RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

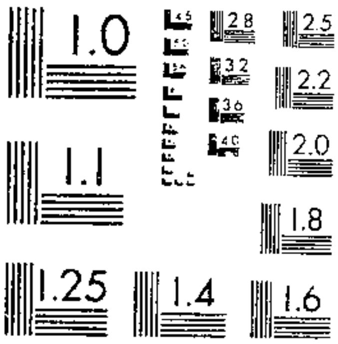
Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

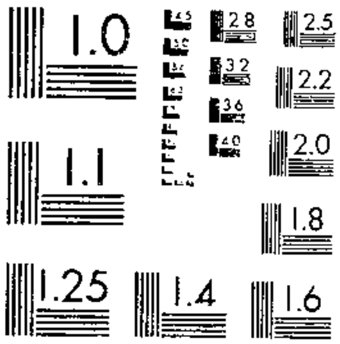
*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

TB 857 (1943) USDA TECHNICAL BULLETINS UPDATA
STAGE ICING IN THE REFRIGERATION OF ORANGES IN TRANSIT FROM CALIFORNIA
MANN, C W; GORMAN, E A JR; HUKILL, W V 1 OF 1

START



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TECHNICAL BULLETIN No. 857 — September 1943

UNITED STATES DEPARTMENT OF AGRICULTURE

WASHINGTON, D. C.

Stage Icing in the Refrigeration of Oranges in Transit from California [1]

By C. W. MANN, *senior pomologist*, E. A. GORMAN, JR., *principal scientific aide, Division of Fruit and Vegetable Crops and Diseases*, and W. V. HUKILL, *senior agricultural engineer, Division of Agricultural Engineering, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration*

CONTENTS

IMPROVING REFRIGERATION OF ORANGES IN TRANSIT

Wartime congestion of traffic on American railroads has seriously affected the movement of perishable freight as well as other commodities. This congestion has placed such a heavy burden on the railroads that every means of relieving the situation is being explored in order to release motive power needed to move war materials as well as ordinary commercial shipments. The greatly increased demand for all kinds of food, particularly the so-called protective foods like citrus fruit, which are highly important from a health standpoint, makes it desirable to adopt the most efficient means of transporting them. Otherwise the supply to people who live at a distance from the producing areas may be curtailed because high transportation costs and the use of relatively inefficient methods make it unprofitable for producers to continue to ship to those markets.

Studies reported in this bulletin show how California orange shippers can safely reduce the amount of ice they use, particularly in the newer types of refrigerator cars, by placing ice in only the upper half of the bunkers. This practice, called stage icing or upper-half-bunker

[1] Submitted for publication April 9, 1943. This work was conducted under the general direction of D. F. Fisher, principal horticulturist in charge of investigations on the handling, storage, and transportation of fruits and vegetables. Special acknowledgment is made of the generous cooperation extended by the California Fruit Growers Exchange, the Pacific Fruit Express Co., and the Santa Fe Refrigerator Department and also by the Southern Pacific Co., Union Pacific R. R., Atchison, Topeka, and Santa Fe Ry., the Chicago, Rock Island, and Pacific Ry. Co., Illinois Central R. R., the Belt Ry. Co. of Chicago, the Indiana Harbor Belt R. R. Co., Erie R. R., and connecting railroad lines over which the tests were conducted. D. F. Fisher, W. C. Cooper, C. J. Thompson, E. M. Harvey, C. O. Bratley, J. S. Wiant, and other members of the staff of the Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, actively assisted in the investigation. M. P. Masure, formerly of this Division, and Wilson P. Green, formerly of the Bureau of Agricultural Chemistry and Engineering, also assisted in the work.

icing, is in reality a most simple one, involving no special equipment in the newer cars and requiring no complicated description.

Stage icing not only reduces the ice bill but also saves needless freight costs—economies that vary in amount with the different types of refrigeration. Choice of a refrigeration service depends on the weather or the season of the year, the distance to the particular market, the kind of refrigerator car available and its physical condition, the condition of the fruit, and frequently the buyer's specifications. Whatever the choice, however, the possibilities of stage icing are too important to be overlooked. Considering that the refrigerated orange shipments from California amount to more than 50,000 cars annually and that ice costs $3.50 to $5 a ton, one can estimate the savings from stage icing, in the cost of ice, at nearly a million dollars to the fruit industry. At the same time the dead weight that must be hauled in order to protect the load adequately during shipment is reduced by as much as 6,000 to 9,000 pounds per car, depending on the type of refrigeration service. The possible saving to the railroads is also important because the unused ice left in cars with full-bunker icing when they are unloaded is ordinarily allowed to melt as the empty cars are hauled back to California—a waste of motive power that can ill be spared under war conditions.

The use of stage icing as a standard practice will be facilitated by an understanding of its development and of the experiments that demonstrated its value.

The refrigeration of citrus fruits in transit from California became organized as a protective service through the early attempts of fruit growers and operators of privately owned refrigerator cars to deliver the fruit in sound condition to markets in the Middle West and the East. The advent of the refrigerator car in California in 1888 made possible a change in the method of transporting citrus fruits from the relatively costly expedited-freight and ventilated-express service to shipment under refrigeration on slower freight schedules.

Thus was developed the standard refrigeration service under which the bunkers of the cars are re-iced at all regular icing stations en route, usually at least once every 24 hours. This service was intended to provide maximum protection for the more perishable agricultural products. For many years oranges had been considered in this category. As long as the prices received from the shipments yielded good profits to the growers and particularly with the earlier types of refrigerator cars, the necessity of using standard refrigeration was not seriously questioned. However, when returns began to shrink under the influence of greatly increased production and shippers had to cut costs, the United States Department of Agriculture was requested to start investigations to develop more economical methods of shipping oranges. As a result of these studies it was determined that California oranges are less exacting in their temperature requirements than most other fruits and that satisfactory market condition is obtainable by shipping them at an average transit temperature of 50° F. or lower, the rate at which the fruit is cooled being an important factor in preventing decay and in retarding softening and aging.[2]

The changes in the use of various refrigeration services for oranges and grapefruit in California in recent years are indicated in the record

[2] MANN, C. W., and COOPER, W. C. REFRIGERATION OF ORANGES IN TRANSIT FROM CALIFORNIA. U. S. Dept. Agr. Tech. Bul. 505, 88 pp., illus. 1936.

of shipments presented in table 1, which also shows the number of carloads moved under ventilation. The table includes about 72 percent of the total shipments for the three seasons, 1928–29, 1932–33, and 1940–41. It is based on the shipments of the California Fruit Growers Exchange, as carload shipments of other shippers were not available. The extent to which the modified refrigeration services tested in the earlier investigations have replaced standard refrigeration for citrus fruits in California can be seen by comparing the total shipments forwarded according to the methods used in the 1928–29 season and those of 1940–41. All of the iced shipments listed in table 1 moved under full-bunker icing.

Some preliminary studies of upper-half-bunker, or stage, icing of oranges and lemons were made in 1934. Half-tank refrigeration (stage icing) was already employed in the transportation of bananas, coconuts, and certain packing-house products, and had formerly been used to a limited extent for shipments of Florida oranges and of apples and other fruits in Virginia, Michigan, and Colorado.[3]

The study of stage icing, in comparison with full- and lower-half-bunker icing, of oranges in transit from California to New York was continued from 1936 to 1941 under various weather conditions. Stage icing was found to compare favorably with full-bunker icing in its effects on the rate of cooling of the fruit during transit. In all tests the top-layer temperatures were satisfactory for the control of decay and softening, regardless of the weather. Lower-half-bunker icing, on the contrary, was found to give fruit temperatures in the upper part of the load from 8° to 10° F. higher than were given by upper-half- or full-bunker icing and correspondingly more favorable conditions for softening and decay

Refrigeration of oranges in transit is obtained only from ice that is melted. Since this meltage was found to occur chiefly in the upper half of the bunkers, the actual surplus ice hauled between regular icing stations under standard refrigeration service is represented by the amount remaining in the bunkers when cars are re-iced. In these tests comparatively little of the ice in the lower half of the bunkers was melted in the refrigeration of nonprecooled oranges forwarded under standard refrigeration service.

Under full-bunker icing, standard refrigeration, the ice is kept at a high level in the bunkers by frequent re-icing, and this can be accomplished most economically by raising the grates for stage, or upper-half-bunker, icing. Stage icing reduces the average weight of ice that is hauled in the bunkers 50 percent or more and the gross weight of fruit and ice that is hauled by more than 12 percent.

The average weight of the ice hauled from California to Jersey City in upper-half-bunker icing of precooled fruit was usually little more than one-third that of full-bunker icing. Fruit that was precooled to about 40° F. or lower and forwarded in refrigerator cars having 6,000 to 7,000 pounds of block ice in the upper half of the bunkers usually required no re-icing en route during a 10- to 12-day period. In very warm weather, however, such shipments, if made in the older type cars, may require re-icing with 1 to 2 tons of ice. Re-icing may also be necessary in warm weather for shipments which are subject to delay en route or are held on track at destination.

[3] KELLEY, J. N. THE DEVELOPMENT OF THE REFRIGERATOR CAR AND ITS USE IN THE BANANA INDUSTRY. Chicago Car Foremen's Assoc. Proc. 34: 17–23. 1936.

TABLE 1.—*Shipments of oranges and grapefruit under various methods of refrigeration*

[Total shipments reported by California Fruit Growers Exchange; they amount to about 72 percent of the total for California and Arizona]

Type of service	Total	November		December		January		February		March		April	
	1928–29	1932–33	1940–41	1932–33	1940–41	1932–33	1940–41	1932–33	1940–41	1932–33	1940–41	1932–33	1940–41
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Standard ventilation		2,710	1,708	2,516	3,140	2,396	2,502	2,494	1,416	2,535	258	1,755	227
Standard refrigeration:													
Dry-car-loaded	30,861	44	10	0	0	0	0	0	0	0	0	0	6
Pre-iced by carrier	1,171	21	103	1	0	0	0	0	0	0	0	0	2
Precooled and pre-iced by shipper:													
No re-icing in transit	7,170	549	433	0	0	0	33	0	694	193	1,332	793	2,217
1 re-icing in transit		0	1	0	0	0	0	0	0	0	9	0	59
2 re-icings in transit [1]		0	0	0	0	0	0	0	0	0	0	0	0
Precooled and initially iced by carrier:													
No re-icing in transit	150	61	35	0	0	0	27	3	586	169	1,530	395	550
1 re-icing in transit		247	44	0	0	0	0	0	0	0	48	44	389
2 re-icings in transit [1]		0	0	0	0	0	0	0	0	0	0	0	0
Precooled only by carrier ("Do not ice")		0	0	0	0	0	21	0	17	0	0	0	0
Pre-iced or iced after loading by carrier:													
No re-icing in transit	2,828	7	11	0	792	0	1,155	1	285	21	291	18	226
1 re-icing in transit		4	5	0	0	0	4	0	11	0	13	7	32
2 re-icings in transit [1]		0	0	0	0	0	0	0	0	0	0	0	2
Pre-iced or iced after loading by shipper:													
No re-icing in transit		88	50	0	47	2	195	5	448	172	497	416	334
1 re-icing in transit		120	14	0	0	0	13	0	18	0	50	22	101
2 re-icings in transit [1]		0	0	0	0	0	0	0	0	0	0	0	0
Pre-iced and replenished at first icing station by carrier:													
No re-icing in transit		0	43	0	4	0	61	0	93	58	129	70	190
1 re-icing in transit		0	32	0	0	0	1	0	10	0	53	0	29
2 re-icings in transit [1]		0	0	0	0	0	0	0	0	0	0	0	0
Pre-iced car furnished, precooled, and replenished after precooling by carrier:													
No re-icing in transit		0	68	0	0	0	0	0	21	0	207	7	75
1 re-icing in transit		0	202	0	0	0	0	0	0	0	82	0	191
2 re-icings in transit [1]		0	0	0	0	0	0	0	0	0	0	0	0
Total	42,180	3,851	2,759	2,517	3,983	2,398	4,012	2,503	3,599	3,148	4,499	3,527	4,630

[1] Made available with shipments of March 25, 1941.

TABLE 1.—*Shipments of oranges and grapefruit under various methods of refrigeration*—Continued

[Total shipments reported by California Fruit Growers Exchange; they amount to about 72 percent of the total for California and Arizona]

Type of service	May		June		July		August		September		October		Total shipments	
	1932–33	1940–41	1932–33	1940–41	1932–33	1940–41	1932–33	1940–41	1932–33	1940–41	1932–33	1940–41	1932–33	1940–41
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Standard ventilation	1,150	159	1,034	8	540	13	333	2	231	4	317	42	18,011	9,479
Standard refrigeration:														
Dry-car-loaded	2	3	4	8	21	0	40	3	9	0	6	1	126	31
Pre-iced by carrier	0	6	0	27	2	4	2	0	0	188	0	193	26	523
Precooled and pre-iced by shipper:														
No re-icing in transit	1,606	1,454	877	2,009	977	3,067	1,015	2,553	1,293	2,466	1,777	2,136	9,080	18,394
1 re-icing in transit	0	39	0	35	0	72	0	148	0	118	2	62	2	543
2 re-icings in transit [1]	0	0	0	0	0	0	0	1	0	1	0	0	0	2
Precooled and initially iced by carrier:														
No re-icing in transit	302	173	459	142	311	44	215	88	247	81	242	105	2,404	3,361
1 re-icing in transit	33	287	444	308	491	338	499	222	473	136	318	221	2,549	1,993
2 re-icings in transit [1]	0	5	0	11	0	0	0	67	0	80	0	79	0	242
Precooled only by carrier ("Do not ice")	0	1	0	3	0	0	0	0	0	0	0	0	0	42
Pre-iced or iced after loading by carrier:														
No re-icing in transit	168	619	112	56	35	64	25	155	28	63	65	45	480	3,762
1 re-icing in transit	24	235	103	105	27	56	5	44	3	24	12	18	185	547
2 re-icings in transit [1]	0	8	0	4	0	1	0	5	0	2	0	0	0	22
Pre-iced or iced after loading by shipper:														
No re-icing in transit	212	466	189	404	221	401	222	346	217	388	184	427	1,928	4,003
1 re-icing in transit	185	267	198	315	301	346	192	295	178	244	181	187	1,377	1,850
2 re-icings in transit [1]	0	2	0	2	0	0	0	6	0	0	0	2	0	12
Pre-iced and replenished at first icing station by carrier:														
No re-icing in transit	159	883	366	732	93	274	157	236	279	221	351	175	1,533	3,041
1 re-icing in transit	0	887	301	360	412	144	515	133	360	100	263	77	1,851	1,826
2 re-icings in transit [1]	0	4	0	0	0	1	0	1	0	2	0	1	0	9
Pre-iced car furnished, precooled, and replenished after precooling by carrier:														
No re-icing in transit	33	137	209	144	165	205	195	307	186	194	352	198	1,147	1,556
1 re-icing in transit	0	723	168	970	382	1,394	357	1,257	306	833	171	886	1,384	6,538
2 re-icings in transit [1]	0	60	0	211	0	183	0	355	0	383	0	400	0	1,592
Total	3,874	6,418	4,464	5,854	3,978	6,007	3,772	6,224	3,810	5,528	4,241	5,255	42,083	59,368

[1] Made available with shipments of March 25, 1941.

When shipments are to be held on track it is cheaper to re-ice at destination than to haul this ice across the country. In re-icing at destination upper-half-bunker icing makes it possible to protect shipments by the use of less ice than is required in full-bunker icing.

Re-icing under upper-half-bunker icing service may be avoided on practically all direct shipments of precooled, pre-iced fruit to eastern markets if those shipments are made in the more heavily insulated refrigerator cars of recent construction. Most of the refrigerator cars built or rebuilt since 1936 have been equipped for stage icing as a result of the earlier tests described herein.

In the block icing of precooled oranges under full-bunker icing service, from 12,000 to 14,000 pounds of ice is placed in the car bunkers. Under upper-half-bunker icing the weight of the ice, or the nonrevenue freight load, may be reduced 50 percent or more. The tests indicate that only a small proportion of precooled shipments under stage icing require re-icing in transit and that it should be more economical for the carriers to forward these shipper-precooled, pre-iced loads under stage icing service than to haul full bunkers of ice from the loading point.

Records taken in the tests showed that in shipments of nonprecooled oranges under full-bunker icing, standard refrigeration, which are re-iced 9 or 10 times between California and New York, the bunkers are usually about seven-eighths full of ice when the cars arrive. When the cars are unloaded promptly on arrival, from 8,000 to 9,000 pounds of unused ice is left in the bunkers. With precooled, pre-iced shipments forwarded in efficient cars directly to auction markets without re-icing, the surplus ice remaining in the bunkers when the cars are unloaded often amounts to 6,000 to 8,000 pounds. The back hauling of this ice, which is sometimes not completely melted until after the cars reach California, increases the cost of the refrigeration service to the railroads and indirectly to the shippers through tariff rates.

