Chapter 2
Quality Control

2.1 Quality Control is a Flexible, Polyvalent Concept

The standards adopted for product assurance are manifesting themselves not only in the domains of inspection and testing but also in the examination of rejected and borderline units. Inspection, testing, and investigative feedbacks from the contains of throwaway bins are quality in the small (Chap. 1). It is wise as well to appreciate that:

- No complete verification by inspection operations is ever possible;
- A 100% inspection, if and when it can be done, is by no means a 100% protection.

The second bullet underlines the importance of statistical quality control (SQC, Chaps. 12–15), and the basis for inference which it offers. Statistical inference, however, presupposes that we know what we are looking for and what kind of risks we would like to keep under lock and key if and when we can do so.

This emphasis on the relative merits and limitations of statistical inference (see also Chaps. 8–11) is deliberate because a manufacturing organization is a system involving human beings whose attitudes tend to mix objective and subjective factors. On the other hand, the success of any industrial quality control system is largely contingent upon its ability to handle people by providing a solution which:

- They can easily understand;
- They are willing to use it in their day-to-day work without being overburdened by its complexity.

Quality control is in no way intended to be a way of putting people under stress; properly applied it acts as a smart structure endowed with an array of sensors—the workers, supervisors, and engineers at factory floor. Their feedback produces a stream of data to be analyzed to provide continuous monitoring of quality's integrity.

D. N. Chorafas, *Quality Control Applications*, Springer Series in Reliability Engineering,
DOI: 10.1007/978-1-4471-2966-0_2, © Springer-Verlag London 2013

This is written in a factory-wide sense. As for the quality control (QC) department, its responsibility is to assure that the production output conforms to the engineering specifications. For this reason QC is usually attached to manufacturing, though it may as well be given a broader mission including incoming material rating.

Indeed, well-managed companies establish a procedure by which QC and purchasing work in close cooperation. This avoids QC problems down the line because of defective materials which were not properly screened out at reception. Let us look at this alternative through a small case study, which exemplifies what companies do for obtaining good quality supplies at minimum cost. A sound procedure has three steps:

- Where past supplier data are available, the QC organization compiles a list of items (using drawing and part numbers) which quality-wise are considered troublesome.
- The purchasing organization prepares a list of problem items in a like manner, including source of procurement; hence supplier service and dependability. Such items are considered troublesome due to quality, price, or service.
- Based on the aforementioned two lists of items in common agreement, QC and purchasing create a single list to be used in the company's procurement and incoming materials rating program.

If there was no past supplier information, reference data will have to be asked from the clients of a given supplier and further enriched with future information as it becomes available. At first instance, in this case a tightened control is advisable. In addition, a supplier's appraisal programs should be scrutinized and compared to our company's quality control plan(s). Company Alpha, a real entity, has been using three factors for determining a source of supply. In order of importance:

1. Quality
2. Price
3. Service

In its evaluation Alpha allocated 50 points to quality; 36 points to price; and 20 points to service. This allocation of weights was flexible enough to suit departmental requirements if necessary, without changing the basis of the overall QC plan or the way in which it worked.

QC and purchasing based their rating on the assumption that incoming lots are either acceptable or rejectable. If all lots were acceptable over a specified period of time during which a given item was rated, such as 1 month, a number of 50 was assigned to *quality*. Otherwise, this number 50 was reduced according to the degree the lots were unacceptable, by:

- Determining the ratio of acceptable lots received as a percentage and multiplying it by 50;
- The resulting number gave the weight to be assigned to quality.

A similar procedure computed was employed for the price factor. The lowest price was assigned a weight of 30. Higher prices were used as denominators in a ratio with the numerator as the lower price. Multiplied by 30, this ratio gave the weight to be assigned to the vendor's offer in terms of the cost factor.

Purchasing based its rating of service quality on the vendor's handholding, timely delivery, promises kept, and similar criteria. A percentage of 100, 90, 80, or some other ratio has been used to adjust the maximum weight of 20. Contrary to the quality quotient which was specific to each item and represented product assurance, service rating labeled the dependability of the vendor.

The sum of the compound rating of these three metrics: Quality, cost, and service were judged as excellent (if it were 100 or 98); good (from 93 to 97) and fair (from 86 to 92). If it were 85 or less, purchasing would eliminate that vendor's offer as being questionable at best.

