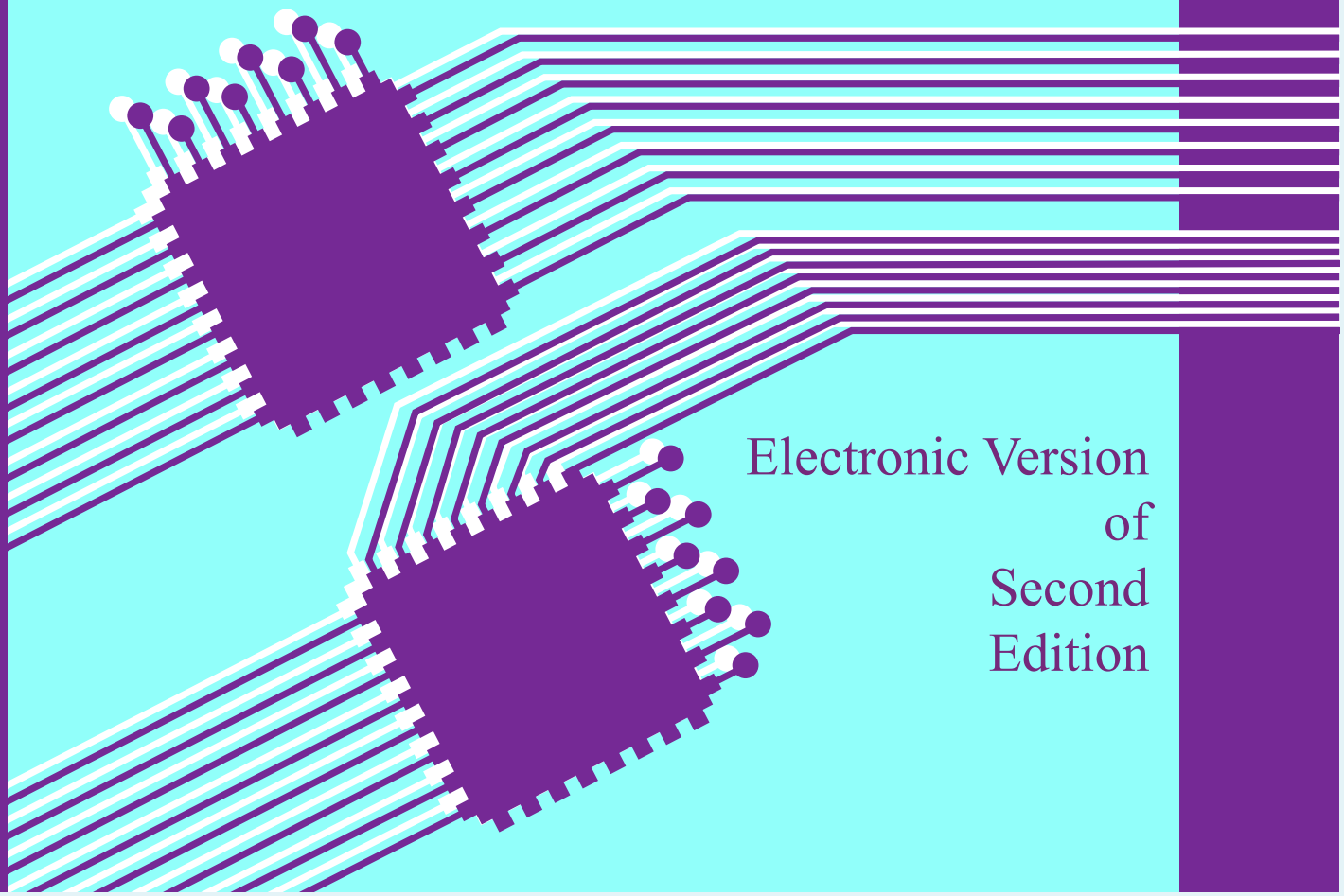
Sample pages from...

The Economics of Automatic Testing

Chapter 2
The quality revolution

Brendan Davis



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to make all of the devices within the engineering specification. The ***variation*** in values results in defects. If we could improve this process to the point where the extremities of the variation in values just fits within the engineering specification points we will have reached the zero defects point. This situation is shown in Fig. 2.3. Here we see the results of the measurement of a population of 64 components plotted as a histogram. There are no rejects so we have reached our goal. But have we? Unfortunately any process that exhibits variation will almost certainly also exhibit shifts and drifts in the central or mean value of the measured parameter. This fact of life is accepted in the definition of six-sigma quality, referred to in Chapter 1.

