TB 434 (1934) USDA TECHNICAL BULLETINS UPDATA
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MALLISON, E.D. ; POWELL, C.L. 1 OF 1

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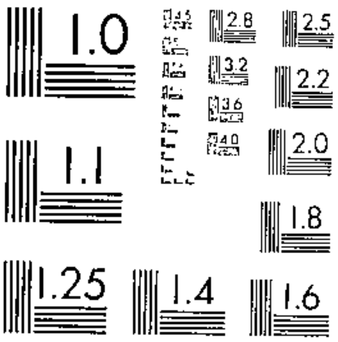
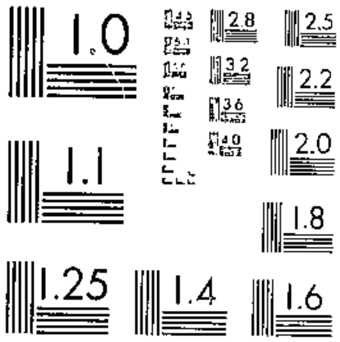


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A



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Technical Bulletin No. 434 October 1934

UNITED STATES DEPARTMENT OF AGRICULTURE

WASHINGTON, D.C.

REFRIGERATED TRANSPORTATION OF BARTLETT PEARS FROM THE PACIFIC NORTHWEST

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INTRODUCTION

The investigation reported in this bulletin dealt largely with the factors affecting the cost of transporting precooled Bartlett pears and the effectiveness of different methods of refrigerating the fruit in transit. Cooling pears prior to transportation improves their keeping quality but at the same time adds materially to the cost of preparing them for market. If pears are already cooled down to good carrying temperatures at the time of loading it is easier to refrigerate them satisfactorily in transit than nonprecooled pears. It is reasonable to expect, therefore, that the load per car might be increased so as to reduce proportionately the cost per box of the refrigeration in transit and effect an important economy for shippers. At the same time this heavier loading would reduce the number of refrigerator cars required to move the crop, which would be an important consideration for the railroads.

That there is a close relationship between the temperatures at which pears are stored and transported and those at which they ripen

[1] Other members of the staff of the Division of Fruit and Vegetable Crops and Diseases who assisted in this investigation were C. O. Bratley, W. C. Cooper, M. P. Masure, M. H. Haller, J. O. Moore, and Henry Hartman. The cooperation and assistance of the various shipping organizations at Medford, Oreg., and Yakima, Wash., and of the various transcontinental railroad companies and refrigerator car lines that made these tests possible is deeply appreciated.

has long been known. Magness, Diehl, and Allen[2] found that the storage life of Bartlett pears at 43° F. is approximately double that at 53°. At 36° the possible storage life is about double that at 43°, and at 31° it is about twice as long as at 36°.

SCOPE OF INVESTIGATION

These investigations were begun in 1928 and were continued during four seasons. Five complete transportation tests, involving 37 experimental car-lot shipments, were made from Medford, Oreg., and Yakima, Wash., to New York City. The shipments studied, as shown in table 1, comprised cars loaded respectively with 520, 640, 664, 720, and 744 boxes of pears and supplied with various quantities of ice and salt in transit. Information was obtained regarding the condition and temperature of this fruit at the time of loading, temperatures and ice meltage during transit, condition of fruit at destination, and its keeping quality during a subsequent storage period. For the most part the tests were made during periods of high outside temperatures in August and September, using the Bartlett variety, which is the first variety to be moved in large quantities from the Pacific Northwest. It was also considered that if the Bartlett, a variety having a short storage life, could be safely transported in the heavier load all other varieties could be safely shipped in the same sized load.

TABLE 1.—*Shipments of test cars of Bartlett pears from Medford, Oreg., and Yakima, Wash., to New York City during the 1928 to 1931 seasons*

Refrigeration	Size of load	Salt used	Test cars shipped from— Yakima, 1928	Medford 1928	Medford 1929	Medford 1930	Medford 1931
	Boxes						
Precooled, standard refrigeration	520	3 percent		2	2	1	1
	520	75 pounds				1	2
	520	50 pounds			[1] 1	1	
	520	None	1				
	720	3 percent			1	1	1
	720	2 percent	1				
	720	75 pounds			[1] 1	1	1
	720	50 pounds			2		
	744	3 percent [2]				1	1
	640	do					1
	664	do		2			
	664	None		2			
Precooled, initial icing with two reicings.	720	None			2	1	
Nonprecooled, standard refrigeration.	520	5 percent			1	1	1
	520	3 percent		1			
	520	3 percent, 75 pounds.[3]				1	

[1] 100 pounds of salt found too large; changed to amount shown in third column.
[2] Boxes loaded on end; all others on side.
[3] 318 pounds of salt used on initial salting; 75 pounds at all other icing stations.

Supplementing this information, studies were made at point of origin and at destination on 67 commercial shipments of Bartlett, Bosc, and Anjou pears. Twenty-three of these shipments were loaded with 720 boxes to the car, and a few were made in pairs under comparable conditions, one of the cars being loaded with 520 boxes and the other with 720 boxes.

[2] MAGNESS, J. R., DIEHL, H. C., and ALLEN, F. W. INVESTIGATIONS ON THE HANDLING OF BARTLETT PEARS FROM PACIFIC COAST DISTRICTS. U.S. Dept. Agr. Tech. Bull. 140, 28 p., illus. 1929.

TERMINOLOGY

A number of terms commonly used in shipping circles and similarly used in this bulletin are defined below.

"Standard refrigeration" means that the refrigerator car was iced to capacity prior to loading and reiced to capacity at all regular icing stations while in transit. Icing stations are so spaced along the railroad lines that the cars can be reiced once, or possibly twice, each 24 hours. "Preiced" means that the car is iced to capacity prior to loading. "Initially iced; Do not reice" in connection with these shipments indicates that the cars were preiced and not reiced in transit. "Initial icing with two reicings" indicates that the car was preiced and reiced to capacity at two icing stations several days apart.

"Percent salt" designates the quantity of salt used in refrigeration, the weight of salt supplied at the initial salting being a percentage of the weight of the ice required to fill the bunkers to capacity and the same percentage of the ice added at each reicing station. In some cases instead of adding salt on this percentage basis a definite and empirically determined quantity of salt was added at each icing regardless of the amount of ice placed in the bunker. "Initial salting" indicates the first salting of the ice in a car.

The "bunkers" are the compartments at both ends of the car where the ice is placed. The "quarter-length position" is midway between the doors and the bunkers. The term "divided load" is used to designate a load having an open space of varying width between the doors, where it is braced with timbers to prevent shifting of the load. A "through or solid load" is one that is continuous between the bunkers. "Minimum load" is the least amount of weight that will be carried at the carload freight rate.

A "layer" is a course or stratum of the load parallel to the floor of the car and one package in height. A "stack" is a pile of packages extending from one side of the car to the other, parallel to the end of the car and one package in width. A "row" is a pile of packages extending lengthwise of the car, parallel to the sides and one package in width.

The condition of the pears is designated by the terms "hard", "firm", and "ripe." In these tests pears were considered hard when the average resistance of the pear flesh to the 5/16-inch plunger of the pressure tester [3] was 12 pounds or above. When the average test was between 8 and 11.5 pounds the pears were considered firm; when below 7.5 pounds the fruit was termed ripe.

EXPERIMENTAL PROCEDURE

REFRIGERATOR CARS

The cars used in each test were selected from those regularly used in the shipment of pears and had been in service for 5 to 8 years. The insulation in the different cars varied from 1½ to 2 inches in thickness in the sides and ends, and from 2 to 2½ inches in the roof and floor. All cars were equipped with floor racks and insulated bulkheads. The bunker capacity was 10,600 to 10,700 pounds of chunk ice. Although there was a variation in the specifications of the cars used in the 1928 and 1929 tests, those used for the 1930 and 1931 tests were comparable.

[3] MAGNESS, J. R., and TAYLOR, G. F. AN IMPROVED TYPE OF PRESSURE TESTER FOR THE DETERMINATION OF FRUIT MATURITY. U.S.Dept.Agr.Circ. 350, 8 pp., illus. 1925.

THERMOMETERS

Electrical resistance thermometers were used to obtain fruit and air temperatures within the cars. The sensitive part or bulb of the instrument was inserted into a fruit or hung in the air at desired locations in the car. Leads from these bulbs were connected to a master cable which was carried out of the car through a thin doorplate placed at the top of the doorway and thence to the running board on the top of the car, as shown in figure 1. Readings were made by connecting the end of the master cable to an indicator or reading box equipped with a suitable selector switch by which the electrical resistance in any of the 12 bulbs could be determined. The indicator box is a modified Wheatstone bridge utilizing a sensitive galvanometer. Changes in the temperature of the bulb produce a corresponding change in the resistance of the coil in the bulb, which the indicator registers directly in degrees Fahrenheit. As a slight variation exists in the different instruments, calibrations of individual bulbs and indicators are necessary for accuracy. It will thus be seen that the instruments are so constructed and placed that temperature readings may be obtained at a number of places within the car without opening the doors. In the tests under discussion, readings were made at intervals of 4 to 6 hours. Outside air temperatures were obtained at the same time with a mercury thermometer.

In the 1928–29 tests fruit temperatures were obtained in the center row at the bottom, middle, and top layers of the quarter-length and doorway stacks and in the top and bottom layers of the stack next to the rear bunker. Air temperatures were taken at the top and bottom of the load at the doorway and rear bunker. Thus, extremes of temperatures as well as average conditions in the load were determined. However, in the 1930 and 1931 tests, thermometers were placed in the next-to-the-top layer at the quarter-length and doorway stacks instead of in the middle layer. This change was made because it was found in the earlier tests that the keeping quality of the top-layer pears was sometimes impaired by the higher temperatures in the top part of the load. It therefore became desirable to ascertain whether or to what extent the next-to-the-top layer is similarly affected.

EXPERIMENTAL FRUIT

It is impractical to attempt to draw conclusions from apparent effects on fruit of unknown or uncertain history, such as the average commercial shipments. In this work, therefore, reliance was placed on the observation of carefully selected comparable small lots of known history which were placed in representative positions in the different experimental cars.

The fruit selected for this purpose was usually taken from 3 or 4 normal trees and was picked at the usual harvest time and placed immediately in cold storage and cooled to 32° F. All lots were handled in the same way and held under comparable conditions prior to shipment. During transportation the test boxes were placed at selected positions in the cars and after arrival were placed in cold storage for further study. Inspections of the fruit were made at the time of arrival and at intervals during the subsequent storage periods to determine quality and condition and the rate of ripening. The firmness of the pears was determined by the use of a pressure tester.

