Quality and its Attainment

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Development of Quality Specifications

Primitive industrial societies required no *specifications*. Commerce was by *barter*. The transaction involved goods then and there physically present, subject to inspection and evaluation by both parties. In such circumstances specifications were not required.

The traditional absence of specification goes far to explain the great extent to which people once leaned on the good craftsman. The craftsman both designed and made the product. He knew not only the design: he knew very well the extent to which the product *conformed* to the design. Knowing all this gave him a great advantage over the consumer. A man who could design a good product and then make the goods conform to the design was much sought after.

With the growth of commerce, many, even most, transactions took place away from the market place. *Producer* and *consumer* did not meet face to face but only through intermediaries. The goods were not present physically, the goods may not even have been in existence. Hence understanding the nature of goods had to come from other means. i.e. samples, descriptions, *specifications*.

The spread of commerce gave rise to specification by sample. The sample divided between seller and buyer, became a durable statement of specification. The use of specification 'per sample' remains prevalent even today in some industries such as textiles and clothing.

Specification by sample presents many limitations. The expense, bulk, weight, etc., of samples can be substantial if not prohibitive in many situations. With the development of writing, specification by written description was evolved and has been used extensively ever since.

The written quality specification is as old as recorded history. The Bible gives specifications for buildings, food, and other products. Records before Christ include Babylonian (under Nebuchadnezzar, 605-562 BC); Chinese pottery-making in the factories at King-To-Ching (1644 BC.) and Egyptian manufacture of linen (2000 BC).

In the absence of measurement, quality characteristics were described in words. There was great uncertainty in the interpretations of words, and the law courts avoided getting into the controversies by putting the risk on the buyers. The rule was *caveat emptor* (let the buyer beware). The rule of *caveat emptor* was entirely logical in market place barter. It was considered that the opportunity to examine the goods prior to barter was an adequate basis for a meeting of the minds of the parties. Once their minds had met and the bargain was struck, the courts avoided the question of whether the one or the other had made a bad bargain.

To a large extent, the principle of *caveat emptor* still prevails when the purchase is for a specific article-this can of tomatoes, this suit of clothes. Reputable companies are, however, less strict than the legal rule permits, and there is also some implied warranty. The can of 'tomatoes' must contain tomatoes and not beans. However, if the tomatoes have a flat taste, or no taste at all, there is no legal recourse. Similarly, if the suit shrinks drastically in the first rain, the buyer has no legal recourse unless there was some representation that the suit would not shrink. This shrinkage warranty if present, would be an element of the specification and would then be binding on the seller.

Historically, the great majority of goods have been sold 'as is'. The movement to define and to label goods as to their ingredients, their formulae, their impurities, the process by which they were made, etc., is of very recent origin.

With the rise of the science of measurement, there arose the great possibility of specification by numbers. Industry as we know it today could hardly function otherwise. Even this development took place in a series of stages.

Measures of length were probably the first to develop. Standards of length evolved for the city, state, empire, the prime standard bearing the king's name and being deposited in the leading temples. The Egyptian royal cubit is known to have been standardised at about 20.63 inches $\pm$0.2 inches prior to 1550 BC. However, different states had cubits of different length (the cubit was meant to measure the length of a man's forearm from the elbow to the tip of the middle finger). There was no international standardisation.

Measures of weight and volume likewise evolved, the early standards varying about $\pm$5 per cent for weights and about $\pm$10 per cent for volume, even within the same state. Improvements in accuracy were slow until the nineteenth century. As late as the sixteenth century the legal definition of the foot in Germany was the average of the length of the left feet of 16 men as they emerged from church on Sunday.

In the simple societies the specification served mainly to facilitate a meeting of the minds between buyer and seller. In the complex industrial society of today, the specification has meaning far beyond this. The quality specification more nearly takes on the characteristics of an industrial law.

The modern factory is an industrial community complete with laws to specify what is right and wrong, and with law enforcement officers to observe the acts of the citizens and to judge whether these acts conform to the laws. One of these systems of industrial legislation is that which includes laws in the form of quality specifications, and law enforcement officers in the form of inspectors. This parallel is remarkably useful in understanding the fundamentals underlying the inspection job. This can well commence by analysing the nature of the quality specification, for it is the quality law of the industrial community.