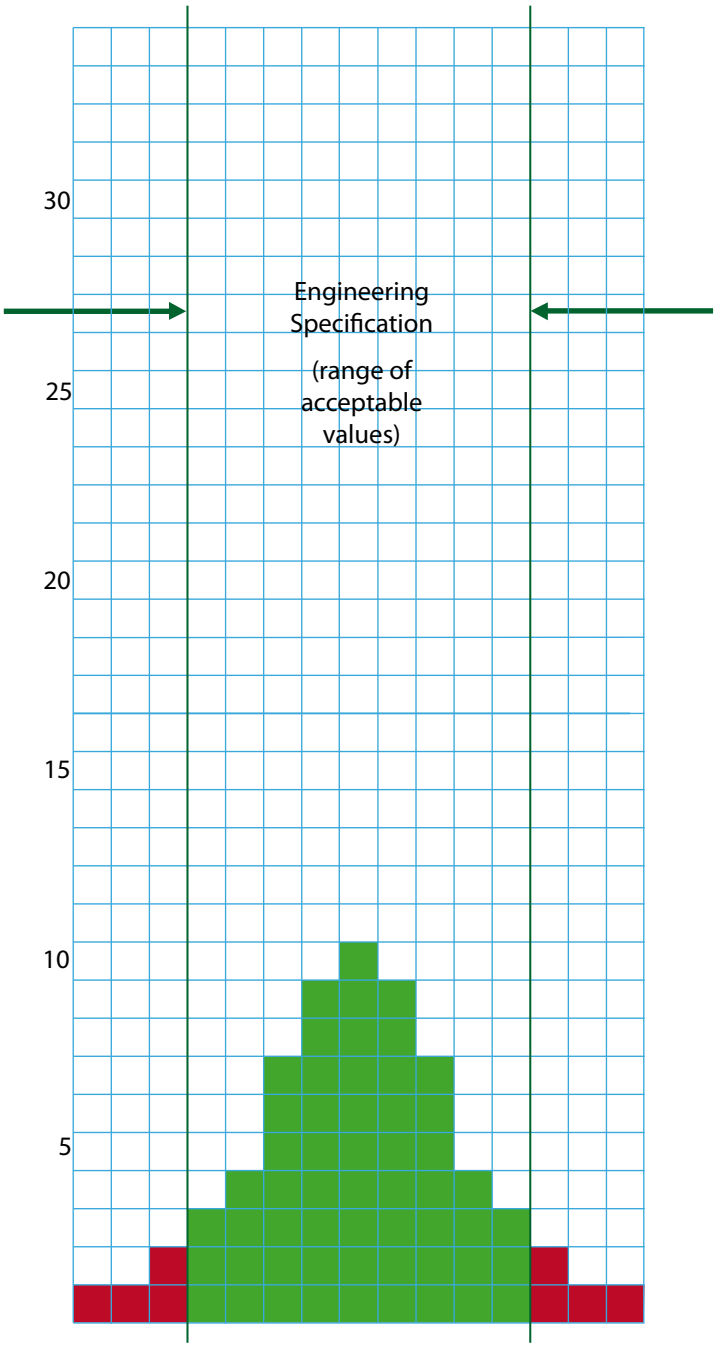

Figure 2.2 A process that cannot match the engineering specification—too much variation!

The result of such a shift or drift is shown in Fig. 2.4. Here we see 64 components with the same degree of variation in values as in Fig. 2.3 but with the mean value changed. Now the process has produced three defective devices even though the degree of variation is the same. We can see what Dr Deming meant when he said that we have to achieve better than zero defects. We have to go beyond the zero defect point to such a degree that any normal shifts and drifts in the mean value will still not result in a defective device being produced. This situation is shown in Fig. 2.5 and requires much less variation in the process. The objective is to keep the mean value midway between the upper and lower specification limits and to monitor this closely. If the mean value shifts or drifts this change will be spotted quickly and corrective action can be taken before any defectives are produced. In this example the mean value can shift or drift by plus or minus two cells of the x axis and there will still be no defects. Notice in this example how the 64 items form a taller but narrower curve as the variation reduces, thus implying a low value for the standard deviation. This in turn will mean that there will be more 'sigmas' between the engineering specification limits.

This need for constant monitoring implies a changing role for the testing process. For defect prevention and constant monitoring of the manufacturing process, test systems need to provide data to the quality management system. The automatic test systems are in the best position to do this because they know the quality status of the items being manufactured. Is it good? Is it bad? If it is bad, why is it bad? The three basic issues for manufacturing management are cost, quality and schedule. However, the quality status of the work-in-progress will have a major impact on its cost and its schedule possibilities. Only if you have accurate information about quality can you hope to have accurate information on cost and schedule. The quality status of a printed circuit board will determine where it goes next, how long it will remain in-process and what costs it will incur.

