The law of conservation of energy can also apply to part of a process. For example, considering the heating section of the heat exchanger in the pasteurizer, the heat lost by the hot water must be equal to the sum of the heat gained by the milk and the heat lost from the heat exchanger to its surroundings.

From these laws of conservation of mass and energy, a balance sheet for materials and for energy can be drawn up at all times for a unit operation. These are called material balances and energy balances.

Overall View of an Engineering Process

Using a material balance and an energy balance, a food engineering process can be viewed overall or as a series of units. Each unit is a unit operation. The unit operation can be represented by a box as shown in Fig. 1.1.

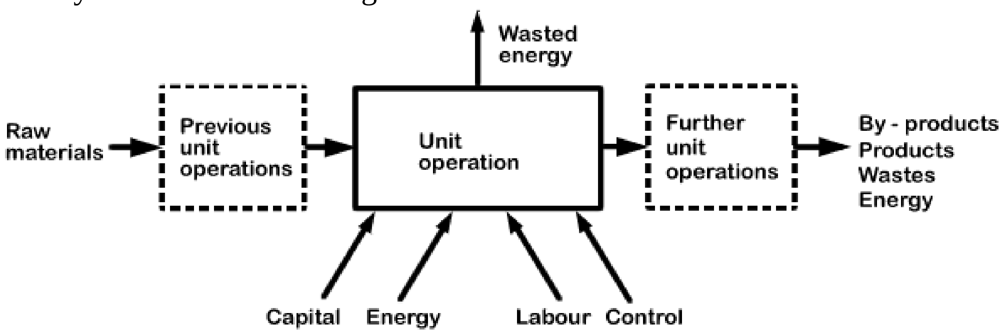

Figure 1.1 Unit operation

Into the box go the raw materials and energy, out of the box come the desired products, by-products, wastes and energy. The equipment within the box will enable the required changes to be made with as little waste of materials and energy as possible. In other words, the desired products are required to be maximized and the undesired by-products and wastes minimized. Control over the process is exercised by regulating the flow of energy, or of materials, or of both.

DIMENSIONS AND UNITS

All engineering deals with definite and measured quantities, and so depends on the making of measurements. We must be clear and precise in making these measurements.

To make a measurement is to compare the unknown with the known, for example, weighing a material compares it with a standard weight of one kilogram. The result of the comparison is expressed in terms of multiples of the known quantity, that is, as so many kilograms.

Thus, the record of a measurement consists of three parts: the dimension of the quantity, the unit which represents a known or standard quantity and a number which is the ratio of the measured quantity to the standard quantity.

For example, if a rod is 1.18 m long, this measurement can be analysed into a dimension, length; a standard unit, the metre; and a number 1.18 that is the ratio of the length of the rod to the standard length, 1 m.

To say that our rod is 1.18 m long is a commonplace statement and yet because measurement is the basis of all engineering, the statement deserves some closer attention. There are three aspects of our statement to consider: dimensions, units of measurement and the number itself.

Dimensions

It has been found from experience that everyday engineering quantities can all be expressed in terms of a relatively small number of dimensions. These dimensions are length, mass, time and temperature. For convenience in engineering calculations, force is added as another dimension.

Force can be expressed in terms of the other dimensions, but it simplifies many engineering calculations to use force as a dimension (remember that weight is a force, being mass times the acceleration due to gravity).

Dimensions are represented as symbols by: length [L], mass [M], time [t], temperature [T] and force [F].

Note that these are enclosed in square brackets: this is the conventional way of expressing dimensions.

All engineering quantities used in this book can be expressed in terms of these fundamental dimensions. All symbols for units and dimensions are gathered in Appendix 1.

For example:

Length = [L] area = $[L]^2$ volume = $[L]^3$

Velocity	= length travelled per unit time	=	$\frac{[L]}{[t]}$
Acceleration	= rate of change of velocity	=	$\frac{[L]}{[t]} \times \frac{1}{[t]} = \frac{[L]}{[t]^2}$
Pressure	= force per unit area	=	$\frac{[F]}{[L]^2}$
Density	= mass per unit volume	=	$\frac{[M]}{[L]^3}$
Energy	= force times length	=	$[F] \times [L]$
Power	= energy per unit time	=	$\frac{[F] \times [L]}{[t]}$

As more complex quantities are needed, these can be analysed in terms of the fundamental dimensions. For example in heat transfer, the heat-transfer coefficient, *h*, is defined as the quantity of heat energy transferred through unit area, in unit time and with unit temperature difference:

$$h = \frac{[F] \times [L]}{[L]^2 [t]\, [T]} = [F]\, [L]^{-1}\, [t]^{-1}\, [T]^{-1}$$