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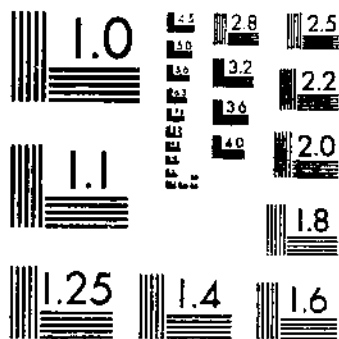
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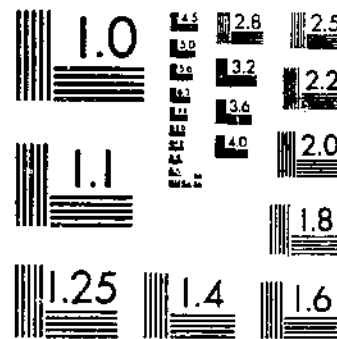
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TRANSPORTATION OF APPLES FROM THE SHENANDOAH-CUMBERLAND SECTION TO
HARDING, P. L.; POWELL, C. L. 1 OF 1

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



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

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

TRANSPORTATION OF APPLES FROM THE SHENANDOAH-CUMBERLAND SECTION TO OVERSEAS MARKETS¹

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INTRODUCTION

The general objective of the investigation was to determine the most satisfactory method of handling and transporting apples to overseas markets that ordinarily receive the major portion of the crop from the Shenandoah-Cumberland producing section of Virginia, West Virginia, Maryland, and Pennsylvania. Serious losses had at times been experienced in overseas shipments due to the development of decay, internal break-down, and overmaturity in transit, and especially to the prevalence of slack barrels which are always

¹This work was done under the general direction of D. F. Fisher, principal horticulturist in charge of fruit and vegetable handling, transportation, and storage investigations, who also assisted in the preparation of the report. The cooperation and assistance of the Baltimore & Ohio and the Pennsylvania Railroad Cos., the Southern Railway Co., the Fruit Growers' Express Co., the Cunard, White Star, and the American Merchant Lines are gratefully acknowledged, as well as that of the following members of the staff of the Division of Fruit and Vegetable Crops and Diseases, who participated in the investigation: W. W. Aldrich, D. H. Rose, E. A. Gorman, Jr., and R. L. Newton. Special acknowledgment is due to F. A. Motz, principal marketing specialist, and E. A. Foley, agricultural attaché, both of the Bureau of Agricultural Economics, stationed in London, whose assistance in the English ports was invaluable.

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DEPOSITORY

subject to a discount, depending upon the degree of slackness. This condition of the barrels may arise not only from improper packing at the orchard but also from the development of decay and internal break-down after packing.

In barreling apples for export a certain amount of bruising and "skin breaks" is unavoidable. Undoubtedly, also, injuries are increased in the unloading and loading transfer in New York. In unloading cars of barreled fruit in New York it is the common practice to pull the bottom barrels from under the load, letting the upper ones bounce and roll to the bottom of the car. There are several difficulties in the way of obtaining more careful handling at this point. The quantity of fruit arriving for export is often so great that the handling facilities are taxed to the utmost to make the transfer to the ship in the time available. Frequently shipments are delayed to avoid holding fruit at the dock or a carload of apples may be diverted to New York for export. In this case shippers request rapid service from the railroads in order that their fruit may make a certain ship. At the present time fruit shipments are not given any specialized supervision; they are handled by the longshoremen much the same as general cargo, and it is very difficult to induce them to exercise the care needed in the handling of apples. It is their common practice to roll or truck the barrels on the side or bilge, which is known to be harmful, but the extent of injury from this cause was not ascertained in this investigation.

In the studies reported, information was secured relative to: (1) Air and fruit temperatures occurring throughout the entire period of transportation from orchard to destination, and (2) the effect of transit conditions upon the development of decay, physiological break-down, and maturity as indicated by pressure tests and slackness of pack.

It was not possible to cover all angles of the problem and since it has not been feasible to resume the transportation tests since 1931, a summary of the information developed is presented herewith, together with such conclusions as can be drawn therefrom. Lighterage and methods of loading and unloading barreled apples are illustrated in figures 1, 2, 3, 4, and 5.

REVIEW OF LITERATURE

The effects of low temperatures in retarding the growth of rot organisms and the physiological activity of the fruit are the basis of the common recommendation that apples be placed in cold storage immediately after picking. With each degree rise in temperature there is an increase in the metabolic activity of the fruit itself and, up to certain limits, in the growth of decay organisms, each of which has optimum ranges of temperature as well as maximum and minimum limits for growth. At temperatures above 70° F. apples ripen very rapidly and respiratory activity is high. Various investigators have reported the optimum temperature conditions for apple-decay organisms.

Bigelow, Gore and Howard (1)² and Gore (6) showed that the rate of respiration increases with the rise of temperature according

² Italic numbers in parentheses refer to Literature Cited, p. 25.

to Van't Hoff's law. Morse (17) measured the amount of carbon dioxide given off from apples stored at 32°, 50°, and 68° F., and showed that lower temperatures retard respiratory activity and prolong the life of the fruit. Magness and others (15) showed that there is a very close agreement between the rate of respiration and the rate of softening of Grimes Golden apples. Haller (8) showed that softening of apples in storage is apparently due to the conversion of insoluble pectic substances, principally protopectin, into soluble form and that the rate of conversion at different temperatures is proportional to the rate of softening.

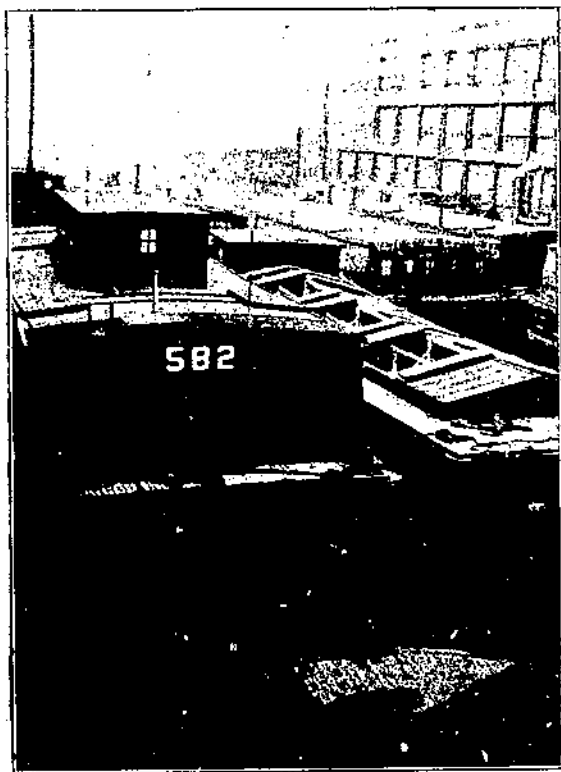


FIGURE 1.—Typical lighter (barge) used in transporting fruit from railroad sidings in Jersey City, N. J., to trans-Atlantic ships docked at New York, N. Y., piers.

Kidd and West (14) have pointed out that it might be possible to predict the keeping quality of apples from observations of certain chemical properties and a knowledge of their respiratory activity. Kidd and West (19), (7) agreed with Magness and others (15) and Burroughs (4) that long life of apples is related to low respiratory activity. Harding (10) pointed out that the rate of respiration increases with the development and maturity of the fruit under a uniform temperature.

Plagge (18), Plagge and Maney (19), and Harding (9, 10) have shown that changes which accompany wide temperature fluctuations may result in certain functional disorders. Brooks and Fisher (3) and Fisher, Hurley, and Brooks (5) found that water core of apples

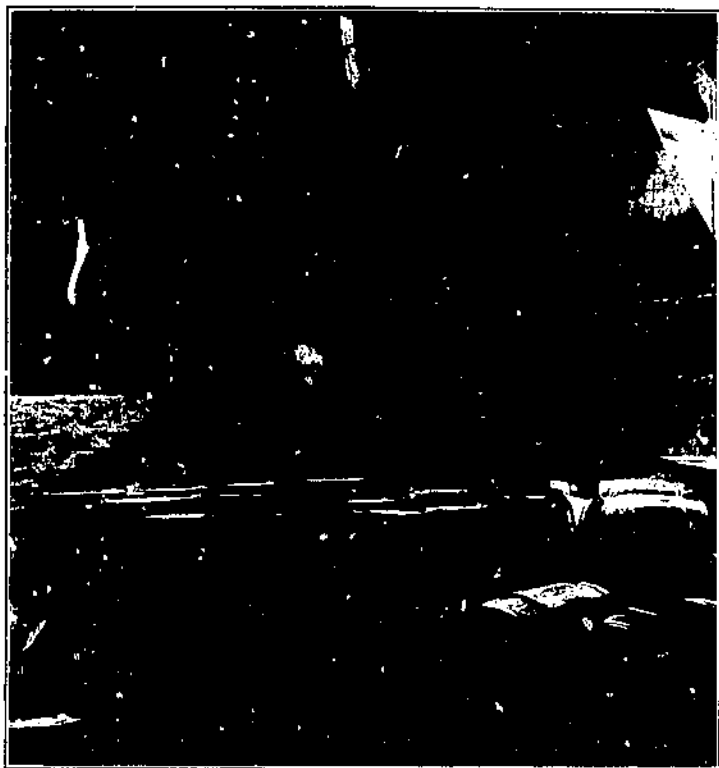


FIGURE 2. Sixteen barrels of apples in position on a net sling ready to be swung aboard ship (New York pier).

