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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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THE CONCEPTS OF QUALITY AND QUALITY CONTROL AND CRITERIA FOR THEIR DEFINITION [1]

by

Agnes H. Zaludová
Czechoslovakia

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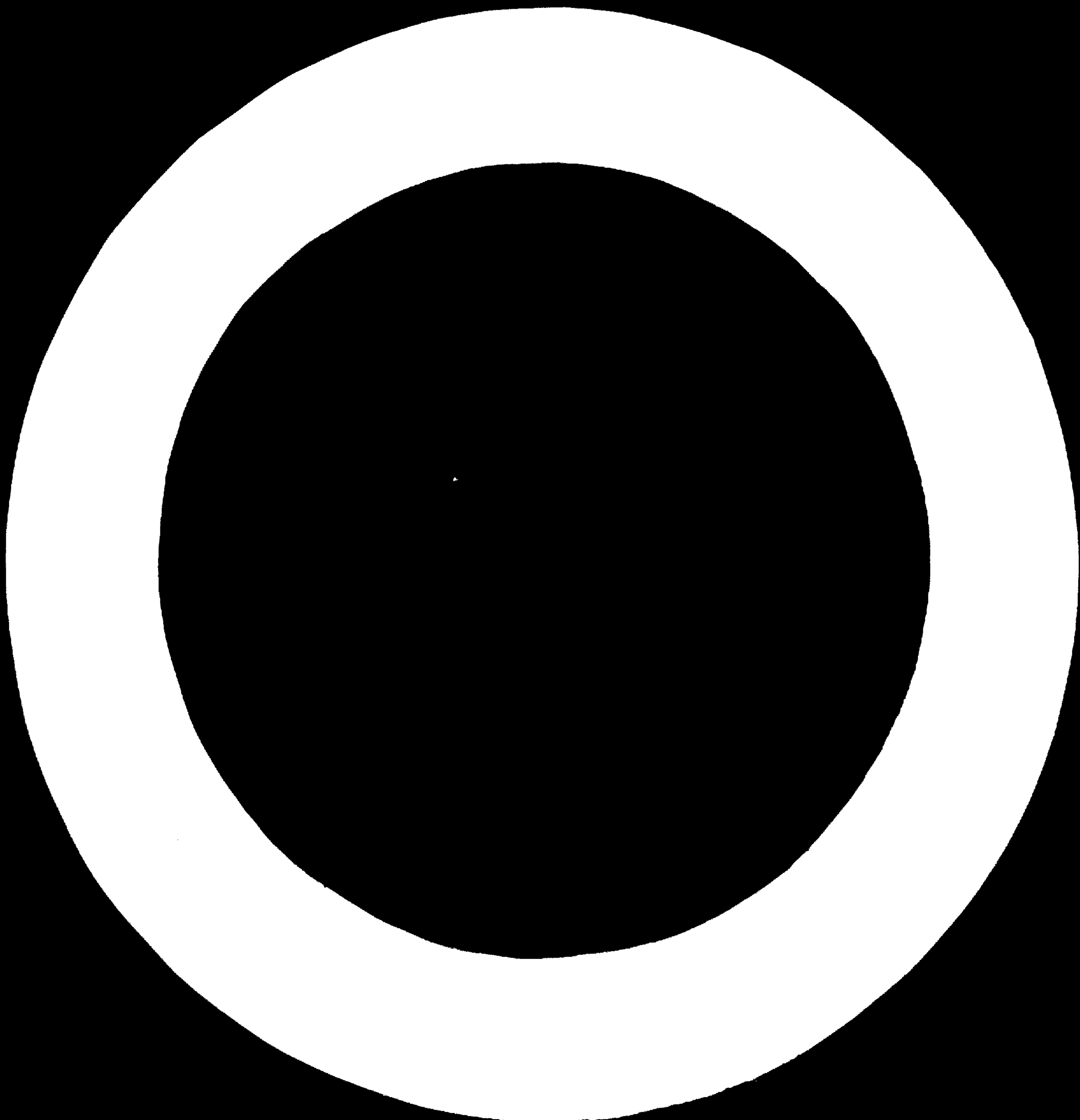

Introduction

Allow me at the start to say how honoured I feel to have been invited to participate in this Training Workshop in Quality Control for African Countries. It is a great pleasure for me to take part and I look forward to the interchange of experiences and views which I hope will ensue during the next few days. It is my sincere hope that the Workshop will fulfil one of its main purposes and that is to contribute to reducing the technological gap between the advanced and developing countries of the world.

In view of my profession as a practising applied statistician I must admit to having displayed a certain hesitancy in agreeing to give the two opening lectures on basic concepts of Quality Control /QC/ and the role of QC in industrial development. Certainly it would have been easier for me to talk about sampling inspection and control procedures or reliability. Nevertheless, I hope my introduction to the subject of our Workshop will be comprehensibl and balanced and will form a suitable basis for the lectures which are to follow.

For general background knowledge, I should like to mention that it is exactly forty years since one of the pioneers in QC, A.W.Shewhart published in 1931 his famous book "The economic control of quality of manufactured product" [1], based on his work at the Bell Telephone Company, USA. About the same time, B.F.Dudding in the General Electric Company of Great Britain and E.S.Pearson, Professor of Statistics at University College, London were working along similar lines and published in 1935 a fundamental paper [2] and book [3] which revolutionized industrial, laboratory and standardization practice of that time. Since then, the art and science of industrial QC has travelled a long way till it now has thousands of professional adherents in all countries of the world and is an ackowledged branch of scientific management. A wealth of publications is now also available, among which the most valuable and widely read are the books by J.M. Juran [4], A.V.Feigenbaum [5], and J. van Ettinger and J. Sittig [6].

With the advance of technical progress, the development of large-scale production of products of all kinds /industrial, agricultural, building, etc./ and with the introduction of more complex and automated technical equipment*, the problems of quality and reliability are growing in dimension and complexity. Not only industrially advanced countries like the USA, Britain, France, Japan and others but also developing countries like South America, India and your own countries in Africa have begun to realise the benefits ensuing to the national economy from a systematic approach to problems of the quality of products and services. These benefits result from a more rational use of the country's natural, human and financial resources.

If I make a correct estimate, I expect that QC philosophy and techniques can bring about a significant increase in productivity and efficiency in a wide range of industrial fields in the African countries, for example in mining, foundries and metal casting, in the production of textiles and textile machinery, boots and shoes and the necessary machinery, in the production of bicycles, radios, fans, glass and glass products, pharmaceuticals, cigarettes, plywood, cement and prefabricated building parts to mention only a few.

Equally effective will be the introduction of similar principles and methods into the agricultural and food-processing field,

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* providing us with electric power, transport, radio, television and other services,

as for instance into the cultivation and processing of groundnuts, cocoa, coffee, sisal, palm oil, tobacco, etc.

Such a programme will undoubtedly accelerate the transition of the African economies from predominantly agricultural ones to economies with a strong industrial sector based on the most up-to-date scientific and technical knowledge.

1. Need for definitions and terminology

Despite the importance of quality of products and services to modern society, there is a considerable amount of confusion in the definition of the word "quality". Fortunately the lack of unanimity has not prevented the development of QC and its fruitful application in industry.

A clarification of the concepts and definitions of terms in the field of quality and QC is also difficult in view of the fact that many national and international terminological standards are still in process of elaboration or are being revised in order to reflect the latest results of advanced theory and practice in this dynamically evolving branch of applied science. In this connection it is interesting to note that during the past few years, some original work has been in progress in the USSR on the subject of qualimetry, the branch of science dealing with the measurement and evaluation of quality. For this reason, the Soviet terminological standards [7], [8] have been published as recently as 1970 and 1971.

As far as the terms which we shall be using during this Workshop are concerned, I refer your attention to the twelve-language EOQC Glossary of terms in QC [9], the third edition /revised/ of which is due to appear before the end of this year. In the following remarks, I shall adhere as far as possible to the EOQC Glossary and only on occasion shall justify a slightly different interpretation of some of the terms.

To begin with, let us agree that the primary object of our study will be processes and the products or services which comprise the end effects of these processes. We shall be specially interested in production processes /industrial and agricultural/ and in product quality and its control.

