chocolate will freeze from 90–92 F. Actually these freezing points are the lowest temperatures at which the particular grade and type of chocolate is sufficiently fluid to permit easy handling. Chocolate can be subcooled below its melting point without any rate of crystallization. In fact, it does not crystallize *en masse*, but rather in successive stages to the extent that solid solutions are formed of a very unstable crystalline state under certain conditions. The latent heat of crystallization (or fusion) is a direct function of the manner in which it has been cooled and solidified. Once crystallization has started, it will continue until completion, taking from several hours to several days, depending upon its exposure to cooling, particularly with respect to low temperatures (subcooling).

For average purposes, the latent heat of freezing of the usual grades of chocolate used in candy manufacturing will vary from approximately 36–40 Btu per lb. An average value for its specific heat may be taken as 0.56 Btu per lb before freezing and 0.30 after freezing. In any sizable application, however, it is always best to run calorimeter tests on the exact grade and type of chocolate used in the process under consideration before arriving at the final load determinations.

Research on the properties of cocoa butter or chocolate with particular respect to its reaction upon cooling and solidification have definitely established the fact that cocoa butter does exist in two separate and distinct modifications: a very stable form and a metastable or labile form. It was further found that cocoa butter solidifies first in its metastable form, changing very slowly into its stable form.

Pure triglycerides have a *double* melting point. The glyceride, upon melting after suddenly being cooled and solidified, first melts at a specifically lower temperature, resolidifies, and melts again at a higher temperature. If cocoa butter or chocolate is subcooled too rapidly and solidifies below its melting point, all the latent heat is not removed, but is trapped in the solid chocolate in a very unstable form. Upon changing to its stable form, this trapped latent heat is released in direct proportion to the amount of subcooling to which it was subjected. The chocolate will assume an unsatisfactory heavy grained crystalline or *grainy* appearance which is called *bloom*. With a slow crystallization rate in the cooling process, the chocolate will have a better appearance (harder and glossier), longer shelf life, and smoother taste.

Chocolate bars or commercial blocks are cast in metal molds after the tempering process. In this process it is desirable to cool the chocolate in the molds as quickly as possible in order to obtain the maximum amount of luster on the finished product. However, too rapid cooling particularly in the larger size of commercial blocks, which is a standard 10 lb cake, may cause checking or cracking which, while not serious from the standpoint of quality, adversely affects its appearance. Normal practice calls for chilling the metal molds before the warm liquid chocolate is deposited in them. These molds should be cooled to approximately 60 F, which is low enough to permit quick setting at the mold surface but high enough so that condensation on the molds does not become serious. The room containing the depositor should be sufficiently cooled to a dew point below the surface temperature of the mold so that there will be no possibility of condensation on the mold. Therefore, molten chocolate at a temperature of 90–97 F should be cooled very slowly using air at temperatures of approximately 40 F entering and 62 F leaving in a cooling tunnel. Contact cooling by means of brine or chilled water sprays in contact with the confining molds should be at a temperature of approximately 60 F. After the chocolate is deposited in the mold, it can be moved either into a cooling tunnel for a continuous cooling process, or the molds can be stacked up and placed in a cooling room provided with forced air circulation. In either case, temperatures of 40–50 F are satisfactory. Either the discharge room from the cooling tunnel, or the room to which the molds are transferred for packing, should be maintained at a low enough dew point so that no condensation is possible on the cooled chocolate. In load calculations for the cooling tunnel or cold room, it is necessary to account for the transmission and infiltration losses, plus any load derived from further cooling of the molds, and the sensible and latent heat cooling loads of the chocolate itself.

The tunnel is designed so that 40 F air is introduced counter-current to the flow of chocolate so that the coldest air enters the tunnel as the cooled chocolate leaves the tunnel. Thus, as the tunnel air warms up on its way out, the warmest air leaves the tunnel at the point where the warmest molten chocolate enters. The leaving chocolate is cooled to a more marked degree than the entering chocolate and the subcooling is greatly reduced. This in turn reduces the large temperature difference between the chocolate and the cooling air along the path of the entire tunnel length.