As factories grew and departmentalized, and as products became increasingly complex, specification by sample became increasingly cumbersome. Too many people needed to refer to the samples. If, to meet this need, several samples were made up, they were not uniform anyway. Assemblies were always fitted together specially, as there was no interchangeability of of parts.

The development of the idea of interchangeability was a milestone in industrial progress. A limiting factor in manufacture had been the great difficulty of assembly by filing and fitting, requiring much time by a highly skilled workman. But achievement of interchangeability required standardisation of units of measure. If shafts were ordered from shop A, and bearings from shop B, then, even though the first was well designed, the parts would not mate properly, because the length of the 'inch' in shop A was not the same as the length of the 'inch' in shop B. The rise of national standardisation and of international standardisation was a vital factor in achieving the precision industries of today.

When written specifications and drawings began to evolve, the practice was to give 'flat dimensions,' i.e., one number to define the characteristic. But as shopmen began to measure what they were making, they found that, try as they might, the product differed somewhat from the specification. When this was revealed to the designers, their first reaction was of the sort, 'It says three inches. So make it just three inches not more or less.' However, experience proved otherwise, and the concept of tolerance was developed.

Purpose of Quality Specifications

The purpose of specification is definition. The thing defined may be a tract of land, a job, a product. The subject of quality specifications may include: (1) Materials, (2) Processes, (3) Products, (4) Method of test, (5) Criteria for acceptance and rejection and (6) Method of use. Some or all of these may be incorporated in the same document, which is then generally referred to as a 'specification.'

'Materials' refers usually to components, ingredients, or parts entering semi-finished goods, while 'product' usually refers to finished goods.

Once a definition is available, any of the parties in the scheme of industry can communicate with any other and use the shorthand of the specification to define a complex product. A buyer can order a No. 32 blower, or a ton of steel perspecification No. 15 and in each case the seller will know what the buyer is talking about. The production departments of the selling company will know what to make, the receiving inspector of the buying company will know what to test for and so on. The commercial usefulness of the specification needs no elaboration.

Types of specifications

Products and materials specifications—These are specifications which apply to products or materials. They usually include the following clauses:

(*a*) Originator:	This is the author of the specification. This is normally a department of a company, an institution of the government of a country, or a professional society.
(*b*) Specification identification:	This includes the usual name of the product or the material to which the specification applies; a number which serves as a shorthand description; a date and issue number and preferably, in addition, the date and issue number which the current issue has superseded.
(*c*) Scope of the specification:	This sets out the product or class of products to which the specification applies. The scope also includes the limitations where the specification is not to apply generally.
(*d*) Detailed requirements:	This is a listing of the desired quality characteristic and the standards or tolerances applicable to each. These quality characteristics and tolerances are the heart of the specification.
(*e*) Method of test:	The methods by which tests should be carried out to determine quality characteristics given in (d) above are given here. Because of the wide standardisation of test methods expression of these is often by reference to standard test designations published separately. Methods of test generally include the method of preparing the specimen for test.

(*f*) Sampling criteria: The method of test is the means for deciding the degree of conformity, to the tolerances, of a *single unit* or specimen of the product. However, a further need is to judge the degree of conformity of the *lot*. This gives rise to sampling criteria.

(*g*) Packaging, Identification, Handling and Storage: This includes information as to the types of containers, quality of product per container, labelling or other identification, extent of protective packaging, type of transport, transport conditions, method of storage and safety precautions (Operation sheet, job sheet)....

Process specifications—The process specification serves two basic purposes:

(1) Instruction to all hands on how to make the product successfully and economically. With the wide industrial trend to separate planning from execution, the process specification records the agreed on plan.

(2) An indirect means for specifying product quality. A pre-requisite for this is a proved cause and effect relationship between process conditions and subsequent product characteristics. Once such a relationship has been established, evidence of conformance to the process specification is also evidence of conformance to the product specification.

To achieve these purposes, process specifications generally contain,

1. Originator,
2. Specification identification,
3. Materials used, identified by their shorthand designation, and the quantities of each,
4. Sequence of operations to be performed,
5. Description of each operation, including machines and tools to be used, ingredient formulas, sequence of events, process conditions to be maintained, (Time, cycle, temperature, pressure, etc.)
6. Process testing to be performed. This emphasizes process acceptance rather than product acceptance.

What is 'Quality' ?