If any one of you were asked what you considered to be the quality of water /a product of the processes of nature/, I am sure your immediate response would be: "Well, surely it depends on the purpose for which the water is intended. For drinking, for washing clothes or dishes, for paper-making, for engine-cooling?" In each case the main properties of the water which constitute its quality are different. In the case of drinking water, its quality is determined by its purity, freedom from germs or toxic substances; in the case of water for washing /without detergents/, we are mainly interested in its "softness" and capacity to form lather with normal soap powder and hence to remove dirt and grease; in the case of paper-making, the quality of water consists in its freedom from suspended particles and colouring matter; finally, for engine-cooling we are interested mainly in the cooling capacity of the water which in turn depends on its temperature, secondarily in its freedom from scale-forming compounds.

In each individual case, the quality of the water consists in a group of properties, determining the suitability of the water for a particular purpose or use. If we now pass over from natural resources like water to some simple products which are the result of human labour, we find that our concept of quality as fitness for purpose is still correct. For example, the quality of a pair of shoes or boots depends on the purpose for which their owner intends to use them, for town wear, in summer, in winter, for mountaineering, for sports activity, etc. Desirable quality of leather winter boots for a farm worker in Czechoslovakia includes the properties of robustness, warmth, waterproofness, durability and reasonable cost.

To consider a slightly more sophisticated product, an electric iron, we see clearly that its quality comprises the ability to function correctly when switched on, to react correctly to automatic thermostat temperature control, to resist rusting of metal surfaces, the properity of being comfortable to handle, aesthetic in appearance and reasonable in cost.

So we arrive at our first definition:

Quality is the totality of properties of a product which determine its fitness for use /purpose/.

Some typical properties of an automobile which together constitute its quality are: reliability, durability, power, maneuverability, comfort, appearance, economy of running /fuel consumption/, cost [10]; other common properties of engineering parts and machines are: resistance to wear, fatigue and creep, machinability, strength, efficiency. In the case of food stuffs, the quality is determined by properties such as taste, smell, texture, nourishment value, etc. Note: The degree of quality of a product naturally requires that some measure of the actual quality be compared with a specified measure embodying the consumer's requirements, thus giving a relative quality index /see below/.

In industrial terminology, the word "control" generally means a set of activities necessary for the achievement of certain industrial goals within a more or less complex organization /system/. The word may be used either with a management or a technical connotation /see e.g. automatic control/. In both cases control consists in:

a/ specifying objectives and methods of their attainment, delimiting responsibilities, issuing directives, deciding on criteria for assessing fulfilment of goals;

b/ coordinating all efforts in the organizational, material and personnel assurance of goal fulfilment;

c/ checking that directives are respected, that partial and final goals are fulfilled and taking decisions on corrective measures when necessary;

d/ continually promoting the improvement of efficiency of the whole organization /system/, making special analysies, educating and training personnel, etc.

In connection with QC, the above sequence of activities has led to the definition [4]:

Quality control is the totality of functions and activities which must be carried out in order to attain the company's quality objectives.

Analagous activities a/ to d/ are also applicable to "production control" and "cost control".

A more detailed definition is given by A.V. Feigenbaum [5]:

Quality control is an effective system for the quality-development, quality-maintenance and quality-improvement of efforts of various groups in an organization so as to enable production and service at the most economical levels which allow for full consumer satisfaction.

The control of quality of products presupposes that this quality can be measured. For this purpose, it is customary to speak of quality characteristics of individual products. These charecteristics may be quantitative or qualitative /attributive/ in nature.

Examples of quantitative characteristics /sometimes called parameters/ are: dimensions, clearances, surface roughness, percentage content of chemical substance, wear, tensile and fatigue strength, output, fuel consumption, electrical resistance, noise, length of life, moisture content, density, particle size, percentage effective substance in insecticide, etc.

These characteristics are very often random variables, differing from one product to another even when the products are produced in series under apparently similar conditions. They are generally measured in physical, chemical or other units, sometimes they are non-dimensional /e.g. efficiency/.

It is customary for a nominal value to be specified in standards or specifications for such quality characteristics and for a tolerance to be set round the nominal value /see Fig. 1/. We shall see below that such specified values are in fact reference quality indexes.

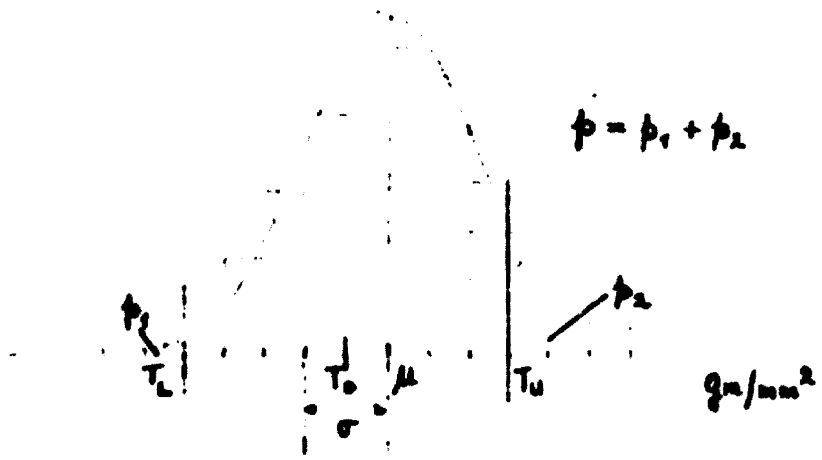

Fig. 1. Typical distribution of the strength of cotton yarn

Examples of attributive quality characteristics are: colour, appearance, taste, smell, appearance or non-appearance of a defect, etc. The assessment of quality in such cases is judged by comparison with some standard product or etalon of specimens. It is also possible to transfer from the attributive assessment to a quantitative evaluation by the introduction of point values /0,1/,/1, 2, 3, 4, 5/, etc.

We may therefore state the definition:

A quality characteristic is a quantity or attribute which characterizes a particular property contributing to the quality of a product. Cf. definition of EOQC Glossary: A characteristic is a property which helps to differentiate between items /either quantitative or qualitative/.

Note 1: In some case the quality characteristic is identical in name with the property, e.g. strength of material /property/ in the sense of resistance to loading, and tensile strength /quality characteristic/ in the sense of maximum load per unit cross-section which material will bear without leading to fracture.

Note 2: It is also possible to speak of quality characteristics /parameters/ of production processes.

Note 3: In the case of several quality characteristics of a product it is customary to distinguish those which are more and those which are less important for the quality of the product, e.g. using the classification (major, minor, trivial), or (major, minor).

Before continuing with our explanation of concepts and definitions we shall have a look at how quality is built into a product.

2. Quality of design, quality of conformance and quality of usage

Let us now consider the increasing requirements of consumers, whether large-scale industrial concerns, government organizations or private consumers, on the quality characteristics of products. Aircraft should fly at ever increasing speeds, new textile and chemical machinery should have higher and higher outputs, television set should transmit in colour, etc.

As far as consumer goods are concerned, the pressure on producers is also to produce more reliable and durable goods, if possible at lower price. In any case, the attainment of required quality characteristics has now become a complicated task necessitating a specialized function on the level of industrial concerns and, as the experience of a number of countries, including Japan, has shown also on the level of government authorities.

On the plant level, it has been necessary to supplement the primitive concept of craftsmanship, based on close relationship between producer and consumer, by many new concepts and activities.

It is customary to distinguish three phases of the production process, all of which play a special role in the creation of the quality of a product. These are (see Figs. 2 and 3) :

a/ the pre-production phase, including market research, technical research and development, design and process engineering, prototype testing, preparation of inspection and control procedures, preparation of instructions for use, purchasing of materials and bought parts;

b/ the actual production phase, including incoming inspection, manufacturing of parts, assembly, process control and final inspection and test, packaging for dispatch or storing;

c/ the post-production phase, incorporating transport, installation, operation and servicing.

The activities during the first phase translate the properties /quality/ required by the consumer into the language of specified quality characteristics, design documentation and corresponding specifications of manufacturing, inspection and control procedures, properties of purchased parts and materials. Insofar as this technical documentation correctly reflects the required quality of the product, we speak of quality of design. EOQC Glossary definition is "the excellence of the design in relation to ease of manufacture and to the customer's requirements".