For any particular problem, only tests will prove the length of time the chocolate should remain in the tunnel and the subsequent temperature requirements. Good cooling is generally a function of tunnel length, belt speed, and the actual time the product is in contact with the cooling medium.

CHOCOLATE COATING

In the modern candy plant, chocolate coatings are applied to the center material in one of two ways. In the coating process, the center material is either formed by hand or cast in starch or rubber molds, and then dipped by hand or mechanically coated. The supply of chocolate for hand dipping is kept in a pan normally maintained at the lowest possible temperature to secure sufficient fluidity for the process. This temperature is higher than the dipping room temperature, and a heat source is required. Modern plants have electrically heated dipping pans which are thermostatically controlled. The dipped candy, to which the chocolate coating has now been added, is placed either on trays or on belts while the setting of the chocolate coating takes place. This setting is controlled by conditioning the air in the dipping room. A dry-bulb temperature of 35–40 F would be best to promote rapid setting and provide a high gloss on the finished goods. However, because most dipping is done by women, the temperature in the dipping room is raised so that they can work efficiently in comfortable conditions. The recommended conditions for hand dipping rooms are 65 F dry-bulb and a relative humidity not exceeding 50–55 percent. The principal problem in an application of this type is to secure uniform air distribution without objectionable drafts. The loads for this type of installation include, the normal loads such as transmission, lights and people, as well as the heat load from the chocolate and the heat used to warm the dipping pots.

For high speed production of bar candy, the chocolate coating is applied in an enrober machine which consists essentially of a reservoir for the fluid chocolate which is heated and thermostatically controlled to maintain the proper temperature of the chocolate. This chocolate is then pumped to an upper flow pan which allows it to flow in a curtain down to the main reservoir. An open chain-type belt carries the centers through the flowing curtain of chocolate where the covering is picked up. At the same time, grooved rolls pick up some of the chocolate and apply it to the bottom of the center. In this type of work, the centers should be cooled to 80–85 F to assist in freezing out and retaining the proper amount of chocolate coating. The coated pieces are transferred from the enrober to the bottomer slab and then into the en-

rober cooling tunnel. The function of the bottomer slab is to set the bottom coating as rapidly as possible in order to maintain this coating and form a firm base for the piece as it passes through the enrober tunnel. This bottomer slab often takes the form of a simple plate type evaporator which may be fed either with chilled water or brine or may be supplied directly with refrigerant. The belt carrying the candy passes directly over this plate and heat transfer must take place from the candy through the belt to the surfaces of the bottomer slab. A bottomer slab is sometimes used *before* the enrober in order to obtain a good chocolate bottom prior to full coverage. In this case the bottomer slab *after* the enrober is not necessary.

The enrober tunnel serves to set the balance of the chocolate coating as rapidly as practicable consistent with high quality and good appearance of the finished goods. The discharge end of the enrober tunnel is normally in the packing room where the finished candy is then wrapped and packed.

While not an absolute necessity, air conditioning of the enrober room is highly desirable. Because the chocolate used in the coating process is exposed to the room atmosphere, the atmosphere in the room should be as clean as practicable. Since filtration is a part of any air-conditioning system, this prevents the contamination of the chocolate with foreign material. When conditioned, it is advisable to maintain room conditions of 80 F dry-bulb and 50–55 percent rh. These conditions will be low enough to prevent the centers from materially warming up during the time they are exposed in the enrober room, and will also assist in the setting of the chocolate coating after it is applied to the centers and as it passes over the bottomer slab, often located within the enrober room.

