CHAPTER 28

CHOCOLATES, CANDIES, NUTS, DRIED FRUITS, AND DRIED VEGETABLES

CANDY MANUFACTURE

AIR conditioning and refrigeration are essential for successful candy manufacturing. Proper atmospheric control increases production, lowers production costs, and improves product quality.

One or more of several standardized spaces or operations is encountered in every plant. These spaces include hot rooms; cold rooms; cooling tunnels; coating kettles; packing, enrobing, or dipping rooms; and storage.

Sensible heat must be absorbed by air-conditioning and refrigeration equipment, which includes the air distribution system, plates, tables, cold slabs, and cooling coils in tunnels or similar coolers. In calculating the loads, such sensible heat sources as people, power, lights, sun effect, transmission losses, infiltration, steam and electric heating apparatus, and the heat of the entering product must be considered. See Chapter 12 for more information. Table 1 summarizes the optimum design conditions for refrigeration and air conditioning.

Two of the basic ingredients in candy are sucrose and corn syrup. These change easily from a crystalline form to a fluid, depending on temperature, moisture content, or both. The surrounding temperature and humidity must be controlled to prevent moisture gain or loss, which affects the product's texture and storage life. Temperature should be relatively low, generally below 70°F. The relative humidity should be 50% or less, depending on the type of sugar used. For chocolate coatings, temperatures of 65°F or less are desirable, with relative humidity 50% or less.

In processing areas where lower relative humidity and temperature are required and production demands are high, serious consideration should be given to using ASHRAE extreme conditions as the design criteria for the air-handling equipment.

MILK AND DARK CHOCOLATE

Cocoa butter is either the only fat or the principal fat in chocolate, constituting 25 to 40% or more of various types. Cocoa butter is a complex mixture of triglycerides of high molecular weight fatty acids, mostly stearic, oleic, and palmitic. Because cocoa butter is present in such large amounts in chocolate, anything affecting cocoa butter affects the chocolate product as well.

Because cocoa butter is a mixture of triglycerides, it does not act as a pure compound. Its physical properties, melting point, solidification point, latent heat, and specific heat affect the mixture. Cocoa butter softens over a wide temperature range, starting at about 80°F and melting at about 94°F. It has no definite solidification point;

Table 1 Optimum Design Air Conditions[a]

	Dry-Bulb Temperature, °F	Relative Humidity, %
Department or Process		
Chocolate pan supply air	55 to 62	55 to 45
Enrober room	80 to 85	30 to 25
Single cooling tunnel	36 to 45	85 to 70[b]
Double cooling tunnel, entering	50 to 55	
Double cooling tunnel, leaving	38 to 45	
Hand dipper	62	45
Molded goods cooling	36 to 45	85 to 70
Chocolate packing room	65	50
Chocolate finished stock storage	65	50
Centers tempering room	75 to 80	35 to 30
Marshmallow setting room	75 to 78	45 to 40
Grained marshmallow (deposited in starch) drying	110	40
Gum (deposited in starch) drying	125 to 150	25 to 15
Sanded gum drying	100	25 to 40
Gum finished stock storage	50 to 65	65
Sugar pan supply air (engrossing)	85 to 105	30 to 20
Polishing pan supply air	70 to 80	50 to 40
Pan rooms	75 to 80	35 to 30
Nonpareil pan supply air	100 to 120	20
Hard candy cooling tunnel supply air	60 to 70	55 to 40
Hard candy packing	70 to 75	40 to 35
Hard candy storage	50 to 70	40
Caramel rooms	70 to 80	40
Raw Material Storage		
Nuts (insect)	45	60 to 65
Nuts (rancidity)	34 to 38	85 to 80
Eggs	30	85 to 90
Chocolate (flats)	65	50
Butter	20	
Dates, figs, etc.	40 to 45	75 to 65
Corn syrup[c]	90 to 100	
Liquid sugar	75 to 80	40 to 30
Comfort air conditions	75 to 80	60 to 50

Note: Conditions given in this table are intended as a guide and represent values found to be satisfactory for many installations. However, specific cases may vary widely from these values because of such factors as type of product, formulas, cooking process, method of handling, and time. Acceleration or deceleration of any of the foregoing will change the temperature, humidity, or both to some degree.

[a] Temperature and humidity ranges are given in respective order (i.e., first temperature corresponds to first humidity).

[b] Optimum conditions.

[c] Depends on removal system. With higher temperatures, coloration and fluidity are greater.

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this varies from just below its melting point to 80°F or lower, depending on the quantity and hardness of cocoa butter and the time it is held at various temperatures. The presence of milkfat in milk chocolate lowers both the melting point and the solidification point of the cocoa butter. High-quality milk chocolate remains fluid for easy handling at temperatures as low as 86 to 88°F. Sweet chocolate remains fluid at temperatures as low as 90 to 92°F.

Chocolate can be subcooled below its melting point without crystallization. In fact, it does not crystallize en masse but rather in successive stages, as solid solutions of a very unstable crystalline state are formed under certain conditions. The latent heat of crystallization (or fusion) is a direct function of the manner in which the chocolate has been cooled and solidified. Once crystallization has started, it continues until completion, taking from several hours to several days, depending on exposure to cooling, particularly to low temperatures (subcooling).

The latent heat of solidification of the grades of chocolate commonly used in candy manufacture varies from approximately 36 to 40 Btu/lb. Average values for the specific heat of chocolate may be taken as 0.56 Btu/lb·°F before solidification and 0.30 Btu/lb·°F after solidification. The average value for the specific heat of cocoa butter is 0.5 Btu/lb·°F, for milk chocolate is 0.484 Btu/lb·°F, and for roasted cocoa bean is 0.44 Btu/lb·°F. In calculating the cooling load, a margin of safety should be added to these figures.

Cocoa butter's cooling and solidification properties exist in five polymorphic forms: one stable form and four metastable or labile ones. Cocoa butter usually solidifies first in one of its metastable forms, depending on the rate and temperature at which it solidifies. In solidified cocoa butter, the lower-melting labile forms change rapidly to the higher-melting forms. The higher-melting labile forms change slowly, and seldom completely, to the stable form.