That is all, with regard to QC relating to incoming materials and devices . In connection to its own production, Alpha has used SQC targeting quality in the small within each factory's walls. There have also been charts for *trend of trends* assisting the management's thinking in terms of corporate-wide quality of manufactured products.

Many of the tools Alpha employed for stochastic inference were its own, though based on generally accepted principles. The underlying concept of experimental inference can be expressed through *if, then* rules which, among themselves, reflect one of the basic scientific laws:

- *If* the experimentation tells me something is erroneous;
- *Then* I have an evidence it is erroneous;
- *If* Experimentation tells me something is *not* erroneous;
- *Then*, I have *no* evidence as to whether it is erroneous or correct. Therefore, I tentatively accept the hypothesis as being right.

In science, SQC is a scientific tool implemented in an industrial environment; we are far more sure when we *reject* than when we *accept* a hypothesis, or a "fact" under test. What we mean by accepting is that we have no evidence for rejecting it, but we know that a "nasty" new fact may pop up in subsequent experimentation, leading to its rejection.

In Alpha company, the trend of trends and specific SQC charts were not filed away and forgotten. The output of SQC enriched the product assurance database just like sensor networks collect information elements all over the environment where they are implemented. This constituted the quality assurance database of the company's corporate memory facility (CMF) [1].

A CMF is an important and integral part of the governance of a modern enterprise. Inter alia, it registers all decisions being taken, the justification supporting them and the names of the decision makers. Quality data is an important part of a company's memory. As David Shenk suggests "Without (memory) all life and thought are an unrelated succession. As gravity holds matter from flying into space, so memory gives stability to knowledge…. It holds us to our family, to our friends. Here a home is possible; hereby only a new fact has value [2]."

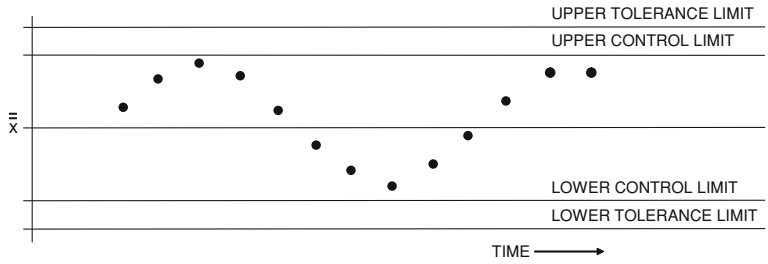

Fig. 2.1 Statistical QCC by variables: A preview

Information elements in the quality assurance database of Alpha's CMF permitted to reconstruct online, on request, statistical charts by variables and by attributes of any operation in any one of the company's factories, at any time. As a preview of the discussion in Chap. 13, Fig. 2.1 gives a glimpse of how an SQC chart by variables looks like.

An additional advantage, in terms of industrial management is that the stream of SQC data permits to identify and challenge chance causes: What makes the normal pattern of variation look the way it does? Can the cause(s) of variation be clearly identified? If yes, can they be eliminated? Should changes to the process pattern of variation be expected? This brings into the picture the need for inference, but it is good to remember that:

- In principle, the process pattern of variation may be predicted if only chance causes operate.
- To the contrary, the process pattern of variation may *not* be predicted if assignable causes of variation hold the upper ground.

In conclusion, the methodology defined in this section helps in identifying the importance of QC at large, and most specifically SQC: A process is said to be in control when it has a stable pattern of variation within prescribed limits and assignable causes are not operating in this process. Control charts tell us when the production process is in a state of statistical control (Chaps. 12 and 15).

2.2 The Expanding Horizon of Industrial Statistical Methods

During nearly seven decades since the end of World War II, statistical methods have progressively become an important adjunct not only to engineering but also to most industrial and financial sectors of the economy. From manufacturing processes, statistical methods expanded into procurement and acceptance inspection (Sect. 2.1); then into applications in finance and banking.

In historical sequence, the first industrial domain where statistical methods demonstrated their importance has been the control of quality in the production

process, including sampling inspection (Chap. 9) and quality reports for management. The performance of experiments in scientific laboratories (Chap. 1) is another example. This has permitted engineers, physicists, and other professionals to:

- Draw objective conclusions from their experiments; and
- Base them on verifiable data rather than subjective considerations.