Tests with cars equipped with fans showed that more efficient refrigeration was obtained in such cars than in standard refrigerator cars. However, the fruit tends to warm up if the cars are not unloaded promptly after reaching destination, because the fans operate only while the cars are in motion. In fan-equipped cars it was possible to obtain as good refrigeration for a 693-box load as for a 462-box load without fans. This finding is important because the shortage of refrigerator cars during the present emergency makes it necessary to increase the size of the load.[4]

When fans are used the air circulation is not dependent upon natural convection, and in this case the location of the ice is not very important. The air velocities are greater than with natural circulation. The air moves past the ice much more quickly and has less time to be cooled. For this reason the longer exposure to the larger mass of ice, which is provided in a full bunker, may result in lower air temperatures than the limited exposure in half-bunker icing, when forced circulation is used.

---

[4] The minimum load now prescribed by the Office of Defense Transportation is 2 layers of boxes on end (the old standard load) plus 1 layer flat, covering the entire area of the loading space; this amounts to 567 boxes for most cars.

EQUIPMENT AND METHODS

In the investigation reported herein the tests were planned to compare upper-half- or lower-half- with full-bunker icing and to show the relative effectiveness of the three methods. The effects of these methods of icing on the circulation of air in the car were studied on a number of test trips by use of electric anemometers, the readings being taken in the air channels under the floor racks (fig. 1). The air velocities 18 or 24 inches in front of the bulkhead of the ice bunker in the forward end of the car were determined for upper-half-, lower-half-, and full-bunker icing. These were correlated with the fruit and air temperatures, and data were obtained on the effect of diminishing ice in the bunkers on the circulation of air in the car.

These transit tests were conducted during different seasons of the year in cool, moderate, and hot weather. Records of fruit and air temperatures under the various methods of refrigeration were obtained (fig. 2). The amount of ice melted in transit and that remaining in the bunkers at destination and later when the fruit was unloaded were also recorded for each shipment.

Fruit and air temperatures were recorded at intervals of 6 to 8 hours during the trip from California to Jersey City, N. J. Temperature readings were taken with electric resistance thermometers (fig. 3, *A*), each set consisting of 12 thermometer bulbs and a master

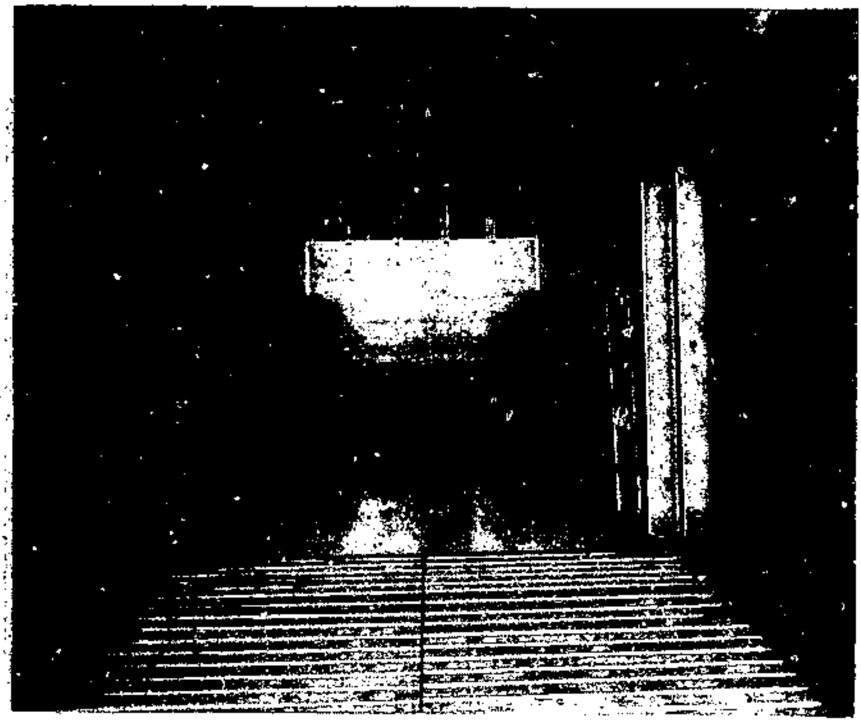


FIGURE 1.—Interior view of refrigerator car with floor racks in one end raised to show open channels under the racks formed by 2- by 4-inch supports, cross slats, and openings into ice bunkers.

FIGURE 2.—Weighing ice and filling the bunkers of refrigerator test cars. The blocks of ice were chopped into 20- to 50-pound pieces.

cable. The bulbs were inserted in the pulp of the fruit at 8 or 10 different locations in each car or were suspended in the air at certain key positions (fig. 3, *B*).

In some cases two or more sets of thermometers were used in the same car to obtain temperature readings at additional locations. The thermometer leads were connected to a master cable which extended to the running board on top of the car, where readings were taken with a suitable indicator.

Fruit temperatures were taken in the lower halves of the boxes in the bottom layer of the load and in the top halves of the boxes in the top layer. (See p. 9 for method of stowing boxes.) The thermometers were usually placed in the half of the load in the forward end of the car, in stacks 1, 4, 8, and 12, numbering from the ice bunker. Each was inserted in a fruit about halfway from the center to the outside of the box. The boxes in which the thermometers were placed were in the center row of the load. Other positions were sometimes used, the thermometers being placed in top- and bottom-layer fruit at the center of the load between the car doors or at the north or south side of the load in the doorway and in stack 8.

The amount of ice melted in transit under upper-half-, lower-half-, and full-bunker icing was obtained by means of drip meters designed for this purpose.

The rate at which the ice melted during the first few days of the trip when the fruit was cooling most rapidly, and later when the ice was melted chiefly by heat transmitted through the car insulation, was recorded by meter readings taken several times a day during the trip.

Refrigerator cars of the Pacific Fruit Express Co. and the Santa Fe Refrigerator Department were used in the tests. These included both new or recently rebuilt cars and others that had been in service for several years. In the earlier tests of upper-half-bunker icing the ice grates had to be raised on temporary supports to the desired height. In the cars used in the later tests the bunkers were permanently equipped for stage icing when the cars were built (fig. 4).

The older refrigerator cars used for California fruits are of conventional wood construction and are equipped with end ice bunkers of the wire-basket type. Those of more recent construction are of the same general design but have heavier insulation—3 inches in sides, ends, and roof, and 3½ inches in the floor—and many have steel sheathing. The height of the floor racks is 5 inches in the newer cars and 4 inches in those of earlier construction. The older cars included in the tests had about 1 inch less insulation in the car bodies. (Many of these have since been rebuilt with heavier insulation.) The inside dimensions are approximately 33 feet 2¾ inches between ice bunkers, 8 feet 2¾ inches between side walls, and 7 feet to 7 feet 2¼ inches from floor rack to ceiling.

The standard load of oranges consists of 462 packed boxes, 33 stacks long, 7 rows wide, and 2 layers high, boxes on end. It is possible, especially in the newer cars with higher ceilings, to increase the load to 693 boxes by adding a third layer. In the 3-layer-high load there is an air space of about 6 to 8 inches between the top of the boxes and the ceiling of the car.

FACTORS IN REFRIGERATION OF ORANGES

In shipper-precooled, pre-iced shipments of oranges the ice is largely melted in absorbing heat which passes through the insulation and structural materials of the car body and through small openings that may occur around the doors and ventilators or in other parts of the car. Relatively a very small amount of ice is melted in cooling the interior of the car itself. In cars loaded with warm fruit the ice is melted chiefly in cooling the fruit. There is some meltage of ice by heat that is produced in the respiration of oranges; this varies with the temperature of the fruit. When the average fruit temperature is 72° F., the heat produced by the respiration of a carload of 462 boxes of oranges during each period of 24 hours has been found to be

FIGURE 3.—*A*, Master cable and thermometer leads suspended from ceiling of refrigerator car. *B*, A partly loaded test car showing electric resistance thermometers as used in tests. The bulbs were inserted in the fruit at different locations in boxes in top and bottom layers as the cars were loaded.

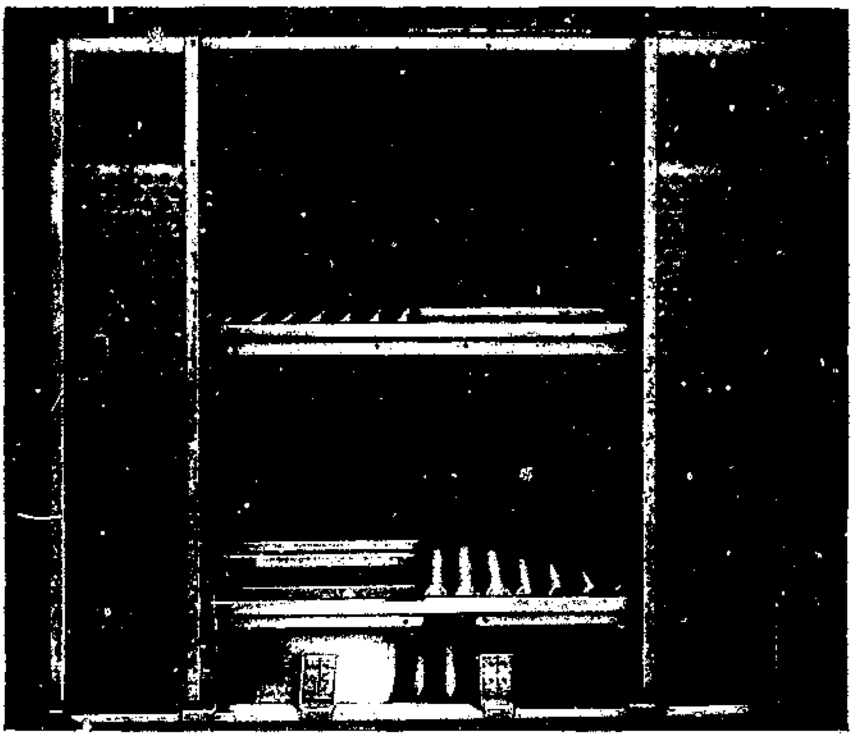


FIGURE 4.—An all-steel ice bunker equipped for upper-half-bunker, or stage, icing, illustrating the position of the grate bars for full-bunker icing (*A*) and for upper-half-bunker icing (*B*).

the equivalent of 467 pounds of ice meltage; at 40° the heat produced in 24 hours is equivalent to 115 pounds of ice meltage, according to Mann and Cooper.[5] Accordingly, during the 9¼-day trip from California to Jersey City the total heat of respiration of a carload of precooled oranges having an average temperature of 40° would account for the meltage of less than 1,100 pounds of ice.

Since in precooled shipments ice is melted principally in absorbing the heat which enters from the outside, the amount of ice melted during any period in transit will vary with the outside temperatures, but rapid fluctuations in the temperature may have little effect on the average rate of meltage. During cool weather the ice melted on the entire trip may be only a small part of the total amount placed in the bunkers. In very warm weather meltage of ice is much greater, even in the more efficient refrigerator cars.

PRECOOLING AND CAR-ICING PRACTICES

About 38 percent of the oranges shipped under refrigeration from California are precooled in the warehouse-type precooling plants of packing houses (shipper-precooled). The fruit forwarded from packing houses not having precooling facilities is either shipped in iced cars without precooling or precooled after loading, practically all of this

[5] See footnote 2, p. 2.

precooling being done at railroad-operated plants (carrier-precooled). Carrier precooling is performed in about 8 hours, while from 72 to 94 hours is required to lower the temperature of the fruit to 40° F. or below at shipper-precooling plants. The warehouse type of precooling, used at the packing houses, usually provides for more thorough cooling than is obtained under the car-precooling systems of the railroads.

Records obtained in earlier transportation tests with precooled shipments of oranges showed that often less than half of the ice placed in the bunkers of the cars in California was melted by the time of unloading at market. The possibility of reducing refrigeration costs by using upper-half-bunker, or stage, icing was suggested from the amount of surplus ice. This surplus was noted not only in many shipper-precooled, pre-iced shipments in which there was an initial icing of 14,000 to 15,000 pounds of block ice but also in cars iced to capacity with chunk ice (mostly 10,000 to 11,000 pounds) by the railroads. In view of this it appeared desirable to determine the comparative efficiency of upper-half-, lower-half-, and full-bunker icing in the refrigeration of both shipper-precooled, pre-iced oranges and nonprecooled oranges re-iced at all regular icing stations en route under standard refrigeration as well as under various modified refrigeration services.

Shipments that are precooled and pre-iced by the shipper are iced with block ice at the packing house. In this method of icing the whole 300-pound blocks are corded in the bunkers, more of the space being filled than when chunk, coarse, or crushed ice is used. Chunk ice is ice broken in pieces not exceeding 100 pounds, coarse ice that in pieces of 10 to 20 pounds each, and crushed ice that in pieces of about 1 pound each or less.

TRANSPORTATION TESTS

In the earlier investigations of Mann and Cooper [6] it was found that temperatures obtainable in the shipment of California oranges under various types of modified refrigeration in which the fruit was cooled in transit to about 40° to 45° F. were generally comparable with those furnished by standard refrigeration and that these temperatures are desirable to insure satisfactory market condition of the fruit upon arrival at eastern destinations. However, differences of a few degrees only in the temperature of the fruit usually have less effect on the condition of the fruit in transit than such factors as maturity and relative freedom from mechanical injuries resulting from improper methods of handling of the fruit in harvesting and in its preparation for shipment. Therefore, prompt cooling of warm fruit and maintaining transit temperatures below 50° are usually necessary for the control of decay, softening, and aging of oranges in transit. The tests comprising the present investigation were concerned chiefly with the relative effectiveness of full- and half-bunker icing in producing satisfactory refrigeration for oranges in transit.

Shipments of oranges from California under standard ventilation are made chiefly from about November 1 to February 15, after which they are forwarded under some form of refrigeration. During warm summer weather more attention is given to re-icing in transit. The

[6] See footnote 2, p. 2.

chief factors which influence the amount of ice used are the loading temperature of the fruit and the outside temperatures en route. Since there is a considerable difference in the normal temperatures encountered during the spring and summer months on all the routes, the transportation tests have been roughly grouped with reference to the season of the year when they were made. The prevailing outside temperatures rather than the date of the test determined the grouping.

Tests Conducted During Moderate Weather

NONPRECOOLED FRUIT UNDER STANDARD REFRIGERATION

Shipments under full- and half-bunker icing were included in a transportation test from California to Jersey City, June 3 to 12, 1936, when outside tempera-

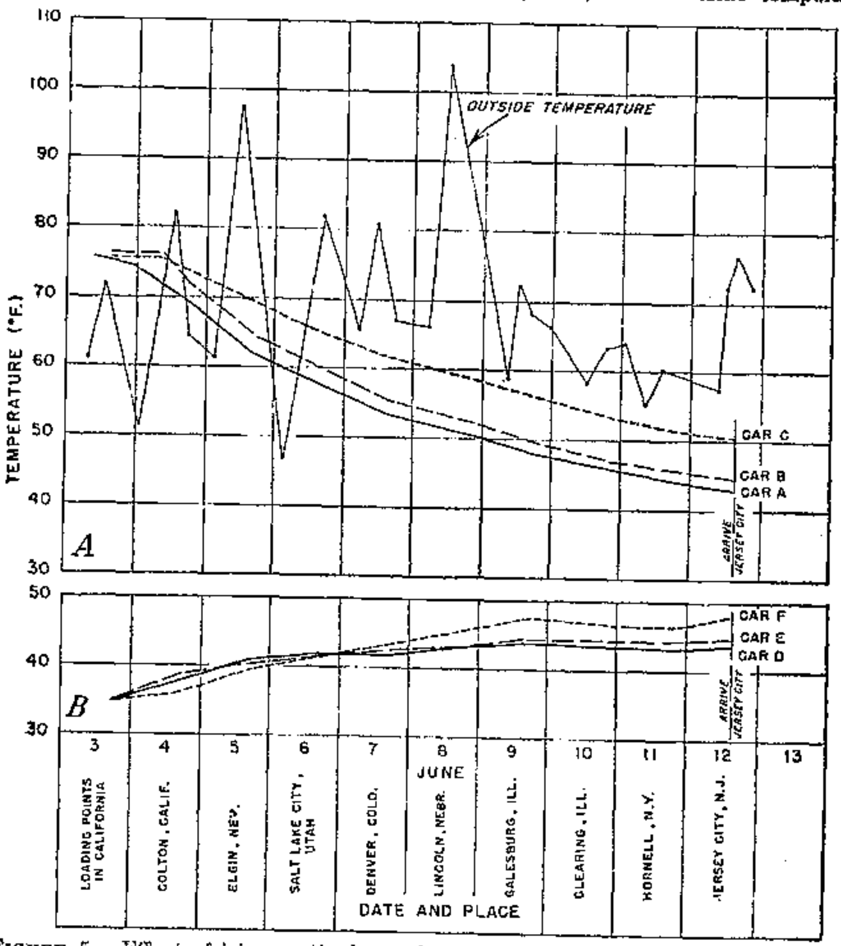


FIGURE 5.—Effect of icing methods on the top-layer temperature of oranges en route from loading points in California to Jersey City, N. J., via Union Pacific R. R., the Denver and Rio Grande Western R. R., Chicago, Burlington and Quincy R. R., the Belt Ry. of Chicago, and Erie R. R., June 3 to 12, 1936 (United States Department of Agriculture 1936 test No. 1): *A*, Nonprecooled fruit, under standard refrigeration; *B*, precooled fruit, pre-iced, not re-iced. Cars A and D, full-bunker icing; cars B and E, upper-half-bunker icing; cars C and F, lower-half-bunker icing.

tures encountered averaged 68° F. The effect of the icing methods used in the refrigeration of nonprecooled oranges is shown in figure 5, *A*. All the cars in this test were of conventional type with wood superstructure. Those used for nonprecooled fruit were pre-iced the day before loading and re-iced at all regular icing stations en route, standard refrigeration service.