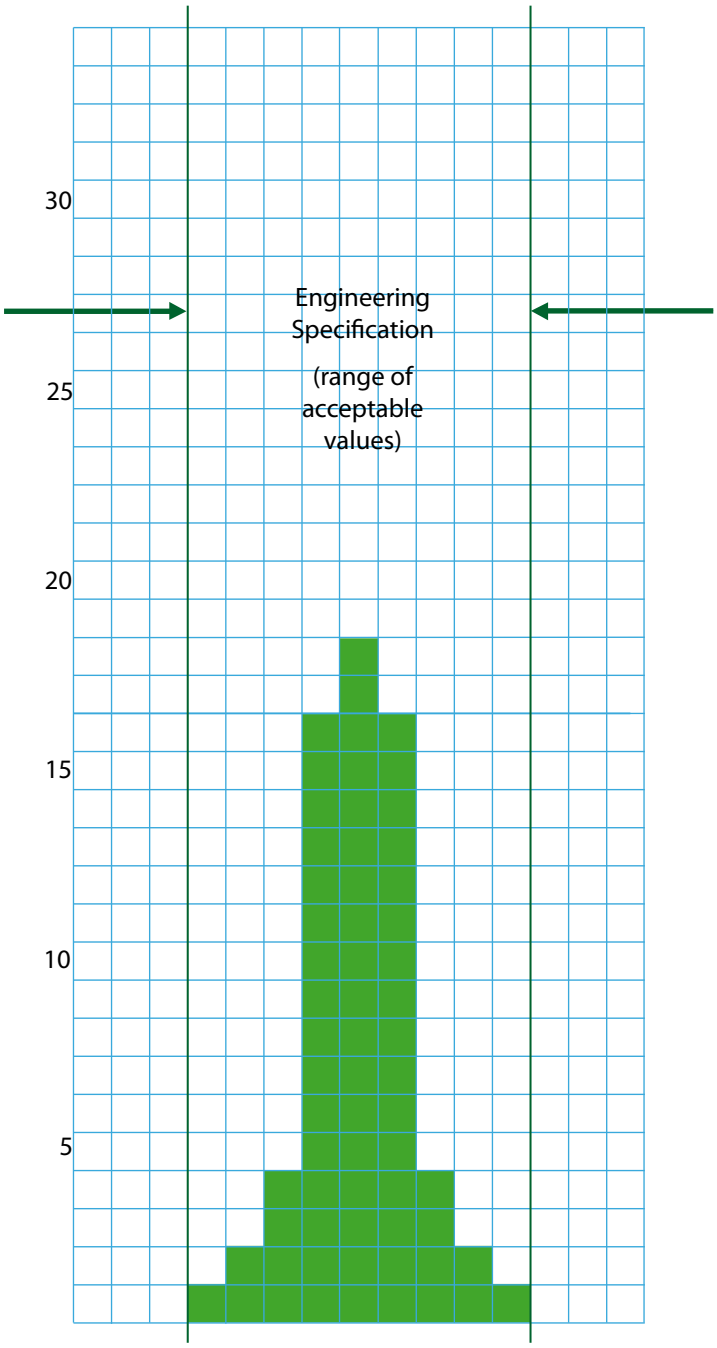

Figure 2.3 'Zero defects'—when all items produced are within the engineering specifications—less variaton.

Commercial test systems are beginning to reflect these new requirements by providing the essential quality data. However, generating masses of data is not necessarily going to help. You need the right kind of data and you need it in the right form. If the test system simply provides data about defects it is not going far enough for two main reasons. First of all the defect data generated by the test system may be incorrect. The diagnostic accuracy of test systems is not perfect by a long way. Frequently the repair action that needs to be taken to fix a problem differs from the diagnosis made by the tester. Also, the diagnostic resolution may be poor in some situations. For accurate quality information which can be used to track down the cause of the defects you need to have verified data. You need to know what repair action fixed the problem, so the repair process has to be included in the data collection scheme as well. The second major problem concerns the nature of the data. Simple defect data will help you to determine the cause of defects and, by Pareto analysis, which

defects you should track down first. However, as you approach zero defects you get less and less data to analyse. Eventually if you reach the zero defects point there will be no defect data at all. There will still be variation, and shifts and drifts, in the process. At this point we need measured values rather than simple pass/fail or good/bad information.

Some of the quality data will have to come from the process itself because some defects do not manifest themselves as a shift in a measurable parameter once the zero defects point has been reached. A good example is the common solder short. You can plot all of the usual quality charts by counting the number of shorts on a batch, daily or weekly basis to determine the defect rates, the variation and the trends. Once you get to zero defects there is nothing to count any more. There is still variation, shifts and drifts in the soldering process and this can now only be monitored by monitoring the variables within the soldering system.