The activities during the second phase determine how the quality characteristics specified in technical documentation are realized in the manufactured product ready to leave the factory. This naturally depends to a large degree on the quality of the technological equipment and on the adherence to design, manufacturing and control procedures /i.e. on the quality of operators/. A contributing factor is also the quality of bought parts and materials.

Quality of conformance /or manufacture/ is the name used to express the **agreement of actual quality characteristics** of the manufactured product with the characteristics specified in technical ducumentation.*

A third contributing factor to product quality may be called the quality of usage, meaning the correctness of installation and operating and maintenance procedures.

A low quality product may arise due to inadequacy of the quality of design or of conformance or of usage, even though the other two qualities are adequate.

Until relatively recent years, product quality was considered to be a synonym for quality of conformance and quality control departments devoted their attention mainly to inspecting and checking whether the final quality characteristics were in agreement with those specified in standards and specifications, i.e. to phase b/.

With the revised notions on the definition of quality and all the factors contributing to it, it is now generally recognised that QC must extend its activity, to cover all three phases which influence product quality. Hence we arrive at the definitions of QC given in paragraph 1 /see p. 9 / A more detailed list of the functions involved is given in paragraph 8/see p. 24 /.

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* EOQC Glossary definition: The fidelity with which the product conforms to the design.

3. Quality of specific products and of groups of products

1 In the series production of products we are often less interested in the quality characteristics of individual items than we are in some quality characteristic of a whole series of items /batches of products/, produced under similar conditions on the same machine or by the same process. In this case we must return to Fig. 1 where we have the typical curve illustrating the probability or frequency distribution of a dimension /e.g. diameter of cylindrical rollers processed on a grinding machine/ or the strength /e.g. of cotton yarn measured on specimens from a spinning machine/. This curve is an idealization of the histogram which we obtain when we make measurements on a finite numbers of items, group the measurements into classes according to the values of the measured characteristic and represent graphically the relationship between the frequency of occurrence of the characteristic in the different classes.

In such cases, we have the possibility of choosing several quality characteristics of the batch /quality indexes/, the most common of which is the fraction defective p , i.e. the proportion of the batch with characteristics lying outside the specified tolerance limits, or its complement $q = 1-p$, the proportion of satisfactory products. This proportion depends in turn on the position of the distribution with respect to these limits and on its scatter. It is also possible, therefore , to consider as quality indexes of the batch the mean value μ and the standard deviation σ or their sample values $(\bar{x}, s)$ which we obtain on the basis of a small number of observations.

In the case of an attributive quality characteristic like the appearance on non-appearance of a flaw on the product, the quality characteristic /index/ of the batch is again the fraction defective p or the fraction satisfactory $q = 1-p$.

Using the above approach, we see that we can form relative quality indexes with respect to one quality characteristic of the product by dividing the absolute index by a specified reference index. For instance, if the specified mean life of a particular type of lamp is given by the value $\mu = 1000\,h$, then $\mu = 1000\,h$ is the reference quality index. Measurments on ten bulbs give an average time to failure of $\bar{t} = 950\,h$. Then a simple relative quality index with respect to lamp life would be $K = \bar{t}/\mu = 0{,}95$.

When it is necessary to measure and evaluate the quality of a product with respect to more than one quality characteristic, it is clearly possible to form a weighted average of the individual quality indexes, the weights being proportional to the importance of the corresponding quality characteristics.

The distinction between measures of the quality of individual products and groups of products is very important in connection with sampling inspection procedures to decide on the acception or rejection of batches of products.

4. Grades and grading

We have seen that the end product of the pre-production phase is a set of documents, drawings, procedures containing specifications of the quality characteristics of raw materials, purchased parts, machined and processed parts during production and finally of the end product itself.

An interesting question arises during the specification of characteristics of a product intended for the same functional use but for different consumer markets with respect to price level. A difference in specification for the same functional use is a difference in grade. A wrist watch for a young child with relatively low precision, say variations of 60 seconds per day, and low cost is a different grade of watch from that required by a top executive wishing an expensive, gold, water- and dust-proof watch with self-winding and alarm, high precision and high price. Having ascertained the market for both grades of watches and specified the quality characteristics accordingly, manufacturing may proceed and produce two grade of watches, both of which are of excellent quality / fitness for use/ for a different consumer market. The cheap watch is not of inferior quality than the expensive one but it is of lower grade.

The characteristics which are generally altered when considering the choice of grade are [4] :

Life of product /durability/
Appearance
Extent of maintenance required
Reliability
Interchangeable features
Luxury features
Factors of safety
Ease of installation and use and others.

The consumer market must first be investigated for requirements according to such criteria as sex, age, profession, income, social standing, geographical area, hobbies, etc. The numbers of items produced in each of the grades decided upon then follow from the commercial aspect of the market research.

From the point of view of costs, it should be noticed that changing to a higher grade or to a higher quality of design generally costs more; on the other hand, higher quality of conformance generally costs less because of reduction of losses from scrap and reworking. According to J.M.Juran, the grade of a product is the value inherent in the design.

The failure of design to reflect correctly the consumer's quality needs has been a main factor in the development of the concepts of reliability.

5. Conformity with specification

The out-dated interpretation of quality was the degree of conformance of the quality characteristics of the product with those specified in standards or other specifications. As we have seen, this conformance is still a necessary requirement in the quality cycle on the assumption that the specifications have been correctly set.

Checking the conformance with specification is the original domain of the activity of inspection departments and testing laboratories. The activity in this field is generally divided into the areas of

a/ inspection and testing of incoming materials and components,

b/ inspection and control of manufacturing processes using control charts or by automatic control,

c/ inspection and testing of outgoing ginished products

Ad a/. It is common sense that 100% screening of every delivered item, component or unit /bag, tank, etc/ of raw material is non-economical. Indeed, in the cases of destructive testing, 100% inspection is impossible. Hence the development of sampling inspection plans which enable the manufacturer to verify the quality of incoming batches of material or components on the basis of the inspection of only a small number of units.

For this purpose, it is necessary to have worked out inspection procedures, giving details of the quality characteristics to be tested and their classification as to seriousness, method of inspection or testing /by variables or by attributes/, the sample size, method of assessing the results, procedures for handling rejected batches, etc.

Ad b/. As in case a/, control procedures must be prepared, listing process or product quality characteristics to be checked, frequency of control, sample size, type of control chart and level of control limits, scrap and repair procedures, etc.

Ad c/. The outgoing inspection and testing of complex finished products is usually of a screening nature with respect to function /e.g. radios, refrigerators, bicycles, etc./. In some highly automated processes, e.g. food canning, electric bulb manufacturing, etc the final checking may be part of the production process. It is then sufficient for the outgoing inspection to be done on a sampling basis.

The original notion that the majority of defectives occurring during production were due to the poor quality of work of operators has long proved to be wrong. Wide studies show that in the majority of production processes, only 20 to 30% of defectives are directly operator controllable. The causes of the other 70 to 80% of losses can be traced to other sources outside the control of the operator /e.g. insufficient machine precision, bad lighting and others/. This type of analysis shows the importance of analysing reports on defectives according to cause and responsible person or department.

From an economic point of view, the highest preventive benefit is gained from process control and investigation of the causes of sporadic or systematic lack of control, immediately evident from control charts.

6. Consumer preference

The feed-back of information from consumers as to their satisfaction or non-satisfaction with products is invaluable to the manufacturer when deciding on measures for quality improvement and introduction of new products. Complaints during the guarantee period reach the producer automatically and constitute one source of information. However, data on failure rates and minor troubles arising outside the guarantee period can be gained only by special sampling.

surveys using questionnaires, by field investigations, by systematic reporting from a selected group of users or by consumers' panels. These measures are more typical of a scarcity market which is not yet saturated by a variety of competitive products serving the same use.

In the case of a highly competitive market, price, quality and service are the three most important aspects affecting the consumer's decision to buy. Quality is becoming more and more important is this respect, in particular quality of design. Some of the methods of improving the company's position in this respect are [4]:

1. designing the product so that it has high customer appeal from the point of view of function, appearance, durability, packaging, name of brand, etc.,
2. utilizing knowledge of "market quality" to strike the correct balance between quality costs and value of quality,
3. developing a positive quality reputation through prompt delivery of good quality products,
4. introducing quality guarantees to minimize consumers' losses due to defectives and failures,
5. using advertising media to inform the public on product performance,
6. avoiding notorious failure which can seriously damage quality reputation.