A comparison of top-layer temperatures of car A (full-bunker icing) and car B (upper-half-bunker icing) shows about equally satisfactory refrigeration of the fruit under the two methods (fig. 5, *A*). After the first day the fruit in car B cooled at about the same rate as that in car A. The record of car C indicates that lower-half-bunker icing resulted in much slower cooling of the fruit than upper-half- or full-bunker icing. During the trip 62 percent of the ice in car A, 76 percent in car B, and 74 percent in car C melted. The icing records of the three cars are given in table 2.

TABLE 2.—*Icing records, United States Department of Agriculture 1936 orange-transportation test No. 1*

Place	Date	Time	Weight of ice in— Cars with nonprecooled fruit: A (full bunker)	Cars with nonprecooled fruit: B (upper-half bunker)	Cars with nonprecooled fruit: C (lower-half bunker)	Cars with precooled fruit: D (full bunker)	Cars with precooled fruit: E (upper-half bunker)	Cars with precooled fruit: F (lower-half bunker)
			Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Orange, Calif.	June 3	1:35 p. m.				14,353		
Do.	do.	2:15 p. m.					7,062	
Do.	do.	2:55 p. m.						7,087
Los Angeles, Calif.	June 4	4:00 a. m.	10,600					
Colton, Calif.	do.	10:15 a. m.		5,300				
Do.	do.	10:45 a. m.			5,300			
Do.	do.	3:25 p. m.	1,554	657	466			
Las Vegas, Nev.	June 5	12:15 a. m.	3,411	3,023	2,666			
Milford, Utah	June 6	5:15 a. m.	1,507	1,781	1,538			
Salt Lake City, Utah	do.	4:50 p. m.	932	1,026	1,190			
Grand Junction, Colo.	June 7	6:10 a. m.	991	858	1,323			
Denver, Colo.	do.	9:55 p. m.	1,001	1,248	1,042			
Lincoln, Nebr.	June 8	7:10 p. m.	1,182	939	987			
Galesburg, Ill.	June 9	7:40 p. m.	1,401	1,733	1,400			
Clearing, Ill.	June 10	10:30 a. m.	602	640	1,144			
Marion, Ohio	June 11	2:15 a. m.	551	1,051	42			
Hornell, N. Y.	do.	11:00 p. m.	608	814	818			
Total ice supplied			24,670	19,070	17,916	14,353	7,062	7,087
Ice in bunkers at Jersey City, N. J.	June 12	5:00 p. m.	9,300	4,600	4,600	8,100	1,800	2,550
Ice melted in transit			15,370	14,470	13,316	6,253	5,262	4,537
Ice in bunkers at unloading	June 14	5:00 p. m.					750	
	June 15	6:00 p. m.				7,200		1,000

In a test en route in June 1937 data were also obtained on comparable shipments of nonprecooled oranges under full- and half-bunker icing, standard refrigeration. These shipments were loaded in dry cars which moved under ventilation from the packing houses to the icing station at San Bernardino, Calif., where they were initially iced. They were re-iced under standard refrigeration service at nine additional icing stations between San Bernardino and Jersey City (table 3). Top-layer temperatures at San Bernardino, as shown in figure 6, *A*, varied from 69° to 72° F. The fruit in car B (upper-half-bunker icing) cooled in transit at about the same rate as that of car A (full-bunker icing). Lower-half-bunker icing (car C) resulted in less satisfactory refrigeration of the fruit than either full- or upper-half-bunker icing.

The weights of ice taken at points where the cars were iced in transit and the weights remaining at destination are given in table 3. Only 58 percent of the ice supplied to car A melted in transit, whereas 72 and 70 percent, respectively, melted in cars B and C. The surplus ice in the bunkers when the cars arrived at Jersey City would have been largely wasted if the cars had been unloaded immediately. Since approximately the same temperatures were maintained in cars A and B, it is evident that more economical refrigeration was maintained with upper-half- than with full-bunker icing. In addition a great saving resulted to the railroads in the reduced weight of ice hauled in car B. It is evident that the effectiveness of refrigeration depended on both the proportion of the ice melted and the air circulation (p. 26), which affects especially the cooling of the fruit in the top layer. Although approximately as much ice was melted in car C as in car B, the cooling was less satisfactory than in cars A and B, apparently as a result of slower circulation of air.

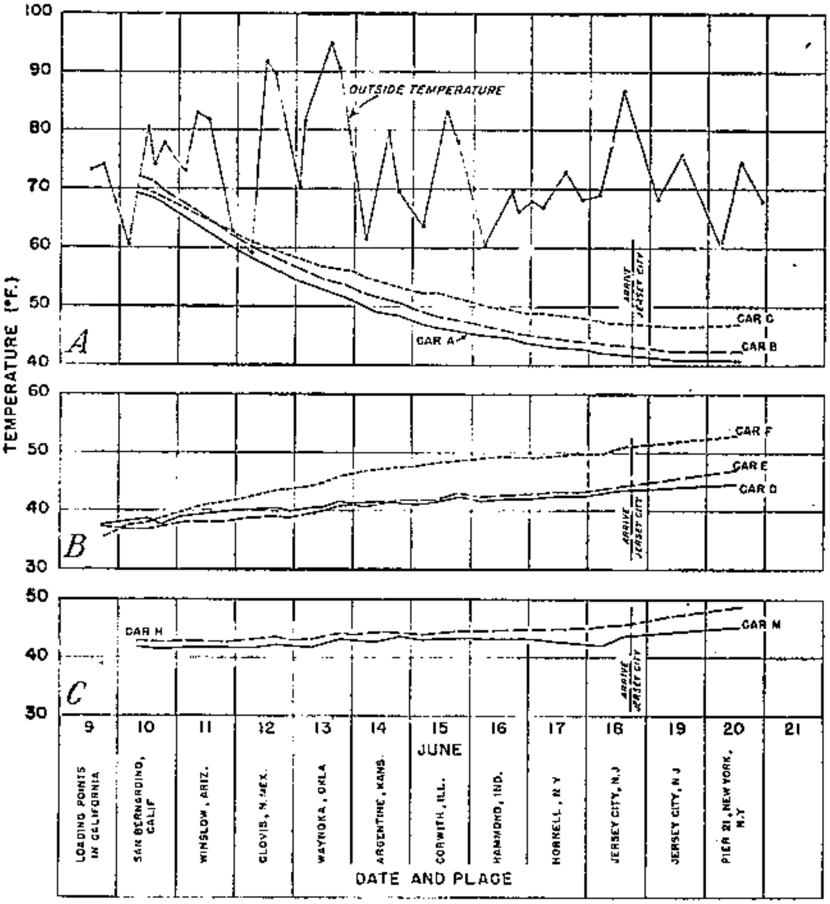


FIGURE 6.—Effect of icing methods on the top-layer temperature of oranges en route from loading points in California to New York, N. Y., via Atchison, Topeka, and Santa Fe Ry., the Belt Ry. of Chicago, and Erie R. R., June 9 to 20, 1937 (United States Department of Agriculture 1937 test No. 1): *A*, Nonprecooled fruit under standard refrigeration. *B*, Precooled fruit (35° to 37° F.), pre-iced, not re-iced. *C*, Precooled fruit (42° to 43°), pre-iced, not re-iced. Cars A, D, and M, full-bunker icing; cars B, E, and H, upper-half-bunker icing; cars C and F, lower-half-bunker icing.

SHIPPER-PRECOOLED FRUIT, PRE-ICED, NOT RE-ICED

In 1936 test No. 1, June 3 to 12, there were also shipments of precooled oranges under full-bunker (car D), upper-half-bunker (car E), and lower-half-bunker (car F) icing. The record of these three shipments is presented in figure 5, *B*. The fruit was loaded at a temperature of 34° F. As shown by the graphs, top-layer temperatures of cars D and E were about the same during the entire trip from California to Jersey City; the average temperature of the top layer of car D increased from 34° to 43.5° and of car E from 34° to 45°.

TABLE 3.—*Icing record, United States Department of Agriculture 1937 orange-transportation test No. 1*

Place	Date	Time	Weight of ice in—							
			Cars with nonprecooled fruit			Cars with precooled fruit				
			A (full bunker)	B (upper-half bunker)	C (lower-half bunker)	D (full bunker)	E (upper-half bunker)	F (lower-half bunker)	M (full bunker)	H (upper-half bunker)
			Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Loading point, Calif	June 9									
San Bernardino, Calif	June 10	7:00 a. m.				13,508	6,754	6,754	13,508	6,754
Do	do	8:00 a. m.	11,796	5,898	5,898					
Needles, Calif	June 11	3:30 a. m.	2,058	1,557	1,764					
Winslow, Ariz	do	9:30 p. m.	1,415	1,711	1,798					
Belen, N. Mex	June 12	11:00 a. m.	994	1,409	1,125					
Clovis, N. Mex	do	10:40 p. m.	1,308	1,049	971					
Waynoka, Okla	June 13	1:00 p. m.	899	896	608					
Argentine, Kans	June 14	11:15 a. m.	1,877	1,733	1,910					
Corwith, Ill	June 15	9:30 p. m.	1,929	2,224	1,806					
Marion, Ohio	June 17	3:00 a. m.	851	1,054	1,046					
Hornell, N. Y	do	11:00 p. m.	719	826	624					
Total ice supplied			23,846	18,357	17,550	13,508	6,754	6,754	13,508	6,754
Ice in bunkers at Jersey City, N. J	June 18		10,000	5,200	5,200	5,900	1,100	1,700	5,100	400
Ice melted in transit			13,846	13,157	12,350	7,608	5,654	5,054	8,408	6,354
Ice in bunkers at unloading	June 20		8,000	2,600	3,400	3,400	300	1,100	2,900	2

As indicated in the graph for car F, lower-half-bunker icing permitted fruit temperatures to rise faster than upper-half- or full-bunker icing during the first 6 days, when outside temperatures were highest. During the whole trip the average temperature of the top layer increased from 34° to 47.7° F.

It will be noted from table 2 that 44 percent of the ice in car D, 75 percent of that in car E, and 64 percent of that in car F melted in transit. At the time of unloading there was more ice left in car D than there was in cars E and F at the beginning of the test.

EFFECT OF TEMPERATURE AT LOADING

The refrigeration methods tested with the steel-sheathed cars of the Pacific Fruit Express Co., just discussed, received further study in a later test with similar refrigerator cars of the Santa Fe Refrigerator Department. The shipments in this test, United States Department of Agriculture 1937 test No. 1, were en route from California to Jersey City from June 9 to 18, 1937. Outside temperatures were about normal for the first 5 days of the trip from San Bernardino to Argentine, Kans., and slightly below normal during the remainder of the trip, with the average of 73° F. for the entire period.

Shipments of precooled oranges receiving full- and half-bunker block icing are compared in figure 6, *B*. The oranges in car D (full-bunker icing) and in car E (upper-half-bunker icing) were precooled to a temperature of about 37° F. As indicated in the graphs, the average top-layer temperatures in cars D and E were nearly the same during the entire trip from California to Jersey City. While the cars were on track, 2 days after arrival at Jersey City the temperature of the fruit in car E increased slightly more than that in car D, owing to the small amount of ice in the bunkers of car E. The unsatisfactory refrigeration from lower-half-bunker icing is indicated in the graph for car F. The top-layer fruit of this car increased 15°, or from 35° to 50°, during the trip, and there was a further increase to 53° during the 2 days the car was held before being unloaded. This rapid rise in the temperature of the fruit should be compared with that of car D in which the fruit warmed up only 6° in transit, from 37° to 43°, and with that of car E, which warmed up 7°, from 37° to 44°.

The icing records of cars D, E, and F are given in table 3. The percentages of ice melted in transit were, respectively, 56, 84, and 75.

EFFECT OF SIZE OF LOAD

Upper-half-bunker icing of standard and heavy loads of oranges was tested in shipments en route to Jersey City from June 5 to 14, 1940. Average top-layer and bottom-layer temperatures in car A (462 boxes) and in car B (693 boxes) are shown in figure 7.

As indicated by the graphs, there was only 1° to 3° F. difference in the temperature of the fruit in the two cars during the trip. The top-layer temperature in car A rose from 36° to 45° and in car B from 37° to 48°. Temperatures in the bottom layer were about 1° to 2° lower than those in the top layer during most of the trip.

The icing records of the two shipments are given in table 4. The cars were pre-iced at the packing house with 8,400 pounds each of block ice and neither car was re-iced en route to Jersey City. In car A 81 percent of the ice melted and in car B 62 percent. In this, as in other tests with oranges precooled to 40° F. or below, increasing the load 50 percent did not result in increased meltage of ice; usually less ice melted in transit with the heavier load, probably because of the greater mass of cold fruit.

Shipments of oranges precooled to about 42° or 43° F. were also forwarded in this test under full-bunker (car M) and upper-half-bunker block icing (car H). Transit temperatures of these shipments are shown in figure 6, *C*. At the higher loading temperature upper-half-bunker icing afforded nearly as satisfactory refrigeration as full-bunker icing. A comparison of cars D and E (fig. 6, *B*) with cars M and H (fig. 6, *C*) shows that the fruit precooled to 37° warmed up about 6° to 7° in transit and that precooled to 42° or 43° warmed up about 2° or 3°. The lower precooling temperature of the fruit in cars D and E resulted in less meltage of ice in transit (table 3). During transit 62 percent of the ice in car M and 94 percent of that in car H was melted.

In a later test conducted in June 1941 the refrigeration of heavy loads of oranges under full- and upper-half-bunker icing was tested on shipments in fan-equipped refrigerator cars. The fans were permanently installed under the

TABLE 4.—*Icing record, United States Department of Agriculture 1940 orange-transportation test No. 2*

Place	Date	Weight of ice in cars with precooled fruit	
		A (upper-half bunker)	B (upper-half bunker)
		Pounds	*Pounds*
Loading point, Calif	June 5	8,400	8,400
Ice in bunkers at Jersey City, N. J	June 14	1,600	3,150
Ice melted in transit		6,800	5,250
Ice in bunkers at unloading	June 16	50	1,250

floor racks adjacent to the ice bunkers. Fans of the type used are driven from the car wheels. A special design of the housing caused the air, while the fans were operating, to flow upward through the ice bunkers and out over the top of the load, thus reversing the normal direction of circulation of air in the car.

In this test car A contained a shipment of 462 boxes of oranges and car B 693 boxes, both under full-bunker icing, and car C 693 boxes, under upper-half-bunker icing. Cars B and C containing the heavy loads were equipped with fans. The fans were not operated while the cars were en route from the packing houses to the railroad yard at San Bernardino, but they were in continuous operation while the cars were in motion between that point and Jersey City.