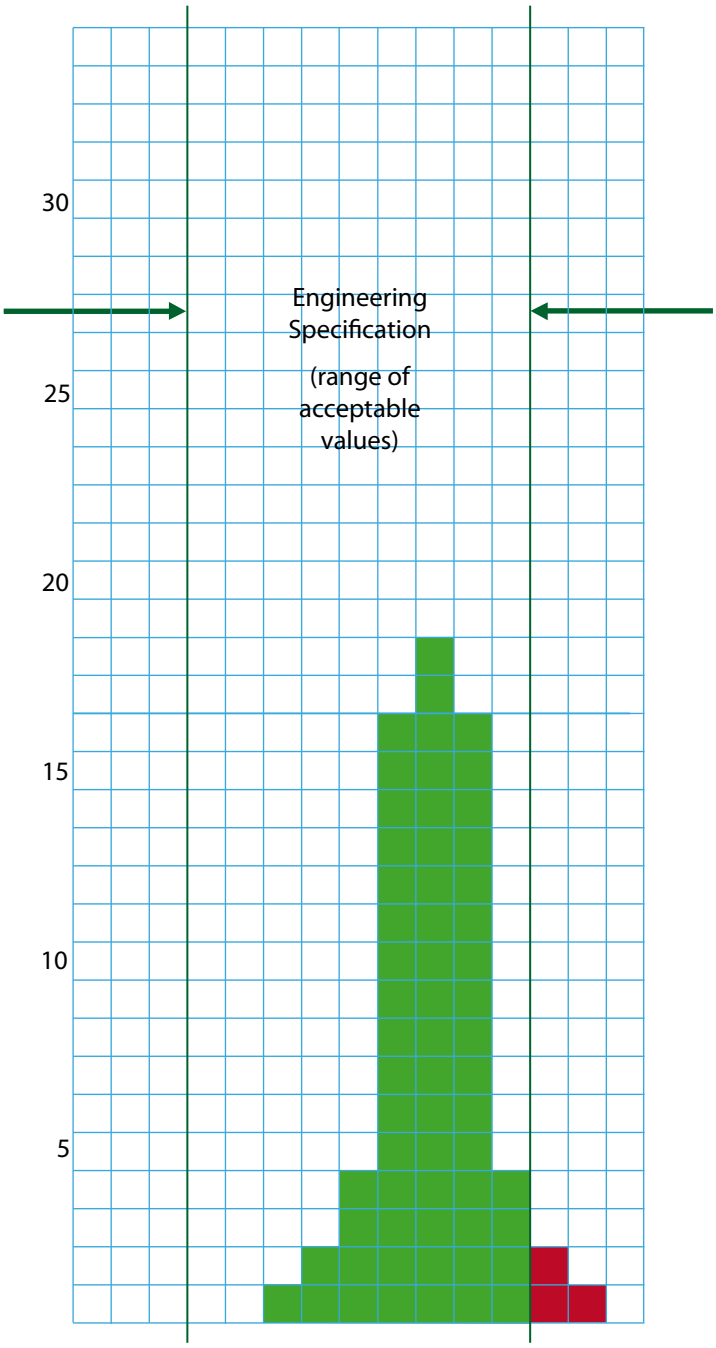

Figure 2.4 The same degree of variation as ib Figure 2.3 but with a shift or drift in the mean value. Defective items produced.

2.5 Quality and test economics

There is complete agreement among quality gurus on one point in particular. This is the need to base your quality improvements system on the prevention of defects rather than simply adding more quality control, testing and inspection in order to detect more of the defects. This view of test and inspection as theoretically superfluous operations led in part to the concept that testing adds no value to the manufacturing process or the product being made. This concept was discussed in Chapter 1. The electronics industry had traditionally used a 'detect and fix' approach prior to the quality revolution because it was generally assumed that it would be too expensive to build it right first time. The availability of automatic test equipment that could detect and diagnose most of the defects in seconds provided a cost effective solution to bringing the quality

up to par following a relatively sloppy manufacturing process. In a way the ATE helped to make this sloppy manufacturing process a viable operation. Component suppliers were also content to ship relatively simple devices with defect rates of 1 per cent or higher, at least until the Japanese showed what could be done. When the quality revolution began, many of the early 'gains' in component quality were achieved by 'testing quality in' rather than by improving the process. In the early eighties it was not uncommon for users to find that the spread of values followed a 'double-humped curve' rather than the expected 'normal' or 'Gaussian' distribution. The reason for this was that the component suppliers were selecting the better devices to ship to their bigger customers who by this time were already insisting on better quality. The remaining devices, still mostly within specification, were then shipped to the smaller customers. This phenomenon is illustrated in Fig. 2.6.