Commercial chocolate blocks are cast in metal or plastic polycarbonate molds after the tempering process. During this process, it is desirable to cool the chocolate in the molds as quickly as possible, thus requiring the shortest possible cooling tunnel. However, cooling the blocks too quickly (particularly large commercial blocks, which can range in size from 10 to 50 lbs) may cause checking or cracking, which, while not injurious to quality, adversely affects the appearance and strength of the block. Depositing the chocolate into molds at 85 to 90°F is common.

Dark chocolate should be cooled very slowly at 90 to 92°F; milk chocolate, at 86 to 88°F. Air entering the cooling tunnel, where the goods are unmolded, may be 40°F. The air may be 62°F where the goods enter the tunnel. After the chocolate is deposited in the mold, it can be moved into a cooling tunnel for a continuous cooling process, or the molds can be stacked up and placed in a cooling room with forced-air circulation. In either case, temperatures of 40 to 50°F are satisfactory. The discharge room from the cooling tunnel or the room to which the molds are transferred for packing should be maintained at a dew point low enough to prevent condensation on the cooled chocolate. In load calculations for the cooling or cold room, it is necessary to account for transmission and infiltration losses, 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 to introduce 40°F air countercurrent to the flow of chocolate; the coldest air enters the tunnel where the cooled chocolate leaves the tunnel. Because 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 markedly cooler 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 entire tunnel length.

For any particular application, only testing will determine 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 contacts the cooling medium.

HAND DIPPING AND ENROBING

The candy centers of chocolate-coated candies are either formed by hand or cast in starch or rubber molds. They are then dipped by hand or enrobed mechanically. The chocolate supply for hand dipping is normally kept in a pan maintained at the lowest temperature that still secures sufficient fluidity for the process. Because this temperature is higher than the dipping room temperature, a heat source, such as electrically heated **dipping pans** with thermostatic controls, is required. The dipped candy is placed either on trays or on belts while the chocolate coating sets.

Setting is controlled by conditioning the air in the dipping room. A dry-bulb temperature of 35 to 40°F best promotes rapid setting and provides a high gloss on the finished goods. However, the temperature in the dipping room is raised for human comfort. The suggested conditions for hand-dipping rooms are 64°F dry bulb and a relative humidity not exceeding 50 to 55%. The principal aim is to achieve uniform air distribution without objectionable drafts. The loads for this room include transmission, lights, and people, as well as the heat load from the chocolate and the heat used to warm dipping pans.

In high-speed production of bar candy, the chocolate coating is applied in an **enrober machine**, which consists essentially of a heated and thermostatically controlled reservoir for the fluid chocolate. This chocolate is pumped to an upper flow pan that allows it to flow in a curtain down to the main reservoir. An open chain-type belt carries the centers through the flowing chocolate curtain, where they pick up the coating. At the same time, grooved rolls pick up some chocolate and apply it to the bottom of the centers. The centers should be cooled to 75 to 80°F to assist solidification and retention of the proper amount of coating.

The coated pieces are transferred from the enrober to the **bottomer slab** and then pass into the enrober cooling tunnel. The function of the bottomer slab is to set the bottom coating as rapidly as possible in order to form a firm base for the pieces as they pass through the enrober tunnel. The bottomer slab is often a flat-plate heat exchanger fed with chilled water or propylene glycol or directly supplied 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. The bottomer slab is sometimes located before the enrober to create a good bottom prior to full coverage.

The **enrober cooling tunnel** sets the balance of the chocolate coating as rapidly as is consistent with high quality and good appearance of the finished pieces. Typical enrober cooling tunnel times are approximately 7 to 8 min for milk chocolate and can be as low as 3 to 6 min for vegetable-fat-based coatings. The discharge end of the enrober tunnel is normally in the packing room, where the finished candy is wrapped and packed.

Although not absolutely necessary, air conditioning the enrobing room is desirable. Because the coating is exposed to the room atmosphere, the atmosphere should be clean to prevent contamination of the coating with foreign material. It is advisable to maintain conditions of 75 to 80°F dry bulb and 50 to 55% rh; that is, low enough to prevent the centers from warming up and to assist in the setting of the chocolate after it is applied.

BAR CANDY

The production of bar candy calls for high-speed semiautomatic operations to minimize production costs. From the kitchen, the center material is either delivered to spreaders, which form layers on tables, or cast in starch molds. Depending on the composition of the center, the hot material may be delivered at temperatures as high as 160 to 180°F. Successive layers of different color or flavor may be deposited to build up the entire center material. These layers usually consist of nougat, caramel, marshmallow whip, or similar ingredients, to which peanuts, almonds, or other nuts may be added. Because each of the ingredients requires a different cooking process, each separate ingredient is deposited in a separate operation. Thus, a 1/8 in. layer of caramel may be deposited first, then a layer of peanuts, followed by a 3/4 in. layer of nougat. Except for nuts, it is necessary to allow time for each successive layer to set before the next is applied. If the candy is spread in slabs, the slab must be cooled and then cut with rotary knives into pieces the size of the finished center.

HARD CANDY

Manufacturing hard candy with high-speed machinery requires air conditioning to maintain temperature and humidity. Candy made of cane sugar has somewhat different requirements from that made partly with corn syrup. For example, a dry-bulb temperature of 75 to 80°F with 40% rh is satisfactory for corn syrup (as the corn syrup percentage increases, the relative humidity must decrease), whereas the same temperature with 50% rh is satisfactory for cane sugar.

Where relative humidity is to be maintained at 40% or less, standard dehydrating systems employing such chemicals as lithium chloride, silica gel, or activated alumina should be used. A combination of refrigeration and dehydration is also used.

The amount of air required is a direct function of the sensible heat of the room. Approximate rules indicate that the quantity should be between 1.5 and 2.5 cfm per square foot of floor area, with a minimum of 15% outdoor air or 30 cfm per person. The sensible heat in hard candy, which is at a high temperature to keep it pliable during forming, must also be taken into account.