The concept of 'Quality' is very difficult to define precisely. No one single definition has yet been established. However a number of definitions exist which describes this very useful concept in many ways.

The International Organisation for Standardisation gives the following meaning to 'Quality':

'Quality' is the term covering any and every *characteristic property* and/or *performance* of a product or service that can be evaluated to determine whether the product or service meets the *demands* of those to be served. In more simple words the concept 'Quality' is often associated with 'consumer quality' that is, 'the total of all characteristics of a product as looked upon by the consumer.'

Also the notion of 'quality of goods' comprises their properties both at the time of their *purchase* and in the process of using them (eg. durability, reliability, etc.)

In the field of statistical quality control, the quality of a product is often referred to as the *degree* to which it meets the requirement of the customer. The European Organisation for Quality Control (EOQC) adopted the definition of quality as the following:

"The quality of a product is the degree to which meets requirements of the customer. With manufactured products quality is a combination of quality of *design* and quality of *manufacture*."

It is to be noted that this definition makes a distinction between 'quality of design' and 'quality of manufacture.'

A difference in specification for the same functional use of a product is a difference in quality of design, often called the grade. The Rolls-Royce and the Ford automobiles serves the same basic function. However they differ in many features of design.

Quality of manufacture on the other hand, relates to the degree with which the product conforms to the design. A Ford which can run and a Ford which cannot run have the same quality of design, but they differ in quality of manufacture.

What is 'Quality Control' ?

We have discussed in the earlier section the meaning attached to 'Quality'. The means and tools of achieving the 'Quality of products or services' may be designated 'Quality Control' within an organisation. This may be put in the form:

"The functions or collections of duties which must be performed in order to carry out the organisation's quality objectives."

In some organisations, the functions referred to by the term "Quality Control" are very broad, extending to the complete list of functions associated with quality. In other organisations, the term "Quality Control" is used to refer to a limited function such as inspection of the product or analysis of data.

How to achieve 'Quality Control'

Statistical Tools used—data. The achievement of good "Quality Control" practices is intrinsically connected with the practices adopted for collection of data. The entire scheme of control used in an organisation can fail if the 'data' used are not factual or not properly collected, since in statistical quality control, the decision as to whether the method of doing a particular job is appropriate is based on inferences made on analysis of data. The manufacturing procedure will be correct only if the data are analysed properly and the right judgements made. There is no chance of this happening unless the original data gathered is both accurate and appropriate.

In collection and analysis of data there are two basic points to keep in mind.

1. Will the data taken reveal the facts?
2. Are the data assembled, ordered and compared so as to reveal the facts?

No. 1 is a problem of sampling, and No. 2 is a problem of statistical treatment.

The method of sampling must be appropriate for the type of data required. When impurities present is the problem in a certain product, to take only one sample per day is hardly sufficient. Also in comparing defects produced by two workers, it is essential to take numerous samples. In other words, one must give full consideration to the reason for collecting data, proper sampling methods, and stratification. Simply because certain data can be collected easily, one should not take a disproportionate amount. Also partial data, which happens to be convenient to collect is not necessarily effective data.

And even using the correct sampling method in itself is not sufficient. It is necessary to see that the data represents the facts and that the statistical method employed is such that an objective judgement can be made.

Kinds of data—Even though one understands the necessity for having correct data, one may say 'I can't discover any data on my job' or 'I can't collect data.' Certainly on our jobs it is often difficult to obtain data in neat numerical values. For example, when the human being becomes the instrument of measure, say for softness of fabrics, plating lustre or the whiteness of paper, it is only natural that neat numerical figures such as one finds for size and weight are an impossibility.

Imagine for the moment that you are to determine the softness of several kinds of fabric. You cannot measure the exact softness, but by arranging the fabrics in order of softness, you can obtain excellent data.

As stated previously the purpose of collecting data and putting it in proper order is not to put everything into neat numbers but to provide a basis for action. The data itself can be in any form.

Generally data can be classified into the following groups.

1. Measurement data: computation values length, weight, etc.
2. Countable data: No. of production failures, No. of defects, reject rates, etc.

The statistical tools used in the analysis of data are:-

1. Histograms,
2. Pareto Charts
3. Cause and effect diagrams
4. Control charts
5. Scatter diagrams
6. Binomial probability paper, etc.