REFRIGERATION RECORDS

Except at the first icing, when the bunkers were filled to known capacity, observers accompanying the cars weighed the ice and salt used before they were placed in the bunkers. The amount of ice

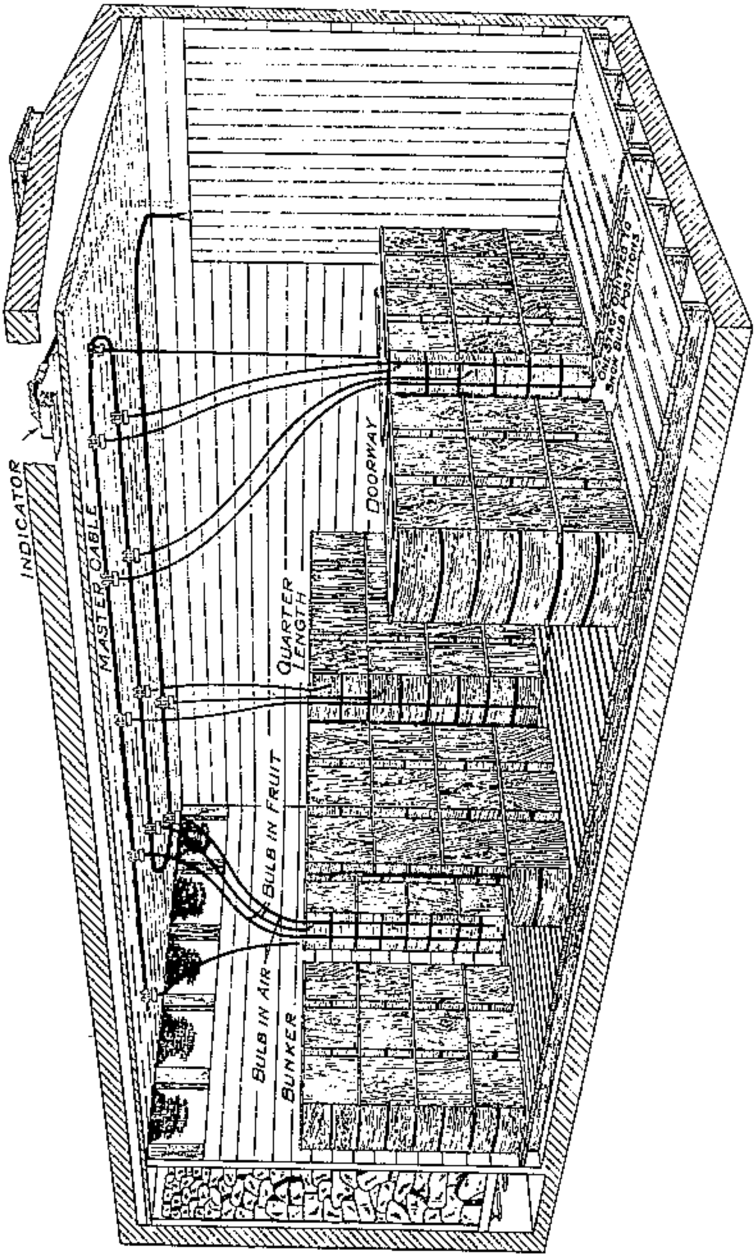

FIGURE 1.—Perspective view of the interior of a refrigerator car showing method of installing resistance thermometers in test cars loaded with pears with master cable connecting to indicator box on roof of car where all temperatures were read.

remaining in the bunkers at destination was estimated as closely as possible in all cases. The procedure was to pike the ice to a level surface and determine the proportion of the bunker space that it filled.

DESCRIPTION OF LOADS

Four different loads were compared with the standard load of 520 boxes. The 640- and 744-box loads were through loads, whereas the others were divided loads braced at the doorway. All the layers were stripped and nailed. With the exception of the 744-box load, in which the boxes were loaded on end, the boxes were loaded on the sides in the usual manner.

For the 520-box load, the boxes were loaded 8 rows wide, 18 stacks long, and 4 layers high in the last 6 stacks next to one bunker and in the last 5 stacks next to the other bunker, and 3 layers high in the 7 stacks adjacent to the doorway in the center of the car.

For the 640-box load, the boxes were loaded 8 rows wide, 4 layers high, and 20 stacks long.

For the 664-box load, boxes were loaded 8 rows wide, 18 stacks long, and 5 layers high in the last 6 stacks next to one bunker and in the last 5 stacks next to the other bunker, and 4 layers high in the remaining stacks adjacent to the doorway.

For the 720-box load, the boxes were loaded 8 rows wide, 5 layers high, and 18 stacks long.

For the 744-box load the boxes were loaded 8 rows wide, 3 layers high, and 31 stacks long.

ROUTE OF TESTS

Each test was made over the route commonly used by the shippers, and each varied slightly from the others. The approximate routes of these tests are shown in figure 2.

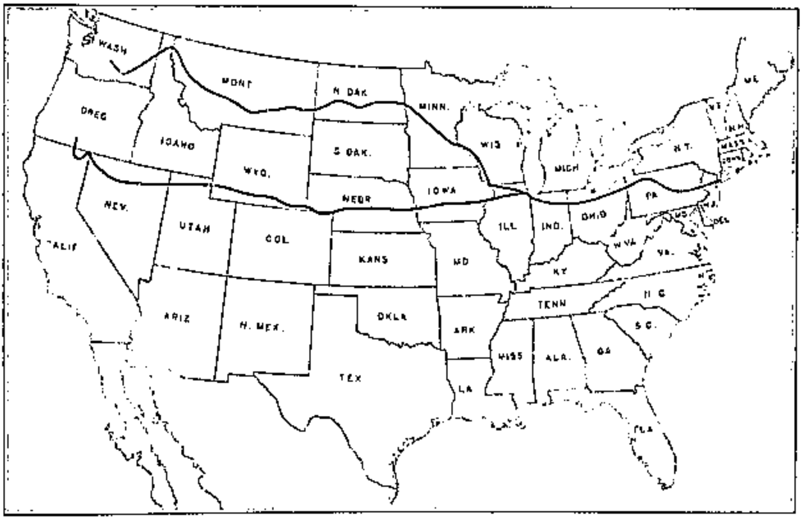

FIGURE 2.—Map showing approximate routes of experimental shipments of pears from Medford, Oreg., and Yakima, Wash., to New York City, 1928 to 1931 seasons.

EXPERIMENTAL WORK

HEAVIER LOADING OF PRECOOLED PEARS

A preliminary experiment to determine the practicability of heavier loading of precooled pears was made in September 1928. This test was a comparison of a 520-box load with a 664-box load. The results obtained with the heavier load were encouraging, so a second test was made in October of the same year with a still larger load of 720 boxes. The results of this test were not conclusive because the weather was cool.

The next three experiments (1929, 1930, and 1931) were made with Bartlett pears shipped during the early part of the season, when weather conditions were more favorable, as shown in table 2. The results of these three tests showed that precooled pears, shipped under comparable conditions, reached destination at about the same stage of maturity when shipped in either 520- or 720-box loads. Conditions under which the tests were made varied each season, yet the relation between the 520-box and the 720-box loads in the tests remained about the same. The results of the test made in 1930, as shown in table 3, are typical of the results obtained in the other tests mentioned.

TABLE 2.—*Maximum, minimum, and mean outside temperatures in transit during the pear transportation tests of 1928, 1929, 1930, and 1931*

Origin of shipment	Year	Date started	Date completed	Outside temperature in transit		
				Maximum	Minimum	Mean
				° F.	° F.	° F.
Oregon	1928	Sept. 12	Sept. 25	91	36	57.0
Washington	1928	Oct. 13	Oct. 25	93	36	59.3
Oregon	1929	Aug. 29	Sept. 9	104	50	72.5
Do	1930	Aug. 18	Aug. 28	89	44	69.4
Do	1931	Aug. 14	Aug. 25	92	50	72.7

TABLE 3.—*Length of time, expressed in hours and in percentage of the transit period, during which the temperature of precooled fruit was within certain temperature ranges*

[Test conducted in August 1930]

Position of fruit and amount of salt added	Time [1] in transit during which temperatures of precooled fruit were within range of—							
	30°–35° F.		35°–40° F.		40°–45° F.		45°–50° F.	
	Hours	*Percent*	*Hours*	*Percent*	*Hours*	*Percent*	*Hours*	*Percent*
Top layer:								
3 percent salt:								
520-box load	0	0.0	34	15.1	127	56.2	65	28.7
720-box load	0	.0	72	31.8	71	31.4	83	36.8
75 pounds salt:								
520-box load	0	.0	63	27.8	163	72.2	0	.0
720-box load	0	.0	72	31.8	154	68.2	0	.0
No salt:								
720-box load	18	8.0	33	14.6	64	28.3	111	49.1
Next-to-top layer:								
3 percent salt:								
520-box load	0	.0	161	71.3	65	28.7	0	.0
720-box load	78	34.5	94	41.6	54	23.9	0	.0
75 pounds salt:								
520-box load	44	19.4	182	80.6	0	.0	0	.0
720-box load	65	28.7	161	71.3	0	.0	0	.0
No salt:								
720-box load	34	15.0	69	30.6	123	54.4	0	.0
Bottom layer:								
3 percent salt:								
520-box load	126	55.8	100	44.2	0	.0	0	.0
720-box load	22	9.7	177	78.3	27	12.0	0	.0
75 pounds salt:								
520-box load	216	95.6	10	4.4	0	.0	0	.0
720-box load	226	100.0	0	.0	0	.0	0	.0
No salt:								
720-box load	58	25.6	168	74.4	0	.0	0	.0

[1] Total time in transit was 226 hours.

With precooled pears only a small difference was found between the temperatures at comparable positions in cars with 520- and 720-box loads when both received the same amount of refrigeration in transit.

Temperature differences between layers in the same car were generally less in the heavier loads. In the 520-box load the next-to-the-top layer was the second from the floor at the doorway and the third from the floor in the quarter-length and bunker stacks. In the 720-box load it was the fourth layer from the floor in all stacks, and therefore was nearer to the top of the car than in the 520-box load. Despite this, temperatures were slightly lower in the next-to-the-top layer of the 720-box load than in the next-to-the-top layer of the 520-box load, which indicates that there is not a definite or regular stratification of temperatures within the car regardless of the size of the load, as has been commonly believed. Typical examples are shown in table 3. The lower average temperature in the next-to-the-top layer of the 720-box load was doubtless due to the influence of the larger mass of precooled fruit in the heavier load.