If concentrations of the finished product in containers or tubs are located in the general conditioned area, the quantity of air must be increased to prevent the product from sticking to the container.

Unitary air conditioners employing dry coils are satisfactory if they have a sufficient number of rows and adequate surface. A central station apparatus employing cooling and dehumidifying coils of similar design may also be used. Good filtration is essential for air purity as well as for preventing dirt accumulation on cooling coils. Reheat is required for some temperature and humidity conditions. Air distribution should be designed to provide uniform conditions and to minimize drafts.

HOT ROOMS

Such products as jellies and gums can best be dried in air-conditioned hot rooms. These products are normally cast into starch molds. The molds are contained in a tray approximately 35 by 15 by 1.5 in. with an extra 0.50 to 0.75 in. blocking at the bottom for air circulation. These trays are racked up on trucks, with the number of trays per truck (usually 25 to 30) determined by the method of loading. The trucks are loaded into the hot room where the actual drying is accomplished.

When starch drying is being used, careful consideration must be given to the proper design of all process and utility equipment in the immediate are because of the explosive nature of dry starch. Refer to the National Electrical Codes and most recent NFPA guidelines for design criteria.

Normal drying conditions average between 120 and 150°F dry bulb with 15 to 20% rh. While humidity is important, close humidity control is not necessary.

Some operators prefer manual humidity control, which requires frequent inspection of actual conditions; others prefer automatic humidity control by instruments calibrated to maintain desired dry-bulb temperature and relative humidity in the hot room regardless of the moisture from the candy. With full automation, the supply air system should provide dry air to the unit and also cool the air usually needed in hot weather to purge the hot room after the drying cycle.

For proper air distribution in the hot room, the maximum amount of air must be in contact with the product. Providing space between trays is one means of accomplishing this. The trucks within the hot room must be placed to ensure continuous airflow from truck to truck with the shortest airflow path. Space must also be maintained at the entering and leaving air sides to ensure flow from the top to the bottom tray for each truck. A large air quantity is required to secure uniformity over the entire product zone.

One device for achieving uniformity is the **ejector nozzle system**. This system consists of a supply header fitted with conical ejector nozzles designed to have a tip velocity of 2000 to 5000 fpm with a static pressure behind the nozzle ranging as high as 12 in. of water. Nozzles arranged in this way induce a flow of air about three times that actually supplied by the nozzles. This ratio gives the most economical balance between air quantity supplied and fan power. The ejector system causes the primary and induced airstreams to mix over the product and the space between the top tray and the ceiling. Sufficient ceiling height must be allowed for this mixing, which rapidly decreases the differential between the air supply temperature and the actual room temperature. The high airflow thus created decreases the temperature drop across the product. Because the temperature drop is proportional to the heat pickup, a greater airflow has a lower temperature drop. Thus, the spread between the air temperatures entering and leaving the product zone is reduced, promoting uniform drying.

When drying is completed, the product must be cooled rapidly to facilitate unloading. This quick cooling is provided by a second outdoor air intake, which bypasses the heating coil or air-conditioning unit. When this bypass intake is activated, drop dampers are opened in the bottom of the ejector header, so the air also bypasses the ejector nozzles and removes the heat from the room. A ceiling exhaust fan is also recommended for removal of the rising heated air.

The equipment for this operation consists of a fan and heating coil located outside the hot room. No electric motors should be in the room because of the hazard of sparking. This unit has outdoor air intakes, ejector headers, return air dampers, and dampers for the outdoor air intake. A recording controller to maintain an accurate record of each batch is recommended. The controller simply regulates the flow of steam to the heating coil to maintain the desired room temperature. Control switches should be provided to position the outdoor and return air dampers because a rise in humidity requires more outdoor air and a drop in humidity requires more return air. In some cases, this function can be achieved automatically with a humidity control. An end position can be included on the control switches for the cooling-down period to start the exhaust fan when the outdoor air damper is opened wide.

COLD ROOMS

Many confectionary products (e.g., marshmallows, certain types of bar centers, and cast cream centers) require chilling and drying but cannot withstand high temperatures. Drying conditions of about 75°F and 45% rh are required in the cold room, and the drying period varies from 24 to 48 h. An ejector-type system similar to that for hot rooms is used, the difference being that cooling coils are provided in the unit. The sensible and latent heat components of the load must be carefully determined so that the actual air quantity, together with the air supply and refrigerant temperatures, can be calculated.

Controlling relative humidity is an inherent part of the system design. The control system is similar to the one used for the hot room, except that its recording regulator must control the flow of steam to the heating coil in winter and regulate the flow of refrigerant to the cooling coil in summer. Flushing dampers and a cooling-down cycle are necessary. One precaution in connection with starch or sugar dust picked up in the return airstream must be observed. During the cooling cycle, condensate forms on the cooling coils, so that any starch or sugar dust deposits on the coils as a paste. This reduces capacity and necessitates frequent maintenance and cleaning of the equipment. Thus, air filters should always be used for the outdoor and return air entering the cooling coil. In addition, a coil wash system should be provided to aid in cleaning the coils.

COOLING TUNNELS

Various candy plant cooling requirements can best be handled in a cooling tunnel, including the cooling of (1) coated centers after they leave the enrober, (2) cast chocolate bars, and (3) hard candy. These operations are usually set up for a continuous flow of high-rate production. The product is normally conveyed on belts through either the enrober or the casting machine and then through a cooling chamber.

A cooling tunnel consists of an insulated box placed around the conveyor so that the product may travel through it in a continuous flow. Refrigerated air is supplied to this enclosure to cool the product. To achieve maximum heat transfer between the air and product, air should flow counter to the material flow. In general, air supply temperatures of 35 to 45°F with air velocities up to 500 fpm have been found satisfactory.