We shall look into only two important tools out of these, the control chart and the cause and effect diagram (Ishikawa Diagram).

The details of others are given in standard references.

Control Chart

This is a chart which detects changes in a production process. Fig. 1 is a histogram based on a measurement data collected five times a day at a textile plant. Fig. 2 shows a graph made using these data, showing the daily average value (X) and daily range (R).

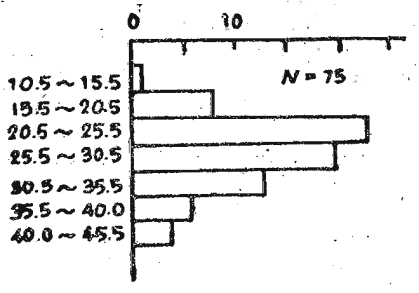

Figure 1 Frequency

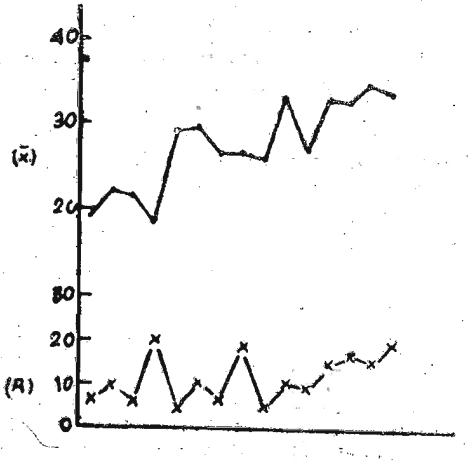

Figure 2

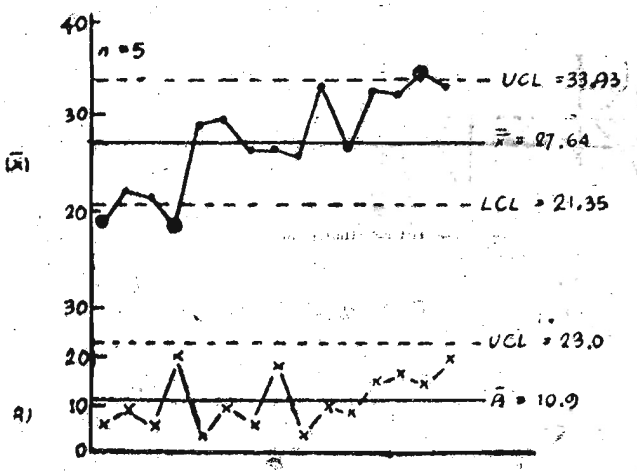

Fig. 3. Changes in Manufacturing Process

On the basis of this graph we can see that the values were low in the beginning and showed a tendency to increase over a period of time. By looking at the histogram in Fig. 1 we could not learn that fact.... In other words, the change of data gives us new information. Now, the problem is the determination of whether the points of the graph are abnormal or not. For example the first four points of the $\bar{x}$ might be normal or lower than normal. Thus, when the limits are not clear the graph is not of very much use. Therefore it is necessary to have some kind of limits within which X and R should fall, if the process is working under normal conditions. Control lines are written into these graphs for this purpose. If we add control lines to Fig. 2 we get Fig. 3. Now we can see where any abnormality lies and take action as required. A graph or chart with control lines on it is known as a control chart. There are three kinds of lines, the upper control limit, the central line and the lower control limit. They can be written as UCL, $\bar{x}$ or R and LCL.

Types of Control Chart

A control chart's form varies according to the type of data it contains. For example, part measurements, (mm) or masses (g) are measurable amounts (known as indiscrete values). Also there are reject numbers, or defect numbers, which are countable amounts (known as 'discrete values'). Control charts based on these two kinds will differ.

Type of data	*Control chart used*
Indiscrete	
Examples: measurements (say mm or g)	$\bar{X}$ — R
volume (ml)	$\tilde{X}$ — R
Discrete	
Examples: number of defects	pn
defect rate	
sub-standard product rate	p
etc.	

Reading of control charts

In order to use control-charts effectively we must know, how the changes in manufacturing processes are reflected on a control chart, i.e.

(*a*) When the manufacturing process is changed how do points on the control chart get changed?
(*b*) When the manufacturing process changes in degree, how is this reflected in the control chart?

These two situations are illustrated in the figures below.