The results of the test are presented in figure 8. The graphs for cars B and C indicate that during the trip from the packing houses to San Bernardino the tem-

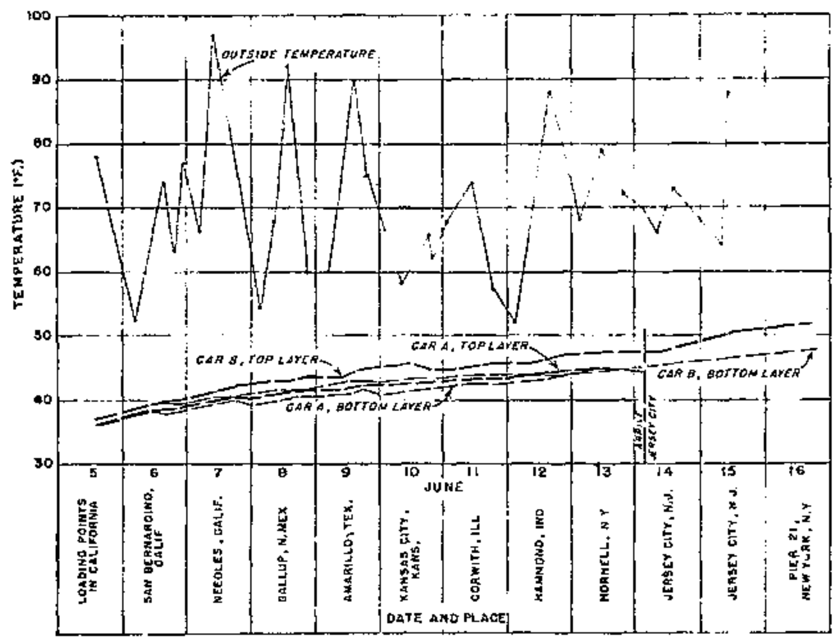


FIGURE 7.—Effect of size of load on the temperature of precooled oranges, pre-iced, upper-half-bunker icing, en route from loading points in California to New York, N. Y., via Atchison, Topeka, and Santa Fe Ry., the Belt Ry. of Chicago, and Erie R. R., June 5 to 16, 1940 (United States Department of Agriculture 1940 test No. 2). Car A, 462 boxes, pre-iced, precooled, upper-half-bunker icing; car B, 693 boxes, pre-iced, precooled, upper-half-bunker icing.

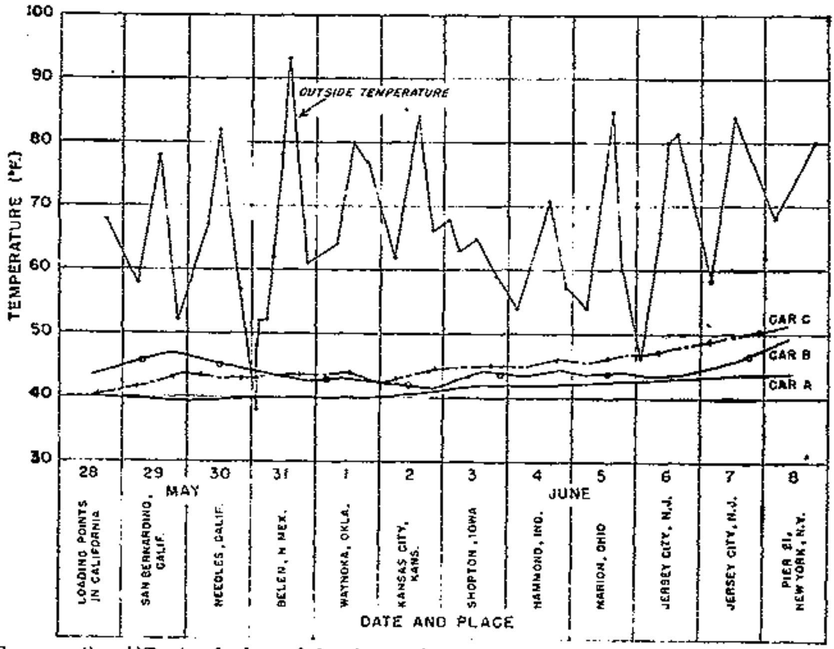


FIGURE 8.—Effect of size of load on the top-layer temperature of precooled oranges, pre-iced, not re-iced, en route from loading points in California to New York, N. Y., via Atchison, Topeka, and Santa Fe Ry., the Belt Ry. of Chicago, and Erie R. R., May 28 to June 8, 1941 (United States Department of Agriculture 1941 test No. 1). Car A, 462 boxes, precooled, pre-iced by shipper, full-bunker icing; car B, 693 boxes, precooled, pre-iced by shipper, full-bunker icing, fans; car C, 693 boxes, precooled, pre-iced by shipper, upper-half-bunker, or stage, icing, fans. Data for car A obtained from Ryan recording thermometers and for other cars from resistance thermometers.

perature of the fruit in the top layer of both cars increased about 4° F. Thereafter, while en route to Jersey City, fruit temperatures in car B dropped 3° and in car C they increased 4°. When the cars were unloaded 2 days after arrival the top-layer-fruit temperatures were 44° for car A, 49° for car B, and about 51° for car C. There was a marked rise in the temperature of the fruit in the top layers of cars B and C when the fans were not in operation, as during the trip from the packing house to San Bernardino and again while the cars were held on track at Jersey City.

As shown by the icing record (table 5), the amount of ice melted in transit was relatively high in the fan-equipped cars. The meltages in transit were, respectively, 60, 82, and 87 percent for cars A, B, and C.

TABLE 5.—*Icing record, United States Department of Agriculture 1941 orange-transportation test No. 1*

Place	Date	Time	Weight of ice in cars with precooled fruit		
			A (full bunker)	B (full bunker)	C (upper-half bunker)
			Pounds	*Pounds*	*Pounds*
Loading point, Calif	May 28	8:30 a. m.	15,600	13,200	8,400
Ice in bunkers at Jersey City, N. J	June 6	2:00 p. m.	6,300	2,400	1,100
Ice melted in transit [1]		-----	9,300	10,800	7,300

[1] No record was made of ice remaining in bunkers at unloading.

Tests Conducted During Hot Weather

NONPRECOOLED FRUIT UNDER STANDARD REFRIGERATION

The effect of extremely high outside temperatures on fruit temperatures and ice meltage was shown in a test in August 1937, when daily maximum temperatures en route were many degrees above normal. The test included full- and half-bunker icing of nonprecooled oranges under standard refrigeration (fig. 9, *A*) and shipper-precooled, pre-iced shipments re-iced once in transit (fig. 9, *B*, and p. 23).

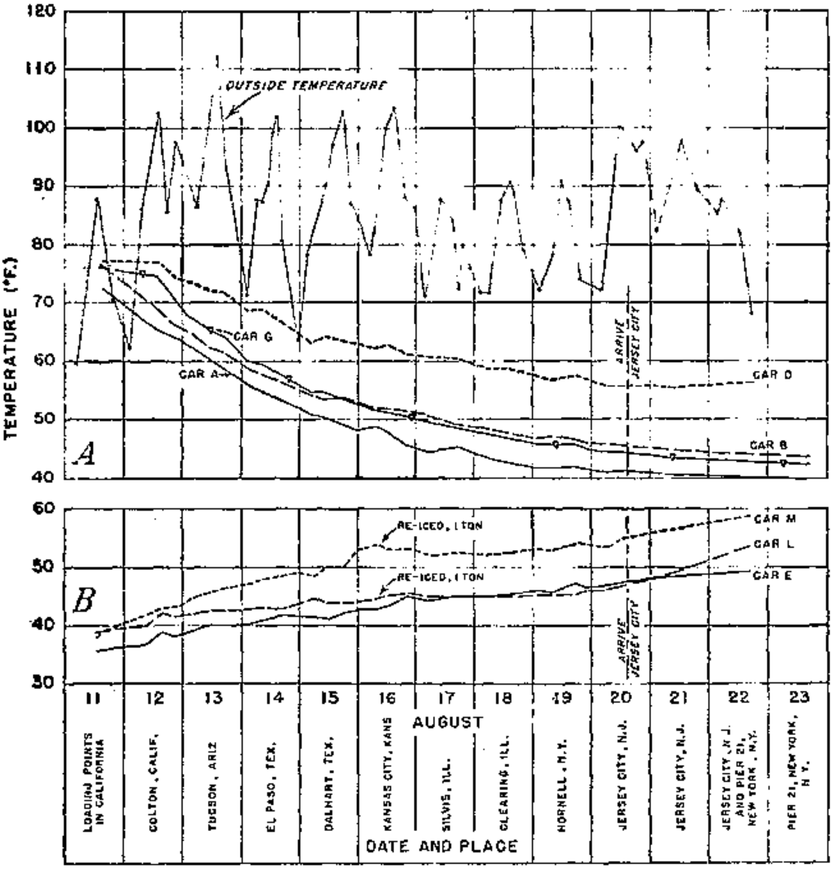


Figure 9.—Effect of icing methods on the top-layer temperature of oranges en route from loading points in California to New York, N. Y., via Southern Pacific R. R., the Chicago, Rock Island, and Pacific Ry., the Belt Ry. of Chicago, and Erie R. R., Aug. 11 to 23, 1937 (United States Department of Agriculture 1937 test No. 2): *A*, Nonprecooled fruit under standard refrigeration; *B*, precooled fruit, pre-iced, partially re-iced. Cars A and E, full-bunker icing; cars B and L, upper-half-bunker icing; cars D and M, lower-half-bunker icing; car G, dry-car-loaded, full-bunker icing.

In the nonprecooled shipments car A received full-bunker icing, car B upper-half-bunker icing, and car D lower-half-bunker icing. Car G, which was under the method called dry-car-loaded, standard refrigeration (car initially iced at first icing station en route), received full-bunker icing.

Although, when the loading temperatures are considered, there was little difference in the refrigeration of cars A and B and almost the same amounts of ice were supplied and melted in transit, there was almost twice as much ice left in car A on arrival (table 6). When the cars were unloaded after being held on track for 2 or 3 days during which time the average drop of the temperature was approximately the same in both cars, there was about 6 times as much ice in car A. This test indicates that upper-half-bunker icing was almost as effective as full-bunker icing and that a substantial saving was obtained in the weight of ice hauled. Refrigeration in car B was approximately the same as in car G, and that in car D was much less effective.

Table 6.—*Icing record, United States Department of Agriculture 1937 orange-transportation test No. 2*

Place	Date	Time	Weight of ice in— Cars with nonprecooled fruit: A (full bunker)	B (upper-half bunker)	D (lower-half bunker)	G (full bunker)	Cars with precooled fruit: E (full bunker)	L (upper-half bunker)	M (lower-half bunker)
			Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Los Angeles, Calif	Aug. 10	3:00 p. m.	9,966	5,577	4,973				
Upland, Calif	Aug. 11	7:00 a. m.					13,200		
Orange, Calif	do	6:30 a. m.							6,600
Covina, Calif	do	7:15 a. m.						6,600	
Los Angeles, Calif	Aug. 12	1:00 a. m.				10,026			
Do	do	5:00 a. m.	4,654	3,897	3,318				
Colton, Calif	do	4:00 p. m.	628	1,093	755	1,103			
Yuma, Ariz	Aug. 13	3:30 a. m.	1,719	1,906	1,367	2,225			
Tucson, Ariz	do	5:30 p. m.	1,907	1,731	1,805	2,582			
El Paso, Tex	Aug. 14	9:00 a. m.	2,116	1,808	1,748	2,310			
Dalhart, Tex	Aug. 15	12:00 m.	1,381	1,851	1,674	1,557			
Kansas City, Kans	Aug. 16	3:50 p. m.	2,637	1,971	1,881	2,361		2,000	2,000
Silvis, Ill	Aug. 17	6:00 p. m.	1,657	1,054	1,770	1,868			
Clearing, Ill	Aug. 18	5:00 a. m.	747	813	927	871			
Marion, Ohio	Aug. 19	2:45 a. m.	779	1,008	962	770			
Hornell, N. Y	do	10:30 p. m.	1,123	1,111	1,233	1,133			
Total ice supplied			29,314	24,840	22,482	20,812	13,200	8,600	8,600
Ice in bunkers at Jersey City, N. J	Aug. 20		8,700	4,900	4,400	9,000	3,700	550	1,850
Ice melted in transit			20,614	19,940	18,082	17,812	9,500	8,050	6,750
Ice in bunkers at unloading	Aug. 22				500				
	Aug. 23		5,300	900		5,000	2,100	50	600

In figure 10, *A*, full-bunker icing is compared with upper-half-bunker in shipments of nonprecooled oranges en route from California to Jersey City, June 9 to 17, 1938. This test was conducted during hot weather, the average outside temperature being 75° F. The fruit temperature of cars A and B at loading was 76° to 77°, and the cars moved from the packing house to the initial icing station at San Bernardino under ventilation. They were forwarded under the method dry-car-loaded, standard refrigeration, being re-iced at all regular icing stations en route.

As indicated in the graphs for the average top-layer temperatures, the refrigeration obtained from upper-half-bunker icing (car B) and from full-bunker icing (car A) was about equally satisfactory. The fruit cooled at about the same rate under both methods during the first 3 days, but during the remainder of the trip and while the cars were held on track at Jersey City, top-layer temperatures of the fruit were about 2° F. lower under upper-half- than full-bunker icing. Bottom-layer temperatures were from 2° to 6° higher under upper-half- than full-bunker icing. As discussed on page 24, these temperatures resulted from the circulation of air, which was 2° to 6° warmer in car B than in car A (fig. 10, *A*). However, with the more rapid circulation of the air in car B the fruit in the top layer cooled at about the same rate as that in car A, despite the higher temperature of the air in car B.

Table 7 shows the amount of ice supplied at all icing stations en route, the amount melted in transit, and the amount remaining in the bunkers when the cars arrived at Jersey City, June 17. The meltage was 59 percent in car A and 75 percent in car B. In this test, as in others previously discussed, upper-half-bunker icing under standard refrigeration service gave as satisfactory refrigeration of the fruit as full-bunker icing, and there was a considerable saving in the amount of ice supplied and hauled in the bunkers of the cars.

TABLE 7.—*Icing record, United States Department of Agriculture 1938 orange-transportation test No. 1*

Place	Date	Time	Weight of ice in— Cars with non-precooled fruit: A (full bunker)	B (upper-half bunker)	Cars with precooled fruit: H (full bunker)	K (upper-half bunker)	L (upper-half bunker)
			Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Orange, Calif	June 8	8:15 a. m.			15,000	7,800	7,800
San Bernardino, Calif	June 9	8:15 a. m.	11,500	5,750			
Needles, Calif	June 10	9:45 a. m.	2,315	3,222			
Winslow, Ariz	June 11	5:30 a. m.	1,783	1,532			
Belen, N. Mex	do	7:00 p. m.	1,298	1,642			
Clovis, N. Mex	June 12	6:50 a. m.	986	823			
Waynoka, Okla	do	0:00 p. m.	925	974			
Kansas City, Kans	June 13	1:20 p. m.	1,499	1,427			
Clearing, Ill	June 15	8:00 a. m.	2,321	2,755			
Marion, Ohio	June 16	8:00 a. m.	1,288	1,040			
Hornell, N. Y	June 17	12:20 a. m.	607	923			
Total ice supplied			24,522	20,088	15,000	7,800	7,800
Ice in bunkers at Jersey City, N. J			10,000	5,000	8,400	1,700	1,300
Ice melted in transit			14,522	15,088	6,600	6,100	6,500
Ice in bunkers at unloading	June 21		5,750	800	5,000	165	15

SHIPPER-PRECOOLED FRUIT, PRE-ICED, RE-ICED AT DESTINATION

In a test conducted September 2 to 14, 1936, the fruit was precooled to 34° to 35° F. and forwarded under full- and upper-half-bunker icing with no re-icing in transit. The outside temperatures at this time were slightly above normal. The refrigerator cars were of recent construction.

The results obtained under the various methods of icing used in this test are presented in figure 11. Car A (full-bunker icing) was initially iced with 12,378 pounds of block ice and car B (upper-half-bunker icing) with 6,274 pounds (table 8). The fruit in car A was precooled to 34° and that in car B to 35° F. The graphs for the top-layer temperatures show that during the 9 days en route to Jersey City the fruit in car B averaged from 1° to 3° higher than that in car A. There was a gradual rise in the fruit temperature under both methods of icing; after the first 6 days the fruit in car B warmed up faster than that in car A.

