accurately calculate the enthalpy of a food product for a commercial application certain precautions should be followed. It is necessary to know the exact moisture of the specific product. Errors in moisture content can vary the enthalpy by over 10 percent. The amount of water not frozen in the product should be known. This is very important with all foods but is especially so with fruits in which substantial quantities of sugar are added. Also the average temperature of the product before and after freezing should be accurately established. If some error is introduced by each of these factors a variation of over 20 percent could easily occur.

QUALITY CONTROL

The quality control program should be given major consideration by the frozen food packer. Quality control in the broader sense begins with the selection of varieties for freezing and extends through production, harvesting, handling, processing, freezing, distribution and marketing.

In covering the broader sense of quality control, the plant manager, foremen and fieldmen are involved in the program along with the quality control department which is responsible for carrying out several programs. Generally this department tests raw material for fieldmen to accurately determine and follow the development of the crop. Insect infestations and spray residue on raw material should be checked by the quality control group. Handling procedure for raw material should be established by quality control and enforcement of the program should also come under the same jurisdiction.

In the factory the sanitation program is of prime importance. Sometimes the clean-up crew works under the general supervision of the quality control director. Certain standards of sanitation should be established and the quality control representative should have the authority to prevent use of equipment which has not received proper cleaning. Washers, blanchers and quality separators should receive regular inspection during operation to assure satisfactory performance.

Grading of finished product is another important duty of the quality control department. Practically all frozen food packers use a standard of quality in evaluating their finished products. These standards may be of their own design or they may use grade standards developed by the Agricultural Marketing Service, USDA. The latter government grade standards are not mandatory but many frozen food buyers insist upon their use. The government grade standards can be used by the quality control workers. Government graders can be employed to grade the product continuously during production or sample and grade the product from storage. Some packers prefer to have government graders evaluate the pack as it is produced which allows the frozen food company to advertise that their operation is under continuous government inspection. Certificates, stating the product grade, are issued by the government graders.

Organoleptic evaluation of the products is very important. Generally the main evaluation is carried out once each day and management, production and quality control people participate. The product should be coded and the complete history, code and organoleptic ratings should be recorded.

Complete and factual records should be kept on each day's operation. These records are very valuable if complaints against the product are registered. Many times recurrence of the complaint can be prevented by examination of the records.

STORAGE OF FROZEN FRUITS AND VEGETABLES

Frozen foods undergo deteriorative changes during the period between production and consumption. The extent of such changes depends upon a number of factors, such as protection afforded by the package. However, the most important are storage temperature and storage time. In 1948 the Western Utilization Research Branch of the USDA at Albany, California, undertook a study of this subject. To date about 20 publications are available and additional information will be forthcoming. It is believed that herein lies the most significant problem before the frozen food industry at the present time.

Products vary as to their susceptibility to deteriorative changes when subjected to undesirable temperatures and times of frozen storage. Although a lower storage temperature requires higher refrigeration costs, this study clearly shows that frozen foods should be held at as low a temperature as commercially possible, at least 0 F, and for no longer periods than necessary.

The product temperature and length of time it remains at that temperature are important at each step in the distribution chain from the processing plant to the consumer. One day at a high temperature causes a quality loss equivalent to many days at the usual storage temperature. It makes no difference whether the temporary abuse is early or late in the storage period. The combined effect of time and temperature accumulates until the product becomes unacceptable.

Industry representatives and government officials agree that storage of frozen foods should be at 0 F or below. However, the maximum temperatures permitted during loading, transportation, and at the retail outlet is still under negotiation by these groups. Current information on legal requirements should be obtained from the National Association of Frozen Food Packers, Washington, D. C., or the Federal Food and Drug Administration, and state food regulating agencies.

DEHYDROFREEZING OF FRUITS AND VEGETABLES

Dehydrofreezing is a process involving both dehydration and freezing. Fruits and vegetables such as apples, apricots, peas and pimientos are dehydrofrozen by partially drying the product before freezing. The process retains the advantages of each of the two parent processes while eliminating, as far as possible, the disadvantages of each. Dehydrofreezing makes possible substantial savings in the cost of shipping and storing foods without sacrifice of product quality as compared with the frozen equivalent. How this is possible is best illustrated by considering the problems inherent in the dehydration process.

Dehydrated fruits and vegetables enjoy the advantages of greatly reduced weight and volume, but these advantages are gained at the expense of a marked deterioration in product quality. The bulk of this deterioration occurs during the final stages of drying as the temperature of the product gradually drifts from the wet bulb towards the dry bulb temperature of the air (Fig. 1). During this period of slow drying at high piece temperatures, deteriorative chemical changes, such as the Maillard type or the irreversible denaturation of proteins, can occur at appreciable rates. Rehydration of fully dehydrated foods is not only time consuming, but is also incomplete because of some of these changes.

