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Generic techniques for improving the quality of design

In this section I shall look at techniques which can be used within the design processes I have described in Sections 1 and 2. The first technique, quality function deployment, has been referred to already. The second, *poka-yoke*, can be used to enhance design for manufacture and assembly, and its equivalent in service operations, by removing opportunities to make errors. The third, design review, is used to monitor the design process and assure its quality and the quality of its outcome; and the final technique, benchmarking, holds out the promise of improving the quality of the design process, and hence of its outcomes.

3.1 Quality function deployment

Quality function deployment is a means of ensuring that *customer* requirements are translated into appropriate *company* requirements at each stage of the development of a new product, from research and design through to manufacture and delivery. The technique was developed initially at Mitsubishi's Kobe shipyard in 1972 and it is claimed that use of QFD has enabled Toyota, which began using the technique in 1977, to reduce the length of its design cycles by a third and dramatically reduce start-up costs whilst also improving the quality of its output.

QFD is essentially a planning tool. Its purpose is to provide a framework for a team-based approach by marketing, design, engineering, production, quality, purchasing, financial managers, and so on, to the design and development process. The teams take a design project forward through four phases using a series of charts.

The phases are:

- 1 product planning
- 2 parts deployment
- 3 process planning
- 4 production planning.

The house of quality

At the core of the technique is a matrix called the *house of quality*, a typical form of which is shown in Figure 18 (overleaf). This matrix is, however, much more than a chart to be filled in; it is a conceptual framework which can be used to guide teams through the transformation process that converts customer requirements into successful products.

If you look at Figure 18 you will see that I have given numbers to various 'rooms' in the house. I shall now use these numbers to explain the key features of the chart more fully.

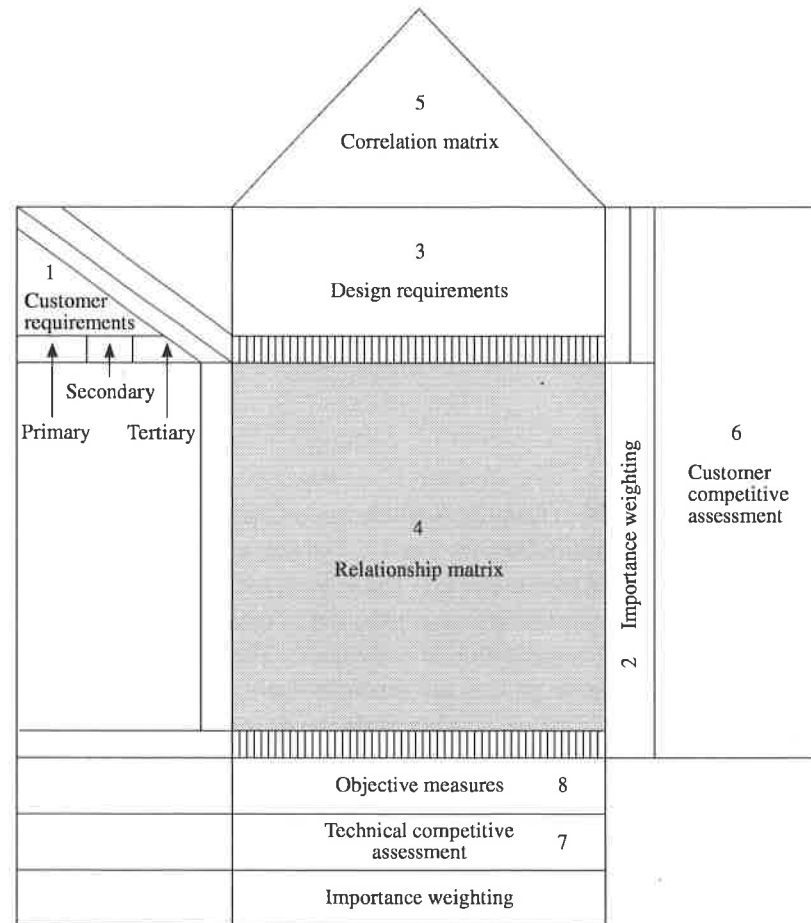


Figure 18 *The house of quality*

1 Customer requirements

The first step of a team using QFD is to work together with colleagues, and with customers and potential customers, to determine customer requirements, in a broad sense. 'Unspoken' as well as 'spoken' requirements have to be identified and similar demands consolidated in order to give a list that is complete, but of a manageable size. The requirements are usually categorised as primary, secondary and tertiary but the distinctions between these three categories vary between practitioners. For example, some view them hierarchically, so for a car a primary requirement might be 'easy to drive', a secondary 'good all-round visibility', and a tertiary 'good view through rear window'. Others use them as labels for three exclusive sets, such as ease of operation, performance and ease of servicing, or, as you will see in Figure 22, taste, value and appearance.