The data in table 3 show the length of time the various layers of fruit were in certain ranges of temperature, and table 4 shows the comparative rate of softening of the fruit after being subjected to the temperatures shown in table 3. Comparison of these two tables indicates that the storage life of the pears after shipment in the 520-box and 720-box loads under comparable conditions was about the same. This, of course, was to be expected, considering the comparable transit temperatures and the subsequent comparable storage temperatures. The data in these tables indicate that in some instances the 720-box load might be slightly preferable from the standpoint of maintaining both lower transit temperatures and longer storage life for the fruit after arrival at destination. However, the differences that occur are neither sufficiently large nor consistent enough to justify concluding more than that the temperatures and the storage life of the fruit were about the same, no matter whether the fruit was shipped in the 720-box load or the 520-box load. The most pronounced difference was found at the time of the last two inspections with fruit from the top-bunker position of cars receiving 75 pounds of salt at each reicing en route. At these inspections the fruit from the 720-box load was 2.4 to 3.5 pounds firmer than that from the same position in the 520-box load.

TABLE 4.—*Comparative rate of softening of precooled pears from doorway and bunker positions in top layer during the 1930 test*

Item	Pressure test on—				
	Aug. 17[1]	Aug. 28	Sept. 26	Oct. 20	Nov. 10
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Doorway:					
3 percent salt:					
520-box load	14.0	13.6	10.6	9.0	8.7
720-box load	14.0	12.5	11.8		10.9
75 pounds salt:					
520-box load	14.0	13.0	13.0	11.5	10.4
720-box load	14.0	13.2	11.7		11.3
No salt:					
720-box load	14.0	13.3	8.8	9.0	7.3
Bunker:					
3 percent salt:					
520-box load	14.0	13.7	10.3		9.1
720-box load	14.0				
75 pounds salt:					
520-box load	14.0	13.3	12.0	8.0	8.9
720-box load	14.0	14.2	12.0	11.5	11.8
No salt:					
720-box load	14.0	13.3	8.8	8.0	

[1] Date of loading test cars.

In the 3-year tests a comparison of the total average amount of ice placed in the bunkers and the amount melted in the refrigeration of the 520- and 720-box loads of precooled pears (table 5) shows that there was very little difference in the amount of ice melted by these two loads. In each instance an average of about 57 percent of the total amount of ice placed in the bunkers was melted, about 43 percent of the total being left in the bunkers and not utilized in the refrigeration of the pears.

TABLE 5.—*Quantity of ice placed in bunkers and amount melted in cars of precooled pears in tests made in 1929, 1930, and 1931*

Year of test	520-box load				720-box load			
	3 percent salt		75 pounds salt		3 percent salt		75 pounds salt	
	Ice in bunkers	Ice melted	Ice in bunkers	Ice melted	Ice in bunkers	Ice melted	Ice in bunkers	Ice melted
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1929	20,790	13,574	----------	----------	21,684	13,864	21,771	12,951
1930	19,701	10,291	20,202	12,542	19,031	9,585	19,485	9,449
1931	19,425	10,544	21,320 20,184	12,515 11,028	19,781	10,488	20,056	11,312
Average	19,972	11,470	20,571	12,028	20,165	11,312	20,437	11,237
Percent	----------	57.4	----------	58.4	----------	56.1	----------	55.0

These results were to be expected under the conditions of these experiments, since the amount of heat given off in the respiration of precooled fruit is comparatively small, and the larger amount of cold fruit in the 720-box load would be expected to help maintain lower temperatures for a longer period.

USE OF SALT AS AN AID TO REFRIGERATION

The use of salt with the ice in refrigerator cars has been general for several years. In commercial practice there is a variation in the amount used, depending largely upon the season of the year and whether the lading is precooled or not. The weight of the salt added is a stated percentage of the amount of ice necessary to fill the bunkers to capacity. The common practice with shipments of pears from the Pacific Northwest during the early part of the shipping season is to use 3 percent of salt when the fruit is precooled and 5 percent when it is not precooled. In most instances the largest percentage of the total amount of salt used in a trip is placed in the bunkers at the initial icing and only small amounts are added at reicings in transit. In the test made in 1928 between Medford and New York, for example, 571 pounds of salt was placed in the bunkers of a car containing 520 boxes of precooled pears. Of this amount 318 pounds was used at the initial icing. The remaining 253 pounds was distributed among 10 reicings at various stations en route.

When precooled pears are shipped during warm weather, fruit temperatures are lower at the time of loading than at any other period during transit. Consequently, under customary methods, the largest quantity of salt is added when least needed, making this a questionable practice.

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Figure 3 shows that during a 48-hour period after the 318 pounds (3 percent) of initial salt was added, the drip water from cars loaded with precooled pears contained from 7 to 14 percent of salt, indicating that the salt was being rapidly removed from the car, and that during the last 8 days of the trip the 14 to 25 pounds of salt added at the reicing stations was not sufficient to replace that leaving the car in the drip water. It shows further that the amount of salt in the bunkers of the car diminished rapidly from 3 percent during the first few hours after the initial salting to a small fraction of 1 percent of the ice in the bunker during the last 5 days of the trip. This condition was correlated with the temperature in transit, for during the last 4 or 5 days of the trip the fruit and air temperatures in cars receiving 3 percent salt were approximately the same as in

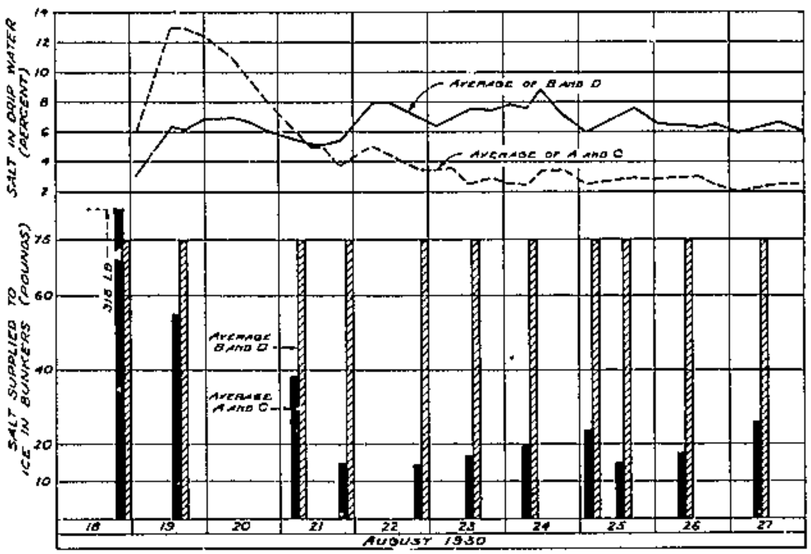


FIGURE 3.—Amount of salt in the drip water of cars *A*, *B*, *C*, and *D* (loaded with precooled pears) and the amount of salt supplied to the ice in the bunkers. All cars under standard refrigeration and salted at each icing; *A* and *C* with 3 percent, averaging 559 pounds per car; *B* and *D* with 75 pounds, averaging 825 pounds per car.

cars receiving no salt. A comparison of the temperatures obtained in cars shipped with 520- and 720-box loads receiving no salt, 3 percent of salt, and 75 pounds of salt at each reicing is shown in table 3, and the influence of these temperatures on the fruit is shown in table 4. Table 3 shows that lower temperatures were obtained in the cars receiving 75 pounds of salt at each reicing.

Since the temperatures in the car throughout the journey were directly related to the quantity and distribution of the salt in transit, different methods of salting were tried out in the experiments of 1929 and 1930. In some of the test cars the amount of salt used at the initial salting was reduced to 50, 75, or 100 pounds; in others the same amounts of salt were also used at each reicing station.

From the data obtained, 75 pounds of salt applied at each reicing station is apparently the most satisfactory amount to use with precooled pears. When this amount was used the air and fruit temperatures in the bottom layer usually ranged from 30° to 35° F., whereas with 3 percent salt the fruit temperatures at the bottom of the bunkers were sometimes as low as 27° and air temperatures were 16° to 18° for a short period following the initial salting. The application of 100 pounds of salt at the initial salting and at each of the reicing stations reduced the temperatures too much, since they dropped nearly to the freezing point by the fourth or fifth day in transit. In this test it was accordingly necessary to omit the application of salt at two reicing stations in these cars and to use only 50 or 75 pounds at the remainder of the icing stations.

Under the modified practice of adding fixed amounts of salt at all reicings, temperatures in transit were more favorable. When 50 or 75 pounds of salt was placed in the bunkers at each reicing, the fruit temperatures of precooled pears usually varied between 35° and 45° F., whereas with 3 percent salt the temperature ranged as high as 50°. The more favorable temperatures (table 3) obtained with the larger amounts of salt at all reicings make it possible for the fruit to be kept longer after arrival at destination. Obviously, the use of 50 or 75 pounds of salt should be limited to shipments of precooled pears during the early part of the season when outside temperatures are high, and shipments later in the season should have the amount of salt materially reduced.

As shown in table 5, the ice meltage was practically the same in all cases. During the test of 1930, for example, the ice meltage in two comparable 720-box loads of precooled pears, one supplied with 75 pounds of salt and the other with 3 percent of salt at each reicing, was 9,449 and 9,585 pounds, respectively.

Nonprecooled pears require a salting treatment different from that of precooled pears. When the fruit has not been precooled it is desirable to remove as much of the field heat as possible immediately after loading. The use of 5 percent salt, which is the standard commercial practice, seemed to give the best results in such cases. A test was made in 1930 to determine whether the use of 318 pounds (3 percent) of salt at the first reicing and 75 pounds at all other reicings would give more satisfactory results than the use of 5 percent salt throughout, but no significant difference in results was obtained.

In 1929 a test was made to determine the possibility of shipping precooled pears without using salt. Two cars carrying a load of 720 boxes each were shipped under standard refrigeration without salt, and two similar cars were shipped under standard refrigeration with 3 percent salt. The results obtained in this test indicated that salt is desirable even with precooled fruit during warm weather. The fruit in the top layers of the cars shipped without salt was turning yellow in color and was getting soft on arrival, whereas the fruit in similar layers in cars shipped with salt was still green and firm.

TRANSIT CONDITIONS WITH PRECOOLED AND NONPRECOOLED PEARS

There is still a large tonnage of pears shipped from the Pacific Northwest that is not precooled because of lack of facilities at shipping points. However, the value of precooling has been amply demonstrated by previous investigations. Pentzer et al.,[4] conducted experiments

[4] PENTZER, W. T., MAGNESS, J. R., DIEHL, H. C., and HALLER, M. H. INVESTIGATIONS ON HARVESTING AND HANDLING FALL AND WINTER PEARS. U.S. Dept. Agr. Tech. Bull. 290, 36 pp., illus. 1932.

which indicated that the lower temperatures secured by precooling may be expected to add 1 to 2 months to the subsequent storage life of pears held at 31° F. beyond that which can be expected from nonprecooled fruit.