TABLE 8.—*Icing record, United States Department of Agriculture 1936 orange-transportation test No. 2*

Place	Date	Time	Weight of ice in cars with precooled fruit: A (full bunker)	B (upper-half bunker)	C (lower-half bunker)	D (upper-half bunker)
			Pounds	*Pounds*	*Pounds*	*Pounds*
Loading point, Calif	Sept. 2	9:00 a. m.	12,378	6,274	6,300	6,300
Ice in bunkers at Jersey City, N. J.	Sept. 11	4:00 p. m.	6,200	1,000	1,900	900
Ice melted in transit			6,178	5,274	4,400	5,400
Re-icing at Jersey City, N. J	Sept. 11	4:30 p. m.	0	1,200	900	1,300
Total ice supplied			12,378	7,474	7,200	7,600
Ice in bunkers at unloading	Sept. 14	11:00 p. m.	5,700	40	850	0

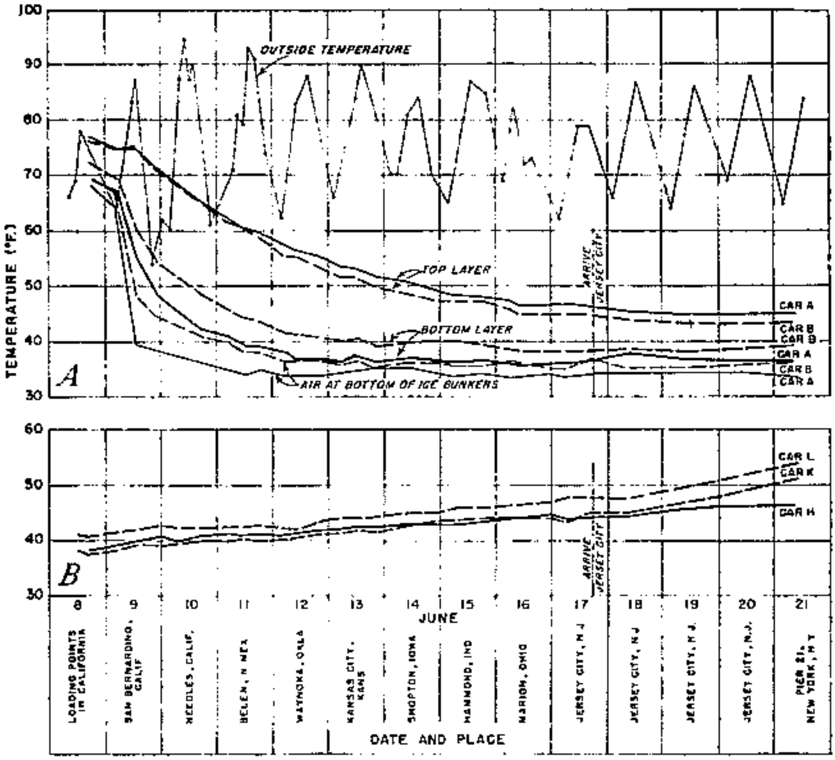


FIGURE 10.—Effect of icing methods on the temperature of oranges en route from loading points in California to New York, N. Y., via Atchison, Topeka, and Santa Fe Ry., the Belt Ry. of Chicago, and Erie R. R., June 9 to 21, 1938 (United States Department of Agriculture 1938 test No. 1): *A*, Nonprecooled fruit, dry-car-loaded, standard refrigeration; *B*, precooled fruit, pre-iced, not re-iced. Cars A and H, full-bunker icing; cars B, K, and L, upper-half-bunker icing.

The top-layer temperatures of cars A and B were about equally favorable for the control of decay and softening of the fruit during the 9-day trip to Jersey City. Inspection of the fruit in the two shipments made after the cars were unloaded indicated that there was no difference in appearance or firmness of the oranges. The percentage of decay in both shipments was negligible.

The effect of the temperature to which fruit is precooled on transit temperatures under upper-half-bunker icing is indicated in the curves for cars B and D (fig. 11). Car B was precooled to 35° and car D to 45° F. Top-layer temperatures in car D increased from 45° to 52.5° and in car B from 35° to 46.5° during the 9-day trip to Jersey City. Because of the lower temperature at loading the fruit in car B remained at a lower temperature than that in car D throughout the trip. Because of the faster rise in the temperature of the fruit in car B, however, the 10° difference in the loading temperatures of the two cars was reduced to 6° by the time of arrival. Although both cars were pre-iced with the same amount of ice, top-layer temperatures in car B rose faster than those in car D because of the greater initial difference between fruit and air temperatures in car B. The more thorough precooling of car B, however, provided sufficient refrigeration to keep the temperatures of the fruit lower than in car D during the trip.

It is interesting in this test to compare the graph of car C (lower-half-bunker icing) with the graphs of cars B and D (upper-half-bunker icing). The poor refrigeration obtained from ice in the lower half of the bunkers in car C is indicated in the top-layer temperature curve (fig. 11). The rate of rise in top-layer temreatures was considerably faster in car C than in car B; by the fifth day the temperatures in car C had almost reached those of car D, which started 7° warmer. In both car C and car D the top-layer temperatures were above 45° F. after the third day and above 50° after the eighth day and, therefore, less satisfactory for transportation of oranges than those of car B.

The effect of re-icing shipments under half-bunker icing on arrival at destination is shown also in figure 11. The test-trip icing record is given in table 8. Outside temperatures were 61° to 85° F. Ice meltage in transit was 50 percent for car A, 84 percent for car B, 70 percent for car C, and 86 percent for car D.

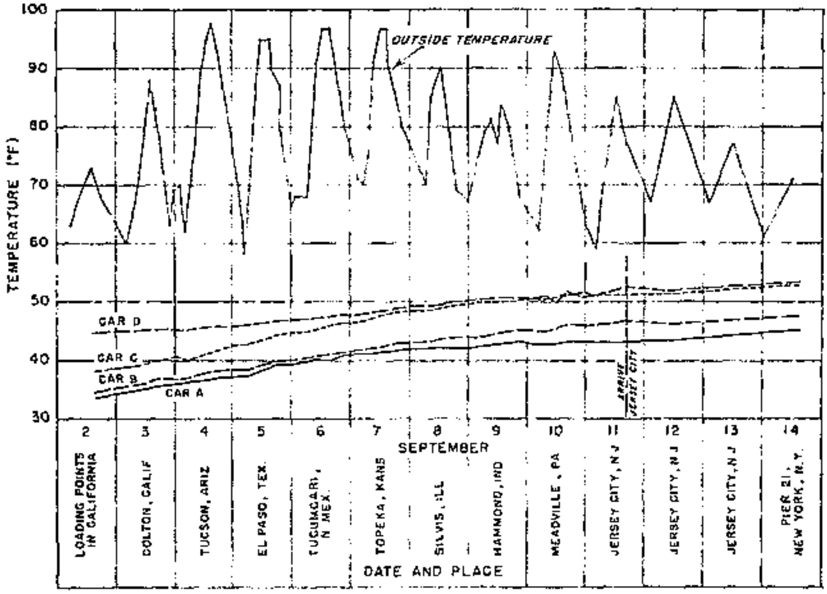


FIGURE 11.—Effect of icing methods on the top-layer temperature of precooled oranges en route from loading points in California to New York, N. Y., via Southern Pacific, the Chicago, Rock Island, and Pacific Ry., the Belt Ry. of Chicago, and Erie R. R., Sept. 2 to 14, 1936 (United States Department of Agriculture 1936 test No. 2). Car A precooled to 34° F., full-bunker icing; car B precooled to 35°, upper-half-bunker icing; car C precooled to 38°, lower-half-bunker icing; car D precooled to 45°, upper-half-bunker icing.

In none of the cars was initial icing sufficient to prevent some rise in the temperature of the fruit after the first day. The relatively small quantity of ice supplied at destination, however, caused top-layer temperatures to drop slightly; this slight drop was followed by a gradual rise the last 2 days as the ice melted. The results of this and later tests with precooled oranges indicate that if it is desirable to re-ice cars to be held for several days on track in warm weather, at least 1 ton of ice should be used. The ice should be broken into 10- to 25-pound pieces. The tests have shown that under stage icing, with the fruit loaded at a low temperature, re-icing in transit may not be necessary until the ice in the bunkers is practically gone, because the ice is used more effectively than in full-bunker icing. It is also more economical to avoid re-icing in transit, because of the higher charge, and to re-ice at destination if necessary when unloading is delayed.

SHIPPER-PRECOOLED FRUIT, PRE-ICED, RE-ICED ONCE IN TRANSIT

The results with precooled, pre-iced fruit shipped under various methods of icing when the average outside temperature was 85° F. are presented in figure 9, *B*. During the first 5 days en route when the maximum outside temperature was above 100° the top-layer temperatures of the fruit increased 8° in car E (full-bunker block icing), 6.5° in car L (upper-half-bunker block icing), and 15.5°

in car M (lower-half-bunker block icing). As a result of this more rapid warming up, the temperature of car E, which was 3° lower at the time of loading, approximated that of car L when they reached Kansas City. The more rapid rise in the temperatures in cars E and M was probably partly due to slower air circulation than in car L.

The icing records given in table 6, in connection with figure 9, *B*, indicate that re-icing of cars L and M in Kansas City prevented a significant rise in temperature of the fruit during the rest of the trip. They also indicate that upper-half-bunker icing was more economical than full-bunker icing and more effective than lower-half-bunker icing. In car E 72 percent of the ice was melted in transit, in car L 94 percent, and in car M 79 percent.

The tests just discussed indicate that refrigeration in cars of conventional design depended chiefly on the ice in the upper half of the bunkers and that the ice in the lower half contributed comparatively little to the refrigeration of the fruit. It was more economical to forward shipments of precooled oranges under upper-half-bunker icing and to re-ice at some point en route than to forward them under full-bunker icing. Under this procedure there is a material saving in the cost of ice supplied as well as in the cost of hauling it.

An analysis of the results of this and other tests indicates that when half or more of the ice has melted under full-bunker icing the effectiveness of the ice is greatly reduced. This is illustrated in cars L and M (fig. 9, *B*). Car M is representative of a fully iced car in which the ice has melted to half height in the bunkers.

SHIPPER-PRECOOLED FRUIT, PRE-ICED, NOT RE-ICED

Half-bunker icing was applied to shipments that were precooled to different temperatures in a test en route June 9 to 21, 1938. The graphs for the shipments which were precooled and pre-iced under full- (car H) and upper-half-bunker icing (cars K and L) are shown in figure 10, *B*. There was a difference of about 3° between the temperatures of the fruit in cars K and L; this difference lasted during the entire trip. The fruit in cars H and K, however, was precooled to approximately the same temperature, 38° F. Little difference occurred in the refrigeration of the fruit in transit under the two methods of icing, satisfactory temperatures being maintained in all three cars. The icing records are given in table 7. It is interesting to note that in car H, precooled to 38°, 44 percent of the ice was melted in transit; in car K, precooled to 38°, 78 percent; and in car L, precooled to 41°, 83 percent. The fruit in car L was about 3° warmer than that in car H when loaded, but about the same amount of ice melted in transit in both cars.

Test Conducted During Cool Weather

CARRIER-PRECOOLED FRUIT, INITIALLY ICED AFTER PRECOOLING, NOT RE-ICED

In 1939 test No. 2, en route April 12 to 23, 1939, the average outside temperature was 47° F. Car A was forwarded under full-bunker icing and car B under upper-half-bunker icing. The cars were initially iced after precooling at San Bernardino and were not re-iced in transit, except for about 500 pounds of ice placed in the bunkers of car B through error at Needles, Calif.

The effect of precooling at a carrier-operated precooling plant combined with full-bunker and with upper-half-bunker icing is shown in the temperature graphs in figure 12. The temperature of the fruit at loading was 73.5° F. in car A and 72° in car B. These temperatures were lowered about 11° by the 8-hour precooling at San Bernardino. During the first 5 days of the trip, between San Bernardino and Shopton, Iowa, further cooling of the fruit took place, at nearly the same rate in both cars. During the next 3 days en route to Jersey City there was slightly slower cooling in car B than in car A, doubtless because of the small amount of ice remaining in the bunkers of car B. As in practically all tests of half-bunker icing, the fruit in the bottom layer showed slightly higher temperatures under upper-half-bunker icing than under full-bunker icing throughout the trip. This difference in fruit temperatures was due to higher temperature of the air leaving the ice bunkers of car B.

Because of the relatively inadequate cooling obtained in the 8-hour period used at carrier-precooling plants, there is further cooling of the fruit in transit. This is not the case with shipper-precooled, pre-iced shipments which with the longer precooling period are cooled to much lower temperatures before being shipped. With the lower loading temperature there is usually some rise in the temperature of the fruit in transit.

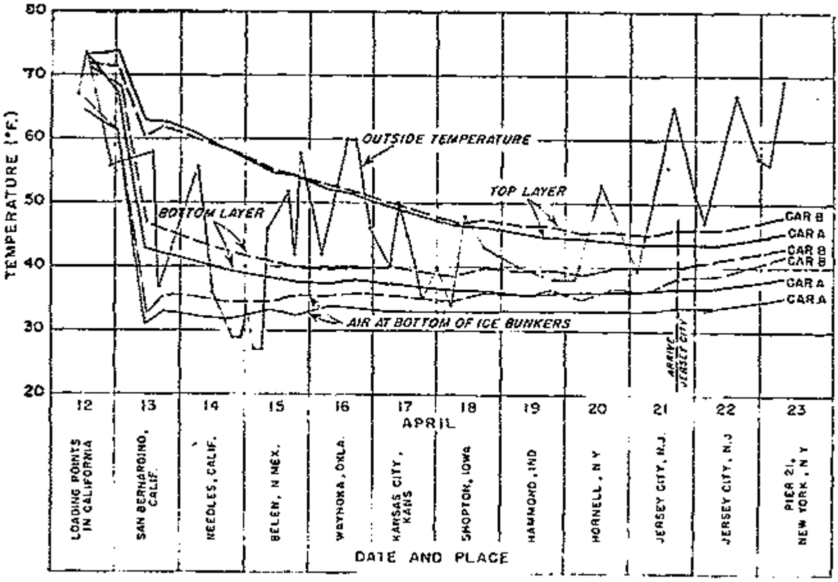


FIGURE 12.—Effect of icing methods on the temperature of precooled oranges en route from loading points in California to New York, N. Y., via Atchison, Topeka, and Santa Fe Ry., the Belt Ry. of Chicago, and Erie R. R., April 12 to 23, 1939 (United States Department of Agriculture 1939 test No. 2). Car A, precooled by carrier, initially iced, full-bunker icing; car B, precooled by carrier, initially iced, upper-half-bunker icing.

The amounts of ice supplied cars A and B, the amounts melted in transit, and those remaining in the bunkers on arrival at Jersey City and when the fruit was unloaded are given in table 9. In car A 63 percent of the ice melted in transit, and in car B 93 percent.

In this test also precooling with upper-half-bunker icing, under standard refrigeration service, resulted in a considerable saving in the initial icing of shipments and in the "dead weight" of the ice hauled in the bunkers of the car. These economies in methods of icing were accomplished with no significant loss of refrigeration of the fruit in transit.

TABLE 9.—*Icing record, United States Department of Agriculture 1939 orange-transportation test No. 2*

Place	Date	Time	Weight of ice in cars with precooled fruit	
			A (full bunker)	B (upper-half bunker)
			Pounds	*Pounds*
San Bernardino, Calif	Apr. 13	10:00 a. m.	11,600	6,400
Needles, Calif	Apr. 14	5:00 a. m.		524
Total ice supplied			11,600	6,924
Ice in bunkers at Clearing, Ill	Apr. 19	8:00 a. m.	5,100	1,400
Ice in bunkers at Jersey City, N. J	Apr. 21	3:00 p. m.	4,300	500
Ice melted in transit			7,300	6,424
Ice in bunkers at unloading	Apr. 23	7:00 p. m.	3,000	15

Circulation of Air in Refrigerator Cars [7]

FACTORS AFFECTING AIR CIRCULATION

In refrigerator cars of the conventional type fruit is cooled by air which circulates through the ice bunkers at the ends of the car. As the cold air from the bunkers absorbs heat by contact with the fruit, it rises and finally passes back into the bunkers through the openings at the top of the bulkhead.

Since air circulation in an iced refrigerator car is caused by the difference in weight between the cold, or relatively heavy, air in the ice bunkers and the warmer, somewhat lighter air surrounding the load, there is always a slight movement of air as long as a temperature difference exists between the ice bunkers and the loading space. If, for example, when the warm fruit is loaded, the outside temperature is 34° F. in the ice bunkers and 74° in the loading space the difference in weight of the air is approximately 0.1 of an ounce per cubic foot. The total difference in pressure, which causes air circulation, is the product of this weight difference by the height of the cold-air column. This height is always somewhat less than the inside height of the car. With ice bunkers full this height would not be more than about 7 feet, in which case the pressure difference would be only 0.7 ounce per square foot with the temperatures cited. This is the maximum that can be expected under the most favorable conditions. Under average conditions it would be still less. It may be seen that the force which causes circulation is very weak and may easily be counteracted. The pressure difference is greatest when there is a relatively high column of cold air.

Warm air entering at the top of the bunker is cooled in contact with the ice, by far the greater part of the cooling taking place in the upper part of the ice. The level of the top of the ice in the bunker, therefore, determines the height of the cold-air column. In a stage-iced car, the reduction of resistance to air flow due to the shorter path of the air through the ice is such that the air circulation set-up by the smaller quantity of ice somewhat exceeds the circulation set-up in a full-bunker-iced car by the much larger amount of ice, with the two cars iced to equal levels. This condition is maintained until the greater part of the ice in the stage-iced car has been melted.