2 Importance weighting

Having identified the customer requirements, which typically number between 30 and 100, the next task is to prioritise them in order to indicate the importance of each requirement *to the customer*. One method is to give each requirement a percentage score so that the total for all requirements adds up to 100. A simpler method is to score the requirements using a five-point scale where 1 = 'of little importance' and 5 = 'very important'.

3 Design requirements

The next stage is to translate the customer requirements (usually expressed as action statements such as 'easy to use'), which are subjective and difficult to transform into action, into design requirements (usually expressed as nouns). These take the form of measurable and controllable specific technical characteristics (often

referred to as *substitute quality characteristics* or SQCs). An example of this translation process is shown in Figure 19. A customer requirement is translated into SQCs at two levels: the *total system expectation* level, which is concerned with the final product's performance and which uses an objective measure that should correlate with the customer's perception; and the *measurable system parameter* level, which identifies variables that directly affect the product's performance but are of no immediate interest to the final customer.

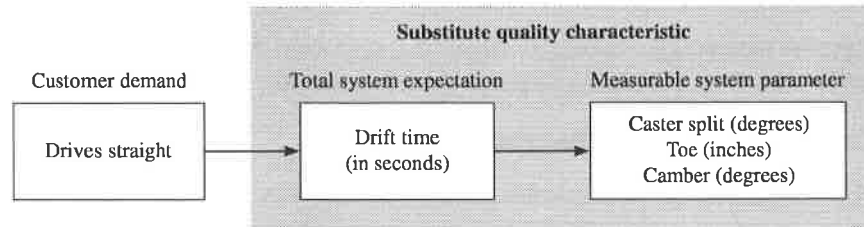


Figure 19 The translation of a customer requirement into SQCs (Source: Slabey, 1991)

4 The relationship matrix

The purpose of the relationship matrix is to indicate the direct cause-and-effect relationships between the customer requirements and the design requirements. The strength of the relationship is denoted by a symbol: $\odot$ = strong relationship; $\circ$ = moderate relationship; $\triangle$ = weak relationship. For example, if *seat position* is identified as a design requirement, it will have a moderate relationship with the customer requirement for a good view through the front windscreen, a strong relationship with the need to be able to use the rear-view mirror easily, and no relationship with a customer requirement for good fuel economy.

Use of the symbols makes it easier to distinguish between the important design requirements (those with many strong relationships) and the less important ones (those with only a few relationships, particularly if those relationships that have been identified are weak).

5 The correlation matrix

The correlation matrix is used to indicate which design requirements support each other (positive correlation) and which are in conflict (negative correlation). Again, symbols are used to denote the nature of the relationship: $\odot$ = strong positive; $\circ$ = positive; $\times$ = negative; $\otimes$ = strong negative. On the face of it, positive correlations may sound the most promising because they often indicate the opportunity to make savings by removing implicit duplication. However, negative correlations do in fact sometimes signal the greatest opportunities to gain a competitive edge. Almost all well-designed and well-engineered products require some trade-offs between conflicting requirements, but tremendously successful products often owe their success to innovations that were discovered as a result of trying to reconcile conflicting objectives. For example, after the oil crisis in the 1970s Ruston Gas Turbines, a subsidiary of GEC, recognised that the customers for industrial gas turbines would begin to demand greater fuel efficiency from the machines they bought. Greater fuel efficiency could, however, be achieved only by increasing the temperature and pressure at which the engines operated, and that in turn would reduce the life of critical components, notably the turbine blades, to below what was acceptable to customers. Ruston, in trying to reconcile the conflict between high efficiency and long life, hit upon a novel solution – the introduction of air-cooled turbine blades – which enabled it to gain a competitive advantage when its new engine came on to the market in the early 1980s.