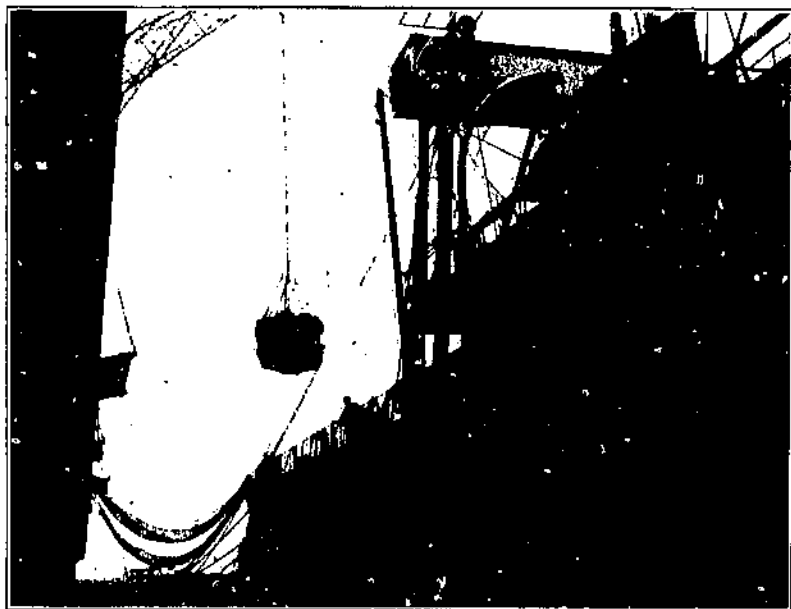


FIGURE 3.--Unloading barreled apples from the ship at Liverpool, England.



FIGURE 4.—A close-up view of a typical double sling used for unloading barreled apples at the Liverpool quay.

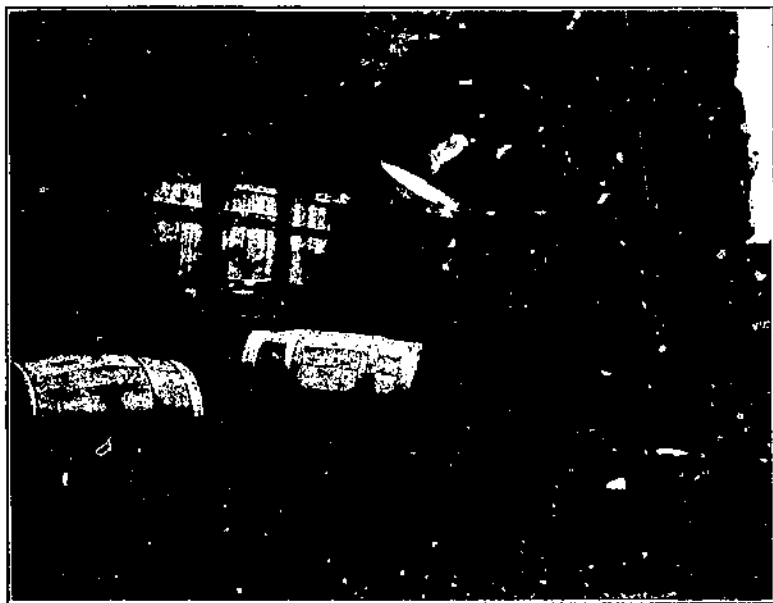


FIGURE 5.—An electric truck, called a "bogey", used for moving fruit on the quay at Liverpool, England. Note the "cushions" used to reduce bruising when the barrels are rolled from the bogey.

was greatly increased by overmaturity and high temperatures, and that mild forms of the disease were likely to disappear in storage.

Brooks and Cooley (3) reported on the temperature responses of apple rot fungi. Blue mold (*Penicillium expansum*) was found to be the most serious decay organism of stored apples. Its most rapid development occurred within the first 2 to 3 weeks at a temperature of about 68° to 77° F. Its growth was greatly delayed by low temperatures, but it was found capable of producing serious decay at 32° by the end of an 8-week storage period.

Harding and others (11, 12) have studied the influence of packing and handling methods on the condition of apples barreled for export. The results of their investigation showed that shaking barrels 2 or 3 times while they were being filled, racking 15 times when the barrels were nearly full with the "plug" or "follower" in place, and then filling to about three-fourths of an inch above the staves was sufficient to prevent appreciable settling of the apples in transit.

EXPERIMENTAL PROCEDURE

TERMINOLOGY

"Ventilation", "standard ventilation", or "ventilated car" refer to the method of carrying fruit during rail transit in which no ice is placed in the bunkers of the car and the hatches are left open when the outside temperature is above 32° F. In some of the tests, boxcars or cattle cars were used to forward the fruit under ventilation to the docks. The boxcars were those used for general merchandise, and were not insulated. When they were used for fruit shipments the doors were replaced by slatted gates to permit ventilation and the benefit in cooling, if any, resulted from admittance of the outside air. Cattle cars permit even greater exposure to outside air because of their slatted sides.

"Refrigerated car", "refrigeration during rail transit", or "iced car" refer to the method of carrying fruit during rail transit in which the car bunkers contain ice, the plugs of the bunkers are in place, and the hatches are closed. "Standard refrigeration" means that the cars were iced to capacity at the point of origin and at all regular icing stations thereafter and at destination if necessary. "Initial ice" means that the cars were iced only at point of origin. "Five percent salt" means that salt was added to the bunker in the amount of 5 percent of the weight of ice supplied at any icing station.

"Ordinary stowage" refers to those compartments on the ship which receive no refrigeration.

"Refrigerated stowage" refers to those compartments aboard ship which are refrigerated.

METHOD OF OBTAINING TEMPERATURES

THERMOMETERS

Electrical resistance thermometers were used to obtain fruit and air temperatures within the cars and the compartments aboard ship. The bulb of the instrument was inserted into an apple at the center of the barrel or hung in the air at desired locations in the car or

compartment of the ship. Leads from the bulbs were connected with a master cable which was carried out of the car through a thin door-plate placed at the top of the doorway and thence to the running board on the top of the car. In the case of a ship, the master cable was threaded up through the thermometer tubes or other convenient places so that readings could be made from the upper decks. The master cable led to an indicator box equipped with a 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 of reading. Small, compact thermographs especially designed to be placed inside a fruit package were also used in some of the tests. These instruments were operated by 30-day clocks and provided a continuous record of the temperature throughout the transit period.

TIME OF READING

The instruments were so constructed and placed that temperature readings could be obtained at a number of places within a car or compartment without opening the doors. In the tests under discussion, readings were made after the cars were loaded and as frequently as possible during transit to Jersey City, N. J. After the fruit was loaded aboard ship, temperatures were recorded at 2- to 4-hour intervals during the first day and at 6- to 12-hour intervals thereafter until the fruit was unloaded in Great Britain. Outside air temperatures were obtained at the same time with a mercury thermometer.

Fruit and air temperatures in the cars during transit were usually obtained at the following positions: Top and bottom layers at the rear bunker, and top and bottom layers at the quarter-length position. In the compartments aboard ship, fruit and air temperatures were obtained in the top and bottom layers in the center of the compartment and usually in the top and bottom layers at the corners or the side of the compartment.

Sea-water temperature was recorded twice daily in the ship's log and this record together with other pertinent ship data were made accessible to the observers conducting the various tests.

PRESSURE TESTS

The firmness of the fruit at shipping point and again at destination was determined by the Magness and Taylor pressure tester (16). By use of this instrument the pressure in pounds necessary to force a smoothly rounded plunger seven-sixteenths of an inch in diameter into the pared flesh of an apple to a depth of five-sixteenths of an inch is obtained, affording a reliable index of the comparative physical condition of the apples. Three pressure tests were made on each of 15 or 20 apples selected at random from each lot.

