see Chapter 11). Numerous attempts have been made to fine-grind crystallised sugar within these limits. However, practice has shown that these restrictions are extremely difficult to conform to, even when the grinding process is combined with a separation/classification stage. It is equally impractical to achieve a controlled crystallisation of the sugar within this narrow particle range at the production stage in the sugar factory (Heidenreich and Huth, 1976). Also for taste reasons it is not advisable to use sugar ground separately to its final fineness (see Section 4.6). In order to obtain ultimate fineness in chocolate with a satisfactory texture, the mass containing relatively coarse sugar is normally processed by means of roller refining.

Icing sugar shows a tendency to form lumps. This is because freshly ground crystallised sugar possesses amorphous surface layers, which are able to take up moisture at higher rates and lower relative humidities than is the case for the crystallised parts. Those amorphous surface layers take up water vapour until they recrystallise, expelling water in the process. This leads to the formation of sugar solution, which bonds the particles together and becomes even firmer as the solution solidifies on drying. It is these solid bonds between the particles that cause a hardening of the icing sugar (Roth, 1977). It is thus advisable to process any ground sugar as speedily as possible and to use a tank with an agitator and screw discharge.

The risk of sugar dust explosions calls for special attention. The explosion of a sugar dust/air mixture may be triggered when a minimum concentration of sugar dust has been reached simultaneously with high ignition energy. This may be due to electrostatic charging, friction or impact sparks. Only particle sizes of about 400 μm and bigger cannot cause explosions (Beck and Jeske, 1996). Tests have shown that a concentration of 30 g/m^3 (0.8 oz/yd^3) of sugar dust with particle sizes up to 250 μm (0.01 in) is sufficient to cause an explosion (Schneider, 1969). These conditions can be roughly determined by visibility. With a concentration of 20 g/m^3 (0.5 oz/yd^3), the visibility is 1 m (3.3 ft) at the most. At a concentration of 50 g/m^3 (1.3 oz/yd^3), a 25 W light bulb is barely visible from a distance of 3 m (9 ft; Dietl, 1961).

A great many preventive measures can be taken to avoid explosions and it is not possible to discuss them all here in detail. However, it is useful to briefly discuss some of the most important safety measurers (Schneider, 1969; Barth *et al.*, 1996)).

Powder mills should be situated in separate, enclosed rooms, which should, if possible, have a high ceiling, be well ventilated and situated on the top floor. Massive, sufficiently pressure-proof walls and fire-resistant doors, opening to the outside, should separate these rooms from all other production facilities. A lightweight exterior wall or a "louvered" ceiling, which pressure vents to outside atmosphere, can serve as a pressure release system.

The equipment in the silos, the mill casing and the drive shaft must be electrostatically earthed. The feed devices should be equipped with magnetic solenoids to detect and remove any metal impurities, which might cause sparks, leading to an explosion inside the mill. These magnets should be interlocked with the mill drive in such a manner that the powder mill automatically shuts down under failure. Mill and elevator heads must be fitted with explosion ducts that vent a long distance away over the roof. Any dust accumulation must be removed from the point of formation.

Within the production localities, the concentration of the sugar dust in the air, when kept within normal operating conditions, is far below the level at which explosions can occur. However, dust deposits can give rise to an unexpected danger. This is because they may be carried up within any piece of production equipment by the pressure wave of a primary explosion within that machine and may then ignite themselves. It is absolutely essential to prevent any dust deposits building up in the production rooms. This is achieved by reducing dust production to a technically feasible minimum, frequent cleaning and a high standard of housekeeping. Suitable measures include the installation of air filters and the use of stationary vacuum equipment for the removal of sugar dust from the air and floor (Kordes, 1998).

All electrical installations should be kept out of rooms with an explosion risk. For example, it is preferable to install switches for electric lighting outside the milling rooms.

4.6 Amorphous sugar

Normally sugar is present in the crystalline state. Even the so-called "açucar amorfo" made in Brazil is not a truly amorphous sucrose, but only refined sugar of extremely small crystal size made from crude cane sugar (Bezerra, 1993). Truly amorphous sugar may be produced by spraying a sucrose solution into a hot and very dry atmosphere or by drying a thin film of sucrose solution at an extremely low relative humidity. The material produced in this way is highly hygroscopic (Powers, 1980).

Whilst crystallised sugar produces a sharp X-ray diffraction pattern, freshly prepared freeze-dried concentrated sugar solution, for instance, as well as sugar that has been ground over a longer period of time, does not produce such a diffraction pattern; that is to say it is amorphous. The heat of solution for crystallised sucrose is 16.75 J/g; however, for amorphous sucrose a heat of –41.45 J/g has been recorded (Van Hook, 1981). It is also known that amorphous surface layers are formed when icing sugar is produced by grinding crystallised sugar. The estimated proportion of this amorphous phase comes to approximately 2%, with an average layer thickness of 0.75×10^{-2} μm (0.3×10^{-6} in; Roth, 1977).

Apart from rapid moisture uptake from the ambient air, the other interesting facet of amorphous sugar from the chocolate manufacturer's point of view is its flavour absorption properties (Niedieck, 1981). It has been estimated that about 30–90% of the sugar become amorphous during the roller refining of