6 and 7 Competitive assessments or benchmarking

Two forms of competitive assessment are used to evaluate the products of various other manufacturers with which the product under discussion would compete. The results of surveys that ask customers to rate products according to how well they meet their needs are placed in 6. A set of technical benchmarks is built up in 7 by obtaining the competitors' products and testing them.

8 Objective measures

Objective measures are the design targets that stem from the construction of the first house. They form the starting-point for the next part of the team's work.

Constructing further houses

QFD is a multi-stage technique that progresses through the four phases identified earlier. As you have just seen, the output of the first phase is a set of objective measures that relate to the substitute quality characteristics. This becomes the input to the next phase, parts deployment, in which the design requirements are translated into specific parts (including raw materials and components), and the critical characteristics of those parts which would enable the essential functions to be performed are determined.

The part characteristics provide the input to the third phase: process planning. Within the constraints – financial, technological and so on – that are imposed upon the design project, this phase seeks to specify the operations that will be needed to manufacture the product. Particular attention is paid to those operations which are most critical in achieving the significant part characteristics and to the process parameters which will have most influence on product quality. This information is then fed into the fourth and final stage, production planning, where the operating procedures are specified.

The inputs and outputs to all four phases are summarised in Figure 20. In practical terms, the way in which the output of one stage feeds in as the input to the next is shown as a row of houses in Figure 21.