Knowledge of consumer preference and of the quality characteristics of competing products is of vital importance in deciding on quality objectives and pricing policy. Value analysis has developed over the past few years and is of assistance in comparing the firm's cost of achieving quality with that of competitors. In addition, today there exist in many countries consumers' unions which are actively engaged in testing competing products and informing the public on their relative performance and value for money.

A number of companies, however, wish to have independent data on the rating of their own product in the eyes of consumers and organize special field investigations, where the most important quality characteristics of their own product are compared by orderi the consumer's preference compared with several other competing products. Table 1 is a modified version of a table from [4] and shows the main results of such evaluation. The home company is assessed as first with respect to properties C and D but has low rating with respect to properties E and F.

Table 1

Properties	Ranking of companies				Average evaluation of competing Cos.
	Home Co.	Competitors			
		Co.X	Co.Y	Co.Z	
A	3	2	1	4	2.3
B	2	4	3	1	2.7
C	1	3	2	4	3.0
D	1	4	2	3	3 0
E	4	2	3	1	2.0
F	4	1	2	3	2.0
Total	15	16	13	16	15.0

The home company must now decide whether they should devote special attention to improving features E and F depending on their importance and the cost involved. They can also decide whether to retain features C and D on the present high level and emphasise them in their adverting or whether to use them as a basis for cost reduction.

In the countries with socialist economies, the state authorities have taken over the function of consumer protection with respect to the quality of key products by means of a system of quality marking operated by state testing laboratories. Similar systems are in operation also in Japan and India and are developing elsewhere in the world /see below/.

7. Dependability, durability, maintainability, reliability, availability, taste

Within the last twenty years, a special set of product properties has come to the forefront of product quality. These are properties relating to the ability of the product to serve its purpose /perform its function/ over a specified period of time / i.e. to retain its quality in time/. The most general property of this nature is dependability /operational reliability/, related to which are reliability /inherent reliability/, reliability /in use/, maintainability and durability.

These properties have gained increasing importance due to the growing complexity of technical equipment, both for military and civil purposes, and to the continuous trend towards automation. The failure of such equipment is usually associated with losses of high magnitude and in some cases with danger to health and loss of life. In addition to higher complexity, more severe environmental conditions and internal stresses due to higher static and dynamic, electrical and thermal loading, chemical aggressivity etc. have accelerated failure mechanisms and led to higher failure rates, necessitating designing with special regard to reliability and durability requirements.

The increasing tempo of technical progress no longer permits the normal cycle of product development, comprising /after research/ the building and testing of models for design qualification, the preparation and release of production drawings, construction and test of production prototypes, eventual redesign and production of a small number of products for field test.

Time compression has led to the omission of some or all of these test phases or at least to their overlapping and has increased the importance of achieving a high degree of reliability the first time. Hence the need to develop the means for evaluating the quality of design at the design stage in order to detect and correct as many deficiencies as possible prior to going into series production. In order to compensate partially for the meagreness of laboratory test results, it became increasingly important to develop means for the collectán and analysis of field data on the rate and nature of field failures.

This new aspect of quality assurance has led to an an extension of the importance of complaint analysis during the guarantee period and of the activity of technical service departments in charge of repair and maintenance services of the company to users. Especially it has led to the establishment of a formal program for reliability assurance either wholly or partly within the quality control department. An example of the utility of such complaint analysis is shown in Fig. 4. Here we see the relative frequency and costs associated with the failure of different subsystems of a heavy lorry produced by the Tatra Company.

As in the case of quality, dependability and its contributing properties are defined as properties which can be measured by means of various indexes /probabilities, parameters, quantiles, etc./. The random variable /quality characteristic/ associated with each product or its components is most commonly the time to failure or time between failures, time to repair, etc. Measures of reliability are then a/ the probability that the time to failure with exceed a specified time interval, b/ the failure rate, c/ the mean time to failure and others. Their theoretical values are seldom known but they can be estimated from test results or from the results of field operation as in the case of other quality indexes used to measure the quality of a batch of items produced under similar conditions.

One of the advantages arising from a knowledge of life and reliability characteristics can be seen from Fig 5. The life distributions of different components in say the engine or gear box should be approximately the same, so as to facilitate block replacement as a maintenance policy. If they are widely different, maintenance and repair procedures are greatly hampered and inefficient.

Problems of reliability and storeability of food stuffs can be approached in the same way . To a greater extent, however, use must be made of sensory testing.

8. Functions and duties of quality control

Analysis of quality control systems reveals a certain common job pattern regardless of the particular product produced and of the detailed organisation of the QC department.

J.M.Juran divides the jobs of QC staff according to the following functions:

I. Functions common to all stages of progression of the product.
II. Functions special to new products.
III. Functions special to vendor relations.
IV. Functions special to process control.
V. Functions specially associated with customer relations.
VI. Functions specially associated with measurement laboratories.
VII. Special analysis, audit and consulting function.

A.V.Feigenbaum divides the QC function into three sub-functions

a. Quality Control Engineering,
b. Quality Information Equipment Engineering,
c. Process Control Engineering, including Inspection and Testing,

and lists the main work elements of these three sub-functions.

The following schematic representation of the main QC activities during the manufacturing cycle is taken from [4] and [5] /see Fig. 6/.

Below are listed the chief functions and duties of QC with the classification number I - VII of Juran or letter a,b or c of Feigenbaum added in brackets:

(1) Recommending realistic quality objectives in agreement with the company's quality policy; cooperating with Marketing a d Engineering in setting specific quality requirements /character-istics and indexes/ on products on the basis of customer needs /function, reliability, serviceability, maintainability, price, etc./; cooperating in the formulation of problems requiring research solution / VII, a /.

(2) Reviewing new and revised designs for quality characteristics; recommending improvements to Engineering which will remove causes of chronic difficulties with previous designs, increase new pro-duct reliability, improve quality characteristics and reduce losses due to failures and complaints; recommending use of value analysis and methods of simplifying control of manufacturing process and evaluating quality, thus reducing quality costs; developing check lists for new designs / II, a /.

(3) Reviewing engineering prototypes; evaluating results of all performance, environmental, life and other tests and other technical documentation /drawings, manufacturing procedures and final product specifications/; analysing and evaluating the prototype from the point of view of reliability; preparing esti-mates of quality costs for new product design; approving the prototype and technical documentation / II, a /.

(4) Assessing manufacturing engineering procedures and, in the case of series production, the results of the test series; recommending measures aimed at eliminating the technical and other factors which have a negative effect on product quality; approving the commencement of series production / II, a /.

(5) Cooperating with Marketing and Engineering in the setting of quality standards for such characteristics as appearance, colour, surface roughness, noise, vibration, etc. / I, a /.

(6) Establishing methods and procedures for controlling the quality of products and manufacturing processes; fixing quality characteristics to be measured, sampling statistics to be calculated and used for control purposes, frequency and location of control, suitable measuring techniques and instruments, suitable methods of statistical control; determining how inspection and control results will be processed and who shall receive feed-back information; ensuring that control procedures shall be incorporated into manufacturing engineering procedures with the appropriate cost and time estimates; preparation of clear instructions for patrol inspectors during manufacturing operations / I, IV, VI, a /.

(7) Preparing procedures for inspection of incoming parts and materials; establishing the relative importance of various quality characteristics with regard to the requirements of design, process engineering and product dependability; determining measurable quality characteristics and methods of evaluating lot quality, including test and inspection equipment and sampling inspection plans; planning vendor ratings and material certification by vendors / I, III, VI, a/.

(8) Cooperating with manufacturing engineering in specifying the required quality capability of current and new production devices, also, in establishing shop standards in the absence of engineering specifications; establishing methods of testing the actual capability of production equipment and methods of preventive maintenance / I, a /.

(9) Ensuring on the basis of results of capability analyses, control charts and other statistical methods, that production equipment has sufficient capability to meet quality requirements; determin-

ing which product and process characteristics require special analysis; analysing the results of such studies and recommending measures for the improvement of machine or process / VII, a /.

