cooled by the boiling refrigerant (low side). The juice cycle is the same as in Fig. 1 except that the water vapor is directly and intimately mixed and condensed in cold water. The condensate is drawn from the hot well. The pressure is maintained by a relatively small steam ejector or mechanical vacuum pump. Note that the essential difference lies in interposing water as a heat transfer medium between the hot refrigerant and the juice, and between the vapor and the cold refrigerant.

Advantages of this system are:

1. Centrally located standard unitary refrigeration equipment can be used. Controls and instrumentation can be standard.
2. Refrigerant lines are short, and hold-up is low.
3. Evaporators need not be designed to hold refrigerant.
4. No danger of refrigerant contaminating the juice.
5. Very little steam or water are required. Steam is needed only to maintain pressure, and water only to remove heat of compression.

Disadvantages of this system are:

1. Because of the use of water as an intermediate heat transfer medium, the hot refrigerant gas must be hotter and the cold refrigerant must be colder than in Fig. 1. The suction to discharge temperature spread on the refrigeration unit is greater, and therefore, the energy input to the compressor per pound of water evaporated is greater than for Fig. 1.
2. Equipment for handling water streams is required for this process which is not required in Fig. 1.

Vapor Recompression and Thermo-Compression

Fig. 3 shows a schematic system for concentration in which the vapor from the juice, instead of being condensed, is compressed to a higher temperature and pressure and used to evaporate more juice. The vapor is compressed by a booster steam ejector. This can also be accomplished by a mechanical compressor, but to date none are being used for fruit juice concentration in this country.

The evaporator is heated with steam and the condensate is pumped out to drain. The juice cycle is similar to Figs. 1 and 2 except that the vapor is recompressed and eventually leaves the system as condensate. The work of compression is supplied by the high pressure steam fed to the booster ejector.

Advantages of this system are:

1. The capital investment for steam ejectors is low compared to that for refrigeration systems.
2. No low temperature condenser is required.
3. No intermediate water circulation system is required.

Disadvantages of this system are:

1. More steam is required than for either Fig. 1 or 2 and its use is relatively inefficient.
2. More cooling water is needed than for either Fig. 1 or 2.

Plate Evaporator

A plate evaporator, essentially a modified plate type heat exchanger, has recently been introduced to the concentrating processors with installations in Florida for oranges and in California for lemons. This unit combines the functions of heat treating and concentrating, single or multiple effect, with or without vapor recompression. It operates at a considerably higher temperature for a much shorter time than conventional equipment, with claimed improvements in product flavor.

The $\frac{1}{16}$-in. thick stainless steel plates with $\frac{1}{4}$-in. thick gaskets, operate in groups of 4 to provide a single-pass, climbing and falling film evaporator. Through suitable ported and sealed cut-outs, juice flows up between plates 1 and 2 and down between plates 3 and 4, with steam between plates 2 and 3, and 4 and 1 of each group. From the large discharge manifold the mixture of concentrate plus vapor passes to a horizontal cyclone separator. Using this equipment, orange juice has been concentrated from 10 percent solids to 72 percent solids; although at the higher, more viscous, concentrations, some of the concentrate must be recirculated to insure a wetted wall.

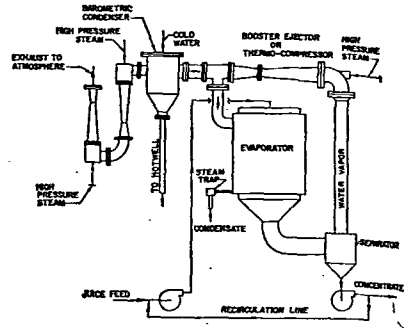

Fig. 3 . . . . System of Concentration Using Heat Pump Principle (Direct Vapor Recompression)

The following operational and performance data were obtained on an early production installation of plate evaporators for frozen orange concentrate:

a. Double effect (40 plates each) with vapor recompression.
b. 1800 gph feed, 245 gph product at 60 deg Brix (1300 lb per hr water removed).
c. Preheat feed to 200 F for 2½ to 3 sec.
d. Contact time with heat exchange surface is 10 sec.
e. First effect: 165 F, 19 in. vacuum.
f. Second effect with 30 percent recycle: 120 F, 27 in. vaccum.
g. Flash cooler: 80 F, 29 in. vacuum.
h. Total throughput time of 30–75 sec.