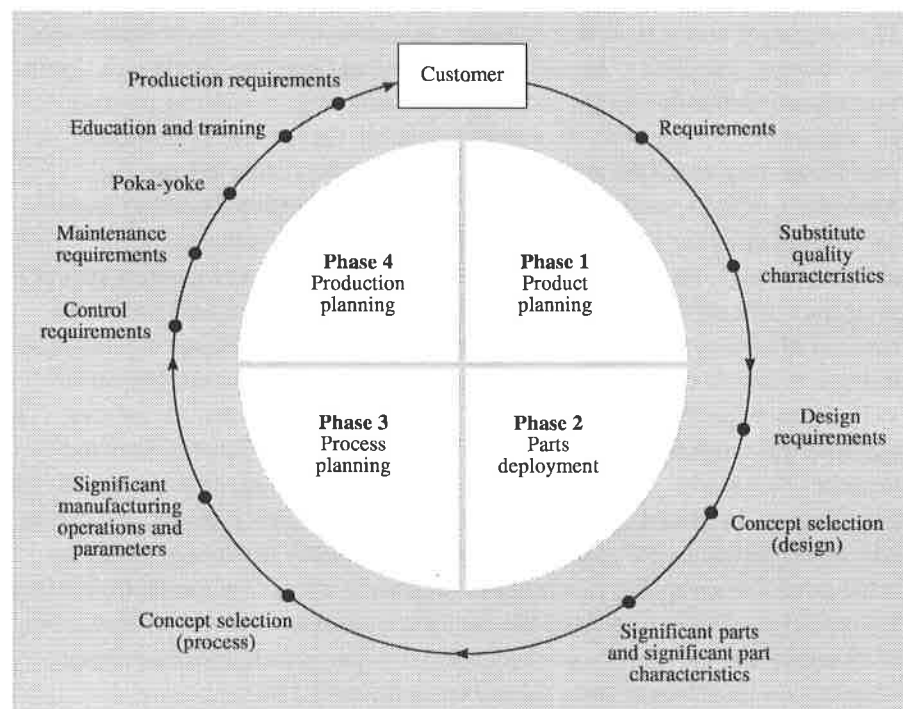


Figure 20 The four phases of QFD

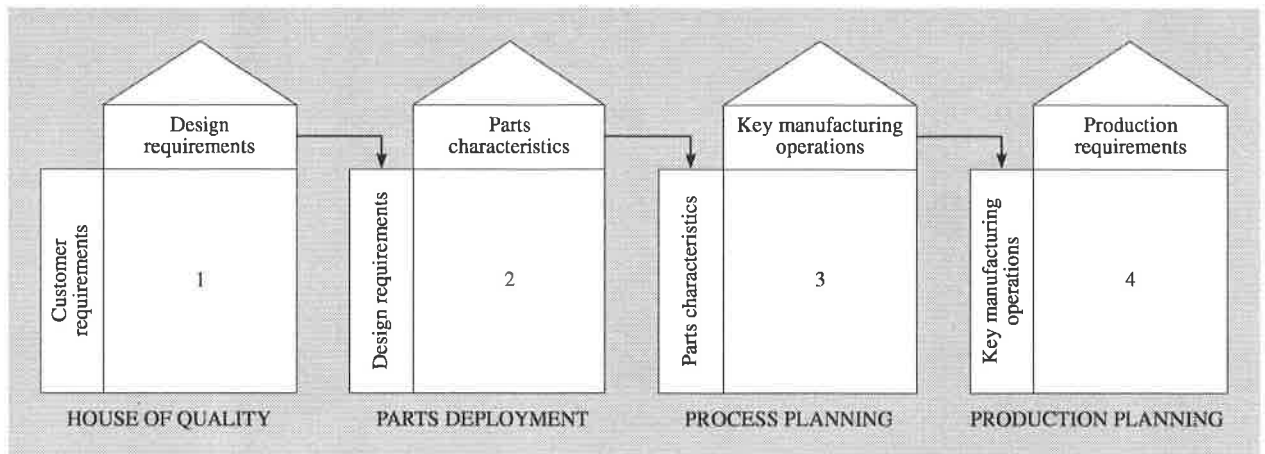


Figure 21 The row of houses

An example of a completed house for phase 1 is shown in Figure 22, whilst Figure 23 (overleaf) shows examples for all phases. As you can see, the precise layout of the chart and the words used in some of the headings differ from those in Figure 18. Different organisations do, in effect, custom-build their houses. Some incorporate information on past customer complaints about similar products, for example; others indicate the degree of technical difficulty associated with meeting the various objective values; and so on.

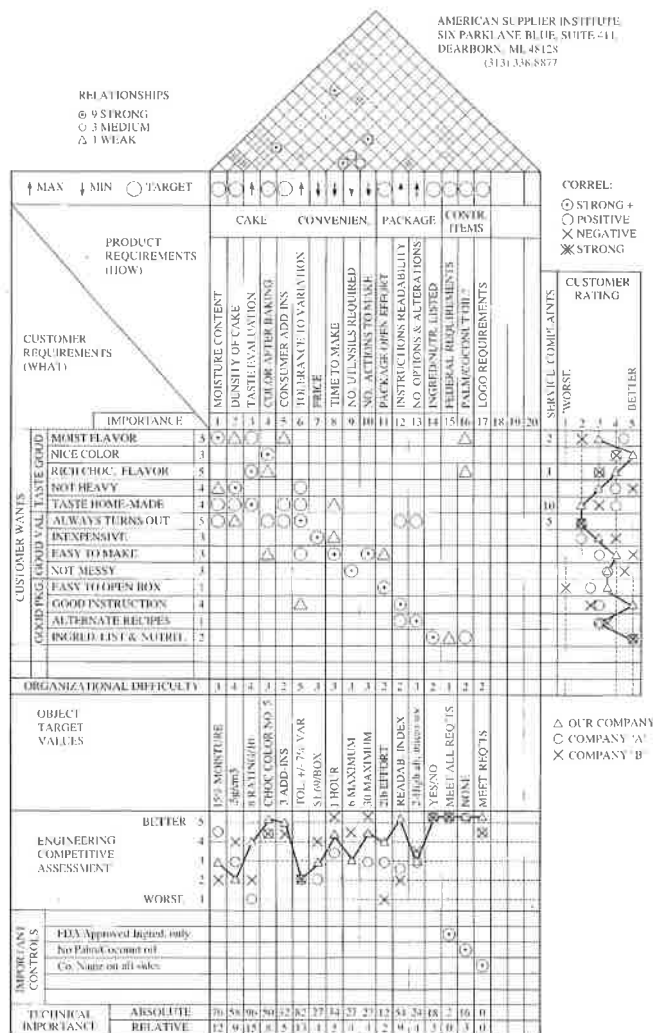


Figure 22 A completed house for phase 1 (Source: Rothwell and Gardiner, 1983)