1. The $\bar{x}$-R chart for the daily production of a certain product is shown in Fig. 4., let us call this distribution A. The manufacturing process in this factory is stable.

2. When a factor (such as raw materials, machines, work methods, workers etc.,) changes and consequently the mean value of a characteristic of the product changes. Fig. 5 shows the resulting distribution and the control chart.

3. Now let us see what happens to the points on the control chart when the dispersion of the manufacturing process changes. The mean of the distribution remain as at A, but the dispersion becomes larger. this is shown in Fig. 6.

Now for the above situations, the $\bar{x}$—R control chart shows:

Distribution A

1. All points within the control lines and no clustering of points to one side of the central line. The manufacturing process is said to be in a stable state.

Distribution B:

2. Points go outside the control lines in $\bar{x}$ chart although in the R chart the points lie within the control lines. There is clustering of the points in both charts. The shift from distribution A to distribution B is clearly shown on the control chart.

Distribution C:

3. When the dispersion of the manufacturing process changes a large abnormality is seen on the R control chart. Also note that the spread of the points on the $\bar{x}$ control chart becomes bigger and goes beyond the control limits.

Thus the control chart is a very valuable tool in detecting abnormalities in a manufacturing process. (For further details see references). When abnormality of the process is shown on a control chart, the cause should be investigated and put right.

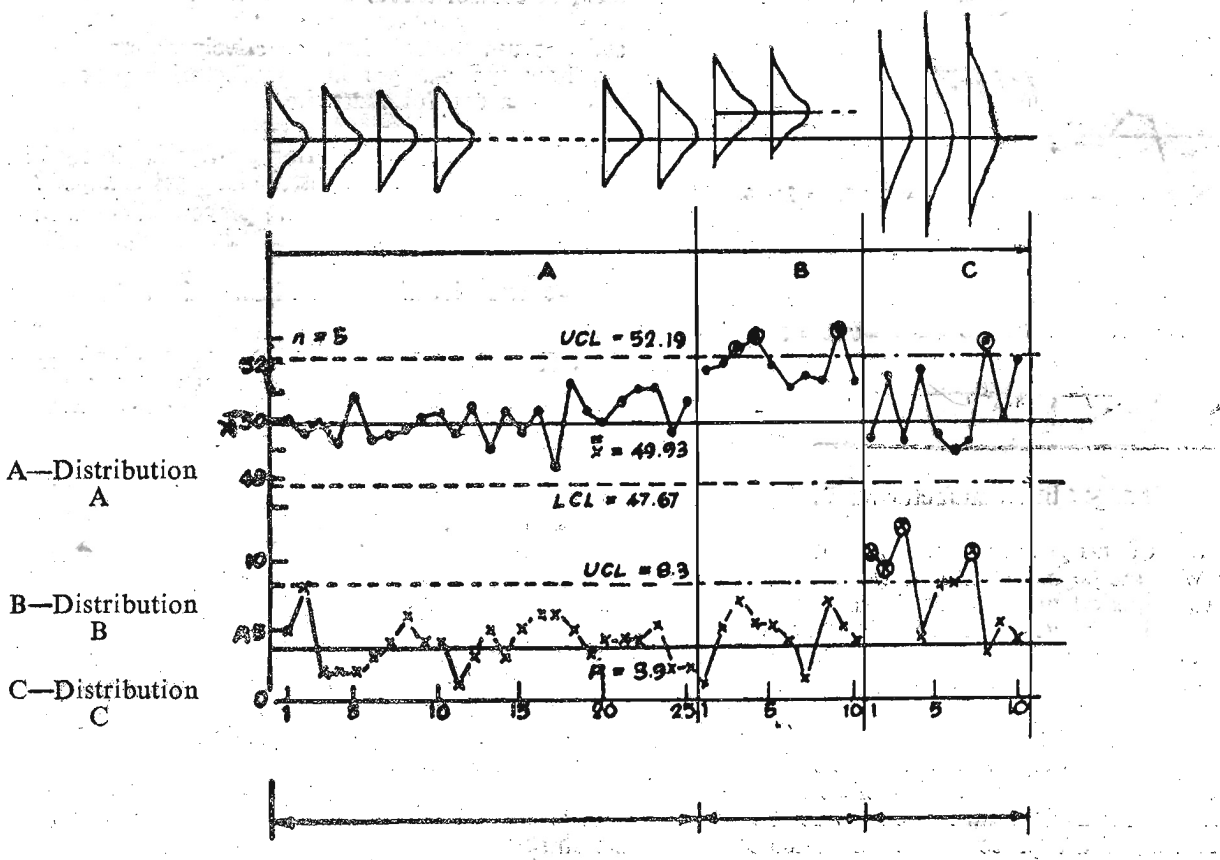

Fig. 4

Fig. 5

Fig. 6

Cause and Effect diagram (*Ishikawa diagram*)