(10) Establishing a complex index of outgoing product quality (incorporating information on complaints and field results) and continually analysing its trend /I, V, a /.

(11) Establishing a centralised information feed-back to all key-personnel in Manufacturing Engineering and Marketing including recommendations for corrective action / I, VII, a /.

(12) Diagnosing chronic manufacturing quality problems to determine basic causes of difficulties; presenting results of analysis in such a way thet the necessary remedial action is clear; following up and reporting progress to menagement / VII, a /.

(13) Analysing main elements of quality costs as a basis for initiating positive action in the field of prevention, appraisal and failure aimed at an over-all reduction in quality costs / VII, a /.

(14) Developing quality certification plans for products dispatched to customers; cooperation with Marketing in the preparation of brochures outlining the quality system and the quality features of products / V, a /.

(15) Analysing customer complaints according to mode and cause of failure; recommending corrective action in cooperation with other departments and informing management / V, a /.

(16) Preparation of QC oriented training programs for all company personnel; organising courses for QC staff, for other management, technical and commerciol staff, for shop foremen and operators on the basic principles of QC programs, techniques and procedures / VII, a /.

(17) Developing and introducing efficient methods for regularly reporting to management on the current state of product quality with respect to quality objectives in order to stimulate quality.

improvement and continued quality efforts / VII, a /.

(18) Verifying the effectivness of proposed alterations in technical documentation; approving such changes only after they have been justified and proved not to have a deleterious effect on product quality .

(19) Developing, constructing and proving test equipment and inspection and control devices, especially in-process quality measuring devices; planning calibration schedules; cooperation with Manufacturing Engineering to incorporate, where possible, quality inspection and control devices with the production equipment to provide optimal mechanization and automation with integrated analysis and feed-back of quality data; conducting research and development of advanced quality measurement and control techniques and equipment aimed at improving product quality at reduced cost / VI, b/.

(20) Assisting Manufacturing with performing analysis of quality capability of processes and with implementation of the quality plan during actual manufacturing; ensuring maintenance and calibration of quality information equipment; ensuring that incoming parts and materials and the final product meet the engineering specifications; assisting in the analysis and solution of quality problems /trouble shooting/; performing special tests on request; analysing in detail the causes of customer complaints; cooperating with the QC representatives of sub-contractors or customers in achieving mutual understanding on quality specifications; maintaining quality records; supervising incoming, in-process and outgoing inspection, control and test operations; ensuring that inspection and test personnel are trained in job requirements / IV, c /.

9. Causes and prevention of chronic troubles

A fundamental concept to the quality control function is the prevention of chronic troubles, i.e. the discovery of the causes of these troubles and taking measures for their permanent remedy.

The complementary activity is the maintaining of a satisfactory state of performance all round the quality cycle and the isolation of sporadic, causes of lack of control. This is the fundamental theory of control charts as first propounded in detail by W.A.Shewhart [1]. Dr. Juran refers to this activity as "holding the status quo".

Our problem, however, is to change the undesirable "status quo" in which a chronic "disease" is prevalent.

An invaluable tool in this connection is provided by several simple statistical techniques, beginning with Pareto diagram analysis and ending up with more sophisticated statistical methods like regression analysis.

It is a well known fact that every production process is influenced by a large number of different factors, by the quality of raw materials, by technological factors and the accuracy and precision of manufacturing equipment, by the skill and conscientiousness of the operator and so on. The effect of these factors on the quality characteristics of the product should be thoroughly investigated during the manufacturing engineering stage and the specification of process parameters set accordingly, e.g. machine setting, cutting and milling feeds and speeds, temperatures and time of duration of annealing processes, mixing times for rubber or other mixtures, pouring temperatures of molten iron and steel, etc.

But to quote Rabbie Burns, the national poet of Scotland: " The best laid plans o' mice an' men gang aft aglee". In other words, despite the best of intentions to prepare ideal specifications, it often happens that losses from scrap and complaints are persistently high and hence require cause diagnosis and corrective action. A typical method of making the first analysis is using the Pareto diagram as shown in Fig. 4. Here it is clear that the main problem area is the engine of the heavy lorry under investigation and that the other assembly groups contribute relatively much less to the total costs. A similar analysis of causes of failure of engine parts revealed that 70% of the trouble was attributable to cracks in the cylinder heads due to thermal stresses. A change in design removed the chronic trouble with a corresponding decrease in the number of complaints and losses involved.

It is often necessary to make some special analysis of the relationship between operating conditions and some quality index, e.g. percentage defective. For example, during the production of a grey iron casting, the percentage defective due to sand inclusions was very high despite the fact that the specified technological procedure for mould hardness /lower tolerance limit 80 GF units/ was being observed. It was therefore decided to make a special study of the hardness of moulds and the corresponding percentage defective on both the upper and lower halves of 49 moulds. The results illustrated in Fig. 7 demonstrate that the percentage defective decreases with increasing hardness.

Without determining the regression equations for the relationships in the case of upper and lower halves, we see that it is necessary for the lower tolerance limit for upper halves to be raised from 80 GF units to 86 units, and in the case of lower halves to about 84 units. A further important piece of information from the analysis is the greater sensitivity of the upper halves of moulds to lower hardness. The new specifications were incorporated into instructions for control charts on ramming hardness with a subsequent monthly reduction in scrap of value 30 000 Kčs.

This example demonstrates very well the erroneous view that lack of technological discipline is the only cause of production faults. On the contrery, the cause is often to be found in incorrect design and process specifications.

An interesting form of chronic trouble analysis has been adopted by Quality Control Circles in Japan. It consists in brainstorming the members of the circle in order to list all the possible causes of the trouble and then to isolate a few "vital" causes for special investigation. An example will be given making use of the Ishikawa "fishbone" diagram.

10. Quality assurance

The term quality assurance is generally used in the sense of reviewing and evaluating how the company's activities with respect to quality are being carried out /are effective/ and of reporting this information to the upper management and others concerned.

According to J.M.Juran, quality assurance bears to the quality function the same relationship as auditing does to the accounting function. In view of its short life as an acknowledged independent activity as compared to the action phase of the quality function, there is still some variation in practice as to what activities should be assigned to the assurance function. Generally, however, the following activities are included in quality assurance:

- the processing of field complaints and results of special field analysis,

- quality rating of outgoing product,
- quality survey or audit,
- preparation of executive reports on quality.

The quality audit in Japan is of special interest since it has been developed in considerable detail and is systematically practised in industrial concerns in two forms [11]:

(1) Audit by outside organizations

The most common types are:

a/ audit of sub-contractor's QC system by the producer of the final product,

b/ audit by authoratative organs awarding the Deming prizes or awarding quality marks,

c/ audit by consultant to the enterprise which wishes to improve its QC system or to introduce the system.

(2) Audit performed by the management inside enterprise

This type of audit is common practice once or twice annually in enterprises where QC is well developed. The audit gives continual stimulus to the improvement of the QC system and has extremely beneficial psychological effects, since it permits exchange of opinion between top and middle management and the workers. It broadens the outlook of middle management and gives top management an insight into everyday production problems and appreciation for their solution.

11. Exports and internal markets

The ultimate aim of any national economy or industrial enterprise should be to make no distinction between the quality of goods produced for export and that of goods produced for the home market. It may be necessary, however, for an interim period in particular when demand exceeds supply, to make an exception to this rule.

To demonstrate this point, the experiences of Japan are interesting. Before World War II, Japanese goods had a reputation for inferiority in the sense that they were intended for lower grade markets and in addition the quality of conformance and hence the overall quality was below average. After the war, a national policy was adopted of systematically improving the quality of Japanese goods through the implementation of QC principles and methods. The effect has been visible to the whole world, since Japan as a small country with scarce resources must import much of her food and raw materials and hence must export a large proportion of her products. We are all acquainted with Japanese radios and TV sets, cameras, watches, ships, steels, motorcycles, automobiles, agricultural machinery and other reputable goods.

At the moment, we shall not investigate in detail how the Japanese QC movement developed, but shall note what steps were taken to ensure that export articles in the first place should be of specially high quality.