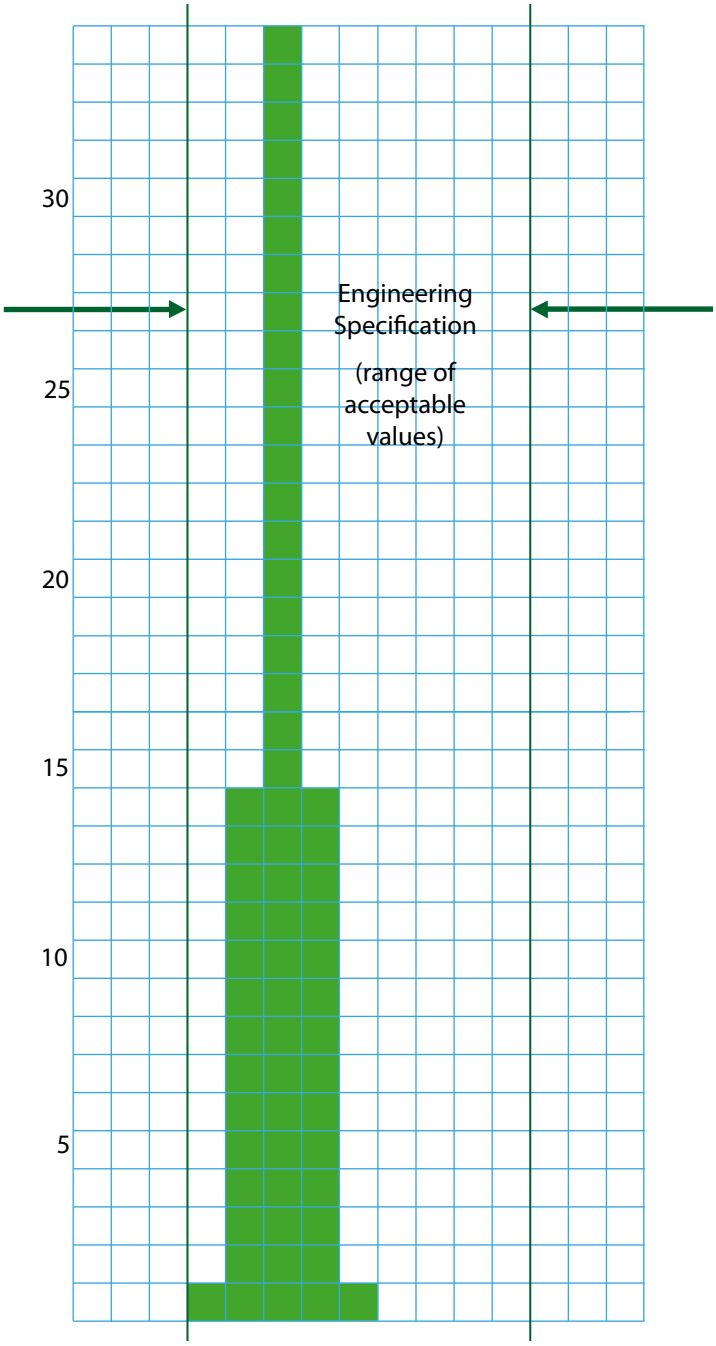

Figure 2.5 Less variation. Still no defects even though there is a shift or a drift away from the mean value. Beyond Zero Defects!

Unfortunately there are still many companies that have not yet seen the quality light and are still using the defect and fix approach. This worries me greatly because the amount of publicity that quality has had throughout the eighties and the early nineties has been enormous. Indeed, as I pointed out in Chapter 1, for many companies quality is now taking second place to 'time to market' as the most important of the four market forces. This does not reflect a reduction in the importance of quality, rather it reflects a situation where the quality problem is virtually solved so they are now moving on to solve the time to market problems. Among all of the publicity on quality there have been many success stories showing how companies have improved their financial performance as a direct result of their quality process. Therefore, why, with all of this proof around, are there still companies who do not understand or believe in the quality ethic? Some of the answer lies in poor

communications or training. When I give training courses or presentations I often ask how many people in the room have heard of Deming, Juran, Feigenbaum or Crosby. All too often the show of hands is pitifully small. It is easy to dismiss this situation by declaring