This is a rather recent tool of statistical Quality Control, nevertheless it is a very useful tool. In this diagram all the causes that give rise to an effect are listed and the important and true causes are selected for further analysis. Fig. 7 shows a basic cause and effect diagram, for analysing the wobble of a spindle in a rotating machine. The diagram is developed in the following way.

Step 1 — Decide the quality characteristic (wobble during rotation) in order to stop the wobble we must find its causes.

Step 2 — Write the quality characteristic on the right. Draw a broad arrow from the left to the right.

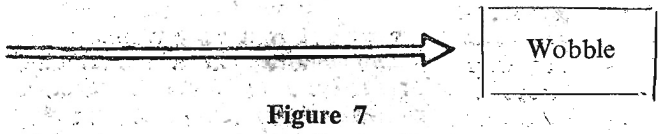

Figure 7

Step 3 — Write the main factors which may becausing this wobble along the arrow.

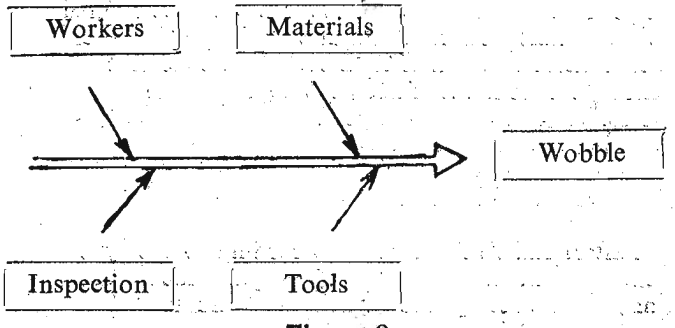

Figure 8

The four main causes have been grouped under: Workers', 'Material,' 'Tools,' and 'Inspection.'

Step 4 — Now, under each of these main reasons (causes) write in the components in detail. If you keep arguing in the following way you cannot help but find the cause of the problem.

1. Why do defects occur? Owing to machine wobble (dispersion)
2. Why does the machine wobble? Owing to dispersion in the materials. 'Materials' written on the diagram as a cause.

3. Why does dispersion in the materials occur? Owing to dispersion in the axle sleeve. The axle sleeve becomes a subcause.

4. Why does dispersion in the axle sleeve occur? Owing to dispersion in the size of the axle sleeve. Size becomes a sub-cause.

5. Why does dispersion in the size of the axle sleeve occur? Owing to dispersion at the 2.6 mm point. The 2.6 mm point becomes a sub-cause.

In this way we add to a cause and effect diagram until it fully shows the cause of the dispersion. Fig 9 shows the completed form.