All barrels of test fruit in the experimental lots were examined immediately after they were unloaded in Great Britain and notes were taken on the slackness and condition of the fruit.

1929-30 TESTS

During the fall of 1929, three rail tests were made from Winchester and Front Royal, Va., to Jersey City, N. J., where the tests ended. In the fall of 1930 one rail test was made from Front Royal to Jersey City and four complete tests were made from points in Virginia to Liverpool, England. In the complete tests, the fruit was under observation from the time it was packed into barrels until it was unloaded from the ship at its overseas destination.

In the commercial shipments used in the work of the first 2 years the apples were for the most part very hard (barely mature) when harvested and of course they carried well, although their dessert quality when ripened was not equal to that of more mature fruit. The temperature records were chiefly of value in planning the more complete tests of 1931 but will not be given in detail since the same points are brought out in the records of that year's work. In the 1931 work more mature apples were used. Their temperatures in transit were found to be rather strongly reflected in the condition of the fruit upon arrival overseas. The 1931 data will therefore receive chief consideration in this report.

1931 TESTS

In the fall of 1931 transportation tests were made between points in Virginia and Maryland and England. In the first and third tests made, respectively, on the R. M. S. *Scythia* of the Cunard Line and the S. S. *American Farmer* of the American Merchant Line, the observers accompanied the fruit in transit from shipping point to ports of discharge in England, in order to obtain a record of the fruit and air temperatures at different positions in the cars and ships. These two tests will be referred to later as Virginia 1931-1 and Virginia 1931-3, respectively. This method of designation refers to the State of origin, the year of the test, and the serial number of each. This system of designating test trips is followed throughout this report.

Two unaccompanied tests were also made in which thermographs were placed in the centers of test barrels for recording temperatures. In the first of these, Virginia 1931-2, made on the R. M. S. *Lancastria* of the Cunard Line, a temperature record was obtained from the time the fruit was picked to the time when it was unloaded in Liverpool. At the time of the last test, Maryland 1931-1, unsettled financial conditions in England and the uncertainty of export sales made it impossible to obtain cars at any shipping point which were definitely consigned for export; consequently, it was necessary to use barreled fruit which had already arrived at the dock in Jersey City, N. J. The thermographs were therefore installed at the latter point and the temperature record obtained covers the time of transfer from car to ship in New York and of ocean transit on the S. S. *American Trader* of the American Merchant Line.

VIRGINIA 1931-1 TEST

For this test Bonum apples picked August 31, Wealthy picked August 25 and 31, and Grimes Golden picked August 31 at Culpeper, Va., were packed into barrels immediately after picking and consti-

tuted the test fruit used for special study which, with other commercial consignments of apples, were loaded into three cars. One car was shipped under standard refrigeration with 5 percent salt; the second was iced to capacity before being loaded and it was not re-iced; the third was a ventilated boxcar. These cars left Culpeper September 2 and arrived at Jersey City September 3. The test barrels were loaded aboard the *Scythia* and placed in refrigerated and ordinary stowage. Intermittently during the voyage the refrigerated compartment was ventilated by connecting an electric suction pump to the thermometer tubes and drawing off the air for short periods. The ordinary stowage compartments were ventilated by opening hatches when weather permitted and by turning the ship's ventilators in the direction of the wind.

The *Scythia* left New York City September 5 and arrived at Liverpool September 15. Test barrels were inspected September 16 and 17.

VIRGINIA 1931-2 TEST

For this test, barrels of King David apples picked September 8, Bonum picked September 5 and 8, and Jonathan picked September 7 were obtained at Applewood, Va. Thermographs were placed in the center of each test barrel at the time of packing and all were forwarded with commercial shipments in two refrigerator cars, one being under standard ventilation and the other under standard refrigeration. The two cars left Applewood September 9 and arrived at Jersey City September 11. Test barrels from each car were placed in ordinary and refrigerated stowage aboard the *Lancastria*. The method of ventilation was similar to that on the *Scythia*.

The *Lancastria* left New York City September 12 and arrived at Liverpool September 21. All test barrels were inspected and thermographs were removed September 21, 22, and 23.

VIRGINIA 1931-3 TEST

The experimental lots for this test consisted of 4 barrels each of Delicious, Grimes Golden, Mother, and Bonum apples, and 8 barrels of Jonathan, all picked September 12; 4 barrels each of Grimes Golden and Bonum and 16 barrels of Jonathan picked September 14; and 4 barrels each of Delicious and Mother, and 8 barrels of King David apples picked September 15. Each lot was divided so that representative barrels of each variety and picking date could be loaded at the bottom quarter length in a refrigerated car and at the top quarter length of a ventilated refrigerator car. In the case of Jonathans the fruit from each of the two lots was divided into four parts and placed at the top and bottom quarter-length positions in the two cars. In the ship the lots of fruit of each variety, from each picking, and from each position in the car were divided and comparable barrels were placed in refrigerated and ordinary stowage compartments. The barrels were loaded into the cars at Front Royal and Linden, Va., September 15, unloaded in Jersey City September 17, and loaded into the ship September 18. The *American Farmer* left New York City September 18 and arrived in London September 28. The test fruit was inspected September 30 and October 1.

MARYLAND 1931-1 TEST

The test lots consisted of Delicious, Lowry, and Jonathan apples from Hancock, Md., all of which had reached the docks September 19-21, too late for an earlier ship connection and accordingly were held over. The Jonathan apples were shipped to Jersey City in iced refrigerator cars and the Delicious and Lowry apples in a boxcar. On September 19 the latter were transferred to a refrigerator car at Jersey City which was supplied with a small amount of ice while the apples were being held awaiting departure of the ship. A thermograph was placed in the center of each test barrel before transfer to the *S. S. American Trader* on September 24. The ship left New York City September 24 and arrived in London October 4. The test barrels were inspected and the thermographs removed October 6.

RESULTS

EFFECT OF DIFFERENT METHODS OF REFRIGERATION AND VENTILATION UPON FRUIT TEMPERATURES DURING RAIL TRANSIT

1929-30 TESTS

The results of eight rail tests conducted during 1929 and 1930 showed that the use of either initial ice or standard refrigeration brought about a material reduction in fruit temperatures during the period of rail shipment. The extent of this reduction was dependent upon the initial temperature of the fruit, atmospheric temperature during transit, and the length of time the fruit was in the car. Fruit temperatures of top-layer barrels were reduced 5° to 16° F. and those at the bottom bunker position 22° to 36°. The data indicated that under ordinary conditions refrigeration as compared with ventilation reduced the fruit temperature approximately 10° in the top layer and 25° in the bottom-layer barrels during a 40-hour transit period.

In one test the use of initial ice before loading was found to give lower temperatures than initial icing after loading. On arrival in Jersey City, fruit temperatures in two cattle cars were found to be 10° and 14° F. lower than temperatures in a ventilated refrigerator car. This test was made during a period of cool nights, and the results indicate that the fruit in the cattle cars was more effectively subjected to the outside air than that in the ventilated refrigerator car. Had atmospheric temperatures increased after loading this would have been disadvantageous for the consignments loaded in the cattle cars.

1931 TESTS

In the rail portion of the Virginia 1931-1 test the Bonum, Wealthy, and Grimes Golden apples were shipped September 2 from Culpoper, Va., in a ventilated boxcar and two refrigerator cars, one of which was initially iced and the other had standard refrigeration with 5 percent salt. The cars were unloaded at Jersey City on September 4, 43 hours after they were loaded. Fruit temperatures in the ventilated boxcar ranged between 70° and 85° F. during the transit period with an average fruit temperature of 78°. The temperature of the fruit at the time it was unloaded was slightly lower than

when loaded. The average fruit temperature at the time the initially iced car was loaded was 77°. When it was unloaded at Jersey City temperatures in the top-layer barrels had been reduced to 65° and in the bottom-layer barrels to 50°. Average fruit temperatures in the car under standard refrigeration were reduced from 76° to 62° in the top-layer barrels and to 49° in the bottom-layer ones. This type of refrigeration cooled the fruit in the bottom layers 27° and in the top layers 14° (table 1).