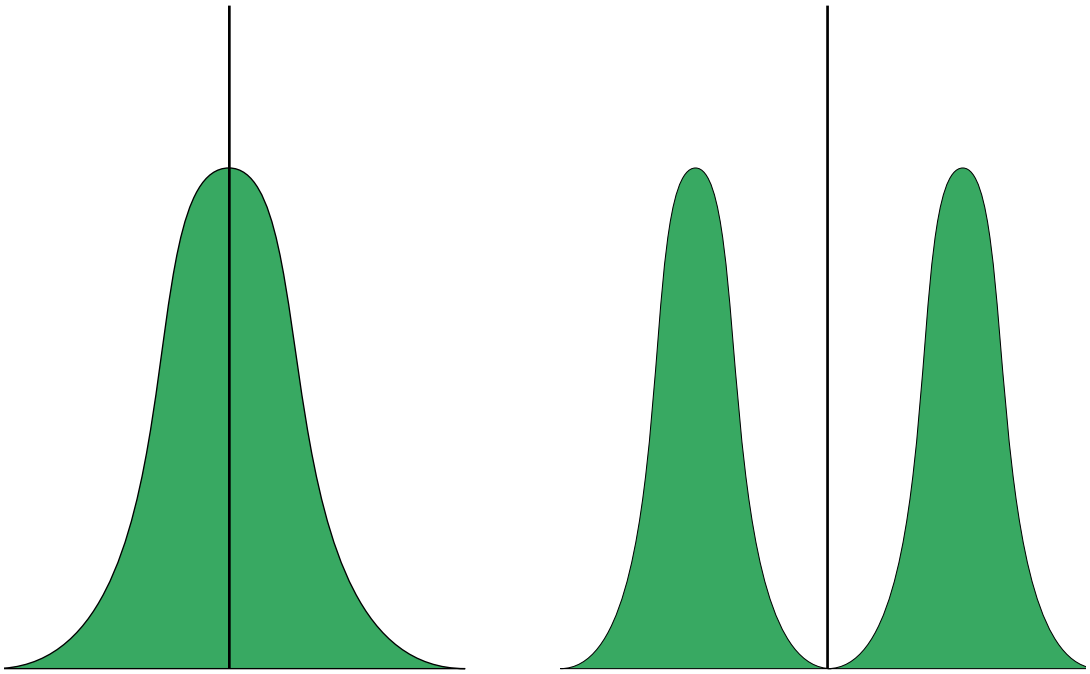

Figure 2.6 The double humped distribution curve, caused by selecting closer tolerance devices from a large batch in order to offer a choice (e.g. 2%, 5% and 10%) with premium prices for the better devices. This can also occur when devices are selected for shipment to favoured customers.

that these are the companies that will not survive, and indeed many of them will not, but perhaps quality has become a victim of its own success. Too much publicity and too much hype can often put some people off. They dismiss it as the latest fad.

I have also had some people tell me that they cannot improve their quality beyond a certain point because of their company's dependence on service revenues for profitability. This kind of comment is symptomatic of a lack of understanding about the degree to which the industry has changed. Quality is a vital part of being competitive. Customers do demand better quality and lower costs. Poor quality does cost more than good quality. These and all the other reasons that are quoted as justification to move to a TQC-CI (total quality commitment-continuous improvement) approach to running a business are all true. The weight of evidence is far too great to be denied.

Another reason why some companies simply pay lip-service to quality, without really doing much about it, stems from the problems of 'short-termism'. The arbitrary way in which a company's financial performance is judged in annual or quarterly periods means that there is never a good time to implement a good idea. Short-term profitability considerations always seem to override the longer term improvements that can be achieved.

Burning the toast

Yet another reason for a less than 100 per cent commitment to TQC is that the concept of

the business benefits that are available just does not get fully understood. The concept is really quite simple. Dr Deming uses a brilliantly simple analogy to explain it. He says that ***"...industry has got used to burning the toast and then scraping it".*** The brilliance of this simple analogy lies in the fact that it encompasses all the key points about quality, productivity, profitability and market share. The toast is the product and the toaster is the process. The fact that the toast gets burnt implies that the product is spending longer in production than is necessary. This increases costs and reduces the potential capacity of the process. Scraping the toast is a repair or re-work operation. Potentially unnecessary, this increases production costs and capital equipment costs, because you need a knife to scrape the toast with. Inventory costs also increase as a result of all the extra work-in-process. Test and inspection costs increase because of all the re-test required for toast that has been re-worked. Scrap costs also increase because there is only a small difference between scraping and scrapping.

Eventually, having scraped all the toast and re-tested it you can give it to the customer. Productivity has clearly suffered and since fierce competition prevents you from passing on the extra costs to your customer, so has profitability. It is worse than that. The toast you deliver is still not as good as toast that was made properly in the first place. It will still retain some of that burnt taste even after the scraping and it will of course have gone cold. The result is that your customers will gradually drift away and buy their toast from someone who makes their toast right the first time. Your market share now begins to decline and the inevitable pressure on profitability will result in the need to layoff some of your staff. You start down a spiral of decline that can only be reversed by fixing your quality. Other approaches will only have temporary effects. You can increase your promotion, cut your prices, offer free entertainment or hire attractive waitresses. However, after a short increase in business the deficiencies of the product will override these incentives and the customers will once again drift away.