A contributing factor to the expansion of implementation of statistical methodology has been the war effort in the US, over the 1940–1945 timeframe. Military specification MIL-Q-5923, which specifies the contractor's duties (that he shall develop and sustain an effective and economical QC system)—saw to it that QC has been charged with assuring:

- Adequate inspection coverage, present throughout the entire process of manufacture, including packaging and shipping; and
- Evidence of required inspection to be provided by the contractor prior to submission for acceptance, so that an objective quality evidence is evaluated and verified by the representative of the defense procurement agency.

To the question of what is needed for an objective report on quality, US military specifications stated that experimental evidence is an absolute requirement, documented by means of actual test results. To the question regarding sampling inspection or 100% inspection, WWII US military specifications left no doubt that sampling inspection is required not only when the test destroys the product units but also when it is a more economical or efficient solution, as it is so frequently the case. Other questions revolved around quantity and quality viewpoints in manufacturing (see also Chap. 10 on operating characteristics curves):

- The producer's viewpoint is that he aims for quantity and hopes for the benefits of quality. He demands protection against the rejection of a good product.
- The consumer's viewpoint is that he aims for quality and hopes for the benefits of quantity at reasonable cost. He demands protection against the acceptance of a poor product.

Both viewpoints have weighted on the way SQC methods have been implemented and developed over time. To the question when does SQC best apply? originally the answer was: "When units are produced in quantity," but it has been superseded by the more accurate response: "When the quality measurements with which we are concerned vary." If we take fine enough measurements, all machines and processes exhibit variation. When this variation increases we have a quality problem which can be solved by SQC techniques, as well as through experimentation. As Chap. 1 has made reference to this happening by bringing to the reader's attention that product assurance is a system with several variables having an effect on the result.

This raises the question about the best method for studying these variables' effect. When testing a device, product, or system a number of approaches are available for finding the optimum combination of variables.

- The classical method suggests that one variable be measured while all others are held constant.

This has been the classical approach, but it takes time and there is a risk of missing hidden, essential information resulting from the variables' interaction. An alternative method chooses values for each variable at random (largely by intuition), scattering them about in a way which will expose major trends. Its downside is that data of this sort are not readily analyzed in a mathematical way.

To the contrary, by means of statistical inference (Chap. 8) the analysis can be systematic. All points statistically scattered yield tables of data which are easily reduced to a series of equations.[1] Through analytics, we obtain computed values for the amount of variation. But as we will see in Chap. 11 the experiment must be planned and only a researcher with considerable technical knowledge and judgment can plan experiments and properly interpret their results.

Experimentation and QC have a symbiosis. As QC, practically the first major industrial application of statistics gained ground, the requirements grew for more sophisticated tools and this led to better focused research and experimentation (see also the Omega case study in Chap. 1). Experimentation returned the compliment by promoting more advanced application of statistics in the industry beyond the original confines of:

- Frequency distribution, as visual representation of a pattern of variation (which, in a more coercing manner is also given by a simple histogram).
- Central tendency (or value) about which the other measurements tend to concentrate or spread;
- Pattern of variation of a quality characteristic which describes the value at which this characteristic has been measured or would be measured under certain conditions; and
- Spread of the pattern of variation describing not only the extent to which the values deviate from the central value but also the outliers and long leg of the distribution.

One of the milestones in the expanding horizon of industrial application of statistical methods has been a whole family of *quality control charts* (QCCs) related to a quality characteristic or group of quality characteristics resulting from a production process. Figure 2.1 has presented an example of QCC. Notice that upper and lower control limits are within the engineering tolerances (more on this in Chaps. 13 and 14).

This chart comes from *inspection by variables* where the actual measurement of the quality characteristic is taken and recorded (see Chap. 13). The alternative is *inspection by attributes* where units of product are classified as defective or non-defective with respect to an attribute or set of attributes (see Chap. 14).

Each point on the quality control chart represents one sample drawn from the production process. The information from the sample is summarized into a statistic

[1] However, data which have not been scattered statistically cannot yield statistical information.

whose value determines the vertical location on the chart. The time, the sample was taken determines the horizontal location of the point. The chapters on SQC by variables and by attributes will provide much greater detail on this process.

With experience accumulating throughout business and industry, the sophistication of QCC implementation has grown, and statistical inference got a boost. One of the most interesting applications of SQC thinking has been to help us choose one of two hypotheses about the production process:

H_0: The production process if in a state of statistical control; hence *in control*.

H_1: The production process is not in a state of statistical control; therefore, it is *out of control*.