Magness and Diehl[5] found that Bartlett pears held at temperatures approximating those in cars thoroughly precooled prior to loading could be safely stored at 31° F. for periods of 30 to 45 days and ripen with good quality, provided the fruit had been promptly and thoroughly cooled. Bartletts held at temperatures approximating those in the top of nonprecooled cars were ripe at the end of a 12-day holding period, whereas fruit held at temperatures equivalent to those prevailing in the lower half of the load was generally suitable for holding up to 45 days at 30° to 31°.

In the investigations covered by this bulletin, tests were made each year to compare precooled and nonprecooled shipments of Bartlett pears. As the customary commercial procedure is to use 5 percent salt with nonprecooled shipments and 3 percent with precooled shipments, the various test cars accordingly received these amounts. The temperature of the warm fruit at the time of loading the cars ranged from 65° to 75° F., whereas the average loading temperature of the precooled fruit was between 32° and 34°, a difference of 33 to 41 degrees. During transit 6 to 7 days elapsed before the temperature of the nonprecooled fruit reached that of the precooled fruit, so that the former necessarily ripened much more rapidly than the latter while they were en route to market, a period of 9 to 10 days.

The results obtained in this phase of the investigation were about the same in each year's tests. The temperatures in the cars loaded with warm fruit were above 50° F. for about one-third of the time that the cars were en route and between 45° and 50° for the remainder of the time. Precooled shipments were between 35° and 40° for a short time, between 40° and 45° about 60 percent of the time, and between 45° and 50° approximately a fourth of the time, with none of the temperatures going above 50°. A typical example of the range of transit temperatures is given in table 6.

TABLE 6.—*Comparison of average fruit temperatures obtained in the top and next-to-top layers of 520-box loads of precooled and nonprecooled pears in tests made during August 1930*

Position of fruit and amount of salt added	Time[1] in transit during which temperatures of precooled and nonprecooled fruit were within the range of —											
	35°–40° F.		40°–45° F.		45°–50° F.		50°–55° F.		55°–60° F.		60°–65° F.	
	Hr.	*Pct.*	*Hr.*	*Pct.*	*Hr.*	*Pct.*	*Hr.*	*Pct.*	*Hr.*	*Pct.*	*Hr.*	*Pct.*
Precooled:												
3 percent salt:												
Top layer	34	15.1	127	56.2	65	25.7	0	0.0	0	0.0	0	0.0
Next-to-top layer	161	71.3	65	28.7	0	.0	0	.0	0	.0	0	.0
Nonprecooled:												
5 percent salt:												
Top layer	0	.0	0	.0	133	61.0	38	16.8	20	9.0	30	13.2
Next-to-top layer	0	.0	152	67.2	37	16.4	13	5.8	13	5.8	11	4.8

[1] Total time in transit was 220 hours.

A direct correlation was found between the condition of the fruit upon arrival at destination and its temperature during transit. The pears in the top layers of the nonprecooled loads generally arrived in a

[5] See footnote 2.

firm to ripe condition and ripened shortly after being placed in storage, whereas the precooled fruit from the top layers arrived in a firm to hard condition and remained firm after being in storage at 32° F. for 60 to 80 days. It was found, furthermore, that after arrival at destination, precooled Bartletts had a storage life 6 to 10 weeks longer than those that had not been precooled. Results obtained in 1930 are typical and are shown in table 7. In this connection, however, Hartman [6] has reported that Bartlett pears do not ripen with maximum dessert quality if held longer than 4 to 6 weeks in storage, even under ideal conditions, and Magness, Diehl, and Allen [7] found that while Bartletts could be stored 3 to 5 months under proper conditions, the longer the pears were held in cold storage the poorer the dessert quality of the ripened product. The poorer dessert quality was not noticeable until after 30 days in cold storage.

TABLE 7.—*Comparative rate of softening of pears from top layer of 520-box loads of precooled (8 percent salt) and nonprecooled pears (5 percent salt) during test made in 1930*

Item	Pressure test on—				
	Aug. 17 [1]	Aug. 28 [2]	Sept. 28 [3]	Oct. 20 [4]	Nov. 10 [5]
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Doorway:					
Precooled	14.0	13.5	10.0	9.0	8.7
Nonprecooled	14.0	12.6	7.1	[6] 4.5	[6] 0.0
Bunker:					
Precooled	14.0	13.7	10.3	----------	9.1
Nonprecooled	14.0	9.8	3.3	[6] 4.2	[6] 4.2

[1] Date of loading cars.
[2] Unloaded and placed in storage at 32° F.
[3] First inspection in storage.
[4] Second inspection in storage.
[5] Third inspection in storage.
[6] Showing scald and core breakdown.

TYPICAL FRUIT TEMPERATURES DURING TRANSIT WITHIN A CAR LOADED WITH PRECOOLED PEARS

The approximate boundaries of temperature zones in the load for the different days in transit as indicated in figure 4 were determined by direct computation on the basis of the difference in temperature and the distance between the points at which thermometer records were obtained. It will be noted that on the first day the temperatures were fairly uniform throughout the load a few hours after loading was completed. The succeeding diagrams show that the fruit temperatures gradually rose during the entire time in transit. From the beginning to the end of this time there was a noticeable increase in the fruit temperatures from day to day. The contrast between the temperatures on the first day and those on the eleventh day is striking because of the temperature increase throughout the load. During this period it appears that as the fruit warmed up, the progressively higher temperature zones that resulted had about the same boundaries.

As the load warmed up, the highest temperatures were found on the south side of the top layer in the quarter-length stack, and from this point they gradually spread over the top of the load. This is more

[6] HARTMAN, H. INVESTIGATIONS RELATING TO THE HANDLING OF ROGUE RIVER VALLEY PEARS ON EASTERN MARKETS. Oreg. State College, 27 pp. 1931. [Mimeographed.]
[7] See footnote 2.

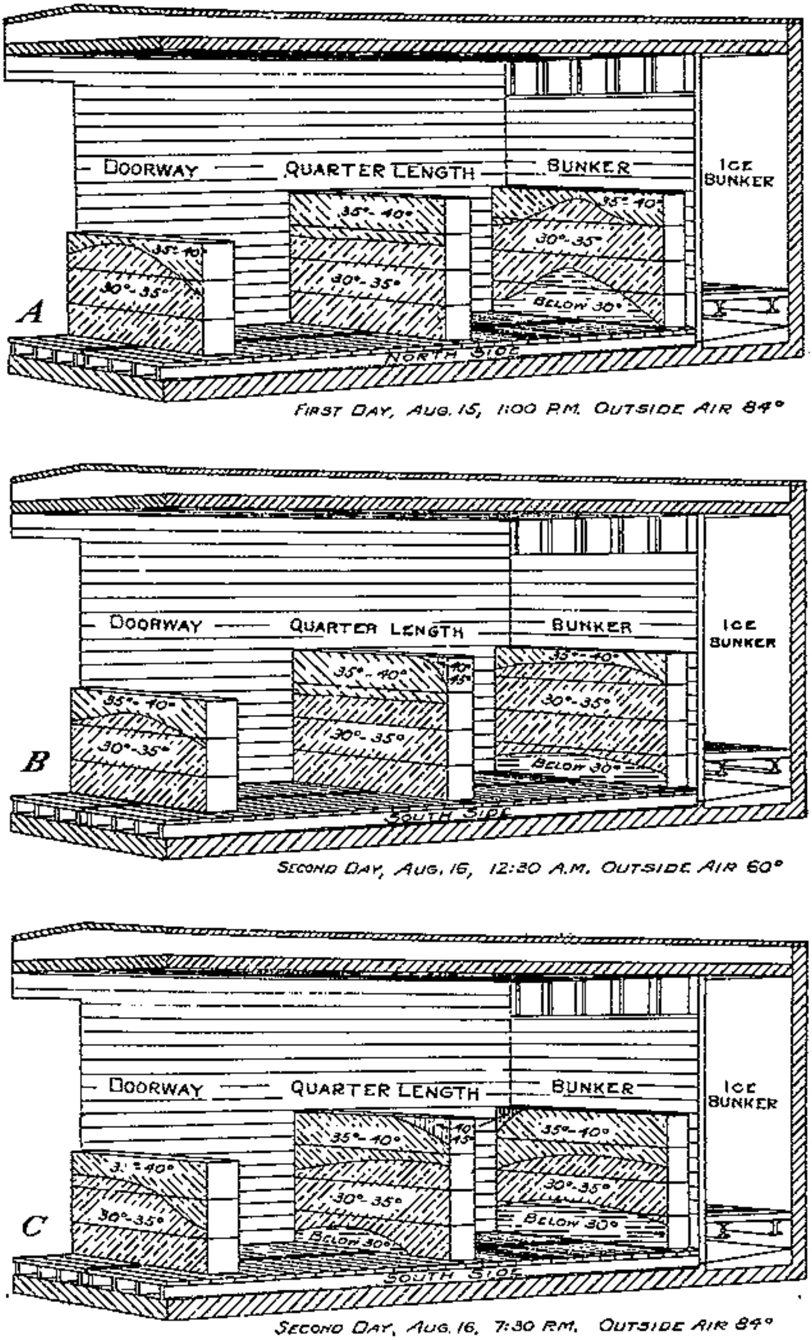
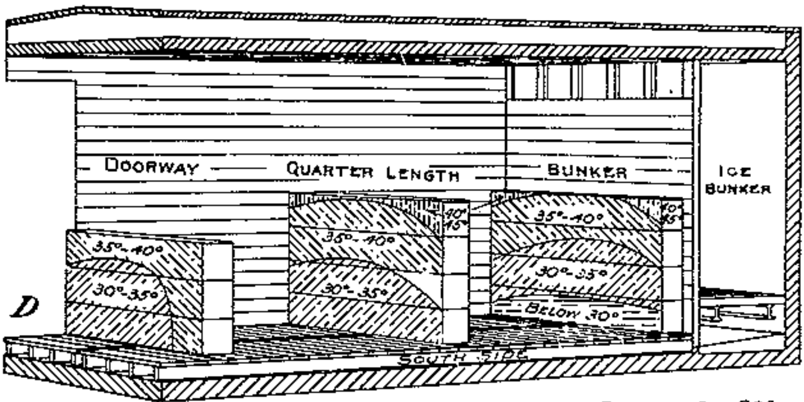


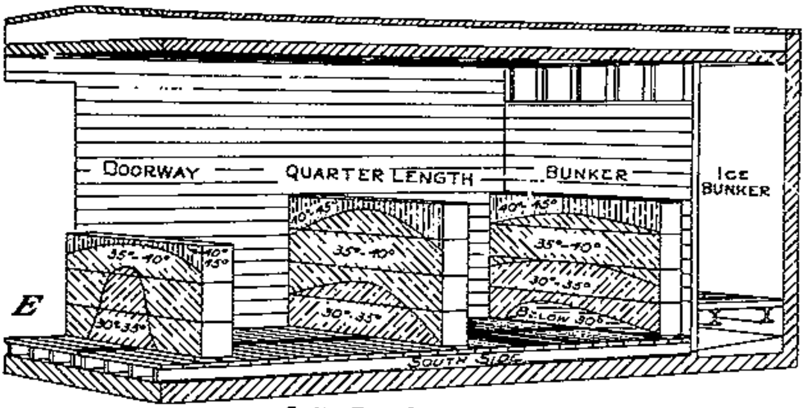
FIGURE 4.—Temperatures of a carload of pears in transit from Medford, Oreg., to Jersey City, N.J. (520 boxes; precooled; standard refrigeration; 3 percent salt). After the first day the position of the car on the tracks was reversed, when the north side of the car became the south side.