BAR CANDY

Present day operations for the production of bar candy call for high speed semi-automatic production in order to keep production costs to a minimum. The center material is delivered from the kitchen to spreaders which form layers on tables, or it is cast in starch molds. Depending on the composition of the center, the hot material may be delivered at temperatures as high as 160–180 F. Successive layers of different color or flavor may be placed one on top of the other to build up the entire center material. These will normally consist of nougat, caramel, marshmallow, whip, or similar ingredients, to which peanuts, almonds, pecans or other nuts may be added if desired. Since each of the ingredients requires a different cooking process, each separate ingredient such as caramel or nougat is normally deposited in a separate operation. Thus, a ⅛ in. layer of caramel may be first deposited and then a layer of peanuts, followed by a ¾ in. layer of nougat. Each of these layers is applied in a separate and distinct operation to build up the completed center. Except for nuts, normally it is necessary to allow some time for setting each successive layer as it is deposited and prior to the application of each succeeding layer. If the centers are spread in slabs, the slab must first be cooled and then cut into pieces the size of the finished center, using rotary knives.

HARD CANDY

Hard candy manufacture with high speed machinery requires the use of air conditioning to maintain both temperature and humidity. There is some difference in the requirements of candy made of cane sugar as contrasted to that which is made of glucose. For example, a dry-bulb temperature of 75–80 F with 40 percent relative humidity is satisfactory for plants using a high percentage of glucose, whereas the same temperature with a relative humidity not to exceed 50 percent is necessary for cane sugar.

Where relative humidity is to be maintained at 40 percent or less, it is desirable to consider the use of standard dehydrating systems employing chemicals such as lithium chloride, silica gel or activated alumina or other proven types. A combination of refrigeration and dehydration is also used.

The quantity of air required is a direct function of the sensible heat of the room. Approximate rules indicate the quantity should be between 1½ and 2½ cfm per sq ft of floor area with a minimum of 15 percent outdoor air or 30 cfm per person. Consideration must be given to the sensible heat in the hard candy which is at a high temperature to keep it in a pliable condition during the forming operation.

Where concentrations of the finished product in containers or tubs are located in the general conditioned area, special consideration must be given to the increased quantity of air required in these areas to prevent sticking of the finished product.

Unitary air conditioners employing dry coils having a sufficient number of rows and adequate surface are satisfactory. Central station apparatus employing cooling and dehumidifying coils of similar design also may be used. Good filtration is essential for air purity as well as for prevention of dirt accumulation on cooling coils. Reheat control is needed for constant temperature and humidity conditions.

Air distribution should be designed to provide uniform conditions and eliminate the possibility of drafts.

HOT ROOMS

The drying of such products as jellies and gums can best be accomplished in air-conditioned hot rooms. These products are normally cast by moguls into starch molds. The molds are contained in a tray approximately 35×15×1½ in. in size, with an extra ½–¾ in. blocking at the bottom for air circulation. These trays are then racked up on trucks, with the number of trays per truck being determined by the method of loading. Usual practice calls for approximately 25–30 trays per truck. The trucks are then loaded into the hot room where the actual drying is accomplished.

The normal drying temperatures for this type will average between 120 and 150 F dry-bulb. While humidity is of importance, close control of humidity is not necessarily required since, even with the maximum normal outdoor temperature conditions normally encountered when this air is heated to 120–150 F, the relative humidity will be low (from 19–13 percent).

Some operators prefer to have manual control of humidity which requires frequent inspection of actual conditions. Other operators prefer automatic humidity control by instruments so calibrated that the desired dry-bulb temperature and relative humidity are maintained in the hot room at all times, regardless of the moisture coming out of the candy and the supply air. With the fully automatic system, the supply air should be conditioned to provide dry air to the unit and also to cool the air usually needed in hot weather to purge the hot room after completion of the drying cycle.

For proper air distribution in the hot room it is necessary to arrange the product and the air flow so that the maximum amount of air will be in contact with the product. Providing space between trays is one means of accomplishing maximum contact. Also, the trucks within the hot room must be so placed that a continuous flow of air from truck to truck can be assured with the shortest possible path for the air flow. In addition, space must be maintained at the entering and leaving air sides in order to assure flow from the top to the bottom tray for each truck. A large air quantity is required in order to secure uniformity over the entire product zone.

One method of securing this which has proven satisfactory