Phase 4
Food Production
Planning

Phase 2/3
Ingredients & Process
Planning

Phase 1
Product Planning

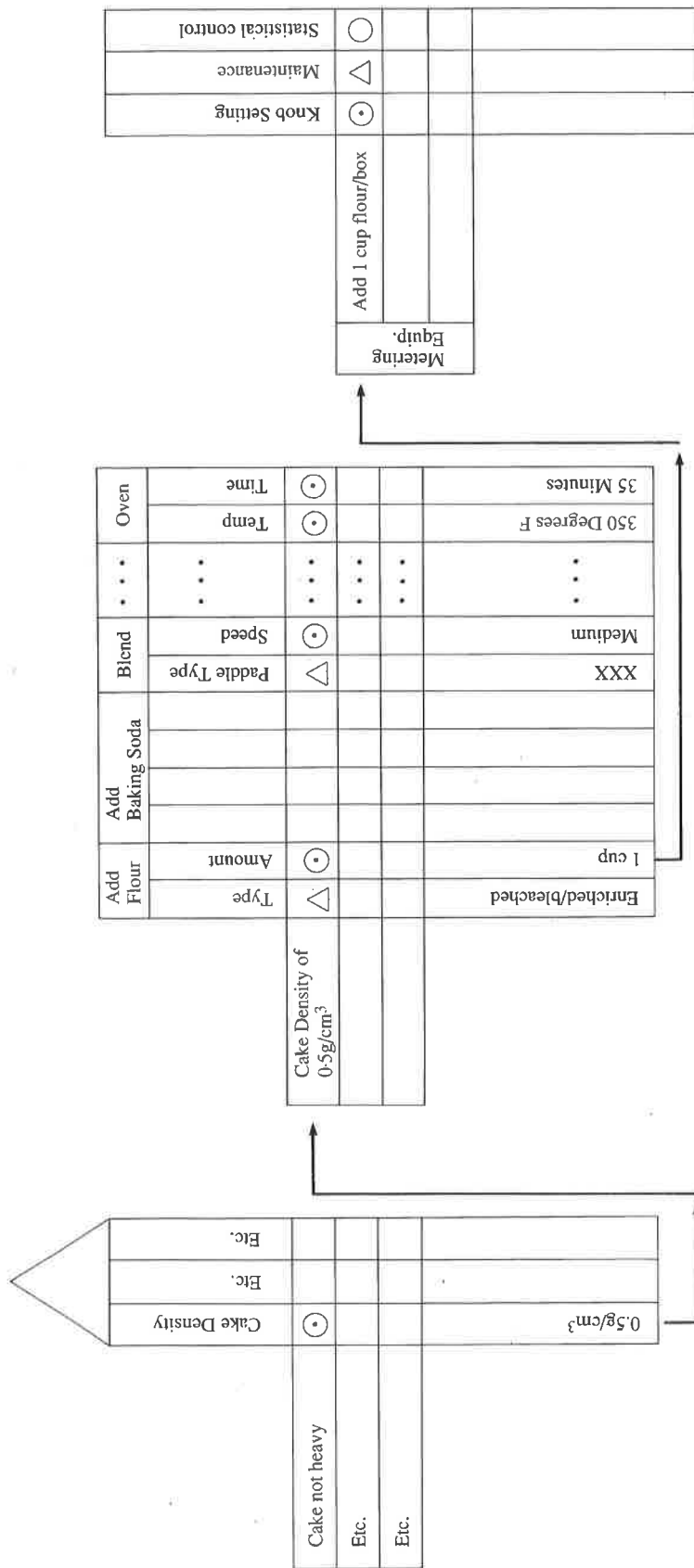


Figure 23 Outline of all phases

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Assuming you were part of a team that was using the QFD method to design a hand-held portable telephone, which of the following characteristics would you categorise as customer requirements, which as design requirements and which as parts characteristics?

- Light weight
- Low-power microphone
- Small batteries
- Ability to operate for long period whilst away from base
- Low power consumption
- CMOS components
- Minimal power consumption whilst not in use

QFD in the service sector

Research conducted by Terry (1995) found that 'the number of service organisations that have applied QFD in designing new services is minimal' (p. 65), but he was able to cite four success stories:

- complete refurbishment of a Japanese hotel
- refurbishment of the second and third floors of a Japanese shopping centre
- improvement of the consumer credit service of the Italian bank Banca Antoniana
- redesign of Alitalia's B747 Intercontinental Business Class service.