Figure 2.2 offers a bird's-eye view of the quarter spaces in a test of hypothesis. This is a preview of this most important tool of mathematical statistics which is explained in Chap. 8. The application of statistical inference in business and industry has brought us, as tools, the test of hypothesis and statistical quality control charts. The underlying process can be summed up as follows:

- Identify the production process
- Choose the particular quality characteristic with which the control activity will be used
- Select a random sample of *n* units from the production process
- Inspect the sample by testing or measuring each of the *n* units and record results
- Calculate the value of the statistic and plot the point on the control chart
- Make a decision dictated by the rule governing QC, with two options: *accept* or *reject*[2]

Taken together these six steps add up to a rule which underpins the test of hypothesis: *If* the pattern of measurements falls between the lower and upper control limits, *then* accept the null hypothesis: H_0. By contrast, *if* one or more points fall outside the control limits, then reject H_0; accept the alternative hypothesis H_1 and render the consequences of this decision. When statistical quality control charts are used to arrive at our decision, our options are limited in the four quarter spaces of Fig. 2.2.

2.3 Instituting a Quality Control Program

Experience in quality planning and control indicates that a product assurance program will only succeed when it reports directly to top management, is staffed with the best of brains, and has been given clear objectives. The function of the group whose responsibility is to watch after quality should be to establish, monitor, and evaluate the performance of all planning and control programs affecting quality and reliability.

[2] In Chap. 9, on sampling, we will also examine a three-option system: accept, continue sampling, reject.

		DECISION MADE	
		H_0 : IN CONTROL	H_1 : OUT OF CONTROL
ACTUAL STATE IN PRODUCTION PROCESS	H_0 : IN CONTROL	CORRECT	ERROR*
	H_1 : OUT OF CONTROL	ERROR**	CORRECT

* THIS IS α (TYPE I ERROR, PRODUCER'S RISK). SEE THE DISCUSSION ON OPERATING CHARACTERISTICS CURVES (OCC) IN CHAPTER 10

** THIS IS β (TYPE II ERROR, CONSUMER'S RISK) IN OCC

Fig. 2.2 The test of hypothesis "in control" by using QCC

Since quality planning starts at the drafting board (Chap. 3), the leader and members of the quality assurance group should furnish design engineers, procurement specialists, manufacturing engineers, and sales engineers with methods and tools that assist them in meeting product assurance parameter(s). *Thinking* makes the difference and thinking must be part of every professional's job. One of the most resourceful businessmen, Thomas Watson, Sr., used the logo THINK almost at par with IBM. In his Cambridge lecture on August 31, 1837, Ralph Emerson said:

> *If* one is a true scientist, *then* he is one who THINKS.

Niels Bohr, the nuclear physicist, was teasing his peers, his assistants, and his students by telling them: "You are not thinking, you are only being logical." Great men in history have always appreciated that thinking means challenging the "obvious", therefore, doubting and experimenting. Both *doubting* and *experimenting* are the roots of high quality and of quality-oriented services.

This quality-oriented professional group should delegate teams of specialists from among its members to work with specific engineering, manufacturing, and field service personnel (where applicable). Its quality planning and control expertise must be available wherever needed both for consulting and for quality and reliability auditing reasons.[3]

[3] The work which I have done many times in my professional experience. Consulting and auditing should never be done by the same expert in the same program, project, or product.

For example, the procurement operations may require assistance in controlling the quality of complex supplies, components, equipment, and systems which became more sophisticated and for which current requirements are inadequate to provide the needed quality assurance. Part of the aforementioned group's contribution should be to assure that purchased materials and devices conform to upgraded quality requirements. Another equally important duty is to examine and ascertain interface compatibility between new devices and those already used by the company.

No QC program can be successful unless it employs highly knowledgeable personnel, preferably by developing an in-house experience which presents greater possibilities for continuity, though some outside assistance is also very helpful. This calls for the ability of maintaining key people. (The president of a Silicon Valley company was saying in a meeting that every evening watching his engineers take the elevator to go home was asking him if next morning they will be also taking the same elevator to come to his firm.)