The right approach, quite clearly, is to adjust the toaster (the process) to make the toast correctly in the first place. If there is too much variation in the output of the toaster, get it fixed or buy a new one with better process control.

What then is the impact of all this quality emphasis on design and test? What is the impact on test economics? At the design stage there is an obvious need for much better verification of complex designs. Quality has to be designed in and built in. At the custom chip level this requirement has been met for some time by a number of design tools including simulation and synthesis packages. However, the use of simulation techniques for board design has lagged behind for several reasons. The first relates to the availability of simulators powerful enough to cope with complex board designs and the problems of handling a mix of digital and analogue circuitry. Another reason is that many companies are unwilling to take the extra time needed to perform fault simulation on their designs. This is a classical trade-off between cost and quality, on one hand, and time to market, on the other.

Simulation and synthesis technologies are improving all the time, as is the price/performance ratio of the computing power needed to perform the processing. To some degree this will also reduce the time needed to do the job but time to market has become such a big issue that faster processing alone may not be the complete answer to this part of the problem. Some effective method for optimising the design decisions that involve trade-offs between quality cost and time is essential. The technology issue cannot be left out of this equation either, since that is what drives the verification problems in the first place.

Models based upon the time to market model described in Chapter 3 may well form the basis of a design decision model for this kind of analysis.

The most obvious impact that the quality focus should have on test strategy and test tactic decisions is a greater emphasis on fault coverage. Minimise the number of defects by defect prevention and then maximise the detection of the defects you fail to prevent. Strangely, however, the reverse appears to have been the case in some companies. At the time of writing this (mid 1992) there is a strong pressure in the ATE market-place for lower priced testers. This is fine as a concept so long as 'less expensive' does not mean 'less performance'. To some degree this desire for cheaper test systems has been driven by a long and deep recession, but there is also a view that less thorough testing is acceptable now that yields out of manufacturing have improved substantially… ***"With fewer faults to find maybe we can get by with less fault coverage".*** This kind of thinking can result in throwing the quality baby out with the bath water. A yield of 88 per cent and a fault coverage of only 85 per cent will result in exactly the same escape rate as a 70 per cent process yield and a 95 per cent fault coverage. The fault coverage has to be maintained or improved in order to benefit from all of the efforts to improve the process yield. If there is an opportunity to improve quality it should be taken unless the cost is prohibitive. Therefore it boils down to a cost analysis to see what makes most sense. In almost all of the analyses that I have been involved in the higher performance tester, even with a higher price tag, usually turns out to be the most cost effective solution. The simple example used in Chapter 1 illustrates why this is so.

Think 'Escape Rate'—not 'Fault Coverage'

If you compare a test system with a potential fault coverage of 94 per cent with another system that has a potential fault coverage of 97 per cent, then the 97 per cent system will usually have substantially lower life cycle costs (see Fig. 2.7). The amount of this cost difference will depend on volumes, yields, the nature of the product, field-service costs and so on. The reasons for the differences are simple. The 94 per cent system allows 6 per cent of the input faults to escape and the 97 per cent system only allows 3 per cent to escape.

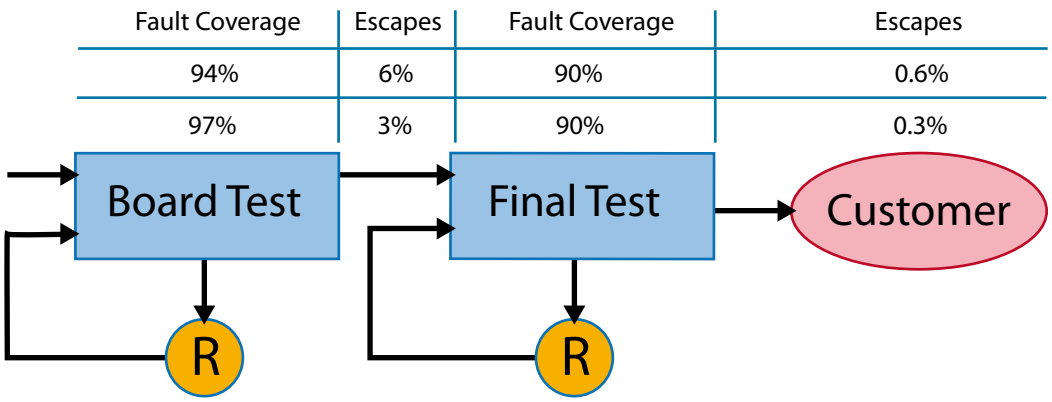

Figure 2.7 If you are serious about quality you should think in terms of 'escape rate' rather than 'fault coverage' (see text).