D



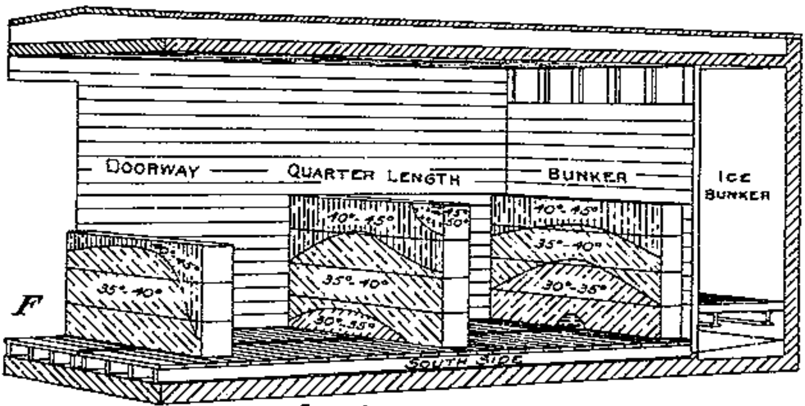
THIRD DAY, AUG. 17, 11:50 A.M. OUTSIDE AIR 90°

E



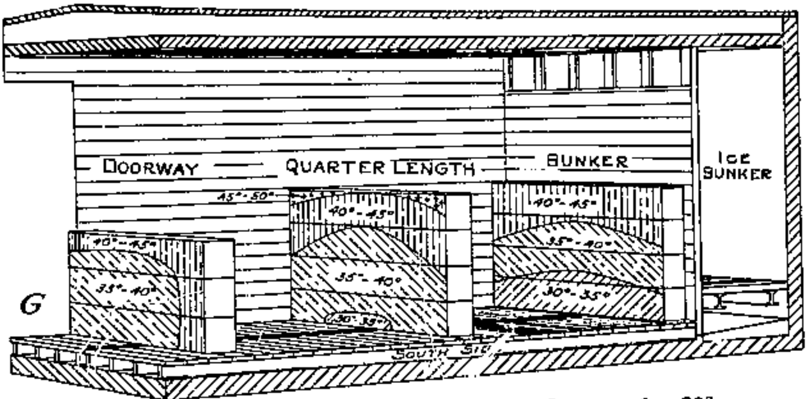
FOURTH DAY, AUG. 18, 10:30 A.M. OUTSIDE AIR 80°

F

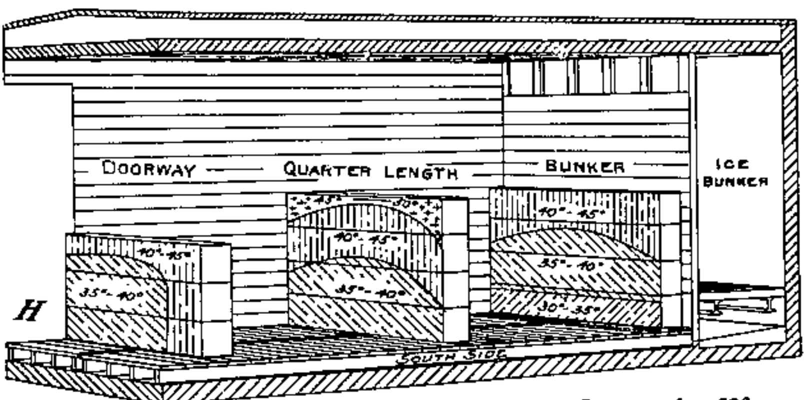


FIFTH DAY, AUG. 19, 3:45 P.M. OUTSIDE AIR 89°

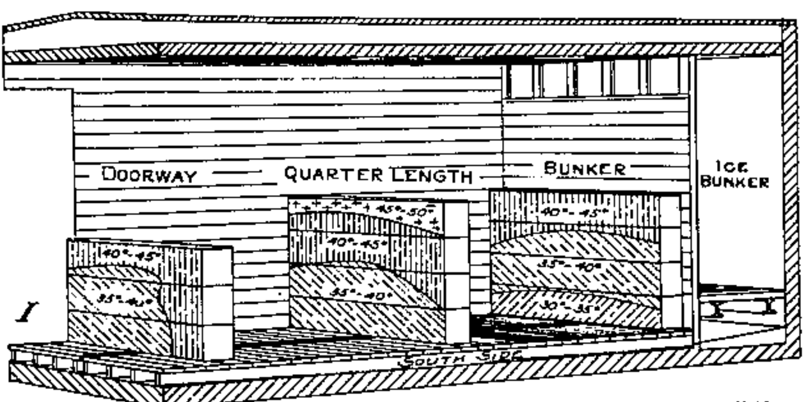
FIGURE 4.—Continued.



SIXTH DAY, AUG. 20, 1:15 P.M. OUTSIDE AIR 88°



SEVENTH DAY, AUG. 21, 6:30 A.M. OUTSIDE AIR 60°.



EIGHTH DAY, AUG 22, 2:00 P.M. OUTSIDE AIR 77.°

FIGURE 4.—Continued

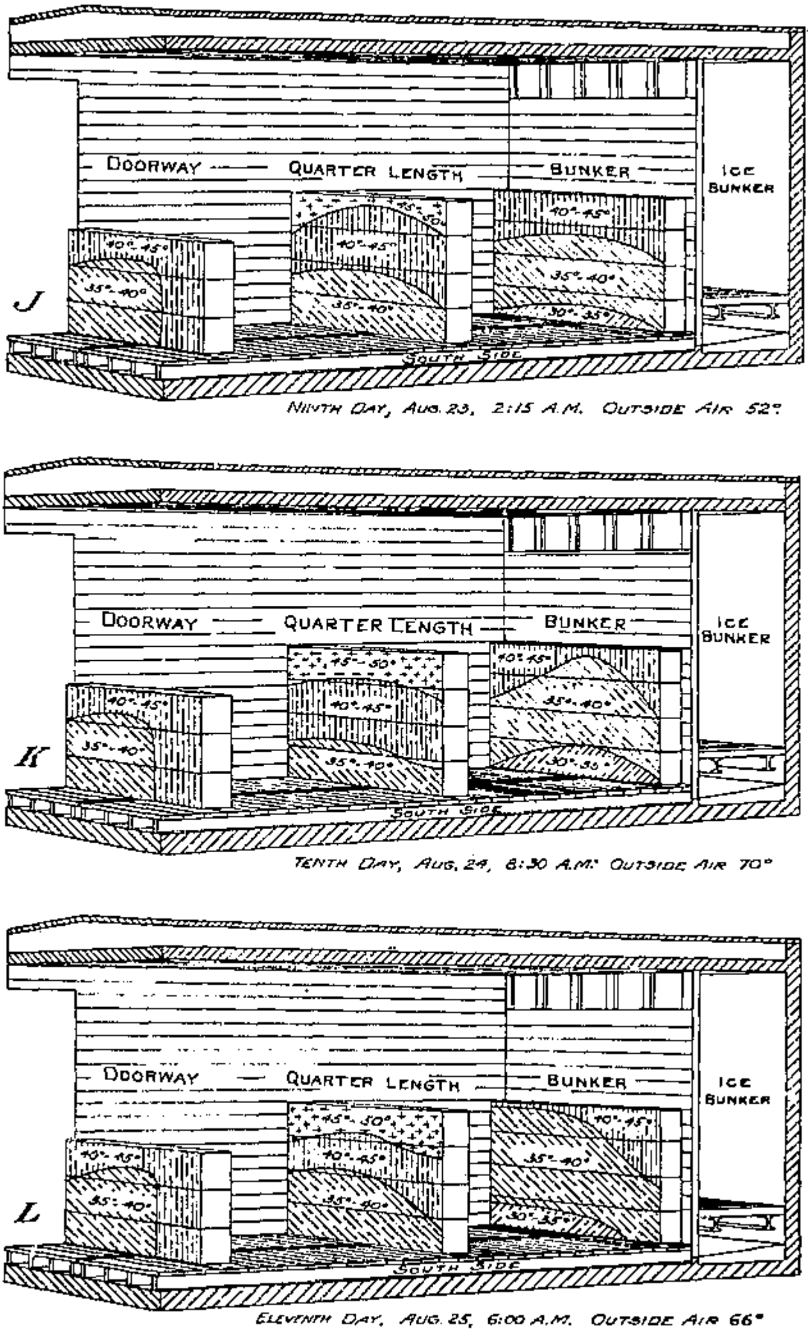


Figure 4.—Continued.

clearly illustrated by following the 40° to 45° F. zone. These temperatures were first noticed on the second day at 12:30 a.m. on the south side of the quarter-length stack. By noon of the following day they had spread over the top of the quarter-length and bunker stacks, and 23 hours later they were over the top of the doorway stack. The 45° to 50° temperature zone appeared on the fifth day in transit (fig. 4) in the same location that the 40° to 45° zone first appeared, and likewise spread over the top of the load in about the same manner.

The effect of the sun on the south side of the car is noticeable in that the higher temperature zones extend closer to the floor on this side than on the north side. This condition is especially noticeable in the doorway stack.

The lowest temperatures were found at the bottom bunker, the minimum being 26.8° F., which is slightly below the freezing point of pears (28.4°).[8] These low temperatures lasted only a few hours and commonly occur when 3 percent salt is used with precooled pears. Apparently this had no deleterious effect on the pears, as an inspection at destination of fruit from the bottom bunker showed no evidence of freezing. Air temperatures at this position went to a minimum of 19.2°. Fruit temperatures below 30° were noted in the bottom of the quarter-length stack for a short time. These low temperatures were doubtless due to the heavy application of salt (318 pounds) at the initial salting.

These figures show that there are large temperature variations within the load and indicate that the outside air temperatures have a very significant effect on temperature conditions within the car. Such conditions cause a variation in the length of the storage life of the fruit from different parts of the load.