At project level, a team of product assurance specialists should be headed by a group leader who reports directly to an executive vice president, who himself reports to the president. Depending on the project, the EVP may be heading R&D, Manufacturing, or After Sales Service.[4]

This type of direct reporting structure helps in assuring that the members are not placed in the untenable position of having a subordinate status to the people whose work they are expected to plan or control. In the case of technical audits of quality and reliability, reporting to the president is a "must". No A subordinate ?? status will make the technical audit function ineffective. Here are ten challenges I encountered in my technical audits:

1. Predict system product assurance based on paper designs or a breadboard model.
2. Providing information needed by QC in upholding tolerances during pilot production, while manufacturing engineering has not yet completed its homework.
3. Testing product prototype(s) with pilot equipment to determine whether specific quality (or reliability) figures are being met.
4. Suggesting means of improving quality after testing without returning to and redoing the original design.
5. Assisting parts procurement in a mandatory switch of supplier(s) and evaluating their non-standard parts.
6. Suggesting methods of further improving quality (or reliability) through better components or design techniques.
7. Providing an adequate model of possible tradeoff while using a limited number of parameters.
8. During manufacturing audit and improve QC methods, tracking obtained results through statistical quality control charts.

[4] See also the discussion of after sales service in Chap. 4.

9. Assisting QC in setting up production tests and/or administers such test independently of the manufacturing organization.
10. Provide support for good internal communications between design and manufacturing engineering, and between manufacturing engineering and field maintenance (see also Sect. 2.5).

Many of these challenges are present not only in average designs but also in good ones. An example of good design, when product reliability warrants it, is to have two separate automatic control subsystems so that the total system can survive the loss of one and still function. This has been the case of A380 (Qantas Flight QF32) on November 4, 2010. The Airbus superjumbo touched down after suffering a potentially devastating engine failure shortly after takeoff from Singapore, but thanks to control system redundancy the pilots made a safe landing.

As we will see in Chap. 6, the redundancy of critical systems is a design strategy that both presents advantages and has constraints. Originally practiced with weapons systems, it migrated to civil aviation and now the automotive industry is following the aerospace industry's lead. Automotive experts forecast more and more parallels in the automotive world [3].

This evolution in design strategy toward greater product assurance came as automotive engineers watched and learned from potential failures in aerospace which could well materialize in their own business. Neither is design the only area of a transfer in experience—QC concepts, standards, methods, tools, and tests have to be further upgraded because of the so-called "global platform" which gives auto companies the chance to push down production costs,[5] but lacks multi-manufacturer standards—and if lower quality sneaks in—that practice can be very expensive.

It does not need explaining that there are great practical challenges not only in the manufacturing of totally homogeneous platforms in all the countries, an auto company has such facilities, but also in partnerships between motor vehicle firms. Although manufacturers are still trying hard to achieve a truly global quality, in practice this may never be the case as they source most of their parts and materials locally.

These are precisely challenges confronting QC engineers, and can be found in the background of challenges No. 6, 7, and 8 in the list earlier in this section. If raw materials are different from one plant to the other, what kinds of tradeoffs are available to lift product assurance? In practical terms, the task breaks down into a series of control functions:

- Better design control
- More focused procurement control
- System analysis aimed to flash out discrepancies
- Tight inspection in production QC

[5] AT Kearney has estimated that global platforms will become increasingly important, accounting for almost 50% of global production by 2015.

- Cross-factory homogeneity evaluation
- Steady field feedback control.

While these missions are largely technical, they are not solely technical in nature because they also involve financial issues, like cost control and senior management's strategy. Costs matter; to shore up its balance sheet, General Motors in the process of making substantial cost cuts are in prospect too.

For instance, as older workers retire many are replaced on GM's assembly lines by new ones earning half as much, under a two-tier wage structure agreed with the United Auto Workers. This is one reason that the carmaker has closed a cost gap with its Asian rivals that was once $2,000 or more per vehicle [4].

It will however be short-sighted to believe that all the reduction done in wages and in health costs will save GM from another bankruptcy. The longer term answer is greater productivity and much greater attention to quality, because as I never tire repeating there is nothing more expensive than low quality—from breakage and rejected materials to recalls and the loss of reputations which negatively affects the customer base.

2.4 Unwarranted Resistance to Better Methods for Quality Control

Section 2.2 provided the reader with evidence that the application of mathematical statistics in production offers valuable means for the detection of errors involved in the manufactured goods. It also helps in creating a corporate memory facility, most valuable in estimating developments taking place in outgoing quality level because something is happening in the production process.

There is no better evidence of a QC system's product assurance deliverables than the results obtained during the World War II years, particularly in the United States. This strategy of reliance on tough quality measures, assisted through statistics, was further reinforced during most of the decade which followed WWII. Curiously enough, however, it then ebbed and started to decline in the West while it rose in Japan (but by year 2000 it also declined in Japan).

