The narrow gap situation is defined by a maximum ratio of the outer cylinder radius (R_i) to the inner cylinder radius (R_e) of 1.0847 which is often quoted as:

$$\left(R_i/R_e\right)^2 = 0.85 \tag{11.3}$$

The analysis of wide gap situations is more complex and may not be available in the software of commercial equipment if the supplier does not specifically offer large gap geometries. Details of the requirements for the dimensions of a concentric cylinder geometry can be found in rheology textbooks, for example Mezger (2006).

11.6 Vibrational viscometers

During chocolate manufacture, processes involving shaking or vibrating of the product are frequently encountered (Chapter 14) to aid the removal of air bubbles or to level the chocolate in moulds. An overview on the effect of vibration on chocolate has been written by Vavreck (2004). Vibrating a Brookfield viscometer at 50 Hz with an amplitude of 0.12 mm has been shown to remove the yield stress. Other sources quoted by Vavreck showed that the apparent viscosity (at a slow shear rate of 1 s^{-1}) decreased with increasing amplitude of vibration and he postulated that the yield value had disappeared. This was confirmed on both milk and dark chocolate. Here the effect of frequency was found to be more important than amplitude. It was possible to obtain chocolate with a Newtonian flow by vibrating it at 50 Hz and an amplitude of 0.1 mm (0.004 in). The effect was reversible however and the chocolate regained its previous viscosity as soon as the vibration stopped. As an alternative to rotating devices with superimposed vibration, Vavreck described an efflux vibratory viscometer (Figure 11.13) and reported that for milk chocolate that the efflux flow rate was almost linearly correlated to the peak vibration acceleration (Vavreck, 2004). This type of measurement can be used to optimise the operation of shaking machines.

11.7 Oscillatory rheometers

Oscillatory rheology presents an alternative method to unidirectional continuous shear rheology for measuring yield stress of structured materials such as chocolate. It has been reported to differentiate between chocolates that were not different when using the Casson model (De Graef *et al.*, 2011). In this method, the torque or the strain oscillate periodically and the corresponding changing strain or torque response is detected. The phase shift between torque and strain provides information on the flow behaviour of the sample. In the case of fully elastic behaviour the phase shift is zero, while it is 90° for totally viscous samples.

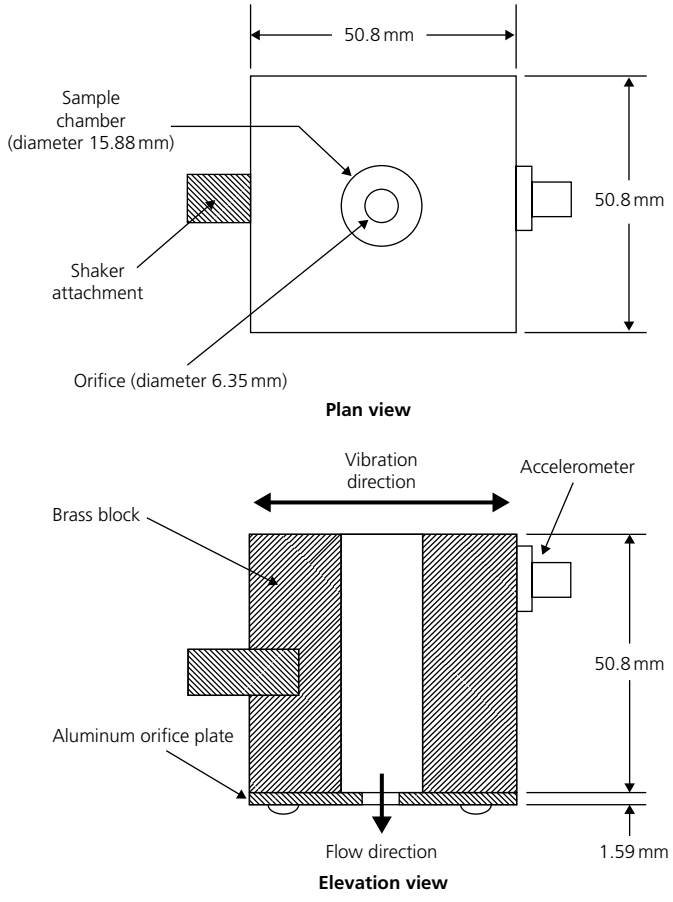

Figure 11.13 Vavreck's efflux vibratory viscometer (Vavreck, 2004; reproduced with permission).

Materials showing phase shifts between 0° and 90° are referred to as viscoelastic. Results of oscillatory rheology tests are often reported as the storage modulus (G′) and the loss modulus (G″), which represent the elastic behaviour and the viscous behaviour respectively of the test material. The reader is referred to rheology textbooks for a detailed introduction to oscillatory rheology (e.g. Mezger, 2006; Goodwin and Hughes, 2008; Rao, 2014).

11.8 Sample preparation and measurement procedures

11.8.1 Sample preparation

The sample being tested must be representative of the chocolate being used. Liquid chocolate should be stirred thoroughly before the sample is obtained and, where possible, it should not be taken from the top of storage tanks, as some separation of fat may have taken place.