EFFECTS OF CAR TEMPERATURES IN TRANSIT ON BEHAVIOR OF PEARS IN STORAGE

Most of the Bartlett pears produced in the Pacific Northwest for consumption as fresh fruit are shipped to eastern markets. They are shipped under refrigeration either in nonprecooled carloads immediately after harvest or after varying lengths of time in storage. Many of these shipments are held in storage for varying periods after arrival on eastern markets. During transit, temperatures within the refrigerated car vary not only in different parts of the load from day to day but also in cars shipped at the same time resulting in a great lack of uniformity in the condition of the fruit on arrival at destination. This is due to a number of circumstances, chiefly the temperature of the fruit at the time of loading, the heat of respiration, atmospheric temperatures en route, and the amount of salt added with the ice at the different icing stations.

An average of the temperatures within comparable experimental cars loaded with precooled fruit during this investigation shows that the temperature of the fruit in the top layer of a 520-box load, shipped under standard refrigeration with 3 percent salt, ranged between 35° and 40° F. about 15 percent of the time in transit, between 40° and 45° about 60 percent of the time, and between 45° and 50° about 25 percent of the time. The average top-layer temperatures in the same-sized load shipped under standard refrigeration with 75 pounds of

[8] WRIGHT, R. C., and TAYLOR, G. F. THE FREEZING TEMPERATURES OF SOME FRUITS, VEGETABLES, AND CUT FLOWERS. U.S. Dept. Agr. Bull. 1133, 8 pp. 1923.

salt at each reicing were between 40° and 45° about three-fourths of the time in transit, and between 35° and 40° for the remainder of the time. The average temperatures of the fruit in the bottom layers of both cars were rather uniform, being between 30° and 35° about two-thirds of the time and between 35° and 40° for the remainder of the time in transit.

Temperature conditions in carloads of nonprecooled pears differ greatly from those in precooled loads. It was found that the average

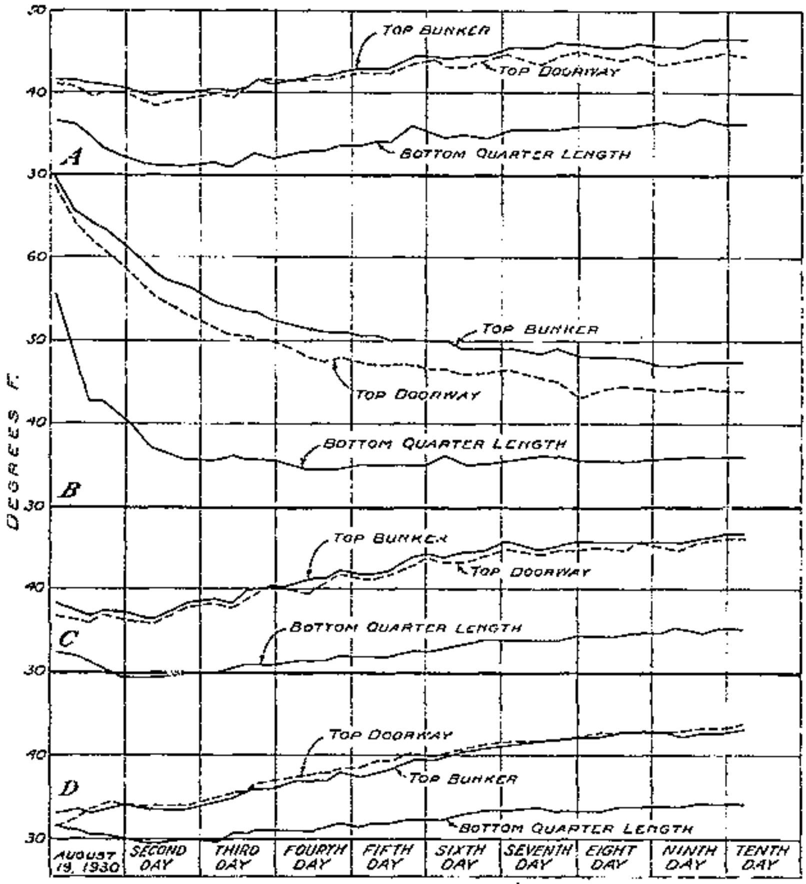


FIGURE 5.—Fruit temperatures in transit of carloads of Bartlett pears shipped during the 1930 test: *A*, 520-box load, precooled, standard refrigeration, 3 percent salt; *B*, 520-box load, nonprecooled, standard refrigeration, 5 percent salt; *C*, 720-box load, precooled, 3 percent salt; *D*, 744-box (through) load, precooled, standard refrigeration, 3 percent salt.

temperature in the top layer of nonprecooled loads shipped early in the season was between 45° and 50° F. about 72 percent of the time in transit, between 50° and 55° about 15 percent of the time, between 55° and 60° about 8 percent of the time, and above 60° about 5 percent of the time. The average of the bottom layer was between 35° and 40° about 86 percent of the time in transit, between 40° and 45° about 7 percent of the time, and above 45° the remainder of the time.

Temperature curves are shown in figure 5 to illustrate the temperature trend in the top and bottom layers of the various loads. It will be noted that there was a gradual rise of temperatures in the precooled load and a gradual decline in the nonprecooled load, the temperatures in both loads being about the same during the last 3 or 4 days in transit. The significance of these temperature differences will be readily apparent by reference to table 7. A comparison of the rate of softening of the experimental fruit shipped in precooled and nonprecooled loads as given in table 7 indicates the importance of low fruit temperatures at time of shipment rather than at time of unloading.

Fruit temperatures were obtained in the boxes of experimental fruit during transit in the various test cars. Averages of the transit temperatures for each box are shown in figure 6, with the average

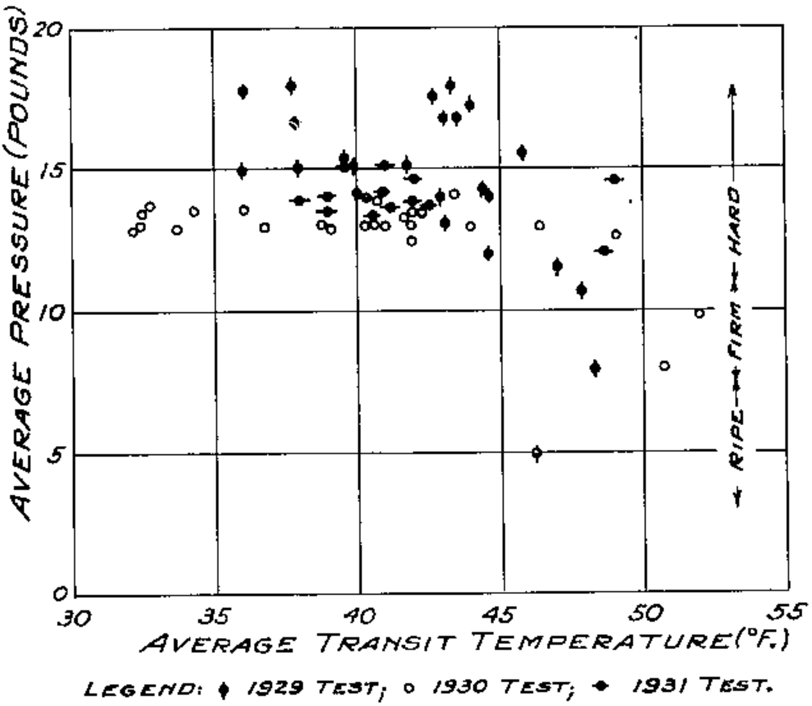


FIGURE 6.—Relation between average temperatures in transit and average pressure tests of experimental fruit on arrival in New York in the 1929, 1930, and 1931 tests.

firmness of pears from each box at time of unloading the cars in New York, for the three tests made in 1929, 1930, and 1931. It will be noted that the experimental fruit used in 1929 was firmer than that in the two following years, because the fruit shipped in 1929 was firmer at time of picking than in the succeeding years. The average pressure test of the experimental fruit on the day of loading was 16.6 pounds in 1929 and 14.2 pounds in 1930 and 1931.

These results show that the Bartlett pears in transit for 10 to 12 days at an average temperature below 46° F. were in a hard condition at the time of unloading. However, it was shown that Bartlett pears can be delivered in a firm condition and yet reach advanced maturity before the end of their normal storage life because of the influence of warm temperatures to which they may have been subjected either in the orchard after picking or in transit, or a slow rate of precooling.

In figures 7 and 8 is summarized the behavior of the test fruit after different lengths of time in storage at 32° F. These data show that after approximately 30 days in cold storage at destination the pears that arrived in a firm condition had become ripe to eating ripe; those that were in a hard condition on arrival but were carried at an average temperature between 45° and 50° F. in transit had reached a firm condition, and those carried below an average of 45° were still hard. It is further apparent that pears transported at an average

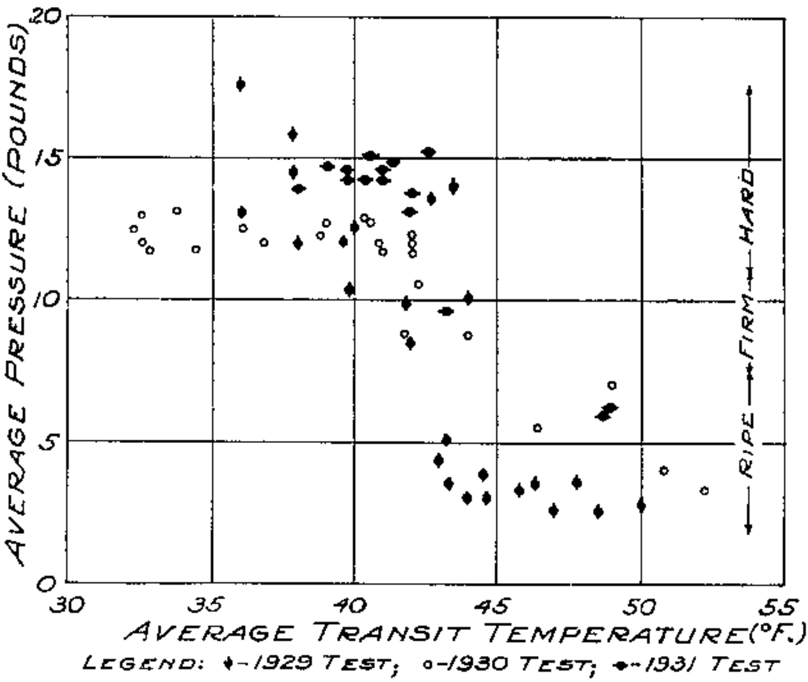


FIGURE 7.—Relation between average temperatures in transit and average pressure tests of experimental fruit after 30 to 36 days in 32° F. storage for the 1929, 1930, and 1931 tests.

temperature as high as 41° to 43° remained in good marketable condition at the end of a storage period of 50 to 60 days.

