In the previous chapter various aspects of manufacturing system design were outlined. Here the operation and control of a manufacturing system is considered under the headings of quality control, materials management, labour control, project management, maintenance management, and management information systems.

10.1 QUALITY CONTROL
The design department of an engineering company indicates the specified level of product quality by means of the drawings and specifications it issues. The quality levels it specifies should be appropriate to the company's products and to its markets. The marketing and production departments are also concerned with quality standards but frequently have differing views on the level that is appropriate.

Comparison of actual and specified levels of quality is the responsibility of the manager of the quality control department. It is desirable that he should report to the design director, rather than to the production director; this arrangement reduces the risk of undue pressure on quality control staff to pass substandard work.

10.1.1 Measurement of Quality Performance
There is no single parameter that enables an adequate assessment to be made of product quality. However, three factors taken together provide management with a reasonable idea of the general level of achievement.

(1) The value of scrapped work.
(2) The cost of rectifying faulty work.
(3) The quantity of faulty products returned under guarantee by customers.

These factors can be measured monthly and plotted to establish trends. To avoid adjustments for inflation and/or variations in output, items (1) and (2) can be expressed as a percentage of the value of monthly production and item (3) can be expressed as a percentage of monthly output.

10.1.2 The Organisation of Inspection
Manufacturing operations always produce a proportion of substandard work. It is the task of the quality control department to monitor actual quality levels and to reject work that does not reach the specified level of quality.

Purchased supplies, such as raw materials and components, are normally sampled and checked before they are accepted into stock. If the level of quality is below that specified, the whole consignment...
of goods may be returned to the supplier. However, should supplies be needed urgently, the goods are sorted and only those that are faulty are returned.

Factory-produced parts and sub-assemblies are normally monitored for quality during production and substandard work is rejected. It is desirable that faulty work is detected as soon as possible after it has been produced; the two control charts described in the next section are suitable for this purpose.

It is usual for finished products to be given a final inspection which can take the form of functional and endurance tests. Some companies undertake an inspection audit after final inspection; this is a detailed reinspection of a small sample of goods awaiting despatch to customers. The audit may be undertaken by the quality control department in some companies or by the design department in others. Likewise, the analysis of faults in products returned under guarantee may or may not be the responsibility of the quality control department.

10.1.3 Statistical Quality Control
The inspection of every item produced or received is not only expensive but is less accurate than might be expected. This inaccuracy is due to the boredom created by 100 per cent inspection and the consequent careless mistakes of inspection staff. Sampling plans based on statistical theory not only reduce inspection costs but still provide a reasonably representative impression of total quality. Sampling techniques used to control production fall into two distinct types. One is where there is an actual measurement of a variable quantity, such as size or weight, and the other is where an attribute is checked on an accept or reject basis, for instance, when using a 'go' and 'not go' gauge to check a part.

Control Charts for Variables
Mean and range charts are used to control the size of a particular variable such as the diameter of a shaft. Examples of mean and range charts are shown in figure 10.1. Samples, typically of four to six parts, are taken from production and measured at given intervals of time or output. In the case of the shaft diameter, the average diameter of the sample is plotted on the mean chart and the difference between the largest and smallest shaft is plotted on the range chart. The process itself cannot be said to be in control unless both mean and range charts are in control, that is, the plotted points lie between the limit lines on the charts. It is of interest to note that although the production process may produce parts that form a skewed or multi-modal distribution, the distribution of sample means will form a normal distribution.

Control chart limits are conventionally fixed so that, with the process in control, the warning limits will exclude 5 per cent of the samples and the action limits will exclude 0.2 per cent of the samples. The warning and action limits are drawn respectively at 1.96 and 3.09 standard deviations from the chart means. Usually, upper warning and action limits only are drawn for range charts; the lower limits are close to zero and of little interest in engineering manufacture. Should a point on either the mean or the range chart fall between the action and warning limits, a second sample is taken. If this second sample falls inside the warning limits, the process is allowed to continue. Should two successive samples fall