Cooling tunnel air velocity can have a significant impact on the degree of chocolate temper found in the finished candy. Temper is a measure of the percentage of stable fat (cocoa butter) crystals that form during the chocolate solidification process. Too rapid a cooling often results in poor final temper, causing the finished candy to have a dull matte finish and poor snap (soft chocolate), and over time will result in the cocoa butter migrating to the surface of the piece, giving it a grayish cast. It is generally recommended to expose the chocolate candy to higher initial cooling temperatures (55 to 60°F) and lower initial air velocities to avoid cooling the candy too rapidly. Product temperature at the exit of the cooling tunnel is also critical. Finished product must exit the cooling tunnel at a temperature well above the dew point of the packaging area to avoid condensation on the surface of the candy. On larger, higher-speed cooling tunnels, this is often accomplished by dividing the cooling tunnel into several zones, where the air temperature and velocity can be adjusted independently.

The actual size of the tunnel is determined by the size of the conveyor belt and the air quantity. The air quantity depends on the heat load and the desired rate of cooling. The rise in air temperature through the tunnel should be limited to 15 to 20°F maximum. Each tunnel generally has one refrigerated air handler, which normally consists of a fan and coil with the necessary duct connections to and from the unit. An outdoor air intake is advisable in appropriate climates because cooling can at times be accomplished with outdoor air (without operating the refrigeration plant). The outside air intake should be equipped with suitable air filters to minimize contamination. The tunnel should be made as tight as possible, and the entrance and exit openings for the candy should be as small as possible to limit air loss from the tunnel or air infiltration into the tunnel; in some cases, it is advisable to use a flexible canvas curtain to control airflow. As some loss is unavoidable, it is practicable in some applications to take a small amount of outdoor air or air from adjoining spaces to provide a slight excess pressure in the tunnel.

For chocolate-enrobing work, the condition of the air is the paramount factor in securing the best possible luster and most even coating. The best results are obtained with rather slow cooling, but this requires either a low production rate or excessively long tunnels; the final design is a compromise. The coating must be in the proper condition when it is poured over the centers because improper temperature at this point causes blushing or loss of luster. Proper temperature, however, is a function of the enrober machine and its operation; no amount of correction in the tunnel can compensate.

A variation of the standard single-pass counterflow tunnel has been used for enrobing. The tunnel is divided horizontally by an uninsulated sheet metal partition. The belt carrying the candy rides directly on this partition, and the return belt is brought back through the space below the partition. Cold air is supplied to the lower chamber near the enrober, progresses to the opposite end of the tunnel, is transferred to the top chamber, progresses back to a point near the enrober, and is then returned to the cooling equipment. This tunnel has two important advantages: (1) it chills the return belt so that the belt can act as a bottomer slab to quickly set the base of the coated piece, and (2) the uninsulated partition, with the coldest air below it, assists in this bottoming operation. Thus, the air supply has already absorbed some of its heat load by the time it is actually introduced to the product-cooling zone. The method approaches the advantage of slow cooling but keeps the tunnel at a minimum length.

For some applications, a spiral belt cooling tunnel can be used to save floor space. Products that are sensitive to injury or abrasion due to lateral movement of the belt underneath are generally unsuitable for a spiral conveyor. Typical cooling tunnel configurations are described and illustrated in Chapter 15.

COATING KETTLES OR PANS

Originally, revolving coating kettles or pans were merely supplied with warm air, ranging from 80 to 125°F. This air was then exhausted from the kettle to the room, creating a severe nuisance from sugar dust blowing out of the kettle. Another difficulty was that a portion of the energy required to rotate the kettle was converted to heat in the centers being coated, causing enough expansion to produce cracking or checking. To mitigate this problem, the following practice evolved: a portion of the coating is applied, the product is withdrawn for a seasoning period of up to 24 h, and the material is then returned to the kettles for additional coating.

Some installations overcome most of the sugar dust problem by providing a conditioned air supply to the kettles and positive exhaust from the kettles. The wet- and dry-bulb temperature of the air supplied to the kettles is controlled so that the rate of coating evaporation and the drying are uniform, at a high production rate and reduced labor cost. Evaporation of the moisture in the coating material tends to take place at the wet-bulb temperature of the air supplied to the kettle. A large portion of the heat of crystallization entering the product is absorbed, and the centers are not overheated. This eliminates the need for a seasoning period and permits continuous operation.

In order to minimize drying times, a relative humidity of less than 40% is often used for the panning supply air. This requires the use of a desiccant system using chemicals such as lithium chloride or activated alumina. The design of any desiccant system for year-round candy production should be based on ASHRAE extreme conditions to avoid quality problems as seasonal changes occur.

With air conditioning applied to coating kettles, the number of rejects caused by splitting, cracking, uneven coating, or doubles can be reduced considerably. Sugar dust recovery is accomplished with cyclone-type dust-collecting devices.

PACKING ROOMS

Manufacturers spend considerable time and effort in the design and application of packaging materials because of their effects on product keeping quality. Important packaging considerations are moisture-proof containers, vapor retarders for abnormally high humidity conditions, and protection against freezing or extreme heat. Controlling the air in the packing room is essential for proper packing.

For example, air surrounding products packed in a room at 85°F dry bulb and 60% rh, which is not unusual in a normal summer, would have a 69°F dew point. If this sealed package were subjected to temperatures below 69°F, the air in the package would become supersaturated and moisture would condense on the surfaces of the container and the product. If the product were then subjected to a higher temperature, the moisture would reevaporate. In the process, chocolates would lose their luster or show sugar bloom, and marshmallows would develop either a sticky or a grained surface, depending on the formula used.

In practice, packing room conditions of 65°F dry bulb and 50% rh have been found most practicable. Results improve if the relative humidity is reduced several points. In the case of hard candy, which is intensely hygroscopic, the relative humidity should be reduced to 35 to 40% at 70 to 75°F.

REFRIGERATION PLANT

Large candy manufacturers often use a central refrigeration plant for cooling water and/or a secondary coolant for circulation throughout the plant to meet the various load requirements. Propylene glycol is the current secondary coolant of choice for food plants. See Chapter 4 for design and application information regarding secondary coolants.

The central refrigeration plant for cooling water and/or propylene glycol may use ammonia or one of the environmentally suitable halocarbon refrigerants. Heat transfer equipment both for new plants and for retrofits for cooling water or propylene glycol may be welded-plate heat exchangers or extended-surface shell-and-tube heat exchangers to increase plant efficiency and to reduce the refrigerant charge. They are usually piped for gravity-flooded or liquid overfeed operation. Compressors vary with the refrigerant used, plant size, initial and operating costs, and plans for future expansion. All installations should adhere to applicable refrigeration codes and regulations.