TABLE 1.—Average fruit temperatures during rail transit from Culpeper, Va., to Jersey City, N. J.; Virginia 1931-1 test

Place	Date	Time	Outside air temperature	Average fruit temperature during rail transit					
				Standard refrigeration with 5 percent salt		Initial ice		Ventilated box-car	
				Top quarter length	Bottom quarter length	Top quarter length	Bottom quarter length	Top quarter length	Bottom quarter length
Culpeper, Va.	Sept. 1	4:30 p. m.	87	76.2	76.5	73.4	75.8	82.8	79.2
Do.	do.	9:05 p. m.	79	75.8	74.9	77.5	74.2	78.8	77.1
Do.	Sept. 2	7:45 a. m.	77	73.3	69.1	74.3	68.4	79.3	78.0
Do.	do.	12:50 p. m.	80	70.5	64.9	71.1	61.8	79.4	78.0
Potomac Yards, Va.	Sept. 3	1:00 a. m.	73	69.5	59.3	67.3	66.0	70.7	78.6
Wilmington, Del.	do.	12:40 p. m.	75	67.5	54.9	68.4	53.7	75.0	76.4
Jersey City, N. J.	do.	9:40 p. m.	65	61.4	51.4	66.7	52.3	75.0	76.4
Do.	Sept. 4	7:00 a. m.	67	62.3	49.0	65.1	50.4	73.4	77.6

In the Virginia 1931-2 test, a car of King David, Bonum, and Jonathan apples was shipped under standard ventilation and a similarly loaded car under standard refrigeration. The two cars were loaded at Applewood, Va., on September 9, and were unloaded at Jersey City 30 to 35 hours later. During the rail transit atmospheric temperatures increased from 70° F. when they were loaded to 78° when they were unloaded. At the time of the unloading the average fruit temperature in the ventilated car was 75°.

In the standard refrigeration car temperatures were lowered from 70° F. at the time the fruit was loaded to a range of 64° to 68° in the top-layer barrels and of 53° to 55° in the bottom ones at the time it was unloaded. The average fruit temperatures in the top layer of the refrigerated car were 9° lower and in the bottom layer 21° lower than in comparable barrels of the ventilated car.

In the Virginia 1931-3 test outside air temperatures between shipping point and Jersey City ranged between 65° and 86° F. The fruit temperatures in the car under standard ventilation remained at approximately 80°, although in a few barrels in which the temperature at time of loading was 86° the fruit temperatures were reduced to approximately 81° at the time of unloading. In the initially iced car during the 41-hour transit period, fruit temperatures were reduced from approximately 80° to a range of 59° to 61° in the bottom layer and to approximately 69° in the top layer. Hence, during rail transit initial icing was responsible for a reduction of 21° in the temperature of bottom-layer barrels and of 11° in top-layer barrels.

SUMMARY OF RAIL TESTS

In the tests conducted during 1931 fruit temperatures generally changed very little in the ventilated cars during rail transit. They increased or decreased with the outside air temperature, but generally at the time of unloading were a few degrees higher than the mean atmospheric temperature during transit.

At the time the fruit was unloaded in Jersey City, after a transit period of about 35 hours, temperatures in the top layers of refrigerated cars were 9° to 14° F. lower and those in the bottom layers 21° to 30° lower than comparable fruit shipped in ventilated cars. In general this confirms results obtained during 1929 and 1930 in which the data indicated that refrigeration, as compared with ventilation, was responsible for an average of 10° and 25° lower temperatures in top and bottom barrels, respectively, during the period of rail transit.

During 1929 it was found that the temperature of the fruit shipped in a cattle car was 10° to 14° F. cooler than that of fruit shipped in two ventilated refrigerator cars during a transit period of cool nights. The difference in temperature secured by the use of the cattle car is indicative of the greater exposure of the load to the outside air than is the case when ventilated refrigerator cars are used.

INFLUENCE OF OUTSIDE AIR UPON FRUIT TEMPERATURES DURING CAR-TO-SHIP TRANSFER

Most of the fruit exported from New York is unloaded at Jersey City and transferred on lighters to the ocean-going ships docked on the other side of the Hudson River. This usually requires several hours and sometimes as long as 24 hours during which the fruit is exposed to prevailing air temperatures. Sometimes the cars are unloaded and the consignments are held in nonrefrigerated dock warehouses for several days, when the effects of atmospheric temperatures become more pronounced. Refrigerated lighters are sometimes used for fruit which has been refrigerated during rail transit.

1930 TESTS

In one test conducted during 1930 fruit temperatures rose during the car-to-ship transfer from a range of 43° to 47°, to 68° F., or at the rate of about 3° per hour when the air temperatures ranged between 71° and 82°. In two other tests the rise was about 1° per hour from an average of 43° to an average of 56°, when atmospheric temperatures ranged between 66° and 71°; in another test fruit temperatures rose from a range of 39.6° to 52.5° to a range of 46.4° to 54.7° during a 14-hour transfer period during which outside air temperatures ranged from 50° to 74°.

1931 TESTS

In the Virginia 1931-1 test, the fruit from the refrigerated cars was transferred in a refrigerated lighter and the fruit from the ventilated boxcar was lightered at the same time without refrigeration. Six hours were required to make the transfer from the cars to the refrigerated compartment of the ship, and 10 hours to complete the transfer from the car to the ordinary stowage compartment.

During this transfer period fruit temperatures in barrels from the ventilated car changed very little, since they so closely approximated the outside air temperature (average 76° F.). The fruit temperatures of bottom-layer barrels shipped under initial ice increased 10° from an average of 50° to an average of 60° during the transfer period, while fruit temperatures in some of the other barrels showed increases of about 4°, from 65° to 69°. During the same period temperatures of fruit in barrels shipped under standard refrigeration rose 2°, from 49° to 51°. Those in barrels from the top layer in the car, however, remained at about 62° during the transfer.

In the Virginia 1931-2 test the car-to-ship transfer required about 24 hours. All the fruit was transferred on a nonrefrigerated lighter after having been unloaded and left on the wharf overnight before being placed aboard ship. During this longer transfer period the temperature of the fruit shipped under standard ventilation rose about 5° or to the approximate mean of the outside air (79°), but the average fruit temperatures in some of the coldest barrels from the standard refrigeration car increased 15°.

In the Virginia 1931-3 test the outside air temperature during transfer ranged from 64° to 78° F. All the fruit was transferred on a nonrefrigerated lighter. Temperatures of the fruit refrigerated during rail transit rose from a range of 59° to 69° to a range of 66° to 71° during a 22-hour transfer period. However, temperatures of the fruit from the ventilated car were reduced from an average of 80° to approximately 77° during the 27 hours taken for transfer.

The transfer of barrels from refrigerated cars to the ship on a nonrefrigerated lighter in the Maryland 1931-1 test required 20 hours. During this time outside air temperatures ranged from 68° to 83° F. Average fruit temperatures from the standard refrigeration car increased during this period from 58° to 65°. Fruit temperatures in the ventilated car showed a decrease from 80° to 77°.

A summary of the data shows that much of the cooling effect of the rail refrigeration was lost during the time taken to transfer the fruit from car to ship.

INFLUENCE OF REFRIGERATION AND VENTILATION DURING RAIL TRANSIT UPON TEMPERATURE OF FRUIT IN ORDINARY STOWAGE ABOARD SHIP

1930 TESTS

Results of the transportation tests conducted during 1930 indicated that in ordinary stowage there was a significantly lower fruit temperature in barrels refrigerated during rail transit only during approximately the first 48 hours after unloading at Jersey City.

1931 TESTS

In the Virginia 1931-1 test, six barrels of the coldest fruit from the bottom layers of the standard refrigeration car (standard refrigeration plus 5 percent salt) had a range of temperature from 45.5° to 54° F. when loaded into the ship. During the next 50 hours the average fruit temperature of those barrels rose to 70°. Barrels from the ventilated boxcar loaded adjacent to these in the same hold were only about 5° warmer at the end of this period, fruit temperatures in two of the former barrels approximated those of adjacent

barrels from the ventilated car, but the temperature in the other four barrels remained slightly cooler throughout the voyage.

The fruit in four of seven barrels from the initially iced car, when placed in ordinary ship stowage, warmed up to the temperature of that in adjacent barrels from the ventilated boxcar within 45 hours. After 93 hours the temperature of all seven barrels of fruit approximated that of adjacent barrels from the ventilated boxcar.

In ordinary stowage in the Virginia 1931-2 test, 48 hours after unloading the car, fruit temperatures from the top layers of the car under standard refrigeration had increased from 66° to 78° F. After 72 hours, temperatures of fruit from the bottom layers of this car under ordinary stowage conditions approximated the temperatures of barreled apples shipped under standard ventilation (79° to 82°).

In the Virginia 1931-3 test, 5 hours after the fruit was placed in ordinary stowage aboard ship, fruit temperatures from the bottom of the refrigeration car were approximately 10° F. lower than those from the top layer and approximately 5° F. lower than the corresponding temperatures of the fruit from the ventilated car.