The rise and fall of quality assurance conscience can be approximated by the log-normal curve. Indiscriminate cost cutting is one of the reasons, the other being a new generation's lack of appreciation of the important role played by quality in the company's growth and survival. Reduced skills in mathematical analysis has been a third reason which saw to it that not all firms were ready to apply SQC. Negativism about SQC includes some of the following arguments.

But we have always made money using the system we have. Why change?

That's a very defensive statement and a wrong one. It also shows the lower level of know-how and shop experience existing in the firm. Sharpening up the

whole decision process about accepting or rejecting a product, or a lot, on quality reasons enables a company to go much further in product assurance.

This is a general tool, but my problem is unique.

Although each product and process has its own characteristics, something really "unique" is a very rare bird indeed. This is just an excuse for doing nothing, and it also shows that the person using it does not understand the flexibility and applicability of an SQC methodology. A factory should use SQC to gain competitive advantage. Practically any process is adaptable to this technology.

They tried it at so-and-so's and it did not work; therefore we don't try it.

As Dr. Edward Coleman, my professor of QC at UCLA, used to say: "Just because one cannot make a board smooth with an axe does not mean that the axe is a bad tool. A professional must know a misapplication or failure of a tool or method due to misunderstanding or lack of skill. This, however, does not detract from the validity of the tool when properly used.

We have too many variables in our process to use it.

If it is really so, *then* this is one of the best reasons for using not only SQC but also experimental design (Chap. 11) as basic prerequisite to better management. Properly applied, SQC will help determine which of the many possible causes of past failures is really affecting the quality of the factory's produce.

It is too technical (or too complex).

It is true that the use of tools based on mathematical statistics requires (indeed involves) something of a revolution in the company's culture and skills. But SQC is by no means "too technical" or "too complex". People with a high school or even grade school training have learned to use successfully the simpler SQC methods (see Chap. 15). The basis for SQC is mathematical. However, what lies behind its evolution does not have to be understood any more than one has to be a mechanical engineer to drive a car.

It is fine for long runs, but we only make short runs.

As an argument this, too, is a fake. SQC technology can be applied to as few as 1 (one) piece. This is by excellence the domain of percent defective (Chap. 14). The economics of the situation and the length of run may determine the techniques used, but length of run alone will not determine the applicability of SQC.

While the foregoing six examples of pseudo-reasons for not using SQC are dirty excuses often heard by reactionaries who are unable to change their professional culture, it is no less true that—like the microscope—a more powerful methodology or tool reveals hidden or latent problems in a so far "traditional" process.

This negativistic view is by over 90% defensive. It also documents lack of know-how. A case in point is errors in measurements where one is unable to distinguish between:

- Random errors and
- Systematic errors.

Here is an example. When the same object is measured repeatedly we get a series of measurements which, due to a large number of uncontrollable factors of small importance, vary *at random* about a certain value. They vary in such a way that:

- Really random errors can be considered as normally distributed about zero; and
- The uncertainty of the method being used is characterized by the standard deviation(s).

By contrast, *systematic* errors are usually due to some isolated factors with an impact. They result in a displacement (or translation) of the measurements in one direction, with observations distributed about a "new" value, say, μ different from the expected mean population value μ_0.

- The systematic error is equal to $\delta = \mu - \mu_0$

Sometimes when examining the systematic error of a method of measurement, it is possible to design our approach so that the expected mean value of a measured quantity becomes known. Systematic deviations from the standard indicate that the production process is not functioning as it should. An investigation of the raw materials, of the machines, of workers skills, and of the manner the machines have worked is necessary in order to find the causes of the trouble. In principle, the larger the change in the population mean, the greater the probability of getting warn signals through the control chart.

Another problem associated to product assurance in engineering and manufacturing is labeling. Both for the producer and for the consumer, it is advantageous to identify the quality characteristics of a product through a label attached to the product itself, but there are prerequisites which are not always observed:

- The label must be truthful in its contents; and
- Its contents must be understood and appreciated by its user(s).

If every manufactured product has a "quality characteristics label", then a great deal of repetitive work will be avoided. For example, in the case of Omega (see also Chap. 1) we instituted a policy of quality labeling each individual tungsten ingot, each wire package, and each lot of filaments made by the same wire. Prior to this, there was only a monosyllable description which said practically nothing in real about the quality term to the user. Hence, he had to do all over again the QC routines. In addition, to be successful a quality labeling policy:

- Must start at the lower level of the food chain (in the Omega case the ingot); and
- Continue uninterrupted as step-by-step the product gets transformed, either within the same company or by another entity.