Secondary coolant temperatures usually vary between 28 and 32°F for central refrigeration plants. These temperatures seldom require an artificial defrost system for the evaporator coils. Some cooling tunnel applications may require lower coolant temperatures and associated defrost cycles.

A secondary coolant distribution system makes it feasible to connect all service points to one source of refrigeration and, with control systems, to maintain dry-bulb and dew-point temperatures precisely. In addition, this system can be extended to comfort cooling in offices and other nonproduction areas.

Smaller manufacturing plants may be better served by multiple condensing units and direct-expansion evaporators using an environmentally suitable refrigerant such as R-134a. These condensing unit/evaporator combinations may be grouped at appropriate refrigeration or air-conditioning load points as dictated by the plant layout. This arrangement provides flexibility to expand or retrofit a plant a portion at a time at a reasonable investment and operating cost.

STORAGE

CANDY

Most candies are held for 1 week to over a year between manufacture and consumption. Storage may be in the factory, in warehouses during shipping, or in retail outlets. It is important that the candy maintain quality during that time.

Low-temperature storage does not produce undesirable results if the following conditions are met:

- The candies are made of proper ingredients for refrigerated storage.
- The packages have a moisture barrier.
- The storage room is held at equilibrium humidity with desirable moisture conditions for preserving the candy.
- The candy is brought to room temperature before the packages are opened.

Table 2 Expected Storage Life for Candy

			Storage Life, Months			
			Storage Temperature, °F			
Candy	Moisture Content, %	Relative Humidity, %	68	48	32	0
Sweet chocolate	0.36	40	3	6	9	12
Milk chocolate	0.52	40	2	2	4	8
Lemon drops	0.76	40	2	4	9	12
Chocolate-covered peanuts	0.91	40 to 45	2	4	6	8
Peanut brittle	1.58	40	1	1.5	3	6
Coated nut roll	5.16	45 to 50	1.5	3	6	9
Uncoated peanut roll	5.89	45 to 50	1	2	3	6
Nougat bar	6.14	50	1.5	3	6	9
Hard creams	6.56	50	3	6	12	12
Sugar bonbons	7.53	50	3	6	12	12
Coconut squares	7.70	50	2	3	6	9
Peanut butter taffy kisses	8.20	40	2	3	5	10
Chocolate-covered creams	8.09	50	1	3	6	9
Chocolate-covered soft creams	8.22	50	1.5	3	5	9
Plain caramels	9.04	50	3	6	9	12
Fudge	10.21	65	2.5	5	12	12
Gumdrops	15.11	65	3	6	12	12
Marshmallows	16.00	65	2	3	6	9

The storage period depends on (1) the marketing season of the candy; (2) the stability of the candy; and (3) the storage temperature and humidity (see Table 2).

The shelf life of a candy is determined by the stability of its individual ingredients. Common candy ingredients are sugar (including sucrose, dextrose, corn syrups, corn solids, and invert syrups), dark and milk chocolates, nuts (including coconut, peanuts, pecans, almonds, walnuts, and others), fruits (including cherries, dates, raisins, figs, apricots, and strawberries), dried milk and milk products, butter, dried eggs, cream of tartar, gelatin, soybean flour, wheat flour, starch, and artificial colors.

Refrigerated storage of candy ingredients is especially advantageous for seasonal products, such as peanuts, pecans, almonds, cherries, coconut, and chocolate. Ingredients with delicate flavors and colors, such as butter, dried eggs, and dried milk, retain quality more evenly year-round if kept properly refrigerated. Otherwise, ingredients containing fats or proteins may lose considerable flavor or develop off-flavors before being used.

Candies are semiperishable: the finest candies or candy ingredients may be ruined by a few weeks of improper storage. This includes many candy bars and packaged candies and some choice bulk candies. Unless refrigeration is provided from time of manufacture through the retail outlet, the types of candies offered for sale must be greatly reduced in the summer.

Benefits from refrigerated storage of candies, especially during the summer, are the following:

- Insects are rendered inactive at temperatures below 48°F.
- The tendency to become stale or rancid is reduced.
- Candies remain firm as an assurance against sticking to the wrapper or being smashed.
- Loss of color, aroma, and flavor is reduced.
- Candies can be manufactured year-round and accumulated for periods of heavy sales.

Color

Many colors used in hard candies, hard creams, and bonbons gradually fade during storage at room temperature, especially in the light. However, the most marked effect of storage temperature on color occurs with chocolates. In candies high in protein and nuts, there is a gradual darkening of color, especially at higher storage temperatures.

Temperatures of 85 to 95°F cause graying of chocolates in only a few hours and darkening of nuts within a month. **Graying** or **fat blooming** is caused by crystals of fat on the surface of the chocolate coating. While this condition is usually associated with old candies, new candies can become gray after one day under adverse storage conditions. Chilling of chocolates following exposure to high temperatures produces graying very quickly, but chilling without previous heat exposure does not.

Sugar blooming of chocolate looks similar to graying or fat blooming and is caused by crystallized sugar deposited on the surface from condensation of moisture following removal of the candy from refrigerated storage without proper tempering. Experiments have shown that chocolate tempered by gradually raising the temperature to normal without opening the package did not incur sugar blooming even after storage at 0°F or lower. Sugar bloom may also occur due to storage in overhumid air and migration of moisture from the centers to the surface.

Flavor

Keeping candy fresh is one of the chief reasons for refrigerated storage. Most flavors added to candies, including peppermint, lemon, orange, cherry, and grape, are distinctive and stable during storage. Proper design of flavor and color storage areas is critical. Many of today's flavors and colors have very low flash points due to their alcohol bases and high levels of organic volatiles. Storage areas for these types of compounds should be adequately ventilated and comply with recent NFPA guidelines. Less-pronounced flavors such as those of butter, milk, eggs, nuts, and fruits are more sensitive to high temperatures.