In 1946 the Japanese Union of Scientists and Engineers was founded and commenced systematic research and training in QC systems with the emphasis on statistical methods. Parallel to this activity, in 1949 the Law on Standardization in Industry was passed and the Japanese Committee for Industrial Standardization for formed as an auxiliary organ of the Agency for Applied Science and Technology attached to the Japanese Ministry of Foreign Trade and Industry. The next few years saw a remarkable interest in statistical quality control and its application in industry supported by the publication of several journals and training manuals under the auspices of JUSE and the Japanese Standards Association.

The latter organization was composed of representatives of industry, consumers, universities and government departments. It checked the validity of current standards and initiated the introduction of new ones. Proposed standards were finally approved by the appropriate ministry and then became Japanese industrial standards. Some of the key products were selected for special attention and had the possibility of gaining the quality mark JIS. In order to qualify for the mark, the manufacturing enterprise of the selected product had to give evidence not only of the instantaneous parameters of the product under test conditions, but also of the fact that in the factory the production equipment and the quality control system were on such a level as to guarantee the continued production of the product on the required quality level. On the assumption that the producer fulfilled these conditions, he received the JIS mark and also the authority to do further testing in his own laboratories with the proviso that at any time a government inspector could check on the maintenance of the high quality level and conditions approved.

This system was one of the basic means of exerting pressure on enterprises to introduce progressive QC methods. A further step was taken to protect the reputation of Japanses industry in 1957 by the passing of an edict making compulsory the inspection of goods for export. The inspection was performed by independent laboratories and in 1967 covered about 40% of exported articles, especially consumer goods of the engineering, textile and food industries /in all 502 different products of which 225 were engineering, 113 general, 62 chemical, 53 textile, 46 agricultural and food and 3 medical/. These products were selected by government authorities on the basis of recommendations of the Council for the Inspection of Export Goods, again comprising representatives of industry, consumers, universities and ministries

This export inspection is performed by 6 state and 39 independent laboratories endowed with government authority. The state employ over 1200 persons and the independent laboratories cca 4500 persons. Time does not permit of detailed description of the methods and criteria used /e.g. design and reliability, dimensional accuracy, performance, special properties like resistance to vibrations, shock, thermal stress, etc., appearence, uniformity, texture, colour-fastness, and others/.

It suffices to state that the system of export inspection contributed in great measure to improving the quality of Japanese products, especially for export, but ultimately also for the home market. The exporting of goods without the export certification given by the inspection laboratories is a serious punishable offence. In a recent paper, Prof. K. Ishikawa admits that there are still some unsolved problems of administration in the export inspection system.

In conclusion of the lecture, some of the basic principles and conditions for the successful introduction of QC systems will be summerized.

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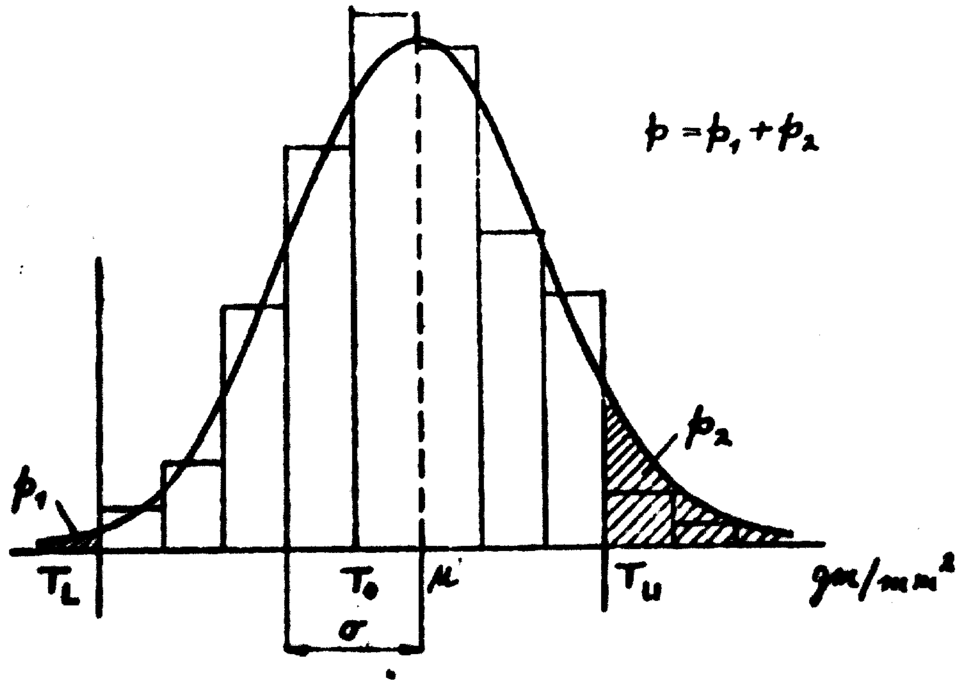