The principal advantages of dehydration, size and weight reduction, are largely realized early in the drying cycle. More than 90 percent of the water normally removed during dehydration is evaporated during the first half of the drying cycle (Fig. 2). The resulting volume reduction is shown graphically in Fig. 3. Thus, for a product originally containing 84.5 percent moisture, dehydration to 50 percent moisture results in weight and volume reduction of approximately 67 percent. Further drying to 10 percent moisture reduces weight and volume by only a few percent more.

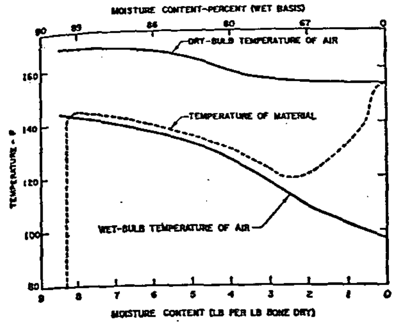

Fig. 1 .... Relation of Piece Temperature to Wet- and Dry-Bulb Temperatures

The dehydrofreezing process capitalizes on the space and weight saving advantages of dehydration without suffering the penalty of quality deterioration by terminating the drying operation after the bulk of the water has been evaporated, but before any deleterious quality changes occur. The partially dried product is then preserved by freezing and has the ease and convenience of frozen foods.

The dehydrofreezing process was first described in a patent application by Howard, Ramage and Rasmussen (1945), which eventually led to the issue of a patent assigned to the Secretary of the U. S. Department of Agriculture (1949). Early experimental studies were conducted on peas, carrots, potatoes, apricots, cherries and boysenberries. Since this early work, more detailed studies on dehydrofrozen fruits and vegetables have been conducted, for example, on the dehydrofreezing of peas and apples. In addition, considerable unpublished data has been accumulated in the laboratories of the Western Utilization Research and Development Division of the USDA on dehydrofrozen lima beans, pimientos, apricots, green beans and celery.

DEHYDROFREEZING PROCESS OPERATIONS

Preparation of Raw Material

The initial steps in preparing dehydrofrozen materials, up to but not including the dehydration step, are somewhat similar to those employed for freezing. However, with certain

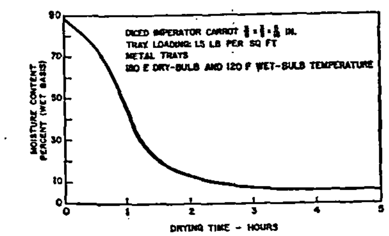

Fig. 2 .... Rate of Water Removal from Diced Carrots During Dehydration

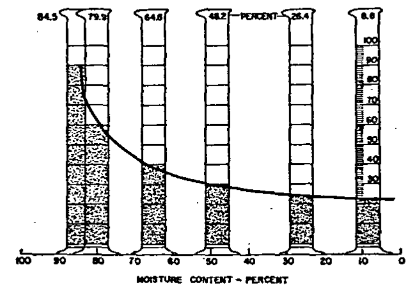

Fig. 3 .... Relation between Moisture Content and Volume of Carrots During Dehydration

commodities, problems arising during subsequent dehydration may necessitate certain changes in the methods of preparation. Washing, peeling, trimming and inspection procedures for preparing the various commodities are identical with those for freezing.

In frozen and canned commodities, uniformity of size of the units in the container is important primarily because of esthetic considerations. In dehydrofreezing, uniformity of piece size is one of the main factors in achieving uniform drying. Thus in the partial dehydration of apple slices or peas, a reasonable amount of size grading may be required to obtain more uniform moisture content in the individual pieces. Reasonably uniform drying is desirable so that dehydration can be continued to the point of maximum reduction in weight and volume without over-drying any of the material and causing irreversible changes which would make rehydration difficult or incomplete.

It is therefore important that deicing of products prior to dehydration be accomplished so as to produce a minimum amount of fines or undersized pieces.

Enzyme Inactivation

Adverse changes in the quality of frozen fruits and vegetables may be minimized by inactivating the enzymes with heat or by inhibiting enzymatic browning with chemicals such as sulfur dioxide or ascorbic acid. Enzymes cause the same type of adverse changes in dehydrofrozen products as in frozen ones. These undesirable changes are prevented by employing procedures quite similar to those in use in freezing preservation. In most vegetables, it is necessary to blanch or scald the vegetable sufficiently to inactivate the enzyme peroxidase. As in freezing preservation, there are certain vegetables, such as peppers and pimientos, that can be dehydrofrozen without any treatment to prevent enzymatic changes during storage.

Fruits such as apples, peaches and apricots, which undergo enzymatic browning when cut surfaces are exposed to oxygen, can be heated or treated with chemicals to prevent darkening during dehydration and subsequent storage. For fruits that soften excessively when heated, use of chemicals such as sulfur dioxide is preferable to heat for preventing enzymatic browning.

Dehydration

For present purposes, drying or dehydration refers to the process of evaporating water from prepared fruits or vege-