Compared to the conventional concentration methods, the plate evaporator requires approximately ½ of the capital, ½ of the building height (9 ft), ½ of the steam, ⅕ of the water and ¼ of the cleanup time (1 hr).

ORANGE JUICE

The production of frozen concentrated orange juice follows the general processing procedure detailed previously.

After the citrus juice and oil are extracted, as separate streams from the pulp by one of several conventional methods, the pecl oil content of the juice is measured. If it is found to exceed the value set by standards, adjustments are made in the extraction process by blending or diversion. To a certain extent, oranges are blended before the juice is extracted. Brix and acid values for extracted juice are determined at frequent intervals (hourly) as a check and control of the fresh fruit blending.

Immediately after concentrating, the juice is cooled to 20 to 32 F. The general rule at present is to concentrate to more than 42 deg Brix and then blend the concentrate with fresh juice, essence, or both to the standard Brix range of 41.5 to 43.5 deg Brix. It is conventional to blend sweet late season juice with tart, sour early season juice of the same crop of oranges through the bulk storage of the concentrate, thus extending the processing season (early is usually before July 1st in California). Proper blending is done on the basis of the data noted in the section Selection, Grading, and Storage. Frequently simultaneously harvested fruit will represent the earlier stages of one crop and the later stages of another.

These are blended by mixing oranges before juice extraction, again on the basis of grading and storing data.

United States standards for frozen concentrated orange juice have been established, effective 25 July 1949. In brief, they require that the best grade of concentrate when reconstituted "possesses the appearance of fresh orange juice, possesses a very good color; is practically free from defects; possesses a very good flavor."

A *very good color* is a bright yellow to yellow-orange color typical of fresh orange juice.

Defects refer to particles of membrane, core, skin, seeds and portions thereof, recoverable oil and others.

Very good flavor refers to that typical of fine distinct fresh orange juice extracted from fresh mature sweet oranges. Further standards are set for the ratio of Brix value to the weight percent of acid (as anhydrous citric acid). The range of standard Brix-to-acid ratios of Florida oranges is not less than 12 to 1 and not more than 18 to 1. The ratio for California oranges is not less than 10 to 1 nor more than 16 to 1.

The Brix value of the concentrate has been standardized at not less than 41.5 deg and not greater than 43.5 deg.

GRAPEFRUIT JUICE

In the production of frozen concentrated grapefruit juice, essentially the same equipment is used—fruit washers, finishers, falling film evaporators—as in the production of frozen concentrated orange juice. Some adjustments at the extractors are necessary to accommodate grapefruit, the larger fruit.

While either seedless or seeded grapefruit may be used, seeded varieties, such as the Duncan, are generally preferred because they tend to yield a product of better flavor. Zero storage of the product is recommended. As in the manufacture of the orange product, concentration is carried beyond that of the finished product (to 55 Brix or higher) and fresh *cut-back* juice is added until the desired strength is obtained. This cut-back juice restores much of the volatile aroma that was lost during the concentration. When reconstituted from properly prepared concentrate, the product is of excellent flavor and resembles the fresh juice closely.