Fig. 1 Typical distribution of the strength of cotton yarn

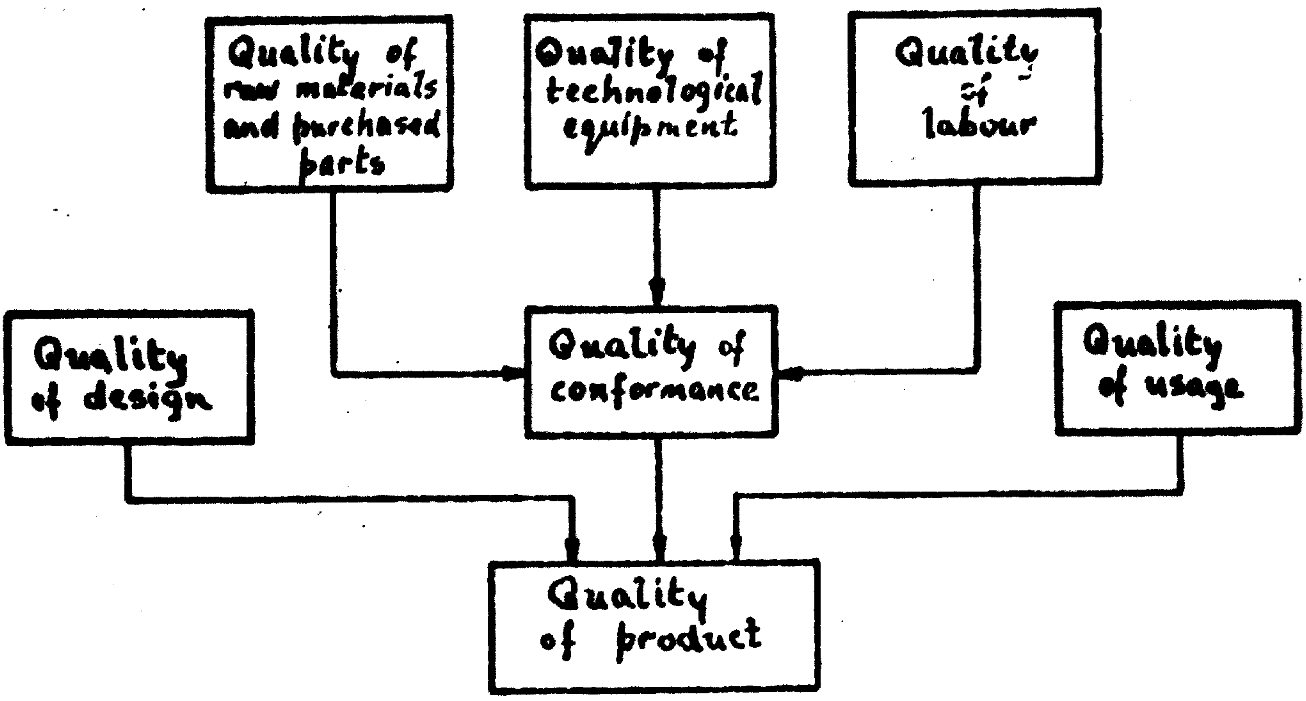


Fig. 2 The creation of quality

Fig. 3 The quality cycle

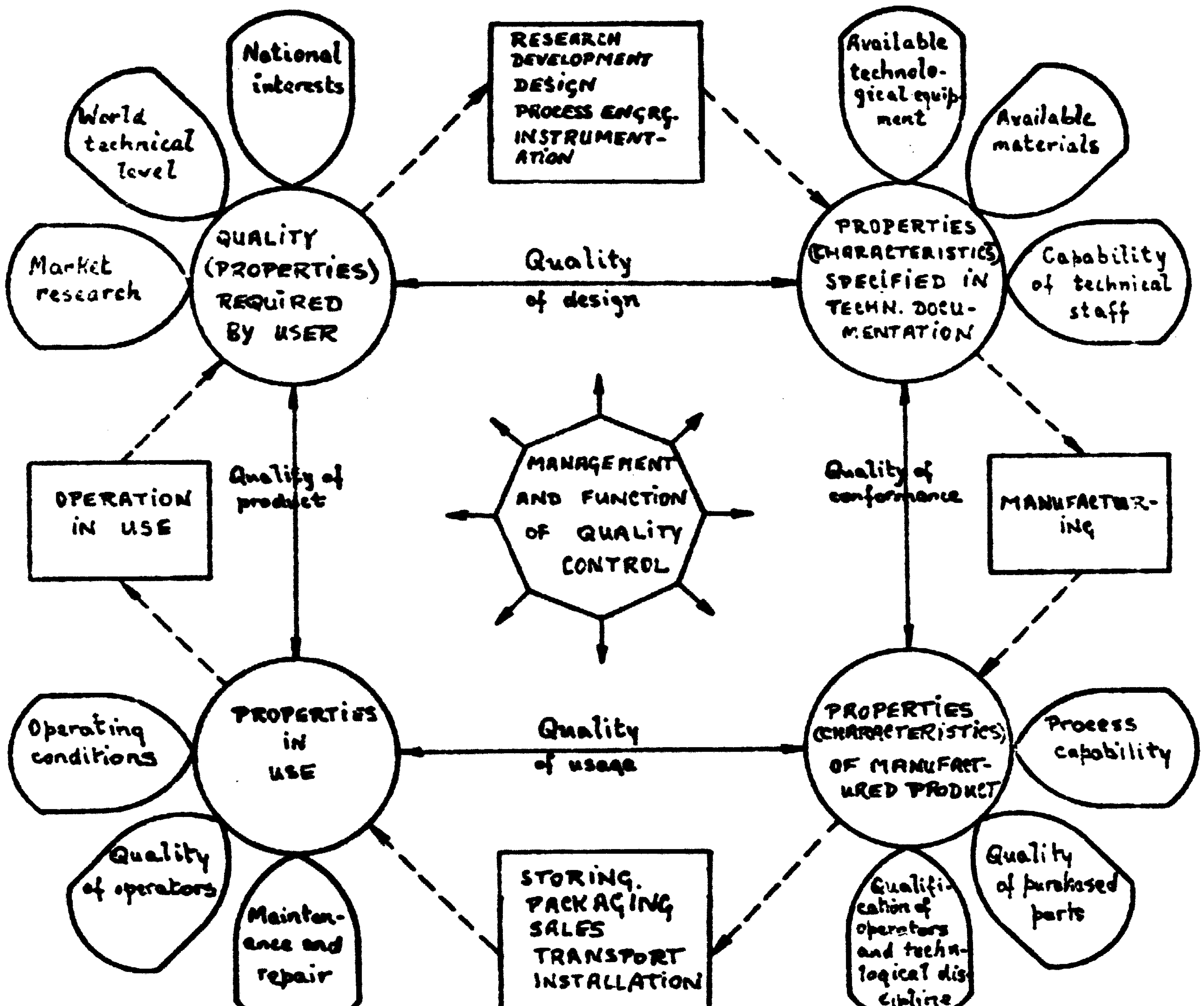


Fig. 4 Analysis of complaints according to assembly groups of heavy lorry T 138

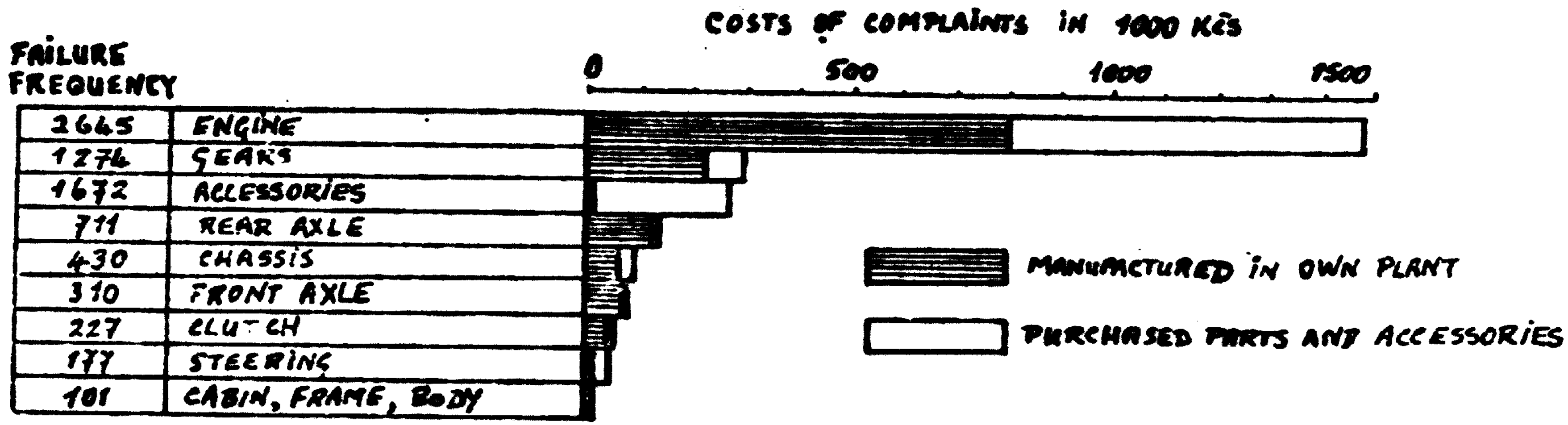
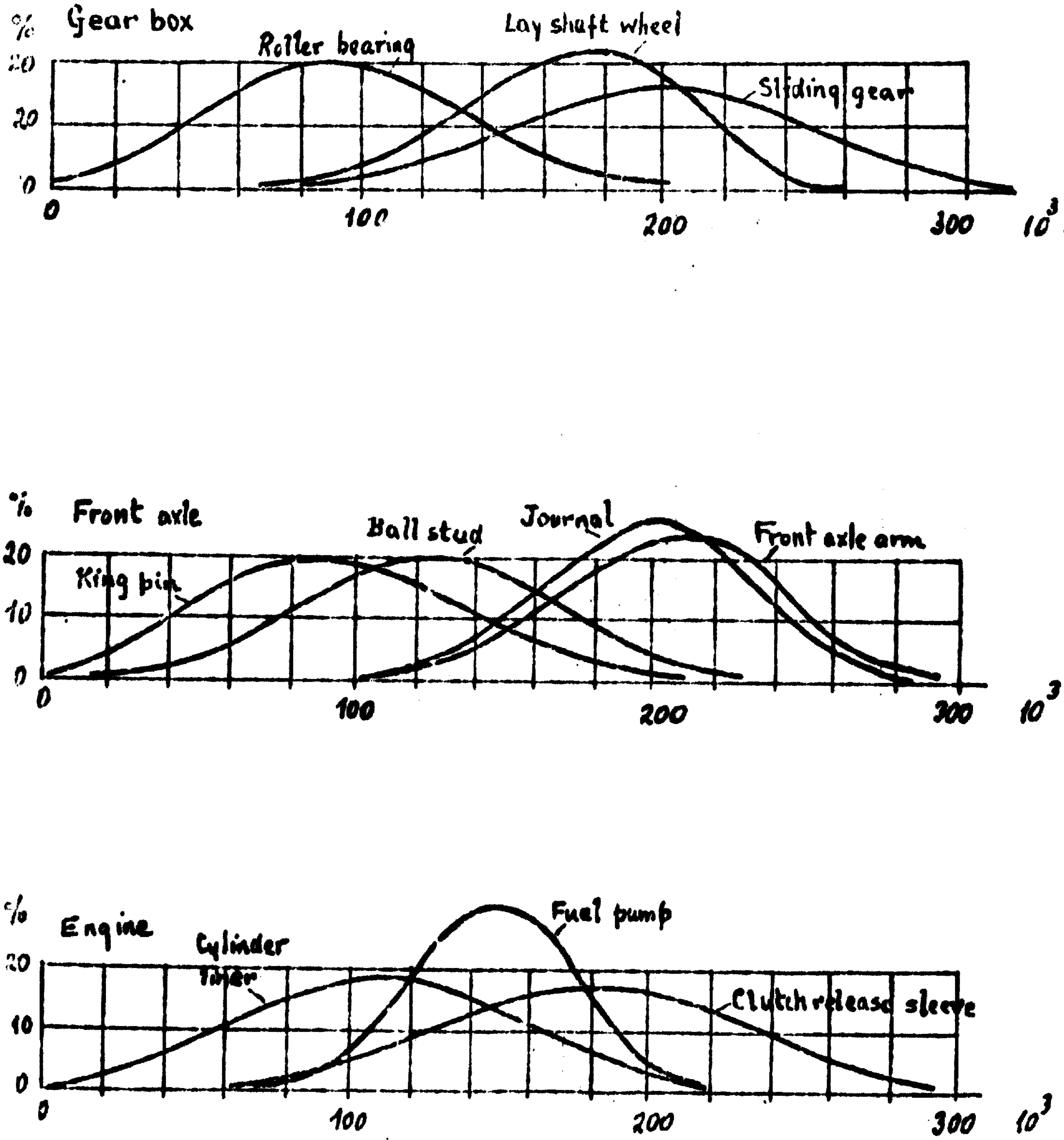


