Table 24.3 Typical examples of mass/force-based measurements.

	Dimension as example	**Typical examples**
Mass as basic variable		
in grams	g	Product weight, e.g. 100 g
in kilograms	kg	Weight of balls in a ball mill
in tonnes	t	Amount of raw material to be processed
Density		
Mass/volume	g/cm^3	Density of aerated chocolate
Force		
in Newtons	$1\ N = 1\ m/kg/s^2$	Moment for non-positive connections, such as nuts or screws
Moment of force Force* distance	N m	
Pressure, tension Force/ area in Pascals	$1\ N/m^2 = 1\ Pa$	Mass pressure downstream from a pump, Contact pressures between rolls in a refiner and in a cocoa press, air pressure
Dynamic viscosity, Kinematic viscosity = dyn. viscosity/density	$1\ N*s/m^2 = 1\ Pa*s\ (N*s/m^2)/(kg/m^3) = m^2/s$	Is used to describe the flow characteristics of chocolate masses, cocoa butter, special fats
Work, energy in Joules	$1\ J = 1\ N\ m = 1\ Ws = 1\ m^2\ kg/s^2$	Installed refrigeration capacity
Power in Watts	$1\ W = 1\ J/s = 1\ m^2\ kg/s^3$	Motor performance
Mass flow rate Mass/time	Kg/h	Output of a moulding plant, throughput of a ball mill,
Mass/Mass	dimensionless	Proportion of shell in the nibs (%)
Mass flow density	$kg/s*m^2$	Related to fat migration

maintaining the specified ratios to ensure adherence to the recipe. Comparisons between *target* and *actual* values within the recipe database, product database, weighing records or process control charts can be automated and documented. Finished products are weighed once again in their package, before being placed in the multipack.

Often, the addition of solid recipe ingredients relies upon weighing operations. This is especially true for the process steps of ingredient addition and mixing when producing the initial chocolate masse, but it also applies to ingredients being discharged from silos with the aid of feeders. With the aid of belt weighers, milled material can be fed directly into the mixer, pre-refiner or conches in accordance with the recipe. Their operation requires regular cleaning and calibration. Smaller amounts of dry material, such as free-flowing vanillin, are added to the mixer automatically with the aid of screw feeders.

A belt weigher (Schenk, 2014) in a refining line has been developed with an additional control circuit to automatically adjust the belt load. By changing the speed of the belt drive motor, it can always measure the load on the belt within its optimum operating range. The result is that the error in measurement is independent of the number of operating refiners, as well as their location.

In another example the time it takes for the masse to reach a particular refiner is controlled by a PLC to be dependent upon its position in the refining line.

24.2.6.1 Weighing liquids

Often, the addition (metering) of liquid recipe ingredients is connected with solid weighing operations, for example for mixing and conching. With some liquids, the amount to be metered can easily be adjusted using solenoid valves in conjunction with a weighing scale. The type of metering pump chosen depends strongly upon the viscosity of the material, in particular the yield value (see Chapter 12). Smaller amounts of liquid ingredients, such as lecithin, can be added using rotary piston meters. In contrast to piston-type metering devices, rotary piston meters generate no signal when idle and so are more useful for control systems.

24.2.7 Measuring temperatures

Temperature represents one of the most important measured variables in cocoa and chocolate production (see Table 24.4 for typical measurement units). A few examples of frequently used temperature measurements are:

1. In conventional tempering to ensure chocolate is de-crystallised before returning to the temperer.
2. The viscosity of chocolate and filling masses depends directly upon their temperatures.
3. To maintain the correct temperature in air, refrigerants, water heating jackets on piping, depositing heads, holding tanks and so on.
4. Dew point determination and other relative humidity measurements.
5. Product surface temperature and internal product temperature are important criteria for the cooling process.
6. Uniformity of the mould temperature after re-warming and of the product temperature itself gives good processing consistency.
7. During conching, texture changes and formation of enhanced flavours can be influenced by altering the temperature and shear conditions.
8. By changing the temperature of alkalised cocoa mass/fractured cocoa nibs, the release of cocoa butter from the cell structure is changed.
9. Changing the temperature during the roasting of cocoa beans is a critical process parameter for expelling water, enhancing aroma and loosening the shell.
10. Temperature and time are critical in controlling microbiological growth.

Measurements in *the gaseous state* include ambient air, the chilled air in refrigerators and steam. In other situations, solid–gas mixtures are present, for example milling and cooling cocoa press cake and powder. Here the temperature measurement is essential for controlling the process.

The most common temperature measurements however involve *liquid* masses. With tempered chocolate and filling masses, it is especially important to