The problem of implementing SQC at all levels of production discussed in the first half of this section (albeit from the negative viewpoint of resistance to change) and that of correct labeling correlate with one another.

- SQC provides most valuable input for the labels; and
- The labels inform the next production stage regarding the quality information it needs, without having to reinvent the wheel.

Quantitative data is important because part of the problem with labels is that their message is not always understood. Take carbon footprint labels as an example; the idea has been that carbon labels would let shoppers identify products with the smallest carbon footprints, just as other labels already indicate bio-production telling the shopper that this merchandize is greener.

However, a survey carried out in 2010 by *Which?*, a British consumer group, found that just 20% of shoppers recognized the carbon footprint label compared with a recognition rate of 54% for organic labeling (which, it should be noticed dates back to the 1970s in Britain) [5].

This has been disappointing because adding a carbon label to a product is a rather complex and costly process that involves tracing its ingredients back up their respective supply chains and through their manufacturing processes, to work out their associated emissions. As if this lack of public recognition was not enough, the current practice is also confusing.

Different carbon foot printing and labeling standards have emerged in different countries, preventing direct comparisons between the various types of labels. This should be seen as a reminder that when we talk of more sophisticated approaches to information relating to industrial production and merchandizing, standardization is a "must". It is even more so in a globalized environment.

In conclusion, at one side the last four decades have seen a regression of QC standards and a relative abandonment of methodologies—like SQC—which time and again have proven their value. On the other side there is a push, largely by politicians toward identifications made in a way not clearly comprehensive as well as suspect, because they lack the needed support by analytical methods, like SQC, which could make them unavailable.

2.5 Open Communications Channels and Quality Improvement

Generally speaking, data acquisition and data presentation for product assurance reasons has not yet reached the level of standardization and sophistication required by a knowledge society, and this is particularly true in certain cases where technological developments continue to run at high pace. Data whose acquisition has not been planned, will be found lacking vital details or even headline information such as:

- Component identification
- Functionality specifics
- Operating conditions for acceptance

- Reliability characteristics
- Performance measurements
- Description of failure mode(s)
- Failure symptoms and aftereffects
- Diagnosis of past failures and their avoidance

In other cases the inadequacy of information content comes from the fact that not only test conditions vary from one outfit to the other, even in the same country, but also there is diversity in approaches to gathering, analyzing, and presenting quality-related data. This is easily observable in the case of reliability studies.

Just like a successful product assurance program must start at the very beginning of a new project, the gathering of quality and reliability data should begin at the product's drafting board. *If* the company's QC procedures are only designed to address problems at the final production level, *then* quality information will be skin-deep and its use will be ineffectual.

Fulfilling adequacy requirements for data analysis is not so difficult because in manufacturing the majority of man-made products go through a number of phases which can be seen as discrete steps. An example is the case of supplier–client relationship(s).

Going back to the case study of the Omega lamp company, which we followed in Chap. 1, the dichotomy created by the existence of discrete steps will characterize the passage from the Wolfram mineral-to-ingot transformation (done in one factory), to the ingot-to-wire fabrication (executed by another manufacturing entity), and finally the wire to filament process.

The first company is a provider to the second, and the second to the third. In every case there is a client who asks for information about quality assurance. Omega engineers suggested that in order to state in a documented way whether or not electric conductivity is of any value in pre-telling the quality behavior of wire and filament, it is necessary to have information about a number of physical tests done by the ore-to-ingot plant.

For example, the measurement of resistance (Ohm) at the sintered ingot level. These data will be so much more dependent if quality measurements were based on statistically valid samples. For this, it is not enough that the appropriate physical study is taking place; it is also important that measurements are taken from samples representative of the population, their labeling is correctly done (Sect. 2.4), and they are databased.

The communication of correct information about product quality can be invaluable not only in connection to the needs of R&D but also in regard to product assurance experiments. In Omega's case, once these product experiments found that *if* a bar of Tungsten has equal conductivity throughout, *then* the resultant wire is good—though none of the experts was able to explain "why" this is so. Said one of the experts: "The future of the wire's quality is embodied in this bar but, as things now stand, we cannot measure it in advance. More research is necessary;" and, I would add, open communication channels which informed all players on the finding some of them have made and the conclusions they reached.