Low temperatures retard the development of staleness and rancidity in fats, preserve flavors in fruit ingredients, and prevent staleness and other off-flavors in candies containing such semiperishable ingredients as milk, eggs, gelatin, nuts, and coconut. Candies containing fruit become strong in flavor when they are stored at room temperature or higher for more than a few weeks; those containing nuts become rancid. There are no specific critical temperatures at which undesirable changes occur, but the lower the temperature, the more slowly they take place.

Texture

Candy becomes increasingly soft at high temperatures and increasingly hard and brittle at low temperatures, reaching an optimum for eating at about 70°F. Changes in texture are reversible from below 0°F to 80°F, enabling refrigerated candies to be returned satisfactorily to any desired temperature for eating. This is extremely important because the texture of most candies subjected to very low temperatures (or even shipped in contact with dry ice at about –110°F) is not permanently changed.

Most candies are manufactured at controlled temperatures. Their texture (except in hard candies and hard creams) is maintained best at temperatures below 68°F.

Insects

Candies containing fruit, chocolate, nuts, or coconut are favorite hosts for insects. Because fumigation and insect repellants are seldom permissible, refrigeration is used to inactivate insects in candy and candy ingredients.

Common insects become active at about 50°F, and activity increases as the temperature is raised to 100°F. Although common cold storage temperatures do not kill many insects, temperatures below 50°F do inactivate them. Both adults and eggs may exist for months at above-freezing temperatures without feeding or propagating. Candies with insect eggs on either the product or wrappers may be refrigerated for long periods with no apparent damage, but when they are warmed up, a serious insect infestation may develop.

Both adults and eggs are killed at storage temperatures of about 0°F. Storing candies at 0°F for a few weeks usually destroys all forms of insect life. Lower temperatures and long storage periods are lethal to insects.

Storage Temperature

Regarding effect on candies, storage temperature is difficult to separate from humidity, but the latter is more important. There are no specific critical refrigerated temperatures at which certain types of candy must be held. In general, the lower the temperature, the longer the storage life, but the greater the problem of moisture condensation on removal.

Air Conditioning (68 to 70°F). Because the storage of candies begins in the tempering room of the manufacturing plant, 68°F and 50% rh is desirable to prevent pieces from being packaged when they are soft and sticky. Under these conditions, all candies remain firm and there is little or no graying of chocolates; their original luster can be held.

Hard candies and candies containing only sugar ingredients keep in good condition for more than 6 months at 68 to 70°F. Other types become stale, lose flavor and luster, and darken in color.

Under prolonged storage, candy containing nuts or chocolate becomes musty or rancid, and even the colors and flavors of some hard candies may fade. Only **summer candies** should be held for more than a few weeks at 68 to 70°F or higher. Unless precautions are taken, the temperature of truck or rail shipments may rise to the melting point of semisoft candies or to the graying point of chocolates. Candies temporarily stored in the sunshine or in warm places in buildings may suffer severe loss of shape, luster, and color. Some companies use refrigerated trucks and railroad cars for hauling candies. Portable refrigerated containers provide a viable means of ensuring that candies maintain their quality from manufacturer to retail outlet.

Cool Storage (48 to 50°F). Candies stored at this temperature remain firm and retain good texture and color; only those containing nuts, butter, cream, or other fats become stale or rancid within 4 months. Candies that remain practically fresh for 4 months are fudge, caramels, sugar bonbons, gumdrops, marshmallows, lemon drops, hard creams, and semisweet chocolates; they are wrapped in aluminum foil to give added protection. Candies that become stale at this temperature are peanut butter taffy kisses, peanut brittle, uncovered peanut rolls, chocolate-covered peanut rolls, and nougat bars.

Cold Storage (32 to 34°F). Most candies can be successfully held in cold storage for at least one year, and many for much longer. Only those containing nuts, coconut, chocolate, or other fatty materials become stale or rancid.

Freezer Storage (0°F). The need and economic justification for freezing candy is the same as for any other food—better preservation for a longer time. This method of preservation is suitable for candies (1) in which high quality standards must be maintained; (2) in which a longer shelf life is desired than is accomplished from other methods of storage; (3) that are normally manufactured 6 to 9 months in advance of consumption; and (4) that are especially suitable for retailing as frozen items. Because of their high sugar content and low moisture content, little ice formation occurs in candies at 0°F.

One of the chief reasons for freezing candies is to hold them in an unchanged condition for as long as 9 months, then thaw and sell them as fresh candies. Experience shows that this is not only possible but also practical if the manufacturer (1) freezes only those candies that would lose quality when held at a higher temperature; (2) eliminates the few kinds that crack during freezing; (3) packages the candies in moistureproof containers similar to those used for other frozen foods; and (4) thaws the candies in the unopened packages to avoid condensation of moisture on the surface.

Moistureproof Packaging. Experiments show that candies for freezing require more protection than those for common storage because the storage period is usually longer and condensation on removal is more likely. A single layer of moistureproof material (e.g., aluminum foil, plastic film, or glassine) affords adequate protection. Candies not fully protected from desiccation become hard and grainy and lose flavor.

Adequate protection is provided when the moisture barrier is in contact with the candy in the form of a sealed, individual wrapper. Inner liners for the boxes protect candy, provided they are sealed (which is difficult and seldom accomplished). Moisture barriers are usually applied as overwraps for the boxes, chiefly because overwraps are easiest to apply and seal by machines. Overwraps provide less protection than wraps for individual pieces of candy because of the larger amount of air enclosed in the box. Also, boxes with extended edges offer less protection.

Thawing. Frozen candies should be thawed in the unopened packages. While freezing itself affects only a few types of candies, the manner of removal from storage affects all candies, especially those unprotected by special coatings or individual wraps.

Improvement. Candies that are improved in freshness, mellowness, or textural smoothness by freezing include those with high moisture content and without protective coatings or individual wrapping. Usually these are candies ordinarily subject to surface drying. Marshmallows, jellies, caramels, fudges, divinities, coconut macaroons, fruit loaves, coconut bonbons, panned Easter eggs, malted milk balls, and chocolate puffs are in this group.