The circulation of air in the car is influenced by the method of loading, the amount and height of the ice in the bunkers, the fruit temperature, and the efficiency of the car as determined by such factors as the kind, thickness, and condition of the insulation; adequate floor racks and ice bunkers; and the tightness of the car body. Other conditions, such as the shifting of the load and variations in the amount of heat transfer through the car body, may also affect air circulation. Usually the most important factors affecting rapidity of circulation are the air temperature difference between bunker and loading space and the height of the ice in the bunker. Because of these variable factors it is usually difficult to obtain comparable data on air circulation in refrigerator cars in transit. The observed velocities should be regarded as only approximately typical rates of air movement for the locations where the readings were taken.

MEASUREMENTS OF AIR VELOCITIES

In a number of tests studies were made of air circulation in cars of precooled and nonprecooled oranges under half- and full-bunker icing. Air velocity was measured with electric anemometers [8] placed under the floor rack in one end of the car. The anemometer was a specially built thermocouple, both junctions of which were in the air stream, with one junction heated by an electric current. It was mounted on a 1- by 4-inch hard-rubber plate. Air movement over the thermocouple modified the temperature difference between the hot and cold junctions. The electromotive force resulting from the temperature difference was measured with a potentiometer. An electric current of predetermined amplitude from two dry cells was used to heat the junction, and thermocouple readings were converted into feet per minute of air movement. The instrument was calibrated for velocities within the recorded range. The anemometers were attached to the under side

---

[7] Acknowledgment is made to Wilson P. Green, formerly assistant mechanical engineer, Bureau of Agricultural Chemistry and Engineering, and C. J. Thompson, instrument maker, Bureau of Plant Industry, Soils, and Agricultural Engineering, for assistance in measuring air velocities.

[8] Hukill, W. V. An anemometer for measuring low air velocities. Refrig. Engin. 28: 197, illus. 1934.

of the floor rack of the car or to the floor itself in each of the channels in which velocities were measured, usually 18 or 24 inches from the bulkhead of the bunker. The floor racks were of the usual two-section type, each section having three channels formed by 2- by 4-inch supports which extended from end to end of the car (fig. 1).

AIR VELOCITIES IN NONPRECOOLED SHIPMENTS

Measurements of air velocity were taken in three cars of nonprecooled oranges moving under full-bunker or half-bunker icing, standard refrigeration, in 1936 test No. 1. Anemometers were placed in the same locations in all three cars; namely, in the middle air channel of each floor rack about 2 feet from the bulkhead of the ice bunkers.

During the first 12 to 18 hours of the trip the velocities in car A (full-bunker icing) and car B (upper-half-bunker icing) were slightly over 130 feet per minute. As the fruit cooled circulation decreased; at the end of the first 3 days readings dropped to 60 to 80 feet per minute and during the next 6 days they fluctuated within this range. Conditions in both cars were very nearly alike. Reduction of fruit temperatures apparently was the chief cause of the slowing down of air circulation. In car C (lower-half-bunker icing) lower air velocities were recorded, starting at about 90 feet per minute and dropping to 40 to 60 feet per minute at the end of the third day. The slower circulation in car C was due to the low level of the ice in the bunkers, even though the fruit temperatures in this car were higher.

In another test with nonprecooled oranges under full-bunker icing standard refrigeration, en route September 2 to 11, 1936, during warmer weather, the air velocity reached a maximum of 120 feet per minute with a fruit temperature of 73° F. Subsequent cooling of the fruit resulted in a decline in the rate of air circulation. When the average fruit temperature reached 39° on the seventh and eighth days in transit, the air velocity under the floor rack was only 44 feet per minute. Thereafter, as a result of increased heat leakage into the interior of the car after several hours of comparatively high outside temperatures, there were temporary increases to 75 and 85 feet per minute. In a comparable car under lower-half-bunker icing with an average fruit temperature of 79° at the beginning of the trip, the velocity was 50 feet per minute. After the fruit had cooled to 52° the velocity dropped to 20 feet per minute and was affected but little by the re-icing of the car. The record of the comparable car under upper-half-bunker icing was, unfortunately, not obtained because of failure of the anemometers.

The effect of filling the bunkers too full of ice was to slow down air circulation. When the hatchways and upper part of the bunkers were packed with ice according to the usual practice, there was no increase in air circulation for several hours after re-icing. Circulation, as well as cooling of the fruit, may be improved by leaving a little space above the ice to permit the passage of air to the sides and back of the bunkers. For this reason, also, coarse ice was found to be better than fine ice in promoting air circulation. When chunk ice was used with the blocks broken into large pieces, mostly 10 to 50 pounds, the larger air channels permitted freer circulation in the bunkers and better cooling of the fruit than when the ice was broken into small pieces. Since in block icing the blocks usually freeze together solidly, the amount of surface by which heat is absorbed from the air is less than with broken ice. For this reason block ice is less effective than chunk ice in the cooling of warm fruit.

In this test a few hours of extremely high outside temperatures caused air velocities under the floor racks to increase from 90 to 150 feet per minute. This was doubtless the result of an increase in the amount of heat reaching the interior of the car.

In 1938 test No. 1 (fig. 13) air velocities were measured in car A (full-bunker icing) and car B (upper-half-bunker icing). The anemometers were placed in the three channels of the south half of the floor rack and in the center channel of the north half, all about 18 inches from the forward bulkhead. The positions were designated as channels 1, 2, and 3 of the south section of the floor rack, and channel 4 of the north section. Also one anemometer, position 5, was placed in the center of channel 2, halfway between the bunker and doorway, in order to compare velocities at the bunker and quarterway positions. As indicated by the graphs, the rate of air flow from the bunkers was rather variable. This was apparently an effect of heat penetration, which varied with outside temperatures.

The velocity data of cars A and B are presented in table 10.

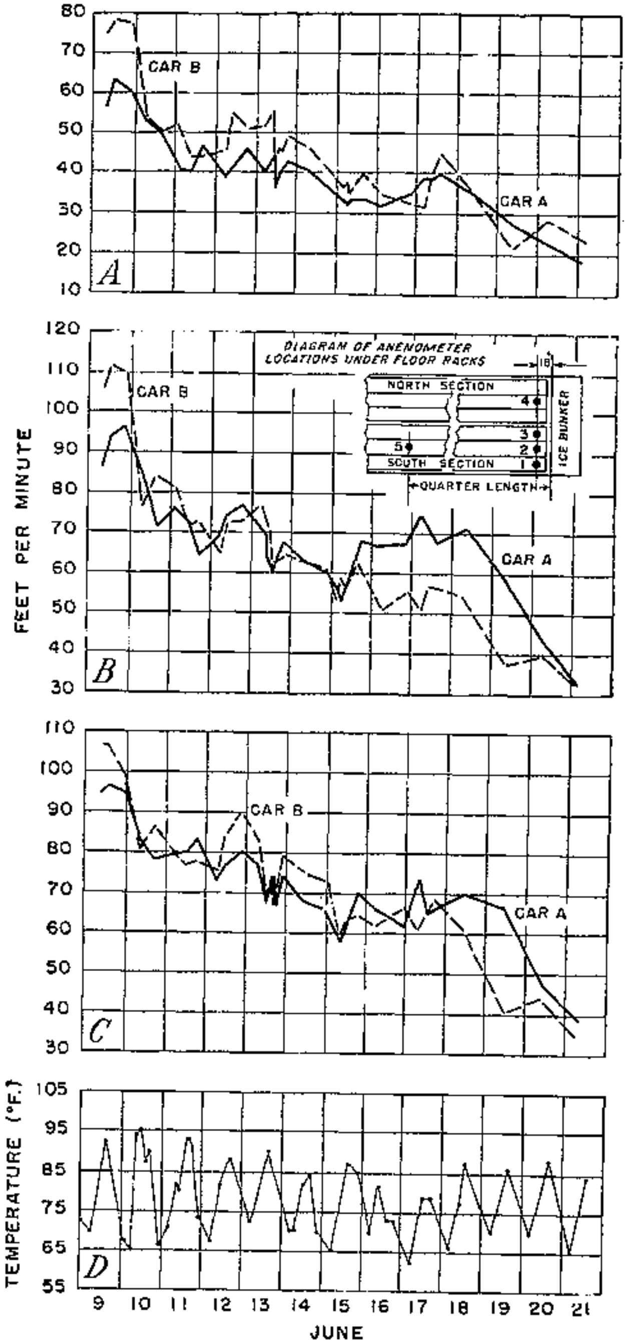


FIGURE 13.—Air velocities under floor racks (United States Department of Agriculture 1938 test No. 1, June 9 to 21): *A*, Channel 5; *B*, channel 2; *C*, average of channels 1, 2, 3, and 4. *D*. Outside temperature. Car A, full-bunker icing; car B, upper-half-bunker icing.

of strong winds adults cease flying and crawl to the base of plants or under clods and debris for protection.

Egg deposition began as early as 2 days and as late as 29 days after emergence. The average preoviposition period was 11 days. In laboratory cages first eggs were obtained on April 15, 1934, and the latest date that eggs were obtained was June 27, 1931. Of the 4,505 eggs under observation, 42 percent were deposited during the first week after oviposition began, 28 percent during the second week, 15 percent in the third week, 7 percent in the fourth week, 6 percent in the fifth, and 2.3 percent in the sixth and seventh weeks.

The first larvae were obtained on May 13, May 15, and June 2 in the years 1932, 1934, and 1933, respectively. The latest hatching date was July 6, 1933. Although larvae were reared under identical conditions of food, temperature, and moisture, their rate of development in the different years varied considerably. Of a total of 200 larvae reared in salve cans on various quantities of wheat, 76 percent matured and 24 percent succumbed. Of the surviving larvae, 45 percent matured in 2 years, 35 percent in 3 years, 16 percent in 4 years, 2.6 percent in 5 years, and 0.7 percent in 6 years. None completed development the first year in either salve cans or tile cages.

A total of 1,066 larvae were reared in tile cages, and of these 686, or 64.3 percent, succumbed or were the victims of cannibalism. Of the larvae that matured, 92.8 percent completed development in 2 years, 5.5 percent in 3 years, and 1.7 percent in 4 years. The more rapid acceleration in development of these individuals was attributed mainly to the higher temperatures prevailing out of doors during the early part of the spring and summer.

The first pupation in salve cans occurred on July 18, 1932, and the latest record was on September 28, 1936. Ten percent of the larvae pupated in July, 65 percent in August, and 25 percent in September.

The first adult transformed on August 12 and the last on October 28. The adults remain in the soil in the pupal cells during the fall and winter and emerge in the spring.

NATURAL CONTROL

Except for the carabids *Calosoma cancellatum* Esch. and *C. semilaeve* Lec., which have been found feeding on the adult, and birds—as listed by Graf (*2, pp. 46–47*)—which also destroy larvae, pupae, and adults of *Limonius californicus* during plowing operations, no other important enemies of *Melanotus longulus* have been observed.

SUMMARY

Except for the carabids *Calosoma cancellatum* Esch. and *C. semifornicus* in importance as a pest of vegetable and grain crops in southern California. The larvae not only destroy germinating seeds but also burrow into and kill growing plants and damage potato and root crops. Lima bean growers whose fields are infested plant an additional 40 to 50 pounds of seed per acre, and even then there are times when replanting is necessary in order that a satisfactory stand may be obtained. This wireworm and the species *L. californicus* may also be responsible for the "thinned-out" condition observed in sugar beet, tomato, corn, lettuce, and alfalfa fields. Based on

counts made in lima bean rows, the larvae of *M. longulus* comprise about one-fourth of the wireworm population in beanfields.

Dissemination is mainly by flight, both male and female beetles being strong, vigorous fliers, especially active on cool, cloudy days.

In moist soil, as shown in data obtained by confining beetles outdoors in oviposition cages, females deposit over 70 percent of their eggs in the first inch, 18 percent in the second inch, 7 percent in the third, and 3 percent in the fourth.

Judging by experiments conducted in salve cans, the duration of the incubation period was found to vary according to the changes in temperature in the different months and years. Individual records of incubations were from 25 to 45 days, averaging 31 days. The shortest monthly average was 25.5 days for eggs deposited during April and May 1934, when temperatures averaged 72.5° F., and the longest monthly average recorded was 39.5 days for eggs deposited during April 1933 at an average temperature of 66°.

Of three broods of larvae, reared in salve cans in 1931–33, hatched between May 13 and July 6, and fed various quantities of wheat monthly, 45.4 percent matured in the second year, 35.5 percent in the third, 15.8 percent in the fourth, 2.6 percent in the fifth, and 0.6 percent in the sixth year. Because of the slow rate of development of these larvae during the first summer, none under observation had completed development in the first year. The average duration of the larval period was 433 days for the 2-year-cycle individuals, 803 days for the 3-year cycle, 1,176 days for the 4-year cycle, 1,547 days for the 5-year cycle, and 1,885 days for the one individual completing development in 6 years.

Of a total of 1,066 larvae of the broods of 1932, 1933, and 1934, reared in outdoor cages, only 34 percent matured as adults. A few were killed when the soil was being removed for examination, but the greater number either succumbed or were the victims of cannibalism. Higher soil temperatures outdoors in the early spring and summer accelerated larval development, as these rearings, based on the total number of adults recovered, show that 92.8 percent matured in the second year, 5.5 percent in the third, and 1.7 percent in the fourth year.

Larval development was accelerated and pupations occurred prematurely when larvae of this species were confined in salve cans at a constant temperature of 80° F. At 70° larval development and pupations were in accord with the rearings conducted at basement temperature. Larvae fed on sterile lima beans in salve cans developed much more slowly than those fed on fertile moistened wheat. The group fed on sterile lima beans, with the exception of one pupa in 1938, failed to complete development over an elapsed period of 7 years.

Judging by records of individuals confined in salve cans, the duration of the prepupal period was found to range, according to the changes in temperature, from an average of 7 days in 1937 to 11.4 days in 1936, and the average for all years was 8.5 days. The earliest pupation in salve cans occurred on June 10, 1934, and the latest was on September 28, 1936. The longest period of pupation was 68 days in 1934, and the shortest was 42 days in 1937. Over a period of 6 years, the average period of pupation was 54 days. A summary of all pupations

DEPOSITORY

CORRECTION

Technical Bulletin No. 858. Life History of the Wireworm *Melanotus longulus* (Lec.) in Southern California.

On page 27, in the paragraph under the heading "Summary," the first line of the paragraph should read as follows:

The wireworm *Melanotus longulus* ranks next to *Limonius cali-*

Table 10.—*Air velocities in feet per minute in refrigerator cars, United States Department of Agriculture 1938 orange-transportation test No. 1 with nonprecooled fruit*