No ripening tests were made on the fruit used in the 1928 and 1929 experiments; that from the 1930 and 1931 tests was ripened at room temperatures. All lots ripened normally and with good quality except those shipped in the nonprecooled loads of the 1930 test. Magness, Diehl, and Allen [9] report similar results with California Bartletts picked in midseason. These pears were held at 43° for 12 days and then were placed in storage at 31° F. for 50 days. At the end of that time the fruit was removed from storage and held at 60°. It ripened

[9] See footnote 2.

in 5 days, and on the ninth day after removal from storage it was discarded as being overripe.

The average firmness of the experimental fruit used in the 1929, 1930, and 1931 tests, as shown in figures 6, 7, and 8, at time of unloading and after intervals in storage, is shown in figure 9. The curves in this figure indicating average maturity were obtained as mathematical averages of the pressure tests for each difference of 1° of the average temperatures in transit. It is apparent that the greatest change took place during the first 30 days in storage. The firmness of the fruit at the end of 53 to 60 days was very much the same as at the end of 30 days in storage. This indicates that precooled Bartlett pears may be transported at an average temperature as high

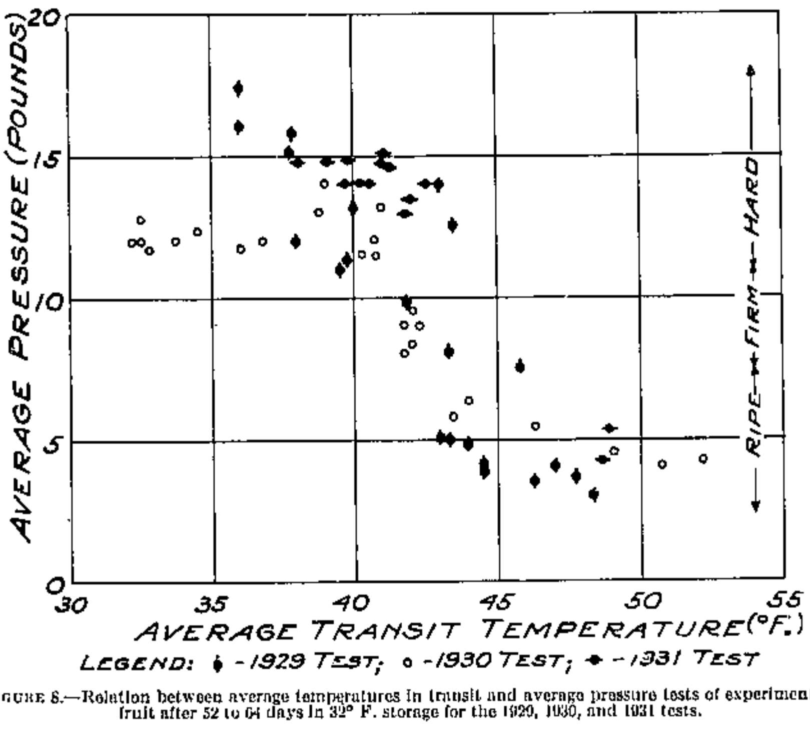


FIGURE 8.—Relation between average temperatures in transit and average pressure tests of experimental fruit after 52 to 64 days in 32° F. storage for the 1929, 1930, and 1931 tests.

as 41° to 43° F. during the 10- to 12-day transit period and still be in good marketable condition at the end of their normal storage life.

TEMPERATURES FOUND IN DIVIDED AND THROUGH LOADS

The divided load commonly used for both precooled and nonprecooled pears in the Pacific Northwest is one in which a space of varying width is left between the doors and braced with wooden timbers to prevent shifting and breakage of the boxes. It is also common practice, especially with nonprecooled pears, to leave a 6- to 12-inch air space between the rows. This method of loading obviously gives a clear channel for the passage of cold air from the bunkers and facilitates the removal of heat from the fruit.

In a load of precooled pears refrigeration is necessary primarily for the removal of heat that enters the car from the outside. With nonprecooled fruit, refrigeration is necessary not only to remove the heat which enters the car from the outside but also to remove the large amount of field heat in the fruit at the time of loading and the heat of respiration which it produces in transit. It appears, therefore, that although the divided and spaced load is probably the best method of loading for nonprecooled pears, a through load with a space between the load and side walls should be best for fruit that has been precooled because it provides a compact mass of cold material from which refrigeration is not as quickly lost.

The differences in temperature during transit of precooled fruit loaded in a through and in a divided, but not spaced, load were studied

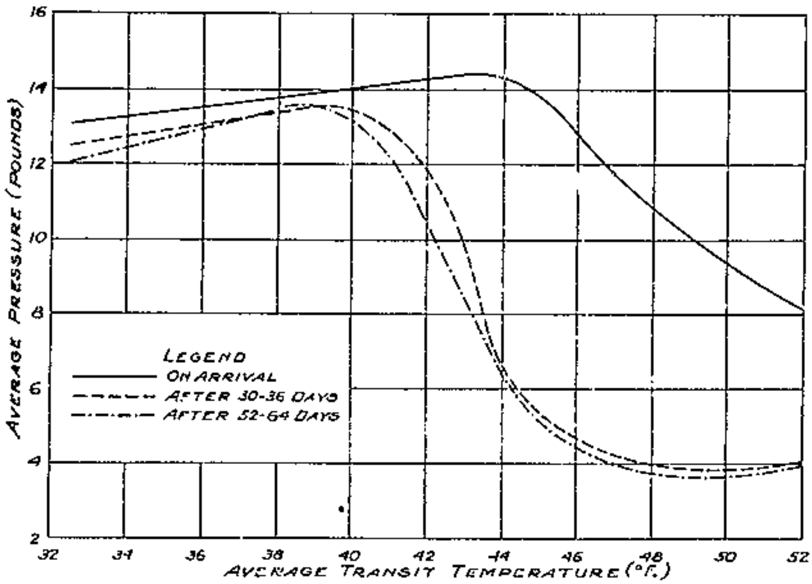


FIGURE 9.—Average firmness (3 years' tests) of experimental fruit on arrival at destination and after storage at 32° F. after being transported at various temperatures.

during the 1930 and 1931 transportation tests, using the 520-box and 720-box divided loads and the 640-box and 744-box through loads. The top-layer temperatures in the solid loads rose more slowly and did not reach the maximum temperatures shown in the divided loads. Results of the 1930 tests are shown in figure 5, *A*, *C*, *D*; those of the 1931 test are shown in table 8. As shown in figure 5, *D*, in a 744-box through load, the top-layer temperatures were below 40° F. for about half the time in transit and between 40° and 44° for the remainder of the trip. Those in the 720-box divided load (fig. 5, *C*) were between 35° and 40° about one-third of the time in transit, between 40° and 45° one-third of the time, and between 45° and 47° one-third of the time. The fruit for both these loads was comparable, having come from the same precooling plant, and was cooled to an average of 32° at the time of loading.

TABLE 8.—*Length of time, expressed in hours and in percentage of the transit period, during which the temperatures of precooled pears were within certain temperature ranges, in a test conducted in 1931*

Position of fruit and type of load	Time[1] in transit during which the temperatures of precooled fruit were within range of—							
	25°–30° F.		30°–35° F.		35°–40° F.		40°–45° F.	
	Hours	*Percent*	*Hours*	*Percent*	*Hours*	*Percent*	*Hours*	*Percent*
Top layer:								
Divided, 720-box	0	0.0	0	0.0	50	20.0	200	80.0
Through[2], 744-box	0	.0	0	.0	94	37.6	156	62.4
Through, 640-box	0	.0	0	.0	64	25.6	186	74.4
Next-to-top layer:								
Divided, 720-box	0	.0	27	10.8	116	46.4	107	42.8
Through,[2] 744-box	0	.0	92	36.8	158	63.2	0	.0
Through, 640-box	0	.0	100	40.0	150	60.0	0	.0
Bottom layer:								
Divided, 720-box	50	20.0	189	75.6	11	4.4	0	.0
Through,[2] 744-box	54	21.6	196	78.4	0	.0	0	.0
Through, 640-box	45	18.0	205	82.0	0	.0	0	.0

[1] Total time in transit was 250 hours.
[2] Boxes on end; all others on side.

The rate of softening of the experimental fruit in the top layer of the 744-box through load was comparable with that from the bottom layer of the 520-box divided load (both precooled), indicating a very important advantage for the solid load.

In the 1930 test no settling in the bottom end of the box, bruising, or other undesirable conditions were observed to result from loading the boxes on end. However, in the 1931 test a brown discoloration of the skin developed where the fruit came in contact with the bulged box lids. The packages in both shipments were lined with paraffined toweling pads on the top, bottom, and four sides of the box, but in the 1931 test it was noticed that the paraffined side was next to the lid and the heavy coarse paper was next to the fruit. The pear skin is very easily bruised by rubbing or abrasion, becoming discolored as a result. It is believed that the discoloration noted in this case was due to the mistake in the placing of the pads under the lids. This is indicated by the fact that a number of boxes of the same lot shipped in the 744-box load in 1931 were left at Medford, and when the fruit ripened no discoloration was found. The discoloration was doubtless caused by the vibration or shaking of the car en route and the consequent rubbing of the pears against the wrong side of the pad.

The advantages of the through load for precooled fruit were also shown by the lower temperatures obtained in the 640-box through load, where the boxes were loaded on their sides in the usual manner. Another advantage of the through load for precooled pears is that it saves the expense of bracing necessary with the divided load. The breakage of boxes shipped in the test cars was small. However, observations made on these cars and as many other cars as possible indicated that the greatest amount of breakage occurred in the 511[10]- or 520-box loads, and generally at the doorway. Breakage was more noticeable when the rows were spaced. The least breakage was noted in the through and 720-box loads.

[10] Load commonly used in the State of Washington.

PRECOOLING REFRIGERATOR CARS

Prior to 1929, in the Medford district the initial salting generally took place at the time the cars were preiced. To some extent this practice is still followed in the other districts of the Pacific Northwest. The object of this procedure is to precool the interior of the car and have maximum refrigeration for the pears as soon as loading is completed.