Both sweetened and unsweetened frozen concentrated grapefruit juices have been produced—the sweetened product in greater quantities. Both types are covered by U.S. Department of Agriculture Grades. With the unsweetened product, the final Brix may vary from 38–42. The sweetened concentrate, exclusive of sweetening ingredient, must total at least 36 Brix, and the finished concentrate may vary from 38–48 Brix. The sweetening ingredient is added according to the Brix-acid ratio in the fresh juice and that desired in the finished product. Current opinion favors a Brix-acid ratio of about 12 to 1 in sweetened concentrates. It is intended that all the types mentioned be reconstituted by adding three parts of water to one of concentrate. Frozen concentrated grapefruit juices are covered by military specifications.

BLENDED GRAPEFRUIT AND ORANGE JUICE

Properly prepared frozen concentrated blended grapefruit juice and orange juice is of excellent quality and resembles the freshly prepared product. Although it is less popular than frozen concentrated orange juice, it finds a place in any line of frozen food products.

The same procedures are used in producing this blend as are used in preparing the straight products. During blending, cutback of both juices is added to restore fresh flavor and aroma.

Blended products of both sweetened and unsweetened types are covered by USDA Standards for Grades and military specifications. The USDA Grade standards recommend not less than 50 percent orange juice in the mixture and as much as 75 percent orange juice when it is light in color. The military specifications call for from 60–75 percent orange juice. With the unsweetened product, the USDA Grades call for 40–44 Brix in the final concentrate. With the sweetened product, the Brix value must be 38, exclusive of the sweetening ingredient, and from 40–48 in the finished product. Brix-to-acid ratios may vary from 8:1 to 18:1 with the unsweetened product and from 9:1 to 13:1 if sweetening ingredients are added.

TANGERINE JUICE

Differences in the nature of the tangerine require modification in the methods of handling during picking, hauling and storage at the plant. While the grapefruit and orange are generally round and quite firm and will withstand considerable rough handling, the tangerine is somewhat flat, irregular in shape, and has a loose, tender skin which is easily broken. If the skin is broken and the fruit bruised, bacteria and yeasts readily attack the fruit and undesirable enzyme actions occur. For these reasons they cannot be handled in orange bins but must be handled in boxes or loose in trucks to a depth of not over two feet. The Dancy tangerine is the common variety.

The processes and equipment used in manufacturing the concentrated tangerine juice are, however, practically the same as with oranges. Since the fruit is smaller, the yield of juice from a given number of extractors is smaller and about double the amount of extracting equipment is required to furnish juice to keep the evaporators operating at full capacity. Usually the freshly extracted juice is centrifuged in a continuous machine to remove a large portion of the suspended pulp and reduce the tendency for off-flavors to form.

USDA Standards for grades have not been established for frozen concentrated tangerine juice. Usually, the value for Brix-to-acid ratio, concentration and peel oil content follow closely those prescribed for the orange product. Some consider that the 41.5 Brix is a little too strong for a 4-fold tangerine product and believe that about 39 Brix results in a better reconstituted juice.

PINEAPPLE JUICE

Pineapple juice is prepared from small fruit and the parts of larger pineapples that are not suitable for packing as pieces of fruit. The main sources are the cores, the layer of flesh between the shell and cylinder that is cut for the preparation of pineapple slices, and juice which drains from the crushed pineapple. The juice material amounts to about ½ of the weight of the fresh fruit. It is inspected in order to remove pieces of shell and spoiled flesh. The juice is extracted by passing through disintegrators and screw presses. It is then centrifuged to remove heavy foreign material and excessive insoluble solids. Processing of juice up to this point is the same for the production of either single strength or concentrate.

Pineapple concentrate is produced from single strength juice in equipment similar to that used for the production of orange and other fruit juice concentrates. The first step in the concentrating operation is to strip out the volatile flavoring materials. These are separated as about a 100-fold product and added back to the final concentrate. The concentration takes place in multiple effect evaporators, with the final effect at about 70 F.

Pineapple concentrate is produced either as a 3-to-1 product which has a Brix of about 46.5, or as a 4½-to-1 product with a Brix of about 61 F. The 3-to-1 concentrate is produced in both a sterile and a frozen form; however, even the sterile product