently falls below 0.37 x R then there is a strong suspicion that the process has improved; if it falls below 0.16 x R then the process has almost certainly improved. If such results have not been caused by deliberate attempts to reduce the variability of the process, then they should also be investigated because they may lead to the discovery of a technique or a set of conditions that can be utilised to improve the overall process reliability.

After the variability of the process has been permanently improved, then new Normal and Action Tolerances should be calculated, to make sure that the improvement is maintained.

Action criteria are essentially the same as for the Simple Control Chart. In this case, however, the action to be taken will be such as to reduce variability in the process, which of course may not be being caused by the process itself, but by the variability of the products being fed to it. In addition it must always be remembered that the instrumentation, or the test methods being used to measure the control parameter, or the operatives who are making the measurements can also contribute to the variability. Therefore the first step is to recheck the variability of measurement.

Cusum Control Charts

The Cusum chart is a sensitive way of detecting small amounts of drift in a control parameter, which might not easily be visible on the simple chart or the sample average chart. Cusum is a contraction of "cumulative sum of deviations".

With a Cusum chart it is not the actual measurements that are plotted but the *accumulated differences* between the measurements and the Target Value. Thus, for every observation, the Target value is first subtracted and the difference is added to an Accumulator.

At the start of a series, the Accumulator is zero. For every successive observation, the value of (Observation minus Target) is added to the Accumulator and the new Accumulator value is plotted. Sometimes the difference will be positive and sometimes negative, depending on whether the observation is greater or smaller than the Target value.

If the process is under control, then the successive values of the Accumulator will wander around the zero line. How close they are to the zero line will depend on the Standard Deviation of the observations. For this reason the differences are often divided by the Standard Deviation before adding to the Accumulator. This has the advantage that all Cusum Charts are standardised on the same vertical scale, and can be compared directly one with the other.

As soon as the mean of the control parameter starts to move away from the Target value, then the observations will show a tendency to lie on one side of the zero line. By accumulating the differences, this drift away from target will very quickly become noticeable.

Monitoring Design and Control Limits

Quality Charts can also be used to check whether a process is operating within the design specification for the product. In this case, instead of Normal Tolerances and Action Tolerances, Design Tolerance boundaries are used. These can be, for example, in terms of percentage deviation from the specification.

Such charts should not be used to control a process, only to see how it is performing with respect to some desirable standard. If the Design Tolerances are regularly being exceeded, then this may be ground for launching an investigation into the sources of variation in materials, equipment or operating procedures.

This type of chart can sometimes be used to optimise the cost of manufacturing to a given customer tolerance. For example, if the customer lays down a specification for 150 grams per square metre with a tolerance of plus or minus 5%, then this means that the customer is prepared to accept a proportion of deliveries that are at or about 142.5 gm^2 and a proportion that are at or about 157.5 gm^2.

From the point of view of cost control, the manufacturer would prefer to deliver most of the cloth on the lighter side, and little of it on the heavy side (provided that this did not compromise other quality characteristics).

If a Quality Chart for weight is being maintained, and if it shows that fabrics are being delivered consistently with less than 3% variation, then it would be fairly safe to target weight on the light side.

On the other hand, if the Quality Chart shows that the control of variation in the product weight is no better than 5%, then the fabric may have to be delivered on the heavy side to avoid complaint. In this case the manufacturer would be well advised to put some effort into discovering how to control the variability of the weight more closely. If only 1% of material costs can be saved in this way, then the cost of close Quality Assurance will be more than repaid.