Regardless of what testing follows the ATE, this two-to-one difference remains fixed. If the following test stages detect 90 per cent of the remaining defects then the escapes to the field will be 0.6 and 0.3 per cent respectively. If the following test stages detect 99 per

cent of the remaining defects then the escapes will be 0.06 and 0.03 per cent respectively. Quite simply this results in a two-to-one difference in the cost of test stages that follow the ATE in the factory and a two-to-one difference in field-service costs. There will also be a two-to-one difference in your quality reputation and customer satisfaction. If you then factor in the cost of losing customers and the increased risk of 'product liability litigation', paying a premium for that extra 3 per cent fault coverage could be the bargain of the year.

2.6 Product liability

In case you are not familiar with 'product liability litigation' this is the process whereby a company can be sued if one of their products causes damage, injury or death. Product liability lawsuits have become very popular in the United States where very large sums of money are awarded if the case is proved. A major turning point in product liability cases occurred some years ago when a very large manufacturer was sued by a lady who had put her dog into a microwave oven to dry it. When the poor animal died she sued, claiming that there were no warnings in the instruction book about the dangers of drying pets in the oven. She was right; there was no mention of it in the manual, so the judge found in her favour. This case caused major problems. If such a ridiculous case could be won then the door was open to all kinds of crazy suits—and that is what happened!

2.7 The right approach

The example of the 94 per cent tester and the 97 per cent tester leads to a very important concept. In Chapter 1 I mentioned that the four major market forces of cost, quality, time and technology are often thought to be in conflict with each other. At least that is the conventional wisdom. This example supports my assertion that the reverse is true in the case of cost and quality. The lowest life cycle cost will usually be achieved when the quality is high. Thus, improving quality primarily by defect prevention and then using the best level of defect detection to catch the defects that you failed to prevent will result in lower costs. This now brings me back to Dr Deming and the other quality gurus. Statements frequently heard include…

"Do it right the first time and test and inspection can be eliminated."

"Better than zero defects is the goal."

"Reduce variation in the process."

"Testing adds no value to the product."

With the exception of the ***"Testing adds no value…"*** comment these are all admirable goals and we should all be aiming to reach them, but the reality of the situation in electronics is that the continuous increase in complexity makes it that much harder than it is

in most other industries. Remember Dr Deming's response (page 15) when I asked him if he thought that we could get beyond zero defects in the electronics industry. The example in Chapter 1 showed that six-sigma quality is not good enough to eliminate testing. Maybe seven-sigma will be close (0.019 ppm), but until we can reach these levels the best strategy is to prevent as many defects as possible and then test with as high a fault coverage as possible.

To be fair to the quality gurus, the "Testing adds no value…" comment seems to have mainly come from within the electronics manufacturing industry. Possibly from a misunderstanding of what the quality gurus mean when they say this. What they are actually saying is that ***"testing that achieves nothing—adds no value"*** **.** This issue is discussed in section 1.9 - Does Tesing Add Value?

2.8 Quality data collection systems

The quality revolution brought about a change in the role of automatic test systems away from being simply defect detection devices to becoming defect prevention devices. Indeed the ATE industry was somewhat ahead of the game in that the first network systems for linking testers together were actually shipping in 1980—the same year that the agreement was reached to develop Ethernet. The network was a prerequisite for the operation of any automation of the repair loop process and also necessary for any real verification of the defect data needed to improve quality. It is of course possible to collect data directly from a test system without the need for any network. The data can be transferred via floppy disk to a computer containing the quality management system and the necessary database and report generation software. What gets lost by doing it this way is the verification that the defect reported by the tester really was the cause of the failure. With a fully networked system the repair stations also provide data about the repair action that took place. When the board is re-tested after the repair, the quality system will know if the repair action fixed the problem or not. If it did then the reported defect really was the problem; if not then the repair will have to be performed again. Only when the repair action successfully fixes the fault will the 'defect' be added to the database. This approach prevents the defect database from becoming contaminated with incorrect data, and since this data will be used for defect prevention (quality improvement) actions this can be quite important.

Several ATE vendors offer quality data collection capabilities in some form. If all of the other evaluation criteria are similar then this capability could well be the deciding factor when choosing a tester. In any event, the primary objective of board testers should be viewed as the monitoring of the manufacturing process and a real-time quality monitoring system built into the tester can be invaluable.

2.9 Summary

Quality is one of the four primary market forces that drive the electronics industry today and it has become a major competitive issue. The eighties saw a veritable revolution in quality as US companies began to respond to the threat from the Japanese electronics industry. As more people became better educated about quality, its real meaning and its potential for increased profitability, the revolution gained pace. The early adopters of the new quality ethic soon reaped the benefits, but there are still many companies who, for one reason or another, just talk about it but do very little real quality improvement. The increased importance of quality should lead naturally to a greater need for high levels of