Fig. 5 Life curves of some components according to assembly groups



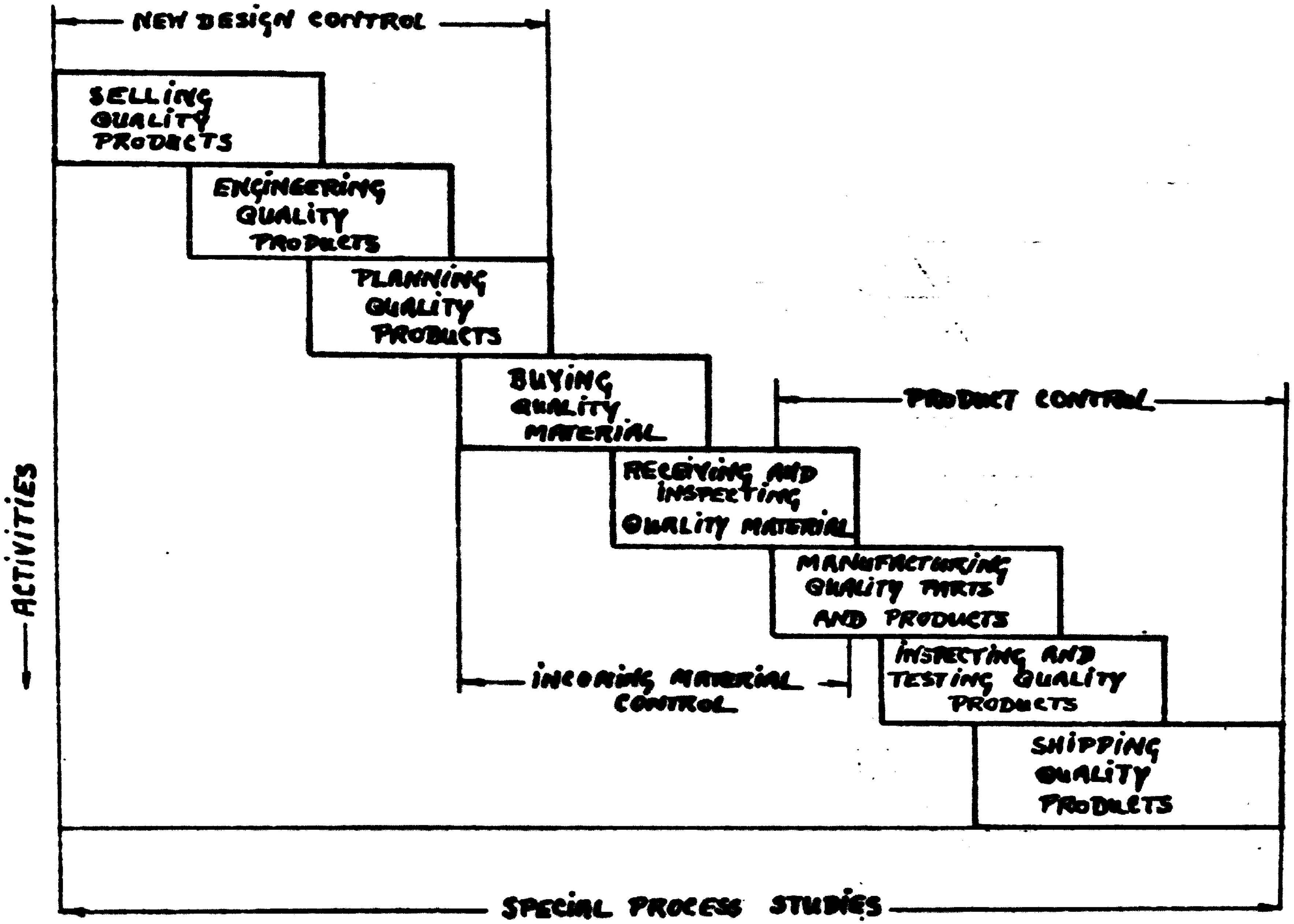


Fig. 6 Schematic representation of quality control activities during the manufacturing cycle

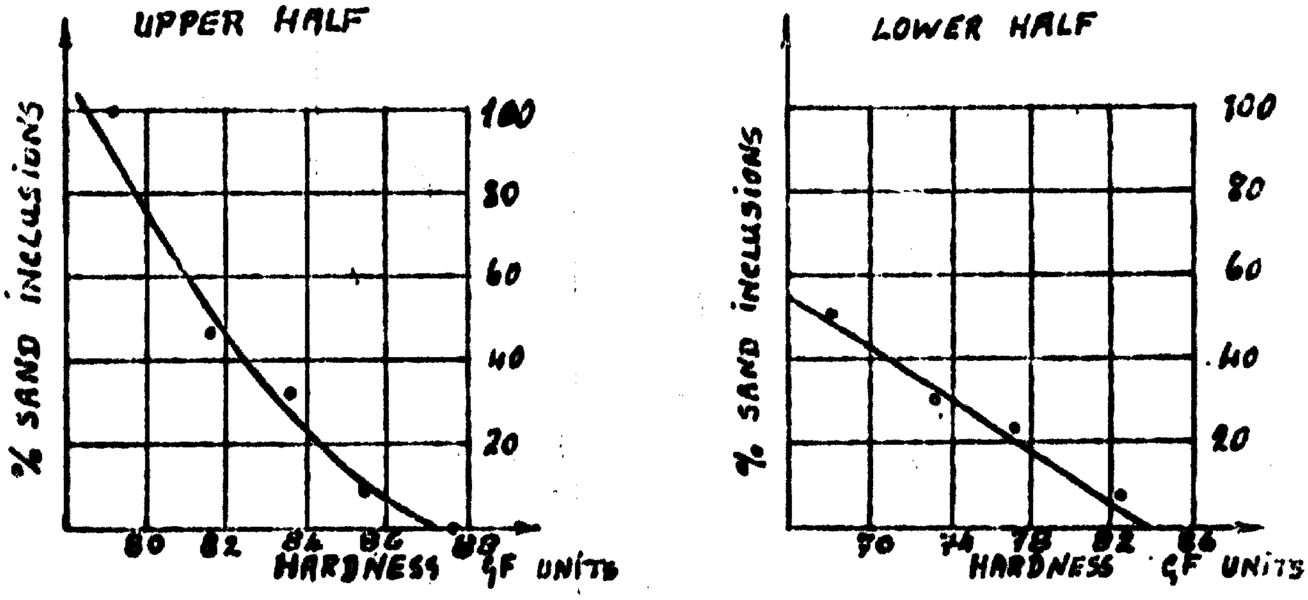


Fig. 7 Relationship between percentage defective due to sand inclusions and mould hardness

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