Stability. The stability of candies after freezing is good. Candies may be held frozen for 6 months or more, carefully thawed, and then sold as fresh. Some candies are prepared especially for freezing. These are made of low-melting-point fat, have more flavor and softer texture than most candies, and should be eaten while they are cold.

Humidity Requirements

Sugar ingredients are stable over a wide range of storage temperatures, but they are sensitive to high or low humidity. The initial moisture content of candies largely determines the optimum relative humidity of the storage atmosphere. Candies with a moisture content of 12 to 16%—marshmallows, gumdrops, coconut sticks, jelly beans, and fudge—should be stored at 60 to 65% rh to avoid becoming (1) sticky, runny, or moldy or (2) hard and crusty. Candies with a moisture content of 5 to 9%—most fine candies, nougat bars, nut bars, hard and soft creams, bonbons, and caramels—should be stored at 50 to 55% rh to retain their original weight, finish, and texture. Candies with a moisture content below 2%—milk chocolate bars, chocolate covered nuts, and all kinds of hard candies—should be stored at 45% rh or lower.

The hygroscopicity of the ingredients also determines the relative humidity at which candies must be held to retain their original firmness and finish. Candies with a high proportion of invert syrups, such as taffy kisses, must be kept very dry, even though their moisture content is not extremely low. Other candies containing high proportions of invert syrup, honey, or corn syrup must be held in a drier atmosphere than the moisture content indicates.

Candies stored at low temperatures have a wider range of critical relative humidities than those stored at high temperatures. For example, nougat bars stored at 65% rh (10% too high) become sticky within a few days at room temperature, but at 40°F or lower, stickiness might not develop for many weeks. Similarly, marshmallows stored in a room with 55% rh (10% too low) become dry and crusty within a few days at room temperature, but at 40°F or lower, they show little change for several weeks. Refrigeration retards the ill effects of storage under improper humidity conditions. Humectants, such as sorbitol, glycerine, and high conversion corn syrup, are advantageous for maintaining original moisture content of certain candies.

NUTS

Commonly refrigerated nuts include peanuts, walnuts, pecans, almonds, filberts, chestnuts, and imported cashews and Brazil nuts. The advantages of refrigerated storage of nuts are the following:

- Marketable life is increased as much as 10 times.
- Natural texture, color, and flavor are retained almost perfectly from one season to the next.
- Staleness, rancidity, and molding are retarded for more than 2 years, depending on the temperature.
- Insect activity is arrested at temperatures below 48°F.

With optimum temperature, humidity, atmospheric conditions, and packaging, good-quality nuts may be successfully stored for up to 5 years.

Temperature

Other conditions being equal, the lower the temperature, the longer the storage life of nuts. Storage life may be doubled or tripled with each 20°F drop in temperature. The freezing points of nuts, depending on the moisture content, are about 23°F for chestnuts; 14°F for walnuts, pecans, and filberts; and 13°F for peanuts. Normal moisture content for stored nuts is as follows: chestnuts, 30%; peanuts, 6%; walnuts, 4.5%; pecans, 4%; and filberts, 3.5%.

Shelled nuts to be stored from one harvest season to the next without appreciable loss in quality must be held at 36°F or lower; those to be stored for 6 to 9 months must be kept at 48°F or lower; and all nuts stored for 4 to 6 months should be held below 68°F. Storage life at a given temperature doubles if the nuts are unshelled.

Relative Humidity

Although the storage temperature of nuts may range from 68 to –20°F or lower, the relative humidity must remain between 65 and 75%. This is to maintain the optimum moisture content for desired texture, color, flavor, and stability. If the moisture content rises as much as 2% above normal, the nuts (except chestnuts) darken, become stale, and may become moldy. If the moisture drops more than 2% below normal, the nuts become objectionably hard and brittle.

When the relative humidity is suitable, nuts that are too high or too low in moisture may be safely stored with the assurance that rapid air circulation will bring the moisture content to a safe level. In this sense, the storage room acts as a conditioning room.

Atmosphere

All nuts (again, except chestnuts) contain 45% or more oil and readily absorb odors and flavors from the atmosphere and surrounding products. Certain gases, particularly ammonia, react with tannin in the seed coats of nuts, causing them to turn black. Therefore, the atmosphere in the nut storage room must be free of all odors. This includes the containers, walls of the room, pallets, and other stored products.

Products that can be safely stored with nuts include dried fruits, candies, rice, and goods packaged in cans, bottles, or barrels. Commodities that should not be stored with nuts are onions, meats, cheese, chocolate, fresh fruits, and other products having an odor or a high moisture content.

Packaging

The storage life of nuts may be greatly influenced by the choice of package. Nuts become bruised when they are shelled, and oil *crawls* over the surface and onto the package in a very thin film.

Unless this crawling is retarded by a package that acts as a barrier, contains an antioxidant, or removes air by vacuum, the nuts become stale and rancid. Furthermore, some packaging materials (e.g., polyethylene) should be avoided because they impart an undesirable odor to the nuts.

DRIED FRUITS AND VEGETABLES

Dried fruits and vegetables differ from each other in the following ways:

1. Fruits contain sugars that render them more hygroscopic, harder to dry, and greater absorbers of moisture during storage.
2. Moisture in dried fruits may range from 32% with sorbate treatment to as low as 2%, while that in vegetables ranges from 7% to a low of 0.3%.
3. Dried fruits are acid, more highly colored, and more stable during storage than vegetables, which are nonacid.
4. Fruits are generally dried raw with active enzyme and respiration systems, while vegetables are blanched or precooked, with no active enzymes (thus, dried fruits are more responsive to storage temperature and humidity conditions than are vegetables).
5. The high sugar and acid content of dried fruits provides an adverse physical environment for bacteria, thus making their growth almost impossible even though the moisture level is higher than that in dried vegetables.