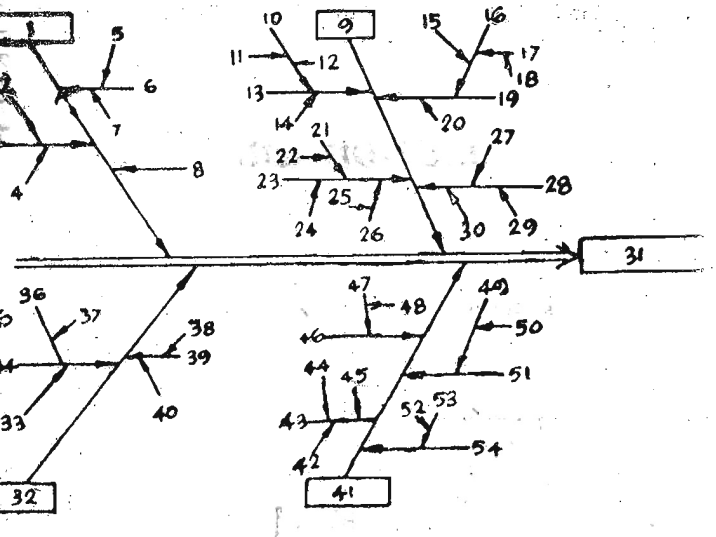

Figure 9 Cause and effect diagram

1. Worker	19. G axle retainer	37. Errors
2. Content	20. Material quality	38. Training
3. Training	21. 11.6	39. Inspector
4. Knowledge	22. Uneven	40. Experience
5. Over-Experienced	23. F cover	41. Tools
6. Experienced	24. Axle hole	42. Punch width
7. Under-experienced	25. 9	43. F axle cover
8. Personality	26. Interval	44. Metal drill
9. Material	27. Threads	45. Axle stop
10. 6.4	28. Nuts	46. G axle cover
11. Small	29. Tight	47. Off centre
12. Large	30. Loose	48. Adjustment
13. Central axle	31. Wobble	49. Off centre
14. Material quality	32. Inspection	50. Cover hole
15. 2.6	33. Judgement method	51. G. axle sleeve cover
16. Size	34. Judgement	52. Uneven
17. 6	35. Measuring tool	53. Plating
18. Large	36. Measurement	54. F cover.

Step 5 — Finally, one must check to make certain that all things which may be causing dispersion appear on the diagram. If they are all shown and the relationships are clear then the diagram is complete.

There are many varying methods for making cause and effect diagrams according to how one organises and arranges them. These methods can be divided into the following three types:-

1. **Dispersion Analysis Type—**
The cause and effect diagram which we just studied falls under this type. The secret of making it is to keep asking 'why does dispersion occur.?"

2. **Manufacturing classification type—**
With this method the diagram's main line follows the manufacturing process and all factors which may affect the quality are added. If Fig. 9 were written as a manufacturing classification diagram it would appear as Fig. 10.

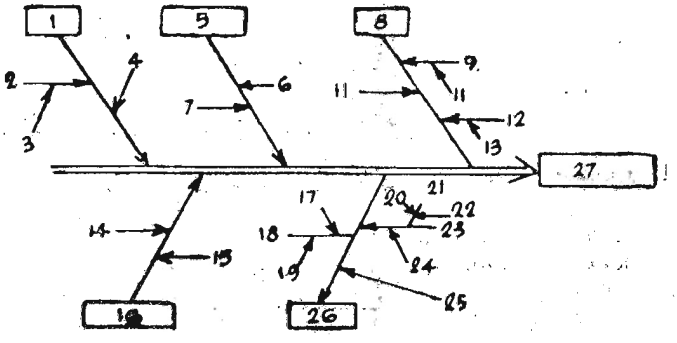

Fig. 10 — Cause and Effect diagram for wobble of a spindle (manufacturing classification type)

1. Tools	15. Cover
2. Construction	16. F resistor
3. Design	17. F cover
4. Accuracy	18. Cover caulking
5. G. resistor	19. Body G.
6. Axle sleeve	20. F
7. Axle	21. Axle sleeve
8. Inspection	22. G
9. Measurement	23. Axle caulking
10. Measuring standard	24. Axle
11. Gauge	25. Punch
12. Judgement	26. Assembly
13. Person	27. Wobble
14. Axle hole	

3. **Cause Enumeration Type—**
In this type all the possible causes are simply listed. When doing this, everyone's ideas are necessary and the use of a blackboard is helpful when listing the causes. These causes must be organised so as to show their relationship to product quality. In making this type of diagram, one has to remember not to confine one's thoughts to types of causes or assembly line order but think freely as one can. The real cause or the cure will come out of this kind of free thought.

A cause and effect diagram should fit the purpose for which it was drawn and be easy to use. There are several uses of them the chief ones among them being:-

(*a*) Making a cause and effect diagram is educational in itself.

(*b*) A cause and effect diagram is a focus for discussion.

(*c*) The causes are aggressively pursued and the results are written in the diagram.

(*d*) The data are collected with a cause and effect diagram.

(*e*) A cause and effect diagram shows the level of ability of the workers and supervisory personnel.

Conclusions

The successful application of principles of quality control does not rest only on the Quality Control Department or the Inspection Personnel of the factory. These concepts have to permeate into every level of the organisation, right from the top management down to the production floor staff. It is the involvement and the consciousness for quality of all these personnel that could bring about a revolution in quality in the factory and thereby in the country.

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