Car and place	Date	Time	Velocity per minute for anemometers[1] at indicated positions in air channels under the floor rack: At ice bunkers 1	2	3	4	Average	Quarter-way 5	Air passing quarter-way in relation to air passing position 2
			Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Percent*
Car A (full-bunker icing):									
San Bernardino, Calif	June 9	9:30 a. m.	97	86	108	89	95	57	66
Do	do	2:00 p. m.	96	93	101	97	97	63	68
Barstow, Calif	do	11:00 p. m.	90	96	102	93	95	60	62
Needles, Calif	June 10	8:30 a. m.	82	85	87	79	83	53	62
Seligman, Ariz	do	6:00 p. m.	77	71	86	70	77	50	70
Winslow, Ariz	June 11	5:00 a. m.	77	70	88	75	79	41	54
Gallup, N. Mex	do	12:30 p. m.	82	72	93	72	80	40	56
Belen, N. Mex	do	6:30 p. m.	93	64	95	78	82	47	73
Clovis, N. Mex	June 12	6:30 a. m.	77	69	80	66	73	39	57
Amarillo, Tex	do	11:30 a. m.	77	74	80	76	77	41	55
Waynoka, Okla	do	8:30 p. m.	83	77	81	77	79	46	60
Emporia, Kans	June 13	7:00 a. m.	73	72	77	87	77	40	56
Kansas City, Kans	do	1:00 p. m.	76	69	73	77	74	44	64
Do	do	1:30 p. m.	66	64	65	87	70	38	59
Do	do	2:30 p. m.	68	61	65	81	69	36	59
Do	do	3:30 p. m.	76	60	68	96	75	40	67
Do	do	4:30 p. m.	72	60	68	----	67	41	68
Do	do	6:00 p. m.	71	64	69	64	67	41	64
Do	do	9:30 p. m.	83	68	82	67	75	43	63
Shopton, Iowa	June 14	10:30 a. m.	76	63	69	65	68	41	65
McCook, Ill	do	12:00 p. m.	71	60	73	60	66	36	60
Clearing, Ill	June 15	7:00 a. m.	66	50	64	57	59	33	59
Do	do	8:30 a. m.	60	52	57	61	57	32	62
Do	do	10:00 a. m.	63	55	59	60	59	33	60
Hammond, Ind	do	6:30 p. m.	69	68	82	65	71	34	50
Marion, Ohio	June 16	6:30 a. m.	69	67	66	63	66	32	48
Hornell, N. Y	do	12:00 p. m.	68	68	56	54	61	35	51
Susquehanna, Pa	June 17	8:30 a. m.	72	75	77	71	74	39	52
Port Jervis, N. Y	do	1:00 p. m.	72	71	53	65	65	30	55
Croxton, N. J	do	5:30 p. m.	74	68	62	61	66	40	59
Jersey City, N. J	June 18	10:30 a. m.	69	72	74	65	70	36	50
Do	June 19	11:30 a. m.	61	59	59	49	57	28	47
Do	June 20	9:30 a. m.	58	44	48	43	48	23	52
Do	June 21	10:00 a. m.	46	33	39	38	39	18	55
Car B (upper-half-bunker icing):									
San Bernardino, Calif	June 9	9:30 a. m.	100	105	109	105	107	75	71
Do	do	2:00 p. m.	114	111	94	110	107	78	70
Barstow, Calif	do	11:00 p. m.	100	98	96	100	99	77	78
Needles, Calif	June 10	8:30 a. m.	82	70	82	81	80	53	70
Seligman, Ariz	do	6:00 p. m.	92	84	82	90	87	55	65
Winslow, Ariz	June 11	5:00 a. m.	78	81	78	81	79	52	64
Gallup, N. Mex	do	12:30 p. m.	84	72	76	75	77	44	61
Belen, N. Mex	do	6:30 p. m.	88	73	76	75	78	44	60
Clovis, N. Mex	June 12	6:30 a. m.	87	64	74	73	74	46	72
Amarillo, Tex	do	11:30 a. m.	106	72	80	79	84	55	76
Waynoka, Okla	do	8:30 p. m.	122	73	82	82	90	51	70
Emporia, Kans	June 13	7:00 a. m.	96	77	82	76	83	52	68
Kansas City, Kans	do	1:00 p. m.	78	72	72	72	74	56	78
Do	do	1:30 p. m.	73	64	65	67	67	43	67
Do	do	2:30 p. m.	81	68	69	69	72	46	68
Do	do	3:30 p. m.	79	61	64	65	67	46	75
Do	do	4:30 p. m.	81	59	65	68	68	45	76
Do	do	6:00 p. m.	73	63	67	71	68	46	73
Do	do	9:30 p. m.	100	65	77	73	79	49	75
Shopton, Iowa	June 14	10:30 a. m.	100	63	72	64	75	46	73
McCook, Ill	do	12:00 p. m.	97	61	69	65	73	40	66
Clearing, Ill	June 15	7:00 a. m.	79	53	57	53	60	36	68
Do	do	8:30 a. m.	69	50	56	55	60	38	64
Do	do	10:00 a. m.	81	56	60	53	62	35	62
Hammond, Ind	do	6:30 p. m.	78	63	63	57	65	40	63
Marion, Ohio	June 16	6:30 a. m.	86	51	58	54	62	35	60
Hornell, N. Y	do	12:00 p. m.	95	58	59	58	67	33	59
Susquehanna, Pa	June 17	8:30 a. m.	86	51	53	53	61	32	63
Port Jervis, N. Y	do	1:00 p. m.	94	57	64	53	64	40	70
Croxton, N. J	do	5:30 p. m.	99	57	59	59	68	45	70
Jersey City, N. J	June 18	10:30 a. m.	87	55	55	49	61	36	65
Do	June 19	11:30 a. m.	52	38	40	33	41	22	58
Do	June 20	9:30 a. m.	57	40	40	44	45	20	72
Do	June 21	10:00 a. m.	44	33	29	35	35	24	73

[1] See diagram in figure 13 for location of anemometers under floor racks.

The flow of air from the ice bunkers was quite evenly distributed to the different channels under the floor rack, with the exception of channel 1 at the south wall. Velocities in this channel were higher than in channels 2 and 4. This may have been due to irregular spacing of the boxes in the load or to the stronger convection currents along the south wall where the heat effect was greater than at the north wall because of the higher surface temperatures of the south wall. During the first 3 days of the trip, when fruit temperatures were high, the circulation in car A was greatest in channel 3.

As shown in table 10 air velocities decreased during the first 2 days as the difference between fruit and air temperatures became less (fig. 10). Average velocities at the ice bunkers in car A (full-bunker icing) was 97 feet per minute at San Bernardino and 66 feet per minute on arrival at Croxton, N. J. (Jersey City). While the car was held on track, June 18 to 21, circulation decreased to 39 feet per minute. The average velocity in car B (upper-half-bunker icing), which was 107 feet per minute at San Bernardino, had diminished to 68 feet per minute on arrival at Croxton. It declined to 35 feet per minute on June 21 when the ice in the bunkers was practically all melted. During the first 4 days the average rate of movement of air under the floor racks was, in general, greater in car B than in car A. It was practically the same in both cars from the fifth to the ninth day of the trip and was slightly lower in car B than in car A while the cars were held on track at Jersey City.

The velocity in channel 2 at the bunker (anemometer 2) and at the quarterway position (anemometer 5) is also given in table 10. Since the cross section of channel 2 was uniform throughout its length, the volume flow at any point was proportional to the velocity at that point. Thus, in car A the average velocity during the trip at position 5 (quarterway) being 60 percent of that at position 2 (bunker) indicates that 60 percent of the air entering the channel passed the quarterway position before it emerged from the floor rack. In car B 69 percent of the air passed the quarterway position. The higher percentage in car B would normally occur with a slightly faster rate of air movement under the floor rack in this car. The results of subsequent tests also show that from 60 to 80 percent of the air entering the space under the floor racks travels beyond the quarterway position before it passes upward into the load.

The records of the two cars indicate that during the first half of the trip average velocities were higher for upper-half than for full-bunker icing. About equal cooling of the fruit was obtained under both methods of icing, but the temperature of the air as it entered the space under the floor rack was higher in car B than in car A (fig. 10). In both cars circulation diminished as the fruit cooled. It dropped sharply when the cars were placed on the holding track at Jersey City, as shown in table 10. Table 10 shows air velocities in cars A and B, but the volume of the air circulated would be in the same ratio since the channels under the floor racks were of approximately the same size.

These studies on air circulation emphasize the importance of having suitable floor racks to facilitate the distribution of air from the ice bunkers for the refrigeration of the fruit near the center of the car; that is, of having adequate space beneath and between the slats free from obstructions.

AIR VELOCITIES IN PRECOOLED SHIPMENTS

In tests with precooled oranges the rate of circulation of air from the ice bunkers increased as the load temperature increased. In 1936 test No. 1, previously discussed (fig. 5), air circulation under the floor rack was measured in shipments under full-, upper-half-, and lower-half-bunker icing. The oranges were precooled to 34° F. and forwarded in cars that had been pre-iced with block ice, but were not re-iced in transit. As would be expected, the circulation under all three methods of icing was much slower in cars containing precooled fruit than in those containing nonprecooled fruit.

In this test air velocities under the floor racks of car D (full-bunker icing) and car E (upper-half-bunker icing) were about 30 feet per minute during the first 12 to 18 hours. As temperatures of the fruit rose the rate increased to 40 and 60 feet per minute, respectively. For car F (lower-half-bunker icing) velocities started at about 10 feet per minute and increased to 25 feet per minute during the first 18 hours.

The temperature to which the fruit was precooled affected the rate of air circulation as shown in two shipments under lower-half-bunker icing in the same test. With a fruit temperature of 34° F. the initial velocity under the floor racks was 10 feet per minute, and with a fruit temperature of 42° it was 20 feet per minute.

Air velocities were also measured in the two carrier-precooled shipments shown in figure 12, United States Department of Agriculture 1939 test No. 2, en route April 13 to 21. During the test the weather was relatively cool, the mean outside temperature being 47° F.

The anemometers were located in all six channels under the floor rack in the forward end of the cars. They were attached to the car floor about 18 inches from the bulkhead of the ice bunkers. Air velocities in car A and car B are given in table 11 and are compared in the graphs in figure 14. Channels 1 to 3

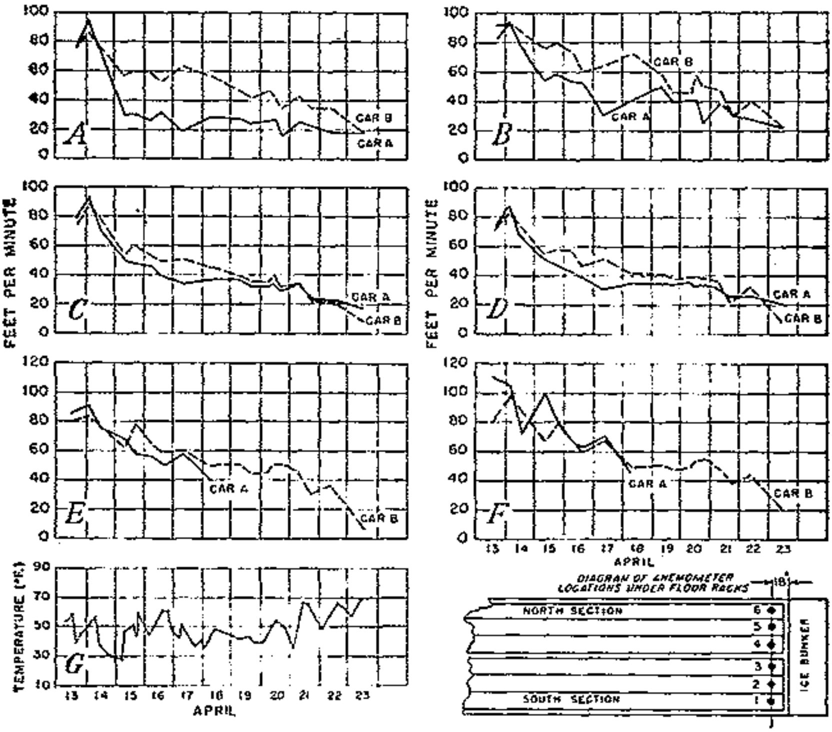


FIGURE 14.—Air velocities under floor racks (United States Department of Agriculture 1939 test No. 2, April 13 to 21): *A*, Channel 1, *B*, channel 2; *C*, channel 3; *D*, channel 4; E, channel 5; *F*, channel 6. *G*, Outside temperature. Car A, full-bunker icing; car B, upper-half-bunker icing.

were in the section of the floor rack that extended along the side of the car which faced south most of the time and was exposed to the direct rays of the sun more than the opposite side in which channels 4, 5, and 6 were located. The anemometers in channels 5 and 6 in car A were broken on the sixth day of the test, and no further readings could be taken at these locations.

During the first or first 2 days en route the circulation of air in both cars was probably affected to some extent by the unbalanced temperatures within the load, resulting from the method of precooling used. For the second to fourth day en route average velocities under the floor racks were 64 feet per minute for car A and 71 feet per minute for car B. From the fourth to the ninth day, when the test reached Jersey City, average velocities were 41 feet per minute for car A and 47 feet per minute for car B. In this test also air circulation fell off while the cars were held at Jersey City.

The rate of air movement was more uniform under the north and south sections of the floor racks in car B than in car A. Until the seventh day of the trip, April 19, (fig. 14) velocities were higher in car B (upper-half-bunker icing) than in car A (full-bunker icing). At this time 5,100 pounds of ice remained in the bunkers of car A and 1,400 pounds in car B (table 9). As more of the ice melted the rate of air circulation declined faster in car B than in car A, and on arrival of the test cars at Jersey City, April 21, the velocities in car B, with only 500 pounds of ice in the bunkers, were practically the same as those in car A with 4,300 pounds of ice.

TABLE 11.—*Air velocities in United States Department of Agriculture 1939 orange-transportation test No. 2 on precooled fruit*

Car and place	Date	Time	Velocity per minute for anemometers at indicated positions in air channels under the floor racks								
			South side				North side				Car average
			1	2	3	Average	4	5	6	Average	
			Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
Car A (full-bunker icing):											
San Bernardino, Calif.	Apr. 13	8:15 a. m.	289	295	298		298	289	275	------	------
Do	do	9:30 a. m.	298	278	307	------	300	300	281	------	------
Do	do	9:45 a. m.	284	288	290	------	295	298	272	------	------
Barstow, Calif	do	6:00 p. m.	75	82	79	79	74	86	111	90	84.5
Needles, Calif	Apr. 14	5:00 a. m.	95	95	93	94	88	92	105	95	94.5
Belen, N. Mex	Apr. 15	10:00 a. m.	31	54	51	45	51	68	100	73	50.0
Vaughn, N. Mex	do	6:50 p. m.	31	58	47	45	47	57	80	61	53.5
Amarillo, Tex	Apr. 16	7:00 a. m.	27	54	46	42	43	56	66	55	48.5
Waynoka, Okla	do	4:30 p. m.	33	52	39	41	38	49	62	50	45.5
Quenemo, Kans	Apr. 17	8:35 a. m.	15	30	35	27	31	57	70	53	39.5
Cardy, Mo	Apr. 18	7:30 a. m.	29	39	38	35	35	40	44	40	37.5
Chicago, Ill	Apr. 19	8:00 a. m.	29	45	38	37	35	----	-----	35	36.5
Hammond, Ind	do	6:05 p. m.	26	38	33	32	34	----	-----	34	32.0
Marion, Ohio	Apr. 20	7:15 a. m.	28	40	33	34	36	----	-----	36	34.5
Kent, Ohio	do	12:00 m.	28	40	35	34	33	----	-----	33	34.0
Corry, Pa	do	5:30 p. m.	17	25	30	24	34	----	-----	34	26.5
Port Jervis, N. Y.	Apr. 21	6:50 a. m.	27	38	35	33	32	----	-----	32	33.0
Jersey City, N. J	do	5:40 p. m.	24	29	24	26	25	----	-----	25	25.5
Do	Apr. 22	10:00 a. m.	21	27	24	24	26	----	-----	26	24.5
Pier 21, New York, N. Y.	Apr. 23	1:30 p. m.	20	21	18	20	21	----	-----	21	20.0
Car B (upper-half-bunker icing):											
San Bernardino, Calif.	Apr. 13	8:15 a. m.	684	600	82	----	45	74	48	------	------
Do	do	9:30 a. m.	328	320	362	----	350	328	296	------	------
Do	do	9:45 a. m.				----				------	------
Barstow, Calif	do	6:00 p. m.	75	92	75	81	72	80	80	77	70.0
Needles, Calif	Apr. 14	5:00 a. m.	87	93	89	90	83	84	99	89	89.0
Belen, N. Mex	Apr. 15	10:00 a. m.	58	76	54	63	54	61	66	60	61.5
Vaughn, N. Mex	do	6:50 p. m.	60	70	66	66	58	78	78	71	69.0
Amarillo, Tex	Apr. 16	7:00 a. m.	60	73	54	62	57	65	68	63	63.0
Waynoka, Okla	do	4:30 p. m.	54	60	50	55	47	59	60	55	55.0
Quenemo, Kans	Apr. 17	8:35 a. m.	64	64	51	60	52	60	67	60	59.5
Cardy, Mo	Apr. 18	7:30 a. m.	58	72	47	59	42	50	48	47	53.0
Chicago, Ill	Apr. 19	8:00 a. m.	48	58	41	49	42	50	50	47	48.0
Hammond, Ind	do	6:05 p. m.	44	46	36	42	38	44	46	43	42.5
Marion, Ohio	Apr. 20	7:15 a. m.	48	46	36	43	39	45	48	44	43.5
Kent, Ohio	do	12:00 m.	44	58	40	47	40	50	53	48	47.5
Corry, Pa	do	5:30 p. m.	37	50	32	40	39	50	55	48	44.0
Port Jervis, N. Y	Apr. 21	6:50 a. m.	44	48	35	42	37	45	48	43	43.0
Jersey City, N. J	do	5:40 p. m.	36	30	23	30	22	30	38	30	30.0
Do	Apr. 22	10:00 a. m.	37	39	23	33	32	36	43	37	35.0
Pier 21, New York, N. Y	Apr. 23	1:30 p. m.	20	15	9	15	8	7	17	11	13.0

In this test also, as indicated in table 11, the circulation rate declined as the fruit cooled. The temperature of the circulating air is given in table 12. These temperatures were taken near the anemometers, and were generally 2° to 3° F. higher in car B (upper-half-bunker icing) than in car A (full-bunker icing). On April 19 the air temperature at the anemometers was 35.5° in car B and 32.8° in car A; on April 21 the air temperature was 36.1° in car B and 33.0° in car A. The slower cooling of the fruit in the bottom layer under upper-half-bunker icing was apparently the result of the higher temperature of the circulating air. However, the temperatures of the fruit in the bottom layers of both cars were satisfactory, being below 45° after the second day. Although the air temperatures were generally higher in car B than in car A, the more rapid circulation under upper-half-bunker icing resulted in about as good cooling of the fruit in the top layer as with full-bunker icing. These results indicate that the cooling was accomplished in car A by a relatively slower movement of colder air and in car B by a more rapid movement of air that was not so cold. This, of course, is in accord with well-recognized principles of refrigeration.