Dried fruits and vegetables maintain quality longer when stored at low temperatures. The storage life of dehydrated vegetables has been extended by packing them in a nitrogen or carbon dioxide atmosphere in the presence of a desiccant to achieve further reduction in moisture content. Staleness (charred flavor or off-flavor) and other deteriorative changes in dehydrated vegetables are inhibited by packing in nitrogen. In air-packed samples, the rate of staling is reduced at low temperature. Cut fruits and dried vegetables are widely treated with sulfite to retain color and extend storage life. A light coating of laundry starch applied to diced carrots prior to dehydration has achieved excellent results in retention of color and other quality factors during storage in cellophane at 84°F without sulfite.

Refrigerated storage at 40 to 50°F or lower retards and controls insect infestation. Substantial killing occurs with exposure at 32°F for 6 months or longer, and a temperature of 0°F kills insects within a few hours. An alternative method is fumigation, which is generally used in commercial practice.

Nonenzymatic browning (browning in products that have been scaled or blanched adequately to inactivate enzymes) is reduced in dehydrated vegetables at low temperature. Cold storage offers protection for several years.

Increasing the temperature of dried apricots accelerates oxygen consumption, carbon dioxide production, disappearance of sulfur dioxide, and darkening.

Molds and yeasts do not grow in dried fruits that have an adequate sulfur dioxide content or less than 25% moisture. At 32°F, relative humidity is less important than at higher temperatures.

Methods of dehydration include the following:

- **Dehydrofreezing.** Raw, prepared product is dried to about 50% in weight, followed by freezing. This method yields excellent fruit and vegetable products with storage at 0°F or lower. Concentration of juices by low temperature and high vacuum followed by preservation of the concentrate by freezing (Chapter 24) is another application of the process.
- **Freeze Drying.** Products to be freeze dried are usually frozen slowly to form larger ice crystals to increase process efficiency while retaining quality. Frozen product is placed in freeze-dry chambers, where moisture is removed by sublimation through the application of vacuum and low heat such that product porosity is preserved for subsequent reconstitution. This method is successfully used with products of high value, high protein, low fat, and low sugar content. Although refrigerated storage is not necessary to prevent freeze-dried food from spoiling, it is necessary in order to preserve maximum flavor and natural color.

Dried Fruit Storage

Refrigeration augments drying as a means of preserving fruits. The optimum conditions for holding most dried fruits are about 55% rh and just above the individual fruit's freezing temperature. Because the sugar content of these products is high, the freezing point varies from about 22°F to 26°F. Refrigerated storage helps in retaining natural flavor, ascorbic acid, carotene, and sulfur dioxide and in controlling browning, insects, rancidity, and molding. Other than for insect control, low humidity is more important than low temperature for storing dried fruit. Packaged, sulfured cut fruits keep adequately at higher humidities.

Although most dried fruits are adversely affected by softening and injured by freezing, dates are held best by freezing. Before storage, dried fruits should be brought to the desired moisture content.

When practical, dried fruits should be packed in moistureproof containers made of metal or foil that not only ensure a constant moisture content in storage, but also prevent injury from moisture condensation on removal from storage. The permeability of the packaging medium is extremely important due to the adverse effects of storage humidity. The following are dried fruit storage recommendations:

Raisins. At 32 to 40°F and 50 to 60% rh, sugaring is prevented for one year, provided the moisture content of the dried fruit is not unusually high. Raisins contain 15 to 18% moisture; for extremely long storage, the lowest possible moisture content should be maintained.

Figs. These may be held for a year at 32 to 40°F and 50 to 60% rh. A temperature of 55°F or lower prevents darkening for more than 5 months, and low humidity controls sugaring.

Prunes. These may be held for a year at 32 to 40°F and 50 to 60% rh. For storage of 4 to 5 months, a relative humidity of 75 to 80% is not detrimental.

Apples. At 32 to 40°F and 55 to 65% rh, dried apples retain excellent color and texture for more than a year. A relative humidity of 70 to 80% is not objectionable at 32°F, but at 40°F enough moisture may be gained to cause the fruit to mold within 8 months. Browning develops gradually at 40°F and above.

Pears. Same as for apples.

Peaches. Sun-dried freestone peaches are harder to store than most dried fruits. Therefore, the temperature should be held close to 32°F with a relative humidity of 55 to 65%. At 40°F and moderate humidity, the moisture pickup causes rapid molding and browning.

Clingstone peaches (dehydrated after steam scalding) should be stored at 32 to 40°F and 55 to 75% rh. Sun-dried peaches tolerate a slightly higher humidity than dehydrated peaches.

Apricots. Dried apricots are easy to keep in refrigerated storage at 32 to 40°F and 55 to 65% rh. They remain in excellent condition for more than a year. At 40°F and moderate humidity, there is enough gain in moisture content to cause molding.

Dates (sucrose or hard type). For storage of 6 months or less, dates may be held at 32°F and 70 to 75% rh, but for longer storage they should be stored at 24 to 26°F. Usually it is more convenient to store them at 32°F, at which temperature they can be stored for over a year.

Soft or invert sugar-type dates may be held for 6 months at 28 to 32°F, but if storage is for 9 to 12 months, the temperature should be 0 to 10°F. Uncured dates should be stored at 0 to 10°F.

Dried Vegetable Storage

Few specific recommendations for dehydrated vegetable storage temperatures are available. Low storage temperatures retard deterioration, but cold storage is considered necessary only for long storage periods. Among the advantages are (1) control of insects at 45°F or lower; (2) preservation of natural colors; and (3) retention of initial flavors and vitamins.

Because most dried vegetables have very low moisture content, are well packaged, and are usually surrounded by an atmosphere of nitrogen or rarefied air, refrigeration is less essential than it is for fresh vegetables.

CONTROLLED ATMOSPHERE

Low oxygen in the storage atmosphere suppresses the growth of insects and molds, retards rancidity and staleness, and reduces oxidative changes in flavors, odors, and colors. In small packages, oxygen can be reduced by vacuum; in storage and large shipping containers, oxygen can best be flushed out with nitrogen. Excellent results have been obtained by substituting up to 98% of the atmosphere with nitrogen. Nitrogen is preferred to carbon dioxide, ethylene, or other gases for storage of low-moisture products; it greatly extends the shelf life even with refrigeration.