Fruit from the refrigerated car remained cooler than that from the ventilated car until after the second day of the voyage, when the differences in fruit temperatures became negligible.

In the Maryland 1931-1 test, 4 days after transfer from the refrigerated car at Jersey City, the temperature of the fruit in ordinary stowage had risen from an average of 58° to 76° F., approximating that of the fruit from the boxcar which had been reloaded into a refrigerator car with only a partial and inadequate icing while awaiting transfer at Jersey City.

A summary of the data secured in 1930 and 1931 indicates that the temperature of fruit refrigerated during rail transit as compared with that ventilated, usually remained cooler for 2 days after being placed in ordinary stowage. After this time very little difference was noted between the temperatures of fruit from refrigerated cars and ventilated cars.

INFLUENCE OF REFRIGERATION AND VENTILATION DURING RAIL TRANSIT UPON TEMPERATURE OF FRUIT IN REFRIGERATED STOWAGE ABOARD SHIP

The data from three tests conducted in 1930 indicated that although much of the cooling resulting from rail refrigeration was lost during transfer from car to ship, especially during periods of high atmospheric temperature, the fruit from refrigerated cars remained appreciably cooler than that from ventilated cars for a period of 2 to 4 days after loading into refrigerated chambers aboard ship. By this time, however, the fruit from the ventilated cars had cooled to about the same temperature.

In the Virginia 1931-1 test, three barrels of the coldest fruit from the standard refrigeration car had temperatures of 48.6°, 49°, and 50.6° F. when unloaded at Jersey City. During the car-to-ship transfer the fruit warmed up so that 48 hours of ship refrigeration was necessary to reduce the fruit temperatures to their former level. At the same time, test barrels from the ventilated car placed in refrigerated stowage aboard ship required from 50 to 62 hours to reach the approximate fruit temperature of comparable barrels from the

refrigerated cars. At the end of the voyage the average fruit temperature of six barrels from the refrigerated carlot stowed under ship refrigeration was 38°, whereas the average fruit temperature of six barrels from the ventilated car under similar ship refrigeration was 40°.

Barreled fruit from the bottom layers of the initially iced car, when placed in ship refrigeration, recooled at about the same rate as fruit from the bottom layer of the standard refrigeration car. However, barrels of fruit from the top layers of the initially iced car required 66 hours of refrigeration on board ship in order to reduce fruit temperatures to between 48° and 50° F. (table 2).

TABLE 2.—Average fruit temperatures in refrigerated stowage aboard ship from New York City to Liverpool, England; Virginia 1931-1 test

Place	Date	Time	Out- side air tem- per- ature	Average fruit temperatures in refrigerated stowage aboard ship—					
				From standard refrigeration car		From initially iced car		From standard ventilation car	
				Top quarter length	Bottom quarter length	Top quarter length	Bottom quarter length	Top quarter length	Bottom quarter length
New York City	Sept. 4	7:30 p. m.	69	° F. 61.2	° F. 59.8	° F. 67.4	° F. 55.4	° F. 77.2	° F. 74.9
Do	do.	10:30 p. m.	69	60.8	51.8	66.8	57.0	74.5	74.3
Do	Sept. 5	8:00 a. m.	71	59.6	52.2	64.8	59.9	71.2	71.4
At sea	do.	1:00 p. m.	66.5	59.3	51.4	63.5	56.2	68.4	70.2
Do	Sept. 6	9:00 a. m.	64.5	55.8	51.1	60.1	55.4	66.6	66.6
Do	do.	4:30 p. m.	78.0	53.0	50.7	57.7	54.7	58.7	62.6
Do	Sept. 7	9:30 a. m.	69.0	51.7	48.2	53.0	51.3	53.7	53.2
Do	do.	9:30 p. m.	68	48.8	45.1	49.4	47.6	49.6	53.4
Do	Sept. 8	9:30 a. m.	67	46.5	43.6	46.8	46.8	46.7	50.3
Do	do.	9:30 p. m.	66	45.7	41.9	44.0	46.4	44.5	46.8
Do	Sept. 9	9:30 a. m.	66	43.3	39.5	43.4	41.5	42.7	44.7
Do	do.	9:30 p. m.	64	42.1	38.1	40.7	39.5	41.1	44.4
Do	Sept. 10	9:30 a. m.	68	41.0	38.0	41.4	40.6	40.8	44.0
Do	Sept. 11	9:30 a. m.	65	39.6	35.8	39.3	38.9	39.5	42.1
Do	Sept. 12	9:30 a. m.	66	39.8	37.5	39.4	39.0	39.1	42.6
Do	Sept. 13	9:30 a. m.	60	39.2	37.7	39.4	39.1	39.0	41.8
Do	Sept. 14	9:30 a. m.	64	39.7	37.1	40.3	39.1	38.9	41.5
Liverpool, England	Sept. 15	4:15 a. m.	61	38.8	37.2	38.6	38.6	38.3	41.1

¹ Fruit temperatures from 1 barrel only.

² Left New York Sept. 5, 11:05 a. m.

In the Virginia 1931-2 test, the average minimum fruit temperature in the standard refrigeration car when unloaded at Jersey City was 54° F. During car-to-ship transfer the fruit temperature of these same barrels increased to 70°; 72 to 84 hours of ship refrigeration were required to recool the fruit to 54°. Fruit temperatures in the standard ventilation car averaged about 75° when the car was unloaded at Jersey City. This fruit required 96 hours of ship refrigeration to cool to 52°. At the end of the voyage fruit temperatures in all the test barrels were about 37°.

In the Virginia 1931-3 test 2½ days after unloading at Jersey City the temperature of the fruit from the bottom layer, the coldest part of the refrigerated car, was 5° below that from a similar part of the ventilated car, but by the end of 4 days the difference was negligible. By the end of the third day, the temperature of fruit from the top layer of the refrigerated car was approximately the same as that from the top layer of the ventilated car.

In the Maryland 1931-1 test, after 5 days, the temperature of fruit from the car which was iced only after arrival at Jersey City before it was unloaded for shipment had cooled to 47° F. Fruit temperature under standard refrigeration was 44° and remained about 3° cooler throughout the remainder of the voyage.

A review of the data shows that for a period of from 2 to 4 days in refrigerated stowage, fruit shipped in refrigerated cars was ap-

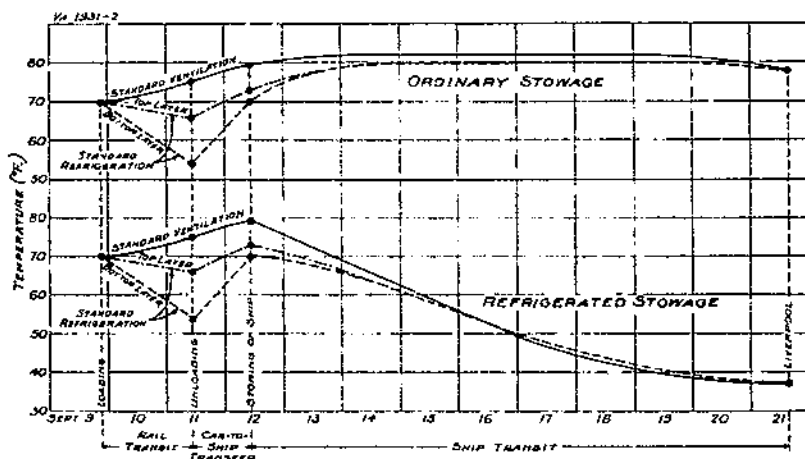


FIGURE 6.—Average temperatures of apples during transit from Applewood, Va., to Liverpool, England, September 9-21, 1931.

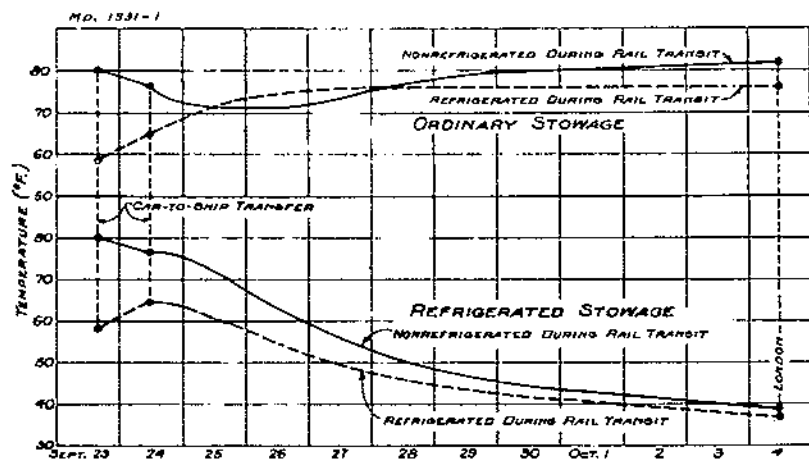


FIGURE 7.—Average temperatures of apples during transit in and from New York, N. Y., to London, England, September 23 to October 4, 1931.

preciably cooler than that shipped in ventilated cars. After this time, however, little difference was noted, which was attributable to differences in rail carriage (figs. 6 and 7).