Since loading and bracing the load may require several hours, during which time the doors are open, there is a steady loss of cold air from the bottom doorway and an inflow of warm air at the top. This warms the car, causes heavy ice meltage, and results in a wastage of both salt and ice. Consequently, much of the benefit of the salting of the

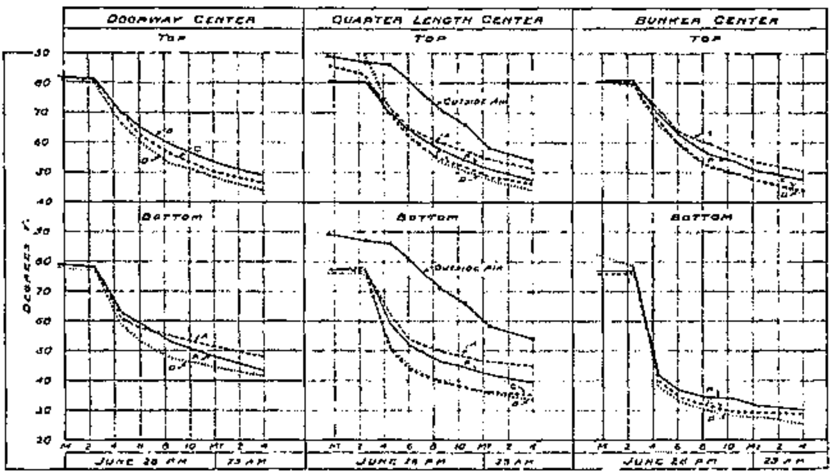


FIGURE 10.—Air temperature in various parts of empty refrigerator cars, with 11,000 pounds of ice in the bunkers of each car, at Yakima, Wash., June 28-29, 1929. Car *A* received no salt; car *B* received 1 percent, car *C*, 2 percent, and car *D*, 3 percent salt at time of initial icing.

initial ice is lost, in proportion to the length of time the doors are open.

If the car is iced far enough ahead of loading to cool it without the aid of salt there should be less loss of refrigeration. A test was made with four cars to determine the effects on the cooling of empty refrigerator cars when 1, 2, and 3 percent salt and no salt were used, with bunkers filled to capacity with ice. This test was made in Yakima on June 28 and 29, 1929. Temperatures of the air were obtained near the ceiling and floor along the center line and near the side wall of each car. Little difference in the temperature was found between the center and side positions. Temperatures along the center line of the car are shown in figure 10.

The use of salt gave lower temperatures and faster cooling in the empty refrigerator car. The use of ice alone cooled the air near the ceiling from 83° to about 50° F. in 12 to 14 hours, whereas the same result was accomplished in 4 to 5 hours by the use of salt. It is evident, therefore, that icing the car 10 to 12 hours prior to loading should satisfactorily cool it without the necessity of using salt. The most satisfactory and economical refrigeration of the lading can therefore be secured by delaying the initial salting until after loading has been completed.

ECONOMIC ADVANTAGES OF HEAVIER LOADING OF PRECOOLED PEARS

The heavier loading of precooled pears has brought economic savings. Some of these savings are too involved to estimate, but certain others which can be determined are briefly discussed below.

The charge for refrigeration is based on a fixed amount per car, not on the number of boxes in the car, and is in addition to the freight charges, which are based on the weight of the load.

If the load is increased from 520 to 720 boxes the cost of refrigeration per box is thus materially lowered. A comparison of the cost of refrigeration per box under standard refrigeration, initial icing, and initial icing with one reicing, is given in table 9, based on tariffs in effect in 1933. Depending upon the kind of refrigeration, the saving from heavier loading is from 2.4 cents (for initial icing only) to 5.6 cents (for standard refrigeration) per box, or a saving of about 28 percent in refrigeration charges.

TABLE 9.—*Comparative cost per box of shipping 520- and 720-box loads from the Pacific Northwest to eastern markets during the early part of 1933*

Item	Cost per box		Saving per box from use of heavier load
	720-box load	520-box load	
	Cents	*Cents*	*Cents*
Standard refrigeration ($105 per car)	14.58	20.19	5.61
Initial ice	6.22	8.62	2.40
Initial ice and one reicing	9.30	12.88	3.58
Freight at $1.55 per hundred pounds [1]	79.05		
Freight at $1.73 per hundred pounds		88.23	9.18

[1] This rate applies only to a 36,000-pound minimum load (720 boxes).

The freight rate for pears prior to 1933 was $1.73 per 100 pounds for a 26,000-pound minimum load. Early in 1933 a new rate of $1.55 was granted for a 36,000-pound (720-box) minimum load of pears, or a saving of 9.18 cents per box. This gives a total saving to the shipper of 11.6 to 14.8 cents per box, depending upon the type of transit refrigeration. Since the cost of precooling is from 10 to 15 cents per box, the saving in refrigeration and freight charges more than offsets the cost of precooling, which is essential to the use of this method of shipment. Aside from the considerations just mentioned, the cost of precooling has generally been considered a good investment because of the improved carrying and storage qualities of the fruit.

Precooling of pears has resulted in a saving, due to the fact that less ice is required in transit. The average difference in ice meltage by shipments of precooled and nonprecooled pears under standard refrigeration is shown in table 10 to be about 6,000 pounds during the time these tests were made, or a saving of 23 percent in favor of the precooled load. As shown in table 5, the differences in ice meltage between shipments of precooled pears in 520-box and 720-box loads are negligible.

TABLE 10.—*Total and average quantities of ice placed in bunkers and melted in cars containing 520-box loads of precooled pears receiving 3 percent salt and nonprecooled pears receiving 5 percent salt*

Year of test	Precooled pears		Nonprecooled pears	
	Ice in bunkers	Ice melted	Ice in bunkers	Ice melted
	Pounds	*Pounds*	*Pounds*	*Pounds*
1929	20,790	13,574	26,388	18,668
1930	19,701	10,291	26,269	17,318
1931	19,425	10,544	25,359	16,478
Average	19,972	11,470	26,005	17,488
Percent melted		57.4		67.2

The 720-box load gives the carrier the same revenue-paying tonnage with a reduction of 28.5 percent in the amount of nonrevenue-paying tonnage necessary to be hauled; that is, the tare weight of refrigerator cars. According to a study made by the Pacific Northwest Advisory Board of the American Railway Association [11] it was found that for the years 1928 to 1931, inclusive, 77.7 percent of the refrigerator cars sent east loaded were returned west empty. The empty haul west is entirely nonrevenue paying. It requires 100 cars to haul approximately the same quantity of pears in 520-box loads that can be hauled in 72 cars with 720-box loads. With the 520-box load 78 of the 100 cars would be returned empty, whereas with the 720-box load only 56 of the 72 cars would be returned empty. This would result in a saving of 28 percent in the number of empty cars hauled west.

The freight cost, as shown in table 9, is 88.2 cents per box when the rate is $1.73 per hundredweight. An increase in the load from 520 to 720 boxes increases the revenue per car by $176.46. Likewise, when the rate is $1.73 per hundredweight for the 520-box load and $1.55 for the 720-box load, the revenue, due to the heavier load, is increased $110.36 per car. Savings in rolling stock, switching, maintenance, and office work, on account of the heavier load, are also material, but no attempt is made here to estimate the amount.

DISCUSSION

These investigations have shown that the precooling of pears prior to loading in refrigerator cars make certain changes desirable in the manner of handling and refrigerating the fruit during the transportation period. The removal of field heat eliminates many of the difficulties encountered in the transportation of warm pears to market. The methods necessarily employed with warm fruit are neither economical nor entirely applicable to precooled shipments.

It was found that if the fruit is precooled, the number of boxes of pears which can be loaded in a car can be increased from 511 or 520 to 720 without increasing transit temperatures or the rate of ripening.

[11] ARNETT, H. J. REPORT OF PACIFIC NORTHWEST ADVISORY BOARD, AMERICAN RAILWAY ASSOCIATION, 2D QUARTER. P. 2. 1932.

Since these tests were conducted with the Bartlett variety during periods of high atmospheric temperatures, it is believed that similar results would be obtainable with later varieties, which doubtless would be shipped under more favorable weather conditions.

With nonprecooled shipments it was found that satisfactory results were secured from use of the present method of adding salt, i. e., the amount of salt added being a percentage of the ice supplied. This provides the coldest temperature at the beginning of the trip, when it is needed most. However, for precooled shipments, refrigeration is needed only to counterbalance the heat that enters through the walls of the car and the small amount given off through respiration. Consequently, a large amount of refrigeration at the beginning of the transit period, such as that secured when the salt is added on the percentage basis, is not necessary. It would be preferable to add the salt so as to afford uniform refrigeration during the entire transit period, or to secure more refrigeration at the end of the trip when fruit temperatures would otherwise be the highest.

The application of 75 pounds of salt at each reicing station with shipments of precooled fruit, rather than 3 percent salt, produced more constant and lower temperatures in all the layers, especially at the end of the transit period, and insured a longer storage life for the fruit after arrival at destination. As these studies were made when atmospheric temperatures were high, the quantity of salt to be used at each reicing should be reduced during cooler weather.

It is evident that while Bartlett pears are in transit they require the maximum refrigeration that can be furnished without freezing the fruit. Shipments under standard refrigeration without salt or under initial icing with two reicings en route did not arrive at destination with the top layer in a satisfactory condition for either storage or immediate sale with the high atmospheric temperatures prevailing during these tests.

SUMMARY

The transportation of pears from the Pacific Northwest to eastern markets was studied during the period from 1928 to 1931, inclusive. The investigations were made primarily to determine (1) the feasibility of increasing the size of the load when precooled pears are shipped, (2) the effect of different methods of loading, and (3) the most efficient method of applying salt for refrigeration during transit.

It was found that precooled pears shipped in 720-box loads arrived at the market in a firm condition and were as suitable for storage as those shipped in 520-box loads. The pears were shipped in cars taken from those that were being used for shipping pears and were from 5 to 8 years old. In all of the tests the fruit was handled throughout according to the usual commercial practice, both at shipping point and at destination.

In precooled shipments the placing of 75 or 50 pounds of salt on the ice at each icing station produced lower and more uniform temperatures and was more effective in retarding ripening than the application of 3 percent salt.

The initial salting was more effective and economical in producing low fruit temperatures when applied after rather than before loading.

Lower temperatures were obtained in precooled shipments when the boxes were loaded close together and an air space was left between the load and the side of the car.

The transit temperatures of precooled pears shipped in the through load were lower and the subsequent storage life was longer than when the pears were shipped in the divided load.

Bartlett pears from the Pacific Northwest when picked at the proper stage of maturity can be shipped at an average temperature as high as 41° to 43° F. for the 10 or 12 days necessary to reach eastern markets and subsequently remain in good marketable condition after 2 months' storage at 32°. They can be transported at an average temperature as high as 50° if intended for immediate consumption. Average transit temperatures higher than 50° are not desirable.

The heavier loading of precooled pears gives a material economic saving to both the shippers and the carriers.

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U. S. GOVERNMENT PRINTING OFFICE: 1934

For sale by the Superintendent of Documents, Washington, D.C. - - - - - - - Price 5 cents

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