Open communication channels can also carry the message of return on investment. There are research projects that have a significant direct financial impact. An Omega example is a study on the effects of doubling the length of the sintered bar (from 600 mm to 1200 mm). This was intended to reduce the rejection rate, as in a sintered bar 10% has to be dropped from each side.

The aforementioned study was motivated by the fact that prior efforts using trial and error provided no valid solution. Research was needed because doubling the length of the sintered bar presented both a materials and an equipment challenge; a fact which serves as a reminder that in a significant number of cases research on quality assurance involves a dual perspective:

- Materials and
- Equipment.

Open communications let company people know that research results are strong and serious. When a research project on product quality is successful it motivates other people to suggest another one able to provide a better understanding of their problem. There is always a "next step".

The sequential progression toward wire quality described in, Sect. 1.5, did not end with the steps presented in that text. More people came forward with hypotheses to be validated through experimentation. A sample is shown in Table 2.1.

One of the interesting research projects focused on rethinking and re-establishing conditions under which a spool is rejected. In many lamp companies roughly 8% of wire production is thrown away at that very step, in an effort to improve the highly variable (and usually low) outgoing quality. Rejection evidently impacts on outgoing quality level but also affects manufacturing cost/effectiveness.

Altogether, the technical audit brought up 25 necessary research projects brought forward by company people who were previously too timid to ask for them. Most of these were aimed at correcting faulty product and process situations that were carried along by "tradition".

Some of them were counterproductive. When I asked the director of one of the Omega factories how it happens that the wire spools were not labeled for outgoing quality level, I received the answer: "It is company policy that the wire factory controls its quality, but that it should not give out any data" (see also in Sect. 2.4 the discussion on labeling). One should not be polemic but is allowed to ask:

- By whom, when, why, and how was this wrong policy established? and
- How it happens that the high rate rejection at coil manufacturing level has not led to a sharp policy revision?

Among the properties that data coil manufacturing factories wish to have are weight, diameter, resistance, crystallization, tearing features, and fusion. As one of Omega's factory directors put it: "For our operation, it is most important to know this data. It is also vital to be able to trace mistakes to each machine as they happen. Today, we simply cannot do that kind of tracing and until it is done, we

Table 2.1 Research requested by the omega factories to help them meet quality standards

Wire manufacturing process	Needed research
Recrystallization at 8.3 mm	Thorough and documented study on the properties of crystallization
Mechanical treatment to 2.8 mm	Optimization to reduce the resulting materials waste which reaches up to 5% of the weight of the material, but could be reduced to 1.5% (optimistic estimate) or 3% (pessimistic estimate)
Test for Splits (electronically done)	The prevailing 1/10 rule needed rethinking and research aiming to help in reducing the percent rejection of coils
Packaging in spools	A relatively small project was needed to establish the kind of quality information to be forwarded with the spool from "producer" to "user", in accordance with the firm's new product assurance principles

will not be able to control outgoing quality levels." From design to procurement, manufacturing, sales and after sales service, the sharing of information is not just the best policy, it is the only one able to support and promote product assurance.

In conclusion, both analytical approach to product and process quality and open communications should become corporate policy—replacing the silos approach which in most companies characterizes quality and cost information. When this happens, it makes sense to interconnect computer aided design (CAD) workstations into a firm-wide network for sharing R&D, design, and production data on quality. On the contrary,

- *If* secrecy continues being the rule of the day,
- *Then* CAD networking provides only an illusion of something happening, while in reality wrong-way policies prevail and there is no improvement in the results.

CAD workstations or no CAD workstations, an engineering database cannot be established let alone operate under silo conditions. Neither can a factory systematically improve its quality. If a manufacturing process does not control the incoming quality, it cannot control its outgoing quality no matter what sort of wizardries it introduces to its technology and in its inspection operations.

After, and only after, doing away with secrecy and the silos, it becomes highly advantageous to handle *all* product assurance problems within the organization by interconnecting the different design, manufacturing, testing, and other decision steps. It also makes sense to model the cascade of events taking place within the firm and between the firm and the market—to provide ways and means for correcting faults and steadily improving quality.

References

1. Chorafas DN, Steinmann H (1994) Database mining. Lafferty publications, London and Dublin
2. Shenk D (2001) The forgetting. Alzheimer's: portrait of an epidemic. Doubleday, New York
3. www.automotivedesign.eu.com, Sept 2010
4. *The Economist*, Nov 13, 2010
5. *The Economist*, June 4, 2011