TEMPERATURES IN ORDINARY STOWAGE ABOARD SHIP

Temperatures of fruit carried in ordinary stowage aboard ship are largely influenced by the temperature of the air and sea water

and the effectiveness of any ventilation of the ship's holds which it may be possible to give.

1930 TESTS

The four tests conducted during September and October when air and sea-water temperatures were relatively high showed that fruit carried in ordinary stowage had temperatures ranging from 58.8° to 81° F. During September the temperature of most of the fruit was above 70° during overseas shipment.

1931 TESTS

During the Virginia 1931-1 test from New York to Liverpool, September 3 to 15, the atmospheric temperatures ranged from 56° to 72° F. and sea-water temperatures from 59° to 70°. In ordinary stowage fruit temperatures ranged from 62° to 78°, with a mean daily average temperature of 74° (table 3).

TABLE 3.—Average fruit temperatures in ordinary stowage aboard ship from New York City to Liverpool, England; Virginia 1931-1 test

Place	Date	Time	Out- side air tem- per- ature	Average fruit temperatures in ordinary stowage aboard ship—					
				From standard refrigeration car		From initially iced car		From standard ventilation car	
				Top quarter length	Bottom quarter length	Top quarter length	Bottom quarter length	Top quarter length	Bottom quarter length
New York City	Sept. 4	7:30 p. m.	° F.	68	54.1	59.2	71.0		
Do.	do.	10:30 p. m.	° F.	69	61.3	68.2	74.2		76.8
Do.	Sept. 5	8:00 a. m.	° F.	71	65.8	61.1	71.2	64.5	74.6
At sea	do.	1:00 p. m.	° F.	66	67.2	64.4	72.3	66.2	74.8
Do.	Sept. 6	9:00 a. m.	64.5	70.7	68.5	73.6	69.6	75.1	75.0
Do.	do.	4:00 p. m.	78	72.0	69.8	74.5	70.8	75.4	74.7
Do.	do.	9:30 p. m.	68	72.0	70.3	74.3	71.1	75.5	74.7
Do.	Sept. 7	9:30 a. m.	69	73.2	71.8	74.6	71.6	74.9	72.6
Do.	do.	9:30 p. m.	68	73.7	72.2	75.3	73.6	76.4	75.0
Do.	Sept. 8	9:30 a. m.	67	74.6	73.2	75.3	74.0	76.2	74.7
Do.	do.	9:30 p. m.	66	74.5	73.2	75.3	74.3	75.5	74.8
Do.	Sept. 9	9:30 a. m.	65	74.4	73.5	75.3	74.8	74.7	75.0
Do.	do.	9:30 p. m.	64	74.2	73.7	75.1	75.3	75.9	75.3
Do.	Sept. 10	9:30 a. m.	63	73.4	73.2	74.7	75.5	75.3	74.5
Do.	Sept. 11	9:30 a. m.	65	74.8	73.7	74.9	75.7	75.4	75.4
Do.	Sept. 12	9:30 a. m.	66	75.3	73.8	75.7	76.0	75.9	76.1
Do.	Sept. 13	9:30 a. m.	69	74.3	73.5	74.7	75.5	74.9	75.1
Do.	Sept. 14	9:30 a. m.	64	74.2	73.2	74.9	75.6	74.8	75.1
Liverpool, England.	Sept. 15	4:00 p. m.	64	73.0	72.1	74.1	74.1	73.1	74.0

¹ Left New York Sept. 5, 11:05 a. m.

Greater extremes of temperature were noted in the Virginia 1931-2 test (fig. 6) from September 12 to 21, 1931, when outside air temperatures ranged from 58° to 80° F. Fruit temperatures in ordinary stowage ranged from 70° to 88°, with a daily average of about 80° which was about 6° higher than the daily average in the preceding test, Virginia 1931-1.

The Virginia 1931-3 test was made during the latter part of September when atmospheric temperatures ranged from 52° to 79° F. (mostly 57° to 63°) and sea-water temperatures were between 57° and 80°. In one of the lower holds of the ship, fruit temperatures in the top layer in the hatchway were between 80° and 83°.

Air temperatures at other points in this compartment were 2° to 11° cooler, indicating that the hatchway was the warmest position. Fruit temperatures in a lower 'tween-deck compartment ranged mostly between 73° and 77°; however, in barrels near the ventilator which were therefore affected by outside air currents the fruit temperature was lower. The temperature of the coolest fruit was below 70° for the last 8 days, the minimum fruit temperature being 56°.

In the case of the Maryland 1931-1 test shipment, which left New York September 24 and arrived in London October 4, atmospheric temperatures ranged from 53° to 76° F. and sea-water temperatures between 60° and 74°. Fruit temperatures from the nonrefrigerated car averaged 77° when loaded aboard ship. During the first 2 days of the voyage temperatures decreased to an average of 71°, then rose gradually throughout the remainder of the trip, reaching an average of 82° at the time of unloading.

Fruit temperatures from the standard refrigeration car averaged 65° F. at the time the fruit was loaded aboard ship, and rose gradually for 2½ days, at which time temperatures averaged 76°, and remained at this temperature the remainder of the voyage (fig. 7).

Commercial experience in the handling of apple crops has shown that when apples are held at about 60° F. or above for periods comparable to the transit time in these tests, they soften considerably and decay very rapidly if injured. The results of the present investigation are in substantial agreement with commercial and experimental observations in this connection. Magness and others (15) have shown that "at 70° F. softening proceeds approximately twice as fast as at 50°. At 50° it is almost double the rate at 40°, while at the latter temperature softening proceeds fully twice as rapidly as at 32°." In the four tests made during 1931 maximum fruit temperatures in ordinary stowage were 78°, 88°, 84°, and 82° while average fruit temperatures were well above 70° in all tests. An examination of this fruit at destination showed that it was in relatively poor condition due to the high temperatures which had prevailed in the ordinary stowage compartments (table 3 and figs. 6 and 7).

TEMPERATURES IN REFRIGERATED STOWAGE ABOARD SHIP

1930 TESTS

In the first 1930 test, it was found that approximately 4 days were required in a refrigerated compartment to lower the temperature of warm fruit to below 40° F., while in the second 1930 test about 5 days were required to reduce it to below 45°. In the first 1930 test, refrigeration as compared with ordinary stowage produced a 30° lower average fruit temperature during the voyage.

1931 TESTS

During the first 5 days of the voyage of the Virginia 1931-1 test, fruit temperatures in barrels from the ventilated boxcar averaged 53° F., those from the initially iced car averaged 50.2°, and from the standard refrigeration car 47.6°. The average air temperature in the refrigerated compartment during the same period was 41°.

At the end of the voyage the average air temperature in this compartment was 37° and the average fruit temperature was 38.8° (table 2).

In the Virginia 1931-2 test, little difference was observed in the fruit temperatures from the ventilated car and the standard refrigeration car for the first 3 days after the fruit was stowed in the refrigerated compartment. During this period fruit temperatures from the ventilated car averaged 50° F., and from the standard refrigeration car 49°. At the end of the voyage the average fruit temperature in this compartment was 36° (fig. 6).

Approximately 5 days were required to reduce fruit temperatures to an average of 40° in the Virginia 1931-3 test, whereas at the end of the voyage they ranged from 38° down to 30°. Refrigeration compared with ordinary stowage in the Virginia 1931-3 test produced 25° mean lower temperature.

In the Maryland 1931-1 test the fruit temperatures of apples loaded into a refrigerated compartment were reduced within 5 days to an average of 44° F. At the end of the voyage fruit temperatures in all the test barrels ranged from 32° to 40° but they averaged 38°.

In the 1931 tests the average daily temperature of fruit in ordinary stowage was about 75° F. and of the fruit under refrigeration about 42°. Thus, refrigeration kept the fruit about 33° lower than ordinary stowage. This is in very close agreement with results obtained in 1930 in which refrigerated stowage produced a 30° lower average temperature than ordinary stowage (fig. 7).