As a result of his research he concluded that 'the QFD process and its associated charts [as used by manufacturers] must be modified to suit a service organisation' (p. 64). He suggested that the framework shown in Figure 24 be used instead.

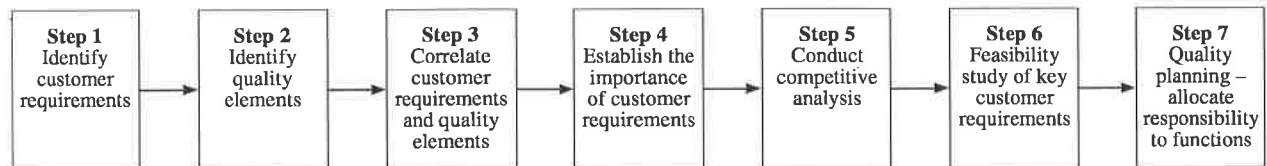


Figure 24 QFD framework for the service sector (Terry, 1995, p. 64)

Wherever it is applied, a technique such as QFD is, of course, only as good as the people who use it. It offers no miracle solutions, but does provide a framework, a discipline even, to assist people with different areas of expertise to work together to maximum advantage. Further, it facilitates the emergence of the craft knowledge that normally remains hidden because the 'agenda' does not draw it out.

Whilst the use of techniques does not provide solutions, it can alert those responsible for product design and development to the likely problems and possible corrective actions, and so go some way towards helping to achieve quality objectives at the design stage. Where software product development is concerned, Zairi cites the following benefits:

- QFD shortens development schedules: it helps assure that testing verifies conformance to the customer's requirements.
- QFD promotes creativity: it removes design details out of the functional specification. This allows the engineer more flexibility in deciding what kind of technology will best meet customer requirements.

- QFD helps take the politics out of decisions: it helps the user and all members of the development team to better understand inconsistencies and trade-offs and leads them to arrive at a consensus.
- Credibility with customers is enhanced.
- Unmet customer needs are discovered.
- Development start-up is quicker because of improved communication.

(Zairi, 1993, p. 10)

3.2 Poka-yoke

Poka-yoke or, to give it its more graphic name, 'idiot-proofing' derives its formal name from two Japanese words: *yoker* (to avoid) and *poka* (inadvertent errors). Its development is usually credited to Shigeo Shingo, who worked on it extensively in the early 1960s, but examples of its application are, in a sense, much older than the technique itself. Look, for example, at a standard British 3-pin plug. Why do you always plug it in the right way up? Because that is the only way it will go! That is idiot-proofing or mistake proofing.

Classical examples of poka-yoke are all of this type, as can be seen from examination of a book on poka-yoke, published in the late 1980s (Nikkan Kogyo Shimbun/Factory Magazine, 1988), which gives 240 descriptions of simple devices that have been used to prevent quality problems. The author shows, for example, the 'before' and 'after' representations of the positioning of mounting holes on speaker boxes (see Figure 25). Before the application of poka-yoke it was difficult to determine the correct orientation because the top and bottom holes were symmetrical; now it is simple. Figure 26 shows a similar example. Before poka-yoke the design of an integrated circuit was such that it could be inserted backwards. By making the changes shown it was possible to prevent the problem from occurring.

There is, however, slightly more to the technique than this. Poka-yoke devices can be deployed to prevent defects from occurring even when inadvertent errors are made. In addition it can be used to provide devices that warn that a mistake is about to be made or has just been made. The prevention or warning is accomplished in one of the following three different ways.

- 1 *By shutting down the process.* For example, an automatic check-weighing machine can be used to stop a canning line if an under-weight fill is detected.
- 2 *By controlling the process more carefully.* For example, Nikkan cites the case of a lens-rinsing process which resulted in a number of scratched lenses. The problem was caused by the lenses knocking against the blades of the rack that was holding them. By redesigning the rack so that the lenses were held at an angle rather than vertically it was possible to prevent the damage.
- 3 *By giving a visual or auditory warning.* For example, a temperature sensor and audible alarm were fitted to a cabinet used to sterilise ampoules of water for injection; this enabled operators to be alerted to any dangerous falls in temperature that occurred during the long heating cycle.