TABLE 12.—*Temperature of circulating air in car A (full-bunker icing) and car B (upper-half-bunker icing), United States Department of Agriculture 1939 orange-transportation test No. 2*

Place	Date	Time	Temperature in—			
			Car A [1]		Car B [1]	
			Delivery air	Return air	Delivery air	Return air
			° *F.*	° *F.*	° *F.*	° *F.*
Loading station in Calif	Apr. 12	1:00 p. m.	65.0	68.0	66.6	69.5
San Bernardino, Calif	Apr. 13	1:30 a. m.	61.5	69.3	61.5	68.3
Do	do	11:30 a. m.	31.2	50.4	32.5	51.6
Barstow, Calif	do	6:00 p. m.	33.0	56.1	35.7	56.5
Needles, Calif	Apr. 14	5:00 a. m.	32.5	54.5	35.5	55.0
Williams, Ariz	do	6:30 p. m.	32.0	52.0	34.7	53.0
Belen, N. Mex	Apr. 15	10:00 a. m.	33.4	49.6	34.6	50.4
Vaughn, N. Mex	do	7:00 p. m.	32.6	51.1	35.5	52.3
Amarillo, Tex	Apr. 16	7:00 a. m.	34.2	48.7	35.4	49.1
Waynoka, Okla	do	6:30 p. m.	33.6	50.5	36.0	50.7
Quenemo, Kans	Apr. 17	8:30 a. m.	33.0	46.4	35.5	40.5
Cardy, Mo	Apr. 18	7:30 a. m.	32.8	44.2	34.3	39.5
Streator, Ill	do	5:30 p. m.	33.0	44.5	36.1	46.5
Clearing, Ill	Apr. 19	6:00 a. m.	32.8	42.8	35.5	44.3
Hammond, Ind	do	6:00 p. m.	33.0	43.5	36.5	44.7
Marion, Ohio	Apr. 20	7:00 a. m.	33.0	41.8	35.1	42.7
Columbus, Pa	do	5:15 p. m.	33.2	43.5	36.7	45.0
Port Jervis, N. Y	Apr. 21	7:00 a. m.	33.0	41.3	36.1	42.7
Jersey City, N. J	do	5:30 p. m.	33.7	47.7	38.2	49.3
Do	Apr. 22	10:00 a. m.	33.4	44.7	38.6	46.7
Do	Apr. 23	10:00 a. m.	34.8	48.2	41.5	50.6

[1] The delivery-air temperature was taken under the floor rack at the bottom opening of the ice bunker; the return-air temperature was taken in front of the top opening of the ice bunker.

ICE MELTAGE AND WEIGHT OF ICE HAULED IN TEST SHIPMENTS

The results of the studies of the effectiveness of half-bunker icing indicate that a large amount of surplus ice is transported in the bunkers of refrigerator cars and that the cost of refrigeration service is thereby increased on that portion of the crop refrigerated in transit. The percentage of the oranges shipped from California and Arizona under some form of refrigeration varies in different seasons; in some seasons, as in 1940–41, it amounts to more than 80 percent of the total shipments.

The charge for freight on the ice transported in the bunkers of refrigerator cars has been established on the basis of the average weight of ice hauled, as determined by estimates of ice in the bunkers. No exact method has heretofore been developed for measuring the amount of ice melted in transit or the amount hauled during any part of the trip from California to market destinations. Accurate information also has been lacking regarding the effects of fruit and outside temperatures on ice meltage. This lack of reliable data has resulted in uncertainty regarding the average weight of ice transported on which to base an ice-haulage charge in the refrigeration tariff on citrus as well as other fruits.

In order to determine the weight of the ice hauled under half- and full-bunker icing, a water-metering device, or drip meter, was employed. The drip meters, as illustrated in figure 15, were adapted for use on refrigerator cars. They were clamped to the car sills at the ice bunkers, connection being made to the drain pipes with a rubber hose. Each unit consisted of a strainer tank, hose connections, and a water meter of standard type. The meters recorded the accumulated ice meltage, which was checked with the actual weight of the ice placed in the bunkers of the cars at icing stations. The amount of ice melted was recorded by the meters, which were read at 4- to 6-hour intervals during the trip.

In United States Department of Agriculture 1936 test No. 1, June 3 to 12, 1936, a record of daily ice meltage was obtained in cars containing nonprecooled oranges forwarded under standard refrigeration and in other cars containing precooled oranges pre-iced with block ice (fig. 5). The total ice melted in cooling the fruit and by the heat that entered the car through the insulation and in other ways is given in table 13, together with data on accumulated and hourly ice meltage and weight of ice hauled on each day of the trip. With nonprecooled fruit during the first 3 or 4 days the ice was melted chiefly in absorbing the field heat of the fruit and thereafter by heat that entered the car from the outside. When precooled the fruit absorbed more of the heat that entered the car from the outside during the first 3 or 4 days; this caused fruit temperatures to rise and there was correspondingly less draft on the ice.

As shown in table 13 meltage of ice in the nonprecooled shipments (cars A, B, and C) was considerably greater during the first 3 days (June 4 to 6) while the

FIGURE 15—Drip meter used to record ice meltage in test cars. Strainer tank and water meter were clamped to the underframe of the car, with hose connections to drain pipes of the ice bunkers.

fruit and the interior of the car were being cooled than it was later after the initial cooling had been done. During this portion of the trip heat that entered the car through the insulation was a less important factor in causing ice meltage than was the heat absorbed from the fruit. Table 13 shows a reduction in ice meltage after the first 3 days, although the highest outside temperature, 104° F., was not until the fifth day. The average rate of meltage per hour June 4 to 6 was 138.9 pounds for car A (full-bunker icing), 127.7 pounds for car B (upper-half-bunker), and 107.9 pounds for car C (lower-half-bunker). During the last 6 days of the trip, June 7 to 12, the average hourly meltage was 53.8 pounds for car A, 55.5 for car B, and 55.2 for car C.

TABLE 13.—*Icing and ice meltage records for United States Department of Agriculture 1936 orange-transportation test No. 1*

Place	Date	Time	Car A (dry-car-loaded, standard refrigeration, full-bunker icing)				Car B (dry-car-loaded, standard refrigeration, upper-half-bunker icing)			
			Drip-meter reading	Total ice supplied (initial and re-icing)	Average ice meltage per hour	Average for period indicated	Drip-meter reading	Total ice supplied (initial and re-icing)	Average ice meltage per hour	Average for period indicated
			Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Orange, Calif.	June 3	2:00 p. m.								
Los Angeles, Calif.	June 4	3:55 a. m.		[1] 10,600						
Do.	do.	8:00 a. m.								
Colton, Calif.	do.	10:30 a. m.						5,300		
Do.	do.	2:00 p. m.	1,818		182.0		355		101.4	
Do.	do.	3:55 p. m.	2,230	12,154	206.0		638	5,957	141.5	
San Bernardino, Calif.	do.	6:00 p. m.	2,588		179.0		1,006		184.0	
Yermo, Calif.	June 5	2:00 a. m.	3,818		153.7		2,240		154.2	
Kelso, Calif.	do.	7:00 a. m.	4,530		142.4	138.9	2,964		144.8	127.7
Las Vegas, Nev.	do.	12:00 m.	5,130	15,565	120.0		3,564	8,080	120.0	
Elgin, Nev.	do.	7:00 p. m.	5,927		114.0		4,454		127.1	
Milford, Utah	June 6	5:00 a. m.	6,816	17,162	88.9		5,427	10,761	97.3	
Boulter, Utah	do.	12:15 p. m.	7,416		82.7		6,056		86.7	
Salt Lake City, Utah	do.	4:00 p. m.	7,727	18,094	82.9		6,394	11,787	90.1	
Helper, Utah	do.	11:15 p. m.	8,280		77.5		6,959		77.9	
Grand Junction, Colo.	June 7	6:15 a. m.	8,751	19,055	66.0		7,493	12,645	76.3	
Bond, Colo.	do.	12:00 m.	9,121		64.3		7,883		67.8	
Tolland, Colo.	do.	5:45 p. m.	9,486		63.5		8,264		66.3	
Denver, Colo.	do.	10:00 p. m.	9,745	20,056	60.9		8,503	13,893	56.3	
Akron, Colo.	June 8	6:30 a. m.	10,279		62.8		9,084		68.3	
Holdrege, Nebr.	do.	2:00 p. m.	10,626		46.3		9,450		48.8	
Lincoln, Nebr.	do.	7:00 p. m.	10,919	21,238	58.6		9,749	14,832	59.8	
Omaha, Nebr.	do.	11:45 p. m.	11,250		69.7		10,082		70.1	
Pacific Junction, Iowa	June 9	7:00 a. m.	11,702		62.3		10,502		66.2	
Chariton, Iowa	do.	1:00 p. m.	12,064		60.3	53.8	10,010		58.0	55.5
Galesburg, Ill.	do.	7:15 p. m.	12,387	22,729	51.6		11,233	16,565	51.6	
Chicago, Ill.	June 10	1:00 a. m.	12,674		49.9		11,547		54.6	
Do.	do.	7:15 a. m.	12,933		41.4		11,749		32.3	
Clearing, Ill.	do.	10:30 a. m.	13,090	23,421	48.3		11,969	17,205	67.7	
Huntington, Ind.	do.	8:15 p. m.	13,391		30.9		12,380		42.1	
Marion, Ohio	June 11	2:15 a. m.	13,785	23,972	65.6		12,681	18,256	50.1	
Akron, Ohio	do.	9:15 a. m.	14,042		36.7		12,921		34.3	
Meadville, Pa.	do.	3:15 p. m.	14,280		39.7		13,146		37.5	
Hornell, N. Y.	do.	11:00 p. m.	14,577	24,670	38.3		13,421	19,070	35.5	
Susquehanna, Pa.	June 12	7:30 a. m.	14,857		32.9		13,717		34.8	
Port Jervis, N. Y.	do.	12:00 m.	15,012		34.4		13,882		36.7	
Croxton, N. J.	do.	4:45 p. m.	15,202		40.0		14,076		40.8	

[1] Estimated weight by railroad; all other re-icings "weighed in."

TABLE 13.—*Icing and ice meltage records for United States Department of Agriculture 1936 orange-transportation test No. 1*—Continued

Place	Date	Time	Car C (dry-car-loaded, standard refrigeration, lower-half-bunker icing)				Car D (Precooled, pre-iced by shipper, full-bunker icing)				Car E (precooled, pre-iced by shipper, upper-half-bunker icing)			
			Drip-meter reading	Total ice supplied (initial and re-icing)	Average ice meltage per hour	Average for period indicated	Drip-meter reading	Total ice supplied (initial)[2]	Average ice meltage per hour	Average for period indicated	Drip-meter reading	Total ice supplied (initial)[2]	Average ice meltage per hour	Average for period indicated
			Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Orange, Calif.	June 3	2:00 p. m.						14,353				7,062		
Los Angeles, Calif.	June 4	3:55 a. m.												
Do.	do.	8:00 a. m.					88		4.9		157		8.7	
Colton, Calif.	do.	10:30 a. m.		5,300										
Do.	do.	2:00 p. m.	231		66.0									
Do.	do.	3:55 p. m.	463	5,760	116.0									
San Bernardino, Calif.	do.	6:00 p. m.	810		178.0		156		6.8		269		11.2	
Yermo, Calif.	June 5	2:00 a. m.	1,825		125.7		257		12.6	10.9	375		13.2	13.9
Kelso, Calif.	do.	7:00 a. m.	2,424		119.8	107.9	312		11.0		443		13.0	
Las Vegas, Nev.	do.	12:00 m.	2,918	8,432	98.8		369		11.4		519		15.2	
Elgin, Nev.	do.	7:00 p. m.	3,693		110.7		494		17.8		675		22.2	
Milford, Utah	June 6	5:00 a. m.	4,584	9,070	89.1		687		19.3		874		19.9	
Boulter, Utah	do.	12:15 p. m.	5,210		86.3									
Salt Lake City, Utah	do.	4:00 p. m.	5,574	11,160	97.1		888		18.2		1,106		21.1	
Helper, Utah	do.	11:15 p. m.	6,116		74.7		1,044		21.5		1,287		25.0	
Grand Junction, Colo.	June 7	6:15 a. m.	6,631	12,483	73.6		1,192		21.1		1,469		26.0	
Bond, Colo.	do.	12:00 m.	6,967		58.4		1,305		19.6		1,600		22.8	
Tolland, Colo.	do.	5:45 p. m.	7,301		58.1		1,444		21.2		1,759		27.6	
Denver, Colo.	do.	10:00 p. m.	7,572	13,525	63.8		1,544		23.5		1,863		21.5	
Akron, Colo.	June 8	6:30 a. m.	8,105		62.7		1,712		19.8		2,099		27.8	
Holdrege, Nebr.	do.	2:00 p. m.	8,472		48.9		1,875		21.8		2,292		25.7	
Lincoln, Nebr.	do.	7:00 p. m.	8,744	14,512	54.4		2,025		30.0		2,476		36.8	
Omaha, Nebr.	do.	11:45 p. m.	9,071		68.8		2,190		34.7		2,557		17.0	
Pacific Junction, Iowa	June 9	7:00 a. m.	9,511		60.7		2,355		22.7		2,913		49.1	
Chariton, Iowa	do.	1:00 p. m.	9,840		56.3	55.2	2,559		31.0	25.5	3,137		37.3	27.0
Galesburg, Ill.	do.	7:15 p. m.	10,161	15,912	49.9		2,765		33.0		3,352		34.4	
Chicago, Ill.	June 10	1:00 a. m.	10,484		56.1		2,952		32.5		3,545		33.6	
Do.	do.	7:15 a. m.	10,785		48.1		3,096		23.0		3,679		21.4	
Clearing, Ill.	do.	10:30 a. m.	10,944	17,056	48.9		3,178		25.2		3,755		23.4	
Huntington, Ind.	do.	8:15 p. m.	11,390		46.7		3,458		28.7		4,024		27.6	
Marion, Ohio	June 11	2:15 a. m.	11,716	17,098	52.8		3,619		26.8		4,188		27.3	
Akron, Ohio	do.	9:15 a. m.	11,977		37.3		3,798		25.6		4,333		20.7	
Meadville, Pa.	do.	3:15 p. m.	12,214		39.5		3,967		28.2		4,475		23.7	
Hornell, N. Y.	do.	11:00 p. m.	12,507	17,916	37.8		4,184		28.0		4,661		24.0	
Susquehanna, Pa.	June 12	7:30 a. m.	12,827		37.6		4,384		23.5		4,849		22.1	
Port Jervis, N. Y.	do.	12:00 m.	12,906		37.5		4,509		27.7		4,956		23.8	
Croxton, N. J.	do.	4:45 p. m.	13,183		30.3		4,0[illegible]6		30.9		5,073		24.6	

[2] Not re-iced.

The meltage rate throughout the trip was influenced chiefly by the temperature of the fruit when loaded. When fruit temperatures were relatively high variations in outside temperature had little effect on ice meltage. For example, although the outside temperature on June 5 (fig. 5) rose from 61° F. at 4 a. m. to 97° at 2 p. m., ice meltage decreased. Later, however, when the fruit had cooled, a rise in the outside temperature increased ice meltage. On June 8, when the fruit temperatures were lower, a rise in outside temperature from 66° to 104° was followed by increased meltage of ice.

The effect of outside temperatures on ice meltage is shown in the meter readings of the two cars containing precooled oranges (cars D and E) for the 4 days June 5 to 8 (table 13). The fruit was precooled to 34° F. before loading. Only a small amount of ice was melted by the heat produced by the fruit itself,[9] and practically no ice was used in further reducing the temperature of the fruit.

In cars containing these precooled, pre-iced shipments the ice melted during the first 3 days (June 4 to 6) at the rate of 10.9 pounds an hour for car D (full-bunker icing) and 13.9 pounds an hour for car E (upper-half-bunker icing). Although mean outside temperatures for the last 6 days were about the same as for the first 3, the rate of ice meltage increased as fruit temperatures became higher. During this period the meter readings showed the average hourly meltage to be 25.5 pounds for car D, and 27.0 pounds for car E. After the sixth day en route there was little change in the fruit temperatures, the heat that entered the cars through the insulation being absorbed by the melting ice.

[9] For discussion of vital heat, see Technical Bulletin 605, p. 24 (footnote 2, p. 2).

U. S. GOVERNMENT PRINTING OFFICE: 1945

END