EFFECT OF TEMPERATURE UPON PHYSIOLOGICAL AND PATHOLOGICAL CONDITION OF FRUIT

1930 TESTS

Refrigeration as compared with ventilation during the rail-transit period appeared to result in slightly greater firmness of the fruit at the time of arrival in Liverpool, but the difference was hardly significant. However, refrigerated stowage as compared with ordinary stowage on board ship kept the fruit from 2½ to 6 pounds firmer (pressure test), making a very significant difference in its market condition. No decay or internal break-down was observed in any of the test lots, all of which were hard when harvested.

VIRGINIA 1931-1 TEST

WEALTHY AND BONUM APPLES

The different types of rail transit as used in this test did not significantly affect the rate of softening, as indicated by pressure tests of Wealthy and Bonum apples carried in ordinary stowage aboard ship. However, inspection of the test lots at Liverpool did show marked differences in slackness of pack, in the amount of decay, and in the general market condition which was directly correlated with the type of rail transit used. Practically all the fruit forwarded from shipping point to Jersey City under standard refrigeration and transferred to ordinary ship stowage arrived at destination firm-ripe to ripe, comparatively free from decay, and in good market condition. Apples forwarded in an initially iced car and transferred

to ordinary stowage aboard ship likewise arrived at destination firm-ripe to ripe, but with fewer barrels showing slackness and with a lower percentage of decay than comparable barrels forwarded in a ventilated boxcar without refrigeration.

The Wealthy apples used in this test were firm-ripe, testing 18 pounds when shipped, but the Bonum apples were very hard, testing 24 pounds. When carried in refrigerated stowage aboard ship both varieties arrived at Liverpool comparatively free from decay and in good market condition, regardless of the manner in which they had been forwarded to shipside.

The apples under refrigeration the entire distance from Virginia to Liverpool arrived at destination in the best market condition. The Wealthy apples softened an average of 2.2 pounds and the Bonum 5.1 pounds in transit. Both varieties forwarded in a ventilated boxcar and in ordinary ship stowage softened 4.2 and 12 pounds, respectively. However, test lots of the same varieties also arrived at destination in quite satisfactory market condition when refrigeration was applied either during the rail- or ocean-transit period. On the other hand, test lots of Wealthy apples shipped the entire distance without any refrigeration arrived at Liverpool fully ripe, with from 2 to 20 percent decay, and in most instances showing slackness of pack. Bonum apples shipped under similar conditions likewise showed many slack barrels upon arrival and about 5 percent decay (table 4).

TABLE 4.—Effect of various methods of shipping fruit on rate of softening and general market condition upon arrival at Liverpool, England; Virginia 1931-3 test

Variety	Type of rail transit	Type of ship stowage	Average pressure test at—		Softened	General condition at Liverpool
			Cul-peper, Va.	Liver-pool, Eng-land		
			Pounds	Pounds	Pounds	
Wealthy	Standard ventilation	Ordinary	12.00	8.83	4.16	5 to 20 percent decay; barrels showed slack pack.
Do	do	Refrigerated	12.00	10.10	2.89	0 to 5 percent decay; fair to good.
Do	Initial ice	Ordinary	13.01	0.0	3.11	Good.
Do	do	Refrigerated	12.06	10.63	2.03	2 percent decay; slight slackness.
Do	Standard refrigeration	Ordinary	13.02	0.23	3.79	Good.
Do	do	Refrigerated	13.02	10.80	2.22	Do.
Bonum	Standard ventilation	Ordinary	24.10	12.10	12.00	About 5 percent decay; barrels showed slack pack.
Do	do	Refrigerated	24.10	13.70	10.40	Fair to good.
Do	Initial ice	Ordinary	24.10	12.35	11.75	Good.
Do	do	Refrigerated	24.10	17.70	6.40	Do.
Do	Standard refrigeration	Ordinary	24.10	12.00	11.20	0 to 2 percent decay; top layer badly bruised.
Do	do	Refrigerated	24.10	19.63	5.07	Good—very firm

GRIMES GOLDEN APPLES

Grimes Golden apples forwarded from shipping point, either under standard ventilation or standard refrigeration followed by ordinary stowage aboard ship, arrived at Liverpool in firm condition with an average pressure test of 15 pounds, having softened about

9 pounds in transit. There were no significant differences in firmness between lots which could be attributed to the type of rail transit used. However, inspection at destination showed about 20 percent decay in barrels shipped by rail in a ventilated car as compared with only 5 percent decay in barrels from the standard refrigeration car. Similar barrels of Grimes Golden apples from the same two cars which were stowed under refrigeration aboard ship arrived at Liverpool in hard condition and entirely free from decay. Grimes Golden apples shipped the entire distance from Virginia to Liverpool under refrigeration softened an average of only 3.2 pounds, and averaged 21.6 pounds when tested at destination. The apples which were refrigerated only while aboard ship softened 5 pounds and averaged 19.2 pounds when tested at Liverpool.

VIRGINIA 1931-2 TEST

At the time of picking, the King David, Bonum, and Jonathan apples used in this test were hard, having an average pressure test of 19.8, 19.5, and 16.9 pounds, respectively. Regardless of the type of rail transit, however, the apples placed in ordinary stowage aboard ship arrived at destination firm-ripe with small percentages of decay and break-down. When tested upon arrival in Liverpool the fruit refrigerated during rail transit was found to be slightly firmer than similar apples from the ventilated car.

Jonathan and King David apples under refrigeration all the way from Virginia to Liverpool arrived at destination in excellent condition, still being hard and from 4 to 7 pounds firmer than apples not refrigerated. No decay was observed in any of these lots.

When comparable lots were shipped without refrigeration or were refrigerated only during rail transit, it was found that they arrived at destination in a much softer condition and with small percentages of decay and break-down (table 5).

TABLE 5.—Effect of various methods of shipping fruit on the rate of softening and general market cond. on upon arrival at Liverpool, England; Virginia 1931-2 test

Variety	Type of rail transit	Type of ship stowage	Average pressure test at --		Softened	General condition at Liverpool
			Applewood, Va.	Liverpool, England		
Jonathan	Standard ventilation	Ordinary...	Pounds 16.9	Pounds 10.67	Pounds 6.23	2 to 5 percent decay; slack pack; slight break-down.
Do	do	Refrigerated	16.9	14.47	2.43	Good.
Do	Standard refrigeration	Ordinary...	16.9	11.25	5.65	2 to 5 percent decay; slack pack; bruised.
Do	do	Refrigerated	16.9	15.57	1.33	Good.
King David	Standard ventilation	Ordinary...	19.8	12.40	7.40	Fair. 2 to 5 percent decay; slack barrels.
Do	do	Refrigerated	19.8	17.15	2.65	Good, bruised.
Do	Standard refrigeration	Ordinary...	19.8	12.15	7.65	
Do	do	Refrigerated	19.8	10.3	.50	Good.
Bonum	Standard ventilation	Ordinary...	19.5	11.00	8.50	Slight slack; good.
Do	do	Refrigerated	19.5	18.20	1.30	Good.
Do	Standard refrigeration	Ordinary...	19.5	10.9	8.60	Good; slight slack.
Do	do	Refrigerated	19.5	17.5	2.00	Good; very firm.

VIRGINIA 1931-3 TEST

Jonathan, Grimes Golden, Delicious, and Bonum apples arrived in London in good salable condition regardless of the type of rail transit, although stem punctures, bruising, and other mechanical injury caused by packing and handling were very much in evidence. Mother apples which were well matured at the time they were picked and King David apples from ordinary stowage showed small percentages of decay.

In general, refrigeration during rail transit did not significantly decrease decay, indicating that injuries sustained in packing were largely responsible for the damage. However, the amount of decay was appreciably less with Grimes Golden and King David apples from the bottom layer of the refrigerated car which points to the retarding influence of low temperatures, particularly immediately after packing, on the development of decay. The temperature of this fruit was cooler during rail transit and remained cooler in ordinary stowage aboard ship during the first part of the voyage.

In apples shipped in ordinary stowage there was 1 to 5 percent decay in the King David, Mother, and Jonathan varieties, 2 to 10 percent in the Grimes Golden, and 3 percent in the Bonum and Delicious varieties.

The data obtained in this test indicated that although rail refrigeration slightly retarded decay and maturity, its effect alone was insufficient to insure good condition of the fruit upon arrival at Liverpool. In most instances refrigeration aboard ship was sufficient to insure good condition upon arrival, irrespective of the type of rail transit previously used.

MARYLAND 1931-1 TEST

In this test Lowry, Delicious, and Jonathan apples refrigerated aboard ship arrived at London in good market condition. Decay and break-down were present in the lots from ordinary ship stowage. Lowry apples contained from 10 to 15 percent decay and break-down; Jonathan, 2 to 6 percent; and Delicious, 1 percent.

SLACK BARRELS

Since "slack" barrels which arrive on English markets are usually discounted from 1 to 8 shillings (\$0.25 to \$2.02) in price, depending upon the degree of slackness, it is important to determine the possible effect of transportation methods upon the development of slackness. At the time the fruit was unloaded at Liverpool or London, observations were made on the slackness of barrels from all the test lots. It was found that slackness of pack and decay were generally associated in the same barrels and were closely correlated with conditions of temperature in transit, especially in those lots of apples which were shipped without refrigeration, more particularly without ship refrigeration. With early picked very hard fruit, such as that used in the 1930 tests, or during cool weather, it is probable that most shipments could be forwarded without refrigeration and the apples would be in good condition for immediate marketing upon arrival. However, with riper apples and during hot weather the extra cost of refrigeration especially on board ship would seem to be justified, particularly if it is desired to have sufficient potential storage life

to insure retention of good marketable condition for some time after arrival overseas.

DISCUSSION

From points in Virginia to Jersey City, N. J., the rail-transit period is generally not more than 40 hours. This is a comparatively short time for cooling fruit, and the cost is \$0.25 per barrel. The lower temperatures obtained from rail refrigeration in these tests were mostly lost in the transfer from car to ship. Despite this fact, however, it cannot be assumed that the entire value of this initial cooling was lost, because the effect of lower temperatures on the development of decay depends largely upon the time when the apples are subjected to these temperatures in relation to the time of infection. Many rots will not start at low temperatures, but when once started at a high temperature they will continue to grow slowly at lower temperatures. Therefore, from the standpoint of decay control, it is more important to cool the fruit quickly after harvest than to reduce the temperature at a later period. In the control of decay in export apples, for example, the cooling accomplished by refrigeration from shipping point to shipside is more important than an equivalent cooling during a similar period just prior to docking at overseas destination. However, if the transfer period could be shortened, or methods used which would prevent any considerable rise of temperature, it seems very likely that refrigeration by rail would prove to be more worth while. This would be especially true with late-picked fruit of early and midseason varieties which has become somewhat ripe on the trees, delayed at the orchard, or packed and shipped during periods with high daily temperatures of 80° to 100° F.

Under the conditions of these tests it was impossible to segregate the test fruit from the regular commercial export shipments. Barrels of test apples were loaded, with other fruit, into ventilated and refrigerated cars, but placed in key positions in order to obtain comparative results, which was a satisfactory arrangement for rail-transit conditions. Aboard ship, however, conditions were not so satisfactory when it was necessary to stow barrels of cold apples from refrigerated cars with commercial shipments of warm fruit from ventilated cars. When warm and cold fruit were stowed together in a refrigerated chamber, the cold fruit quickly warmed up, especially when the bulk of the load in the chamber was warm. The practice of stowing warm and cold fruit together, therefore, is not recommended, and efforts should be made by shippers to see that fruit refrigerated during rail transit is stowed by itself, in separate chambers, if possible.

Refrigeration aboard ship, as compared with ordinary stowage, was found to reduce the average temperature of the fruit during the voyage about 30° to 32° F., and cost an additional \$0.50 per barrel more than ordinary stowage. This temperature reduction decreased the rate of softening, maintained quality, reduced decay, and held prices at higher levels.

Before further discussion of the economic aspect of refrigerated versus ordinary stowage for the shipment of eastern barreled apples to European markets, the question of what foreign markets want and expect in apples after they arrive should be considered. The

British market answers this question by demanding that apples reach them in a firm condition with sufficient potential storage life to insure good market condition after reshipment to various secondary markets. As for color, the British markets want a Jonathan or a Bonum to be red and well colored and a Grimes Golden apple to be green. In either case the consumer wants a firm, ripe apple.

It is quite possible that apples shipped in ordinary stowage during cool weather and reaching the overseas market when the demand is strong might bring as good returns as those forwarded at the same time under refrigeration. However, the price that barreled apples will bring at the auction is quite impossible to foretell, because any market is influenced by supply and demand. Should apples be shipped during cool weather and reach foreign ports when the demand is strong, it is quite possible that even those carried under ordinary ship stowage might bring as high returns as refrigerated fruit. Contrarily, during periods of hot weather, especially if the supply is large, refrigerated fruit has sold for enough to more than pay for the additional refrigeration charges.

The Foreign Agricultural Service Division, Bureau of Agricultural Economics, United States Department of Agriculture, has compiled sales prices on refrigerated and nonrefrigerated fruit from the English auction catalog.² Some of these figures were collected during 1931 and are particularly applicable because they give information during September and October, or at the time some of these tests were made. This report states:

Without exception, fruit listed as being refrigerated brought several shillings over that described as ordinary (stowage). During the month of September, the difference between the selling price of refrigerated and ordinary stowage (fruit) was quite pronounced. For instance, on the 24th, U. S. No. 1 Jonathans, refrigerated, ruled at from 28/6 to 30/6 (\$5.45 to \$5.93) per barrel, as against 21/6 to 25/6 (\$4.18 to \$4.96) for ordinary stowage.

Owing to an over-heated condition, a large volume of fruit was sold for from 10/- to 14/- (\$1.95 to \$2.72) per barrel, i. e., common stowage fruit testing from 75-83° F., upon being removed from the ship. New York Wealthys at the same time were making from 23/- to 25/- (\$4.17 to \$4.86) per barrel for refrigerated as against 15/- to 18/- (\$2.92 to \$3.50) for ordinary stowage. On the first of October, refrigerated Bonums, on the London market, sold at 22/- to 24/- (\$4.37 to \$4.76) as against 18/- to 20/- (\$3.57 to \$3.97) for common stowage.

From these data and all other information available, the extra cost of refrigeration aboard ship or shipping fruit under refrigeration the entire distance from Virginia to Liverpool during the early fall would appear to be more than compensated for by the higher sales return.

Aside from this economic advantage, American prestige and reputation will assuredly be better maintained and enhanced if every effort is used to supply a high standard product.

SUMMARY

Refrigeration of apples during rail transit from Virginia to Jersey City, N. J., as compared with ventilation under the prevailing weather conditions in 1929 and 1930, reduced the temperature of the fruit in the top layers of the cars 5° to 16° F., and that

² MUEZ, F. A. SUMMARY OF THE APPLE EXPORT SEASON, 1931-32. F. S. A-434 August 1932.

[Micrographed]

in the bottom layers of the cars 22° to 36°. In 1931 refrigeration reduced fruit temperatures 9° to 14° in the top layers and 21° to 30° in the bottom layers of the cars.

At Jersey City the fruit was unloaded from refrigerated cars for transfer to the ship. The length of this transfer period varied from 6 to 24 hours, during which time the fruit warmed very rapidly under the influence of the relatively warm outside air, with the result that low temperatures derived from the car refrigeration were almost lost at this point. In some of the tests, 48 to 84 hours of refrigeration aboard ship were necessary to recool the fruit to the same low temperature which it had at the time of unloading at Jersey City.

When fruit from refrigerated cars was placed in ordinary stowage aboard ship, the low fruit temperatures derived from rail refrigeration were practically lost within 2 or 3 days.

The average daily fruit temperature in ordinary stowage was about 75° F. and of the fruit under refrigeration about 42°. Refrigeration during ocean transit as compared with ordinary stowage kept the fruit 30° to 32° cooler and retarded softening and decay.

Apples shipped under refrigeration from points in the Shenandoah-Cumberland section via New York to England arrived at destination practically free from decay and in the best condition, and apples shipped without refrigeration were usually ripe upon arrival at destination, with varying amounts of decay and sometimes with internal break-down as well.

Refrigeration during rail transit did not significantly retard the rate of softening. However, in many instances there were smaller percentages of decay in barrels refrigerated during rail transit. Grimes Golden apples responded somewhat more favorably than other varieties to this method.

Slackness of pack and the amount of decay observed at destination were closely correlated and also correlated with stowage conditions. Slackness was nearly always noted in those barrels of fruit shipped without refrigeration and particularly without ship refrigeration.

Fruit refrigerated during rail transit and forwarded under refrigeration aboard ship should be stowed by itself, in separate chambers if possible, since the data from tests made indicate that a large volume of warm fruit stowed in the same chambers causes an undesirable warming up of previously cooled fruit immediately after loading aboard ship and prolongs the time ordinarily required for the latter to reach a satisfactory carrying temperature.

The sales returns of refrigerated summer and early-fall varieties of apples as compared with similar fruit shipped in ordinary stowage, particularly during September, indicate that refrigeration is economically profitable.

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